Industrial Maintenance
Pumps Training System

Single Pump Systems

Job Sheets - Courseware Sample

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Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current

Safety and Common Symbols

Symbol	Description
	Earth (ground) terminal
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Preface

The Pumps Training System, Model 46106, faithfully reproduces an industrial environment where students can develop their skills in the installation and maintenance of industrial pumps. The system can be used to teach how to start up, operate, and troubleshoot industrial pumps in different configurations.

Due to its modular design, the Pumps Training System can be configured to fit various training needs. The following equipment is available to adjust the curriculum to various training levels:

- Centrifugal Pump - Pedestal
- Centrifugal Pump - C-face
- External Gear Pump
- Vane Pump
- Flexible Impeller Pump
- Progressive Cavity Pump
- Peristaltic Pump
- Pneumatic Diaphragm Pump
- Metering Pump
- Piston Pump
- Centrifugal Pump - Stuffing-Box
- Multi-Stage Centrifugal Pump
- Magnetic-Drive Centrifugal Pump
- Variable Speed Drive
- Upper Reservoir
- Lubrication Kit
- Alignment Kit
- Air Compressor
- Software and configuration software components
- Measuring instruments, including Paddle Wheel Flowmeters, Pressure Gauges, Current Clamp Meter, Pyrometer, Vibration Meter, Tachometer, Stroboscope, and more
- Tools and toolbox
- Hoses and accessories

All of the above components consist of industrial-type equipment and tools for realistic training.

We hope that your learning experience with the Pumps Training System will be the first step of a successful career.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

The job sheets in this manual provide a systematic and realistic means of learning how to install, use, and perform maintenance on industrial pumps.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

You should complete the basic safety procedures listed in Appendix B of this manual whenever you begin a job sheet.

Reference material

Refer to the manual *Pump Handbook* from McGraw-Hill as reference textbook (*Pump Handbook* is an option).

Appendices

Appendix A: *Equipment Utilization Chart*, indicates the components that are required to complete each job sheet.

Appendix B: *Safety Procedures*, lists the basic safety procedures to be performed before you begin a job sheet.

Appendix C: *Variable Speed Drive – Quick Start Guide*, summarizes the basic steps needed to install, start up, and program the Variable Speed Drive.

Appendix D: *Digital Pressure Gauge – Operating Instructions*, gives the instructions to operate the digital pressure gauge.

Prerequisite

To perform the job sheets of this manual, you should have a basic knowledge of mechanical drive systems.

Systems of units

Both U.S. customary units and SI units are used in this manual. The values associated with the SI units are shown between parentheses. When you have to fill a table with measurement results or plot a graph, do not forget to indicate the units associated with your measurement results.

Equipment manipulation

The pipe fittings at the inlet and outlet of the components are not designed to support and manipulate the components. Always support the components by the base.

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

NCCER accreditation

Contact the National Center for Construction Education and Research (NCCER), at *www.nccer.org*, to obtain the requirements relative to the NCCER accreditation of this course.

Care and maintenance of the Pumps Training System

Every week

- Check the general condition of the Pumps Training System.
- Check the condition of the snap-grip clamps on the hoses.
- Make sure the expanding work surface is solidly fixed on the Bench. Check the condition of the four (4) push-lock fasteners.

Once a month

- Check the operation of the ground fault circuit interrupter (GFCI).
- Make sure that an O-ring is present and in good condition in each hose coupling.

Every 6 months

- Replace the water in the reservoir.
- Add the following solutions to the water in the reservoir:

  - 2 fl oz (60 ml) of Antibacterial, p/n 38097.
  - 8 fl oz (240 ml) of Rust Inhibitor, p/n 38096.

Job Sheet 6

You should supervise the removal and installation of the bearing-shaft assembly. Damage to the Centrifugal Pump could occur if the work is not correctly done.

Sample
Extracted from
the Job Sheets Student
and the Job Sheets Instructor

Troubleshooting

Troubleshooting chart

Troubleshooting an ordinary centrifugal pump is mostly a process of logical elimination consisting of identification of the general problem followed by the solution. Typical symptoms and causes associated with centrifugal pumps are outlined in Table 7.

