SDC-91-00015

SDC
SOLENOIDAL DETECTOR NOTES

SDC MUON BARREL TOROID CONCEPTUAL DESIGN REVIEW

W. R. Edwards, J. Doggett, R. F. Boyce, D. Eartly, J. Grimson,
H. J. Stredde, M. P. Krefta, H. J. Sweet

March 25, 1991

SDC Muon Barrel Toroid
Conceptual Design Review

Final Report of the Review Committee

March 25, 1991

SDC-91-00015

Chairman:	W. R. Edwards	(LBL)
Deputy Chair:	J. Doggett	(LLNL)
Committee:	R. F. Boyce	(SLAC)
	D. Eartly	(FNAL)
	J. Grimson / H. J. Stredde	(FNAL)
	M. P. Krefta	(Westinghouse S&TC)
	H. J. Sweet	(Sweet & Aiken, Inc.)

Table of Contents

1. Introduction

2. Summary of Conclusions
   - 2.1 structural findings
   - 2.2 manufacturing findings
   - 2.3 installation & alignment findings
   - 2.4 field quality & measurement findings
   - 2.5 cost & schedule findings

3. Recommendations

Acknowledgements

Appendices

Appendix A:	Committee Member Reports
Appendix B:	L. Ditterts comments on the change to alternative B
Appendix C:	Action Items, Responses, and Committee Responses
Appendix D:	Additional Notes from Conceptual Design Review
Appendix E:	Toroid Review Schedule
Appendix F:	Conceptual Design Reports
Appendix G:	Committee Members
Appendix H:	Committee Member Assignments

Final Report from the Review Committee

1. Introduction:

In November of 1990, Gil Gilchriese, SDC Technical Manager, issued a charge to the SDC muon group. As part of that charge, a review committee was appointed. This committee was to provide a formal engineering conceptual design review of the muon barrel toroid steel. The committee was then to submit, to the SDC Technical Board, which of the three barrel toroid steel concepts it recommended for further design development.
The Design Review took place at the SSC Lab on February 28, 1991. Action items were prepared and distributed to the concept presenters on March 4th, responses were received on March 8th, the committee reviewed these responses over the following week and issued individual reports on March 15th. The report of the committee follows.

2. Summary of Conclusions:

The committee studied the feasibility as well as technical, cost and schedule risk associated with each of the three designs. All of the concepts are in the conceptual design phase, therefore we realized that all of the details had not yet been worked out. Our intent for this review was to search for critical flaws in the designs, and insure ourselves that the issues we discovered could be worked out in later phases of the design.
The conclusions presented here are either taken from the individual committee reports of appendix A, or are comments that were made after the review by the committee members. When looking for further explanation of the summary conclusions, please refer to appendix A.

2.1 *Summary of the structural findings:*

The structural integrity of the plate joining welds in large block design is a concern expressed by all. The concern is that the

analysis to predict weld stresses could significantly understate their magnitude and that these stresses in combination with weld residual stresses and stresses resulting from handling and service would combine to cause failures. With the exception of weld integrity, the committee felt that the Large Block design was structurally feasible.
The alternating block concept (KEK/IHI) may offer advantages in terms of strength and rigidity, but given the present crude state of analysis, there would be too much risk associated with it's recommendation from a structural perspective.
The structural feasibility of the Kaiser design has been best demonstrated. The structural subcommittee could find no concerns that they felt could not be overcome in later phases of design.

2.2 *Summary of the manufacturing findings:*
Machining is required on all sides of the "blocks" for both the Large Block and KEK/IHI concepts. Additionally, the Large Block concept, because of the piece size and weight, could limit the number of potential vendors. Care has been taken to require the minimum of surfaces and surface areas to be machined on the Kaiser design. This will most likely result in a faster, simpler, and cheaper to machine block design. It was however felt that, with the Kaiser concept, some technical risk was involved in assuming that when the blocks are assembled, they would combine to form a straight, alignable, steel toroid. In other words, that with no machining of the z-surface, the stack up of individual block thickness taper and non-flatness would be random enough to create a square and straight toroid. Selection and bolting plates together into medium size blocks (50-90 Tons) prior to machining could be an option within the Kaiser concept. This could not only speed up installation, but by machining the z plane face in this configuration, could limit the risk of unacceptable tolerance stack-up.
Pre-assembly of at least a portion of the barrel toroid steel, at the manufacturing facility, should be seriously considered for any of these designs. For the KEK/IHI design, 1/3 of the barrel is the minimum necessary for preassembly. For each of the other two designs, smaller subassemblies can be made resulting in a less expensive facility being required and less assembly time spent prior to discovering problems.

2.3 *Summary of the installation and alignment findings:*
It is the feeling of everyone on the committee that the Large Blocks are too large. Transportation, rigging and handling of these 193

short ton blocks present major limitations and risk. It is believed that this concept would be possible to construct, however, the general conclusion was that blocks of half the weight would be more reasonably handled and installed.
Muon chamber installation and alignment feasibility has not been demonstrated in the KEK/IHI design. There are several open issues in this area which led us to believe that a wider interaction hall would be required with this design. The piece weight of 40-60 tonnes is about right.
Transportation, rigging and handling options are maximized with Kaiser design. The ability within this concept to transport 10-20 ton pieces and then perform some preassembly prior to lowering into the hall, maximizes available options (ie, vendors, transportation options, etc. are maximized). Installation logistics have been best thought out and best demonstrate the feasibility of this concept.

2.4 *Summary of the field quality and measurement findings:*
The field quality is best, or at least easiest to understand and analyze, in the Large Block and Kaiser designs. The three-dimentionality of the KEK/IHI concept makes it the most difficult to analyze and makes the risk of field non-uniformity highest.
In the Large Block and Kaiser designs, by leaving a gap in the iron which is filled with a non-ferromagnetic material accessible to Hall probes, the field measurements are easy. The Large Block concept offers the easiest analysis since the measurement can take place in the joints or corners of the octants where the magnetic flux is normal to the gap. The Kaiser design gives only a component of the flux density which is less convenient. In the KEK/IHI design, no method of measurement was offered.

2.5 *Summary of the cost and schedule findings:*
The KEK/IHI cost estimate is hard to assess. In the first place it includes the cost of the end toroids which could not be separated. Secondly, it is simply not comparable to the other two estimates. It is the opinion of the cost subcommittee that this concept is not very significantly different than the other two concepts in terms of overall cost.
The Kaiser and PSL/SSCL concept costs will not be significantly different. In terms of manufacturing costs, there are some trade offs which should be made. Minimizing the overall set-up time for machining can reduce costs. For the Large Block design, this has been accomplished by maximizing block size and therefore minimizing the number of handling operations. By reducing the

amount of surface area to be machined the Kaiser concept milling cost has been minimized. Also, by eliminating the perimeter welding the Kaiser concept has eliminated a fairly large fraction of the total machining cost. By allowing piece weights of between 10 and 100 Tons, the transportation and handling options available to the Kaiser concept are maximized and will reduce these costs. The additional expense of a 200-250 ton hall crane in the PSL/SSCL design will be measurable (approximately $1 M ?). It is the opinion of the cost subcommittee that the Kaiser design concept, with the addition of pre-bolting prior to milling, will be cheapest overall. The schedule estimates presented for installation in the hall, when compared on similar terms, are to first order equal. The time necessary to construct the toroid support structure, prepare for steel installation, perform the erection, and test and align the steel will be of order 6 months +/- 1 month.
There are two factors which still need to be optimized. Fewer blocks to be assembled in the hall means less time spent in assembly in the hall. On the other hand, the smaller blocks offer the advantage of handling ease. By optimizing the block size in terms of lowering and handling ease - vs - assembly time, the time spent in the hall erecting muon steel, can be minimized. It is believed that this can be accomplished in any of the concepts, therefore a clear advantage cannot be given to any one in particular.

