studies are also desirable when applying neutralizing amines. Rectangular specimens are preferred because the nature of corrosion can be observed more clearly with this type of coupon. See also Chart 37, showing the recommended corrosion test specimen for a closed loop bypass installation.

3.2.5.3. Hot Water Boiler Systems

3.2.5.3.1. Make-up - It is important to recognize that hot water systems and boilers will require some amount of raw water make-up. This make-up requirement may be due to leaks in pump seals, piping, or other equipment; drain down for inspection or system repairs; weeping relief valves; improper expansion tank operation; and various other causes for water loss.

Raw make-up introduced to hot water boilers must be properly treated for oxygen and hardness. These impurities are the two basic causes of hot water boiler failures. One should also note how much make-up is being fed to the system.

A recommendation for a hot water make-up system is illustrated in Chart 38 showing a Water Boiler Piping Diagram.

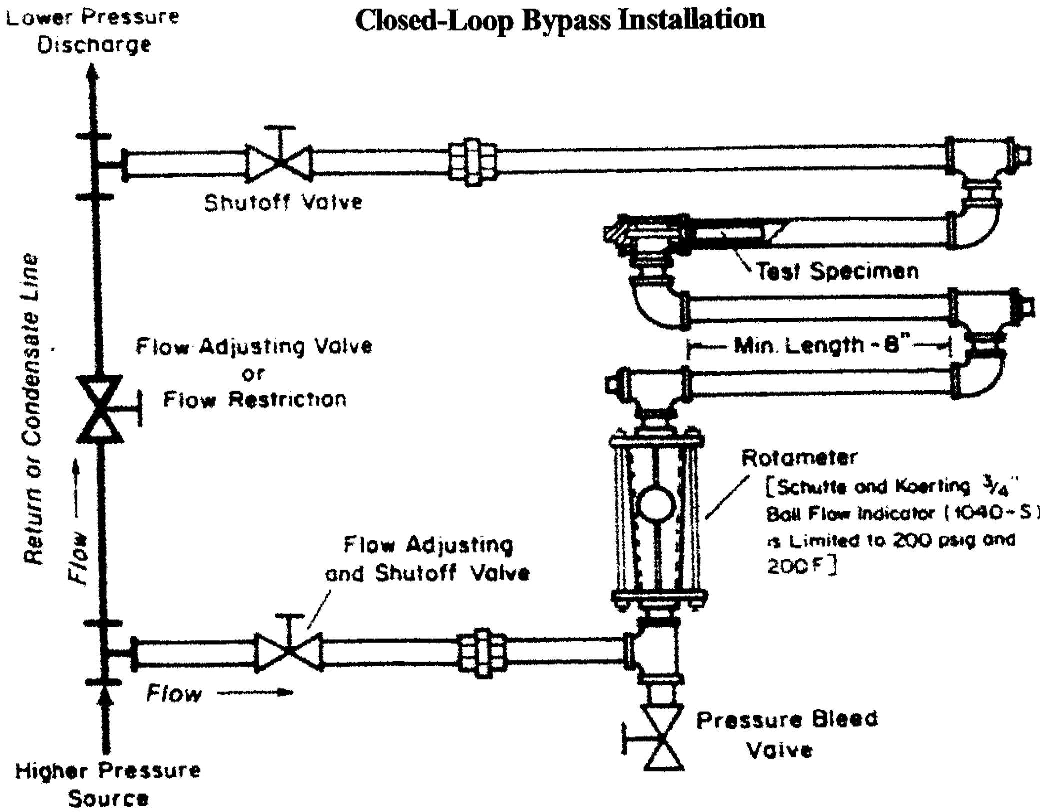
Its use in new or existing installations will help the boiler operator recognize system leaks and assist in maintaining water treatment within guidelines.

The quantity of make-up used is usually more important than the quality (hardness). Scale formation is not ordinarily a problem in systems which do not have significant water losses. A suitable monitoring device which measures the quantity of make-up water used not only indicates when unknown increased water losses occur, but may also prove helpful in establishing whether the quality of the make-up should be improved through softening.

