BNL-105154-2014-TECH

Booster Technical Note No. 110;BNL-105154-2014-IR

Some design considerations for extension of HITL to the Booster

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February 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

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AD
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FEBRUARY 8, 1988

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SOME DESIGN CONSIDERATIONS FOR EXTENSION

OF HITL TO THE BOOSTER

T. ROBINSON

As a result of our discussions some weeks ago, I have been investigating several alternatives for the route of the HITL extension to the Booster. The options include two different paths within the AGS ring, and an exterior, separate tunnel outside of AGS. The three scenarios are presented here along with some pro and con considerations.

Since the line to be built will be both a physical and logical extension of HITL, perhaps a review of some details and operating procedures of the existing transfer line is in order.

HITL BEAM TRANSPORT SYSTEM

The beam transport system from the TVDG to the AGS is comprised of 6 dipoles, 2 quadrupole singlets, 14 quadrupole doublets, 2 quadrupole triplets and 27 dipole trim magnet x-y pairs. The dipoles are high quality double focussing magnets, with 2 of them (the 90 degree pair) having a bending radius of 60" and the rest having a radius of 30". The beam is taken through 3 major bends of 180, 48, and 138 degrees, each bend being made doubly (both in position and in angle) achromatic through the use of 2 dipoles of equal angle with appropriate quadrupoles between them. The dipole magnets and associated power supplies were fabricated by Danfysik of Denmark. The quadrupole lenses were also made by Danfysik, but their multi-channel power supplies, as well as the trim magnets and their power supplies (also multi-channel), were made by Bruker of West Germany.

The first bend, of 180 degrees, is accomplished using two 90 degree double focussing dipoles arranged such that a symmetry plane exists at the midpoint between them (@ 2 radii from each magnet). The addition of two horizontal quad singlets, one on either side of the midpoint, results in a doubly achromatic bend. In the original transport design, achromaticity was considered to be not essential, but desirable. However, recent studies of a q=33 gold beam, show that double achromaticity is crucial to efficient transport of beams having high charge states. For Tandem-generated heavy ion beams thus far accelerated in AGS ($Z<=14$), original transport design called for final post-acceleration stripping to take place at the image point of the first 90 degree dipole (i.e. at the symmetry plane). For these beams, the dispersion through the second magnet due to the stripper-imparted momentum spread was noticeable, but not particularly troublesome. However, recent studies using heavier, higher charge state (gold) beams that have been stripped prior to entering the magnet pair (thus being dispersion corrected by the achromatic nature of the system) show a significant improvement in transport efficiency.

Approximately 1000' farther, the second dipole pair, with each magnet having a bend of 24 degrees, is arranged so that beam minima occur at the center of each dipole; the double focussing properties of these magnets are not utilized. Two quad doublets are located midway between the pair to supply the requisite symmetry for the doubly achromatic bend.

Likewise, the third pair, each of 69 degrees, is found at the AGS end of HITL. Double achromaticity is again achieved using beam minima at the dipoles' centers and a midpoint quad doublet pair for symmetry.

Between the major bends, in the two approximately 1000 foot straight legs of the tunnel, there are focus/defocus quadrupole doublets spaced typically 250 feet apart with x/y beam minima occurring 125 feet after each quad doublet at a beam diagnostic location dubbed a "BIP" (Beam Instrumentation Package). Each BIP consists of two vertically oriented, pneumatically operated shafts- one having x and y wire planes called "harps" for monitoring beam profiles in both transverse planes, and the other having a faraday cup for measuring total beam current. The actuators are located in a specially constructed chamber approximately 2 feet long, which has pneumatically-operated high-vacuum VAT valves at either side. The harps and faraday cups, along with the chambers, were manufactured by NTG, West Germany.

Immediately after each quad doublet and also prior to each BIP there is an x/y trim (steerer) dipole pair which is used to center the beam at the next BIP or quad. These magnets have a nominal BL of 1 kilogauss-inch at Imax, yielding a correcting angle of about 2.8 milliradians.

Finally, after the last 69 degree bend, and within the AGS tunnel, there are two quadrupole triplets for phase space matching prior to injection into the ring.

BEAM TUNING

The normal Tandem mode of acceleration (DC, currents up to 10 microamps) has been altered to supply AGS with the appropriate pulsed beams required for injection. This has been accomplished by pulsing the ion source to allow Tandem acceleration of high current (200-300 microamps), short duration (several hundred microseconds) pulses. To improve the waveform of the pulses, post-acceleration chopping is done prior to injection into HITL. During preparation for delivery to AGS of heavy ion beams, a low level DC "trace" beam (~10 na) is initially transported through

HITL, and is used for the primary tune of the line from the TVDG to the first 69 degree magnet (~ 1900 feet). After this primary DC tune has been achieved, the pulsed and chopped beam is transported through HITL and handed over to the AGS MCR for final matching and injection into the ring. Once chopping has begun, the DC trace beam is no longer available for tuning purposes. Therefore, a second pulse (named the "diag" pulse), is transmitted between main pulses, and is used for HITL touch-up tuning by inserting and retracting harps and/or faraday cups very rapidly, without perturbing the main pulses.

POWER SUPPLIES AND CONTROL ELECTRONICS

All magnet power supplies, ion pump power supplies, beam instrumentation controls and distribution as well as Relway drops are grouped at three power supply house locations; one near each end of HITL and one roughly at the midpoint of the tunnel's length. This allows for the distribution of the low level magnet power cables (5 amps for steerers and 25 amps for quads) along the tunnel, yet permits the high current dipole cables to be routed away from the beam line so that their stray fields do not influence the beam.

All signals from the BIPS are conditioned locally in the tunnel to minimize noise before being shipped to the power supply house for distribution via analog mux's or the Relway LAN. Vacuum system status readbacks and controls, where implemented, are handled likewise.

VACUUM SYSTEM

The HITL vacuum system is unique in that it is for the most part passive, utilizing a proprietary non-evaporative getter (NEG) strip as the basis for the distributed pumping. HITL is believed to be the world's largest example of a NEG strip distributed system with a total pumping speed approaching 200,000 liters/sec. Base pressures after a year and a half of operation range from 1.0 E-9 to 8.0 E-11 torr. Besides using no power during operation and having an estimated lifetime exceeding 10 years before requiring reactivation (at 70 amps/strip for 24 hrs), they contribute absolutely no magnetic or electric fields to perturb the beam. To take advantage of the maximum nominal length available from the manufacturer, the basic beam pipe is 32 feet of 3-5/8" dia tubing containing a 10 meter length of NEG strip in a specially designed cradle. The strip assembly occupies approximately the bottom 5/8" of the pipe bore, and the beam is thus offset slightly above the pipe center to allow maximum spatial extent for the beam envelope.

The NEG strip requires relatively high temperatures for activation, and the design of the beampipe supports must allow for axial expansion of the pipe. This is accomplished in HITL by the utilization of a beampipe suspension system in which the first stand supporting each 32 foot pipe clamps it both radially and axially, whereas the remainder of the stands (usually 2) only restrain the pipe radially, thus allowing axial movement during the expansion phase. The expansion is taken up by bellows between the pipe sections, the bellows being restrained from downstream movement by the next pipe section's first double-clamping stand. Thus, this type of construction lends itself very nicely to long, straight sections of beampipe. Proper support design will be complicated by the use of short sections of beampipe as would be the case for an AGS/HEBT route for the booster transport line. It is not possible to install the NEG strip either within the bore of quadrupoles or in the dipole gap areas. These volumes are therefore not available for active pumping, and in fact are large contributors to the vacuum loading. The number of these spaces should be minimized to obtain the best base pressures.

The vacuum system is logically partitioned by VAT valves on either side of the instrumentaion chambers. These valves are automatically closed upon sensing of a vacuum fault, and may only be re-opened locally by an operator after the condition that caused the closure has been remedied. Fast acting valves at either end of HITL serve to retain the vacuum integrity of the remaining two systems (AGS, Tandem or HITL) in the event of a catastrophic vacuum accident in one.

The beampipe tubing for HITL was obtained from CBA stockpiles, thus resulting in a slightly smaller aperture than desirable. It is suggested that the extension of HITL to the booster be designed with a larger diameter pipe to allow a larger available bore for tuning.

BOOSTER TRANSFER LINE CONSTRUCTION FACTORS

In investigating the various possibilities for the transfer line extension route, the following assumptions were made:

1) It is desirable to build the transfer line without having to abandon the present capabilities of injecting into AGS either protons from the 200 Mev Linac or heavy ions from HITL (i.e.- do not abandon either the HITL injection area or the HEBT line).

2) That full advantage should be taken of the technology developed and lessons learned during HITL construction and operation, and therefore adaptation of as much of the present HITL equipment as possible to the booster line is desirable.

3) Separation of the booster transfer line, AGS and Linac facilities - to the largest extent practicable - is desirable to avoid programmatic interference.

Keeping these points in mind, we now describe the possible routes, their strong points and weaknesses.(Refer to Fig. 1 for the existing accelerator complex and the new booster site.)

The three routes to be considered are:

1) Continuation of the heavy ion beam transport from the point where the present HITL line enters the AGS tunnel, then bend the beam approximately 90 degrees to the left, follow the outer curve of the AGS tunnel approximately 69.6 degrees clockwise to the present HEBT tunnel intersection, bend about 25 degrees to the left into the HEBT tunnel then follow HEBT upstream to a point where an 80 degree right bend will prepare the beam for injection into the booster ring.

2) Continuation of the heavy ion beam transport from the first 69 degree magnet; send it straight through this magnet to an existing pipe that presently enters AGS from the end of the HITL booster extension tunnel (added during the construction phase of HITL). From injection into the AGS tunnel, the angle to be traversed inside AGS is about 42 degrees clockwise to the HEBT intersection, and thence to booster injection as in 1) above.

3) Construction of a new tunnel outside of AGS in line with the HITL tunnel, going about 400 feet NW to a double 16.4 degree bend, then about 400 feet north to the booster. Beamline access to the booster ring would be through a transverse penetration across and above the existing HEBT line.

ROUTES 1 & 2 - INSIDE AGS

Both scenarios inside AGS have serious problems, some of which are cataloged here.

First, establishing the beamline inside the existing AGS tunnel will necessarily result in a reduction of the present aisle space, with the degree of incursion primarily dependent on the number of sub-cells used in the transport system. Using a nominal subcell that subtends an angle of 14 degrees, the furthest extent of the chord from the outer tunnel wall will be about 5', and a mid-subcell quadrupole doublet of the type used in HITL would add another 13" of interference, bringing the total loss of aisle space to about 6'-1". Of course smaller sub-cells could be used, but this increases the number of dipole magnets needed and adds to the complexity of beam tuning. Once inside the HEBT tunnel, the total incursion will be less due to the absence of curved tunnel walls (it probably could be kept to about 24"), but the available space is also much less than in AGS. A cursory inspection of this area indicates that a beamline constructed along the NE wall of HEBT will render almost useless the overhead crane, which presumably is presently used to handle HEBT magnets and assorted beamline hardware.

Routing of high current DC dipole cables to the several required bending magnets inside AGS may be a slight problem. They should be routed away from the beamline to avoid possible perturbation of the beam. The present AGS cable tray system, being along the inner ring wall, is certainly far enough away not to be a problem from this standpoint, but getting cables to several new dipoles located along the outer wall without resorting to cable trays parallel to the beamline should be done cautiously.

The BIP electronic packages in HITL did not need to be radiation hardened since the radiation levels within the tunnel are tiny or non-existent, but this is not the case inside the AGS ring. There are presently 2 cabinets of BIP electronics that reside inside AGS, but to avoid high radiation fields they have been relocated about 25 feet away from their optimum locations, in a toilet. This was done by lengthening the interconnecting cables beyond what is thought to be the safe maximum length prior to signal conditioning. It is thought that further lengthening may degrade the beam monitoring signals by introducing large levels of noise. Due to the lack of more toilets, BIP electronics will need to be located elsewhere, perhaps outside the ring shielding entirely, with requisite cable penetrations being made through the berm. Similarly, LAN drops, magnet power supplies and vacuum pump power supplies will also have to be located somewhere outside the ring. Since there is no space available for more power supplies and other electronics in the existing Bldg. 908, other accommodations will have to be found, in the form of one or more new power supply houses, for the booster extention of HITL.

Similarly, ALL equipment installed inside AGS will need to be constructed of radiation insensitive material as much as possible to avoid deterioration. This includes magnet coils, wiring, hoses and other ancillary equipment- this will of course increase the costs of these articles to some degree.

In order to transport the beam through the AGS tunnel and then up the HEBT tunnel, it is necessary to have an elevation change to cross the HEBT injection line. The beamline crossover may be accomplished either over or under the HEBT line, but both are difficult to arrange and will require pitching magnets. The area around HEBT injection is very congested, and going under the HEBT line will necessitate rearranging many of the existing magnet and vacuum chamber stands. Thus, the better solution is to go over HEBT, but that will require either very large stands for the dipole(s) that will be required to bend into the HEBT tunnel, or these magnets must be suspended from the ceiling. The actual bend into the HEBT area is also very problematic, since the most desirable point to bring the line in occurs directly in the center of a massive concrete support column. Close attention is warranted to beam line routing in this critical area. See the section concerning transport details for a more in-depth discussion of the area.

More importantly, it will be very difficult to arrange a doubly achromatic beam transport through the AGS tunnel due to the physical obstacles that must be avoided, as well as the unfavorable geometry involved. The transport of highly charged beams of moderate momentum spreads through a multi-magnet, non-achromatic system will at the very least result in degradation of beam quality and may in fact not permit an acceptable tune.

