ELETTRA ALIGNMENT
(Preliminary)

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ABSTRACT

The Sincrotrone Trieste ELETTRA facility has been designed to provide users with high brightness photon beams over a wide range of photon energies (10eV-30keV) from its insertion devices in a low emittance 1.5-2GeV electron storage ring. Now it is under construction. For the magnet positioning a relative accuracy of one tenth of a millimeter and an absolute accuracy of two millimeters are envisaged. This report describes the ELETTRA alignment methods.

INTRODUCTION

The Sincrotrone Trieste Elettra facility has been designed to provide users with high brightness photon beams over a wide range of photon energies (10 eV-30 keV) from its insertion devices in a low emittance 1.5-2 GeV electron storage ring.

ELETTRA consists basically of three parts: Linac, transfer line and storage ring (See Fig. 1). The beam orbit of the storage ring is 3.9 meters above the linac axis. The beam is accelerated through the 100 meter long Linac to the full energy. Then it is bent horizontally three times and vertically twice by 101 meter long Transfer line to reach the inner side of the storage ring where then the injection takes place in the horizontal plane.

The storage ring is approximately circular in the shape and has a circumference of 260 meters. In order, to build a new state-of-the-art synchrotron light source the magnet components have to be aligned as precisely as possible for both high absolute accuracy and extreme relative accuracy. From the alignment point of view the quadrupoles are the most critical components. The bending magnets are combined function elements and therefore are critical too. Accelerator physics requires 0.1 mm relative transverse standard deviation σ for ELETTRA quadrupoles, sextupoles and bending magnets and 2 mm absolute accuracy for all the storage ring magnets.

1. ELETTRA GEODETIC NETWORK

In order to keep the Linac, the transfer line and the storage rings in correct position relative to each other, a minimum of four monuments M0, M1, M2 and M3 has to be fixed on the rock before the building construction starts. Two datum marks D1 and D2 have to be mounted on the tunnel floor before the tunnel is covered. The accuracy of monument positioning should be about 5 mm. The measurement accuracy of the monument center position should be less than +/- 1 mm. (see Fig. 2A)

The monument M1 is the origin of the coordinates at the center of the storage ring, The coordinate axis Y passes monument M0. The LINAC axis just passes the monument M3. The sights from M0 to M3 and from M1 to M2 should never be blocked. There are two monuments M4 and M5 on the reinforced concrete beam of the storage ring roof. The sights from monument M4 and M5 to all other four monuments should be kept free. Therefore, it is possible to check the positions of monuments M1 and M2 with respect to monument MO and M1 through monuments M4 and M5 when the need should arise. (see Fig. 28)

D3 is the double datum mark fixed in the flyover crossing between tunnels of the transfer line and the storage ring respectively. It consists of two marks D3a and D3b which are located at same horizontal positions and different levels. D3a is a mark fixed on the transfer tunnel floor. D3b is a reference hole fixed on the floor of the storage ring. The hole is vertically through whole the concrete between the storage ring tunnel and the transfer line tunnel. They are used to check both the horizontal and the vertical positions of the transfer line referring to the position of the storage ring.

2. REFERENCES OF LINAC

The Linac axis is determined by monument M3 and datum D1. The references V52-V59 are fixed on the floor (see Fig. 3). They are used to check deformation of the tunnel base in the long range.

The Linac alignment will be made by the LINAC constructor referring to monument M3 and Datum D1.

3. REFERENCES OF TRANSFER LINE (see Fig. 4)

The transfer line from Linac to the storage ring consists of 7 bending magnets and 30 quadrupole magnets. The transfer line axis is determined by D1, D2, D3 and the storage ring network. The common optical instruments such as Theodolite E2 and Precision Level N3 will be used. The reference V49-

V51 are fixed on the floor (see Fig, 4). They are also used to check the long range deformation of the tunnel base in long term too.

4. NETWORK OF THE STORAGE RING

There are 24 vertical reference points V1-V24 on the floor of the storage ring. Among them there are 6 vertical reference points V1, V5, V9, V13, V17 and V21 as check points. The elevations of the 6 check points are determined by using the Precision Level N3 in respect to the monument M1 through the holes of the wall of the storage ring tunnel. The elevations of other vertical references are measured with respect to the two adjacent check points. (see Fig. 5)

The two sockets Bi.1 and Bi.2, i=1 to 24, are on top of each bending magnet. There are in total 48 sockets used as the horizontal reference points. The 24 sockets Bi1 are chosen as the storage ring network. Among them there are 6 horizontal reference points B1.1, B5.1, B9.1, B13.1, B17.1 and B21.1 as check points for the horizontal position. (see Fig. 6)

5. PREPARATION OF THE COMPONENTS

There are two sockets as references on top of each components such as bending magnet, quadrupole, sextupole and so on. The positions of the sockets are adjusted with respect to the magnet field during field measurement.

6. ALIGNMENT OF THE BENDING MAGNETS

6.1 Mark the positions of the sockets of the bending magnets on the floor of the storage ring using Theodolite E2 and Mekometer ME5000.

The deviation of the marks should be less than 5 mm.

6.2 All the bending magnets will be installed on their positions roughly with respect to the floor marks in both the horizontal and the vertical directions.

6.3 The tilt of all the bending magnets will be measured by a bubble level and be adjusted within 0.05 mm/m.

6.4 The elevations of the bending magnets will be measured by a Precision Level WILD N3 with respect to the nearest vertical reference H1-H24 and will be adjusted.

