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## 1.0 - Objective

This standard operating procedure (SOP) outlines the proper operation of the Amatrol series & parallel pump system using centrifugal and gear pumps. This document can be used to install all required equipment, prime the pumps, and operate them under various conditions. Any issues should always be brought to the attention of the supervising TA or Unit Ops supervisors.

## 2.0 - Responsibilities

1. Chemical engineering faculty (Course instructors, TAs) are responsible for ensuring that this document is accurate and allows safe operation of the amatrol pump system.
2. Undergraduate students (or operators) are responsible for following this procedure and reporting any issues encountered.

## 3.0 - Definitions

- P XXX - Pump # XXX
- V XXX - Valve # XXX
- NPSH – Net positive suction head
- TDH – Total dynamic head
- RPM – rotations per minute (pump motor impeller speed)

## 4.0 - Equipment Description

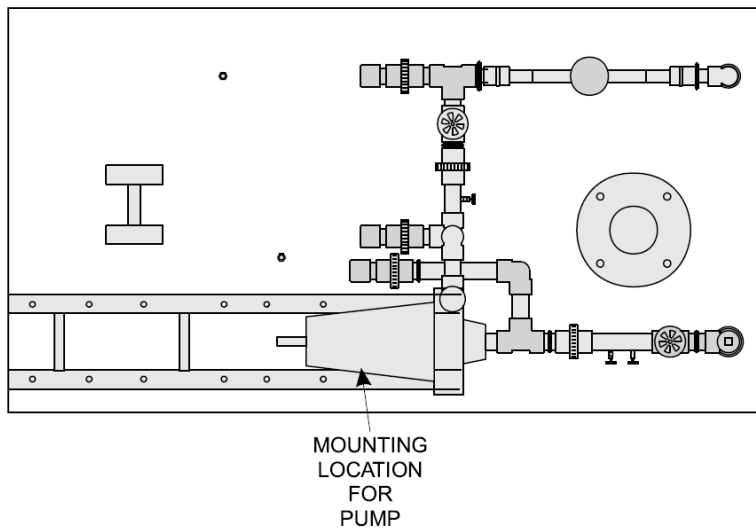
- Centrifugal pump set to 100% speed runs at 1725 rpm.
- The max rated power for all motors is 0.33hp.

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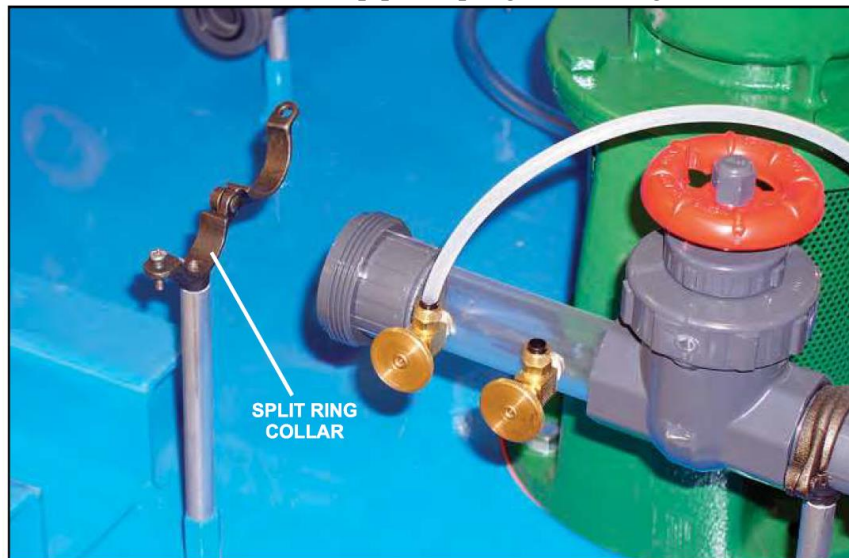
## 5.0 – Centrifugal pumps

### 5.1 – Centrifugal pump installation

1. **Make sure the system power is off, unplugged, and that the motor is unplugged.**
2. Make room for the centrifugal pump assembly on the mount.
3. Place the centrifugal pump assembly on the mount and align with the existing piping as shown below, taking care not to hit the pump coupling (in red).

