Industrial Maintenance
Pumps Training System

Multiple 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

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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 any of the job sheets in this manual.

Prerequisite

To perform the job sheets of this manual, you should have completed the manual Single Pump Systems, p/n 37894.

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.

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

Centrifugal Pumps in Series

When the centrifugal pump of an existing system no longer meets the requirements in regard to maximum head, a second pump can be added in series. This is performed by connecting the discharge line of one pump to the suction line of the other pump as shown in Figure 4.

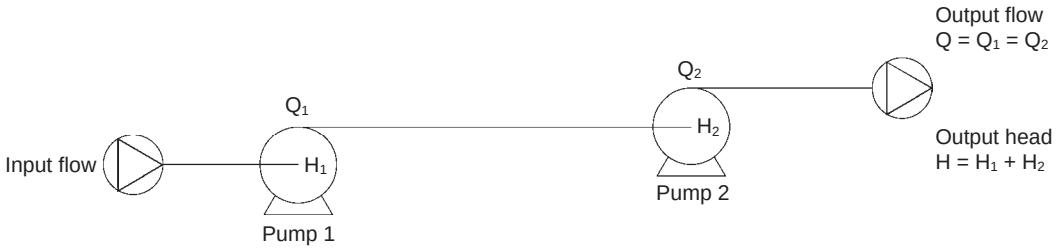

Figure 4. The discharge line of one pump is connected to the suction line of the other pump.

When both pumps are identical and driven at the same speed, the following occurs:

- Both pumps deliver the same flow rate. Consequently, the output flow rate of the system is equal to the flow rate passing through each pump.
- Both pumps produce the same discharge head, so that they both contribute to the head developed in the system. Consequently, the head produced by both pumps is the sum of the individual heads.

Figure 5 shows an example of the resulting head versus flow rate curve for two identical pumps driven at the same speed in series, compared to that for a single pump.

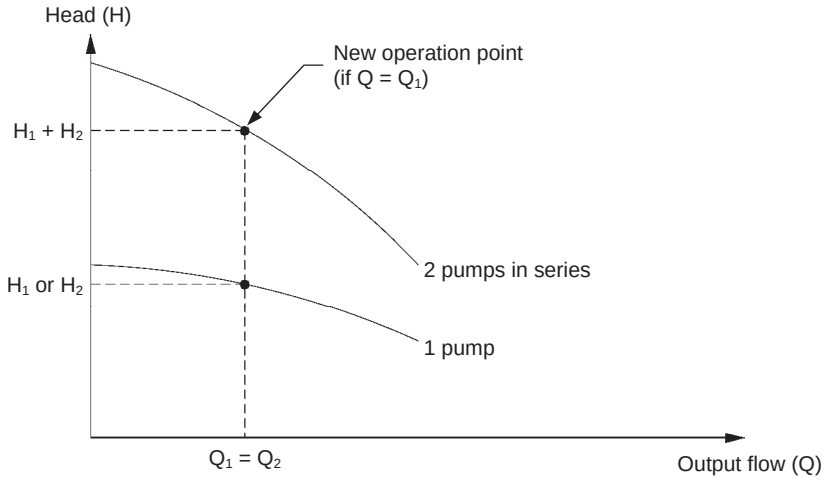

Figure 5. Head versus flow rate curves for a single pump, and two identical pumps in series.

To obtain the same flow rate with two pumps in series, it is usually necessary to increase the head losses (restrictions) in the flow, for example, by further closing a valve in comparison with the circuit with one pump alone.

Centrifugal Pumps in Series

OBJECTIVE

To observe the effects that connecting two centrifugal pumps in series have on the maximum head and flow rate, as compared to when a single pump is used.

PROCEDURE

⚠ CAUTION

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

Circuit setup

1. Setup the circuit shown in Figure 6.

To prevent component damage, make sure to place the components at the locations shown in the figure.