Table 7. Troubleshooting chart.

Symptom	Possible cause
Low or no flow rate	- restrictions in suction or discharge lines - clogged foot valve, strainer, or pump - air leak in suction line - air leak in mechanical seal - suction lift too great - reverse rotation of pump shaft - pump is not primed adequately - suction piping too small - discharge height too great - pump located too far from fluid source - impeller damage - pump is not operating at required speed
Low pressure	- pump is not primed adequately - air leak in suction line - excessive flow - clogged foot valve, strainer, or pump - reverse rotation of pump shaft
Pump vibrates and/or makes excessive noise	- misalignment - bent pump shaft - improper mounting - starved suction - worn bearings (or not adequately lubricated) - motor out of balance - operating beyond pump capacity - cavitation problem
Pump is leaking	- mechanical seal needs replacing - O-rings in pump housing damaged - oil seals needed replacing - piping not sealed properly - liquid being pumped too hot

Symptom	Possible cause
Motor runs hot or stops	- bad connection - excessive ambient temperature - binding rotation in the pump shaft - worn bearings (or not adequately lubricated) - specific gravity or viscosity of liquid higher than design conditions

Cavitation

Cavitation means that cavities or bubbles are forming in the liquid being pumped. It occurs when the pressure of the liquid at any point within the pump falls below the vapor pressure of the liquid being pumped.

To understand the occurrence of cavitation, it is important to remember that a liquid will vaporize at a relatively low temperature if its pressure is reduced sufficiently. Water, for instance, vaporizes at 100°F (38°C) when exposed to a vacuum of 28 inHg (711 mmHg).

Cavitation causes a loss in capacity, head, and efficiency. Implosion of the bubbles when they pass into the higher regions of pressure causes noise, vibration, and damage to pump. Most of the damage usually occurs within the impeller.

The minimum head required to prevent cavitation with a given liquid at a given flow rate is called the net positive suction head required (NPSHr).

Troubleshooting

OBJECTIVE

To troubleshoot a pumping circuit using a troubleshooting chart and by measuring the motor currents. To observe the effect of air ingestion and cavitation in the suction line.

PROCEDURE

⚠ CAUTION

Before proceeding with this job, complete the safety check list in Appendix B.

1. By referring to the troubleshooting chart in Table 7, give at least one symptom the following operating conditions may cause:

a. The pump shaft rotates in the wrong direction:

Low or no flow rate, low pressure.

b. The mechanical seals are broken:

Low or no flow rate, low pressure, pump leaks.

c. The motor shaft is not aligned with the pump shaft:

Pump vibrates and/or makes excessive noise.

d. Air leaks are present in the suction line:

Low or no flow rate, low pressure.

e. Bearings are worn:

Motor runs hot or stops.

f. The foot valve is clogged:

Low or no flow rate, low pressure.

g. There is no foot valve:

If the liquid source is lower than the pump inlet, the suction line will empty each time the pump stops. Priming the pump may be impossible.

Circuit setup

2. Replace the brass cover of the pump with the transparent cover as shown in Figure 33. Use the long screws with O-rings supplied with the transparent cover.

Figure 33. Centrifugal Pump with transparent cover.

CAUTION

Once the transparent cover is in place, hand-turn the impeller to make sure it does not touch the cover. If the impeller touches the cover while rotating, the transparency of the cover will be permanently affected.

3. Set up the circuit shown in Figure 23.

4. Install the Flow Control Valve FCV1 on the Expanding Work Surface as shown in Figure 34. Connect a tube between the Flow Control Valve and the Strainer inlet.

