STEAM DECENTRALIZATION

THE REST OF THE STORY!

Presented by

Jack Ames, P.E.

Problem Solving Engineer

136 Stevenson Lane

Baltimore, Maryland 21212

410-337-3721

jackamespe@aol.com

www.steamtraining.com

Advantages and Disadvantages

- Traditional central steam
- High efficiency gas-fired hot water boilers in each building
- Medium temperature central hot water

Description
Traditional Central Steam System
(also known as District Steam System)

- All boilers typically located in a single centrally located plant
- Underground or overhead steam mains originating at central plant distribute steam to various and numerous buildings often located miles away
- These buildings use this steam directly or indirectly for:
  - Building heating
  - Domestic hot water
  - Humidification
  - Cooking
  - Sterilization
  - Snow melting
  - Absorption chillers

Major Usage

Minimal Usage

Advantages of Central Boiler Plant

- All boilers are typically located on main floor
- Extra boilers are available for emergencies and peak load situations
  - Most systems designed for 50% reserve capacity
- Auxiliary equipment such as condensate pumps, deaerators, feed water pumps, economizers, and water treatment equipment are all in same building – typically in basement.
- Multiple fuel capability
  - Interruptible gas with #2 oil or propane
  - Wood chips or sawdust are possible
- Boiler economizers are very feasible for increasing boiler efficiency
- Lots of steam can be transmitted through an 8”Ø main
  - 5# 12,000#’s/hour
  - 100# 40,000#’s/hour
  - 180# 61,000#’s/hour
  - 250# 83,000#’s/hour
- New buildings along existing mains can be easily added.

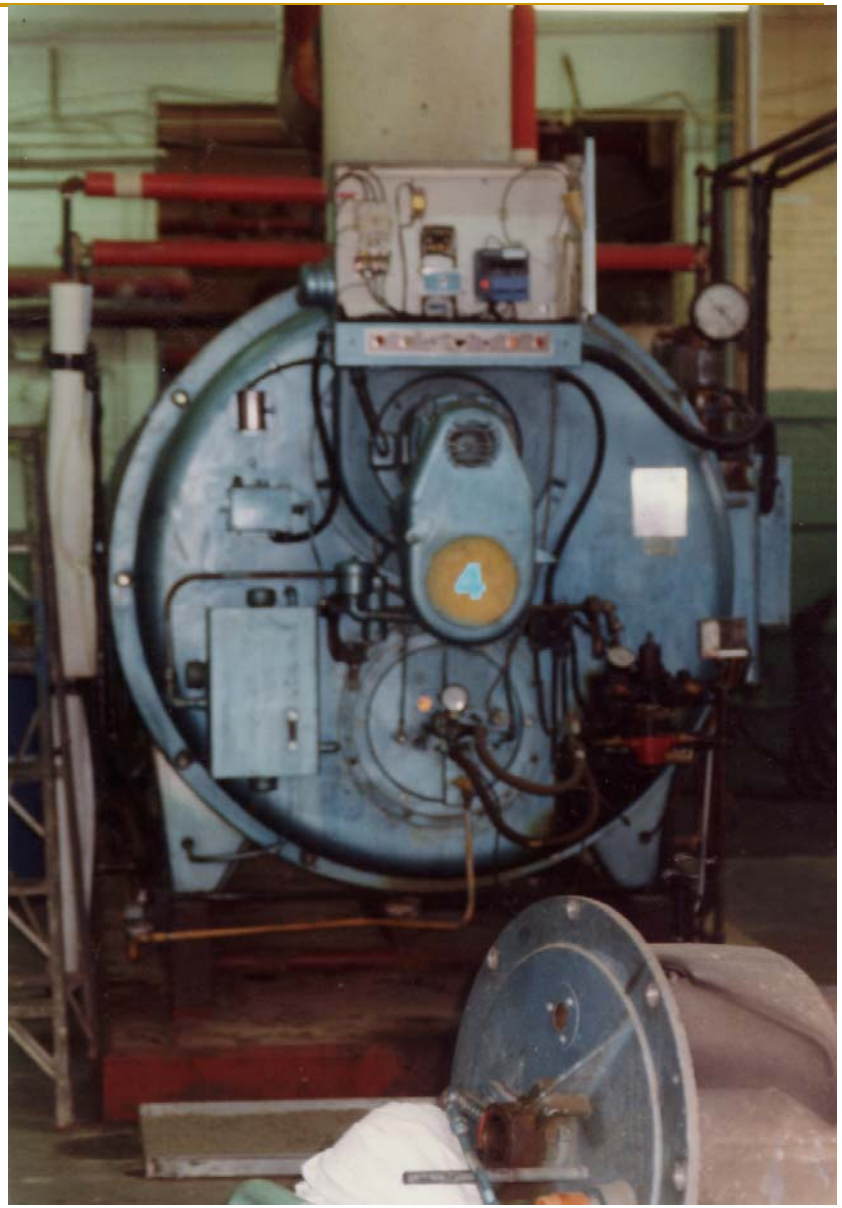
Advantages (continued)

- At pressures of 100 PSIG and higher, extremely long runs are possible.
  - Example: 100 PSIG line could be sized for 10 PSI drop at far end of system.
- Real time energy management systems let boiler plant operators know what's going on in the distribution system and the buildings.
  - Higher than normal make-up water rate means something may be radically wrong in steam distribution system, condensate return system, or in buildings served.
  - Real time steam flow metering in buildings may indicate a problem in a particular building.
  - Real time monitoring of steam pressures entering various buildings and at various points in the distribution system is also extremely helpful.

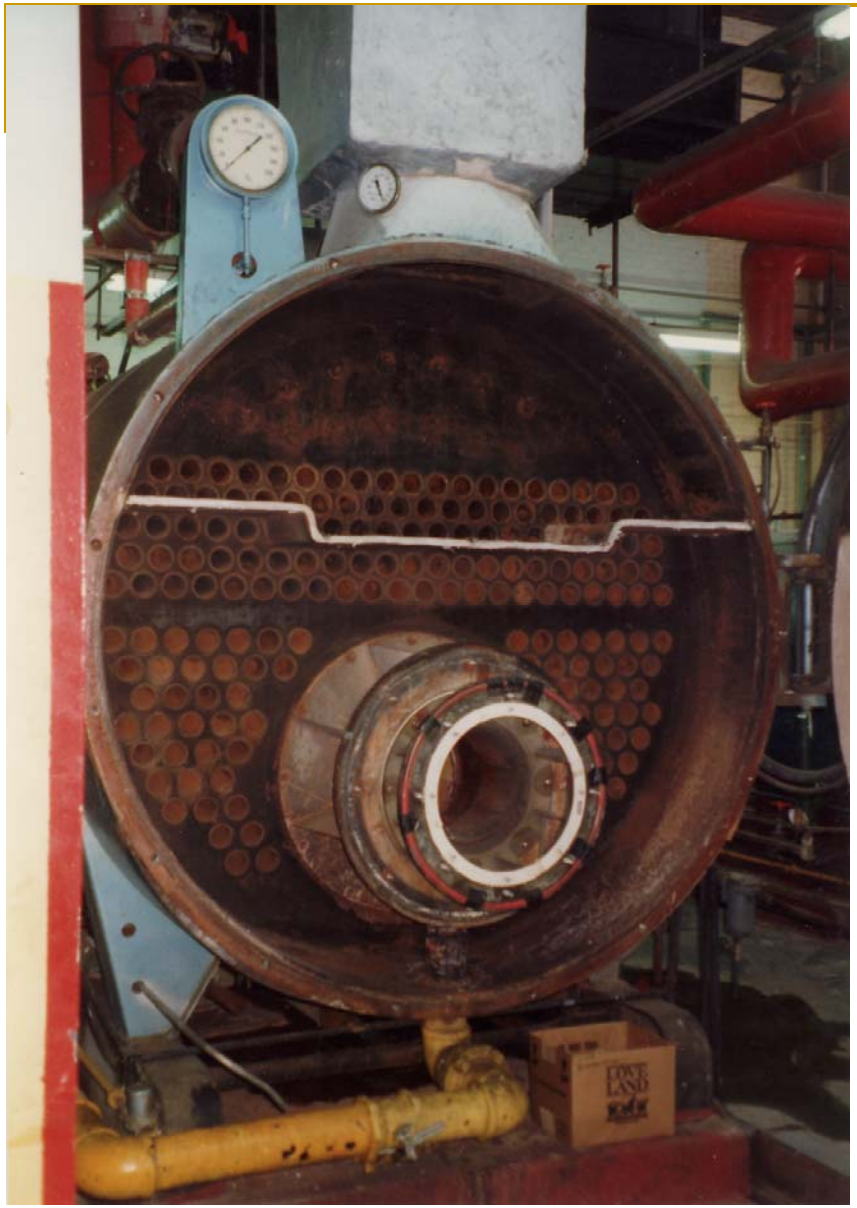
I-A-1 Typical medium size high pressure steam boiler plant

