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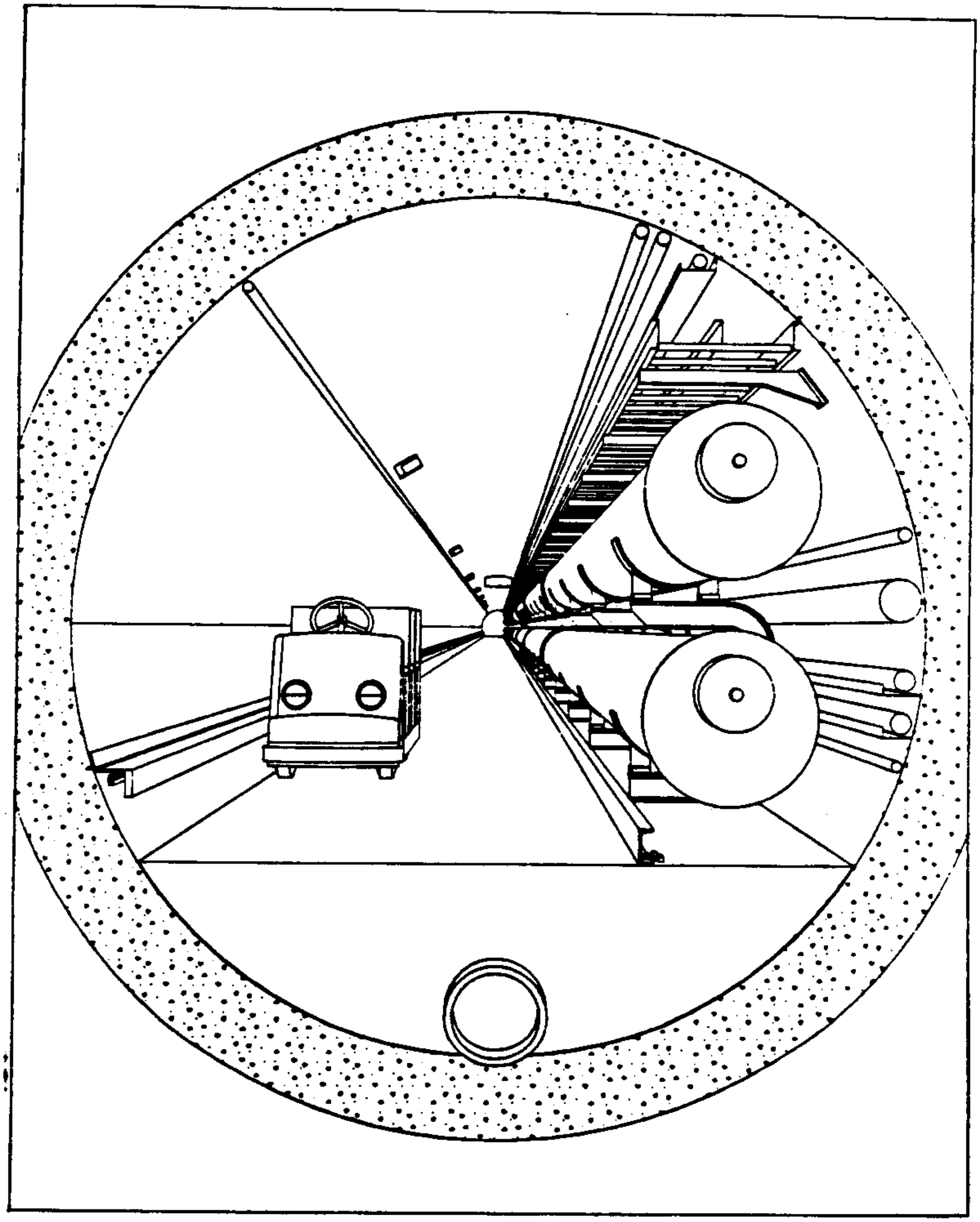
KAISER ENGINEERS



SSC TUNNEL CROSS SECTION STUDIES

SSC TUNNEL CROSS SECTION STUDIES

SEP-21-88

This report covers studies leading toward definition of the tunnel cross section. Factors considered in evaluating the cross section are magnet handling, installation, maintenance and the magnet support system.

The report covers only the handling of dipole and quadrupole magnets. It does not cover the handling of spools or other equipment within the tunnel. It also does not consider specialized requirements at installation, such as cable reels for power installation, transformers, etc.

The following studies are included:

- o PART 1 TUNNEL CROSS SECTION ALTERNATES
- o PART 2 MAGNET TRANSPORTER/HANDLER - FNAL CONCEPT
- o PART 3 MAGNET TRANSPORTER/HANDLER - ALTERNATE A
- o PART 4 MAGNET TRANSPORTER - DOLLY SYSTEM
- o PART 5 MAGNET SUPPORT ALTERNATES
- o PART 6 C-TYPE MAGNET SUPPORT PRELIMINARY DESIGN

These studies should be considered as preliminary and should only be used to approximately define the minimum size and configuration of the tunnel. It is recommended that before the final configuration of the tunnel is defined, given the financial consequences, a very detailed series of studies be made with more concrete data regarding all elements to be handled and utilities to be installed.

The following is a suggested list of studies that should be made:

- COMPLETE LAYOUT OF TUNNEL SECTION WITH MAGNET, SUPPORTS, UTILITIES, GUIDE RAILS, ELECTRIC RAILS, ETC.
- LAYOUT OF SPECIAL TUNNEL SECTIONS, eg. INSPECTION AREAS, RF, STRAIGHT SECTIONS, POWER & ELECTRONICS ALCOVES, QUADRUPOLE AND SPOOL AREAS.
- SPOOL SUPPORTS AND UTILITY CONNECTIONS.
- DETAIL DESIGN OF MAGNET, SPOOL AND QUADRUPOLE INCLUDING FABRICATION, CONSTRUCTION, INSTALLATION TOLERANCES AND ADJUSTMENT TECHNIQUES.
- STRESS ANALYSIS OF MAGNET SUPPORTS Due to temperature induced deflections in the different magnet components.
- COMPLETE VIBRATION ANALYSIS OF THE MAGNETS AND SUPPORTS DUE TO THE EFFECTS OF GROUND FORCES FROM SEISMIC ACTIVITY, HIGHWAY OR RAILROAD TRAFFIC ABOVE, ETC. The study should consider the natural frequencies of each element and of the system as a whole.
- TRANSPORTER/HANDLER. This study should be done in enough detail, defining all member and component sizes, so as to ensure its' feasibility and final overall dimensions. It does not need to be a final design for manufacturing. Also this design should be combined with the design of spool and magnet supports so that the transport and support system can be optimized together.
- STORAGE AND HANDLING OF MAGNETS AT THE PICK-UP AREA.

PART 1

TUNNEL CROSS SECTION

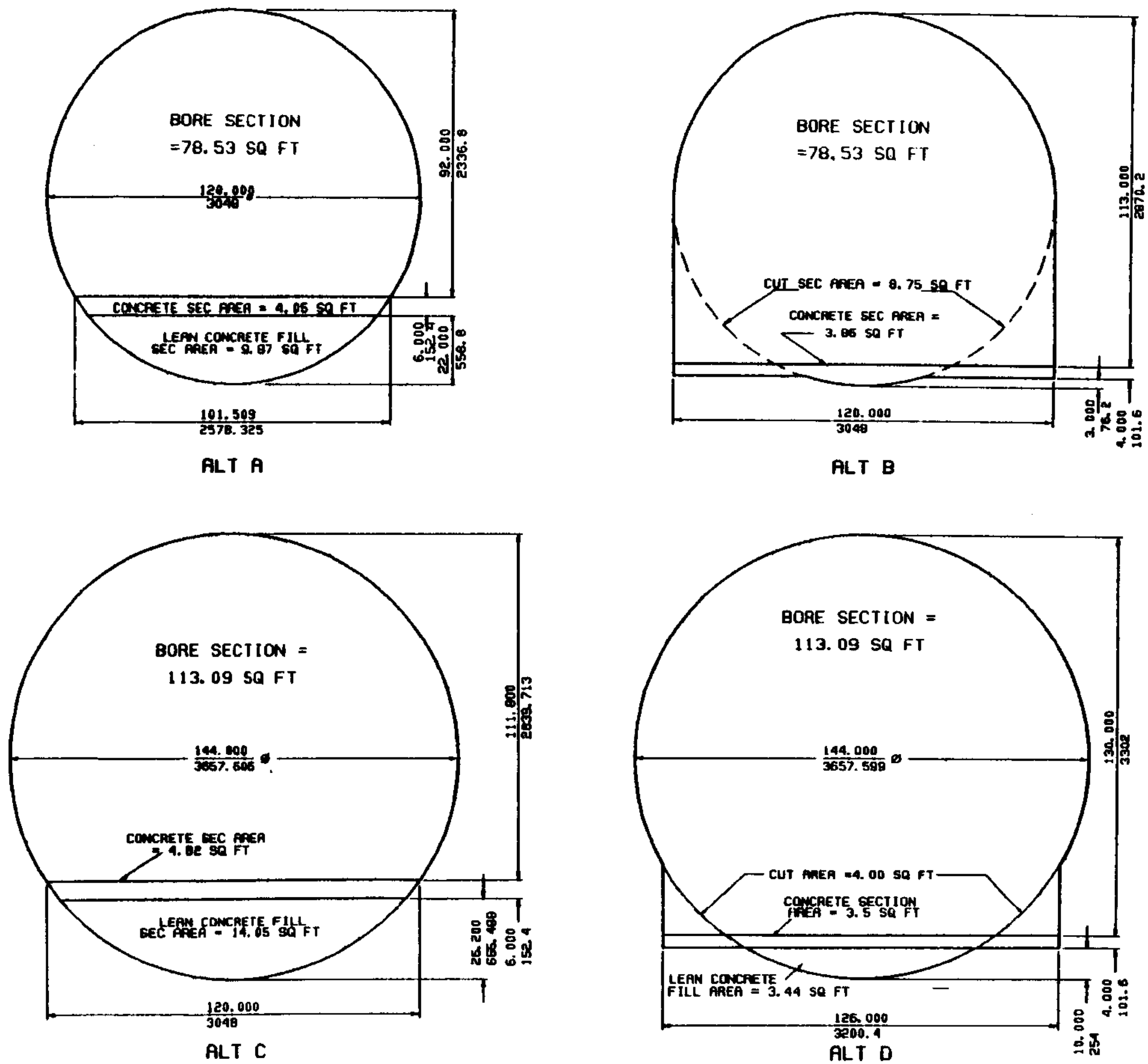
ALTERNATES

TUNNEL DIMENSIONS

This section addresses the problems and considerations given to minimizing the tunnel dimensions, relative to installation and operational requirements. Several alternates were analyzed: Alternate A (as proposed in the Conceptual Design Report–CDR), Alternate B (presently being considered), Alternate C (considering a large tunnel without extra cuts) and Alternate D (analyzes an optimized cut and fill situation within the tunnel). Tunnel dimensions used in all alternates are shown in Figure 1.

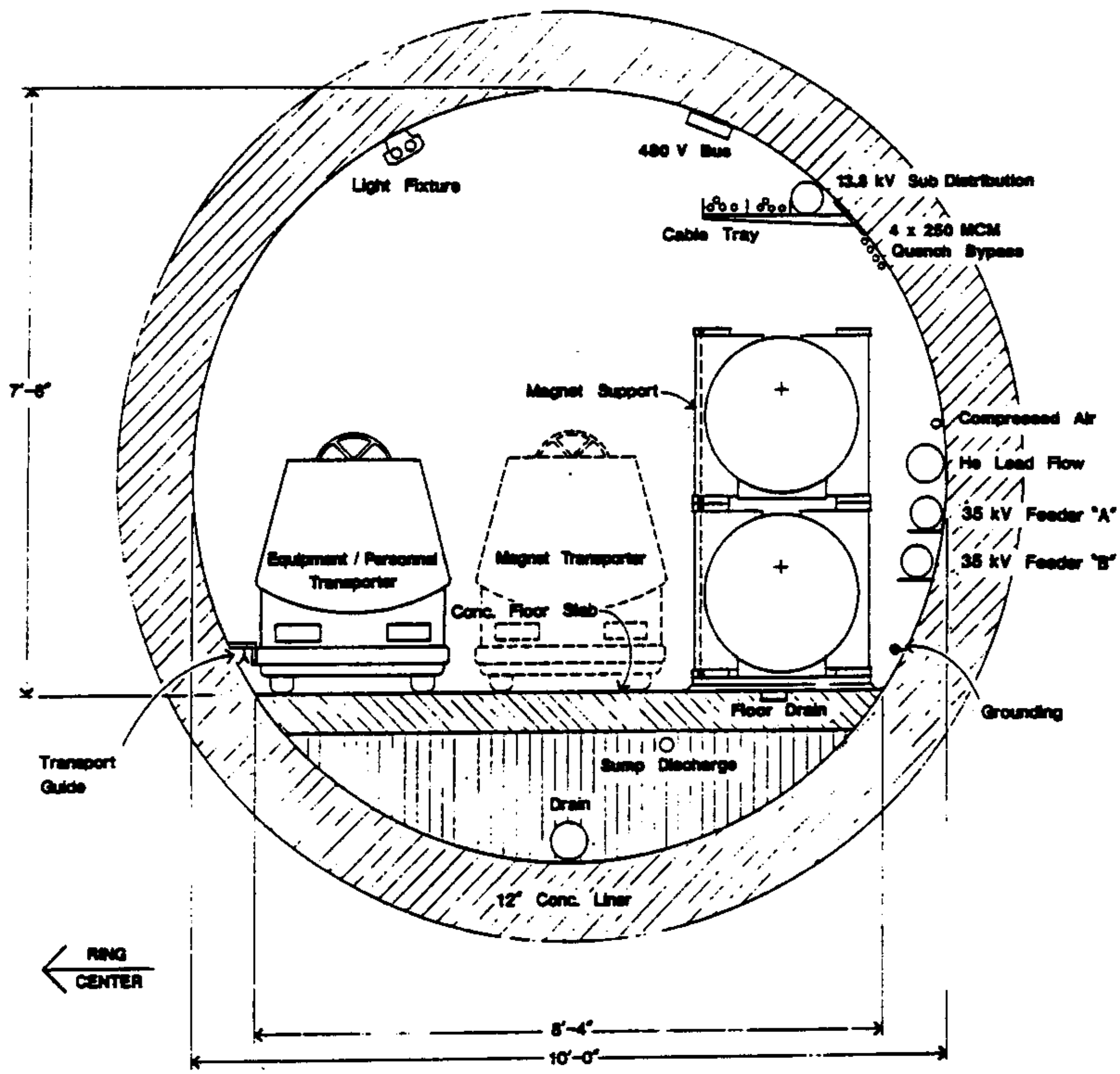
Alternate A

The tunnel dimensions used in the CDR are shown in figure 2. Early experience with connecting magnets indicate that access may be required on the backside of the magnets for personnel to operate the welding equipment and quality control devices used during installation. A 20" clearance between the magnet body and the wall of the tunnel was adopted for this purpose, which reduced the clearance for vehicle by-pass. Related studies in this report indicate that the transverse space required for the magnet handling machine and transporter may be 36" or more, as compared with 30" shown on the CDR. These requirements are illustrated in figure 3, which indicates that the CDR cross-section is not viable under these constraints. A further disadvantage of Alternate A is that the magnets are supported by a slab which is on top of fill material. To avoid differential settlement it will be necessary to have a highly controlled fill or a lean concrete fill, coupled with an extra thick and reinforced concrete floor slab.



SSC TUNNEL
ALTERNATES

FIG 1



TUNNEL CROSS SECTION

Beam Separation 70 cm

Figure 6.6-1. Collider Ring Tunnel profile showing the position of the two collider rings, the tunnel service vehicle and routing of tunnel utilities service mains.

FIG 2

ALTERNATE B

This alternate considers drilling the same size bore as Alternate A but adding extra excavation to increase the width of the invert. This alternate solves the tunnel width and height requirements illustrated in Figure 3 and the potential differential settlement problem. A cost trade off is made for extra tunnel excavation and lining, versus the savings of lean concrete fill and floor slab reinforcing.

Figure 4 illustrates Alternate B. In this illustration the magnets are shown independently mounted on special frames. However, the clearance situation would be the same if the magnets were mounted one on top of the other, as shown in Figure 3.

Please note that only 1" of clearance is left for vehicle bypass which is extremely tight. Careful consideration should be given to the possibility of enlarging this alternate 2 or 3 inches to remedy this situation.

ALTERNATE C

This alternate considers a 12' boring machine which provides the same invert with crown height as Alternate B without the added excavation. The material to be removed by the machine is 30% greater than for the 10' bore of Alternate A or B, but efficiencies provided by the greater working space may affect greater machining volume. However even if the boring and excavation costs were the same or lower than for Alternate B the extra lining, floor slab and extra fill required might affect any cost saving in the excavation. This alternate shares with Alternate A the disadvantage of having the magnet systems resting on fill.

Figure 5 illustrates alternate C.

ALTERNATE D

In alternate D an attempt was made to balance cut and fill and to increase floor space without increasing the diameter of the bore. Alternate D shows 6" more floor space than alternate C.

Figure 6 illustrates alternate D.