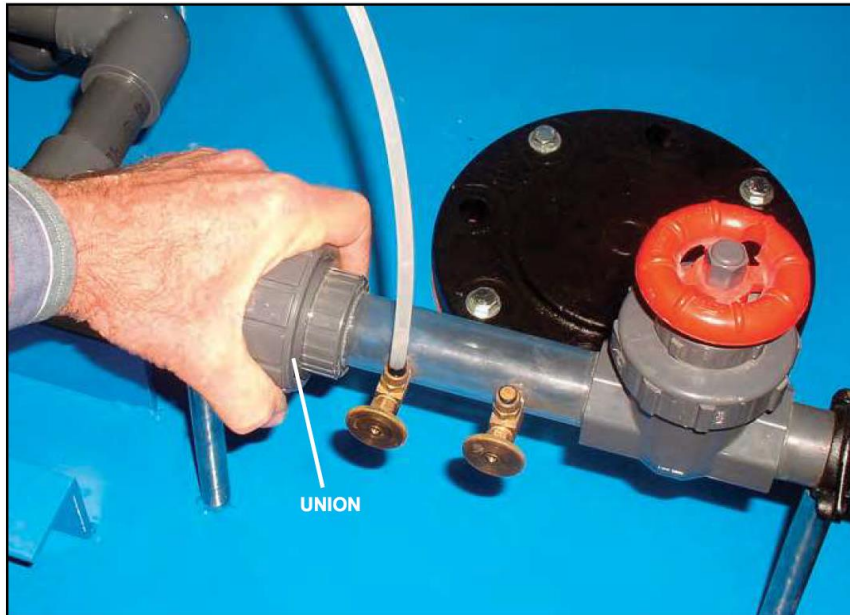


- a. The pump inlet and outlet piping should rest on the split ring collar (e.g. below). Make sure the collar of the threaded pipe coupling is on the right side of the rest.

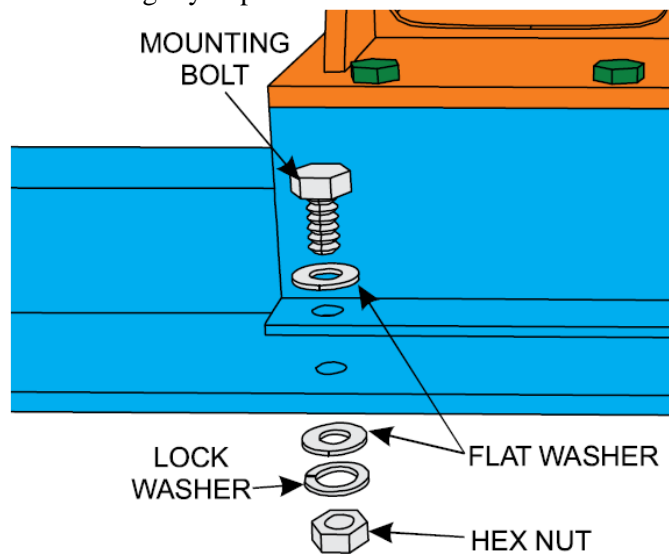


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- b. Align the pump mount so that bolts can be threaded through the slots that are 2<sup>nd</sup> and 3<sup>rd</sup> from the right.
4. Connect the pump inlet and discharge piping to the system by rotating the collar on the union clockwise until tight. Do not overtighten (**ask TAs for help if unsure**).

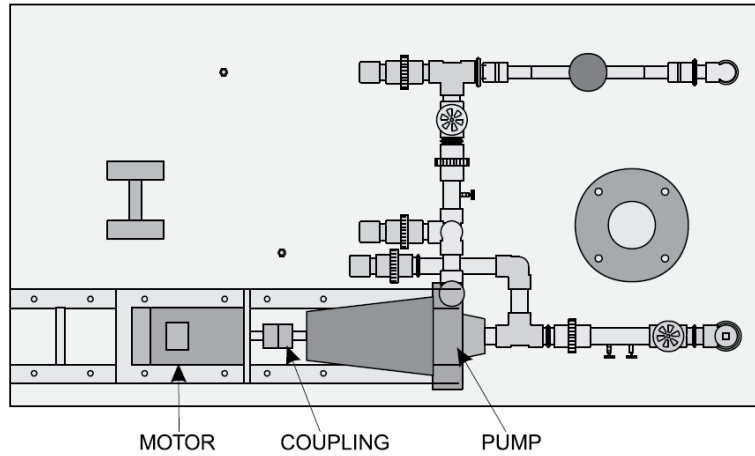


5. Once the piping is connected, begin to thread the pump mounting bolts through each of the 4 corners.
  - a. Add a bot and a flat washer on top, with a flat washer->lock washer->hex nut below, as shown in the figure. **Only tighten the nut enough that it does not fall off.** We want the pump to be able to move slightly in place for now.



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6. Double check that the pump and all piping is aligned.
7. Lock down the split ring collars around the piping (from 2a) using a Phillips head screwdriver.
8. Align the motor with the pump and connect the coupling:

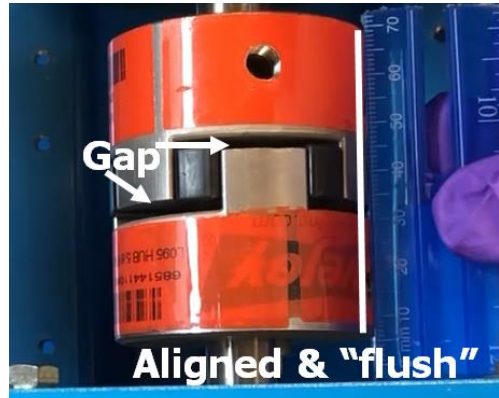


- a. Place the “rubber spider” (rubber coupling insert) on the motor coupling as shown.



