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An Introduction to Petroleum Fuel Facilities: Marine Fueling Facilities

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An Introduction to Marine Fuel Facilities: Marine Fueling Facilities

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1. FUNCTION. Design marine fuel receiving and dispensing facilities for the purpose of receiving fuel and/or loading fuel aboard ships, barges and boats for consumption or as cargo. In many cases, the marine receiving and dispensing facilities will be combined.

2. FUEL PIERS AND WHARVES. When required and approved by the Owner, design fuel piers for dispensing and receiving fuel. Ensure that the size of the facility is compatible with the fuel requirements of the activity and the number of simultaneous loadings and off-loadings to be accommodated. For dispensing of fuel, consider the number, type, and size of vessels to be fueled or loaded to provide the required number and locations of fuel outlets. In most cases, use dedicated fuel piers and wharves for fuel receipt. Include in the design an energy absorbing fender system.

3. BERTHING PIERS. In some cases, permanent fuel piping and equipment may be installed on berthing piers which were not primarily designed for handling fuel. These facilities are normally used only for dispensing fuel to surface combatants for consumption. Operational requirements usually dictate a clear berthing pier surface area. This imposes restrictions on the use of loading arms and above deck piping. For these areas, trench-contained piping may be considered. Prior to designing facilities on berthing piers for receiving and/or dispensing of bulk fuel for transport, review plans with appropriate port operations agency.

4. OFFSHORE MOORINGS. When operations of an activity do not warrant construction of fuel piers, provide offshore moorings for vessels to discharge or receive fuel through underwater pipelines connecting to the shore facility. Clearly mark the moorings so that the vessel, when moored, will be in the proper position to pick up and connect to the underwater connection.

5. GENERAL REQUIREMENTS. Do not start the design of any fueling system without first becoming completely familiar with guidance on spill prevention, air quality control, and other environmental, safety and fire protection issues.

6. GENERAL LAYOUT. Provide pier loading and off-loading connections, with blind flange and with ball valve for throttling and isolation, at the pier edge for each product to be transported. The intent is for a loading arm manifold with a separate manual isolation plug valve for each product connection. This will allow simultaneous loading and off-loading of different products, each through a dedicated arm. Provide a double block and bleed plug valve at the point which the line is being stripped. Use the following criteria:

a) Provide each branch line to the pier edge with a manual isolation valve located at the main line. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See figure 1.

b) Do not provide a gauge outboard of the hose connection shutoff valve because hose movement will indicate the presence or absence of pressure in the hose.

c) If required, provide one or more loading arms at each station.

d) Provide a liquid-filled pressure gauge for each loading arm, located to be easily read from the operator position. This gauge is provided because the drybreak check valve at the end of the loading arm and the rigid piping will not intuitively indicate the presence or absence of pressure at the loading arm.

e) Provide for venting and draining of the branch lines and loading arm manifolds. Provide for manual venting of the branch lines, connect the vents to the oil waste line, similar to a sanitary vent system to avoid spillage. When pier drain lines cannot be sloped back to the pierhead stripping pumps, a design including separate oil waste drain lines, holding tank and dedicated stripping pump is a viable alternative.

f) Provide segregated handling of multiple products through the loading arms, while allowing easy selection of the products to be transported. Double block and bleed valves can be used for this application.

g) Provide a separate pipe and connection for ballast water or offspec fuel if the size of the facility and level of activity warrants it.

h) Provide each hose handling and loading arm area with fixed spill containment as defined in 33 CFR Part 154.

i) Provide hydraulic shock surge suppressors (if required).

7. PIPING SYSTEMS.

7.1 PIPING ARRANGEMENT. Comply with the following criteria:

a) Where simultaneous deliveries of the same fuel may be made by more than one vessel, size fuel headers and related equipment for the total flow rates of all vessels discharging into the headers. Ensure that flow rates are in accordance with requirements.

b) Place pier piping above the pier deck within a containment area for fueling piers and within a trench on berthing piers. Slope piping toward shore to permit stripping. Use gratings as required to allow access across the piping.

c) Provide flexibility in the piping between the pier and the shore to allow for small movement of the pier relative to the shore. Use a suitable pipe bend or offset configuration, preferably in a horizontal plane, that will allow three-dimensional movement. If vertical bends are used, install vents and drains.

d) Provide flexibility in the piping along the pier to allow for pipe growth due to thermal expansion. Horizontal expansion loops are preferred. In cases where space is tight provide vertical expansion loops or bellows expansion joints where necessary. Where practical provide vertical expansion loops with vents and drains.

e) Include in the pier facilities, pipe manifolds for each fuel type arranged parallel to the face of the pier.

f) Pipe hangers are not allowed.

8. EQUIPMENT DESCRIPTIONS.

8.1 LOADING/OFF-LOADING ARMS. Provide articulated marine loading arms for receiving and shipping fuel cargoes so that the connected vessel can move 15 feet (4.6 mm) forward, 15 feet (4.6 mm) aft, and 10 feet (3 m) off the face of the pier and vertically as caused by loading or off-loading of the vessel and tidal changes, without damage to the arm. Provide a hydraulic power assist system for operating loading arms larger than 8-inch (200 mm) nominal size. Equip the end of the loader to be connected to the ship's manifold with an insulating section, a standard ANSI forged steel flange, and a steel quick coupling device, manually or hydraulically operated. Consider breakaway couplings for locations with strong current.

