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OAK RIDGE NATIONAL LABORATORY

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Cross-Connection Control of the Potable Water Lines at Oak Ridge National Laboratory

Rebecca Minturn Moore

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
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Office of Quality Programs and Inspection
Quality Engineering and Inspection Section

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NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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ABBREVIATIONS

ADP	automated data processing
AVB	atmospheric vacuum breaker
BPD	backflow prevention device
CCCC	Cross-Connection Control Committee
DC	double check
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
gal	gallon (U.S.)
IE	inspection equipment
IR	inspection request
NT/NC	nontransient, noncommunity
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
P&E	Plant and Equipment Division
PVB	pressure vacuum breaker
QE&I	Quality Engineering and Inspection Section
RPPBP	reduced-pressure-principle backflow preventer
RPZ	reduced pressure zone
SSI	safety surveillance inspection
TDEC	Tennessee Department of Environment and Conservation

GLOSSARY

air gap—An unobstructed vertical air space to prevent back siphonage and back pressure. Used for high hazard installations.

backflow—The undesirable reversal of flow of water or other substances or mixtures into the drinking water distribution system.

back pressure—Occurs when pressure in the downstream piping is higher than the supply pressure, thus pushing the water (or other substances) back into the supply line causing a reversal of normal flow.

back siphonage—The reversal of normal flow of water in a system that occurs when the pressure at some point in the water distribution system drops below atmospheric pressure due to negative or reduced pressure in the supply line.

cross connection—Any actual or potential connection between the potable water supply and any other source or sources that may be considered nonpotable. A direct arrangement of a piping line that allows the potable water supply to be connected to a line that contains a contaminant.

cross-connection control program—A combined cooperative effort between ORNL water distribution personnel, Industrial Hygiene personnel, Quality Engineering and Inspection personnel, and owners to establish and administer guidelines for controlling cross connections and implementing means to ensure their enforcement so the potable water supply will be protected to and within the buildings.

degree of hazard—A relative scale of the water condition. A high hazard poses a health risk that could cause sickness or death.

direct cross connection—A connection that is rigidly tied together and is subject to back siphonage and back pressure.

indirect cross connection—A connection that is not rigidly attached and may only be subject to back siphonage.

nonpotable water—Process water or water unfit for human consumption or personal hygiene.

potable water—Water that is safe to drink.

process water—Water that has the potential to be contaminated.

reduced-pressure-principle backflow preventer—A device used to protect against back siphonage and back pressure. Used for high hazard installations.

water purveyor—One who has the primary responsibility of protecting individuals from the possibility of contaminated water. The water purveyor also ensures that water at the service connection is safe for the consumer under all foreseeable circumstances.

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ABSTRACT

A 1991 independent U.S. Department of Energy (DOE) audit of Oak Ridge National Laboratory (ORNL) identified the need for establishing a cross-connection control program for the potable and nonpotable water systems at the facility. An informal cross-connection policy had been in place for some time, but the formal implementation of a cross-connection program brought together individuals from the Quality Engineering and Inspection Section of the Office of Quality Programs and Inspection, Industrial Hygiene, Health Physics, Plant and Equipment Division, and the Atomic Trade and Labor Council. In January 1994 a Cross-Connection Control Committee was established at ORNL to identify potential and actual cross connections between potable and nonpotable water systems. Potable water is safe to drink, and nonpotable or process water (e.g., sewage, laboratory wastewater, cooling water, and tower water) is not intended for human consumption, washing of the body, or food preparation.

The program is intended to conform with the Federal Safe Drinking Water Act Amendment of 1986 and with state and local regulations. Although the Occupational Safety and Health Administration addresses cross-connection functions, it does not define specific program requirements. The program at ORNL is designed to ensure that necessary recommendations are implemented to safeguard all internal and external potable water distribution lines. Program responsibilities include a thorough engineering assessment to (1) identify the potable water lines, (2) identify any existing or potential cross connections, and (3) inspect the integrity of the water lines. If any cross-connection deficiencies are found, corrective actions are initiated according to industry standards.

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) recommends that all municipalities with public water supply systems have cross-connection control programs.[1] The purpose of a cross-connection control program is to ensure that potable water is safe to drink by verifying that no potential or actual cross connections with nonpotable water exist. State and federal laws require that organizations such as Oak Ridge National Laboratory (ORNL) fund a program that prevents potable (drinking) water from becoming contaminated by nonpotable (waste or process) water. Employees and visitors could be threatened with health effects ranging from nausea to death if the drinking water is contaminated (Fig. 1). According to Tennessee's Safe Drinking Water Act,[2] a cross connection is

> . . . any physical arrangement whereby a public water supply is connected, directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device which contains, or may contain, contaminated water, sewage, or other waste or liquid of unknown or unsafe quality which may be capable of imparting contamination to the public water supply as a result of backflow. Bypass arrangements, jumper connections, removable sections, swivel or change-over devices through which, or because of which, backflow could occur are considered to be cross-connections.

The Occupational Safety and Health Administration (OSHA) does not allow a cross connection in an installation unless it is properly protected with an approved backflow prevention device (BPD). State and federal requirements also mandate the use of BPDs.

Tennessee does not have a state-wide plumbing code or legislation requiring the licensing of plumbers; however, it does have a state-wide program under the Tennessee Department of Environment and Conservation (TDEC) aimed at establishing effective, ongoing local programs for each public water system. The TDEC Division of Water Supply educates water officials, conducts training workshops, prepares and distributes cross-connection control manuals and other guidance material, and provides technical assistance when needed. Effective ongoing local programs are required by Section 1200-5-1-17(6) of the *Tennessee Rules for Public Water Supplies,* which complements Tennessee Code Annotated 68-13-701 through 68-13-719.

ORNL has adopted the Standard Plumbing Code and is considered a nontransient, noncommunity (NT/NC) water system by the TDEC Division of Water Supply. An NT/NC water system is a public water system that regularly serves at least 25 of the same persons for more than 6 months per year. TDEC does not require that NT/NC water systems have a cross-connection control program. However, because the lack of a cross-connection control program increases the potential for contamination, ORNL has established a cross-connection control plan to safeguard its water supply, and this plan is reviewed by the State office in Knoxville every 3 years. The cross-connection control program described in the cross- connection control plan is a combined cooperative effort between health officials (Industrial Hygiene), water plant operators [Plant and Equipment (P&E) Division pipe fitters], division facility managers, and backflow preventer testers [Quality Engineering and Inspection (QE&I) Section of the Office of Quality Programs and Inspection]. The program was established to administer guidelines for controlling cross connections

Fig. 1. Possible route of contamination of potable water through an inadvertent cross connection.

and implementing means to ensure enforcement so that the potable water supply is protected both to the building and within the building. This program can establish the type of protection required and is responsible for administration, training, and enforcement.

ORNL does not operate a potable water treatment plant. The local treatment plant is operated by Johnson Controls and serves the city of Oak Ridge and the nearby DOE facilities, including ORNL. Johnson Controls' responsibility for the ORNL potable water supply ends at Valve Pit No. 2, about one-half mile before the first ORNL reservoir. At Valve Pit No. 2, ORNL's distribution center, and therefore the water purveyor's area of responsibility, begins. ORNL employs a state-certified water distribution operator to service the line from Valve Pit No. 2 to the first ORNL reservoir.

Public Law 99-339, the Safe Drinking Water Act Amendment of 1986, and state and federal regulations state that a water purveyor has the primary responsibility of protecting individuals from the possibility of contaminated water. The water purveyor also ensures that water at the service connection is safe for the consumer under all foreseeable circumstances. At ORNL the water purveyor is the Utilities Systems Section of the P&E Division. The purveyor's area of responsibility extends from the potable water reservoir to the outside wall of each building. Beyond that point, the building occupant (owner) is responsible for all internal potable water operations.

The water purveyor must operate the water system in accordance with the Federal Safe Drinking Water Act Amendments of 1986 and as defined in Section 1200-5-1 of the *Tennessee Rules for Public Water Systems*. Tennessee must follow the regulations of the Public Acts of 1983, Chapter 324, and must meet the intent of the Clean Water Act. If the state fails to do so, EPA intervenes and initiates appropriate corrective actions.

A Cross-Connection Control Committee (CCCC) was formed to assist the potable water program manager and provide oversight in the prevention of cross connections on potable water lines within the buildings at ORNL. The committee reports to the Office of Safety and Health Protection and is an ongoing, standing committee due to the continuous modifications and new construction projects inherent to ORNL. The primary role of the CCCC is to locate and identify all potable water cross connections and provide recommendations for corrective action to ensure the existence of a safe potable water system at ORNL. The CCCC's responsibilities include performing initial surveys and overseeing modifications of existing and proposed potable water systems, including the following: (1) maintaining existing BPDs and installing new ones; (2) identifying and labeling all potable and process lines according to Section 15074 of the ORNL Engineering Technical Specifications; (3) identifying existing cross connections; and (4) providing recommendations on and responding to complaints and concerns.[3] The authority having jurisdiction will have authority and responsibility for actions recommended by the CCCC and are vested in the program manager.[3]

The cross-connection control program at ORNL will verify (if funded) that all buildings are surveyed for potential or actual cross connections that could present a health hazard to occupants or visitors. All survey records will be used to establish a baseline. Once the baselines are established, the CCCC can return to the surveyed buildings to check for any additions to the water lines that could pose a cross-connection problem. BPDs currently in service are inspected semiannually. If new devices need to be installed, they should be installed as soon as possible to ensure the safety of the potable water supply.

2. REVIEW OF BACKFLOW PREVENTION DEVICES

2.1 TYPES OF BPDs

A cross connection is the link through which contaminating materials may enter a potable water supply. The first reported incident of a hazardous cross connection occurred in Chicago in 1933 when improper plumbing contaminated the drinking supply, resulting in 1409 cases of amoebic dysentery and 98 deaths. This incident prompted health officials and water purveyors to take responsibility and exercise control over public water distribution systems and all connected plumbing systems.[4]

A correctly operating BPD will help maintain the safety and integrity of the potable water system (Fig. 2). Nonpotable water can enter the potable water system by three means: (1) backflow, (2) back siphonage, and (3) back pressure.

1. Backflow is the flowing of water in the direction in which gravity is pulling the water (downhill). This is created when the downstream pressure exceeds the supply pressure.

2. Back siphonage is caused by negative pressure (vacuum) in the supply line. This effect is similar to sipping a coke by inhaling through a straw, which induces a flow in the opposite direction.

3. Back pressure is caused by higher pressure in the system than is in the supply line. This can be caused by turning on a pump in the system that has a higher pumping pressure than that of the supply line. If the pump line is contaminated with a hazardous chemical, the higher pressure in the system could force the hazardous chemical back into the supply line or water main.

Any of these conditions could cause illness or death, depending on the contaminant in the potable water. The degree of hazard determines what type of BPD will be used for protection against cross connection.

A wide choice of devices is available to prevent backflow, back siphonage, and back pressure. All of these devices are manufactured to one or more of three basic standards: (1) American Society of Sanitary Engineers, (2) American Water Works Association, and (3) University of Southern California Foundation for Cross-Connection Control and Hydraulic Research.[1] Five basic devices are used to protect against cross connections: (1) air gaps, (2) atmospheric vacuum breakers, (3) pressure vacuum breakers, (4) double check valves, and (5) reduced-pressure-principle backflow preventers or reduced pressure zones. Before selecting a BPD, the present condition(s) (back siphonage or back pressure) must be evaluated. Other considerations to ensure proper operation include location of the BPD, pipe size, and ease of testing the device in place. The five basic devices are described here.