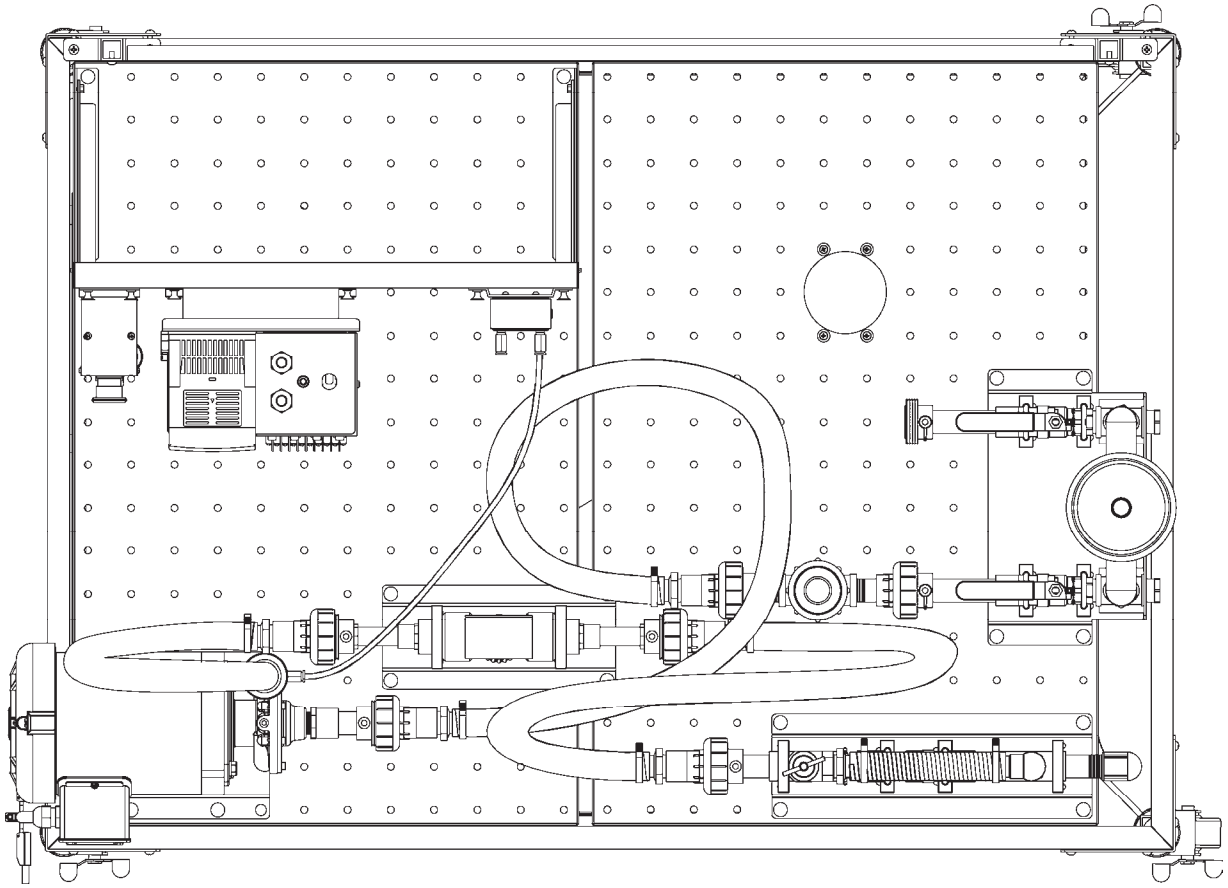

Figure 6. Circuit using a C-face Centrifugal Pump.

2. Make sure the water level in the reservoir is correct.

Settings

3. Perform the following settings on the Relief Valve module:
   - Turn the lock nut fully counterclockwise.
   - Turn the control knob fully clockwise.

4. 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.

CAUTION

Prior to supplying liquids to the C-Face Centrifugal Pump, check the rotation direction by momentarily energizing the motor. Incorrect rotation can cause pump damage.

