**Comments on Decay Pipe Review**
**July 9, 2001**

**Responses by Bruce Baller**
**May 6, 2004**

<u>Design & Engineering of the Pipe</u>
<u>Presenter: D. Pushka</u>

1. (<u>Reviewer: J. Anderson</u>) Consider removing one (1) foot of concrete from each end of the decay pipe to allow for easier installation and possible removal of the decay pipe ends in the future. The current design leaves a marginal amount of space for welding the flanges on.

The decay pipe ends will be highly radioactive and cannot be so readily removed.

2. (<u>Reviewer: J. Anderson</u>) Consider the addition of a water drain port at the downstream end of the decay pipe.

Done.

3. (<u>Reviewer: J. Anderson</u>) Review the specification of the vacuum pump to insure water from pump down operations does not cause a problem with contaminating the vacuum pump oil.

Done.

4. (<u>Reviewer: J. Anderson</u>) Review the use of the water soap testing of welds. Weld leaks after the pipe has been grouted in place will be near impossible to repair.

All welds were tested.

5. (<u>Reviewer: J. Anderson</u>) How will the grout shrinkage effect the decay pipe uniformity, alignment tolerances, cooling pipes, etc. A possible test of the contractors plan, when submitted, should be considered. Once the decay pipe is grouted in place, there are no possible repairs.

No effects on alignment were found after backfilling.

6. (<u>Reviewer: J. Anderson</u>) Have the effects of radiation damage to the PVC piping been reviewed for use as an insulator to the copper cooling piping.

Radiation damage to the cooling piping jacket is not a concern. The potential difference between the decay pipe and the cooling pipe is a small fraction of a volt. Any conductivity increase due to radiation damage will not promote corrosion.

7. (Reviewer: J. Anderson) A drip ceiling should be considered for covering the muon chamber electronics, the decay pipe vacuum systems, absorber RAW water system, and instrumentation racks near the absorber.

Done.

8. (Reviewer: J. Anderson) The upstream cooling water manifold design should be reviewed to insure a single cooling pipe could be isolated in the event of a leak. The design should be such that individuals performing the repair would receive minimal radiation exposure.

The system has been designed to minimize the possibility of leaks, by eliminating the use of valves. The system has been pressure tested.

9. (Reviewer: J. Anderson) With the deletion of the hadronic hose from the project, is there still a need for cooling the decay pipe?

Yes.

10. (Reviewer: S. Childress) I am concerned that current design of the cooling pipe manifold does not provide viable options for isolating a bad pipe and continuing to flow water through the remainder. It seems not very realistic to attempt to remove manifold shielding, isolate which pipe leaks, and redo manifold to isolate in a hot radiation area - as I believe was discussed. Manifold-ing enabling independent flow loops should be done at the beginning, along with isolation capability OUTSIDE the shield.

The system has been designed to minimize the possibility of leaks, by eliminating the use of valves. The system has been pressure tested.

11. (Reviewer: S. Childress) A vacuum access port near the upstream end, as was discussed, seems very important. Best would be a small diameter side access pipe - several inches in diameter (a reduced size version of the 24" downstream access port), where the port extends outside the shield. Each - upstream and downstream - should have flanged, not welded ends. With the flanges outside the shield, and use of double metal seals, these would be very robust - and enable access options.

Access to the decay pipe is not feasible given the radiation levels, particularly in the upstream end.

12. (Reviewer: M. Gerardi) I could be mistaken but the pumps are slated to be near the closed loop system which will be behind locked gates the decision to place the pipe against the rock has groundwater implications. Re-calculations should be considered.

Activation of the ground water outside the shotcrete lining due to RAW piping near the walls is negligible. Furthermore, this ground water makes it's way into the sump water, which is discharged above ground.

13. (Reviewer: M. Gerardi) PVC is a poor choice of insulator if the resulting dose rates in the region are high.

See response above.

14. (Reviewer: M. Gerardi) There does not appear to be any means for locating, let alone repairing, a vacuum leak should one occur once the system is activated with beam. If there is an intent, the procedure should be developed.

This is correct. The decay pipe has been vacuum tested successfully. No repairs are envisioned in the event a leak develops. Instead, the pipe would be filled with helium.

15. (Reviewer: M. Gerardi) My guess would be that acces to the pipe, once activated, will be difficult if not impossible. Is there a plan "B" ?

See above response.