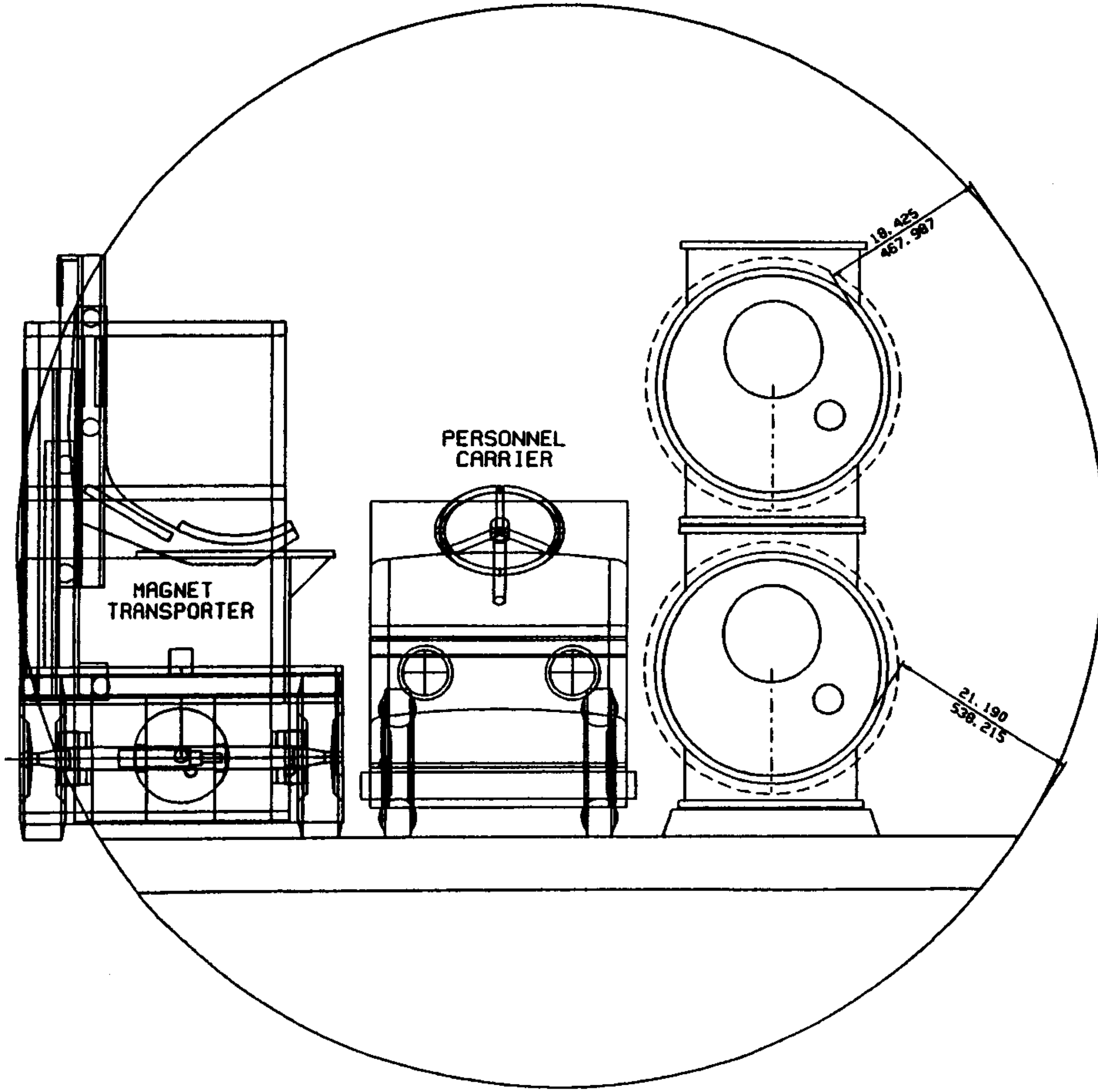

18.425
467.987
21.190
538.215
PERSONNEL
CARRIER
MAGNET
TRANSPORTER

FIG 3
ALT A

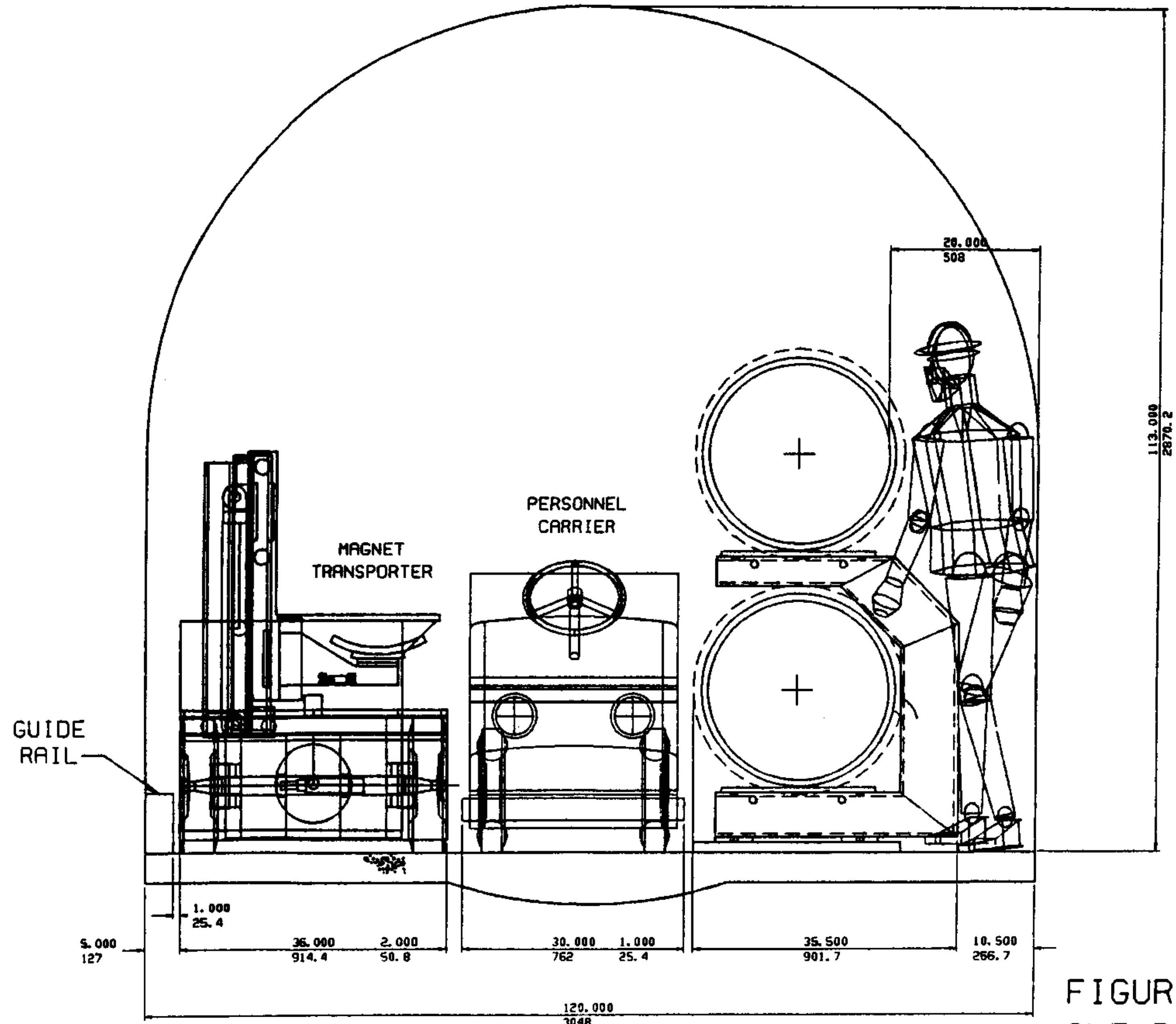


FIGURE 4
ALT B

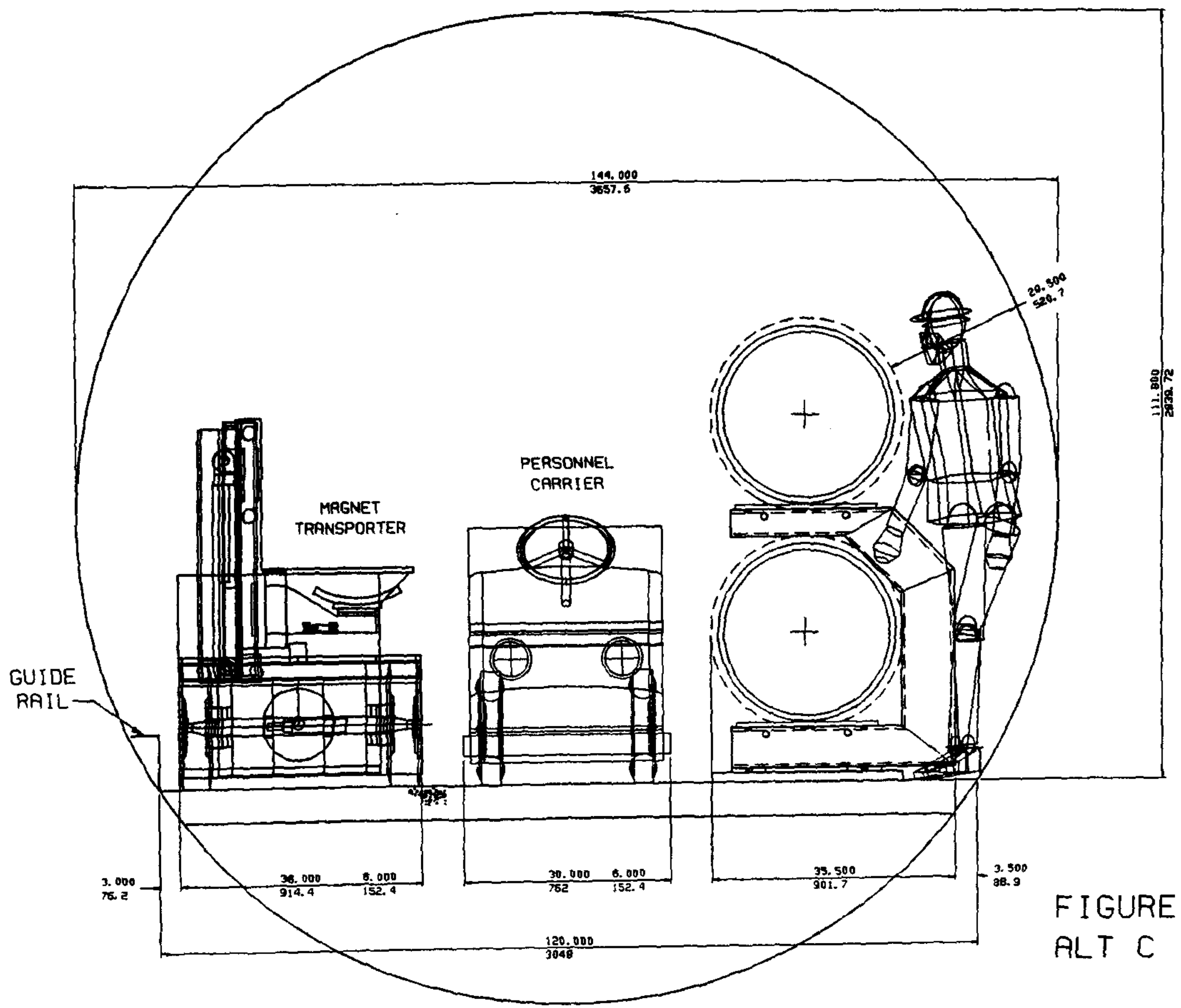


FIGURE 5
ALT C

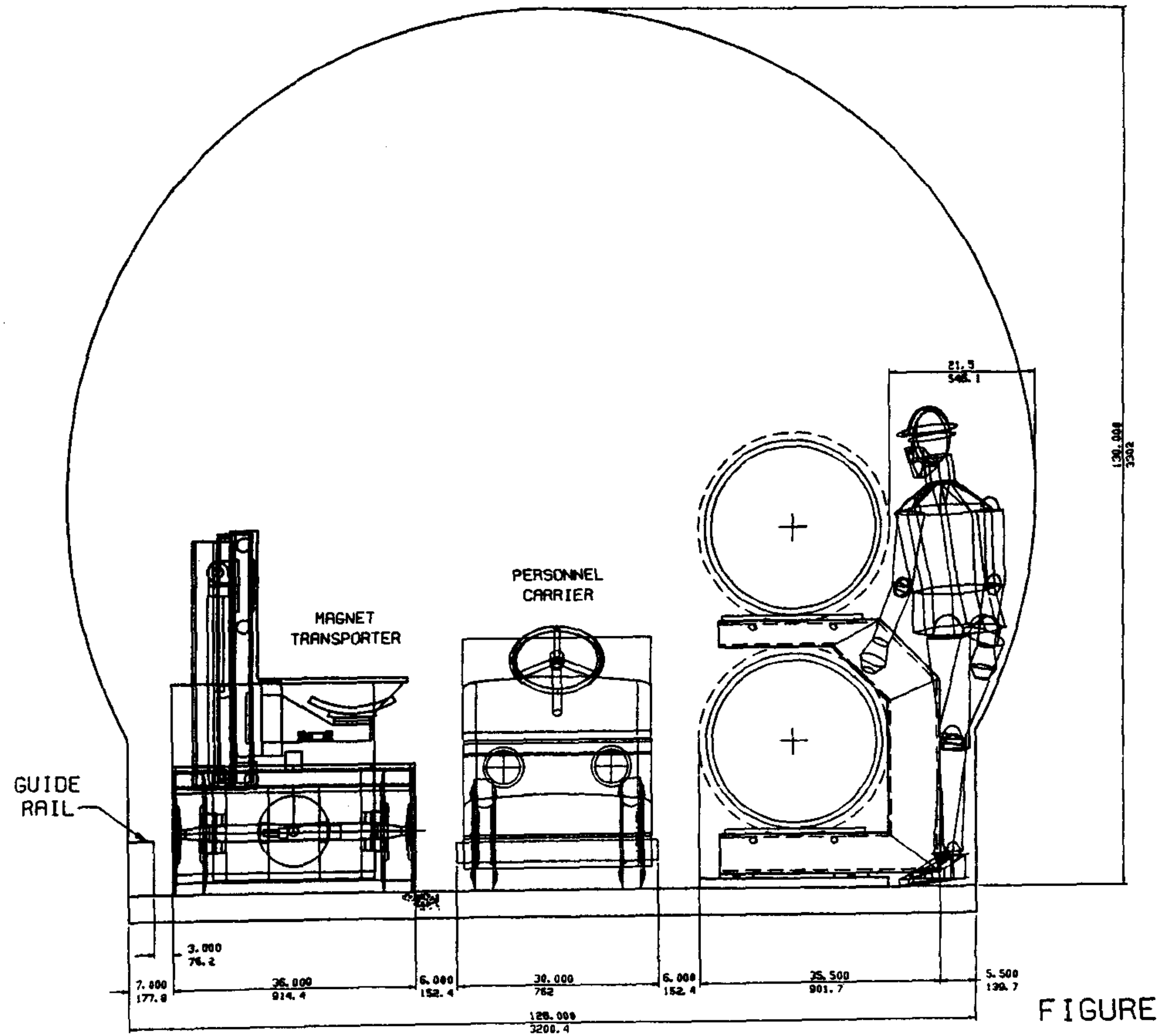


FIGURE 6
ALT D

PART 2

MAGNET TRANSPORTER/HANDLER

FERMI NATIONAL ACCELERATOR LABORATORY

CONCEPT

MAGNET TRANSPORTER/HANDLER, FNAL CONCEPT

This concept was developed for the CDR case of one magnet ring stacked on the other. The transporter picks up a magnet from above and places it in its proper location using extending arms as shown in the attached diagrams. The transporter is folded for locomotion and unfolds to clamp to the floor and ceiling for magnet insertion and removal. The clamping provides frictional forces to compensate for overturning moments.

The original Fermi National Accelerator Laboratory (FNAL) concept is given in the first figure expanded in the following drawings. The design shown is only conceptual and further development would be needed to take place to establish its feasibility.

No further development was considered for several reasons that speak negatively of this alternate:

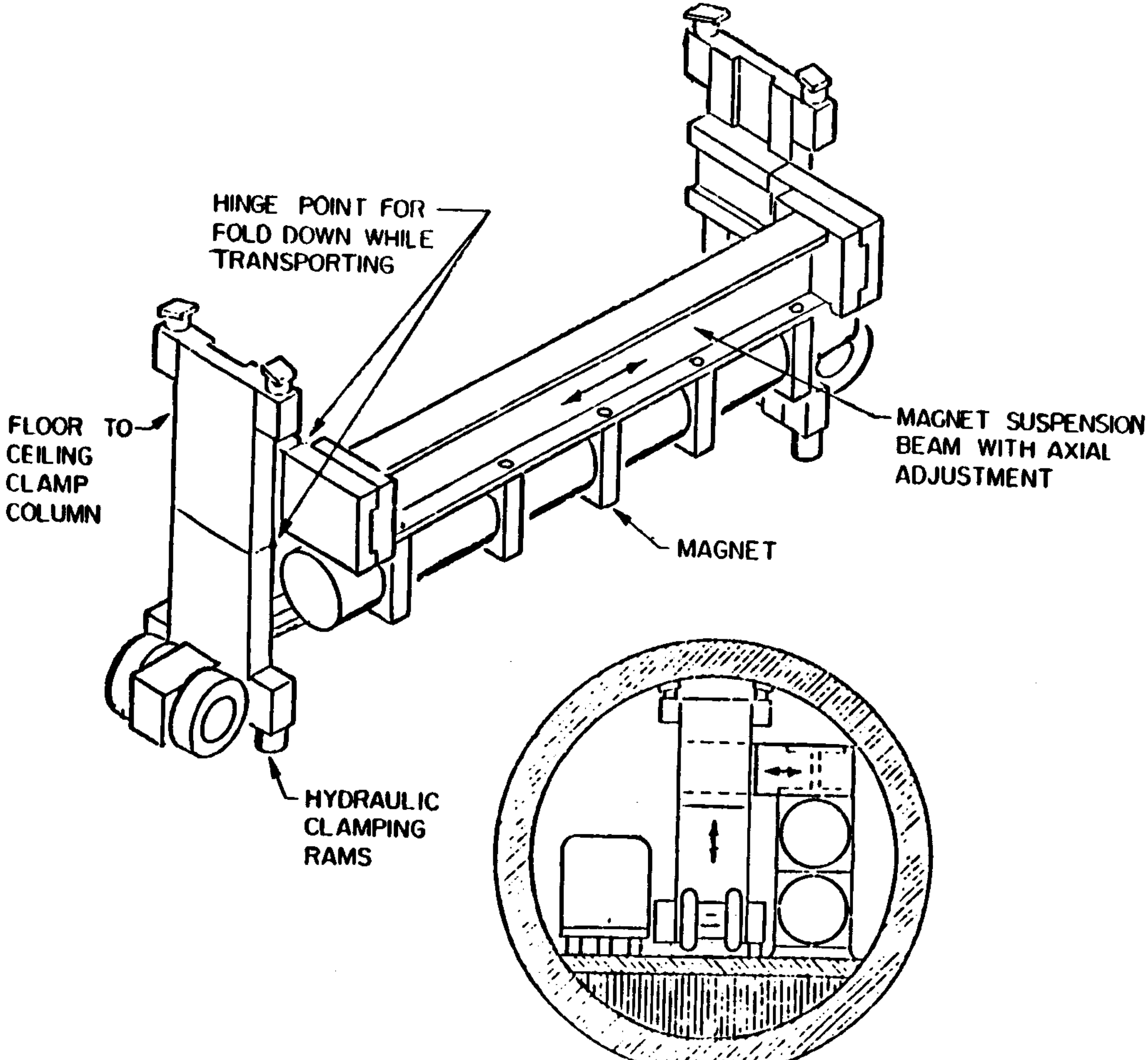
1. The transporter would be able to place bottom and top magnets in that order. The transporter would not be able to extract the bottom magnet without extracting the top magnet first.
2. The transporter would only be able to place or extract a bottom magnet if the upper magnet and the two adjacent upper magnets were not in place, since all three pose interference problems.
3. The transporter roof clamping mechanism would prevent considering certain tunnel lining options. In addition, the pressures exerted by the clamping devices would require a more accurate and possibly a stronger tunnel lining which would add a significant amount to the tunnel cost.

4. The folding requirements of the transporter make this an inherently unsafe device even though many protection devices could be installed.

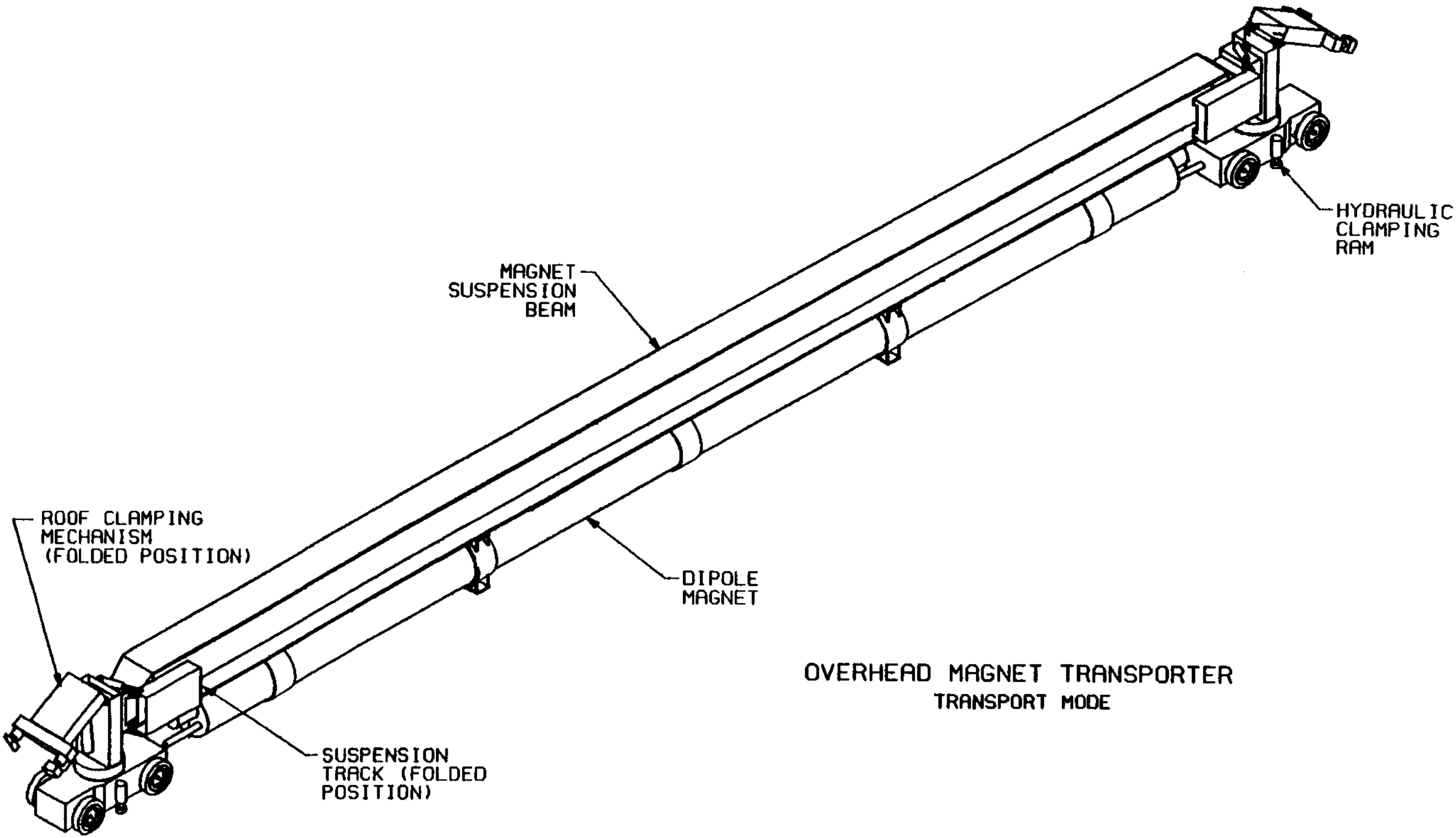
5. The clamping locations would interfere with, or at least restrict the location of the cable trays and utilities which are planned to go along the roof of the tunnel.

6. The height of the folded unit may be incompatible with the tunnel height in the transport zone, for the nominal CDR tunnel.

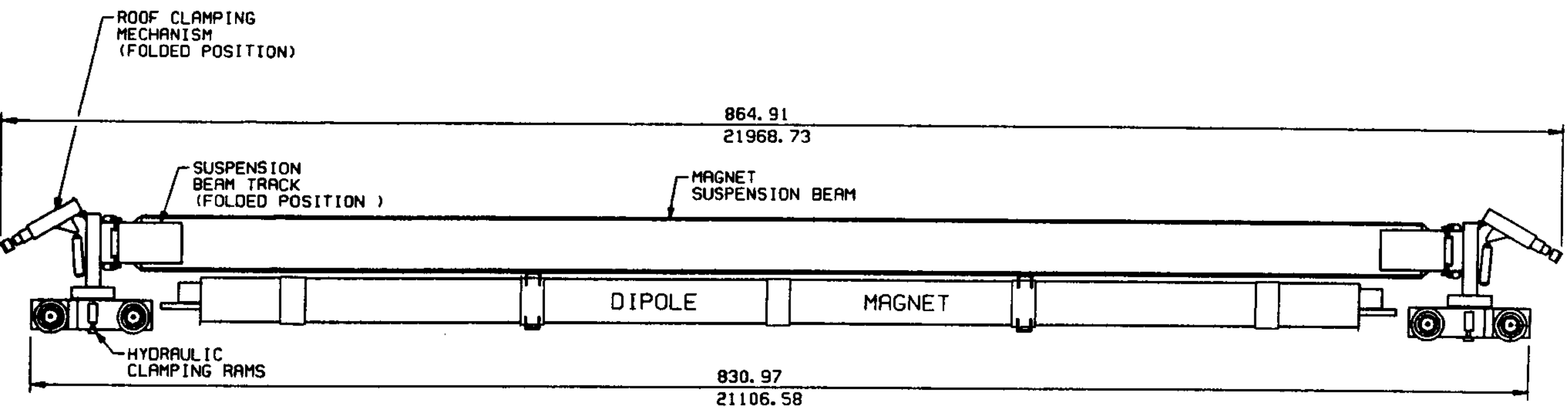
7. A companion transporter would be required to handle the lower magnets once the upper ring is in place.



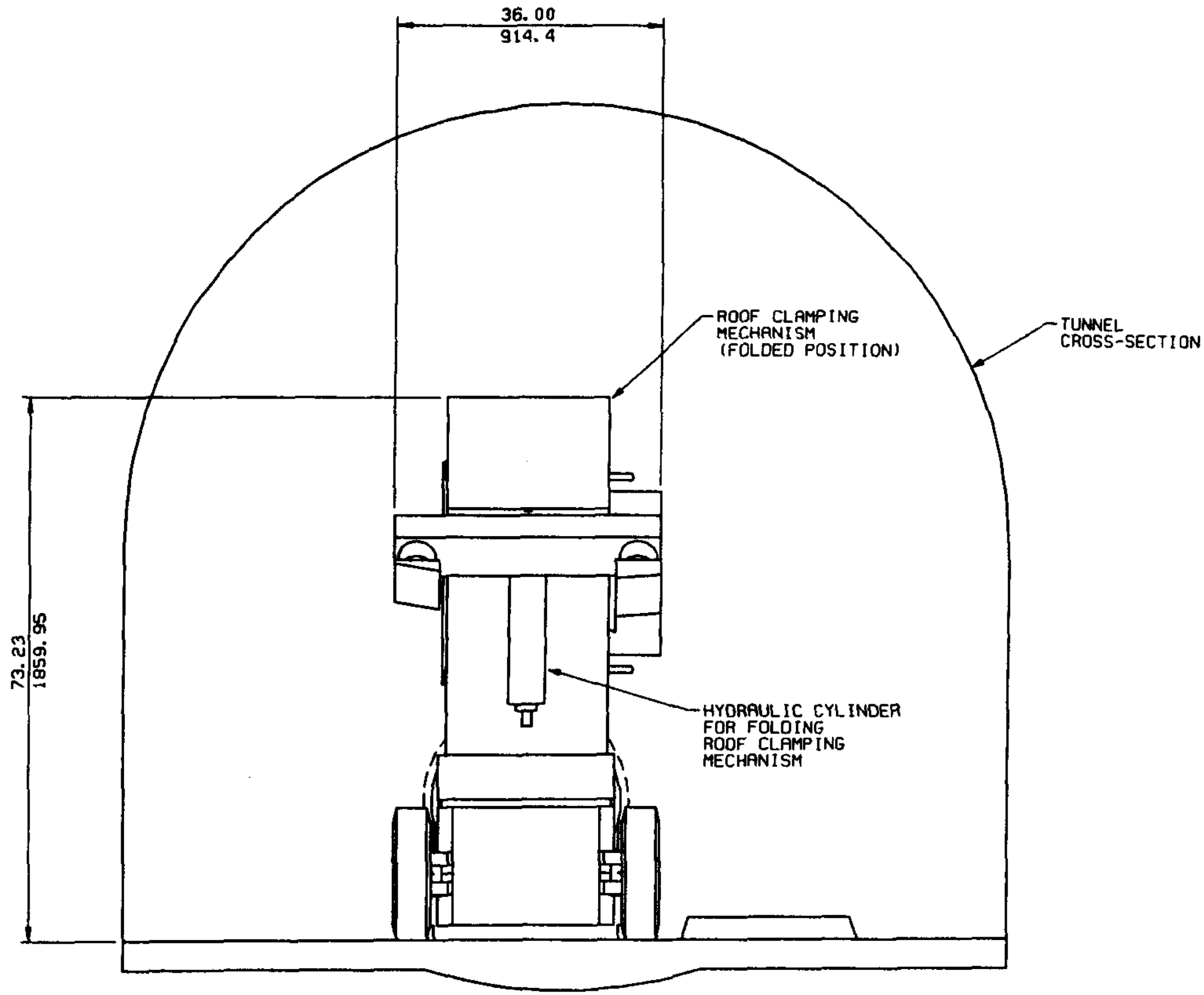
MAGNET TRANSPORT VEHICLE



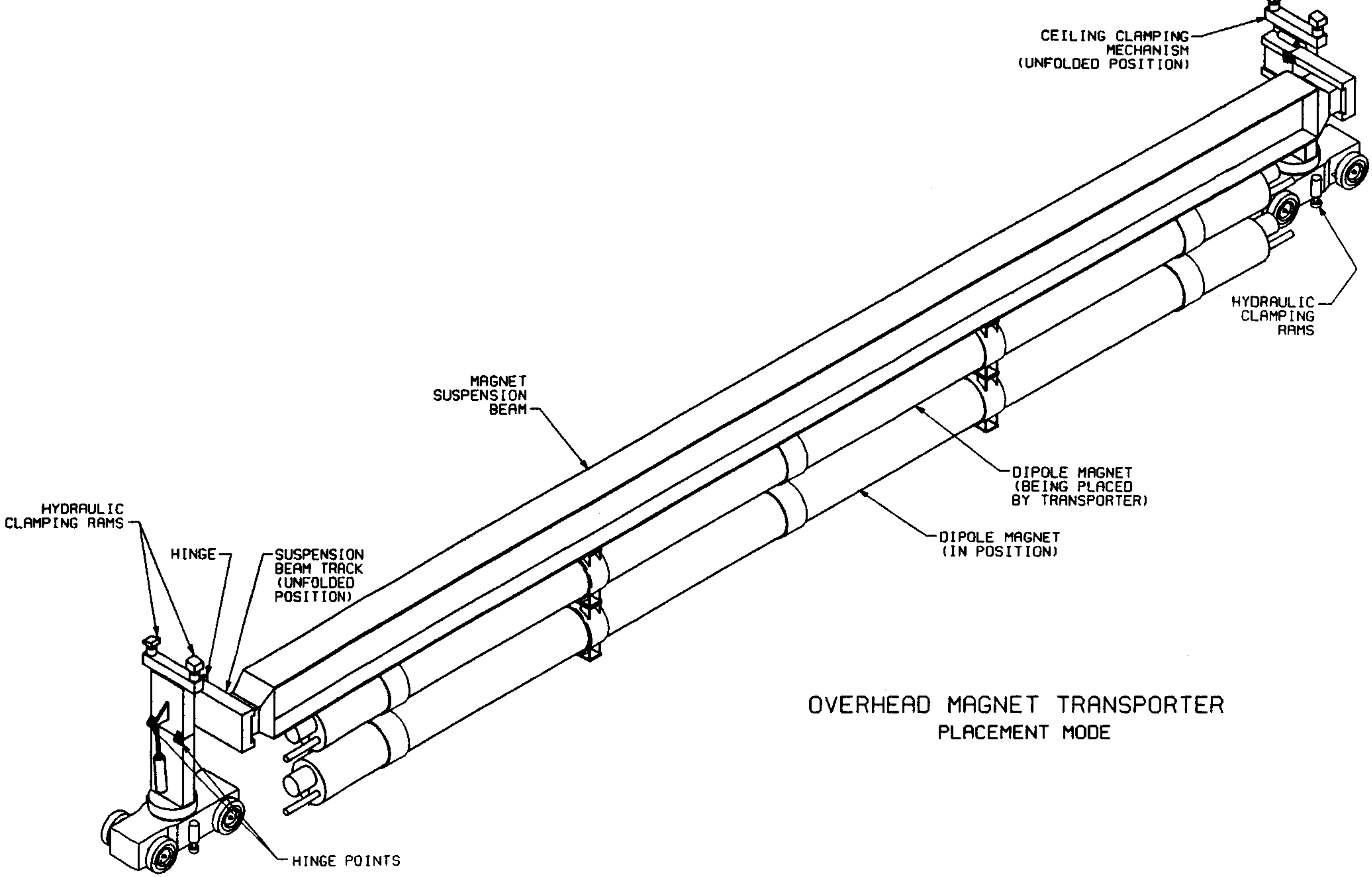
OVERHEAD MAGNET TRANSPORTER
TRANSPORT MODE