3. Recommendations:

All of the concepts are now or can be made feasible. For the reasons presented in section 2 and the fact that the KEK/IHI concept had not addressed the structural and installation issues adequately, we cannot at this point recommend this design. Additionally, muon chamber installation and Hall width requirements will most likely be more severe for the KEK/IHI design.
The differences between the Kaiser and PSL/SSCL concepts are in the details. However, some of these details were of concern to the committee. The 3 concerns in the PSL/SSCL concept which lead us to choose the Kaiser design were block size, welding, and the details of corner bolting. It is felt that the Kaiser concept offers more flexibility, and better solutions to our concerns.

Therefore, of the three barrel toroid designs reviewed, the PSL/SSCL Large Block, the KEK/IHI, and the ICF Kaiser Alternative B concepts, the committee recommends that the ICF Kaiser Alternative B

concept be selected for further development. In addition, the committee recommends that some further investigation be done of pre-assembling several blocks into 80-90 Ton sub-assemblies above ground, prior to being lowered into the interaction hall and perhaps even prior to machining.

Acknowledgements:

The committee would like to express its appreciation to all those who were so helpful in allowing us to accomplish this review. A special thanks to the concept presenters and their support infrastructure who did a phenomenal job of getting the Conceptual Design Reports together and who made high quality presentations. All the way thru this review effort, we received information as it was requested, often on very short notice. Jeff Tseng from the SSCL did a very good job noting questions during the CDR (Appendix D). I would like to personally thank the review committee for doing a very complete and fair job in reviewing these three concepts, submitting their comments in such a timely manner, and especially for being such a pleasant group to work with.

Appendix A

Individual Committee Member Reports

1) H. J. Sweet

2) D. Eartly

3) H. J. Stredde

4) M. P. Krefta

5) R. F. Boyce

6) W. R. Edwards & J. Doggett

SWEET & AIKEN, INC.
CONSULTING ENGINEERS
13231 CHAMPION FOREST DRIVE, SUITE 205
HOUSTON, TEXAS 77069

HARRY J. SWEET, P.E., PH.D.
DIRECT LINE - (713) 580-8805
FAX - (713) 580-6016

March 13, 1991

Mr. Bill Edwards, M.S. 90-2148
Lawrence Berkeley Laboratory
One Cyclotron Road
Berkeley, California 94720

Re: SDC Toroid Steel Review

Dear Bill:

This is in response to your request for a statement of my recommendations with regard to the design concept selection for the Muon Barrel Toroid Steel for the SDC Detector. My opinions are based on reviews of reports submitted by three different organizations, attendance at the presentations by these three organizations at Desoto, Texas on February 28, 1991, and a review of the responses to action item questionnaires.

The stated preferences are based on structural considerations alone and should be considered in that light.

The three organizations and their design concepts can be described as follows:

1. University of Wisconsin Physical Science Laboratory and Superconducting Supercollider Laboratory, presented by Jeff Cherwinka.

   Large Block Concept.

2. KEK, National Laboratory for High Energy Physics, Osaka City University, and University of Tsukuba, presented by A. Maki.

   Alternating Block Concept.

3. ICF Kaiser Engineers, Inc., presented by L. I. Dittert.

   Thin Plate Concept.

As presented, the Large Block Concept and the Thin Plate Concept are similar except that welding of component assemblies to provide large blocks that would be delivered to the site for final assembly was proposed for the Large Block Concept while, for the Thin Plate Concept, all the assembly would take place at the site. As a result, the Large Block Concept would result in an assembly that would be held together partly by welds and partly by bolts. The Thin Plate Concept would result in an assembly that would be held together entirely by bolts.

For both concepts, the short transverse direction for the individual plates would be parallel to the centerline of the Muon Barrel Toroid Steel.

The Alternating Block Concept would be entirely different from the other two. The wall of the Muon Barrel Toroid Steel would consist of four layers of plate with the short transverse directions essentially normal to the centerline and with the long rolling directions alternating from one layer to the next.

I recommend that the Thin Plate Concept be selected for further development. This recommendation is based primarily on my opinion that the feasibility of this concept has been demonstrated more conclusively than for the other two.

My primary concern about the Large Block Concept is that serious welding problems could occur. I am concerned that the analysis to predict weld stresses resulting from flattening the plates, welding them, and then releasing them could significantly understate their magnitudes and that these stresses in combination with weld residual stresses and those due to handling and service could result in failures in the welds or in the adjacent parent metal.

I believe the Large Block Concept should be considered only if it offers major advantages over the Thin Plate Concept in areas other than structural integrity.

The Alternating Block Concept may be the best of all. The problem is that the finite element analysis that was done to evaluate this concept represented such a gross over simplification of the structure that it would be risky to base a favorable recommendation on the available data.

It is possible, however, that a more rigorous analysis would show that the Alternating Block Concept would be significantly superior to the others from strength and rigidity points of view. If that concept appears desirable from other perspectives, it would make little sense to rule it out because of limitations in the

analysis to date.

With regard to some of the design details that were presented, I would suggest:

1. That all bolts be screwed into high strength nuts rather than directly into the plates.

2. That the support structure would be designed as a truss, with lateral loads carried in direct tension or compression of diagonal members, rather than a frame, with lateral loads carried in bending. For the same amount of metal, this would result in a structure that is more stable and that would be better able to accommodate unexpected side loads.

   I therefore favor the support concept offered by L. I. Dittert over that offered by Jeff Cherwinka.

3. That the foundation the support structure rests on be designed at least as carefully as the Muon Barrel Toroid Steel. In my opinion, the final design should be evaluated with an integrated finite element model representing the Muon Barrel Toroid Steel, everything it will support, the foundation, and the surrounding soil.

Sincerely yours,

Harry Sweet

March 13, 1991

To: Wm. Edwards, Chairman
From: D. Eartly D. Eartly
Subject: SDC Muon Barrel Toroid Designs

With the concepts of special fabrication, handling, transport, and installation fixtures along with the safe coordination of two cranes; it should be possible to assemble a Large Block magnet with the procedures described to us. However, I have concern over the edge welding of heavy pressed plates into large blocks. Also there is a tight tolerance between the machined tapered ends and the block (inter) faces. To create an adiabatically deflecting assembly with Z bolting, the ring assemblies need to be in a plane and pulled together. The assembly schedules given in the presentations did not seem to be very sensitive to the number of pieces involved. Thus I would recommend reducing the piece weight to the hall crane capacity. This would also greatly broaden the spectrum of potential fabricators and relieve the transport and handling problems.

With the presentation of alternative "B" for the Pieced Lamination design magnet, premium flat material selection, continuous Z bolting (clamping) in assembly, and following the procedures described, I believe that a uniform magnet with minimum gaps and continuous mechanical properties would be obtained. In terms of a Muon system mounted on the iron on an uncertain floor, THIS WOULD BE THE BEST CHOICE because of adiabatic deflections. To reduce the assembly and handling, I would recommend the preassembly of two or three layer lamination pieces.

For the Longitudinal plate design, I have problems with the fact that all four nonflat layers are hinged at the four transverse supports. This can lead to surface and deflection discontinuities on an uncertain floor. What would happen to a transverse or longitudinal Muon system guidance/mounting rail system is uncertain. Even with the spacer pads and bolting keys, there are shear stress questions especially in relation to motions of inner loads and the floor. I am very uncomfortable with this design as presented.

March 14, 1991

To: Bill Edwards, Chairman
From: Herm Stredde,FNAL
Subject: SDC Barrel Toroid Review and Recommendation

I have a number of concerns with the KEK proposal. The spacer blocks are really "keys" that have bearing and shear loads. Although there are at least 8 keys in any assembly, we can only consider two that will take the load. That analysis needs to demonstrated as safe. Further the machining of the pockets and keys, along with the assembly procedure must be very time consuming and expensive. The toroid design as proposed sits on four(4) independent supports, hence the barrels are essentially hinged at the supports. When the floor moves, what happens to the detector as the supports move independently. This clearly poses a serious problem not yet addressed. Chamber installation, one unit at a time, not only is time consuming, but will be detrimental to alignment after detector settlement. The toroid supports effectively block lines of sight(along the Beam Line) for the bottom three(3) octants.