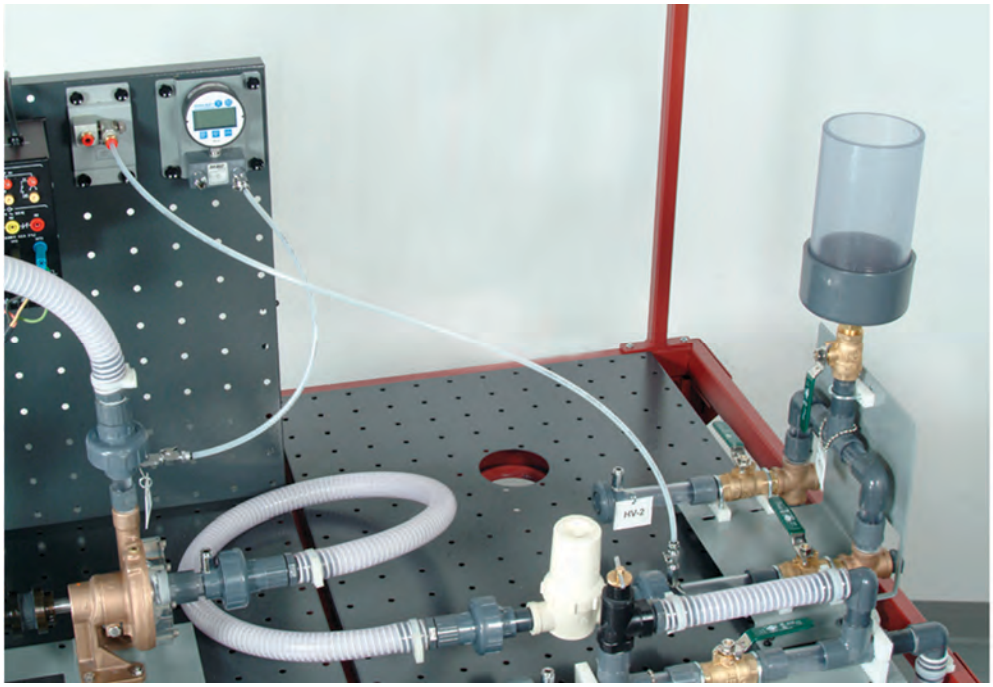

Figure 34. Circuit to troubleshoot.

Settings

5. Perform the following settings on the Relief Valve module:
   - Turn the lock nut fully counterclockwise.
   - Turn the control knob fully clockwise.
   - Open valve HV-4 by turning the handle fully counterclockwise.

6. Perform the following settings on the Variable Speed Drive:
   - Reset the parameters to default values.
   - Set the acceleration time to 5 seconds.
   - Display the output frequency.
   - Set the direction of rotation at reverse.

7. Close Flow Control Valve FCV1.

8. Prime the Centrifugal Pump.

9. Start the Centrifugal Pump, then set the output frequency to 40 Hz.

Make sure the suction of the pump is correct. If the suction is not correct, stop the pump, prime it, and restart.

Phase current measurements

10. Using a Current Clamp Meter, measure the current of each phase as shown in Figure 35.

U/T1: _____

V/T2: _____

W/T3: _____

U/T1: 1.7 A

V/T2: 1.7 A

W/T3: 1.7 A

Figure 35. Measuring the current using a Current Clamp Meter.

In normal operation, the phase current values are lower than the nominal value shown on the motor nameplate, and the current value on each phase is approximately equal.

11. Are the phase current values below the nominal value shown on the motor nameplate and approximately equal?

❑ Yes ❑ No

Yes

Cavitation

12. Install the Digital Stroboscope as shown in Figure 36. The Digital Stroboscope is used to observe the cavitation bubbles in the water.

The Digital Stroboscope is optional. If you do not have a stroboscope, you will not be able to see bubbles as clearly.

