Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Title: TEC Header Assembly, Testing, Installation, and Recommended changes

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Abstract Summary:

This note details the assembly, testing, and installation methods used in constructing and mounting the TEC headers on the IPND. Recommended changes are also discussed.

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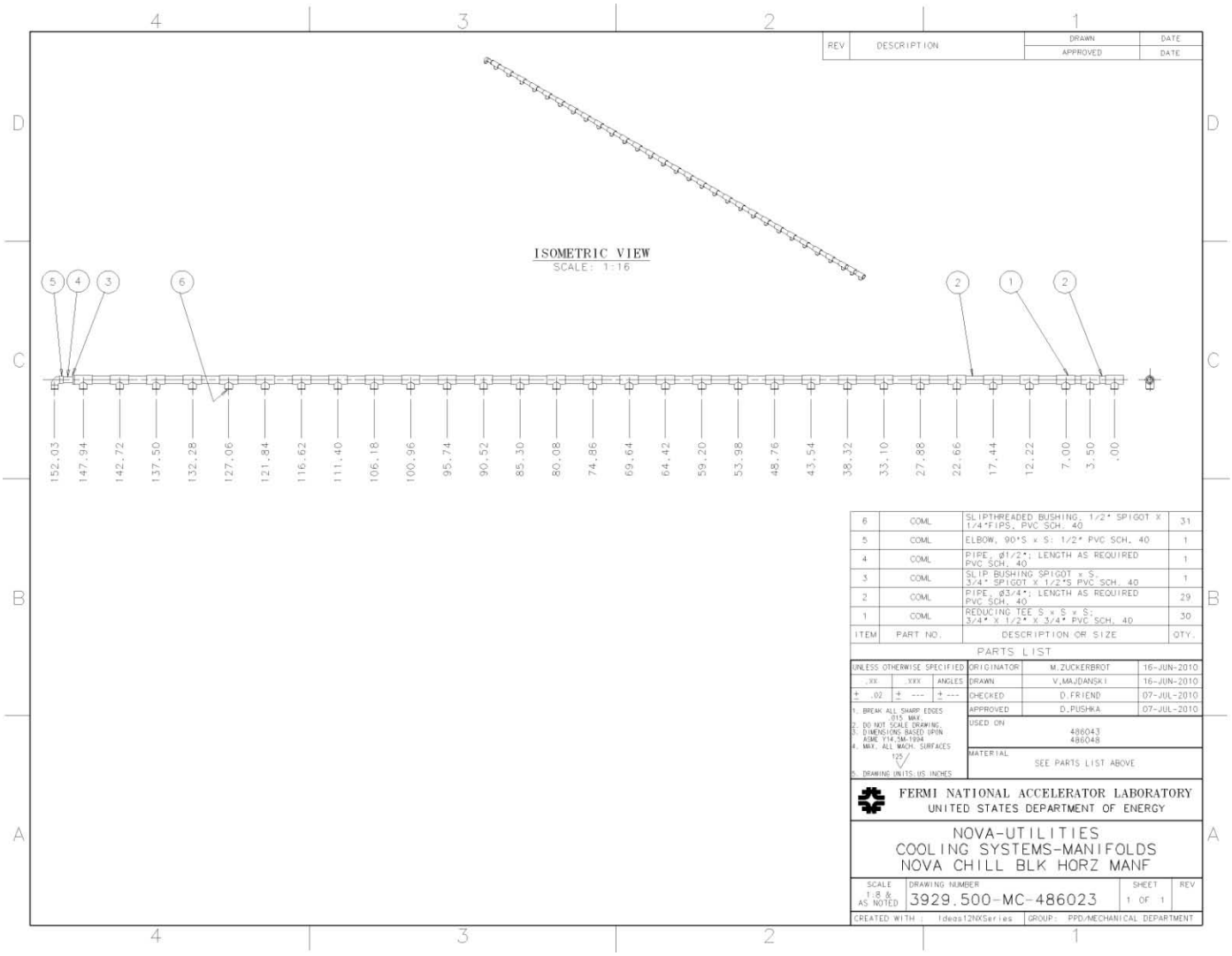
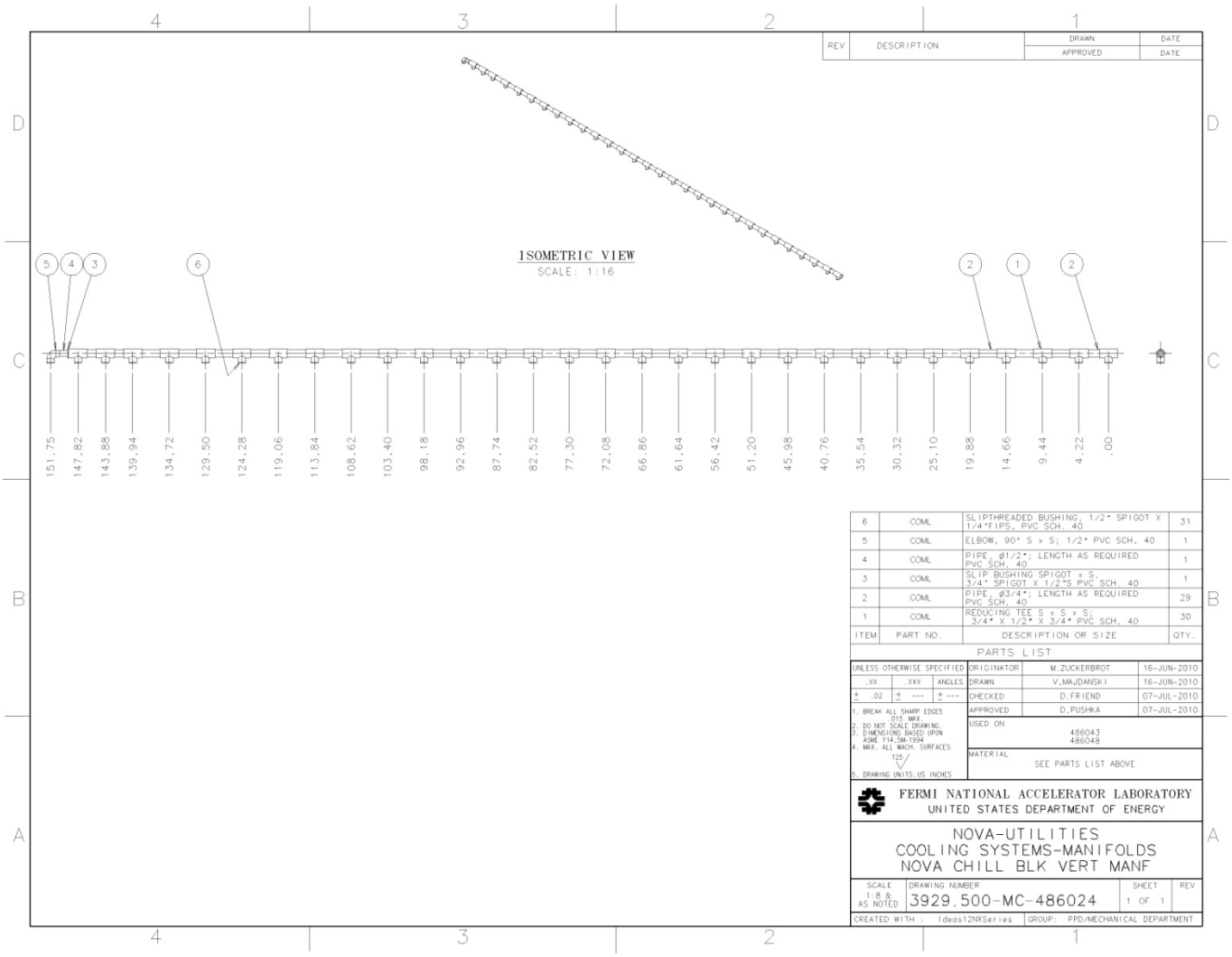
I. Assembly

