



## **Particle Physics Division Mechanical Department Engineering Note**

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Project Internal Reference:

Project:

Title: NOvA Near Detector Chiller System

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Reviewer(s):

Key Words: NOvA, Near Detector, chiller system

Applicable Codes:

Abstract Summary:

The near detector will be moved into the surface building in two parts; first the superblock, then the final A block and muon catcher. The chiller system has been designed to fit a superblock without any overhang in order to place multiple systems in a row for the far detector's case, and also to be fitted with extension arms to service the muon catcher and last A block when they are inserted for the near detector. Designing to fit a superblock will also keep all sections generic for the far detector. Hydraulics and heat loss analysis have been performed on both setups, as well as a basic support system for the piping.

## Full System Labels

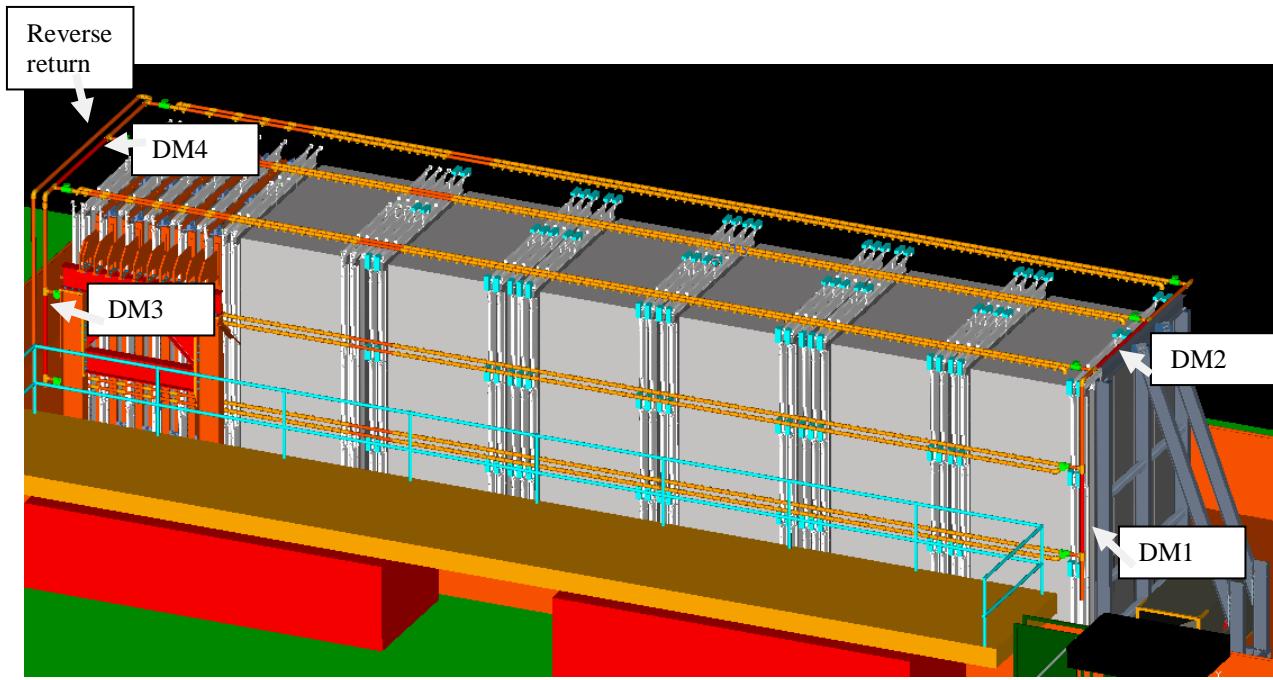


Figure 1: Distribution manifolds labeled (discussed on page 4)

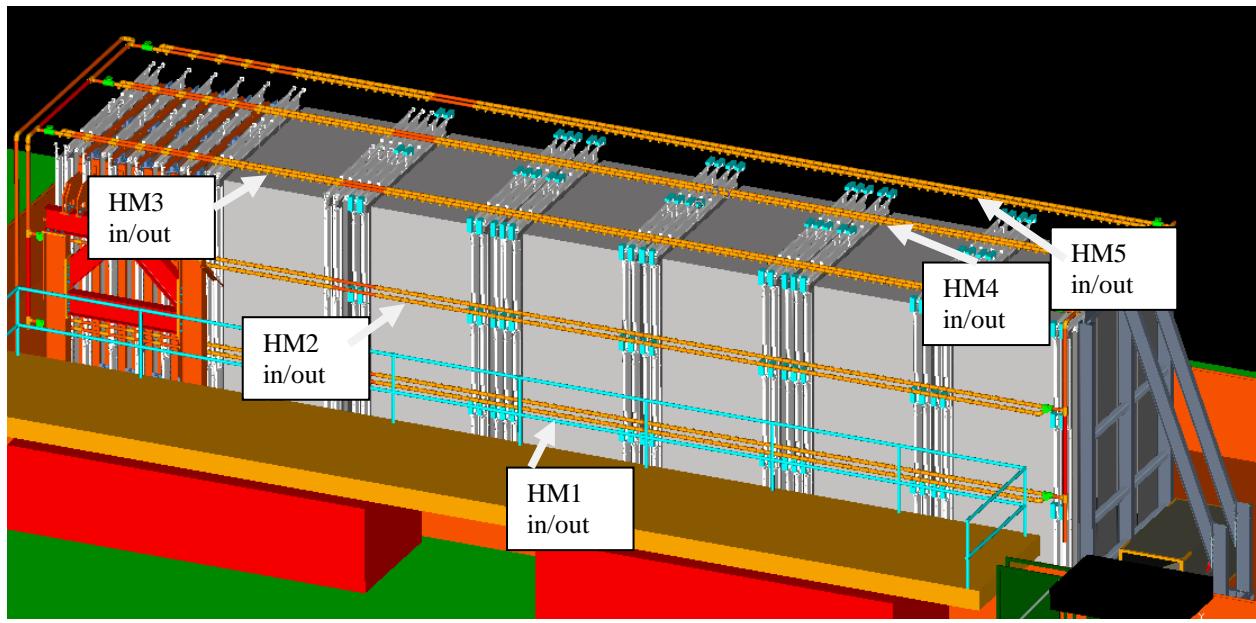


Figure 2: Hose manifolds labeled (discussed on page 5)

## 2 Setups

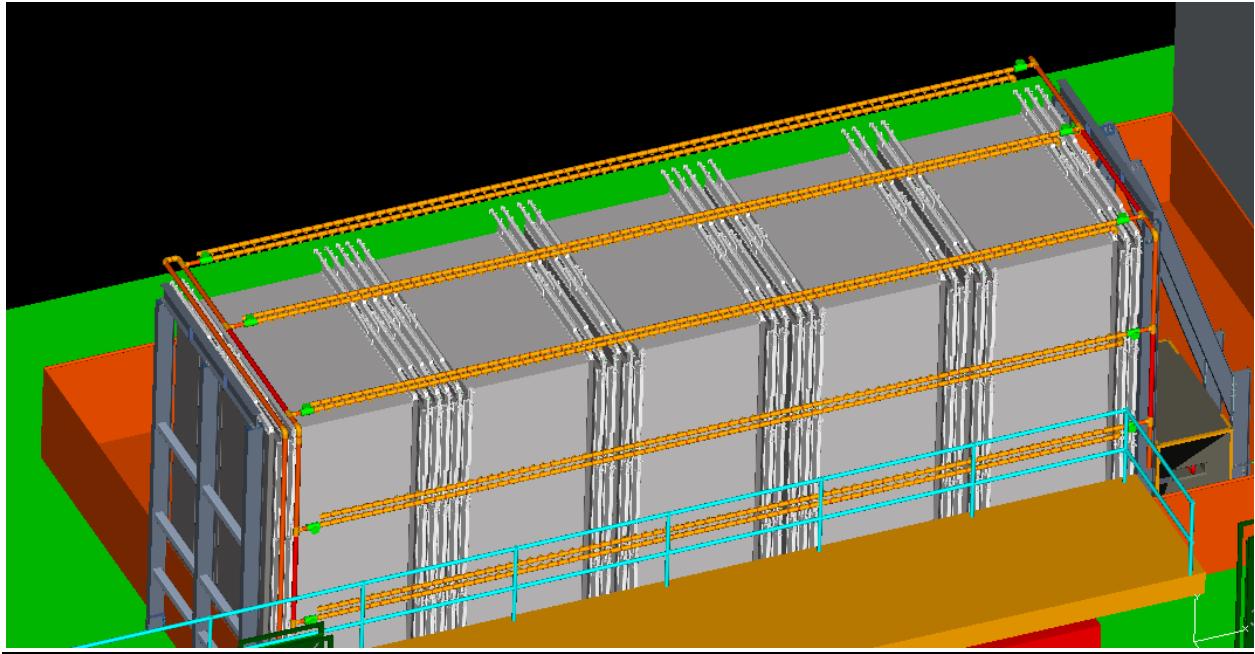


Figure 3: Initial setup, superblock only with distribution manifolds 3 and 4 connected to the end of the fifth generic A or B hose manifold section (HM sections discussed on page 6)

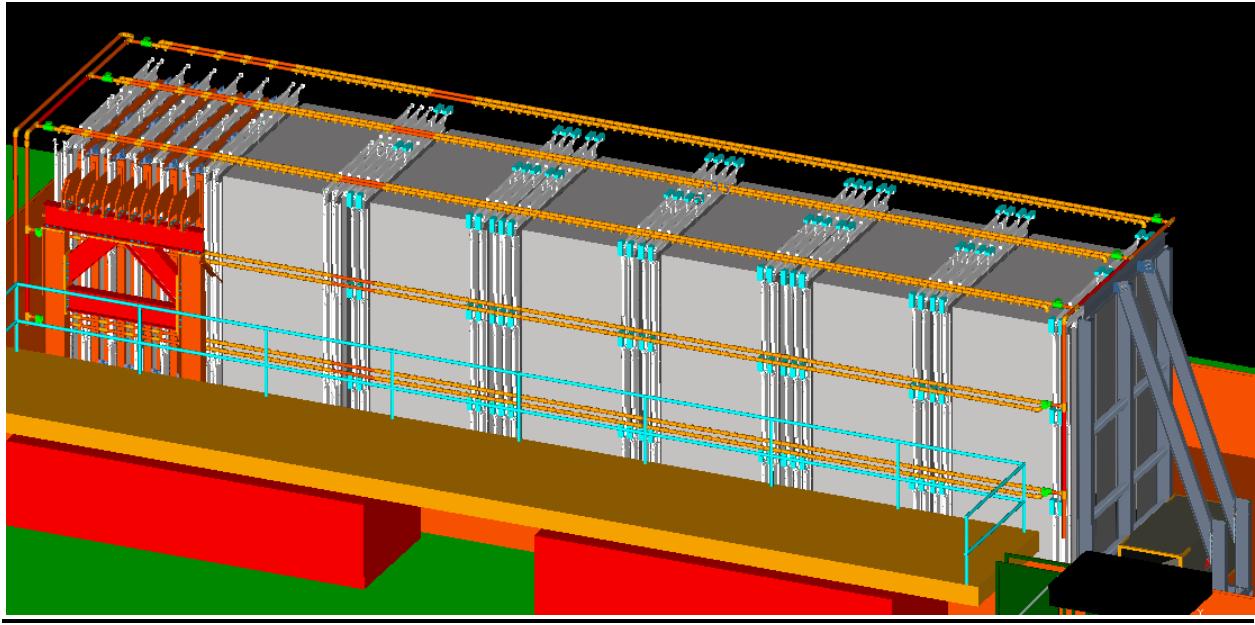


Figure 4: Final setup, last A block and muon catcher inserted. Distribution manifolds 3 and 4 have been removed to be replaced with spacers, a final A or B hose manifold section, and muon catcher sections; then reattached at the end of the muon catcher sections. (Hose manifold information on Page 6)

## Components

**Distribution Manifolds:** Each superblock section will be equipped with four distribution manifolds. There are two generic sections of DM's (each superblock section having two of each), a side section servicing the first two rows of horizontal plane APD's, and a top section servicing the third row of horizontal plane APD's and the two rows of vertical plane APD's. All distribution manifolds are schedule 40, 1.25" n.d. pipe, equipped with 1-1/4x1-1/4x3/4 reducing tees. Spacers between valves and DM's are 5" on DM1, DM2, and DM4 (**\*\*Note: DM4's spacers will be 15.9"** when the extension arms are put on due to the muon catchers unique structure), while DM3 spacers will be 10".

Figure 5: DM1 and DM3 (side sections).

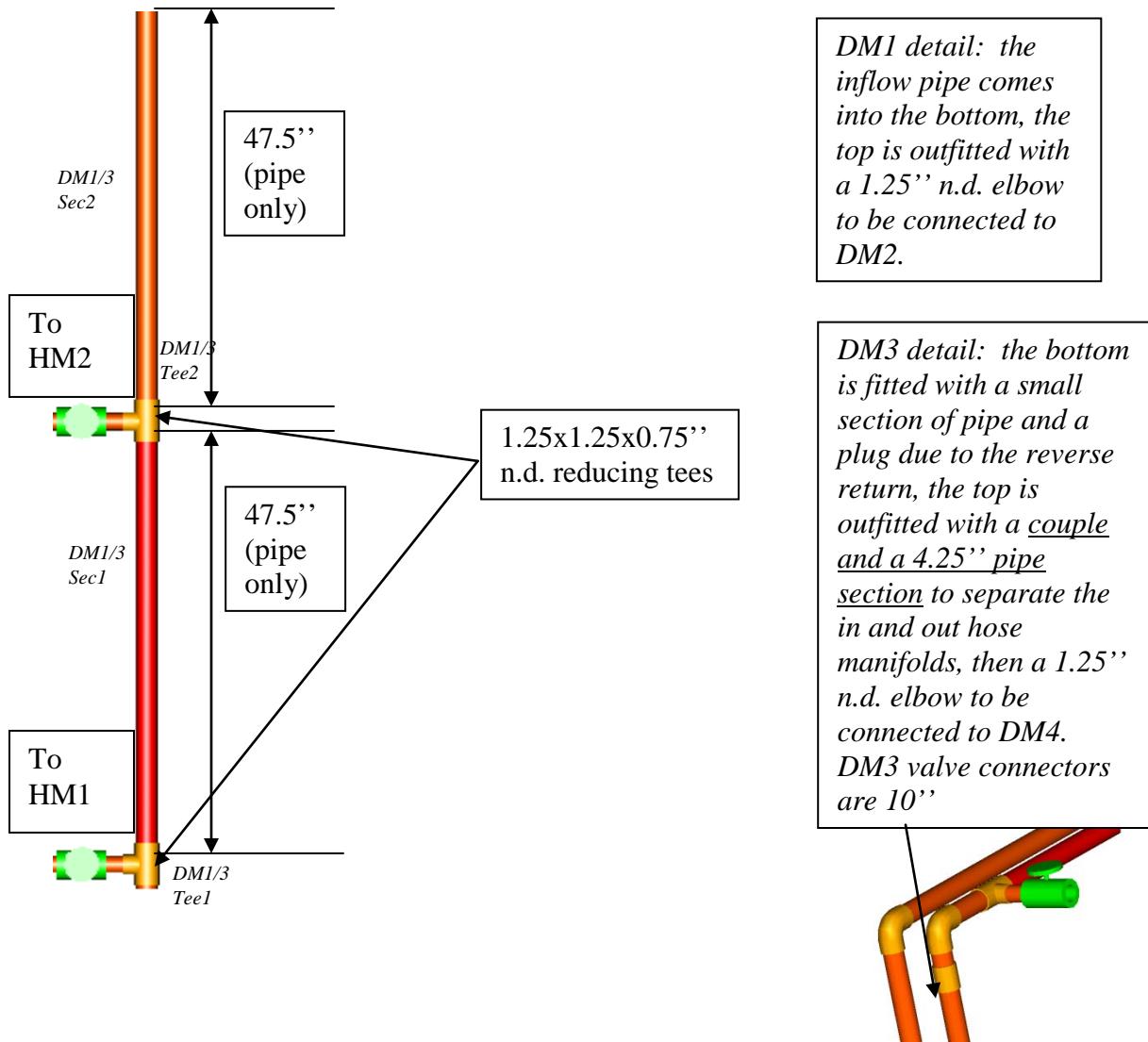
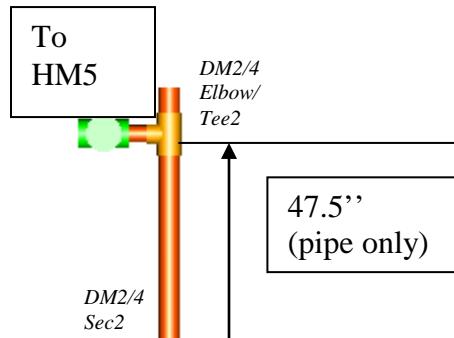
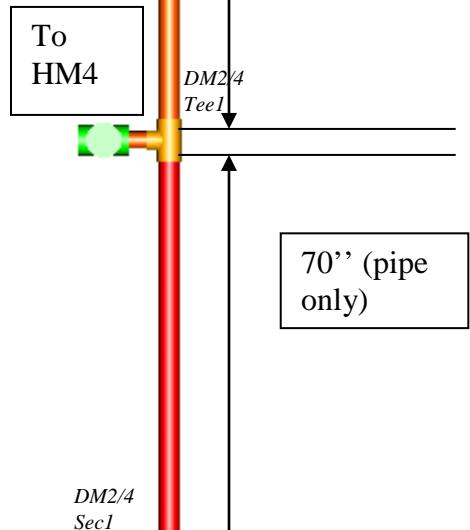


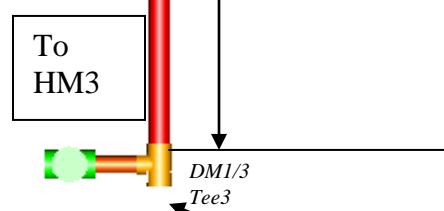
Figure 6: DM2 and DM4 (top sections). The bottom Tee will be considered to be part of DM1/3 as it serves HM row 3, and this tee on DM4 will be fitted with a 10" spacer section as in DM3.



*DM2 detail: the bottom tee will be equipped with 12'' section of pipe to space the in and out hose manifolds, and then connected to the elbow on DM1. The top tee will have a small section of pipe and a plug.*



*DM4 detail: the bottom tee will be equipped with 8'' section of pipe to space the in and out hose manifolds, and then connected to the elbow on DM3. The top tee will have a small section of pipe and run into the reverse return pipes.  
DM4 has a different set of spacers connecting the valves with the extension arms connected, see above for details.*



*8 or 12'' spacer here (DM1 and DM3 sec. 3 in hydraulic analysis), then to DM1 or DM3*

**Hose Manifolds in Superblock Setup:** Each superblock section will contain 10 full hose manifolds (5 for inflow, 5 for outflow), each consisting of a combination of 5 individual generic A (15 hose) or B (16 hose) sections. Hose manifolds are schedule 40,  $\frac{3}{4}$ " n.d. PVC pipe (all HM section lengths = 3.713" [pipe only]), equipped with  $\frac{3}{4}$ " x  $\frac{3}{4}$ " x  $\frac{1}{2}$ " reducing tees, with the  $\frac{1}{2}$ " outlet filled with a plug bored out to a 1/4" NPT thread. The four sections of pipe connecting the A and B sections on each full row are 4". \*Note: center to center distance for the snouts is 5.22085", but center to center of the HM tees has been reduced in order to be fit without overhang, this will require some hoses to be longer than others, and the true length for the hoses will be the greatest needed distance. Final tees will be replaced with elbows on last A or B sections in full rows.