2.1.1 Air Gap

The air gap gives the highest level of protection. This nonmechanical BPD is used mainly where back siphonage or back pressure conditions may occur. The air gap must provide, as a

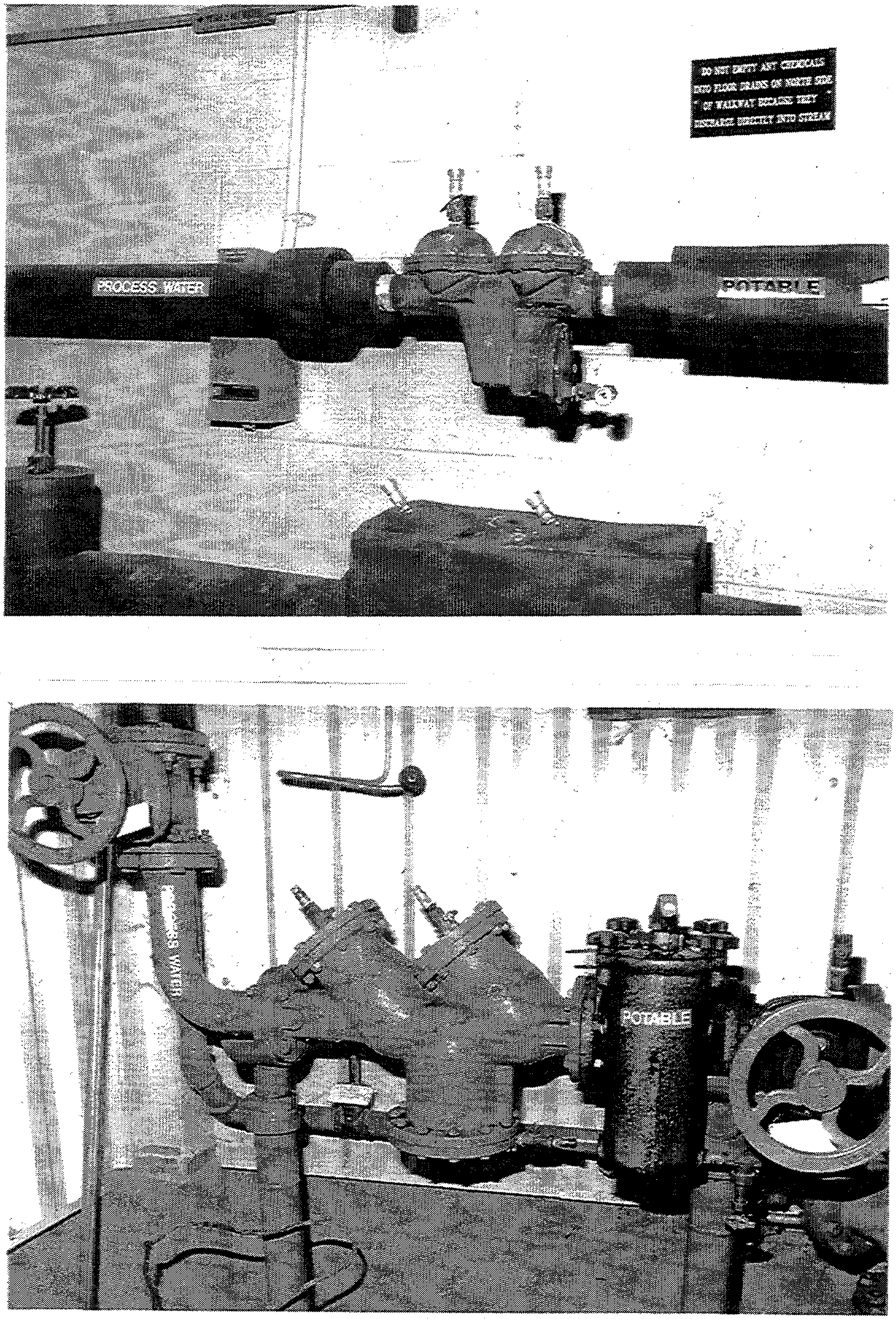


Fig. 2. Examples of backflow prevention devices in use at ORNL.

minimum, unobstructed vertical air space twice that of the supply pipe diameter above the flood rim of the fixture, or 1 in. of vertical air space, whichever is greater.

Air gaps are valuable only on systems that do not require continuous pressure because of their intermittent use, such as an open tank, a sink, or a drinking fountain. Air gaps are for high hazard conditions. A limitation of air gaps is that they can be altered easily to nullify protection.

2.1.2 Atmospheric Vacuum Breaker

The atmospheric vacuum breaker (AVB) is the simplest and least expensive mechanical type of BPD available. It provides excellent protection against back siphonage but will not protect against back pressure. Once installed, an AVB cannot be tested but remains dependable and trouble free for back siphonage protection. AVBs are used only for low hazard conditions and for short periods of intermittent use. AVBs cannot be tested under field conditions, cannot handle back pressure, and should not be relied upon for high hazard applications. This device consists of (1) a polyethylene float that travels freely on a shaft and (2) a seal in the uppermost position against atmosphere with an elastomeric disc. Water flow lifts the float, causing the disc to seal. Water pressure keeps the float in the upward sealed position. Termination of the water supply will cause the disc to drop, venting the unit to atmosphere and thereby opening downstream piping to atmospheric pressure, thus preventing back siphonage. AVBs range in size from 1/2 in. to 3 in. and (1) must be installed vertically, (2) located downstream from the last control valve, (3) installed at least 6 in. above the flood rim or the highest water outlet, and (4) must not have shutoffs downstream.

2.1.3 Pressure Vacuum Breaker

A pressure vacuum breaker (PVB) is used only for protection against back siphonage. It is used under constant pressure and can be tested. PVBs are used for low hazard conditions and are designed for use where pressure will be on the unit for long periods (e.g., agricultural irrigation). A PVB is similar to an AVB except that the air inlet and check valve are spring loaded to assist in opening the air vent and closing the valve when flow ceases. This device has a spring on top of the disc and float assembly, two shutoff valves before and after the unit, test cocks, and an additional first check. Sizes range from 1/2 in. to 10 in. These devices must be installed at least 12 in. higher than the existing outlet in a vertical upright position. PVBs (1) cannot protect against back pressure, (2) should not be relied upon for high hazard applications, and (3) must be field tested at least annually.

2.1.4 Double Check Valve

The double check (DC) valve protects against back siphonage and back pressure conditions. It is used mainly to protect against low to medium hazard installations, such as apartment projects and food processing steam kettles, and can be used under continuous pressure. The DC valve must be located aboveground, protected from flooding if at all possible. A DC valve has two springs or weight-loaded resilient seat check valves in series, test cocks, and two tightly closing gate valves before and after the unit. A DC valve (1) will not indicate malfunctioning of check valves (it does not have a relief port), (2) should not be used for high hazard installations, and (3) must be field tested semiannually.

2.1.5 Reduced-Pressure-Principle Backflow Preventer or Reduced Pressure Zone

The reduced-pressure-principle backflow preventer (RPPBP) or reduced pressure zone (RPZ) gives maximum protection against back siphonage, back pressure, and backflow (Fig. 3). These devices, similar to the DC valve which has two single check valves, have an atmospheric vent capability placed between the two checks and are designed such that the zone between the two checks is always kept at least 2 lb less than the supply pressure. Even if both check valves fail, the device can still protect against back siphonage and back pressure. The RPPBP can be used under constant pressure and for high hazards. The devices range in size from 1/2 to 10 in. and include test cocks, gate valves, and strainers.

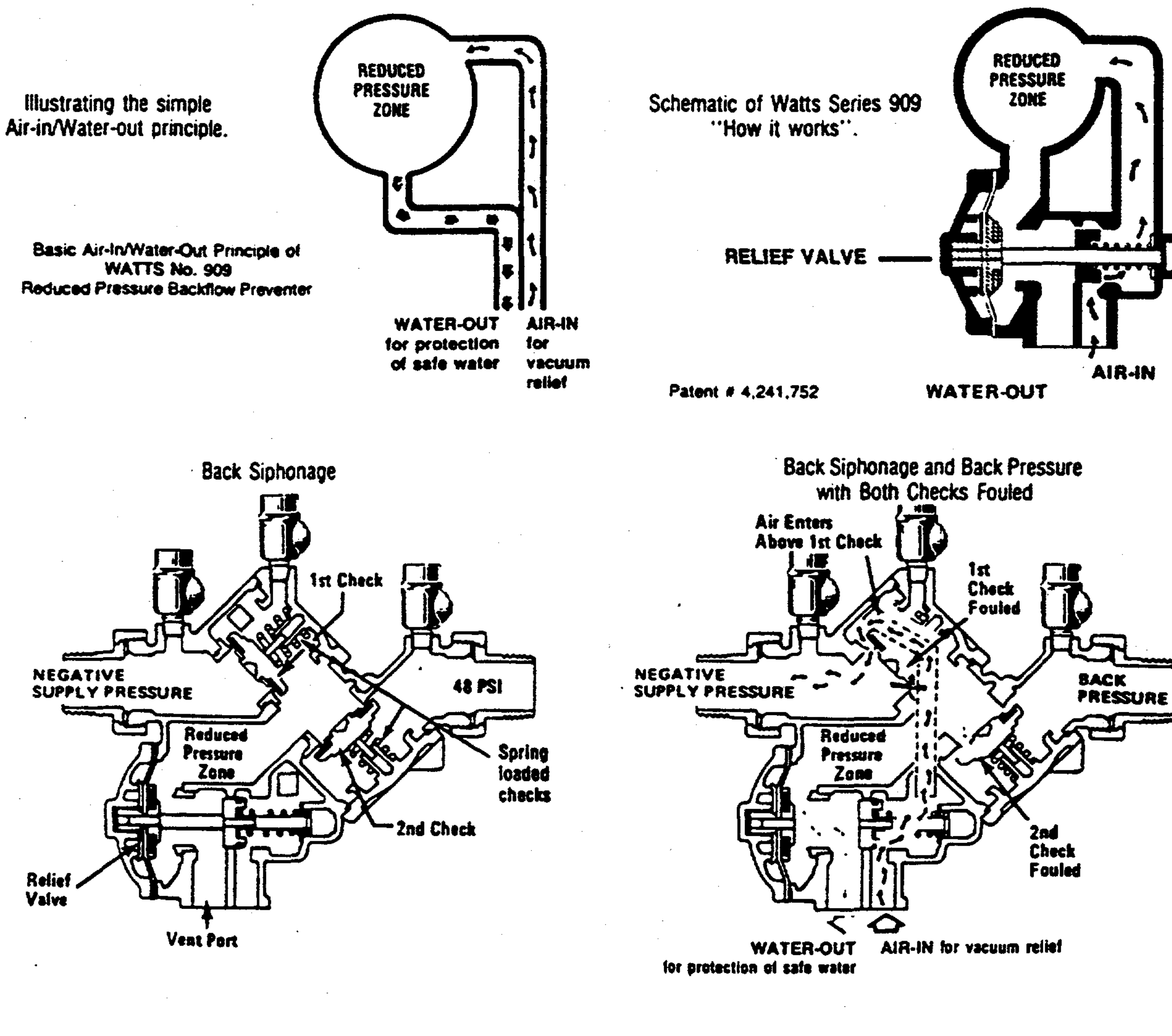


Fig. 3. Schematic diagrams of backflow preventers used for high potential health hazards to prevent back siphonage and back pressure.

Both the check valves and the relief valve are spring loaded. The first check valve has a nominal spring tension of 8 lb closing pressure when installed in the valve. The second check valve has a nominal spring tension of 2 lb closing pressure when installed in the valve. Consequently, there is an approximate 10-lb pressure drop across the device. So if the incoming line pressure to the RPPBP is 60 psi, then the pressure at the exit or downstream side of the RPPBP would be 50 psi, thus resulting in a 10-psi pressure drop across the valve.

Located between the two check valves is the pressure relief valve that has a nominal spring tension of 4 lb opening pressure when installed in the valve. The relief valve is kept closed by the incoming water pressure exerting its force over the area of a rubber diaphragm that forces the relief valve to close. If the incoming water pressure is 60 psi over the area of the diaphragm, then it is apparent that this pressure will overcome the 4 lb of pressure on the relief valve spring and thus close the relief valve. If there is a pressure drop of 4 psi or more in the relief valve zone, the relief valve will open (either partially or fully depending on the amount of pressure drop) and water will discharge from the relief port. This discharge of water can range from a few drops to several gallons depending on the size of the valve and the amount of pressure drop.

An RPPBP usually is equipped with two shutoff valves, one located immediately upstream of it and one located immediately downstream. These valves are usually either gate valves or full-ported ball valves and should have a resilient rubber seating mechanism. An RPPBP cannot be tested if it does not have a second (downstream) shutoff valve.

Because RPPBPs and RPZs must never be subject to flooding, they cannot be used in a pit or other area subject to flooding. If a unit is enclosed, provisions must be made for discharging water at ground level from the enclosure housing the unit. The relief valve should be located a minimum of 12 in. plus the nominal pipe diameter of the service line above the top of the drain port(s). The manufacturer's space recommendations for adequately servicing the relief valve should be followed. The unit must be installed where it can be easily tested and serviced. It should not be installed higher than 7 ft above floor level unless special provisions have been made for testing and servicing. The lines (1) should be flushed thoroughly before installing the unit, (2) must be protected against freezing, and (3) must be provided with adequate means for handling the discharge from the relief valve.

RPPBPs and RPZs have some limitations. These devices must be tested at least annually to be relied upon and, depending upon the operating conditions, may require frequent repairs.

2.2 TESTING AND REPAIRING BPDs

2.2.1 In-Service Testing and Repair

A BPD must have test cocks so the hoses can be attached to the test gauge. A BPD usually has four test cocks, three of which are normally used during testing. The test cocks are numbered sequentially, with No. 1 on the high pressure side and No. 4 located closest to the discharge side. For testing purposes, the No. 1 test cock is not used (Figs. 4 and 5).