3.2.5.3.2. Boiler Water - The hardness will normally stabilize at some average level which will be related to the make-up water characteristics and operation of the system. Increases in hardness would tend to indicate higher than normal water usage and the increased potential for scale formation.

The pH should be monitored because it is desirable to maintain moderately alkaline concentrations to minimize the potential for corrosion. (NOTE: These levels shall be established by operation and the experience of the water treatment consultant.)

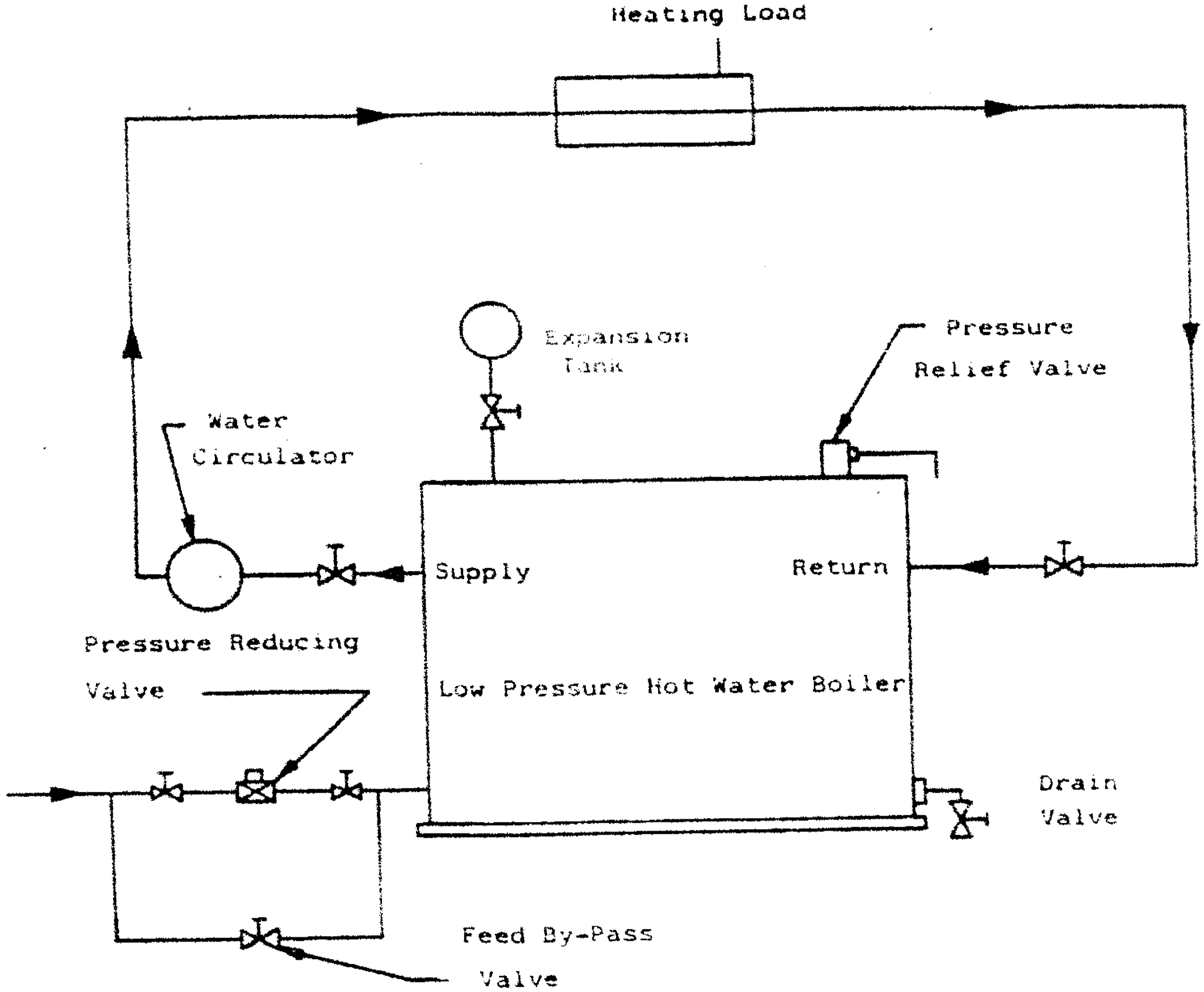
Chart 37
Recommended Corrosion Test Specimen
Closed-Loop Bypass Installation