- b. Carefully slide the motor coupling so that it connects with the coupling on the pump.
- c. Align the motor so that there is a small gap (~10-15mm) between the teeth of one coupling and the other coupling, and so that the coupling is “flush” (flat all the way across, for a full rotation). **See the following figure or ask a TA for clarification.**

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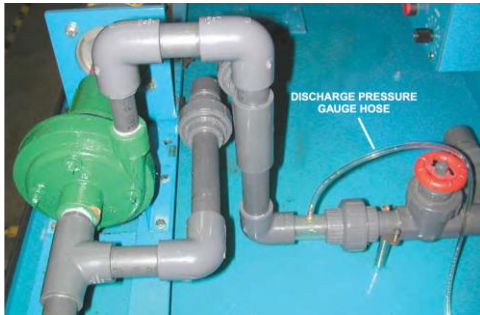


9. Once the coupling is aligned, thread all the bolts through the motor mount “loosely” as was done with the pump in step 4a. The system should look like so:

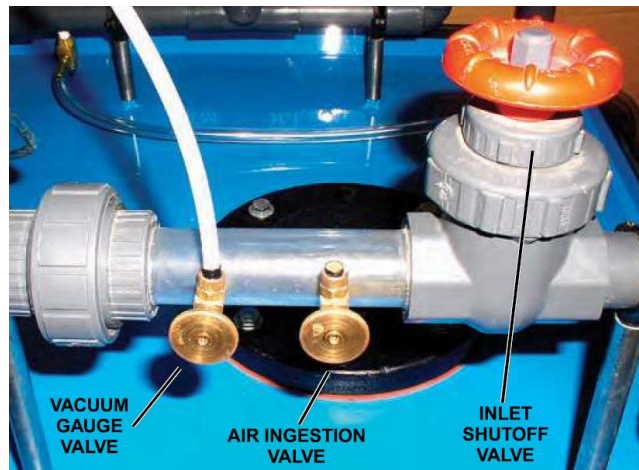


10. Use the combination and socket wrenches provided to tighten the bolts on the pump mount using a “criss-cross” pattern as indicated (#1->#4). **Do not overtighten – bolts could break and release the pump or motor from the mount.** Double check with your TA if you are unsure.
11. Double check the coupling alignment and adjust the motor mount placement if necessary. Tighten all motor mount bolts in a criss-cross pattern as before.
12. Double check the alignment of the coupling, and all piping connections.
13. Place the safety shield over the coupling and secure it with the provided screws.
14. Connect the discharge pressure gauge hose to the lower pressure gauge as shown below.

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15. Make sure the vacuum gauge and air ingestion valves on the pump inlet line are closed. Open the inlet shut off valve.



16. Open the drain valve on the pump inlet line located on the side of the unit next to the reservoir.
17. Wait 5-10 seconds and then close the drain valve.
18. Make sure the pump discharge line shutoff valve is closed. Note that a few turns clockwise will close the valve; the handle will continue turning even when the valve is closed.
19. **PROCEED TO PUMP PRIMING (Section 5.2).**

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### 5.2 – Centrifugal pump priming

1. Open the air vent valve on the centrifugal pump by turning it 1.5 turns counterclockwise.



2. Remove the “prime plug” on the pump inlet/suction line.
3. Add water to prime the entire suction line. The water level at this inlet will become constant when the lines are primed.



4. Close the air vent valve on the pump.
5. Replace the “prime plug” removed in step 2.

### 5.2 – Centrifugal pump operation

1. Verify that the main power switch is in the **OFF** position.
2. Set the speed dial to 0%.
3. Verify that the direction control is turned to the CW direction.
4. Ensure that the motor control system main power cord is plugged in.
5. Turn on the main power switch.
6. Ensure the power frequency on the variable speed AC driver controller is correct.
  - a. Press “P”
  - b. Press the up or down arrow until “P1082” is displayed.
  - c. Press “P”
  - d. Press the up or down arrow until “60.0” is displayed on the screen. The FN button can be used to change which digit is being edited.



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- e. Press “P”
7. Fully open the pump discharge line shutoff valve, and then close it by one turn.
8. Make sure that the shutoff valves going to a secondary pump (if installed) are fully closed.
9. Double check that all lines (valves on suction and discharge are open as appropriate). **Check that the setup is complete with a TA.**
10. Make sure that the pump coupling is clear.
11. Start the motor:
  - a. Press the green “START” button. “MOTOR ON” should light up green.
  - b. Slowly ramp the pump speed up to 50%.
12. Fully open the vacuum gauge valve on the pump inlet/suction line (see 5.1 step 14).
13. The vacuum gauge and digital flowmeter should show a reading, while the low pressure gauge (on the discharge) should show almost nothing.
14. Continue to step 5.2 to study single pump performance, or continue to step 5.3 to shift to parallel pump operation.

