VIKING®

TECHNICAL DATA

WATER SPRAY DESIGN

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CAUTION

THESE DESIGN PROCEDURES ARE PROVIDED TO YOU ONLY FOR THE GENERAL GUIDANCE OF OUR WATER SPRAY SYSTEM DESIGNERS. THEY CONTAIN BROAD OUTLINES OF THE TYPES OF CONSIDERATIONS, WHICH ENTER INTO THE DESIGN OF WATER SPRAY SYSTEMS. BECAUSE OF THE MANY DIFFERENT TYPES OF EQUIPMENT AND APPLICATIONS ENCOUNTERED IN PRACTICE, WE CANNOT PROVIDE GENERAL SYSTEM DESIGN, WHICH WILL SATISFY ALL THE VARYING NEEDS OF OUR CUSTOMERS. THEREFORE YOU MUST RELY ON THE EXPERTISE OF YOUR SYSTEM DESIGNER AND ENCOURAGE THEM TO USE ALL AVAILABLE INFORMATION FROM THE OWNER, INSURANCE AUTHORITIES AND LOCAL GOVERNMENTAL UNITS. VIKING DOES NOT WARRANT OR GUARANTEE THAT FOLLOWING THESE PROCEDURES WILL RESULT IN SATISFACTORY SYSTEM DESIGN FOR YOUR PARTICULAR PROJECT.

I. GENERAL CONSIDERATIONS

Deluge systems are used in applications where there is an extreme hazard. The principal purpose of a deluge system may be either extinguishment or cooling or both. In the case of volatile liquids, particularly outdoors, the principal purpose of the deluge system is to cool the equipment so that it is not significantly damaged by the fire. In many cases it is permissible to lose the material being stored or processed as long as the equipment used to store or process it can be put back into service in a relatively short time when the fire is extinguished. Actual extinguishment is often accomplished by either letting the fire burn itself out or by other means.

Cooling must accomplish two important functions. It must keep the structure below the temperature at which deformation or physical weakening occurs and it must limit the heat input into the liquid or gas contained in the equipment in order to keep the pressure in the equipment within tolerable limits.

Equipment can be expected to be exposed to heat from basically two sources, either a spill fire where burning liquid or gas is present over, under or around the equipment or an exposure fire adjacent to the equipment but not actually involving it.

A vessel filled with liquid has a considerable capacity to absorb heat without raising its temperature significantly. The liquid acts as a heat sink and because of the good heat transfer characteristics between the vessel shell and the liquid, the shell is kept relatively cool. It should be noted, however, that the inside of a tank is seldom clean and deposits tend to build upon the lower walls and the bottom. These deposits act as an insulator and can greatly reduce the heat transfer to the liquid. When the vessel is empty or filled with a gas, its heat absorbing capacities are dramatically reduced, therefore, an empty vessel is much more susceptible to fire damage than a full one. Similarly, if a vessel is partially full the top portion is much more susceptible to damage than the bottom portion.

When a gas or volatile liquid is heated, the result is a rapidly increasing pressure that must either be reduced or relieved or there is danger that the equipment will rupture. If portions of the equipment have been either weakened or overstressed by the fire, these provide specific points where failure can more easily occur. Venting is usually employed to keep the pressure within safe limits, however, if the fire is severe enough, the venting capacity may not be sufficient to keep the pressure at safe levels. Cooling of the equipment may well insure that the venting capacity is adequate.

Structural supports not encased in concrete or sufficiently fireproofed must be protected since their failure could well result in either damage to or collapse of the equipment.

Adequate cooling must be provided to protect the equipment from excessive heat transfer applied by either direct impingement of flame or radiation.

In most cases it is necessary to protect all portions of the equipment. (Often very high tanks such as cracking towers are only protected up to about 30 ft (9 m). Ideally, one would wish to apply a uniform density of water over every bit of the exposed surface. This is an impossibility since spray patterns of sprinklers rarely, if ever, exactly match the contours of the equipment. The effects of wind and gravity further compound the problem. In an outdoor installation, because of wind problems, spray nozzles should be placed within 2 ft (.6 m) of the surface being protected unless this surface is relatively shielded from the wind.

Normally, water applied at the top of the equipment will run down the vertical sides, however, the actual amount of rundown is not entirely predictable due to wind conditions, the fact that the equipment may not be exactly vertical, protrusions from the equipment which may “roof off” certain areas and perhaps most important, loss of water through vaporization due to intense heat of the fire. In addition, the equipment may be or will shortly become dirty. This dirt is usually water repellent to some degree and this will cause the rundown to “channel” rather than be evenly distributed. If the equipment is elevated from the ground, there will be virtually no rundown on the bottom. Therefore, rundown must be considered but cannot be taken for granted.

Replaces page 208a-o, dated April 18, 2003.
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The designer attempting to fit a spray nozzle layout to a piece of equipment will encounter theoretical dry spots. He should give consideration to whether or not these will turn out to be actual dry spots and attempt to adjust his design accordingly. A dry spot, particularly on the top seam of a tank, can be quite dangerous. If the dry spot is exposed to severe radiation, a carbon deposit can form. This deposit greatly increases the radiation heat transfer potential and, furthermore, because of the nature of the carbon, the spot becomes highly water repellent. Theoretical dry spots are much more important in the top portion of a tank where there is little chance of rundown than they are on the tank shell or the bottom where there usually would be some liquid.

In designing a deluge system primarily for cooling purposes, it is suggested that the designer follow these steps:

1. Determine equipment dimensions and water density requirements
2. Establish individual design areas and total design area.
3. Determine individual and total design area water demand.
4. Determine water supply conditions and probable available pressure for each design area.
5. Determine number and type of nozzles required to give adequate coverage and water delivery (by trial and error).

In selecting a nozzle arrangement to give suitable coverage, the designer has a choice of a number of coverage angles and a number of capacities. It will be necessary to select a proper arrangement to provide adequate density and coverage. Often there will be a number of choices.

II. SPECIFIC DESIGN PROCEDURES

A. Water Spray Protection for Horizontal Tanks

Make a detailed survey of the tank and its surroundings. Note diameter, length, height of ends, locations and dimensions of any irregularities which may impede distribution of water such as ladders, manholes, piping connections and the like. Note size, location and material of supporting structure for tank. Note proximity of other hazard producing equipment. Note the presence of dikes, walls and barriers. Determine contents of tank and establish water density requirements for protection.

Tank Diameter	=	D
Tank End Height	=	h
Tank Shell Length	=	L
Density Required	=	d

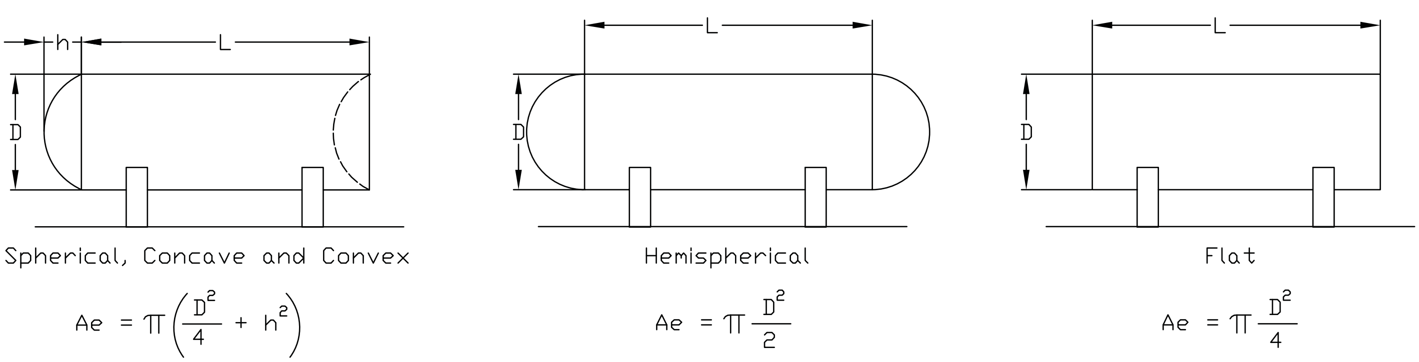

Figure 1: Design Area of Horizontal Tanks

1. **Find the area of the cylindrical shell (A_S)**

   See Figure 1. Shell area = $A_g = \pi DL$

2. **Find the water required for the shell (Q_S)**

   Water required is the shell area times the required density.