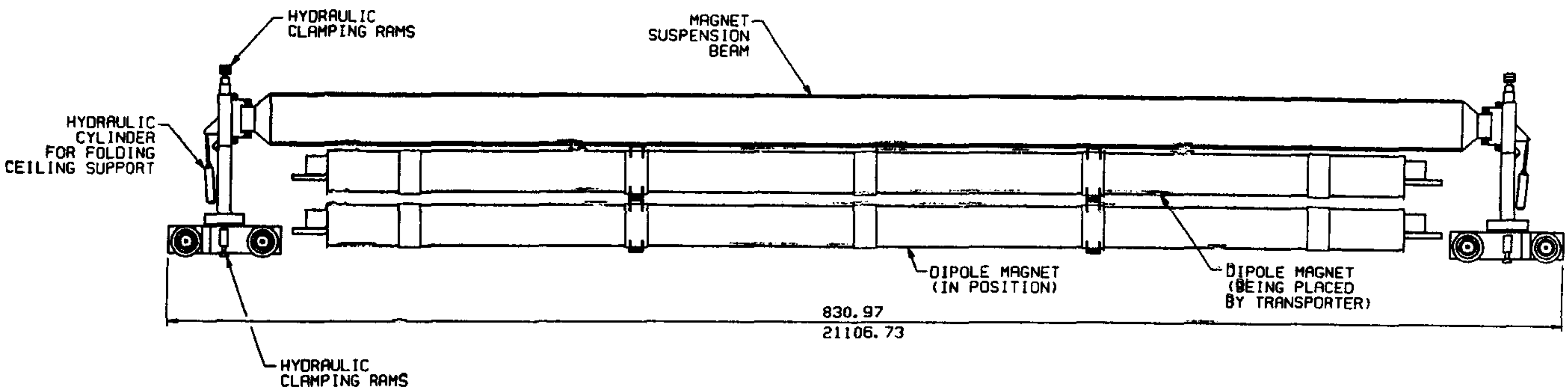
OVERHEAD MAGNET TRANSPORTER - ELEVATION
TRANSPORT MODE



OVERHEAD MAGNET TRANSPORTER - SECTION
TRANSPORT MODE



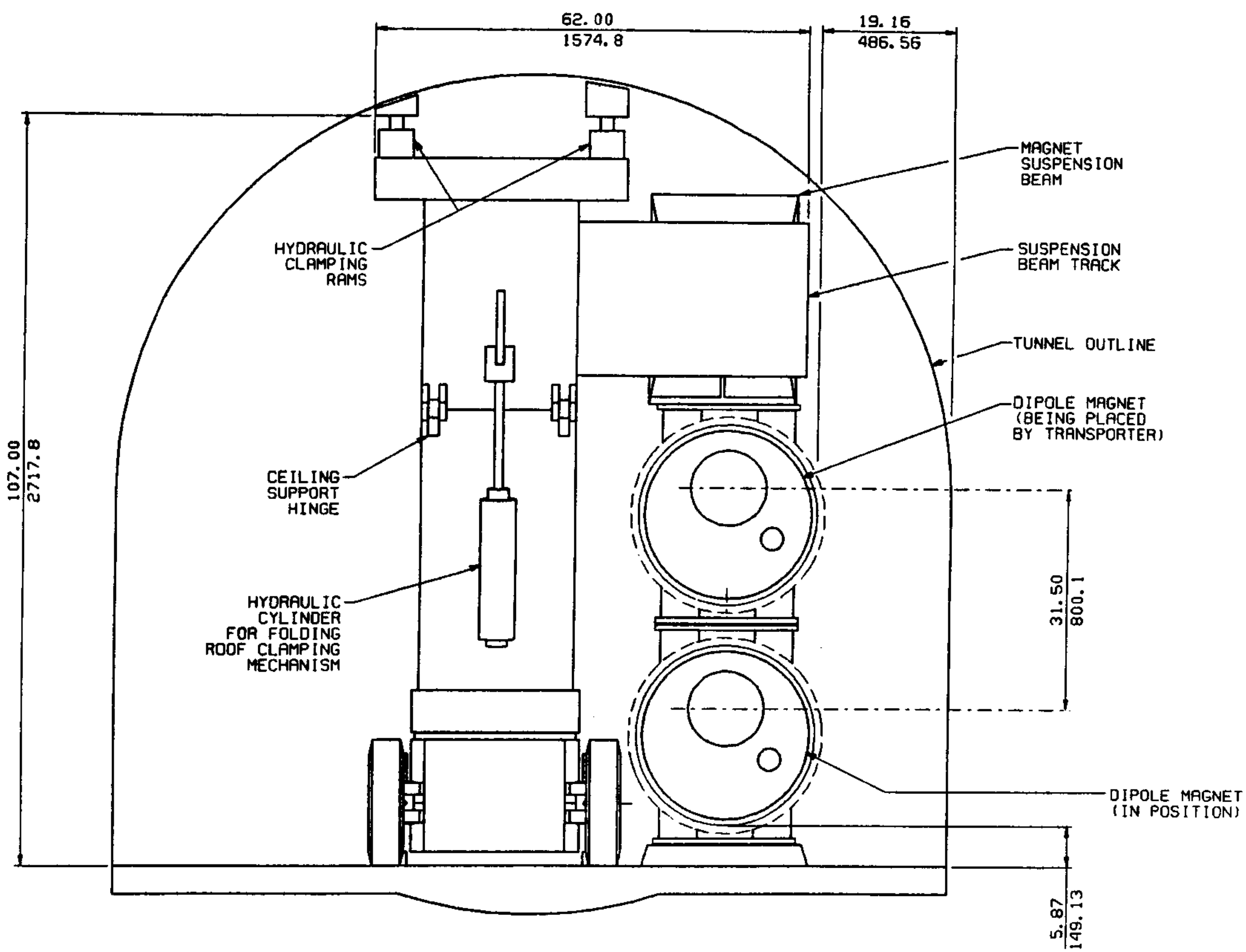
OVERHEAD MAGNET TRANSPORTER
PLACEMENT MODE



OVERHEAD MAGNET TRANSPORTER - SECTION

PLACEMENT MODE

SCALE: 3/16" = 1'-0"



OVERHEAD MAGNET TRANSPORTER - SECTION

PLACEMENT MODE

SCALE: ¾" = 1'-0"

PART 3

MAGNET TRANSPORTER/HANDLER

ALTERNATE A

MAGNET TRANSPORTER/HANDLER - ALTERNATE A

This alternate studies the characteristics of a magnet transporter and handler which lifts the magnet in a similar fashion as a forklift, transports it to a destination and places it in its proper location in the tunnel.

DESCRIPTION

The transporter is made-up of a main frame which is designed to be as low as possible consistent with reasonable deflections.

Supporting the main frame are two boggies which are both steerable and self propelled by high torque electric motors. The boggies will be power steered by remote control from control consoles located at each end of the vehicle. The vehicle will be steered by two drivers in a similar manner as fire engines with long ladders are steered.

During long distance travel, the vehicle will be guided by an arm which travels with one extreme in a guide rail and operates the power steering automatically.

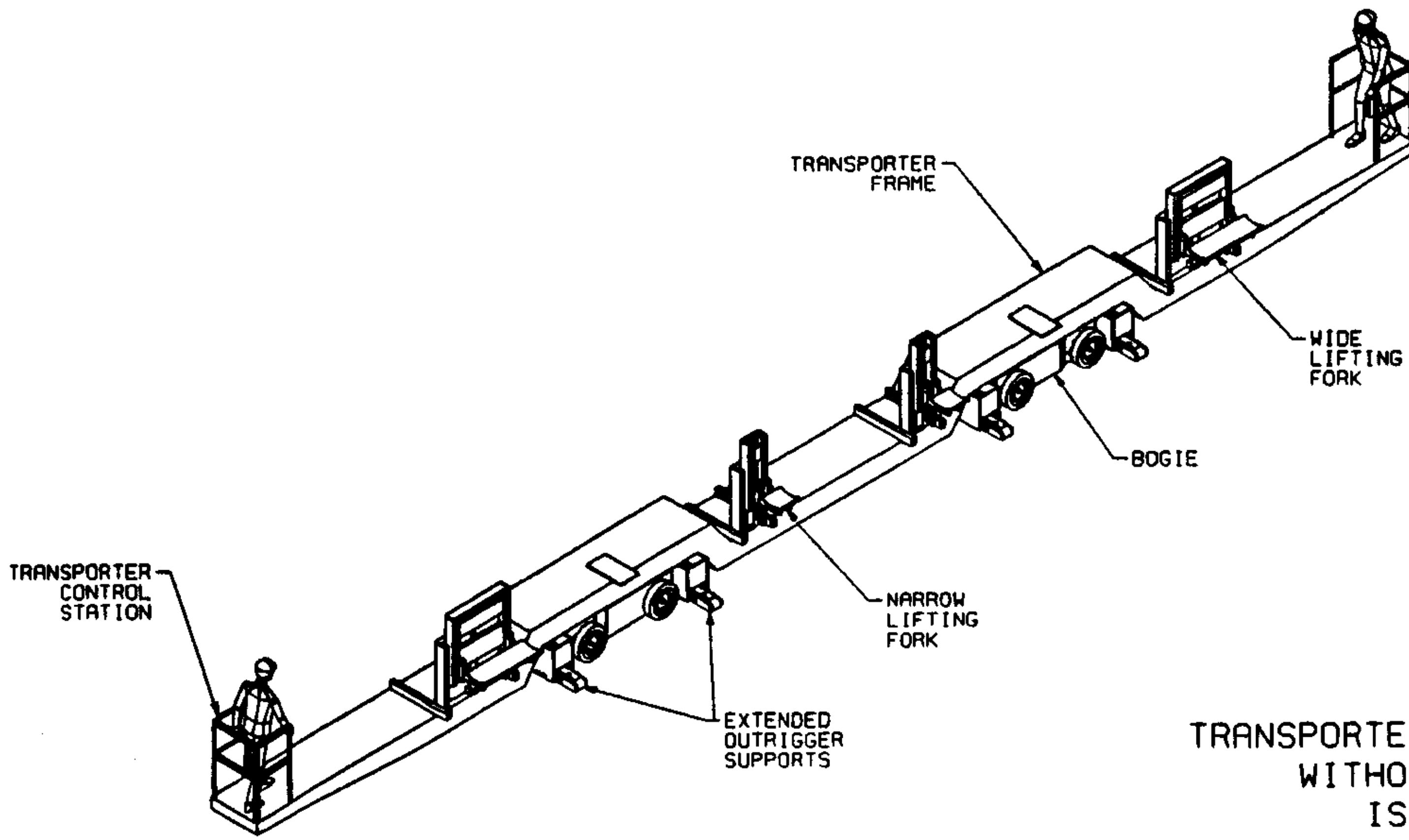
On top of the frame will be four fork-lift type masts and loading arms. The four masts are needed to accommodate either a dipole or three quadrupoles. A critical area of the design is the base of the masts as they would be narrower than would be desired for a sturdy design. However, this is needed to avoid enlarging the width of the transporter and consequently the width of the tunnel. This is an area that deserves special attention in the final design.

The loading arms will be contoured to accommodate the body of the dipole or quadrupole, other than that, they operate just like a fork-lift.

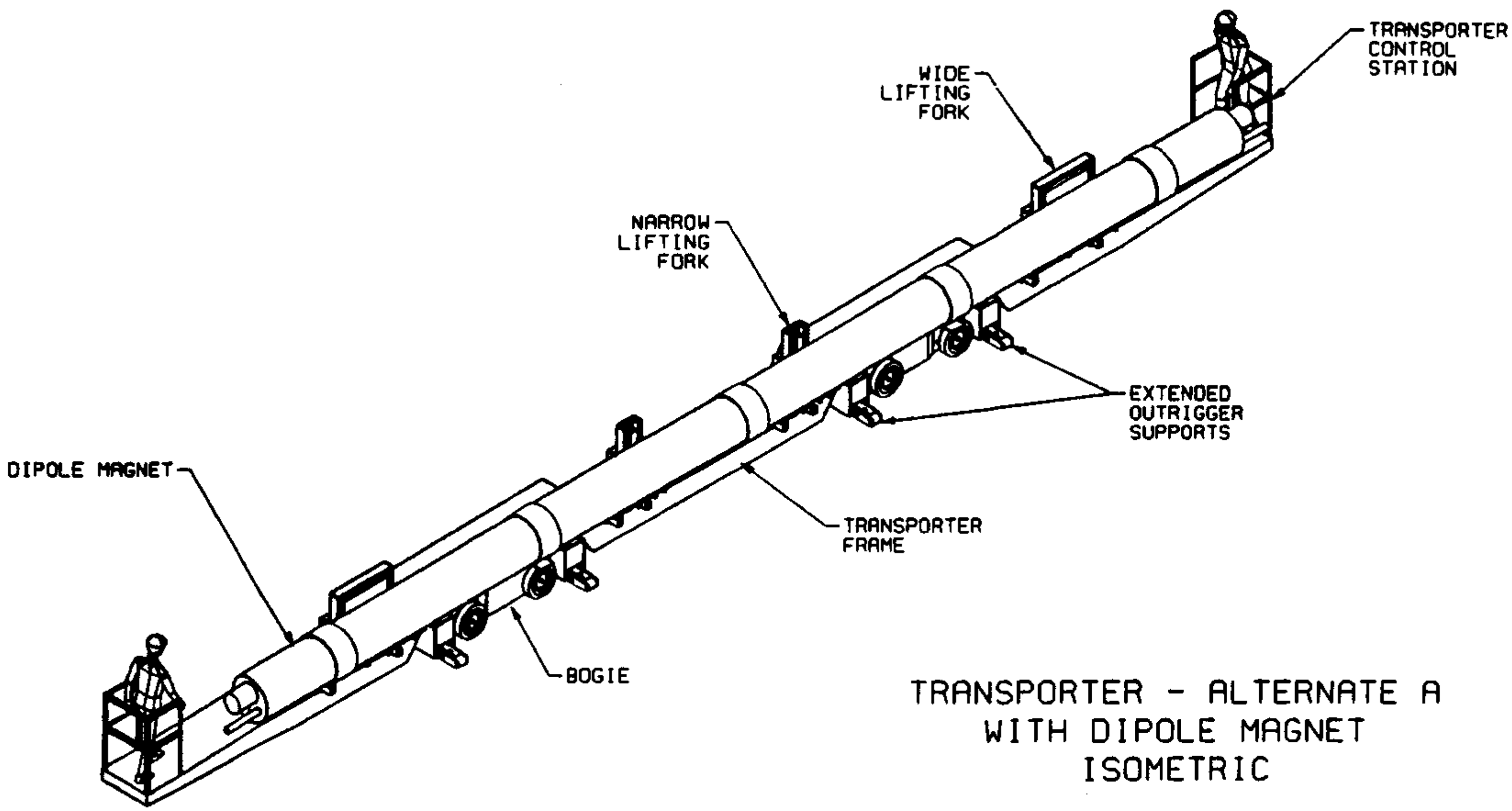
Under the frame there will be four devices which will act as a combination of outrigger and side travel mechanism. The outrigger characteristic is required to compensate for the off-center forces imparted by the magnet when it is being placed in position. The side travel characteristic is required to extract the lower magnet without affecting the upper one or to clear the magnet support.

Once the magnet is close to it's final position small adjustments in the horizontal direction will be required. This can be accomplished in the perpendicular direction by the outrigger travel mechanism and in the longitudinal direction by small cylinders located in the lift arms which will allow up to 2" adjustment by pivoting around a vertical shaft.

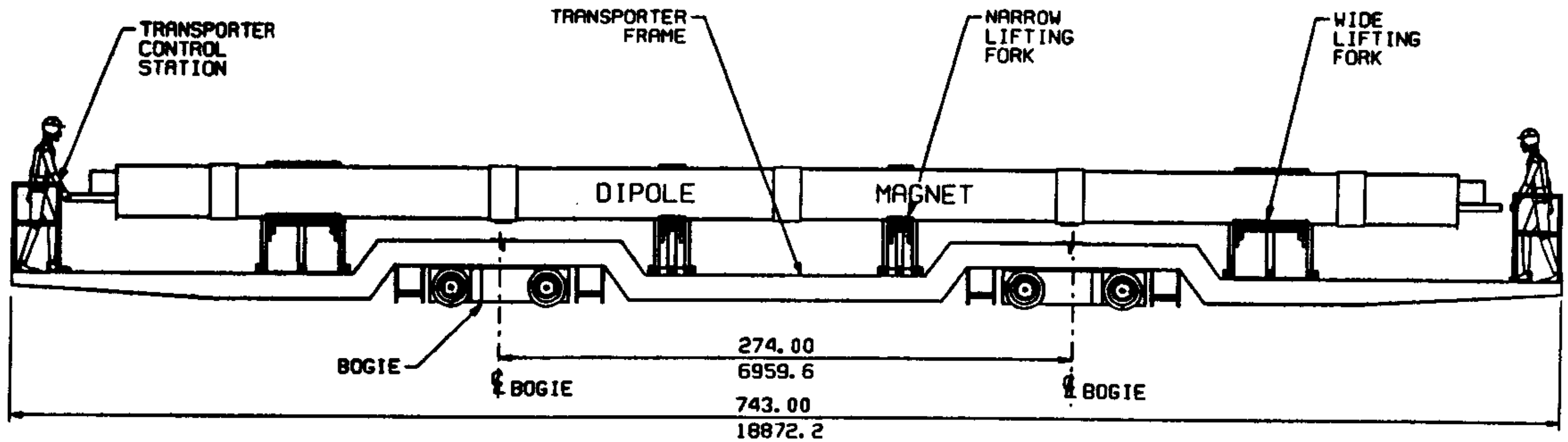
Note: This design does not consider transport or handling of spools or other equipment as no data has been received for that purpose.



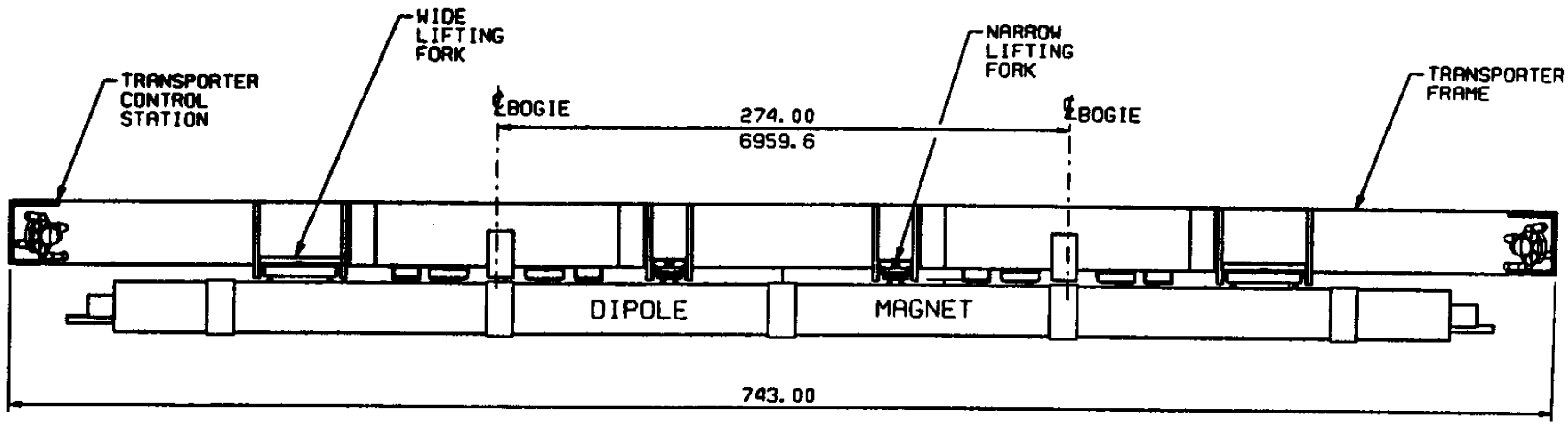
TRANSPORTER - ALTERNATE A
WITHOUT MAGNETS
ISOMETRIC



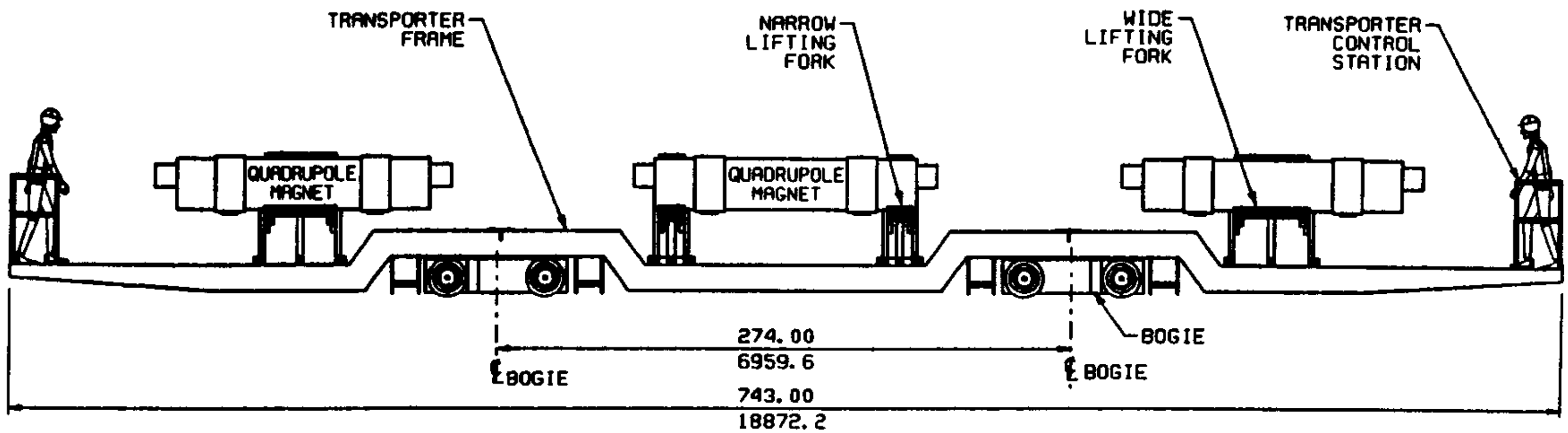
TRANSPORTER - ALTERNATE A
WITH DIPOLE MAGNET
ISOMETRIC