1. Current Header Engineering drawings



Current horizontal TEC header engineering drawing shown. The farthest centerline distance is listed at 152.03'', and there are 31 hose connections.



Current vertical TEC header engineering drawing shown. The farthest centerline distance is listed at 151.75'', and again there are 31 hose connections.

2. Assembly Procedure

The TEC headers were assembled in two steps. Tee subassemblies were first made, then pieced together using relevant center-to-center gauge's as well as a track to keep the nozzles in line. This will all be detailed below. When gluing the PVC pieces together, the following steps should be followed to minimize the risk of leaks:

a. Basic PVC Cementing Procedure

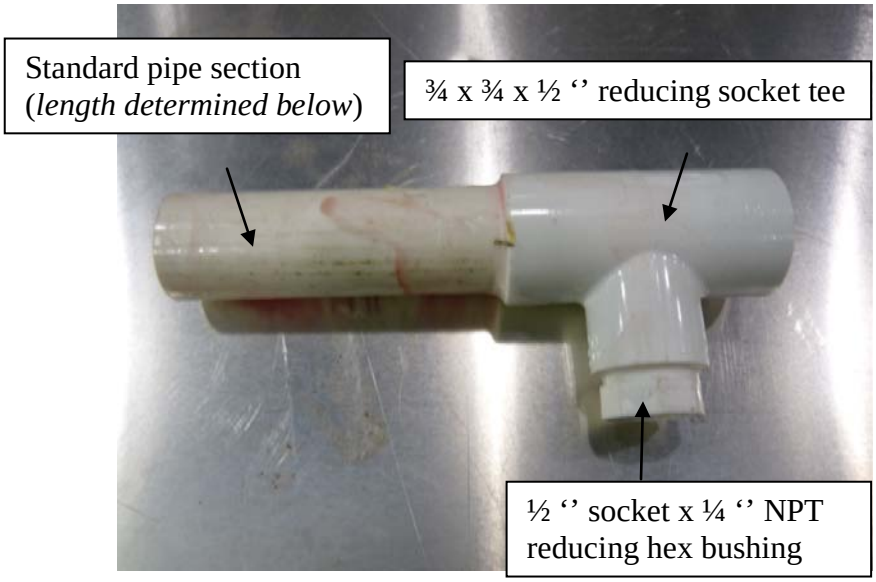
➔ Prime both parts well, and allow time for excess primer to evaporate (usually about 5-10 seconds). If the part sits without being cemented for an extended period, it must be re-primed.

➔ Coat both parts with plenty of PVC cement and insert quickly, then twist 90 degrees (whenever possible) to eliminate air bubbles all in a fluid motion. The pieces should be inserted as far into the socket as possible unless a relevant sized gauge is being used.

➔ The two parts then must be held together for several seconds until the glue begins to harden to prevent the parts from separating themselves.

3. Tee Subassembly

The tee subassembly consists of a ¾ x ¾ x ½ '' reducing socket tee, a ½ '' socket x ¼ '' NPT reducing hex bushing, and one section of ¾ '' pipe (referred to as a standard section form here on) as seen below. All parts can be twisted 90 degrees upon assembly of these sections.



Tee subassembly

a. Tee subassembly Steps

→Basic PVC cementing procedure (sec. I-2a) should be followed

→Prime 5-10 sets of parts at a time then start to glue in order for excess primer to evaporate

→Cement the pipe section to the tee first, then follow with the bushing in order to minimize glue dripping into the thread

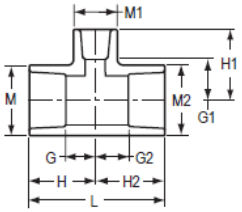
→Stand the section vertically on the pipe section end to minimize glue dripping into the tee while drying.

b. Standard pipe section length

The standard pipe section length will be determined here using Spears schedule 40 PVC pipe fitting dimensions. *****Note depending on the brand of the fittings, the pipe section length will be different and must be determined using the fittings in hand**.

REDUCING TEE

Socket x Socket x Socket



Part Number	Size	G	G1	G2	H	H1	H2	L	M	M1	M2	Approx. Wt. (Lbs.)
401-053	3/8x3/8x1/2	17/32	21/32	17/32	2-1/32	1-3/4	2-1/32	4-1/16	7/8	1-3/32	7/8	.08
401-074	1/2x1/2x3/4	9/16	9/16	9/16	1-5/16	1-9/16	1-5/16	2-5/8	1-1/16	1-9/32	1-1/16	.07
401-075	1/2x1/2x1	25/32	17/32	25/32	1-17/32	1-11/16	1-17/32	3-1/16	1-1/16	1-5/8	1-1/16	.11
401-094	3/4x1/2x1/2	9/16	21/32	1/2	1-9/16	1-13/32	1-1/4	2-13/16	1-5/16	1-3/32	1-1/16	.08
401-095	3/4x1/2x3/4	13/16	11/16	5/8	1-13/16	1-15/32	1-3/8	3-3/16	1-5/16	1-5/16	1-1/16	.10
401-101	3/4x3/4x1/2	17/32	5/8	17/32	1-7/16	1-3/8	1-7/16	2-29/32	1-5/16	1-1/8	1-5/16	.08
D401-101	3/4x3/4x1/2	9/16	19/32	17/32	1-17/32	1-27/32	1-17/32	3-1/16	1-5/16	1-3/32	1-5/16	.11
401-102	3/4x3/4x1	23/32	5/8	23/32	1-21/32	1-21/32	1-21/32	3-5/16	1-5/16	1-5/8	1-5/16	.11
401-122	1x1/2x1	23/32	23/32	27/32	1-25/32	1-25/32	1-19/32	3-7/16	1-5/8	1-5/8	1-3/32	.14

Spears schedule 40 PVC reducing tee dimensions. Relevant tee dimensions are boxed in red, with relevant pipe section length determinants (G and G2) boxed in blue, and relevant gauge length determinant (L) boxed in green.