8.2 FUEL HOSES. Loading/off-loading arms are the preferred method to be used. Provide a facility for storing and protecting the hose as near as practical to the pier if hose is provided in lieu of loading/off-loading arm.

8.3 SUBMARINE FUEL HOSES. Provide submarine fuel hose where offshore moorings are used. Use heavy duty, smooth bore, oil and gasoline, marine cargo, discharge hose rated for a working pressure of not less than 225 psig (1550 kPa) and built-in nipples with Class 300 flanges with stainless steel bolts and Monel nuts. Hoses should be U. S. Coast Guard certified.

8.4 METERS.

Provide a turbine or positive displacement meter for each dispensing outlet that might be used simultaneously. With the approval of the Owner, use portable meters where fueling operations are intermittent. Also consider the use of alternative technologies such as ultrasonic meters. Require temperature compensation feature at each meter used for custody transfer.

8.4.1 METERS – POSITIVE DISPLACEMENT. Require flange-connected, cast steel bodied positive displacement meters of the desired pressure and flow rating for the applicable service requirements. Ensure meter has case drain and register. Provide \1\ meter with temperature compensation and adjustable calibration /1/ when there is custody transfer. Ensure meter accessories are compatible with either the mechanical or electronic support equipment selected. Provide an accuracy of plus or minus 0.5 percent when used for custody transfer. Consult the Owner for requirements for the meter to communicate to a remote location or equipment. Consider the use of a card-operated or key-operated data acquisition system. Cards or keys, as appropriate, are coded to identify the receiver of the fuel and to allow access to the fuel. The quantities taken are transmitted to a data-receiving device by electronic pulse transmitters mounted on each meter, and each transaction is automatically recorded.

8.4.2 METERS – TURBINE. Use flange-connected, steel bodied turbine meters of the desired pressure and flow rating for the applicable service requirement. Provide a flow straightener before turbine meters or provide a straight length of pipe at a minimum of ten pipe diameters upstream and five pipe diameters downstream of all turbine meters, or as required by manufacturer. Ensure meter has case drain and register. Provide meter with temperature compensation and adjustable calibration when there is custody transfer. Ensure all supporting equipment for meter is compatible with the turbine meter selected. Provide an accuracy of plus or minus 0.5 percent when used for custody transfer. Consult the Owner for requirements for the meter to communicate to a remote location or equipment. Consider the use of a card-operated or key-operated data acquisition system. Cards or keys, as appropriate, are coded to identify the receiver of the fuel and to allow access to the fuel. The quantities taken are transmitted to a data-receiving device by electronic pulse transmitters mounted on each meter, and each transaction is automatically recorded.

8.5 STRAINERS. Require a basket strainer to protect centrifugal pumps, unless it precludes meeting the net positive suction head of the pump. Whether or not strainers are installed on the suction side of centrifugal pumps, install a spool piece so that temporary strainers can be installed during startup of the system. Strainers are required on the suction side of all pumps, meters, and receipt filtration. Strainers are not required upstream of issue filter/separators or diaphragm control valves. Also:

a) Use flanged basket strainers constructed of steel and fitted with removable baskets of fine Monel metal or stainless steel mesh with large mesh reinforcements.

b) Unless otherwise specified, provide a fine screen mesh as follows:

	Mesh	Size of Opening
Pump suctions (Centrifugal)	7	0.108 inch (2.74 mm)
Pump suctions (Positive Displacement)	40	0.016 inch (0.40 mm)
Receipt Filtration	40	0.016 inch (0.40 mm)
Meter inlets (unless downstream of a filter/separator)	40	0.016 inch (0.40 mm)

c) In all cases, ensure the effective screen area is not less than three times the cross sectional area of the pipe.

d) Strainers upstream of pump shall be quick opening, single screw type.

e) Provide pressure gauges on both sides of the strainer and a differential type gauge across the strainer.

8.6 SURGE SUPPRESSORS. Every effort should be made to control hydraulic surge or shock to acceptable limits by the design of the piping system rather than by the use of surge suppressors. Where this is not possible or becomes extremely impractical, surge suppressor(s) may be incorporated. Use the diaphragm or bladder type equipped with a top-mounted liquid-filled pressure gauge, wafer-style check valve at the bottom, drain above the check valve, and isolation valve. Provide a needle valve around the check valve to permit controlled bleed back of the surge suppresser without rebounding. Locate surge suppressors as close as possible to the point of shutoff that is expected to cause the shock. Surge suppressors can reduce shock pressure but will not eliminate it entirely. The preferred solution to hydraulic shock is conservative piping design, use of loops, and slow-closing valves. Surge suppressors are strictly a last resort solution and require the approval of the Owner prior to designing into a system.

8.7 VALVES.

8.7.1 MATERIALS OF CONSTRUCTION. Require valves to have carbon steel bodies and bonnets. Do not allow valves with aluminum, cast iron, or bronze materials. Use only API fire-safe valves.