   $Q_S = A_S(d)$

3. **Find the area of the ends (A_e)**

   See Figure 1. Use the proper formula for the tank end. If both ends are not the same, use the appropriate formula for each end. Neglect the presence of tank fittings.

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4. **Find the water required for the ends (Q_e)**

   Water required is the end area times the required density for each end.

   $Q_{e1} = A_{e1}$ (d)

   $Q_{e2} = A_{e2}$ (d)

5. **Determine the water required for appendages (Q_a)**

   If there are appendages to the tank, which increase the basic area of coverage, estimate the water required to protect these appendages using the required shell density.

   $Q_{a1}=A_{a1}$(d)

   $Q_a = Q_{a1}+Q_{a2}$ . . . .

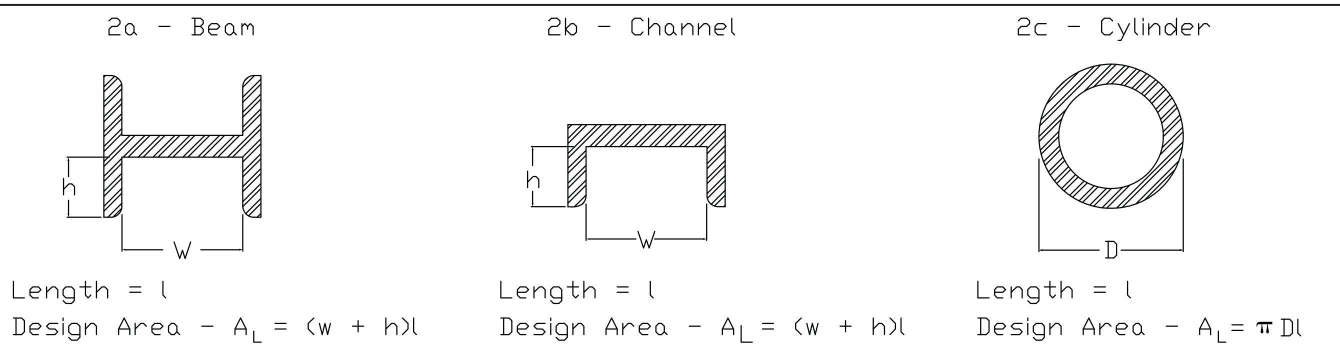

Figure 2: Design Area for Legs or Supports

6. **Determine the design area for legs or supports (A_e)**

   Concrete or fireproof steel supports generally require no protection. A short unprotected steel support up to about 1 ft (.3 m) generally requires no protection as long as it receives some rundown or splash. Longer unprotected supports require spray protection over the design area indicated in Figure 2.

7. **Determine water required for each leg or support (Q_l)**

   The water demand equals the design area times the required density. (Table A)

   $Q_{l1}=A_{l1}$(d)

8. **Determine the total amount of water required (Q_{tot})**

   The total amount of water required is the sum of the water for the shell, both ends, the appendages and the supports

   $Q_{tot} = Q_s+Q_{e1}+Q_e2+Q_a+Q_{l1}+Q_{l2}$ + ...

9. **Assume a nozzle pressure**

   Based upon known water supply conditions and/or assumed pump conditions and supply piping conditions, calculate pressure available to the tank. Note that in small diameter tanks the static pressure differential between the highest and lowest nozzle will not be very great.

10. **Select the most probable nozzle arrangement**

    A wide range of nozzle capacities and angles are available. The objective is to obtain adequate coverage and flow with a minimum number of nozzles with no overspray. Overspray will occur on the shell when a large angle nozzle is used on a small diameter tank. For nozzles located 2 ft (.6 m) from the tank surface, overspray will occur on tanks smaller than those listed:

Nozzle Angle Used	Minimum Tank Diameter	
	(ft)	(m)
30	1.4	.43
60	4.0	1.2
90	10.0	3.0
120	26.0	8.0
140	62.0	19.4

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Nozzles can be used on tanks smaller than listed by mounting closer to tank. Eliminate those nozzles which are suitable only for larger tanks.

Lay out the tank to scale and place nozzles in accordance with the following:

a. Nozzle direction

Nozzles protecting the tank shell should be pointed directly at the tank. Nozzles protecting the tank end should be pointed directly at the ends except in the case of flat surfaces. In the case of vertical flat surfaces, the nozzle should be pointed down approximately 10°.

Nozzles protecting supports should be located at the point where the tank protection will not cover the support and should point down the length of the support.

b. Distance of nozzle from surface

Unless tanks are located indoors, where there are no wind considerations, the face of the nozzle should be located no more than 2 ft (.6 m) from the surface of the tank. Small angle nozzles or window sprinklers protecting columns should be located close to surface and arranged to spray down the columns.

c. Number of nozzles

The distance between nozzles covering the shell and the end of the tank depends upon a number of factors. When the water spray hits the tank, there will be a certain amount of tangential movement on the tank surface. The amount of this tangential movement depends upon the pressure and the angle at which the spray strikes the surface. Also, it should be noted that the coverage area of the pattern on the shell increases around the circumference as opposed to the axis.

Similarly the density decreases. Generally the number of nozzles indicated in the below listed tables can be arranged to produce adequate coverage.

Tank End-See Table B

Tank Shell-See Table C

d. Overspray

If nozzles are located too far from the tank, or if the tank is of a too small diameter, there will be overspray, that is, water coming from the nozzle will not impinge on the tank and will be wasted. In order to avoid overspray, locate the nozzle closer to tank or use smaller angle.

e. Rundown considerations

Rundown will occur over the top half of the tank shell, over the top half of a convex spherical end and over an entire flat end. There will be little or no rundown over the bottom half of the shell, the bottom half of a convex end and a concave end. There also may be projections from the tank, which will “roof off” certain areas, which would normally be covered by rundown. These “roofed off” areas often require specific nozzle coverage. In horizontal tanks, the designer generally should protect the “roofed off” areas first and apply the remainder of the required water uniformly over the entire outside surface.

f. Support Nozzles

Concrete or adequately fireproofed steel supports require no protection. Short unprotected steel supports up to about 1 ft (.3 m) long generally require no protection as long as they receive some rundown or splash. Longer steel supports require protection. Water should be applied on the inside of the channel or H column at or above the point where rundown or splash becomes ineffective. Often a small angle spray nozzle or window sprinkler can be effective.

11. Find water required from each nozzle (Q nozzle)

For each design area divide the water required by the number of nozzles discharging into the design area.