## 5.2 – Studying pump performance

1. Set the motor speed such that a discharge pressure can be read when the discharge valve is fully open.
  - a. If the pump is not running go to 5.1 step 10.
2. Note the speed (%).
3. Throttle the discharge pressure by slowly closing the discharge valve.
  - a. Record the discharge pressure, suction pressure, and flowrate at multiple points.
  - b. Allow ~5 minutes for the system to become steady before recording data.
  - c. **Note that for parallel pump operation both discharge valves should be opened/closed by the same amount.**
4. When adequate data has been collected slowly ramp down motor speed to 0% and press “STOP.” “MOTOR ON” should turn off.
5. Continue to section 5.3 (multiple pump operation, series 5.3.1 or parallel 5.3.2) or 5.4 (centrifugal pump removal/shutdown).

## 5.3 – Setting up for multiple centrifugal pump operation

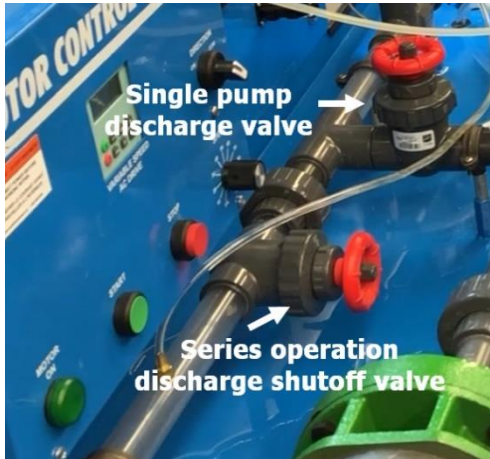
1. If the pump is currently running, slowly ramp down the motor speed to 0% and press the “STOP” button. The “MOTOR ON” light should turn off.
2. Turn the system power off using the main power switch, if necessary.
3. Ensure that the second pump is correctly installed and set-up for operation. **Check with your TA if unsure.**

### 5.3.1 – Series pump operation

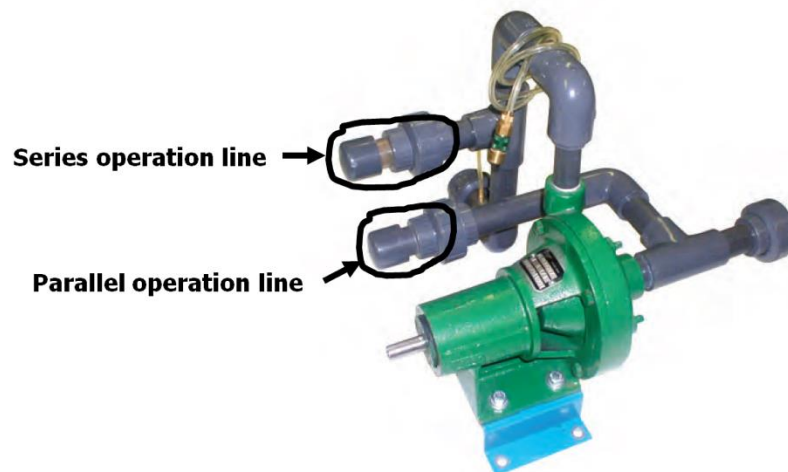
1. Ensure that pumps are not running and turn off main power if necessary.
2. Remove the series operation line cap (see below).

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3. Ensure that the series operation shutoff valve is fully closed.



4. Connect one end of the provided flex hose to the second pump suction line.



5. Prime the flex hose by filling it with water (make sure the water level is constant).
6. Connect the second end of the flex hose to the series operation line.
7. Plug both pumps in.
8. Turn on the main power switch.
9. Ensure the power frequency on the variable speed AC driver controller is correct.
  - a. Press “P”
  - b. Press the up or down arrow until “P1082” is displayed.
  - c. Press “P”
  - d. Press the up or down arrow until “60.0” is displayed on the screen.
  - e. Press “P”
10. Ensure that the primary pump is still primed.
11. Close the primary pump discharge valve.

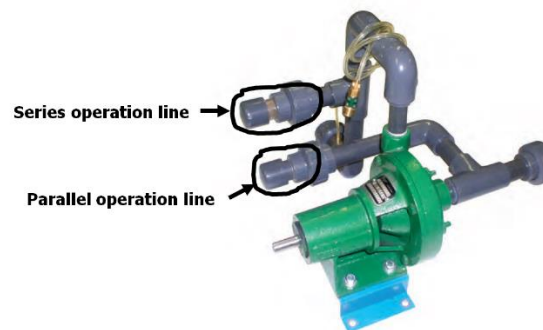
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12. Ensure the series discharge shutoff valve is also closed. Turn on the pumps by pressing “START” and setting the motor speed to 50%. Once the medium pressure gauge starts to increase, slowly reopen the primary pump discharge shutoff valve (1/4-1/2 turn). Water movement through that pipeline should be visible.
13. Once the flow meter starts showing a value, slowly open the series discharge valve and look for water flow through that valve.
14. Fully close the primary pump discharge shutoff valve.
15. If flow meter still shows 0, restart the process from Step 12.
16. Study pump performance as in Section 5.2, otherwise press “STOP”, turn off main power and proceed to shutdown (section 5.4).

