CLEAN-IN-PLACE UNIT
Construction and Operation Manual

Low-cost, Clean-In-Place (CIP) unit for small and very small meat processors
ADVANCE COPY

Construction and operation manual for:
Low-cost, Clean-In-Place (CIP) unit for small and very small meat processors
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INTRODUCTION
Many small and very small meat processors around the country need improved cleaning equipment and techniques for food-contact surfaces – especially for vessels, tanks, pumps, mixers, and similar equipment with surfaces that are difficult to access. Larger tanks are dangerous to enter, making them nearly impossible to effectively clean by hand. Smaller tanks and mixers cannot be entered at all and many are brush-washed from awkward angles.

Manual cleaning methods are difficult to validate and are not as repeatable as mechanical cleaning cycles. Also, manual cleaning can subject operators to handling, inhalation and splashing hazards associated with cleaning chemicals which may be strong acids or bases. Finally, manual cleaning systems may be more expensive to operate than mechanical systems due to an increased usage of chemicals, water, energy, labor, process time, and other resources.

Clean-In-Place (CIP) systems are the state-of-the-art for cleaning dairy and pharmaceutical processing systems. They are often highly automated, and are designed to completely clean a processing system without disassembly of equipment. CIP systems have the following advantages:

- Repeatable process that can be validated
- Save energy and chemical costs
- Reduce labor requirements
- Reduce wear-and-tear on equipment
- Reduce operator hazards associated with handling and inhaling cleaning chemicals

CIP systems are rarely installed in small and very small meat processing operations for one or more of the following reasons: (1) they are expensive; (2) most facility managers do not have experience with CIP systems techniques; (3) operator training is required; and, (4) selection of cleaning chemicals is not well understood. Commercially available CIP systems are expensive, with prices starting at over $30,000 for a single-use, skid-mounted unit. Freight, installation, and training costs are additional. Selection of chemical cleaning supplies for CIP systems is highly dependent upon the nature of the surfaces to be cleaned, the soils present in the system, the CIP methodology, and the chemistry of the cleaning agent(s). Cleaning chemical selection is often a complex process that brings an unwanted, additional responsibility to facility managers.

The purpose of this document is to report on an inexpensive, reliable, and simple CIP system designed to facilitate equipment and product-contact surface cleaning for small and very small meat processors. Processors will be able to build the CIP unit themselves, using off-the-shelf components that are readily available. The CIP unit will be a single-use system (cleaning chemicals and rinse solutions are not saved for reuse) with capacity to clean vessels up to 12 feet in diameter and all instrumentation necessary for cleaning process verification.
CIP THEORY
Control and documentation of four variables is critical to the operation of the single-use CIP system described:

1. Temperature
2. Pressure
3. Chemical concentration
4. Cleaning time

Temperature
Temperature of the CIP cleaning solutions is critical to their effectiveness and should be recorded throughout the cleaning process for verification. The operating temperature range is determined by process requirements and cleaning chemical activity. Very often the cleaning chemical supplier will recommend the ideal temperature range for the optimal use of their product under the given process conditions.

Pressure
Adequate pressure in CIP fluid circulation systems is necessary for reliable performance of spray devices. Pressure also serves as an indication of flow (CIP solution pressure is proportional to the square of its velocity). Design pressures are determined by the requirements stated by the manufacturer of the spray device. For example, the manufacturer of a stationary drum nozzle might recommend a minimum pressure of 40 psi for effective operation. Fluid pressure is periodically measured and recorded in the CIP system for documentation of proper cleaning.

Chemical Concentration
Cleaning chemical concentration is an important measurement of cleaning effectiveness. Too much chemical may be a waste of material; too little may result in an incomplete cleaning process. Optimal chemical concentration levels are recommended by the chemical supplier and determined by experience. Chemical concentration is measured in the described system either volumetrically (e.g. teaspoon, cup, gallon) or gravimetrically (e.g. grams, ounces, pounds). Chemicals are measured in the appropriate amount and added to the system’s water holding tank. See appendix A for sample calculations of cleaning chemical amounts.