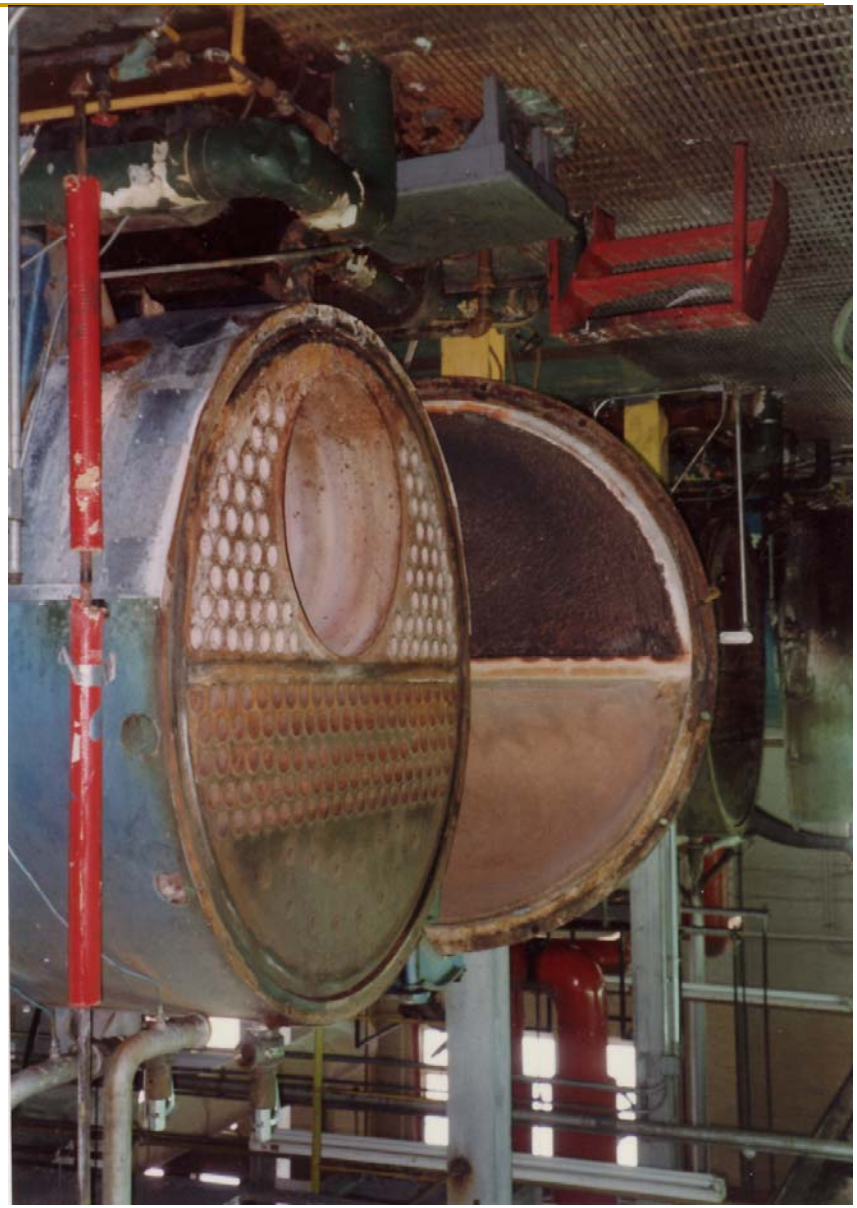
I-A-2 Notice vines on front wall

I-A-3 Notice tree growing in abandoned ash chute



I-A-4 High pressure fire tube boiler



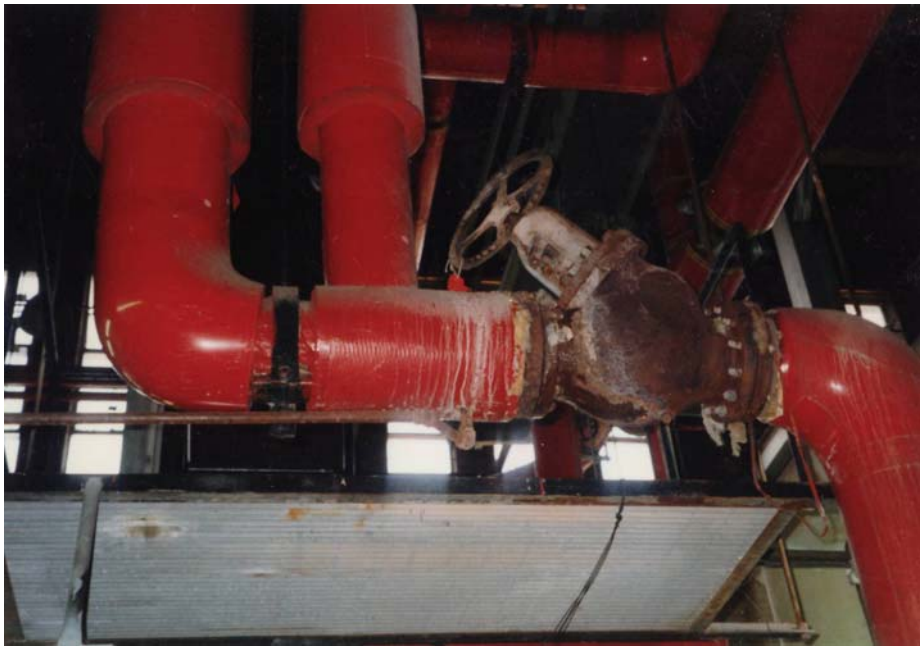


I-A-5 This boiler down for maintenance

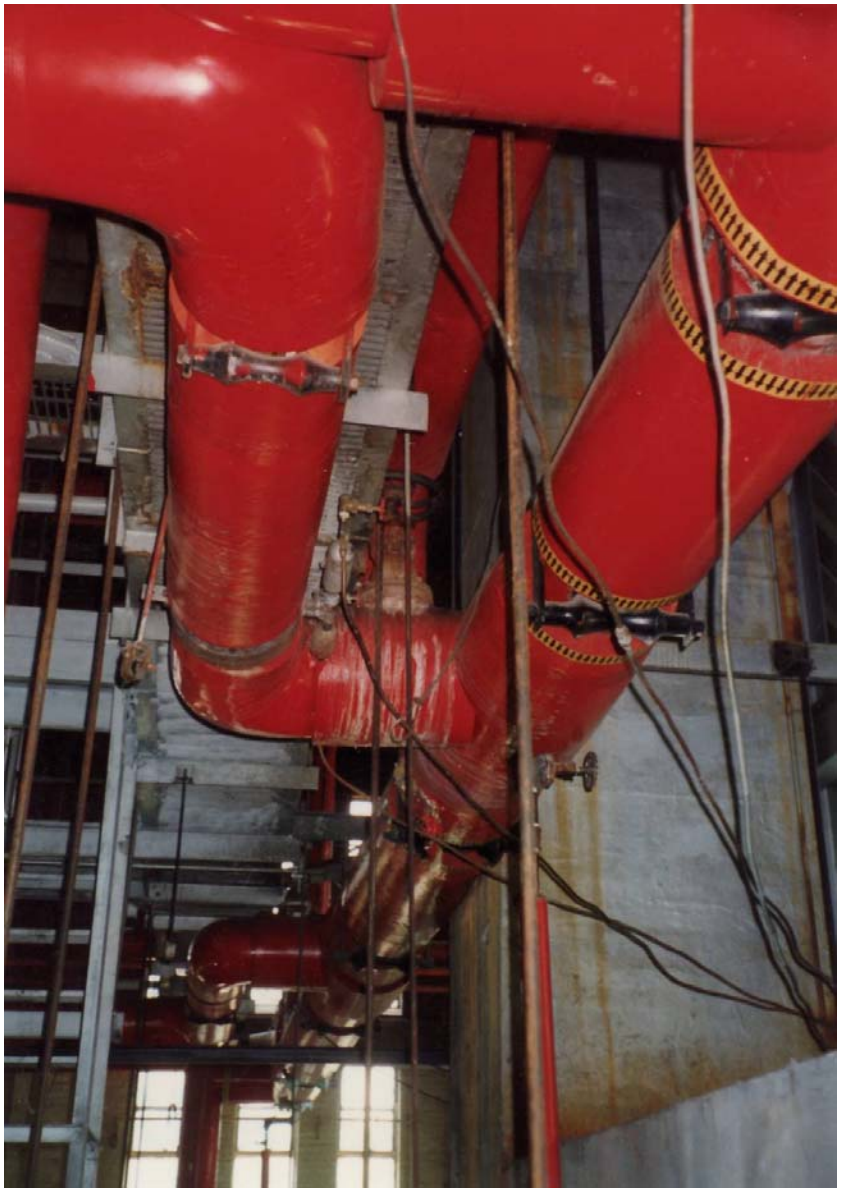
I-A-6 Back end of same boiler

I-A-8 Typical safety relief valves on steam boilers

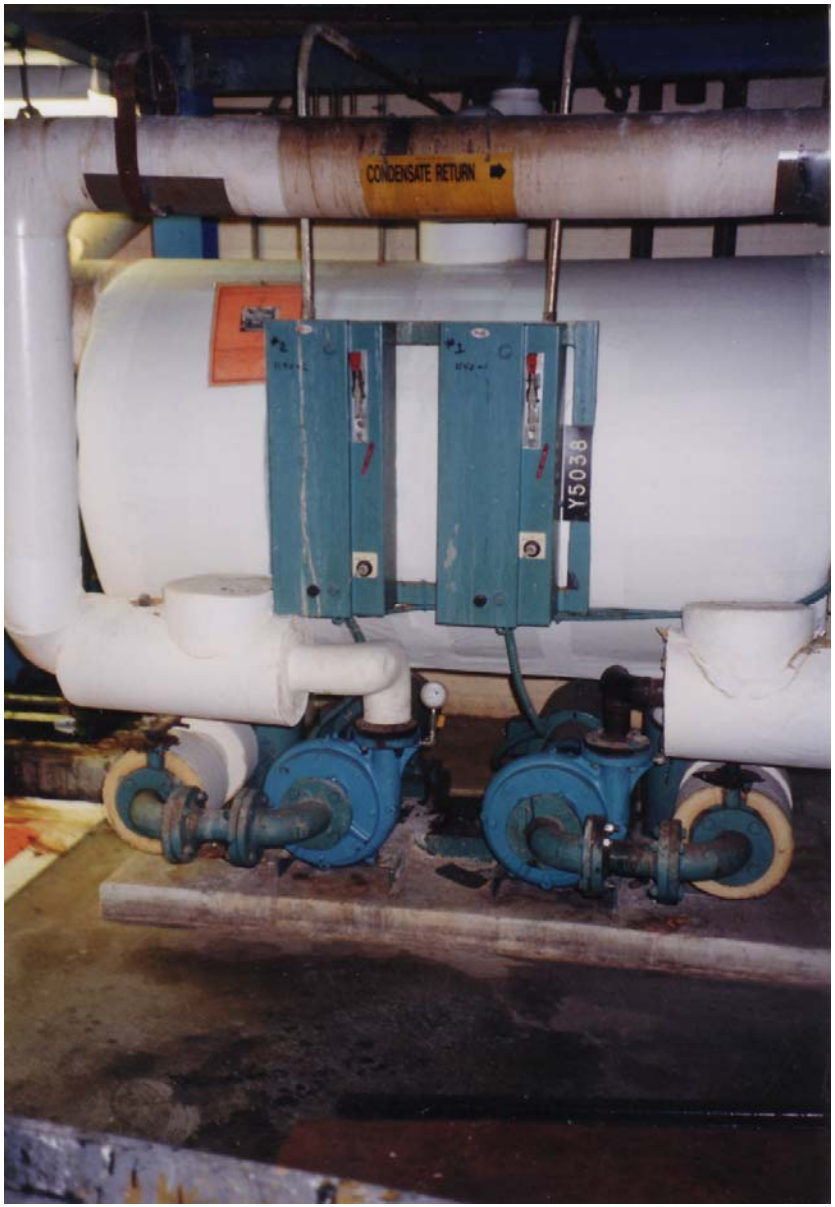
I-A-7 Removed gasketing for boiler doors



I-A-9 Typical overhead piping for manifolding boilers



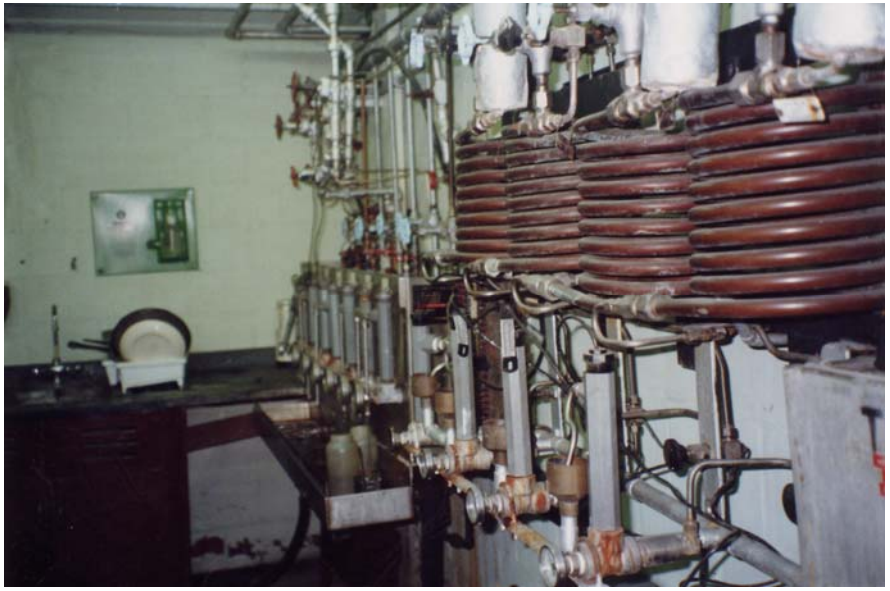
I-A-10 Overhead steam piping downstream of boilers



I-A-11 Typical large condensate return tank in basement

I-A-12 Typical deaerator tank for removing oxygen and other gases

I-A-13 Typical steam discharge from deaerator tank



I-A-14 Water treatment is an absolute must!

I-A-15 Water treatment sampling lines

I-A-16 Flue gas economizers are a great way to increase boiler

I-A-18 Larger water tube boiler with multiple burners

I-A-17 Close-up of flue gas economizer piping

I-A-19 Safety considerations require harness

I-A-20 Typical control room for large high pressure boiler plant

Steam Distribution System Requirements

- Drip traps are a must to remove steam that has already condensed in steam distribution mains. Otherwise, destructive water hammer can occur.
- Isolation valves are a must in distribution mains and services to buildings for outages and repairs.
- Expansion joints/expansion loops and anchors are a must to compensate for and to control expansion and contraction of steam mains and condensate mains.
- Condensate returns are required to get hot condensate back to the central plant
  - Corrosion of steel lines
  - Fiberglass failures
- Ideally, we need two condensate return mains – one for high pressure drip traps from manholes and one for pumped condensate from buildings.
  - Otherwise, destructive water hammer can occur.
  - To reduce first cost, these two mains are often married together using dispersion fittings.
- In older downtown systems, condensate is typically **not returned** from buildings.

Overhead Steam Distribution Issues

- Mains are typically 15-20 feet above ground.
  - Relatively easy to access with advent of bucket trucks, but very few systems do such maintenance.
- Unsightly for situations such as campuses and urban areas, but excellent for most military bases and industrial complexes.
- Fairly high losses due to
  - Insulation losses due to water intrusion
  - Mains that are often many miles long
  - Many blowing difficult to identify and maintain drip traps
  - Much more maintainable than underground steam distribution systems
- Many systems are under maintained because of insufficient budgeting and lack of sufficient skilled maintenance personnel.
- Infra-red thermography, including flyovers of large system, is a great way to pinpoint deteriorating insulation.

I-C-11 Long overhead run of steam and condensate mains between 2 roads

I-C-12 Overhead steam and condensate mains on 9 foot high trestle

I-C-7 Deteriorating insulation is causing huge energy losses

I-C-8 More deteriorating insulation

I-C-9 Close-up of deteriorating insulation

I-C-10 Leak on overhead steam line – possibly at valve stem

I-C-13 Typical drip trap station on overhead main

I-C-14 Another leak on overhead condensate main

I-C-1 Typical slip type expansion joint

I-C-2 Bellows type expansion joint – pipe guide to left

I-C-5 Anchor at elbow to keep piping from moving at that point

I-C-6 Notice how flimsy U-bolts holding down steam main are distorting badly.

I-C-4 Vertical expansion loop

I-C-3 Horizontal expansion loop

Underground Steam Distribution Issues

- Mains are in tunnels, conduits, or are direct buried.
- More acceptable aesthetically
- Mains can sometimes become very deep because they must be pitched in direction of flow to remove condensate.
- Mains also become deep because they have to go under rivers, creeks, and other utilities, and because they often cannot follow hilly terrain.
- Manholes are definitely required to house
  - Expansion joints
  - Anchors
  - Drip traps
  - Isolation valves
  - Pumps to remove ground and storm water

Underground Steam Distribution Issues (continued)

- Manhole Issues
  - Confined space requirements
  - Harnesses required – teams of three typically required
  - Extremely hot because it is very difficult to keep piping insulation intact in manholes
  - Ventilation is almost always required before entering.
  - Testing for hazardous gases in manholes is always recommended.
  - Ladder required for entrance and egress
  - Heavy manhole covers or gratings are required, which can become very hot in themselves.
  - Ground water and storm water removal are huge issues.

Underground Steam Distribution Issues (continued)

- Secondary vapor is generated and primary steam is lost due to ground water and storm water.
- Very high steam losses due to deteriorating insulation between manholes.
- Very high losses due to little or no insulation in manholes.
- Distribution losses are typically constant regardless of building loads and time of year.
- These already high losses can easily increase by a factor of 20 immediately after a serious rain storm until insulation is dried out by the steam flowing through the main.
- Turning off steam systems during summer may save energy in short run. However, it will lead to costly corrosion, pipe leaks, pipe repair, and pipe replacement unless a nitrogen blanket is used to prevent corrosion.

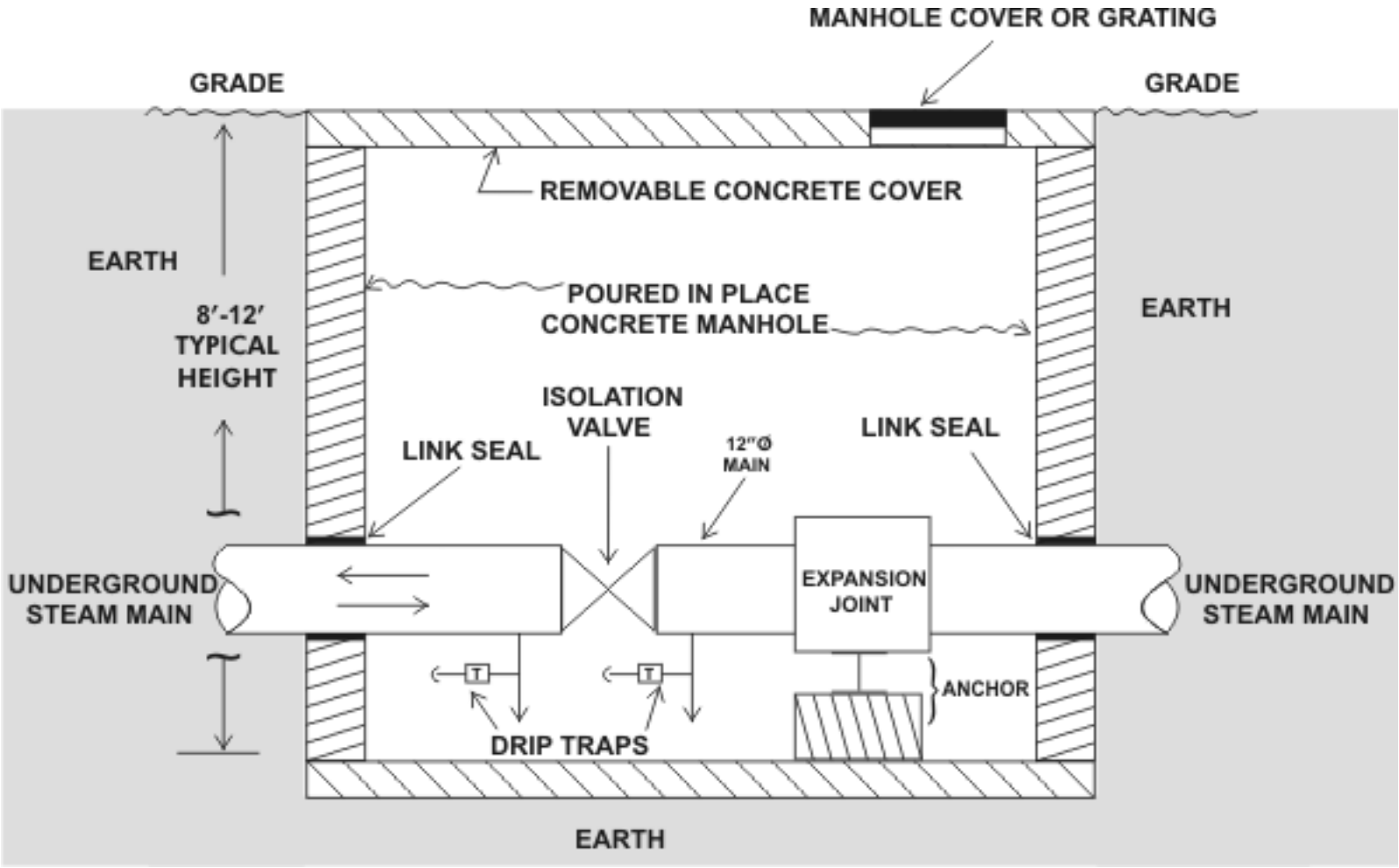
Reducing Losses in Manholes and Underground Piping

- Manhole improvements
  - Heavy duty custom fitted removable insulated covers are available to insulate every isolation valve, expansion joint, anchor, and steam main in a manhole.
  - Energy savings are tremendous.
  - The jury is still out on their longevity when flooding is an issue.
  - A new insulation known as **PYROGEL** which is water repellent is being tested.
  - Steam powered float actuated ejector pumps are available for keeping manholes dry.
  - Electric powered pumps are a disaster in steam manholes.
  - Many manholes still need to be pumped out by maintenance crews using gasoline generator powered pump after heavy rains.