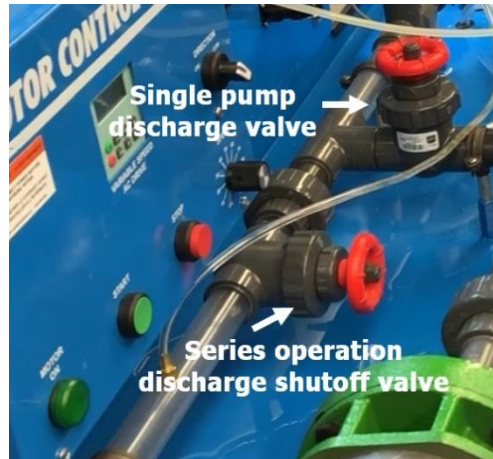
### 5.3.2 – Parallel pump operation

1. Ensure that the pumps are not running and turn off main power if necessary.
2. Drain the pump suction lines by fully opening the drain valve beside the reservoir.
3. Once the lines have drained, fully close the drain valve.
4. Remove the parallel operation line cap (see below).



5. Connect the parallel operation line to the suction inlet on the secondary pump.
  - a. Replace the cap on the series operation line if necessary.
6. Fully close the discharge valves for both pumps.

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**7. Prime the new suction lines:**

- a. Open the air vent valve on the centrifugal pump by turning it 1.5 turns counterclockwise.



- b. Remove the “prime plug” on the pump inlet/suction line.
- c. Add water to prime the entire suction line. The water level at this inlet will become constant when the lines are primed.



- d. Close the air vent valve on the pump.
- e. Replace the “prime plug” removed in step b.

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8. Check that all lines are prepared for pump operation in parallel. **Check with TAs before continuing.**
9. Turn on the main power switch.
10. Ensure the power frequency on the variable speed AC driver controller is correct.
  - a. Press “P”
  - b. Press the up or down arrow until “P1082” is displayed.
  - c. Press “P”
  - d. Press the up or down arrow until “60.0” is displayed on the screen.
  - e. Press “P”
11. Fully open the discharge shutoff valves.
12. Start the pumps by pressing “START,” “MOTOR ON” should light up.
13. Slowly ramp up motor speed to 50%.
14. Study pump performance as in Section 5.2, otherwise press “STOP”, turn off main power and proceed to shutdown (section 5.4).

#### 5.4 – Centrifugal pump tear-down

1. Ensure that all pumps are off. Slowly ramp down to 0% motor speed and press “STOP” if necessary.
2. Turn off main power. Unplug all pumps from the motor control center.
3. Close the vacuum pressure gauge valve fully.
4. Open the air vent valve on the centrifugal pump by 1-1.5 turns.



5. Open the pump suction line drain valve located beside the reservoir.
6. Remove the main suction line priming port plug.

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7. Drain water out of the centrifugal pump by removing the lower bolt with a wrench. **Check with TAs to ensure that this is necessary first.** Repeat with the second pump if needed.



8. Once the system has drained, remove the safety cover over the pump coupling.
9. Loosen all the bolts on the pump mount in a criss-cross pattern as before and then remove them.
10. Loosen all the bolts on the motor mount in a criss-cross pattern as before, and then remove them.
11. Slowly and carefully de-couple the motor from the pump by sliding it to the left.



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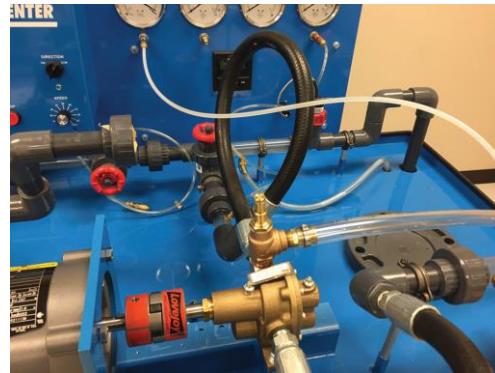
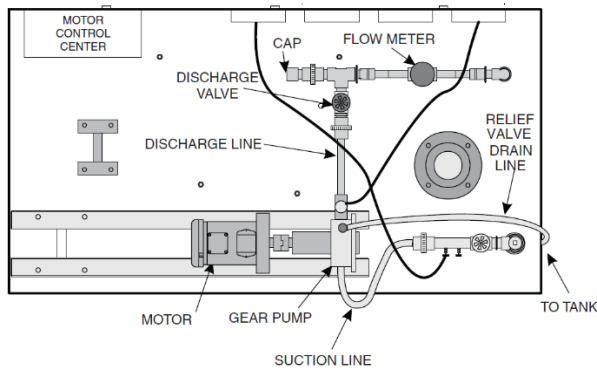
12. Use a Phillips head screwdriver to open all split cap collar piping mounts that were closed during installation.
13. Remove the collar from all unions on the piping connected directly to the centrifugal pump.
  - a. Some water should drain from each connection.
14. Remove the centrifugal pump piping assembly from the pump station.
15. Continue to gear pump installation/operation (Section 6.0) or check in with TAs for further shutdown instructions.