Notes:

1. All piping and valves for the bypass are to be ¾ inch steel.
2. To minimize any tendency for the accumulation of sediment or entrapment of air around test strips, install the bypass in a vertical line, around two points where there is a pressure differential.
3. Close shut off valves and open bleed valve before removing any test specimen.
4. Test specimens must be handled carefully to avoid coating with natural oils from the skin, with thread compound or any similar material.
5. The end of the pipe plug holder is notched parallel to the flat side of the test specimen. When installing, the notch (consequently the specimen) is to be positioned vertically.
6. As a rule, all specimens are to be installed at the same time. Removal is to be at intervals to measure the effect of exposure time.
7. Adjust flow through the bypass to 3-5 gallons per minute, equivalent to 1.8-3.0 feet per second with ¾ inch pipe.
8. When removed each specimen is to be carefully disconnected from the holder and then immediately dried with a blast of hot air, or by sponging with a paper towel or tissue. Do not clean.
9. Analysis of corrosion tests can be obtained from your contracted water consultant

Chart 38
Hot Water Boiler Piping Diagram



This is a general diagram of components that make up a water boiler piping system. Follow the boiler manufacturer's recommendations as to location and size of the piping components. Care should be taken to follow their recommendations on piping and operation in order to prevent thermal shock on the boiler.

The concentration of water treatment chemicals should be closely monitored. Such materials would usually be employed to control corrosion and/or scale formation.

Corrosion monitoring is desirable. It serves to insure that optimum conditions are being maintained in the boiler water.

3.2.5.4. Condensate System Protection

3.2.5.4.1. Carbon Dioxide - Corrosion in steam/condensate return systems is usually caused by carbon dioxide. This is because it dissolves in water formed when condensation occurs, producing carbonic acid. Corrosion caused by carbonic acid will occur below the water level, and it can be identified by the channeling or grooving of the metal wall.

Breakdown of the make-up alkalinity is the source of carbon dioxide. This occurs as the water is heated in the boiler. If the amount of carbon dioxide in the steam is to be reduced then treatment of the make-up water is required to reduce the alkalinity.

3.2.5.4.2. Oxygen - Oxygen can also cause corrosion in condensate systems. However, it is not as common as carbon dioxide corrosion because oxygen is controlled in a hotwell or deaerating heater and by the use of chemical oxygen scavengers. Oxygen corrosion occurs wherever moisture is present, so it will be found both above and below the level of water in the piping or vessel. It is easily recognized because of the characteristic pitting.

3.2.6. Treatment

3.2.6.1. Neutralizing Amines - These are organic compounds which are used to neutralize the acidity of the condensate. The corrosivity is greatly reduced by maintaining the condensate pH in the alkaline range. <u>A pH somewhere between 8.0 and 9.0 is usually recommended</u>. The severity of oxygen corrosion is also reduced at this high pH.

The properties of neutralizing amines vary with respect to their neutralizing ability and also the manner in which they are distributed throughout the steam distribution system. Accordingly, they may be used alone or in combination to achieve desired results. Cyclohexylamine, diethylaminoethanol, and morpholine are the most commonly used neutralizing amines. This is primarily because they are approved for use in plants which are regulated by the Federal Drug Administration (FDA) and U.S. Department of Agriculture (USDA).

3.2.6.2. Filming Amines - Unlike neutralizing amines, filming amines do not neutralize acidity or raise pH. Rather, they form a nonwettable barrier which repels the corrosive environment of the condensate. They are known as polar amines because one end of the molecule attaches itself to the metal surface when condensation occurs. Filming amines can handle severe oxygen corrosion problems more effectively than neutralizing amines.