8.7.2 ISOLATION VALVE TYPES.

a) Double Block and Bleed Isolation Valves:

- Use these for separation of product services, on tank shell connections, when piping goes above or below ground, between pier and tank storage, and other locations critical to pressure-testing of piping.

- Plug Valves (Double Block and Bleed): Use double-seated, tapered lift, lockable, plug type valves with a body bleed between the seats (double block and bleed) in critical applications such as separation of product services, when piping goes above or below ground, between pier and tank storage, and other locations critical to pressure-testing of piping. Valves shall be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Lubricated plug valves are not allowed. Include integral body cavity thermal relief valve.

- Ball Valves (Double Block and Bleed): Use double-seated, trunion mounted, lockable, ball type valves with a body bleed between the seats (double block and bleed). These will be very rarely used but are acceptable as an alternative to double block and bleed plug valves in applications where the valve is operated very infrequently. An example is isolation valves in the middle of piers that are only closed to perform pressure testing of piping. Valves shall be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Include integral body cavity thermal relief valve.

- Gate Valves (Double Block and Bleed). Use double-seated, lockable, gate type valves with a body bleed between the seats (double block and bleed). These will be very rarely used but are acceptable as an alternative to double block and bleed plug valves and double block and bleed ball valves only when other double block and bleed valves will not physically fit. Valves shall be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Single seated gate valves are not allowed. Include integral body cavity thermal relief valve.

b) Quick Opening/Frequent Opening Isolation Valves

- Use these for less critical applications where double block and bleed shutoff is not required.

- Ball Valves: Ball type valves may be used as valves for quick or frequent opening applications when a double block and bleed valve is not required. Ball valves shall be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Use Teflon or Viton synthetic seals or seating material. Use full port ball valves with exact same diameter of the pipe within ten pipe diameters upstream and/or five pipe diameters downstream of a flow or pressure control valve, or a flow-sensing device such as a venturi. Valves should comply with API Std 608.

c) Butterfly Valves: Butterfly valves are not allowed.

d) Use full port valves with exact same diameter of the pipe when line pigging is required.

8.7.3 ISOLATION VALVE OPERATORS. Provide manually operated valves not specified for remote, automatic, or emergency operation. Use geared operators for ball and double block and bleed plug valves larger than 6 inches (150 mm). Double block and bleed gate, ball and double block and bleed valves specified for remote, automatic, or emergency service may have electric motor operators, if approved by the Owner. Provide locking tabs on isolation valves to allow padlock to be used for lock-out during maintenance. Provide chain operators on valves which are located 72 inches (1800 mm) or higher above grade.

8.7.4 ISOLATION VALVE LOCATIONS.

a) Provide an isolation valve on each line at the shore end. For piping used only for receiving fuel, also provide a check valve at the shore end. Use double block and bleed type, which may be motor-operated with remote control. To minimize surge potential, use a slow-closing speed, if possible.

b) Provide double block and bleed isolation valves on the aboveground piping at each barge or tanker off-loading and loading connection.

c) Provide double block and bleed isolation valves near the shoreline of a submerged pipeline to offshore moorings.

d) Provide double block and bleed isolation valves on the inlet and outlet connection of each line strainer, filter/separator, meter, diaphragm control valve, and other equipment that requires periodic servicing. One inlet valve and one outlet valve may be used to isolate more than one piece of adjacent equipment which are connected in series.

e) Provide thermal relief valves around all isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See figures 1, 2, 3 and 4.

8.7.5 ISOLATION VALVE PITS. Provide fiberglass or concrete pits with a rolling or hinged cover designed in accordance with the DoD Standard Design AW 78-24-28 for all isolation valves installed in non-traffic areas on underground fuel systems. Design valve pits and valve operators so that the valves can be operated by personnel, without confined space entry.

8.8 OTHER VALVES.

8.8.1 CHECK VALVES. Use check valves to prevent backflow through pumps, branch lines, meters, or other locations where runback or reverse flow must be avoided. Check valves may be of the swing disk, globe, dual plate hinged disk, spring-loaded poppet, ball, or diaphragm-actuated types. Use checks of soft-seated non-slamming type with renewable seats and disks. Ensure check valves conform to API Spec 6D. Use non-surge check diaphragm control valves with flow control feature on the discharge of all pumps. When using non-surge check diaphragm control valves on pump discharge, consider the use of a spring type wafer check before the diaphragm control valve to prevent sudden flow reversals during shutdown from passing back thru the pump before the diaphragm control valve diaphragm chamber is filled and reacts by closing the valve.