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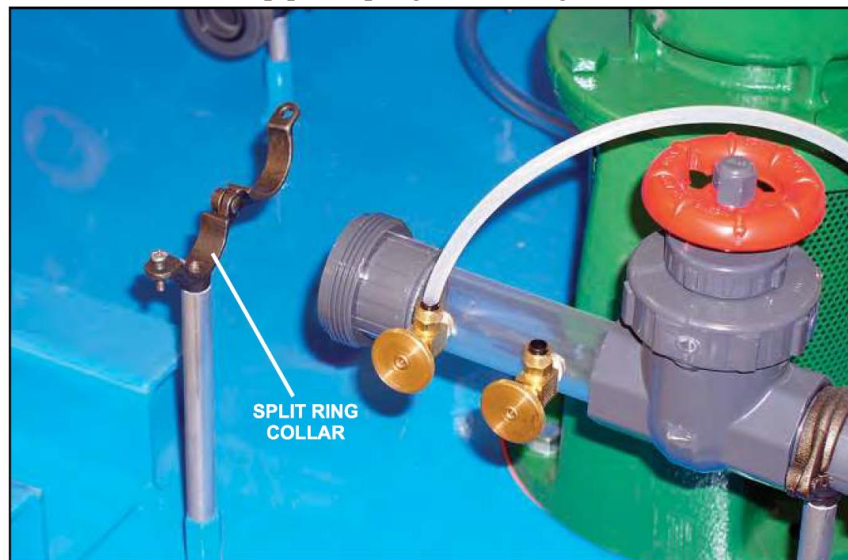
## 6.0 – Gear pumps

### 6.1 – Gear pump installation

1. **Make sure the system power is off, unplugged, and that the motor is unplugged.**
2. Make room for the gear pump assembly on the mount.
3. Place the centrifugal pump assembly on the mount and align with the existing piping as shown below, taking care not to hit the pump coupling (in red). Place the relief valve line in the reservoir.



- a. The pump inlet and outlet piping should rest on the split ring collar (e.g. below). Make sure the collar of the threaded pipe coupling is on the right side of the rest.



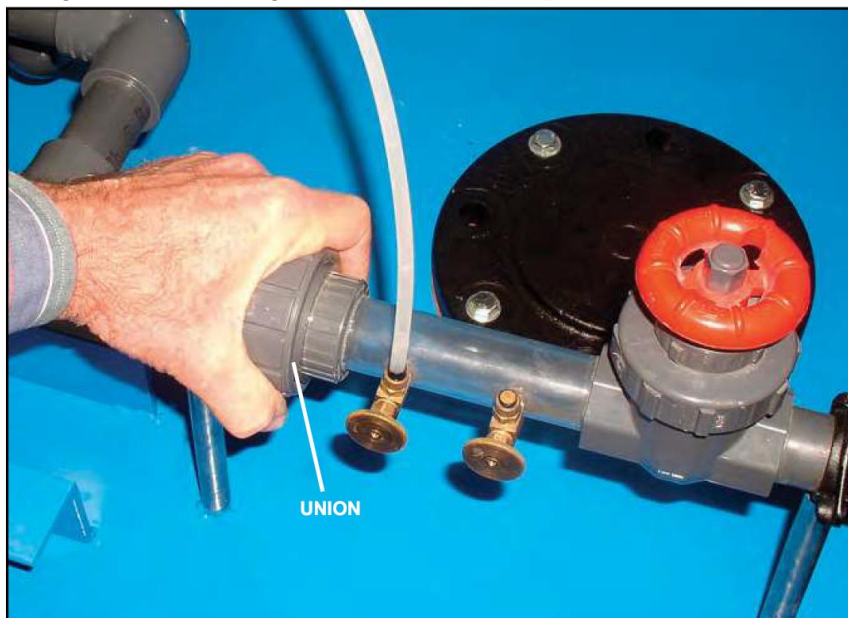
- b. Align the pump mount on the far right (the last slot for bolts on the mount).



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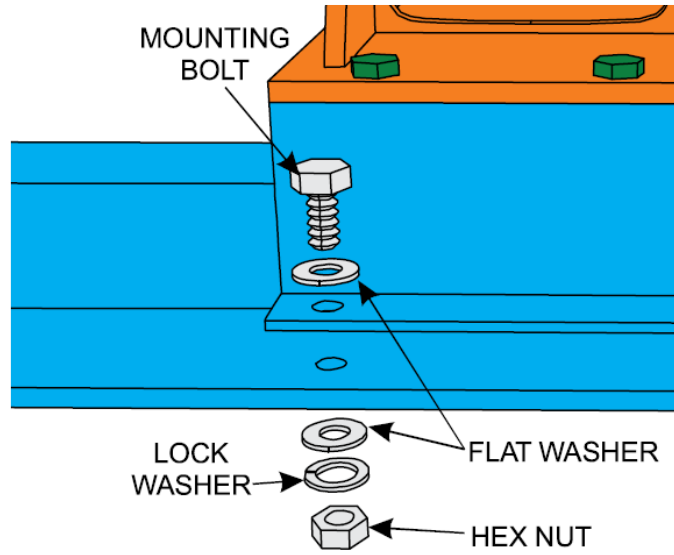


4. Connect the pump inlet and discharge piping to the system by rotating the collar on the union clockwise until tight. Do not overtighten (**ask TAs for help if unsure**).