The properties of filming amines also vary, particularly with respect to the corrosion resistance of the water repellant film. Combinations of filming and neutralizing amines are often employed. Octadecylamine is the only filming amine approved for applications in FDA/USDA regulated plants. Unlike neutralizing amines, it is preferable to inject filming amines directly into the steam header. This is largely because the boiling point of these materials usually exceeds that of the boiler water.

CAUTION:

In existing systems the gradual introductions of filming amines is recommended to avoid the rapid removal of corrosion products. Fast removal of rust will cause plugging of traps and strainers.

3.2.6.3. Organic Oxygen Scavengers - Volatile or organic oxygen scavengers are employed as supplementary treatments, particularly where oxygen is causing corrosion. Portionating oxygen scavengers have the ability to establish and maintain a corrosion resistant film on the metal surfaces. This is usually called metal conditioning. In condensate treatment, these materials are not usually fed to completely remove oxygen from the system.

3.2.7. Monitoring

The sample point or method of sampling can influence results. If the condensate is hot or under pressure and flashes then the carbon dioxide may be lost. This raises pH. Accordingly, it is preferable to cool the condensate sample to room temperature.

It is not absolutely necessary to use a completely representative test or sample to assure success in effectively regulating a condensate corrosion control program. Rather, it is the consistency in sampling and testing that is important.

As mentioned previously, corrosion monitoring is important when using the filming amines for corrosion control because there is no simple, suitable test available. Corrosion studies using test coupons are recommended. These studies are also helpful when employing organic scavengers and neutralizing amines.

3.2.8. Electric Boilers - Special Considerations for Water Treatment

3.2.8.1. General - Electric boilers are comprised of two types: Immersion Element (Resistance type), and the Electrode type. Of the two, the Electrode boiler will require a greater awareness of the water quality and treatment control for proper operation. The difference between the two types of boilers is in the manner which electric energy (kW) is converted into thermal energy (Btu), and in the way thermal energy is transferred to the water.

In Immersion Element boilers, electricity flowing through a resistance wire generates heat. This heat is transferred from the element wire to the sheath, and then to the water by conduction.

Electrode boilers use the water surrounding the electrodes as the resistance necessary to create heat. As an alternating current is applied on the electrodes the current passing through the water generates heat due to the electrical resistance created by the water.

The primary problem associated with immersion units would be control of scaling and maintaining dissolved solids low enough to prevent foaming and carryover in steam boilers. It should be noted that in immersion type units, the metal surfaces must be heated to temperatures higher than the water in order to effect heat transfer. Since scaling is a function of surface metal temperatures, water hardness must be controlled.

Water treatment for immersion units should be the same as discussed for fossil fuel fired boilers in this publication. As a minimum, all immersion units should have a water softener connected to the make-up water supply. The pH of the boiler water should be maintained above 8. Oxygen control should be done externally or, at least, by chemical scavenging. As a minimum, Table 28 should be used as a guideline for water conditioning in the boiler.

3.2.8.2. Electrode Boilers - A critical requirement for Electrode boilers is proper water treatment. One should contact a water treatment consultant and the specific boiler manufacturer for water conditioning guidelines. The make-up water should be carefully analyzed noting that the analysis must take water variations into account. Variations in water quality may occur from multiple water sources, municipality water treatment, percent and type of condensate return, amount of make-up, etc. The water treatment program must be capable of handling the entire range of water quality.

Water softeners are a must for make-up in hot water and steam systems. It should be noted that softeners reduce only hardness and do not reduce alkalinity or silica concentrations. It is possible that a demineralizer may be required.

Since Electrode boilers operate on the principle that water conducts electricity, it is essential to maintain the range of proper conductivity. It is also necessary to ensure that the entire system (steam or water) is clean. The higher the conductivity, the more current the water will be able to carry at a constant voltage. If conductivity is too high, current concentrations may reach levels at which electrodes erode. Total dissolved solids will cause foaming if conductivity is too high providing short circuit paths from the electrodes to ground which can cause current surges and boiler off-line failures.