5. Prime the C-face Centrifugal Pump.

6. Start the C-face Centrifugal Pump, then set the output frequency to 50 Hz.

Measurements

7. By adjusting valve HV-4, vary the flow rate from 0 to 20 gal US/min (0 to 75 l/min) by increments of 2 gal US/min (7.5 l/min). For each setting, measure the head at the C-face Centrifugal Pump outlet. Enter your results in Table 1.

Table 1. Head and flow rate characteristics for a single pump and two pumps in series.

Flowrate	Head	
	One pump	Two pumps in series

Table 1. Head and flow rate characteristics for a single pump and two pumps in series. Results shown in U.S. customary units.

Flowrate (gal US/min)	Head (ft)	
	One pump	Two pumps in series
0	35.5	77.2
2	31.4	69.0
4	29.3	65.5
6	27.2	61.5
8	24.7	57.3
10	21.4	52.4
12	18.5	47.3
14	14.3	40.4
16	-	33.0
18	-	24.8
20	-	-

Table 1. Head and flow rate characteristics for a single pump and two pumps in series. Results shown in SI units.

Flowrate (l/min)	Head (m)	
	One pump	Two pumps in series
0	10.82	23.53
7.5	9.57	21.03
15.0	8.93	19.96
22.5	8.29	18.75
30.0	7.53	17.47
37.5	6.52	15.97
45.0	5.64	14.42
52.5	4.36	12.31
60.0	-	10.06
67.5	-	7.56
75.0	-	-

8. Stop the C-face Centrifugal Pump.

9. Disconnect the C-face Centrifugal Pump from the Variable Speed Drive.

10. Modify your circuit to add a centrifugal pump in series with the existing pump as shown in Figure 7.

To prevent component damage, make sure to place the components at the locations shown in the figure.