A test gauge has three hoses that are attached to the BPD. The high pressure hose is attached to the high pressure side of the relief valve that is the No. 2 test cock. The low pressure hose is

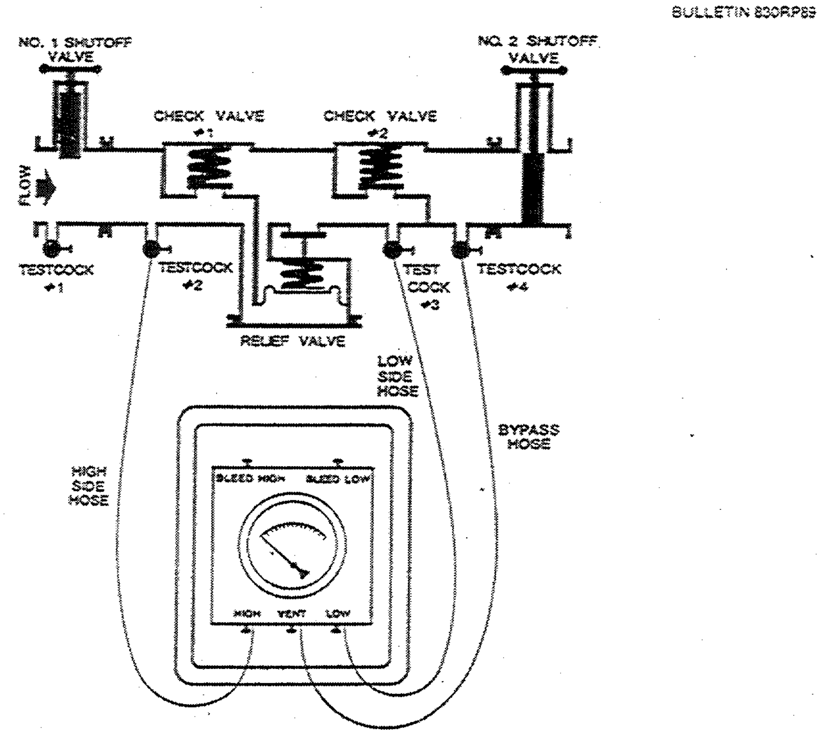


Fig. 4. Mid-West Instrument Model 830 test kit.

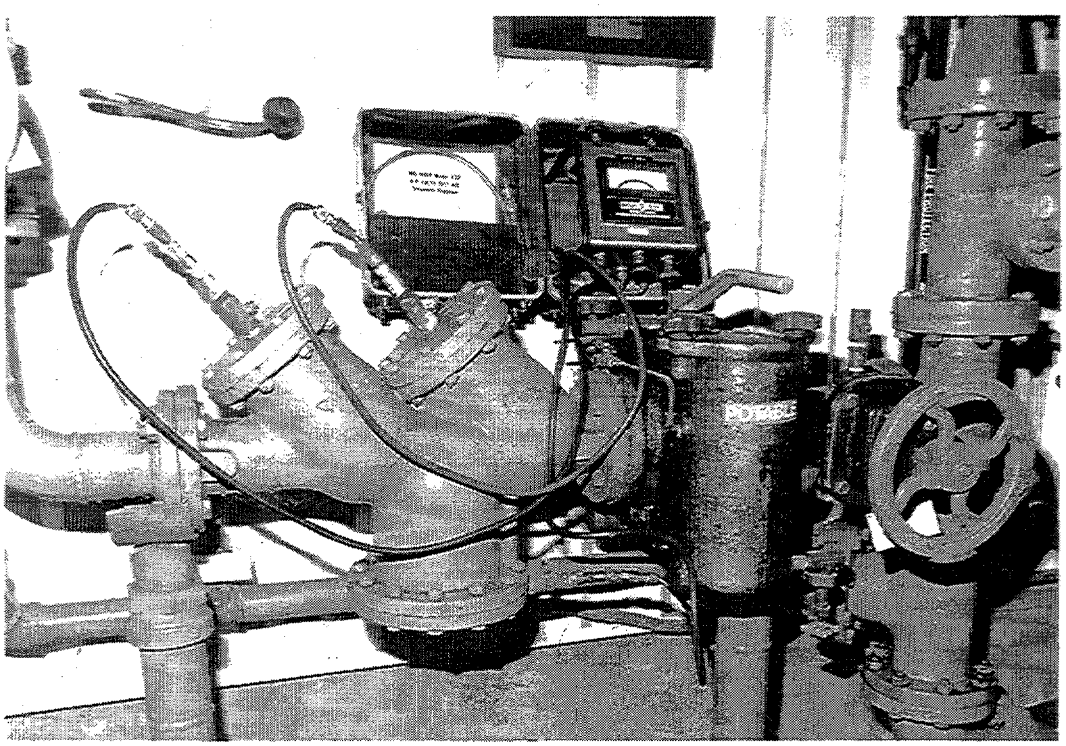


Fig. 5. A test kit being used on a backflow prevention device at ORNL.

attached to the first check valve that is the No. 3 test cock. The vent hose is attached to the No. 2 check valve that is the No. 4 test cock.

Proper testing of a BPD can determine whether it is operating correctly or if a segment of the valve is malfunctioning. The checks on an RPPBP verify that

1. the first check valve is holding tight;
2. the second check valve is holding tight;
3. the relief valve is opening at a pressure differential of 2 psi or greater; and
4. the static pressure drop across check valve No. 1 is at least 3.0 psi or greater than the pressure differential at which the relief valve opens, which reduces excessive spitting resulting from minor variations in the line pressure.

At ORNL, RPPBPs are tested by QE&I either (1) semiannually, (2) when one malfunctions, (3) when one is newly installed, or (4) when any maintenance is performed on the device. The state requires testing at least annually but recommends testing more frequently for high hazard installations. QE&I has the responsibility of performing the certified tests and keeping the certified testing records on all the RPPBPs at ORNL.

ORNL Safety Surveillance Inspection Procedure SSI 2001 requires that inspectors be certified by the state to test BPDs.[5] The Tennessee Division of Water Supply administers and regulates the training and certification of testers with assistance from the Julian R. Fleming Training Center at Murfreesboro. The certification requires six months of on-the-job training, 4 days of practical and hands-on instruction, and a passing score on the examination. The certification must be updated every 3 years. It is a good idea to take the refresher course once a year because BPDs contain parts that are captured in place (i.e., springs) and if improperly disassembled could cause serious injury or death.

The certified inspector should witness the installation of any BPD to ensure that the BPD is an approved device and that it meets all requirements of the state, ORNL engineering standards, and the University of Southern California Foundation for Cross-Connection Control and Hydraulic Research. Certified inspectors must then do an initial inspection and test of the BPD. If it meets requirements and is acceptable, proper paper work and data entering must be done. The BPD is then added to the semiannual schedule of inspections, which includes approximately 160 BPDs. Approximately 25 BPDs are tested each month.

Before an inspector can inspect BPDs, the inspector must

1. receive proper training,
2. obtain necessary access training to gain access to the various locations at ORNL, and 3. contact the facility manager of each building to gain access and get approval to shut off the process water for the period needed to complete the testing of each BPD.

The BPD can then be tested. An average test posing no logistic problems takes about 15 minutes. If the test results are acceptable, an acceptance sticker is placed on the BPD and proper paper work is completed. If the test results are unacceptable, a reject tag is placed on the BPD. The facility manager and the P&E Division supervisor and pipe fitters are notified with a copy of the worksheet stating when and why the BPD was rejected.

If a BPD is rejected, it is the responsibility of P&E personnel to contact the facility manager to arrange a time to shut down the water system to work on the BPD. The inspector should witness the repair of the device to document the parts that were replaced and any problems that arose.

Once the BPD is repaired, the inspector again performs acceptance testing. Afterwards, the facility manager is notified that the device is back in service, the reject tag is removed, and the water is turned on again.

P&E personnel are trained to field test BPDs, and when a repair is warranted, then they contact QE&I for the certified test. A BPD that has not been tested by a certified QE&I person is not returned to service until the testing has been accomplished.

ORNL Safety Surveillance Inspection Procedure SSI 2001 covers the inspection and testing of new and in-service RPPBPs. The testing procedure for RPPBPs (or RPZs) is as follows:

1. Obtain permission to take the RPPBP out of service. This involves getting the water turned off to the building/device.
2. Verify that the RPPBP shows no evidence of continuous leakage. If it does, unit needs to be flushed and/or repaired. Most times the relief port needs repair.
3. Verify that the manufacturer's data tag is in compliance with QE&I's inspection records.
4. Connect the No. 2 test cock of the device to the "high" hose. Connect the No. 3 test cock with the "low" hose.
5. Close the No. 2 gate valve of the device tightly.
6. Open test cock No. 2 and No. 3. Open "vent" valve of the gauge.
7. Open the "high" valve and bleed to atmosphere until all the air is expelled. Close the "high" valve. Open the "low" valve and bleed to atmosphere until all the air is expelled. Close the "low" valve. Close the "vent" valve. On kits equipped with bleed valves, alternately open and close until all air is expelled from gauge.
8. To determine if the No. 1 check valve leaks, with both the "high" and "low" gauge valves closed observe the pressure differential gauge. If there is a decrease in the indicated value the No. 1 check valve is reported as leaking.
9. To determine if the No. 2 check valve leaks, connect the "vent" hose to the No. 4 test cock and open the test cock. Observe the differential pressure with all gauge valves closed. Open the "high" and "vent" valves and keep the "low" valve closed. If the indicated pressure differential decreases, the No. 2 check valve is reported as leaking.
10. To determine the relief valve opening differential pressure, open the "high" valve a number of turns. Open the "low" valve very slowly until the differential gauge needle starts to drop. Hold the valve at this position and observe the gauge reading at the moment the first discharge is noted from the relief valve. Record this as the opening differential pressure of the relief valve.[7]

The results of the differential pressure tests are recorded on worksheets, and the results are entered into a database. Rejected RPPBPs are tagged with a rejection tag. These rejected devices should be repaired within 48 hours. Worksheets are filed under the appropriate Inspection Request file 13521. An inspection sticker is placed on the RPPBP device showing it is acceptable. The technique for testing follows the manufacturers' recommendations.

ORNL does not routinely test all types of BPDs in service. For example, ORNL does not test any DC valves since without a relief zone, a visual inspection cannot determine if it is failing (these devices can be tested in line). AVBs are not tested because they are used only in low hazard installations, such as on commodes, urinals, and the soap dispenser on the dishwasher in the cafeteria.

2.2.2 Testing at an Approved Testing Laboratory

The University of Southern California Foundation for Cross-Connection Control and Hydraulic Research is an approved backflow preventer assembly testing laboratory. The Foundation is considered by many to have the most stringent approval processes in the world for backflow prevention assemblies. The University of Southern California ensures that the Foundation remains unbiased.[1]

If a manufacturer wishes to have its assemblies evaluated by the Foundation, a random sample is submitted for laboratory and field evaluations. For BPDs up to and including 2 in. in size, a minimum of three assemblies are submitted. For sizes larger than 2 in., the manufacturer submits at least one randomly chosen assembly. Any special tools or techniques needed for the installation or removal of the assembly are identified and supplied by the manufacturer. The manufacturer chooses an acceptable field evaluation site on which to install the assemblies. This site should provide a wide range of water conditions, such as line pressure and flow rates, and be accessible during normal work hours.

The laboratory evaluation is performed according to the manufacturer's orientation of horizontal, vertical, and axial flow.

After three assemblies of each size and model have successfully complied with the initial field test, the field evaluation period begins. Readings are taken, disassembly and physical inspection of all components are completed, and field test data are recorded. The three assemblies must operate trouble free for a minimum of 12 consecutive months in order to meet the field evaluation specifications of the Foundation for Cross-Connection Control. If two of the three assemblies fail to comply with the performance requirements, all of the assemblies are rejected.

The concluding field test includes recording field test data, recording static differential pressure readings across each check valve, recording inlet line pressure, disassembling and physically inspecting all components, reassembling the components, and recording the field test data according to Section 9 of the *Manual of Cross-Connection Control.*[8]

If a unit fails to comply with its specifications as listed in the *Manual of Cross-Connection Control,* the manufacturer, health agency, plumbing authority, and water purveyor warrant being notified. If a manufacturer's assembly does not gain approval from an approved testing laboratory, the manufacturer is responsible for replacing the field test assemblies in all field evaluation sites with currently approved assemblies.

Once the assembly satisfactorily passes the laboratory and field evaluations, the manufacturer supplies the approved testing laboratory with the sales, installation, and maintenance literature for that particular model and size of assembly. The manufacturer must also give the serial number of the first assembly manufactured in the approved configuration.

The Foundation for Cross-Connection Control and Hydraulic Research grants an approval for the specific size and model for a period of no more than 3 years, and the approval may be rescinded for cause before that time. The Foundation issues a list of all assemblies that are currently approved.

For the approval to be renewed, verification of compliance of field performance must be accomplished every 3 years. The approving agency determines the extent of the reevaluation required. The manufacturer's current sales, installation, and maintenance literature is submitted and reviewed. Part of the renewal process is past performance of the assembly under field operating conditions, and spare parts availability is also reviewed. Failure to meet these requirements results in the automatic rescinding of the approval for that size and model of assembly.

