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# Case Studies

## Biochemical Hazards in a Jewelry Manufacturing Facility

**Dawn Tharr, Column Editor**

**Case Report by Katharyn Grant, Daniel Habes, Thomas Hales, and William Daniels**

### Introduction

Cumulative trauma disorders (CTDs) of the upper extremity often afflict workers whose jobs require stereotyped, repetitive movements; awkward postures; forceful exertions; and exposure to hand-transmitted vibration.[1-3] High prevalence rates of CTDs have been associated with a number of occupations, including butchers and meat packers, auto workers, garment makers, postal workers, and VDT operators, whose work tasks have many of the aforementioned features.[4-8]

Occupational hazards presented to jewelry workers (SIC #3911) have been previously described. Recognized hazards include exposures to toxic substances and noise.[9-12] Jewelry workers are also at high risk of physical injury from working with improperly guarded machine tools and power presses.[13] Nonetheless, the biomechanical hazards presented to jewelry workers have not been well characterized, despite evidence that jewelry workers are at significant risk for upper extremity CTDs.[14,15]

The purpose of this article is to describe the results of a detailed ergonomic survey conducted at a jewelry manufacturing facility. The survey was conducted by the National Institute for Occupational Safety and Health (NIOSH) in response to a Hazard Evaluation and Technical Assistance (HETA) request by management.[15] Plant management requested help in identifying and resolving potential biomechanical hazards after a review of their injury and illness records (OSHA 200 logs) for the years 1988–1990 revealed seven CTD cases among plant employees. This article describes the hazards identified during this survey and presents general recommendations to reduce these hazards.

### Methods

The evaluation was conducted at a jewelry manufacturing facility that produces custom-crafted gold jewelry for wholesale and retail distribution. At the time of the survey, the company employed approximately 100 workers in 10 specific departments within the plant. These operations are described in Table I.

Data for the evaluation were collected during a walkthrough survey of the facilities. A procedure established by ergonomists at the Division of Biomedical and Behavioral Science (DBBS), NIOSH, was used to identify biomechanical risk factors for upper extremity CTDs.[16] The activities of at least one employee in each department were recorded on videotape. The videotapes were reviewed in slow motion by two NIOSH ergonomists to identify tasks associated with awkward upper body postures, forceful exertions, repetitive movements, and hand–arm vibration exposure. Awkward upper body postures are defined in Table II. Force exertion was evaluated subjectively based on the size and weight of the objects handled and on the type of grip used to hold the object. Repetitive motions were defined as movement patterns recurring at least once every 30 seconds. Hand–arm vibration was not directly measured; however, exposure was assumed in all instances where workers were required to use hand-held, motor-driven tools.

After CTD risk factors were identified, handles and tools, workstations, and work methods were evaluated to determine their contribution to the existence of these risk factors. Instances where design features appeared to

**TABLE I. Operations Performed in Jewelry Manufacturing**

| Department | Number of Workers | Task Description |
|---|---|---|
| Casting (lost wax process) | 8 | Workers produce wax model castings using rubber molds. Afterwards, another worker molds plaster around the wax models and places the molds in a furnace. The wax vaporizes and molten metal is drawn into the newly formed plaster mold. |
| Stamping | 1 | Worker stamps decorative gold leaves from thin sheets of gold foil using a foot-operated press. |
| Soldering | 30 | Workers join jewelry pieces together using compressed air/gas soldering torches or small spot welding machines. Workers remove rough edges and metal fragments from jewelry pieces with files. |
| Grinding | 12 | Workers grind away rough edges and polish gold surfaces using rotating grinding and polishing wheels. |
| Plating | 2 | Workers immerse jewelry in a series of baths to clean metal surfaces and apply a thin layer of metal to a base metal jewelry piece. |
| Waxing | 2 | Workers mount jewelry pieces on wooden posts with wax. |
| Wriggling | 16 | Workers chip away metal fragments and etch designs into jewelry surfaces with vibrating linear actuators. |
| Bright Cutting | 10 | Workers cut away fragments and etch designs into jewelry surfaces with small hand-held tools (awls, wire cutters, files, etc). |
| Repair and Design | 9 | Workers remove metal fragments, repair cracks, replace stones, etc., with small hand-held tools and brushes. |
| Packing and Shipping | 9 | Workers mount jewelry on paper cards and place cards in small boxes. Workers then wrap boxes for shipping to wholesale and retail distributors. |