On the other hand, if conductivity is too low, the boiler may not operate properly. Therefore, conductivity must be monitored and controlled. High conductivity may be controlled by continuous blowdown. The amount will be determined by the conductivity of the boiler water. Bottom blowdown will be required on a daily basis to remove sludge.

3.2.8.3. Types Of Treatment - The water for all boilers must have proper treatment for hardness, pH, O_2 and conductivity. The treatment selected will be dependent upon the application and manufacturer's specific recommendations along with a qualified water consultant. As a minimum, the following should be assured:

3.8.3.3.1. Conductivity - As noted before, proper blowdown is required. If blowdown does not provide proper conductivity, chemical additives may be required.

In hot water electrode boilers, the conductivity must be maintained at the proper level for the operating temperature, kW output, applied voltage and the boiler design. It is important that the iron content be as low as possible and pH controlled within the specific guidelines.

High voltage boilers may require demineralized water to provide the proper conductivity levels. Boilers operating below 600 V usually do not require demineralized water.

3.2.8.3.2. Scale - It is recommended that the control of scale be done primarily by ion-exchange and not by chemical means. Total chemical addition for scale control could have a detrimental effect on conductivity levels or foaming. Therefore, as noted before, water softeners are a must to reduce hardness to near zero. Alkalinity should be maintained high enough to keep the silica in solution and removed through blowdown.

3.2.8.3.3. Corrosion - In all boilers the control of O_2, CO_2 and alkalinity is very important.

It is recommended that mechanical deaeration be used for the removal of oxygen from the boiler feedwater. Sodium sulfite or organic oxygen scavengers should be used as a feed to the boiler as the final oxygen scavenger. Organic materials may be preferred where conductivity requirements are low or TDS must be limited.

In electrode boilers using porcelain insulators, the control of alkalinity and CO_2 is important because of their potential to attack the porcelain. This does not mean that these boilers will not tolerate any alkalinity or CO_2, but that excess CO_2 and alkalinity should not be permitted to occur. It is the excess which causes the problems.

3.2.8.3.4. External Treatment - As a minimum, a softener must be employed to remove as much hardness as possible. If the raw water contains excessive hardness and alkalinity, the softened water can be fed into a chloride-anion dealkalizer.

In general, mechanical deaeration is recommended. Reverse osmosis and demineralizers should be employed if justified by an economic and water quality analysis.

3.2.8.3.5. Internal Treatment - Chemical treatment must take into account the conductivity levels. Any chemicals added must consider the effects on conductivity and it should be noted that excessive chemicals may promote operating problems and failures. Refer to Table 29 for guidelines.

3.2.8.4. Installation And Start-Up - Start-up for electric boilers should follow the same guidelines set forth in this publication for fossil fuel boilers. All boilers and systems must be cleaned prior to initial use.

Table 28
Water Conditioning Guidelines for Resistance Type Boilers[1]

Type of Boiler	Feedwater Hardness ppm	Boiler Water pH	Alkalinity ppm	Iron ppm	Conductivity Micro-mhos	TDS ppm	Oxygen cc./liter
Immersion Element	< 3	> 8	< 700	< 3.0	<7000	<3500	< 0.005

Note 1: Values given are considered starting points. Consult with boiler manufacturer for the correct values for a specific boiler model and type.

Table 29
Water Conditioning Guidelines for Electrode Type Boilers [2]

Type of Boiler	Feedwater Hardness ppm	Feedwater TDS ppm	Boiler Water pH ppm	Alkalinity (Total) ppm	Iron ppm	Oxygen cc/liter	Conductivity Micro-mhos
Low Voltage	< 3	< 750	8.5 - 10.5	< 400	< 0.5	0.005	< 3000
High Voltage	< 0.5	Note 1	8.5 - 10.5	< 400	< 0.5	0.005	Manufacturers recommend^{n}

Note 1 : TDS is dependent on the amount of blowdown and frequency. Limits should be determined after operational analysis is made by feedwater consultant.

Note 2: Values given are considered starting points. Consult with boiler manufacturer for proper values for the specific boiler model and type.

