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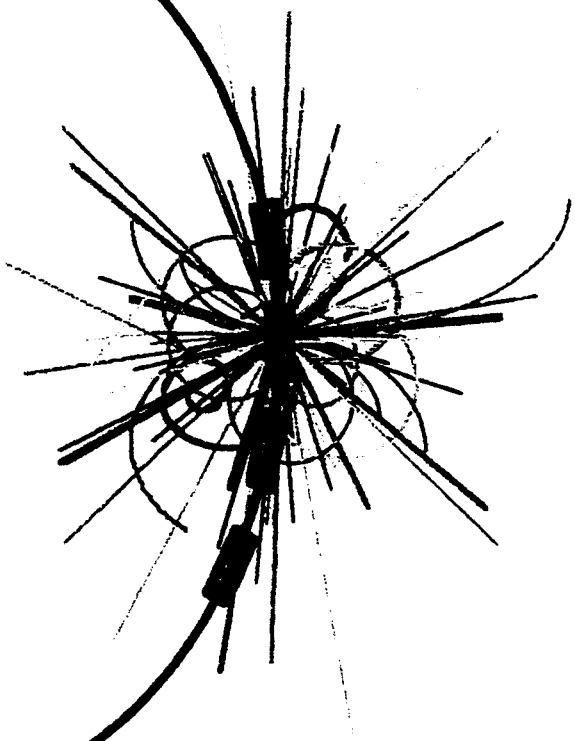
SSC UNDERGROUND TECHNOLOGY ADVISORY PANEL



UTAP REPORT

Recommendations Following the Meeting of April 12-13, 1993 Held at the SSC Laboratory, Dallas, Texas

SUPERCONDUCTING SUPER COLLIDER LABORATORY

UNIVERSITIES RESEARCH ASSOCIATION

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INTRODUCTION

This report summarizes recommendations made by the Underground Technology Advisory Panel (UTAP) to the Superconducting Super Collider (SSC) Laboratory after meetings held on April 12-13, 1993. The Panel was convened at the request of Mr. Jon Ives, Associate Director, Conventional Construction Division (CCD), and Dr. Timothy E. Toohig, Deputy Director, CCD, for the SSC. A list of UTAP members and meeting agenda are appended to this report. The meeting was held at the SSC Laboratory, Dallas, TX, during which time presentations were made by members of the SSC Laboratory staff and the Architect-Engineer/Construction Manager (A-E/CM) on the underground construction status, West Utility Straight design, management issues, safety concerns, tieback test results, design of the Interaction Region (IR) halls, tunnel requirements, and groundwater flow modeling. Information conveyed at the meetings is in the public domain, and is collected and filed as part of the SSC Laboratory Notes which are available through the SSC Laboratory.

In preparation for the meeting, UTAP members received materials prepared by CCD; Parsons Brinckerhoff/Morrison Knudsen (PB/MK), the A-E/CM for the SSC project; and the Texas National Research Laboratory Commission (TNRLC). The following materials were received in advance by UTAP members:

- Letter entitled "Prediction of 'Dry' Zone" to G. Dretke (DOE) from M. Smith (TNRLC), March 25, 1993 [with attached letter to M. Smith from A. Dutton (TBEG)]
- Information sheet on Collider Tunnel footage, 3/30/93
- Weekly Status Report - Collider, 3/12/93; J. Shively, Task Leader, CCD
- IFB/RFP/Addendum, Geotechnical Instrumentation, SC-A00-1215, 2/17/93; F. Fong, Task Leader, CCD
- Drawings: IR5 GEM Exp. Hall Basic Con. CCU E405 Title II Issue for Bid, 3/5/93

- Drawings: IR8 SDC Exp. Hall Basic Con. CCU E305 Title II Issue for Bid, 3/5/93
- IR5 & IR8 Exp. Facs-Basic Construction CCU E305 & CCD E405, GDSR Vol. 2 of 2, Issue for Bid

Before the meetings, members of the Panel on 11 April toured the sites of the N20-N25 and N40-N55 Tunnels. The field inspections afforded by these visits have helped the Panel in understanding the in-situ nature of the rock and its performance during construction operations.

On 12 April, a meeting was convened at which UTAP members were able to discuss aspects of the project with senior SSC Laboratory managers. In addition to UTAP, those present at the meeting were E. Siskin, G. Robertson, J. Dugan, J. Ives, and T. Toohig of the SSC Laboratory. Discussions during this meeting were of benefit to UTAP, and helped the Panel obtain an integrated view of the SSC project.