With the standard center-to-center distance between tee nozzles being 5.22’’; the standard pipe section should be 5.22’’ – (G + G2) – 2(1/8’’) or 5.22 – (17/32 + 17/32) – 2(1/8) = 3.9’’.

*Standard pipe section length = 3.9’’ (only relevant to Spears sch. 40 fittings)

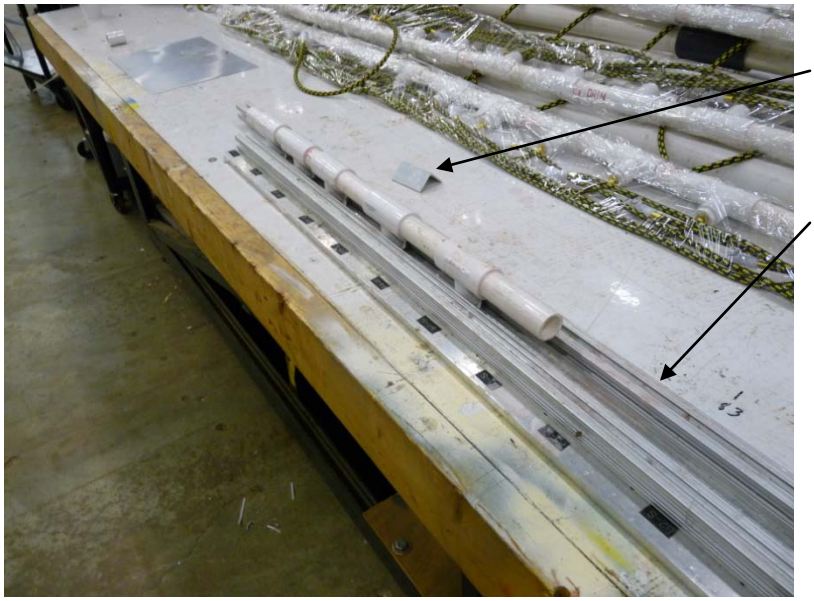
***Note the additional 1/8’’ taken off each end**; this is due to the occasional difficulty fully inserting sections and prevents center-to-center distances from growing to long.

4. <u>Header Assembly</u>

Both the vertical and horizontal headers will have 30 tees and an elbow on the end, allowing for 31 hose connections. According to the current drawings (p. 3-4); the horizontal headers require 27 of the tee subassemblies, 3 tees with shorter spacing on one end, and a shorter spaced elbow on the other. The vertical headers require 26 of the tee subassemblies, one shorter spaced tee on one end, and three shorter spaced tees and an elbow on the other. I will detail recommended changes to this at the end of this chapter.

a. Additional Required Assembly Aides

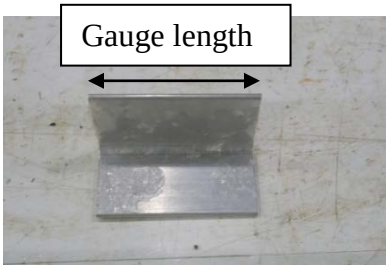
Two aides are needed to begin assembly of the full headers



1. Angle gauge cut at the length between faces of tees (detailed below)

2. In-line track with the gap set at the width of the tee nozzles in order to keep said nozzles in line with each other

Double sided track shown with header assembly in progress



Standard angle gauge

To determine gauge length:

-Center-to-center distance (5.22’’) – Full length of tee, L, seen boxed in green on the previous page.

-Therefore, 5.22’’ – 2-29/32’’ = 3.4’’ standard gauge length (*only applicable to Spears sch. 40 fittings*)

*Note for the tees with shorter spacing, 1 additional shorter gauge is required for the current horizontal headers, and 2 additional gauges for the current vertical header, lengths being determined by the same method.

b. Header assembly steps

➔ Basic PVC cementing procedure (sec. I-2a) should be followed, *however it may not be possible to twist each section 90 degrees and insert into the in-line track quickly enough*. If this proves to be too difficult or inaccurate, the twisting step can be discarded during this phase of the assembly. If an excessive amount of glue is used, leak detection stays at a minimum even without twisting.

In-line track shown with two tee subassemblies being glued together. Notice the gauge is what sets the center-to-center distance, not necessarily the pipe section length.

➔ It is most efficient to prime 5-10 tee subassemblies at a time, and then start gluing.

➔ With two tee subassemblies primed and coated with glue (1. Already in the track at the end of a partially assembled header, and, 2. The next tee subassembly to be added), the second one should be inserted with the gauge hat sitting on top and pushed together until the face of each tee sits flush on the ends of the gauge. This will ensure an accurate center-to-center spacing.

➔ If it is suspected that too much glue was used the partially completed header should be lifted out of the track, and the thread of the bushing should be inspected for glue. If glue is found in the thread it should be immediately wiped out as thoroughly as possible. If the glue has hardened or cannot be completely removed from the thread, the tee subassembly should be cut off and replaced.

➔ Once the 26 (vertical header) or 27 (horizontal header) tee subassemblies, and the 4 (vertical header) or 3 (horizontal header) shorter spaced tees are put together, the overall length should be measured, and the final elbow should be put on at a length to not exceed a total of about 153’’.

➔ Once the header is fully assembled the hose NPT’s should be Teflon taped and tightened into the headers. **Note hoses should be tightened down until they are flush with the bushing face to prevent leaking threads.