#### Superblock Section Order:

-Horizontal plane hose manifold (HM1, 2 and 3) full row--section order: **ABABA**

-Vertical plane hose manifold (HM4 and 5) full row--section order: **BABAB**

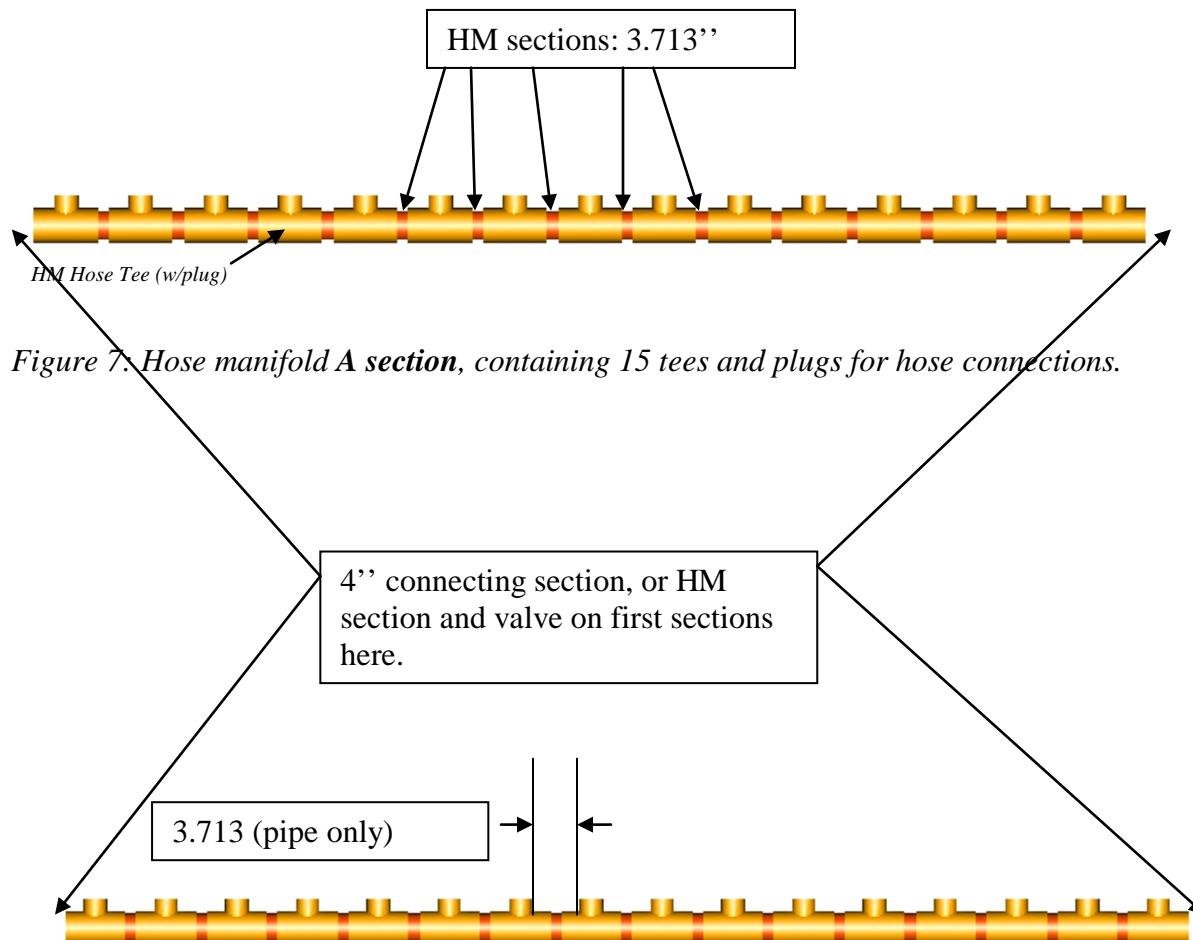


Figure 7: Hose manifold **A section**, containing 15 tees and plugs for hose connections.

Figure 8: Hose manifold **B section**, containing 16 tees and plugs for hose connections.

**Hose Manifolds with Extensions:** Each superblock with extension section will contain 10 full hose manifolds (5 for inflow, 5 for outflow), each consisting of a combination of 6 individual generic A (15 hose) or B (16 hose) sections (seen in figures 7 and 8), and a final MCA (6 hose, HM row 4 and 5) or MCB (7 hose, HM row 1, 2, and 3). MC sections are 13.781249" (pipe only). Hose manifolds are schedule 40,  $\frac{3}{4}$ " n.d. PVC pipe (all HM section lengths = 3.713" [pipe only]), equipped with  $\frac{3}{4}$ " x  $\frac{3}{4}$ " x  $\frac{1}{2}$ " reducing tees, with the  $\frac{1}{2}$ " outlet filled with a plug bored out to a 1/4" NPT thread. The four sections of pipe connecting the A and B sections on each full row are 4". \*Note: center to center distance for the snouts is 5.22085" (15" on muon catcher), but center to center of the HM tees has been reduced in order to be fit without overhang, this will require some hoses to be longer than others, and the true length for the hoses will be the greatest needed distance.

#### *Superblock with Extensions Section Order:*

-Horizontal plane hose manifold (HM1, 2 and 3) full row--section order: **ABABA-A-“MCB”**

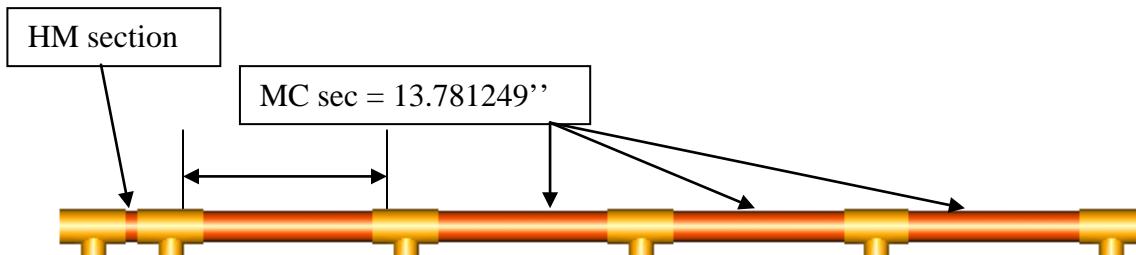
- The spacer connecting the final 2 A sections is 32.8"

- The spacer connecting the final A section to the MCB section is 12.35"

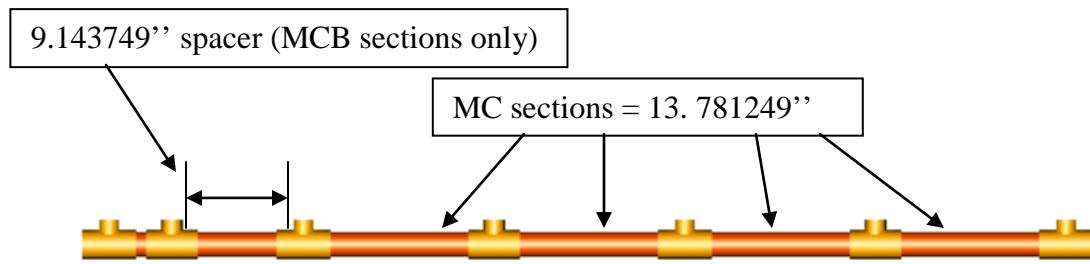
-Vertical plane hose manifold (HM4 and 5) full row--section order: **BABAB-B-“MCA”**

- The spacer connecting the final 2 A sections is 26.4"

- The spacer connecting the final A section to the MCA section is 13.35"



*Figure 16: MCA section (HM 4 and 5). The final tee (left) will be outfitted with small section of pipe and a plug on the inflowing hose manifolds. On the out flowing hose manifolds the tee will be connected to the distribution manifold with a spacer (see above for details).*



*Figure 17: MCB section (HM 1, 2, and 3). The final tee (left) will be fitted with a small section of pipe and a plug on the inflowing hose manifolds. On the out flowing hose manifolds the tee will be connected to the distribution manifold with a spacer (see above for details).*

## Superblock System Hydraulic analysis

Pipe diameters have been reset to the tested sizes ( $DM = 1\text{-}1/4''$ ,  $HM = 3/4''$ ) in order to provide enough pressure loss through the system to properly intersect a pump curve. Initially 3 different strength pumps were plotted (Figure 9), but the  $3/4$  horsepower pump was chosen. Curves seen on graphs are polynomial trend lines due to unavailability of intermediate data values, but these trend lines fit the known points extremely well, all with an R value close to 1. The total head loss of the system was calculated from the pressure drops through pipes and fittings plus the head required to drive the required flow through the TEC (data collected and taken from Engineering Note MD-ENG-196).

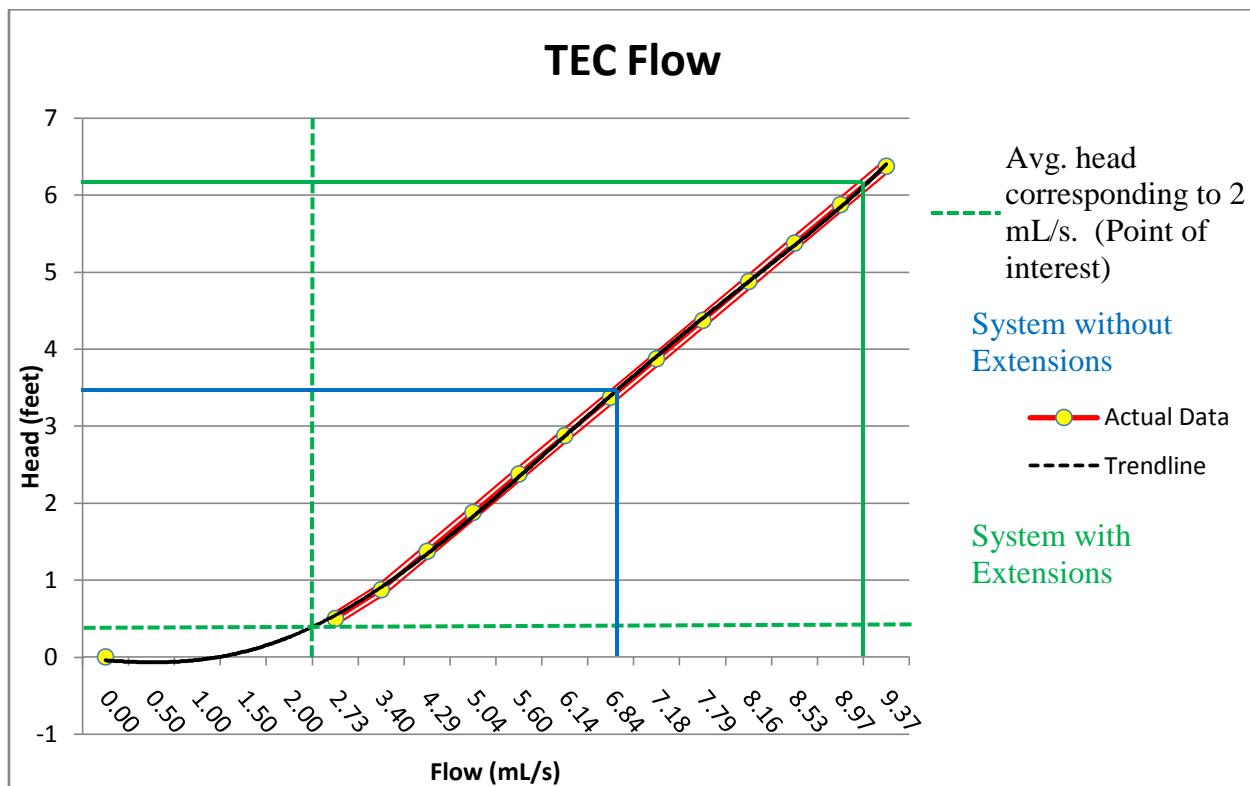


Figure 9: Head corresponding to flow rate of only the TEC's, data from Engineering Note MD-ENG-196. The flow displayed on the bottom axis is in ml/s and shows the head corresponding to flow across one TEC (discussed in more detail on page 9). The green line shows the head value corresponding to the system without the extension arms (see page 9), and the blue line shows the head value corresponding to the system with the extension arms (see page 62).

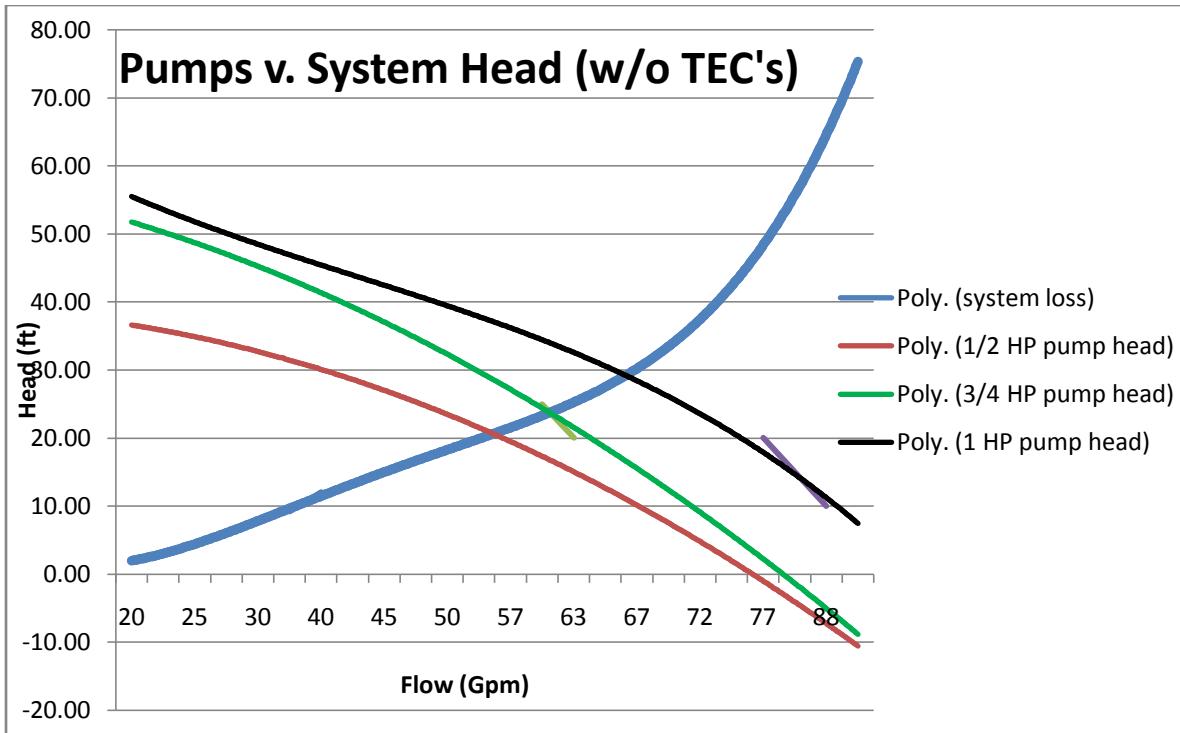


Figure 10: Head loss plotted against flow rate for the system only (thick blue line) without the head of the TEC's factored in.

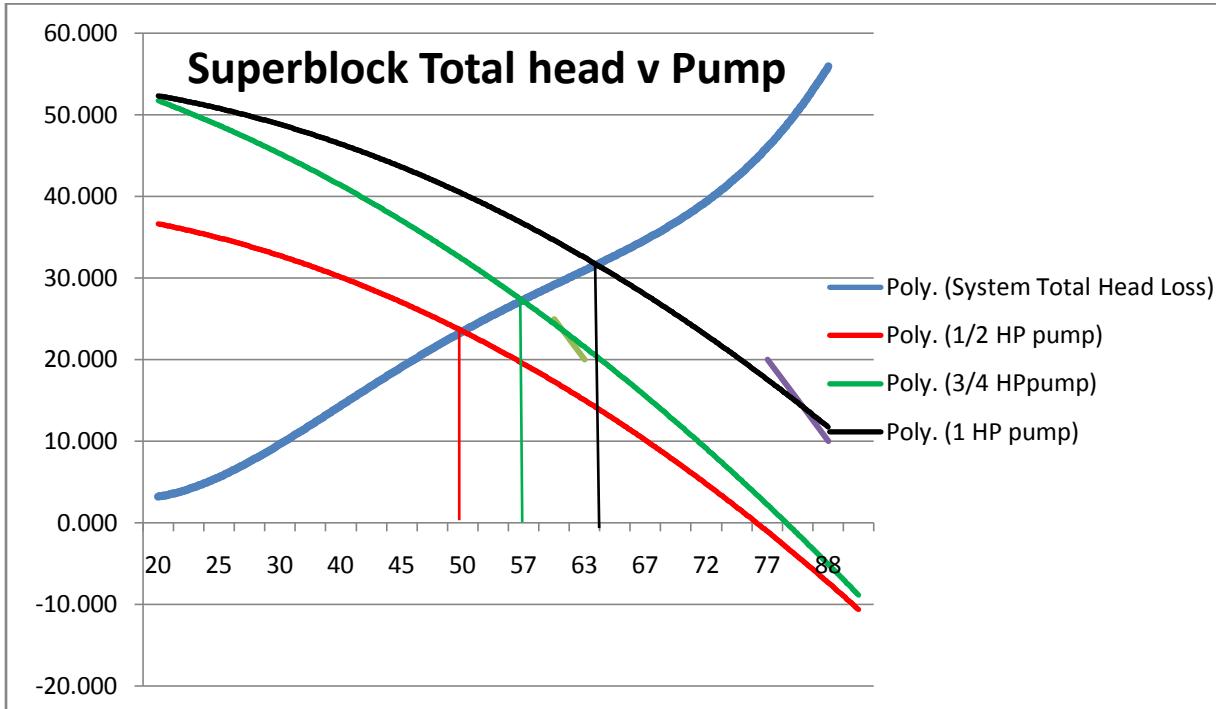


Figure 11: Head loss total of the system at different flow rates (including TEC's), with the three others being pumps of different horsepower.

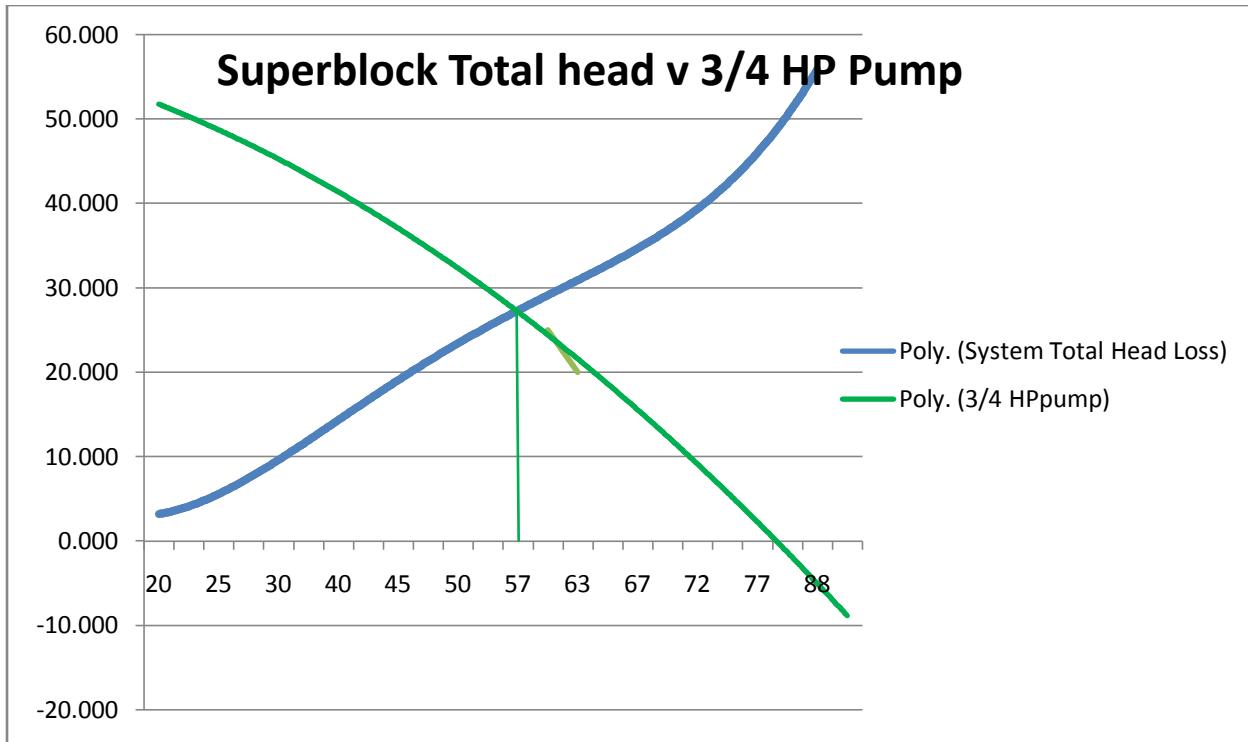


Figure 12: System head loss is seen to intersect the  $\frac{3}{4}$  HP pump at 55 Gpm, and this will be set as the true flow rate of the superblock's chiller system without the extension arms.