6.5 The positions of the bending magnets, on which the sockets for check points are mounted, are adjusted to set the check point sockets at the right radial distances from monument M1. The tolerance of the distance is 0.5 mm.

6.6 All 48 distances and 48 angles shown in Fig. 7 will be measured.

6.7 Using the least squares adjustment method the corresponding residuals of all the measurements could be calculated. According to the Gaussian law of errors most of blunders can be found out, so some wrong measurements can be removed from the computation. The adjustment computation could be repeated once.

6.8 The standard deviation of the network measurements should be less than 0.08 mm.

6.9 Finally, the horizontal adjustment of the bending sockets Bi.1 can be obtained by comparing their existing and ideal positions using the computer program.

6.10 The positions of the sockets Bi.1 can be adjusted according to the results of the adjustment computation.

6.11 The yaw angles of the bending magnets will be adjusted to their ideal values whereas the positions of the sockets Bi.1 are maintained (Fig. 8).

6.12 The procedures from 6.3 to 6.11 will be repeated until the horizontal standard error of the positions of the sockets Bi.1 is less than 0.08 mm.

6.13 The distances from monument M1 to the 6 horizontal check points will be measured by the Mekometer ME5000 to make sure that the errors of these distances are less than 1 mm.

7. ALIGNMENT OF ALL COMPONENTS IN THE STRAIGHT SECTIONS

Alignment of the components in the straight sections of the storage ring will be done individually after the positions of the bending magnets has been adjusted.

There is one bending magnet socket at the ends of each straight section of the storage ring. The 2 or 3 component groups of one straight section will be aligned from the two adjacent bending sockets in the following way:

7.1 The tilt of the components of the straight section will be measured by a bubble level and be adjusted.

7.2 The longitudinal positions of the components of the straight sections will be determined by length measurements.

7.3 The transverse positions of the components of the straight sections will be measured by the Theodolite E2 and Precision Level N3 and then be adjusted.

7.4 The process from 7.1 to 7.3 will be repeated until the transverse deviations are less than 0.03 mm and the tilt less than 0.05 mm/m.

The process 7.1-7.4 will be repeated until all 24 sections have been finished.

8. ALIGNING THE INSERTION DEVICES -- UNDULATOR

The insertion devices will be put in their positions after the ELETTRA commissioning.

There are two kind of insertion devices, undulators and wigglers. Since the design of the frames is the same, their alignment method is similar. For example each set of the undulator consists of three frames. Each frame carries two main sockets on top of the beam axis, and two auxiliary sockets are adjusted to be parallel with the two main sockets. The three frames will be aligned through the six auxiliary sockets. The positions of the complete undulator will be fixed through the two main sockets which are located on the ends of the set. (see Fig. 9)

9. TOLERANCE DISTRIBUTION

The alignment of the quadrupoles is the most critical one. Accelerator physics requires a value of 0.1 mm transverse standard deviation $\sigma(Q)$ for the ELETTRA quadrupole.

In our case there are at least four components which affect $\sigma(Q)$ as explained in the following formula.

$$\sigma(Q)=\sqrt{\sigma^2(1)+\sigma^2(2)+\sigma^2(3)+\sigma^2(4)}$$

In order to achieve the accuracy of $\sigma(Q)=0.1$ mm we expect

standard deviation
between socket and magnet center $\sigma(1)=0.03$ mm,

standard deviation effected by tilt $\sigma(2)=0.025$ mm,

standard deviation
between network and quadrupole $\sigma(3)=0.03$ mm

and
standard deviation of the network $\sigma(4)=0.08$ mm.

ACKNOWLEDGEMENT

The author gratefully thanks all the alignment experts F.Löffler (DESY), W.Schwarz (DESY), M.Maroud (CERN), E.Menant (CERN), J.P.Quesnel (CERN), D.Roux (ESRF) and T.Lauritzen (ALS) for their useful discussions, suggestions and private communications. The author would like to thank A. Wrulich for his advice on the machine side and all colleagues of Technical Office and Assembly Office for their cooperation.