The Large Block concept is certainly feasible from the stand point of handling, assembly, alignment and chamber installation. However, the mere size of these blocks must limit the choices of fabricators and shippers(particularly trucks). Flattening and holding the plates during welding and then releasing the plates does not necessarily give us a weldment with acceptable cracks in the center of the plates. Futhermore, welding of such large plates makes the weldment subject to laminar tearing.

The ICF Kaiser Aternative 'B' with its selective material process, size and weight of plates, method of bolted corner connections and continuous longitudinal bolted or cable connection is very attractive. There are more plates to handle, but machining is straight forward(not all surfaces require machining). One thing to explore in this design is ganging the plates into "mini-blocks", preferably without welding, with the weight at about 80-90 short tons.

I believe that from the three proposals the ICF Kaiser design will yield the best SDC Barrel Toroid.

GENERAL COMMENTS ON ALL THREE DESIGNS

The following discussion is intended to be my overall views on the magnetic aspects of the three designs. If I had to rank the designs from a magnetic point of view, I would do so as follows:

1. Cherwinka Design
2. Dittert Design
3. Japanese Design

The Cherwinka and Dittert design are now very similar. Both designs have a very consistent magnetic path which allow a simplified analysis and assessment of the design. The two differ (from a magnetic point of view) by the location of where the individual blocks are connected. In the case of the Cherwinka design, the blocks are connected on a diagonal through the corners. This turns out to be a good location for measuring the magnetic field (with a Hall probe), since the magnetic flux density is normal to the cut at this location. The Dittert design may give only a component of the flux density which is somewhat inconvenient. The Dittert design does have the advantage of fewer gaps due to the use of fewer laminations (although the thin plates in the Dittert design are thinner than the large blocks, they are thicker than the individual laminations of the large blocks).

The Japanese design originally looked like a good candidate from the magnetic point of view. However, several details have not been worked out. There is no method set for verifying the magnetic field and the vertical support plates have been designed without concern for the magnetic field quality and conductor paths. Further, the magnetic path is inconsistent. This makes the design difficult to analyse without a three-dimensional analysis. This complication makes me suspicious of whether all the details can be adequately examined. I also feel that the accuracy of the magnetic calculations may be overstated in this design.

Mark Krefta

Addendum

Magnetic field quality considerations for the three designs.

The magnetic field associated with the Cherwinka and Dittert design will be very similar. In these two designs the effect of the gaps on the magnetic field is predictable. It is assumed that the gaps will be fairly uniform throughout the axial length, or at least the net magnetic reluctance associated with the gaps will be consistent down the length. If this is true (or a reasonable approximation), then a two-dimensional analysis of the toroid is sufficient. This has been done for the geometry in Fig. 1 with several different size gaps in the corner being analyzed. In particular, the effect of a .050 in. gap on the integral |BxdL| is shown in Fig. 2 to be about 0.4 percent. This is considered to be small enough not to be a problem. Further, the distribution of flux remains uniform throughout the gap region.

Gaps due to axial laminations have a much more pronounced effect. This is due to the fact that the vector direction of the magnetic field is primarily tangential to the iron surface at the interface. Specifically, the case of a .050 in. axial lamination gap shown in Fig. 3 has been analyzed for a small piece of the geometry in the axial direction (i.e. a ϕ-z plane through the iron). The resulting flux density is very small in the gap region in Fig. 4. This will cause problems for the case in which a large percentage of the particle's path is through the low field region. This is true for the case near θ=90 degrees. However, the two solutions suggested by Cherwinka (making the gap small enough or using a horizontal lamination for this region) should be sufficient to keep a large percentage of the path through the high magnetic field region.

The Japanese design is different from either of the other two designs. Since the potential gap location is more complicated, the analysis becomes more complicated. In this case, there are several parallel paths for flux to flow. One concern is the gaps which occur in the the straight section of the plates for every second layer. A two-

dimensional view (r-ϕ plane) of this is given in Fig. 5. It is suspected that the field will be nonuniform for this case due to the shunting path available for the magnetic flux. Of course, the effect of magnetic saturation will help to smooth the magnetic field distribution somewhat. The precise amount of nonuniformity requires a detailed analysis. I suspect it will be on the order of 10 percent (i.e. $\Delta B/B$) or less due to the high level of saturation. Further, the integral quantity Bxdl should be well behaved as a function of ϕ, since the local decrease in flux is offset by a local increase when following a path near the gap region. I expect this plot will be similar to that of Fig. 2.

In conclusion, I don't see a serious problem with any of the designs with respect to the magnetic field quality. In the case of the corner gaps in the r-ϕ plane, the size of the gap is too small to have a substantial effect on the net magnetic flux and the integral BxdL. All three designs will run into the same problem of corner gaps. The Cherwinka design may have a problem with the vertical laminations in the θ=90 degree region. However, he has suggested fixes for this which should work well. The Japanese design may have a problem with local nonuniformity of the magnetic field. If this does indeed become a concern it can probably be cured by spacing the plates radially by a sufficient distance. Given the choice, I would probably want to avoid this potential difficulty.