Cleaning Time
Cleaning cycle time refers to the amount of time that cleaning solutions are in contact with surfaces being cleaned while required conditions (temperature, pressure, concentration) are met. Cycle time is determined by many factors that include processing line availability (considering for example, production and labor factors), chemical concentration and cost, soil amounts and characteristics, composition of flexible seals and metal and plastic surfaces. A data logger is used to time-stamp all data, providing a record of cleaning cycle time.

Cleaning Cycle
A typical CIP cleaning cycle consists of three steps:

1. Rinse
2. Wash
3. Rinse
The first step is a clear-water rinse that removes heavy soils and loose debris. Washing is the second step that places cleaning solutions in contact with the soiled surfaces for a given time at a specified temperature; impingement, flow, and chemical activity of the cleaning solution work together to remove soils. The final (third) step is a rinse that removes any residual cleaning solution and loosened soils. After cleaning, surfaces are air dried, heated to assist evaporative drying, or blown dry using clean, compressed air.

CIP SYSTEM DESCRIPTION

An image of the basic CIP system developed for small and very small meat processors is shown in figure 1. Design, construction, and evaluation of the prototype CIP system was completed in the Food Engineering Laboratory of the Food and Agricultural Products Center (FAPC), at Oklahoma State University, Stillwater. The design is flexible, and can be adapted to suit site conditions and available equipment and materials without sacrificing system performance. The main components of the system are a (1) holding tank, (2) pump, (3) spray device, (4) foaming wand, and (5) data logging system (the foaming wand and data logging system are not shown in figure 1). Table 1 gives a parts list for the CIP system complete with a description of each part, source, part number, quantity and cost. Similarly, tables 2 and 3 list parts for the foaming wand and data logging systems, respectively.

Figure 1. CIP system mounted on carts. Left cart holds water tank (one of two tank carts shown) and right cart holds pump, electrical cord, small parts, and provides a work surface.
<table>
<thead>
<tr>
<th>Part No.</th>
<th>Products Needed</th>
<th>Source</th>
<th>Src. Part No.</th>
<th>Quantity</th>
<th>Price Each</th>
<th>Total Price</th>
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<td>$3.56</td>
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<td>$6.24</td>
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<td>$1.90</td>
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<tr>
<td>11</td>
<td>Portable sprinkler pump</td>
<td>Northern Tool</td>
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<td>$149.99</td>
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<td>12</td>
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<td>US Plastic Corp.</td>
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<td>$0.54</td>
<td>$1.08</td>
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<td>$4.68</td>
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<td>$1.09</td>
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<td>$2.55</td>
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<td>$1.00</td>
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<td>20</td>
<td>pressure gauge (0 to 60psig)</td>
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<td>$23.93</td>
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<td>$1.84</td>
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<td>26040</td>
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<td>32</td>
<td>stationary stainless 270° drum nozzle</td>
<td>McMaster Carr</td>
<td>32225K31</td>
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<tr>
<td>33</td>
<td>rotating plastic drum nozzle</td>
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<td>71445T84</td>
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<tr>
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<td>1/2&quot; threaded PVC coupling</td>
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<td>Part No.</td>
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<td>Price Each</td>
<td>Total Price</td>
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<td>39</td>
<td>utility cart</td>
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<td></td>
<td><strong>Total Cost</strong></td>
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Table 2: Foaming wand parts list

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<th>Quantity</th>
<th>Price Each</th>
<th>Total Price</th>
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<tr>
<td>51</td>
<td>3/4&quot; X 1/4&quot; threaded reducer bushing</td>
<td>US Plastics</td>
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<td>$1.09</td>
<td>$1.09</td>
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<td>52</td>
<td>1/4&quot; male tube connector</td>
<td>US Plastics</td>
<td>58333</td>
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<td>53</td>
<td>3/8&quot; O.D. 1/4&quot; I.D. hose (heavy)</td>
<td>US Plastics</td>
<td>58083</td>
<td>10 ft</td>
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<td>$18.90</td>
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<td>54</td>
<td>1/2&quot; X 1/4&quot; threaded reducer bushing</td>
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<td>59</td>
<td>Foam Jet spray wand nylon body</td>
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<td>60</td>
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<td>61</td>
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Table 3: Data logger system parts list