Tested flow across APD's = 2 — : this is taken as a minimum

True flow of entire system with  $\frac{3}{4}$  HP pump = 55 Gpm

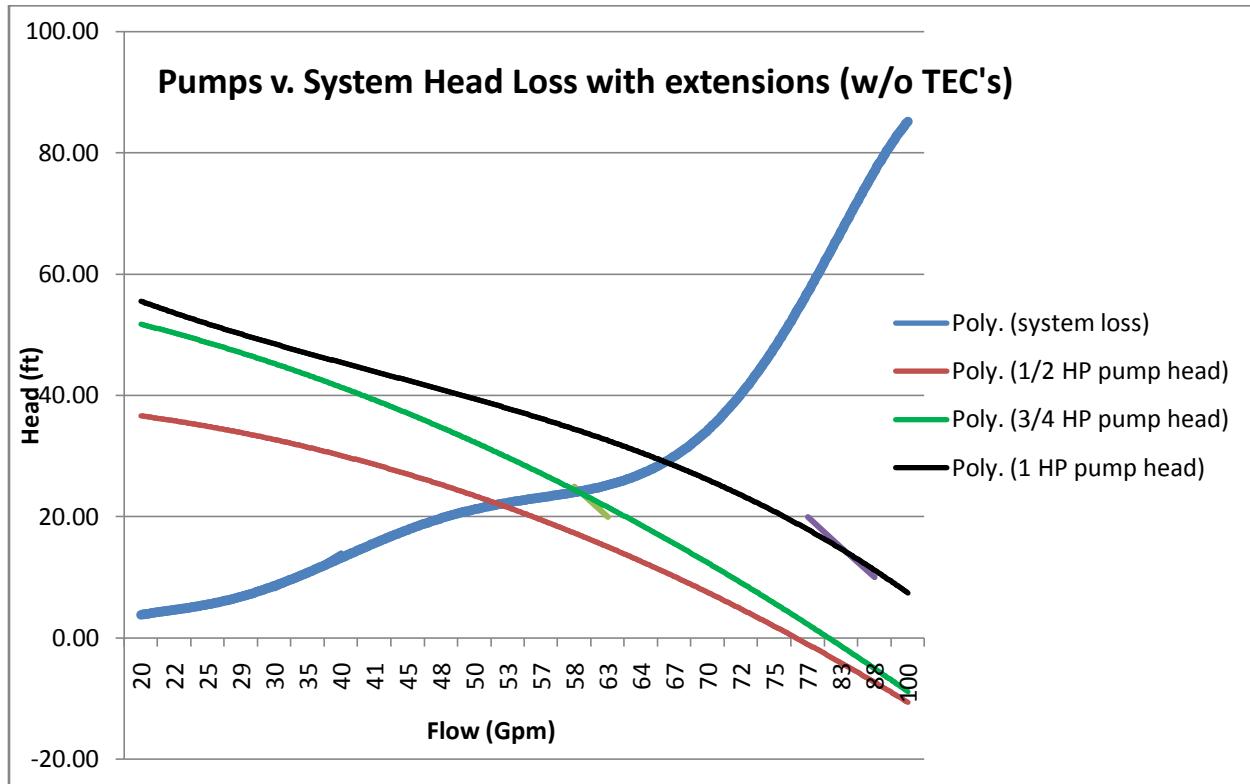
True flow across 387 APD's = 55 Gpm / 387 APD's = 0.142 Gpm per APD

True flow per APD =  $0.142 \text{ Gpm} * 63.09 \text{ } \overline{\text{—}} = \mathbf{8.966} \text{ } \overline{\text{—}}$

-This well within an order of magnitude of the tested value and is acceptable.

-At this flow rate the TEC's require about 6.2 feet of head (see figure 9), which has been accounted for in *Figures 11 and 12*.

*For comparison the flow charts for the system with extensions are shown here, and are also shown prior to the hydraulic analysis for the system.*



*Figure 13: Head loss plotted against flow rate for the system only (thick blue line) without the head of the TEC's factored in.*

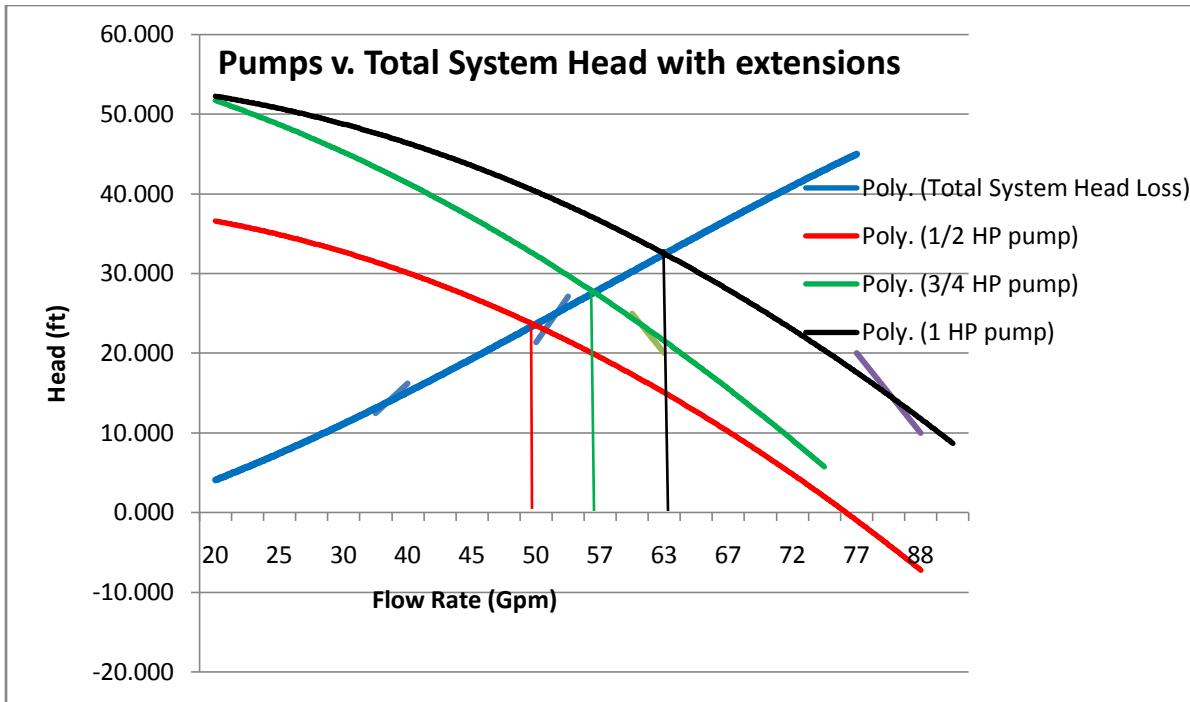


Figure 14: Head loss total of the system (blue line) at different flow rates (including TEC's), with the three other curves being pumps of different horsepower.

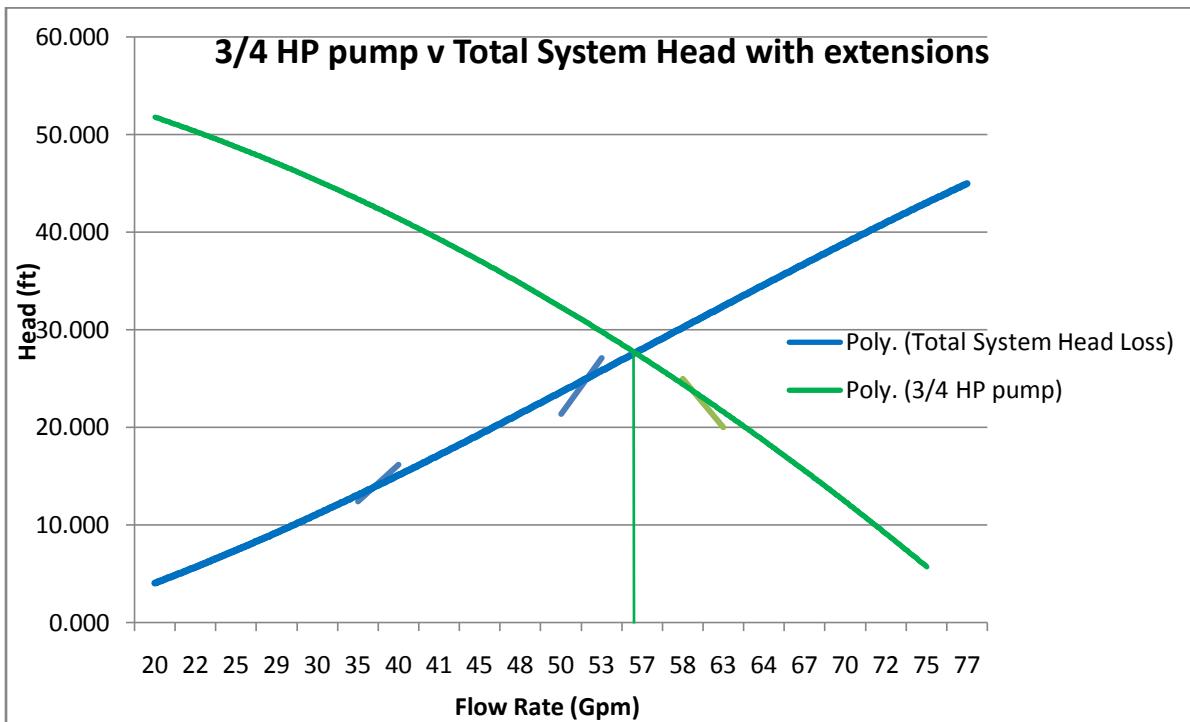


Figure 15: System head loss (including TEC's) is seen to intersect the ¾ HP pump at 54 Gpm with the extensions, and this will be set as the true flow rate of the superblock's chiller system with the extension arms installed.

Tested flow across APD's = 2 — : this is taken as a minimum

True flow of entire system with  $\frac{3}{4}$  HP pump = 54 Gpm

True flow across 497 APD's = 54 Gpm / 497 APD's = 0.109 Gpm per APD

True flow per APD = 0.105 Gpm \* 63.09 — = **6.85** —

-This well within an order of magnitude of the tested value and is acceptable.

-At this flow rate the TEC's require about 3.5 feet of head (see figure 9), which has been accounted for in *Figures* 14 and 15.

## **Pressure loss**

### ***Distribution manifolds***

***\*\*Note:*** There are slightly different length values from the hydraulic equations run and the figures above contributing slightly more pressure loss, but the difference is negligible.

#### **DM1**

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	11.66
	Pressure Loss	psi	0.496
Tee 1 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	49.17
	Pressure Loss	psi	0.329
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.019
	Length	feet	3.958
	Reynolds #	n/a	85299
	Flow Rate	Gpm	43.34
	Pressure Loss	psi	0.37
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.78
	Pressure Loss	psi	0.424
Tee 2 (run only)	Inner Diameter	inches	1.38

	K Factor	n/a	0.44
	Flow Rate	Gpm	37.95
	Pressure Loss	psi	0.196
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	3.958
	Reynolds #	n/a	64028
	Flow Rate	Gpm	32.56
	Pressure Loss	psi	0.226
90° DM1_DM2 elbow	Inner Diameter	inches	1.38
	K Factor	n/a	0.66
	Flow Rate	Gpm	32.56
	Pressure Loss	psi	0.216
Section 3	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	1
	Reynolds #	n/a	64028
	Flow Rate	Gpm	32.56
	Pressure Loss	psi	0.057
Tee 3 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.56
	Pressure Loss	psi	0.407
Tee 3 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44

	Flow Rate	Gpm	27.28
	Pressure Loss	psi	0.101

## DM2

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.67
	Pressure Loss	psi	0.416
Tee 1 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	16.665
	Pressure Loss	psi	0.038
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	5.625
	Reynolds #	n/a	43299
	Flow Rate	Gpm	22
	Pressure Loss	psi	0.161
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.026
	Length	feet	3.958
	Reynolds #	n/a	22299
	Flow Rate	Gpm	11.33
	Pressure Loss	psi	0.035

90° DM2_HM5 elbow	Inner Diameter	inches	0.824
	K Factor	n/a	0.75
	Flow Rate	Gpm	11.33
	Pressure Loss	psi	0.234

### DM3

Component	property	Units	Value
90° DM3_HM1 elbow	Inner Diameter	inches	0.824
	K Factor	n/a	0.75
	Flow Rate	Gpm	11.66
	Pressure Loss	psi	0.248
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.78
	Pressure Loss	psi	0.424
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.026
	Length	feet	3.958
	Reynolds #	n/a	22948
	Flow Rate	Gpm	11.66
	Pressure Loss	psi	0.037
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.78

	Pressure Loss	psi	0.424
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	4.323
	Reynolds #	n/a	44165
	Flow Rate	Gpm	22.44
	Pressure Loss	psi	0.129
90° DM3_DM4 elbow	Inner Diameter	inches	1.38
	K Factor	n/a	0.66
	Flow Rate	Gpm	22.44
	Pressure Loss	psi	0.103
Section 3	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	0.667
	Reynolds #	n/a	44165
	Flow Rate	Gpm	32.56
	Pressure Loss	psi	0.02
Tee 3 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.56
	Pressure Loss	psi	0.407

#### DM4

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824

	K Factor	n/a	1.5
	Flow Rate	Gpm	10.67
	Pressure Loss	psi	0.416
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	5.625
	Reynolds #	n/a	64948
	Flow Rate	Gpm	33
	Pressure Loss	psi	0.33
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.019
	Length	feet	3.958
	Reynolds #	n/a	85948
	Flow Rate	Gpm	43.67
	Pressure Loss	psi	0.376
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	11.33
	Pressure Loss	psi	0.469

### ***Hose Manifold set 1 breakdown***

*Only HM set 1 breakdown will be shown due to space. Within the hose manifolds, there are two values listed, one for the inflow HM, and one for the outflow. These values were used to properly determine the minimum and maximum route pressure losses. \*\*Note: There are slightly different length values from the hydraulic equations run and the figures above contributing slightly more pressure loss, but the difference is negligible.*

### Spacer 1

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
dynamic viscosity	cp	1.162
length	feet	0.588
inner diameter	in.	0.824
flow rate	gpm	11.4
reynolds #	na	37,707.9
friction factor	na	0.0230
pressure loss	psi	0.06278949

### Valve (2)

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
inner diameter	in.	0.824
friction factor	na	0.025
K factor	na	0.075
flow rate (avg)	gpm	11.4
pressure loss	psi	0.02389046
pressure loss total	psi	0.04778093

### Spacer 3

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
dynamic viscosity	cp	1.162
length	feet	0.430
inner diameter	in.	0.824
flow rate	gpm	11.4
reynolds #	na	37,707.9
friction factor	na	0.0230
pressure loss	psi	0.04585110

## HM Sections

A  
section

### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	11.440	0.000
reynolds #	na	37,707.9	0.0
friction factor	na	0.0230	0.0270
pressure loss	psi	0.034418	0.000000

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	11.291	0.149
reynolds #	na	37,218.2	489.7
friction factor	na	0.0230	0.1307
pressure loss	psi	0.033530	0.000033

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	11.143	0.297
reynolds #	na	36,728.5	979.4
friction factor	na	0.0230	0.0653
pressure loss	psi	0.032654	0.000066

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.994	0.446
reynolds #	na	36,238.7	1,469.1
friction factor	na	0.0230	0.0436
pressure loss	psi	0.031789	0.000099

#### HM section 5

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.846	0.594
reynolds #	na	35,749.0	1,958.9
friction factor	na	0.0230	0.0327
pressure loss	psi	0.030935	0.000132

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.697	0.743
reynolds #	na	35,259.3	2,448.6
friction factor	na	0.0230	0.0261
pressure loss	psi	0.030094	0.000165

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.549	0.891
reynolds #	na	34,769.6	2,938.3
friction factor	na	0.0230	0.0218
pressure loss	psi	0.029263	0.000198

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.400	1.040
reynolds #	na	34,279.9	3,428.0
friction factor	na	0.0230	0.0187
pressure loss	psi	0.028445	0.000231

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.251	1.189
reynolds #	na	33,790.2	3,917.7
friction factor	na	0.0230	0.0163
pressure loss	psi	0.027638	0.000264

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.103	1.337
reynolds #	na	33,300.5	4,407.4
friction factor	na	0.0230	0.0420
pressure loss	psi	0.026843	0.000859

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.954	1.486
reynolds #	na	32,810.8	4,897.1
friction factor	na	0.0230	0.0410
pressure loss	psi	0.026059	0.001035

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.806	1.634
reynolds #	na	32,321.0	5,386.8
friction factor	na	0.023	0.041
pressure loss	psi	0.025287	0.001252

HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.657	1.783
reynolds #	na	31,831.3	5,876.6
friction factor	na	0.0230	0.0400
pressure loss	psi	0.024526	0.001454

HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.509	1.931
reynolds #	na	31,341.6	6,366.3
friction factor	na	0.0230	0.0380
pressure loss	psi	0.023778	0.001621

HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.360	2.080
reynolds #	na	30,851.9	6,856.0
friction factor	na	0.0230	0.0380
pressure loss	psi	0.023040	0.001880

**B**

## section

Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	9.211	2.229
reynolds #	na	30,362.2	7,345.7

friction factor	na	0.0230	0.0360
pressure loss	psi	0.020187	0.001849

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.063	2.377
reynolds #	na	29,872.5	7,835.4
friction factor	na	0.0230	0.0360
pressure loss	psi	0.021601	0.002326

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.914	2.526
reynolds #	na	29,382.8	8,325.1
friction factor	na	0.0240	0.0350
pressure loss	psi	0.021807	0.002553

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.766	2.674
reynolds #	na	28,893.1	8,814.8
friction factor	na	0.0240	0.0350
pressure loss	psi	0.021086	0.002862

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824

flow rate	gpm	8.617	2.823
reynolds #	na	28,403.3	9,304.5
friction factor	na	0.0240	0.0350
pressure loss	psi	0.020377	0.003189

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.469	2.971
reynolds #	na	27,913.6	9,794.3
friction factor	na	0.0240	0.0330
pressure loss	psi	0.019681	0.003332