The most distressing eventuality is that the strength of the stray magnetic fields produced during the ramping of the AGS ring magnets will preclude any possibility of achieving a convenient tune of a transfer line. Observations of the uniform magnetic field within the gap of the 2nd 69 degree HITL dipole, which resides at the same relative location as any new booster transfer line dipoles would (and 5 feet farther than the closest beamline approach), reveal NMR fluctuations of more than 1 gauss when the ring magnets are ramped. This fluctuation may be even larger considering the time constant of the NMR. Taking into account the relative reluctances of the magnet air gap and the yoke steel, one is led to believe that the stray fields in free space near the outer AGS ring wall may be many times larger than that seen with the NMR. The heavy ion beams, being very highly charged and relatively soft, may be deflected by these time variant stray magnetic fields to the point of being un-tunable. Recall that the existence of a (constant) component of the Earth's magnetic field requires considerable tuning compensation in HITL. Of course the argument can be made that there is a fixed phase relationship between AGS pulses and the booster injection, and thus a tune can be achieved that compensates for the time varying fields. However, even if a tuning solution can be found, the present ease of tuning using the 10 na DC component of the beam would be lost and transport would necessarily be done using the "diag" pulses at 1-2 sec intervals; a very painful mode of tuning. Booster design parameters call for one heavy ion pulse/AGS pulse; future variation from this mode of operation, in the form of multi-pulse injection into the booster if ever desired, would probably be impossible. Also, beam transport for booster study purposes (commissioning, etc) during periods of AGS shutdown will require a totally different tune. It is strongly suggested that a survey of the stray magnetic fields within the AGS ring be commissioned as soon as possible to learn the extent of the problem. It may be possible to construct a magnetic shield around the beamline, but this solution will certainly be very expensive and will make maintenance, diagnostics and leak detecting, etc. very difficult.

Other arguments can be made regarding AGS/booster programmatic conflicts. For example, assuming that the above mentioned problems concerning stray magnetic fields can be resolved, operation of the booster during periods of proton acceleration in AGS will be complicated by the denial of ring access by MCR for either repair or diagnostic considerations. For example, a vacuum excursion or a failed beamline component that is blocking the beam will result in interruption of the program in progress until access is granted to repair the problem. Likewise, AGS will resist the use of the booster line for tuning and studies while the ring is open to personnel. Concerns regarding possible radiation from heavy ion beams (minimal for Z<10, nonexistent for Z>10 for Tandem beams) and presence of electrical, thermal and magnetic field hazards may preclude booster tests and/or commissioning during AGS shutdown (including the 3-4 month summer period).

To reduce the extent of radiation exposure to the personnel involved in the construction phase of the booster beamline, most of the work within the AGS and HEBT tunnel areas will have to be scheduled during the summer break as well, after a sufficient cool-down period.

SPECIFIC TRANSFER LINE ROUTES

ROUTE #1:

Re-direction of the heavy ion beam to the booster from the last HITL 69 degree magnet location has several drawbacks, one of which of course is the requirement that the Tandem/AGS heavy ion link be severed at this point, precluding any possibility of future AGS heavy ion operation without the booster. It will probably be highly desirable to have the option of continuing with fixed target experiments on the AGS floor using heavy ions up to sulpher during periods of booster maintenance, breakdown or proton studies. Aside from the programmatic implications of this choice, the optical considerations are also formidable. The heavy ion beam will need to be bent about 90 degrees to the left at this point, by a magnet (or series of magnets) placed at the present 69 degree dipole's location. Any attempt at an achromatic solution for transport through this area will have to compensate for the dispersion introduced by the previous 69 degree bend, and will also have to attain the 90 degree bend using magnets that have a minimum radius of 24". The presently available Tandem beams have a B-Rho maximum of about 360; therefore a 24" dipole will require a uniform field of 15 kilogauss, about the comfortable limit for conventional magnets. This 90 degree magnet array must also supply the required symmetry for achromaticity without the benefit of upstream correction elements nearer than 50 feet (placement of magnets within the AGS berm penetration is presently impossible), and must accomplish the bend in less than approximately 10 feet before infringing on the AGS ring magnets.

For the purpose of this study, a representative, non-achromatic transport system internal to AGS was chosen to have 5 subcells, each of approximately 14 degrees (Fig 2). Each subcell requires one dipole magnet, two quad doublets, two trim magnet pairs and two beam diagnostic packages. The loss of AGS aisle space is on the order of 6'at the mid point between dipoles, at a beam diagnostic station. Note that this location is at the point of closest approach to the AGS magnets and is at the point of maximum expected perturbation from them. Each subcell has a chord length of about 104'.

As noted earlier, the AGS/HEBT transition area is also troublesome. The cleanest transport solution through this area would be achieved via a single dipole at the 25 degree bend at the AGS/HEBT junction and another at the 18.3 degree bend 105' further upstream in HEBT (Fig 3). Minimization of the beamline-to-tunnel wall dimension will also be desirable in order to preserve the maximum HEBT aisle space. Unfortunately, the attainment of both these objectives is made more difficult by the presence of a large concrete column at the point where the beamline would optimally be placed, thus a multi-element bend or a compromise in HEBT aisle space will be required.

The only positive prospect of this route is that it requires no conventional construction, with the possible exception of a new power supply house. In my estimation, this route is the least attractive and most difficult to achieve.

ROUTE #2:

This solution requires transport of the heavy ion beam directly through the first HITL 69 degree magnet, and thence to the end of a presently defunct neutrino beam line which penetrates the AGS berm (Fig 4). Provision was made for this path during HITL construction by the inclusion of a 0 degree port in the 69 degree magnet to allow a direct continuous path with the magnet turned off, and also by the addition of approximately 106' of 10' diameter tunnel from the end of HITL to the neutrino line's headwall.

This route is somewhat complicated by the misalignment of the present HITL and the 36" concrete pipe forming the neutrino line penetration. A horizontal dipole of approximately 13 degrees will be required directly after the 69 degree magnet to align the beam with the neutrino line in the horizontal plane, and about 100' later a pitching dipole of 3.7 degrees will be needed to bend the beam down and into the AGS tunnel. Here the line takes a 4.5 degree left bend to follow the outer AGS tunnel wall, then follows about the same non-achromatic path as in Route #1, with the exception that the angle to be traversed within AGS is only 41.5 degrees, and requires only three subcells instead of five to reach the AGS/HEBT transition area, where it then follows the route previously described to booster injection.

Besides also having the already discussed problems of lack of achromaticity, beam perturbation and loss of aisle space, this solution will require a large engineering effort to provide proper vacuum system design of the 120' penetration into AGS.

During HITL construction careful attention had to be given to the section of beampipe within the 20" penetration pipe, which in this case was only 50' long. A specially constructed wheeled carriage had to be devised to allow proper orientation of the beamline within the driven penetration pipe, which had run out considerably during installation. Also, due to the pitch of the line, special consideration had to be given to the construction of the NEG strip holders and electrical connections to prevent catastrophic movement during activation. Similarly, the vacuum pipe had to be made of a single piece to avoid flexibility during installation, which precluded the utilization of a bellows to compensate for the substantial axial expansion of the pipe during NEG activation and bakeout. Heavy thermal insulation and thermocouple readouts had to be provided to insure that the NEG strip reached proper activation temperature, and routing of the activation power leads was also a problem. The close proximity of the beam pipe to the penetration pipe, as well as the presence of occasional high temperatures, prevented current-carrying cables from being routed into AGS through this area. In addition, the ends of the penetration pipe were required to accept the placement of considerable radiation shielding to isolate AGS from HITL. These same considerations for the neutrino pipe are exacerbated by the much longer length to be accommodated (120' vs 50'), and the lack of space in which to construct such an assembly on-site, in that the available tunnel length prior to the penetration is less than the penetration length. On the other hand the pitch is less, and the diameter is greater, both of which will be positive factors in the vacuum system design for the neutrino line penetration. Possible alternatives include choosing a different vacuum pumping system (base vacuum should be 5.0 E-10 or better), and/or excavation of some of the earth around the penetration to reduce the required vacuum pipe length (which will make HITL a radiation area due to the reduction of shielding from AGS).

As is the case for route #1, the solution for route #2 is attractive in that it requires little conventional construction (unless excavation of the berm is chosen) except for a new power supply house. In my estimation, while this alternative is better than route #1 in that it is optically superior, it still has flaws that may prove fatal.

ROUTE #3:

Choice of this route requires construction of about 755' of new tunnel, similar to the existing HITL, but avoids most if not all of the pitfalls of routes within AGS. The path, as for route #2, is directly through the first HITL 69 degree magnet, which is not powered (Fig 5). After an undeflected straight run of about 427 feet, there is a twin 16.4 degree bend that is made doubly achromatic in the manner of the previous twin 24 degree bend. The line then runs in a northwesterly direction for approximately 265 feet, near the present BLIP building. At this point the tunnel ends, and the beamline obliquely crosses the HEBT tunnel through a small opening. The pipe within HEBT can be made removable, through the use of isolation valves, to retain crane access to the existing HEBT equipment. Once across the HEBT tunnel, the line continues about 70 feet to booster injection. The 10' difference in elevation between the HITL 69 degree magnet and the booster midplane can be accommodated by a very slight decline (about 11 milliradians) in the new tunnel. This tilt will yield approximately 9 to 10 inches of vertical separation between the heavy ion beamline and the existing HEBT beamline; sufficient to avoid interference at the crossover point. If chosen, this design should include a power supply house near the double bend location to accommodate the electronics and other services. Appendix A contains a recent OPTIC 358 simulation of this route, complete from the Tandem to booster injection.

The advantages of this route are that the equipment count and therefore complexity is smaller, the line can be made doubly achromatic, there is no beam perturbation from AGS magnets, there is no programmatic interference, vacuum system construction is simplified , beam tuning is uncomplicated and there is no loss of present capability of injecting AGS with either protons or heavy ions. The primary drawbacks are the need to re-design the booster heavy ion injection area in response to a new (yet to be determined) solution to booster injection and the added cost for the conventional construction (which will be to some extent compensated for by the savings made possible through the reduction in number of both magnets and instrumentation).

Achromatic, quadrupole doublet logic solutions were not found for the routes inside AGS. It is recognized that another transport solution may exist, notably a FODO lattice. I am not familiar enough with FODO to undertake even a preliminary design of an internal transport line, but my understanding of FODO properties leads me to believe that any such solution will be very difficult to tune in the absence of HITL-style instrumentation, and may require combined-function magnets. Tandem operators are generally not knowledgeable concerning a FODO tune, and likewise AGS operators are not familiar with the tune of relatively soft DC beams. Determination of future responsibility for the tuning of the booster transfer line should be addressed as soon as possible.

Regardless of the lattice chosen, the arguments made against an internal line still apply. Table 1 is a comparison of the nominal equipment required (estimated dollar amount in K$ is included in parenthesis below each entry) for the three alternate routes discussed earlier. The two internal routes 1 and 2, are for reasonable, quadrupole doublet logic, non-achromatic transport, while the exterior line is of the doubly achromatic HITL type as modelled in Appendix A.

	ROUTE #1 INSIDE AGS	ROUTE #2 INSIDE AGS	ROUTE #3 OUTSIDE AGS
DIPOLE MAGNETS & P.S.	11 (615)	10 (470)	2 (80)
DUAL NMR UNITS	4 (100)	3 (75)	1 (25)
QUADRUPOLE SINGLETS	13 (72)	11 (66)	1 (6)
QUADRUPOLE DOUBLETS	13 (144)	10 (60)	6 (36)
16 CH. QUAD POWER SUPPLY	2 (100)	2 (100)	1 (50)
TRIM MAGNETS	17 (56)	14 (46)	11 (36)
16 CH. TRIM POWER SUPPLY	1 (50)	1 (50)	1 (50)
DIAGNOSTIC LOCATIONS	17 (425)	14 (350)	7 (175)
BIP ELECTRONICS	17 (170)	14 (140)	7 (70)
VACUUM PIPE	804' (213)	840' (221)	840' (221)
(TOTALS K$)	(1945)	(1578)	(749)

A rough estimate for the cost of 755 feet of 10' dia tunnel, based on the HITL costs, is 1.0 to 1.2 M$; it can be seen from the above (again) rough estimates for equipment that an external tunnel solution may indeed be cheaper than the interior routes in overall costs and will avoid all the drawbacks recounted earlier.

SUMMARY

Booster management is herewith presented with what I consider to be realistic assessments of the feasibility, operational considerations and rough costs for three different routes for the connecting link between HITL and the booster. My conclusions are that the exterior route is superior in all respects to those proposed inside AGS, and may in fact not be greatly different in cost. Management is urged to seriously consider the various proposals, both from the immediate viewpoint of a successful booster/AGS marriage, but also in the larger context of future heavy ion acceleration in RHIC. The BNL Directorate, joined by DOE representatives, has expressed its convictions that the future of BNL is firmly attached to the successful implementation of a relativistic heavy ion program in the form of RHIC. The transfer line extension to the booster is a small, but vital, link in this chain. If it is not done correctly, the attainment of such a heavy ion program will be seriously compromised. Prompt formation of a committee to study the problems outlined here is indicated, as time is growing short. I suggest that the composition of such a committee include members from all groups concerned, including Booster, AGS, Tandem and ADD.

Acknowledgments: I would like to thank P.Thieberger, J. Benjamin and I. Feigenbaum for their help in gathering the material presented here.

