Comments on Review of the NuMI Transmission Line
April 23, 2003

Responses by Bruce Baller
May 6, 2004

Overview, Specifications, Concerns
Presenter: N. Grossman

1. (Reviewer: D. Pushka) Perhaps the largest potential show stopper for this system is getting the cap bank into the electrical support room and this was not in the scope of the review. The installation needs to be worked out, plans made, HA's written, engineering notes written and reviewed now, while there is still some time to adapt before the installation is due to start.

The cap bank was successfully moved into the PS room.

Testing at MI8 & Beam Ionization Calculations
Presenter: J. Hylen

1. (Reviewer: F. Nezrick) From our experience at MI8 we have observed that some times systems are assembled with errors. For the massive amount of assembly work required in installing the horn system in the target hall, an improved method of quality assurance is required. This might include check lists, etc., there are well qualified protocols at Fermilab. However I feel one needs more than QA procedures and oversight. I believe that one needs a senior individual (engineer for physicist) who works full time with the mechanical crew doing the assembly and installation and who will be held personally responsible for the quality of the system assembly, e.g. he signs off on each step of the check list. I know the era of personal responsibility is passing, but I don't see an alternative.

Dave Tinsley is charged with this responsibility.

Transmission Line through the Block & Beyond Design/Status
Presenter: B. Boettinger

1. (Reviewer: W. Markel) Swinging Links – In general I think much too much emphasis is being placed on freedom of movement to allow for thermal expansion. I think there should be allowable movement in one direction, but not "free movement". I don't think "swinging links" are a good idea. For something to swing in an arc it actually travels in two directions (horizontally and up & down). The up & down movement is not desirable or necessary. I am skeptical that polyurethane isolator bushings will do more good than harm. This is one of those departures from previous designs that I think should be tested before it is used. Up until now all NuMi and Mini-Boone transmission lines have been

mounted solid. I am worried that both of these flexible elements (especially if used together) will allow the transmission line to vibrate forever. The single direction permissible movement for thermal expansion does not need to be totally free (meaning totally unobstructed, with zero reaction forces). The transmission line can be retained within tracks or with slotted brackets with some fastening force applied, as long as this retaining force is low compared to the force required to break the weakest link.

OK

2. (Reviewer: W. Markel) Floor Stands – Two-legged stands made from double unistrut will have no sway resistance. I recommend four- legged stands made from square tubular steel. In today's economy the cost of welded frames (from outside shops) is very reasonable, and valuable technician time is not consumed at installation. These rigid frames can be made adjustable by adding pieces of unistrut as cross members or as slots in locations where adjustability is needed.

OK

3. (Reviewer: W. Markel) Penetration Pipe Stands – I don't have a problem with the concept. The spring tension wheel provides the needed resistance to free movement both on and off axis. I do, however agree with other reviewers on some already mentioned issues. A transmission Line cover and/or painting of the pipe ID. are needed. The two bottom wheels are at a bad angle so inverting the wheel assemblies looks better. My only concern is whether the spring will be strong enough if the single wheel is on the bottom. The spring must then support the weight of the entire assembly in addition to its job eliminating free movement. Maybe there is another arrangement?

OK

4. (Reviewer: W. Markel) The Loosening of Bolted Connections – A "belt and suspenders" technique that has worked very well on the Min-Boone Stripline for any connection that must never come loose is the use of Belleville washers and Spiralock Nuts together. Spiralock Taps can be deployed where nuts can't be used. The connection is as good as welded, cheap, and can be disassembled.

OK

5. (Reviewer: W. Markel) Assembly – For all the effort put into Engineering, it can all go for nothing if critical errors are made during assembly. Once prototypes have been built and tested and it comes to building the real thing, the opportunity for errors can increase. When you are building a system for the second time, even if it was over a year ago, you "know how to do it". There is a tendency for technicians not to look at drawings. There is a tendency for engineers not to provide heavy supervision. With a lot going on at one time, the engineer may not

be able to provide heavy supervision in any one area. My one suggestion would be to give some thought to each major assembly task and make a brief list of "must do items" and "must avoid items" for each area and review these with the assembly crew at the start of each task. The feedback you get from this exercise may help determine what else is required.

The stripline engineer is very good a field supervision.

6. (Reviewer: J. Hylen) Biggest issue raised to my mind was Frank and Kris comment that mating / unmating the z-link needed to be done in a controlled fashion. In my opinion, a set of daggers or an alignment fixture/tool is needed to guide these together. I am less enthusiasitc about using a small removable link at each end, since we already got into trouble once that way - it does not guarentee alignment.

7. (Reviewer: J. Hylen) A beam spanning the chase should be installed to support the Z-link, rather than trying to attach to the module and one side of the chase. Andy wants to use the same beam to put a curtain (aluminum sheet?) across the chase which would force the air flow up through the otherwise dead space of the shielding bump-up for the stripline. This is an excellent idea and simple to implement. Am not sure if the beam will need to be removeable in order to get the module out - probably does not interfere with the module itself, but likely interferes with the removable shield block just downstream of the module (which we will remove before taking the module out).