Q nozzle = Q area/Number of nozzles

12. Select the proper nozzle capacity

Consult the K tables and determine the nozzle which will produce the discharge closest to the required at the assumed pressure.

13. Determine the required nozzle pressure

Consult the K tables and determine the pressure which will give the required flow for the nozzle selected.

14. Adjust the design

Hydraulically calculate the piping system to produce the required nozzle flow. For each individual design area required, water demand must be discharged into the design area. Discharge from each nozzle must be as uniform as possible. If total discharge of water into design area is below calculated requirements, add additional nozzles.

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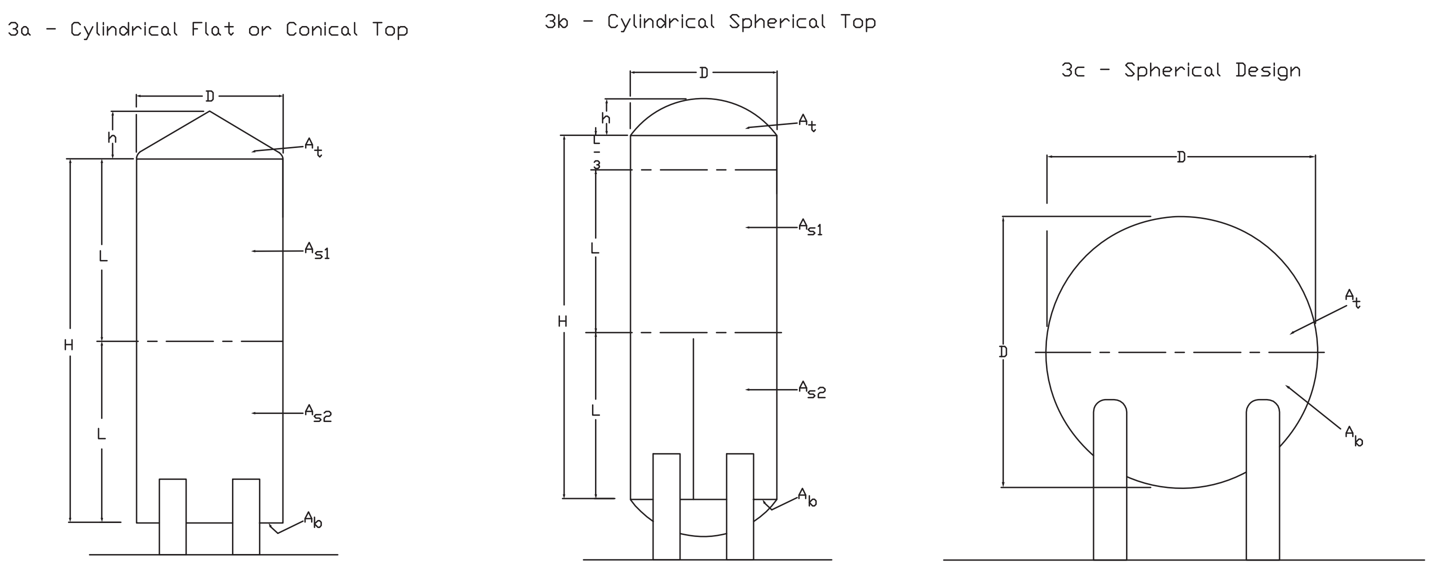
B. Water Spray Protection for Vertical Tanks

Make a detailed survey of the tank and its surroundings. Note diameter, length, height of top and bottom, locations and dimensions of any irregularities which may impede distribution of water such as ladders, manholes, piping connections and the like. Note size, location and material of supporting structure for tank. Note proximity of other hazard producing equipment. Note the presence of dikes, walls and barriers. Determine contents of tank and establish water density requirements for protection.

Tanks are generally protected using nozzles on the top and rings of nozzles around the shell at various levels. These nozzles must provide the proper quantity of water into a “Design Area”.

Tank Diameter	=	D
Top Height	=	h
Shell Height	=	H
Shell Density Required	=	d
Leg Density Required	=	l



3a:

$L = \frac{H}{N}$

N=# of Rings (whole number)
L Must not exceed 12' or 3.7m

Top & Bottom Design Ares:

$\text{Flat} = A_{tf} = A_{bf} \frac{\pi D^2}{4}$

$\text{Conical} = A_{tt} = A_{bc} \pi\left(\frac{D^2}{4} + h^2\right)$

Design Area for Each Ring =

$A_{s1}, A_{s2}, \text{etc.} = \pi DL$

3b:

$L = \frac{H}{N+1/3}$

N=# of Rings (whole number)
L Must not exceed 12' or 3.7m

$\text{Top Design Area} = A_t = \pi\left(\frac{D^2}{4} + h^2 + \frac{DL}{3}\right)$

$\text{Bottom Design Area} = A_b = \pi\left(\frac{D^2}{4} + h^2\right)$

Design Area for Each Ring =

$A_{s1}, A_{s2}, \text{etc.} = \pi DL$

3c:

Design Area for Top and Bottom =

$A_t = A_b = \frac{\pi D^2}{2}$

Figure 3: Design Area of Vertical Tanks

1. **Find the Height (L) and Number (N] of the shell design areas**
   a. **Smooth spherical top tanks (See Figure 3)**
   The total shell height is divided into two or more areas such that the height of the upper area is one-third the height of the lower areas. The height of the lower areas must not exceed 12 ft (3.7 m). (The upper area is included in the top design area - See Step 2-A). (Solve by trial and error)
   b. **Smooth, flat or conical top tanks (See Figure 3)**
   The shell is divided into areas of equal height not exceeding 12 ft (3.7 m). (Solve by trial and error)

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c. **Other considerations**

If there are appendages to the tank which "roof off" areas so that there is no coverage either by rundown or tangential flow, then these areas may constitute additional design areas. When a flange is encountered on the circumference of a tank, the design area begins immediately under the flange and extends downward until the next flange or the bottom. Often the design area of very tall tanks is limited to the lower 30 ft (9.2 m) from the ground because the danger of fire exposure above this level is small. In this case top protection may not be required. In no case should the height of any shell design area exceed 12 ft (3.7 m).

2. **Find the design area of the top (A_t)**

a. **Spherical top tanks (See Figure 3)**

The design area equals the area of the top plus the shell area between the upper tank edge and the upper shell design area. (See Step 1-A).

b. **Flat or conical top tanks (See Figure 3)**

The design area equals the area of the top.

3. **Find the total water required for the top (Q_t)**

The total water required for the top equals the design area for the top times the required density (Table A)

$Q_t = A_t$ (d)

4. **Find the design area for the shell rings (A_s)**

See Figure 3. For smooth tanks the design area will be the same for each ring. For tanks with appendages or obstructions, design areas may differ.

$A_s = \pi DL$

5. **Find the water required for the shell rings (Q_s)**

Water required equals design area times required density (Table A) for each ring. In the case of smooth tanks, water demand will be the same for each ring.

$Q_{s1} = A_{s1}$(d)

6. **Find the design area for the bottom (A_b)**

See Figure 3.

7. **Find water demand for bottom (Q_b)**

Water demand equals design area of bottom times required density

Q_b=A_b(d)

8. **Find water required for appendages (Q_a)**

If there are appendages to the tank which increase the basic area of coverage, estimate this area and multiply by the required density (Table A) to obtain the additional water required.