16. (Reviewer: M. Gerardi) If water is used for decay pipe cooling it will likely need to be a closed loop, even if from only a sampling standpoint to ensure discharge requirements. No one will allow discharge without analysis.

Correct.

17. (Reviewer: M. Gerardi) I might have overlooked this but, can the cooling lines be further away radially to remove the heat ? Do they really need to be close by ?

The cooling lines are as far from the beam as possible.

18. (Reviewer: N. Grossman) It was mentioned that there would be radial cracks in the concrete as it cures. I do not envision this being a radiation issue since access to this area will be very limited. But I would like to know how large one envisions these cracks will be and is there a possibly of somewhat large pieces of concrete breaking off if there are a lot of these cracks. Once again, I do not see this as a concern, but something that would be nice to know about up front.

No significant cracks have been seen.

19. (Reviewer: N. Grossman) I believe the cooling pipes will be surrounded at some level with PVC? If so, are there any issues with PVC and radiation damage over the years? It can release chlorine isotopes upon activation.

See response above.

20. (Reviewer: D. Jensen) Vacuum Gauges: I would suggest a couple at each end. I am a strong believer in redundancy. Allows one to understand the 'systematic error' and to maintain continuity of measurement WHEN one of the gauges fails. Dave Pushka suggested that there should be pipes to a lower radiation area where these gauge(s) might be mounted. If necessary, can always use pure metal gaskets (e.g. conflat - Cu-steel seals) to avoid any possible degredation of the seal over time, to make seals for the instrumentation.

Vacuum gauges are located in the downstream end only and are considered adequate.

21. (Reviewer: D. Jensen) The question of a 'person port' seemed to get a lot of discussion. It is clearly the hope the designers that the system be closed up once and for all - no leaks and no problems for 10 years! The only flanged port is the pumping port (and I hope some gauge ports).

Agreed.

22. (Reviewer: T. Leveling) I strongly suggest that the 2 foot diameter manway not be a welded closure. Instead a gasketed closure should work quite well. If access is EVER required through the manway, a gasketed closure is certainly going to be easier to manage. Contrary to statements made in the meeting, leak tightness of a gasketed closure should not be a problem.

There is no method for accessing the decay pipe.

23. (Reviewer: T. Leveling) There are several problems with setting the decay pipe which perhaps could be attacked in unison.

    a. I would not run cooling through more of the decay pipe region than necessary. It would be sensible to make a break in the decay pipe pour to allow for the decay pipe cooling plumbing to turn around and for personnel access just in case isolation or repair of a broken run is necessary. Portable shielding blocks could be used to fill in the pour.

    The cooling lines run the entire length of the decay pipe.

    b. The use of PVC cooling piping would solve the corrosion problem discussed in the presentation. It should be straight-forward to determine at what distance from the decay pipe surface the PVC should be set to avoid radiation damage over the life of the experiment.

The copper cooling pipes are jacketed to eliminate the corrosion problem.

    c. I didn't get the impression that personnel access into the decay pipe after construction has been very carefully thought out. I think it would be wise to get advice from the fire department and some safety professionals on the size of the access port. I think 2.5 to 3 feet would more reasonable if there's a chance people have to make an entry.

See above response

d. I realize it's the contractor's problem to set the pipe straight in the cement. The upward force on the pipe due to buoyancy works out to about 4200 lbs per linear foot. Blocking the pipe from the ceiling seems like a reasonable way of holding the pipe in place. The bearing surfaces would have to be calculated to prevent deformation of the decay pipe. Support of the pipe from below must also be an issue. One could consider filling the decay pipe with water temporarily during the concrete pour to further reduce the buoyancy force to about 2400 pounds per linear foot.

The decay pipe was installed by the contractor with no problems.

e. It's quite likely that vibrators will be necessary to work the concrete in around the decay pipe. Some care will be necessary to prevent damaging the decay pipe cooling tubing. This is another good reason not to continue cooling for the whole length of the decay pipe. f.) Dixon mentioned that it's a well known problem that pipe wrap can lead to excessive corrosion. I didn't catch if that was in soil, concrete, both, and whether there were other contributing factors. It's not clear then why inserting Cu tubing in PVC is a good idea unless there are no breaks in the PVC run. Again, with concrete vibrators used around the decay pipe, care will have to be taken to ensure that the PVC is not damaged. To summarize, all of these issues should be considered simultaneously in the decay pipe design. The bracing of the decay pipe, shell stiffeners, access to cooling plumbing and support and installation of the cooling plumbing are interrelated. I think NUMI project management should work aggressively with the contractor on this aspect of the project to ensure it is done well. I didn't get the impression this was thought to be possible without incurring some tremendous cost. Since the pipe doesn't exist yet, it can't be too late to get it right.