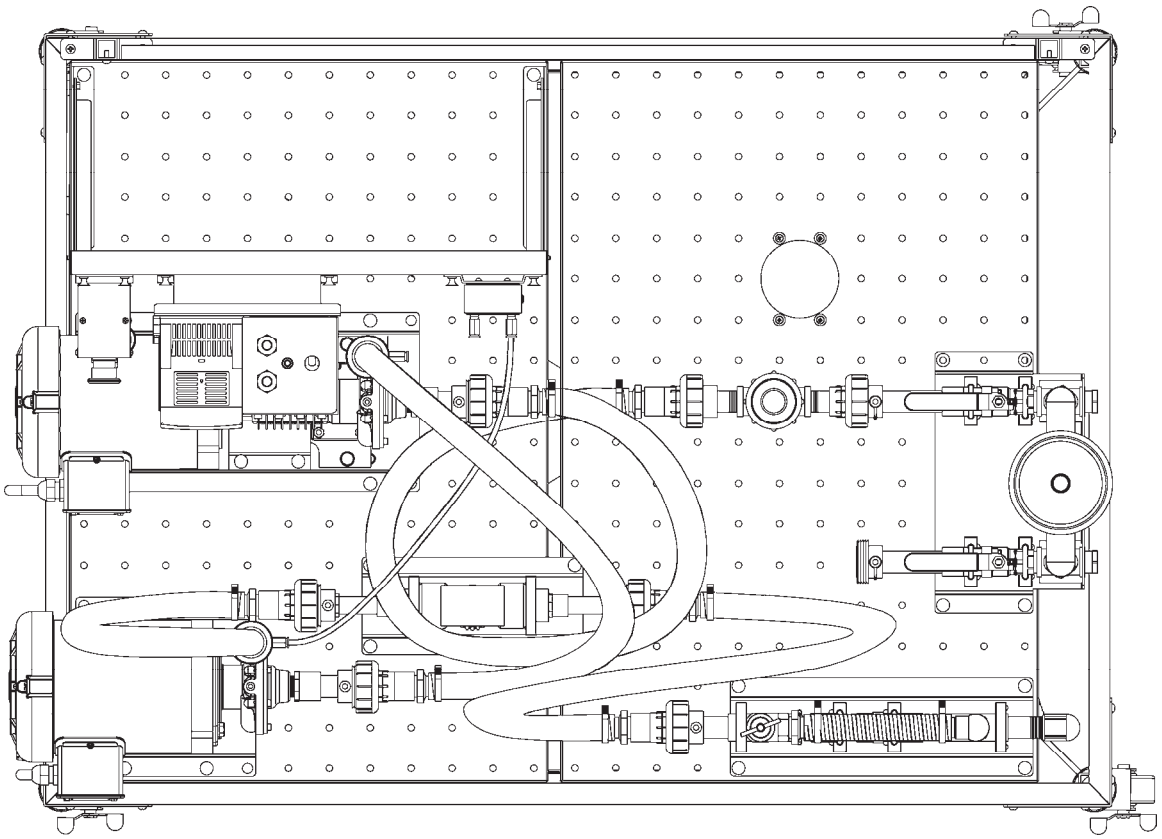

Figure 7. Circuit using two centrifugal pumps connected in series.

11. Connect both centrifugal pumps to the Variable Speed Drive.

To operate both pumps with only one Variable Speed Drive, the PWM frequency parameter must be set to 4 kHz, or less. The available output current may be not sufficient at higher frequencies.

12. Prime the pumps.

13. Start the pumps, then set the output frequency to 50 Hz.

14. Complete Table 1 by measuring the head at the C-face Centrifugal Pump outlet for the flow rate values shown.

15. Stop the pumps.

16. Using the values of Table 1, plot the head versus flow rate curves for a single pump and for two pumps connected in series in Figure 8.

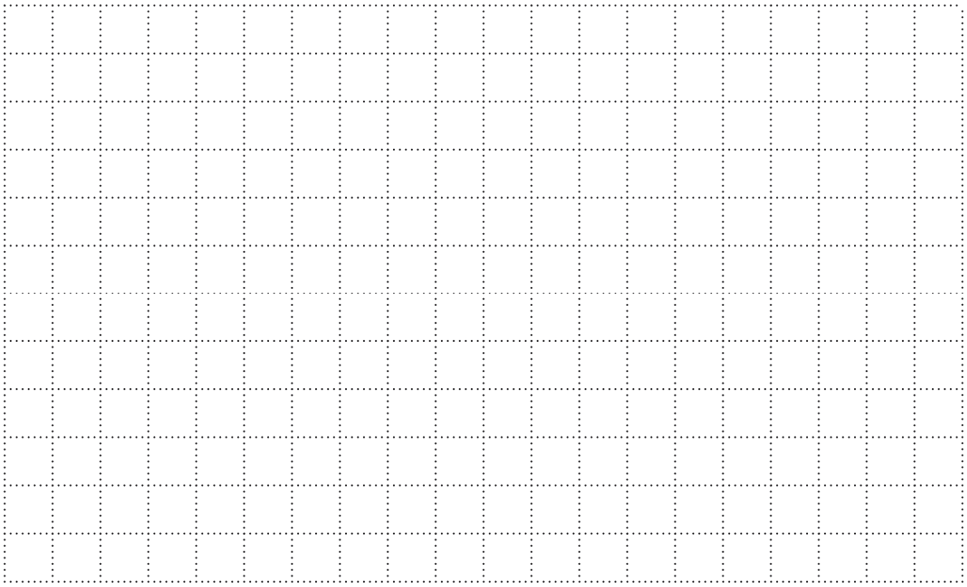

Figure 8. Head versus flow rate curves for a single pump and two pumps connected in series.

17. Compare the head produced by two centrifugal pumps connected in series to that produced by a single pump when the flow rate is 8 gal US/min (30 l/min). What can you conclude from your results.

The head produced by two centrifugal pumps connected in series is approximately double that developed by a single pump.

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

19. Stop and drain the system.

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

Student's work assessment

The following points should be checked:

- The circuit is correctly mounted.
- The students observe that connecting two pumps in series allow higher heads to develop in the system.

Name: _____ Date: _____

Instructor's approval: _____