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.320	3.120
reynolds #	na	27,423.9	10,284.0
friction factor	na	0.0240	0.0330
pressure loss	psi	0.018996	0.003673

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.171	3.269
reynolds #	na	26,934.2	10,773.7
friction factor	na	0.0240	0.0330
pressure loss	psi	0.018324	0.004031

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322

inner diameter	in.	0.824	0.824
flow rate	gpm	8.023	3.417
reynolds #	na	26,444.5	11,263.4
friction factor	na	0.0240	0.0320
pressure loss	psi	0.017664	0.004273

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.874	3.566
reynolds #	na	25,954.8	11,753.1
friction factor	na	0.0240	0.0320
pressure loss	psi	0.017015	0.004652

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.726	3.714
reynolds #	na	25,465.1	12,242.8
friction factor	na	0.0240	0.0320
pressure loss	psi	0.016379	0.005048

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.577	3.863
reynolds #	na	24,975.4	12,732.5
friction factor	na	0.0240	0.0310
pressure loss	psi	0.015756	0.005289

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162

length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.429	4.011
reynolds #	na	24,485.6	13,222.2
friction factor	na	0.0240	0.0310
pressure loss	psi	0.015144	0.005704

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.3	4.2
reynolds #	na	23,995.9	13,712.0
friction factor	na	0.024	0.031
pressure loss	psi	0.014544	0.006134

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.131	4.309
reynolds #	na	23,506.2	14,201.7
friction factor	na	0.024	0.029
pressure loss	psi	0.013956	0.006156

#### HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.983	4.457
reynolds #	na	23,016.5	14,691.4
friction factor	na	0.0240	0.0290
pressure loss	psi	0.013381	0.006588

**A**  
section  
Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow			
rate	gpm	6.834	4.606
reynolds #	na	22,526.8	15,181.1
friction factor	na	0.0255	0.0290
pressure loss	psi	0.012320	0.006363

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.686	4.754
reynolds #	na	22,037.1	15,670.8
friction factor	na	0.0255	0.0290
pressure loss	psi	0.013033	0.007495

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.537	4.903
reynolds #	na	21,547.4	16,160.5
friction factor	na	0.0255	0.0290
pressure loss	psi	0.012460	0.007971

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.389	5.051
reynolds #	na	21,057.7	16,650.2
friction factor	na	0.0255	0.0285
pressure loss	psi	0.011900	0.008315

HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.240	5.200
reynolds #	na	20,567.9	17,139.9
friction factor	na	0.0255	0.0285
pressure loss	psi	0.011353	0.008812

HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.091	5.349
reynolds #	na	20,078.2	17,629.7
friction factor	na	0.0255	0.0285
pressure loss	psi	0.010819	0.009322

HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.943	5.497
reynolds #	na	19,588.5	18,119.4
friction factor	na	0.0255	0.0285
pressure loss	psi	0.010298	0.009848

HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.794	5.646
reynolds #	na	19,098.8	18,609.1
friction factor	na	0.0255	0.0285

pressure loss	psi	0.009789	0.010387
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#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.646	5.794
reynolds #	na	18,609.1	19,098.8
friction factor	na	0.0255	0.0285
pressure loss	psi	0.009294	0.010941

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.497	5.943
reynolds #	na	18,119.4	19,588.5
friction factor	na	0.0255	0.0270
pressure loss	psi	0.008811	0.010903

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.349	6.091
reynolds #	na	17,629.7	20,078.2
friction factor	na	0.0255	0.0270
pressure loss	psi	0.008341	0.011455

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.200	6.240
reynolds #	na	17,139.9	20,567.9

friction factor	na	0.0255	0.0270
pressure loss	psi	0.007884	0.012021

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.051	6.389
reynolds #	na	16,650.2	21,057.7
friction factor	na	0.0255	0.0270
pressure loss	psi	0.007440	0.012600

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.903	6.537
reynolds #	na	16,160.5	21,547.4
friction factor	na	0.0255	0.0270
pressure loss	psi	0.007009	0.013193

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.754	6.686
reynolds #	na	15,670.8	22,037.1
friction factor	na	0.0265	0.0270
pressure loss	psi	0.006849	0.013800

#### B section Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333

inner diameter	in.	0.824	0.824
flow rate	gpm	4.606	6.834
reynolds #	na	15,181.1	22,526.8
friction factor	na	0.0265	0.0270
pressure loss	psi	0.005815	0.013045

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.457	6.983
reynolds #	na	14,691.4	23,016.5
friction factor	na	0.0265	0.0270
pressure loss	psi	0.006020	0.015054

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.309	7.131
reynolds #	na	14,201.7	23,506.2
friction factor	na	0.0265	0.0270
pressure loss	psi	0.005625	0.015701

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.160	7.280
reynolds #	na	13,712.0	23,995.9
friction factor	na	0.0265	0.0265
pressure loss	psi	0.005244	0.016059

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162

length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.011	7.429
reynolds #	na	13,222.2	24,485.6
friction factor	na	0.0265	0.0265
pressure loss	psi	0.004876	0.016721

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.863	7.577
reynolds #	na	12,732.5	24,975.4
friction factor	na	0.0270	0.0265
pressure loss	psi	0.004607	0.017397

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.714	7.726
reynolds #	na	12,242.8	25,465.1
friction factor	na	0.0270	0.0265
pressure loss	psi	0.004259	0.018086

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.566	7.874
reynolds #	na	11,753.1	25,954.8
friction factor	na	0.0270	0.0265
pressure loss	psi	0.003925	0.018788

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.417	8.023
reynolds #	na	11,263.4	26,444.5
friction factor	na	0.0270	0.0255
pressure loss	psi	0.003605	0.018768

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.269	8.171
reynolds #	na	10,773.7	26,934.2
friction factor	na	0.0270	0.0255
pressure loss	psi	0.003298	0.019469

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.120	8.320
reynolds #	na	10,284.0	27,423.9
friction factor	na	0.0270	0.0255
pressure loss	psi	0.003005	0.020184

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.971	8.469
reynolds #	na	9,794.3	27,913.6
friction factor	na	0.0270	0.0255
pressure loss	psi	0.002726	0.020911

#### HM section 12

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.823	8.617
reynolds #	na	9,304.5	28,403.3
friction factor	na	0.0270	0.0255
pressure loss	psi	0.002460	0.021651

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.674	8.766
reynolds #	na	8,814.8	28,893.1
friction factor	na	0.0270	0.0255
pressure loss	psi	0.002208	0.022404

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.526	8.914
reynolds #	na	8,325.1	29,382.8
friction factor	na	0.0285	0.0255
pressure loss	psi	0.002079	0.023170

#### HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.377	9.063
reynolds #	na	7,835.4	29,872.5
friction factor	na	0.0285	0.0255
pressure loss	psi	0.001841	0.023949

**A**  
**section**  
Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	2.229	9.211
reynolds #	na	7,345.7	30,362.2
friction factor	na	0.0285	0.0255
pressure loss	psi	0.001464	0.022381

HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.080	9.360
reynolds #	na	6,856.0	30,851.9
friction factor	na	0.0285	0.0255
pressure loss	psi	0.001410	0.025545

HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.931	9.509
reynolds #	na	6,366.3	31,341.6
friction factor	na	0.0285	0.0255
pressure loss	psi	0.001216	0.026362

HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.783	9.657
reynolds #	na	5,876.6	31,831.3

friction factor	na	0.0285	0.0255
pressure loss	psi	0.001036	0.027192

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.634	9.806
reynolds #	na	5,386.8	32,321.0
friction factor	na	0.0285	0.0255
pressure loss	psi	0.000870	0.028036

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.486	9.954
reynolds #	na	4,897.1	32,810.8
friction factor	na	0.0290	0.0255
pressure loss	psi	0.000732	0.028892

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.337	10.103
reynolds #	na	4,407.4	33,300.5
friction factor	na	0.0290	0.0240
pressure loss	psi	0.000593	0.028010

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.189	10.251

reynolds #	na	3,917.7	33,790.2
friction factor	na	0.0290	0.0240
pressure loss	psi	0.000468	0.028840

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.040	10.400
reynolds #	na	3,428.0	34,279.9
friction factor	na	0.0290	0.0240
pressure loss	psi	0.000359	0.029682

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.891	10.549
reynolds #	na	2,938.3	34,769.6
friction factor	na	0.0310	0.0240
pressure loss	psi	0.000282	0.030536

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.743	10.697
reynolds #	na	2,448.6	35,259.3
friction factor	na	0.0310	0.0240
pressure loss	psi	0.000196	0.031402

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824

flow rate	gpm	0.594	10.846
reynolds #	na	1,958.9	35,749.0
friction factor	na	0.0310	0.0240
pressure loss	psi	0.000125	0.032280

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.446	10.994
reynolds #	na	1,469.1	36,238.7
friction factor	na	0.0320	0.0240
pressure loss	psi	0.000073	0.033171

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.297	11.143
reynolds #	na	979.4	36,728.5
friction factor	na	0.0320	0.0240
pressure loss	psi	0.000032	0.034073

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.149	11.291
reynolds #	na	489.7	37,218.2
friction factor	na	0.0320	0.0240
pressure loss	psi	0.000008	0.034988

## Fittings

A

**section**Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	11.440	0.000
pressure loss	psi	0.159270	0.000000

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	11.291	0.149
pressure loss	psi	0.155160	0.000027

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	11.143	0.297
pressure loss	psi	0.151103	0.000107

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.994	0.446
pressure loss	psi	0.147101	0.000242

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.846	0.594
pressure loss	psi	0.143152	0.000430

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.697	0.743
pressure loss	psi	0.139257	0.000672

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.549	0.891
pressure loss	psi	0.135416	0.000967

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.400	1.040
pressure loss	psi	0.131628	0.001316

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.251	1.189
pressure loss	psi	0.127894	0.001719

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.103	1.337
pressure loss	psi	0.124214	0.002176

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.954	1.486
pressure loss	psi	0.120587	0.002686

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.806	1.634

pressure loss	psi	0.117015	0.003250
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Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.657	1.783
pressure loss	psi	0.113495	0.003868

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.509	1.931
pressure loss	psi	0.110030	0.004540

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.360	2.080
pressure loss	psi	0.106619	0.005265

**B**  
**section**

Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
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density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.211	2.229
pressure loss	psi	0.103261	0.006044

#### Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.063	2.377
pressure loss	psi	0.099957	0.006877

#### Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.914	2.526
pressure loss	psi	0.096706	0.007763

#### Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.766	2.674
pressure loss	psi	0.093510	0.008704

#### Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.617	2.823
pressure loss	psi	0.090367	0.009697

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.469	2.971
pressure loss	psi	0.087277	0.010745

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.320	3.120
pressure loss	psi	0.084242	0.011847

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.171	3.269
pressure loss	psi	0.081260	0.013002

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.023	3.417
pressure loss	psi	0.078332	0.014210

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.874	3.566
pressure loss	psi	0.075458	0.015473

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.726	3.714
pressure loss	psi	0.072637	0.016789

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.577	3.863
pressure loss	psi	0.069870	0.018159

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.429	4.011
pressure loss	psi	0.067157	0.019583

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.280	4.160
pressure loss	psi	0.064498	0.021060

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.131	4.309
pressure loss	psi	0.061892	0.022592

Tee 16 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.983	4.457
pressure loss	psi	0.059340	0.024177

**A**  
**section**

Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.834	4.606
pressure loss	psi	0.056842	0.025815

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.686	4.754
pressure loss	psi	0.054397	0.027508

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.537	4.903
pressure loss	psi	0.052006	0.029254

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500

flow rate (avg)	gpm	6.389	5.051
pressure loss	psi	0.049669	0.031053

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.240	5.200
pressure loss	psi	0.047386	0.032907

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.091	5.349
pressure loss	psi	0.045156	0.034814

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.943	5.497
pressure loss	psi	0.042981	0.036775

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025

K factor	na	0.500	0.500
flow rate (avg)	gpm	5.794	5.646
pressure loss	psi	0.040858	0.038790

#### Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.646	5.794
pressure loss	psi	0.038790	0.040858

#### Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.497	5.943
pressure loss	psi	0.036775	0.042981

#### Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.349	6.091
pressure loss	psi	0.034814	0.045156

#### Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824

friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.200	6.240
pressure loss	psi	0.032907	0.047386

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.051	6.389
pressure loss	psi	0.031053	0.049669

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.903	6.537
pressure loss	psi	0.029254	0.052006

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.754	6.686
pressure loss	psi	0.027508	0.054397

**B**  
**section**

Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.606	6.834
pressure loss	psi	0.025815	0.056842

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.457	6.983
pressure loss	psi	0.024177	0.059340

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.309	7.131
pressure loss	psi	0.022592	0.061892

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.160	7.280
pressure loss	psi	0.021060	0.064498

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.011	7.429
pressure loss	psi	0.019583	0.067157

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.863	7.577
pressure loss	psi	0.018159	0.069870

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.714	7.726
pressure loss	psi	0.016789	0.072637

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.566	7.874
pressure loss	psi	0.015473	0.075458

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.417	8.023
pressure loss	psi	0.014210	0.078332

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.269	8.171
pressure loss	psi	0.013002	0.081260

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.120	8.320
pressure loss	psi	0.011847	0.084242

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.971	8.469
pressure loss	psi	0.010745	0.087277

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.823	8.617
pressure loss	psi	0.009697	0.090367

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.674	8.766
pressure loss	psi	0.008704	0.093510

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.526	8.914
pressure loss	psi	0.007763	0.096706

Tee 16 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.377	9.063

pressure loss	psi	0.006877	0.099957
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## A

### section

#### Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.229	9.211
pressure loss	psi	0.006044	0.103261

#### Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.080	9.360
pressure loss	psi	0.005265	0.106619

#### Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.931	9.509
pressure loss	psi	0.004540	0.110030

#### Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824

friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.783	9.657
pressure loss	psi	0.003868	0.113495

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.634	9.806
pressure loss	psi	0.003	0.117015

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.486	9.954
pressure loss	psi	0.002686	0.120587

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.337	10.103
pressure loss	psi	0.002176	0.124214

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.189	10.251
pressure loss	psi	0.001719	0.127894

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.040	10.400
pressure loss	psi	0.001316	0.131628

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.891	10.549
pressure loss	psi	0.000967	0.135416

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.743	10.697
pressure loss	psi	0.000672	0.139257

Tee 12 (run only)

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.594	10.846
pressure loss	psi	0.000430	0.143152

#### Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.446	10.994
pressure loss	psi	0.000242	0.147101

#### Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.297	11.143
pressure loss	psi	0.000107	0.151103

#### Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.149	11.291
pressure loss	psi	0.000027	0.155160

#### Hose (2)

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
dynamic viscosity	cp	1.162
length	feet	1.500
inner diameter	in.	0.125
flow rate	gpm	0.151
reynolds #	na	3,290.3
friction factor	na	0.0195
pressure loss	psi	0.2953577
pressure loss total	psi	0.59071550

#### Tee (branch only) (2)

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
inner diameter	in.	0.500
friction factor	na	0.027
K factor	na	0.540
flow rate (avg)	gpm	0.2
pressure loss	psi	0.00022231
pressure loss total	psi	0.00044461

#### Pressure Loss Total HM set 1 by Route-77 total possibilities (psi)

route	pressure loss total (psi)	HM 1 % dP difference(min/max)	
1	6.13001349 min		46.879
2	6.31229138		
3	6.51671063	HM 1 % flow difference (min/max)	
4	6.70219470		6.847
5	6.88246114		
---			
37	9.86429916	Average pressure loss through HM set 1	
38	9.88195686		7.38117051
39	9.88348461 max		
40	9.87962463		
41	9.87100462	HM 1 entering flow (GPM)	
42	9.85702559		11.660
---			
76	6.44157787		
77	6.24935559		

**Full route pressure losses (using average pressure loss from each HM set)**

<u>route</u>	<u>pressure loss (psi)</u>	<u>full route % dP difference(min/max)</u>
1	9.65576041	0.945
2	9.74743109	
3	9.72857619	average pressure loss (psi)
4	9.69156999	9.699
5	9.67394764	average head loss (w/o TEC) (ft)
		22.393

Largest HM entering flow (gpm)	11.440	(HM1)	
Largest HM route pressure loss (psi)	9.525	(route 39)	individual HM route only, largest pressure loss % difference
			58.260
Smallest HM entering flow( gpm)	10.615	(HM3)	individual HM route only, largest flow rate % difference
Smallest HM route pressure loss (psi)	5.228	(route 1)	7.633

Total head loss including TEC = 22.393 ft (sys) + 6.2 ft (TEC @ 55 Gpm) = **28.593 ft**

Total pressure loss including TEC = 9.69 psi (sys) + 2.569 psi (TEC @ 55 Gpm) = **12.259 psi**

This set of full route pressure losses was used to determine the true flow rate entering each hose manifold, by doing iterations until the pressure drops across each route were nearly identical.

**Full route pressure losses (using individual max/min HM routes)**

	<u>route</u>	pressure loss (psi)	head loss (ft)
max	1 (HM1 route 39)	12.065	27.854
min	1 (HM1 route 1)	8.566	19.777
max	2 (HM2 route 39)	11.930	27.543
min	2 (HM2 route 1)	8.760	20.225
max	3 (HM3 route 39)	11.802	27.249
min	3 (HM3 route 1)	8.790	20.295
max	4 (HM4 route 39)	11.837	27.328
min	4 (HM4 route 1)	8.715	20.119
max	5 (HM5 route 39)	12.068	27.862
min	5 (HM5 route 1)	8.584	19.817

max pressure loss (psi)-route 1 HM route 39

12.068

min pressure loss (psi)-route 1 HM route 1

8.566

largest route % pressure loss difference

33.943

largest full route % flow rate difference

5.826

## Superblock System with Extensions Hydraulic analysis

Below is the same analysis performed above, but routes and pressure drops have been recalculated with the extra A or B section and muon catcher sections.

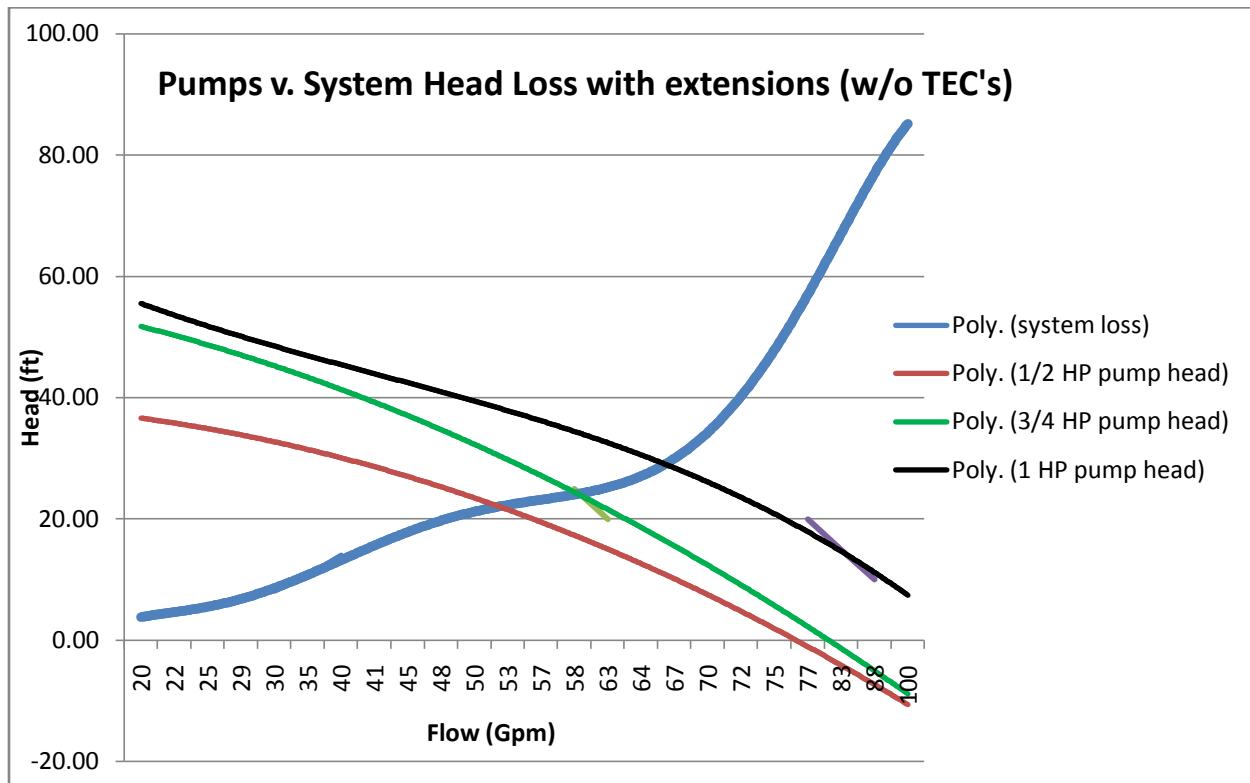


Figure 13: Head loss plotted against flow rate for the system only (thick blue line) without the head of the TEC's factored in.

