DDS 522-1
SHIPBOARD SPRINKLER SYSTEMS

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC 20362-5101

DESIGN DATA SHEET
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NOVEMBER 18, 1987

DDS 522-1
DESIGN DATA SHEET - SHIPBOARD SPRINKLER SYSTEMS

Supersedes DDS 4803-1, Dated 5 November 1957

522-1-a. References

(a) General Specifications, section 521
(b) Design Data Sheet DDS 505-1 Friction pressure drop in piping.
(c) Military Specification MIL-S-24660 (SH) - Heads, Magazine Sprinkler Systems.
(d) NFPA Volumes 13 & 15.

522-1-b. Introduction

The purpose for calculating a sprinkler system is to insure that the required quantity of water will be properly distributed within a ship's magazine or similar compartment in the event of a casualty. The required quantity of water is based on a sprinkling rate developed specifically for shipboard sprinkler systems. Sprinkling in excess of the required amount is undesirable because this additional demand on the firemain system utilizes water required for other vital services.

The calculations consist of determining the quantity of water required to meet the sprinkling rate, determining the number of sprinkler heads required, laying out the system and locating the sprinkler heads, and sizing the pipe in accordance with an appropriate pipe schedule. A friction loss study of the system must be made to insure that a reasonably uniform pressure exists throughout the system and that the pressure required at the source is within the required limits. In some cases it may be necessary to adjust the friction losses within the sprinkler piping system by resizing the pipe.

The friction loss in the pipe is generally dependent upon the pipe interior roughness and fluid velocity, and may vary over quite a wide range of velocities due to corrosion and deposits. Variations can also be found in the discharge from nozzles of apparently the same size and design, and may differ by as much as eight percent due to inconsistancies in the manufacturing process, fluid viscosity and temperature. Consideration of these variations shows that extreme accurracy cannot be obtained in the computations. However, by applying the procedures outlined in the design data sheet with due regard to internal pipe diameters and the relative roughness of pipe materials, the results should be close enough for practical purposes.

522-1-c. Symbols and Abbreviations

The following are common symbols and abbreviations that are used in this design data sheet. Additional uses and further definitions are detailed throughout the text.

D = inside pipe diameter, feet

f = friction factor

g = acceleration constant of gravity, 32.2 feet per second per second

gpm = gallons per minute

K_f = resistance coefficient

K_n = nozzle discharge coefficient

L = length of pipe, feet

psi = pounds per square inch

P = total pressure, psi

P_f = pressure loss due to friction, psi

P_n = normal pressure or discharge pressure at a point, psi

P_t = total pressure at one point as used in calculations, psi

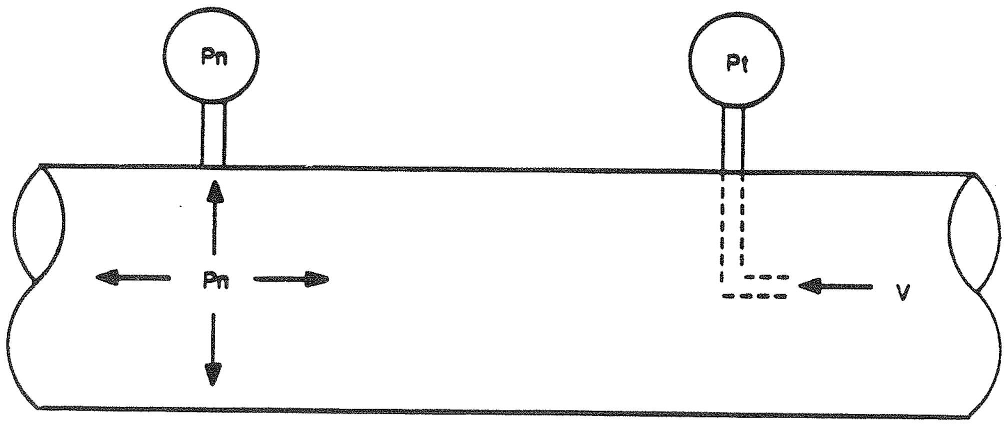
P_v = velocity pressure, psi

V = mean velocity of water in pipe, feet per second

q = flow increment to be added at a specific location, gpm

Q = Summation of flow at a specific location, gpm

522-1-d. General Design Principles



1. In the diagram above P_n equals P_t - P_v; that is, the normal pressure is equal to the total pressure minus the velocity pressure at that point. If the pressure gauge indicating P_n, is replaced by an open nozzle, the pressure available to cause flow from the nozzle is only the normal pressure, P_n. The velocity pressure has no effect. However, at the end of the pipe both the static and the velocity pressures can act; in other words, the total pressure acts on a nozzle at the end of the pipe. These pressure considerations lead to the following rules for calculating pressures and flows in sprinkler systems:

Rule I - At any sprinkler head along a pipe, except the last, only the static pressure can act on the nozzle. At the last sprinkler head of each branch the total pressure can act. This is true whether the last open sprinkler head is at the end of the pipe or not.

Rule II - At the next to last sprinkler head in a branch, the pressure acting to cause flow, the discharge pressure, is equal to the total pressure minus the velocity pressure on the downstream side.

Rule III - At any sprinkler head along a branch line except the last two, the discharge pressure is equal to the total pressure minus the velocity pressure on the upstream side.