Q_{a1}=A_{al}(d)

$Q_a = Q_{al}+Q_{a2}+$. .

9. **Find the design area for legs or supports (A_l)**

Concrete or fireproof steel supports generally require no protection. A short, unprotected steel leg up to about 1 ft (.3 m) generally requires no protection as long as it receives some rundown or splash. Longer unprotected legs require spray protection over the design area indicated in Figure 2.

10. **Find the water required for each leg (Q_l)**

The water required for each leg equals the design area of the leg times the required density

$Q_{l1} = A_{l1}(d_l)$

$Q_{l2} = A_{l2}(d_l)$

11. **Find total water required (Q_{tot})**

Total water required equals the sum of the water demand for the top, bottom, all rings, all legs, and all appendages.

12. **Determine probable nozzle pressure**

Based upon known water supply conditions and/or assumed pump conditions and supply piping conditions and water demand, calculate pressure available to the various areas of the tank. Note that in high tanks there will be a significant static pressure difference between the top and bottom nozzles.

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13. Select the most probable nozzle arrangement

A wide range of nozzle capacities and angles are available. The objective is to obtain adequate coverage and flow with a minimum number of nozzles with no overspray. Overspray will occur on the shell when a large angle nozzle is used on a small diameter tank. For nozzles located 2 ft (.6 m) from the tank, surface, overspray will occur on tanks smaller than those listed:

Nozzles can be used on tanks smaller than listed by moving nozzle closer to tank. Eliminate those nozzles which are suitable only for larger tanks.

Lay out the tank to scale and place nozzles in accordance with the following:

Nozzle Angle Used	Minimum Tank Diameter	
	(ft)	(m)
30	1.4	.43
60	4.0	1.2
90	10.0	3.0
120	26.0	8.0
140	62.0	19.4

a. Distance of nozzle from surface

Unless tanks are located indoors where there are no wind considerations, the surface of the nozzle should be located no more than 2 ft (.6 m) from the surface of the tank. Small angle nozzles or window sprinklers protecting columns should be located close to surface and arranged to spray down the columns.

b. Distance between nozzles

The distance between nozzles covering the shell, the top and the bottom of the tank depends upon a number of factors. When the water spray hits the tank, there will be a certain amount of tangential movement on the tank surface. The amount of this tangential movement depends upon the pressure and the angle at which the spray strikes the surface.

c. Location of top nozzles

In designing tank top protection, a balance must be achieved between a few large nozzles delivering a large quantity of water and many small nozzles delivering a smaller quantity: Because of the rundown and tangential movement of the water, it is not necessary to eliminate all theoretical dry spots. However, these should be kept to a minimum as stated above. On large diameter tanks it may be possible to use nozzles of increasing nozzle angle moving from the center line of the tank to the outside edge. With flat and conical tanks, particular attention should be paid to the top edge of the tank since there could well be no rundown. The top edge of a flat or conical top tank should be protected with a ring of spray nozzles. Generally, the number of nozzles indicated in Table A can be arranged to produce adequate coverage. Different angle nozzles may be used to achieve coverage.

d. Location of shell nozzles

The shell rings should be located so that the spray will impinge at the top boundary of each shell design area. It may be advantageous to stagger the nozzles in each successive ring. Generally, the number of nozzles indicated in Table B can be arranged to produce adequate coverage.

e. Location of bottom nozzles

If the tank is mounted on the ground, no bottom protection is required. If the tank is skirted with the skirt extending to the ground and generally enclosing the tank bottom, sufficient protection is usually provided by a conventional sprinkler or a pendent sprinkler in the upright position delivering .1 gpm/sq ft (4.9 mm/min) over the design area. If the bottom is essentially open, however, it should be protected using somewhat the same system as the top. The difference is that no gravity run-off can be expected. If the tank contains a liquid, the heat absorbing capacity of the bottom will be considerably greater than that of the top. Generally the number of nozzles indicated in Table A can be arranged to produce adequate coverage.

f. Location of leg nozzles

Concrete or adequately fireproofed steel legs require no protection. A short unprotected steel leg up to about 1 ft (.3 m) long generally requires no protection as long as it receives some rundown or splash. Water should be applied on the inside of the channel or H column or as uniformly as possible around the circular column at or above the point where rundown or splash becomes ineffective. Use a small angle spray nozzle or window sprinkler. It may be possible to place a conventional sprinkler or a pendent sprinkler in the upright position as high as possible inside a hollow circular column. In this case use .1 gpm/sq. ft (5 mm/min.) over the leg design area.

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g. **Rundown considerations**

Rundown will occur over the top of a spherical top tank and over the vertical shell. There will be little or no rundown over the bottom. There also may be projections from the tank which will “roof off” certain areas which would normally be covered by rundown. These “roofed off” areas often require specific nozzle coverage. In vertical tanks “roofed off” areas constitute separate design areas and require nozzles which protect directly under the roof.

h. **Nozzle direction**

Nozzles protecting the tank top and bottom should be pointed directly at the tank. Nozzles protecting the tank shell should be pointed down 10”. Nozzles protecting legs should point down the length of the leg.

i. **Overspray**

If nozzles are located too far from the tank shell, or if the tank is of too small diameter there will be overspray, that is, water coming from the nozzle will not impinge on the tank and will be wasted. In order to avoid overspray, locate the nozzle closer to tank or use smaller angle.

14. **Find water required from each nozzle (Q nozzle)**

For each design area, divide the water required by the number of nozzles discharging into the design area.

Q nozzle = Q area/Number of nozzles

15. **Select the proper nozzle capacity**

Consult the K tables and determine the nozzle which will produce the discharge closest to the required at the assumed pressure.

16. **Determine the required nozzle pressure**

Consult the K tables and determine the pressure which will give the required flow for the nozzle selected.

17. **Adjust the design**

Hydraulically calculate the piping system to produce the required nozzle flow. For each individual design area required water demand must be discharged into the design area. Discharge from each nozzle must be as uniform as possible. If total discharge of water into design area is below calculated requirements, add additional nozzles.

C. Water Spray Protection for Transformers

Transformers come in many sizes and configurations. Before attempting to design the protection, it is essential to have the following information:

- Length
- Width
- Height of transformer
- Location and height of bushings
- Height and location of lightning, if any
- Size and location of oil expansion tank, if any
- Location of any switch boxes and any equipment that may interfere with water distribution
- Size of transformer, i.e., high and low voltage
- Phase of transformer, either single or three phase
- Direction of incoming high voltage and low voltage wire or bus bars to the transformer
- Setting of transformer, whether surrounded by concrete or crushed rock
- Elevation of bottom of transformer above grade
- Location of radiators and distance between radiators. When space between radiators exceeds 12 in (.3 m) it must be covered
- Size and location of, if any
- Estimate of possible effects of wind, and size and location of any wind protection.

If the transformer is not existing, it will be necessary to obtain a manufacturer’s dimensional drawing of the proposed transformer.

The drawings for the transformer should be made to a large scale, e.g., 3/8” to 1’-0” or 1/2” to 1’-0” (1/30 or 1/25), and there should be three views: top, side and bottom. If more than one ring is necessary an additional plan view may be necessary.

In addition to the transformer, a detail plan should be drawn to show the general view, such as fire walls between transformers, water supply location, valve location, electrical poles and any other obstructions that may interfere with the sprinkler piping.