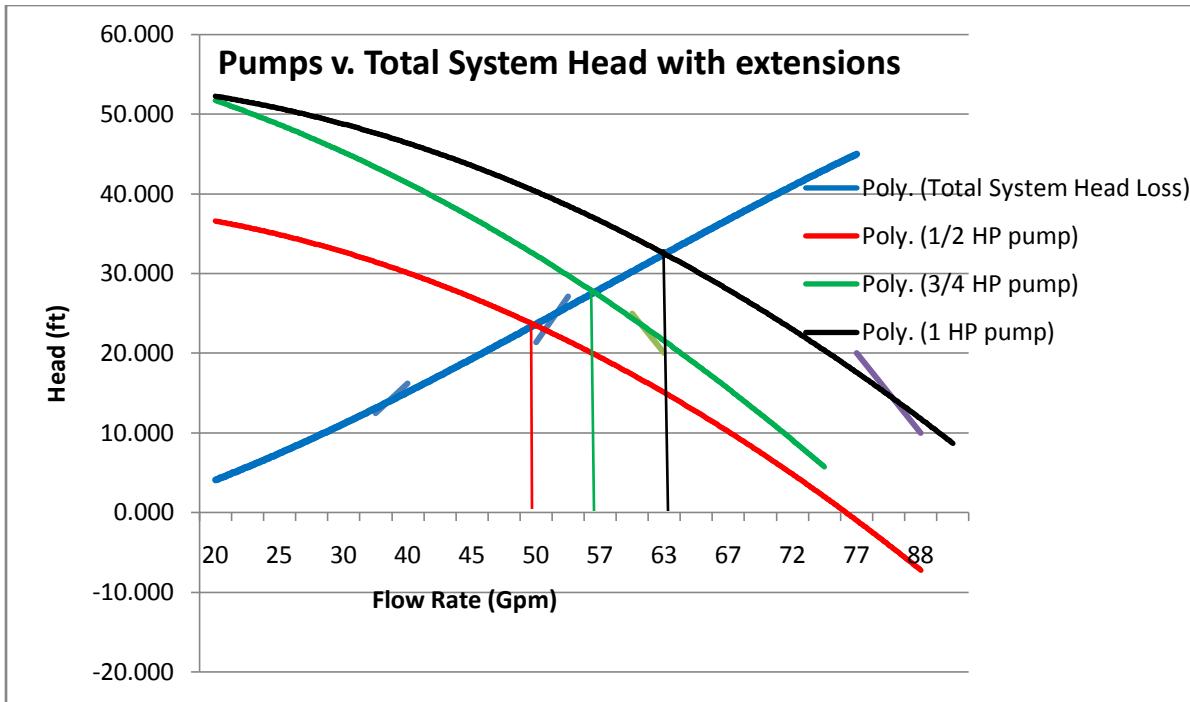


Figure 14: Head loss total of the system at different flow rates (including TEC's), with the three others being pumps of different horsepower.

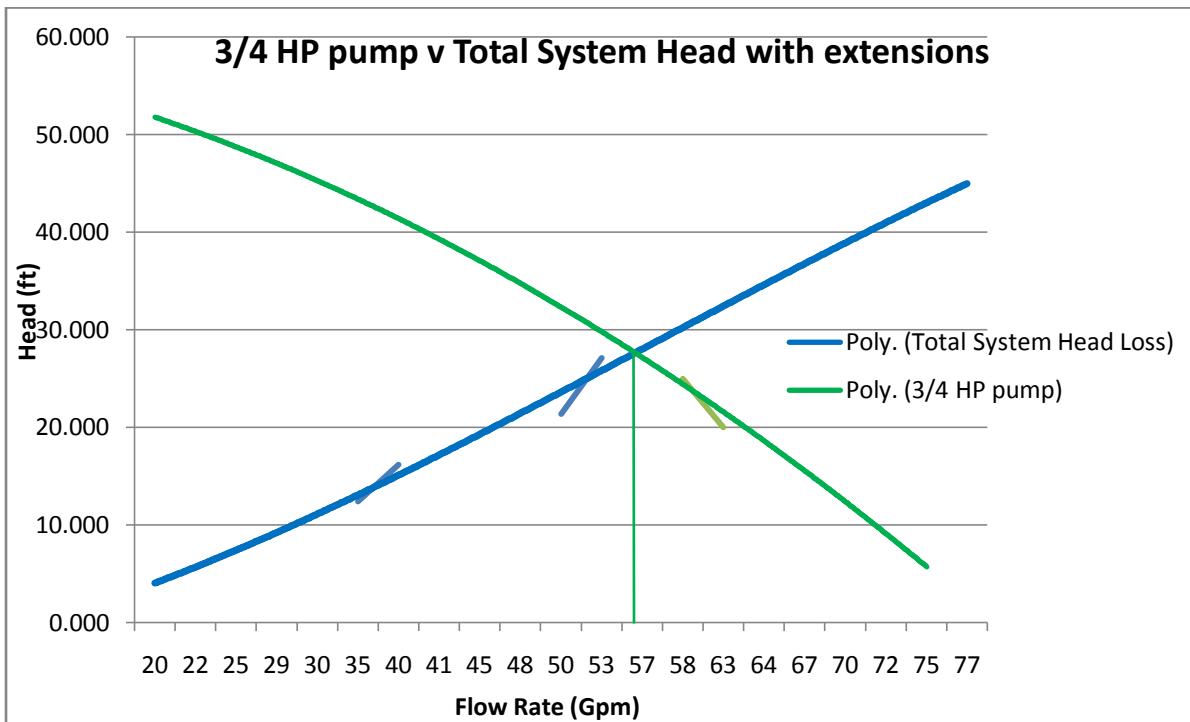


Figure 15: System head loss (including TEC's) is seen to intersect the 3/4 HP pump at 54 Gpm with the extensions, and this will be set as the true flow rate of the superblock's chiller system with the extension arms installed.

Tested flow across APD's = 2 — : this is taken as a minimum

True flow of entire system with ¾ HP pump = 54 Gpm

True flow across 497 APD's = 54 Gpm / 497 APD's = 0.109 Gpm per APD

True flow per APD = 0.105 Gpm \* 63.09 — = **6.85 —**

-This well within an order of magnitude of the tested value and is acceptable.

-At this flow rate the TEC's require about 3.5 feet of head (see figure 9), which has been added in *Figures* 14 and 15.

### Pressure loss (with extensions)

#### *Distribution manifolds*

**\*\*Note:** There are slightly different length values from the hydraulic equations run and the figures above contributing slightly more pressure loss, but the difference is negligible.

DM1

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.452
Tee 1 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	48.4
	Pressure Loss	psi	0.319
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.0185

	Length	feet	3.958
	Reynolds #	n/a	84385
	Flow Rate	Gpm	42.9
	Pressure Loss	psi	0.362
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.7
	Pressure Loss	psi	0.416
Tee 2 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	37.5
	Pressure Loss	psi	0.192
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	3.958
	Reynolds #	n/a	63384
	Flow Rate	Gpm	32.2
	Pressure Loss	psi	0.221
90° DM1_DM2 elbow	Inner Diameter	inches	1.38
	K Factor	n/a	0.66
	Flow Rate	Gpm	32.2
	Pressure Loss	psi	0.212
Section 3	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	1

	Reynolds #	n/a	63385
	Flow Rate	Gpm	32.2
	Pressure Loss	psi	0.056
Tee 3 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.5
	Pressure Loss	psi	0.405
Tee 3 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	26.9
	Pressure Loss	psi	0.099

## DM2

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.6
	Pressure Loss	psi	0.409
Tee 1 (run only)	Inner Diameter	inches	1.38
	K Factor	n/a	0.44
	Flow Rate	Gpm	16.4
	Pressure Loss	psi	0.037
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	5.625

	Reynolds #	n/a	42664
	Flow Rate	Gpm	21.7
	Pressure Loss	psi	0.157
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.0255
	Length	feet	3.958
	Reynolds #	n/a	21830
	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.033
90° DM2_HM5 elbow	Inner Diameter	inches	0.824
	K Factor	n/a	0.75
	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.225

### DM3

Component	property	Units	Value
90° DM3_HM1 elbow	Inner Diameter	inches	0.824
	K Factor	n/a	0.75
	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.226
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.7
	Pressure Loss	psi	0.416
Section 1	Inner Diameter	inches	1.38

	Friction Factor	n/a	0.026
	Length	feet	3.958
	Reynolds #	n/a	21894
	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.034
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.5
	Pressure Loss	psi	0.356
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	4.323
	Reynolds #	n/a	42894
	Flow Rate	Gpm	21.8
	Pressure Loss	psi	0.122
90° DM3_DM4 elbow	Inner Diameter	inches	1.38
	K Factor	n/a	0.66
	Flow Rate	Gpm	21.8
	Pressure Loss	psi	0.097
Section 3	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.022
	Length	feet	0.667
	Reynolds #	n/a	42894
	Flow Rate	Gpm	21.8
	Pressure Loss	psi	0.019

Tee 3 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.5
	Pressure Loss	psi	0.356

#### DM4

Component	property	Units	Value
Tee 1 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5
	Flow Rate	Gpm	10.6
	Pressure Loss	psi	0.409
Section 1	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.02
	Length	feet	5.625
	Reynolds #	n/a	63619
	Flow Rate	Gpm	32.2
	Pressure Loss	psi	0.316
Section 2	Inner Diameter	inches	1.38
	Friction Factor	n/a	0.019
	Length	feet	3.958
	Reynolds #	n/a	84849
	Flow Rate	Gpm	42.9
	Pressure Loss	psi	0.363
Tee 2 (branch only)	Inner Diameter	inches	0.824
	K Factor	n/a	1.5

	Flow Rate	Gpm	11.1
	Pressure Loss	psi	0.449

### ***Hose Manifold set 1 breakdown with extensions***

*Only HM set 1 with extensions breakdown will be shown due to space. Within the hose manifolds, there are two values listed, one for the inflow HM, and one for the outflow. These values were used to properly determine the minimum and maximum route pressure losses.*

**\*\*Note:** There are slightly different length values from the hydraulic equations run and the figures above contributing slightly more pressure loss, but the difference is negligible.

#### Spacer 1

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
dynamic viscosity	cp	1.162
length	feet	0.588
inner diameter	in.	0.824
flow rate	gpm	11.1
reynolds #	na	36,666.3
friction factor	na	0.0230
pressure loss	psi	0.05936861

#### Valve (2)

	<u>units</u>	<u>value</u>
density	lbs/ft^3	62.372
inner diameter	in.	0.824
friction factor	na	0.025
K factor	na	0.075
flow rate	gpm	11.1
pressure loss	psi	0.02258887
pressure loss total	psi	0.04517774

#### Spacer 3

<u>units</u>	<u>value</u>
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density	lbs/ft^3	62.372
dynamic viscosity	cp	1.162
length	feet	0.430
inner diameter	in.	0.824
flow rate	gpm	11.1
reynolds #	na	36,666.3
friction factor	na	0.0230
pressure loss	psi	0.04335305

## HM Sections

**A**

**section**

### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	11.124	0.000
reynolds #	na	36,666.3	0.0
friction factor	na	0.0230	0.0270
pressure loss	psi	0.032543	0.000000

### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	11.012	0.112
reynolds #	na	36,295.9	370.4
friction factor	na	0.0230	0.1728
pressure loss	psi	0.031889	0.000025

### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.899	0.225

reynolds #	na	35,925.6	740.733
friction factor	na	0.0230	0.0864
pressure loss	psi	0.031242	0.000050

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.787	0.337
reynolds #	na	35,555.2	1,111.1
friction factor	na	0.0230	0.0576
pressure loss	psi	0.030601	0.000075

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.675	0.449
reynolds #	na	35,184.8	1,481.5
friction factor	na	0.0230	0.0432
pressure loss	psi	0.029967	0.000100

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.562	0.562
reynolds #	na	34,814.5	1,851.8
friction factor	na	0.0230	0.0346
pressure loss	psi	0.029339	0.000125

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824

flow rate	gpm	10.450	0.674
reynolds #	na	34,444.1	2,222.2
friction factor	na	0.0230	0.0288
pressure loss	psi	0.028718	0.000150

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.337	0.787
reynolds #	na	34,073.7	2,592.6
friction factor	na	0.0230	0.0247
pressure loss	psi	0.028104	0.000175

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.225	0.899
reynolds #	na	33,703.4	2,962.9
friction factor	na	0.0230	0.0216
pressure loss	psi	0.027496	0.000200

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	10.113	1.011
reynolds #	na	33,333.0	3,333.3
friction factor	na	0.0230	0.0420
pressure loss	psi	0.026895	0.000491

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322

inner diameter	in.	0.824	0.824
flow rate	gpm	10.000	1.124
reynolds #	na	32,962.6	3,703.7
friction factor	na	0.0230	0.0410
pressure loss	psi	0.026301	0.000592

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.888	1.236
reynolds #	na	32,592.3	4,074.0
friction factor	na	0.0230	0.0410
pressure loss	psi	0.025713	0.000716

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.776	1.348
reynolds #	na	32,221.9	4,444.4
friction factor	na	0.0230	0.0400
pressure loss	psi	0.025132	0.000832

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.663	1.461
reynolds #	na	31,851.5	4,814.8
friction factor	na	0.0230	0.0380
pressure loss	psi	0.024558	0.000927

#### HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162

length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.551	1.573
reynolds #	na	31,481.2	5,185.1
friction factor	na	0.0230	0.0380
pressure loss	psi	0.023990	0.001075

**B**  
**section**  
Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	9.439	1.685
reynolds #	na	31,110.8	5,555.5
friction factor	na	0.0230	0.0360
pressure loss	psi	0.021195	0.001058

HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.326	1.798
reynolds #	na	30,740.4	5,925.9
friction factor	na	0.0230	0.0360
pressure loss	psi	0.022874	0.001330

HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	9.214	1.910
reynolds #	na	30,370.1	6,296.2
friction factor	na	0.0240	0.0350
pressure loss	psi	0.023297	0.001460

HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow			
rate	gpm	9.101	2.023
reynolds #	na	29,999.7	6,666.6
friction factor	na	0.0240	0.0350
pressure loss	psi	0.022732	0.001637

HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.989	2.135
reynolds #	na	29,629.3	7,037.0
friction factor	na	0.0240	0.0350
pressure loss	psi	0.022174	0.001824

HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.877	2.247
reynolds #	na	29,259.0	7,407.3
friction factor	na	0.0240	0.0330
pressure loss	psi	0.021624	0.001906

HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.764	2.360
reynolds #	na	28,888.6	7,777.7
friction factor	na	0.0240	0.0330

pressure loss	psi	0.021080	0.002101
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#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.652	2.472
reynolds #	na	28,518.2	8,148.1
friction factor	na	0.0240	0.0330
pressure loss	psi	0.020543	0.002306

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.540	2.584
reynolds #	na	28,147.9	8,518.4
friction factor	na	0.0240	0.0320
pressure loss	psi	0.020012	0.002444

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.427	2.697
reynolds #	na	27,777.5	8,888.8
friction factor	na	0.0240	0.0320
pressure loss	psi	0.019489	0.002661

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.315	2.809
reynolds #	na	27,407.1	9,259.2

friction factor	na	0.0240	0.0320
pressure loss	psi	0.018973	0.002887

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.203	2.921
reynolds #	na	27,036.8	9,629.5
friction factor	na	0.0240	0.0310
pressure loss	psi	0.018464	0.003025

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	8.090	3.034
reynolds #	na	26,666.4	9,999.9
friction factor	na	0.0240	0.0310
pressure loss	psi	0.017961	0.003263

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.978	3.146
reynolds #	na	26,296.0	10,370.3
friction factor	na	0.0240	0.0310
pressure loss	psi	0.017466	0.003509

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.865	3.259

reynolds #	na	25,925.7	10,740.6
friction factor	na	0.0240	0.0290
pressure loss	psi	0.016977	0.003521

#### HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.753	3.371
reynolds #	na	25,555.3	11,111.0
friction factor	na	0.0240	0.0290
pressure loss	psi	0.016496	0.003768

#### A section

Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	7.641	3.483
reynolds #	na	25,184.9	11,481.4
friction factor	na	0.0255	0.0290
pressure loss	psi	0.015399	0.003640

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.528	3.596
reynolds #	na	24,814.6	11,851.7
friction factor	na	0.0255	0.0290
pressure loss	psi	0.016525	0.004287

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162

length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.416	3.708
reynolds #	na	24,444.2	12,222.1
friction factor	na	0.0255	0.0290
pressure loss	psi	0.016036	0.004559

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.304	3.820
reynolds #	na	24,073.8	12,592.5
friction factor	na	0.0255	0.0285
pressure loss	psi	0.015554	0.004756

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.191	3.933
reynolds #	na	23,703.5	12,962.8
friction factor	na	0.0255	0.0285
pressure loss	psi	0.015079	0.005040

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	7.079	4.045
reynolds #	na	23,333.1	13,333.2
friction factor	na	0.0255	0.0285
pressure loss	psi	0.014611	0.005332

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.967	4.157
reynolds #	na	22,962.7	13,703.6
friction factor	na	0.0255	0.0285
pressure loss	psi	0.014151	0.005633

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.854	4.270
reynolds #	na	22,592.4	14,073.9
friction factor	na	0.0255	0.0285
pressure loss	psi	0.013698	0.005941

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.742	4.382
reynolds #	na	22,222.0	14,444.3
friction factor	na	0.0255	0.0285
pressure loss	psi	0.013253	0.006258

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.629	4.495
reynolds #	na	21,851.6	14,814.7
friction factor	na	0.0255	0.0270
pressure loss	psi	0.012815	0.006237

#### HM section 10

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.517	4.607
reynolds #	na	21,481.3	15,185.0
friction factor	na	0.0255	0.0270
pressure loss	psi	0.012384	0.006552

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.405	4.719
reynolds #	na	21,110.9	15,555.4
friction factor	na	0.0255	0.0270
pressure loss	psi	0.011961	0.006876

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.292	4.832
reynolds #	na	20,740.5	15,925.8
friction factor	na	0.0255	0.0270
pressure loss	psi	0.011545	0.007207

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.180	4.944
reynolds #	na	20,370.2	16,296.1
friction factor	na	0.0255	0.0270
pressure loss	psi	0.011136	0.007546