2. The flow from each orifice (nozzle) may be calculated by means of the following equation:

$$Q = K_n\sqrt{P_n} \qquad \text{Eq. (1.1)}$$

Q = flow, gpm

P_n = pressure, psi, based on Rules I, II and III

K_n = nozzle discharge coefficient

3. The velocity pressure can be calculated using the equation:

$$P_v = \frac{V^2}{2g}(0.444) \qquad \text{Eq. (1.2)}$$

where

P_v = velocity pressure, psi

V = velocity, ft./sec.

g = 32.2. ft./sec.^{2}

NOTE: Normally, P_v is calculated in terms of feet. To convert P_v into a useable value (psi), the conversion factor (0.444) is included in the equation. Where $0.444 = 64\ \frac{lb}{ft^3} \times \frac{1}{144}\ \frac{ft^2}{in^2}$

4. The pressure loss in the pipe due to friction is a function of the friction factor as defined by the following hydraulic equation:

$$P_f = (fL/D)\ (V^2/2g)\ (0.444) \qquad \text{Eq. (1.3)}$$

where

P_f = pressure loss, psi

L = length of pipe, feet

D = inside diameter of pipe, feet

f = friction factor

Substituting in equation 1.2, P_f reduces to

$$P_f = (fL/D)\ P_v \qquad \text{Eq. (1.4)}$$

or

$$P_f = K_f P_v \qquad \text{Eq. (1.5)}$$

Where K_f = resistance coefficient

Consult reference (b) for the method of determining values of K_f and f.

5. The pressure loss due to the friction resistance of valves and fittings is computed in the same manner as for pipes or tubing, by using the equation:

$$P_f = K_f P_v \qquad \text{Eq. (1.6)}$$

522-1-e. Specific Design Procedures

1. Preliminary Design and Configuration Requirements

(a) Flow Rate Requirements

Determine the required flow rate for the ship's space or compartment from the coverage rates given in reference (a) and any applicable detailed specifications.

From Table I, Figure 3, determine the size of the sprinkler heads to be used, the discharge rate per head, and the pressure required at the most remote head to discharge the desired rate. The number of sprinkler heads required is found by dividing the required rate of flow for the compartment by the discharge rate per head.

The variation in sprinkling rate between the sprinkler head discharging the most water and the sprinkler head discharging the least water should not exceed 30 percent. The total flow rate of a designed sprinkler system should not exceed the required flow rate of the compartment by more than 15 percent.

In special cases where the height or shape of the magazines is such that the number of sprinkler heads specified by the required flow rate provide inadequate coverage, additional sprinkler heads of the same type should be used to ensure the sufficient sprinkler coverage. (NOTE: Generally, if additional sprinkler heads are added, heads with reduced orifice sizes may be needed.)

Generally configure the proposed sprinkler system on a scaled drawing of the magazine or applicable space. Position the sprinkler heads and size the sprinkler piping according to sound piping practices. Consult references (a) and (d) and other applicable references when laying out the system, especially when considering all overhead obstructions. Figure 1, illustrates typical sprinkler system configurations. The two-section, center feed arrangements, Figures (1A) and (1B), are the most desirable. The side feed arrangements, Figures (1C) and (1D), require higher pressures to produce adequate flow rates at the most remote sprinkler heads and produce an undesirable lack of uniformity in the amount of water discharged from each sprinkler head. Branch lines should be limited to 8 sprinkler heads with a maximum spacing distance of 14 feet between each head. (NOTE: Spacing also applies to branches.)

Unless otherwise specified, newly designed sprinkler systems shall utilize the newer 180° discharge nozzles, see reference (c) and Figure 3, Table 2, for information concerning sprinkler heads.

(b) Piping Requirements

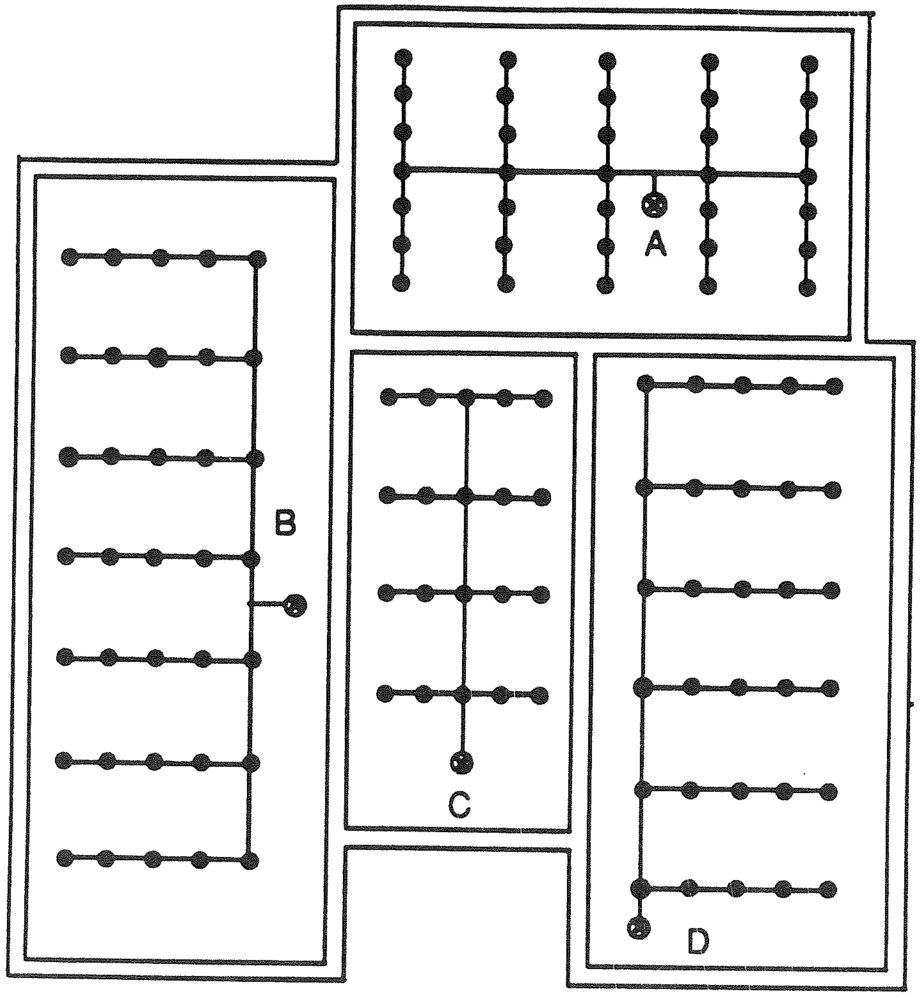
Ordinarily, runs of pipe from sprinkler head to sprinkler head, branch to branch and deck to deck should be initially sized in accordance with one of the schedules as listed in Tables II, III and IV of Figure 3. These tables are provided as general guidance and should prove satisfactory to meet most sprinkler system design requirements. However, to accommodate a special system design it may be necessary to deviate from these tables to obtain the desired flow characteristics.