The report is organized to address issues covered in the agenda for the 11-12 April meeting, and to comment on several additional items not specifically identified in the agenda, but nonetheless brought to the attention of UTAP by discussions during the meeting. The report covers management issues which pertain to verification of tunnel location, change control procedures, construction safety, Disputes Review Boards, and specifications. The report covers technical issues with observations and recommendations made in conjunction with site visits, pressures in Eagle Ford Shale (EFS), implications of tieback test results, West Utility Straight, design and construction of IR halls, IR hall instrumentation, groundwater conditions surrounding IR halls, and liner grouting.

VERIFICATION OF TUNNEL LOCATION

In the UTAP report of 25 January, 1993, the responsibilities for carrying

out verification of tunnel location as construction progresses was discussed. It was mentioned that the Applied Geodesy group has responsibility for verification, and that there appeared to be insufficient resources within the group to perform the verification in a manner to keep pace with construction. Since that time, the CCD has held meetings with the Accelerator Systems Division and other affected groups, which have agreed that verification is the responsibility of Applied Geodesy.

Applied Geodesy now is checking data in the office, but is not yet performing verification in the field. The A-E/CM is performing field checks on its own surveys and locations of monuments. While this adds to the confidence level, it is not the independent verification that has been intended. Applied Geodesy has established resource requirements and is understood to have acquired the ability to hire new staff. No timetable was advanced as to when independent field checks would be performed.

The Panel notes that the SSC Laboratory needs a survey capability not only for conventional construction locations, but for later installation of laboratory equipment after CCD and A-E/CM programs are completed. There still is time for the SSC Laboratory to develop the capability to perform the necessary surveys and verifications, if prompt action is taken.

The Panel's previous recommendations to assign responsibility and to formulate approved procedures appear to have been accomplished. The recommendations to assign adequate resources to perform the verifications presumably are still being worked on. The Panel recommends these matters be completed as soon as possible.

CHANGE CONTROL PROCEDURES

In earlier reports, the Panel has both urged and applauded formation of

policies and procedures for the control and implementation of changes in design. The Change Control Board has been established as the project management's mechanism to control changes. This includes both avoidance of undesired changes and prompt implementation of desired changes, so they may be made as efficiently and economically as possible.

Early submission of change requests and prompt review as to changes which are to be implemented are necessary to prevent delays. These types of activities promote the timely completion of designs packages, bid and award schedules, and construction in the field. The Panel encourages prompt review and rendering of decisions with respect to current design changes. Lack of action not only causes delay in design, but also in subsequent construction.

CONSTRUCTION SAFETY

The A-E/CM reported to the Panel regarding the project safety program. The program appears to be thorough and well conceived. Effort is being expended to develop ever more positive attitudes toward safety at all levels of the project organization.

The work required to build the SSC is inherently hazardous, particularly the underground work. It is paradoxical that this ever present danger sometimes has the effect of engendering in the workers most exposed to the hazards a fatalistic, cavalier attitude toward the risks involved. To the extent that these negative attitudes exist, they must be changed. Doing so is difficult, and is a challenge to the job management. Vigilance and perseverance are required.

There is, of course, no such thing as absolute safety. Despite efforts on the part of all concerned, accidents, including serious ones, will no doubt occur in the future. It is the responsibility of all involved in the project

to assure that accidents will be minimized. While the emphasis on safety at all levels of management is commendable, it is important to recognize that, like in so many management issues, responsibility and authority placed at the lowest possible level is the most effective. In the case of underground construction, the primary responsibility and authority should be with the construction contractor who will, in turn, vest these obligations with working supervisors. The A-E/CM and the SSC Laboratory, in the process of promoting safety, should be careful not to diffuse the safety effort and relieve the contractor of responsibilities, but rather should act firmly to assure that the contractor performs effectively and responsibly in this area.

DISPUTES REVIEW BOARDS

The construction contracts provide for the employment of Disputes Review Boards (DRBs). Experience in the tunneling industry has shown the DRBs to be effective in avoiding disputes, as well as resolving them when they occur. In addition, it has been determined that contractors are disposed to bid lower prices for work when the contract calls for a DRB. A DRB is established at the inception of the work of each contract, and the specifications provide for the DRB to receive regular reports regarding the work and to attend regular jobsite meetings, even when there is no dispute to be considered.

DRB members are selected because, in addition to their expertise, they are respected by the parties. Their occasional presence at the jobsite has the effect of creating a climate in which the parties are unlikely to adopt unreasonable positions. The Panel understands that, even though DRBs have been established for certain underground contracts, a regular meeting routine has not yet been decided. It is recognized that there is a small cost involved, but the Panel believes that money required for DRB meetings is well spent, even in

the absence of a current dispute, and recommends that meetings be held at least three or four times a year, depending upon the work being performed. The publication *Avoiding and Resolving Disputes During Construction*[1] provides useful information regarding the establishment and operation of DRBs.