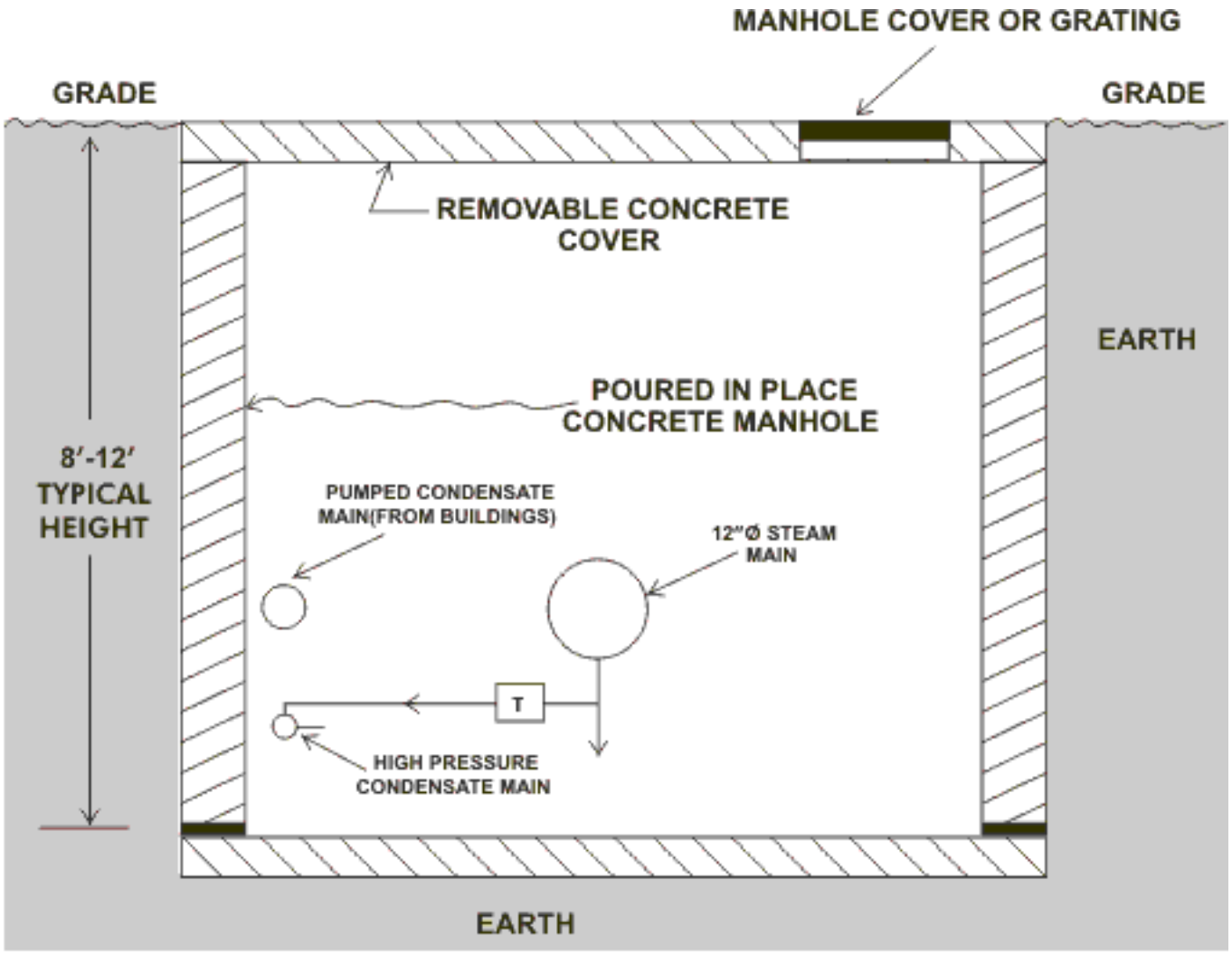
Reducing Losses in Manholes and Underground Piping (continued)

- Losses in underground lines are due to water intrusion into conduits or outer casing of double wall class “A” direct buried piping.
- If there is an empty space between the pipe and the outer conduit, a high temperature foamed insulation known as **polyisocyanurate** can be injected into this space.
- Steam line losses will be reduced about 40% during ordinary operation.
- Most water intrusion from ground water and manholes will be virtually eliminated saving additional energy using this process.
- This patented process can be done without taking the steam main out of service.
- This process is very expensive but there is still an excellent payback.
- This reinsulation process will cost a small fraction of installing new steam mains.

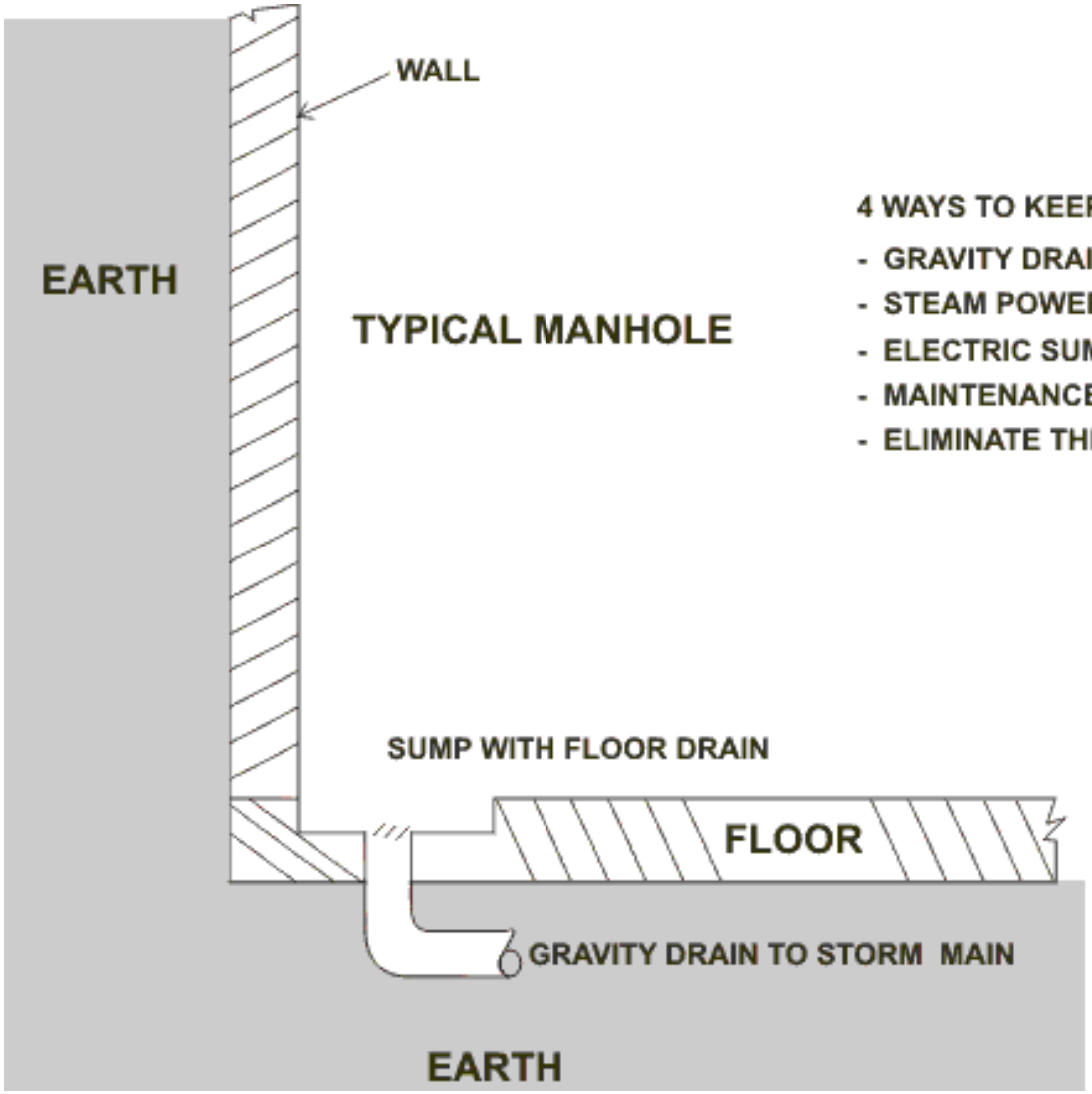
Elevation View – Typical Steam Manhole



Elevation End View – Typical Steam Manhole



Keeping Steam Manholes Dry

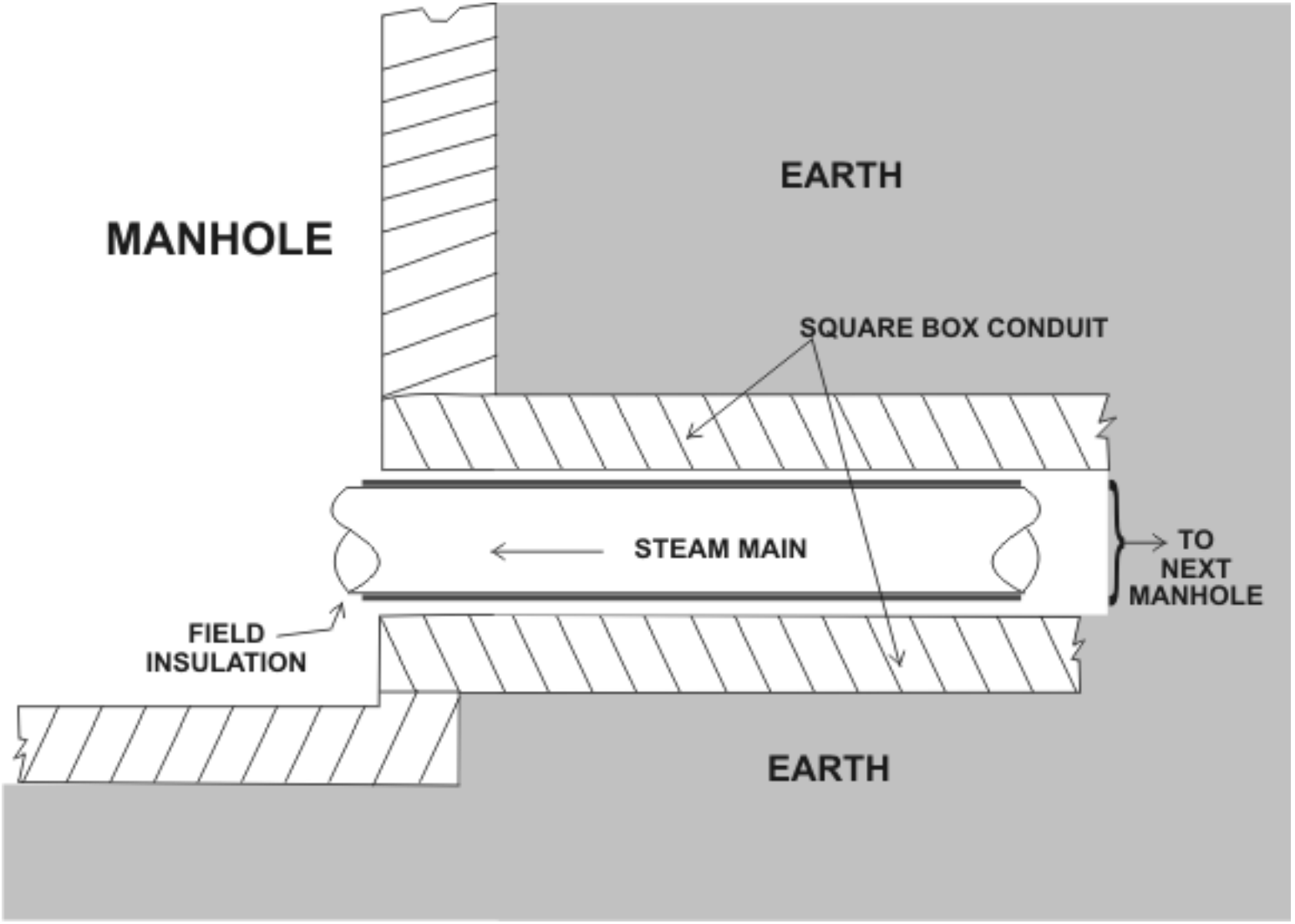


4 WAYS TO KEEP MANHOLES DRY

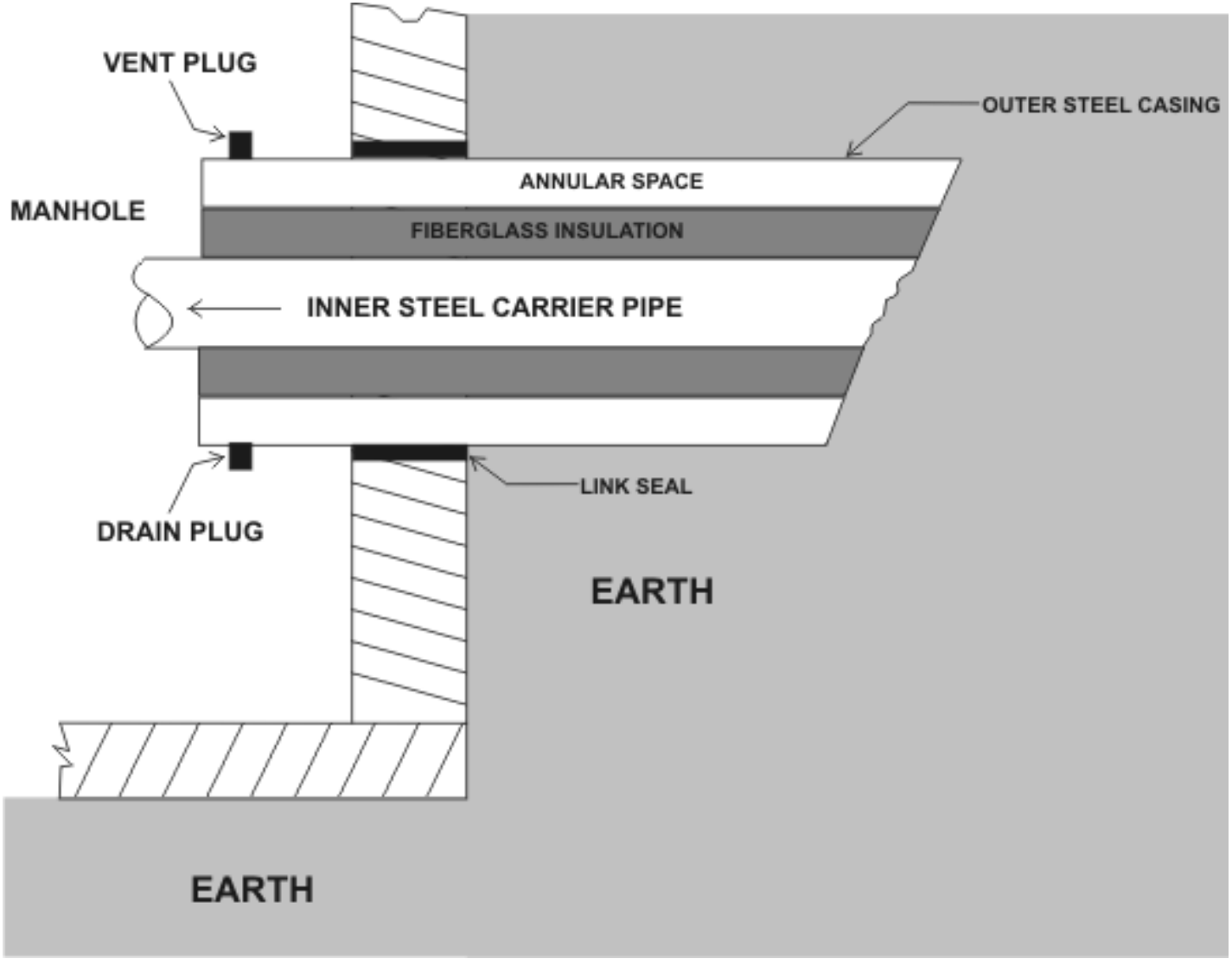
- GRAVITY DRAINS
- STEAM POWERED SUMP PUMPS
- ELECTRIC SUMP PUMPS
- MAINTENANCE CREWS
- ELIMINATE THEM IF POSSIBLE