8.8.2 THERMAL RELIEF. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See figures 1, 2, 3 and 4.

8.9 PRESSURE OR PRESSURE/VACUUM GAUGES. Use glycerin-filled or silicone-filled pressure gauges of range and dial size, as necessary, but not less than 0 to 160 psig (0 to 1100 kPa) pressure range and 4-inch (100 mm) diameter dial. Also:

a) Use pressure gauges upstream and downstream of strainers and filters/separators. A differential pressure gauge may be used in lieu of gauges on each side.

b) Install compound (pressure/vacuum) gauges on the suction side of each pump at fuel storage tanks.

c) Provide a lever handle gauge cock and pressure snubber in each pressure gauge connection.

d) Provide a pressure gauge on each side of the pipeline shutoff valve at the shore end of each pier-mounted pipeline. Provide the indicating pointer with a high-pressure-reading tell-tale indicator suitable for reporting the highest pressure experienced since last reset. Provide for non-contact resetting of the tell-tale by means of a small magnet.

e) Provide a pressure gauge on each branch line at each fueling station on each pier-mounted pipeline. Ensure that the pressure gauge is legible from the fuel hose connection array and from the pantograph loading arm location (if provided).

f) Provide a pressure gauge on each marine loading arm assembly (if provided). Ensure that the gauge is visible by the operator.

g) Pressure gauges shall be installed so that they are testable without removing them from the piping.

8.10 STRIPPER PUMPS. Provide positive displacement stripper pumps for emptying loading arms, hoses, and manifolds. Provide a stripper pump to reclaim each clean product from each main product line, or connect the product lines to the oil waste drain line. Conduct an economic analysis of the two alternatives to determine the appropriate choice. Larger, longer, or more frequently drained lines will favor the stripper pump choice. Use a stripper pump on multi-product lines, but do not exceed acceptable limits of cross contamination. Provide a dedicated stripper pump to each separate product line, such as aviation turbine fuels.

8.11 EXCESS FLOW SENSORS. In piping used for both loading and off-loading, provide a sensor that will alarm both the control room and at the pier to detect excess flow that might occur in the event of a line break.

8.12 SOLID CYCLONIC SEPARATORS. In facilities which receive product by tankers or barge, consider the use of solid separators in the receiving lines as part of pre-filtration to remove gross impurities from the incoming product. In systems equipped with filter/separators in the receiving lines, locate strainers or cyclonic separators upstream of the filter/separator. Ensure that there is no slug valve feature on the filter/separator. Consider the use of automatic water drains. Do not allow reverse flow thru cyclonic separators.

8.13 GROUNDING SYSTEMS. Provide grounding systems for barges.

9. PRODUCT RECOVERY SYSTEMS. Provide a product recovery system to collect and store usable aviation turbine fuel that would otherwise become waste from operational or maintenance activities. Consider a product recovery system for other products.

10. WEATHER SHEDS. Provide adequate shelter for personnel, as well as for spill containment booms, absorbent material, and other weather-sensitive equipment.

11. CANOPIES. Provide a canopy, as directed by the Owner, for all aboveground equipment including pumps, meters, strainers, filters, control panels, electrical panels, and motor control centers (MCCs).

12. SPECIAL CALCULATIONS. Calculate pipeline filling/venting times and draining/stripping times. The larger and the longer the pipeline, the greater the volume of fuel required to fill the line and, therefore, the greater the volume of air required to be vented. Undersized vent lines will delay filling the lines and delay changeover of products in multiproduct lines. Size the vent lines to allow filling of the line at not more than four times the design transit time of the line. Connect vent line to the drain line to avoid spills to the environment. Check vent line air velocity, which must not exceed the allowable air velocity to avoid electrostatic buildup, in accordance with API RP 2003. Vent rate must be not less than the lowest allowable pumping rate from ship or shore. Vent rate must be less than the design transit velocity to minimize hydraulic shock.

13. SAFETY SHOWERS AND EYEWASH FOUNTAINS. Provide manual shutoff valves on the potable water branch to the safety shower and eyewash fountain. Provide a means to seal shutoff valve in the open position. This will ensure operation in an emergency, yet allow for servicing a single shower without shutting off potable water to the whole pier. Design for freeze protection in climates subject to freezing. Install safety showers and eyewash fountains in accordance with ISEA Z358.1.

14 TRAFFIC BOLLARDS. Provide traffic bollards to protect fueling piping and equipment on piers and wharves. Utilize concrete-filled steel pipe of minimum 4-inch (100 mm) diameter and 4-foot (1.2 m) height, embedded in concrete or welded to a steel plate mounted on the structure.

15. SPECIAL DRAINAGE FOR FUELING PIERS.

a) Provide an intercept system to collect oil spills. Place pipes on piers in a curb containment area with a drain system independent of the deck drainage. Provide containment also for loading arms and risers. Provide locking valves in normally closed positions on all containment areas along with sump pumps or other means of removing the spilled fuel to a collection point or tank.

b) In cases where the stormwater collected in the intercept system is contaminated, the water/fuel mixture should be treated as an oil spill as described previously.