Done.

24. (<u>Reviewer: P. Martin</u>) The decay pipe fabrication and installation tolerances are quite tight. The statement in the spec that any out-of-position tolerance must be fixed is almost absurd. Once this is cast in grout, fixing it will be very expensive, and the arguments over whose responsibility it is will delay the project. The NuMI project needs to understand the real implications, both to physics and cost ramifications of these requirements. We did not hear much discussion of the support of the pipe. A good support design is critical to achieving the necessary tolerance. A plan should be developed for the QC to assure that the pipe meets the design tolerance prior to grouting. Since the pipe will want to float as the

grout is placed, perhaps additional supports are required. Not knowing the procedures that Healy will use puts the project in an awkward situation of trying to plan for all possible methods. A better approach is, through contracts, to insist on a detailed plan from Healy. Stress that this will allow us to work with them to meet the required tolerances. There are pitfalls we are all aware of here…we cannot tell the contractor what to do without our assuming liability for the results…but we can lend them calculational support or point out problems that they may not have thought of. We can do some of this without any information from them; e.g. as a function of spacing of infinitely stiff supports, what is the expected sag due to gravity and deflection due to buoyancy of the pipe? Although confidence was expressed in the ability of CBI to do a good job, the MiniBooNE tank was considerably out of specification. You might talk to Peter Kasper about that. I would also recommend adding a stiffener ring, perhaps a special, larger one, at the point where the concrete/grout stops at each end of the decay pipe, to help maintain the circular shape. This will make mating to the end piece easier.

Done.

25. (Reviewer: P. Martin) The cooling piping appears to be very expensive because of its impact on the overall Healy schedule. There is only one way to fix this: make the installation simpler. The design appears to be somewhat overkill, at least if I am interpreting the temperature plots correctly. The bulk of the energy deposition is only in the first 100 m or so, and yet the cooling pipes extend over the entire 2200 foot length. This is extending the installation time, and driving up the cost. Although we do not know in what sequence Healy will do the decay pipe installation, if they start at the upstream end, then perhaps the majority of the cooling pipes, around the upstream end, could be installed concurrently with the downstream decay pipe. The NuMI project should evaluate alternate cooling designs, in which less cooling is installed in the second half of the decay pipe. Perhaps none is needed there. (In the case of MiniBooNE, although the beam power is only 30 kW, it is concentrated over a much smaller region, so the energy density may not be all that different. The only reason we went to cooling at all was to keep the liner, which is 7' from the decay pipe wall, at a safe temperature.) There was considerable concern expressed about the possible galvanic action between the copper piping and the steel decay pipe. As I pointed out during the review, the copper pipes are much closer to the steel than they need to be…the energy deposition is spread out over the first foot or two radially. A brainstorming session might be useful to come up with some other ways of mounting the piping somewhat further away from the decay pipe, and thus avoid any possible contact. As an example, instead of or in addition to using the stiffening rings, (which then needs all the necessary holes drilled), why not some separate, very cheap material (molded plastic?) that supports the pipes and simply gets cast in place. (By the way, you need to worry about the buoyant forces on the pipes too!)

OK

26. (Reviewer: P. Martin) With regard to the specifications, I have already commented on some things above, but here are a few more. First, given the safety problems with Healy to date, the rigging issues for the decay pipe need a written safety plan, approved by the lab. On pipe fabrication tolerance, there is the 1/8" tolerance on the straightness of any 10' section of pipe, but no tolerance is given on the parallelism of the ends. If the ends aren't parallel, it will be very difficult to attain the overall finished straightness tolerance.

The decay pipe was installed as per the specs.

27. (Reviewer: A. Para) There were no details of the concrete shield construction offered. I understand that the thickness of the concrete shield is varying with distance to take advantage of the energy deposition profile and to minimize costs of the installation. It would certainly complicate the process of installation and create new classes of problems. None of this was mentioned at the review.

The decay tunnel was excavated by TBM so the profile was constant down the length.