➔ ***NOTE: DO NOT BEND HEADERS; this will cause glued joints to leak**

5. **<u>Recommended changes</u> (Assembly)**

- <u>Vertical and horizontal header overall length</u>: The longest centerline length of the horizontal header is shown to be 152.03'', and the longest vertical header centerline length is shown to be 151.75''. There are an identical 31 hose connections and an identical maximum length (between row headers) whether you look at horizontal or vertical headers. **I recommend adjusting the two types of headers to be identical to each other, using one type of generic horz./vert. header instead of the two very slightly varied headers**. This will cut down on assembly time, installation confusion, and will allow for only one necessary type of spare headers to be fabricated and available if needed. The shorter header should be used as a guide for the new standard length.

- <u>Pipe section lengths</u>: Pipe section refers to both the standard length section discussed above, as well as the either 2 or 3 sections between the shorter spaced tees. Currently the horizontal headers require 2 smaller sections of pipe and an additional gauge to space them. The vertical headers call for 2 different smaller sections on one end with a corresponding gauge, and an even smaller section and corresponding gauge on the other. Between the two headers, four different lengths of pipe and their corresponding gauges are used without any known logical reason. **I recommend the new generic vertical/horizontal header discussed above have all tees equally spaced.** This will allow for only one necessary pipe length, gauge, and type of tee subassembly to be fabricated rather than the multiple types currently being used. This will also cut down assembly confusion. The end elbow can be left at a unique length (butt-to-butt is a sufficient method to prevent the header from growing too long). With the hoses being sufficiently long at 2 feet, they will not have a problem reaching the TEC's even with a shorter centerline length.

  *New, truly standard, center-to-center lengths can be determined using the following method: Farthest tee centerline length/30 tees
  →147.82''/ 30 tees = 4.927'' →Recommended new standard tee center-to-center length for vertical/horizontal generic headers

- <u>Elbows:</u> Currently both the vertical and horizontal headers call for a ¾ socket x ½ '' socket reducing bushing, a section of ½ '' pipe, a ½'' elbow, and the standard ½ socket to ¼'' NPT hex bushing on one end. **I recommend all this be replaced by a single ¾'' x ½'' socket reducing elbow, and the standard ½'' socket x ¼'' NPT hex bushing used in the tees.** This will eliminate the need for any ½'' pipe, ¾ x ½ '' socket reducing bushings, and ½'' elbows.

- <u>Hoses:</u> Currently the hoses are 24 inches in length which provides excess slack. **I recommend the hose length be reduced by 6 inches**. This will eliminate some of the extra slack, and provide more empty space on the detector. Also, **I recommend replacing the Teflon tape on the hose threads with RTV be considered.** This may or may not decrease the occurrence of leaks at the thread.

II. Testing

1. Hydrostatic Testing Procedure

All TEC headers must be hydrostatically tested prior to installation on the detector. The chiller system is not expected to run above 45 psi even at its peak pressure while running only 1 IPND di-block (155 TEC's), but headers will be tested up to 100 psi.

a. Hydrostatic testing setup:

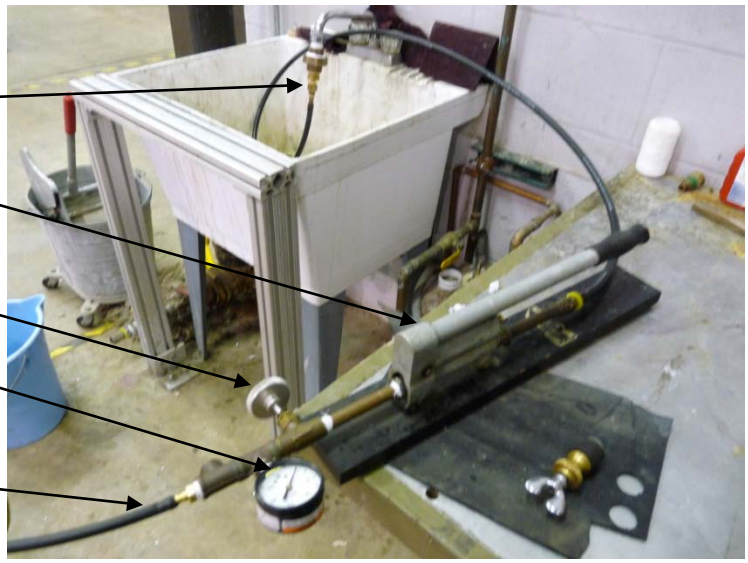
-Input water source

-Hydrostatic hand pump

-Control valve

-Pressure gauge

-Output to header



Hydrostatic testing setup shown.

Tec header shown ready for filling and testing, ****Note the header is supported in three places to prevent bending***

**Note the output line to the header is fitted with a non valved male Colder quick disconnect to fill the header and directly connect to one on the hoses for pressurizing*

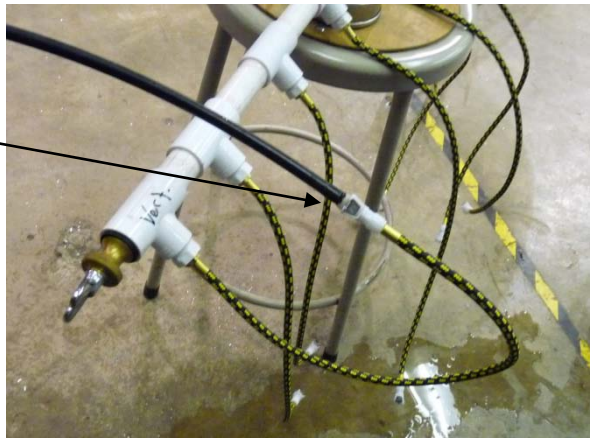
Hose-to-hose jumper with non valved male Colder quick disconnects

b. Testing procedure

- ➔ Place the header at a downward angle (open end up) with multiple supports to prevent any bending as shown on the previous page

- ➔ Open the input water source and the control valve on the hydrostatic testing setup, and fill the manifold through the non valved Colder quick disconnect on the output line.

- ➔ Once the header is full, close the control valve and plug the end with an expanding ¾'' fitting plug; then connect the output line to one of the hoses.



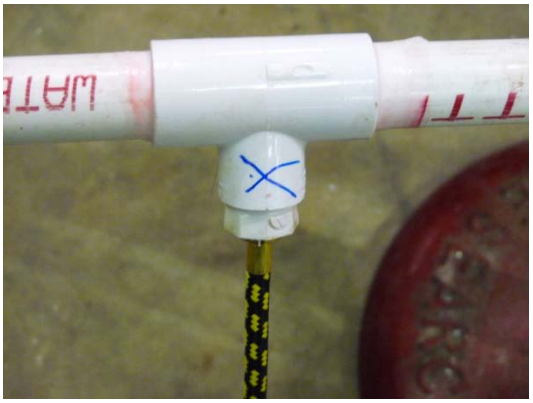
- ➔ Open the control valve (this will supply the header with input source pressure, for a sink this is about 25-30 psi), and use the jumper to bleed each hose for 2-3 seconds. This will purge most of the air from the header and allow for maintained pressurization.