Distribution:

W. Weng (4 copies)

R. Damm

P. Thieberger

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 NOTE: TRANSPORT OF Q=33 GOLD, FROM MP-7 TO BOOSTER VIA EXTERIOR TUNNEL
0                                          SOURCE  ELEMENT:  SOURCE 1
                      ENERGY, MOMENTUM, MASS, CHARGE; VELOCITY, ELECT & MAG RIGIDITY, FREQUENCY
                           E =      15.000000 MEV               V =       .150904 IN/NS
                           P =    2346.329000 MEV/C             ER=      2.307598 MEV
                           M =     197.000000 AMU               BR=    237.023300 KG*IN
                           Q =      13.000000                   RF=     10.000000 MHZ
0                                        NEW VECTORS AFTER ELEMENT:  SOURCE 1
0                 X (INCHES)      X-PRIME(RAD)   Y (INCHES)      Y-PRIME(RAD)    DELTAP/P        PROJ.OP. M

                 1          .04000          .00000          .04000          .00000          .00000          1.00000
                 2          .00000          .00300          .00000          .00300          .00000          1.00000
                 3          .00000          .00000          .00000          .00000          .00000          1.00000
0                                          INPUT DATA                                          BEAM ENVELOPE HALF WIDTHS FROM RAYS 1 THRU 2
         ID  ND1  ND2  ND3  ND4    D(1)    D(2)    D(3)    D(4)    D(5)    D(6)    D(7)    D(8)  X(INCHES)   X'(RAD)    Y(INCHES)   Y'(RAD)

 SOURCE 1    3   10    0    0      .0 13.000 15.000 197.00  .2500 100.00      .0      .0  4.000E-02  3.000E-03  4.000E-02  3.000E-03
  RAY 1                         .0400     .0  .0400     .0     .0     .0
  RAY 2                            .0  .0030     .0  .0030     .0     .0
  RAY 3                            .0     .0     .0     .0     .0     .0
 ST 8   2    0    0    0    0 34.000     .0     .0     .0     .0     .0      .0      .0  1.096E-01  3.000E-03  1.096E-01  3.000E-03
 L55    2    0    0    0    0 6.0000     .0     .0     .0     .0     .0      .0      .0  1.265E-01  3.000E-03  1.265E-01  3.000E-03
 ACCEL  7    0    0    0    0     .0     .0     .0  .0420 600.00     .0      .0      .0  1.265E-01  3.000E-03  1.265E-01  3.000E-03
 NOTE:  SYMMETRIC BEAM CREATED HERE FOR COSMETIC EFFECT.
 TUBE5  7    2 1102    0    0 88.000     .0     .0     .0 88.000     .0      .0      .0  2.309E-01  9.474E-04  2.309E-01  1.929E-03
 L56    2    0    0    0    0 8.0000     .0     .0     .0     .0     .0      .0      .0  2.382E-01  9.474E-04  2.462E-01  6.305E+01MEV
 TUBE6  7    2  202    0    0 88.000     .0     .0     .0 88.000     .0      .0      .0  3.079E-01  7.137E-04  3.109E-01  1.420E-03
 L67    2    0    0    0    0 8.0000     .0     .0     .0     .0     .0      .0      .0  3.135E-01  7.137E-04  3.222E-01  1.111E+02MEV
 TUBE7  7    2  202    0    0 88.000     .0     .0     .0 88.000     .0      .0      .0  3.698E-01  5.963E-04  3.721E-01  1.165E-03
 L78    2    0    0    0    0 8.0000     .0     .0     .0     .0     .0      .0      .0  3.745E-01  5.963E-04  3.814E-01  1.591E+02MEV
 TUBE8  7    2  202    0    0 80.000     .0     .0     .0 80.000     .0      .0      .0  4.187E-01  5.282E-04  4.195E-01  1.018E-03
 TUBE8  7    2    0    0    0 16.000     .0     .0     .0 8.0000     .0      .0      .0  4.248E-01  5.232E-04  4.334E-01  1.010E-03
 L10/1  2    0    0    0    0 80.000     .0     .0     .0     .0     .0      .0      .0  4.663E-01  5.232E-04  5.141E-01  2.072E+02MEV
 VARY       12    0    0    0     .0 1.0000     .0     .0     .0     .0      .0      .0  4.663E-01  5.232E-04  5.141E-01  1.010E-03
 VARY       14    0    0    0     .0     .0     .0 1.0000     .0     .0      .0      .0  4.663E-01  5.232E-04  5.141E-01  1.010E-03
                                                                                                   STRENGTH     B(G/IN)  E(V/IN/IN)
                                                                                        LENS  1    .545316     1164.55     42104.5
                                                                                        LENS  2    .552415     1195.07     43207.9
 >>>>>>>>                          0.  .5453     0.  .5524     0.     0.      0.      0.
 HEQV&H 3  -12    0    0    0 15.000  .5453 15.000  .5524 18.500     .0      .0      .0  6.419E-01  2.466E-03  3.499E-01  1.167E-03
 L10/2  2    0    0    0    0 260.50     .0     .0     .0     .0     .0      .0      .0  1.311E-02  2.466E-03  5.256E-02  1.167E-03
0                                          SOURCE  ELEMENT:  BEAM    1
                      ENERGY, MOMENTUM, MASS, CHARGE; VELOCITY, ELECT & MAG RIGIDITY, FREQUENCY
                           E =     207.192000 MEV               V =       .560404 IN/NS
                           P =    8722.550000 MEV/C             ER=     31.857720 MEV
                           M =     197.000000 AMU               BR=    881.141500 KG*IN
                           Q =      13.000000                   RF=     10.000000 MHZ
0                                        NEW VECTORS AFTER ELEMENT:  BEAM    1
0                 X (INCHES)      X-PRIME(RAD)   Y (INCHES)      Y-PRIME(RAD)    DELTAP/P        PROJ.OP. M

                 1         -.01306          .00010         -.02664         -.00003          .00000          1.00000
                 2         -.00113         -.00246          .04530         -.00117          .00000          1.00000
                 3          .00000          .00000          .00000          .00000          .00000          1.00000
0                                          INPUT DATA                                          BEAM ENVELOPE HALF WIDTHS FROM RAYS 1 THRU 2
         ID  ND1  ND2  ND3  ND4    D(1)    D(2)    D(3)    D(4)    D(5)    D(6)    D(7)    D(8)  X(INCHES)   X'(RAD)    Y(INCHES)   Y'(RAD)