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Transformers present particular design problems for water spray protection, primarily because of their irregular shape and the necessary clearances to be provided from high voltage wiring. Generally speaking, there is much more interference with the water flow on the surface of the transformer than there is on a tank. For this reason protection systems for transformers generally involve a large number of small capacity nozzles. Often it will be necessary to put more water on the transformer than is actually required simply to achieve coverage. It is most useful to use a large scale drawing of the transformer and project theoretical nozzle discharge patterns on it to get an idea of the type of coverage to be expected.

Transformers are generally protected using rings of nozzles around the transformer with the top ring being located near the top of the transformer and subsequent rings being located every 12 ft (3.6 m) from the top to the bottom of the transformer or beneath each continuous obstruction. Nozzles are also employed to spray water on the bottom of the transformer in the event it is more than 12 in (.3 m) above the ground. In addition, if the ground is covered with solid material such as concrete or asphalt, nozzles must be located to wash flammable liquid away from the transformer. Nozzles must be located so as to spray the proper amount of water into the “design area”.

To determine the various design areas of the transformer, consider that the elements of the transformer are a collection of simple geometric figures (cylinders, cubes, etc.). Make a plan and elevation view of the simplified transformer concept. If the transformer is located 12 in (.3 m) or more above grade, also make a bottom view. Neglect small protrusions or increase size of figure slightly to compensate. Radiators should be considered as a single unit unless there is more than a 12 in (.3 m) space between them. In this case, they must be considered as multiple units.

Required Density = d

Required Grade Density = d_g

1. **Determine the design area for the top and sides of the transformer (A_{ts})**

   Referring to the simplified view of the transformer, the design area is the total exposed outside area of the simplified transformer concept less the area of the bottom.

2. **Determine the water required for the transformer top and sides (Q_{ts})**

   Water required equals the design area of the top and sides times the required density (Table A)

   $Q_{ts} = A_{ts}(d)$

3. **Determine the design area of the bottom (A_b)**

   The design area of the bottom is the area of the bottom of the transformer which is 12 in (.3 m) or more above grade.

4. **Determine the water required for the bottom (Q_b)**

   Water required for the bottom equals the bottom design area times the required density (Table A)

   $Q_b = A_b(d)$

5. **Determine the design area for the grade (if any) (A_g)**

   The design area for the grade is the area which appears on the simplified bottom view of the transformer plus an area extending 3 ft (.9 m) on all sides of the view. Grade protection is required only when a nonabsorbing surface such as concrete or asphalt paving is employed. Grade surfaces such as gravel or crushed rock do not normally require nozzle protection. Grade protection is not required directly under the transformer unless it is located at least 12 in (.3 m) above grade.

6. **Find the water required for the grade (Q_g)**

   Water required for the grade is equal to design area for the grade times the required density (Table A)

   $(Q_g) = A_g(d_g)$

7. **Find the total water required for the entire transformer (Q_{tot})**

   Total water required equals the sum of the water demand for the top and sides, the bottom and the grade.

   $Q_{tot} = Q_{ts}+Q_b+Q_g$

8. **Assume a nozzle pressure**

   Nozzle pressures under 30 psi (2 bar) generally do not produce adequate water throw. Based upon known water supply conditions and/or assumed pump conditions and supply piping conditions, calculate the pressure available at the transformer. Note that in high assemblies there will be a significant static pressure difference between the top and the bottom nozzles.

9. **Select the probable nozzle arrangement**

   A wide range of nozzle capacities and angles are available. The objective is to obtain adequate coverage and flow with a minimum number of nozzles with no overspray. Lay out the transformer to scale and place nozzles in accordance with the following:

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a. **Minimum electrical clearances**

One of the most important considerations in locating the piping around the transformer is the distance of the pipe from the electrical components or energized parts, such as bare cables, bus ducts, and the low voltage and high voltage bushings. The clearance between any portion of the water spray equipment and the unenclosed or uninsulated electrical components, at other than ground potential, should not be less than given in the following table. These clearances are for the altitude of 3,300 ft (1,000 m) or less. The distance should be increased at the rate of one percent for each 330 ft (100 m) increase of altitude above 3,300 ft (1,000 m).

Nominal Line Voltage (kV)	Nominal voltage to Ground (kV)	Design BIL (kV)	Minumum Clearance	
			(Inches)	(mm)
To 15	To 9	110	7	178
23	13	150	10	254
34.5	20	200	13	330
46	27	250	17	432
69	40	350	25	635
115	66	550	37	939
138	80	650	44	1117
161	93	750	52	1320
196-230	114-132	900	63	1600
		1050	76	1930
287-380	166-220	1175	87	2209
		1300	98	2489
		1425	109	2768
		1500	120	3048
500	290	1675	131	3327
		1800	142	3606
500-700	290-400	1925	153	3886
		2100	168	4267
		2300	184	4673

There are design variations in the clearance required at higher voltages as shown in the table where a range of voltages is indicated opposite the various BIL test values in the high voltage portion of the table. Up to system voltages of 161 kv, the design BIL kv and corresponding minimum clearances, phase to ground, have been established through long usage. At the higher voltages, the relationship between design BIL kv and the various system voltages has not been established in practice and is dependent upon several variables, so that the required clearance to ground should be based upon the design BIL used, rather than on the nominal line voltage or voltage to ground. Check latest rules of authority having jurisdiction.

b. **Distance of nozzle from surface**

Unless the transformers are located indoors where there are no wind conditions, the surface of the nozzle should be located no more than 2 ft (.6 m) from the vertical surface to the transformer.

c. **Coverage for transformer top**

It is generally not satisfactory to run piping directly across the top of a transformer; therefore, most of the top coverage is obtained by spray nozzles throwing in from the outside. It is, however, often acceptable to run a line between the transformer body and radiators above the transformer. Necessary electrical clearances must be maintained. Generally 30, 60 or 90 degree spray nozzles are installed in this top loop with the nozzles located approximately 1 to 2 ft (.3 to .6 m) above the transformer top and pointed so that the water will impinge upon the transformer. Water should not be directed at the high voltage bushings. The above nozzles have a maximum effective horizontal throw of 6 ft at 30 psi (1.8 m at 2.0 bar). It may be desirable to locate nozzles at the corner to achieve increased coverage.

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d. Horizontal distance between nozzles

The horizontal distance between nozzles should be such that their patterns intersect along the horizontal line. For nozzles located 2 ft (.6 m) from the surface, the following horizontal distances should be used:

30 degrees	13 inches	.33 m
60 degrees	28 inches	.77 m
90 degrees	48 inches	1.22 m

e. Two sets of nozzles from the same ring

Because, generally speaking, small capacity nozzles will be used, it will often be possible to extend the nozzles above and below the loop by means of a nipple. Nipples longer than 2 ft (.6 m) generally require additional support.

f. Bottom nozzles

If the transformer or radiator is located more than 12 in (.3 m) off the ground, it is necessary to protect the bottom. This is generally done with wide angle spray nozzles pointing upward.

g. Between radiator protection

If the radiators are more than 12 in (.3 m) apart, nozzles must be arranged to spray into this space. A nozzle angle should be selected so that the cone diameter at the entrance is equal to or slightly larger than the space between the radiators.

h. Rundown considerations

Rundown will occur on smooth, vertical surfaces. Projections from the surfaces, however, will “roof off” certain areas which would normally be covered by rundown. These “roofed off” areas usually require specific nozzle coverage.