Steam Actuated Ejector Sump Pump

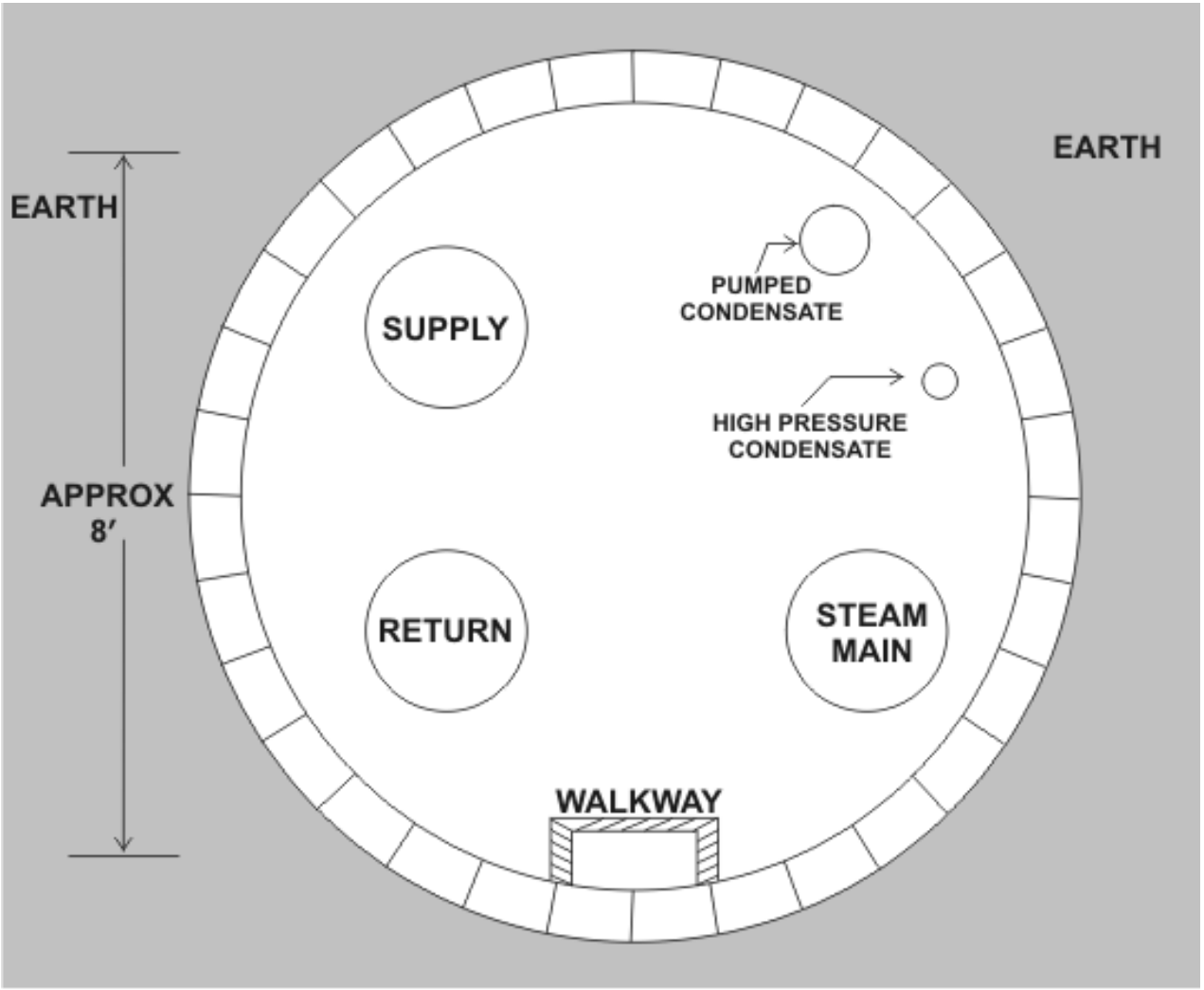
Box Conduit System



Class “A” Direct Buried Factory Insulated Double Wall Steam Piping



Elevation View – Round Utility Tunnel

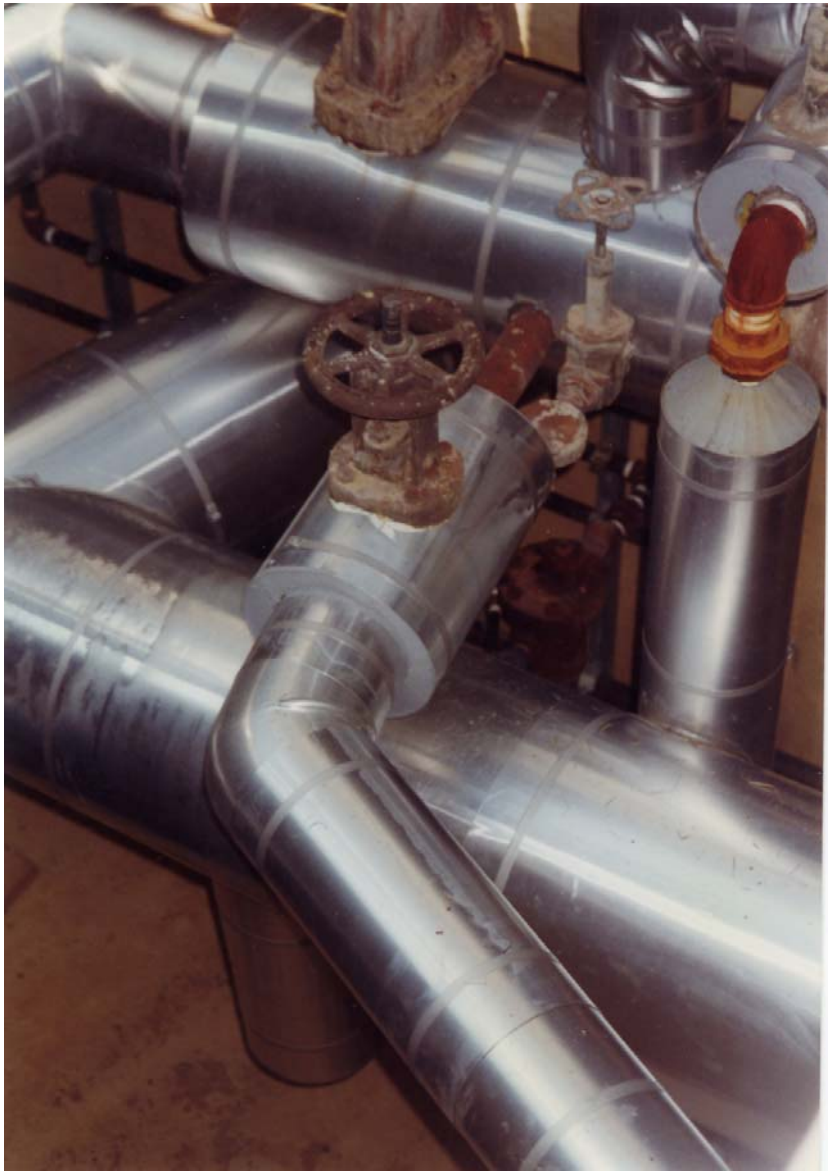


BEST CASE SCENARIO BUT HIGH FIRST COST

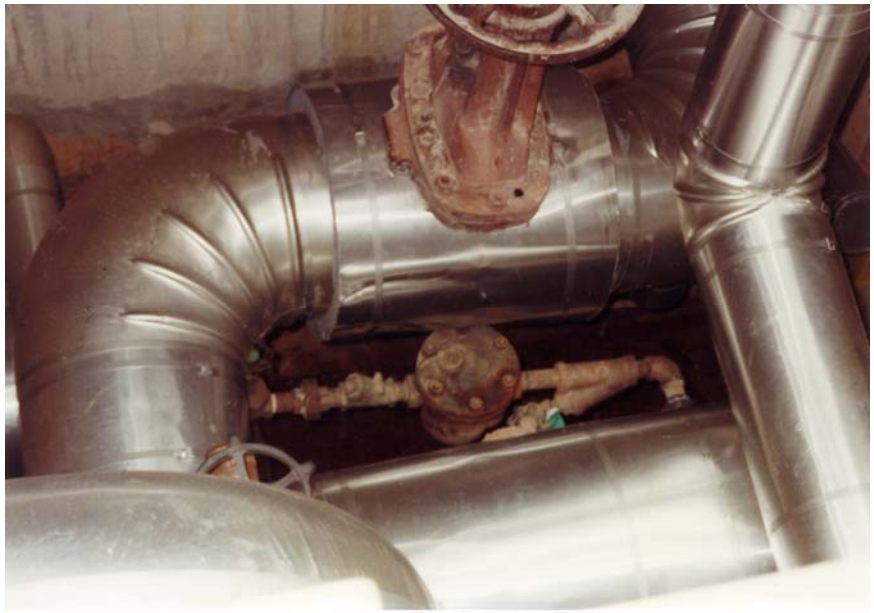
I-D-1 Lots of piping activity in this newly rebuilt manhole

I-D-2 Water in manholes is a huge issue. This steam powered ejector pump should pump such water out. Don’t use conventional floats like this.

I-D-3 Notice the clutter in this newly rebuilt manhole. Insulation will make it worse!



I-D-4 Very hard to work in this newly rebuilt manhole



I-D-5 Drip trap us extremely difficult to access in this manhole

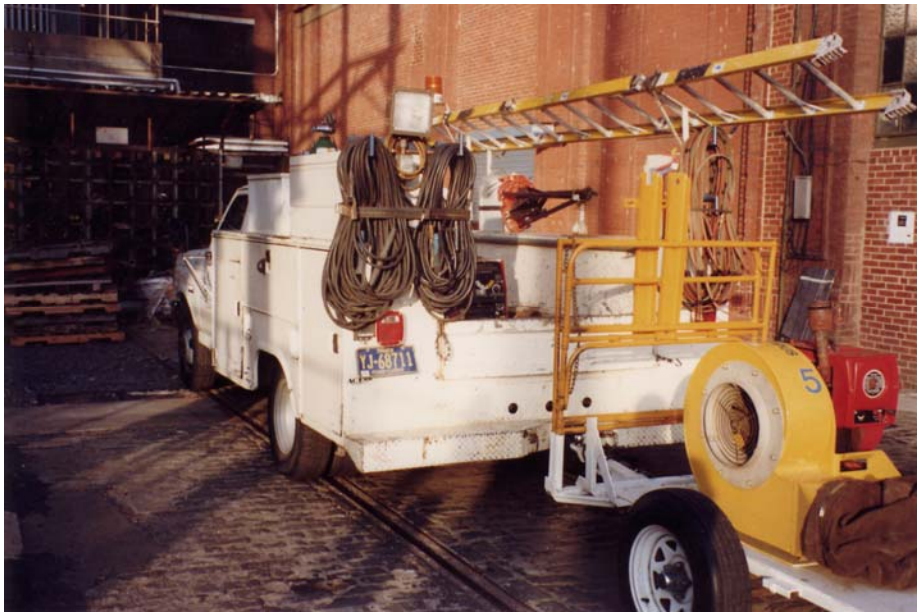
I-D-6 Top of newly rebuilt manhole

I-D-7 Cast iron cover on typical steam manhole

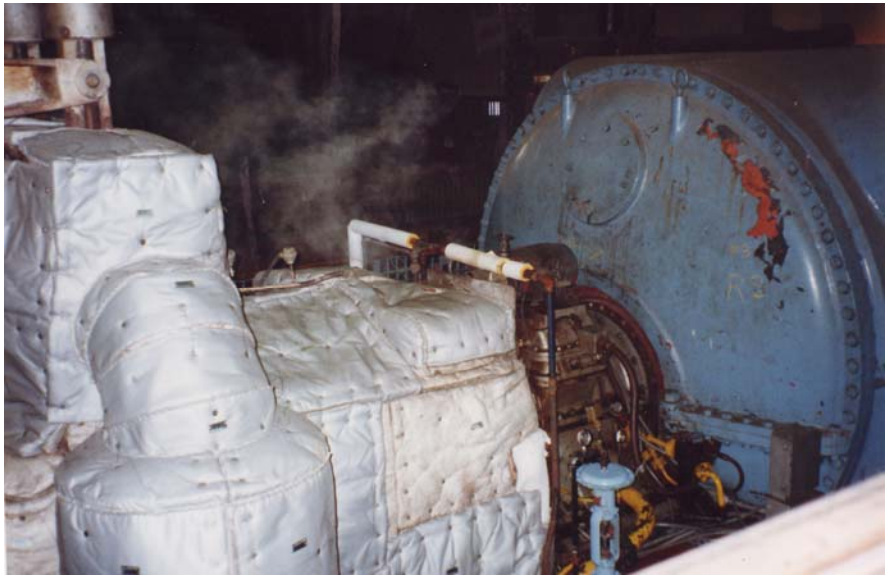
I-D-8 Debris catcher for manholes with grating type covers

I-D-9 Close-up of steel hinged cover

Older manhole with heavy steel hinged cover



I-D-10 This is how manholes are cooled before maintenance can proceed. Sometimes they must also be pumped out.



I-D-11 Removable insulated covers similar to these are sometimes used in manholes to save steam and reduce manhole temperature.

I-D-12 Heat loss from underground steam lines is a great snow melter!

I-D-14 Heat loss from this underground steam main is a great grass burner.

Smoke stack on steaming manholes

Another view of same smoke stack

I-D-16 This is a conventional underground utility tunnel.

I-D-15 Pipe tunnels like this are great for underground utility tunnels but first cost is high.

Entrance to manhole about to be rebuilt

Top of manhole partially removed

Notice expansion joint in manhole about to be rebuilt

Notice temporary expansion loop to keep steam main in service.

Lower half of new pre-cast pre-piped manhole

Top half of replacement manhole being lowered into place

Typical Building Steam System

- Single point of entry for steam supply and condensate return for each building.
- Accurate reliable high turndown steam flow metering is now available.
- Steam is typically reduced from line pressure of approximately 150-100 PSIG to 10 PSIG at service entrance point by a pressure regulating valve station.
- Much steam is converted to hot water for building heating.
- Some steam is used directly for heating such as steam preheat coils and radiators or convectors in older buildings.
- Condensate is typically pumped from buildings back to central steam plant.

Significant Causes of Wasted Steam in Buildings

- Unmaintained blowing steam traps
- Oversized conventional steam traps
- Fixed orifice traps – avoid at all cost!
- Bypassed steam traps and control valves
- Leaking safety relief valves due to improperly piped pressure regulating valve stations
- Poor temperature control due to improperly piped and sized control valves which tend to hunt resulting in wasteful overheating.
- Steam leaks
- Failed condensate pumps due to omission of flash tanks. This leads to condensate dumping.
- Failed or missing pipe insulation
- Poor temperature control of building hot water and domestic hot water generated by steam.