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	6.068	5.056
reynolds #	na	19,999.8	16,666.5
friction factor	na	0.0265	0.0270
pressure loss	psi	0.011156	0.007893

**B**  
**section**  
Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	5.955	5.169
reynolds #	na	19,629.4	17,036.9
friction factor	na	0.0265	0.0270
pressure loss	psi	0.009722	0.007461

HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.843	5.281
reynolds #	na	19,259.1	17,407.2
friction factor	na	0.0265	0.0270
pressure loss	psi	0.010345	0.008610

HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.731	5.393
reynolds #	na	18,888.7	17,777.6
friction factor	na	0.0265	0.0270

pressure loss	psi	0.009951	0.008981
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#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft <sup>3</sup>	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.618	5.506
reynolds #	na	18,518.3	18,148.0
friction factor	na	0.0265	0.0265
pressure loss	psi	0.009564	0.009185

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft <sup>3</sup>	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.506	5.618
reynolds #	na	18,148.0	18,518.3
friction factor	na	0.0265	0.0265
pressure loss	psi	0.009185	0.009564

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft <sup>3</sup>	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.393	5.731
reynolds #	na	17,777.6	18,888.7
friction factor	na	0.0270	0.0265
pressure loss	psi	0.008981	0.009951

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft <sup>3</sup>	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.281	5.843
reynolds #	na	17,407.2	19,259.1

friction factor	na	0.0270	0.0265
pressure loss	psi	0.008610	0.010345

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.169	5.955
reynolds #	na	17,036.9	19,629.4
friction factor	na	0.0270	0.0265
pressure loss	psi	0.008248	0.010746

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	5.056	6.068
reynolds #	na	16,666.5	19,999.8
friction factor	na	0.0270	0.0255
pressure loss	psi	0.007893	0.010735

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.944	6.180
reynolds #	na	16,296.1	20,370.2
friction factor	na	0.0270	0.0255
pressure loss	psi	0.007546	0.011136

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.832	6.292

reynolds #	na	15,925.8	20,740.5
friction factor	na	0.0270	0.0255
pressure loss	psi	0.007207	0.011545

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.719	6.405
reynolds #	na	15,555.4	21,110.9
friction factor	na	0.0270	0.0255
pressure loss	psi	0.006876	0.011961

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.607	6.517
reynolds #	na	15,185.0	21,481.3
friction factor	na	0.0270	0.0255
pressure loss	psi	0.006552	0.012384

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.495	6.629
reynolds #	na	14,814.7	21,851.6
friction factor	na	0.0270	0.0255
pressure loss	psi	0.006237	0.012815

#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824

flow rate	gpm	4.382	6.742
reynolds #	na	14,444.3	22,222.0
friction factor	na	0.0285	0.0255
pressure loss	psi	0.006258	0.013253

#### HM section 15

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.270	6.854
reynolds #	na	14,073.9	22,592.4
friction factor	na	0.0285	0.0255
pressure loss	psi	0.005941	0.013698

#### A section Spacer

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.333	0.333
inner diameter	in.	0.824	0.824
flow rate	gpm	4.157	6.967
reynolds #	na	13,703.6	22,962.7
friction factor	na	0.0285	0.0255
pressure loss	psi	0.005096	0.012802

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	4.045	7.079
reynolds #	na	13,333.2	23,333.1
friction factor	na	0.0285	0.0255
pressure loss	psi	0.005332	0.014611

#### HM section 2

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.933	7.191
reynolds #	na	12,962.8	23,703.5
friction factor	na	0.0285	0.0255
pressure loss	psi	0.005040	0.015079

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.820	7.304
reynolds #	na	12,592.5	24,073.8
friction factor	na	0.0285	0.0255
pressure loss	psi	0.004756	0.015554

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.708	7.416
reynolds #	na	12,222.1	24,444.2
friction factor	na	0.0285	0.0255
pressure loss	psi	0.004481	0.016036

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.596	7.528
reynolds #	na	11,851.7	24,814.6
friction factor	na	0.0290	0.0255
pressure loss	psi	0.004287	0.016525

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow			
rate	gpm	3.483	7.641
reynolds #	na	11,481.4	25,184.9
friction factor	na	0.0290	0.0240
pressure loss	psi	0.004023	0.016021

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.371	7.753
reynolds #	na	11,111.0	25,555.3
friction factor	na	0.0290	0.0240
pressure loss	psi	0.003768	0.016496

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.259	7.865
reynolds #	na	10,740.6	25,925.7
friction factor	na	0.0290	0.0240
pressure loss	psi	0.003521	0.016977

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.146	7.978
reynolds #	na	10,370.3	26,296.0
friction factor	na	0.0310	0.0240
pressure loss	psi	0.003509	0.017466

HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	3.034	8.090
reynolds #	na	9,999.9	26,666.4
friction factor	na	0.0310	0.0240
pressure loss	psi	0.003263	0.017961

HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.921	8.203
reynolds #	na	9,629.5	27,036.8
friction factor	na	0.0310	0.0240
pressure loss	psi	0.003025	0.018464

HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.809	8.315
reynolds #	na	9,259.2	27,407.1
friction factor	na	0.0320	0.0240
pressure loss	psi	0.002887	0.018973

HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.697	8.427
reynolds #	na	8,888.8	27,777.5
friction factor	na	0.0320	0.0240

pressure loss	psi	0.002661	0.019489
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#### HM section 14

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.584	8.540
reynolds #	na	8,518.4	28,147.9
friction factor	na	0.0320	0.0240
pressure loss	psi	0.002444	0.020012

A

section

#### Spacer AA.S

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	2.288	2.288
inner diameter	in.	0.824	0.824
flow rate	gpm	2.472	8.652
reynolds #	na	8,148.1	28,518.2
friction factor	na	0.0330	0.0240
pressure loss	psi	0.016364	0.145785

#### HM section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.360	8.764
reynolds #	na	7,777.7	28,888.6
friction factor	na	0.0330	0.0240
pressure loss	psi	0.002101	0.021080

#### HM section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322

inner diameter	in.	0.824	0.824
flow rate	gpm	2.247	8.877
reynolds #	na	7,407.3	29,259.0
friction factor	na	0.0330	0.0240
pressure loss	psi	0.001906	0.021624

#### HM section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.135	8.989
reynolds #	na	7,037.0	29,629.3
friction factor	na	0.0350	0.0240
pressure loss	psi	0.001824	0.022174

#### HM section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	2.023	9.101
reynolds #	na	6,666.6	29,999.7
friction factor	na	0.0350	0.0240
pressure loss	psi	0.001637	0.022732

#### HM section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.910	9.214
reynolds #	na	6,296.2	30,370.1
friction factor	na	0.0350	0.0240
pressure loss	psi	0.001460	0.023297

#### HM section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162

length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.798	9.326
reynolds #	na	5,925.9	30,740.4
friction factor	na	0.0360	0.0230
pressure loss	psi	0.001330	0.022874

#### HM section 7

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.685	9.439
reynolds #	na	5,555.5	31,110.8
friction factor	na	0.0360	0.0230
pressure loss	psi	0.001169	0.023429

#### HM section 8

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.573	9.551
reynolds #	na	5,185.1	31,481.2
friction factor	na	0.0380	0.0230
pressure loss	psi	0.001075	0.023990

#### HM section 9

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.461	9.663
reynolds #	na	4,814.8	31,851.5
friction factor	na	0.0380	0.0230
pressure loss	psi	0.000927	0.024558

#### HM section 10

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.348	9.776
reynolds #	na	4,444.4	32,221.9
friction factor	na	0.0400	0.0230
pressure loss	psi	0.000832	0.025132

#### HM section 11

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.236	9.888
reynolds #	na	4,074.0	32,592.3
friction factor	na	0.0410	0.0230
pressure loss	psi	0.000716	0.025713

#### HM section 12

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.124	10.000
reynolds #	na	3,703.7	32,962.6
friction factor	na	0.0410	0.0230
pressure loss	psi	0.000592	0.026301

#### HM section 13

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	1.011	10.113
reynolds #	na	3,333.3	33,333.0
friction factor	na	0.0400	0.0230
pressure loss	psi	0.000468	0.026895

#### HM section 14

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.899	10.225
reynolds #	na	2,962.9	33,703.4
friction factor	na	0.0216	0.0230
pressure loss	psi	0.000200	0.027496

### **MCB section**

#### spacer MC.s

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	1.028	1.028
inner diameter	in.	0.824	0.824
flow			
rate	gpm	0.787	10.337
reynolds #	na	2,592.6	34,073.7
friction factor	na	0.0247	0.0230
pressure loss	psi	0.000557	0.089593

#### MCB section 1

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	1.120	1.120
inner diameter	in.	0.824	0.824
flow rate	gpm	0.675	10.449
reynolds #	na	2,225.9	34,440.4
friction factor	na	0.0288	0.0230
pressure loss	psi	0.000521	0.099723

#### MCB section 2

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	1.120	1.120
inner diameter	in.	0.824	0.824
flow rate	gpm	0.563	10.561
reynolds #	na	1,855.5	34,810.8
friction factor	na	0.0345	0.0230

pressure loss	psi	0.000434	0.101879
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#### MCB section 3

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	1.120	1.120
inner diameter	in.	0.824	0.824
flow rate	gpm	0.451	10.673
reynolds #	na	1,485.2	35,181.1
friction factor	na	0.0431	0.0230
pressure loss	psi	0.000347	0.104059

#### MCB section 4

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	1.120	1.120
inner diameter	in.	0.824	0.824
flow rate	gpm	0.338	10.786
reynolds #	na	1,114.8	35,551.5
friction factor	na	0.0574	0.0230
pressure loss	psi	0.000261	0.106261

#### MCB section 5

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.733	0.733
inner diameter	in.	0.824	0.824
flow rate	gpm	0.226	10.898
reynolds #	na	744.4	35,921.9
friction factor	na	0.0860	0.0230
pressure loss	psi	0.000114	0.071046

#### MCB section 6

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
dynamic viscosity	cp	1.162	1.162
length	feet	0.322	0.322
inner diameter	in.	0.824	0.824
flow rate	gpm	0.113	11.011
reynolds #	na	374.1	36,292.2

friction factor	na	0.1711	0.0230
pressure loss	psi	0.000025	0.031883

## Fittings

**A**  
**section**

### Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	11.124	0.000
pressure loss	psi	0.15059247	0.000000

### Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	11.012	0.112
pressure loss	psi	0.147566	0.000015

### Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.899	0.225
pressure loss	psi	0.144569	0.000061

### Tee 4 (run only)

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.787	0.337
pressure loss	psi	0.141604	0.000138

#### Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.675	0.449
pressure loss	psi	0.138669	0.000246

#### Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.562	0.562
pressure loss	psi	0.135765	0.000384

#### Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.450	0.674
pressure loss	psi	0.132892	0.000553

#### Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.337	0.787
pressure loss	psi	0.130049	0.000753

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.225	0.899
pressure loss	psi	0.127238	0.000983

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.113	1.011
pressure loss	psi	0.124457	0.001245

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	10.000	1.124
pressure loss	psi	0.121706	0.001537

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.888	1.236
pressure loss	psi	0.118987	0.001859

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.776	1.348
pressure loss	psi	0.116	0.002213

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.663	1.461
pressure loss	psi	0.113640	0.002597

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.551	1.573
pressure loss	psi	0.111012	0.003012

**B****section**Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.439	1.685
pressure loss	psi	0.108416	0.003457

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.326	1.798
pressure loss	psi	0.105850	0.003933

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	9.214	1.910
pressure loss	psi	0.103314	0.004440

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025

K factor	na	0.500	0.500
flow rate (avg)	gpm	9.101	2.023
pressure loss	psi	0.100810	0.004978

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.989	2.135
pressure loss	psi	0.098336	0.005547

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.877	2.247
pressure loss	psi	0.095893	0.006146

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.764	2.360
pressure loss	psi	0.093481	0.006776

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824

friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.652	2.472
pressure loss	psi	0.091099	0.007437

#### Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.540	2.584
pressure loss	psi	0.088748	0.008128

#### Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.427	2.697
pressure loss	psi	0.086428	0.008850

#### Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.315	2.809
pressure loss	psi	0.084139	0.009603

#### Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.203	2.921
pressure loss	psi	0.081880	0.010387

#### Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	8.090	3.034
pressure loss	psi	0.079652	0.011201

#### Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.978	3.146
pressure loss	psi	0.077455	0.012046

#### Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.865	3.259
pressure loss	psi	0.075289	0.012922

#### Tee 16 (run only)

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.753	3.371
pressure loss	psi	0.073153	0.013829

## A section

### Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.641	3.483
pressure loss	psi	0.071048	0.014766

### Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.528	3.596
pressure loss	psi	0.068974	0.015734

### Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.416	3.708
pressure loss	psi	0.066930	0.016732

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.304	3.820
pressure loss	psi	0.064917	0.017762

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.191	3.933
pressure loss	psi	0.062935	0.018822

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	7.079	4.045
pressure loss	psi	0.060984	0.019913

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.967	4.157
pressure loss	psi	0.059063	0.021035

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.854	4.270
pressure loss	psi	0.057173	0.022187

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.742	4.382
pressure loss	psi	0.055314	0.023370

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.629	4.495
pressure loss	psi	0.053486	0.024584

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.517	4.607
pressure loss	psi	0.051688	0.025829

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.405	4.719
pressure loss	psi	0.049921	0.027104

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.292	4.832
pressure loss	psi	0.048185	0.028410

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.180	4.944
pressure loss	psi	0.046479	0.029747

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	6.068	5.056

pressure loss	psi	0.044804	0.031114
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## B

### section

#### Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.955	5.169
pressure loss	psi	0.043160	0.032512

#### Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.843	5.281
pressure loss	psi	0.041547	0.033941

#### Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.731	5.393
pressure loss	psi	0.039964	0.035401

#### Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372

inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.618	5.506
pressure loss	psi	0.038413	0.036891

#### Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.506	5.618
pressure loss	psi	0.036891	0.038413

#### Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.393	5.731
pressure loss	psi	0.035401	0.039964

#### Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.281	5.843
pressure loss	psi	0.033941	0.041547

#### Tee 8 (run only)

<u>units</u>	<u>value</u>	<u>value out</u>

density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.169	5.955
pressure loss	psi	0.032512	0.043160

#### Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	5.056	6.068
pressure loss	psi	0.031114	0.044804

#### Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.944	6.180
pressure loss	psi	0.029747	0.046479

#### Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.832	6.292
pressure loss	psi	0.028410	0.048185

#### Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.719	6.405
pressure loss	psi	0.027104	0.049921

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.607	6.517
pressure loss	psi	0.025829	0.051688

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.495	6.629
pressure loss	psi	0.024584	0.053486

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.382	6.742
pressure loss	psi	0.023370	0.055314

Tee 16 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.270	6.854
pressure loss	psi	0.022	0.057173

**A  
section**Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.157	6.967
pressure loss	psi	0.021035	0.059063

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	4.045	7.079
pressure loss	psi	0.019913	0.060984

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.933	7.191
pressure loss	psi	0.018822	0.062935

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.820	7.304
pressure loss	psi	0.017762	0.064917

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.708	7.416
pressure loss	psi	0.016732	0.066930

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.596	7.528
pressure loss	psi	0.015734	0.068974

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.483	7.641

pressure loss	psi	0.014766	0.071048
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Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.371	7.753
pressure loss	psi	0.013829	0.073153

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.259	7.865
pressure loss	psi	0.012922	0.075289

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	3.146	7.978
pressure loss	psi	0.012046	0.077455

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500

flow rate (avg)	gpm	3.034	8.090
pressure loss	psi	0.011201	0.079652

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.921	8.203
pressure loss	psi	0.010387	0.081880

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.809	8.315
pressure loss	psi	0.009603	0.084139

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.697	8.427
pressure loss	psi	0.008850	0.086428

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025

K factor	na	0.500	0.500
flow rate (avg)	gpm	2.584	8.540
pressure loss	psi	0.008128	0.088748

**A  
section**

Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.472	8.652
pressure loss	psi	0.007437	0.091099

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.360	8.764
pressure loss	psi	0.006776	0.093481

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.247	8.877
pressure loss	psi	0.006146	0.095893

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.135	8.989
pressure loss	psi	0.005547	0.098336

Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	2.023	9.101
pressure loss	psi	0.004978	0.100810

Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.910	9.214
pressure loss	psi	0.004440	0.103314

Tee 7 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.798	9.326
pressure loss	psi	0.003933	0.105850

Tee 8 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.685	9.439
pressure loss	psi	0.003457	0.108416

Tee 9 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.573	9.551
pressure loss	psi	0.003012	0.111012

Tee 10 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.461	9.663
pressure loss	psi	0.002597	0.113640

Tee 11 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.348	9.776
pressure loss	psi	0.002213	0.116298

Tee 12 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.236	9.888
pressure loss	psi	0.001859	0.118987

Tee 13 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.124	10.000
pressure loss	psi	0.001537	0.121706

Tee 14 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	1.011	10.113
pressure loss	psi	0.001245	0.124457

Tee 15 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.899	10.225
pressure loss	psi	0.000983	0.127238

**MCB section**Tee 1 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.787	10.337
pressure loss	psi	0.000753	0.130049

Tee 2 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.675	10.449
pressure loss	psi	0.000555	0.132863

Tee 3 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.563	10.561
pressure loss	psi	0.000386	0.135736

Tee 4 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500

flow rate (avg)	gpm	0.451	10.673
pressure loss	psi	0.000247	0.138640

#### Tee 5 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.338	10.786
pressure loss	psi	0.000139	0.141574

#### Tee 6 (run only)

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.500	0.500
flow rate (avg)	gpm	0.226	10.898
pressure loss	psi	0.000062	0.144540

#### elbow

	<u>units</u>	<u>value</u>	<u>value out</u>
density	lbs/ft^3	62.372	62.372
inner diameter	in.	0.824	0.824
friction factor	na	0.025	0.025
K factor	na	0.750	0.750
flow rate (avg)	gpm	0.113	11.011
pressure loss	psi	0.000024	0.221303

#### **Pressure Loss Total HM set 1 by Route-99 total possibilities (psi)**

route	pressure loss total (psi)	HM 1 % dP difference(min/max)
1	7.16075811	53.482
2	7.33264155	
3	7.51588741	HM 1 % flow difference (min/max)

4	7.68787898	7.313
5	7.85616913	
---		
48	11.59554472	Average pressure loss through HM set 1 (psi)
49	11.60107804	8.49785606
50	11.82425758	max
51	11.60107804	
52	11.81682438	HM 1 entering flow (Gpm)
53	11.58620478	11.124
---		
98	7.05006506	
99	6.83465532	min

#### Full route pressure losses (using average pressure loss from each HM set)

route	pressure loss (psi)	full route % dP difference(min/max)
1	10.93212000	1.068
2	10.99023929	average pressure loss (psi)
3	11.04951984	10.975
4	10.93956015	
5	10.96467211	average head loss (ft)
		25.339

This set of full route pressure losses was used to determine the true flow rate entering each hose manifold, by doing iterations until the pressure drops across each route were nearly identical.