28. (Reviewer: A. Para) There is very little we can monitor about our beam line. The far and near detector spectra are closely related, but the principal difference in the observed spectra is related to the effective distance from the decay point to the near detector. This is so, because our near detector is so close. The most important beam characteristics, determining our systematics is related to the beam angular divergence. This is, in turn related to the profile of the energy deposition along the decay pipe. Hence: I think it is worthwhile to consider some detectors placed along the length of the decay pipe to provide us information about the energy deposition. Thermocouples? Beam loss monitors? They could be cast into concrete, or better yet, sobe boxes can be cast and detectors place there later..

Instrumenting the decay pipe was considered but abandoned due to cost/benefit considerations.

29. (Reviewer: G. Rameika) A concern that emerged was what if after the pipe is installed in concrete it is found to be way out of alignment tolerance. Someone at the review said that Healy would likely just ask us to accept it any way. What is the consequence if something like that happens? It wasn't clear to me that we really know how much sag or wiggle is acceptable. (I guess I'm not convinced that the 2cm spec is a valid requirement from a physics point of view.) I'd like to see the physics requirement on the pipe alignment more clearly demonstrated.

The decay pipe was installed as per NuMI specs.

30. (Reviewer: G. Rameika) I think it was obvious that the cooling pipes are not really needed ( they were left over from the hose). I'm concerned that keeping

them and using them adds unnecessary complexity that will only lead to operational problems.

The cooling system will be necessary if NuMI runs at higher intensity. The cooling system is in the project scope.

31. (Reviewer: R. Sanders) Decay Pipe Out-Of-Roundness: There appears to be concern that the wet cement, when it is poured, will distort the decay pipe into an oblong cross section at the ends…. A damaged out-of-round decay pipe that does not satisfy UG80 is a serious and difficult safety concern that would have to be addressed through the formal safety review process of the vacuum vessel engineering note. … The contractor is therefore obligated to repair or replace any damaged decay pipe. The contractor must be made to understand that the present contract requires that the entire decay pipe satisfy UG80.

See above response

32. (Reviewer: R. Sanders) Plastic sleeves on Copper Pipe: The copper cooling pipes pass through the ring stiffeners placed every 210" along the length of the decay pipe. Plastic sleeves should be inserted into the holes in the stiffeners through which the copper pipes must pass. One end of the sleeve should have a lip to prevent it falling through. Perhaps the sleeves could be glued in place. Ideally the sleeves would have a snug fit around the copper pipe to help restrain its deflection.

The cooling tubing is insulated.

33. (Reviewer: R. Sanders) Additional Ports: The decay pipe should have a drain at the bottom and a vent at the top. They could be welded off, but my strong personal preference is to run the pipes to an accessible location and install high quality valves such as Whitey ball valves that are vacuum tight and lock them shut. The drain valve could be used to drain water or vacuum pump oil from the decay pipe. The drain and vent valves together could be used to purge the decay pipe with nitrogen gas to dry it, if the need ever arose. Additional vacuum instrumentation ports (i.e. ¼" SS tubing runs) should be installed at the decay pipe top and bottom as well. Do not add instrumentation, but if vacuum problems arose additional instrumentation could be added to these ports to aid with the diagnostics. I would terminate these taps with high quality valves such as Nupro 4BKs and lock the valves closed. These ports may never be needed but this is a cheap thing to do. Minimizing the number of instrumentation ports is not a good practice especially on a on a ½ mile long vacuum vessel.

There is a drain at the bottom but no top vent. No other ports are included,since access to the upstream end and along the decay pipe itself is difficult.

34. (Reviewer: W. Smart) The access port sticks outside the shielding, so we may get by with a bolted flange using organic or metal O-rings. If you design double

seals with a pumpout between them (done in many places on the 15 foot Bubble Chamber) you can constantly verify that the flange is sealed.

See above response.

35. (Reviewer: R. Stanek) I second the suggestions made during the meeting for putting in a drain port, instrumentation lines, and upstream purge line (so that the pipe can be flow purged with dry air).

See above response.

36. (Reviewer: R. Stanek) Given the concern regarding galvanic corrosion, one might want to revisit the decision of putting the cooling pipes outside or inside the vessel. I would look at the choice in terms of failure modes, risk, possible negative long-term ramifications, cost and thermal performance. The project may decide it is easier to add the cooling to the inside of the tank after the contractor is done back filling but before heads are welded onto the vessel.