16. BALLAST TREATMENT AND SLUDGE REMOVAL.

16.1 BALLAST RECEIVING AND TREATMENT FACILITIES.

16.1.1 DESIGN REQUIREMENTS. It is often policy that there should be no discharge of oil or hazardous substances into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone. Petroleum fuel facilities, which transfer fuel by barge or tanker or which fuel large ships, require ballast water collection and treatment facilities to receive and treat oily ballast from cargo or fuel tanks. Also:

a) Blend the fuel oil which has been reclaimed from the ballast water during the collection and treatment process with boiler fuel oil for use in shoreside boilers. Perform a quality assurance check on the reclaimed fuel oil to ensure that it meets the minimum requirements for shoreside boiler fuel. Dispose of sludge accumulated during the collection and treatment of ballast water in accordance with applicable hazardous waste management disposal procedures.

b) Select and design the appropriate treatment system based on an evaluation of the types of oil/water mixtures that may be encountered at the particular facility. If possible, base the evaluation on samples of typical ballast water receipts and tank washings including the following:

- Whether they are simple mixtures, simple gravity suspensions, or chemically stable emulsions.
- The specific gravity and viscosity of the oil in the mixture.
- Whether other substances, such as chemicals or bacteria, in the mixtures must be removed.
- The general condition of the ship's tanks expected to be discharged (e.g., new, clean, coated, well maintained, or dirty and normally full of sludge, scale, and rust).

- Whether ballast water is clean sea water or polluted harbor water.
- Whether the treatment system proposed ("ship's waste off-load barge" or fixed shore-based facilities) meets the standards of effluent water quality established by local environmental regulations.

c) If it is determined that both simple mixtures and emulsions are present, consider the possibility of using two segregated separate systems, one for gravity separation and the other for breaking emulsions. Avoid mixing the two types of suspensions when possible.

16.1.2 RECEIVING AND SETTLING TANKS. The minimal ballast water receiving facility usually requires two storage tanks, usually of equal capacity, to be used alternately as receiving and settling tanks. If these tanks are sized to allow 4 to 5 days undisturbed settlement, separation of simple suspensions of light oils in water can be achieved. Provide the following fittings and appurtenances:

a) An automatic float gauge suitable for use with transmitting device for remote readout.
b) One cable-operated swing-line assembly on the oil outlet pipe.
c) One shell fill nozzle.
d) Valved sample connections in the shell, having nonfreezing-type valves in cold climates, every 2 feet (0.6 m) vertically, easily accessible from the ladder or stairway.
e) When chemical feed is provided, a chemical feed inlet valve, to be nonfreezing type in cold climates.
f) When air blowing is provided, a perforated pipe air sparger for mixing. Make the perforations in the sides of the pipe to avoid plugging by settling solids. Use nonfreezing-type air inlet valve(s) in cold climates.
g) Sight glass or look box on oil outlet line.
h) Sight glass or look box on water outlet line.
i) Oil sump tank with high-level alarm.

j) Water and oil pumps as required to move fluids from receiving tanks or from oil sump tanks. For transfer of oily water, use low-speed-type pumps to minimize emulsification.

k) If heaters are required to reduce oil viscosity and promote separation, use either tank wall heaters or internal pipes. Keep internal pipes at least 2 feet (0.6 m) above the tank floor.

l) Insulation for tanks that will be regularly heated.

m) Provide automatic temperature controls and thermometers for all heated tanks.

16.1.3 OIL/WATER SEPARATORS. Separate water/fuel mixtures from storage or settling tanks with an API oil/water separator. Recycle the fuel portion and pass the water portion to another treatment process. Do not discharge water drawn from tanks to surface water without additional treatment and permits.

17. SLUDGE REMOVAL SYSTEMS.

17.1 DESIGN REQUIREMENTS. Install sludge removal systems where the accumulation of sludge in substantial quantities is likely to occur on a regular basis. Sources of such sludge are a ballast water treatment system, a contaminated fuel recovery system, or frequent cleaning of shore or ships' tanks. If routine cleaning of clean product storage tanks occurs on an irregular basis, sludge removal systems are not required.

17.2 SLUDGE DISPOSAL.

a) Where possible, provide pumps, tanks, and piping to return sludge containing recoverable oil to the contaminated oil recovery system. If this is not possible, consider transferring the sludge to a refinery or waste oil treatment facility.

b) Provide a tank or tanks with transfer pump(s) for pumpable sludges that are unreclaimable. Include piping for receiving sludge and for mixing other low viscosity waste oils for thinning as required. Ensure that tanks are dike-enclosed and have cone bottoms.

c) Provide tank heating where climate conditions prove necessary.

d) Coordinate sludge disposal method and design with facility environmental office.

e) Enclose the sludge disposal facility with a security fence to prevent unauthorized entry. Do not use this facility for disposal of sand, gravel, rust scale, or other solid nonpumpable matter found on tank bottoms.