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<th>Part No.</th>
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<th>Src. Part No.</th>
<th>Quantity</th>
<th>Price Each</th>
<th>Total Price</th>
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<td>Davis Inotek</td>
<td>SU139</td>
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<td>$225.00</td>
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<td>Logit model LL5 PC software</td>
<td>Davis Inotek</td>
<td>SU137</td>
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<td>$60.00</td>
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<td>77</td>
<td>PDA (optional for reading data)</td>
<td>TheNerds.net</td>
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<td>261.03</td>
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<tr>
<td>78</td>
<td>PDA case (optional)</td>
<td>TheNerds.net</td>
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<tr>
<td></td>
<td><strong>Total Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>$285.00</strong></td>
</tr>
</tbody>
</table>

Total Cost (less options) $285.00
Holding Tanks
The holding tanks (table 1, part no. 1) we selected were 55 gallon plastic containers with a cover and a threaded discharge port in the side wall. One tank was used to hold rinse water, while the other was used to hold the cleaning solution. The ideal tank would be corrosion resistant and made of an FDA approved material (for food contact) that will withstand process temperatures and cleaning solutions. Many farm stores have tanks in stock that may work; a clean, food-grade plastic barrel can also be used. Rinse water temperatures may vary from available temperature up to 130 °F, according to the application. Cleaning solution temperatures can be anticipated to be in the range of 130 to 160 °F (the cleaning chemical supplier should be consulted to determine the optimum temperature for cleaning).

Pump
A stainless steel “sprinkler” pump (table 1, part no. 11) was selected for the system because of its low price, corrosion resistance, built in switch, and capability to supply adequate volumes of fluid in the pressure range desired. Pressure and flow requirements are determined by the spray nozzle selected (see below).

Spray Devices
A spray device (table 1, parts no. 32, 33, 36, and 38) is a mechanism used to apply CIP fluids to a surface that require cleaning. Two general types of spray devices are available: static and dynamic. Static spray devices are motionless heads with drilled or fixed “nozzles”. Spray balls are the most common (see figure 2 a). Static spray balls are normally designed for a flow rate of 20 to 30 gpm and 20 to 30 psi pressure drop. The effective cleaning diameter of a static spray ball is about 8 to 12 feet. Dynamic spray devices have a moving spray head or body, which is driven by the cleaning media (see figure 2 b) and/or mechanical means. Dynamic spray devices often have improved cleaning capabilities compared to fixed spray balls, but require increased maintenance due to the moving parts.

Foaming Wand
The CIP system also includes a foaming wand (see figure 3, and table 2) which is capable of producing a rich, foamy lather of cleaning chemicals and water for surface cleaning applications. The foam structure wets the entire area to be cleaned, maintaining prolonged contact between the cleaning compounds and the surface. The foam is applied to a surface and left in place to give the chemical time to dissolve soils. Afterward a water-hose is used to rinse the surface clean.

Figure 2. Spray devices: (a) static and (b) dynamic
CONSTRUCTION
This section provides a construction guideline for the CIP system. The end user is encouraged to use creativity to improve and customize the CIP system to meet the unique needs of the application. For example, equivalent parts can be substituted for those specified based on factors such as cost and availability. The construction guidelines given below refer to Tables 1, 2 and 3, which list parts and materials.

Drum Platform
The drum platform holds an inverted drum for cleaning. The platform is designed to work with open-head drums or drums with bungs. Materials required are 1” square steel tubing (table 1, part no. 40) and 2” round steel tubing (table 1, part no. 41). Tubing was cut to size and welded as shown in Figures 4 and 5. The welds were ground smooth on the top surface. The shape of the frame allowed the cleaning nozzle mount to be placed in the middle of the platform (to coincide with the axis of an inverted, open head barrel) and wherever the bung was located on a closed-end barrel. The platform was coated with a corrosion-resistant paint to prevent rusting. Corrosion-resistant, stainless steel tubing would be a superior choice if it is available.
Nozzle Mount Base
The nozzle mount base holds the spray nozzle in place to deliver the cleaning chemical into a barrel. Materials include a steel plate (table 1, part no. 42), 1” round steel tubing (table 1, part no. 43), and two short sections of 1” square tubing (table 1, part no. 40). Cut a 4” section of the 1” round steel tubing laterally into two semi-circles. These will serve as the cradles for the nozzle mount pipe. Cut and weld the pieces as designated in Figure 6, making sure that the two cradles are in line with each other. The nozzle mount base should also be painted with corrosion-resistant paint, or preferentially made of stainless steel.
Tank Fitting
The tank fitting (table 1, part no. 2) is a threaded female fitting that is attached at the base wall of the tank and attached piping (see drawing in figure 7). The fitting may either be ordered installed on the tank by the manufacturer (recommended) or it can be installed by the user as a separate component. If you elect to install the fitting yourself, cut the hole in the tank wall leaving adequate clearance between the bottom of the tank and the fitting’s outer diameter. If the hole is drilled too close to the base of the tank, the tank fitting will not tighten sufficiently. A photo of the installed tank fitting and piping is given in figure 8.