See above response.

37. (Reviewer: R. Stanek) If the copper water pipes are run external to the vessel, this implies an alignment of the stiffener rings down the entire length of the decay pipe to allow the copper pipes to pass through on a strait path. This should be part of the change order to the contractor (presently not in the contract specification).

See above response.

38. (Reviewer: R. Stanek) Look at the water-cooling system (treated like a RAW system) and assure that it is designed to allow easy maintenance and isolation of any given line (out of the 12) that might develop a leak. The water system should be instrumented to easily detect a leak should it occur.

See above response.

39. (Reviewer: R. Stanek) I am not familiar with the leak testing procedure proposed, however, I imagine that "certified" operators can make it work effectively. I would require that the operators prove to the project that they can detect a known leak (hole or weld crack) in a weld before accepting the verdict that the pipe is leak tight.

See above response.

40. (Reviewer: R. Stanek) Some thought might be given to other forms of NDE to help verify the soundness of the welding. Help might be available from other sources (such as ANL). I assume that the final weld specification (how each pass is performed) will be submitted to the project for approval.

See above response.

41. (Reviewer:  R. Stanek)  It would be beneficial to do an analysis of the vacuum system gas load.  Expand on the calculation of pumping speed and conductance and look at outgas loads and the maximum leak rate that could be tolerated and still meet specification.  The vacuum requirement should be revisited with the intention of setting the nominal and maximum vacuum levels in the decay pipe. The ability to use commercial equipment to separate and filter the water out of the oil of the vacuum pump should be investigated.

OK

42. (Reviewer:  R. Stanek)  Assuming one could ever imagine that the heads would get cut off, one would want to plan how to do it now.  In order to cut off the head and prep the edge for welding, one probably wants to consider using a commercially available process (as was used in NWA for the D0 test cryostat). This requires a certain clear and flat space on the vessel for the rails and a minimum distance to the floor.  The proposal to leave more room between the end of the concrete back fill and the edge of the pipe should be considered.  This might also be beneficial for other reasons, such as ease of hooking up the water lines.

We do not imagine cutting off the decay pipe ends.

43. (Reviewer:  R. Stanek)  There were several comments during the meeting about keeping the pipe round at its ends.  This may or may not be a problem based on the design of the end attachments.  Adding additional external stiffeners or temporary internal bracing was suggested.  This should be looked at with respect to the short (one foot) ends on the decay pipe, future needs to cut off the ends and possible spring back of pipe end once the temporary support is removed.

Done

Design & Engineering of the Windows
Presenter:  E. Chi

1. (Reviewer:  J. Anderson)  Have calculations been performed to demonstrate the upstream decay pipe cap can structurally withstand the intended and accident condition beam power limits? More directly, is it possible to burn a hole through the upstream decay pipe cap causing a vacuum failure.

It is possible but difficult to focus the pre-target quadrupole magnets to create a waist at the upstream end cap. This condition is precluded by the NuMI beam permit system.

2. (Reviewer: S. Childress) I have significant concerns with the expressed intent to remove either of the large (6'6") end caps if there is initial need for leak diagnosis. It was a very good decision to weld these end caps - the parameters are very different than for the side access port(s). However, once welded this should be a final assembly. Access ports should provide the access option if vacuum problems for any part of the pipe must be addressed.

No access ports.

3. (Reviewer: M. Gerardi) What is the beam interaction and resultant dose rate on the upstream decay pipe window ? Does it adversely affect experimental data? It certainly affects groundwater and the sourounding dose rates.

It does affect the experiment data, but in an easily modeled (and correctable) way.

4. (Reviewer: J. Klen) A drain plug should be added to the downstream endcap of the decay pipe.

Done

5. (Reviewer: J. Klen) In both ends of the decay pipe, a temporary support spine could be welded inplace at the factory. This would insure the roundness is kept,within tolerance, inorder to simplify the installation of the endcaps.

OK

6. (Reviewer: A. Para) Vacuum windows are quite elaborate, given the size of them. They are produced by Fermilab and welded to the installed decay pipe. The design is very robust and it does allow for possible distortions of the pipe. I am wondering if one could not simplify matters further by welding a thick stiffener ring to both extremities of the decay pipe (outside or perhaps even inside the pipe). Such a stiffener would prevent any distortions of the pipe and it may simplify the installation of the vacuum window. An inside ring of a considerable radial thickness can be even used to reduce the diameter of the vacuum window.