 BEAM   1    0   10    0    0     .0     .0     .0     .0     .0     .0      .0      .0  1.311E-02  2.466E-03  5.256E-02  2.072E+02MEV
 STRIP 15    0    0    0    0     .0 15.000 12.000     .0     .0     .0      .0      .0  1.311E-02  2.466E-03  5.256E-02  1.167E-03
 NEWQ   7    0    0    0    0     .0     .0     .0     .0     .0 33.000      .0      .0  1.311E-02  2.466E-03  5.256E-02  1.167E-03
 NOTE:  E-LOSS 7   0    0    0    0   0.01   0.00   0.00   0.00  -0.30
 L11/1  2    0    0    0    0 117.00     .0     .0     .0     .0     .0      .0      .0  2.894E-01  2.466E-03  9.596E-02  1.167E-03
                                                                                                   RHO(IN)    B(GAUSS) E(VOLTS/IN)
                                                                                     DIPOLE  1     60.0000     5785.27    209166.8
 11DH1  4    0    0    0    0 26.570 26.570-90.000 60.000     .0     .0      .0      .0  2.926E-01  2.386E-03  1.299E-01  7.352E-04
 L11/2  2    0    0    0    0 96.000     .0     .0     .0     .0     .0      .0      .0  6.469E-02  2.386E-03  6.778E-02  7.352E-04
 VARY       32    0    0    0     .0 1.0000     .0     .0     .0     .0      .0      .0  6.469E-02  2.386E-03  6.778E-02  7.352E-04
                                                                                                   STRENGTH     B(G/IN)  E(V/IN/IN)
                                                                                        LENS  3    .292749      206.59      7469.2
 >>>>>>>>                          0.  .2927     0.     0.     0.     0.      0.      0.
 11QH1  3   11    0    0    0 12.000  .2927     .0     .0     .0     .0      .0      .0  3.484E-02  2.732E-03  6.415E-02  5.056E-04
 L11/3  2    0    0    0    0 12.000     .0     .0     .0     .0     .0      .0      .0  1.182E-02  2.732E-03  6.386E-02  5.056E-04
 WAIST2X6    1    2    2    0     .0     .0     .0     .0     .0     .0      .0      .0  1.182E-02  2.732E-03  6.386E-02  5.056E-04
 WAIST2Y6    3    4    2    0     .0     .0     .0     .0     .0     .0      .0      .0  1.182E-02  2.732E-03  6.386E-02  5.056E-04
 ACHRO  6    2    5    1    0     .0     .0     .0     .0     .0     .0      .0      .0  1.182E-02  2.732E-03  6.386E-02  5.056E-04
 NULL   6    0    0    0    0     .0     .0     .0     .0     .0 20.000      .0      .0  1.182E-02  2.732E-03  6.386E-02  5.056E-04
 L11/4  2    0    0    0    0 12.000     .0     .0     .0     .0     .0      .0      .0  3.485E-02  2.732E-03  6.415E-02  5.056E-04
 VARY       32    1    0    0     .0 1.0000     .0     .0     .0     .0      .0      .0  3.485E-02  2.732E-03  6.415E-02  5.056E-04
                                                                                                   STRENGTH     B(G/IN)  E(V/IN/IN)
                                                                                        LENS  4    .292749      206.59      7469.2
 >>>>>>>>                          0.  .2927     0.     0.     0.     0.      0.      0.
 11QH2  3   11    0    0    0 12.000  .2927     .0     .0     .0     .0      .0      .0  6.469E-02  2.386E-03  6.778E-02  7.352E-04
 L11/5  2    0    0    0    0 96.000     .0     .0     .0     .0     .0      .0      .0  2.926E-01  2.386E-03  1.299E-01  7.352E-04
                                                                                                   RHO(IN)    B(GAUSS) E(VOLTS/IN)
                                                                                     DIPOLE  2     60.0000     5785.27    209166.8
 11DH2  4    0    0    0    0 26.570 26.570-90.000 60.000     .0     .0      .0      .0  2.894E-01  2.466E-03  9.596E-02  1.167E-03
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                                                                                          LENS 20    .452518    451.15    16311.2
>>>>>>>>                          0.   .4206     0.   .4326     0.       0.       0.       0.
17QVH2 3   -12    0     0     0 12.000  .4206 12.000  .4326 18.000     .0       .0       .0  2.125E-01  7.020E-04  1.873E-01  6.294E-04
L17/4  2     0    0     0     0 305.00     .0     .0     .0     .0     .0       .0       .0  4.647E-02  7.020E-04  5.264E-02  6.294E-04
                                                                                                        RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                                            DIPOLE  5   30.0000   11570.54   418333.6
18DH1  4     0    0     0     0 6.0700     .0 12.000 30.000     .0       .0       .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
WAIST9X6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
WAIST9Y6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
                                                                                                        RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                                            DIPOLE  6   30.0000   11570.54   418333.6
18DH1  4     0    0     0     0     .0 6.0700 12.000 30.000     .0       .0       .0       .0  4.647E-02  7.020E-04  5.264E-02  6.294E-04
NOTE:  END   OF 48-DEG BEND.
L18/1  2     0    0     0     0 681.00     .0     .0     .0     .0       .0       .0       .0  4.736E-01  7.020E-04  4.200E-01  6.294E-04
VARY       264    0     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  4.736E-01  7.020E-04  4.200E-01  6.294E-04
VARY       262    0     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  4.736E-01  7.020E-04  4.200E-01  6.294E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 21     .395907     377.83    13660.5
                                                                                           LENS 22     .394212     374.60    13543.8
>>>>>>>>                          0.   .3959     0.   .3942     0.       0.       0.       0.
18QHV1 3    12    0     0     0 12.000  .3959 12.000  .3942 18.000     .0       .0       .0  3.791E-01  3.295E-04  5.343E-01  4.768E-04
L18/2  2     0    0     0     0 1111.5     .0     .0     .0     .0     .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
WST10X 6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
WST10Y 6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
L19/1  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  4.980E-01  3.295E-04  7.099E-01  4.768E-04
VARY        82    0     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  4.980E-01  3.295E-04  7.099E-01  4.768E-04
VARY        84    0     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  4.980E-01  3.295E-04  7.099E-01  4.768E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 23     .342077     282.07    10198.4
                                                                                           LENS 24     .341912     281.80    10188.5
>>>>>>>>                          0.   .3421     0.   .3419     0.       0.       0.       0.
19QVH1 3   -12    0     0     0 12.000  .3421 12.000  .3419 18.000     .0       .0       .0  5.929E-01  3.963E-04  5.962E-01  3.986E-04
L19/2  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  8.148E-02  3.963E-04  8.100E-02  3.986E-04
WST11X 6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  8.148E-02  3.963E-04  8.100E-02  3.986E-04
WST11Y 6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  8.148E-02  3.963E-04  8.100E-02  3.986E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  8.148E-02  3.963E-04  8.100E-02  3.986E-04
L20/1  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  5.929E-01  3.963E-04  5.962E-01  3.986E-04
VARY        84    1     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  5.929E-01  3.963E-04  5.962E-01  3.986E-04
VARY        82    1     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  5.929E-01  3.963E-04  5.962E-01  3.986E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 25     .341912     281.80    10188.5
                                                                                           LENS 26     .342077     282.07    10198.4
>>>>>>>>                          0.   .3419     0.   .3421     0.       0.       0.       0.
20QHV1 3    12    0     0     0 12.000  .3419 12.000  .3421 18.000     .0       .0       .0  4.980E-01  3.295E-04  7.099E-01  4.768E-04
L20/2  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
WST12X 6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
WST12Y 6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  9.799E-02  3.295E-04  6.772E-02  4.768E-04
L21/1  2     0    0     0     0 1111.5     .0     .0     .0     .0       .0       .0       .0  3.791E-01  3.295E-04  5.343E-01  4.768E-04
VARY        92    0     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  3.791E-01  3.295E-04  5.343E-01  4.768E-04
VARY        94    0     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  3.791E-01  3.295E-04  5.343E-01  4.768E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 27     .366485     323.76    11705.6
                                                                                           LENS 28     .366196     323.25    11687.2
>>>>>>>>                          0.   .3665     0.   .3662     0.       0.       0.       0.
21QVH1 3   -12    0     0     0 12.000  .3665 12.000  .3662 18.000     .0       .0       .0  4.628E-01  4.103E-04  4.376E-01  3.864E-04
L21/2  2     0    0     0     0 666.00     .0     .0     .0     .0       .0       .0       .0  1.990E-01  4.103E-04  1.914E-01  3.864E-04
NOTE:  BEGINNING OF BOOSTER EXTENTION- 69 DEG DIPOLE IS OFF
NOTE: 2 FEET TO 69 DEG VAC CHAMBER MINIMUM DIMENSION- CHECK INTERFERENCE
L21/3  2     0    0     0     0 24.000     .0     .0     .0     .0       .0       .0       .0  1.900E-01  4.103E-04  1.831E-01  3.864E-04
NOTE: EXTEND DRIFT TO NOMINAL CELL LENGTH
L21/4  2     0    0     0     0 421.50     .0     .0     .0     .0       .0       .0       .0  7.869E-02  4.103E-04  8.355E-02  3.864E-04
WST21X 6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  7.869E-02  4.103E-04  8.355E-02  3.864E-04
WST21Y 6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  7.869E-02  4.103E-04  8.355E-02  3.864E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  7.869E-02  4.103E-04  8.355E-02  3.864E-04
L24/1  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  6.131E-01  4.103E-04  5.788E-01  3.864E-04
VARY       242    0     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  6.131E-01  4.103E-04  5.788E-01  3.864E-04
VARY       244    0     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  6.131E-01  4.103E-04  5.788E-01  3.864E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 29     .342022     281.98    10195.1
                                                                                           LENS 30     .342127     282.15    10201.3
>>>>>>>>                          0.   .3420     0.   .3421     0.       0.       0.       0.
24QHV1 3    12    0     0     0 12.000  .3420 12.000  .3421 18.000     .0       .0       .0  5.150E-01  3.416E-04  6.891E-01  4.626E-04
L24/2  2     0    0     0     0 1482.0     .0     .0     .0     .0       .0       .0       .0  9.452E-02  3.416E-04  6.980E-02  4.626E-04
WST24X 6     1    2     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.452E-02  3.416E-04  6.980E-02  4.626E-04
WST24Y 6     3    4     2     0     .0     .0     .0     .0     .0       .0       .0       .0  9.452E-02  3.416E-04  6.980E-02  4.626E-04
NULL   6     0    0     0     0     .0     .0     .0     .0     .0   20.000       .0       .0  9.452E-02  3.416E-04  6.980E-02  4.626E-04
L25/1  2     0    0     0     0 1000.0     .0     .0     .0     .0       .0       .0       .0  3.544E-01  3.416E-04  4.678E-01  4.626E-04
VARY       252    0     0     0     .0 1.0000     .0     .0     .0       .0       .0       .0  3.544E-01  3.416E-04  4.678E-01  4.626E-04
VARY       254    0     0     0     .0     .0     .0 1.0000     .0       .0       .0       .0  3.544E-01  3.416E-04  4.678E-01  4.626E-04
                                                                                                       STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                                           LENS 31     .399730     385.16    13925.6
                                                                                           LENS 32     .401248     388.10    14031.6
>>>>>>>>                          0.   .3997     0.   .4012     0.       0.       0.       0.
25QVH1 3   -12    0     0     0 12.000  .3997 12.000  .4012 18.000     .0       .0       .0  4.459E-01  6.787E-04  3.657E-01  5.649E-04
L25/2  2     0    0     0     0 661.00     .0     .0     .0     .0       .0       .0       .0  4.786E-02  6.787E-04  5.844E-02  5.649E-04
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L11/8  2     0     0     0   0 117.80      .0       .0        .0       .0       .0        .0       .0  1.518E-02  2.466E-03  5.558E-02  1.167E-03
L12/1  2     0     0     0   0 142.00      .0       .0        .0       .0       .0        .0       .0  3.518E-01  2.466E-03  2.132E-01  1.167E-03
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS  5      .440000      466.68     16872.8
                                                                                                  LENS  6      .440000      466.68     16872.8
12QHV1 3   -12     0     0   0 12.000   .4400  12.000    .4400  18.000       .0        .0       .0  5.232E-01  4.415E-04  1.834E-01  7.284E-04
L12/2  2     0     0     0   0 380.00      .0       .0        .0       .0       .0        .0       .0  6.898E-01  4.415E-04  4.569E-01  7.284E-04
VARY        42     0     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  6.898E-01  4.415E-04  4.569E-01  7.284E-04
VARY        44     0     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  6.898E-01  4.415E-04  4.569E-01  7.284E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS  7      .361038      314.21     11360.2
                                                                                                  LENS  8      .367426      325.43     11765.8
>>>>>>>>                                 0.   .3610      0.    .3674      0.       0.        0.       0.
12QVH2 3    12     0     0   0 12.000   .3610  12.000    .3674  18.000       .0        .0       .0  5.656E-01  3.907E-04  5.641E-01  3.896E-04
L12/3  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
WAIST4X6     1     2     2   0      .0      .0      .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
WAIST4Y6     3     4     2   0      .0      .0      .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
NULL   6     0     0     0   0      .0      .0      .0        .0       .0   20.000        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
L13/1  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  5.656E-01  3.907E-04  5.641E-01  3.896E-04
VARY        52     0     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  5.656E-01  3.907E-04  5.641E-01  3.896E-04
VARY        54     0     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  5.656E-01  3.907E-04  5.641E-01  3.896E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS  9      .344607      286.26     10349.7
                                                                                                  LENS 10      .344796      286.57     10361.1
>>>>>>>>                                 0.   .3446      0.    .3448      0.       0.        0.       0.