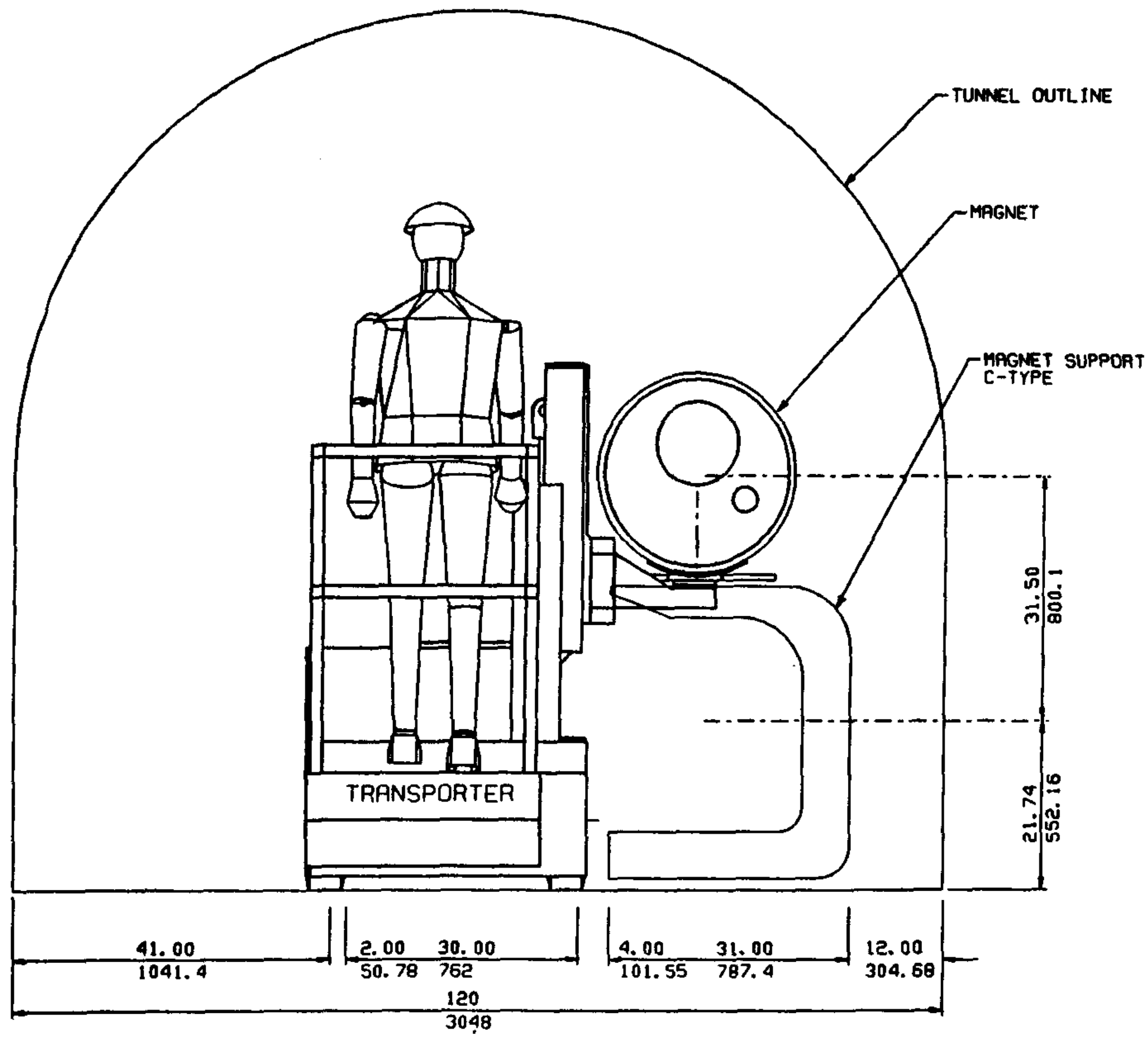
TRANSPORTER - ALTERNATE A
WITH DIPOLE MAGNET
ELEVATION



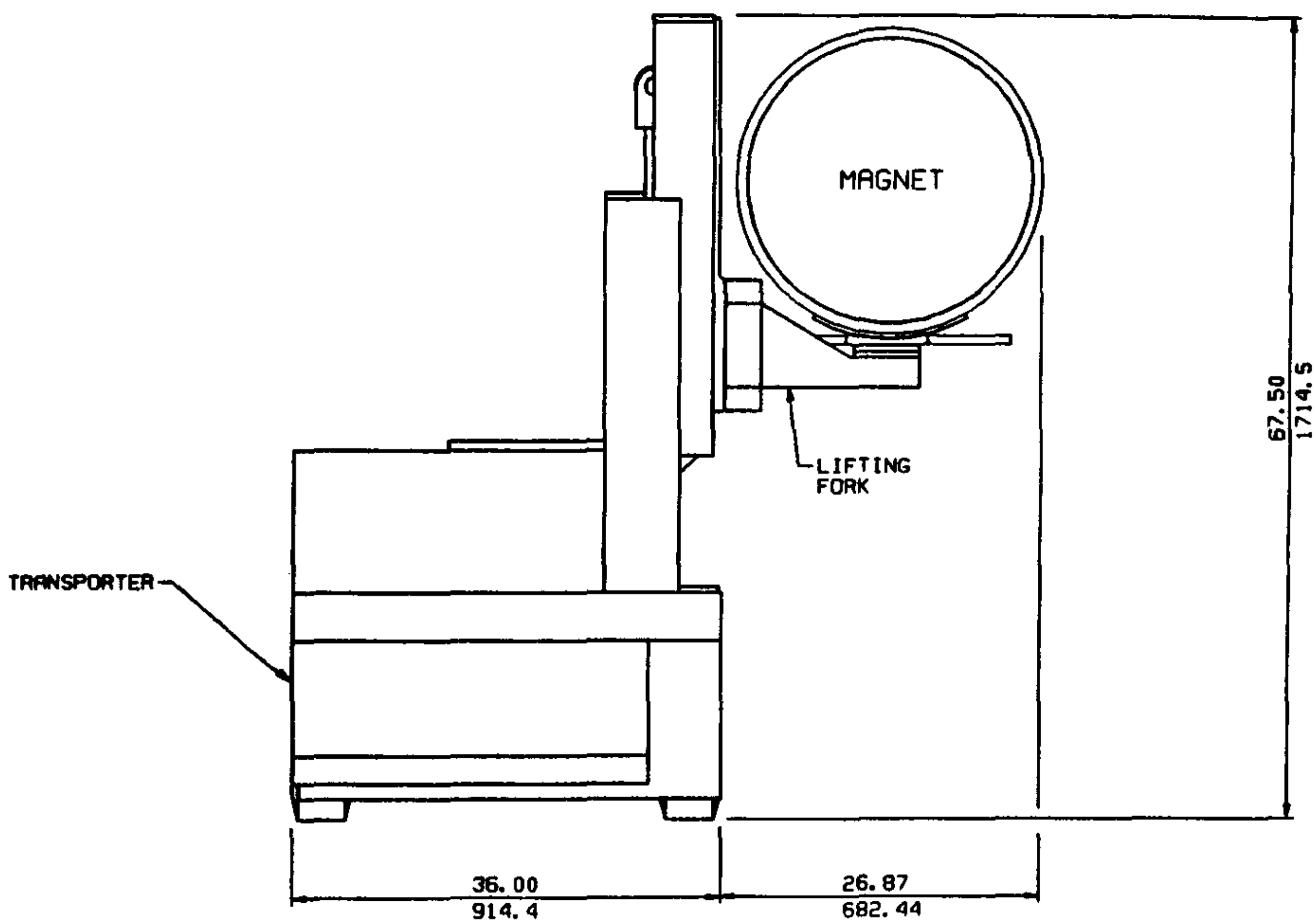
TRANSPORTER - ALTERNATE A
WITH DIPOLE MAGNET
PLAN



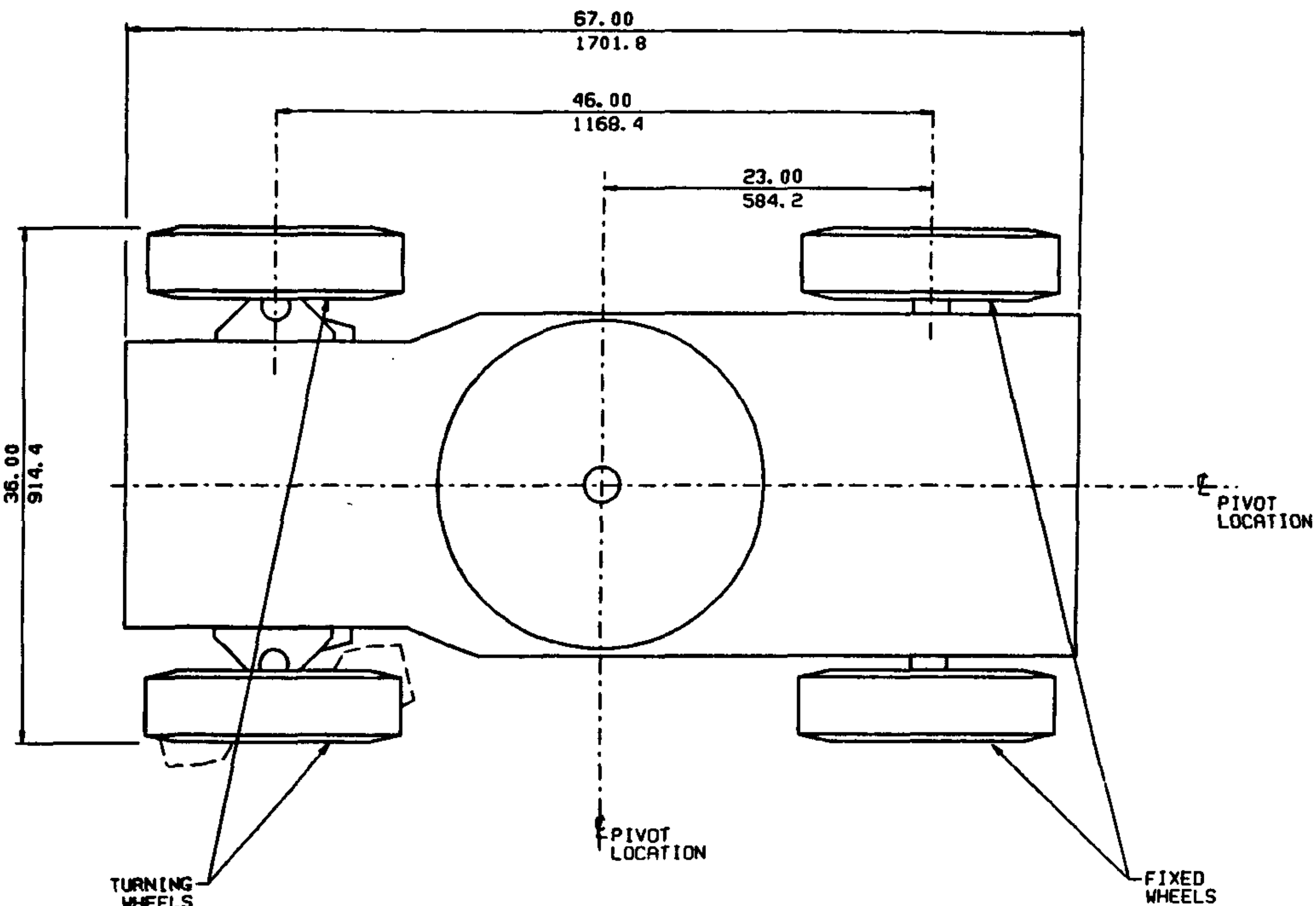
TRANSPORTER - ALTERNATE A
WITH QUADRUPOLE MAGNETS
ELEVATION



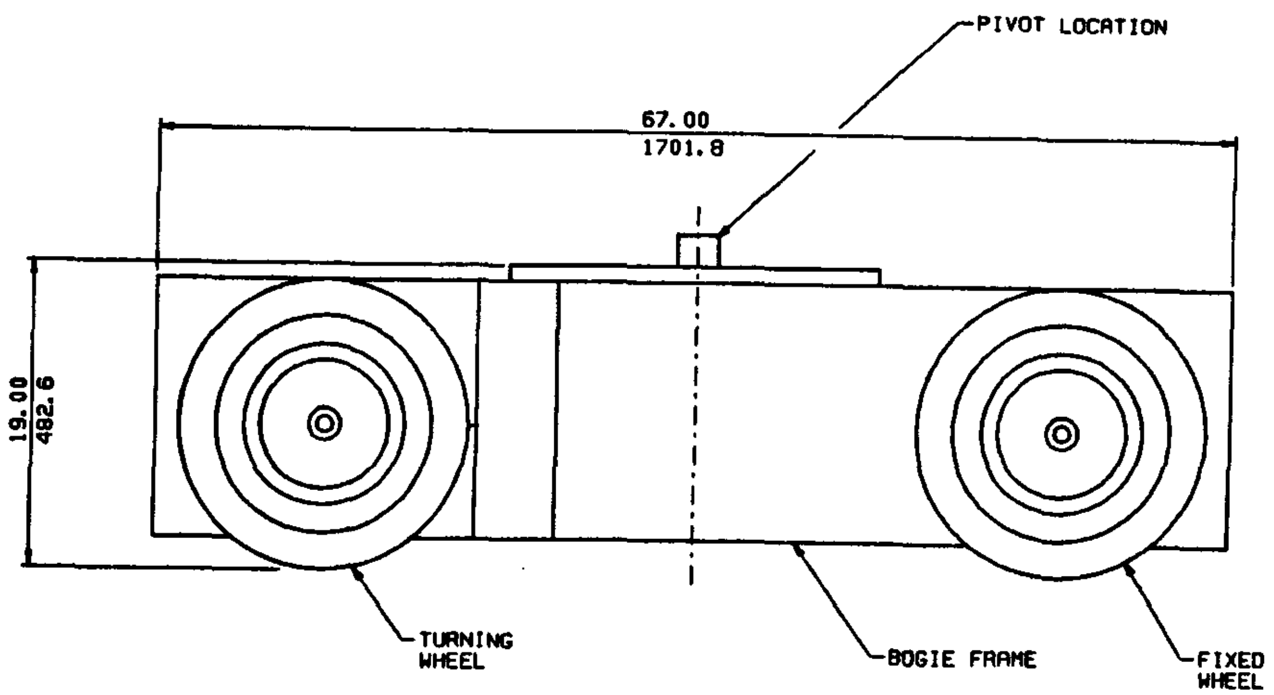
TUNNEL WITH TRANSPORTER AND SUPPORT
SECTION