Pipe sizes should be adjusted according to detailed friction loss calculations to provide a reasonably uniform sprinkler discharge. Cross main and branch line junctions may be smaller in diameter than specified in the pipe schedules and thus serve as "chokes", where needed, to assist in obtaining uniform sprinkler discharge.

2. Branch Calculations

Calculations are usually started at the sprinkler head most remotely located from the fire main. Initially, an assumed discharge and an assumed total pressure are equated to the most remote sprinkler head's discharge flow and pressure. Equating the total pressure to the discharge pressure for the end nozzle is based on Rule 1 which states that for <u>end</u> sprinkler heads, the total pressure can act to cause nozzle flow.

The total pressure at the second sprinkler head is determined by adding the total pressure at the 1st head to the pressure loss due to friction between the two heads. The discharge pressure at the second head is determined by subtracting the velocity pressure between the 1st and 2nd heads from the total pressure, as specified by Rule II. The discharge flow from the second sprinkler head is determined by equation 3.2.



A - TWO SECTION CENTER FEED

C - ONE SECTION CENTER FEED

B - TWO SECTION SIDE FEED

D - ONE SECTION SIDE FEED

FIGURE 1

The total pressure at the third head is then determined by calcuating the friction pressure loss between the second and third heads and adding this to the total pressure at the 2nd head. In order to find the flow rate from the 3rd and subsequent heads, Rule III must be applied -- the discharge pressure at the head is equal to the total pressure minus the velocity pressure on the upstream side of the nozzle. In other words, the velocity pressure between the 3rd and 4th heads must be determined. This is accomplished by assuming a flow from the 3rd head and adding it to the previous flow, then subtracting the velocity pressure corresponding to this flow from the total pressure to determine whether the resulting normal pressure will yield the assumed flow. Repeat the assumptions until an agreement is reached. The total pressure at the 4th head is then found by adding the total pressure from the third head to the pressure loss due to friction between the 3rd and 4th heads. Each remaining head along the branch is calculated by successive approximations in the same manner.

The calculations for the branch lines are complete when they have progressed back to the point where the branch joins the cross main.

3. 2nd Branch - Branch Adjoining 1st Branch at the Cross Main

(a) When two branches with the same total pressure are commonly joined at a cross main, the total flow at the cross main junction is the sum of the total flows required by each branch. The total pressure at the junction is equivalent to the single branch pressure.

(b) When two branches of different total pressures share a common cross main junction, the total pressure is assumed equivalent to the branch with the highest total pressure. Appropriately, the flow to the branch line at the lower pressure must be adjusted to the corresponding higher total pressure, this is done by the using relationship

$$\frac{Q_1}{Q_2} = \sqrt{\frac{P_1}{P_2}} \qquad \text{Eq. (3.1)}$$

solving for Q_2, results in the following:

$$Q_2 = Q_1 \sqrt{\frac{P_2}{P_1}} \qquad \text{Eq. (3.2)}$$

Where

P_1 = higher total pressure, psi

P_2 = lower total pressure, psi

Q_1 = flow corresponding to the higher total pressure, gpm

Q_2 = adjusted flow to the branch having the lower total pressure gpm

The total flow at the two branch cross main junction is equivalent to sum of the flow from the higher total pressure branch line and the adjusted flow from the branch at the lower total pressure.

4. Vertical Risers Between Cross Main and Branch Lines

When a branch or branches are located at an elevation different from that of the cross main and are connected to the cross main by a riser, the pressure loss due to friction in the riser must be added to the branch's or branches' total pressure to give the total pressure at the cross main. The pressure loss due to small elevation differences are generally deemed insignificant and are not considered when determining the cross main total pressure.

5. Cross Main Calculations

In order to calculate the pressures and flows along the cross main, the cross main is treated as a branch line and the branch lines as sprinkler heads. A K factor must be calculated for each point along the cross main where a branch or branches join the cross main. K is determined from the equation

$$Q = K\sqrt{P_t}$$

Where

Q = total flow to the branch or branches under consideration, gpm

P_t = total pressure at the junction under consideration, psi

It is obvious that identical branches have the same K factor and therefore it may be possible to eliminate many calculations.

After all the necessary K factors have been determined, the friction pressure drop in the cross main can be calculated beginning at the point where the most remote branch or branches join the cross main. Rules I and II are applied in the cross main calculations as they were for the 1st and 2nd nozzles in a branch line, with the exception that pressure losses due to branch/crossmain fittings is included. After the calculations have been carried back to the source, the elevation head between the source (sprinkler control valve) and the plane of the sprinkler heads is added to obtain the required supply pressure, the pressure required at the source of the sprinkler system to provide the required sprinkling rate.