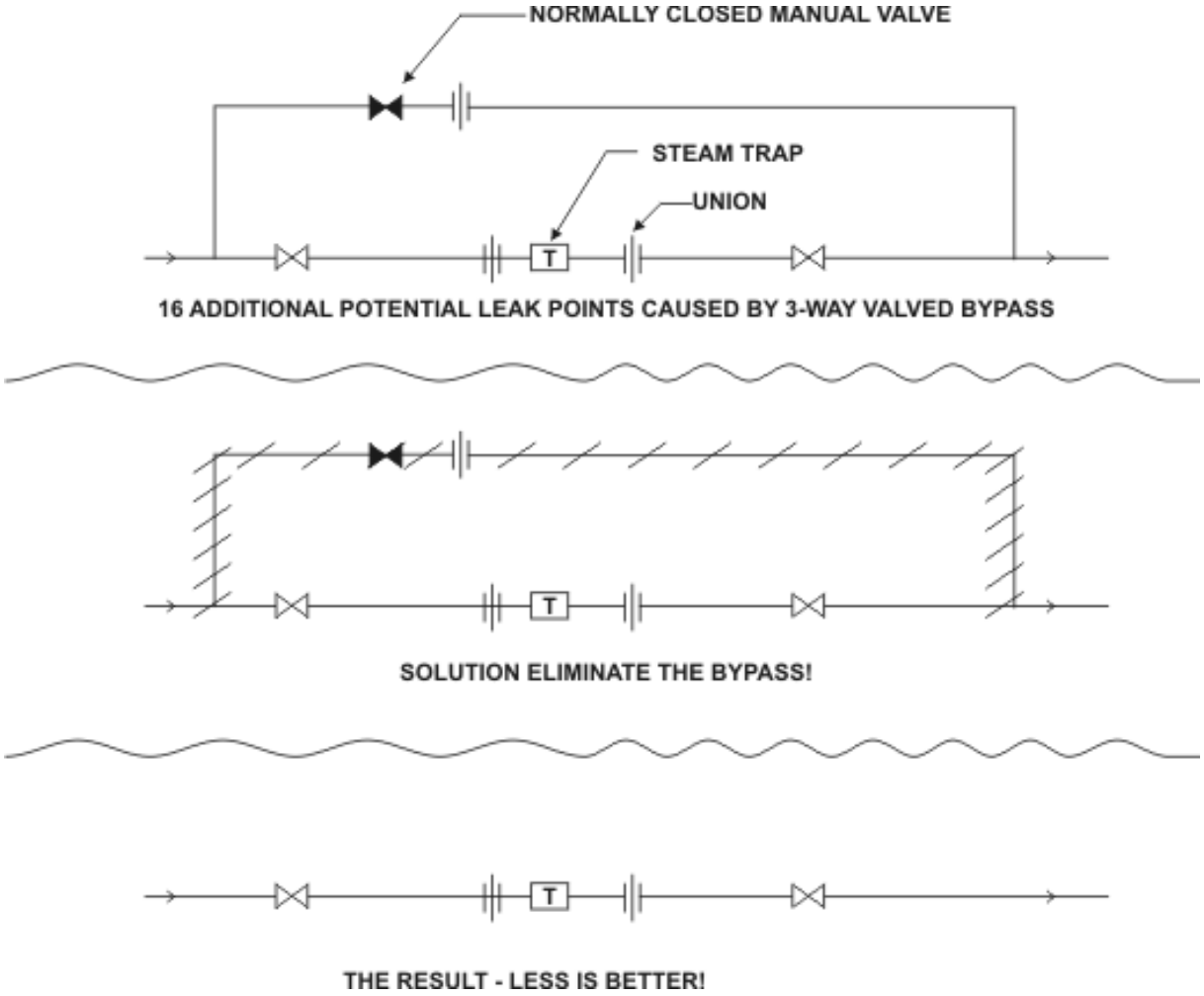
All of these issues can be resolved through good piping practice and minimal maintenance.

Causes of Dangerous and Potentially Lethal Steam Water Hammer

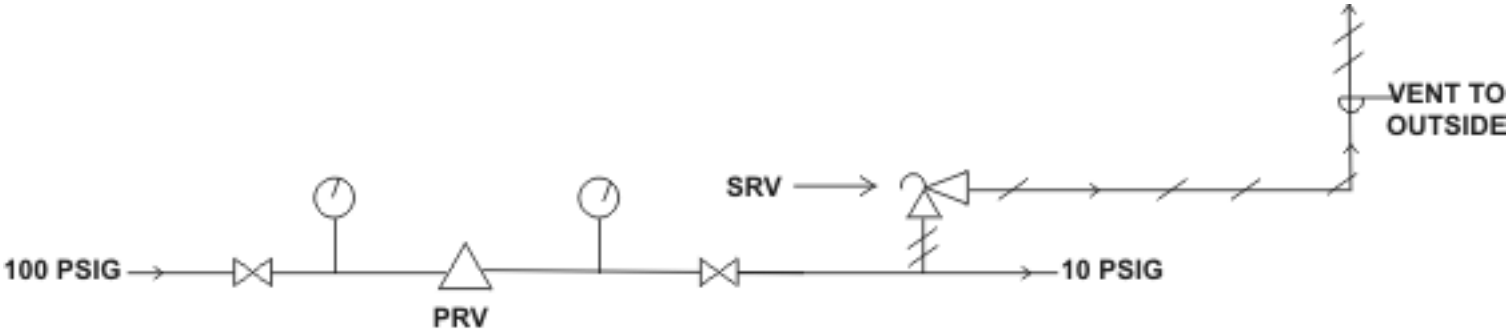
- Undersized drip legs
- Drip traps that have failed closed
- Clogged strainers upstream of drip traps
- Omission of vacuum breakers
- Group trapping of steam coils
- Overhead condensate returns on steam coils and heat exchangers

All of these issues can be resolved through good piping practice and minimal maintenance.

Steam Traps with 3-Way Valved Bypasses



Eliminate Building Safety Relief Valve Where Allowable



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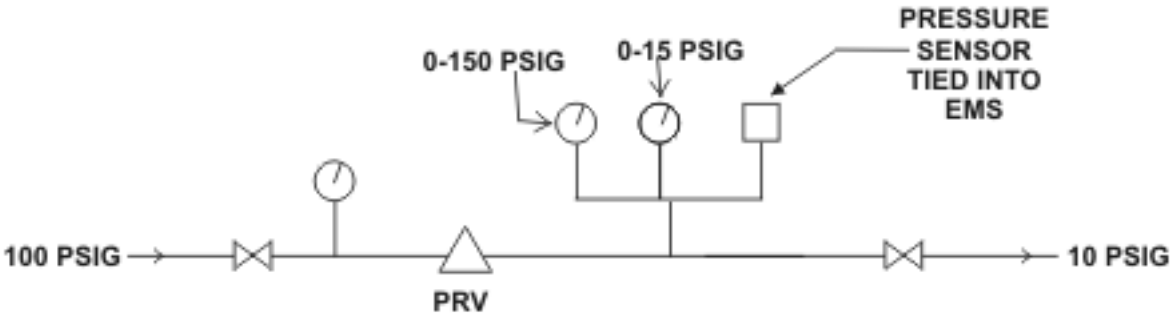
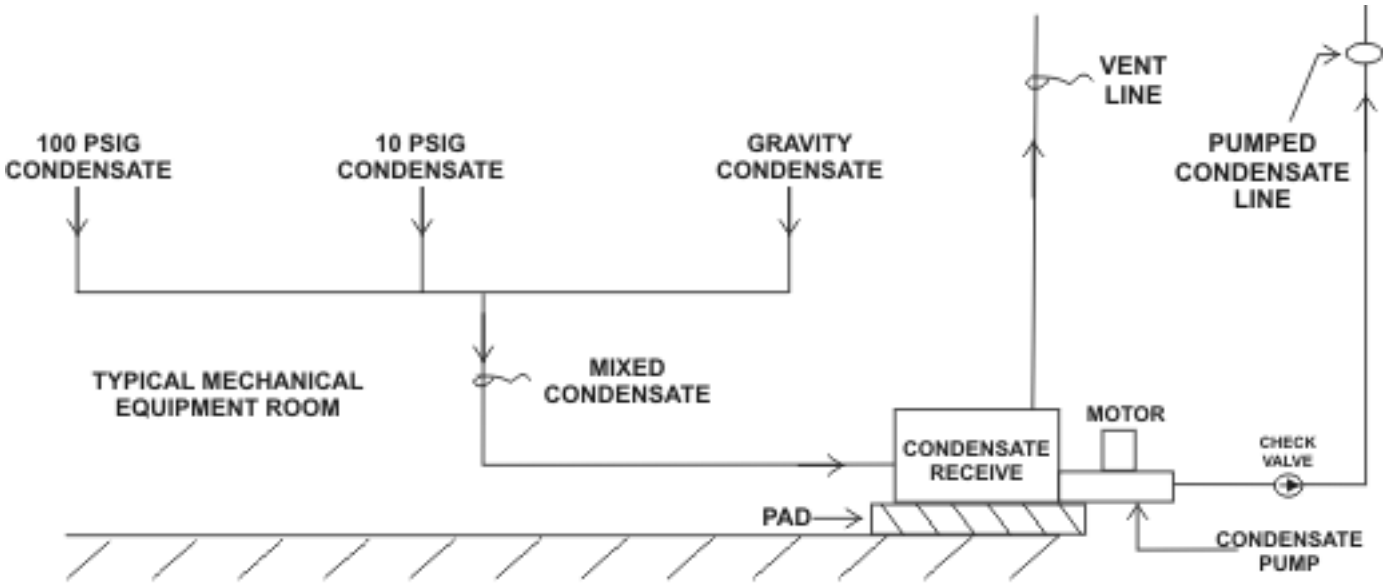


AS MODIFIED WITH SAFETY RELIEF VALVE AND VENT LINE GONE

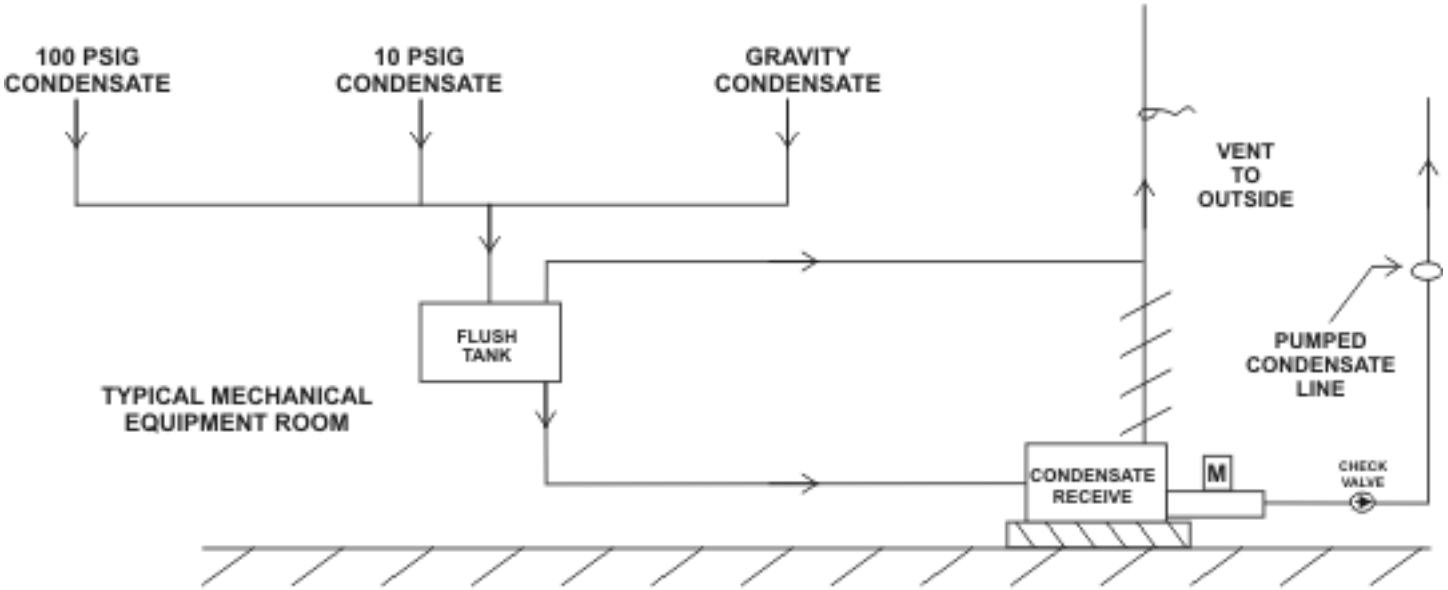
Electric Condensate Pump Failure Scenario



PUMP MOTOR SEALS CANNOT TAKE THE HIGH TEMPERATURE & WILL FAIL!

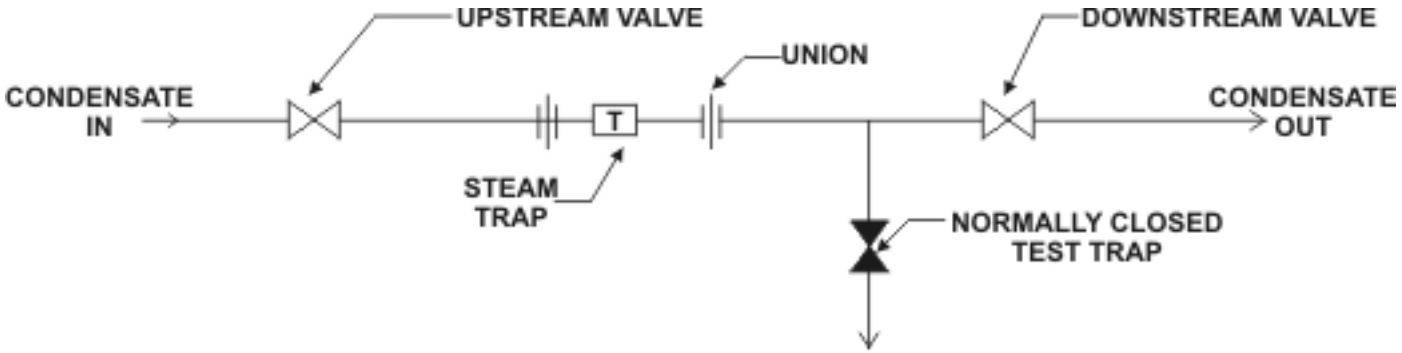
Simple Solution to Eliminate Electric Condensate Pump Failures

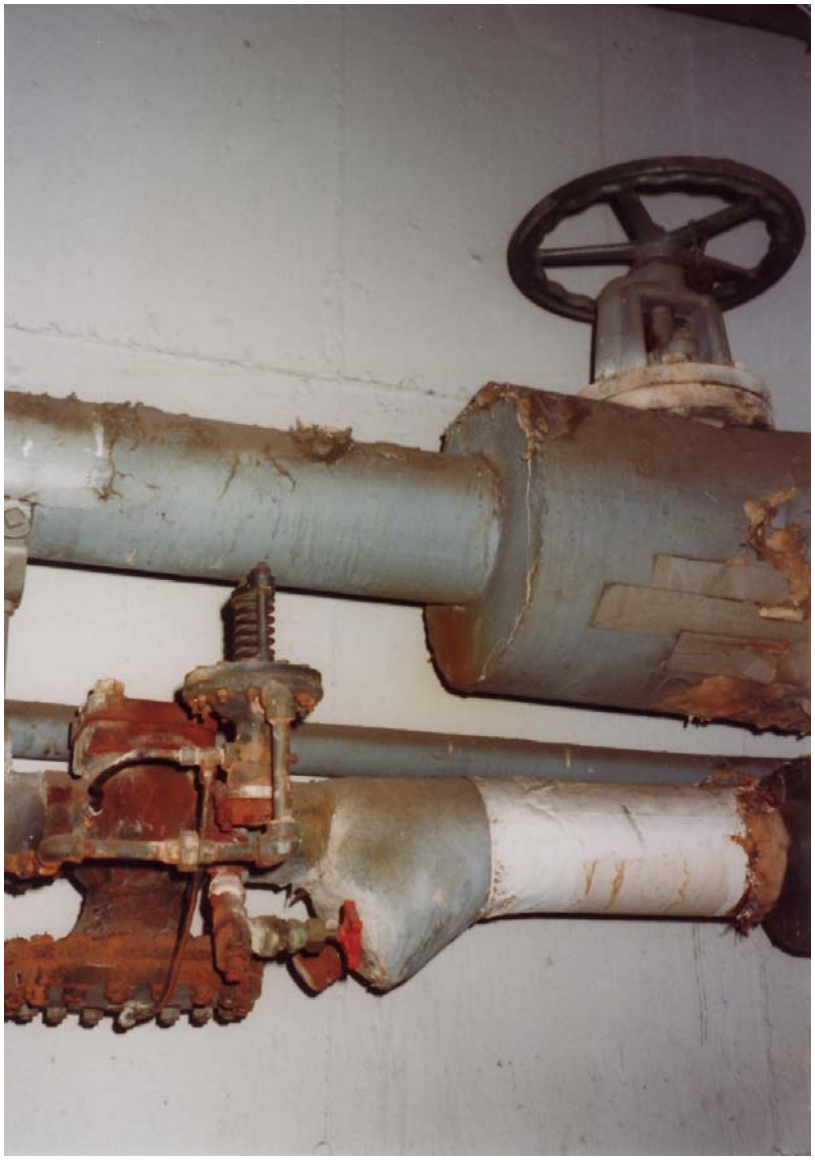
- INSTALL FLASH TANK
- A FLASK TANK IS SIMPLY A 12″ ⦶ DIAMETER PIPE WITH WELDED END CAPS