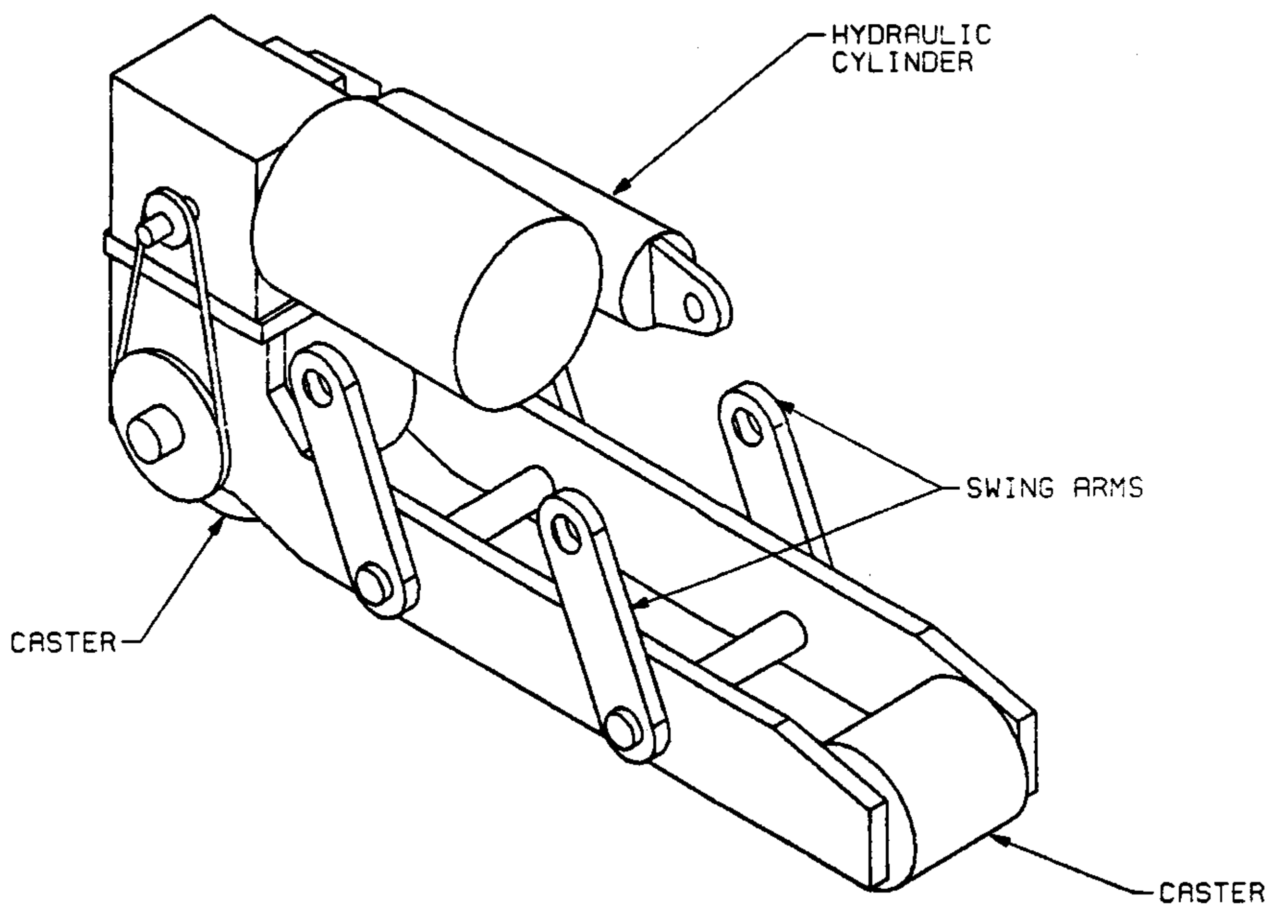
TRANSPORTER - ALTERNATE A
SECTION



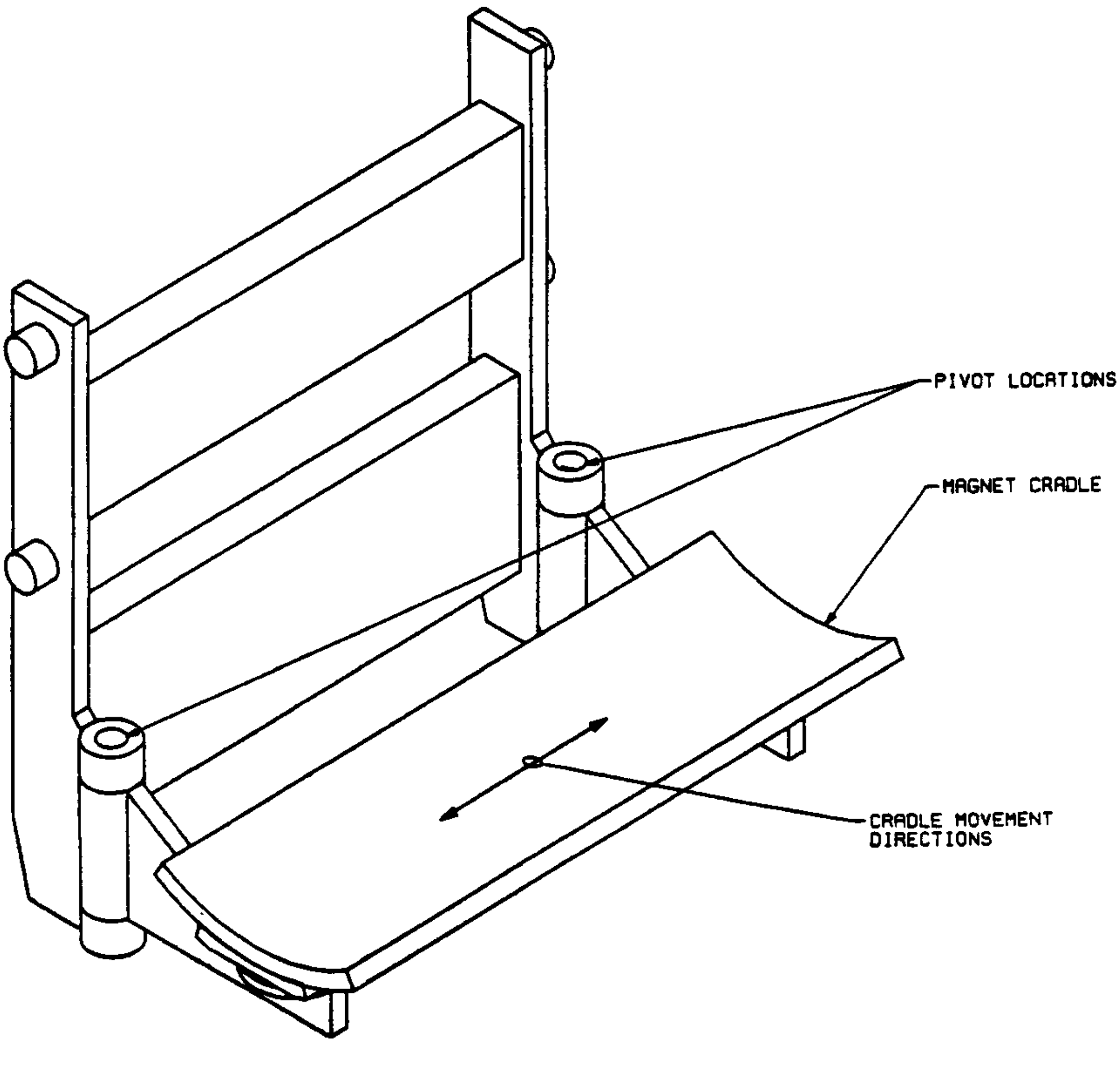
TRANSPORTER BOGIE
PLAN



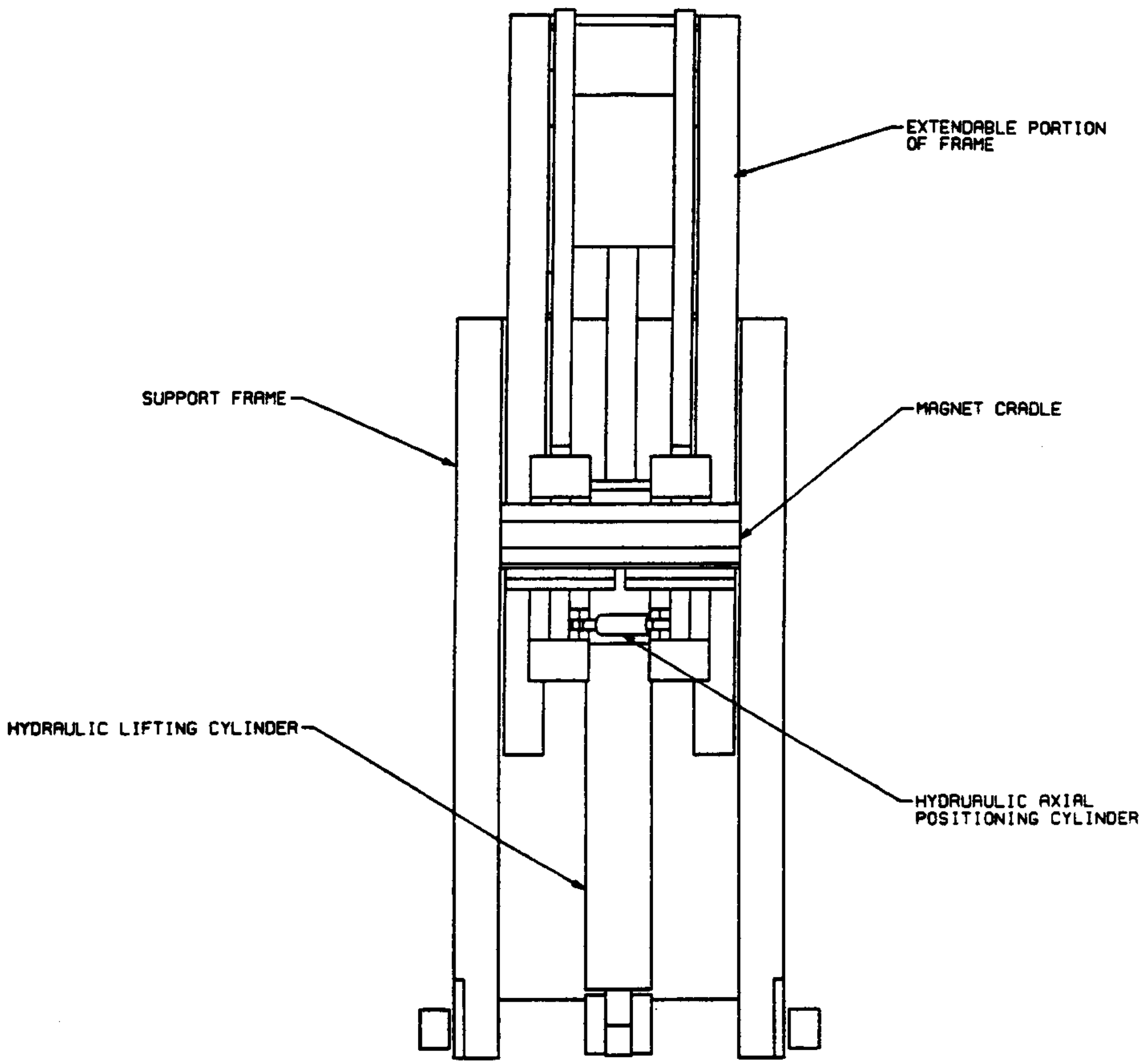
TRANSPORTER BOGIE
ELEVATION



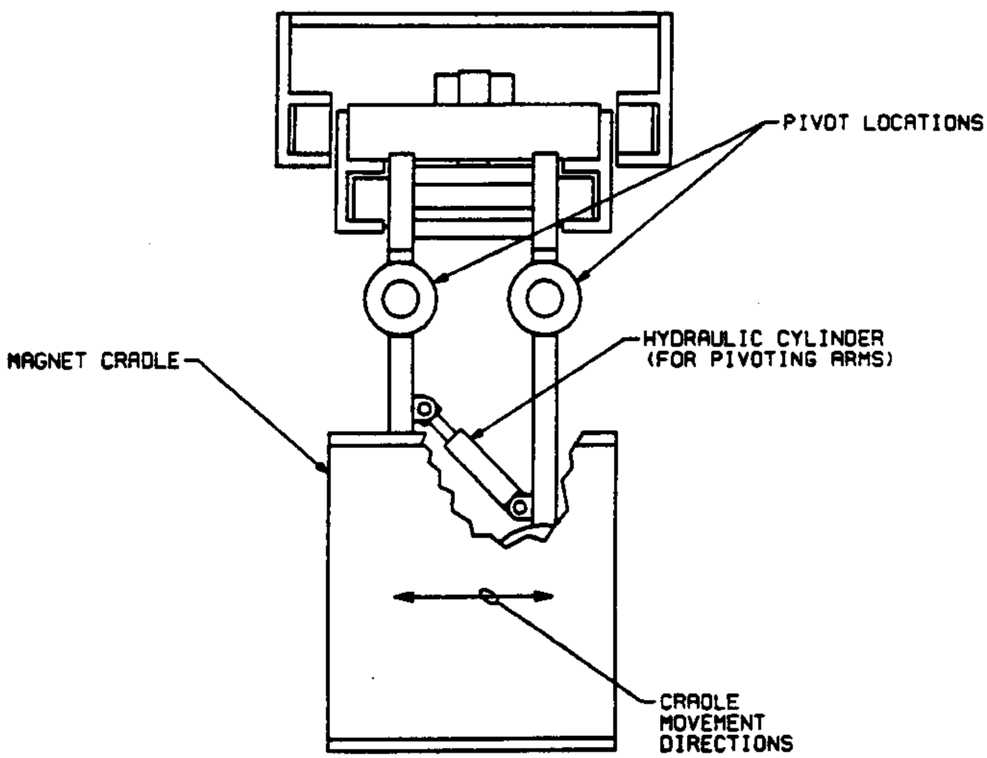
OUTRIGGER
ISOMETRIC



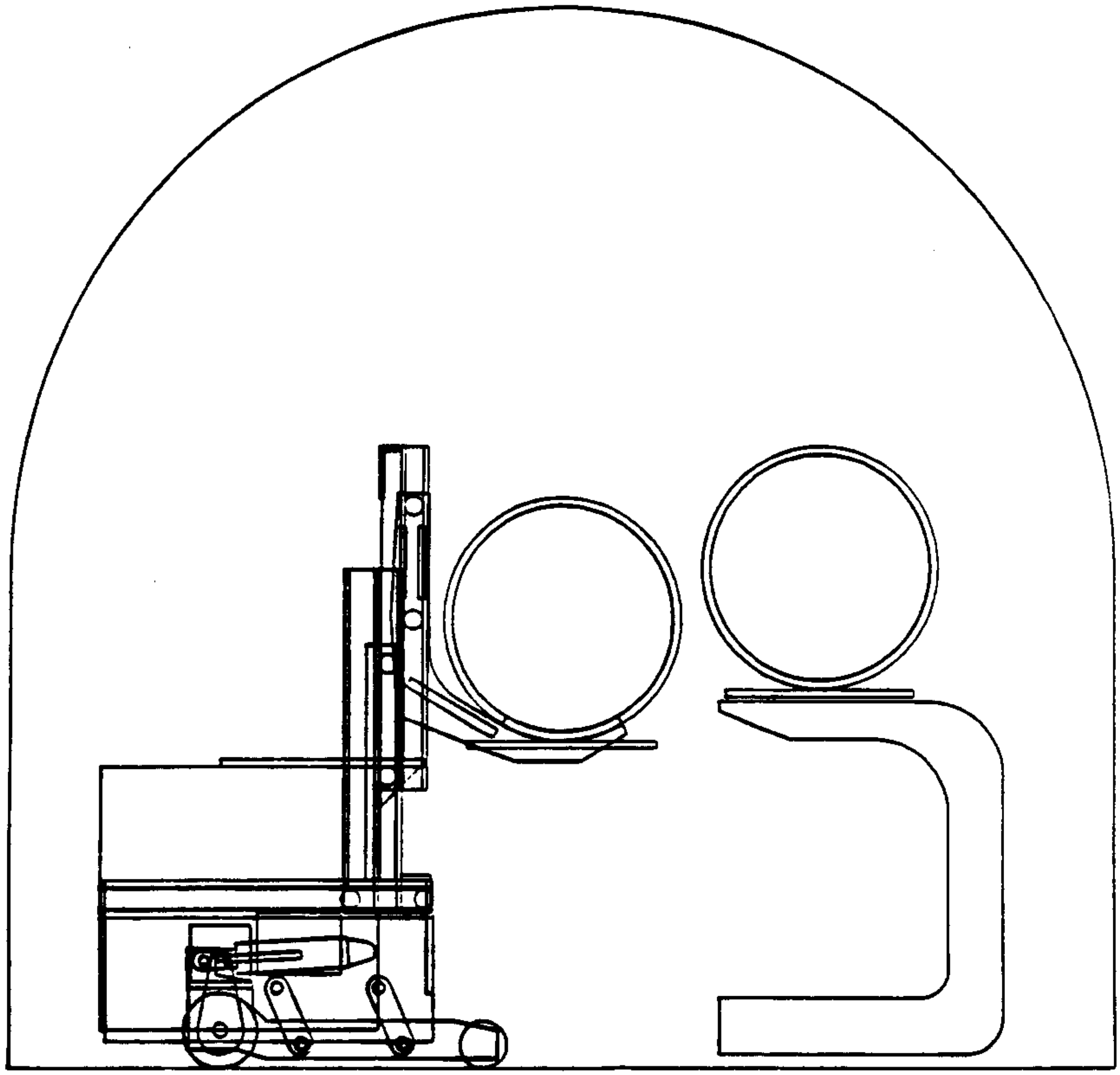
WIDE LIFTING FORK
ISOMETRIC



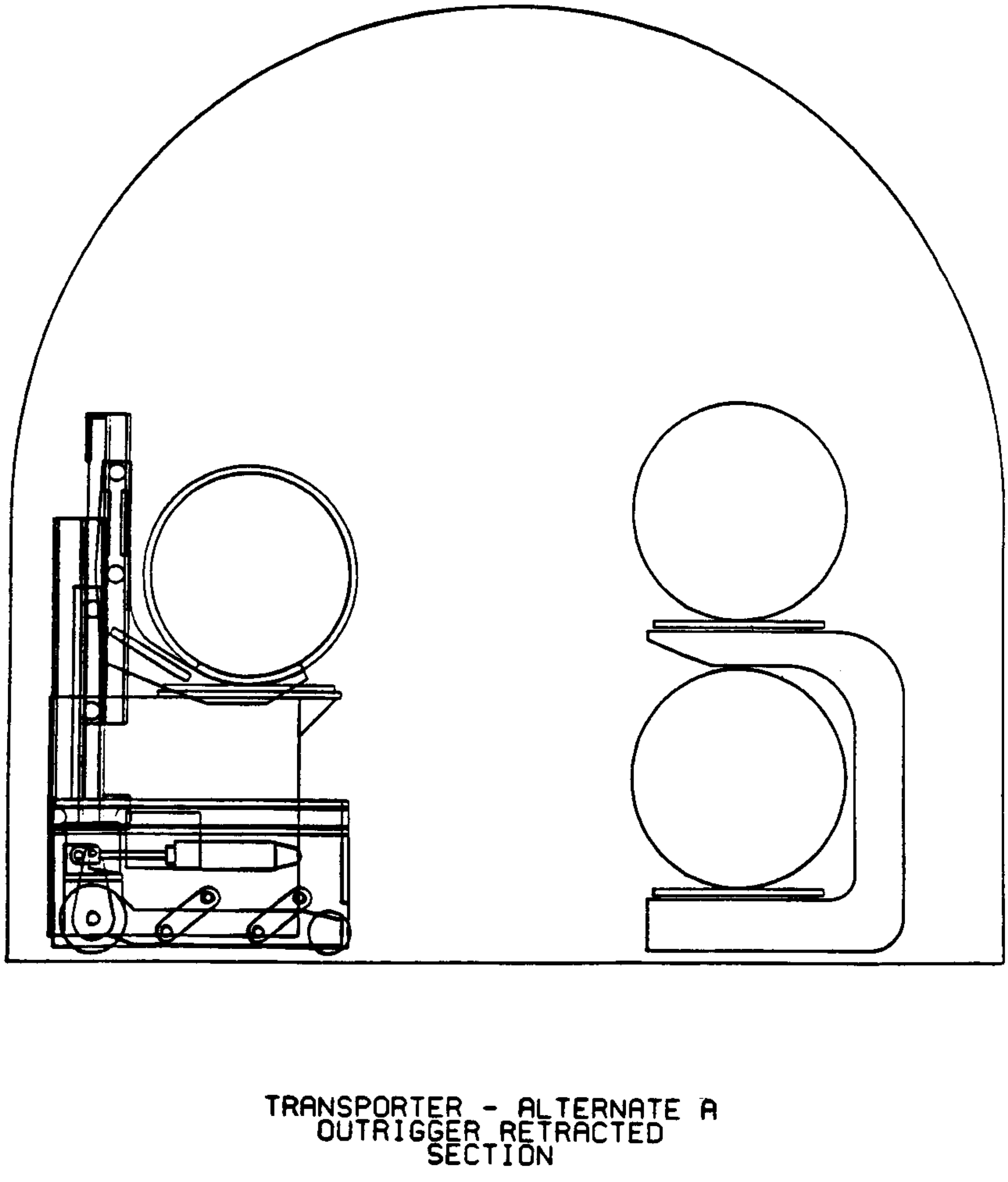
LIFTING FORK WITH FRAME
ELEVATION



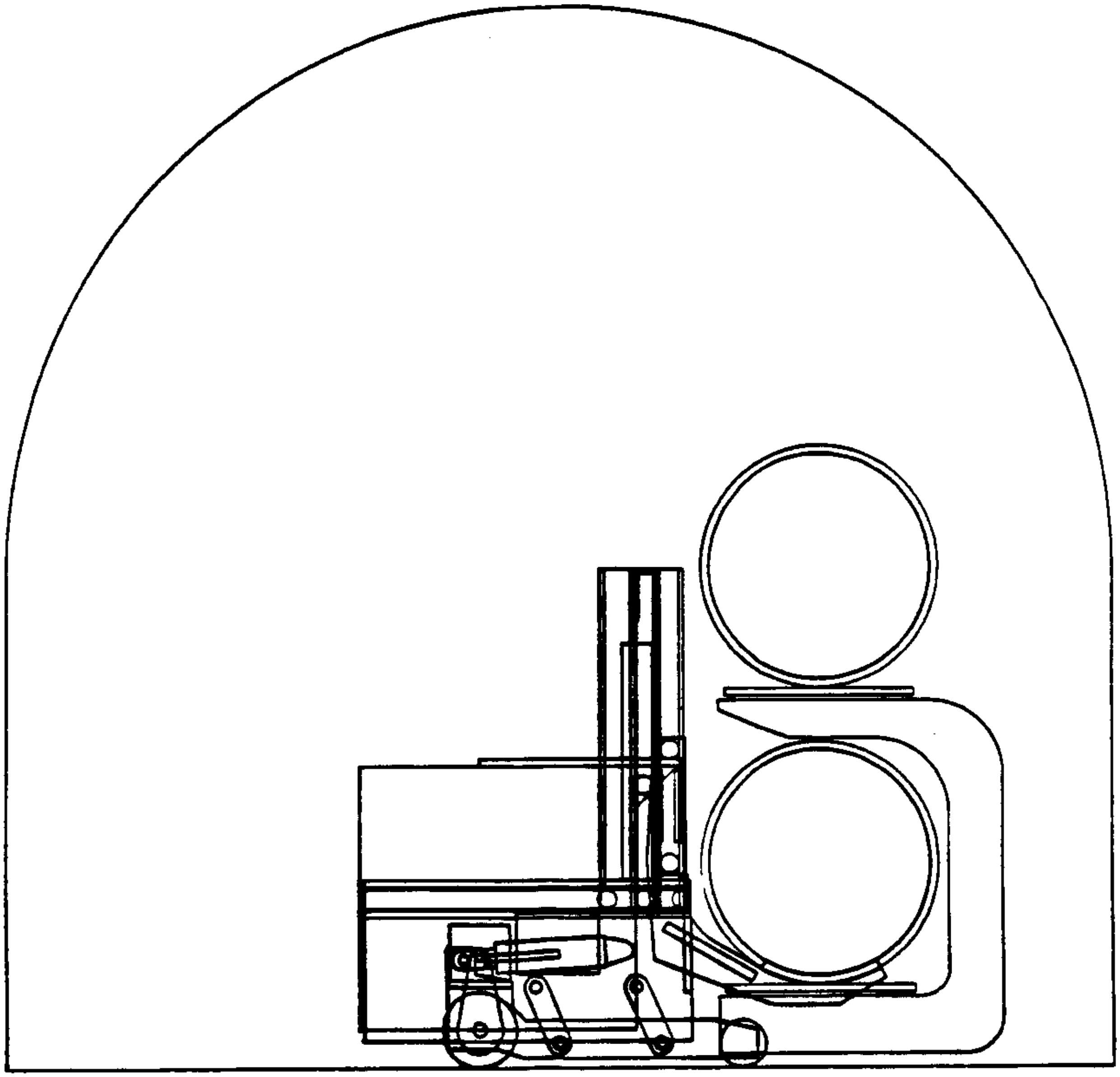
NARROW LIFTING FORK
WITH HYDRAULIC CYLINDER
PLAN



TRANSPORTER - ALTERNATE A
OUTRIGGER EXTENDED
SECTION



TRANSPORTER - ALTERNATE A
OUTRIGGER RETRACTED
SECTION



TRANSPORTER - ALTERNATE A
PLACING MAGNET
SECTION

PART 4

MAGNET TRANSPORTER

DOLLY SYSTEM

MAGNET TRANSPORT DOLLY

Based on experience with SSC prototype magnets at the magnet string test proto-collider tunnel, and on earlier experience during the TeVatron installation, it has been suggested that it would be preferable to separate the magnet transport function from that of setting the magnets on their stands. This magnet transporter is used solely for transporting the magnet and has no capability to lift or place the magnet sections. This transporter must be used in conjunction with a magnet handler which can lift and place the magnet sections in their final locations.

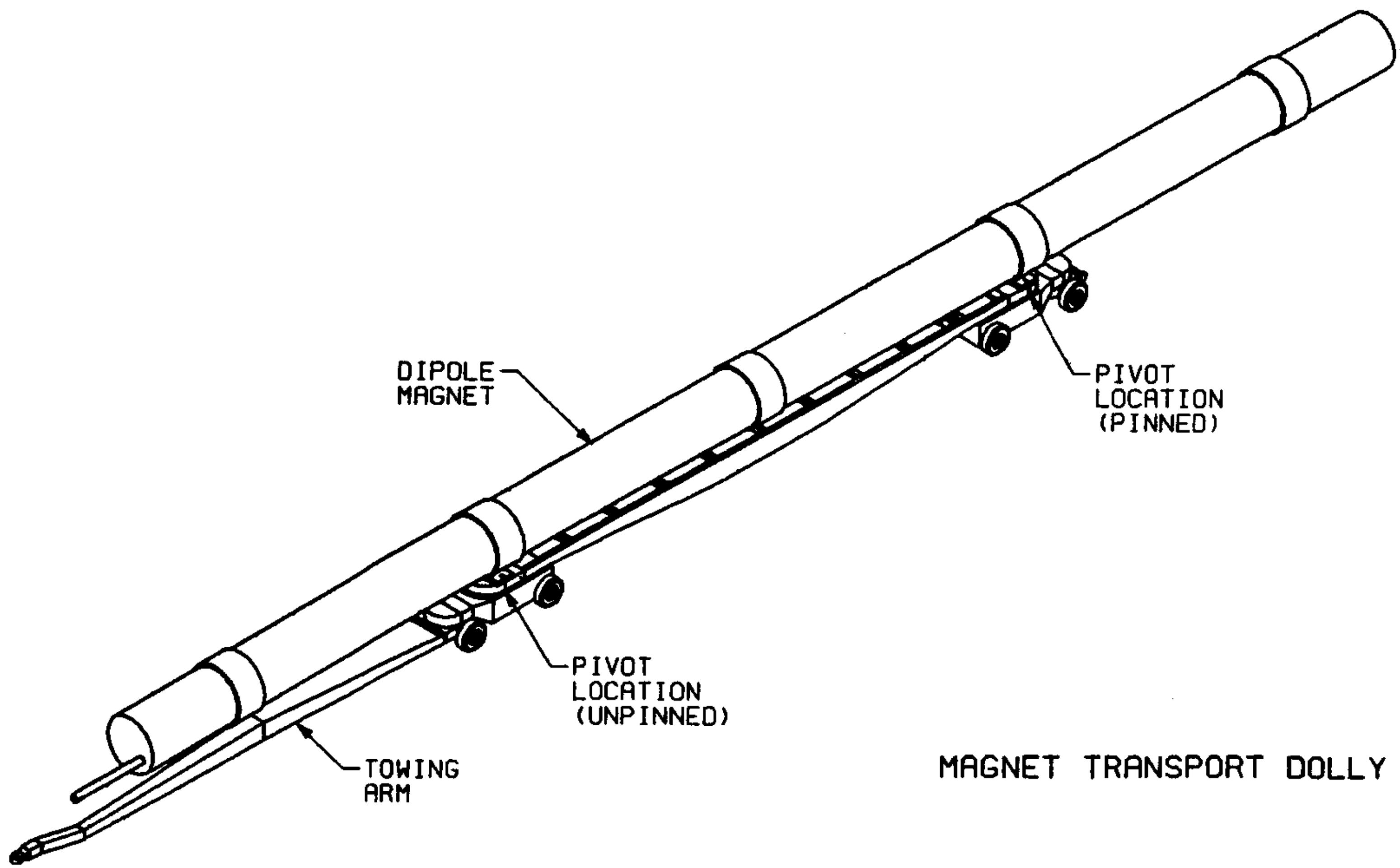
OPERATION

The dolly system is shown in the attached sketches. It consists of two connected dollies having four wheels and a removable tongue to connect the magnet to a tugger. The tongue is removable in order to allow the dolly assembly to be pulled from either end. It would not be feasible to push the assembly due to the confined space of the tunnel. Both dollies are able to pivot with respect to the magnet, but when the magnet is being towed the pivot on the rear dolly will be pinned. The strut connecting the dollies serves as a jig to align the dollies with the magnet supports as the magnet is lowered into place.

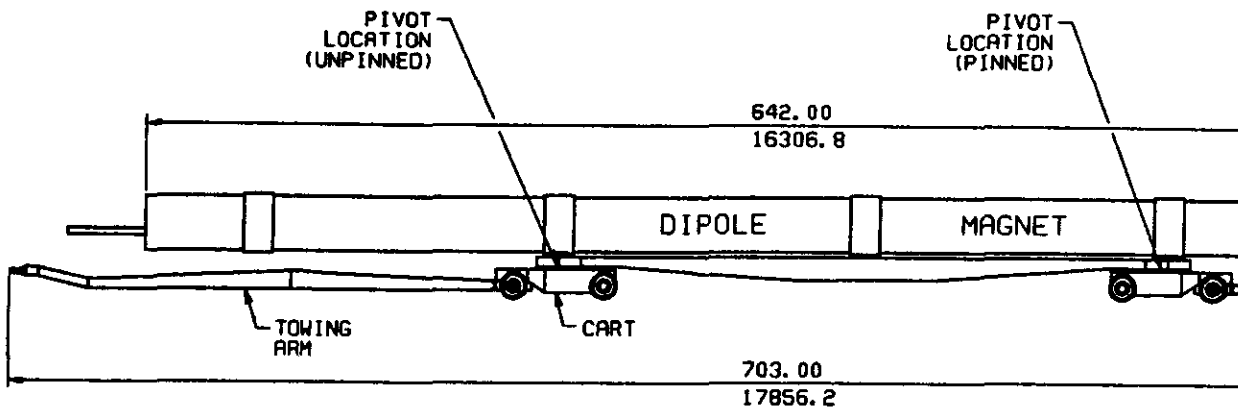
CONCLUSION

The magnet transport dolly would be a fairly inexpensive and simple piece of equipment to design and build. Depending on an overall motion and time study it may or may not be necessary to use this extra piece of equipment. In practice a complement of magnets would be towed on their dollies to their assigned lattice locations and parked there. The transporter/handler would then set them in their stands.