522-1-f. Special Design Considerations for Seawater Actuated Control Systems

When using seawater actuated control valves in the sprinkler systems, a minimum of 15 psi is to be maintained at the most remote sprinkler head. This requirement is stipulated in the event that the seawater supply pressure drops to the operating pressure of 40 psi for the sprinkler control valve. By maintaining 15 psi at the furthest sprinkler head, the heat absorbing quality of the sprinkling water can be maintained. If the nozzle pressure were to drop below 15 psi, the heat absorbing quality of the water is greatly reduced since there is insufficient break-up of the water into small particles. To insure that the requirement is met, the system should be checked using equation 3.1; in the following form:

$$P_2 = P_1 \left(\frac{Q_2}{Q_1}\right)^2 \qquad \text{Eq. (3.3)}$$

Q_1 = Total required flow to the compartment, gpm

P_1 = The required pressure at the source, psi

Q_2 = The total flow at 15 psi per head, gpm

P_2 = The required pressure at the source to maintain 15 psi at the sprinkler heads, psi.

If P_2 is below the operating pressure of the sprinkler control valve (40 PSI), the requirement is met. If P_2 is above the sprinkler control valve operating pressure, steps to meet this requirement must be taken, such as increasing pipe sizes. All modifications to the system should be made at the expense of increased overflow. However, for most compartments, maintaining 15 psi at the furthest sprinkler nozzle will remain within the overflow requirements without any adjustments to the original system layout.

522-1-g. System Evaluation

In order to properly evaluate the sprinkler system, the required supply pressure is tested against an assumed source pressure. The assumed source pressure is equivalent to 75% of the ship's fire pumps rated pressure, and is assumed to be the firemain pressure upstream of the sprinkler control valve. This assumed pressure is based on a casualty condition when the dynamic losses and system overloads result in a 25% reduction of the available firemain pressure.

1. If the assumed source pressure is less than the required supply pressure, the system must be redesigned for lower pressure loss. The following steps are recommended in redesigning the system:

- If possible, the sprinkler head orifices should be increased in size and the system recalculated at a lower pressure. However, the pressure at the most remote head should never be less than 15 psi.

- Increase the pipe sizes to minimize friction losses.

2. If the assumed source pressure exceeds the required supply pressure, the flow rate corresponding to the assumed source pressure should be tested against the flow rate corresponding to the required supply pressure. The percent difference between the two flow rates is not to exceed 15% over-flow.

(a) Before determining the percent difference, the assumed source flow rate must be calculated from equation 3.2.

$$Q_2 = Q_1 \sqrt{\frac{P_2}{P_1}}$$

where

P_1 = Total required pressure, psi

Q_1 = Total required flow at P_1, gpm

P_2 = Available pressure, psi (75% of the fire pump's rated pressure)

Q_2 = Total flow at P_2, gpm

NOTE: Before using the equation above, the pressure due to the elevation head must be determined and deducted (or added) from both pressures.

(b) Once the assumed source flow rate is determined, the percent difference between it and the required flow rate can be found by using the following equation:

$$\frac{(\text{Assumed source flow rate}) - \sum(\text{Required flow rate})}{\sum(\text{Required flow rate})} \times 100 \qquad \text{Eq. (3.4)}$$

NOTE: The summation of required flow rates is necessary for all group magazine arrangements where one magazine control valve services multiple magazines.

(c) If the flow exceeds the 15% limit the system must be redesigned. This can be accomplished by using any one or all of the following steps:

- Introduce additional friction drops in the system by reducing the pipe size.

- Reduce the number of sprinkler heads, within the limits to provide adequate coverage, and recalculate the system at a higher pressure.

- Reduce the size of the sprinkler head orifices and recalculate the system at a higher pressure.