DO NOT INSTALL STEAM POWERED CONDENSATE PUMP
USUALLY MUCH MORE EXPENSIVE

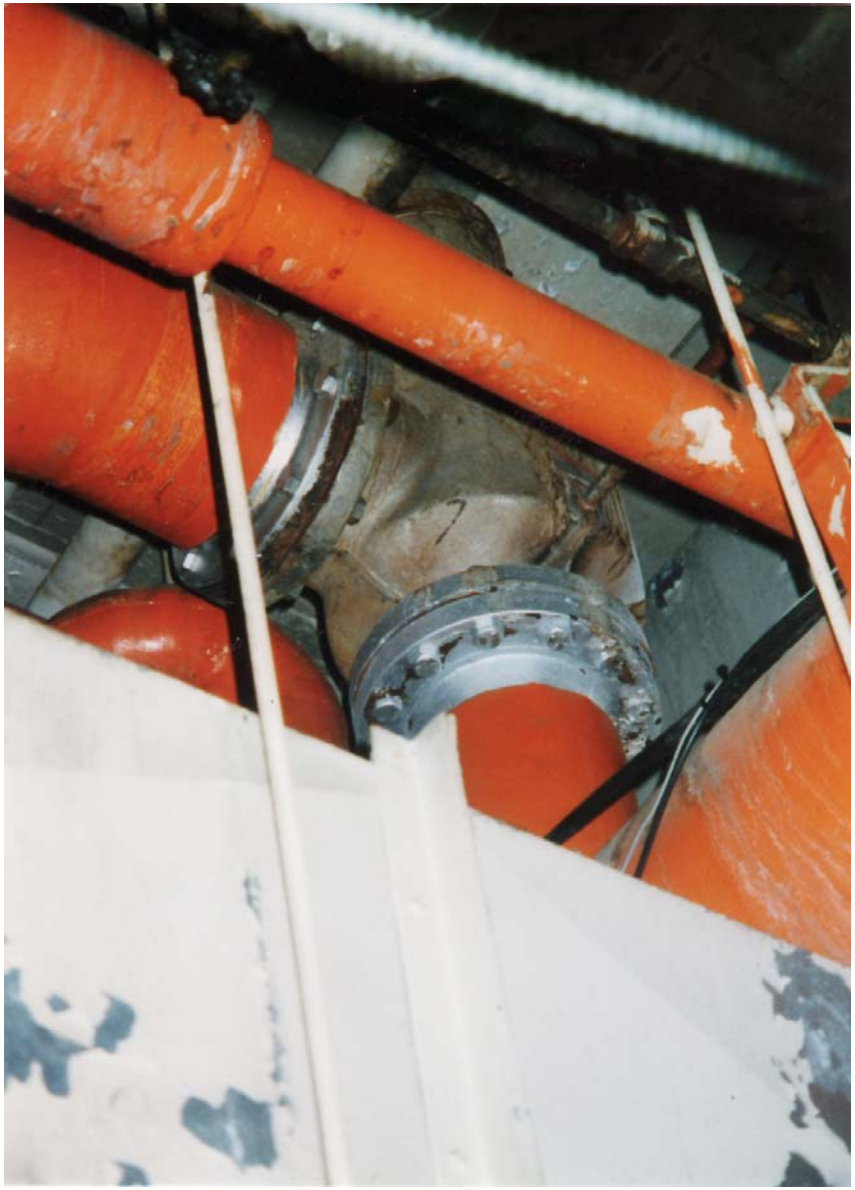
Simple Visual Testing of Steam Traps





I-F-1 Steam pressure regulating valve (PRV) is piped incorrectly which will cause premature failure.

I-F-2 Safety relief valve (SRV) will ultimately relieve and may not reset itself properly due to PRV failure.

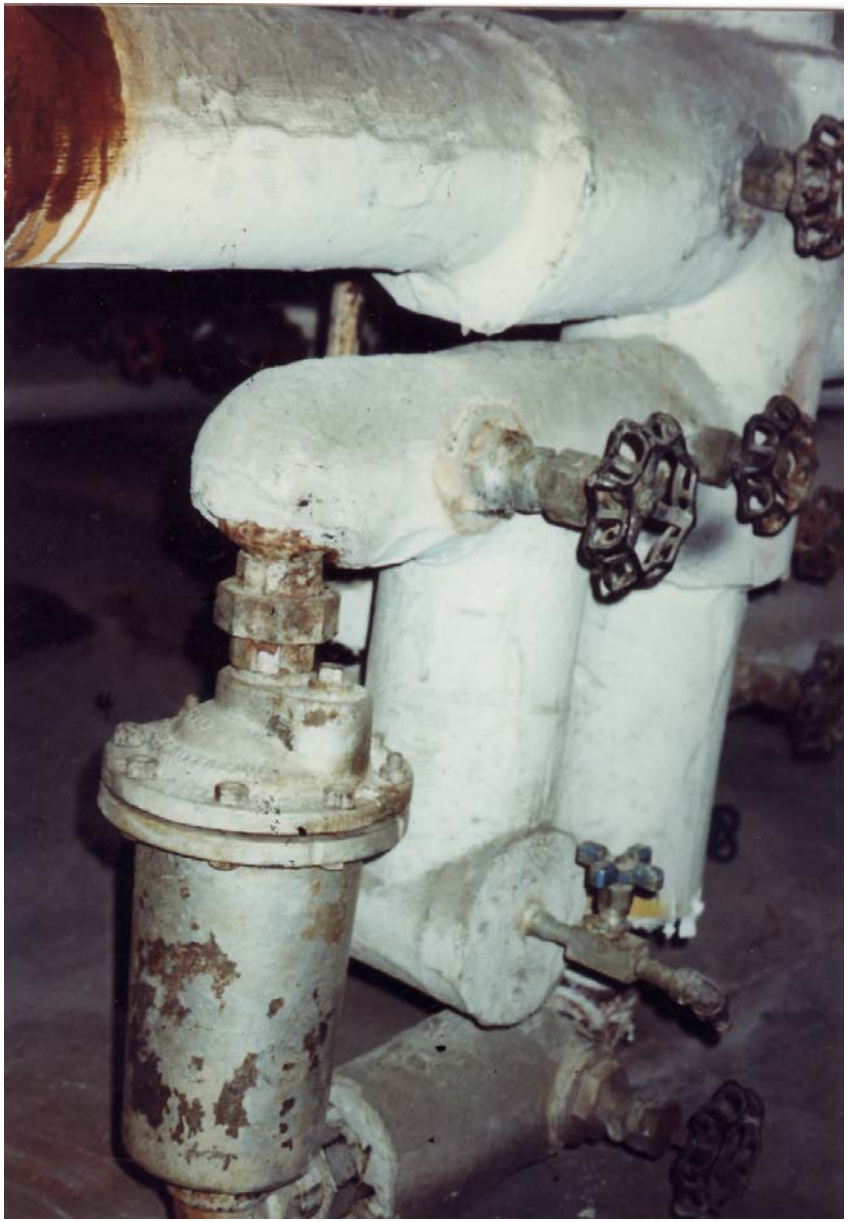


I-F-3 Huge SRV's like this are virtually inaccessible when they do fail.

I-F-4 When SRV's relieve, this is what happens. The steam loss is incredible!

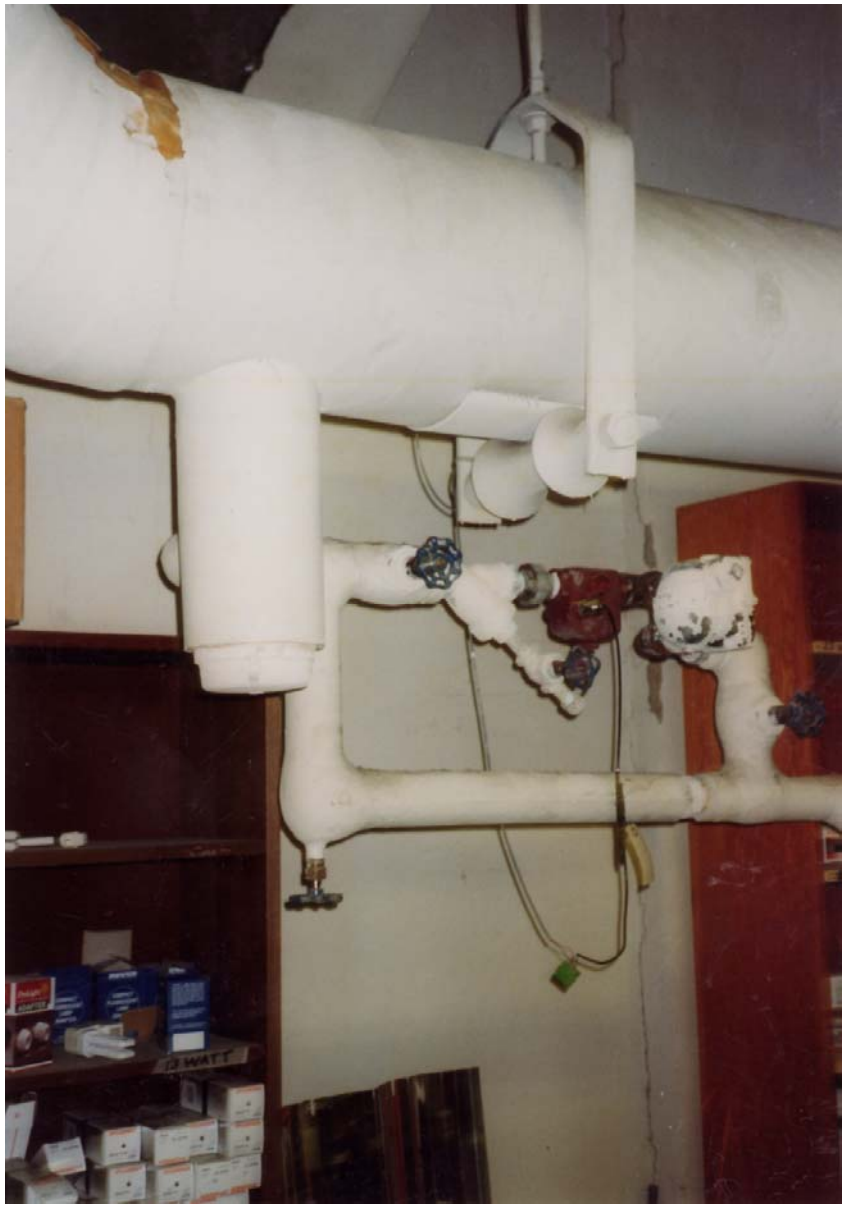
I-F-5 Another SRV relieving

I-F-6 Omission of flash tanks like this is what causes electric condensate pumps to fail.



I-F-8 3-way valved bypass on this trap is not needed and could wastefully blow steam.

I-F-7 This huge bucket trap is grossly oversized!



I-F-9 Another unnecessary 3-way valved trap bypass.

I-F-10 This incorrectly piped temperature control valve will fail prematurely.

I-F-11 This steam coil failed prematurely due to incorrect piping. It did not wear out from old age!

I-F-12 Ditto previous picture for this steam coil.

I-F-13 This shell and tube heat exchanger failed due to lack of a vacuum breaker.

I-F-14 Steam discharge like this at storm grating was probably due to incorrect piping at boiler plant in background.

I-F-15 This high pressure steam main broke loose from the wall due to a water hammer incident. Fortunately, nobody was killed or injured!

I-F-16 Steam discharges like these may be due to blowing traps.

Advantages of Converting to Individual Boilers for Each Building

- Highly reliable boilers are available from numerous manufacturers.
- These boilers are highly efficient (typically 90-95%) gas-fired hot water boilers.
- Typically these high efficiency boilers are very compact and have small footprints.
- Problematic underground and overhead steam distribution mains can be eliminated.
- Central plant requiring full-time operators can be shut down.

Individual Boiler Space Issues

- Boilers can sometimes, be located in the same general space vacated by the steam PRV station, the steam to hot water converter, and condensate pump.
- Domestic hot water can be generated indirectly from these boilers, thereby saving space.
- Often, additional equipment room space needs to be added to provide proper access to these numerous individual boilers.

Individual Boiler Venting Issues

- Each boiler must be vented to outside
  - Side wall venting is great if boiler location is above ground and there are no nearby windows or air intakes.
    - There will be a condensation plume during cold weather.
    - Remember this if aesthetics are an important consideration.
  - If side wall venting is not possible, venting must go to roof which can be a challenge for multiple story buildings where boilers are located on the lower level
  - Ducted combustion air intakes are sometimes required for each boiler.

Noise Issues for Individual Building Boilers

- These boilers can be noisy so sound attenuation must be addressed
  - Sound attenuators in flues will help decrease sound level.
  - Insulated housings around boilers will also decrease sound level.
  - Isolator pads underneath boilers will also reduce noise transmission.
  - Beware of putting boilers immediately above, below or next to occupied spaces which are sound sensitive.

Conversion Issues for Individual Building Boilers

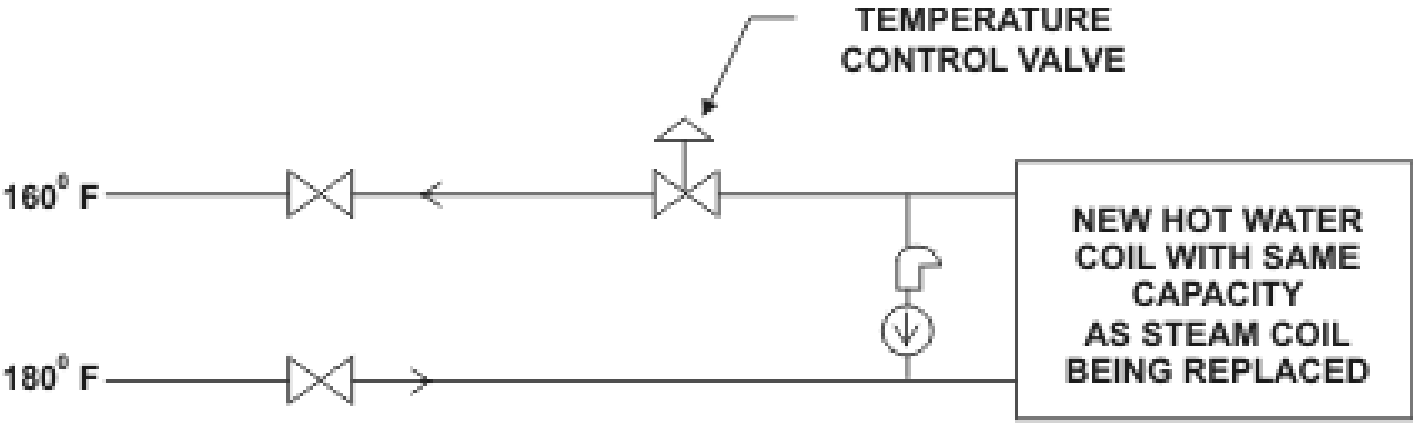
- Most direct steam heating loads can be converted to hot water
  - Examples:
    - Steam preheat coils* (can be done without sacrificing freeze protection)
    - Steam reheat coils*
    - Steam radiators**
    - Steam finned tube radiation**
    - Steam unit heaters**
    - Domestic hot water***

**Coils will have to be retrofitted **May be directly retrofitable*

****Indirect domestic hot water heaters will be required*

- If most or all building steam is already converted to hot water for heating, piping changes to accommodate the boilers should be fairly simple

Converting Outside Air Steam Preheat Coils to Hot Water



Certain Steam Loads Cannot be Converted to Hot Water

- Examples:
  - Kitchen steam (a small gas-fired steam boiler may be required)
  - Steam for humidifiers (consider a separate source of steam, gas-fired steam humidification, fogging systems, electric humidifiers, or simply retiring steam humidifiers)
- Steam for autoclaves (consider a separate steam boiler for grouped autoclaves or converting to non-steam powered autoclaves)

Redundancy Issues – Single vs. Multiple Boilers

- Better not to have all your eggs in a single basket.
- Use multiple boilers for each building – at least 2.
- Usually this is a non-issue since multiple boilers will probably be needed to satisfy peak building heating load.
- Multiple smaller boilers are more easily retrofitted into existing equipment rooms because of their smaller physical size.
- Multiple boilers will follow load changes nicely.