SPECIFICATIONS FOR LATTICE GIRDERS

Tunneling specifications provide for lattice girders in connection with shotcrete where it is deemed necessary to provide more effective support than shotcrete by itself can provide. On the basis of tunneling experience to date, and the work to be performed in the future, it now is anticipated that lattice girders will not be needed in any appreciable quantities, but it is believed that tunneling contracts should continue to provide for them nonetheless.

Typically, the contract provides payment for lattice girders on a unit price basis against a contract estimated quantity. However, if a low quantity is established, bidders are motivated to bid a high unit price because it will not materially affect the total bid. Then, in the event a greater quantity is required, the contractor will reap an unearned benefit. An alternative is to establish an unreasonably high quantity to discourage the bidders from bidding high unit prices. In that event, bidders are likely to unbalance by bidding very low unit prices. Either way, the bidding will not be realistic, and the payment required to be made to the contractor may not be equitable.

Under these circumstances, the Panel suggests that a unit price be established by the A-E/CM in the contract which will be used to pay for the small amount anticipated. To provide necessary funds, a quantity can be given to which the unit price will be applied, and the total will be included in the bid

[1]Technical Committee on Contracting Practices of the Underground Technology Research Council, "Avoiding and Resolving Disputes During Construction," ASCE, New York, NY, 1991.

amount. While one might disagree with the validity of the established unit price, the amount involved will be small enough not to engender a dispute.

SITE VISITS

Visits were made on 11 April by UTAP members to the sites of the N20-N25 and N40-N55 tunneling. From the N20 shaft, the tunnel had been advanced about 1500 ft in Eagle Ford Shale (EFS). Production was going smoothly, and earlier thrust and shield deflection problems had been resolved. Points of interest include the following:

- Some cracking of the liner segments had occurred during handling and erection. While none of the visible cracking appeared to jeopardize the functionality of the lining, steps were underway to minimize these effects. In particular, localized crack damage at the expansion slot had been caused by an expansion screw-jack without a shoe, which resulted in concentrated loads on the segments. This now is being corrected. Some cracking and spalling had occurred at the corners of the segments due to contact stresses, and handling procedures have been modified to correct this.

- Initially, some grout leakage occurred through the segment joints. Use of a mastic seal at the segment contact faces has successfully eliminated this.

- At the expansion slot, which initially is sheeted with plywood, it appears that ground pressures may be building up, evinced by bulging of the plywood. The broken nature of the EFS in this area, compared to the intact nature of the material, which can be seen in the shield slots behind the cutter head, suggests that this "loading" effect may be due to local damage of EFS at the edge of the crown gripper. While this effect is not considered to be a problem, it does suggest that closure of the expansion slot in a timely manner is good practice for minimizing any further degradation of EFS.

From the N40 shaft, tunneling had advanced about 2000 ft in Austin Chalk. Tunneling conditions were good, and excellent progress was being achieved. Points of interest include the following:

- Thin, bentonitic seams have been encountered in the tunnel, as expected. Local corbelling has occurred due to slaking and raveling of this material, with the consequent loss of small overlying

blocks. Remedial actions have been taken to limit this action and ensure that no safety problems arise. The situation is being closely monitored. The use of shotcrete as a plug and sealant to halt this action may be appropriate on a local, as-required basis.

- Longitudinal, horizontal "cracking," often continuous for long distances, is evident in the sidewalls of the tunnel in Austin Chalk. This cracking is likely the result of shrinkage, and similar effects have been noted in previous tunnels in Austin Chalk that were driven at Austin, TX. Crack widths seldom exceed 0.125 to 0.25 in., and crack depths probably do not exceed 6 in. or so. These cracks will result in some relief of the tangential compressive stresses at the immediate periphery of the tunnel. While this action is not expected to cause any significant problems due to loosening in the short-term, it is recommended that the application of the proposed tunnel sealant be undertaken as soon as reasonably possible. The sealant will help to limit the overall extent of shrinkage in the short term, and limit possible dimensional changes at a later stage if there is re-saturation.

PRESSURES IN EAGLE FORD SHALE

There is some evidence of an increase in stress in the steel collar placed in the Exploratory Shaft. The collar was positioned in the upper EFS to measure possible long-term buildup of lateral pressures in that material. It is recognized that an increase in radially-directed loads on a circular tunnel liner is of no great practical concern. However, the West Utility Straight will have various non-circular sections which pass through the chalk-shale interface. It now may be advantageous to utilize circular liner segments in EFS as a means of more accurately estimating the long-term loads applied by the material. Should additional information on such loads be sought, the Panel offers the following guidance.