STEP DIAGRAM

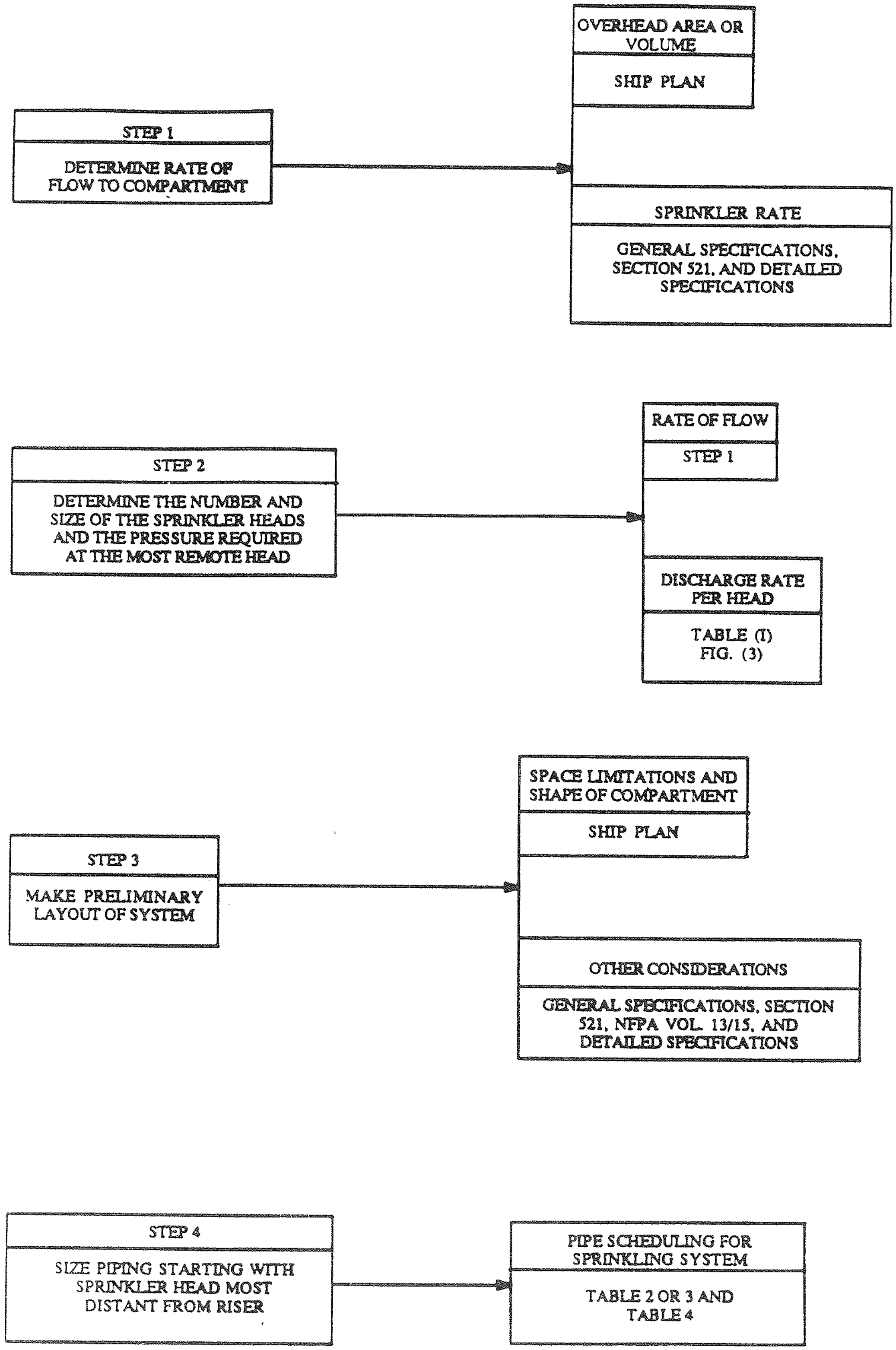


FIGURE 2

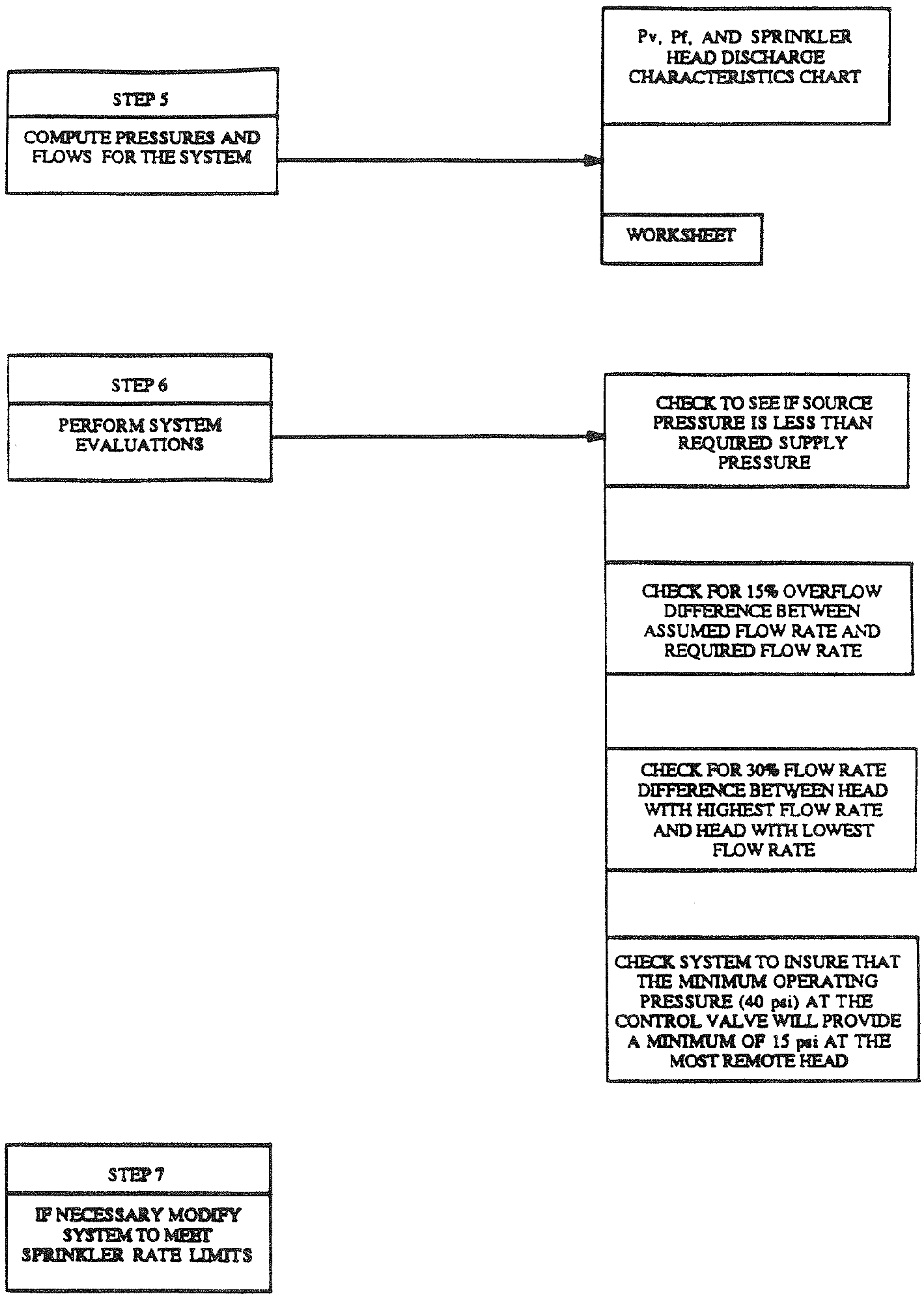


FIGURE 2 (CONT.)