8. (Reviewer: J. Hylen) For the stripline running along the wall, did not see any explicit number for how much thermal expansion it needs to accomodate. Making a guess, it is about delta-T of 20° C, 10 meter run, aluminum thermal expansion coefficient of 25×10^{-6}, or 5 mm = 0.2 inch. Is this accomodated by the Z-link supports? Having some calculation or demonstration that the expansion does not generate unacceptable stresses should be included in an engineering note. (This is already done for the stripline clamp to horn section).

9. (Reviewer: J. Hylen) Although it was suggested to fill in the extra space in the stripline block to keep airflow confined to the stripline itself, I don't want to do that. It could be that cutting down the clamp cross-sectional area to allow MORE air flow would be useful, if this is simple to do. I believe (which needs to be confirmed) that the heating was calculated with the 5.2 ms pulse length - so that for our real operating condition of ~2.3 ms pulse length the energy deposition will be a factor of two less, and even a reduced air flow is fine.

10. (Reviewer: J. Hylen) Making the stripline stand along the wall from bulkier beams below the stripline instead of unistrut over the stripline would appear to make installation of the stripline easier, and make a surdier structure that could be used to damp down vibration if that turned out to be a problem. A few steel beams

might turn out to be cheaper than manpower costs to think about possible vibration problems in detail.

11. (Reviewer: D. Pushka) Couple of bits on the stripline portion thru the 24 " dia. pipe:

    a. Earlier, our contractor put the pipe assembly (weighs 1750#) into a similar 24 inch pipe (sloped down slightly at ~ 14%) with little problem. The pipe assembly has no wheels, just metal pads that slide nicely along the i.d. of the rusty pipe. Therefore, please consider removing the wheels from the stripling assembly. Unless they are metal, they will take a set over time.
    b. The spring loaded top (or bottom wheel) will not really clamp the assembly into the tube. It is a spring afterall. If there is a desire to anchor the stripline into the tube, some wedges need to be actuated from outside the pipe one it is in place. Could this be a location for surplus NASA explosive bolts? Unfortunately, no. But four wedges located 6', 12' 18' and 24' into the pipe (the last two accessible from the other end) would do a fine job of clamping the stripline in place.
    c. A cover over the stripline in the 24 inch penetration seems to be a waste of effort and a potential 'something to go wrong'. Can we be sure that it stays in place and doesn't come loose, shorting out the stripline? No. But the pipe is not going to come loose and if there is a worry about the tightly adhering rust on the i.d. of the pipe, paint the pipe. Besides, the cover would adversely affect the free convection needed in this area.

12. (Reviewer: D. Pushka) Couple of bits on the stripline stands along the west wall (this is not a walkway and should not be referred to as a walkway):
    a. The unistrut stands seem to be a fine, basic design. Easy to build and install. Inexpensive. Might not provide a whole lot of damping, though. If the damping needs can be quantified (not just use this material here because that is what was done in MI-8) one could imagine replacing the unistrut with a carbon steel box section weldment. This weldment could be galvanized for corrosion protection and then filled with concrete to add mass to dampen vibrations from the stripline. This adds cost and so would need to be justified before changing Bill's present design.
    b. I do not understand the bushing links and the need to dampen vibrations. If the bushings are installed, they reduce the transmission of vibration from the stripline to the stand, reducing any damping from the stand. The trapeze is good for accommodating thermal expansions, but at the expense of reducing damping from the stand. Which is more important?

13. (Reviewer: D. Pushka) Twenty-six (26) cfm is shown on the SB&O dwgs to go thru both 24 inch penetrations. The pipe penetration could be blocked-up to cause the majority of the flow to go thru the stripline penetration. 26 cfm is pretty small.

14. (Reviewer: D. Pushka) I would advocate using a pair of C channels or a Box section (maybe two side by side box sections) in lieu of the single wideflange section shown on example 7 (the stripline from the wall to the module) to stiffen up the structure.

15. (Reviewer: D. Pushka) The Z section of stripline appears to be long and heavy. Separating it into two sections will still result in each piece being sufficiently heavy to require crane(s) to handle and throws in one more joint (I assume joints have lower reliability than does a non-joint section). I suspect the existing design is the right way to go so long as the handling fixture (lifting fixture??) is given adequate design time and so long as the fingers at each end can engage simultaneously (like a u-tube on a cyro connections). If both a translation and a rotation are needed to get the fingers at both ends to engage, then I think this will be difficult to achieve a good quality fit up each and every time the Z section needs to be installed.