i. Vertical distance between nozzles

For unobstructed vertical surfaces with no “roofed off” area and unobstructed rundown, a maximum vertical distance between nozzles is 12 feet (3.6m). In practice, however, unobstructed areas of this size are rarely encountered.

j. Nozzle direction

Nozzles protecting the transformer top should be aimed slightly down so that all of the water impinges upon the transformer with either all on the top or some on top and some on vertical sides. Nozzles protecting vertical sides and bottom should point directly at the surface to be protected. Nozzles covering irregular areas should be located for best coverage generally spraying into corners. Overspray must be avoided. Nozzles covering space between radiators should be arranged to spray directly into the open space.

k. Overspray

If nozzles are located too far from the surface, or if the angle is too large, there will be overspray, that is, water coming from the nozzle will not impinge on the transformer and will be wasted. In order to avoid overspray, locate nozzle closer to the transformer or use a smaller angle. Always observe electrical clearances.

l. Grade protection

If the transformer is located 12 in (.3 m) or more above a non-absorbing surface such as asphalt or concrete, nozzles must be located under the transformer pointing down and outside the transformer covering an area 3 ft (.9 m) around the transformer pointing generally outward. The purpose of the grade protection nozzles is to wash flammable liquid away from the transformer (consider grade slope). It is often possible to feed both bottom protection nozzles and grade protection nozzles from the same pipe. In some cases (usually small transformers) it may be acceptable to use an open pendent sprinkler in the upright position. No grade protection is required when readily absorbs the flammable liquid.

m. Wind

Often, because of transformer configuration and electrical clearances, it will not be possible to locate spray nozzles close to the areas that they are expected to protect. When the installation is outside, the effect of the wind must be seriously considered. Small spray nozzles operating at high pressure produce small drops that are particularly susceptible to being blown away by the wind. It may be necessary to increase water density in questionable conditions.

10. Find the total amount of water delivered into each design area by the probable nozzle arrangement

Using the assumed nozzle pressure and the smallest available capacity nozzles, determine the amount of water discharged by each nozzle and the total amount of water in each design area.

11. Adjust the design

Compare the water delivered to the design area by the probable nozzle arrangement with that required. Increase or reduce nozzle sizes and pressures as necessary. (Note that because of the irregularities of transformers, many nozzles are required

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to provide coverage. In addition, because of electrical clearances, some of these nozzles are required to throw at maximum distances. For this reason it may not be possible to reduce the number of nozzles or the operating pressure far enough to approach the minimum. In practice it may be possible to reduce the required pressure below 30 psi (2 bar); however, this should not be done in the design stage.)

III. TABLES AND WORKSHEETS

TABLE A
Commonly Accepted Densities

	GPM/sq ft	mm/min.
Transformers		
Top & Sides	.25	10.18
Bottom	.25	10.18
Grade	.15	6.11
Pipe Racks		
Pipe Surface	.10	4.07
Maximum over plan area projected on grade	.5	20.35
Legs	.10	4.07
Tanks		
Shells	.25	10.18
Supports	.25	10.18

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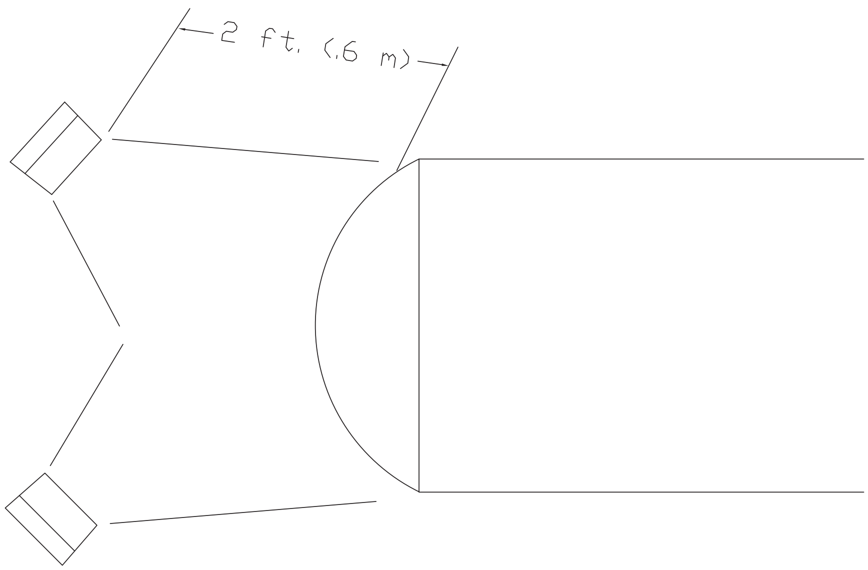
TABLE B

Water Spray Protection
Vertical Tanks: Top and Bottom
Horizontal Tanks: Ends

Commonly accepted maximum tank diameters for effective coverage by generally uniformally spaced spray nozzles located 2 ft. (.6 m) from the surface of vertical or horizontal tank ends of Flat, Concaved or Convex form.



Number of Nozzles Used	Angle Between Nozzles	MAXIMUM TANK DIAMETER FOR VARIOUS ANGLE NOZZLES									
		30°		60°		90°		120°		140°	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
1	--	0.8*	0.24	1.5*	0.46	2.0*	0.61	*	*	*	*
2	180	1.5*	0.46	3.0*	0.92	5.0*	1.5	*	*	*	*
3	120	2.3	0.70	4.6	1.4	8.0*	2.4	*	*	*	*
4	90	2.8	0.85	5.6	1.7	10.5	3.2	17*	5.2	*	*
5	72	3.4	1.0	6.8	2.1	12.5	3.8	20*	6.1	*	*
6	60	4.0	1.2	8.0	2.4	14.8	4.5	24*	7.3	*	*
7	53.5	4.5	1.4	9.2	2.8	16.7	5.1	26.7	8.1	*	*
8	45	5.2	1.6	10.4	3.2	19.5	5.9	30.8	9.3	*	*
9	40	5.8	1.8	11.7	3.6	21.9	6.6	35.1	10.6	*	*
10	36	6.5	2.0	12.9	3.9	24.5	7.4	38.8	11.7	*	*
11	37.7	7.1	2.2	14.2	4.3	27.7	8.2	42.6	12.9	*	*
12	30	7.7	2.4	15.5	4.7	29.0	8.9	45.0	13.6	58.0*	17.6

*Indicates Overspray at 2 ft (0.6 m)

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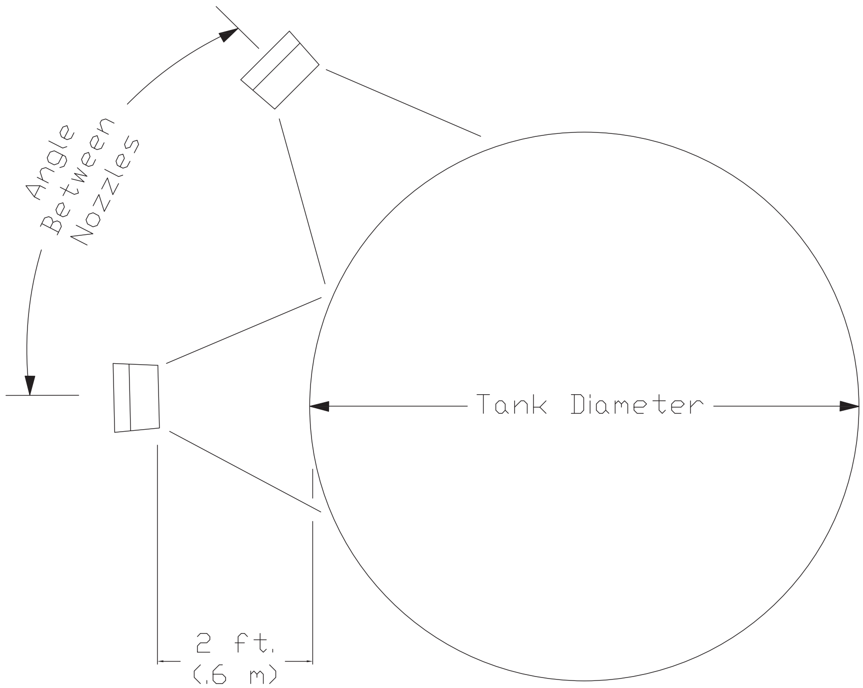
TABLE C