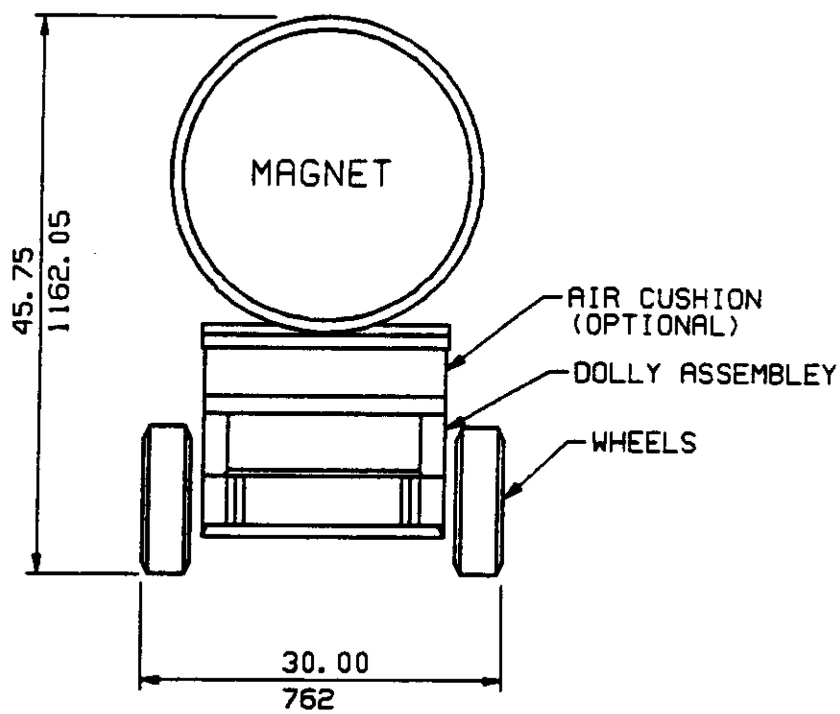
NOTE The coordination of this design with the magnet handler has not been done. Minor modifications may be necessary once the design of the magnet handler is agreed upon.



MAGNET TRANSPORT DOLLY



MAGNET TRANSPORT DOLLY - ELEVATION



MAGNET TRANSPORT DOLLY - SECTION

PART 5

MAGNET SUPPORT ALTERNATES

INTRODUCTION

The design of magnet handling equipment is constrained by the design of the supports on which the magnets are to be placed, and vice versa. In the Conceptual Design Report(CDR) the magnets of the lower ring in the collider serve as the supports for the upper ring. This report studies the feasibility from the point of view of handling equipment, of the CDR approach and of using a frame support to support the magnets separately.

On page 582 of the CDR(copy of page attached), is shown the top magnet being supported by the bottom magnet. Sketch A (attached), shows a proposed alternate means of supporting the magnets.

For comparison, we have listed the characteristics of the two alternatives.

TUNNEL LAYOUT

The static tunnel cross section layout and dimensions are not affected by the choice of either alternate. The space requirements for the magnets have been defined by the size of the magnets, a presumed requirement for personnel access behind them, and clearances for welding equipment, for quality control equipment and alignment access. These requirements are 20" clearance from the magnet vessel to the outside wall of the tunnel for personnel access, approximately 6.0" from the floor to the magnet vessel and between the lower and upper vessel for welding equipment access. An 80 cm (31.5") separation between the beam upper and lower elevations provides the required clearances for welding and alignment.

RIGIDITY AND DEFLECTION

Supporting one magnet on top of the other makes the top magnet as rigidly supported as the bottom one. Using a 4" X 6" boxbeam frame to mount the magnets would cause a deflection of the top magnet at the position of the beam of 0.16867" in the horizontal direction and 0.07190" in the vertical direction. This is a predictable static deflection that can be compensated for in the construction of the stand and the alignment of the magnet.

MAINTENANCE AND REPAIR FLEXIBILITY

There is a great advantage in this category in favor of the separate frame since there is no need to disturb the top magnet in case the bottom magnet requires repair.

In the alternate without the support (see sketch B and C attached), an attempt was made to see if the bottom magnet could be removed without removing the top one. This operation would use a frame to support the top magnet by bolting the magnet to the top frame and then using a device similar to an automobile floor jack to remove the bottom magnet. In order to relieve the pressure on the bottom magnet, the top magnet would have to be lifted in the order of 0.25" to 0.5". This movement would be to compensate for deflection of the different elements and to allow clearance for removal of the lower magnet.

Whether this amount of movement of the top magnet is allowable with the magnet at cryogenic temperatures has not been studied. Nor has the exact amount of movement required been determined. These calculations should be done if this alternate is to be pursued.

Another problem with the method of removal of the top magnet shown in sketches B and C is that it would present an obstruction to traffic. However, this would be only temporary while the bottom magnet was being removed and replaced.

If a temporary support such as is described above proves to be not feasible, the other alternative for replacing a bottom magnet would be to remove the top magnet first. This would double the work and double the inconvenience, as well as obviate any operation of the upper ring, e.g. for studies, until the operation would be completed.

COST

A rule of thumb estimate of the cost for 10,000 C-stands(sketch A) would be in the order of $3,000,000. A complete estimate of the cost of adding longer top and bottom supports for the non-stand alternate would be approximately a third of that, but the additional alignment and handling difficulties and costs for the stacked solution would have to be factored into any cost comparison.(see below)

ALIGNMENT FLEXIBILITY

The C-stand frame option allows the top and bottom magnets to be aligned independently. Without the stand, the bottom magnet alignment adjustments would affect the top magnets alignment adjustments. This would be particularly disruptive when replacing a bottom magnet after the system started operating. Further, in the stacked magnet option the cryostat fabrication is driven by very tight requirements on the alignment of the support stands as magnet field references. The independent stand approach could allow this precision to be transferred to standard alignment references, thus simplifying the cryostat fabrication process.

CONCLUSIONS

Based on the positive and negative aspects discussed above we recommend using frames to support the magnets so that the top and bottom magnets can be installed, removed and aligned independently. Use of C-stands to support independently the upper and lower rings of magnets in the collider tunnel allows for a magnet transport and handling system that is feasible within the confines of the tunnel as described in the CDR or within the tunnel modified as in Part 1 of this report to accommodate modified requirements. There is no clear solution to transport and handling magnets in the stacked configuration. The apparent advantage of stacking the magnet rings is not clear when handling equipment, operational and alignment costs, and cryostat fabrication costs are factored in.

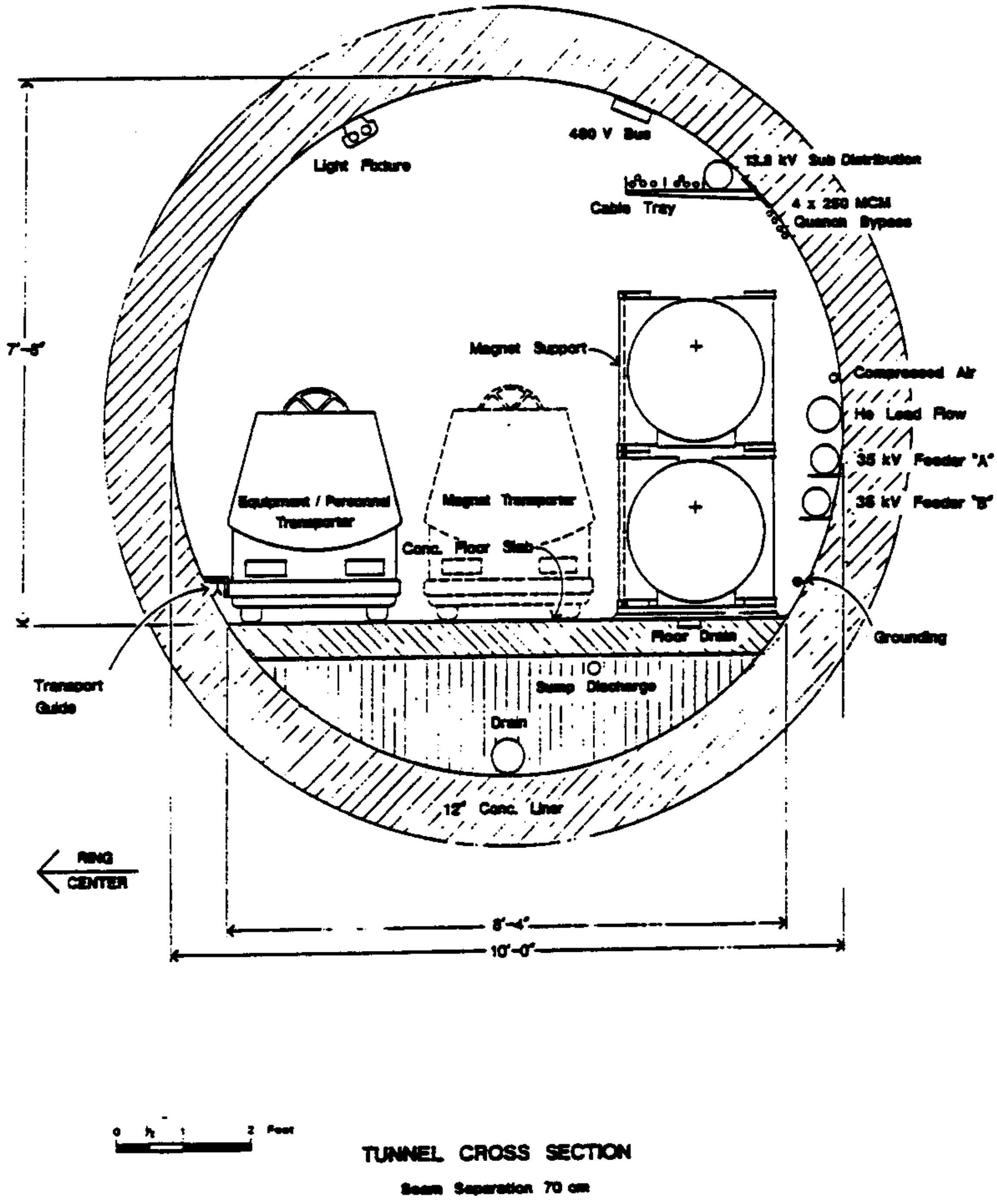
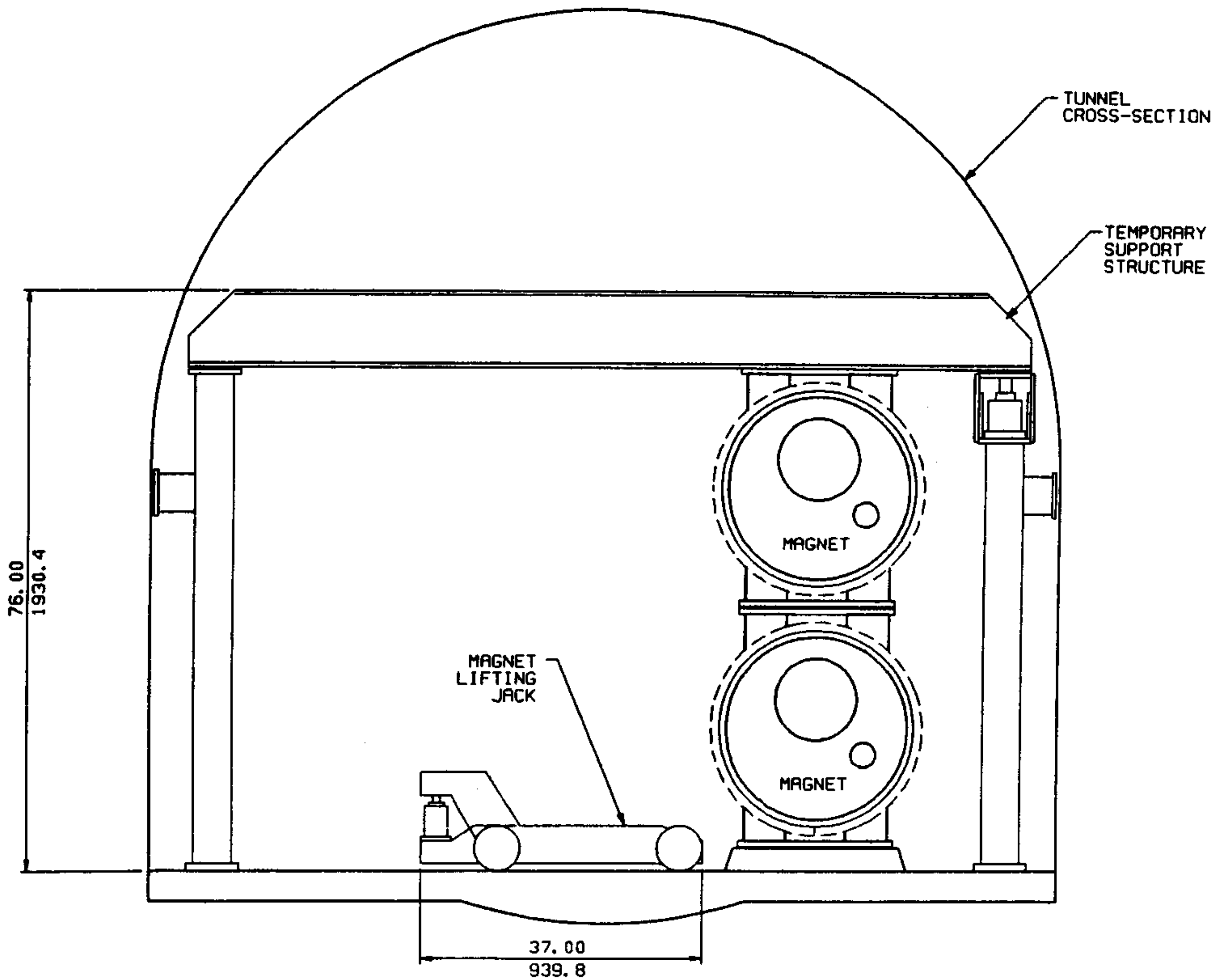
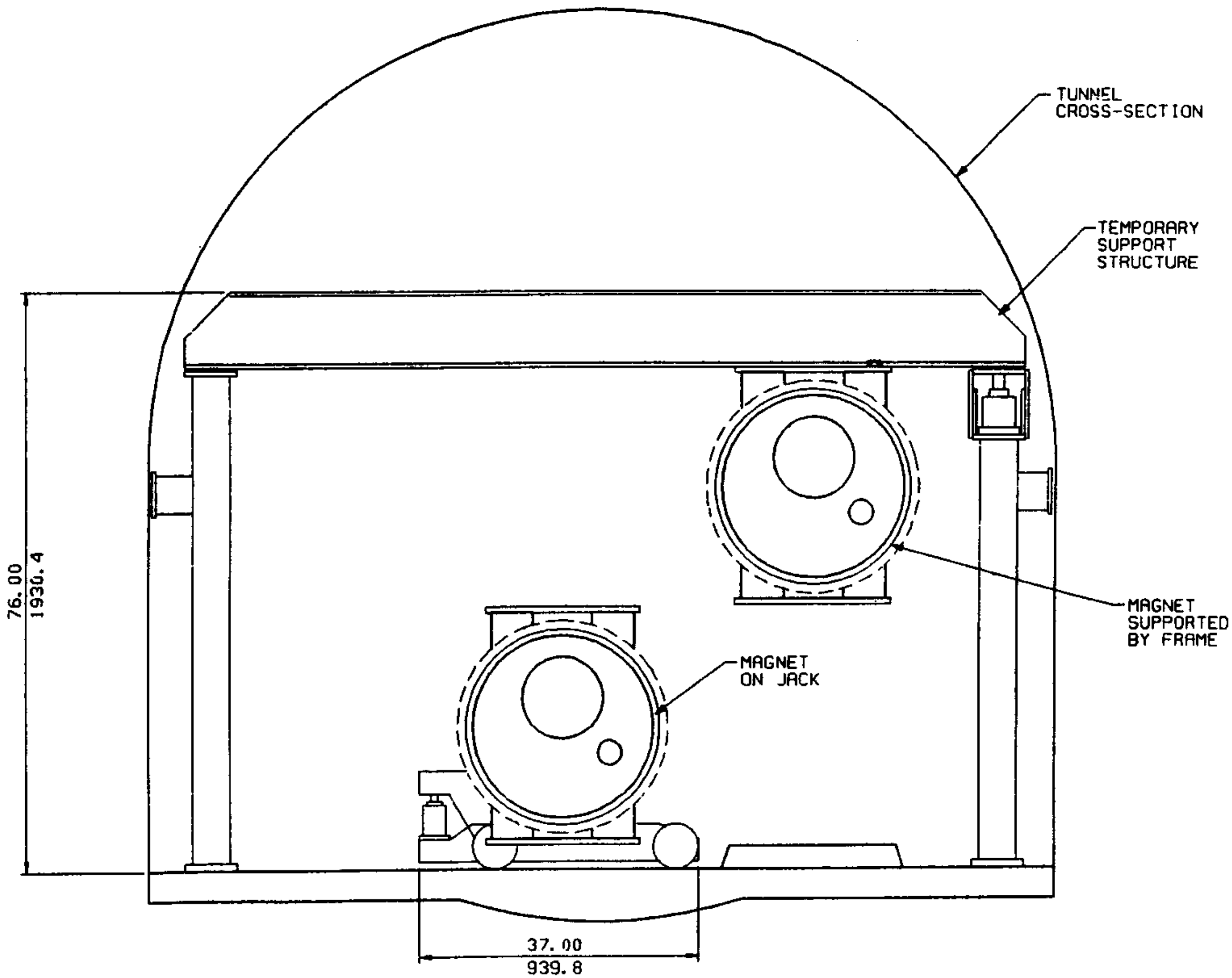


Figure 6.6-1. Collider Ring Tunnel profile showing the position of the two collider rings, the tunnel service vehicle and routing of tunnel utilities service mains.



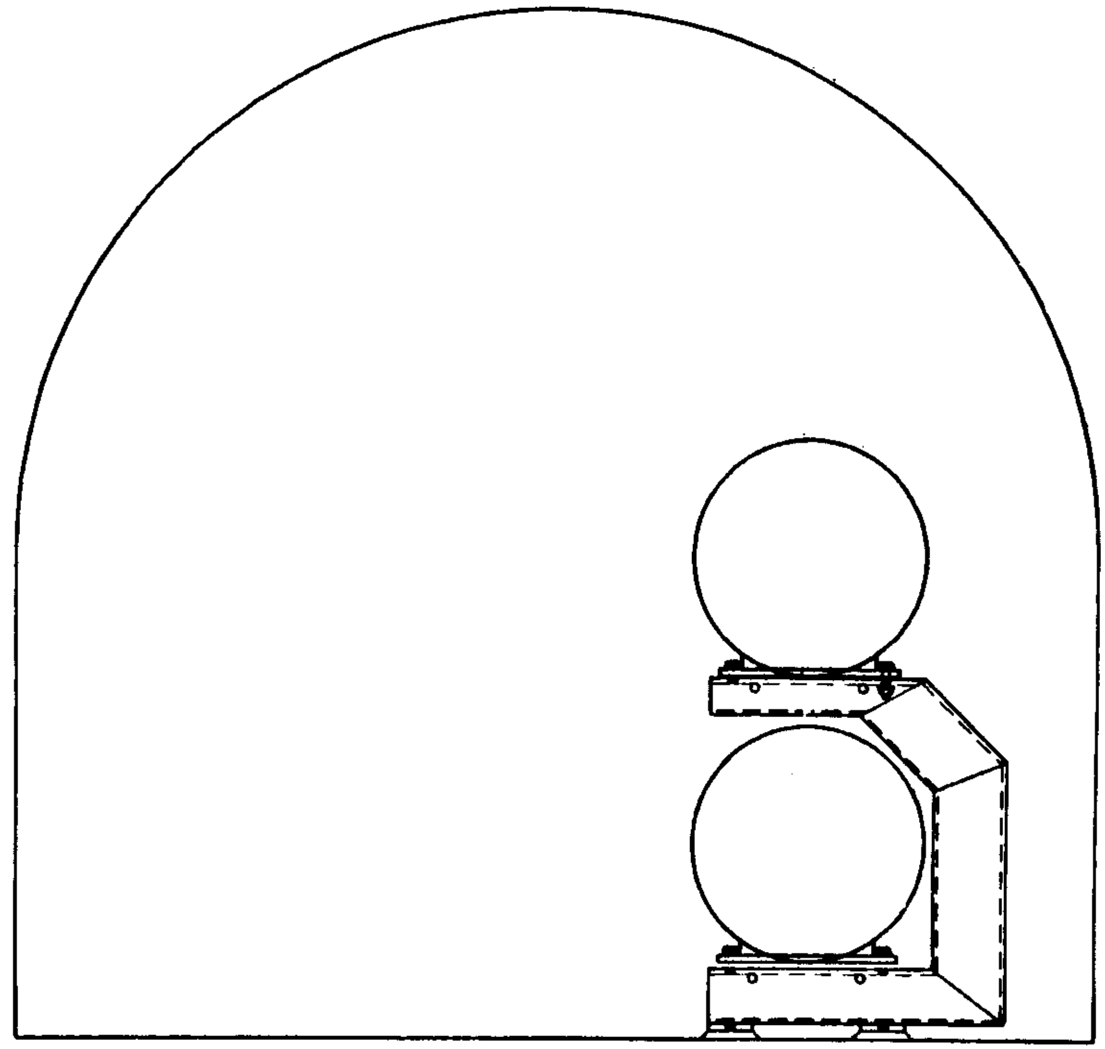
UPPER MAGNET SUPPORT SYSTEM
SECTION
SCALE: 3/4" = 1'-0"

SKETCH B



UPPER MAGNET SUPPORT SYSTEM
SECTION
SCALE: ¾" = 1'-0"

SKETCH C



C-TYPE MAGNET SUPPORT
SECTION

SKETCH A

PART 6

C-TYPE MAGNET SUPPORT

PRELIMINARY DESIGN

MAGNET SUPPORT STAND

The following is a preliminary study of a magnet support stand consistent with the space and weight constraints of the SSC system. The stand will carry two magnets, one above the other, with clearance for magnet alignment. This study is complimentary to the study of possible impacts on the SSC tunnel cross section of magnet transport and handling options.

The design is preliminary in that certain simplifying assumptions were made. The vibratory effects of seismic forces, nearby blasting operations, highway or railroad traffic above, etc. were not considered. Nor were resonance problems of the system considered. However, the analysis should be accurate enough for an evaluation of the deflection characteristics of the support and its effect on the magnet alignment.

The cost of such a stand is estimated to gauge the value of trade offs among various handling and tunnel cross-section options.

If the deflection characteristics of the supports are acceptable, alternate designs should be made and compared, such as castings or welded structures rather than tubing. Also a more accurate stress and deflection analysis should be made on the final design using finite element analysis techniques.

SUMMARY RESULTS

The supports will have a deflection such that it will produce a movement of the magnet beam center line of 0.07190 inches in the vertical direction and 0.18945 inches in the horizontal direction.

The cost of 10,000 supports would be approximately $3,000,000.

SUPPORT DESCRIPTION

The final design is shown in Figs. B,C and D. The frame assembly consists of four sections of rectangular tubing. The tubing has the thickest standard wall size available.

Stress and deflection calculations were made assuming uniform distribution of stresses at the joints. This can be accomplished by welding a plate transversely at each joint, however, this may not be necessary in practice as the stresses are low. The drawings and the cost estimate were made without the transverse plates included, which would add to the cost. To be accurate, a finite element analysis should be made once a decision is made on the type of support to be used.

The assembly has been designed to allow for a 1/4" shim to be mounted under the upper magnet and a larger 3/4" shim to be mounted under the lower magnet. This larger shim allows extra room to manipulate the magnet when it is being installed. The assembly will be affixed with two 3/4" bolts for the upper and lower assembly. The outer bolt will be tightened using regular tools while the inner nut will be attached using a special tool manufactured for the job. The tool will have a hexagonal recess to hold the nut and be inserted through the end of the square tubing.

A program called STAAD Plane was used to estimate the deflections and stresses in the support frame. The detailed program output is in the calculations section. Two loading conditions were considered. The first loading condition is a static condition with both magnets in place and the second load case is with the upper magnet resting on the jacking mechanism. The first load case created the largest deflection and stresses on the support. The analysis shows that stress is not the critical factor, the main concern is with deflection. The maximum deflection occurs at the end of the upper support member. It has a magnitude in the horizontal direction of 0.18945 inches and 0.07190 inches in the vertical direction.

DESIGN CRITERIA

-The support frames are designed to support the 24,000lb. magnet assemblies at the two points shown below.