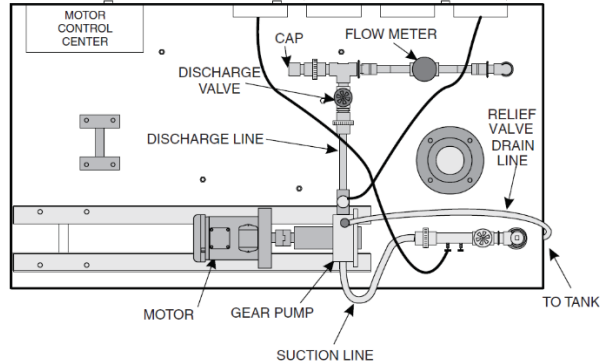


5. Once the piping is connected, begin to thread the two pump mounting bolts.
  - c. Add a bot and a flat washer on top, with a flat washer->lock washer->hex nut below, as shown in the figure. **Only tighten the nut enough that it does not fall off**. We want the pump to be able to move slightly in place for now.

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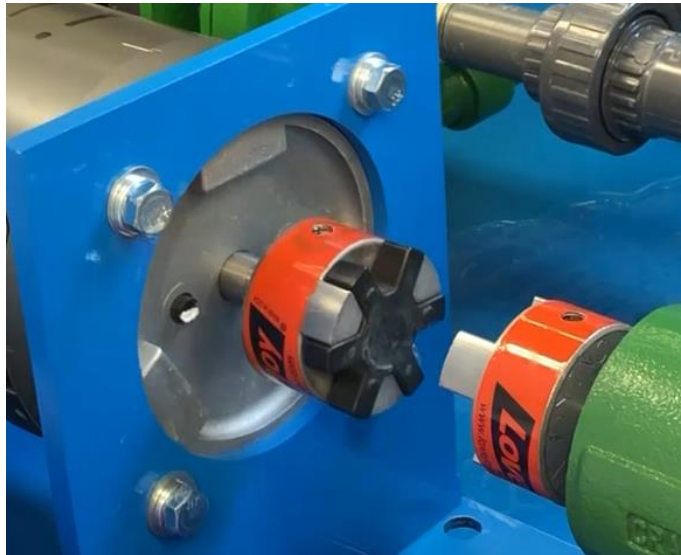


6. Double check that the pump and all piping is aligned.
7. Lock down the split ring collars around the piping (from 2a) using a Phillips head screwdriver.
8. Align the motor with the pump and connect the coupling:

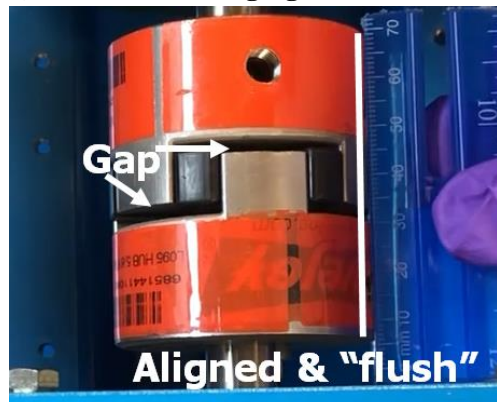


- d. Place the “rubber spider” (rubber coupling insert) on the motor coupling as shown.

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- e. Carefully slide the motor coupling so that it connects with the coupling on the pump.
- f. Align the motor so that there is a small gap (~10-15mm) between the teeth of one coupling and the other coupling, and so that the coupling is “flush” (flat all the way across, for a full rotation). **See the following figure or ask a TA for clarification.**

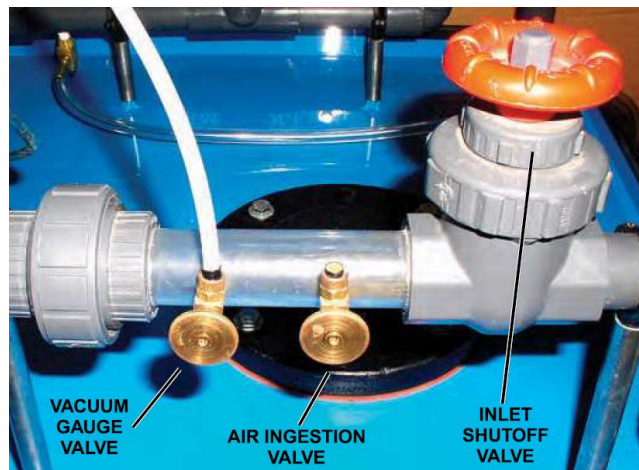


9. Once the coupling is aligned, thread all the bolts through the motor mount “loosely” as was done with the pump in step 4a. The system should like so:

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10. Use the combination and socket wrenches provided to tighten the bolts on the pump. **Do not overtighten – bolts could break and release the pump or motor from the mount.** Double check with your TA if you are unsure.
11. Double check the coupling alignment and adjust the motor mount placement if necessary. Tighten all motor mount bolts in a criss-cross pattern.
12. Double check the alignment of the coupling, and all piping connections.
13. Place the safety shield over the coupling and secure it with the provided screws.
14. Connect the discharge pressure gauge hose to the high pressure gauge as shown below.
15. Make sure the vacuum gauge and air ingestion valves on the pump inlet line are closed. Fully open the inlet shut off valve.