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**TABLE II. Awkward Body Positions Identified During Jewelry Manufacturing**

| Body Part | Definition of Extreme Posture (degrees) |
|---|---|
| Neck | Flexion > 30 |
| Trunk | Flexion > 30 |
| Shoulder | Flexion > 90 |
| | Extension > 20 |
| | Abduction > 90 |
| Wrist | Flexion > 75 |
| | Extension > 50 |
| | Ulnar deviation > 20 |
| | Radial deviation > 10 |

contribute to the awkwardness, forcefulness, repetitiveness, or overall difficulty of various tasks were noted and addressed in recommendations provided to plant management.

**FIGURE 1.** Worker performing stamping tasks.

## Results

Examination of work activities revealed a number of risk factors frequently associated with CTDs. Specifically, workers were observed working in awkward postures involving the arms, shoulders, wrists, neck, and lower back. Although work was unpaced and not highly repetitive, several work tasks required similar movements and postures. Therefore, sustained loading was identified as a source of biomechanical stress. High manual force exertion was common in the wriggling, bright cutting, and repair departments. Vibration exposure was identified as a hazard in the grinding and wriggling departments. The biomechanical hazards associated with specific operations are described in the following sections.

### Stamping

An initial operation at many jewelry manufacturers is stamping, or the mechanical cutting of gold plate to a specific size and shape.[17] In this facility, stamping tasks were performed by a single operator using a foot-operated press (Figure 1). The press design required a seated operator to kick against a foot pedal while holding the gold plate across the die with the hands. Constrained posture and frequent kicking (approximately 6–10 kicks/minute) presented an elevated risk of neck, shoulder, back, and leg fatigue to the operator. The unguarded press also presented a risk of hand or finger injury.

### Soldering

Jewelry workers use hand-held soldering torches to join decorative pieces to earrings, rings, and pendants. Biomechanical hazards in the soldering department included frequent shoulder abduction and ulnar wrist deviation, manual force exertion, and static loading of the shoulder, neck, and arm muscles. The workstation design was identified as the primary hazard source. The height of the workbench caused most work to be performed at or slightly below shoulder level, with the arms raised and the neck and trunk maintained in static flexion (Figure 2).

**FIGURE 2.** Worker performing soldering tasks.

Neither the workbench height nor the chair height was adjustable. Tools were stored in pull-out drawers in the front of the workbench. When open, the location of the drawers increased the operator's reach distance to the worktable, resulting in shoulder flexion and elbow extension. Access to tools was limited during most work activities because operators were forced to move away from the workbench to open the drawers.

Hand tool use was also associated with a number of CTD risk factors. Most soldering tasks involved use of both hands. Small implements such as tweezers, paint brushes, and small files were frequently used and require prolonged application of grip force. Filing tasks required strong applications of force with the wrist deviated from neutral position, placing increased loads on the finger flexor tendons and median nerve in the wrist.