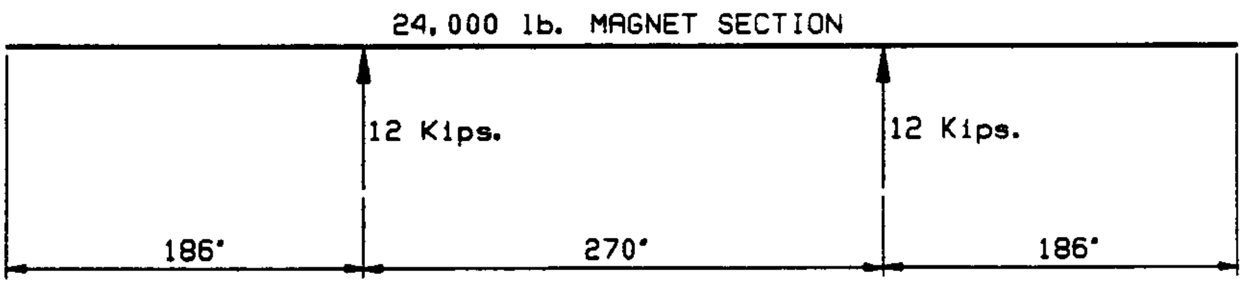
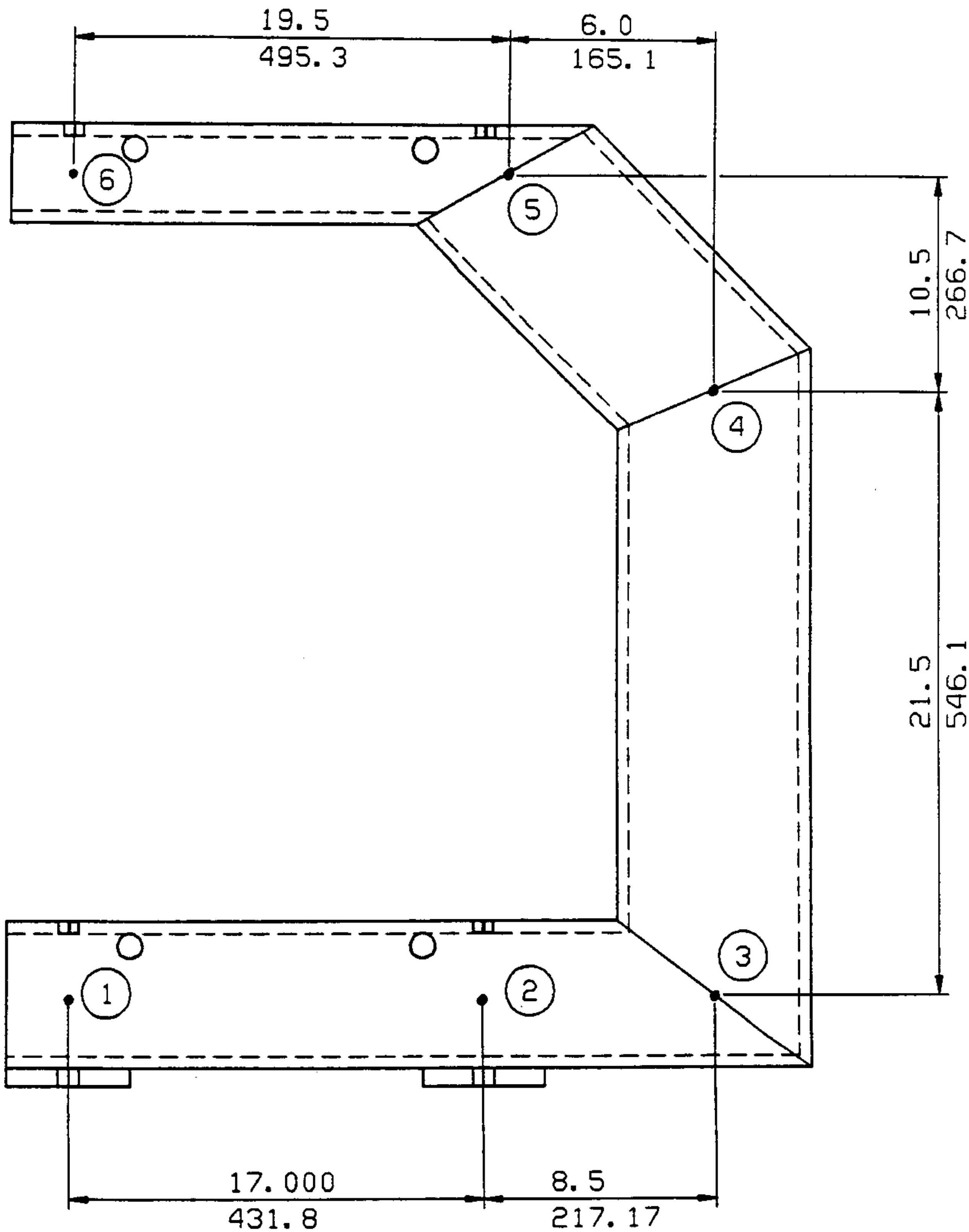


Fig. A

-The support frames are designed to minimize deflection.

CALCULATIONS



NODE DIAGRAM

```
**************************************************
*                                                *
*          S T A A D - III                       *
*          REVISION 10.3 (VERSION 10 LEVEL 3)    *
*          PROPRIETARY PROGRAM OF                *
*          RESEARCH ENGINEERS,INC.               *
*          DATE=    AUG 24, 1988                 *
*          TIME=    11:29:33                     *
*                                                *
**************************************************

   1. STAAD PLANE
   2. UNIT INCHES KIP
   3. JOINT COORDINATES
   4.    1        .000        .000       .000
   5.    2      17.000        .000       .000
   6.    3      25.500        .000       .000
   7.    4      25.500      21.500       .000
   8.    5      19.500      32.000       .000
   9.    6        .000      32.000       .000
  10. MEMBER INCIDENCES
  11.      1    1    2
  12.      2    2    3
  13.      3    3    4
  14.      4    4    5
  15.      5    5    6
  16. MEMBER PROPERTIES
  17. 1 TO 2 TA ST TUBE DT 6.0 WT 6.0 TH 0.5
  18. 3 TO 4 TA ST TUBE DT 8.0 WT 6.0 TH 0.5
  19. 5 TA ST TUBE DT 4.0 WT 6.0 TH 0.5
  20. CONSTANTS ;E 29000 ALL
  21. SUPPORT
  22. 1 PINNED
  23. 2 PINNED
  24. LOADING 1 DEAD+LIVE
  25. JOINT LOAD
  26. 6 FY -6
  27. MEMBER LOAD
  28. 5 CON GY -6.0 2.5
  29. LOADING 2 JACKING LOAD
  30. MEMBER LOAD
  31. 5 CON GY -9.0 5
  32. PERFORM ANALYSIS
** PROCESSING MEMBER/ELEMENT INFORMATION.

** PERFORMING BANDWIDTH REDUCTION.

     ORIGINAL BANDWIDTH =    1
     REDUCED  BANDWIDTH =    1


** CHECKING LOAD DATA.
** PROCESSING SUPPORT CONDITION.
** PROCESSING AND SETTING UP LOAD VECTOR.

** PROCESSING ELEMENT STIFFNESS MATRIX.                 11:29:48
** PROCESSING GLOBAL STIFFNESS MATRIX.                  11:29:49
```

```
** PROCESSING TRIANGULAR FACTORIZATION.          11:29:50
** CALCULATING JOINT DISPLACEMENT.                11:29:50
** CALCULATING ELEMENT FORCES.                    11:29:51

  33. PRINT ALL
```

JOINT COORDINATES

COORDINATES ARE INCH UNIT

JOINT	X	Y	Z
1	.000	.000	.000
2	17.000	.000	.000
3	25.500	.000	.000
4	25.500	21.500	.000
5	19.500	32.000	.000
6	.000	32.000	.000

MEMBER INFORMATION

MEMBER	START JOINT	END JOINT	LENGTH (INCH)	BETA (DEG)	RELEASES
1	1	2	17.000	.00	000000000000
2	2	3	8.500	.00	000000000000
3	3	4	21.500	.00	000000000000
4	4	5	12.093	.00	000000000000
5	5	6	19.500	.00	000000000000

MATERIAL PROPERTIES.

ALL UNITS ARE - KIP INCH

MEMBER	E	G	DEN	ALPHA
1	29000.0	14500.0	.00000000	.00000000
2	29000.0	14500.0	.00000000	.00000000
3	29000.0	14500.0	.00000000	.00000000
4	29000.0	14500.0	.00000000	.00000000
5	29000.0	14500.0	.00000000	.00000000

MEMBER PROPERTIES. UNIT - INCH

MEMB	PROFILE	AX/ AY	IZ/ AZ	IY/ SZ	IX/ SY
1	ST TUB E	10.42	49.38	49.38	83.19
		5.21	6.00	16.46	16.46
2	ST TUB E	10.42	49.38	49.38	83.19
		5.21	6.00	16.46	16.46
3	ST TUB E	12.31	101.03	61.94	130.89
		7.03	6.00	25.26	20.65
4	ST TUB E	12.31	101.03	61.94	130.89
		7.03	6.00	25.26	20.65
5	ST TUB E	8.52	18.04	36.83	41.17
		3.41	6.00	9.02	12.28

SUPPORT INFORMATION (1=FIXED, 0=RELEASED)

UNITS FOR SPRING CONSTANTS ARE KIP INCH DEGREES

JOINT	FORCE-X/ KFX	FORCE-Y/ KFY	FORCE-Z/ KFZ	MOM-X/ KMX	MOM-Y/ KMY	MOM-Z/ KMZ
1	1	1	1	1	1	0
	.0	.0	.0	.0	.0	.0
2	1	1	1	1	1	0
	.0	.0	.0	.0	.0	.0

************ END OF DATA FROM INTERNAL STORAGE ************

34. SECTION 0.0 .25 .5 .75 1.0 ALL
35. PRINT MEMBER FORCES

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP INCH

MEMB	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	1	.00	6.00	.00	.00	.00	.00
		2	.00	-6.00	.00	.00	.00	102.00
	2	1	.00	1.32	.00	.00	.00	.00
		2	.00	-1.32	.00	.00	.00	22.50
2	1	2	.00	12.00	.00	.00	.00	-102.00
		3	.00	-12.00	.00	.00	.00	204.00
	2	2	.00	9.00	.00	.00	.00	-22.50
		3	.00	-9.00	.00	.00	.00	99.00
3	1	3	12.00	.00	.00	.00	.00	-204.00
		4	-12.00	.00	.00	.00	.00	204.00
	2	3	9.00	.00	.00	.00	.00	-99.00
		4	-9.00	.00	.00	.00	.00	99.00
4	1	4	10.42	5.95	.00	.00	.00	204.00
		5	-10.42	-5.95	.00	.00	.00	-132.00
	2	4	7.81	4.47	.00	.00	.00	99.00
		5	-7.81	-4.47	.00	.00	.00	-45.00
5	1	5	.00	12.00	.00	.00	.00	132.00
		6	.00	-6.00	.00	.00	.00	.00
	2	5	.00	9.00	.00	.00	.00	45.00
		6	.00	.00	.00	.00	.00	.00

************** END OF LATEST ANALYSIS RESULT **************

36. PRINT MEMBER STRESSES

MEMBER STRESSES

ALL UNITS ARE KIP /SQ INCH

MEMB	LOAD	SECTION	AXIAL	BEND-Y	BEND-Z	COMBINED
1	1	.0	.000	.000	.000	.000
		.250	.000	.000	1.549	1.549
		.500	.000	.000	3.098	3.098
		.750	.000	.000	4.647	4.647
		1.000	.000	.000	6.196	6.196
	2	.0	.000	.000	.000	.000
		.250	.000	.000	.342	.342
		.500	.000	.000	.683	.683
		.750	.000	.000	1.025	1.025
		1.000	.000	.000	1.367	1.367
2	1	.0	.000 T	.000	6.196	6.196
		.250	.000 T	.000	7.745	7.745
		.500	.000 T	.000	9.294	9.294
		.750	.000 T	.000	10.844	10.844
		1.000	.000 T	.000	12.393	12.393
	2	.0	.000 C	.000	1.367	1.367
		.250	.000 C	.000	2.529	2.529
		.500	.000 C	.000	3.690	3.690
		.750	.000 C	.000	4.852	4.852
		1.000	.000 C	.000	6.014	6.014
3	1	.0	.975 C	.000	8.077	9.052
		.250	.975 C	.000	8.077	9.052
		.500	.975 C	.000	8.077	9.052
		.750	.975 C	.000	8.077	9.052
		1.000	.975 C	.000	8.077	9.052
	2	.0	.731 C	.000	3.920	4.651
		.250	.731 C	.000	3.920	4.651
		.500	.731 C	.000	3.920	4.651
		.750	.731 C	.000	3.920	4.651
		1.000	.731 C	.000	3.920	4.651
4	1	.0	.846 C	.000	8.077	8.923
		.250	.846 C	.000	7.364	8.211
		.500	.846 C	.000	6.652	7.498
		.750	.846 C	.000	5.939	6.785
		1.000	.846 C	.000	5.226	6.073
	2	.0	.635 C	.000	3.920	4.555
		.250	.635 C	.000	3.385	4.020
		.500	.635 C	.000	2.851	3.485
		.750	.635 C	.000	2.316	2.951
		1.000	.635 C	.000	1.782	2.416
5	1	.0	.000 T	.000	14.632	14.632
		.250	.000 T	.000	9.727	9.727
		.500	.000 T	.000	6.485	6.485
		.750	.000 T	.000	3.242	3.242
		1.000	.000 T	.000	.000	.000
	2	.0	.000 T	.000	4.9[illegible]	4.9[illegible]

MEMBER STRESSES

ALL UNITS ARE KIP /SQ INCH

MEMB	LOAD	SECTION	AXIAL	BEND-Y	BEND-Z	COMBINED
		.250	.000 T	.000	.125	.125
		.500	.000 T	.000	.000	.000
		.750	.000 T	.000	.000	.000
		1.000	.000 T	.000	.000	.000

************** END OF LATEST ANALYSIS RESULT **************

37. PRINT JOINT DISPL

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = PLANE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	.00000	.00000	.00000	.00000	.00000	-.00012
	2	.00000	.00000	.00000	.00000	.00000	-.00003
2	1	.00000	.00000	.00000	.00000	.00000	.00048
	2	.00000	.00000	.00000	.00000	.00000	.00011
3	1	.00000	.00619	.00000	.00000	.00000	.00139
	2	.00000	.00110	.00000	.00000	.00000	.00047
4	1	-.04600	.00546	.00000	.00000	.00000	.00289
	2	-.01785	.00056	.00000	.00000	.00000	.00119
5	1	-.08067	-.01475	.00000	.00000	.00000	.00358
	2	-.03247	-.00810	.00000	.00000	.00000	.00149
6	1	-.08067	-.11608	.00000	.00000	.00000	.00580
	2	-.03247	-.04158	.00000	.00000	.00000	.00171

************** END OF LATEST ANALYSIS RESULT **************

38. FINISH

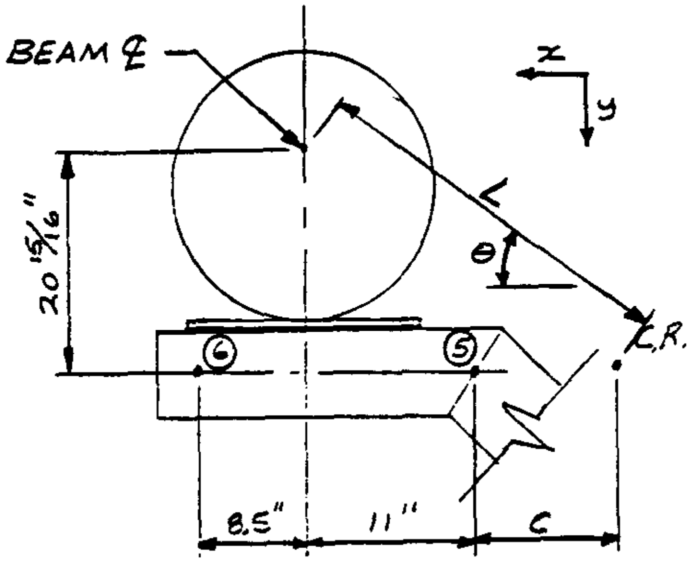
*************** END OF STAAD-III ***************

****** DATE= AUG 24,1988 TIME= 11:30: 0 ******

SSC

	JOB No. ______
	SHEET ___ OF ___
	DESIGNED BY W. EKREN DATE 9/6/8
	CHECKED BY ______ DATE ______

MAGNET BEAM CENTER LINE DEFLECTION



⑥ $\delta_x = .08067''$

$\delta_y = .11608''$

⑤ $\delta_x = .08067''$

$\delta_y = .01475''$

$$\frac{0.01475''}{C} = \frac{0.11608}{C + 8.5 + 11.0}$$

$$C = \frac{0.01475(8.5+11.0)}{(0.11608 - 0.01475)} = C = 2.839''$$

$$L = \sqrt{(20\tfrac{15}{16})^2 + (11 + 2.839)^2} \qquad L = 25.098''$$

$$\frac{\delta_{℄}}{25.098} = \frac{.01475''}{2.839''} \qquad \delta_{℄_1} = .13040''$$

$$\theta = \tan^{-1}\left(\frac{20\tfrac{15}{16}''}{13.839''}\right) \qquad \theta = 56.537°$$

$$\delta_{x_1} = (.13040'')\sin(56.537°) \qquad \delta_{x_1} = 0.10878''$$

$$\delta_y = (.13040'')\cos(56.537°) \qquad \delta_y = 0.07190''$$

$$\delta_x = 0.10878'' + 0.08067'' = 0.18945$$

[illegible] ℄	$\delta_x = 0.18945''$ $\delta_y = 0.07190''$

CALCULATIONS Inc Form No. E-6 Rev. 5-85

COST ESTIMATE

The detailed cost breakdown follows and shows the per unit cost to be $315.00, and the total for 10,000 units is $3,149,000.

TITLE SSC JOB NO. 85 / 122

CLIENT DOE LOCATION DATE 8/30/88

SUBJECT MAGNET SUPPORT STUDY BY IG

SHEET 1 OF

CODE	DESCRIPTION	QUANTITY	UNIT COST	TOTAL AMOUNT	TOTAL $/EA	TOTAL $/LB
	TOOLING & SETUP CHARGE	1 LS		250 000	25	.085
	FABRICATION LABOR @ 30 $/MH × 3.15 MH/EA	10 000 EA	95	950 000	95	.322
	MATERIAL COSTS @ 0^{30} $/LB × 295 LB/EA	10 000 EA	88 ^{50}	885 000	89	.3
	SUBTOTAL	1		2 085 000	209	$0^{.71}$
	FABRICATOR'S OH & P INCL: SUPERVISION, CONSUMABLES MISC SHOP EQUIPMENT, DRAWINGS FOR FRAMES & JIG SETUP	20%		417 000	42	$0^{.14}$
				2 502 000	251	$0^{.85}$
	FREIGHT 10000 EA × (295 LB + 10 LB PKG)	1525 TN	150	229 000	23	$0^{.08}$
				2 781 000	274 $/FRAME	$0^{.93}$ $/LB
	CONTINGENCY	15%		410 000	41	$0^{.14}$
	TOTAL BASED ON AUTOMATIC WELD. UNIT			3 141 000	315 ^{00} $/FRAME	1^{07} $/LB

Raymond Kaiser Engineers

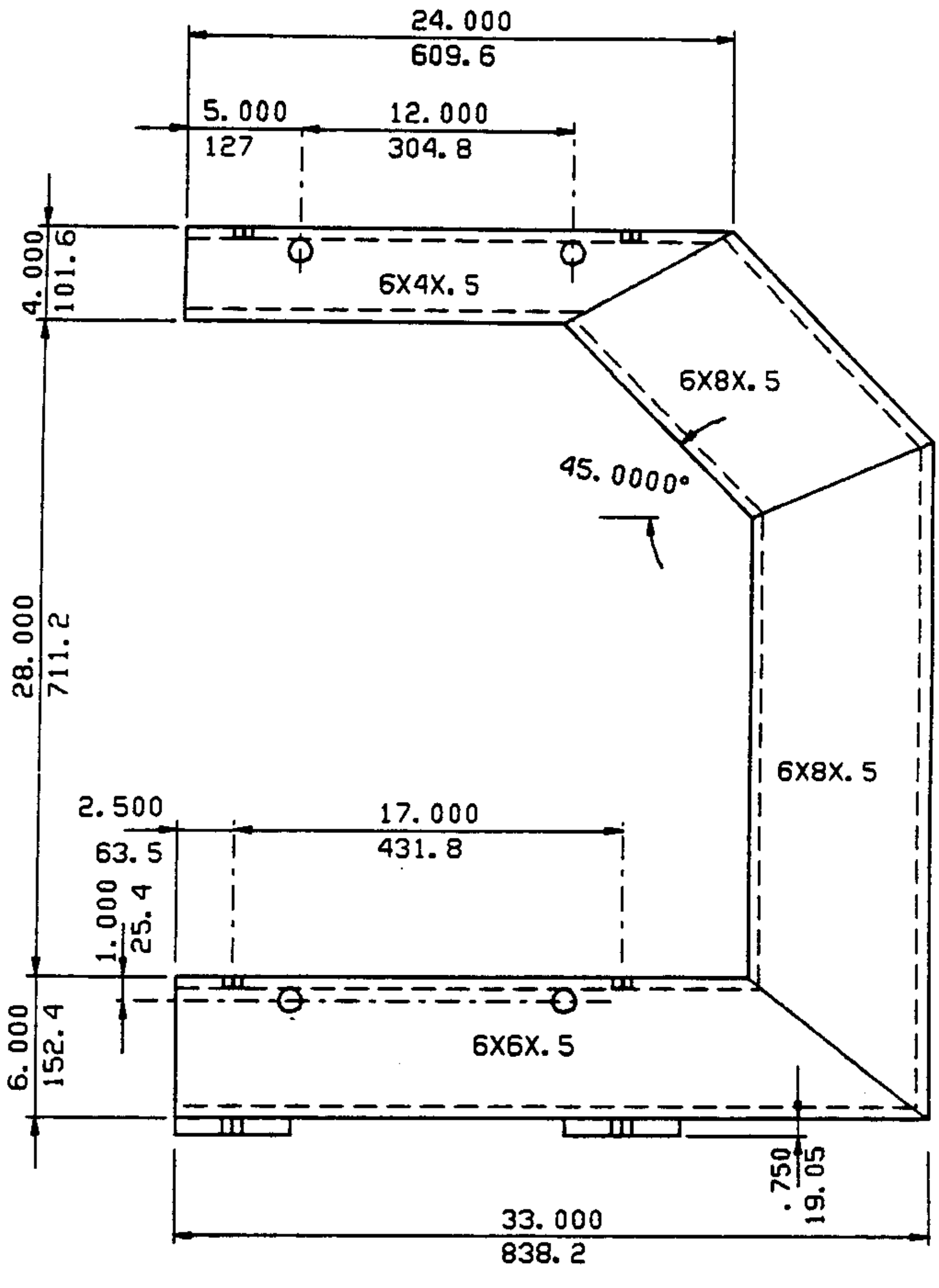
TITLE: SSC JOB NO. 85 122
CLIENT: DOE LOCATION: DATE: 8/30/88
SUBJECT: MAGNET SUPPORT STUDY BY: JK
SHEET 2 OF

CODE	DESCRIPTION	QUANTITY	UNIT ~~COST~~ MH	AMOUNT MH	TOTAL MH
	CUT TUBESTEEL				
	CUTS 8 EA + 2 FINISH FACE CUTS	10 EA	.015	.15	
	AUTOMATIC WELDING TUBESTEEL, ½" FULL PENETRATION, 2x2 SIDES SIMULTAN. x 4 PASSES	3 EA	.133	.4	
	DRILL HOLES IN TUBESTEEL	8 EA	.021	.17	
	MILL SLOTS	4 EA	.025	.1	
	CUT MOUNTING PLATES	2 EA	.017	.03	
	DRILL HOLES IN MOUNTING PLATES	4 EA	.008	.03	
	WELD MOUNTING PLATES TO FRAME, FILLET, SIMULT. PASS	2 EA	.05	.1	
	INSPECTION	1 EA	.1	.1	
	GRIND WELDS	3 EA	.083	.25	
	PAINTING	1 EA		.25	
	SUBTOTAL				1.58
	HANDLING (SHT 3)				1.28
	SUBTOTAL				2.86
	ALLOW FOR REWORK, REPAIR, ADJUSTMENTS. ETC				.29
	TOTAL MH / FRAME				3.15