16. (Reviewer: D. Pushka) Final bolt down installation of the cap bank to the floor should be the last position determined. The horns go where the beam is, the stripline off the horns, and the 28' section is fixed in two directions by the location of the 24 inch pipe (which has not been located with any great accuracy). The cap bank attached to relatively flexible cables and water lines. It can be moved a few inched to accommodate tolerance stack-up in the horn / hall / stripline assemblies with little problem as long as people do not get emotionally attached to having it appear in a particular location in the power supply room.

17. (Reviewer: K. Bourkland) Cooling of stripline in the penetration between PS room and Target Hall. Stripline heat loss is 525 Watts/m at 5.2 ms pulse width and 262 Watts/m at 2.6 ms pulse width, operating at 20 degrees C ambient. For the 28 foot length the penetration heat load is 4.5 kW and 2.25 kW respectively. Airflow velocity through the penetration should be established high enough to reduce linear thermal expansion to acceptable levels. The stripline location in the penetration is fixed at the PS room end, meaning that all linear expansion of this section will have to be absorbed by lateral movement (x- axis relative to beam) of the stripline running along the target hall wall. The proposed air flow of 26 cfm seems inadequate and is this value for an empty penetration or for the reduced cross-section with the stripline installed. 26 cfm means one air change each 3-1/2 minutes.

18. (Reviewer: K. Bourkland) Address cooling the six-foot (nominal) section of stripline presently in dead air at each horn position where the stripline breaks out of the shielding.

19. (Reviewer: K. Bourkland) The temperature co-efficient of resistance for the bus alloy at 20 degrees C is 0.0038/degree C. The temperature of the stripline just downstream of horn 1 is shown approaching 100 degrees C, due mostly to beam heating. Factoring in the co-efficient of resistance for the bus delta-t over its 20

degree C value increases the Ohmic heating by 27%. The power loss for the 8" bus at 90 degrees C is 212 W/conductor/meter length. If this was not factored into the calculation, it would be good to do so to see what the operating temperature might become.

20. (Reviewer: K. Bourkland) The consensus is that the stripline supports are not substantial enough to dampen vibration. I agree.

21. (Reviewer: D. Tinsley) A robust cover to protect the stripline's silvered contact surface from damage during shipping and installation needs to be used.

Dave Tinsley is now the stripline engineer.

22. (Reviewer: D. Tinsley) A tool to align and pull two sections of stripline together would aid assembly in the target hall. This would be used with the current design of long sections of stripline connecting directly together.

Dave Tinsley is now the stripline engineer.

23. (Reviewer: D. Tinsley) An alternate method of connecting two long sections of stripline together would be to use a short, 24 inch long splice joint. An example would be the splice joint connecting the power supply to the stripline. There would be less chance of damaging a contact surface and provide more adjustment. On the down side you would have more joints and have to redesign the stripline.

Dave Tinsley is now the stripline engineer.

24. (Reviewer: D. Tinsley) I don't like the Z shaped stripline because it is more prone to not fitting because the length is not adjustable. If one out of the 8 bus bars is out of tolerance it is less likely to fit. Even if you assemble out of tolerance buses and get them clamped together the contact surface may not be parallel together. I prefer the L shaped stripline because if the length is off by half an inch it doesn't matter, the difference gets taken up in the joint. Also you have a greater chance to get the contact surfaces parallel if there is a long straight before the clamp.

Dave Tinsley is now the stripline engineer.

25. (Reviewer: D. Tinsley) Some thought should be made what would happen if the stripline were solidly bolted down to a ridged support that had some mass to it. Thermal expansion and the forces would be considered. The stripline at MI-8 is solidly bolted down every 2 feet to the I-beam with stripline clamps every 1 foot.

Dave Tinsley is now the stripline engineer.

26. (Reviewer: D. Tinsley) Dow-Corning #4 insulating silicon grease should be used on all silvered contact surfaces to provide lubrication, corrosion protection, and to prevent delaminating of silvered surface during disassembly. On all the stripline connections that were properly made at MI-8 we used the silicon grease we have had no failures. One of the contact pads, which had no silicon grease, on horn 1, had delimitation of the silver plating.

Dave Tinsley is now the stripline engineer.

27. (Reviewer: D. Tinsley) Use Glyptal coating on all G-10 pieces to prevent moisture absorption. This is what I did on the test stripline at MI-8. This should be in the specification when the vendor makes the parts.

Dave Tinsley is now the stripline engineer.

28. (Reviewer: D. Tinsley) Have a fabrication specialist, like Danny Snee, do quality control checks at the vendor during the manufacture of the stripline pieces.

Dave Tinsley is now the stripline engineer.

29. (Reviewer: F. Nezrick) Review cooling conditions for the transmission line system within the T-Blocks using actual dimensions of components being designed. Concern is that the shunt air paths in the T-Blocks may be larger than were anticipated.

30. (Reviewer: F. Nezrick) My concerns regarding the transmission Z-Bar Link are mostly irrelevant since a new design is being developed. However the final design must allow, during assembly and disassembly, a controlled alignment of the transmission lines without causing damage to the transmission line current carrying contact surfaces.