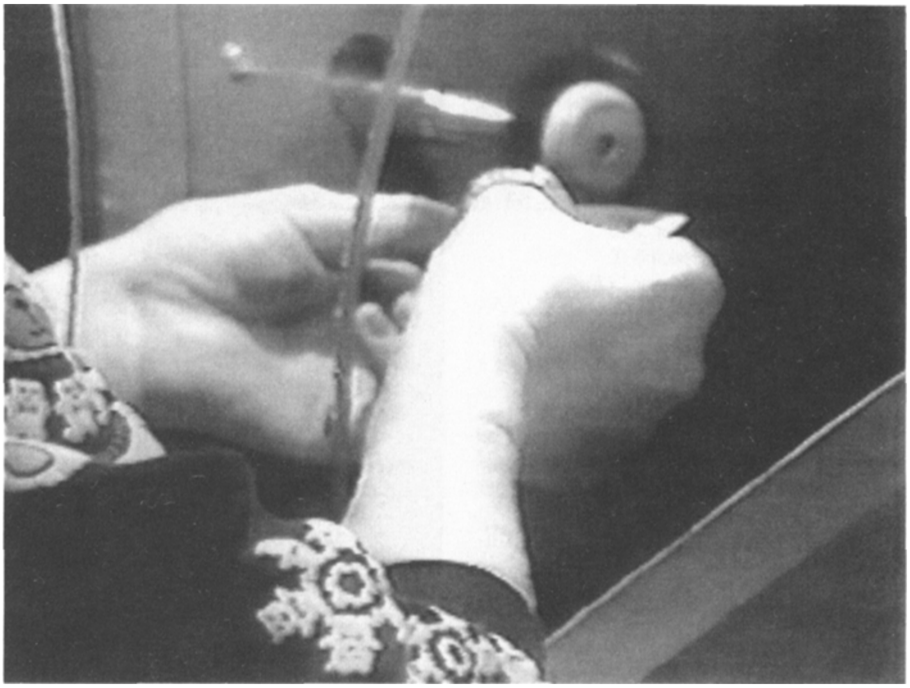

**FIGURE 3.** Worker performing grinding tasks.

### Grinding

Grinding and polishing wheels are used to finish the surface of jewelry pieces. Static loading of the fingers and thumb, force exertion with the wrists extended, and exposure to vibration from the grinding wheel were identified as biomechanical hazards in the grinding department. Workers in the grinding area applied force against the grinding wheel while holding rings and other objects in a pinch grip (Figure 3). Poor back posture was also noted as a concern. Most work was performed at or slightly below shoulder level, with the neck and trunk maintained in static flexion. Neither chairs nor workbenches were adjustable to provide sufficient back or leg support for individual operators. Although grinding operations required attention to small details, no additional lighting or magnification was provided at the workstation.

### Wriggling and Bright Cutting

Wriggling and bright cutting tasks are performed near the end of the manufacturing process to remove remaining metal fragments or rough edges from jewelry pieces and to engrave designs into the surface. Wriggling involved use of a table-mounted linear actuator. Seated operators pressed jewelry pieces against a vibrating tip to etch or chip away at the jewelry surface (Figure 4). Shoulder abduction and ulnar wrist deviation resulted from the height of the wriggling tool above the table top. Because neither the height nor the location of the wriggling tool was adjustable, the operator's neck, shoulders, and elbows were maintained in static flexion for most of the workday. Transmission of vibration energy to the fingers and a need to grip the jewelry piece continuously throughout the work period were also identified as biomechanical stressors.

Inappropriate tool and workstation design were identified as major sources of biomechanical stress in the bright cutting department. Bright cut-