Mark Krefta

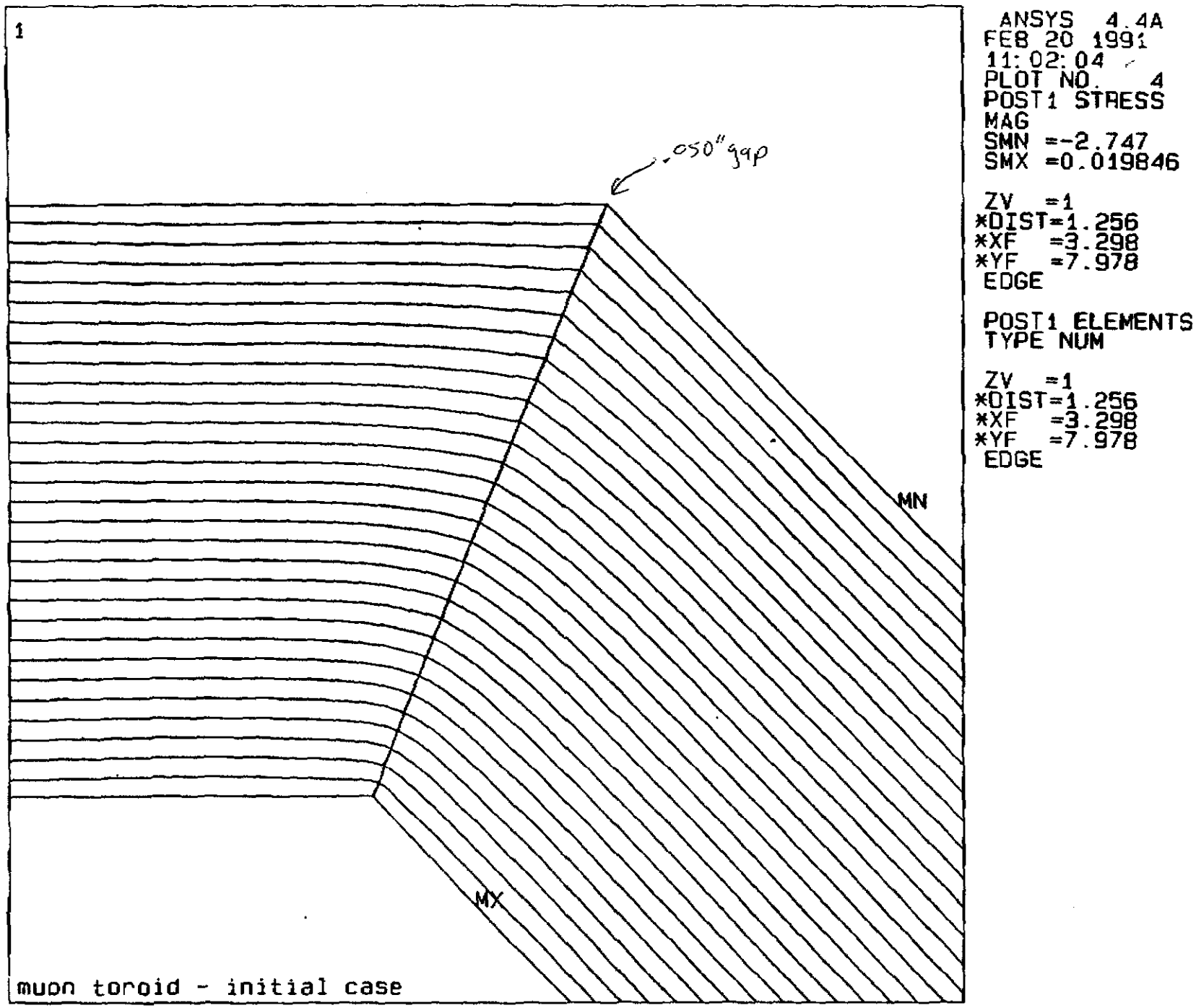


Figure 1 Contours of Az for .050" gap

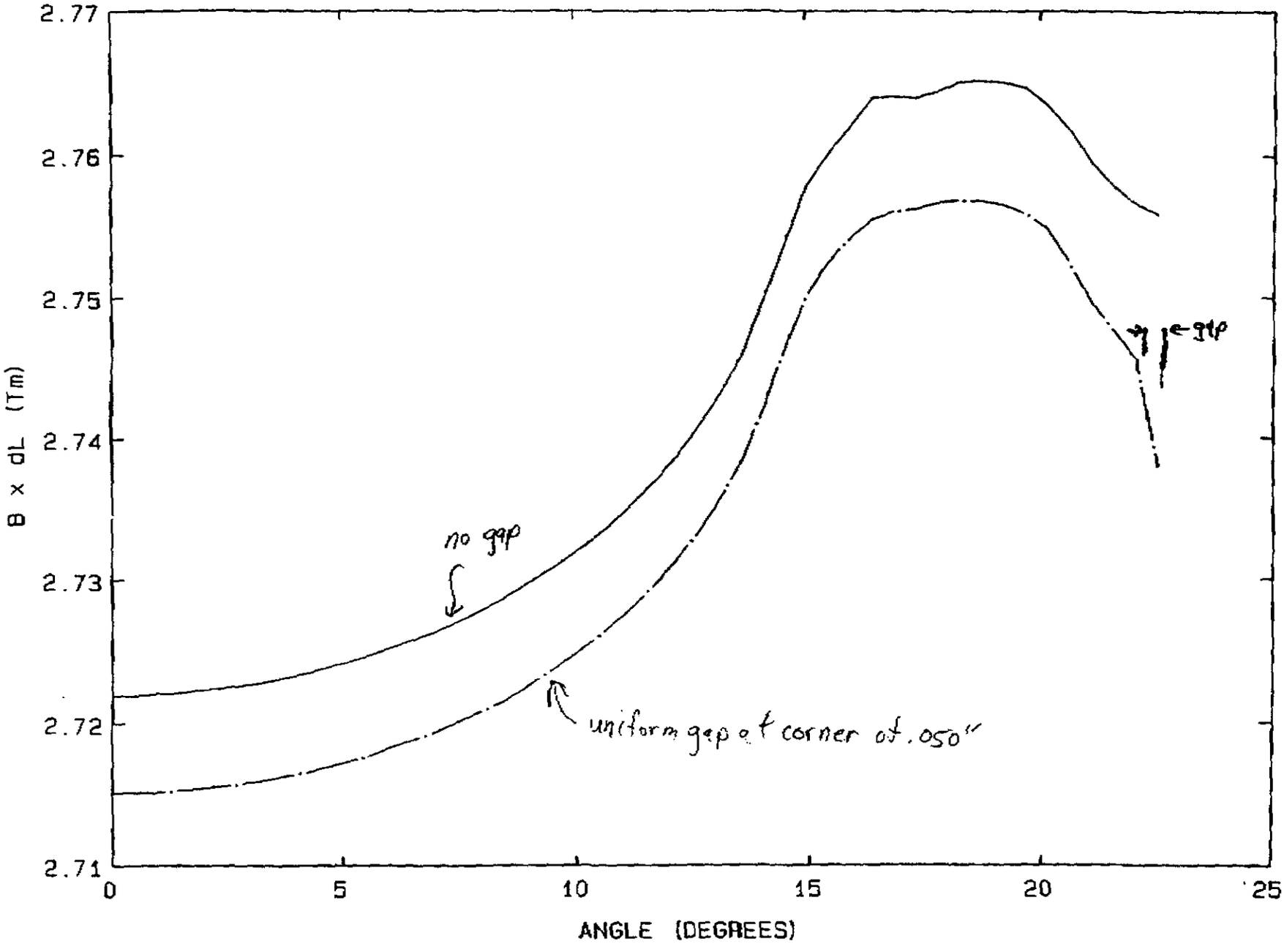
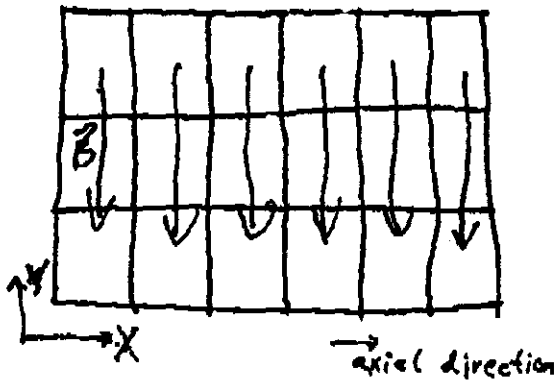
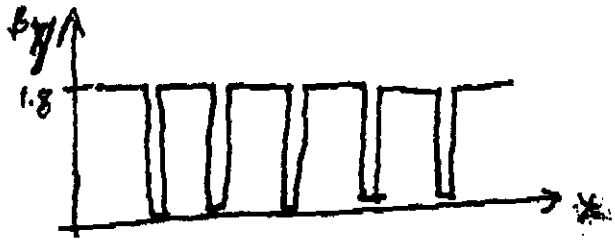


Fig 2. $|\bar{B} \times d\bar{L}|$ vs angle, .050" gap (blow up)

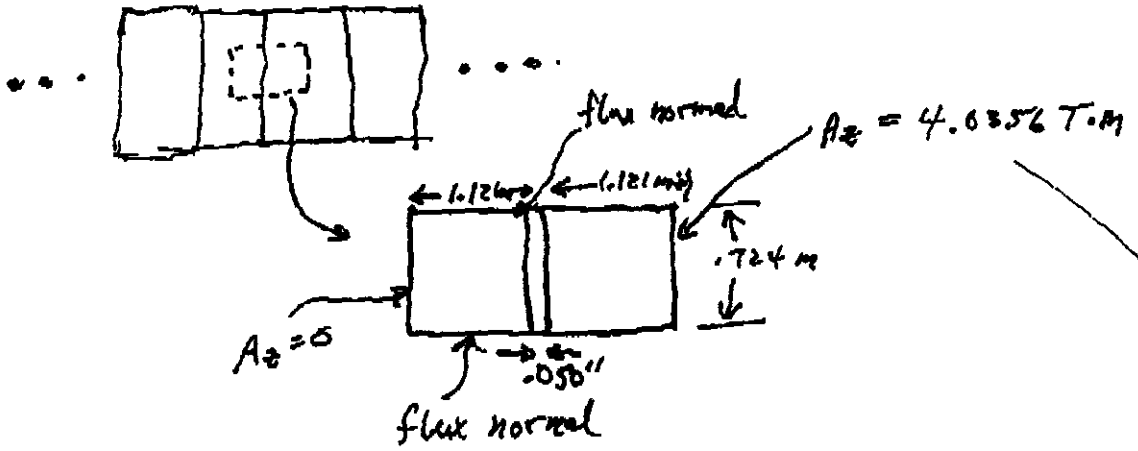
Case 2: Gaps parallel to flux lines





I Expect large discontinuity in flux density B_y due to discontinuity in tangential component accross airgap interface $B_{y1} = \frac{1}{\mu_r} B_{y2}$