Figure 7. Drawing of tank fitting and attached piping.

Figure 8. Photo of tank fitting and attached piping.

Carts
Three plastic utility carts (table 1, part no. 39) were used to manage and transport the pump and holding tanks. The plastic carts are inexpensive, durable, and corrosion resistant, but many alternatives (left to the reader’s
imagination) are available. Holes were drilled in the lower shelf of the pump cart and the sprinkler pump was fixed to the surface with four bolts. The upper shelf of each of the tank carts was cut out to accommodate the tank (see figure 1). Wooden blocks were used to raise the tank outlet level (see figure 8) to a point that was higher in elevation than the pump inlet to promote liquid flow. The hose leading from the tank to the pump should always slope downward toward the pump to prevent air lock. Tanks must be securely attached to the cart using plastic strapping or a corrosion-resistant cord or band.

**Pump Fittings**

The pump fittings connect the pump to the flexible hoses used to supply and discharge fluids from the pump as shown in the drawing of figure 9. Note the inlet and outlet ports of the pump, and tighten all fittings securely to avoid leakage. The data logger’s pressure sensor is attached in parallel to part 20 as shown in figure 10.

![Figure 9. Pump fittings assembly drawing, part numbers correspond to numbers in table 1.](image-url)
Nozzle Mount
The nozzle mount holds the spray nozzle in the proper position (elevation) for cleaning a barrel or tank and is shown in figures 11 and 12. The length of parts 28 and 30 was determined by field conditions. We used a cut length of 24 inches for part 28 and 24 inches for part 30 in our system. PVC glue is required for the construction of these pieces. Glue all of the PVC sockets securely to prevent leakage. Four different nozzles are mentioned in this assembly diagram, but only one is needed for operation. Refer to the Testing and Validation section to review the conclusions about nozzle selection for help with your choice of nozzles. Some patient research will reveal other nozzles that can be purchased for use and experimentation.
Attachment of Nozzle Mount to Nozzle-Mount Stand
Two worm drive clamps (table 1, part no. 23) were used to attach the nozzle mount to the nozzle base (Figure 12). The worm drive clamps should be attached so that the screw side is on the bottom side of the cradle. This will assure that the clamps have a good grip on the nozzle mount, preventing slippage or twisting during operation.

Figure 12. Photo of nozzle mount and base.

Foam System
A wand with a specially-designed nozzle can be used to produce a coating of foamed cleaning chemicals and water. The purpose is to produce long-lasting foam that clings to the surfaces being cleaned. Refer to Table 2 for the products required to build the foaming wand. Concentrated chemicals are stored in a separate container (table 2, part no. 63) and siphoned into the wand through an adjustable valve (table 2, part no. 55). Parts are assembled as shown in Figure 13. Test the grip strength of each tube connector (table 2, part no. 52) on the tubing during construction. Part no. 50 (table 2) mates directly to the pump discharge hose fitting. This will attach directly to the hose-hose adapter (table 1, part no. 22) on the ¾” poly tube (table 1, part no. 24)

Figure 13. Foam system assembly drawing. Numbers correspond to part numbers in table 2.
DATA COLLECTION SYSTEM
The data collection system was selected for simplicity, low-cost, and reliability. It is capable of simultaneously recording pressure and temperature and time data at intervals from 1 second to 6 hours. Figure 14 shows the instrumentation system components (which are listed in tables 1 and 3). The analog pressure gage was used to obtain a quick visual reading of system pressure near the pump outlet and was connected in parallel with the electronic pressure sensor using a quick-connect tee. The thermocouple was placed in the plastic holding tank (table 1, part no. 1) to sense the cleaning solution temperature. The software and interconnecting cable for the data collection system is sold separately from the data logger.