13QHV1 3    12     0     0   0 12.000   .3446  12.000    .3448  18.000       .0        .0       .0  4.738E-01  3.235E-04  6.734E-01  4.677E-04
L13/2  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
WAIST5X6     1     2     2   0      .0      .0      .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
WAIST5Y6     3     4     2   0      .0      .0      .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
NULL   6     0     0     0   0      .0      .0      .0        .0       .0   20.000        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
L14/1  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  4.738E-01  3.235E-04  6.734E-01  4.677E-04
VARY        54     1     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  4.738E-01  3.235E-04  6.734E-01  4.677E-04
VARY        52     1     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  4.738E-01  3.235E-04  6.734E-01  4.677E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS 11      .344796      286.57     10361.1
                                                                                                  LENS 12      .344607      286.26     10349.7
>>>>>>>>                                 0.   .3448      0.    .3446      0.       0.        0.       0.
14QVH1 3   -12     0     0   0 12.000   .3448  12.000    .3446  18.000       .0        .0       .0  5.656E-01  3.907E-04  5.640E-01  3.896E-04
L14/2  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
WAIST6X6     1     2     2   0      .0      .0      .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
WAIST6Y6     3     4     2   0      .0      .0      .0        .0       .0       .0        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
NULL   6     0     0     0   0      .0      .0      .0        .0       .0   20.000        .0       .0  8.263E-02  3.907E-04  8.287E-02  3.896E-04
L15/1  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  5.656E-01  3.907E-04  5.640E-01  3.896E-04
VARY        52     1     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  5.656E-01  3.907E-04  5.640E-01  3.896E-04
VARY        54     1     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  5.656E-01  3.907E-04  5.640E-01  3.896E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS 13      .344607      286.26     10349.7
                                                                                                  LENS 14      .344796      286.57     10361.1
>>>>>>>>                                 0.   .3446      0.    .3448      0.       0.        0.       0.
15QHV1 3    12     0     0   0 12.000   .3446  12.000    .3448  18.000       .0        .0       .0  4.738E-01  3.235E-04  6.734E-01  4.677E-04
L15/2  2     0     0     0   0 1432.0      .0       .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
WAIST7X6     1     2     2   0      .0      .0      .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
WAIST7Y6     3     4     2   0      .0      .0      .0        .0       .0       .0        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
NULL   6     0     0     0   0      .0      .0      .0        .0       .0   20.000        .0       .0  9.982E-02  3.235E-04  6.903E-02  4.677E-04
L16/1  2     0     0     0   0 1132.0      .0       .0        .0       .0       .0        .0       .0  3.795E-01  3.235E-04  5.340E-01  4.677E-04
VARY        62     0     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  3.795E-01  3.235E-04  5.340E-01  4.677E-04
VARY        64     0     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  3.795E-01  3.235E-04  5.340E-01  4.677E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS 15      .393462      373.18     13492.3
                                                                                                  LENS 16      .395205      376.49     13612.2
>>>>>>>>                                 0.   .3935      0.    .3952      0.       0.        0.       0.
16QVH1 3   -12     0     0   0 12.000   .3935  12.000    .3952  18.000       .0        .0       .0  4.736E-01  7.020E-04  4.200E-01  6.294E-04
L16/2  2     0     0     0   0 681.00      .0       .0        .0       .0       .0        .0       .0  4.647E-02  7.020E-04  5.264E-02  6.294E-04
NOTE:  START OF 48-DEG BEND. DO IN 2 STEPS DUE TO XOVER @ CENTER
                                                                                                               RHO(IN)    B(GAUSS) E(VOLTS/IN)
                                                                                                  DIPOLE  3    30.0000    11570.54    418333.6
17DH1  4     0     0     0   0 6.0700      .0  12.000   30.000       .0       .0        .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
WAIST8X6     1     2     2   0      .0      .0      .0        .0       .0       .0        .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
WAIST8Y6     3     4     2   0      .0      .0      .0        .0       .0       .0        .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
NULL   6     0     0     0   0      .0      .0      .0        .0       .0   20.000        .0       .0  4.731E-02  6.824E-04  5.250E-02  6.150E-04
                                                                                                               RHO(IN)    B(GAUSS) E(VOLTS/IN)
                                                                                                  DIPOLE  4    30.0000    11570.54    418333.6
17DH1  4     0     0     0   0      .0  6.0700  12.000   30.000       .0       .0        .0       .0  4.647E-02  7.020E-04  5.264E-02  6.294E-04
L17/1  2     0     0     0   0 305.00      .0       .0        .0       .0       .0        .0       .0  2.125E-01  7.020E-04  1.873E-01  6.294E-04
VARY        72     0     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  2.125E-01  7.020E-04  1.873E-01  6.294E-04
VARY        74     0     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  2.125E-01  7.020E-04  1.873E-01  6.294E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS 17      .432616      451.15     16311.2
                                                                                                  LENS 18      .420647      426.53     15421.2
>>>>>>>>                                 0.   .4326      0.    .4206      0.       0.        0.       0.
17QHV1 3    12     0     0   0 12.000   .4326  12.000    .4206  18.000       .0        .0       .0  1.700E-01  1.899E-04  2.571E-01  1.256E-04
L17/2  2     0     0     0   0 12.000      .0       .0        .0       .0       .0        .0       .0  1.700E-01  1.899E-04  2.571E-01  1.256E-04
NOTE:ACHRO   6     2     5   1   0    0.0
L17/3  2     0     0     0   0 12.000      .0       .0        .0       .0       .0        .0       .0  1.700E-01  1.899E-04  2.571E-01  1.256E-04
VARY        74     0     0   0      .0  1.0000      .0        .0       .0       .0        .0       .0  1.700E-01  1.899E-04  2.571E-01  1.256E-04
VARY        72     0     0   0      .0      .0      .0    1.0000       .0       .0        .0       .0  1.700E-01  1.899E-04  2.571E-01  1.256E-04
                                                                                                              STRENGTH     B(G/IN)   E(V/IN/IN)
                                                                                                  LENS 19      .420647      426.53     15421.2
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NOTE: BEGINNING OF 32D44'20" BEND
                                                                                  RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                       DIPOLE  7   30.0000   11570.54   418333.6
26DH1  4    0    0    0    0 4.1100     .0 8.1850 30.000     .0     .0     .0     .0  4.827E-02  6.690E-04  5.839E-02  5.530E-04
WST25X 6    1    2    2    0     .0     .0     .0     .0     .0     .0     .0     .0  4.827E-02  6.690E-04  5.839E-02  5.530E-04
WST25Y 6    3    4    2    0     .0     .0     .0     .0     .0     .0     .0     .0  4.827E-02  6.690E-04  5.839E-02  5.530E-04
NULL   6    0    0    0    0     .0     .0     .0     .0     .0 20.000     .0     .0  4.827E-02  6.690E-04  5.839E-02  5.530E-04
                                                                                  RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                       DIPOLE  8   30.0000   11570.54   418333.6
26DH1  4    0    0    0    0     .0 4.1100 8.1850 30.000     .0     .0     .0     .0  4.786E-02  6.787E-04  5.844E-02  5.649E-04
L26/1  2    0    0    0    0 345.00     .0     .0     .0     .0     .0     .0     .0  2.338E-01  6.787E-04  1.915E-01  5.649E-04
VARY      262    0    0    0     .0 1.0000     .0     .0     .0     .0     .0     .0  2.338E-01  6.787E-04  1.915E-01  5.649E-04
VARY      264    0    0    0     .0     .0     .0 1.0000     .0     .0     .0     .0  2.338E-01  6.787E-04  1.915E-01  5.649E-04
                                                                                 STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                          LENS 33   .417867     420.91    15218.0
                                                                          LENS 34   .407586     400.45    14478.4
>>>>>>>>                             0.  .4179     0.  .4076     0.     0.     0.     0.
26QHV1 3   12    0    0    0 12.000  .4179 12.000  .4076 18.000     .0     .0     .0  1.893E-01  1.706E-04  2.568E-01  1.257E-04
L26/2  2    0    0    0    0 12.000     .0     .0     .0     .0     .0     .0     .0  1.893E-01  1.706E-04  2.568E-01  1.257E-04
ACHRO  6    2    5    1    0     .0     .0     .0     .0     .0     .0     .0     .0  1.893E-01  1.706E-04  2.568E-01  1.257E-04
L26/3  2    0    0    0    0 12.000     .0     .0     .0     .0     .0     .0     .0  1.894E-01  1.706E-04  2.568E-01  1.257E-04
VARY      264    0    0    0     .0 1.0000     .0     .0     .0     .0     .0     .0  1.894E-01  1.706E-04  2.568E-01  1.257E-04
VARY      262    0    0    0     .0     .0     .0 1.0000     .0     .0     .0     .0  1.894E-01  1.706E-04  2.568E-01  1.257E-04
                                                                                 STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                          LENS 35   .407586     400.45    14478.4
                                                                          LENS 36   .417867     420.91    15218.0
>>>>>>>>                             0.  .4076     0.  .4179     0.     0.     0.     0.
26QVH2 3  -12    0    0    0 12.000  .4076 12.000  .4179 18.000     .0     .0     .0  2.340E-01  6.752E-04  1.915E-01  5.649E-04
L26/4  2    0    0    0    0 345.00     .0     .0     .0     .0     .0     .0     .0  4.798E-02  6.752E-04  5.844E-02  5.649E-04
                                                                                  RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                       DIPOLE  9   30.0000   11570.54   418333.6
27DH1  4    0    0    0    0 4.1100     .0 8.1850 30.000     .0     .0     .0     .0  4.829E-02  6.689E-04  5.839E-02  5.530E-04
WST26X 6    1    2    2    0     .0     .0     .0     .0     .0     .0     .0     .0  4.829E-02  6.689E-04  5.839E-02  5.530E-04
WST26Y 6    3    4    2    0     .0     .0     .0     .0     .0     .0     .0     .0  4.829E-02  6.689E-04  5.839E-02  5.530E-04
NULL   6    0    0    0    0     .0     .0     .0     .0     .0 20.000     .0     .0  4.829E-02  6.689E-04  5.839E-02  5.530E-04
                                                                                  RHO(IN)   B(GAUSS) E(VOLTS/IN)
                                                                       DIPOLE 10   30.0000   11570.54   418333.6
27DH1  4    0    0    0    0     .0 4.1100 8.1850 30.000     .0     .0     .0     .0  4.780E-02  6.822E-04  5.844E-02  5.649E-04
NOTE: END OF 32D44'20" BEND
L27/1  2    0    0    0    0 661.00     .0     .0     .0     .0     .0     .0     .0  4.468E-01  6.822E-04  3.657E-01  5.649E-04
VARY      272    0    0    0     .0 1.0000     .0     .0     .0     .0     .0     .0  4.468E-01  6.822E-04  3.657E-01  5.649E-04
VARY      274    0    0    0     .0     .0     .0 1.0000     .0     .0     .0     .0  4.468E-01  6.822E-04  3.657E-01  5.649E-04
                                                                                 STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                          LENS 37   .394244     374.67    13546.0
                                                                          LENS 38   .392172     370.74    13404.0
>>>>>>>>                             0.  .3942     0.  .3922     0.     0.     0.     0.
27QHV1 3   12    0    0    0 12.000  .3942 12.000  .3922 18.000     .0     .0     .0  3.591E-01  2.838E-04  4.651E-01  3.811E-04
L27/2  2    0    0    0    0 1200.0     .0     .0     .0     .0     .0     .0     .0  1.138E-01  2.838E-04  8.473E-02  3.811E-04
WST27X 6    1    2    2    0     .0     .0     .0     .0     .0     .0     .0     .0  1.138E-01  2.838E-04  8.473E-02  3.811E-04
WST27Y 6    3    4    2    0     .0     .0     .0     .0     .0     .0     .0     .0  1.138E-01  2.838E-04  8.473E-02  3.811E-04
NULL   6    0    0    0    0     .0     .0     .0     .0     .0 20.000     .0     .0  1.138E-01  2.838E-04  8.473E-02  3.811E-04
L28/1  2    0    0    0    0 1200.0     .0     .0     .0     .0     .0     .0     .0  3.591E-01  2.838E-04  4.651E-01  3.811E-04
VARY      282    0    0    0     .0 1.0000     .0     .0     .0     .0     .0     .0  3.591E-01  2.838E-04  4.651E-01  3.811E-04
VARY      284    0    0    0     .0     .0     .0 1.0000     .0     .0     .0     .0  3.591E-01  2.838E-04  4.651E-01  3.811E-04
NOTE: LAST QUAD IS A TRIPLET
                                                                                 STRENGTH    B(G/IN)  E(V/IN/IN)
                                                                          LENS 39   .317454     242.93     8783.0
                                                                          LENS 40   .445355     478.11    17286.0
                                                                          LENS 41   .317454     242.93     8783.0
>>>>>>>>                             0.  .3175     0.  .4454     0.     0.     0.     0.
28QVH1 3  -13    0    0    0 12.000  .3175 12.000  .4454 18.000     .0     .0     .0  3.582E-01  3.207E-04  4.638E-01  4.269E-04
L28/2  2    0    0    0    0 62.000     .0     .0     .0     .0     .0     .0     .0  3.392E-01  3.207E-04  4.377E-01  4.269E-04
NOTE:PENETRATION OF LINAC TUNNEL WALL HERE
L28/3  2    0    0    0    0 474.00     .0     .0     .0     .0     .0     .0     .0  1.992E-01  3.207E-04  2.410E-01  4.269E-04
L29/1  2    0    0    0    0 536.00     .0     .0     .0     .0     .0     .0     .0  1.007E-01  3.207E-04  7.564E-02  4.269E-04
WST28X 6    1    2    2    0     .0     .0     .0     .0     .0     .0     .0     .0  1.007E-01  3.207E-04  7.564E-02  4.269E-04
WST28Y 6    3    4    2    0     .0     .0     .0     .0     .0     .0     .0     .0  1.007E-01  3.207E-04  7.564E-02  4.269E-04
NULL   6    0    0    0    0     .0     .0     .0     .0     .0 20.000     .0     .0  1.007E-01  3.207E-04  7.564E-02  4.269E-04
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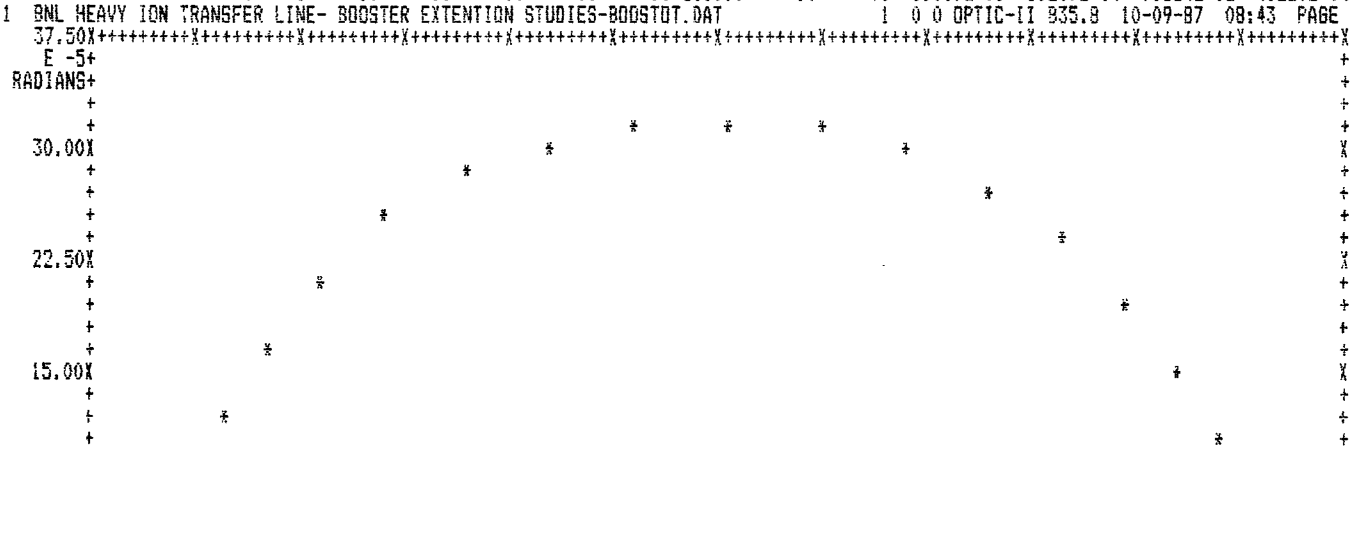
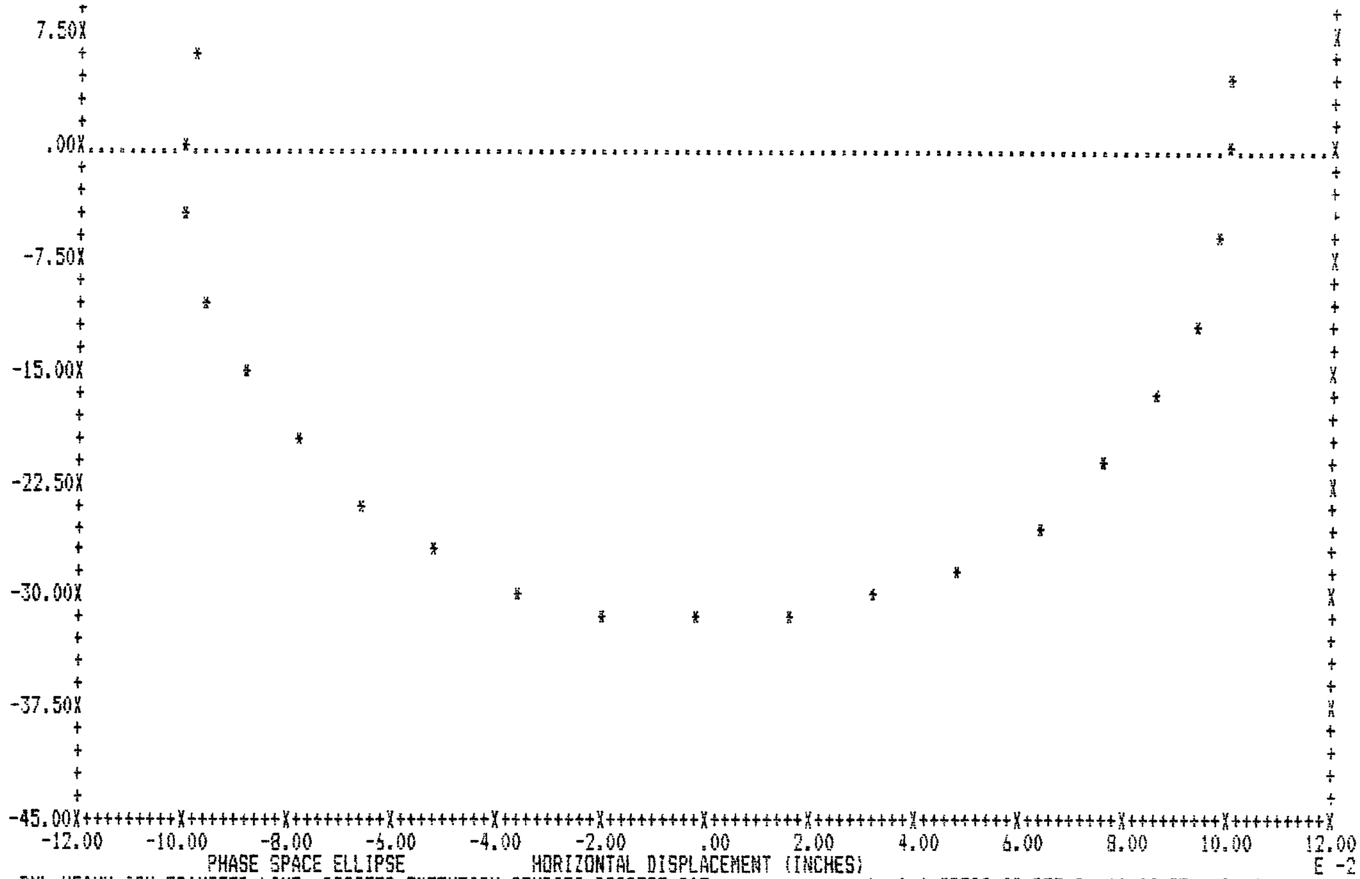
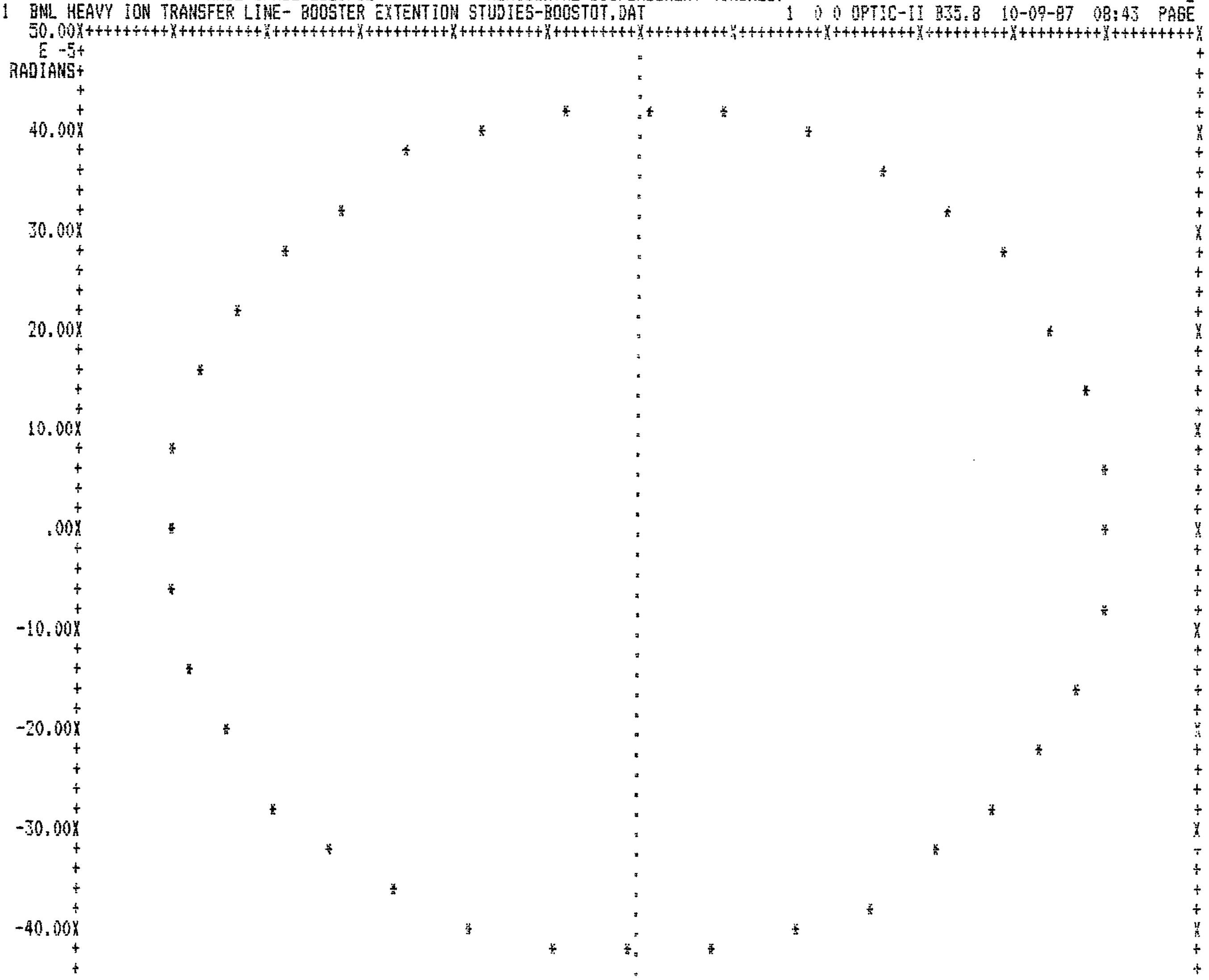
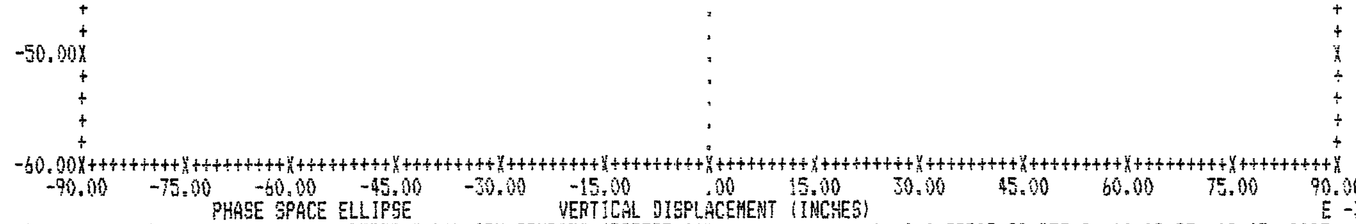