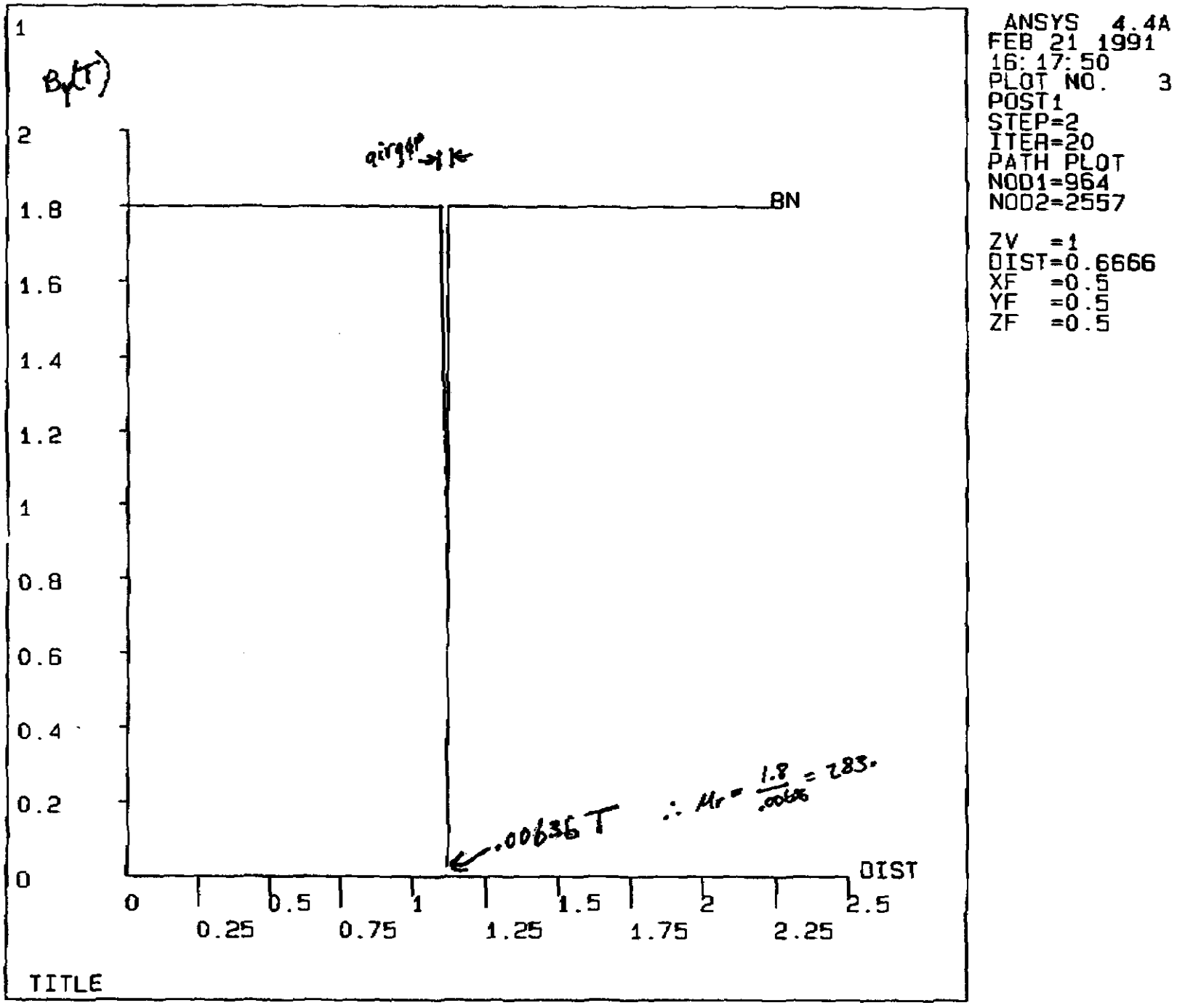
To verify this, obtain f.e. solution to following problem.



$B_y = -\frac{\partial A_z}{\partial x}$ $\quad B_{y\,ave} = 1.8\,T = -\frac{\Delta A_z}{\Delta x}$ $\quad -\Delta A_z = 1.8(\Delta x) = 1.8(2.252) = 4.0356$

Get plot of B_y vs. X.

Figure 3: Effect of vertical laminations on magnetic field



ANSYS 4.4A
FEB 21 1991
16:17:50
PLOT NO. 3
POST1
STEP=2
ITER=20
PATH PLOT
NOD1=964
NOD2=2557

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 4. Effect of air gap on flux density

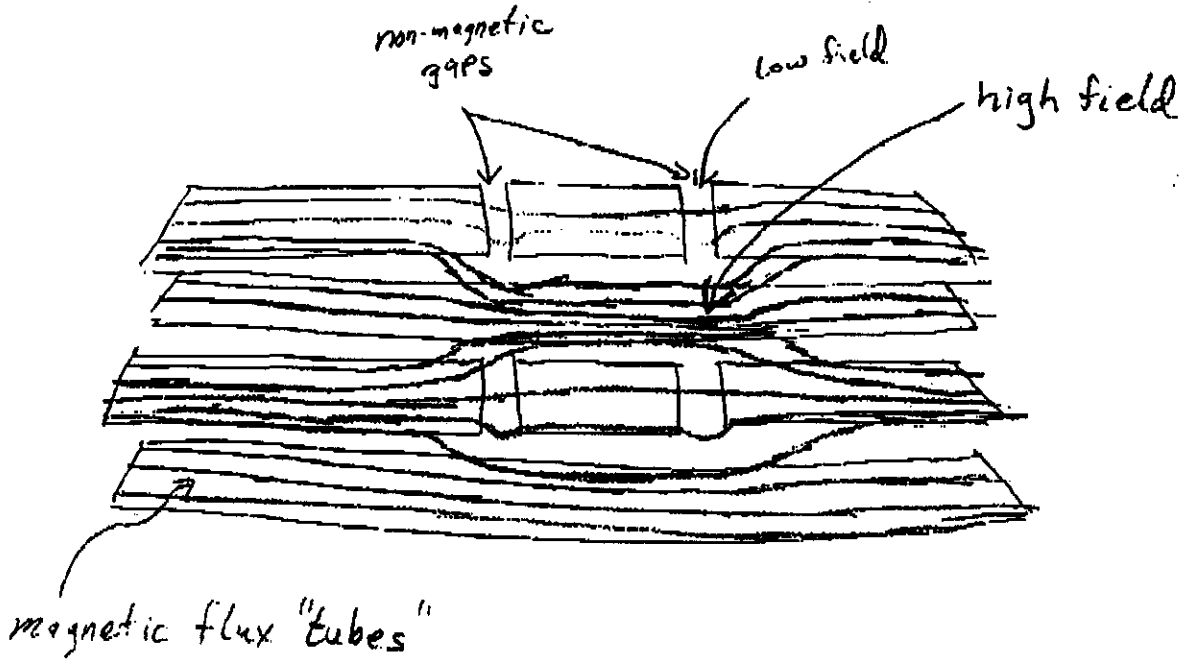


Figure 5: Effect of non-magnetic gaps in Japanese Design illustrating shunting effect of plates

SLAC MEMORANDUM March 20, 1991

TO: Bill Edwards

FROM: Richard F. Boyce (Ext.2932 Page 11-358) RFB

SUBJECT: SSC-SDC Barrel Toroid Review Report

I have reviewed the three proposals and will discuss some general issues before I evaluate the designs.

I see no mistakes in any of the proposals. The structural analyses indicate that each of the designs could be successful with good attention to details and construction.

They all have the same problems with floor motions and alignment. The structure is large, but it will be flexible. Balancing the load in the supports will be important to reduce the structural loads and to maintain good alignment.