16. Open the drain valve on the pump inlet line located on the side of the unit next to the reservoir.
17. Wait 5-10 seconds and then close the drain valve.
18. Make sure the pump discharge line shutoff valve is closed. Note that a few turns clockwise will close the valve; the handle will continue turning even when the valve is closed.
- 19. PROCEED TO PUMP PRIMING (Section 6.2).**

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### 6.2 – Gear pump priming

1. Remove the “prime plug” on the pump inlet/suction line.
2. Add water to prime the entire suction line. The water level at this inlet will become constant when the lines are primed.



3. Replace the “prime plug” and continue to gear pump operation.

### 6.3 – Gear pump operation

1. Ensure that the relief valve is set to 25 psi, use a wrench to change if necessary.



2. Verify that the main power switch is in the **OFF** position.
3. Set the motor speed dial to 0%.
4. Verify that the direction control on the motor control center is turned to the **CCW** direction.
5. Ensure that the motor control system main power cord is plugged in.
6. Turn on the main power switch.

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7. Ensure the power frequency on the variable speed AC driver controller is correct. [**Set to 30Hz for gear pump**]
  - a. Press “P”
  - b. Press the up or down arrow until “P1082” is displayed.
  - c. Press “P”
  - d. Press the up or down arrow until “**30.0**” is displayed on the screen. The FN button can be used to change which digit is being edited.
  - e. Press “P”
8. Fully open the pump discharge line shutoff valve, and then close it by one turn.
9. Make sure that the shutoff valves going to a secondary pump (if installed) are fully closed.
10. Double check that all lines (valves on suction and discharge are open as appropriate). **Check that the setup is complete with a TA.**
11. Make sure that the pump coupling is clear.
12. Start the motor:
  - a. Press the green “START” button. “MOTOR ON” should light up green.
  - b. Ramp the pump speed up to **100%**.
13. Fully open the vacuum gauge valve on the pump inlet/suction line (see 6.1 step 15).
14. The vacuum gauge and digital flowmeter should show a reading, while the high pressure gauge (on the discharge) should show almost nothing.
15. Continue to step 6.4 to test the safety relief valve.

### 6.3 – Gear pump operation

1. Verify that the relief valve is set to 25 psi and that the relief drain line is inserted into the tank.
2. **Ask for TA assistance:** With the motor running at 100% close the discharge valve until it is completely closed.
  - a. Pressure will quickly rise resulting in the relief valve opening and water diverting to the reservoir.
  - b. The high pressure gauge should show ~25 psi (the setting of the pressure relief valve).
3. Fully open the discharge valve and allow the pump to run for 5 minutes before continuing to Section 6.4.

### 6.4 – Studying pump performance

1. Verify that a discharge pressure can be read when the discharge valve is fully open.
2. Study the impact of motor speed, or throttle the system as before:
  - a. To study at constant speed, note the speed % and then:
    - i. Throttle the discharge pressure by slowly closing the discharge valve. **If the relief valve is tripped, open the valve fully and ask a TA for assistance.**
      1. Record the discharge pressure, suction pressure, and flowrate at multiple points. Allow ~5 minutes for the system to become steady before recording data.

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- b. To study at variable motor speed:
  - i. Fully open the discharge valve.
  - ii. Change the motor speeds and measure discharge pressure, suction pressure, and flowrate at multiple points. Allow ~5 minutes for the system to become steady before recording data.
3. When adequate data has been collected slowly ramp down motor speed to 0% and press “STOP.” “MOTOR ON” should turn off.
4. Continue to section 6.5 (gear pump shutdown).

### 6.5 – Gear pump tear-down

1. Ensure that all pumps are off. Slowly ramp down to 0% motor speed and press “STOP” if necessary.
2. Turn off main power. Unplug all pumps from the motor control center.
3. Open the pump suction line drain valve located beside the reservoir.
4. Remove the main suction line priming port plug.



5. Once the system has drained, remove the safety cover over the pump coupling.
6. Close the vacuum pressure gauge valve completely.
7. Loosen all the bolts on the pump mount and then remove them.
8. Loosen all the bolts on the motor mount in a criss-cross pattern as before, and then remove them.
9. Slowly and carefully de-couple the motor from the pump by sliding it to the left.



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10. Use a Phillips head screwdriver to open all split cap collar piping mounts that were closed during installation.
11. Remove the collar from all unions on the piping connected directly to the centrifugal pump.
  - a. Some water should drain from each connection.
12. Remove the gear pump piping assembly from the pump station.
13. Check in with TAs for further shutdown instructions.