PHASE SPACE ELLIPSE HORIZONTAL DISPLACEMENT (INCHES) E -2



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0                                    INPUT DATA                                   BEAM ENVELOPE HALF WIDTHS FROM RAYS 1 THRU 2
       ID  ND1  ND2  ND3  ND4   D(1)   D(2)   D(3)   D(4)   D(5)   D(6)   D(7)   D(8)  X(INCHES)   X'(RAD)   Y(INCHES)   Y'(RAD)

 PLOT  12    1    0    0    0     .0     .0     .0     .0     .0     .0     .0     .0  1.007E-01  3.207E-04  7.564E-02  4.269E-04
 STOP
1  BNL HEAVY ION TRANSFER LINE- BOOSTER EXTENTION STUDIES-BOOSTOT.DAT            1  0 0 OPTIC-II B35.8  10-09-87  08:43  PAGE  5
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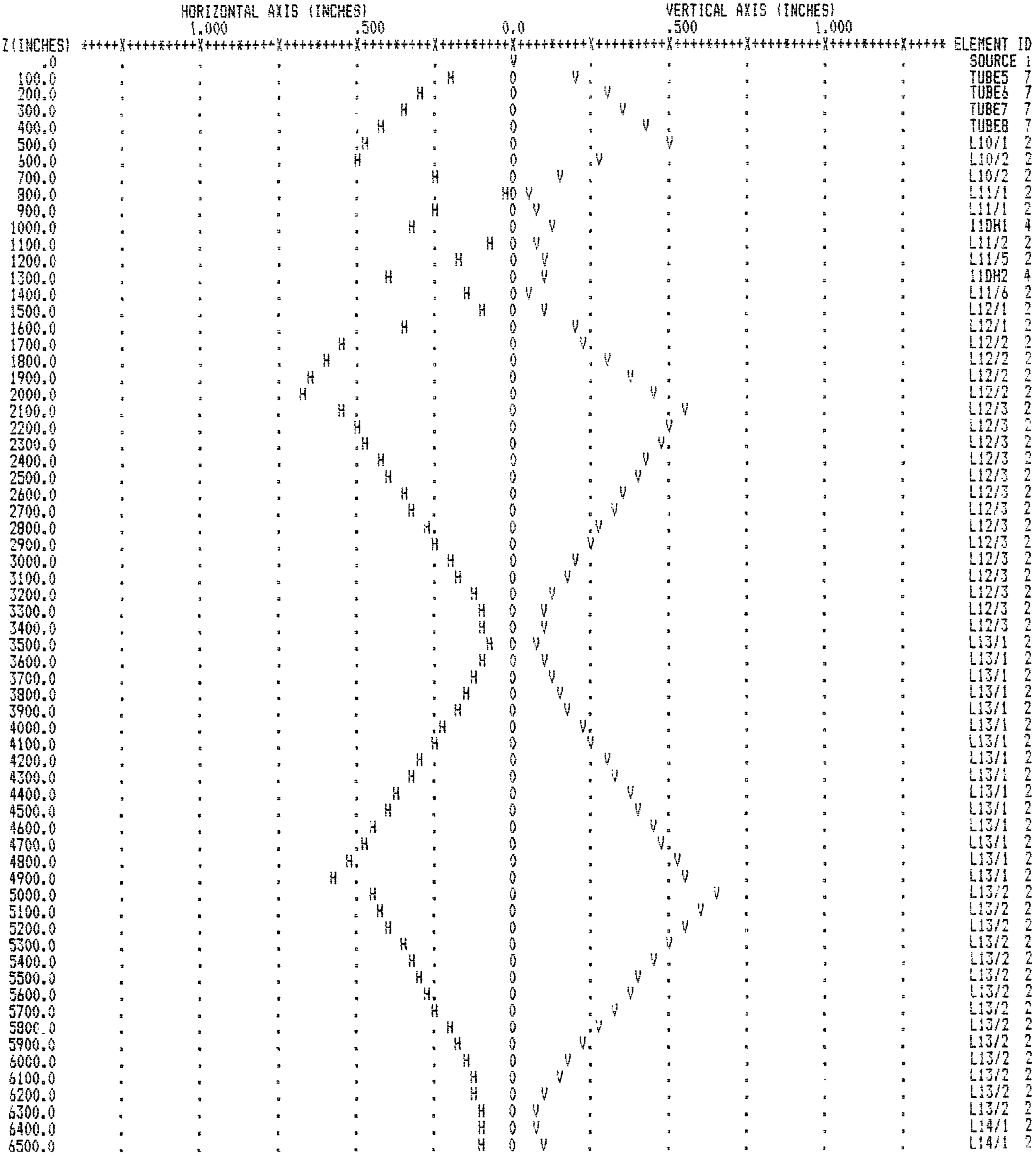

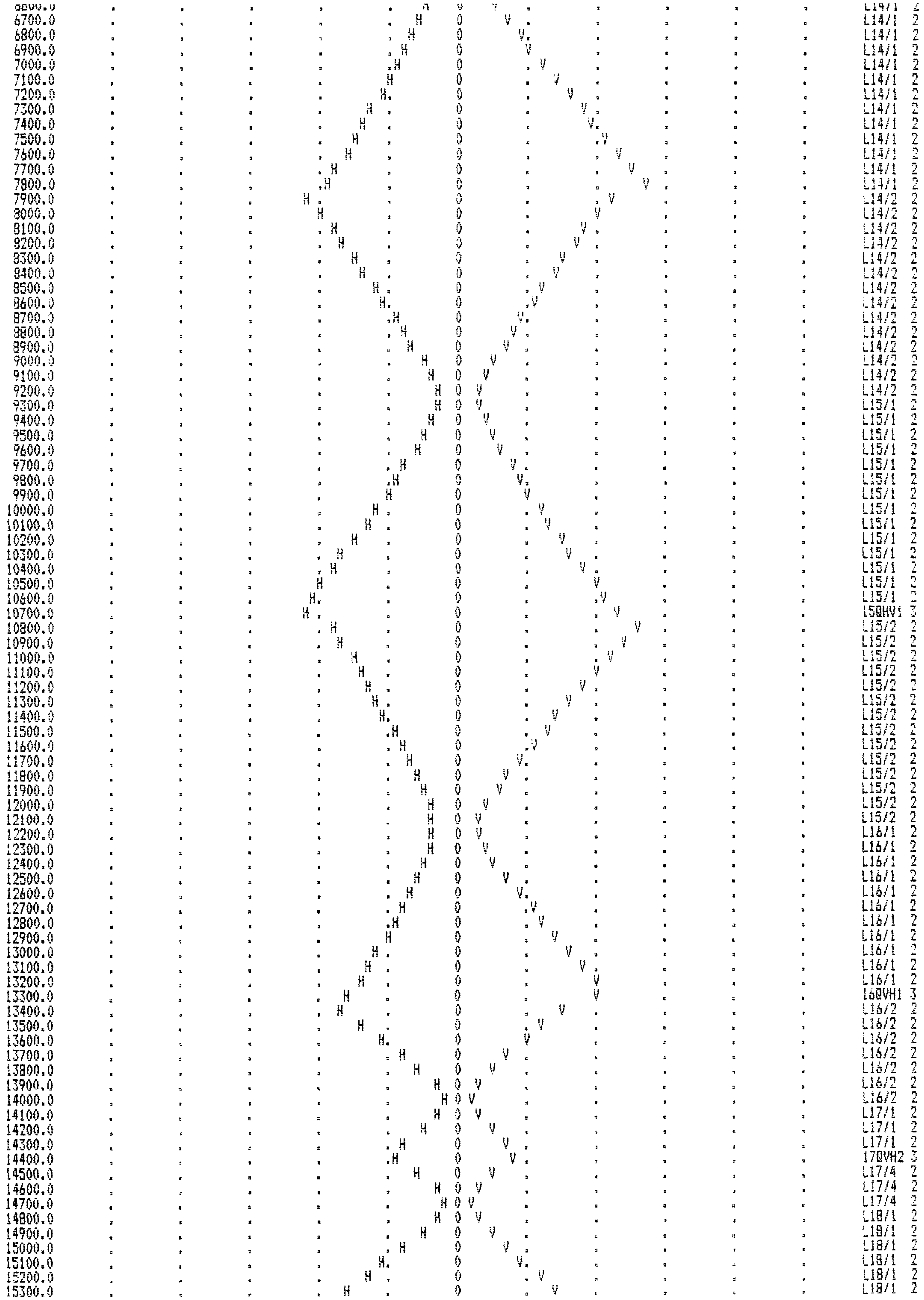

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7400.0 L14/1 2
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7700.0 L14/1 2
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9100.0 L14/2 2
9200.0 L14/2 2
9300.0 L15/1 2
9400.0 L15/1 2
9500.0 L15/1 2
9600.0 L15/1 2
9700.0 L15/1 2
9800.0 L15/1 2
9900.0 L15/1 2
10000.0 L15/1 2
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10300.0 L15/1 2
10400.0 L15/1 2
10500.0 L15/1 2
10600.0 L15/1 2
10700.0 15QHV1 3
10800.0 L15/2 2
10900.0 L15/2 2
11000.0 L15/2 2
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11200.0 L15/2 2
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14500.0 L17/4 2
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15700.0           .         .         .   .       H .         0         .     V   .         .         .         .       L18/2   2
15800.0           .         .         .   .        H.         0         .   V     .         .         .         .       L18/2   2
15900.0           .         .         .   .         .H        0         .  V      .         .         .         .       L18/2   2
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16100.0           .         .         .   .         .  H      0        V.         .         .         .         .       L18/2   2
16200.0           .         .         .   .         .   H     0      V  .         .         .         .         .       L18/2   2
16300.0           .         .         .   .         .    H    0    V    .         .         .         .         .       L18/2   2
16400.0           .         .         .   .         .     H   0   V     .         .         .         .         .       L18/2   2
16500.0           .         .         .   .         .     H   0  V      .         .         .         .         .       L18/2   2
16600.0           .         .         .   .         .     H   0  V      .         .         .         .         .       L19/1   2
16700.0           .         .         .   .         .     H   0   V     .         .         .         .         .       L19/1   2
16800.0           .         .         .   .         .    H    0     V   .         .         .         .         .       L19/1   2
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17100.0           .         .         .   .         . H       0         .V        .         .         .         .       L19/1   2
17200.0           .         .         .   .         H         0         .  V      .         .         .         .       L19/1   2
17300.0           .         .         .   .        H.         0         .    V    .         .         .         .       L19/1   2
17400.0           .         .         .   .       H .         0         .      V  .         .         .         .       L19/1   2
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17600.0           .         .         .   .     H   .         0         .         V         .         .         .       L19/1   2
17700.0           .         .         .   .   H     .         0         .         . V       .         .         .       L19/1   2
17800.0           .         .         .   .  H      .         0         .         .   V     .         .         .       L19/1   2
17900.0           .         .         .   . H       .         0         .         .     V   .         .         .       L19/1   2
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18200.0           .         .         .  H.         .         0         .         . V       .         .         .       L19/2   2
18300.0           .         .         .   H         .         0         .         V         .         .         .       L19/2   2
18400.0           .         .         .   . H       .         0         .       V .         .         .         .       L19/2   2
18500.0           .         .         .   .  H      .         0         .      V  .         .         .         .       L19/2   2
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19000.0           .         .         .   .         .H        0        V.         .         .         .         .       L19/2   2
19100.0           .         .         .   .         . H       0       V .         .         .         .         .       L19/2   2
19200.0           .         .         .   .         .   H     0     V   .         .         .         .         .       L19/2   2
19300.0           .         .         .   .         .    H    0    V    .         .         .         .         .       L19/2   2
19400.0           .         .         .   .         .     H   0   V     .         .         .         .         .       L19/2   2
19500.0           .         .         .   .         .      H  0  V      .         .         .         .         .       L19/2   2
19600.0           .         .         .   .         .      H  0  V      .         .         .         .         .       L20/1   2
19700.0           .         .         .   .         .     H   0   V     .         .         .         .         .       L20/1   2
19800.0           .         .         .   .         .    H    0    V    .         .         .         .         .       L20/1   2
19900.0           .         .         .   .         .  H      0      V  .         .         .         .         .       L20/1   2
20000.0           .         .         .   .         . H       0       V .         .         .         .         .       L20/1   2
20100.0           .         .         .   .         H         0         V         .         .         .         .       L20/1   2
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20300.0           .         .         .   .      H  .         0         .  V      .         .         .         .       L20/1   2
20400.0           .         .         .   .     H   .         0         .   V     .         .         .         .       L20/1   2
20500.0           .         .         .   .   H     .         0         .     V   .         .         .         .       L20/1   2
20600.0           .         .         .   .  H      .         0         .      V  .         .         .         .       L20/1   2
20700.0           .         .         .   .H        .         0         .        V.         .         .         .       L20/1   2
20800.0           .         .         .   H         .         0         .         V         .         .         .       L20/1   2
20900.0           .         .         . H .         .         0         .         . V       .         .         .       L20/1   2
21000.0           .         .         .H  .         .         0         .         .   V     .         .         .       L20/1   2
21100.0           .         .         .   .H        .         0         .         .      V  .         .         .       L20/2   2
21200.0           .         .         .   . H       .         0         .         .     V   .         .         .       L20/2   2
21300.0           .         .         .   .  H      .         0         .         .   V     .         .         .       L20/2   2
21400.0           .         .         .   .    H    .         0         .         . V       .         .         .       L20/2   2
21500.0           .         .         .   .     H   .         0         .         V         .         .         .       L20/2   2
21600.0           .         .         .   .      H  .         0         .       V .         .         .         .       L20/2   2
21700.0           .         .         .   .       H .         0         .     V   .         .         .         .       L20/2   2
21800.0           .         .         .   .         H         0         .   V     .         .         .         .       L20/2   2
21900.0           .         .         .   .         .H        0         . V       .         .         .         .       L20/2   2
22000.0           .         .         .   .         . H       0         V         .         .         .         .       L20/2   2
22100.0           .         .         .   .         .  H      0        V.         .         .         .         .       L20/2   2
22200.0           .         .         .   .         .   H     0      V  .         .         .         .         .       L20/2   2
22300.0           .         .         .   .         .    H    0    V    .         .         .         .         .       L20/2   2
22400.0           .         .         .   .         .     H   0   V     .         .         .         .         .       L20/2   2
22500.0           .         .         .   .         .     H   0  V      .         .         .         .         .       L20/2   2
22600.0           .         .         .   .         .     H   0  V      .         .         .         .         .       L21/1   2
22700.0           .         .         .   .         .    H    0   V     .         .         .         .         .       L21/1   2
22800.0           .         .         .   .         .    H    0     V   .         .         .         .         .       L21/1   2
22900.0           .         .         .   .         .   H     0       V .         .         .         .         .       L21/1   2
23000.0           .         .         .   .         .  H      0        V.         .         .         .         .       L21/1   2
23100.0           .         .         .   .         . H       0         .V        .         .         .         .       L21/1   2
23200.0           .         .         .   .         H         0         .  V      .         .         .         .       L21/1   2
23300.0           .         .         .   .        H.         0         .    V    .         .         .         .       L21/1   2
23400.0           .         .         .   .       H .         0         .      V  .         .         .         .       L21/1   2
23500.0           .         .         .   .      H  .         0         .        V.         .         .         .       L21/1   2
23600.0           .         .         .   .    H    .         0         .         .V        .         .         .       L21/1   2
23700.0           .         .         .   . H       .         0         .      V  .         .         .         .       L21/2   2
23800.0           .         .         .   .   H     .         0         .     V   .         .         .         .       L21/2   2
23900.0           .         .         .   .    H    .         0         .   V     .         .         .         .       L21/2   2
24000.0           .         .         .   .      H  .         0         .  V      .         .         .         .       L21/2   2
24100.0           .         .         .   .       H .         0         .V        .         .         .         .       L21/2   2
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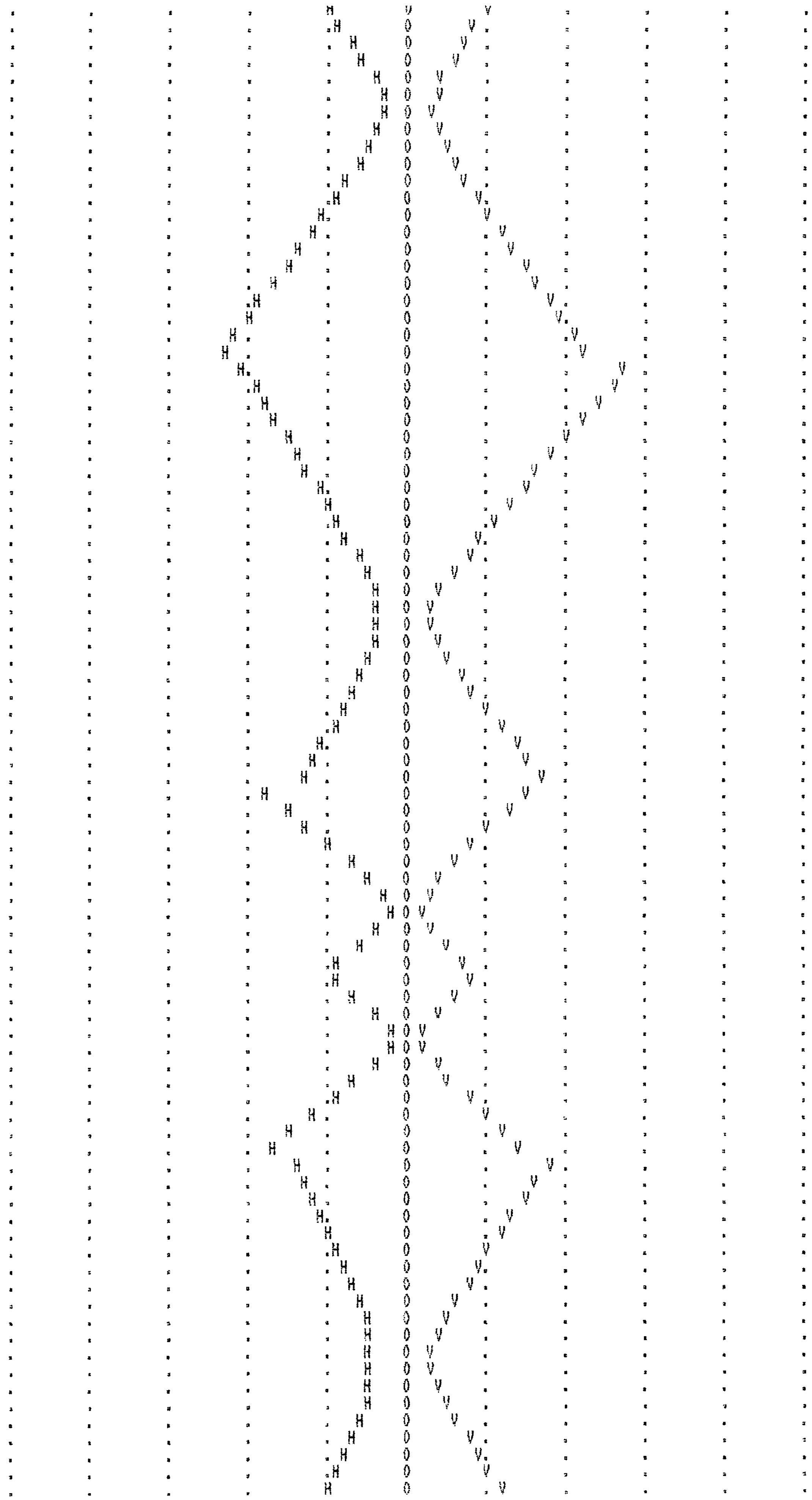