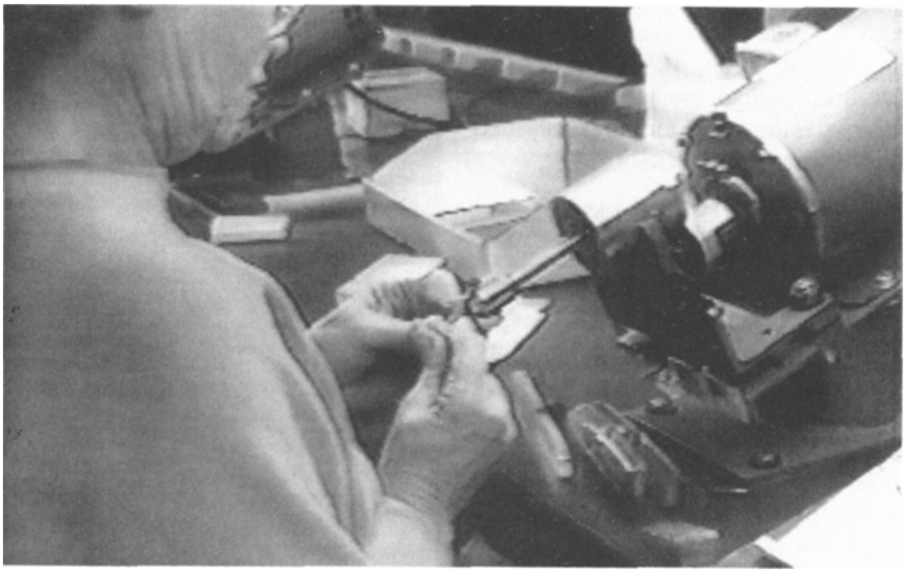

**FIGURE 4.** Worker performing wriggling task.

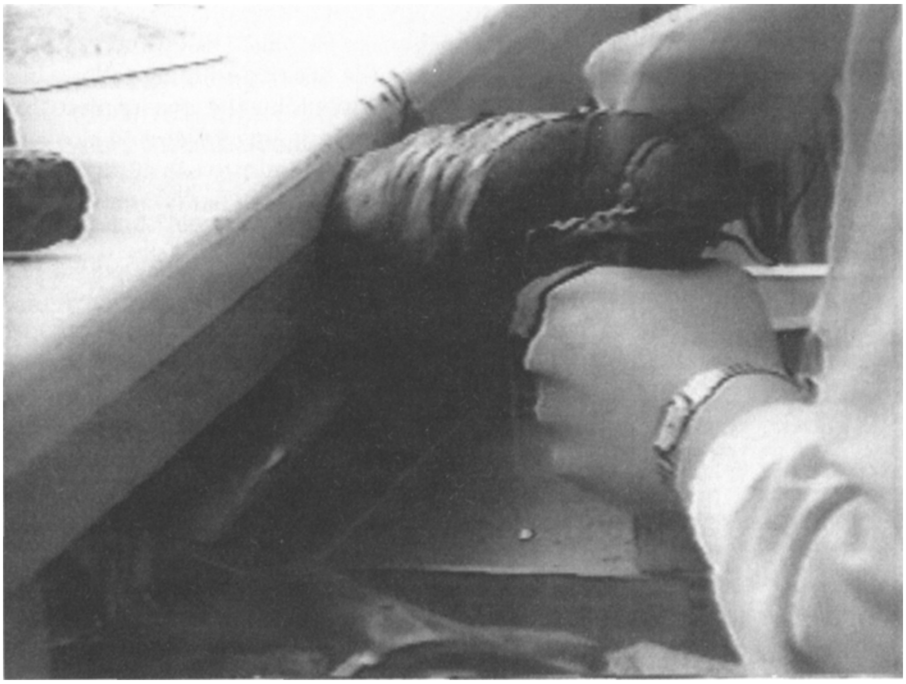

**FIGURE 5.** Pinch grip and manual force exertion in bright cutting task.

ting was a two-handed operation. The nondominant hand was used to hold the jewelry piece while force was applied to the jewelry piece with a cutting tool held in the dominant hand (Figure 5). Continuous force application with the hand can result in fatigue and loss of finger flexibility. Forceful and repetitive exertions involving the shoulder can also result in pain and reduced capacity to continue work. The handle of the cutting tool pressed into the palm at the base of the thumb. Operators were observed tucking small pads into the palm or wearing gloves on the cutting hand in an attempt to alleviate this stress. A nonadjustable workbench, which was too high for most operators, provided potential for neck, shoulder, and arm fatigue. Finally, the finish on the surface of the workbench produced a glare that can cause eye fatigue after long periods of work.

### Packing and Shipping

Jewelry pieces are prepared for shipping to a customer in the packing and shipping department. Biomechanical hazards in the packing and shipping area resulted from the location of packaging materials and the use of small hand tools.

Packing materials were stored throughout the packing area in haphazard fashion, with no system for distributing or storing materials at their point of use. As a result, operators made frequent trips from their workstation to storage areas, interrupting the flow of work. Other materials were stored along the back edge of workstations or on the floor, necessitating frequent long reaches and bends to retrieve various items.

Punch tools and pliers were also frequently used by workers to grasp and insert necklaces and pins into cardboard holders. The palm of the hand was used to apply force against the tool handle, concentrating stress on soft tissues and compressing the area over the median nerve. There was also risk of traumatic injury (laceration or cut) associated with use of the punch tool. Buffing tasks to remove small surface scratches from jewelry items required repetitive and forceful deviation of the wrist combined with application of pinch grip forces.

## Conclusions and Recommendations

Because 90 percent of jewelry manufacturing establishments employ less than 100 workers, they are less likely to have active medical surveillance programs in place, putting jewelry workers at greater risk of occupational illness and injury.[11] The work activities at this facility are believed to be representative of those throughout the industry. Many of the biomechanical hazards identified at this facility are linked to the use of inappropriate hand tools or poor workstation design. In most cases, these problems are easily corrected with commercially available alternatives.