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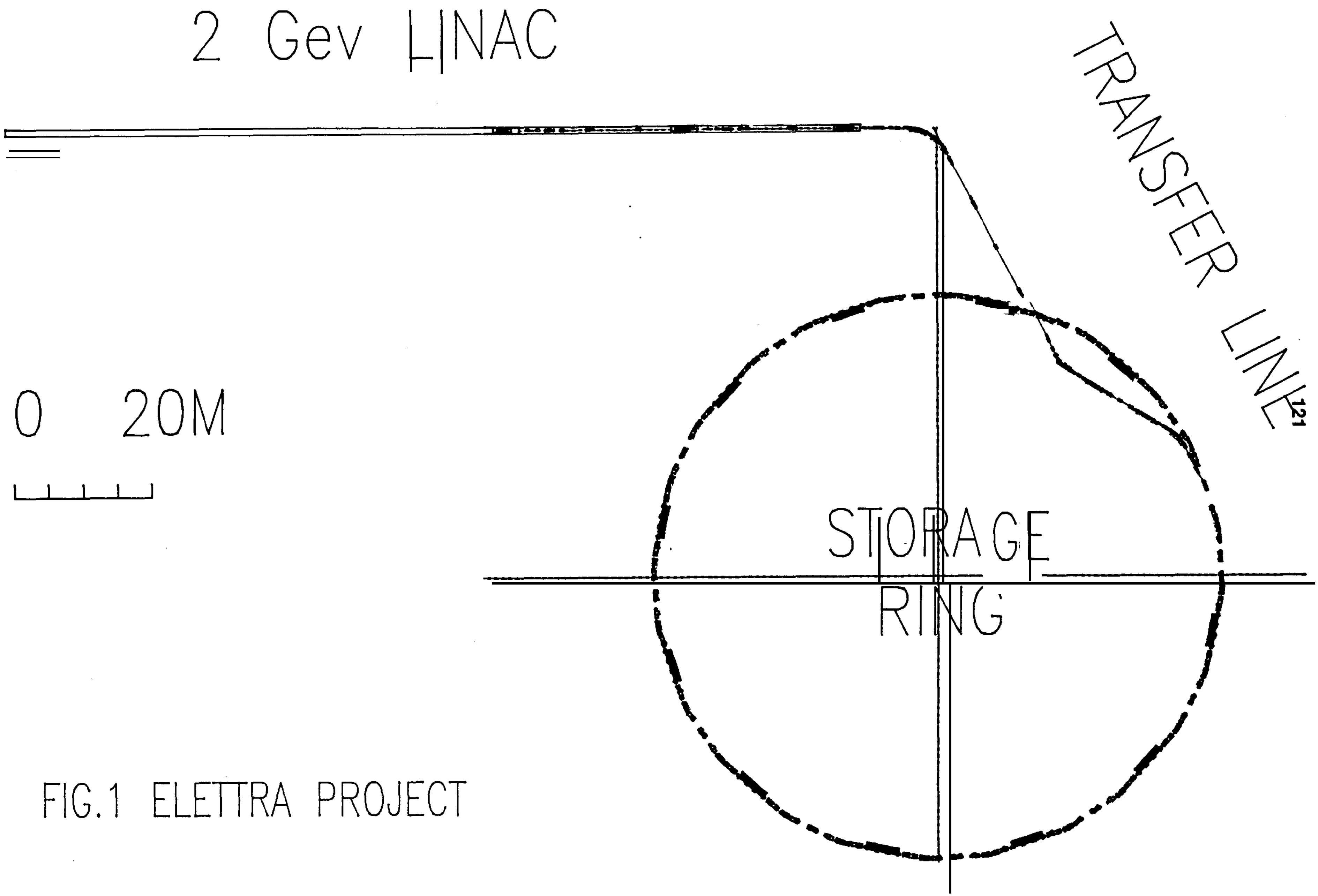