Water Spray Protection
Vertical and Horizontal Tank Shells

Commonly accepted maximum tank diameters for effective coverage by equal radially spaced spray nozzles located 2 ft. (.6 m) from the surface of vertical or horizontal tanks.



Number of Nozzles Used	Angle Between Nozzles	MAXIMUM TANK DIAMETER FOR VARIOUS ANGLE NOZZLES									
		30°		60°		90°		120°		140°	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
1	--	0.8*	0.24	1.5*	0.46	2.0*	0.61	*	*	*	*
2	180	1.5*	0.46	3.0*	0.92	5.0*	1.5	*	*	*	*
3	120	2.3	0.70	4.6	1.4	8.0*	2.4	*	*	*	*
4	90	2.8	0.85	5.6	1.7	10.5	3.2	17*	5.2	*	*
5	72	3.4	1.0	6.8	2.1	12.5	3.8	20*	6.1	*	*
6	60	4.0	1.2	8.0	2.4	14.8	4.5	24*	7.3	*	*
7	53.5	4.5	1.4	9.2	2.8	16.7	5.1	26.7	8.1	*	*
8	45	5.2	1.6	10.4	3.2	19.5	5.9	30.8	9.3	*	*
9	40	5.8	1.8	11.7	3.6	21.9	6.6	35.1	10.6	*	*
10	36	6.5	2.0	12.9	3.9	24.5	7.4	38.8	11.7	*	*
11	37.7	7.1	2.2	14.2	4.3	27.7	8.2	42.6	12.9	*	*
12	30	7.7	2.4	15.5	4.7	29.0	8.9	45.0	13.6	58.0*	17.6

*Indicates Overspray at 2 ft (0.6 m)

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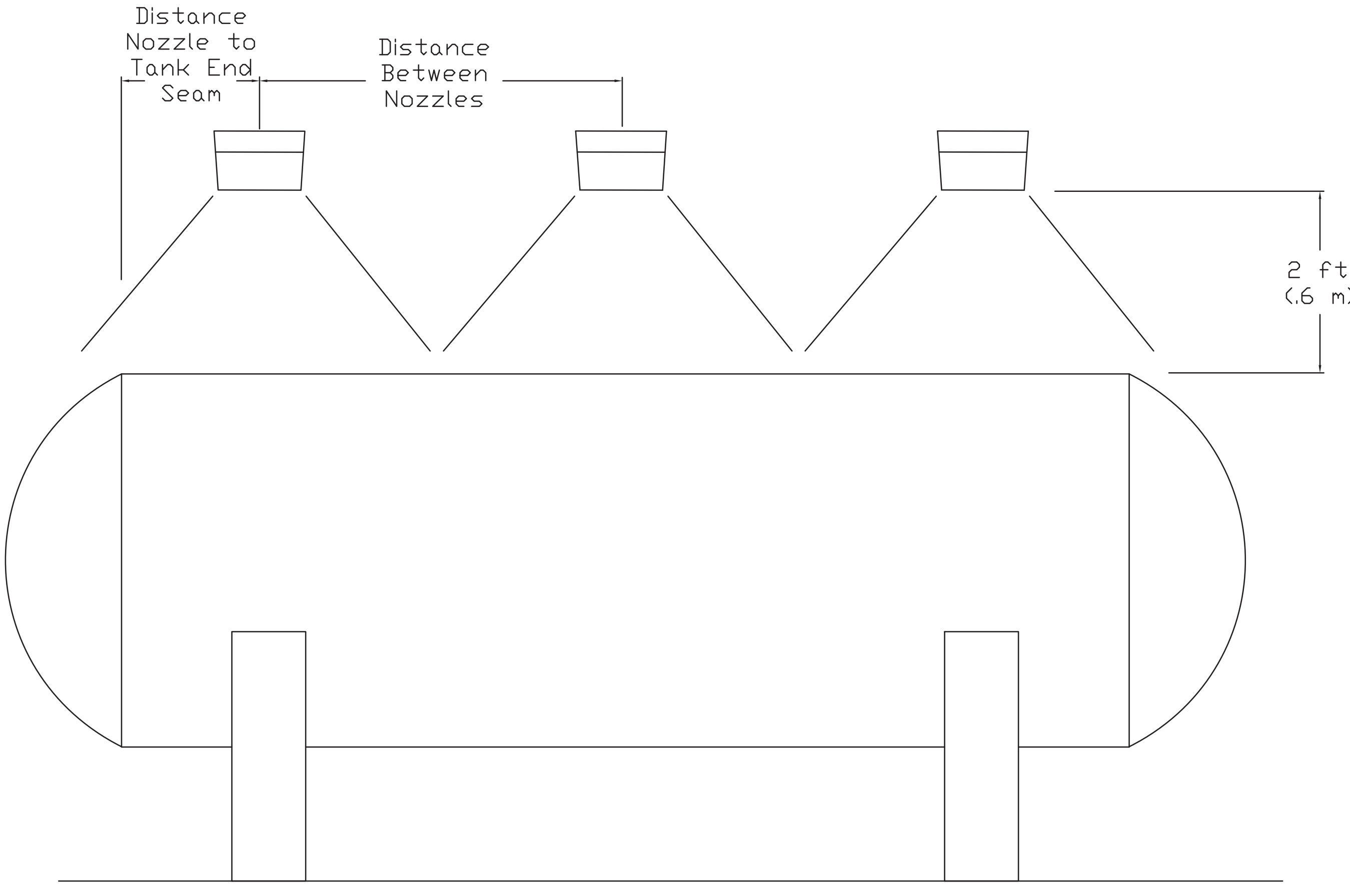

LOCATION OF TANK RINGS - HORIZONTAL TANKS ONLY				
Nozzle Angle	**Max. Distance Nozzle to End Seam of Tank**		**Maximum Distance Between Nozzles**	
	(ft)	**(m)**	**(ft)**	**(m)**
30	1	0.3	2	0.6
60	2	.06	4	1.2
90	3.5	1.1	7	2.1
120	6	1.8	12	3.7
140	7.5	2.3	15	4.6