TABLE I

SPRINKLER NOZZLE CHARACTERISTICS

SPRINKLER HEAD ORIFICE SIZE	NOM DIA	TYPICAL K - FACTORS	DISCHARGE RATE * PER HEAD (gpm)	PRESSURE AT MOST REMOTE HEAD (psi)
16	13/64"	1.2 ± .1	4.8	16.2
18	1/4"	1.8 ± .1	9.7	28.7
21	5/16"	2.1 ± .2	12.9	34.2
24	3/8"	3.0 ± .2	19.0	38.8
28	7/16"	4.1± .2	29.0	47.5
32	1/2"	5.5 ± .3	38.6	47.5

* DISCHARGES ARE BASED ON A PERCENTAGE OF THE FLOW RATE FROM THE No. 32 ORIFICE. NFPA 13, TABLE 3-16.5

TABLE II

PIPE SCHEDULE FOR 100,125 psi AND LOWER PRESSURE SYSTEMS

SIZE OF PIPE (NOMINAL)	MAX. FLOW (gpm)	SIZE OF PIPE (NOMINAL)	MAX. FLOW (gpm)
1-1/4"	48	3-1/2	605
1-1/2"	74	4	840
2"	148	5	1540
2-1/2"	230	6	2500
3"	405		

TABLE III

PIPE SCHEDULE FOR 150/175 psi SYSTEMS

SIZE OF PIPE (NOMINAL)	MAXIMUM FLOW (gpm) 150/175 (psi)	SIZE OF PIPE (NOMINAL)	MAXIMUM FLOW (gpm) 150/175 (psi)
1"	34/39	3"	575/660
1-1/4"	68/78	3-1/2 "	860/950
1-1/2"	105/120	4"	1200/1320
2"	212/294	5"	2190/2300
2-1/2"	330/380	6"	2580/3900

FIGURE 3

COPPER NICKEL ALLOY-SEAMLESS & WELDED PIPE DATA
MIL-T-16420
TYPE I - SEAMLESS
TYPE II - WELDED

TABLE IV

NOM. SIZE IPS	OUTSIDE DIA. INCHES	WALL THICKNESS INCHES	INSIDE DIA. INCHES	TRANSVERSE INTERNAL AREA SQUARE INCHES	TRANSVERSE INTERNAL AREA (SEE NOTE) SQ FEET	WEIGHT OF PIPE POUNDS PER FOOT	WEIGHT OF WATER POUNDS PER FOOT OF PIPE
90-10 & 70-30 CLASS 200 TYPES I & II (UNLESS OTHERWISE INDICATED)							
	• .250	.035	.180	.025	.0018	.092	.011
	• .500	.035	.430	.145	.0010	.198	.062
* 1/4	• .540	.065	.410	.132	.0009	.376	.056
3/8	• .675	.065	.545	.233	.0016	.483	.100
1/2	• .640	.065	.710	.396	.0027	.613	.168
3/4	• 1.050	.065	.920	.665	.0046	.779	.287
1	• 1.315	.065	1.185	1.103	.0077	.989	.480
1- 1/4	• 1.660	.072	1.516	1.805	.0125	1.390	.780
1- 1/2	• 1.900	.072	1.756	2.422	.0168	1.600	1.048
2	• 2.375	.083	2.209	3.832	.0266	2.320	1.660
2- 1/2	• 2.875	.083	2.709	5.764	.0400	2.820	2.497
3	3.500	.095	3.310	3.605	.0598	3.940	3.733
3 -1/2	4.000	.095	3.810	11.401	.0792	4.510	4.944
4	4.500	.109	4.282	14.400	.1000	5.830	6.242
5	5.563	.125	5.313	22.170	.1540	8.280	9.613
6	6.625	.134	6.357	31.739	.2200	10.600	13.733
8	8.625	.148	8.329	54.485	.3780	15.300	23.597
10	10.750	.187	10.376	84.557	.5870	24.000	36.644
12	12.750	.250	12.250	117.859	.8180	38.000	51.065