Disadvantages of Individual Boilers for Buildings

- Some buildings may require as many as 10 boilers.
- Instead of 3 or 4 centrally located boilers, you now have 50 to 70 boilers spread out all over the place to maintain.
- Very often, these boilers are crowded into already tight equipment rooms making required maintenance a challenge.
- These smaller boilers may not have the longevity of larger fire tube and water tube boilers typically used in central plants.

II-1 Old steam plant

II-2 Abandoned steam manhole

II-3 Typical mechanical room from outside

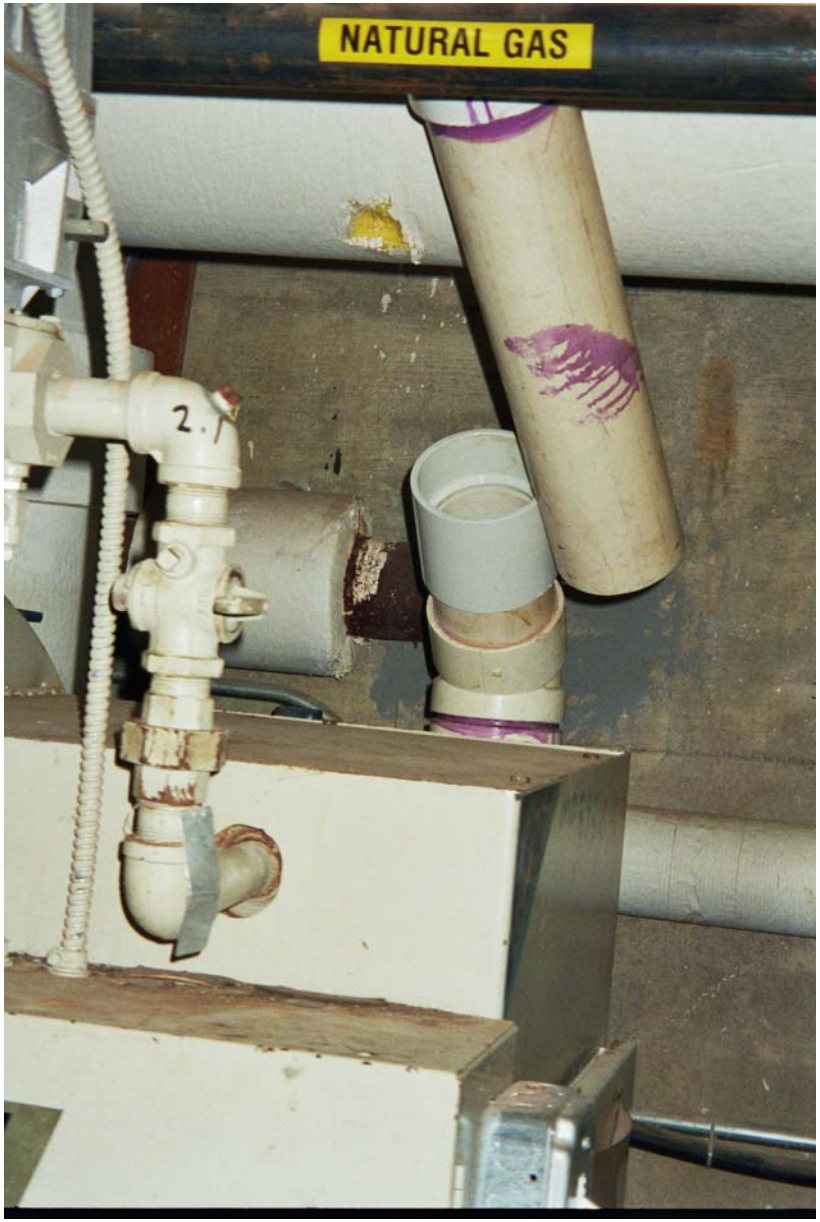
II-4 2 hot water boilers and 1 domestic hot water heater fit in tightly

II-5 2 hot water pumps crammed in very tightly. Only 1 is visible!

II-6 Boilers to left and domestic hot water heater to right

II-7 Older dormitory with 2 steam boilers – flues had to be extended to roof

II-8 Flues going to roof



II-9 Outside air intake on 1 boiler was disconnected.

II-10 Water treatment running while 2 steam boilers were off during summer

II-11 Maze of overhead gas piping and flue piping

II-12 Abandoned-in-place telephone cabinet to right of active domestic hot water storage tank

II-13 Main classroom building

II-14 Close-up view of same building

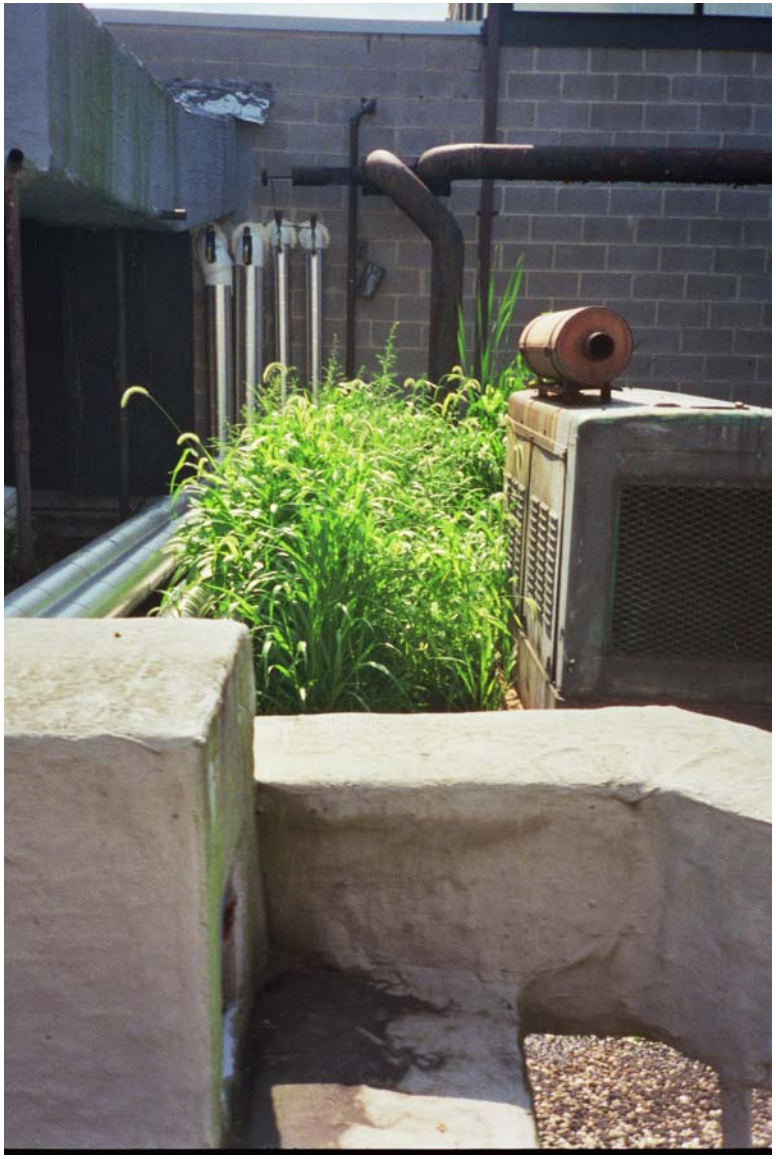
II-15 Armada of boilers

II-16 Armada of flues on boilers

II-17 Notice condensate lines from each boiler plus water on floor!

II-18 More boilers – this building has 10!

II-19 Grass growing around cooling tower – not a good sign!



II-20 More grass on roof next to abandoned-in-place emergency generator.

Medium Temperature Hot Water Combines the Best of Both Worlds

Central Steam and Individual Building Boilers

- Combines benefits of central steam boiler plant with the simplified hot water heating of each building by individual building boilers.
- Eliminates high losses associated with underground steam distribution systems.
- Eliminates complexity of building steam piping.
- All distribution piping is shallow buried – 24” cover is all that’s required.
- Piping is small in diameter because of 80° ◆T vs. 20°◆T design.
- Water leaves plant at 240°F and returns at160^{o}F.
- Because of this 80° ◆T, what would normally be an 8”Ø pipe becomes a 4”Ø pipe.
- No manholes, expansion joints, or anchors are required.
- 100% hot water for entire system – boilers + distribution + buildings.
- Minimal or no water treatment because of closed loop systems and virtually no make-up water.
- No water hammer or other steam piping issues.

Medium Temperature Hot Water Combines the Best of Both Worlds (continued)

- Building heating loops are isolated from underground distribution loop by heat exchangers.
- Multiple fuel capability is possible in central boiler plant.
- Economizers are much more practical in central boiler plant.
- **Hot water boiler plants typically do not require on-site full time licensed operators as do steam boilers operating above 15 PSIG.**
- Central medium temperature hot water boiler plant could also house water chillers for a future campus wide chilled water system using the same type piping.
- Such a chilled water system could also utilize thermal storage which is more cost effective for a central system than an individual building.

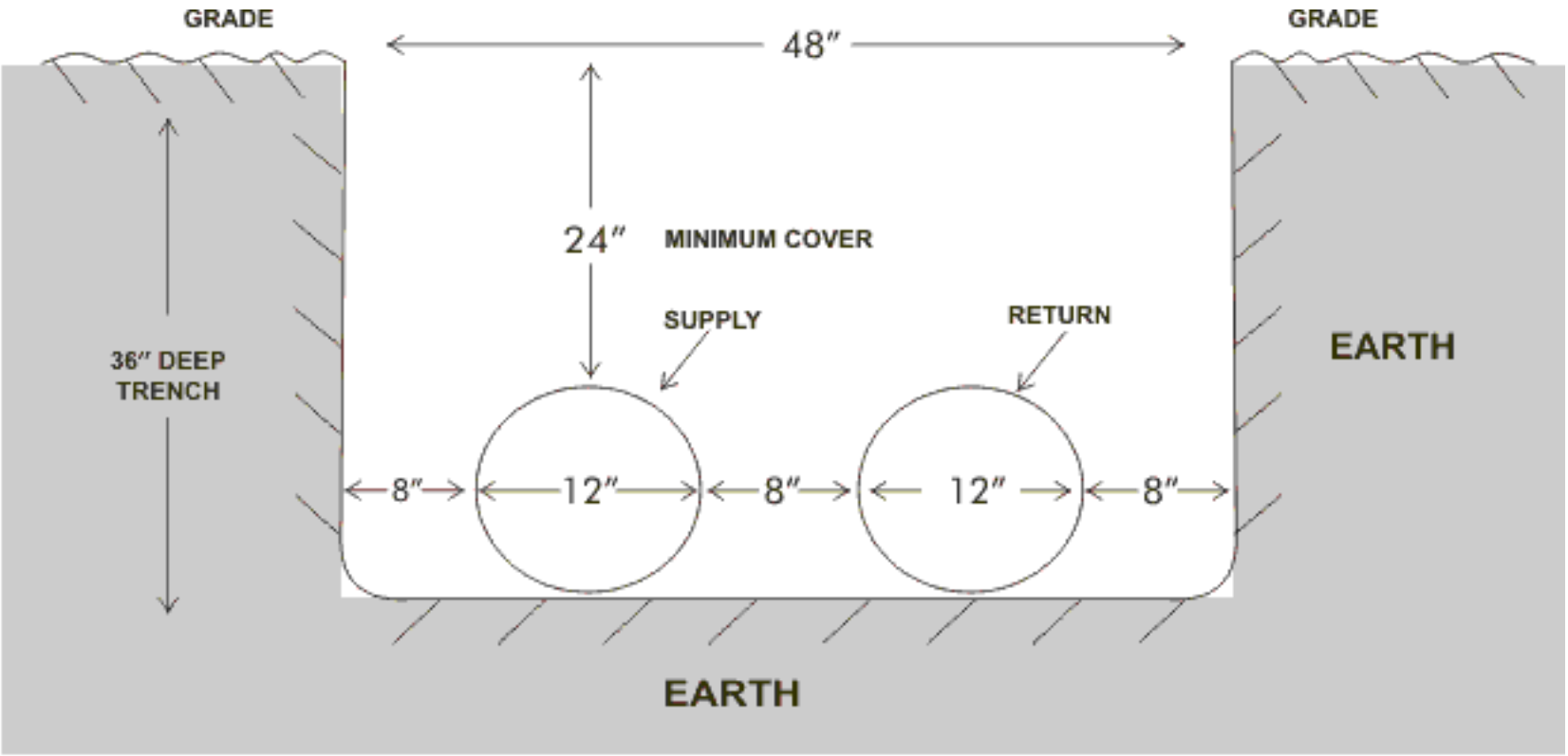
Medium Temperature Hot Water Examples

- St. Paul, Minnesota District System
- Jamestown, New York District System
- Kennedy Airport, New York
- University of Rochester
- Hartford Thermal
- Dozens of installations in Canada
- Thousands of installations in Scandinavian Countries
- Conversion of Pentagon underground steam system now being studied