➔ Pump the hand pump until about 100 psi is achieved. **Note if pressure cannot be maintained; this indicates a leak somewhere. Sometimes this is a result of one of hoses' quick disconnect valves not closing itself. **The valves in the quick disconnects have about a 1 in 60 failure rate**, but can usually be closed by inserting and removing a male fitting one or more times. It is typical to hear the PVC clicking and expanding slightly, which implies additional pumping is necessary to re-achieve the desired 100 psi and maintain it at a steady level.

100 psi

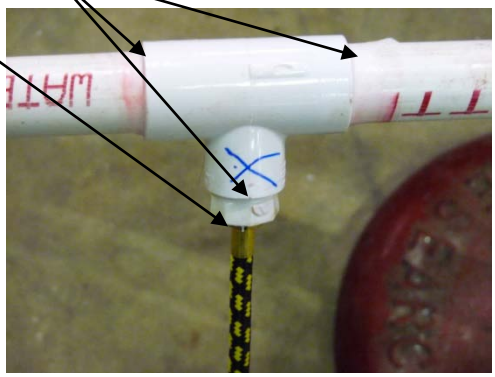
➔ Once a consistent 100 psi is achieved the control valve should be closed, and every connection should be hand checked with a dry paper towel which clearly shows water spots. If water spots are found, the affected fitting should be clearly marked for repair, which will be detailed in the next section

Leak checking with clean paper towel


Clearly marked leaky thread

2. Header repair

When a leak is found in one of the connections, the header should be drained, repaired, and retested. Several different repair methods were attempted all with varied success rates. Leaks can occur at either threaded or tee-to-pipe (or bushing) connections.



a. Approximate leak occurrence rates:

- First, it should be noted that it was quite common for a CAREFULLY assembled header to be tested leak tight without repair.

- Tee-to-bushing leaks: This was the most uncommon type of leak, almost never occurring (1 found per about 10 headers tested). Causes can be found in section b below.

- Tee-to-pipe leaks: These types of leaks were fairly common at about 2-3 per header until bending was discovered to be a major contributor. Once precautions were taken the occurrence of these types of leaks dramatically decreased, to about one found per about 3-4 headers tested.

- Threaded leaks: Once bending precautions were taken, leaks at threads were found to be the most common and most difficult to repair. These occurred at a rate of about 1 leak per every 2-3 headers.

b. Known causes of leaks

****Most common causes in bold**

- Tee-to-pipe (or bushing) leaks: 1.) Inadequate priming, hardening due to part sitting to long after priming, priming one part only. 2.) Inadequate amount of glue, or coating one part only before insertion. **3.) *Bending headers**. **4.) Not inserting far enough into the socket when gluing**. 5.) Not twisting 90 degrees.

- Threaded leaks: 1.) Hose is not tightened down flush to the hex bushing. **2.) Dry glue in the threaded part. 3.) Crossed thread**. 4.) Inadequate amount or improperly used (must be applied in direction of tightening) Teflon tape.

- Other causes: Besides the approximate 1 in 60 failure rate of the quick disconnects' valves causing a free flow of water, it should also be noted if too much stress is put on the collar of the NPT fitting, the crimp will fail and leak. If this is the case the hose must be removed and replaced.

c. Attempted repair methods:

→<u>With the leak at a tee-to-pipe (or bushing) connection</u>:

*Additional coat of PVC cement: Very low success rate as it tends to bubble under pressure. This is *not recommended*

*RTV: Very low success rate, as this also tends to bubble. *Not recommended*

*Plastic welder: This was attempted twice, and was successful. Additional tests may be required to confirm its success rate, but this qualifies as a *recommended repair procedure*

*Cut out entire section and couple in a replacement tee assembly (this process will be detailed in section c). If plastic welder fails this method has proven *ultimately successful*.

→<u>With the leak at a threaded connection</u>

*RTV was attempted with a low success rate again due to bubbling, and *is not recommended.*

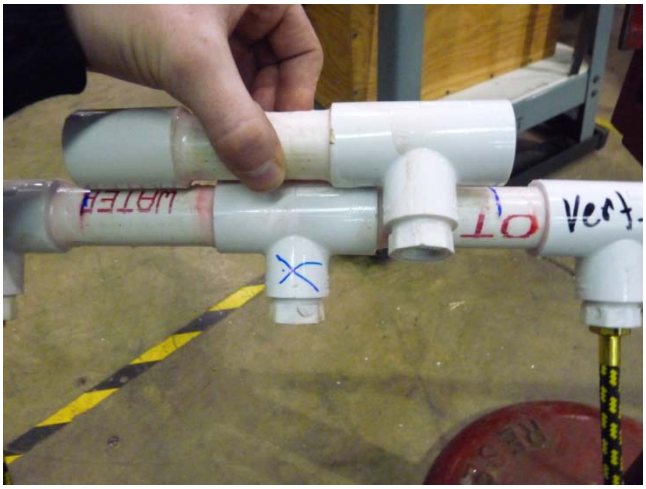
*Cutting out the section and coupling in a replacement tee assembly was the only successful method found to eliminate thread leaks. This is the *only recommended repair method for leaking threads* and will be detailed in section c.

*Note it may also be possible to remove the hose, coat the thread with RTV, and retighten in order to seal threaded leaks; however this was not attempted or tested.

d. Section replacement procedure

- First, a ¾'' socket couple should be glued to an existing tee subassembly.

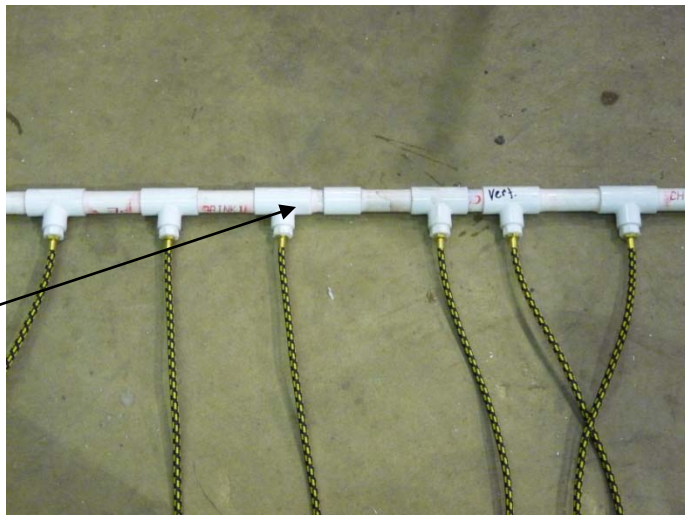
- The ends of the repair subassembly should be marked on the affected part of the header



- Next, the insert length minus the standard 1/8'' for each side should be marked on the header. These are the inside lines shown and serve as the cutting locations to remove the problematic section. The outer lines from the previous step serve as a guide for the insertion length.