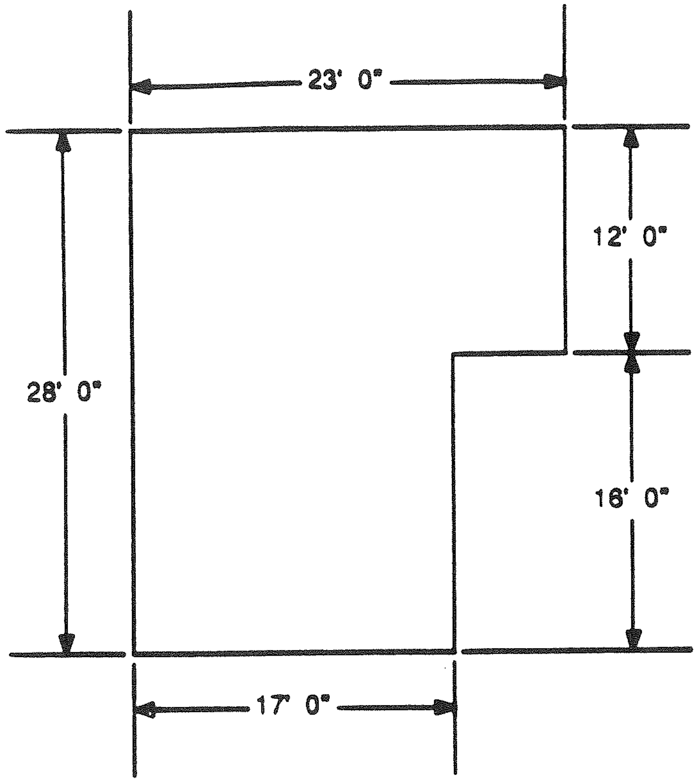
NOTE: THE VALUES SHOWN IN SQUARE FEET FOR THE TRANSVERSE INTERNAL AREA ALSO REPRESENT THE VOLUME IN CUBIC FEET PER FOOT OF PIPE LENGTH.

• TUBE WITH OUTSIDE DIA. 0.250" THRU 2.875" ARE AVAILABLE IN TYPE 1 ONLY

* 70-30 AVAILABLE IN CLASS 600 ONLY

FIGURE 3 (CONT.)

522-1-h. **EXAMPLE CALCULATION**



Given: Compartment with dimensions shown Sprinkling rate: of 0.8 gpm/sq. ft. overhead up to an overhead height of 8'-0" and 0.1 gpm/cu.ft. for the additional gross volume.
Height of overhead: 10'-0"
150 psi firemain system
Schedule 40 copper-nickel pipe

Determine: Layout of system to provide adequate coverage Pipe sizes to provide required flow

Assume: 8'-6'" vertical distance between control valve and cross main.

Step 1 Determine rate of flow to compartment overhead area:
23' x 12' + 16' x 17' = 548 sq. ft.
Volume above 8ft: 548 sq. ft. x 2' ft. = 1096 cu. ft.
Rate of flow:
548 sq. ft. x 0.8 gpm/sq.ft. + 1096 cu.ft. x 0.1 gpm/cu.ft = 548 gpm

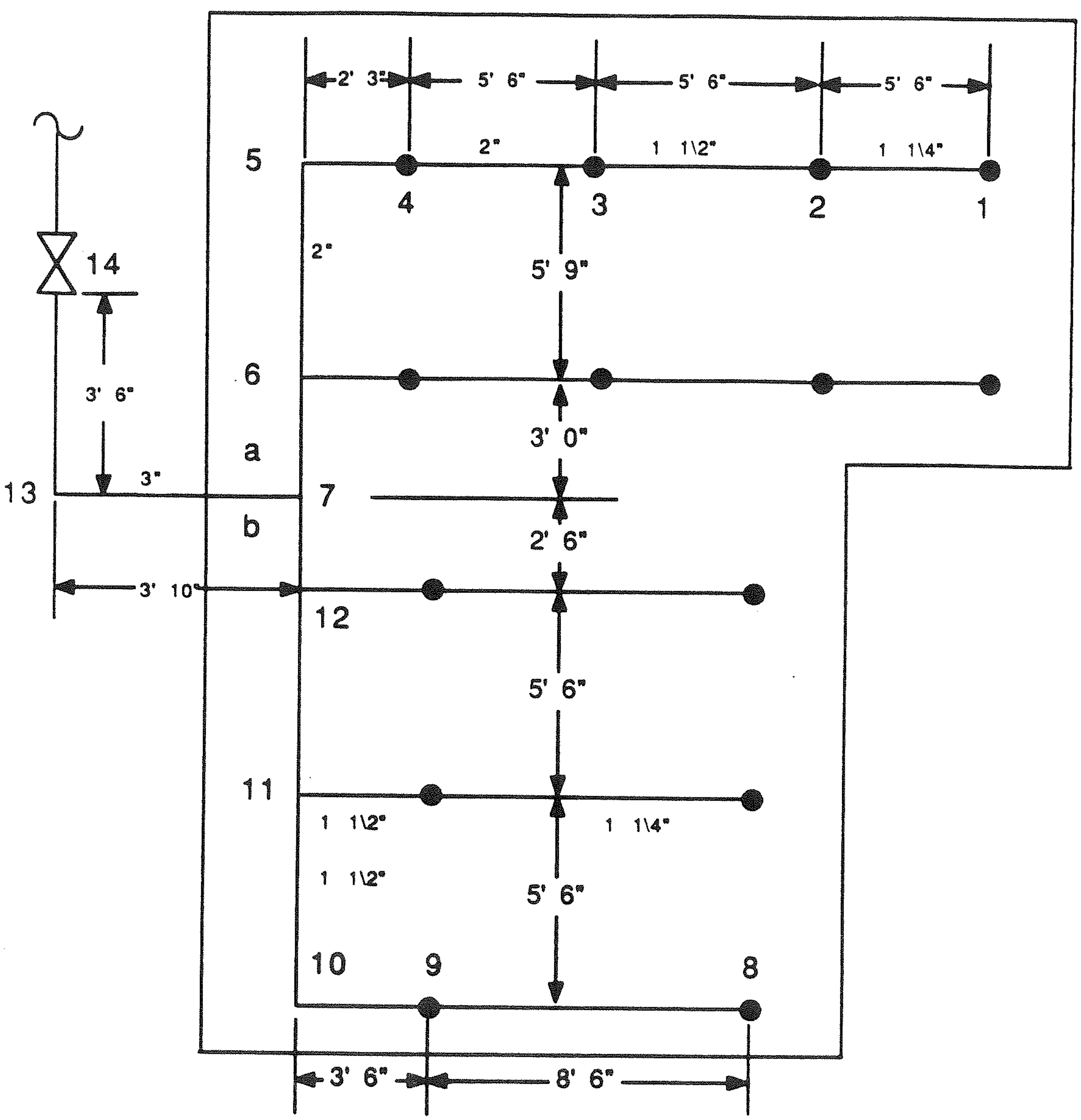
Step 2 Determine number and size of sprinkler heads and pressure required at most remote head.