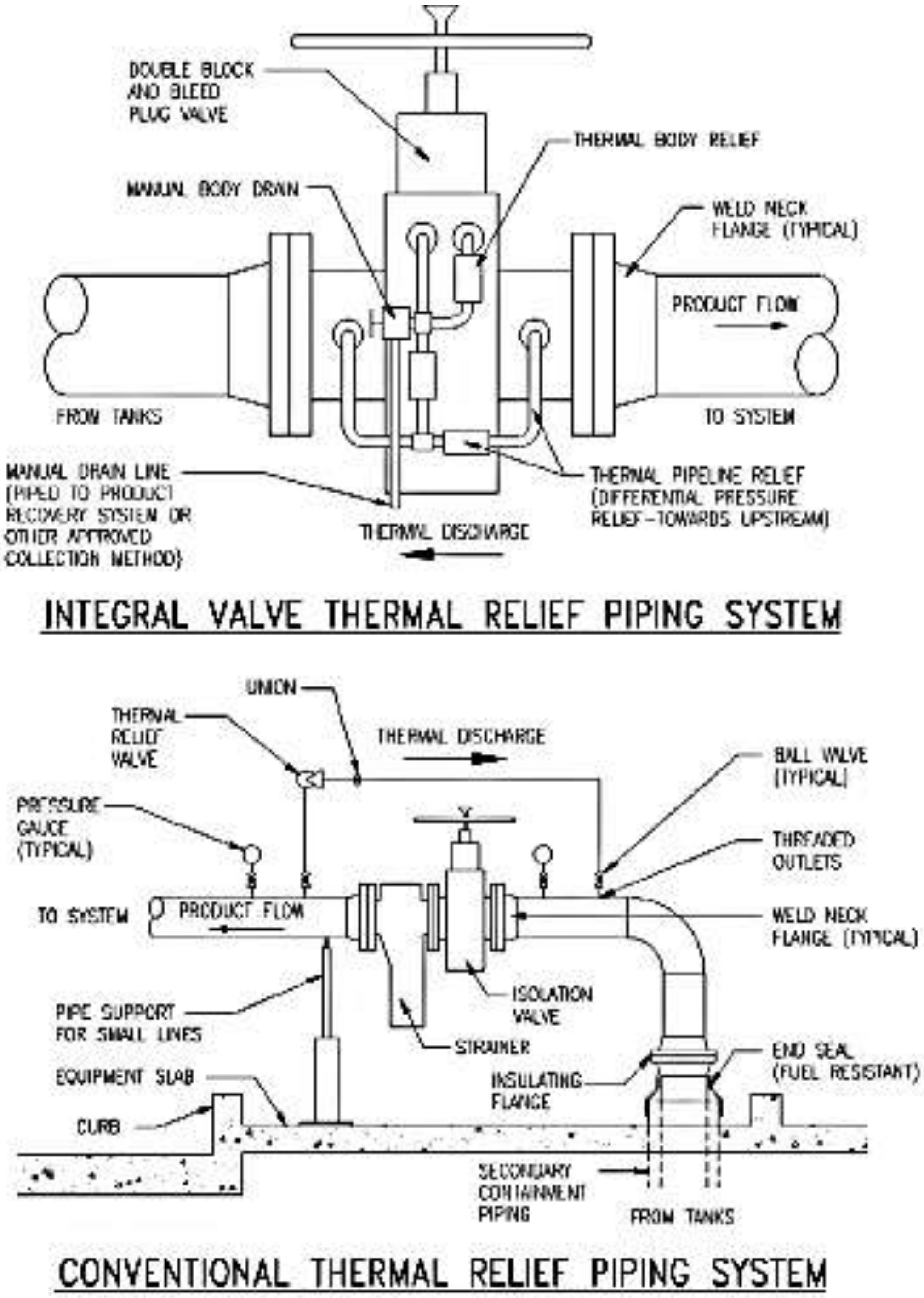
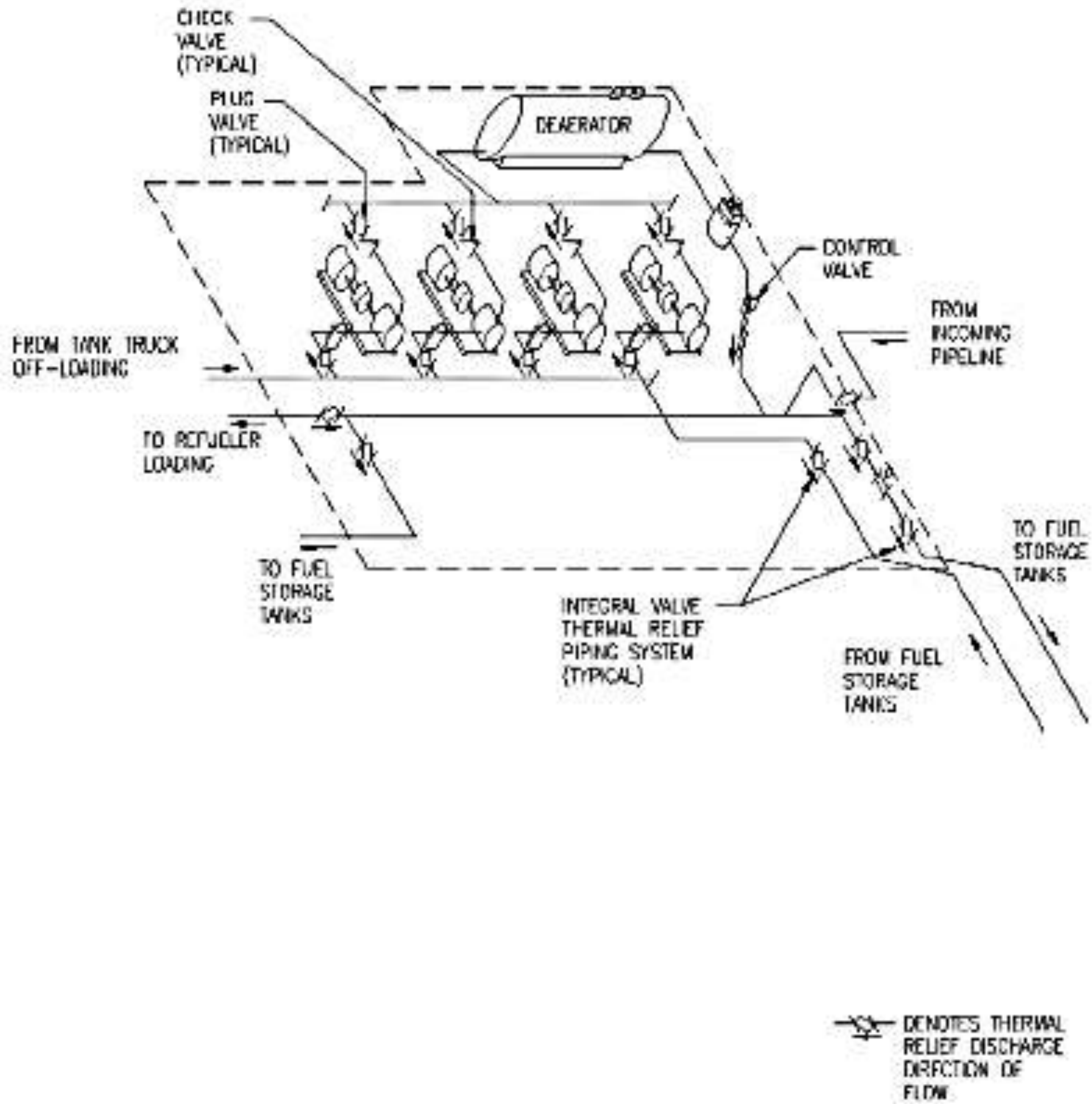