- Once the section is removed, basic PVC cementing procedure should be followed to replace it with the repair tee subassembly. With the hoses in place, the in-line track is not usable, and can be supplemented by ensuring all tee nozzles are evenly pressed against the floor (may require 2 people).

- Repaired header ready to be retested. Note the local centerline distance is no longer even.



3. **<u>Recommended changes</u> (Testing and repair)**

- <u>Single header testing</u>: Currently, the testing method calls for headers to be tested one at a time; however **I recommend using 30 of the jumpers shown in section II-1a to link 2 headers and test them simultaneously.** When using this method, all hoses must still be bled before fully pressurizing. This can be done by disconnecting and reconnecting each end of the jumper individually.

- <u>Tee-to-pipe leak repair</u>: To repair a leaking tee-to-pipe connection, the remove and replace method was exclusively used. However plastic welder was later tried on a larger diameter leaking fitting-to-pipe connection, and was successful. **I recommend plastic welder be tried and used to repair tee-to-pipe connection leaks.** Leaky thread connections must still be repaired by the removing and replacing the tee subassembly.

- <u>Teflon taping hoses</u>: Currently section I-4b calls for hose NPTs to be Teflon taped and tightened down. The recommended changes at the end of section I suggests considering the Teflon tape be replaced with RTV. I will reiterate this consideration here. Once bending had been discovered as a cause of tee-to-pipe leaks, approximately 85% of all leaks detected were of the threaded variety. **Replacing the Teflon tape with a full coat of RTV on the threads may decrease the occurrence of these leaks, or eliminate them all together, and I recommend it be attempted on at least two headers to test it effectiveness.** If threaded leaks are eliminated, hydrostatic testing time would be dramatically decreased, and the semi-common occurrence of crossed threads may no longer be a problem with the RTV filling in the thread gaps. **Note if RTV is used on the NPT fittings, caution should be used as to not plug the small orifice. If the orifice is suspected to be even partially clogged, the hose should be removed and replaced.

III. Installation

1. Transporting

-After the headers have been tested, the hoses can be pre-insulated prior to transporting. Unslit foam rubber insulation should be used for maximum flexibility on the top in order to avoid the moving access platform.

-The precut 2 foot lengths of unslit insulation can be easily slipped over the disconnects using a tube fitted with a male Colder quick disconnect similar to the output line on the hand pump

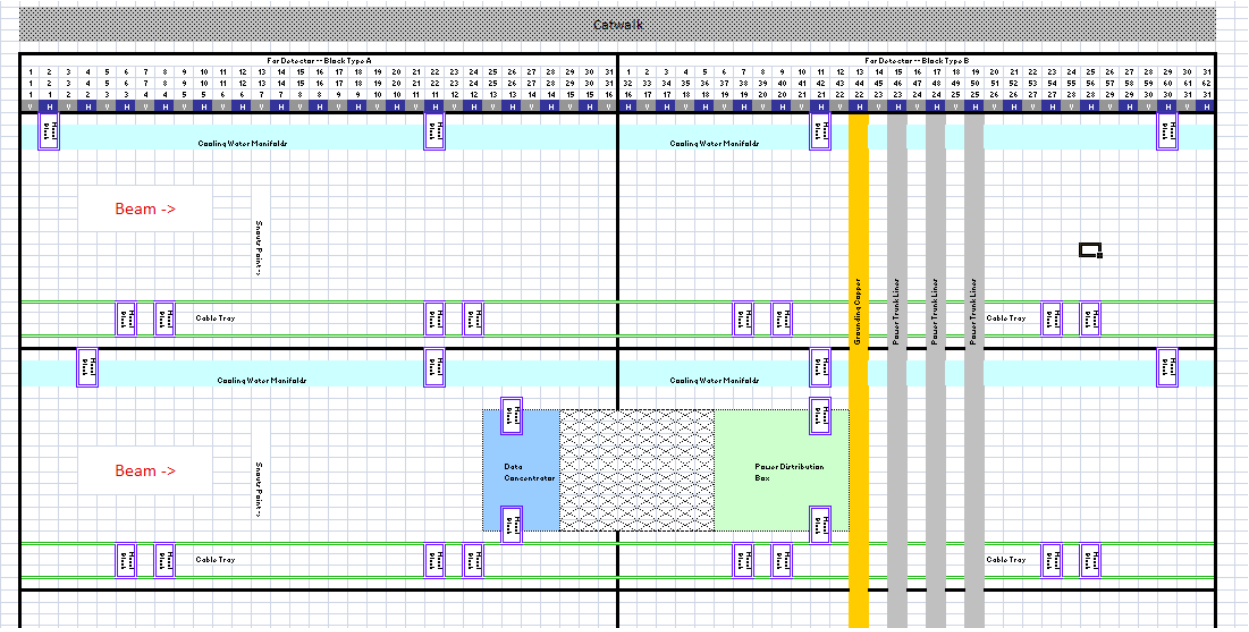
-The tube can then be connected to each hose, and the insulation pushed over it as shown.

-Once two headers have all hoses insulated, they should be faced head to toe relative to each other as they will be installed on the detector, and strapped to a stiffener to prevent bending during transportation.

Opposite facing headers with stiffener ready for transport

2. Header Mounting

Three sets of headers per di-block will be mounted on top of the detector to service the vertical modules and the top row of horizontal modules. Two sets per di-block will be mounted on the side to service the remaining two rows of horizontal modules. For top mounting, four support trees (discussed in section a) per header set should be pre-placed in equal intervals. The following map must be followed to avoid conflicts of space in the channels.