Q per head from Table I = 38.6 gpm
P_t at most remote head, Table I = 47.5 psi

Number of heads required:

$$\frac{548\ \text{gpm}}{38.6\ \text{gpm}} = 14$$

Step 3 Layout of system



Control valve is 8-1/2' below crossmain

Step 4 Size pipe according to Tables II and III of Figure 3 discharge of 38.6 gpm.

LOCATION	PIPE SIZE (in.)	PIPE LENGTH (ft.)	Pt	Pf	Pv	Pn	q	Q
1			47.5	(RULE I)		47.5	38.6	
1-2	1-1/4	5-1/2	+	0.3	0.3			38.6
2			47.8		(RULE II)	48.1	38.6	
2-3	1-1/2	5-1/2	+	0.5				77.2
3			48.3			47.6	38.6	
3-4	2	5-1/2	+	0.3	0.7 (RULE III)			115.8
4			48.6			47.4	38.6	
4-5	2	2-1/4	+	0.2	1.2 (RULE III)			154.4
5			48.8	(RULE I)		48.8		Kn = 22.1 (NOTE 1)
5-6	2	5-3/4	+	1.6	1.2			154.4
6			50.4		(RULE II)	49.2	155.0	(NOTE 2)
6-7a	2-1/2	3	+	2.1				309.4
7a			52.5					
8			47.5	(RULE I)		47.5	38.6	
8-9	1-1/4	8-1/2	+	0.4	0.3			38.6
9			47.9		(RULE II)	47.6	38.6	
9-10	1-1/2	3-1/2	+	0.3				77.2
10			48.2	(RULE I)		48.2		Kn = 11.1 (NOTE 3)
10-11	1-1/2	5-1/2	+	1.1	0.7			77.2
11			49.3		(RULE II)	48.6	77.4	
11-12	2	5-1/2	+	1.6				154.6
12			50.9		(RULE III)	49.7	78.3	
12-7b	2-1/2	2-1/2	+	1.2	1.2			232.9
7b			52.1					233.8 (NOTE 4)
7			52.5					543.2

Calculated pressure at point 7: 52.5 psi

Calculated flow: 543.2 gpm

Pressure drop between points 7 and 14 with 3" pipe and fittings:

Pressure at point 7: 52.5 psi
Drop thru 15' of 3" pipe: 3.0
8'-6" static head: 3.7 $P = \frac{8.5 \times 64}{144}$ lbs./in^2

Drop thru 3" globe valve:	22.8	Ref. (b)
Drop thru regular screwed ell:	3.0	Ref. (b)
Drop thru side outlet tee:	5.9	Ref. (b)
Pressure at point 14	90.9 psi	

Pressure at source is 75% of firemain pressure or 0.75 x 150 psi = 112.5 psi

Flow at this pressure:

$$Q2 = Q1\sqrt{\frac{P2}{P1}} \qquad \text{Eq. (3.2)}$$

$$Q = 543.2\sqrt{\frac{112.5-3.7}{90.9-3.7}}$$

$$Q = 606.8 \text{ gpm}$$

Required flow = 548 gpm

$$\text{Excess flow} = \frac{606.8-548 \times 100}{548} = 10.7\%$$

Step 6 No modification required

Step 7 Check pressure at source for 15 psi at sprinkler heads.
No. 32 head: Q per head at 15 psi = 21.7 gpm
Flow to compartment: 14 x 21.7 = 304 gpm
Pressure at source required for this flow:

$$\frac{Q1}{Q2} = \sqrt{\frac{P1 - 3.7}{P2 - 3.7}}$$

$$\frac{610}{304} = \sqrt{\frac{112.5 - 3.7}{P2 - 3.7}}$$

$$P2 = 30.7 \text{ psi}$$

Operating pressure for the sprinkler control valve is 40 psi. Therefore, the 15 psi requirement at the most remote nozzle will be met at this valve operating pressure.

CALCULATION NOTES:

(1) Since the next branch line toward the source is identical to the first, it is convenient to consider the discharge at point 5 as a sprinkler head and to calculate the discharge coefficient for the branch:

$$Q = Kn\sqrt{P} \quad \text{or} \quad Kn = \frac{154.4}{\sqrt{48.8}} \qquad Kn = 22.1$$

(2) The pressure at point 6 is determined by the first branch. Considering the branches as sprinkler heads, the 6-7 junction is the second from the end, and Rule II applies along with the K found under Note 1.

(3) The discharge coefficient for the branch is calculated in the same manner as it was for point 5 in Note 1:

$$Kn = \frac{77.2}{\sqrt{48.8}}$$

$$Kn = 11$$

(4) There can be only one pressure at point 7. As the pressure at 7a is the higher of the two it is the critical one and the calculated flow at point 7b must be adjusted to conform to it.

$$\frac{Q1}{Q2} = \sqrt{\frac{P1}{P2}}$$

$$Q2 = 232.9\sqrt{\frac{52.5}{52.1}}$$

$$Q2 = 233.8 \text{ gpm}$$