FIG.1 ELETTRA PROJECT

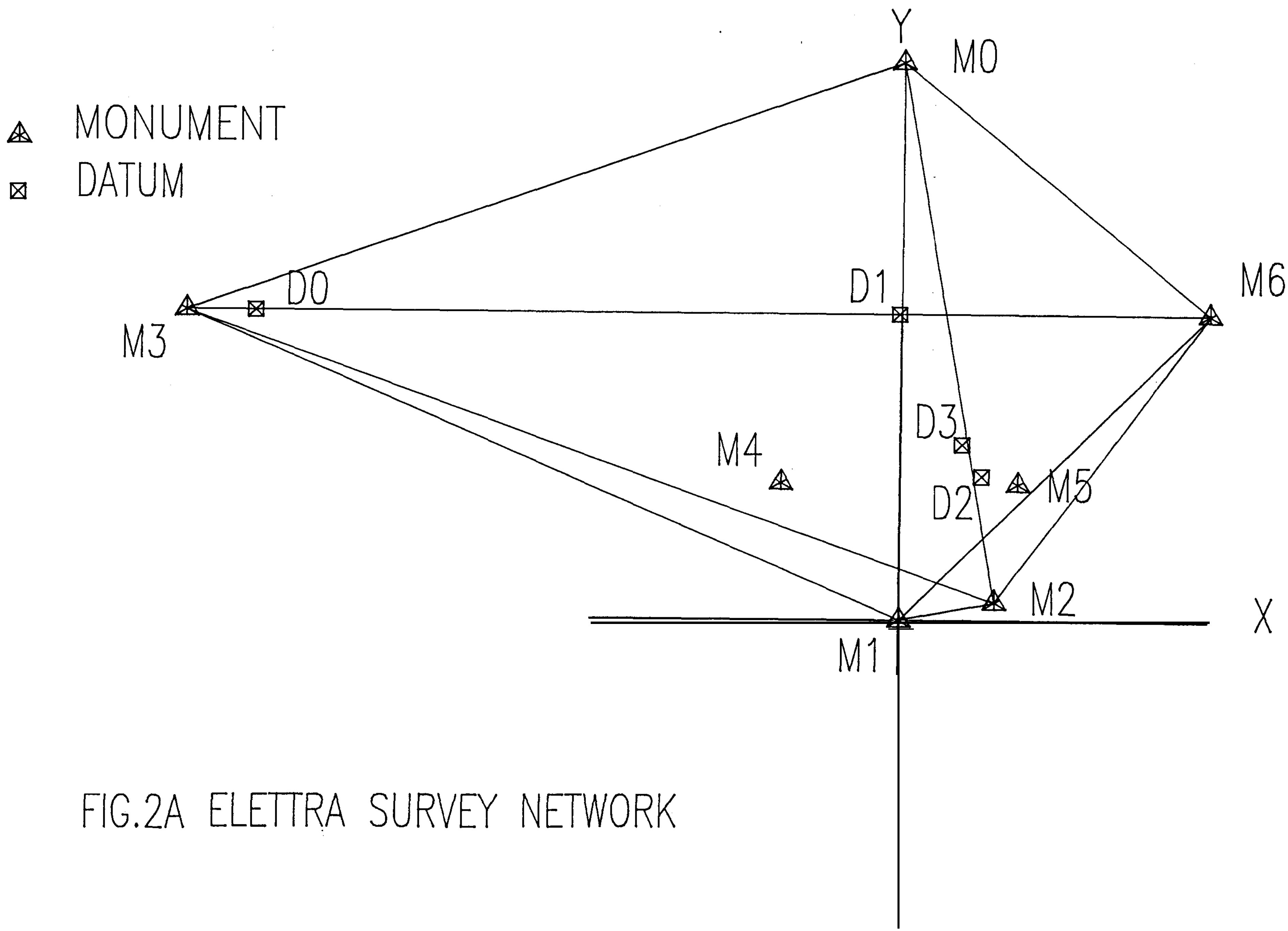

FIG.2A ELETTRA SURVEY NETWORK

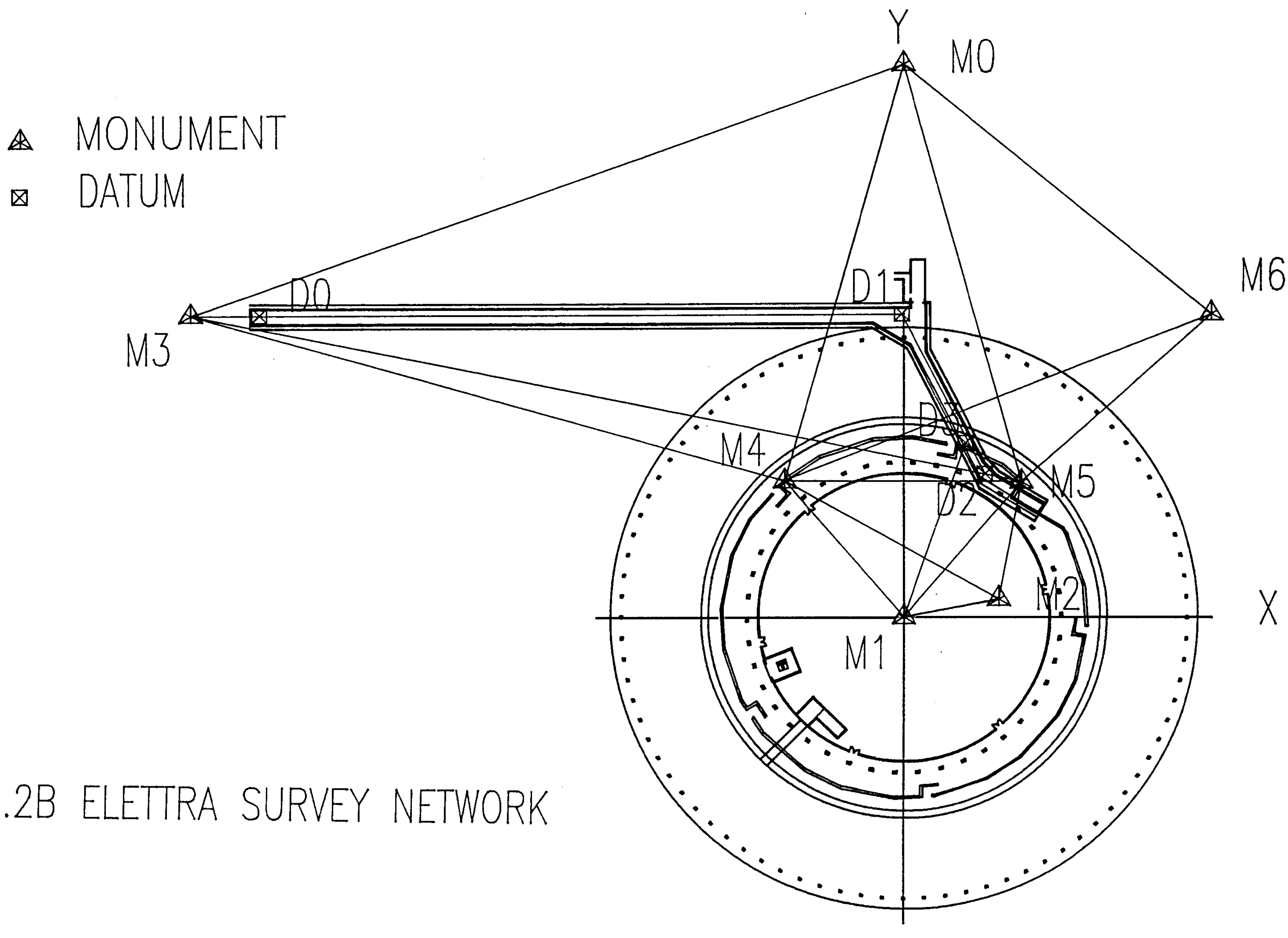