Note 3: Conductivity required is design dependent. Boiler manufacturers instructions must be followed.

3.3. Operations

3.3.1. Preface - The operation of many commercial boilers is remote and automatic. Flame safeguard equipment has been developed to operate reliably to protect these boilers when malfunctions occur. However, all such equipment needs periodic care to assure its reliability. In order to administer such care, all persons who operate or tend this equipment must have experience and training and access to the most recent issue of the instruction manuals.

3.3.2. Recommended Periodic Testing, Verification, And Observation - Packaged commercial boilers are factory fire-tested prior to shipment. During this fire test the manufacturer verifies the proper operation of all controls and safety devices. Further testing and verification may also be done at the time of startup; at this time operating controls are set to the specific installation requirements.

It becomes the owner's responsibility to provide for maintenance once the unit has been placed in service. Such maintenance should provide for periodic testing and verification of controls and safety devices. The owner and/or boiler operator should keep records or logs of such maintenance.

This maintenance and testing is in addition to those inspections required by the various governmental agencies or insurance companies. A suggested checklist showing the recommended frequency of periodic testing appears at the end of this section on page 130

Good practice dictates periodic observation of the boiler's operation. Simple oxygen and temperature monitoring instruments are available which the operators can use to check conditions of the flue gases. The appearance of the effluent from the stack (smoke) can also indicate whether combustion conditions are satisfactory. Give particular attention to these conditions during startup and shutdown, as these operations are those most likely to provide information when something is going wrong.

3.3.3. Burner Care - A planned preventive maintenance program is your direct route to safe, dependable boiler operation. Packaged boilers are supplied with engineered fuel burning packaged equipment that must be maintained through a regular, conscientious maintenance program to keep it in safe satisfactory operating condition.

Oil nozzles, ignitors, electrodes and burner internals should be checked at least monthly. Setting of spark gaps, nozzle openings, and general dimensions should be checked for both wear and cleanliness. Specific instructions as to the method of cleaning and adjustment and proper dimensions and settings are available in the instruction manual furnished by the manufacturer.

The best methods of keeping a planned preventive maintenance program in effect is to keep a daily log of boiler operating parameters such as pressure, temperatures, drafts, water treatment data, etc. When such a log is maintained, variations from normal readings can be analyzed quickly and corrected to avoid serious problems.

Some examples of the use of correlating normal data with variations from them are:

- An oil fired unit showing a drop (from normal) in oil pressure can indicate a faulty regulating valve, a plugged strainer, an air leak in the suction line, or a change in the operation of some other piece of equipment in the oil line.

- An oil fired unit showing a drop (from normal) in oil temperature, when using pre-heated residual oil, can indicate a malfunction of the oil temperature controls, or failure or fouling of the heating element.

- A gas fired unit showing a decrease (from normal) in gas pressure can indicate a malfunction of the regulator, a drop in the gas supply pressure, or some restriction in the gas line caused perhaps by one or more controls operating improperly.

Check items such as linkages and other mechanical fastenings and stops periodically for tightness. Visual checks will help determine whether any vibrations or unacceptable movements are occurring in all equipment. Readjust and repair as necessary any items that are loose, vibrate, or move from their proper positions.

Check stacks or chimneys daily for haze or smoke conditions. A cloudy, hazy, or smoky effluent indicates the possible need for burner adjustment. The fire may not be receiving enough air; there may be improper mixing of the fuel and air; there could be a change in fuel properties which requires different oil temperature or atomizing medium; etc.

Check the temperature of the gases in the stack and note it in the boiler operating log. However, bear in mind that a rise in these temperatures does not always mean poor combustion or fouled heat transfer surfaces. These temperatures also change as the boiler load changes; they can vary as much as 100°F from high to low fire. Therefore, make temperature comparisons at similar firing rates.

Make a periodic inspection of the fireside. When the gas temperature to the stack exceeds normal operating temperatures by 100°F to 175°F, it is very likely that an inspection will show that fireside cleaning is required. If such is the case, do the cleaning immediately upon shutdown. **CAUTION: Care should be taken to avoid soot explosions when cleaning a hot boiler.** Follow the boiler manufacturer's recommended procedure for all fireside maintenance.