Based on the results of the ergonomic evaluation, NIOSH investigators concluded that biomechanical hazards for upper extremity CTDs existed at this facility. To eliminate or reduce the severity of these hazards, recommendations for changing the design of tools, workstations, and work methods were provided to plant management. These recommendations are described in the following paragraphs.

### General

Workers vary in size and strength, and no design is optimal for all people. Therefore, adjustable workstation furniture (chairs and tables) is recommended to eliminate or reduce the occurrence of awkward, static working postures. Neck flexion, shoulder abduction, and ulnar wrist deviation can be reduced by allowing operators to adjust work surfaces to an appropriate height. In areas where highly intensive visual tasks are performed, matte workstation finishes and additional lighting are needed to reduce the risk of eye fatigue during viewing tasks.

### Stamping

Redesign of the stamping press is needed to improve the operator's posture and reduce the force required to execute this task. The foot pedal should be replaced with a pneumatic (air-driven) stamp, activated by a two-handed push button device. This would eliminate the need to forcefully kick against the foot pedal during the stamping process and reduce the risk of lower extremity injury. The die should be raised, and an adjustable chair that allows free swivel and fore-and-aft translation should be provided to allow the operator to see inside the press without flexing the neck or trunk. A holding fixture or alignment device to secure the gold foil inside the machine is needed to free the operator's hands during stamping.

### Soldering

Improved design and placement of tools is needed to reduce manual stress and improve shoulder, neck, and back posture during soldering tasks. Frequently used tools should be placed in a rack within 15 inches of the front edge of the workbench to eliminate excessive reaches. Adjustable workstation furniture is needed to provide individual operators with a working height approximately 4 inches above elbow height. Chairs should allow free swivel and fore-and-aft translation of the seat pan to improve the operator's access to objects in drawers or at the back of the workbench.

Additional fixtures are needed to hold jewelry items in different orientations during soldering. For example, a rotating fixture that permits pieces to be tilted toward the operator would reduce shoulder abduction during use of the soldering torch. Bending the handle or providing an angled attachment for the grinder would help prevent wrist deviation during use of this tool. Finally, a stable holding fixture for the soldering gun is suggested to allow the operator to release the torch without risk of skin burns.

### Grinding

Modifications to grinding tools are needed to allow the operator to perform the task with less force and with the wrist in a more neutral position. The grinding machine should be modified to allow set up of two or more polishing spindles at the same time. Only one spindle would be engaged by the rotating mechanism in the machine at any time; however, operators could change fixtures quickly and easily for coarser or finer grinding tasks. A fixture for holding the jewelry piece during the grinding process is also suggested to eliminate use of static pinch grips and reduce hand–arm vibration exposure.

### Wriggling

Problems associated with improper location of the wriggling tool can be corrected by providing operators with adjustable workbenches or by mounting the wriggling tool on a pedestal which would allow up-and-down movements and fore-and-aft translation of the tool. Adjustable chairs with cushioned armrests are also needed to support the operator's elbows and to prevent shoulder fatigue during prolonged work periods. A magnifying glass mounted on a swivel arm, similar to those used in microelectronics assembly, should be provided to improve the operator's view of the jewelry pieces and reduce neck flexion. A holding fixture for jewelry pieces is suggested to eliminate or reduce the operator's use of pinch-grip forces and exposure to hand–arm vibration during wriggling tasks.

### Bright Cutting

The manual force requirements of the bright cutting and repair tasks can be reduced by substituting a powered cutting tool with antivibration features for the manual tools currently in use. Powered engraving tools would likely give the operator more control over cuts and allow the task to be performed more quickly. Manual cutting tools should be periodically inspected and sharpened. Tool handles should be padded and lengthened to 5 inches to reduce stress in the palm of the hand. Although gloves provide some protection for the operator's hands, gloves can also reduce tactile sensitivity and may cause some operators to grip tools more forcefully. The availability of tools with curved handles should be investigated; bent handles may reduce the amount of wrist deviation required to use various tools needed for bright cutting. Finally, a fix-


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ture mounted to the top of the workstation is needed to hold the jewelry pieces during cutting tasks. This fixture would free the operator's nondominant hand and eliminate some of the potential for static muscle fatigue.