The simplest and most direct means of estimating the magnitude of thrust in the liner segments would be use of "Whittmore" type gage points set on the inside face of the segments with which to measure change in the gage interval in the circumferential direction. Measurements near the springline would provide data on the largest circumferential strains. Moments in the liner could

be important if strain measurements around the interior face vary significantly. To obtain better measurements, it might be desirable to place vibrating wire strain gages on the neutral axis of several segments during their casting, aligned in the circumferential direction, to be able to compute average thrust. The PB/MK instrumentation consultant could provide guidance on the specifics of the installation.

It is advisable to place the gage measuring points and accurately measure gage distances while the liner sections are in the yard. During this period, shrinkage still is occurring, and the trend in compression could be determined before erection in the tunnel. Measurements in the tunnel should start just as soon as the segments go under jacking load. The apparent buildup of compressive stresses when the liner is in final position should be corrected for the trend of shrinkage compression that was determined before erection.

IMPLICATIONS OF TIEBACK TEST RESULTS

As stated in our previous report, the Panel expects that the contractors will try to develop higher anchor capacities by their own specialized procedures, at least in stiffer marl in the lower half of an IR hall wall. Therefore, it is important that specifications be clear that the required flexural capacity of the columns depends on the vertical spacing of the permanent anchor ties. If fewer ties of higher capacity are used, then the flexural capacity of the columns may have to be increased appropriately by the contractor in the proposed alternative scheme.

During the tieback testing program, blasts of compressed air were used to remove rock cuttings from holes drilled with tri-cone bits. The air blasts, at pressures as high as 250 psi, are thought to have fractured the Taylor Marl, leading to interconnectivity of fractures between boreholes. At the IR halls,

such fracturing could promote water infiltration into the anchor zone from the overlying weathered marl and lead to a general weakening of the rock mass. This type of fracturing should be avoided, and appropriate quality control procedures need to be incorporated in the job inspection to prevent high pressure air blasts which could fracture the marl.

WEST UTILITY STRAIGHT

The complicated configuration between the High Energy Booster (HEB) and the collider tunnel was described at the UTAP meeting. It involves road header excavation of irregular cross-sections, where fine adjustments of the beam line will be required within several millimeters. Cross-sections will be non-circular and tunnel separations will be small, possibly 6 ft or less. The HEB chiefly will be in chalk, while the collider tunnel generally will be in EFS. It is for these reasons that strain measurements to estimate the buildup of loads in the EFS tunnels have been recommended on page 8.

The general order of movements at the base of the tunnel and their long-term changes could be made by utilizing the heave point extensometer observations in the Exploratory Shaft and the N15 Magnet Delivery Shaft. The initial effects of elastic rebound caused by stress relief should be separated from gradual heave due to long-term volume increase of EFS beneath these shafts. In this way, a reasonable estimate can be made of delayed vertical movements which could affect the beam transfer tunnels connecting the HEB and the collider.

Stabilization of the pillars and roof blocks separating the tunnels may present special problems, which could be monitored by extensometers installed from the first tunnel of two adjoining ones. It is at these locations where special load carrying provisions may be necessary, such as ribs or lattice girders in EFS and special rock anchor patterns in the chalk.

DESIGN AND CONSTRUCTION OF IR HALLS

The PB/MK team has completed a series of sensitivity studies on the safety factor against wedge failure in the walls of the IR halls, based on the data from consolidated drained (CD) and consolidated undrained (CU) tests of Taylor Marl specimens, and on assumed variations in pore pressure distributions along the wedge failure surfaces. At the UTAP meeting, it was reported that a total of 16 CD and CU tests have been completed. Of the 14 tests for which data were presented at the UTAP meeting, six were assigned a quality rating of "OK," three were listed as "marginal," and five were labeled as "poor." From these small-scale specimens, a mean cohesion of 44 psi has been assigned (with upper and lower 95% confidence values of 77 psi and 11 psi, respectively), with a mean friction angle of 38° (95% limits of 42° and 33°, respectively). For comparison, the baseline design calculations were conducted for cohesion equal to 50 psi and a friction angle of 30°.

Pore pressure distributions have been investigated with the FLAC model, using a coupled stress/pore pressure approach. The analytical results indicate that low pore pressures should be generated in the walls of the IR halls, due to the volumetric expansion and consequent pore pressure reductions occurring in response to excavation. The results indicate that these low pore pressures should be sustained for a considerable period, provided that the system is not significantly modified due to extension cracking and direct water ingress from the upper weathered marl.