3. INSPECTION PROCESS AND RECENT EXPERIENCE

3.1 SYSTEM FOR PERFORMING INSPECTIONS

The safety surveillance inspection (SSI) group of QE&I is responsible for inspecting most safety-related equipment, including BPDs, and for performing cross-connection surveys at ORNL. The inspection of backflow preventers and the surveying of cross-connection control are considered to be two different types of inspection, each having separate inspection request (IR) files in the computerized database.

Each IR file, which is uniquely numbered, contains a listing of all of the pieces of equipment to be inspected during a particular inspection. Further, each piece of equipment has a unique inspection equipment (IE) number that is listed on the IR. Each type of equipment is inspected to a procedure that gives the inspection protocol and the laws and regulations governing the inspection. The applicable procedures for an IR provide the design and functional criteria for data elements, data acquisition, records, report format, and report distribution.

The database, residing on a mainframe computer at ORNL, includes all pertinent information needed to complete an inspection. For instance, accessing the number IR 13521 lets the inspector know the manufacturer, size, model, and serial number of a particular BPD. The database also contains the location, contact, last result, division, and description. It can also print a schedule of when the BPDs are due on a semi-annual basis. With this information the inspector can ensure adherence to the procedure requirements.

With all the equipment that is inspected, a database is necessary to keep track of frequency requirements, new additions, deletions, status (active or inactive equipment), last inspection, next inspection, and inspection results (accept, reject or verify). *Verify* is denoted on all equipment that has not been inspected, and a reason for the lack of inspection is given.

The database is maintained by the Document Controller, whose job is to ensure the accuracy of all records entered and to keep the database updated. The Document Controller is also responsible for keeping track of all hard copies of the inspection reports.

The database generates inspection schedules, worksheets, data, reports, and support documentation for use by SSI staff.

The logic diagram for the ADP Software System is derived from the Safety Program established through QE&I's program and construction projects designated by IRs. The applicable procedures for an IR provide design and functional criteria for data elements, data acquisition records, and report format and distribution.

The inspection worksheets include IR number, IE number, type of equipment, date due, divisions responsible for equipment, location, results (accept or reject), readings (if any), date, and inspector. The inspection equipment worksheets are grouped by IR number and sorted by building and/or IE number. An equipment inspection schedule for each division and the worksheets are computer generated through the computerized database by the Document Controller.

After inspections are completed, the inspector fills out a worksheet in ink and inputs it into the computerized database via the NSPECT program. Each inspector has a personal identification stamp that is used on everything the inspector signs. The inspector stamps the worksheet.

If a piece of equipment is not inspected, is deleted, or if new equipment is added, the proper forms must be filled out and entered in the database file CID.ADD[4375,33] by the inspector. Forms are signed by the inspector's supervisor and then given to the Document Controller.

All inspection data are input by the end of the first working day of the month following the inspection. The Document Controller verifies data entry for all equipment inspections by comparing the data entry checklist against the inspectors' data entered. If inspection data are omitted inadvertently, additional forms must be filled out and signed by the supervisor before the Document Controller updates the database. If a piece of equipment is not inspected in the month that it is due, a delinquent report is generated by the computer.

The purpose of the ADP software system is to provide an encompassing system for data input, output, and management together with functions performed by SSI inspectors as designated by IRs.

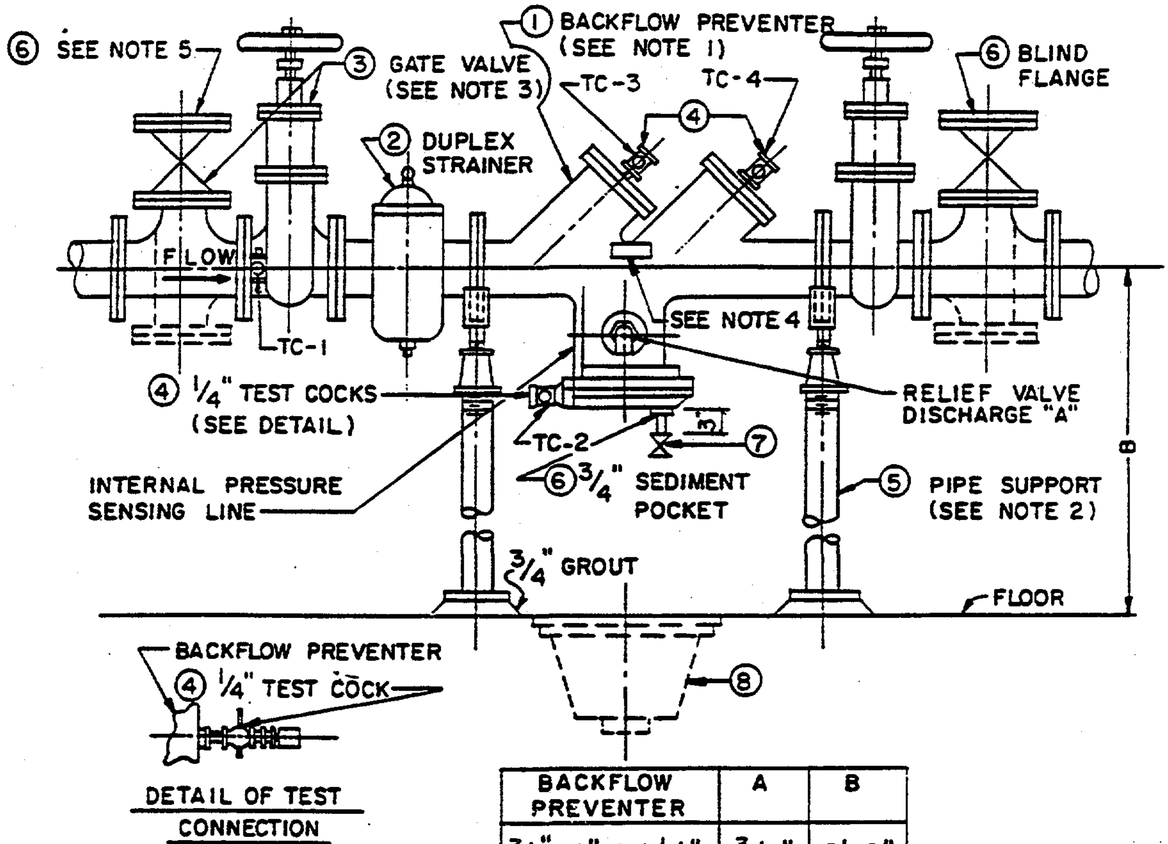
The following is a program listing of the database.

1. CID MASTER.DMS lists corresponding cross-references for inspection equipment.
2. CID DELETE.DMS contains records of deleted inspection equipment. Attributes include IR number, IE number, cross-reference, description, building, location, and date of deletion.
3. CID SCHEDL.DMC is a program used to generate division inspection schedules. It includes all of the equipment inspected under the SSI schedule.
4. CID RESULT.DMC is a program used to generate division inspection status reports.
5. CID DELINQ.DMC is a program used to generate the monthly delinquent report for inspection equipment.
6. CID NSPECT.DMC is the interactive program used by the inspectors to input and edit SSI data for the current month and to generate inspection equipment reports.
7. Consolidated inspection databases are summarized in ADP file CID.DOC.
8. ADP programs related to CID are summarized in ADP file CID.PRO.
9. ADP programs to generate inspectors' inspection schedules are summarized in ADP file CID.SCH.
10. ADP programs to generate inspectors' inspection worksheets are summarized in ADP file CID.WKS.
11. ADP programs to generate worksheet/data entry checklists are summarized in ADP file CID.LST.

This database allows the inspectors to keep abreast of upcoming schedules, revisions, and results of previous inspections.

3.2 RESULTS OF RECENT INSPECTIONS

At ORNL 154 RPPBPs are currently in service in approximately 88 buildings. During a recent survey of the RPPBPs at ORNL, six areas of concern were examined for conformance to state and federal laws and to Energy Systems Engineering Standard ES-4.18-2A (Fig. 6).[10]



BACKFLOW PREVENTER	A	B
3/4"-1" & 1 1/2"	3/4"	2'-0"
2"-2 1/2" & 3"	1 1/4"	2'-0"
4" & 6"	2"	2'-6"
8" & 10"	3"	3'-0"

INSTALLATION NOTES

1. A 3-inch reduced pressure principle backflow preventer (RPPBP), BEECO by Hersey Products, Inc., is shown in a typical installation. The body shape, sizes, and sediment pocket arrangement of other approved makes may be different.
2. When approved for construction, pipe supports other than base supports may be used for nominal RPPBP sizes 2 inches and smaller.
3. Design conditions may require the inlet and outlet gate valves to be mounted in a vertical position when shown on the design drawings.
4. Do not cover the RPPBP nameplate with insulation.
5. Two valved connections with blind flanged ends are for attaching a temporary RPPBP to permit repair or removal of the existing unit without interrupting process water service.

Fig. 6. Energy Systems Engineering Standard ES-4.18-2A, dated January 22, 1981, "Backflow Preventer, Uninterrupted Service—ORNL."

6. Encircled items 1 through 8 are specified as follows:

Item	Description
1	Backflow preventer, reduced pressure principle (RPPBP) type, with two independently operating check valves and an intermediate chamber with independent relief valve that, when open, shall drain the relief chamber to a level one pipe diameter, minimum, below the inlet check valve opening. The RPPBP shall be a manufacturer's model and size, granted full approval by the Foundation for Cross-Connection Control and Hydraulic Research of the University of Southern California (FCCCHR), and listed by the Tennessee Department of Public Health, Division of Water Quality Control. The RPPBP shall include the following: a. Two (inlet and outlet) rising stem gate valves. See Item 3. b. Four test cocks. See installation drawing and Item 4. c. RPPBP units, 2 inches and smaller only, shall also include: (1) Y-type strainer, 20 mesh Monel screen, 125 psig rating, screwed ends with blow-off plug, gate or ball valve. (2) Screwed union with brass-to-iron seats at inlet and outlet. d. Drain or blow-off connection at low point of the pressure sensing chamber of the relief valve diaphragm, plugged. The location shall permit field installation of a 3/4-inch drip leg for effective blow-off of accumulated sediment. e. Each RPPBP shall be operationally and hydrostatically tested by the manufacturer as specified by the FCCCHR. f. Manufacturer's data shall be supplied as specified in contract special conditions. When not so specified, data shall be supplied.
2	2 1/2-inch and larger only, duplex strainer, 20 mesh Monel screen CI body, 125 psig flanges, with blow-off valve. Strainer shall be added to the RPPBP assembly at time of installation.
3	2 1/2-inch and larger, gate valve, OS&Y, 125 psi cast-iron flanges, with bronze trim. Two-inch and smaller gate valves shall have rising stem, bronze body and trim, with screwed ends. Inlet and outlet valves shall be the same type as tested with the FCCCHR approved unit.
4	1/4-inch gauge cock, brass body, tee-handle, female screwed ends, Powell Figure 757, Ashcroft No. 1092, Crane Figure No. 712, or approved equal; each with field installed quick-connect body assembly with male thread end. Note: Swagelok, Item No. 1/4-QC4-B-4PM is a typical example.
5	Pipe support, in accordance with Engineering Standard ES-4.5-2, PS-1, pier A, except that saddle support may be fabricated from steel plate and a pipe nipple.
6	Piping in accordance with Technical Specification P-1.1, Subsection 103 (5.103). Field added sediment pocket is required on units with diaphragm operated relief valve. A typical pocket arrangement is shown.
7	3/4-inch gate valve, V-1, bronze body, screwed ends, Lunkenheimer No. 2125, Crane Figure No. 430, Powell Figure 500, or approved equal.
8	Square open-top floor drain, CI, galvanized, screwed outlet. RPPBP units 2 inches and smaller shall have a 12-inch-square top with 4-inch IPS outlet. Units 2 1/2 inches and larger shall have 16-inch-square tops with 6-inch outlets. Drain shall be installed flush with the floor and shall be centered under the RPPBP as shown, except that drains for units 2 1/2 inches and larger shall be offset 4 inches laterally in front of the unit.

Fig. 6 (continued)

The six areas of concern were (1) approved devices, (2) access and location, (3) parallel devices, (4) strainers, (5) drains, and (6) labels (Table 1 and Fig. 7).

1. **Approved devices.** Each type of RPPBP must have been approved by the Foundation for Cross-Connection Control and Hydraulic Research and listed by the Tennessee Department of Public Health, Division of Water Quality Control. Of the 154 RPPBPs surveyed, 113 were approved and 41 were not. Of the 41 not approved, the Foundation states that the device can stay in service until repairs are needed. When repairs are needed, a new approved device must be installed in its place.