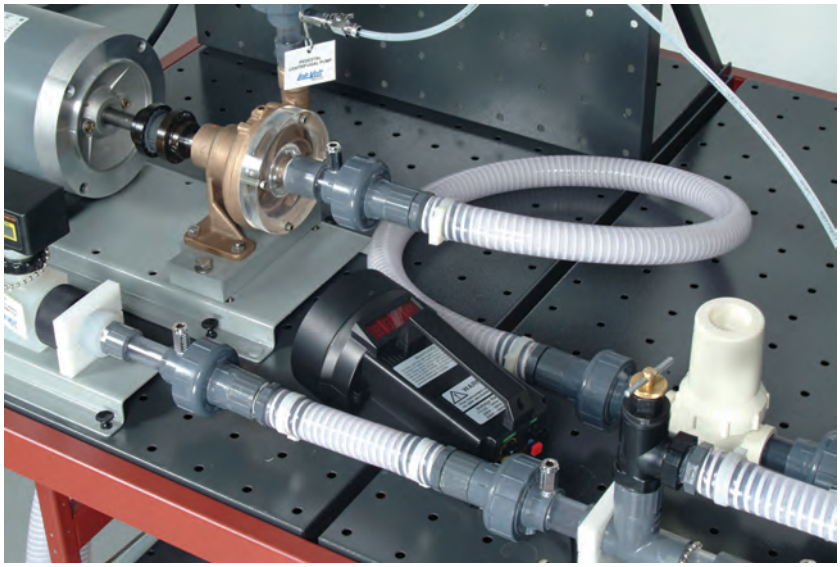

Figure 36. Installation of the Digital Stroboscope.

CAUTION

The lamp used in the Digital Stroboscope, p/n 46794, has time restrictions on usage. Under 3000 r/min (which equals the FPM rate, or strobe flashes per minute), the maximum operating time is 30 minutes, and above 3000 r/min, it is 5 minutes. The cool-off time is 10 minutes.

13. On the Variable Speed Drive, set the output frequency to 30 Hz.

14. Adjust the flash rate of the Digital Stroboscope to obtain a stop-motion of the impeller (approximately 1800 r/min).

15. Close valve HV-3 while observing inside the pump near the eye. Do you observe bubbles?

❑ Yes ❑ No

Yes

16. Measure the pressure at the pump inlet.

Pressure at the pump inlet: _____

Pressure at the pump inlet: -14.5 inHg (-368 mmHg)

17. On the Variable Speed Drive, set the output frequency to obtain a pump speed of approximately 3000 r/min.

18. Adjust the flash rate of the Digital Stroboscope to obtain a stop-motion of the impeller.

19. Measure the pressure at the pump inlet.

Pressure at the pump inlet: _____

Pressure at the pump inlet: -26 inHg (-660 mmHg)

20. What do you observe about the bubbles inside the pump? Explain.

There are many more bubbles inside the pump. More bubbles are forming in the liquid because the pressure at the pump inlet has decreased.

21. Observe the cavitation produced by a valve. To do so, perform the following manipulations:

- Close Flow Control Valve.
- Make sure the suction of the Centrifugal Pump is restored.

- Slowly close valve HV-3 until you observe cavitation. You may use the Digital Stroboscope to observe the bubbles in the transparent section of the pipe near the valve, and you may also be able to hear the noise generated by the bubbles bursting.

Air ingestion

22. Open valve HV-3, make sure that suction of the pump is correct. If the suction is lost, stop the pump, prime it, and restart.

23. On the Variable Speed Drive, set the output frequency to 40 Hz.

24. Adjust the flash rate of the Digital Stroboscope to obtain a stop-motion of the impeller.

25. Measure the flow rate.

Flow rate: _____

Flow rate: 10.45 gal US/min (39.6 l/min)

26. Open Flow Control Valve FCV1 very slowly to inject air in the suction line.Do you observe bubbles in the suction and discharge lines?

❑ Yes ❑ No

Yes

If too much air is injected in the water, the pump will lose its suction. To restart the pumping circuit, stop the pump, close Flow Control Valve FCV1, prime the pump, and restart the pump.

27. Describe a condition that could cause air ingestion in a suction line.

Leakages through valves and flanges above the water line.

Both cavitation and air ingestion produce bubbles. However, the bubbles resulting from air ingestion do very little damage to the impeller and housing walls. The main effect of air ingestion is loss of capacity.

28. Vary the quantity of air injected in the suction line while observing the Paddle Wheel Flowmeter display. How does the flow rate vary when air is injected?

The flow rate decreases when more air is injected in the suction line.

29. What happens to the flow rate when Flow Control Valve FCV1 is fully open?

The Centrifugal Pump loses its suction and the flow rate becomes null.

30. Ask the instructor to check and approve your work.

31. Stop and drain the system.

32. Disconnect your setup and return the equipment to the storage location.

Student's work assessment

The following points should be checked:

- The answers to questions are correct.
- The student is able to observe the oscillations in the discharge line when air is injected into the suction line.

Name: _____ Date: _____

Instructor's approval: _____