Two of the proposals put the cost of fabrication of about $.55/pound of steel. Two of the proposals figure 2.5 years for the fabrication time. Both of these estimates seem reasonable, but bidding will ultimately determine the final numbers.

All of the proposals figure the assembly time to be about 6 months. I would expect it to take at least 9 months, and the costs would increase accordingly.

From my experiences with the SLD magnet steel (2,500 tons) I have found that work in the experimental hall is important to the completion of the detector. Because this work is obviously on the critical path it usually is done under the watchful eyes of the collaboration. As such, it is not only unfortunate when a problem occurs, but it is also difficult to resolve in a calm and professional manner. In addition, there will be limited equipment available to rework parts without taking them out of the hall.

Consequently, of the three designs I prefer Mr. Cherwinka's. The large block approach should reduce the construction time in the hall. His plan to machine the blocks is a direct solution to the problem of assembly fit-up. The possibility of test fitting the rings at the factory should reduce the field fit-up problems. It also allows for the improvement of manufacturing techniques before the parts are shipped. I think that it is important to match the size of the blocks to the size of the crane in the hall. Only one crane should be used to do the lifts.

Mr. Dittert's design seemed to me very similar to Mr. Cherwinka's. There are two major differences; Mr. Dittert uses less machining and more individual pieces. The reduced machining could reduce the fabrication time, but also makes it necessary to survey and catalog all of the plates. The small pieces would simplify rigging, but I think the larger number would increase the amount of work performed in the hall. Also, fit-up problems would have to be solved in the hall.

Mr. Maki's design seems to be somewhere between the two other designs. It has less machining but more pieces than Mr. Cherwinka's proposal. It has fewer pieces but more machining than Mr. Dittert's proposal. It would require more tooling in the hall than the other designs, which adds time to the construction. Also it uses a thickness of steel plate that eliminates many steel suppliers from the bidding.

SEE ADDITIONAL COMMENTS ON FOLLOWING PAGE.

WRE

SLAC MEMORANDUM April 2, 1991

TO: Bill Edwards

FROM: Richard F. Boyce (Ext.2932 Page 11-358) RFB

SUBJECT: Addition to the SSC-SDC Barrel Toroid Review Report

I have reviewed the Final Report of the Review Committee and I would like to comment on the proposed design changes.

I agree with the idea of changing Dittert's design to incorporate the improvements suggested. Bolting the plates to form blocks takes advantage of a block design without using welding. The blocks can be machined on the "Z" surfaces and pre-assembled at the factory to reduce the chances of field fit-up problems. Rigging will be simplified by reducing the block size to less than 100 tons.

I think that this modified design would be the best approach for the SDC Barrel Toroid.

Post-It™ brand fax transmittal memo 7671	# of pages ▸ 1
To Bill Edwards	From Richard Boyce
Co. LBL	Co. SLAC
Dept.	Phone # (415) 926-2932
Fax # (415) 486-6119	Fax # (415) 926-2923

3/14/91

Comments on Muon Barrel Toroid CDR Cost and Schedule:

Bill Edwards (LBL) and Jim Dogget (LLNL)

Cost Estimates:

Kaiser Engr's estimate is a ROM estimate but is probably pretty good. Comment: 8% Texas sales tax can be tossed out. Alternate "A" was costed, including the expense of painting. Alternative B will not cost more, as stated in the paper, because the tolerances have been loosened subsequent to the review. Actually, removing the expensive paint from the estimate may make it cheaper.

The "Big Block" (SSC/PSL) estimate is done in more detail (lower WBS level) than any of the others. Dave Etherton and group coordinated this estimate which includes many vendor quotes (7ish) on certain parts and processes. The assumption in the welding cost estimate is a 1/2" penetration weld around the perimeter of the plates. The discussion at the CDR revolved around 3/4" welds. According to the detailed estimates in the cost appendix, these would add approximately $700K to the cost.

There are some big discrepancies which are hard to believe between the "Big Block" and Kaiser designs. First, when you look at welding/machining costs for the "Big Block", you see that welding is 2/3 of the $4.5M total estimated cost of fabrication. From this, you might expect to find that the Kaiser design, since it avoids welding, would be around 1/3 of this cost, instead it is approximately 4 times this cost at $7.4M.

The KEK/IHI estimate includes not only the barrel, but the end toroids as well. From the viewgraphs Aki showed there was no way to separate the barrel cost from the total cost. We could not get a very detailed breakdown on any portion of the costs. The one comment which should be made here though, is that this estimate is probably very conservative, includes contingencies lumped on contingencies, profits, etc.

An item-by-item gut reaction to "what's the price difference between the 3 designs" is as follows.

a) Material cost should be a wash.

b) While welded structures are typically cheaper than bolted structures, in the case of the toroid, it doesn't seem to work. The Big Block design uses welding in a non-ideal orientation - in cleavage. In this particular case, replacing welding with bolting will be cheaper simply because you can replace hundreds of meters of welding with very few bolts and achieve the same result. Also, machining fewer surfaces will be cheaper. In the Kaiser design, the absolute minimum area is milled, the rest remains in its flame cut state. In fabrication cost, we believe the Kaiser design cheapest.
c) The expense of pre-assembly will be close to a wash for all designs unless it can be avoided all together. We believe that SDC should preassemble some portion of any of the three concepts. The concept requiring the biggest fraction of the entire toroid to be assembled at one time will be the KEK/IHI design. The bigger the chunk being pre-assembled, the bigger the facility required to do it. Therefore, the advantage goes to the Big Block and Kaiser designs which require only one "ring" to be assembled at a time (1/11th or less of the entire toroid).
d) In terms of freight, we cannot assume that one particular design has a distance shipped advantage which may reduce the expense. However, we believe it can be said that reasonable sized pieces (10-75 Tons) have an advantage over large pieces (over 100 Tons) in terms of number of transportation options available, crane requirements in route, etc. Therefore, the 2 winners here are the Kaiser and KEK/IHI designs.
e) For installation, the schedule or duration and crew size are the dominating influences. In these terms, it would seem that you would have to call the 3 designs equal. However, the Big Block design requires a bigger crane in the Interaction Hall. This crane and it's additional support/hall requirements will add an estimated $1M - $2M to the hall cost. The advantage goes to the KEK/IHI and Kaiser designs.

To summarize, we believe that the Kaiser concept will be less expensive than the other 2 designs.

Schedule Estimates:

Kaisers estimate is probably pretty good. They assumed 3 crews (1 above, 2 below) working one 8 hr shift. This scenario takes 6 1/2 months and includes 3 months of initial set-up, and 9 weeks

of intermittent alignment/bolt tightening. Another scenario (not included in detail in the report, but discussed with Les and previously with the RTK clan) is to effectively double the crews in the hall (add 8 people) and work from the center out in both directions. By doing this, Les says that you can save a month or so... 5 - 5 1/2 months. In the response to action item 052, Kaiser states that by "pre-laminating" several plates into blocks, prior to lowering them into the hall, a significant number of weeks can be saved. This savings results in an estimate of 4.8 months to complete construction (in addition to the 2 months of installing and aligning the support structure).

The "Big Block" schedule was, we feel, less worked thru. Two groups at SSCL worked on it and got 2 answers using different assumptions. One group assumed 1.5 blocks assembled per day (and >= 1.5 blocks per day lowered into the hall). The other group assumed 1 block per day (these are 193 short ton blocks remember). The 2 estimates included 1 month for set-up (2 months of install and align support structure not included?) and 1 month for break-down/alignment. The sum of these 3 pieces (set-up, assemble, break-down/align) is 4 & 5.5 months respectively !? our general assessment is that much more work has to go into logistics, rigging/handling fixture conceptual design, etc in order to have a better feeling about this. Moving huge blocks around everywhere (in transit to site, above, and below ground) is going to be much more messy than moving around blocks that weigh less than 90 Tons.