2. **Access and location.** This must meet Tennessee state law. Of the 154 RPPBPs surveyed, 142 met the requirements and 12 did not. The 12 devices are being reviewed for relocation.

3. **Parallel devices.** This is not covered by state or federal law. Using RPPBPs in parallel is very efficient for buildings where the water cannot be turned off for any length of time. This installation keeps water running throughout the building at all times while one RPPBP is being tested or repaired (Fig 8).

4. **Strainers.** This must meet Energy Systems Engineering Standards. Strainers are installed upstream of the RPPBP. Strainers are very effective for keeping debris from entering the RPPBP. Of the 154 RPPBPs surveyed, 101 had strainers and 53 did not.

5. **Drains.** This is covered by state law. Of the 154 RPPBPs surveyed, 145 had drains and 9 did not.

6. **Labels.** This is covered by state law. A label denoting *potable* must appear on the upstream side of an RPPBP and *process* on the downstream side. Of the 154 RPPBPs surveyed, 67 had labels and 87 did not.

The 154 RPPBPs in service at ORNL represent only 5 manufacturers. Three of the manufacturers have a total of 23 RPPBPs in service, but these manufacturers' devices are being eliminated as they need repair. Since there are so few of these devices, parts are hard to find, and pipe fitters and inspectors are less familiar with them. The Crane A model, which accounts for 20 of these RPPBPs, is no longer on the approved list. It is more convenient and cost efficient to limit the number of brands of RPPBPs in use. The manufacturers Beeco and Watts have 139 RPPBPs in service at ORNL (Fig. 9).

Sizes of RPPBPs at ORNL range from 1/2 to 8 in. Most of these devices are 3/4 in. and are used mainly for operations inside the buildings. The larger RPPBPs are on the main lines coming into the buildings (Fig. 10).

RPPBPs need repair for a variety of reasons. The most common problem encountered is debris in the line. (Debris could be rust, scale, sand, rocks, etc.) Another common problem is a damaged seat or gasket resulting from water wear, defective gasket material, or debris damage. The components likely to fail an inspection are listed here in order of rejection rate.

Table 1. Backflow preventer survey

Bldg	IE Number	Mfg/Size	Approved	Access/ Location	Parallel	Strainer	Drain	Label	Comments
1503	10078	Watts 909 - 11/2"	y	y	n	y	y	y	
1504	10092	Beeco 6C - 2"	n	y	n	n	n	y	
1504	10126	Beeco 6CM - 4"	y	y	n	y	y	n	
1505	10035	FRP-II - 2"	y	y	y	n	y	n	
1505	10094	Beeco 6CM - 3"	y	y	y	n	y	n	
1506	10128	FRP-II - 2"	y	y	n	y	y	y	
2000	10102	FRP-II - 3/4"	y	n	n	n	y	y	6' high
2001	10003	Crane A - 2"	n	n	n	y	y	n	Asbestos
2003	10005	Beeco 6C - 8"	n	y	n	n	y	n	
2003	10004	Beeco 6C - 8"	n	y	n	n	y	n	
2007	10103	FRP-II - 1"	y	y	n	n	n	n	Regulated
2008	10152	Watts - 2"	y	y	n	y	y	n	
2010	10156	Watts - 3"	y	y	n	y	y	n	Attic
2013	10149	Watts 909 - 2"	y	y	n	y	y	n	
2013	10148	Watts - 1 1/2"	y	y	n	y	y	n	
2019	10134	FRP-II - 2"	y	n	n	y	y	n	Attic
2026	10012	Crane A - 3"	n	y	y	y	y	n	
2026	10093	Beeco 6C - 2"	n	y	y	n	y	n	
2069	10168	Watts 909 - 2"	y	y	n	y	y	n	
2075	10007	Beeco 6C - 8"	n	y	n	n	y	n	
2099	10167	FRP-II - 2"	y	y	n	y	y	y	
2099	10211	Watts - 3/4"	y	y	n	y	y	y	
2519	10013	Beeco 6C - 8"	n	y	n	n	y	n	
2519	10015	Beeco 6C - 8"	n	y	n	n	y	n	
2519	10014	Crane A - 6"	n	y	n	n	y	y	
2521	10147	FRP-II - 2"	y	n	n	y	y	n	Outside
2523	10150	FRP-II - 1 1/2"	y	y	n	y	y	n	
2525	10158	Watts 909 - 4"	y	n	n	y	y	n	6' high
2528	10132	FRP-II - 2"	y	y	n	n	n	n	
2531	10017	Beeco 6C - 4"	n	y	n	y	y	y	Regulated
2547	10002	Watts 909 - 2"	y	y	n	y	y	y	
2600	10110	Watts 909 - 1"	y	y	n	y	y	n	
2621	10018	Watts 909 - 1"	y	n	n	y	y	n	
2643	10203	Watts 909 - 3/4"	y	y	n	y	y	n	
2644	10114	FRP-II - 3/4"	y	y	n	n	y	y	
2649	10201	FRP-II - 2"	y	y	n	n	y	n	
2649	10200	Beeco 6CM - 3"	y	y	n	y	y	n	
3003	10020	FRP-II - 2"	y	y	y	n	y	y	
3003	10144	FRP-II - 2"	y	y	y	y	y	y	
3019	10023	Crane A - 4"	n	y	n	n	y	n	
3029	10143	Watts 909 - 3/4"	y	y	n	n	y	n	Regulated
3030	10025	FRP-II - 3/4"	y	y	n	n	n	n	Regulated
3031	10026	Watts 909 - 3/4"	y	y	n	n	n	n	Regulated
3032	10161	Watts 909 - 3/4"	y	y	n	y	y	n	Regulated
3033	10138	FRP-II - 3/4"	y	y	n	y	y	n	Regulated
3039	10030	Beeco 6 CM - 3"	y	y	n	n	y	n	Outside
3042	10133	Watts 909 - 3/4"	y	y	n	y	y	y	
3047	10157	Watts 909 - 2"	y	y	n	y	y	n	
3074	10206	Watts 909 - 1"	y	y	n	y	y	y	
3109	10075	Beeco 6C - 1"	n	y	n	y	y	n	Outside
3137	10077	Watts 909 - 1"	y	y	n	y	y	y	
3144	10136	Watts 909 - 11/2"	y	y	n	y	y	n	
3144	10105	Watts 909 - 1"	y	y	n	y	y	n	
3147	10122	Watts 909 - 2"	y	n	n	y	y	n	6' high

Table 1 (continued)

Bldg	IE Number	Mfg/Size	Approved	Access/ Location	Parallel	Strainer	Drain	Label	Comments
3500	10171	Watts 009 - 1/2"	y	y	n	n	y	n	
3500	10172	Watts 009 - 1/2"	y	y	n	y	y	n	
3500	10170	Watts 909 - 3/4"	y	y	n	y	y	n	
3502	10204	Watts 909 - 3/4"	y	y	n	y	y	n	
3505	10040	FRP-II - 3/4"	y	y	n	n	n	y	Regulated
3518	10165	Watts 909 - 2"	y	y	n	y	y	n	Regulated
3525	10044	Beeco 6C - 3"	n	y	n	y	y	n	
3525	10045	Crane A - 3"	n	y	y	y	y	n	Regulated
3525	10104	FRP-II - 2"	y	y	y	n	y	n	Regulated
3544	10001	Beeco 6C - 3"	n	y	y	n	y	y	Regulated
3544	10119	Beeco - 1"	n	y	y	n	y	y	Regulated
3550	10046	Crane A - 2"	n	y	n	y	y	n	
3550	10072	Beeco 6C - 11/2"	n	y	n	n	y	n	Regulated
3587	10108	FRP-II - 3/4"	y	y	n	y	y	n	
3587	10017	Watts 909 - 3/4"	y	y	n	y	y	n	
3608	10135	Beeco 6CM - 3"	y	y	n	y	y	n	
4500N	10208	Watts 909 - 3/4"	y	y	n	y	y	n	
4500N	10049	Beeco 6C- 6"	n	y	n	y	y	y	
4500S	10031	Beeco 6CM - 4"	y	y	n	y	y	n	
4500S	10189	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10190	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10191	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10197	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10186	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10187	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10188	Watts 909 - 3/4"	y	y	n	y	y	n	
4500S	10193	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10183	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10184	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10194	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10196	Watts 909 - 3/4"	y	y	n	y	y	n	
4500S	10182	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10181	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10185	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10179	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10180	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10198	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10193	Watts 909 - 3/4"	y	y	n	y	y	y	
4500S	10192	Watts 909 - 3/4"	y	y	n	y	y	y	
4508	10090	Beeco 6C - 6"	n	y	y	n	y	y	
4508	10089	Crane A - 6"	n	y	y	n	y	y	
4508	10173	Watts 909 - 3/4"	y	y	n	y	y	y	
4508	10174	Watts 909 - 3/4"	y	y	n	y	y	y	
4508	10199	Watts 909 - 3/4"	y	y	n	y	y	y	
4509	10101	Watts 909 - 1"	y	n	n	y	y	n	
4509	10054	Crane A - 2"	n	y	n	n	y	n	
4512	10055	Watts 909 - 3/4"	y	y	y	y	y	n	
4512	10111	FRP-II - 3/4"	y	y	y	n	y	n	
4515	10056	Beeco 6CM - 3"	y	y	n	n	y	n	
4515	10175	Watts 909 - 3/4"	y	y	n	y	y	y	
4515	10176	Watts 909 - 3/4"	y	y	n	y	y	y	
5500	10057	Crane A - 4"	n	y	n	n	n	n	
5500	10058	Crane A - 3"	n	y	n	n	y	n	
5500	10177	Watts 909 - 3/4"	y	y	n	y	y	y	

Table 1 (continued)

Bldg	IE Number	Mfg/Size	Approved	Access/ Location	Parallel	Strainer	Drain	Label	Comments
5500	10178	Watts 909 - 3/4"	y	y	n	y	y	y	
5505	10160	Beeco - 1 1/2"	y	y	y	n	y	n	
5505	10059	Beeco 6C - 2 1/2"	n	y	y	y	y	n	
5507	10060	Beeco 6C - 2"	n	y	n	y	y	n	
5510	10130	Watts 909 - 11/2"	y	y	y	y	y	n	
5510	10162	Watts 909 - 11/2"	y	y	y	y	y	n	
5510A	10166	Conbraco - 3/4"	y	n	n	y	y	n	
6000	10032	FRP-II - 1 1/2"	y	y	n	y	y	y	
6000	10036	Beeco 6CM-21/2"	y	y	y	n	y	n	
6000	10127	Beeco 6CM-21/2"	y	y	y	n	y	n	
6000	10061	Watts 909 - 3/4"	y	y	y	n	y	n	
6000	10076	Crane A - 3"	n	y	y	y	y	n	
6000	10062	Beeco 6C - 2"	n	y	n	n	y	n	
6000B	10064	FRP-II - 2"	y	y	y	y	y	n	
6000B	10107	FRP-II - 11/2"	y	y	y	n	n	n	
6005	10163	Watts 909 - 3/4"	y	y	n	y	y	n	
6010	10066	Beeco 6C - 2"	n	y	n	y	y	n	
6010	10068	Watts 909 - 3/4"	y	y	n	y	y	n	
6012	10154	Febco 825Y - 2"	y	n	n	y	y	n	
7002	10153	Watts 909 - 3/4"	y	y	n	y	y	n	
7503	10073	Crane A - 4" (?)	n	y	n	n	n	n	No access
7567	10051	Beeco 6C - 1"	n	y	n	n	y	y	Regulated
7602	10009	Beeco 6C - 4"	n	y	n	y	y	y	
7710	10146	Watts 909 - 11/2"	y	y	n	y	y	y	
7735	10106	Watts 909 - 3/4"	y	y	n	y	y	y	
7824	10209	Watts 909 - 3/4"	y	y	n	y	y	y	
7830	10096	Beeco 6C - 11/2"	n	y	n	y	y	y	Regulated
7860	10164	Watts 909 - 2"	y	y	n	y	y	n	
7879	10151	Febco 825Y - 2"	y	y	n	n	y	n	
7900	10123	Beeco 6CM - 4"	y	y	y	y	y	y	
7900	10124	Beeco 6CM - 4"	y	y	y	y	y	y	
7900	10081	Beeco 6C - 2"	n	n	n	n	y	y	Ceiling
7900	10080	Beeco 6C - 2"	n	y	n	n	y	y	
7900	10079	Beeco 6C - 1"	n	y	n	n	y	y	
7903	10085	Beeco 6C - 11/2"	n	n	n	n	y	y	
7910	10129	FRP-II - 1"	y	y	n	y	y	y	
7916	10205	Watts 909 - 3/4"	y	y	n	y	y	n	
7920	10069	Crane A - 4"	n	y	n	n	y	y	
7920	10086	Crane A - 4"	n	y	n	n	y	y	
7930	10087	Beeco 6CM - 3"	y	y	n	y	y	y	
7930	10088	Crane A - 3"	n	y	n	n	y	n	
7934	10091	FRP-II - 2"	y	y	n	n	y	y	Regulated
7935	10121	Watts 909 - 2"	y	y	n	n	y	y	Regulated
7961	10210	Watts 909 - 11/2"	y	y	n	y	y	y	Outside
7962	10100	Watts 909 - 1"	y	y	n	n	y	y	
7962	10207	Watts 909 - 3/4"	y	y	n	y	y	n	Regulated
		Approved - y	113	142	26	101	145	67	
		Not Approved - n	41	12	128	53	9	87	