Figure 14. Data collection system components.

OPERATION PROCEDURE
Barrel or Tank Wash
This procedure illustrates the use of a spray device for cleaning the interior surfaces of a tank or barrel. The description below is dedicated to inverted barrels, but can easily be adapted for washing standing tanks and enclosures. In any case, drainage is an important issue. Cleaning solutions must not accumulate (pond) in tanks or barrels. Accumulated cleaning solutions are not effective at cleaning and may leave a “bath tub ring” after drainage.

Setup
1. Setup the data logger according to your needs and process requirements. Normally a data recording interval of about 30 seconds is sufficient. The logger can be programmed to start collecting data when the sliding door on the data cable port is closed. This provides a convenient means of starting the data collection process if the data logger is set up using a PC at a remote location.
2. Close the rinse tank discharge valve and fill with potable water at the appropriate temperature for rinsing the container (normally tap water is used).
3. Close the wash tank discharge valve and add the pre-measured cleaning compound to the tank. Fill with potable water at the appropriate wash temperature to the required level. Immerse the thermocouple from the data logger in the cleaning solution.
4. Connect the pump inlet to the rinse tank outlet using the 1.5” flexible hose with cam-lock connectors.
5. Position the nozzle mount over a floor drain and place the drum platform over the nozzle mount, inserting the nozzle through the center hole of the platform as shown in Figure 15 (for an open-head
drum). If the barrel has a bung, position the nozzle mount in any open area of the platform that corresponds to the bung location of the inverted barrel. Connect the pump outlet to the nozzle mount inlet using the ¾” flexible hose with cam-lock connectors.

![Figure 15. Drum platform and nozzle mount.](image)

6. Invert the drum over the nozzle head and onto the drum platform. The nozzle should be in the center of the drum (if possible) for the most even coverage.
7. Make sure the pump is turned off and plug it into the power source.
8. Activate the data logger by closing the door on the data cable port.

**Rinse**
1. If not already connected, connect the pump inlet to the rinse tank outlet using the 1.5” flexible hose with cam-lock connectors.
2. Open the 1-1/2” ball valve on the rinse water holding tank, making sure that water flows through the tubing and into the pump’s inlet.
3. Open the ½” ball valve on the nozzle mount.
4. Turn the pump on. **Warning: to avoid equipment damage, never operate the pump dry.**
5. After completion of rinsing, turn off the pump and close the ½” ball valve on the nozzle mount and the 1-1/2” valve on the plastic holding tank.

**Wash**
1. Connect the pump inlet to the wash tank outlet using the 1.5” flexible hose with cam-lock connectors.
2. Open the 1-1/2” ball valve on the wash water holding tank, making sure that water flows through the tubing and into the pump’s inlet.
3. Open the ½” ball valve on the nozzle mount.
4. Turn the pump on. Figure 16 (a) shows the system in operation; and 8 (b) is a conceptual diagram showing the cleaning action inside the drum **Warning: to avoid equipment damage, never operate the pump dry.**
5. Turn the pump off and close the ½” ball valve on the nozzle mount and the 1-1/2” valve on the plastic holding tank.
6. Repeat the rinse cycle
Figure 16. CIP drum cleaning photo (a) and conceptual diagram of cleaning action (b).

Complete
1. If more than one drum is to be cleaned, mount a new drum on the platform and restart the rinse/wash/rinse cycles.
2. Turn off the pump and unplug.
3. For storage, detach all cam couplings, allowing water to drain out of the pump and the tubing.

Foaming Wand
The foaming wand provides a rapid means of generating foam for cleaning exposed surfaces. Operation of the wand is as follows:
1. Connect the wand inlet to the pump outlet using the flexible hose (table 1, part no. 24).
2. Fill the detergent jug (table 2, part no. 63) with the appropriate foaming/cleaning agent.
3. Open the 1-1/2” ball valve on the plastic holding tank, making sure that water flows through the tubing and into the pump’s inlet. Do not operate the pump dry.
4. Plug the pump into a power source; then turn the pump on.
5. The siphon injector (table 2, part no. 55) should have its adjustable valve opened about 1/2 turn to start operation and then should be adjusted appropriately by the operator to produce foam with the desired consistency.
6. When foaming is complete, turn off the pump and unplug.
7. Close the 1-1/2” ball valve on the plastic holding tank.
8. Disconnect the cam couplings and drain the hoses and wand for storage.