FIG.2B ELETTRA SURVEY NETWORK

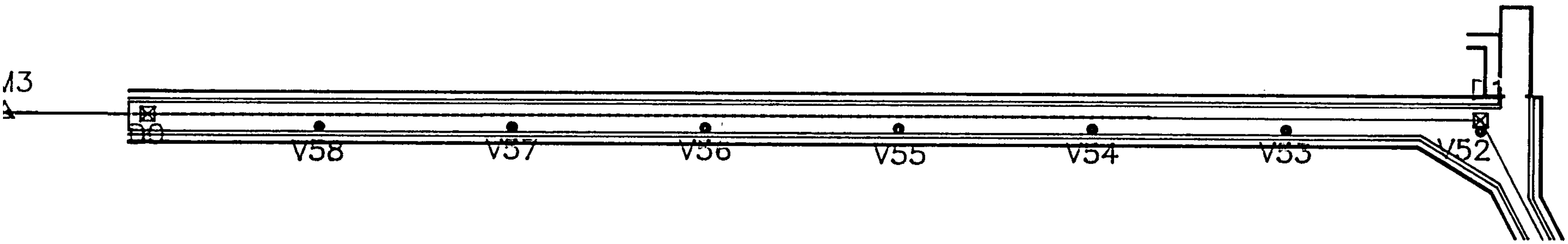

FIG.3 LINAC VERTICAL REFERENCES

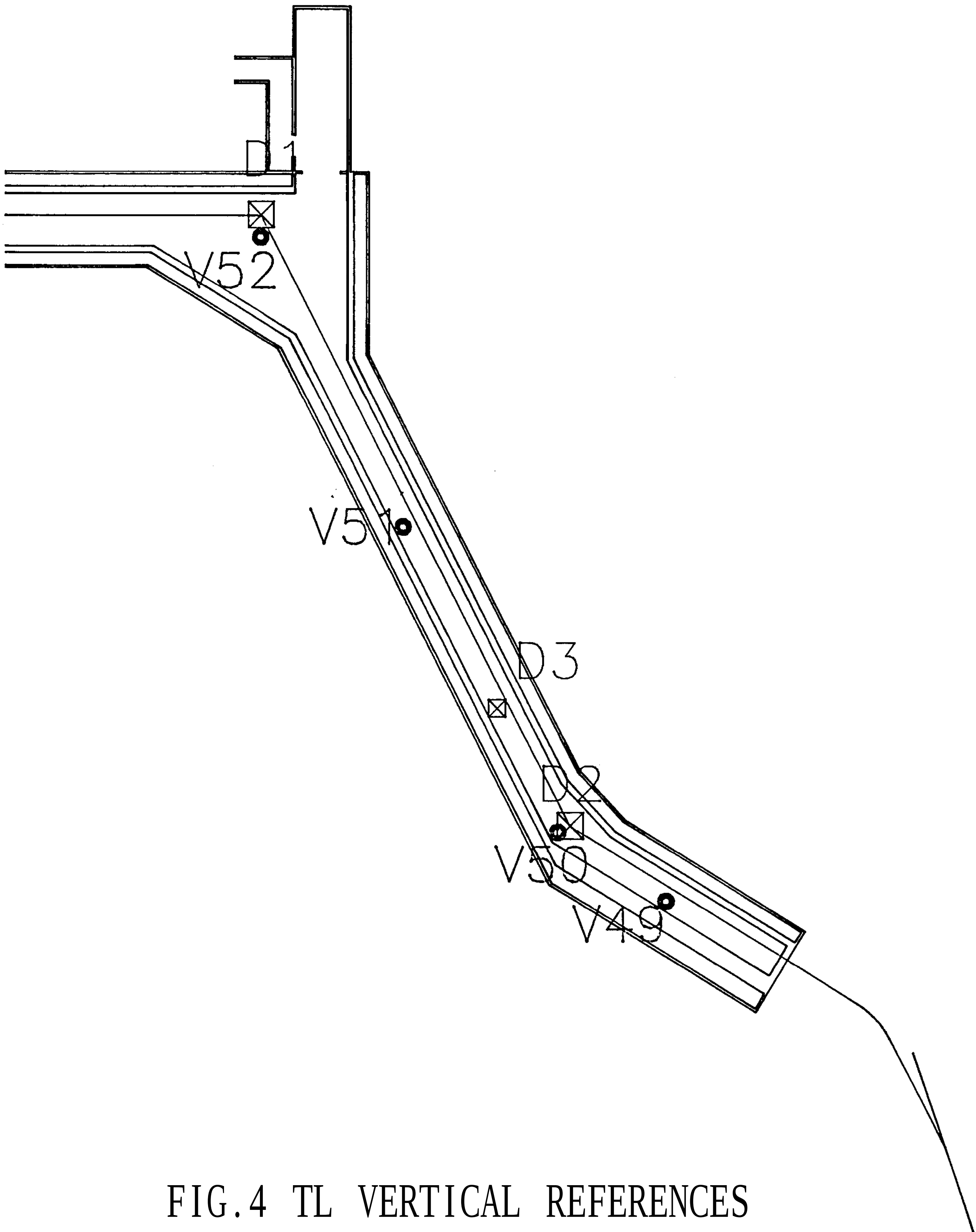