Done

7. (Reviewer: A. Para) Vacuum testing/leaks etc was a matter of concern. I think the whole matter should be reconsidered. To put it bluntly: do we need any vacuum at all? The reason for evacuation of the decay volume is to reduce the amount of material traversed by pions before they decay. Pions have to traverse 50 m of air in the target chase and the entry window, which is equivalent to another 50 m of air. It means that any 'vacuum' below, say, 50 Torr will be acceptable. In fact, most of the particles decay within the first 100-150 meters of the decay pipe. It means that a 'vacuum' of 300-400 Torr is quite adequate. Giving up vacuum completely and having an air tube would probably lead to some

reduction of the flux (5%?) but it would simplify matters enormously: no windows, no vacuum leaks checking, no need for an access tunnel, air cooling if necessary, no vacuum pumps, etc.. This is worth a thought. Should we decide to have some vacuum, after all, we need it only in the first section (a third? a quarter?) of the decay volume. Air or vacuum in the second part would not produce any difference for the neutrino beam. I am not sure if this would simplify matters, but perhaps it is worthwhile to consider an intermediate vacuum window inside the decay volume. Even if this would be a neutral (cost-wise) it is perhaps a worth considering as it would offer us a possibility of installing some kind of a beam stopper there to reduce the muon induced backgrounds.

Air in the decay pipe would increase the level of ground water activation to some extent. This comment recommends a means of operation outside the scope of the project.

Shielding & Installation Issues
Presenter: B. Bernstein

1. (Reviewer: S. Childress) A very close coordination with Healy & CBI is needed during completion of design efforts and the installation process. Many questions remain:
    a. How all details of the installation will be done?

    b. Protection and isolation of cooling pipes during concrete pour?

    c. Ensuring thousands of feet of sound pipe weld, and that these are not damaged during installation, concrete placement.

The decay pipe was successfully installed. It meets alignment and vacuum requirements.

2. (Reviewer: S. Childress) I also have major reservations with an assessment made that, with existence of an initial major vacuum problem, a solution could be to try to overpower it with additional pumping and run. Overwhelmingly, vacuum problems only get worse - and frequently much worse. This type of solution would most likely eliminate diagnostic and repair options prior to radiation exposure.

In the event of a major vacuum problem, we would fill the decay pipe with helium at atmospheric pressure.

3. (Reviewer: M. Gerardi) It still is somewhat disconcerting to hear that the estimates for dose rates are not yet complete. It is of course very difficult to review a number of the radiological aspects without estimates of activation levels.

Done

4. (Reviewer: N. Grossman) Residual dose rates in the vicinity of the decay pipe access port and the decay pipe itself should be determined.

Done

5. (Reviewer: J. Klen) Fermilab Safety Group could be contacted in order to review possible access to the decay pipe,after it is completed. This review could suggest that the present man service hole be eliminated, enlarged or duplicated at both ends.

No access port

6. (Reviewer: P. Martin) On vacuum issues, the stated vacuum requirements aren't too stringent; however, I would strongly question the expressed opinion that small leaks would be OK as long as they could be overpowered with additional pumping. I think this is a serious mistake. An experiment this important and costly should not begin operations with any detectable leaks. Once beam has been delivered at any reasonable level of the NuMI expectations, it will be impossible to enter the decay pipe. The expected pumpdown rate should be calculated, and the vacuum should be datalogged during pumpdown to compare for agreement with the predictions, and if there are indications of leaks, they must be found and fixed prior to high-intensity operations.

Done.

7. (Reviewer: R. Sanders) Damage of Copper Pipe Due to Falling Concrete: The contractor is required by the contract to install the copper cooling pipes in accordance with ANSI standards. The applicable standard here is the ANSI B31.3 piping code. If, while pouring concrete, the contractor damages, bends and twists the copper cooling pipe then the contractor must either demonstrate that the pressure rating of the damaged pipe is adequate in accordance with the ANSI B31.3 piping code or else replace the damaged pipe. Permanent bending of the copper pipe causes work hardening and plastic deformation that will affect the pressure rating of the pipe. By emphasizing this to the contractor, Fermilab also minimizes the chance of the copper pipes being twisted about to touch the decay pipe and causing galvanized corrosion.