Raymond Kaiser Engineers

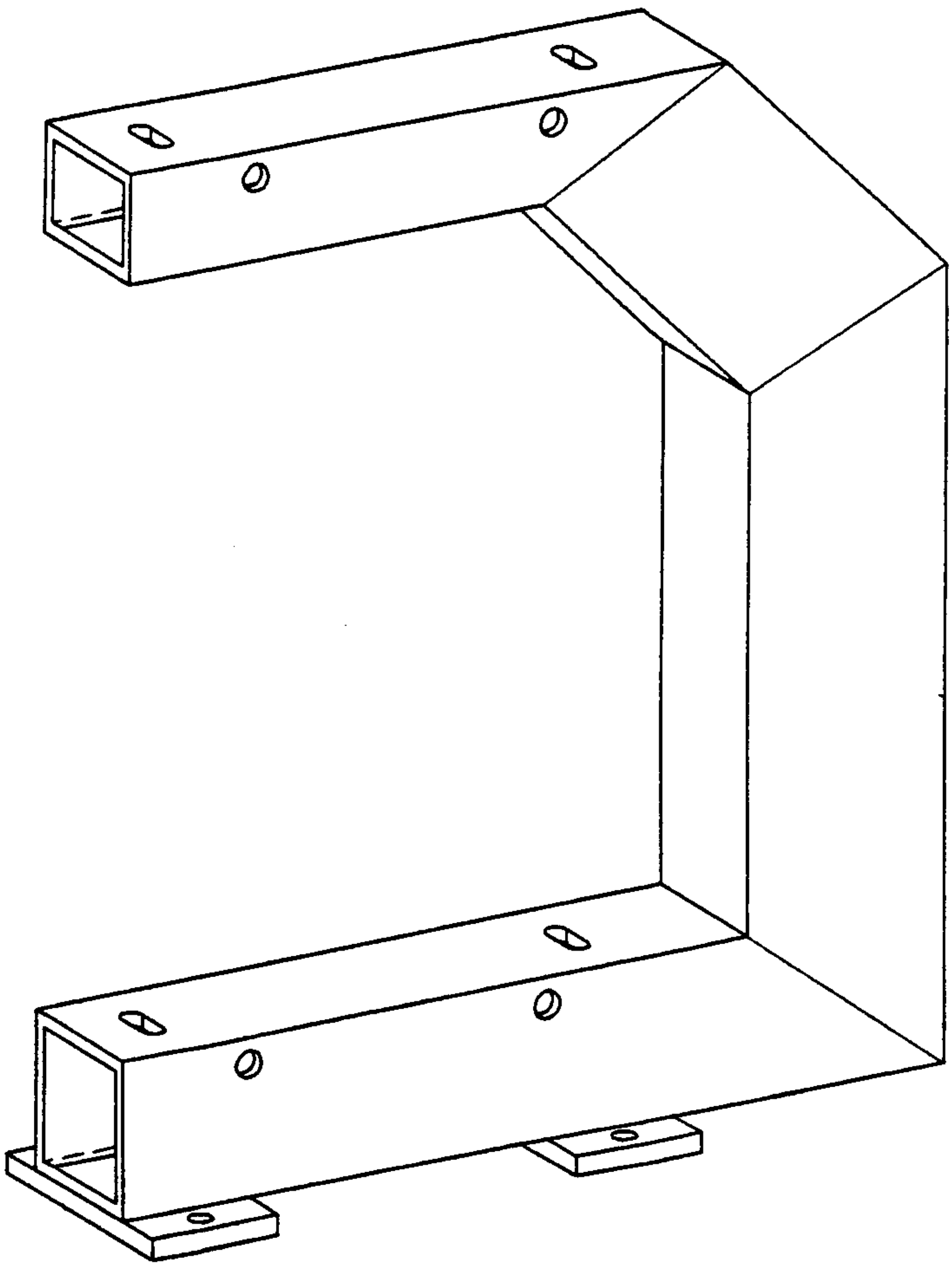
TITLE: SSC
JOB NO.: 85122
CLIENT: DOE
LOCATION:
DATE: 8/30/88
SUBJECT: MAGNET SUPPORT STUDY
BY: JK
SHEET 3 OF

CODE	DESCRIPTION	QUANTITY	UNIT ~~COST~~ MH	AMOUNT MH	TOTAL MH
	HANDLING				
	ASSUME 10'/LENGTH OF	4EA	.025	.1	
	TUBESTEEL TO CUTTING				
	POSITION FOR SUB ASSY	4EA	.083	.33	
	WELD				
	FOR FINAL FRAME WLD	2EA	.17	.33	
	MOUNTING PL. WELD	2EA	.083	.17	
	POSITION FOR DRILLING	1EA	.17	.17	
	TO PAINT BOOTH	1EA	.17	.17	
	TO/FROM CRATING	1EA	.17	.17	
	PACK & CRATE	1EA		.17	
	S/T			1.28	



SUPPORT FRAME

FIGURE B



SUPPORT - ISOMETRIC

FIGURE C

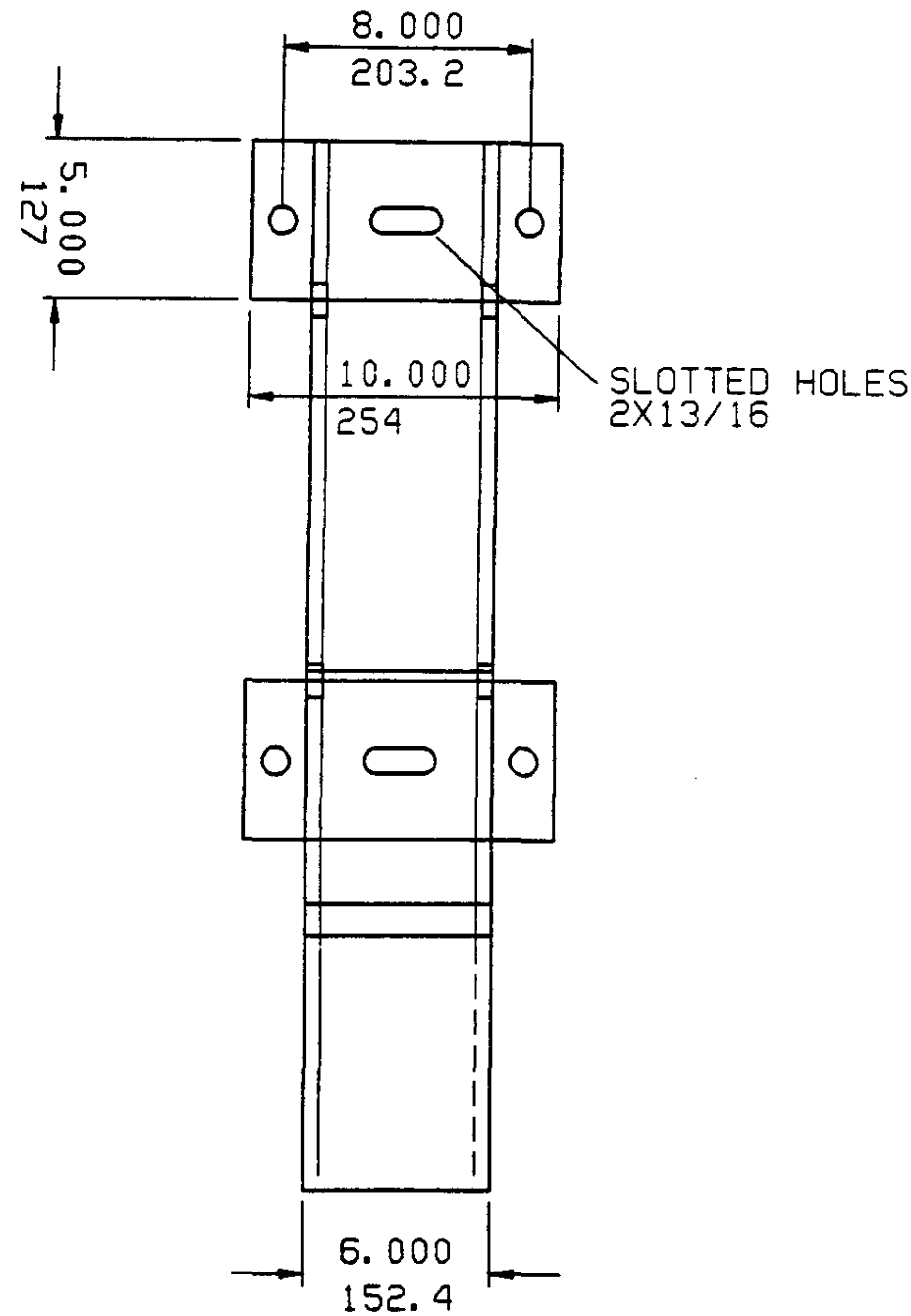
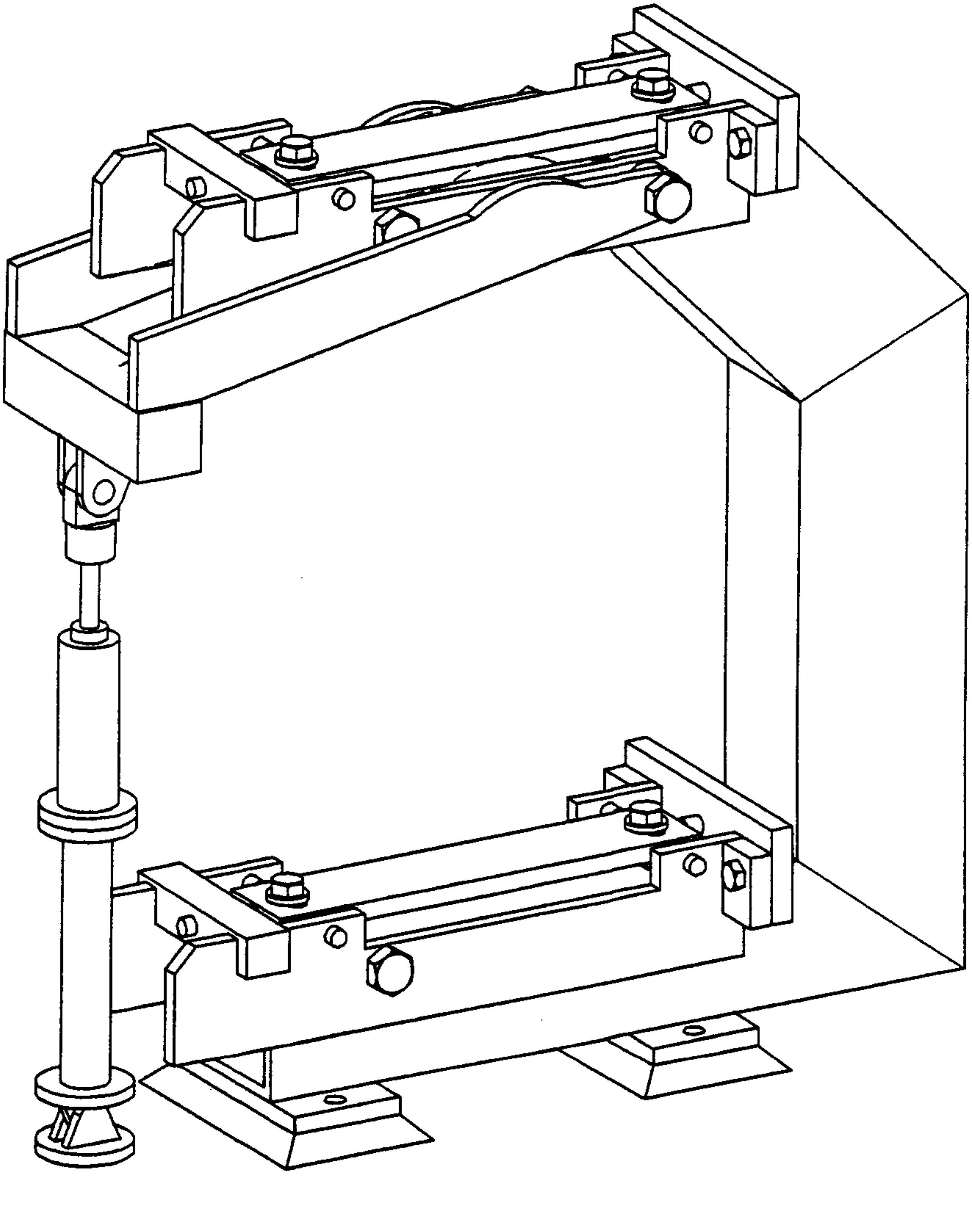


Figure D, SUPPORT - TOP VIEW

FIGURE D

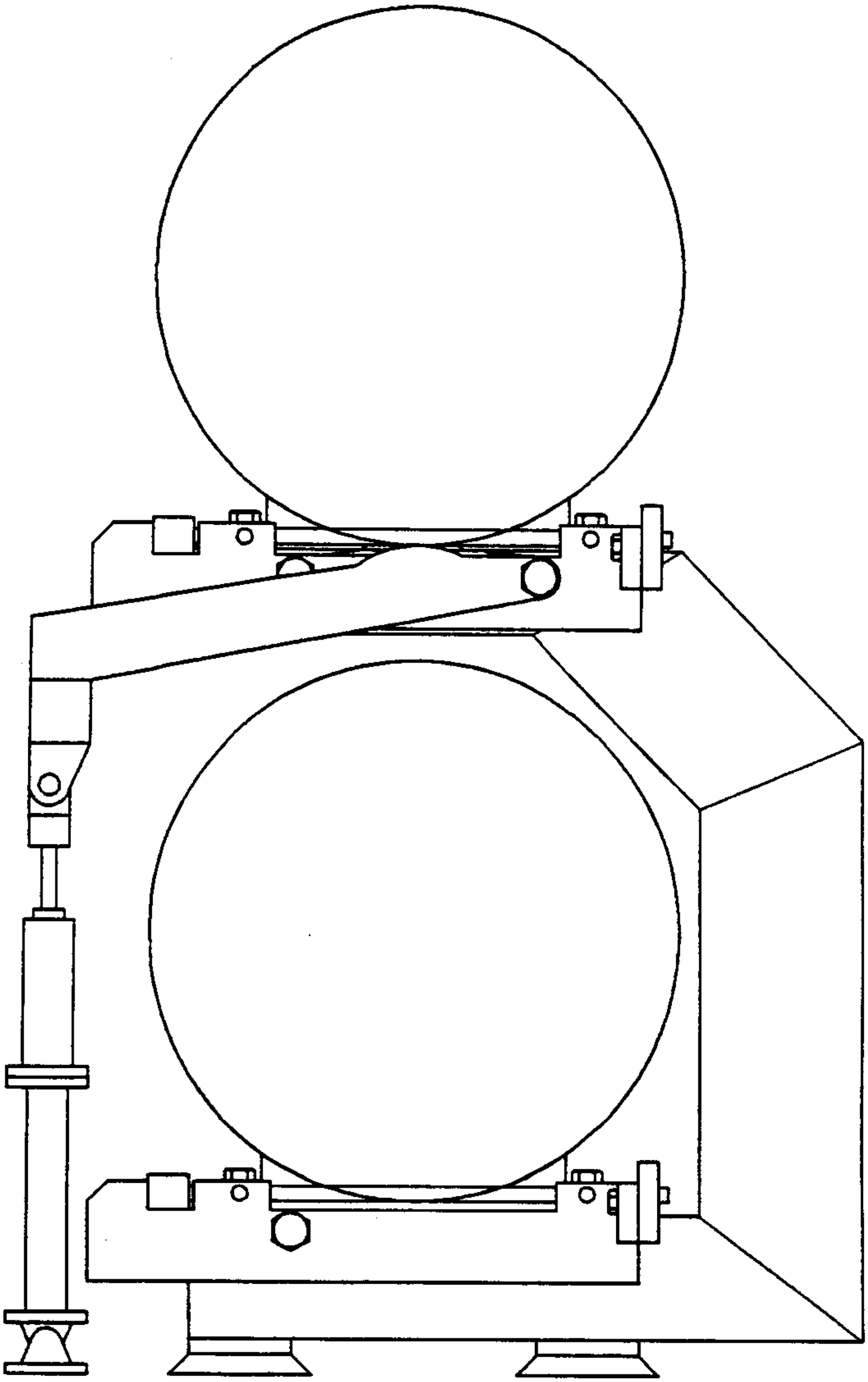
ALIGNMENT MECHANISM DESCRIPTION

In order to accurately adjust the alignment of the magnet a jacking mechanism was designed. The mechanism is shown in Figs. E - H. It is portable and mounts to the support frame with two bolts. The parts that mount on the frame are similar whether they are used for the upper or lower magnet. The hydraulic jacking mechanism used for the upper magnet requires only one hydraulic cylinder since there is adequate access to place the shims under the magnet when it is raised. The lower magnet requires two hydraulic cylinders mounted apart from each other in order to provide access to the magnet for shim placement. An area that will require further study is the contact point between the jacking lever and the magnet assembly. The contact area on the magnet is very small and will require reinforcement to accommodate the forces that the jacking procedure will cause.



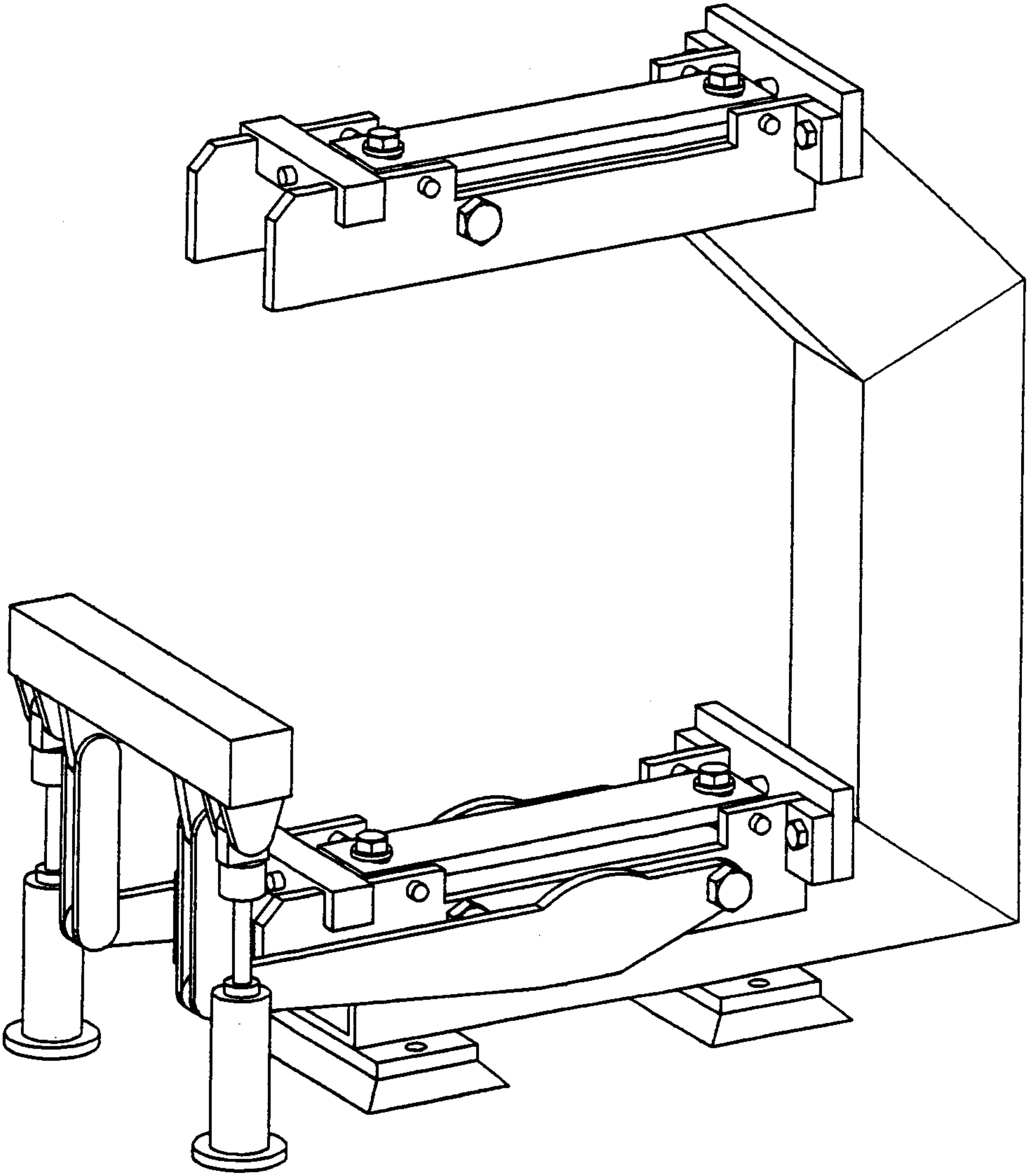
SUPPORT WITH UPPER JACK IN PLACE

FIGURE E



SUPPORT WITH UPPER JACK IN PLACE

FIGURE F



SUPPORT WITH LOWER JACK IN PLACE
FIGURE 6

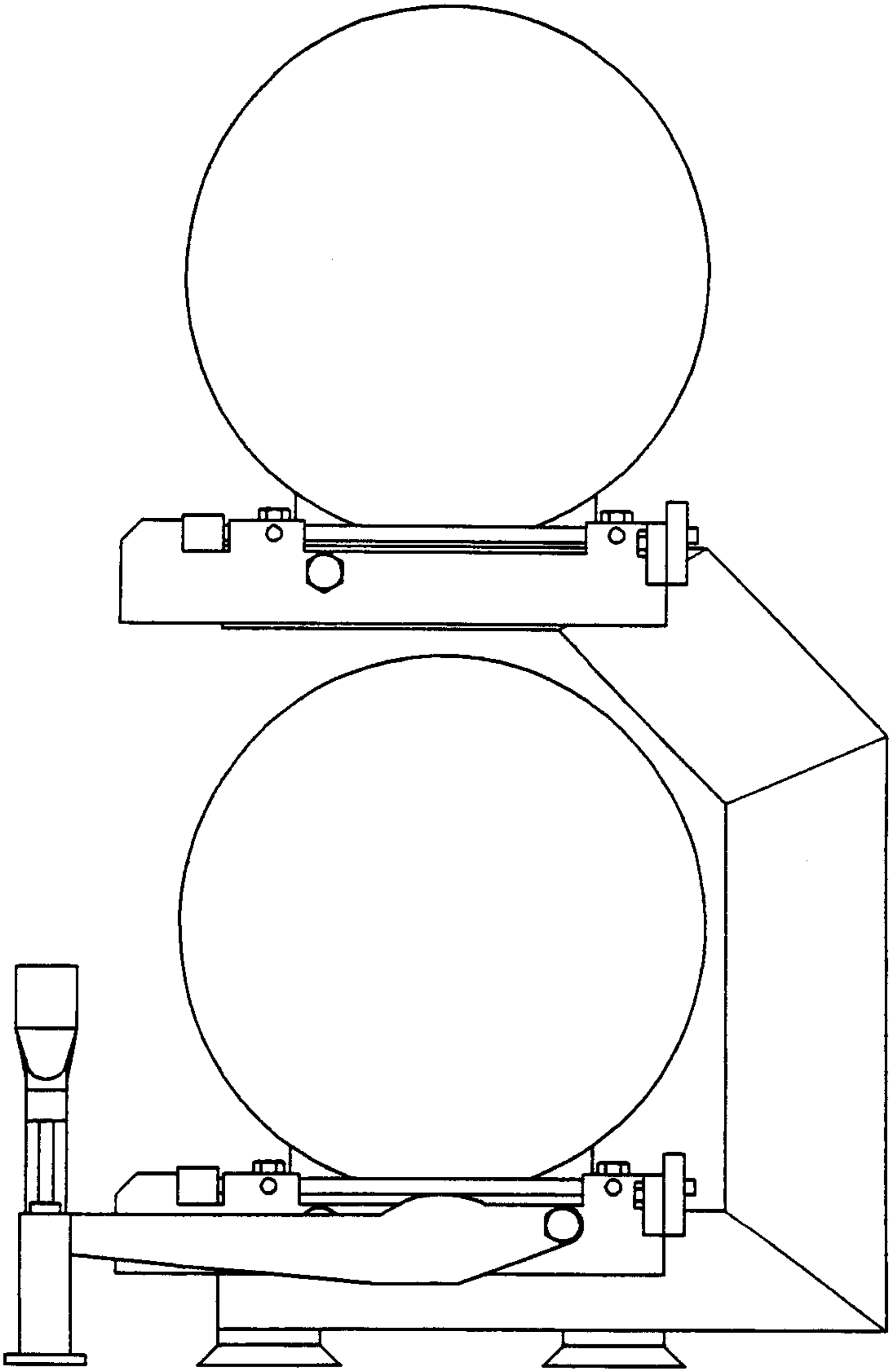


Figure H, SUPPORT WITH LOWER JACK IN PLACE