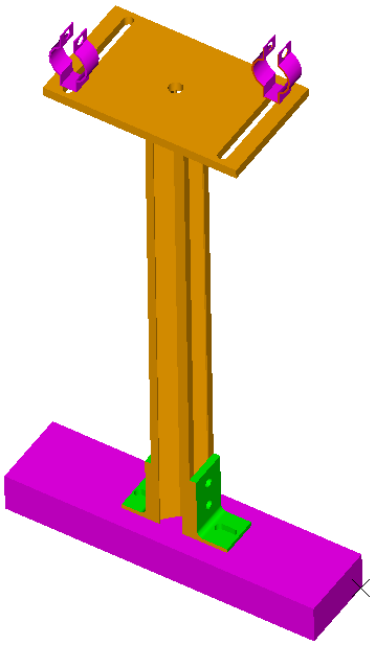
Map of the top of the detector showing which channels to avoid placing supports in.

***Note the headers did not fit through the stairway; they were passed up from the outside of the catwalks from ground level to the correct catwalk floor.**

a. Top mounting

-When mounting on the top of the detector, the stiffener should remain in place until the headers are near the correct position. They can then be detached and lifted by two people onto the four pre-placed tree supports shown below.

-The **middle vertical header and the top horizontal header were mounted to the top of the detector using a tree setup** as shown. The foot is the standard 8 inch plastic foot being used throughout the detector, and has one inch t-slotted channel mounted to it with 2 three hole slotted corner brackets. The top of the channel has been tapped to a ¼''-20 thread to mount the top plate with swivel clamps.



Tree support

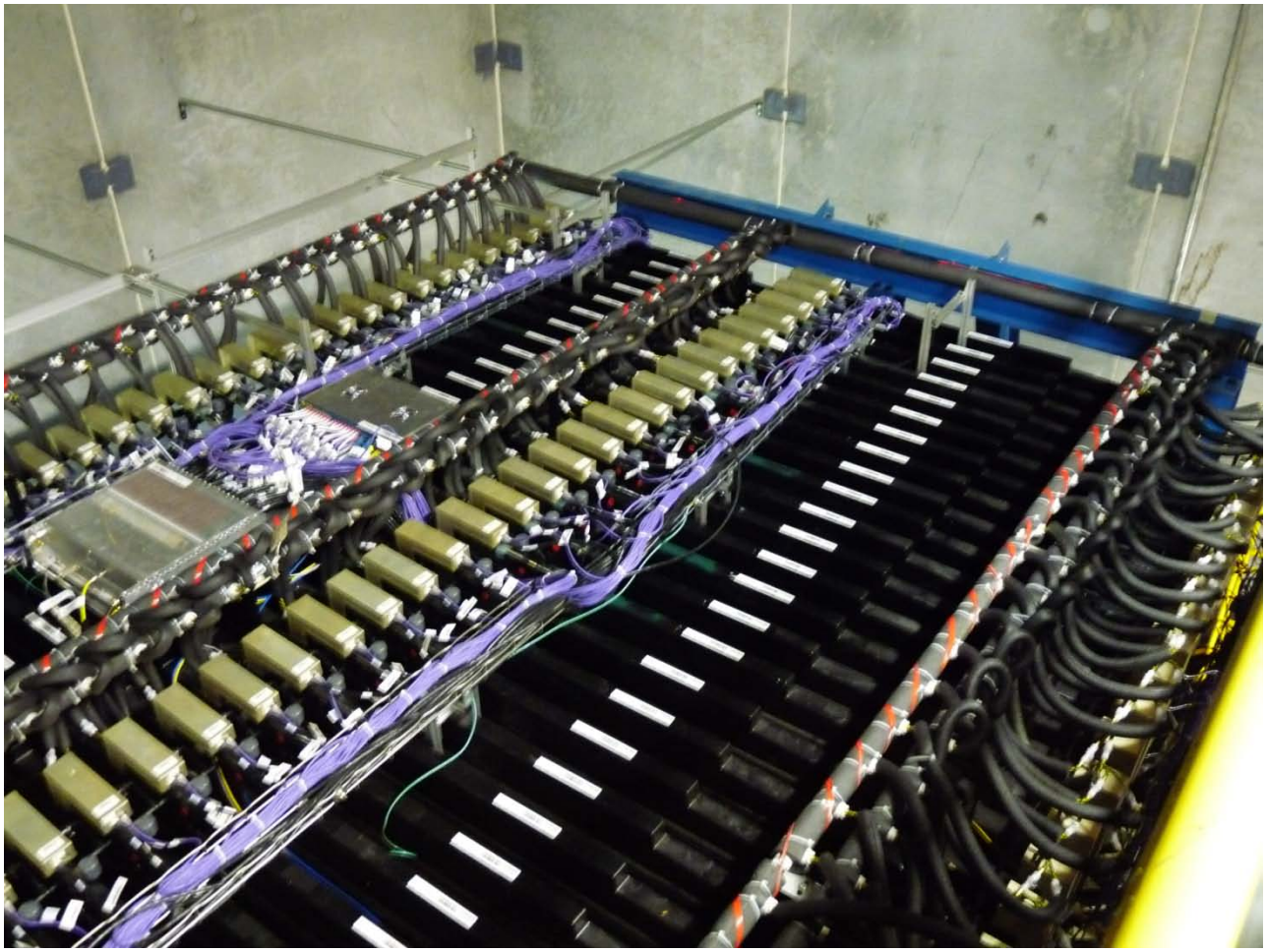
-Note the top plate is slotted in order for the swivel clamps to avoid directly lining up with the tee nozzles, however clamps may still align with the arms of the tee. With this is mind, both ¾'' and 1'' clamps should be kept on hand, or all 1'' clamps can be used with ¾'' pipe if a small saddle is included.