FIG.4 TL VERTICAL REFERENCES

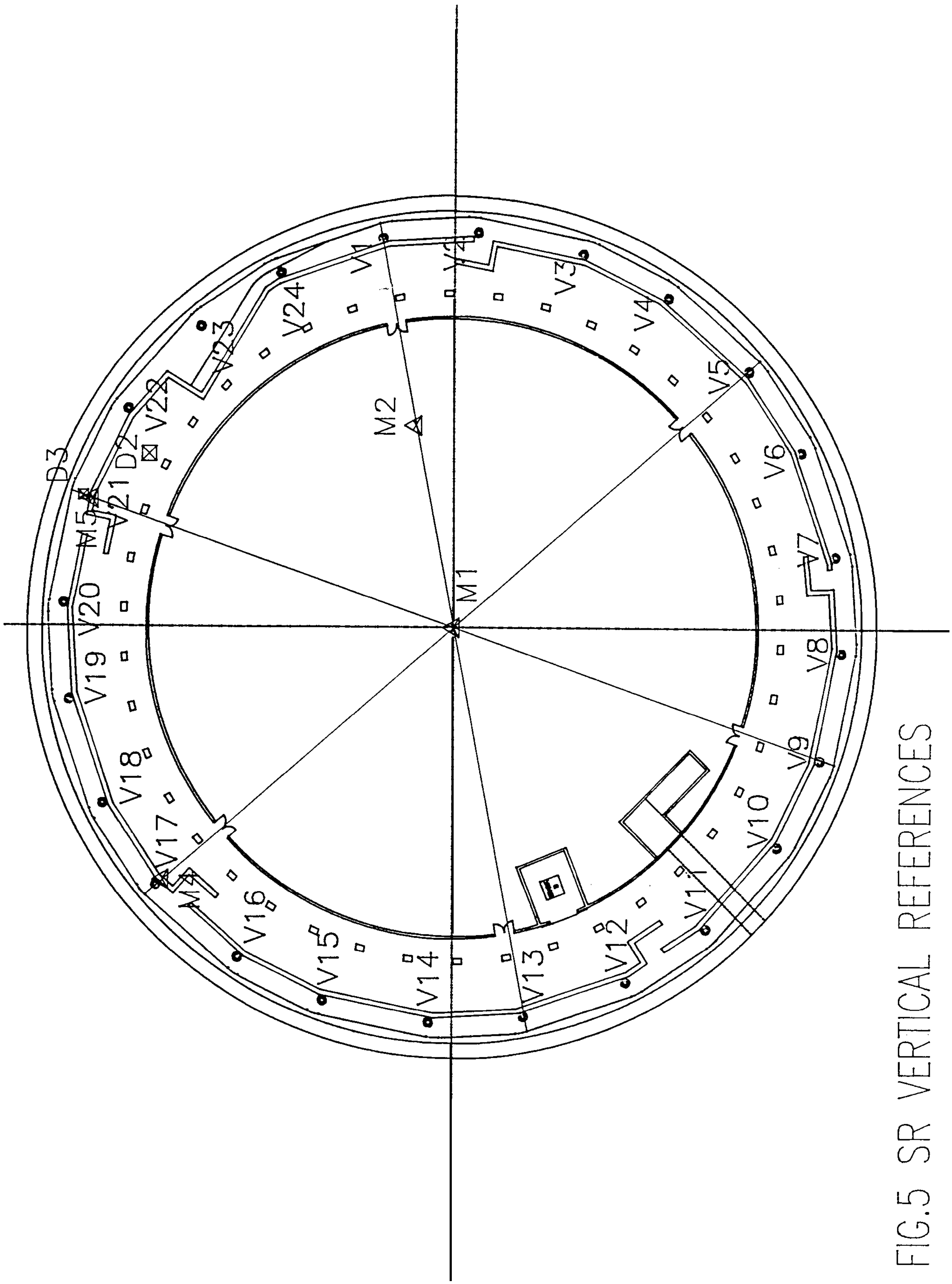

FIG.5 SR VERTICAL REFERENCES

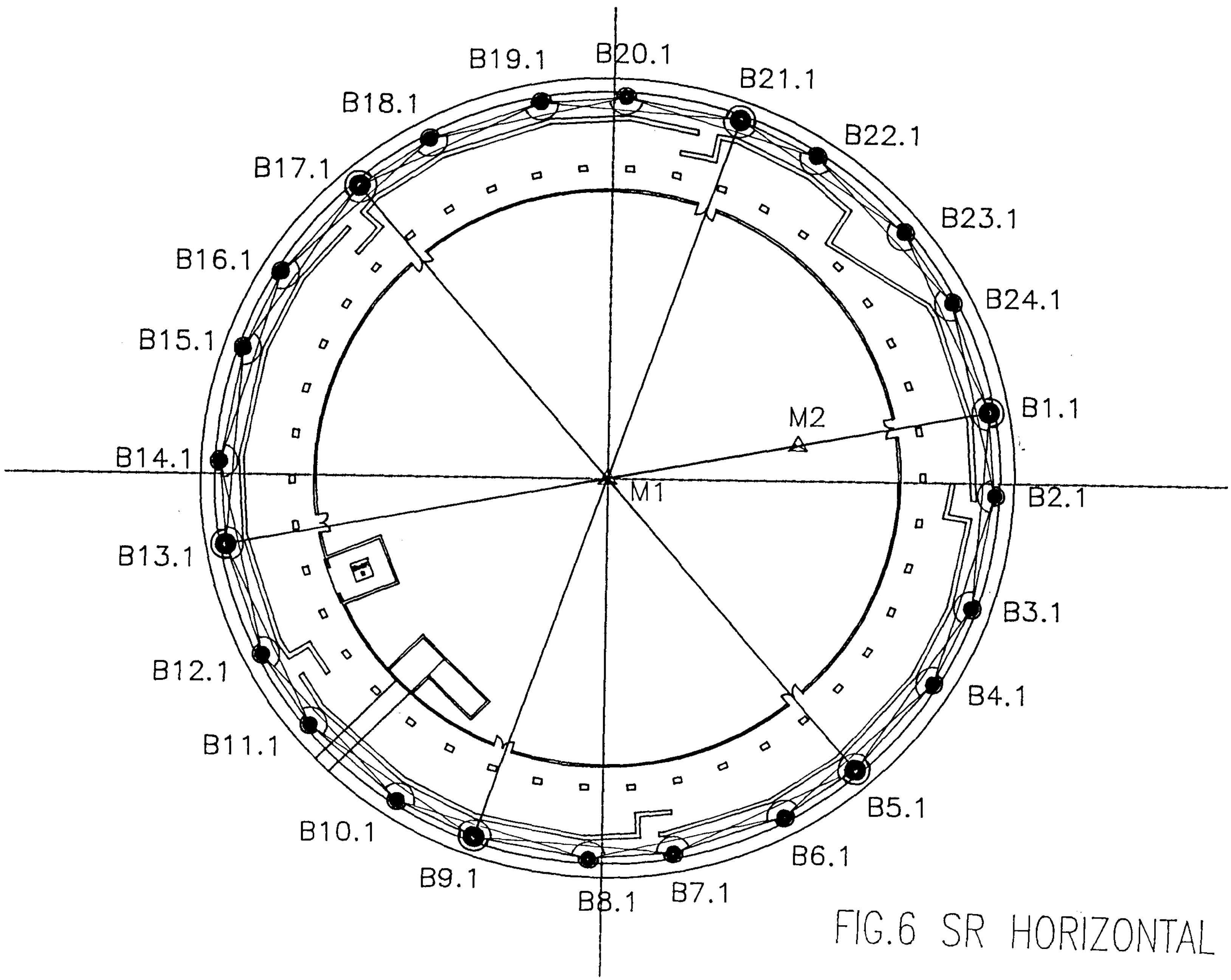