Largest HM entering flow (gpm)	11.124 (HM1)	
Largest HM route pressure loss (psi)	11.824 (route 50)	individual HM route only, largest pressure loss % difference
		63.189
Smallest HM entering flow( gpm)	10.530 (HM3)	individual HM route only, largest flow rate % difference
Smallest HM route pressure loss (psi)	6.147 (route 99)	7.949

Total head loss including TEC = 25.339 ft (sys) + 3.5 ft (TEC @ 55 Gpm) = **28.889 ft**

Total pressure loss including TEC = 10.975 psi (sys) + 1.51 psi (TEC @ 55 Gpm) = **14.49 psi**

**Full route pressure losses (using individual max/min HM routes)**

	<u>route</u>	pressure loss (psi)	head loss (ft)
max	1 (HM1 route 50)	14.259	32.919
min	1 (HM1 route 99)	9.269	21.399
max	2 (HM2 route 50)	14.051	32.440
min	2 (HM2 route 99)	9.460	21.840
max	3 (HM3 route 50)	14.030	32.392
min	3 (HM3 route 99)	9.559	22.070
max	4 (HM4 route 50)	13.836	31.943
min	4 (HM4 route 100)	9.491	21.913
max	5 (HM5 route 50)	14.146	32.658
min	5 (HM5 route 100)	9.374	21.643

max pressure loss (psi)-route 1 HM route  
50

14.259

min pressure loss (psi)-route 1 HM route  
99

9.269

largest route % pressure loss difference  
42.415

**largest full route % flow rate difference**  
**6.513**

## **Hydraulic Analysis Conclusions**

	<i>Superblock setup</i>	<i>With extension arms</i>
Entering flow rate	55 Gpm	54 Gpm
Flow rate across TEC's (avg)	0.142 Gpm	0.109 Gpm
Flow rate across TEC's (avg)	8.966 —	6.85 —
Pressure Loss across TEC's (avg)	2.569 psi	1.51 psi
Head Loss across TEC's (avg)	6.2 ft	3.5 ft
Pressure Loss system (avg)	9.69 psi	10.975 psi
Head Loss system (avg)	22.39 ft	25.339 ft
Pressure Loss Total	12.259 psi	12.485 psi
Head Loss Total	28.59 ft	28.839 ft
Largest % difference in flow rates	5.8%	6.5%

## Heat Transfer Analysis

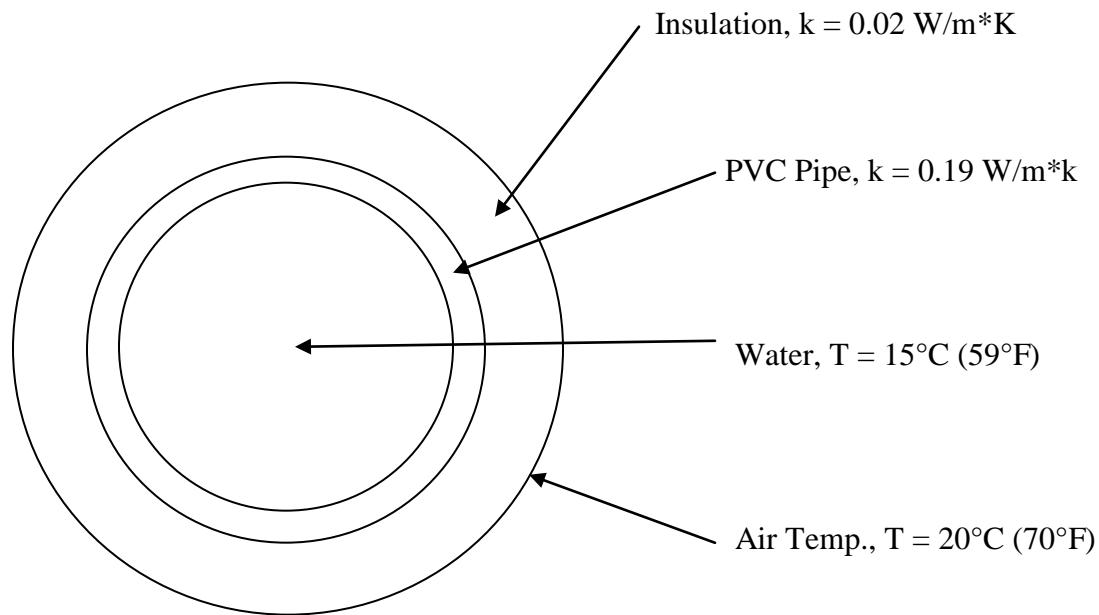
(Only conduction from the ambient air will be considered)

### Discussion/Summary of Heat Transfer Calculations

The following assumptions will be made when calculating the total heat transfer:

- 1.)  $T(\text{inner wall}) = T(\text{bulk fluid}) = 59^\circ\text{F} (15^\circ\text{C})$ ; or internal convection = 0
- 2.)  $T(\text{outer insulation wall}) = \text{fixed air temperature} = 70^\circ\text{F} (21^\circ\text{C})$ ; or external convection = 0
- 3.) Bulk fluid temperature is constant
- 4.) Each TEC contributes 3.35 Watts
- 5.) Heat gain from the ambient air is the other energy source

Therefore, the total heat transfer is the total heat transfer from the TEC's plus the total heat transfer to the pipes from the air;  $q_{\text{Total}} = q_{\text{TEC's}} + q_{\text{Pipes}}$ .



(Figure: PVC pipe with 3/8" foam insulation)

### **Distribution Manifolds**

<b>DM2/4</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	9.583333	ft	2.921	m
Inner radius	0.69	in	0.017526	m
Outer radius	0.83	in	0.021082	m
Insulation outer radius	1.205	in	0.030607	m

#	2	na	2	na
Total Length	19.16667	ft	5.842	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water				
Temperature	59	F	288	K
Thermal resistance Pipe			0.026488	K*m/W
Thermal resistance Insulation			0.507826	K*m/W
Heat				
load			-9.35779	W

<b>DM1/3</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	8.916667	ft	2.7178	m
Inner radius	0.69	in	0.017526	m
Outer radius	0.83	in	0.021082	m
Insulation outer radius	1.205	in	0.030607	m
#	2	na	2	
Total Length	17.83333	ft	5.4356	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water				
Temperature	59	F	288	K
Thermal resistance Pipe			0.028469	K*m/W
Thermal resistance Insulation			0.545795	K*m/W
Heat				
load			-8.70681	W

## Hose Manifolds

<b>HM 1/2/3 (w/o extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	27.00962	ft	8.232532	m
Inner radius	0.412	in	0.010465	m
Outer radius	0.525	in	0.013335	m
Insulation outer radius	0.9	in	0.02286	m
#	6	na	6	na
Total Length	162.0577	ft	49.39519	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.00411	K*m/W
Thermal resistance Insulation			0.086834	K*m/W
Heat load			-54.9785	W

<b>HM 4/5 (w/o extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	27.33519	ft	8.331767	m
Inner radius	0.412	in	0.010465	m
Outer radius	0.525	in	0.013335	m
Insulation outer radius	0.9	in	0.02286	m
#	4	na	4	na
Total Length	109.3408	ft	33.32707	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.006092	K*m/W
Thermal resistance Insulation			0.1287	K*m/W
Heat load			-37.0942	W

<b>Hose's (w/o extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	1.5	ft	0.4572	m
Inner radius	0.0625	in	0.001588	m
Outer radius	0.15625	in	0.003969	m
Insulation outer radius	0.53125	in	0.013494	m
#	774	na	774	na
Total Length	1161	ft	353.8728	m

Thermal conductivity EPDM <i>foam</i> **			0.036	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.011447	K*m/W
Thermal resistance Insulation			0.02752	K*m/W
Heat load			-128.313	W
<b>TEC's</b>	<u>value</u>	<u>units</u>		
#	387	na		
heat load assumed**	-3.35	W/TEC		
<b>heat load total (w/o extensions)</b>	<b>1296.45</b>	<b>W</b>		

<b>HM 1/2/3 (with extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	39.40684	ft	12.01121	m
Inner radius	0.412	in	0.010465	m
Outer radius	0.525	in	0.013335	m
Insulation outer radius	0.9	in	0.02286	m
#	6	na	6	na
Total Length	236.4411	ft	72.06724	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.002817	K*m/W
Thermal resistance Insulation			0.059517	K*m/W
Heat load			-80.2133	W

<b>HM 4/5 (with extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	41.09765	ft	12.52656	m
Inner radius	0.412	in	0.010465	m
Outer radius	0.525	in	0.013335	m
Insulation outer radius	0.9	in	0.02286	m
#	4	na	4	na
Total Length	164.3906	ft	50.10626	m
Thermal conductivity Pipe			0.19	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K

Thermal resistance Pipe	0.004052	K*m/W
Thermal resistance Insulation	0.085602	K*m/W
Heat load	-55.77	W

<b>Hose's (w/ extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	1.5	ft	0.4572	m
Inner radius	0.0625	in	0.001588	m
Outer radius	0.15625	in	0.003969	m
Insulation outer radius	0.53125	in	0.013494	m
#	994	na	994	na
Total Length	1491	ft	454.4568	m
Thermal conductivity EPDM <i>foam</i>			0.036	W/K*m
Thermal conductivity Insulation			0.02	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.008914	K*m/W
Thermal resistance Insulation			0.021429	K*m/W
Heat load			-164.785	W

<b>TEC's (w/extensions)</b>	<u>value</u>	<u>units</u>
#	497	na
heat load assumed**	-3.35	W/TEC
<b>heat load total (w/ extensions)</b>	<b>-1664.95</b>	<b>W</b>

### Totals

<b>Total (w/o extensions)</b>		
Heat load	-1534.9	W
DM's	1.176923	%
HM's	5.99861	%
Hose's	8.359722	%
TEC's	84.46475	%

<b>Total (with extensions)</b>		
Heat load	-1983.78	W

DM's	0.910614	%
HM's	6.854746	%
Hose's	6.468119	%
TEC's	83.92804	%

### Hose insulation analysis

#### Uninsulated Hose's

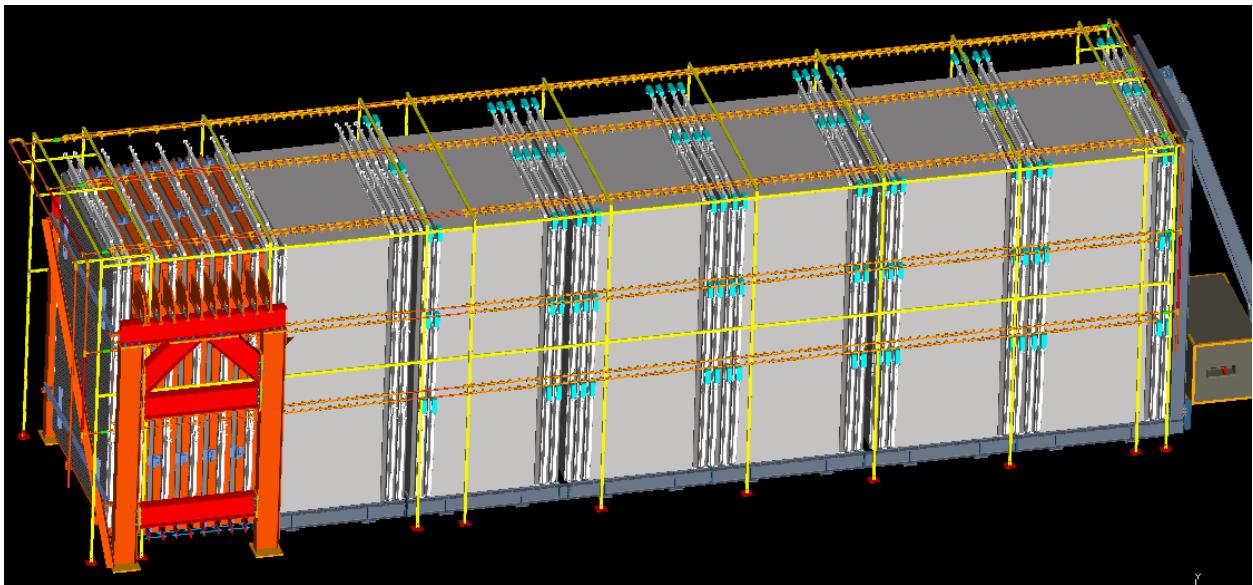
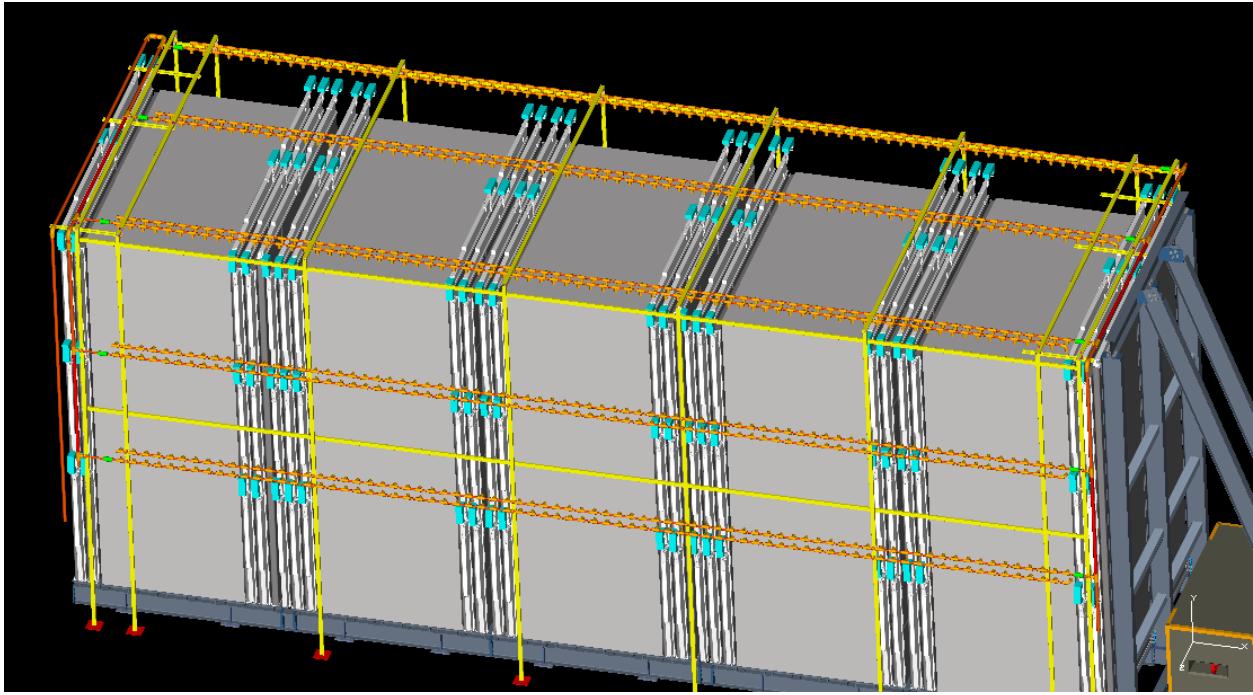
<b>Hose's (w/o extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	1.5	ft	0.4572	m
Inner radius	0.0625	in	0.001588	m
Outer radius	0.15625	in	0.003969	m
#	774	na	774	na
Total Length	1161	ft	353.8728	m
Thermal conductivity EPDM <i>foam</i>			0.036	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.011447	K*m/W
Heat load			-436.784	W

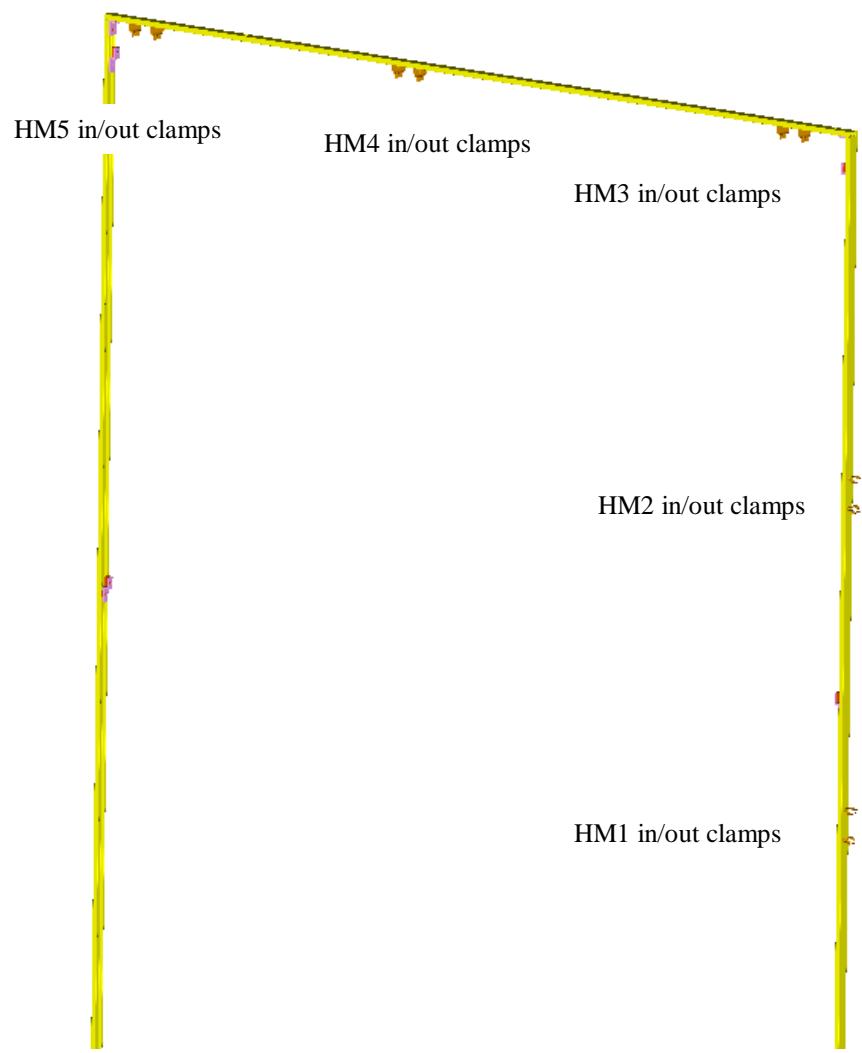
<b>Hose's (w/ extensions)</b>	<u>value</u>	<u>units</u>	<u>value</u>	<u>units</u>
Length	1.5	ft	0.4572	m
Inner radius	0.0625	in	0.001588	m
Outer radius	0.15625	in	0.003969	m
#	994	na	994	na
Total Length	1491	ft	454.4568	m
Thermal conductivity EPDM <i>foam</i>			0.036	W/K*m
Ambient Temperature	70	F	293	K
Water Temperature	59	F	288	K
Thermal resistance Pipe			0.008914	K*m/W
Heat load			-560.934	W

increase in hose heat  
load  
240.4036 %

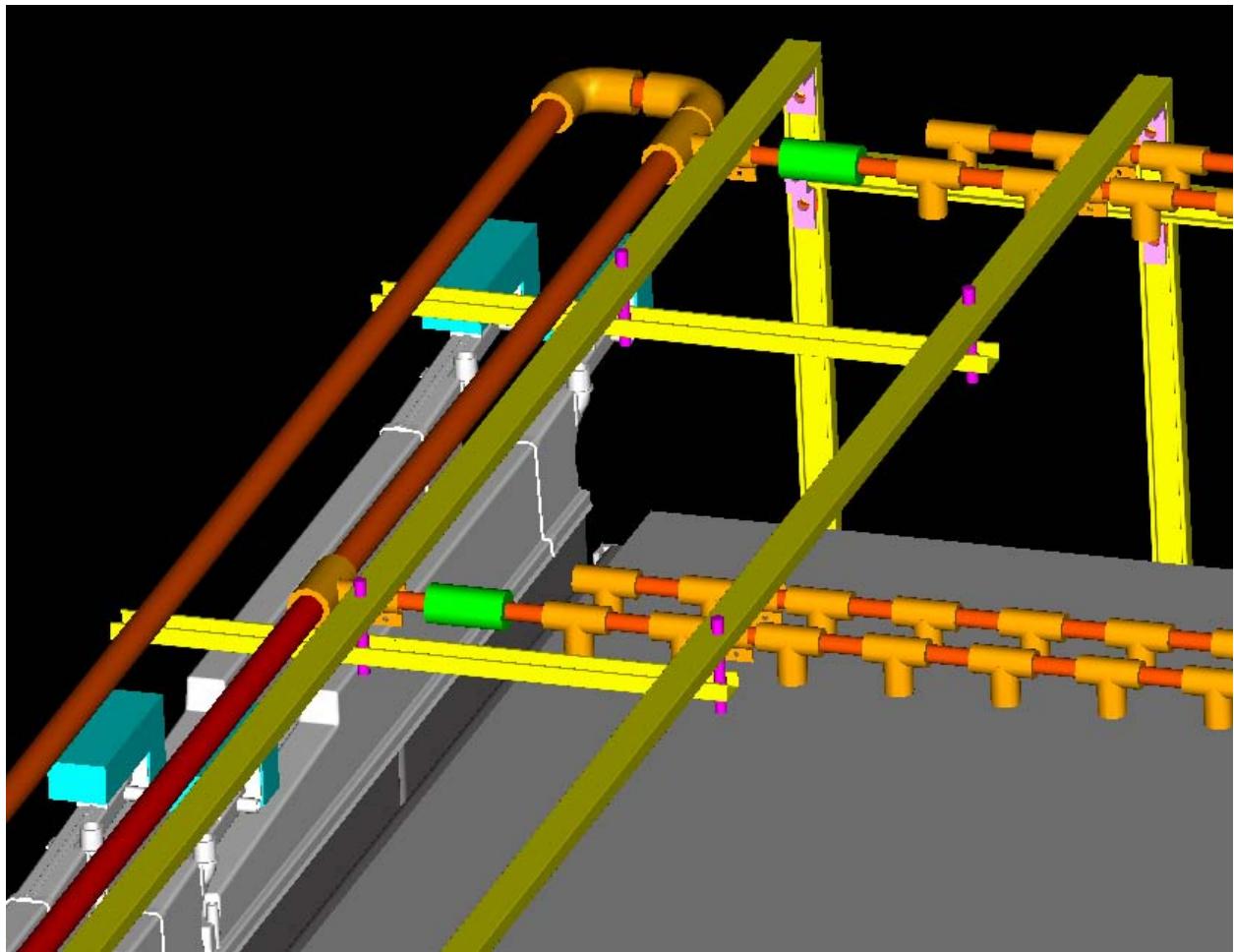
increase in overall heat  
load  
20.09707 %