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24300.0	L21/2	2
24400.0	L21/4	2
24500.0	L21/4	2
24600.0	L21/4	2
24700.0	L21/4	2
24800.0	L24/1	2
24900.0	L24/1	2
25000.0	L24/1	2
25100.0	L24/1	2
25200.0	L24/1	2
25300.0	L24/1	2
25400.0	L24/1	2
25500.0	L24/1	2
25600.0	L24/1	2
25700.0	L24/1	2
25800.0	L24/1	2
25900.0	L24/1	2
26000.0	L24/1	2
26100.0	L24/1	2
26200.0	L24/1	2
26300.0	L24/2	2
26400.0	L24/2	2
26500.0	L24/2	2
26600.0	L24/2	2
26700.0	L24/2	2
26800.0	L24/2	2
26900.0	L24/2	2
27000.0	L24/2	2
27100.0	L24/2	2
27200.0	L24/2	2
27300.0	L24/2	2
27400.0	L24/2	2
27500.0	L24/2	2
27600.0	L24/2	2
27700.0	L24/2	2
27800.0	L25/1	2
27900.0	L25/1	2
28000.0	L25/1	2
28100.0	L25/1	2
28200.0	L25/1	2
28300.0	L25/1	2
28400.0	L25/1	2
28500.0	L25/1	2
28600.0	L25/1	2
28700.0	L25/1	2
28800.0	25QVH1	3
28900.0	L25/2	2
29000.0	L25/2	2
29100.0	L25/2	2
29200.0	L25/2	2
29300.0	L25/2	2
29400.0	L25/2	2
29500.0	L26/1	2
29600.0	L26/1	2
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30100.0	L26/4	2
30200.0	L26/4	2
30300.0	L27/1	2
30400.0	L27/1	2
30500.0	L27/1	2
30600.0	L27/1	2
30700.0	L27/1	2
30800.0	L27/1	2
30900.0	L27/1	2
31000.0	L27/2	2
31100.0	L27/2	2
31200.0	L27/2	2
31300.0	L27/2	2
31400.0	L27/2	2
31500.0	L27/2	2
31600.0	L27/2	2
31700.0	L27/2	2
31800.0	L27/2	2
31900.0	L27/2	2
32000.0	L27/2	2
32100.0	L27/2	2
32200.0	L28/1	2
32300.0	L28/1	2
32400.0	L28/1	2
32500.0	L28/1	2
32600.0	L28/1	2
32700.0	L28/1	2
32800.0	L28/1	2
32900.0	L28/1	2

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33000.0         .          .          .          .         H.          0          .  V       .          .          .          .       L28/1  2
33100.0         .          .          .          .        H .          0          .    V     .          .          .          .       L28/1  2
33200.0         .          .          .          .       H  .          0          .      V   .          .          .          .       L28/1  2
33300.0         .          .          .          .     H    .          0          .        V .          .          .          .       L28/1  2
33400.0         .          .          .          .     H    .          0          .         V.          .          .          .       L28/2  2
33500.0         .          .          .          .       H  .          0          .       V  .          .          .          .       L28/3  2
33600.0         .          .          .          .        H .          0          .    V     .          .          .          .       L28/3  2
33700.0         .          .          .          .         H.          0          .  V       .          .          .          .       L28/3  2
33800.0         .          .          .          .          .H         0          . V        .          .          .          .       L28/3  2
33900.0         .          .          .          .          . H        0          V          .          .          .          .       L28/3  2
34000.0         .          .          .          .          .  H       0         V.          .          .          .          .       L29/1  2
34100.0         .          .          .          .          .   H      0       V  .          .          .          .          .       L29/1  2
34200.0         .          .          .          .          .    H     0      V   .          .          .          .          .       L29/1  2
34300.0         .          .          .          .          .    H     0    V     .          .          .          .          .       L29/1  2
34400.0         .          .          .          .          .      H   0   V      .          .          .          .          .       L29/1  2
Z(INCHES)  *****X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X++++++++++X+++++ ELEMENT ID
                          1.000                 .500                 0.0                  .500                 1.000
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END DATA