FIG.6 SR HORIZONTAL NETWORK

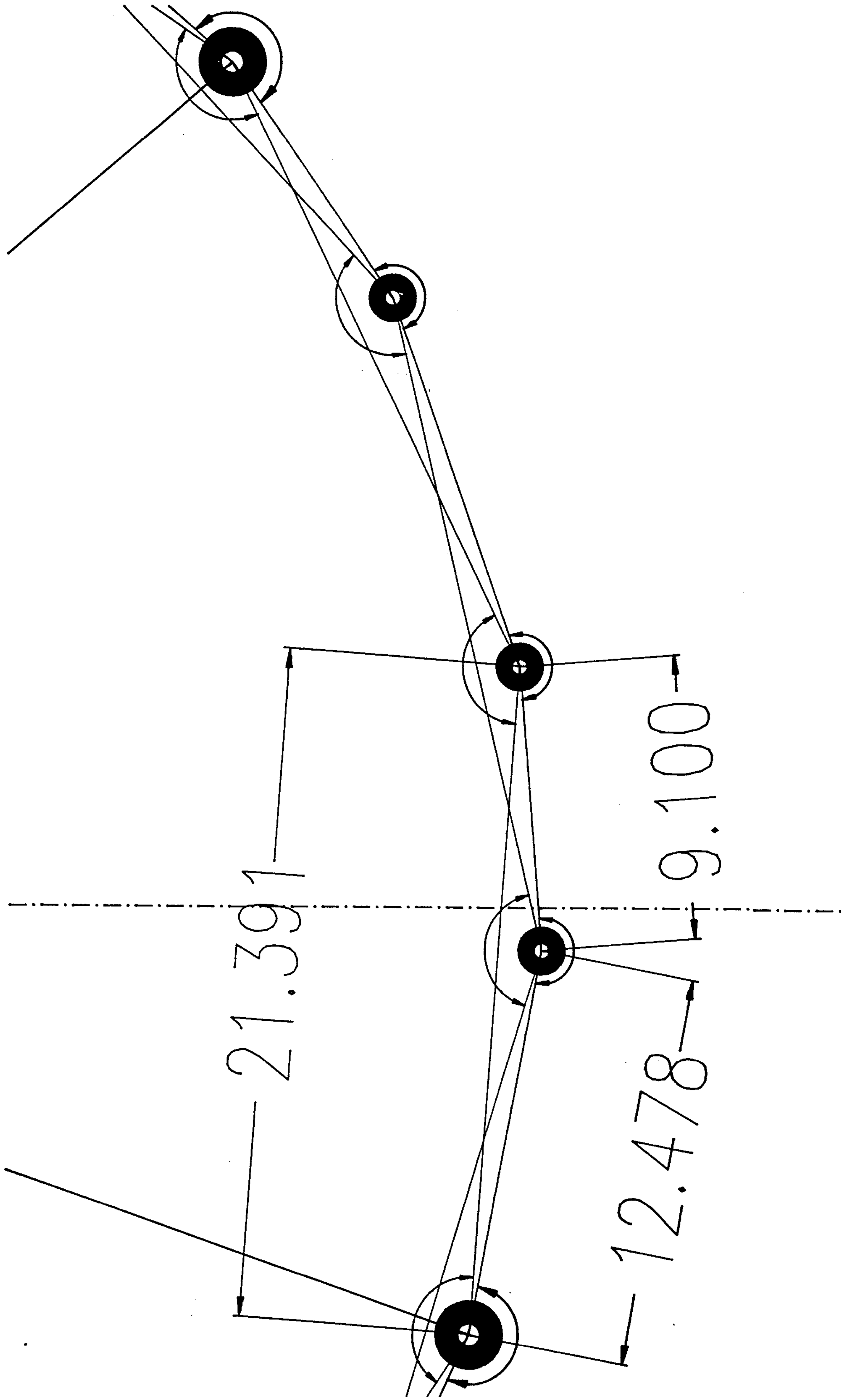

FIG.7 MEASURED DISTANCES AND ANGLES