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IV -- WORK SHEETS

WORK SHEET A

WATER SPRAY PROTECTION FOR HORIZONTAL TANKS

Tank Diameter = D = ________ Tank Shell Length = L = ________

Tank End Height = h = ________ Density Required = d = ________

STEP	INSTRUCTIONS	CALCULATIONS	
1 Find Shell Area	Shell Area = $A_s = \pi DL$	A_s =	
2 Find Water Reqd for Shell	Q_s - A_s x Density = $A_s(d)$	Q_s =	
3 Find Area of Ends	Flat End $A_e = \frac{\pi D^2}{4}$ Spherical End $A_e = \pi \left(\frac{D^2}{4} = h^2 \right)$ Hemispherical End $A_e = \frac{\pi D^2}{2}$	A_{e1} =	A_{e2} =
4 Find Water Required for Ends	$Q_{e1} = A_{e1}$ x Density = $A_{e1}(d)$ $Q_{e2} = A_{e2}$ x Density = $A_{e2}(d)$	Q_{e1} =	A_{e1} =
5 Determine Water Required For Appendages	$Q_{a1} = A_{a1}$ x Density = $A_{a1}(d)$ $Q_a = Q_{a1} + Q_{a2}$- - -	Q_a =	
6 Determine Area of Legs and Supports	A_{l1} = See Figure 2		
7 Determine Water Required For Each Leg or Support	$Q_{l1} = A_{l1}$ x Density = $A_{l1}(d)$	Q_{l1} = Q_{l2} =	Q_{l3} =
8 Determine Total Water Required	$Q_{tot} = Q_s + Q_{e1} + Q_{e2} + Q_a$ $+ Q_{l1} + Q_{l2}$ - - - -	Q_{tot} =	

STEP	INSTRUCTIONS	SHELL	END 1	END 2	APPENDAGES	SUPPORTS
9 Assume Nozzle Pressure	Calculate Based on Water Supply					
10 Select Most Probable Nozzle Arrangement	Lay Out to Scale -- List Number and Angle of Nozzles Chosen					
11 Find Water Reqd. from Each Nozzle	Q Nozzle = $\frac{\text{Q (area)}}{\text{Number of Nozzles}}$					
12 Select the Proper Nozzle Capacity	Consult K Tables -- List Nozzle Size					
13 Determine Reqd. Nozzle Pressure	Consult K Tables -- List Pressure Reqd. For Reqd. Flow					
14 Adjust the Design	Calculate System and Adjust as Necessary					

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WORK SHEET B, Page 1

WATER SPRAY PROTECTION FOR VERTICAL TANKS

Top Diameter = D = ____________ Shell Height = H = ____________

Top Height = h = ____________ Density Required = d = ____________

Type ______________________________

STEP	INSTRUCTIONS	CALCULATIONS	
1. Find Height L and Number N of Shell Design Areas	For Spherical Top $L = \frac{H}{N + 1/3}$ For Flat & Conical Top $L = \frac{H}{N}$ L must not exceed 12 ft. or 3.7 m Solve by Trial & Error	L =	N =
2. Find Design Area of Top Portion	Flat Top $A_t = \frac{\pi D^2}{4}$ Cylindrical Spherical $A_t = \pi \left(\frac{D^2 + h^2}{4} + \frac{DL}{3} \right)$ Conical Top - $A_t = \frac{\pi D}{2} \left(\frac{D^2 + h^2}{4} \right)^{1/2}$ Spherical $A_t = \frac{\pi D^2}{2}$	A_t =	
3. Find Water Demand for Top Portion	$Q_t = A_t$ x Density $= A_t \times d$	Q_t =	
4. Find Design Area of Shell Rings	$A_s - \pi D L$	A_{s1} =	A_{s2} =
5. Find Water Demand for Shell Rings	$Q_{s1} = A_{s1}$ x Density $Q_{s2} = A_{s2}$ x Density	Q_{s1} =	Q_{s2} =
6. Find Design Area for Bottom	Flat Bottom $A_b = \pi \frac{D^2}{4}$ Spherical Bottom $A_b = \pi \left(\frac{D^2}{4} + h^2 \right)$ Conical Bottom $A_b = \frac{\pi D}{2} \left(\frac{D^2 + h^2}{4} \right)^{1/2}$ Hemispherical Bottom $A_b = \frac{\pi D^2}{2}$	A_b =	

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WORK SHEET B, Page 2

WATER SPRAY PROTECTION FOR VERTICAL TANKS

Top Diameter = D = ________ Shell Height = H = ________

Top Height = h = ________ Density Required = d = ________

Type ________

STEP	INSTRUCTIONS	CALCULATIONS				
7 Find Water Demand for Bottom	$Q_b = A_b$ x Density $= A_b$ x d	Q_b =				
8 Find Water Required for Appendages	$Q_{a1} = A_{a1}$ x d $Q_a = Q_a + Q_{a2}$ ----	Q_a =				
9 Find Design Area of Legs	A_l = See Fig. 4	A_l =				
10 Find Water Demand for Each Leg	$Q_{l1} = A_{l1}$ x d_l	Q_{l1}				
11 Find Total Water Demand	$Q_{tot} = Q_t + Q_{s1} + Q_{s2}$ ---- $+ Q_b + Q_{l1}$ Q_{l2} + - - - - + Q_a	Q_{tot}				
		TOP	**RING**	**RING**	**BOTTOM**	**LEG**
12 Determine Probable Nozzle Pressure	Hydraulically Calculate to Each Group of Nozzles					
13 Select the Most Probable Nozzle Arrangement	Layout to Scale - List Number and Angle of Nozzles Chosen					
14 Find Water Reqd. From Each Nozzle	Q Nozzle = $\frac{\text{Q (Area)}}{\text{Number of Nozzles}}$					
15 Select the Proper Nozzle Capacity	Consult K Tables - List Nozzle Size					
16 Determine The Reqd. Nozzle Pressure	Consult K Tables - List Press. Reqd. for Reqd. Flow					
17 Adjust the Design	Calculate and Adjust as Necessary					

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WORK SHEET C

WATER SPRAY PROTECTION FOR TRANSFORMERS

Nominal Line Voltage ______________ Density Reqd. - Transformer ______________

Nominal Voltage to Ground __________ Grade ______________

Design BIL ______________

STEP	INSTRUCTIONS	CALCULATIONS		
1 Find Design Area of Top & Sides	A_{ts} = Total Outside Surface Area Less Area of Plan View of Bottom	A_{ts} =		
2 Find Water Demand for Top & Sides	Q_{ts} - A_{ts} x Density	Q_{ts} =		
3 Find Design Area of Bottom	A_b = Area of Plan View of Bottom (If Transformer is less than 12" (3.6 m) Above Grade, A_b = O)	A_b =		
4 Find Water Demand for Bottom	Q_b = A_b x Density (If Transformer is less than 12" (3.6 m) Above Grade, A_b = O)	Q_b =		
5 Find Design Area for Grade	A_g - A_B + A Strip 3 ft. (.9 m) Completely Around Ab (If the Grade Surface is Non Absorbing A_g = O)	A_g =		
6 Find Water Demand for Grade	Q_g - A_g x Density (If Grade Surface is Non Absorbing Q_g = O)	Q_g =		
7 Find Total Water Demand	Q_{tot} = Q_{ts} + Q_b + Q_g	Q_{tot}		
		Top & Sides	**Bottom**	**Grade**
8 Assume Nozzle Pressure	Calculate Based on Water Supply			
9 Select the Probable Nozzle Arrangement	Layout to Scale - List Number and Angle of Nozzles Chosen			
10 Find the Total Water to Each Design Area	Consult K Tables - Find Water Delivered by Each Nozzle at Assumed Pressure - Total All Water			
11 Adjust the Design	Compare delivered Water with Required Water and Adjust as Necessary			

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