The Japanese KEK/IHI schedule included design, fab, pre-assy, shipping (6 mo) and installation using a 10 man Japanese crew working 10 hour "Japanese" days ("no messing around!"). It looked like they were allowing 8 months (including contingency, I'm sure) if the toroid had been pre-assembled in Japan first. Sounds so feasible that it's probably conservative. IHI has done some strange scheduling in the design, material ordering, machining portion of the schedule. They have "start machining" beginning 3 months after they begin "detailed design". In the cheaper cases (2&3) they are "pre-assembling", "shipping", and "installing" 1/3 of the completed toroid prior to completing "detailed design". There must be some misunderstanding of what they include in "detailed design". There were some comments on the material delivery schedule from the factory (Nippon Steel); we came away with the feeling that it took 2 years to deliver material.

We must at this point call the whole schedule contest a wash - all concepts require an installation schedule of 6 months +or- 1 month.

	A	C	D	E	F	G
1		SDC MUON TOROID CDR COST COMPARISON (in $K)				WRE 3/7/91
2						
3		Big Block		KEK/IHI		Kaiser Engr'g
4		w/o contingency	with contingency	Option 1 *	Option 3 *	
6						
7	Mat'l Cost	11,340	13,155	39,652	34,926	12,020
8						
9	Cutting	329	411	(see Mach'g)	(see Mach'g)	(see Mach'g)
10						
11	Welding	3,064	3,830	-	-	-
12						
13	Machining	1,108	1,466	50,630	42,015	7,422
14						
15	Pre-Ass'y	-	-	35,578	12,688	-
16						
17	Freight	1,793	2,241	10,681	10,681	355
18						
19	Installation	2,310	3,204	4,615	4,615	3,065
20						
22						
23	Total:	19,944	24,307	141,156	104,925	22,862
24			(net 22%)			
25						
26						
27	comments:	* The KEK/IHI costs include both barrel and end toroid				
28		1) Exchange rate assumed 135 Y / $				
29		2) SSCL Barrel Toroid weight is 15400 MT				
30		Kaiser " " " is 14667 MT				
31		KEK Barrel AND End Toroid weight is ... MT (Barrel alone is 15000 MT)				
32						

APPENDIX B

Advantages of Alternative "B" (over Alternative "A")

Les Dittert, ICF Kaiser Engineers, Inc.

- Assembly of the barrel is simpler, as each segment is constructed from the same type ("short" or "long") of plates.
- Pre-assembly of a few plates into blocks in the shop (or on the surface at the site) is possible. This would reduce assembly time in the hall.
- The number and length of bolts at the corners of the octagon (toe bolts) is less.
- The toe bolts are fully accessible for inspection at a later date.
- The structural strength of the barrel is not affected by the expected vertical movement of the detector support floor slab.
- The assembly of the barrel is safer; each plate or block is supported at two points by bearing on the machined recess and temporary supports during erection.
- Painting costs will be less expensive.

Appendix C and F:

Please note that appendix C (Action Items) and appendix F (Conceptual Design Reports) have not been included in this copy of the report. These 2 appendixes are well over 100 pages each. Copies are available by request.

APPENDIX D

MUON TOROID REVIEW MEETING Q&A
FEBRUARY 28, 1991
SSC LABORATORY

"BIG BLOCK" DESIGN - Jeff Cherwinka

1. General Overview

Q: Drawings show that all surfaces of a block are to be machined.
A: No. The four smaller surfaces are completely machined, but one of the larger surfaces is only partially machined in strips in order to help set up some reference point during assembly and meet the tolerance requirement. The machining requirements are also cost dependent and cost driven in addition to the design considerations. The cost estimate includes six passes on the smallest surface, two passes on the trapezodial surfaces, and one pass on each large surfaces.

2. Physics Concerns

Q: what is the gap tolerance relative to the magnetic field?
A: The spec calls for less than 3 mm gaps. The expected gaps are up to 0.6 mm. From the analysis, gaps up to 1.3 mm will not impact the magnetic field.

Q: What kind of tolerance is on the gaps between plates?
A: When plates are welded together, some gaps or distortion may be expected. There is no accurate estimate of what these gaps can be yet. However, the gaps between blocks are controlled by machining tolerances.and they are expected to be up to 0.6 mm.

Q: Will the block stay flat after all plates have been put together?
A: Yes. There should be little stress perpendicular to the plates for the proposed configuration.

3. Engineering Concerns

Q: Is o.6 mm the total tolerance for the gaps among plates?
A: yes. The gaps should be minimized after the blocks are bolted together.

Q: Is there any concern that hardened bolts threads are used in the soft base materials like SAE 1010 steel?
A: Not really. A company has used spiralock threads in brass base materials and found no problems. With the proposed thread profile, the loads can be distributed among the first several threads instead of the first few threads taking all the loads.

Q: How many times can the bolts be rebolted?
A: Once the bolts are fully tensioned, AISC code does not allow the bolts to be reused. They should not be unbolted and rebolted often.

Q: How much of a high spot can be expected during assembly?
A: The exact details have not been looked at yet. The hand calculation in determining the weld size takes into consideration of the obstruction or high spot, but no load is carried by the plate in bending.

Q: How many circuits are considered in the hydraulic floor support?
A: The exact details of the floor design have not been worked out yet. The opposing hydraulic cylinders may be one circuit. There may be many circuits required to allow more flexible adjustment to be made in response to floor variations.

Q: How much oversize is considered for the bolt holes?
A: About 2 mm on diameter oversize is considered at present. The local stress impact on the block will be evaluated in more detail. The oversize should provide enough space to install the bolt.

Q: How are the pockets be sized to install bolts?
A: The pocket size has enough room to apply fillet welds and also can accommodate a torque wrench for tightening the bolt.

Q: After the first ring is assembled with the brace bar in place, there may be a problem to keep it in the vertical plane and put up the second ring.
A: The brace bar can be taken off after the first ring is complete. This will increase the flexibility and allow the second ring to be assembled. The same process can be repeated for each ring.

4. Schedule

Q: Is support design included in the pretest schedule?
A: No. The design of the support is not included in the pretest schedule. But it needs to be included in the pretest schedule to verify the design adequacy.

5. General Questions/Comments

Q: Clarify the bolt configuration, sequence for plate flattening and welding, and the weld size.
A: There are bolt holes in each block. The number of the bolts required depends on whether it is under compression or tension. Bolts are installed from both directions from connecting blocks, not all from one block to the other block. It may be possible to flattening and welding all plates at once. However, the cost estimate is based on two plates being flattened and welded at a time. The hand calculation gives a rough estimate of the weld size that is required to ensure the weld will not fail when plates are deflected during flattening process.

Q: Clarify bolt tightening, and the handling of blocks by two 100-ton cranes in the hall during assembly.
A: Hole sizes are big enough to allow using hydraulic torque wrenches to tighten the bolts. Hopefully the bolts need to be tightened once only. The handling of the blocks from the top to the hall should not require the crane to rotate the block and should not require one 100-ton crane to take the full loads.during assembly.

Q: With respect to magnetic field, are all hole pockets be covered?
A: All hole pockets can be covered if necessary during assembly or after assembly of the barrel.

Q: The aluminum spacer is located off the center of the top block, the magnetic field measured will not be uniform.
A: The magnetic field measured through the aluminum spacer at the top corner space covers more field variations than the center space. The corner gaps can be conveniently utilized in the design for measuring purpose. It is not prudent to cut the block in the center in order to install the gap for measuring purpose unless it is required by physics.

Q: Address logistics of transporting metals from port to site, i.e. road and bridge capabilities, truck loading capacity, railway capability, and routing problems from the port to the site.

A: All these items have been considered during cost estimate. Although not all of the details have been worked out yet.

Q: Is the schedule of completing the assembly of barrel to be in 12 weeks or in 18 weeks? A 12-week schedule may be very aggressive for a crew of eight people working five days a week.

A: Based on the cost estimate, two crews of four people per crew can assemble 1.5 blocks per day. It requires 12 weeks to assemble 88 blocks for the barrel based on five working days a week. In some days, maybe two blocks can be assembled, while some other days, maybe only one block can be assembled. It is an average. In comparison with what has been done in ZEUS, This schedule seems to be achieveable, but the ecrew size and working hours may need adjustment.