Inspect the burner refractory. Look for excessive cracking, chipping, erosion, loose particles, or heavy deposits of fuel residue. Minor cracking is not serious, but major cracking, deformation, and erosion can lead to overheating of the burner front plate and possibly poor combustion. Heavy deposits of fuel residue indicates leaking burner tips. It can also be a hazard and adversely affect combustion.

Inspect and replace, as required, all burner gaskets. - Visually check all fuel solenoid and motorized valves when shutting down. If the fire does not cut off immediately, the valve could be fouling or wearing, causing leak-by. If this occurs, a hazardous condition exists. Repair or replace the valve immediately to avoid serious problems.

Check periodically all switches, controls, safety devices, and other equipment associated with the packaged unit. Do not assume that this equipment operates properly forever. Check it on a regular basis and repair or replace parts as necessary.

Be sure to have spare parts readily available for your equipment. Consult the boiler/burner manufacturer for a suggested parts list. In particular, flame protection relays and burner tips and plugs should be part of your inventory.

3.3.4. Water Level Controls - The purpose of water level controls is to maintain the water inside the (steam) boiler at the proper operating level. All water level controls have a range of operation - not one set point. Water level controls with gage glasses should be set such that the water level is never out of sight, neither high nor low.

Water columns, gage glasses, and low water cut-offs on a steam boiler should be flushed (blown down) at least once each shift. The purpose of this flushing is to prevent any accumulation of sludge or dirt that could cause a control failure. When flushing the water column, it is advisable to test the operation of the low water cut-off.

The water level control that is most frequently found on packaged commercial boilers is a combination pump control and low water cut-off which is often incorporated in a water column arrangement. This combination control may be designed to cycle the operation of a boiler feed pump to maintain a uniform range of water level and also function to interrupt the electric current to a burner circuit in the event that an unsafe water level condition develops.

Local water conditions and the introduction of treatment chemicals to a boiler will vary the amount of sediment accumulation in a control float bowl or water column. For heating boilers it is recommended that the boiler safety control be blown down regularly at least once a week when the boiler is in operation. Power boilers are recommended to be blown down once a shift. When blowing down a control it is advisable to check the operation of the low water cut-off at a low-fire burner setting. This will minimize a boiler upset condition.

Test the low-water cut-off under actual operating conditions. With the burner operating, the boiler steaming lightly, and the boiler water at proper level, close all the valves in the feedwater and condensate return lines for the duration of the test; shut off the feedwater pump if required so the boiler will not receive any replacement water. Carefully observe the water level to determine where the cut-off switch stops the burner in relation to the lowest permissible water level established by the boiler manufacturer. The boiler water level should never be dropped below the lowest visible part of the gage glass. If the cut-off does not function as a result of this test, immediately stop operation of the burner. Determine the cause of this malfunction and remedy it. Repeat the slow steam evaporation test to verify the proper function of the cut-off and control.

If the burner cut-off level is not at or slightly above the lowest permissible water level, move the cut-off to the proper elevation or service, repair, or replace it as necessary.

Qualified technicians should dismantle low water cut-offs at yearly intervals to the extent necessary to insure freedom from obstructions and proper functioning of the working parts. Inspect the connecting lines from the device to the boiler for accumulations of sediment or scale or for corrosion. Clean and replace/repair as required. Examine all visible wiring for brittle or worn insulation and make sure electrical contacts are clean and, where applicable, check mercury switches for any discoloration or mercury separation. Normally, operating mechanisms should not be repaired in the field. Replacement parts and complete replacement mechanisms, including proper gaskets and installation and adjustment instructions, are available from the manufacturer.

It is possible to check the water column operation under operating conditions by shutting off the feedwater pumps and allowing the water to evaporate under normal steaming conditions. A careful check of the gage glass will permit determination of the exact point at which the low water cut-off shuts down the burner. By determining this mark, the operator