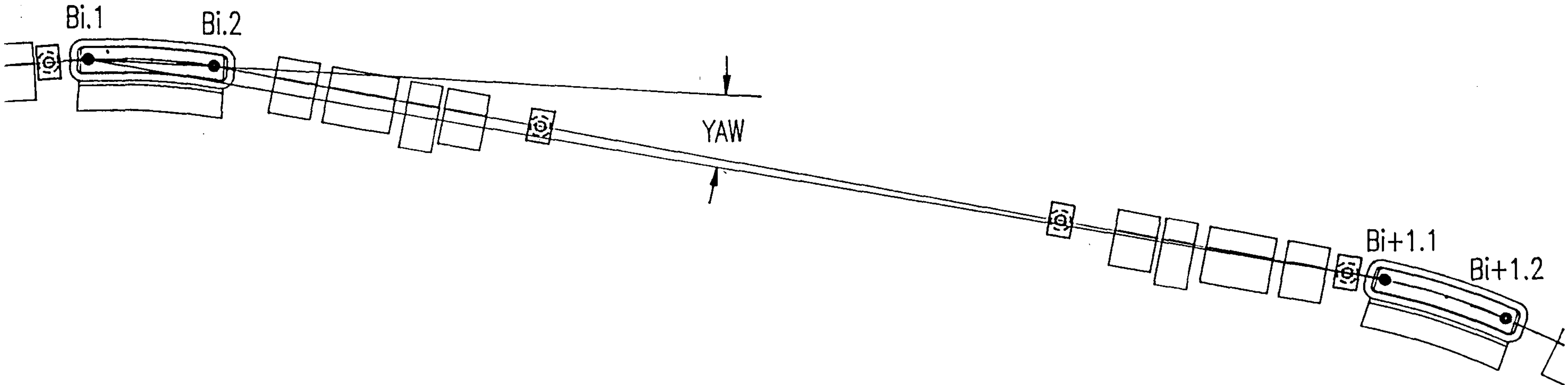

FIG.8 YAW ANGLE FOR THE BENDING MAGNET

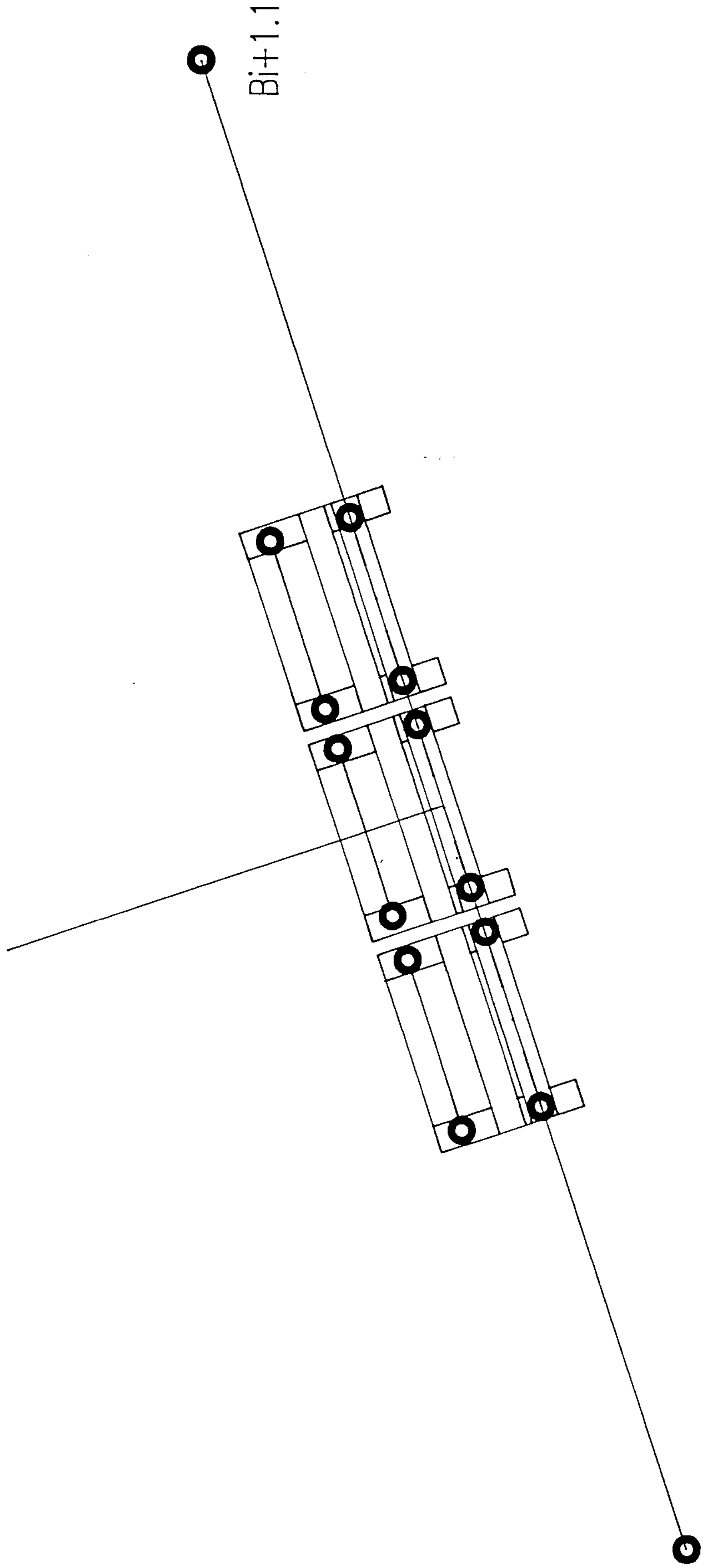

FIG.9 INSERTION DEVICE ALIGNMENT