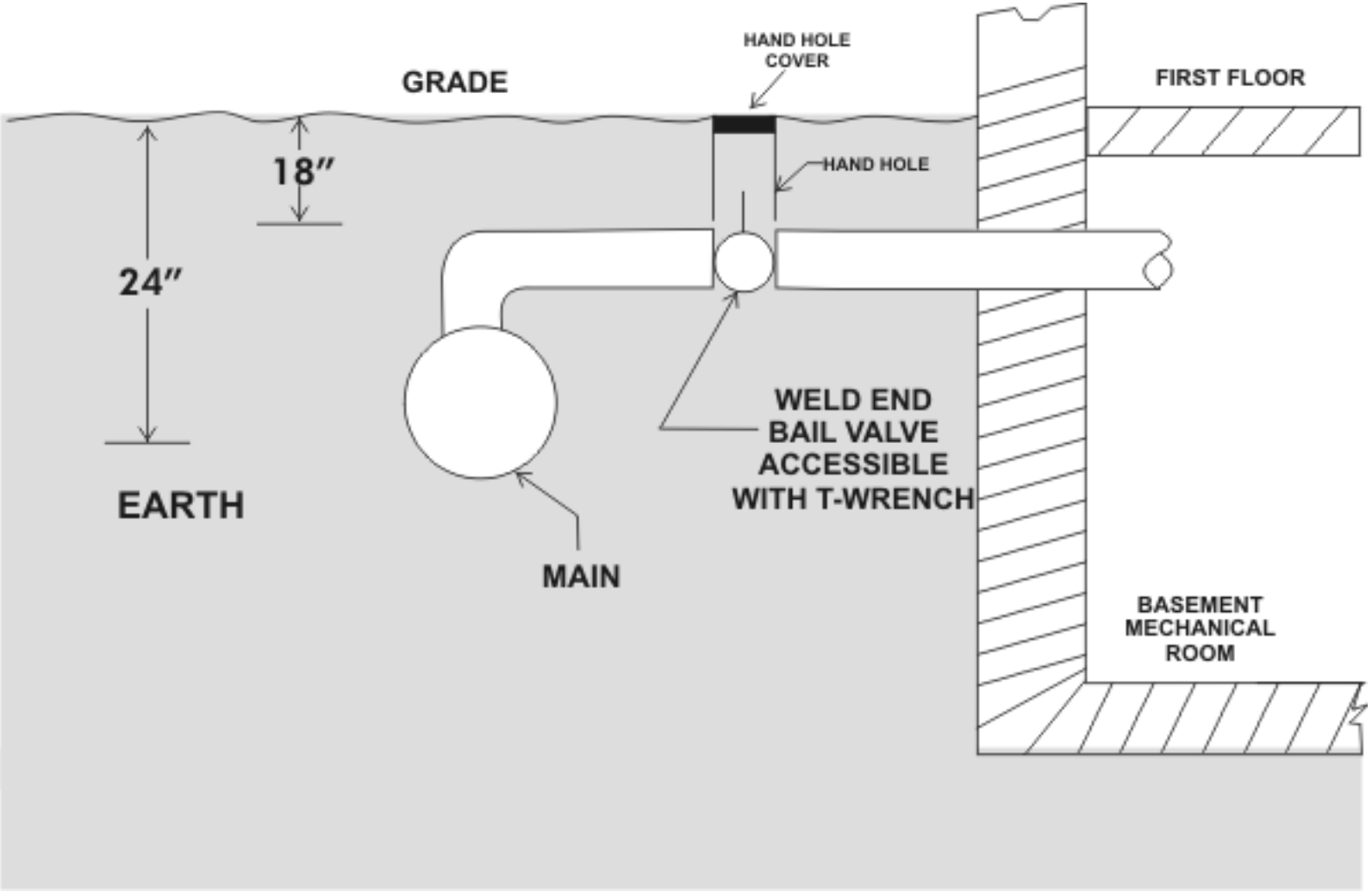
Disadvantages of Medium Temperature Hot Water System

- Only 1 major manufacturer presently supplies this underground piping.
- Because of the devalued $, the cost of this pipe is more expensive than just a few years ago.
- Many years ago, Ricwill, an American company, bought the European patent rights to this system but then sat on them.
- Presently, no American manufacturer of preinsulated piping offers this exact system.
- Not an alternative where huge amounts of steam are required for manufacturing or processing.

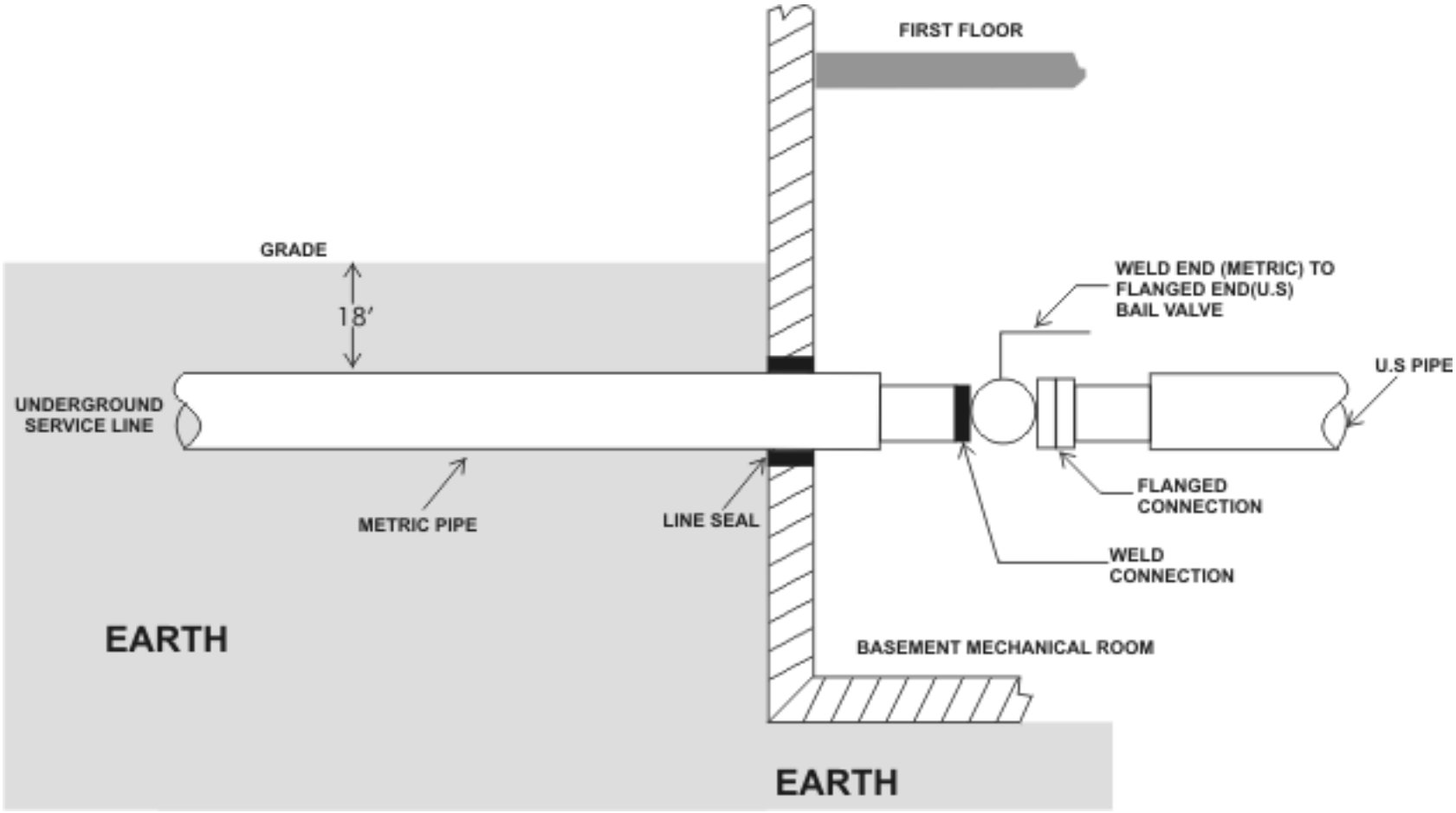
Elevation View – Medium Temperature Hot Water Distribution Mains



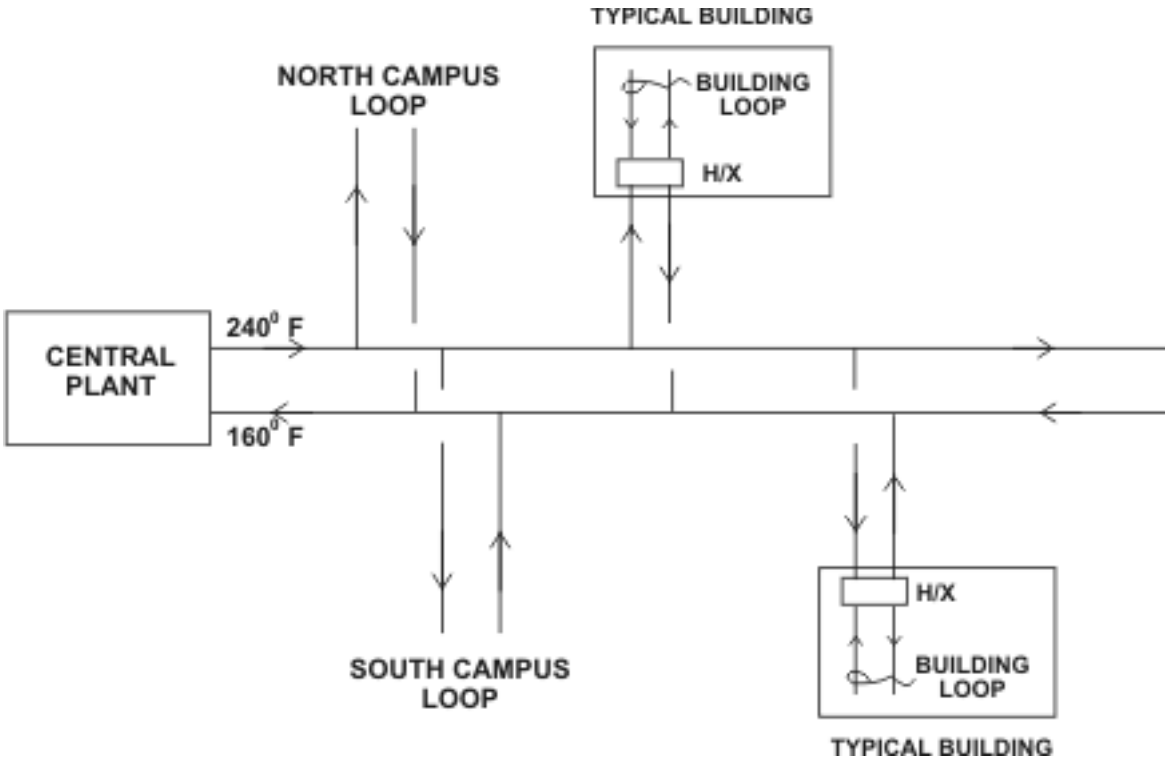
Typical Hot Water Service to Building



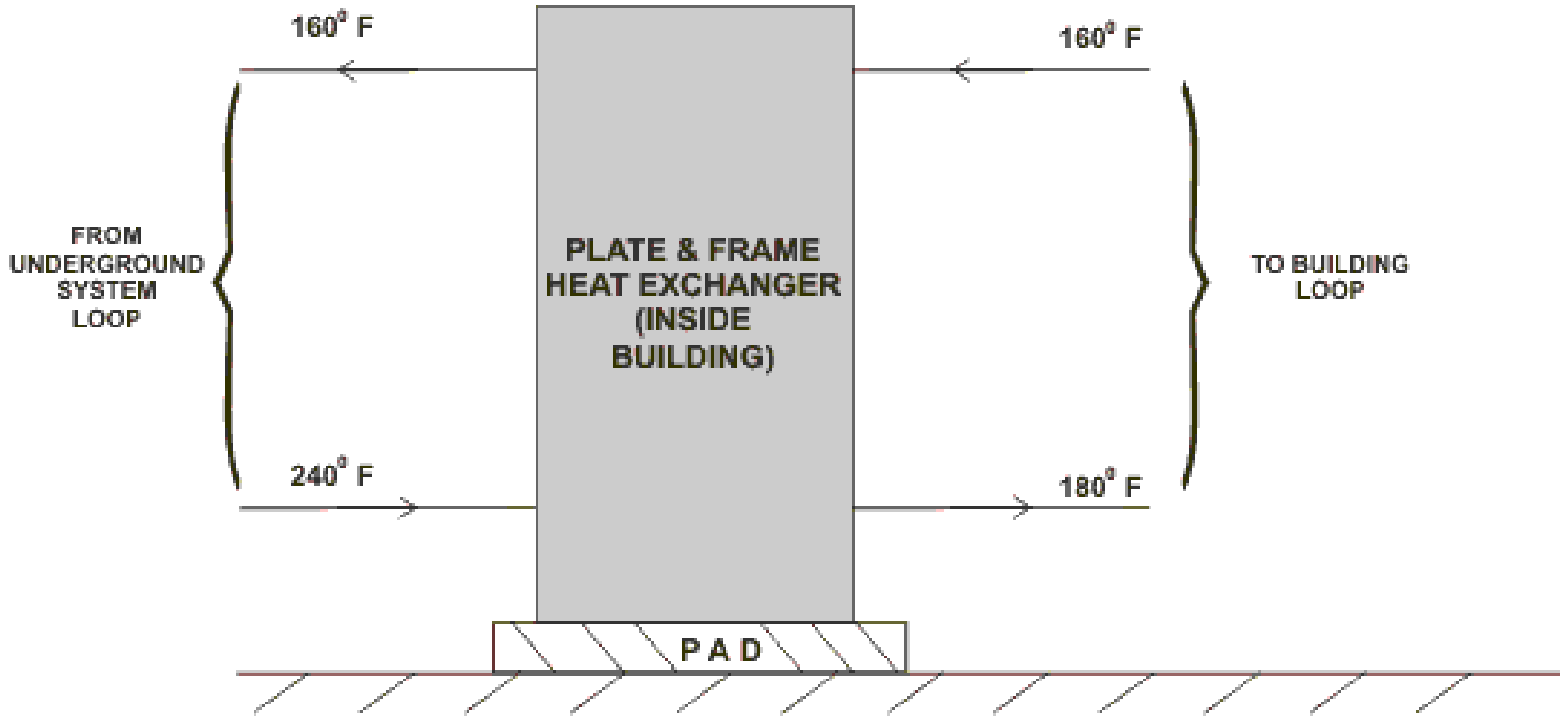
Transition from Metric Piping to U.S. Piping



Typical Schematic for Medium Temperature Hot Water System



Typical Heat Exchanger between System Loop and Building Level



University of Rochester – Medium Temperature Hot Water Distribution System

University of Rochester – Medium Temperature Hot Water Distribution System

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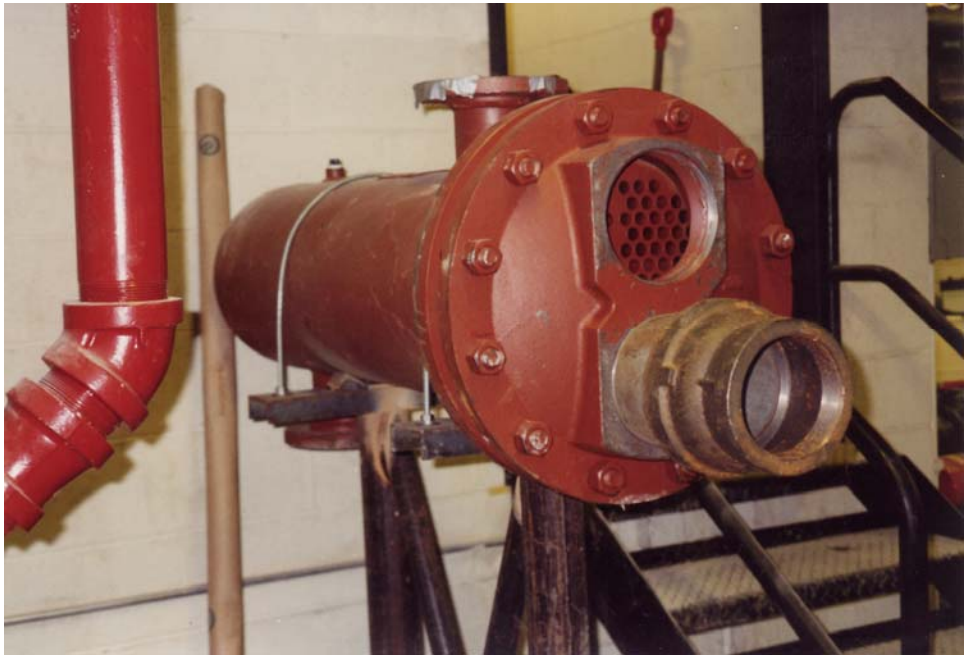
University of Rochester – Medium Temperature Hot Water Distribution System

III-G-1 Small footprint plate and frame heat exchangers like this convert medium temperature water to low temperature water in each building.



III-G-2 Alternative shell and tube heat exchanger has a much larger footprint. There are at least 2 other alternatives.

What's Best for You? It Depends!

A. Upgrading your present central steam system
   - Central plant improvements
   - Distribution system improvements
   - Building piping and control improvements
B. Individual building boilers
C. Medium temperature hot water system
D. Any combination of the above