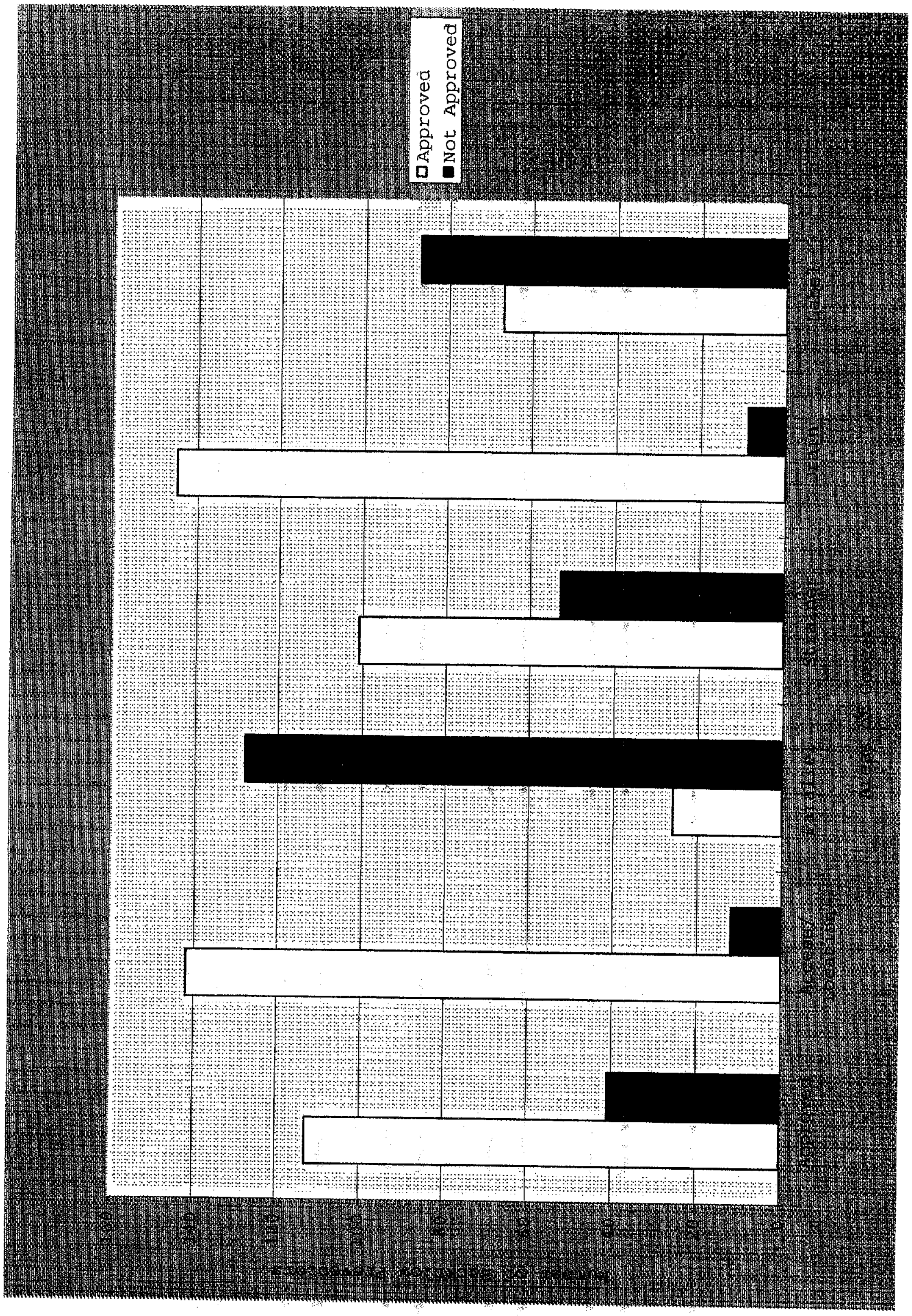


Fig. 7. Backflow preventer survey.

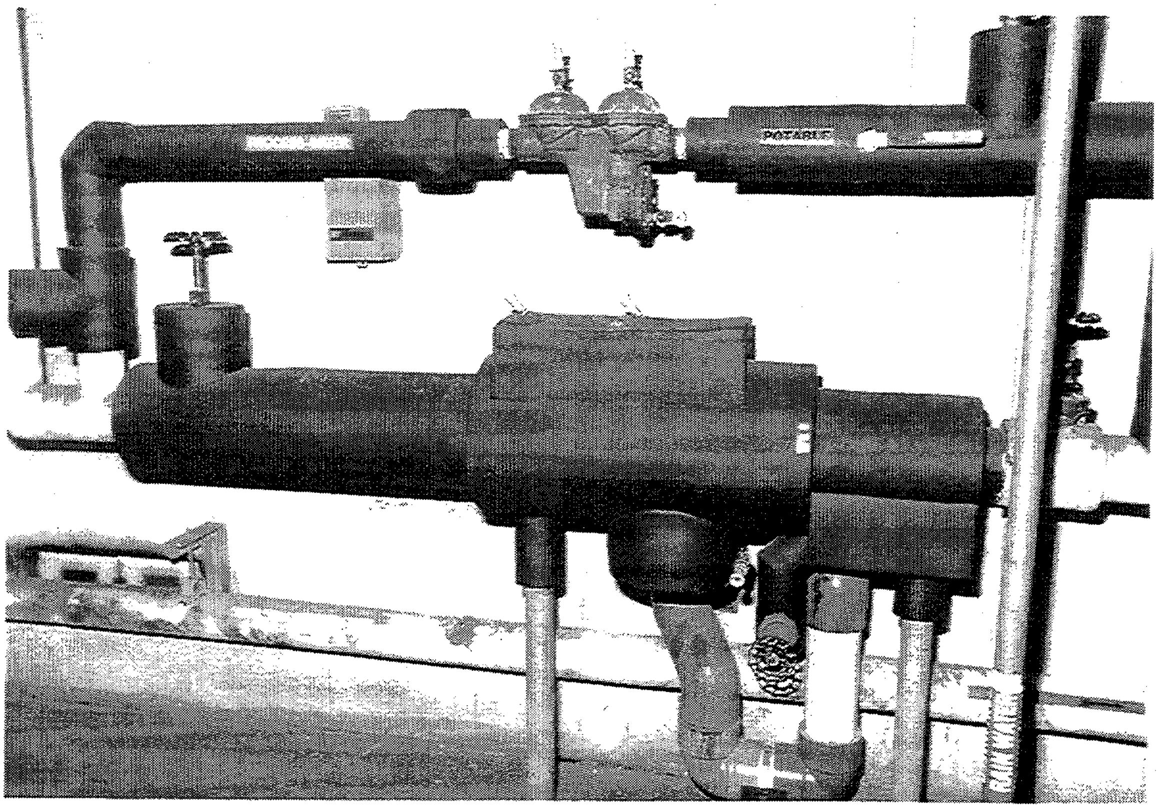
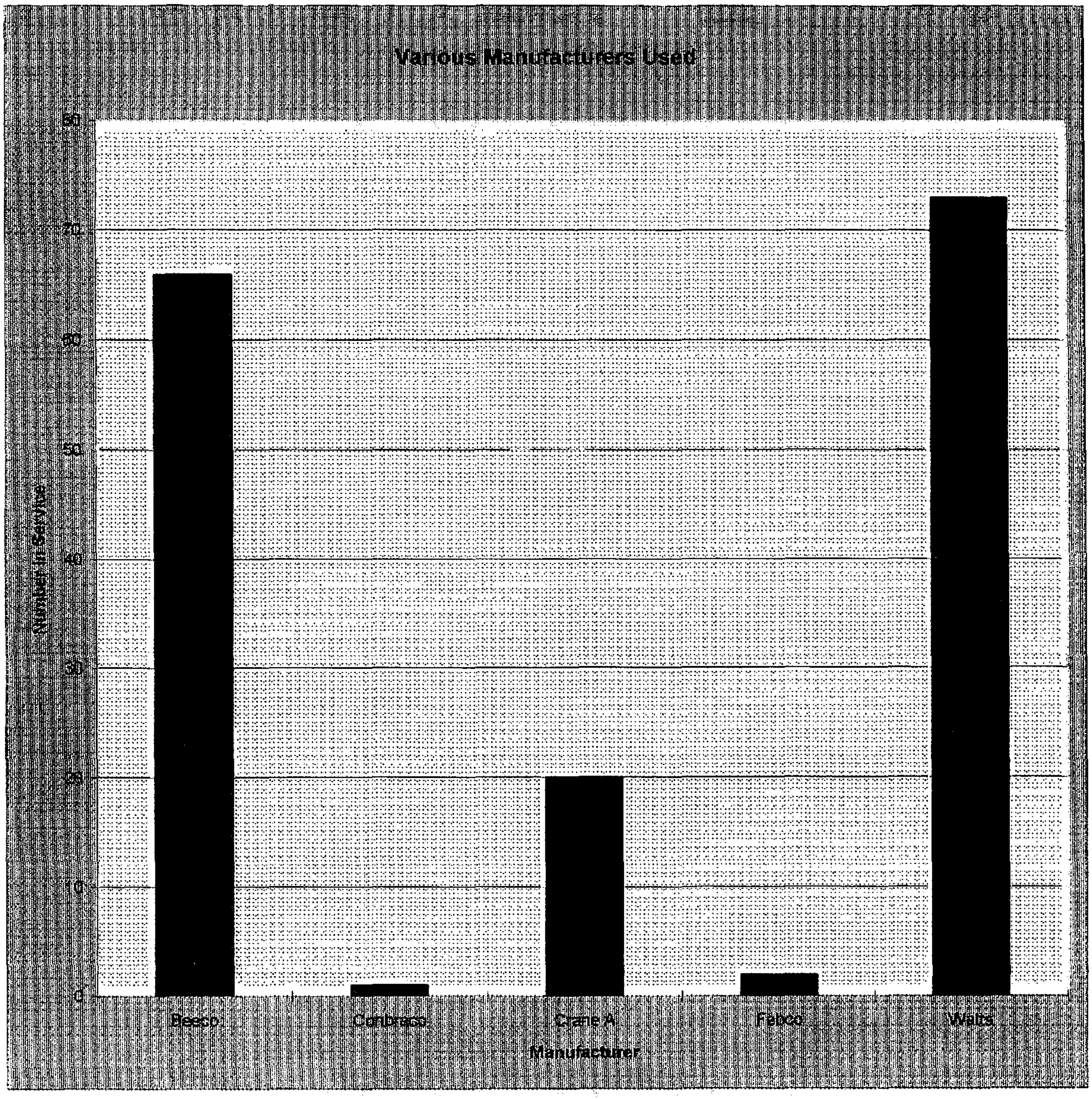
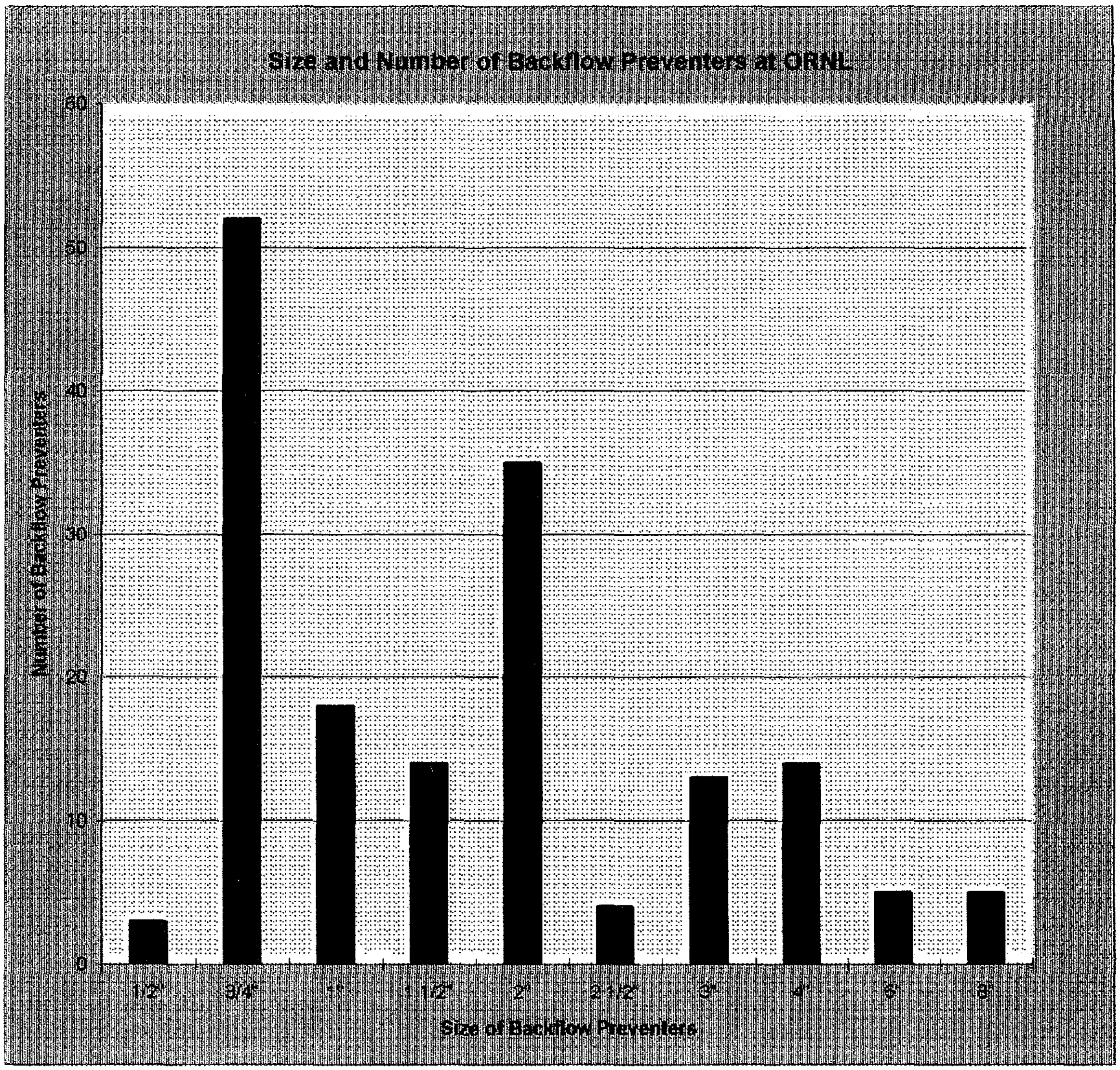