TESTING AND VALIDATION
Several tests were performed to quantify the performance of the drum cleaning system, to evaluate the possible nozzles, and to test the other components. Tests included: (1) a coverage test, which is used to determine how completely a spray nozzle wets a surface for cleaning; (2) spray nozzle evaluation; (3) foaming wand evaluation; and, (4) data logging system evaluation. The tests and results are explained below.

Coverage Test
CIP solutions should contact and thoroughly wet surfaces in order to clean them adequately. A coverage test was designed to evaluate how well a nozzle wetted the surfaces to be cleaned. Tests were performed by coating
a water-soluble dye (0.2 gram/liter SIGMA #R-4500 riboflavin, applied with a hand-pumped agricultural sprayer) on the surfaces to be cleaned and then washing it off using pure water applied through a spray device. Riboflavin dye is easy to spot because it appears bright green under black light (see figure 17 (a) and (b)). Dye removal is visually observed and the system is adjusted until all dye is consistently removed. Adjustments may include the position of the spray nozzle, water flow rate, and changing the nozzle type. Note: if powdered riboflavin is not available, vitamin B-2 tablets can be substituted by crushing the tablet and dissolving in water at approximately the same proportions as the powdered product.

Figure 17. Riboflavin dye test: (a) fluorescent dye appearing on tank surface before rinsing, and (b) residual dye remaining in “shadow” of agitator after rinsing.

For our coverage tests, a solution of riboflavin and water was sprayed on the inside surfaces of a plastic drum. The drum was inverted onto the drum platform. Distance from the nozzle to the bottom of the drum was approximately 2 feet. The drum was rinsed for one minute using tap water at room temperature and at the standard flow rate and pressure specified for the spray nozzle. After rinsing, the barrel was turned upright and inspected with a black light for residual marker dye.

Four different nozzles (see table 1, items no.32, 33, 36, and 38.) were used to test the CIP drum system. Two were stationary nozzles and two were rotating nozzles. Table 4 summarizes the findings for each nozzle tested and also lists initial and annual operating cost estimates for each spray nozzle. Operating cost was estimated based on the recommended flow rate for each nozzle and assuming 10 drums cleaned per day, 250 working days per year, 5 minutes per wash cycle, and $1.50 per 1,000 gallons of water.
Table 4. Nozzle performance (nozzles listed in no particular order).

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Photo</th>
<th>Initial Cost</th>
<th>Operating Cost</th>
<th>Coverage test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>180° Stationary (38)</td>
<td></td>
<td>$115.00</td>
<td>$143/year</td>
<td>Complete coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low impact</td>
</tr>
<tr>
<td>Plastic Rotating (33)</td>
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<td>$47.70</td>
<td>$118/year</td>
<td>Complete coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High impact</td>
</tr>
<tr>
<td>Stainless Steel Rotating (36)</td>
<td></td>
<td>$170.52</td>
<td>$122/year</td>
<td>Complete coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High impact</td>
</tr>
<tr>
<td>270° Stationary (32)</td>
<td></td>
<td>$99.62</td>
<td>$105/year</td>
<td>Incomplete coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>on bottom of drum</td>
</tr>
</tbody>
</table>

Foaming Wand
The foaming wand attachment was tested with “general use” soap from ChemStation (Oklahoma City, product 3051). Based on our tests, a good starting point for dilution of the concentrated chemical used for foam production was about 10 to 20% (in water). The foam was thick and long-lasting and clung well to vertical surfaces. If the soap concentration was less than 10%, the quality of the foam diminished. The dilution of soap should be adjusted for different cleaning purposes (e.g. vertical and horizontal surfaces, soil type and concentration).