### Packing and Shipping

Packing materials should be relocated to improve the operator's access to these items during work tasks. Resources such as labels, boxes, and jewelry items should be stored at individual workstations, within a 15-inch reach of the operator.[4] Adjustable lift tables and tilted storage bins can be used in the packing and shipping areas to provide materials to operators without excessive reaching.

Force application with small hand tools can be reduced by providing prepunched jewelry cards to operators. Punches that make several holes in jewelry cards at one time would also reduce the frequency of force application during packing tasks. Pliers with longer (5 inches), padded handles should be provided to reduce pressure in the palm of the hand during gripping and pulling tasks. Finally, providing the operator with a handle or fixture to hold jewelry pieces during polishing tasks would eliminate many of the pinch grips associated with this operation.

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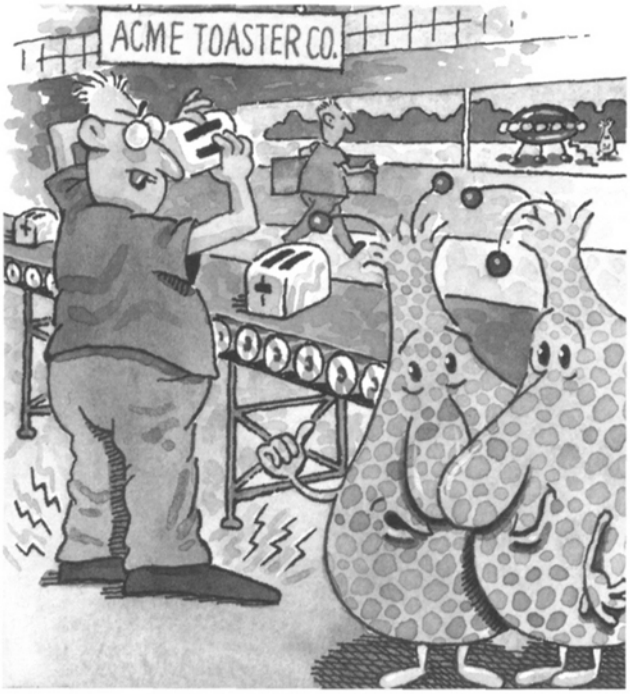


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*Editorial Note:* Katharyn Grant and Daniel Habes are with the Division of Biomedical and Behavioral Sciences of NIOSH in Cincinnati, Ohio. Thomas Hales and William Daniels are in the NIOSH Regional Office in Denver, Colorado. More detailed information on this study is contained in the Health Hazard Evaluation Report No. 90-273-2130, available through NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, OH 45226; telephone: (800) 35-NIOSH.



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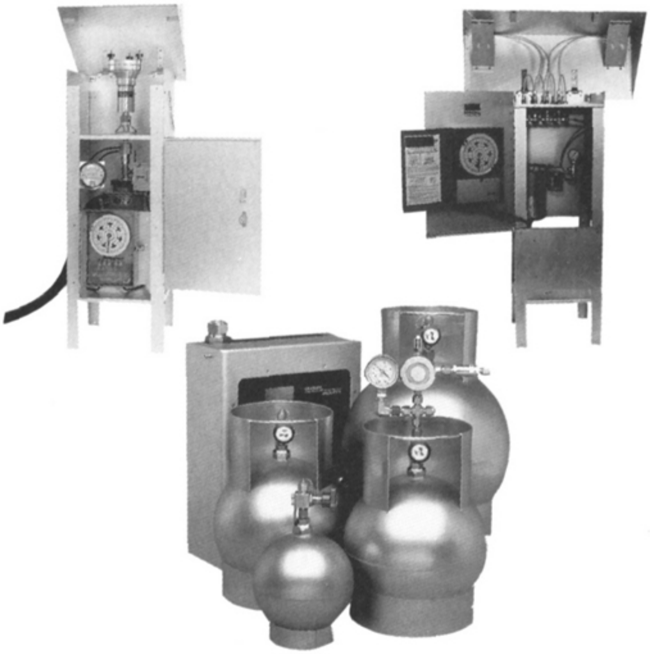

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