Figure 1

Thermal Relief Piping Systems Integral Valve and Conventional



EQUIPMENT PUMPHOUSE OR PADS

NOT TO SCALE

Figure 2

Thermal Relief Piping Systems Equipment Pump House or Pads

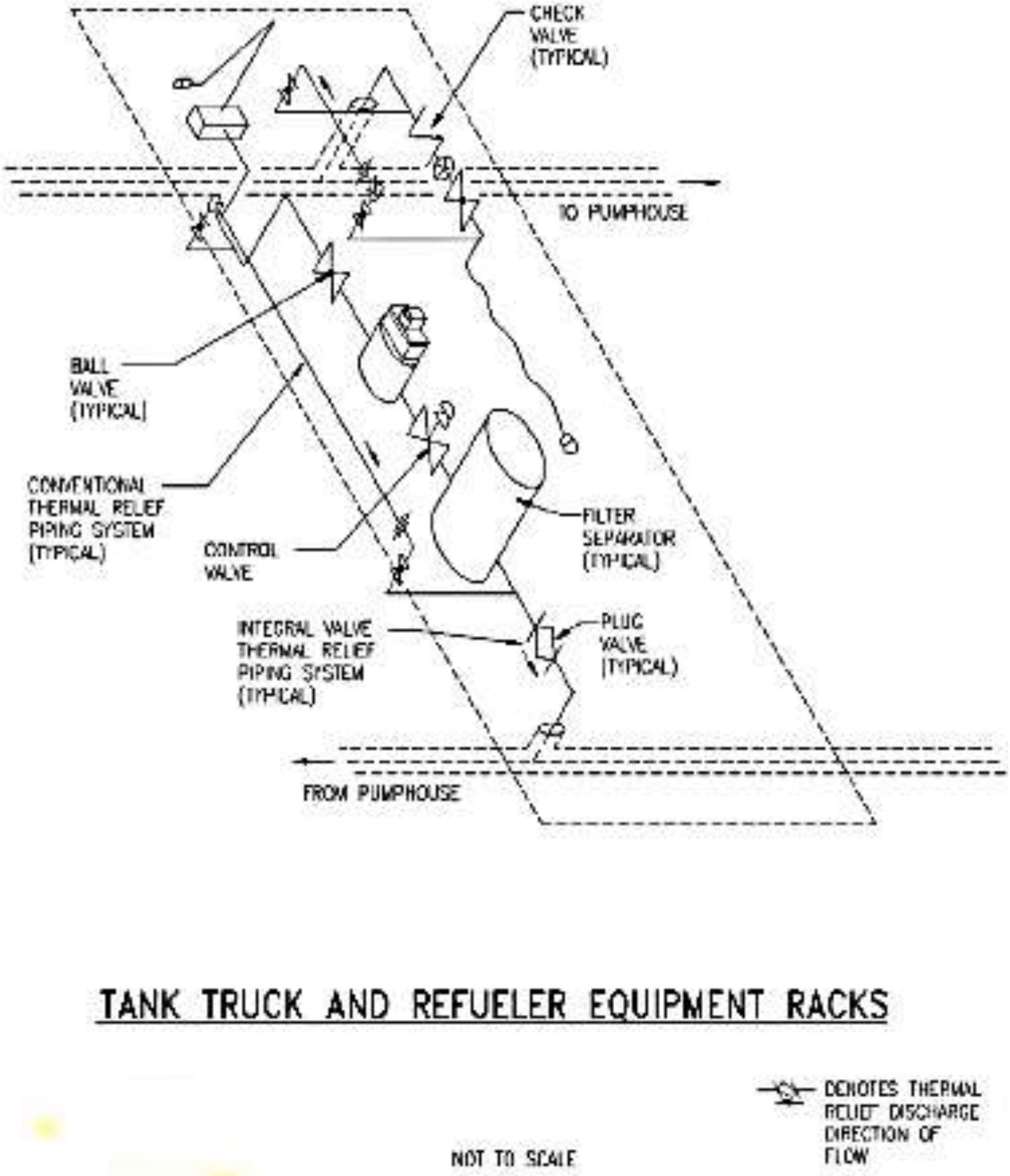


Figure 3

Thermal Relief Piping Systems Tank Truck and Refueler Racks

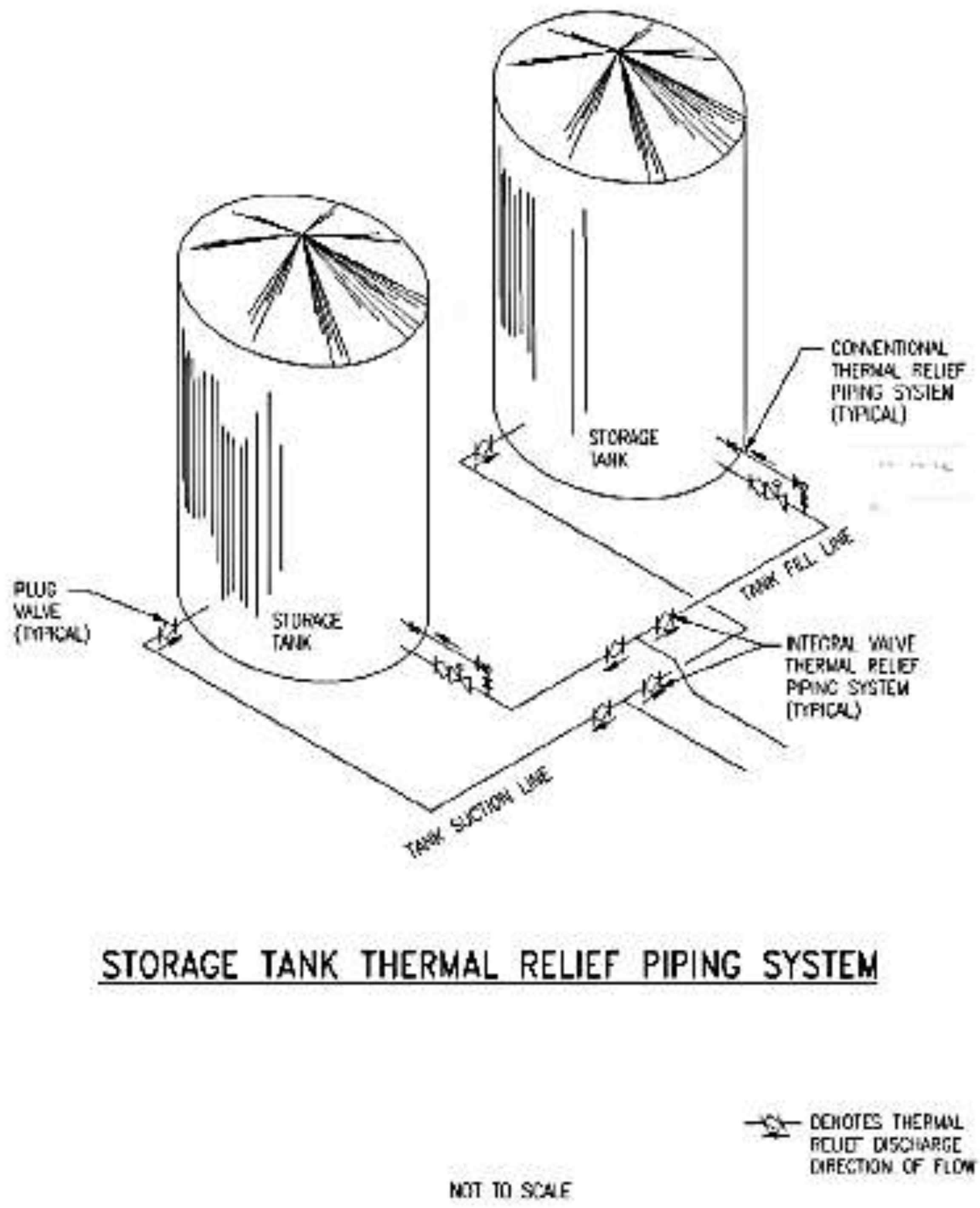


Figure 4

Thermal Relief Piping Systems Storage Tanks