Fig. 8. A parallel or bypass reduced-pressure-principle backflow preventer.



Manufacturer	Number In Service
Beeco	66
Conbraco	1
Crane A	20
Febco	2
Watts	73

Fig. 9. Graph of the number of reduced-pressure-principle backflow preventers in service at ORNL per manufacturer.



Size	Number
1/2"	3
3/4"	52
1"	18
1 1/2"	14
2"	35
2 1/2"	4
3"	13
4"	14
6"	5
8"	5

Fig. 10. Graph of the size and number of backflow preventers at ORNL.

1. **No. 1 check valve.** Damage is usually caused by debris in the line (38% rejection rate).

2. **Relief valve.** Damage usually results from debris or a pressure fluctuation (a sudden extreme use of an upstream line) (36% rejection rate).

3. **No. 2 check valve.** Damage is usually caused by debris in the line (14% rejection rate).

4. **No. 2 gate valve.** This gate valve is sometimes defective (12% rejection rate) (Fig. 11).

The rejection rate varies by year. Data for ORNL go back to September 1988. Many RPPBPs were rejected in 1989, possibly because of their age, and replaced with new ones during 1989 and 1990. The more recent years show a more normal trend (Fig. 12). During the past 7 years, the number of RPPBPs in service at ORNL has increased, while the number of RPPBP devices taken out of service has remained essentially constant. Typically, when one RPPBP is removed from service, another one is put into service to replace it (Fig. 13).

3.3 CROSS-CONNECTION SURVEY OF THE ORNL CAFETERIA

As a result of the 1991 DOE audit, the CCCC was established and performed the first cross-connection survey at ORNL. The cafeteria was selected as the area to be surveyed. The cafeteria is serviced by a 3-in. potable water line located at the northwest corner of the facility and is protected by a 3-in. Watts RPPBP. All potable water service lines, both cold and hot, and the steam lines were traced and appropriately labeled from the attic to each of the following individual service areas: salad preparation, potable ice machine production, cooking, steam kettle, dishwashing, servicing line, and takeout service area.

The major findings of the survey are summarized here.

1. The attic area had a 3/4-in. cross connection of cold water directly to the steam line. Here, the cold water line needed to be connected to the existing cold water line.
2. The salad preparation area had a refrigeration unit that needed an adequate air gap between the condensate discharge line and the sanitary discharge line.
3. The potable ice machine needed an adequate air gap at the drain line.
4. The cooking area had a cross connection of potable cold water with the steam line rinse piping area. To correct this deficiency, the cold water line needed to be connected to the existing cold water line.
5. The steam kettle area had a fill hose that was not protected from back siphonage. A vacuum breaker needed to be installed.
6. The dishwashing area had a hose faucet unprotected. A vacuum breaker needed to be installed. The three-compartment sink, pre-wash hose, and power soap dispensers were unprotected. A vacuum breaker needed to be installed.

The survey of the cafeteria took approximately 38 hours, which included meetings, report writing, and field consultations. Actions were taken subsequently to address the major findings.

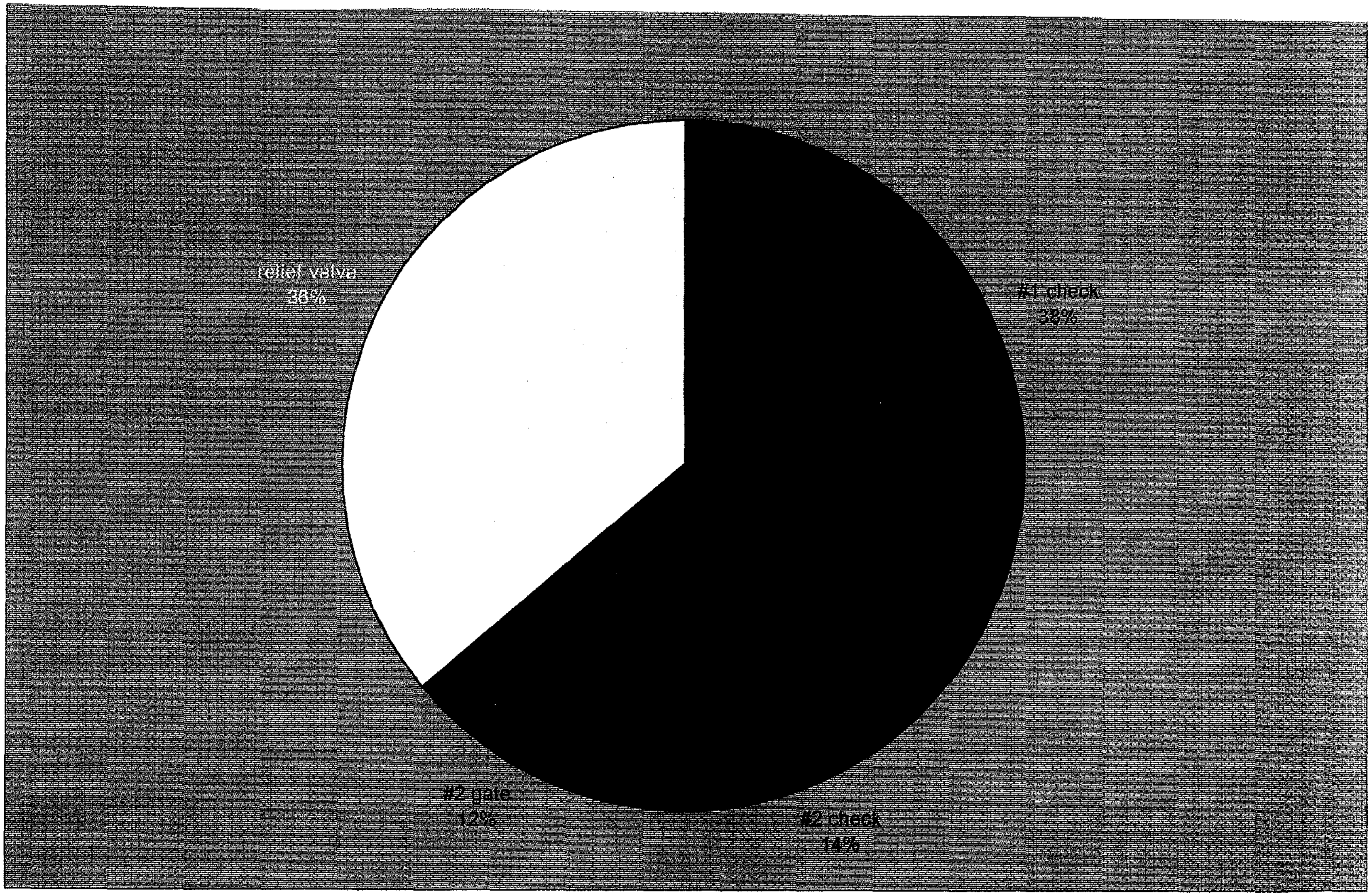


Fig. 11. Rejection rate data for reduced-pressure-principle backflow preventers.