Data Logging System
The data logging system was simple to use. It was used to collect data on temperature and pressure throughout the wash cycle. Afterward it was connected to a PDA (table 3, part no. 77) or a personal computer to download the data. Figure 18 shows data collected from a trial run. The temperature gage was inserted into the water in the holding tank and the pressure sensor was attached in parallel with the pressure gage (table 1, part no. 20).
CLEANING CHEMICALS
The Food Master equipment supplies and services guide (available online at www.foodmaster.com) lists suppliers of cleaning compounds under sixteen separate categories. The categories range from acidic to scale-removal cleaning compounds with some categories listing over 40 suppliers. To those that are unfamiliar with cleaning chemicals, the multitude of possibilities can create confusion. In this case, the individual should search for a supplier with relatively broad experience and a strong local presence. The ideal supplier would carry a wide selection of chemicals and have experienced personnel to meet with you, review your needs, and make recommendations. Also, suppliers should be willing provide product samples for you to evaluate in your facility.

CONCLUSION
An economical, safe, effective, and simple CIP system for small and very small meat processors was described in this document. Virtually anyone with basic shop skills and tools can assemble and operate this CIP system that is powerful enough to clean large vessels, common ingredient barrels, and some process equipment. The unit can also be used to generate foam for cleaning surfaces. Steps for testing and validating the cleaning system were also described. In the process of reading this document and building and operating a CIP system, the owner will gain a great deal of experience and insight on effective CIP cleaning of surfaces in food processing operations.

ACKNOWLEDGEMENTS
Many persons participated in the design, construction, testing, and evolution of the CIP system; however, none of these activities would have been possible without the support of a 2005 Cooperative Agreement Grant from the Food Safety and Inspection Services of the USDA. Dr. Kris Murthy, Senior Staff Officer, New Technology Staff, was responsible for overseeing the project for the USDA.

Mr. Wayne Kiner, Shop Manager, and the skilled craftsmen of the Biosystems and Agricultural Engineering Department at Oklahoma State University, fabricated the stands and modified the rolling carts for the CIP system. Many faculty, staff, and student workers at the Food and Agricultural Products Center at Oklahoma State University assisted with the evaluation and testing of the CIP system. Special thanks go to Joshua Grundmann, for testing and photographing some of the CIP system and components.
APPENDIX A

Calculations for Cleaning Chemical Solutions

Example 1. Volumetric calculation (%):
The manufacturer calls for a 5% solution of a cleaning chemical and the plastic holding tank is to be filled to 50 gallons, then 5/100 X 50 gallons = 2.5 gallons of cleaning chemical.
2.5 gallons of the cleaning chemical should be measured and added to the tank; then the tank should be filled to the 50 gallon mark with water at the appropriate temperature.

Example 2. Gravimetric calculation (weight)
The manufacturer recommends 2% by weight of a cleaning compound, and the holding tank is to be filled to 30 gallons, then 2/100 X 30 gallons X 8.3 lbs/gallon = 5.0 lbs cleaning chemical.
5.0 lbs of the cleaning chemical should be weighed and added to the tank (could be partially filled with water); then the tank should be filled to the 30 gallon mark with water at the appropriate temperature.

Example 3. Parts per million (ppm)
Some chemical suppliers recommend concentrations in parts per million (ppm). If the entire volume of cleaning solution is divided into one million parts, this method lets the user know how many parts consist of pure water, and how many parts are made up of the cleaning compound. To calculate ppm, divide the final contents of the tank (finished cleaning solution) by 1 million to determine the weight or volume of the individual parts. Multiply the number of ppm for the cleaning solution by the weight or volume of an individual part to find the weight or volume of the amount of cleaning compound to be added.
Calculating ppm based on volume: The tank is to be filled to 40 gallons and the cleaning chemical is specified at 100 ppm: 40 gallons/1,000,000 parts X 100 parts = 0.004 gallons. This is a difficult volume to measure, so we must convert it to something smaller, like teaspoons. Since 1 gallon is equal to 768 teaspoons, then 0.004 gallons X 768 teaspoons/gallon = 3.07 teaspoons (about 3 teaspoons of cleaning compound).
Calculating ppm based on weight: The tank is to be filled to 40 gallons and the cleaning chemical is specified at 100 ppm: 40 gallons/1,000,000 parts X 100 parts X 8.3 lb/gallon = 0.033 lb. Since there are 16 ounces in a lb, then 0.033 lb X 16 oz/lb = 0.53 oz (or about ½ ounce).
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