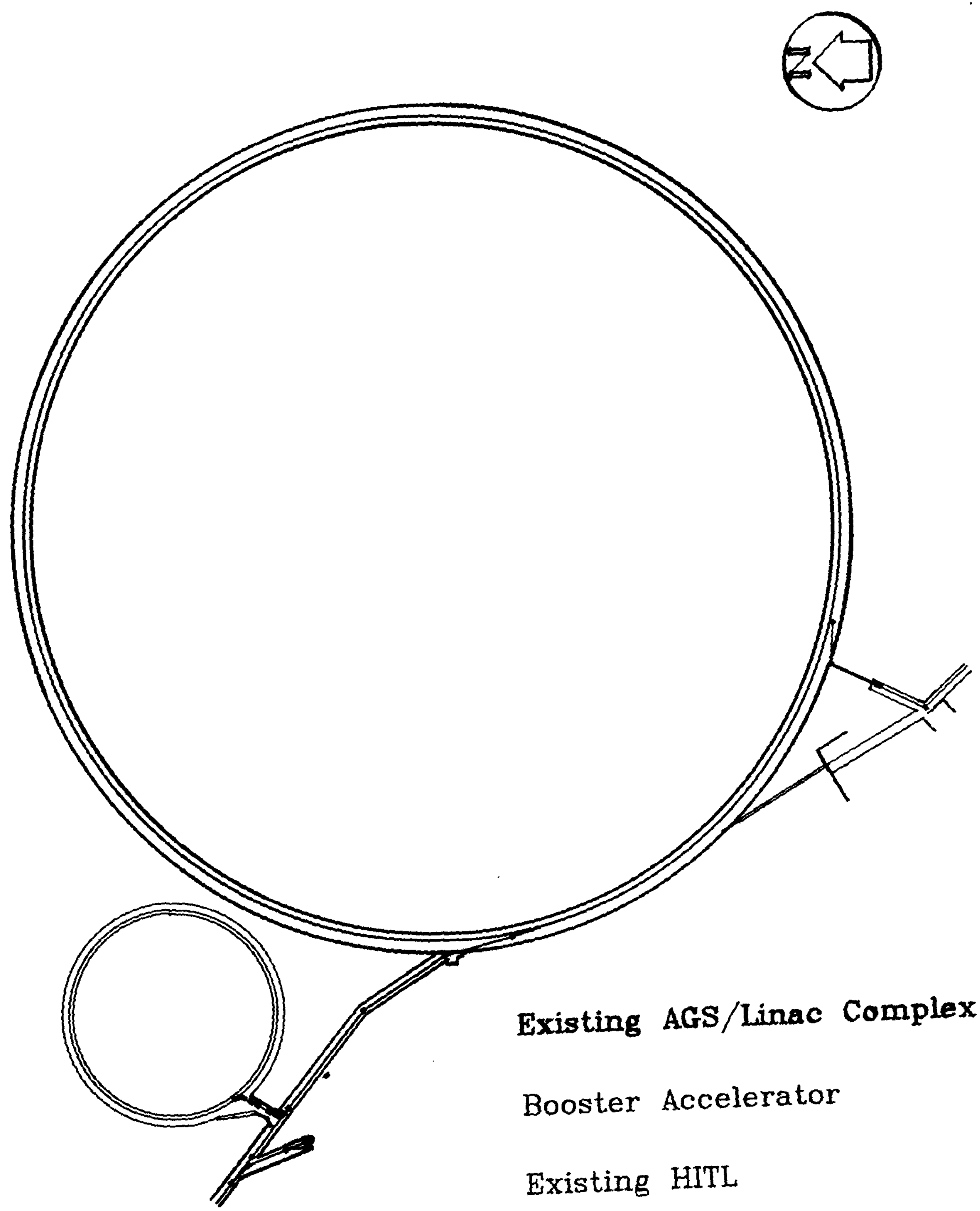

N
Existing AGS/Linac Complex
Booster Accelerator
Existing HITL

FIGURE 1

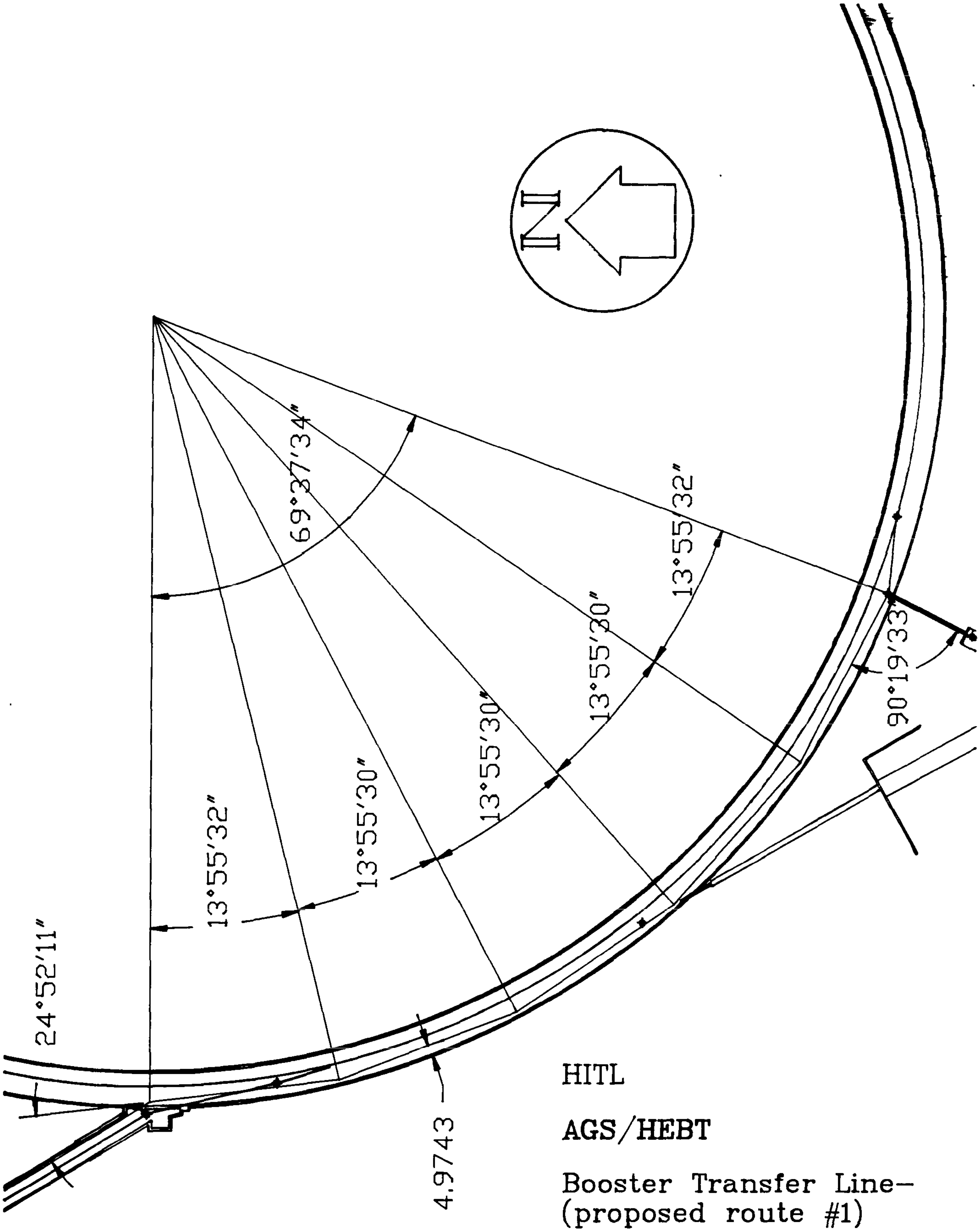

N
69°37'34"
13°55'32"
13°55'30"
13°55'30"
13°55'30"
13°55'32"
24°52'11"
90°19'33"
4.9743
HITL
AGS/HEBT
Booster Transfer Line–
(proposed route #1)

FIGURE 2

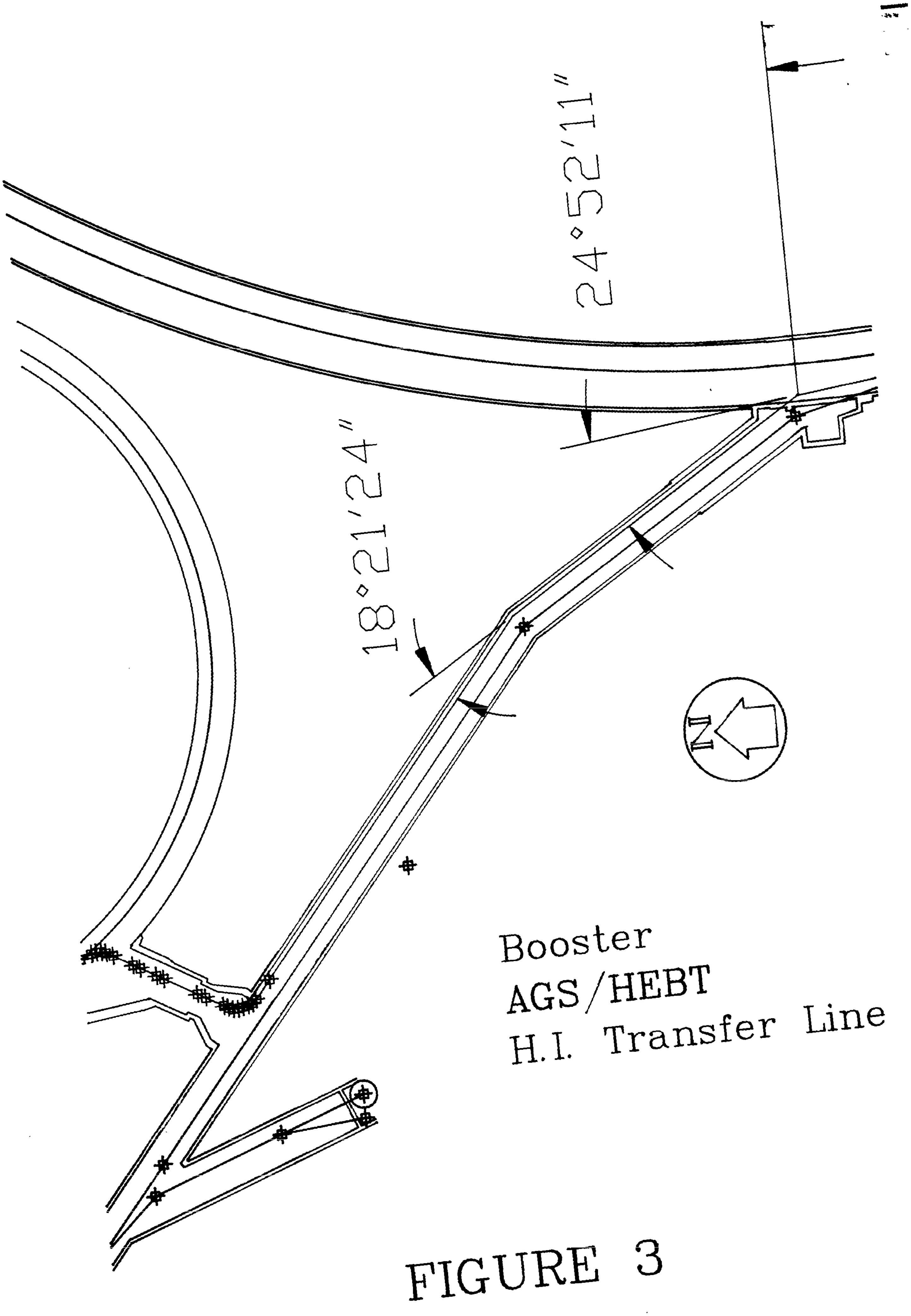
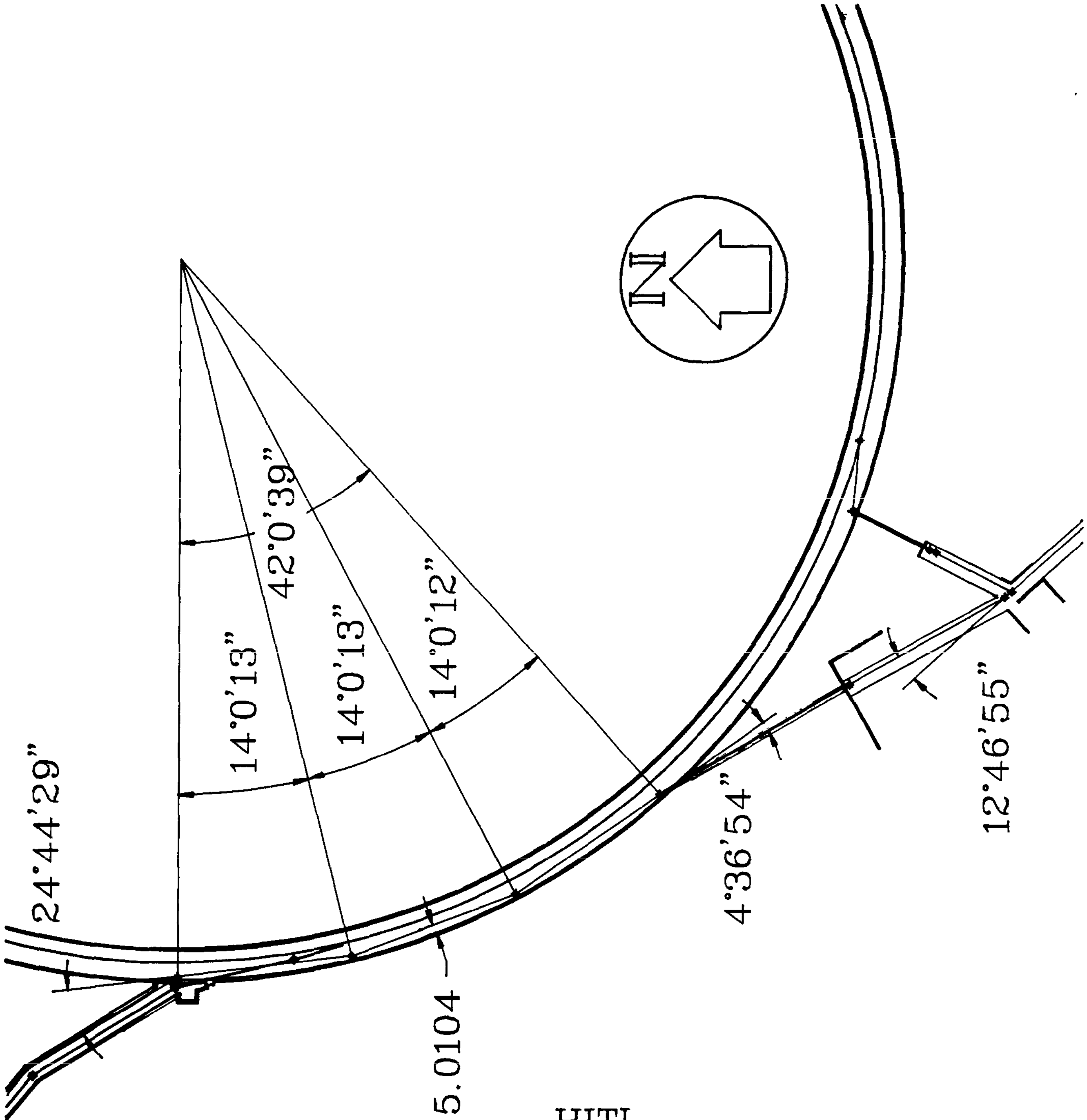


FIGURE 3

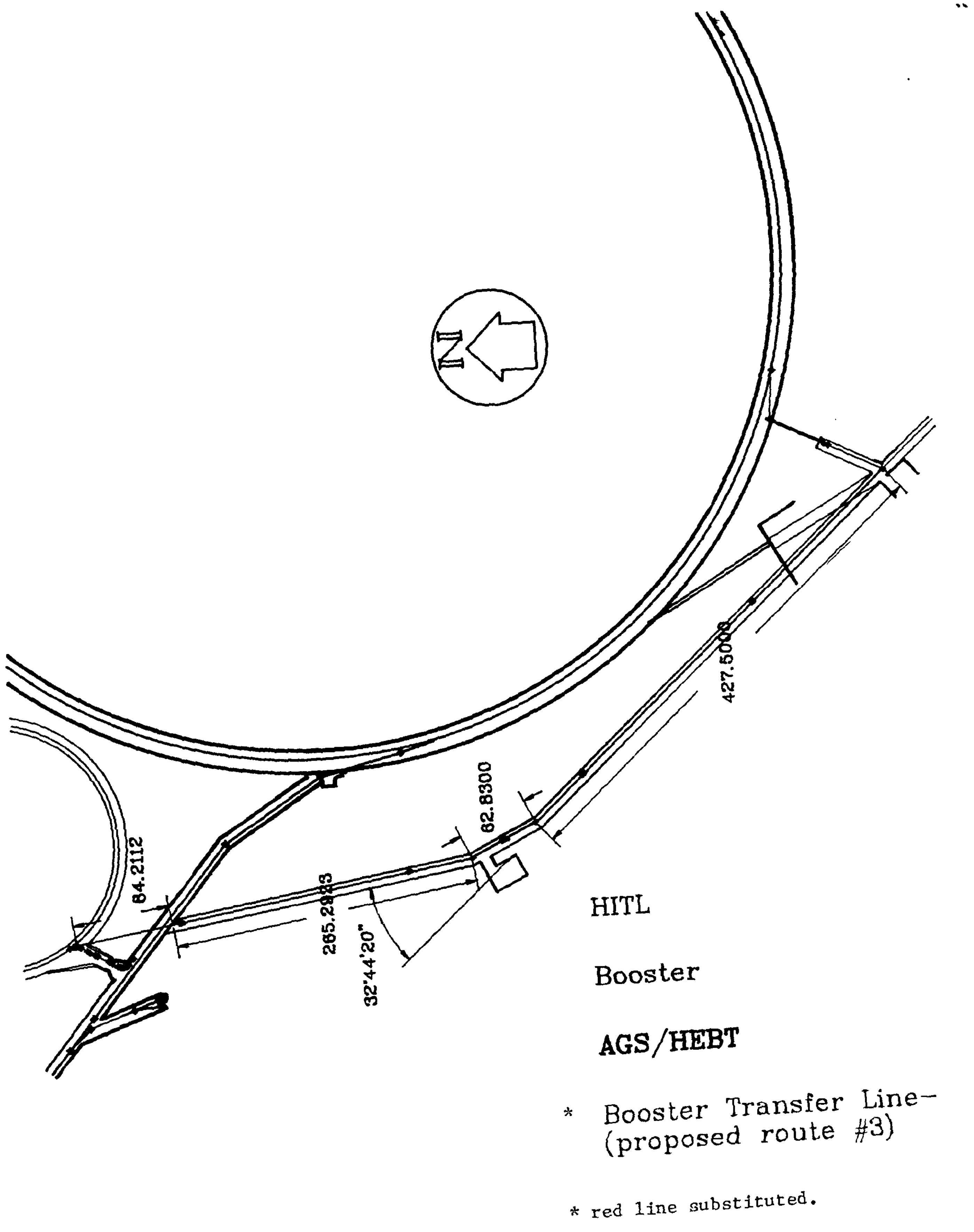


HITL

AGS/HEBT

Booster Transfer Line-
(proposed route #2)

FIGURE 4



N
427.5000
62.8300
84.2112
265.2923
32°44'20"
HITL
Booster
AGS/HEBT
* Booster Transfer Line–
(proposed route #3)
* red line substituted.

FIGURE 5