**Chiller System Support Frame/ 2 Setups**



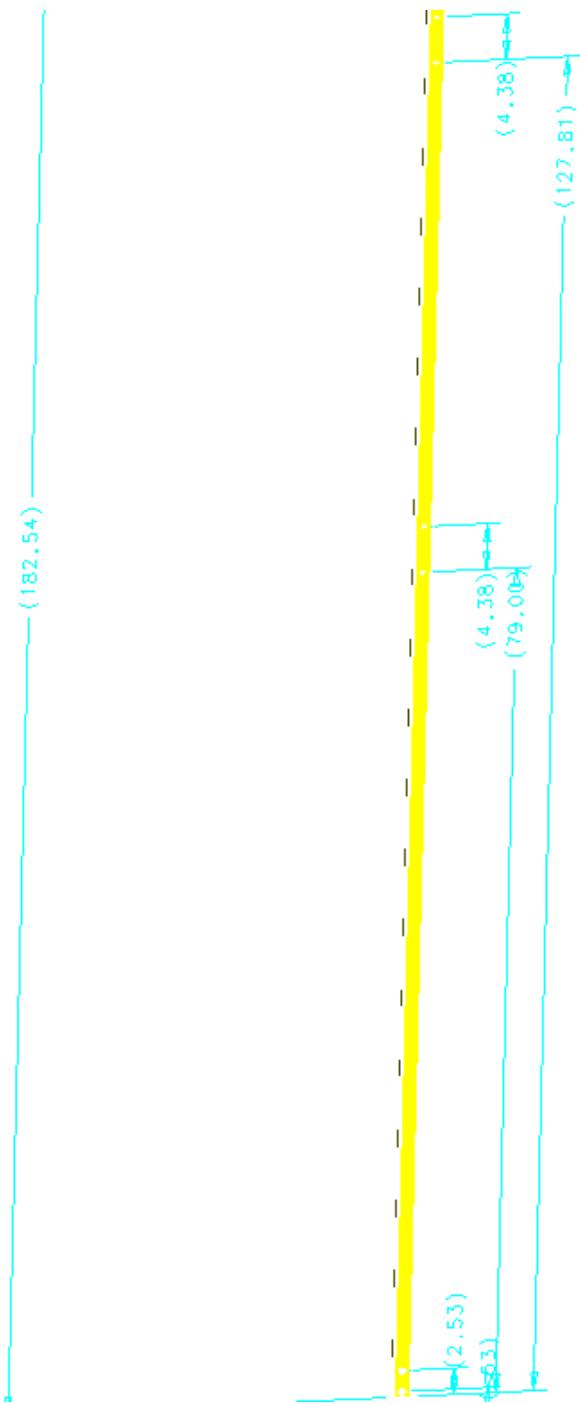


*One section of support frame*



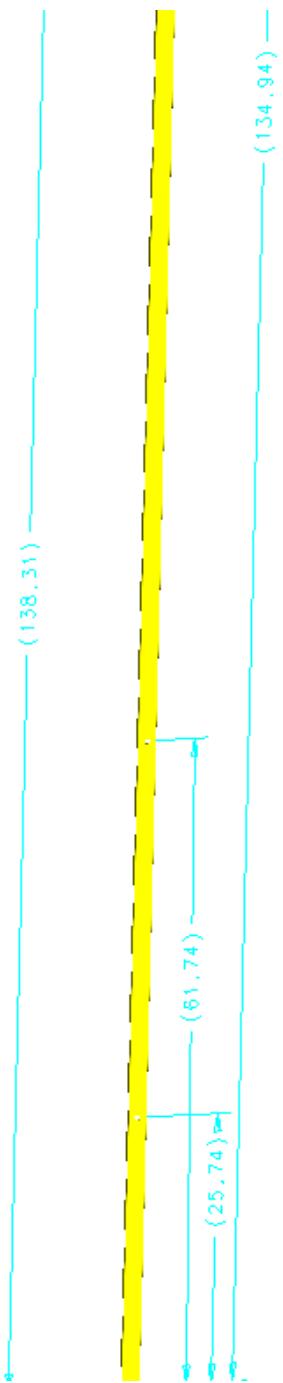
*Small unistrut sections hanging by a threaded rod 1.33" below top horizontal supports to support distribution manifolds and reverse return pipe.*

*Vertical supports*



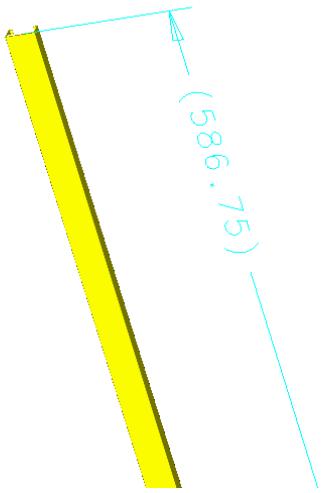
Leftmost dimension is the overall length, all others are to 9/16" diameter holes for base plates and clamps

*Top horizontal supports*



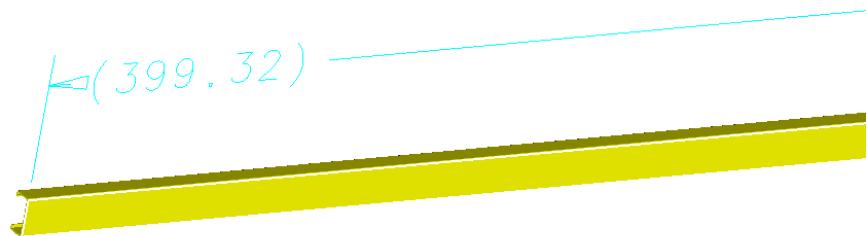
Leftmost dimension is the overall length; all others are to 9/16" diameter holes for distribution manifold support, needed only on two closest frame sections to either end.

*Side horizontal supports (with extensions)*



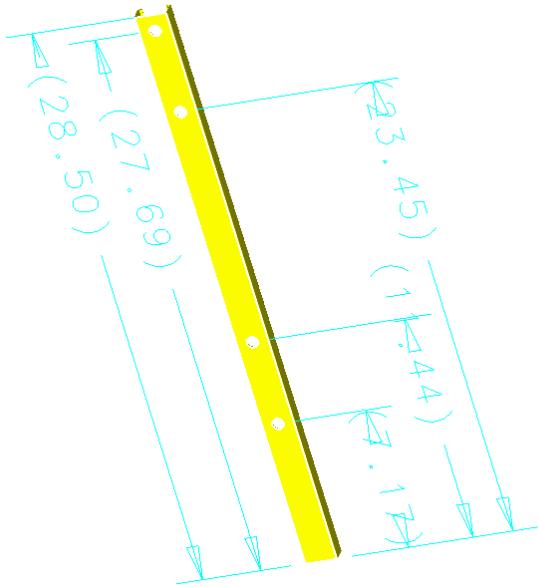
Overall length shown; there is no need for holes to be drilled in this section as it is connected with Z braces and adaptors.

*Side horizontal supports (without extensions)*

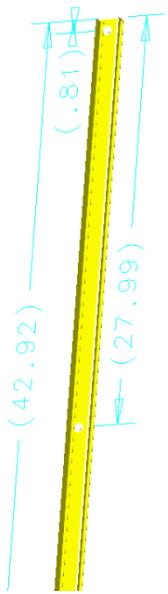


Overall length shown; there is no need for holes to be drilled in this section as it is connected with Z braces and adaptors.

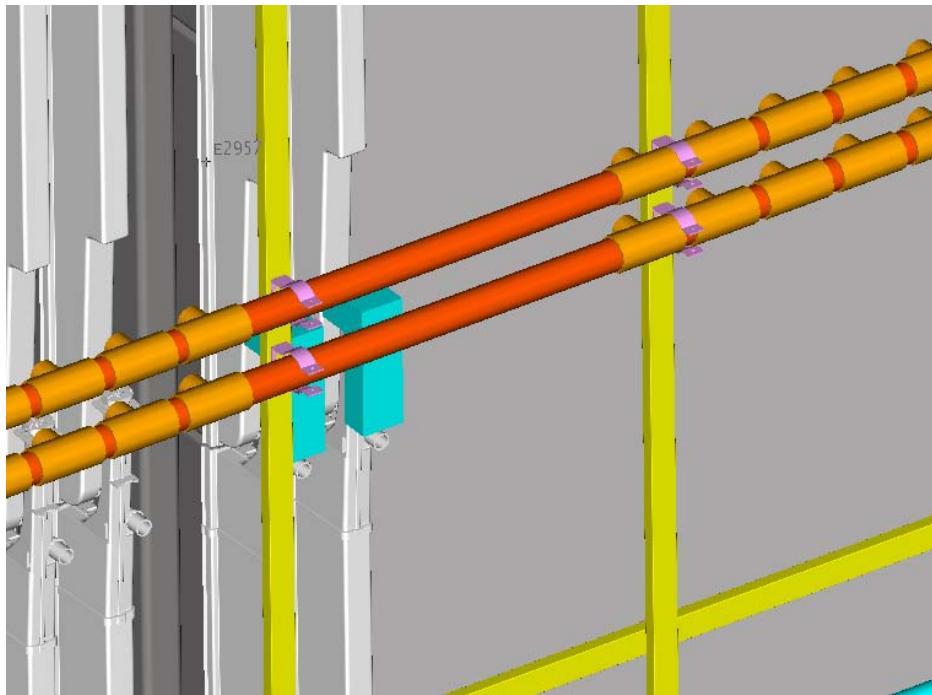
### *Distribution Manifold/Reverse Return Supports*



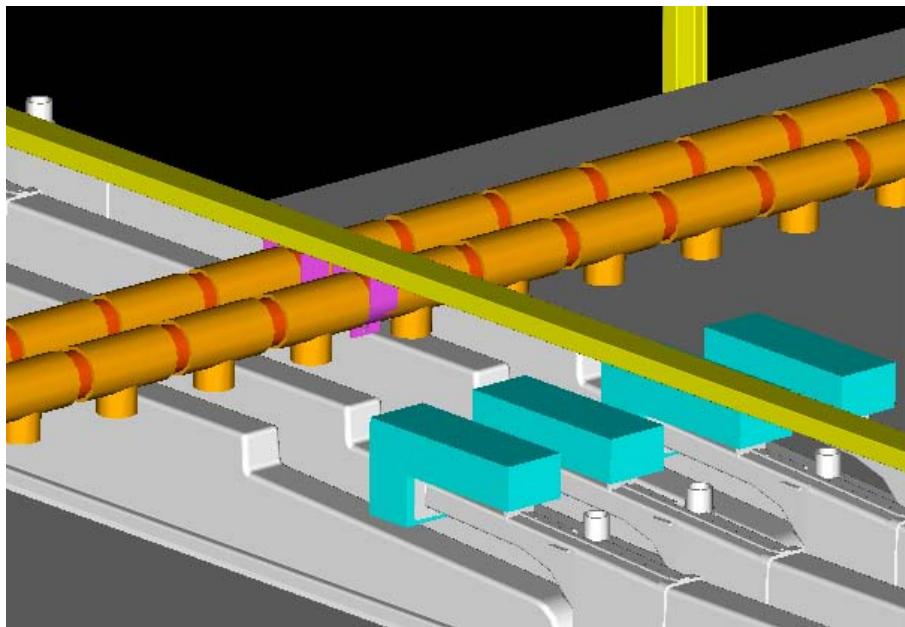
This section is set up to be used on either side to support the distribution manifold, or distribution manifold and reverse return pipe in the superblock setup.



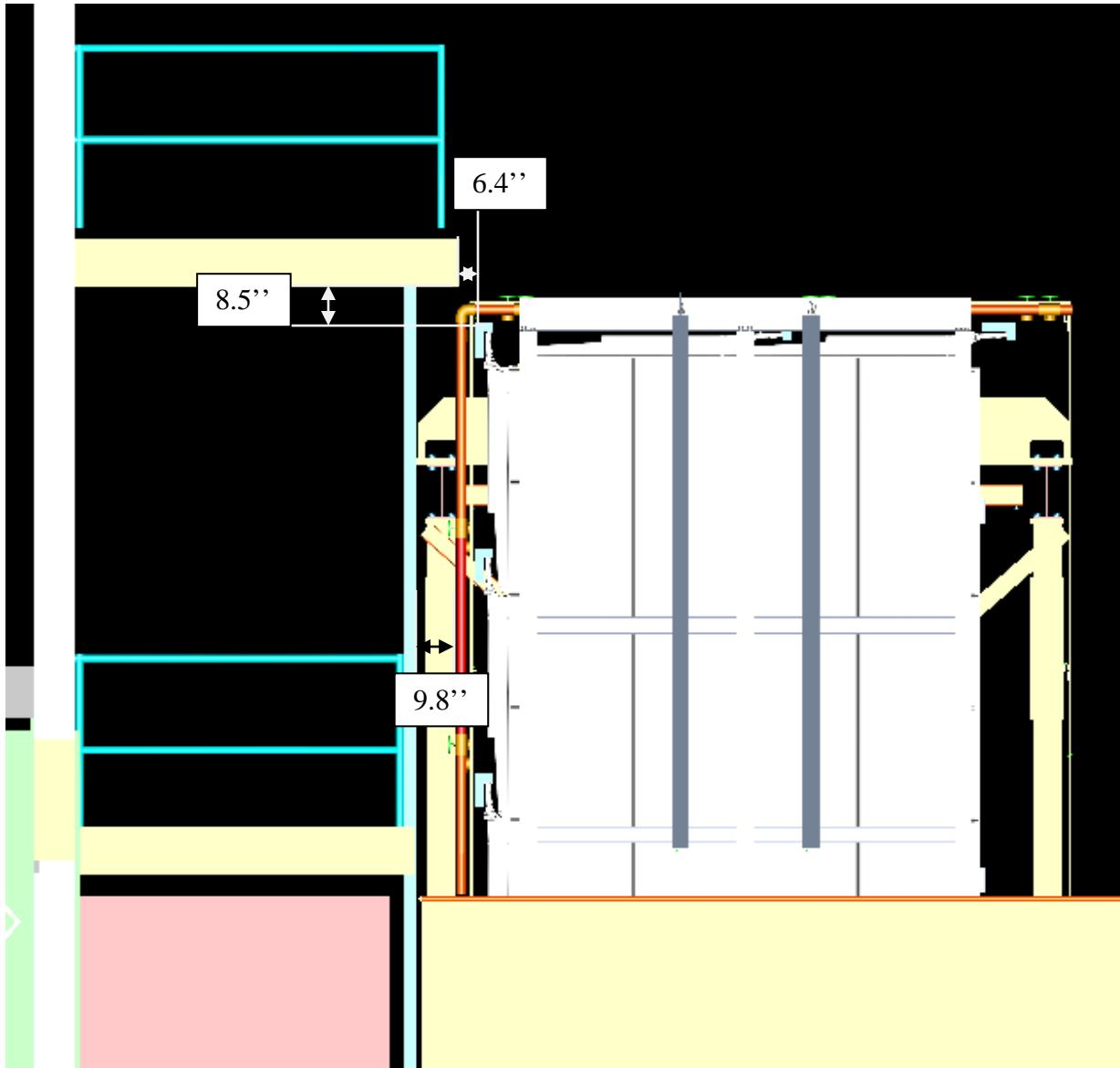
This section is set up to be used on the out flowing side to support the distribution manifold and reverse return pipe in the superblock setup with the extension arms, as the muon catcher creates a need for longer sections.



Side clamps



Top clamps



Side profile view of the full setup with platforms shown. Top dimensions from top corner of the snout to the bottom corner of the second floor platform. Bottom dimension from distribution manifolds to walkway supports.

## **Equations used**

-Pressure drop

$$(\Delta P) \text{ Pipes} = [0.000216 * (f * L * \rho * Q^2)] / d^5$$

$$(\Delta P) \text{ Fittings} = [0.00001799 * (K * \rho * Q^2)] / d^4$$

$$\text{Reynolds } \# = 50.6 * (Q * L / d * u)$$

$$(\Delta P) \rightarrow \text{head loss} = \Delta P * 144 / \rho$$

Where      f = friction factor

L = length (ft)

Rho = density (lb/ft<sup>3</sup>)

Q = flow rate (Gpm)

d = inner diameter (inches)

K = resistance coefficient

-Heat Transfer (Conduction only)

$$q = (T_{in} - T_{out}) / R_{total} + (q - TEC's)$$

$$R_{total} = R_{insulation} + R_{pipe} \quad (\text{conduction only})$$

$$R_{insulation} = \ln(r_{oi}/r_{ii}) / (2 * \pi * l * k_i)$$

$$R_{pipe} = \ln(r_{op}/r_{ip}) / (2 * \pi * l * k_p)$$

Where      q = Total heat transfer (W)

q-TEC's = total heat transfer from TEC's (W)

R = thermal resistance

r<sub>oi</sub> = outer radius of insulation (m)

r<sub>ii</sub> = inner radius of insulation (m)

l = length (m)

k<sub>i</sub> = thermal conductivity of insulation (W/mK)

r<sub>op</sub> = outer radius of pipe = r<sub>ii</sub> (m)

r<sub>ip</sub> = inner radius of pipe (m)

k<sub>p</sub> = thermal conductivity of PVC pipe (W/mK)

T<sub>in</sub> = temperature of water in pipe (constant, uniform) (K)

T<sub>out</sub> = temperature of ambient air (K)