The cooling lines were pressure tested before acceptance.

8. (Reviewer: R. Sanders) Concrete Pouring: In light of comments above, it is mandatory that the wet concrete be poured in such a way that the decay pipe and copper cooling pipes do not suffer permanent deformation or damage.

Done.

9. (Reviewer: R. Sanders) Deflection of Copper Pipe: To prevent the copper pipe from deflecting and touching the decay pipe, consider keeping the copper cooling pipes under tension when pouring concrete. This will greatly minimize the lateral pipe deflection while being agitated by the swirling motion of the wet cement. Copper pipe of this type are sometimes pulled through holes in the ground much like pulling wires through conduit. It effect, you would be pulling the copper pipes into the straight paths you want through the wet cement. One could also consider using circular disks of plastic with annular holes that slide over the copper pipes. These spacers, placed at discrete intervals, would keep the copper pipes from touching the decay pipe. The axial position of the plastic spacers could be maintained with clamps (or tie-wraps???) around the copper pipes. The possibility of using commercial processes to coat the copper pipe with dielectric coating could be considered.

The cooling lines were banded to the decay pipe to hold them in position.

10. (Reviewer: R. Sanders) Safety What-If questions: What would happen if the entire decay pipe filled with water? Also what would happen if the entire decay tunnel filled with water but not the decay pipe?

There is no credible scenario for filling the decay pipe with water. The consequences of filling the decay tunnel with water are severe; the impact on the decay pipe would be minimal.

11. (Reviewer: R. Sanders) Leak Testing Advice: If expert advice is needed on the solution film leak teak testing decay pipe, there are independent non destructive testing (NDT) labs and companies in the Chicago area. Argonne National Lab , many years ago, had a very good non-destructive testing group and for all I know, it may still be good. If you really don't trust the contractor, an outside NDT group could be brought in to do some spot checks on the leak testing.

Done.

12. (Reviewer: R. Sanders) Decay Pipe Paint Job: Underground pipelines are common. The companies than put in underground natural gas and oil pipe lines certainly expect their pipelines to last much longer than 10 years. By applying the same technology used for these underground pipelines, it should be possible to get the decay pipe to last 10 years. Since there is concern about corrosion on the decay pipe, Fermilab should look at proven techniques used to prevent corrosion on underground pipes. I recommend reviewing the adequacy of contract specification 2.1 D for painting the decay pipe. Perhaps (and perhaps not) an additional coating should be applied to the decay pipe or the copper cooling tubes to prevent corrosion. For example if a dielectric coating is needed, there is a company BendTec ( http://www.bendtec.com/coatline.html ) which among other things can paint and apply dielectric coatings to large underground pipes to prevent corrosion.

OK

13. (Reviewer: R. Stanek) I sensed a heightened level of anxiety and concern over the initial cost and schedule for this project (and rightfully so). What I am worried about is that the same level of concern should be shown towards the long-term care, maintenance and possible repair of the system. The project needs to assure that design decisions made now, will not have adverse effects on long term operation and maintenance of the system. It might be worth doing a "what if or failure mode" analysis on this project in order to assure that possible failures do not result in extremely negative conditions (such as someone receiving a large radiation dose when doing maintenance/repair or loss of radioactive water to the environment). It is clear that project participants have this as one of their primary focus points in general, however, sometimes the pressure to "bring in the project on time and on budget" detracts from looking at the long-term aspects of decisions.

We believe that adequate analysis has been done.

14. (Reviewer: R. Stanek) Everyone seemed to agree that placing the decay pipe in the correct position and within the specified tolerance was crucial and that there would be no second chances (independent of what the contract states). I would suggest that some alignment monitoring or control happen when the pipe is first placed in position and that the Lab oversee and verify that the contractor is keeping the position of the pipe under control during the concrete fill. This would require some sort of monitoring during the back fill process. The Alignment Group seems to be quite active in the project so this may be in their plans already.

Done

15. (Reviewer: R. Stanek) It may be worth the effort to set up a partial model (scaled down version) to observe the proposed process of backfilling with concrete before they use it on the real thing. One might better understand issues such as the thermal distribution of a known heat input, cracking of the concrete, adhesion to the pipe, the effect of the concrete pour on things like pipe position, abrasion of the primer paint on the outside surface of the pipe, position and possible damage to the copper tubing, etc.

This was not done, however the decay pipe was successfully installed.