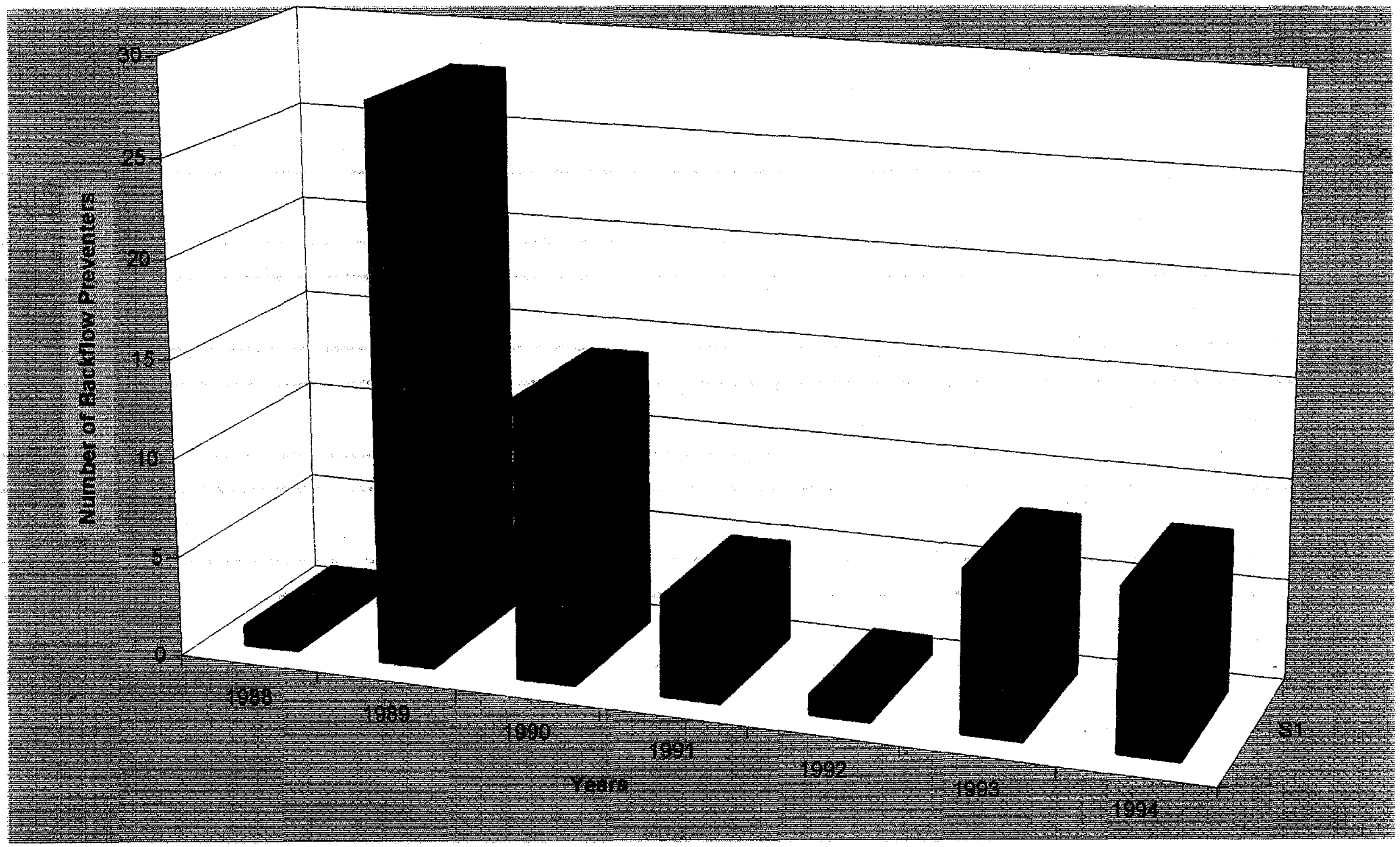
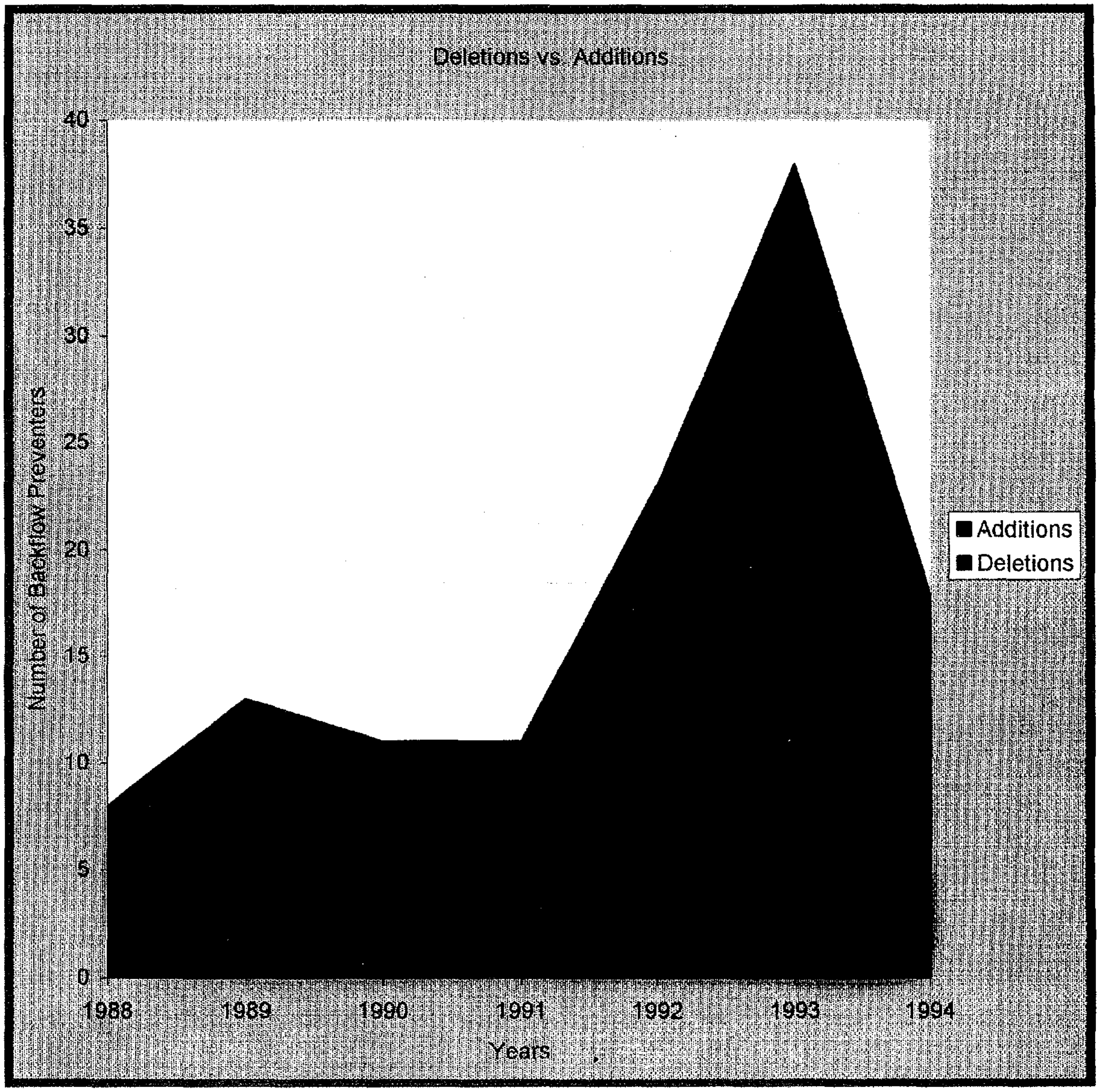


Fig. 12 Rejection rates of backflow preventers for the years 1988–1994.



Year	Deletions	Additions
1988	8	0
1989	8	5
1990	4	7
1991	1	10
1992	15	8
1993	2	36
1994	6	12

Fig. 13. Deletions and additions of backflow preventers at ORNL from 1988–1994.

4. WATER USE AT ORNL

4.1 WATER REQUIREMENTS

ORNL is organized into 35 divisions, all of which use potable water. Each employee is assumed to use 30 gal of potable water per workday. Potable water use is calculated as follows:

$$\text{number of employees} \times 30 \text{ gals per day} \times 5 \text{ days per week} .$$

According to ORNL's Work Force Report of January 1994, the total number of employees (including visitors) was 7,523, which equates to a weekly potable water use of 1,128,450 gal.

Fifteen divisions use only potable water. These divisions have 1,608 employees and thus require 241,200 gal of potable water each week.

Only 20 of the 35 total divisions require process water. These divisions need process water to run equipment used in their work. The 20 divisions have a total of 5,915 employees, so they require 887,250 gal of potable water each week.

Below is a breakdown of total water use (both potable and process) at ORNL.[9]

Water user	Weekly consumption (gal)
ORNL divisions that use both process and potable water	19,238,548
ORNL divisions that have no process water needs and therefore use only potable water	241,200
Calculated total	19,479,748
Actual total (based on data for the past 2 years and 10 months)	19,277,097

4.2 POTABLE WATER

The following is a list of the top nine users of potable water and their weekly requirements. These nine divisions account for approximately 50% of the potable water use at ORNL.

Division	Potable	Process
Plant & Equipment	134,400	4,525,440
Metals & Ceramics	89,400	5,311,060
Environmental Sciences	80,550	463,678
Health Sciences Research	65,100	360,280
Engineering	63,150	None used
Chemical Technology	61,500	205,728
Instrumentation & Controls	59,700	240
Solid State	51,600	110,264
Physics	48,600	503,320

4.3 PROCESS WATER

Of the 20 divisions that use process water, 9 divisions use 92% of it. The nine highest users of process water and their weekly requirements are listed here.[9]

Division	Process gallons	Potable gallons	Process % of total
Research Reactors	6,067,580	21,900	31.148
Metals and Ceramics	5,311,060	89,400	27.265
Plant and Equipment	4,525,440	134,400	23.232
Physics	503,320	48,600	2.584
Environmental Sciences	463,678	80,550	2.38
Health Sciences Research	360,280	65,100	1.85
Safety and Health Protection	215,100	19,800	1.104
Chemical and Analytical Sciences	210,380	39,750	1.08
Chemical Technology	205,728	61,500	1.06

As shown, the divisions that use most of the process water are not the same divisions that use most of the potable water.

The top nine users of process water were asked the following questions concerning the protection of their processes.

1. Is the building protected by any BPDs?
2. What is the process water being used for?
3. Are these processes protected by any BPDs?
4. Does this process ever change?
5. What is the degree of hazard for these processes?

In general, the users responded as follows:

1. All of the buildings are protected by a RPPBP device.
2. The biggest percentage of process water used at ORNL is used for cooling tower makeup, the cooling of many types of equipment, boilers, and laboratory sinks.
3. These processes are protected by a RPPBP or by another approved BPD.
4. These processes do not change.
5. The degree of hazard for these processes range from low to high hazard.

A description of the process water use by all 20 divisions is on file. Use by the top nine divisions is summarized here.

Research Reactors Division uses more process water than any other division, approximately 6 million gallons per week. The process water is used mainly for the cooling towers. Water use for cooling towers is calculated as follows:

$$75\% \text{ of the listed gph} \times \text{hours/week operating frequency.}$$

This calculation allows for variable use conditions. Research Reactors Division uses approximately 31% of the total process water used at ORNL.

Metals and Ceramics Division uses approximately 5.3 million gallons per week of process water. The process water is used mainly for cooling high-temperature furnaces. The Metals and Ceramics Division uses approximately 27% of the total process water used at ORNL.

Plant and Equipment Division uses approximately 4.5 million gallons per week of process water. The process water is used mainly at the steam plant for the production of steam by one gas-fired and four coal-fired boilers. Approximately 3 million gallons every 2 weeks is needed just for boiler use. There is approximately 700 million pounds of steam used per year. Dividing this by 8.34 lb gives a total of approximately 84 million gallons per year of process water used. Approximately 7 million gallons of both potable and process water are used a month at the steam plant. These processes, all considered low hazard, are protected by three RPPBPs. The Plant and Equipment Division uses approximately 23% of the total process water used at ORNL.

Physics Division uses approximately 500,000 gal/week of process water. Most of the process water is used for various types of vacuum pumps, such as diffusion and cryo pumps, mechanical vacuum pumps, and assorted experimental devices. These processes are protected by RPPBPs and are considered low hazard. The Physics Division uses approximately 2% of the total process water used at ORNL.

Environmental Sciences Division uses approximately 464,000 gal/week of process water. The process water is used mainly for aquatic experiments and in laboratories. The Environmental Sciences Division uses approximately 2% of the total process water used at ORNL.

Health Sciences Research Division uses approximately 360,000 gal/week of process water. The process water is used mainly for diffusion pumps that have a continuous 24-h/day water flow. These processes are protected by RPPBPs and are considered low hazard. The Health Sciences Research Division uses approximately 1.850% of the total process water used at ORNL.

Office of Safety and Health Protection uses approximately 215,000 gal/week of process water. The main use of the process water is for laboratories. These processes are protected by RPPBPs and are considered low hazard. The Office of Safety and Health Protection uses approximately 1.1% of the total process water used at ORNL.

Chemical and Analytical Sciences Division uses approximately 210,000 gal/week of process water. The process water is used mainly as cooling water for diffusion pumps. Process water is also used in all laboratory sinks. Approximately 600 gal/h is used in one building. All of these processes are protected by RPPBPs and are considered low hazard. The Chemical and Analytical Sciences Division uses approximately 1.1% of the total process water at ORNL.

Chemical Technology Division uses approximately 206,000 gal/week of process water. The process water is used for cooling many types of equipment, such as heat exchangers and diffusion pumps, for cooling tower makeup, and in laboratories. The Chemical Technology Division uses approximately 1.1% of the total process water at ORNL.

The aforementioned nine divisions use almost 92% of the total process water at ORNL. All of the main process water uses are protected by RPPBPs. All laboratory sinks at ORNL use process water.

5. SUMMARY AND RECOMMENDATIONS

ORNL has formed the CCCC and has written a cross-connection control plan to address the needs of the ORNL potable and nonpotable water systems, but this effort needs considerably more attention. The biggest constraint is having sufficient funding to fulfill the requirements of ORNL, the Foundation for Cross-Connection Control and Hydraulic Research, and state and federal laws and regulations.

ORNL has begun to meet many requirements. A backflow prevention inspection program has been set up to perform semiannual inspections on new and existing RPPBPs. These devices are installed between the buildings and the main water line to prevent potential contaminants from entering the main water supply. Because potential areas of risk exist, the only sure way to determine the true status is to do complete cross-connection surveys of every building at ORNL. These surveys will be performed by the CCCC.

Of the 154 BPDs already in service at ORNL, the six areas of concern listed in Section 3.2 all need attention.

- With regard to **approval,** when an unapproved backflow preventer needs to be repaired, it should be replaced with an approved BPD.
- The **access** and **drain** concerns require input from the facility, engineering, and P&E personnel to determine new locations and piping arrangements and will consequently be costly and time consuming to rectify.
- With regard to **parallel devices**, it is up to the Facility Manager to justify installing a second BPD. Additional costs would be incurred for the device and installation, but it would prevent the problem of shutting off water in buildings that have equipment operating continuously.
- According to Energy Systems Engineering Standard ES-4.18-2A,[10] a **strainer** shall be included on units 2 in. or smaller and installed on RPPBPs at time of installation.[10] Several devices need strainers.
- With regard to **labeling**, some labels need to be made and then placed before and after the BPD.

Because of budget constraints, the cross-connection control program is being implemented slowly. There are still many concerns, and many surveys need to be conducted before the program is fully implemented.

Of the approximately 100 buildings at ORNL that use potable and process water, only one building (the cafeteria) has been surveyed for cross connections. The surveys for the other buildings should be given priority in order to bring ORNL into full compliance and to protect its employees and visitors.

The survey at the cafeteria was a demonstration effort to justify the expansion of the program. The survey provided an estimate of budget requirements, labeling, training requirements, number of trained personnel needed, and time needed to perform a survey. Because each building is different, the time required to complete a cross-connection survey will vary from building to building.

Without a fully implemented cross-connection control program, an upset condition could threaten ORNL with health effects ranging from nausea to death. ORNL has taken the first steps in a long journey toward full compliance. The survey of the cafeteria showed that ORNL can come into compliance if the program is included in the budget in the years to come. ORNL has the dedicated personnel and the expertise to complete this task and to maintain safety in the workplace.

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