Swivel clamps

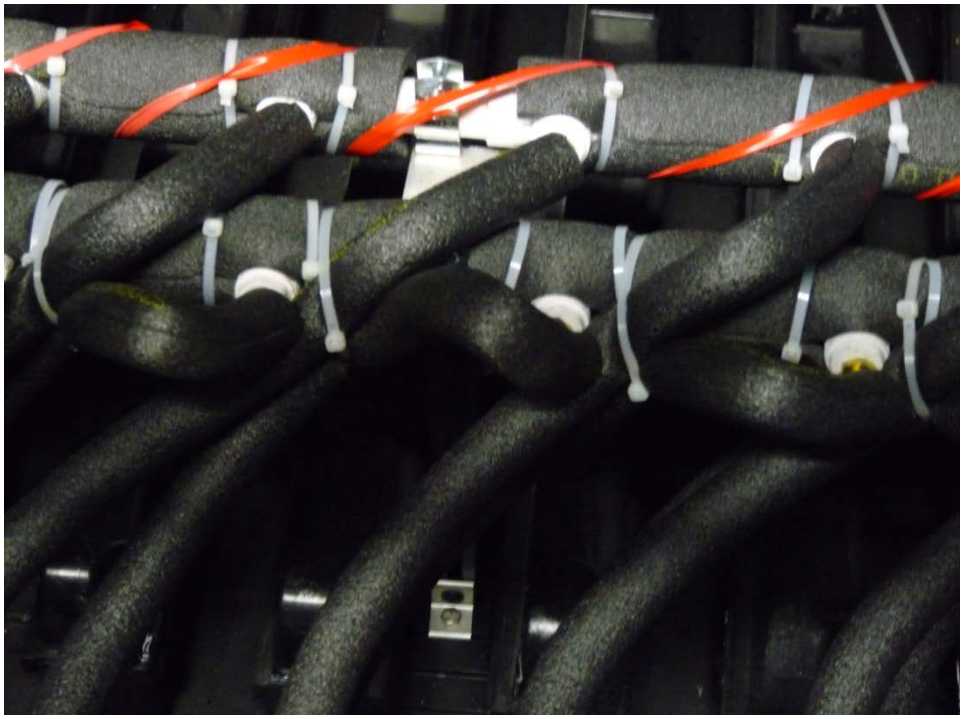
-The last vertical headers, which overhang off the detector, were mounted using an L-shaped support composed of t-slotted channel and swivel clamps as shown below.

L-shaped support

*Note the tops of the swivel clamps should be a minimum of 3 inches below the moving access platform



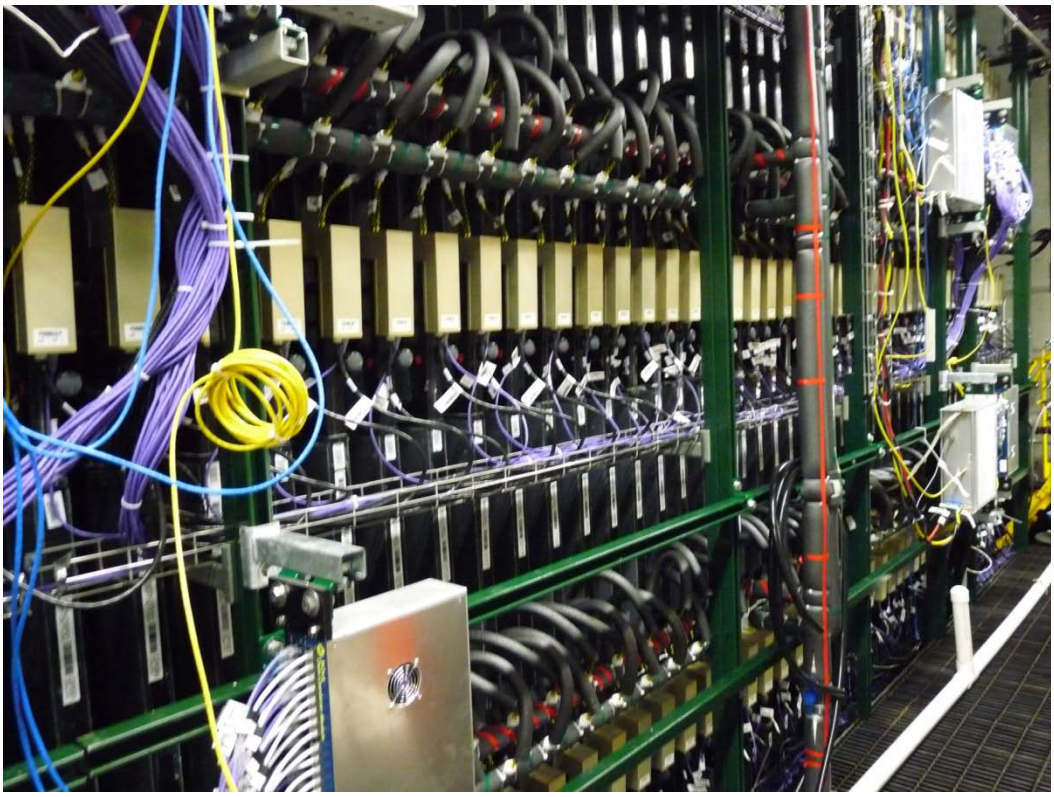
Fully outfitted di-block - top view – red tape indicates a return line



Close view of top horizontal header with the tree support partially visible on the top and bottom. ***Note the hoses must be zip-tied to the headers to avoid the moving access platform snagging one and tearing apart the system.***

b. Side Mounting

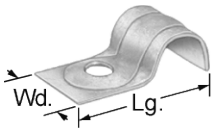
When mounting headers to the side of the detector, the stiffeners can be removed, and the headers passed between the unistrut rail structure and the detector by two or more people to prevent bending. All vertical unistrut supports have swivel clamps already directly mounted to them, so when the headers are passed through, they can be immediately hung.



Fully outfitted detector-side view. Red and green tape indicates return and supply lines respectively.

3. **<u>Recommended Changes</u> (Installation)**

-<u>Top mounting</u>: Currently the tree supports and L-shaped supports use swivel clamps which must be pre-tightened prior to header installation due to the location of the bolt, which makes in-field adjustments difficult. **I recommend switching these to a one-hole mount pipe clamp like the one shown to the right.**



-<u>Side mounting</u>: Currently when mounting headers to the unistrut infrastructure on the side of the detector swivel clamps are used. This again makes it difficult for in-field modifications once the headers are in place. **I recommend switching the side mounting swivel clamps to strut mount clamps like the one shown to the right**.

-<u>Clamp size</u>: Both ¾'' and 1'' clamps were used depending on if the clamp aligned with a section a pipe, or the arm of a tee respectively. It was found that if small sections of 1'' pipe were cut in half along their axis to form a type of saddle for the ¾'' pipe, only 1'' pipe clamps were necessary regardless of alignment.

IV. Conclusions and Discussion

There have been several changes discussed, which will be highlighted in this section. First, the headers should be redesigned to a single generic horizontal/vertical header rather than the varied designs being used. Within this generic header, all tees should be evenly spaced; the end elbow can be left for a best suited length. This end elbow assembly should also be rethought to minimize the number of fittings necessary (detailed in section I-5). When testing, two headers should be joined by thirty hose jumpers to test them simultaneously. When non-threaded leaks are found plastic welder should be used for quickest repair. Threaded leaks are more difficult and are detailed in section II-2.c. When installing, all swivel clamps should be switched to top mounting type 1'' clamps, with saddle if necessary, for easy adjustment.