The sensitivity studies of wall stability in the IR halls were performed using limit-equilibrium analyses of critical wedges. These analyses have provided important back-up evaluations concerning the capacity of the permanent tieback system, and the Panel commends the PB/MK team for having completed these analyses under conditions of extreme work pressure.

The key conclusion of these analyses is that wall stability is adequate, even under pore pressure conditions which increase linearly with depth to the base of an assumed vertical tension crack (and then decrease linearly to the toe of the assumed sliding plane), provided that the actual cohesion of the overall rock mass is not significantly less than the "mean" value obtained from the lab testing, as noted above.

The actual cohesion of the rock mass remains as a key strength parameter, but one which cannot be measured directly, and thus the monitoring of this key parameter in the field must be done on an indirect basis by measurements of wall movements and pore pressures. Thus, the instrumentation and monitoring of the IR halls will be a critically important task, as recognized by the design team and as emphasized in the previous UTAP report.

IR HALL INSTRUMENTATION

The Panel is aware that a significant instrumentation program is being planned for the IR halls. The Panel strongly encourages a comprehensive instrumentation system for the halls, and recognizes that there will be notable expenses associated with such a program. The instrumentation is a critical part of the permanent tieback support and drainage systems. Because of its vital role and contribution to the performance of the permanent hall structure, the cost of the instrumentation should be regarded not only as a percentage of the IR hall shell construction, but of the entire experimental facilities to be housed at the hall construction sites.

The A-E/CM currently is negotiating a contract with the selected Geotechnical Instrumentation Contractor (GIC), and final review of all instrumentation issues associated with the IR halls will not be completed until the GIC contract is in place. As part of this review, the Panel strongly recommends that the

quantity and distribution of instruments around the IR halls be carefully assessed, particularly with regard to the piezometers. One critical purpose of these instruments is to ensure that, in the event of large wall movements, rapid decisions can be made concerning the most appropriate remedial actions. The principal remedial measures include additional drainage holes (which are relatively inexpensive), additional tiebacks, or both. Such choices are, of course, an essential and entirely appropriate part of a balanced geotechnical design based on the observational approach.

Given the importance of pore pressure distribution and drainage, it would be advantageous to deploy more piezometers around the IR hall excavations than presently indicated in the instrumentation plans. Piezometers are relatively inexpensive, and represent a good investment with regard to evaluating sidewall response.

The tiebacks in Taylor Marl will be permanent and will function, in essence, as the primary structural support system over the design life of the halls. It seems appropriate, therefore, that plans for a long-term program of measurements be formulated. A plan for long-term measurements needs to address what instruments will be read, the frequency of measurements, and who will have responsibility for collecting and interpreting the data. The Panel recommends that a careful assessment of the long-term instrumentation goals be undertaken soon, so that conclusions drawn from these considerations can be accommodated in the design of the instrumentation program.

GROUNDWATER CONDITIONS SURROUNDING IR HALLS

The Panel heard with interest the analyses presented by Dr. Alan Dutton of the Texas Bureau of Economic Geology, and PB/MK of the capture zone of the groundwater surrounding the IR halls. It is likely that extension strains in

the marl surrounding the hall excavation and the ready recharge provided by adjacent drainage channels and storm water collection ponds will cause relatively rapid equilibrium, with a tendency to limit the spread of the radius of influence. This could create steep gradients directed toward the inclined drainholes, and cause flow into the halls in the upper range of the PB/MK analysis. The uncertainty created by these imposed hydrogeologic conditions and the resulting possibility of higher positive pore pressures than indicated in the analyses are a further justification for supplementing the piezometer installations, as recommended by the Panel on page 12 of this report.

Both the quantity of inflowing seepage and the amount of water potentially exposed to radiation would be decreased by placing simple and reasonably complete impervious linings under the relocated stream channels and storm water management ponds near the IR halls. These linings might consist of plastic sheeting, with a cover material protecting it from erosion or construction damage. Concrete linings of the control structure should be backed by waterproof membranes, plus underdrainage to protect from blowouts. The storm drain channel should be lined, and discharge pipes into the ponds or streams should be equipped with reliable one-way check valves.

LINER GROUTING

Contract specifications call for continuous grouting behind concrete linings erected in EFS. In the last UTAP report, it was noted (p. 10) that it may prove unnecessary to inject any significant quantities of grout behind the lining, due to its tight fit with EFS. Under current conditions, it would be advisable to discontinue grouting near the invert. Grouting, however, should be continued near the crown to fill voids associated with overbreak and any incomplete expansion of segments.