KEK/IHI DESIGN - A. Maki/I. Ohno

Q: What kind of material is to be proposed for the design? How is the material compared to SAE 1010? steel?

A: The SS41 steel has been proposed for the design. The SS41 steel is similar to SAE 1010 steel and it is not the super steel originally considered.

Q: What will be the schedule and cost?

A: The schedule will be distributed. The cost is done by IHI and will not be distributed for proprietary reason.
The costs includes muon toroid barrel, end caps and support structures. They do not include coils, power supplies, jackup systems or moving mechanism for end caps.
There are three cases under consideration. Case 1: Machine both top and bottom of plates; pre-assemble the whole system once. Case 2: Machine both top and bottom of plates; pre-assemble 1/3 of the whole system at a time. Case 3: No machining of plates; pre-asssemble 1/3 of the whole system at a time.
The transporation of the barrel from Japan to Waxahachie is estimated to take six months in six freights. For pre-assembly, it is estimated to take 51/2 months to assemble and 4 months to disassemble by a seven-man crew working 10 hrs/day.

THIN PLATE DESIGN - L. Dittert

Q: How much lateral load can be taken by the support?
A: A 30% unbalanced load will not fail the support.

Q: How many bolts are required in the design?
A: The exact number was not counted. In the short plate, there are 8 bolt holes per plate. In the long plate, there are 28 bolt holes per plate for option A and 16 bolt holes per plate for option B. There are a total of 1080 plates in the design.

Q: Which one of the two proposed options do you support?
A: It may depend on the ground conditions. The toe-bolted plate alternative (option B) may be more desirable than the overlapping plate alternative if the foundation condition is poor.

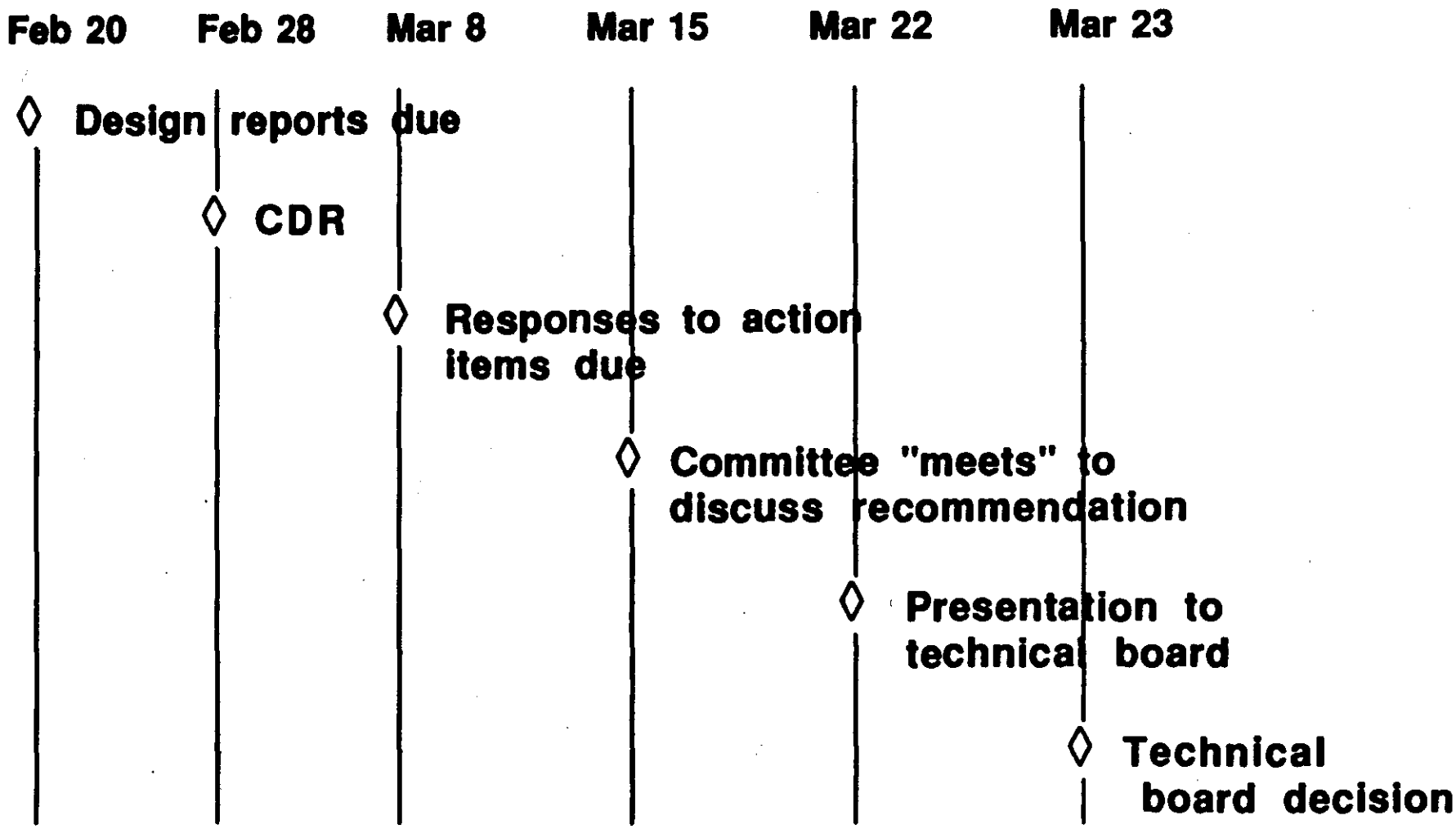
Q: Will the individual 3m section be bolted together after completion of assembly?
A: Originally they are to be bolted together. Now they will not be bolted together due to many difficulties.

Q: What difference is there between your toe-bolted design and the big block design ?
A: The slip in the toe-bolted design is much greater than the big block design. The reason of this is not known yet. It is still under investigation. Maybe some instability in the model is the cause of this.

APPENDIX E

Schedule for barrel toroid steel CDR

SDC



APPENDIX G

Who's on the review committee

SDC

	Richard Boyce	[SLAC]	Fabrication, Installation, Cost/ Sched., Structural Analysis
(Deputy Chair)	Jim Dogett	(LLNL)	O/A Feasibility, Cost & Schedule
	Dave Eartly	[FNAL]	Installation, Alignment, Field Uniformity
(Chair)	Bill Edwards	[LBL]	OA Feasibility, Cost & Schedule
	John Grimson	[FNAL]	Installation & Alignment
	Mark Krefta	[WS&TC]	Magnetic Field Analysis/Uniformity
	Harry Sweet	[Sweet & Aiken Inc.]	Structural Analysis/Feasibility

APPENDIX H

2/6/91

MEMORANDUM

To: Muon Toroid Review Committee
From: Bill Edwards
Subject: Review Assignments

ASSIGNMENTS:

General:
This review is primarily for the benefit of the review committee. We are charged with formulating a recommendation on which of the 3 conceptual designs to be continued thru construction. Therefore, you are all asked to be active and vocal participants in the review. If you have a question, ask it; if you have a concern, express it!

Specific:
You are a part of this review committee because of your background and experience in one or more specific areas which are important for this review. The specific areas for which I wish you to concentrate (not to exclude other areas in which you feel competent) are as follows:

Note: Please review your assignment and tell me if you do not feel comfortable with any part of it.

R. Boyce:
- fabrication cost and schedule
- installation procedure, cost, and schedule
- structural analysis
- alignment issues

D. Eartly
- installation procedure and schedule
- alignment issues
- field uniformity issues

J. Grimson
- installation procedure and schedule
- alignment issues

M. Krefka
- field uniformity
- how tolerances effect uniformity

H. Sweet	-	structural analysis
	-	structural feasibility
J. Doggett &	-	overall feasibility and risk
B. Edwards	-	cost and schedule