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MDT Chamber Precision Assembly

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1 Introduction

The Monitored Drift Tubes (MDT) concept for the ATLAS muon spectrometer is based on the high precision positioning of the tubes with respect to fiducial marks on the chamber and the positioning of the wires inside the tubes by means of wire locators.

The precision aimed at is 20μm.

In order to achieve such a precision two conditions have to be fullfilled:

1. Tubes with adequate tolerances are needed (the present specifications are [1]: outer diameter = 30 ± 0.015 mm , wall thickness = $400 \pm 20\mu$m , eccentricity $\leq 10\mu$m)

2. The tubes must be positioned with precision and the build up of the errors must be limited with the use of an external precision jigging to position the tubes.

The assembly procedure and the design of suitable jiggings are being studied intensively.

Two basic approaches have been proposed, one by the Seattle group and one by the Nikhef group.

They have been described in various presentations and notes.

Apart from the technical details, not yet finalized, there is a conceptual difference between the two proposals.

In the Seattle scheme, the position is controlled by the jigging only for the external tubes of a multilayer, while the internal tubes are positioned by the contact of the neighbouring tubes.

In the Nikhef scheme, the idea is to position each layer of tubes by means of the jigging, leaving room between neighbouring tubes, so that they never touch each other, to avoid interferences and incontrollable deformations.

A common feature of the assembly procedure is that, in both cases, multilayers are prepared first, and then glued to the spacer.

The two approaches are complementary, one aiming at the ultimate precision, the other at a somewhat "simpler" assembly procedure.

In Frascati, both approaches have been considered in view of the laboratory prototype construction plans. Studies of various aspects, conceptual and/or technical, have been made. They are reported in ATLAS-Frascati Internal Technical Notes [2-6].

In this Note, an assembly scheme is presented, which, in our view, represents a way of implementing the Nikhef approach.

2 Errors in tube positioning

Considerations concerning the errors in tube positioning and their propagation led us to prefer the assembly scheme presented in the following.

The first layer is the best positioned in a multilayer, beeing directly controlled by means of the jigging.

If the precision of the jigging is, as it must be, much better than the tube tolerances, the precision achieved in the first layer is the best one, only due to the fluctuation of the individual tube parameters.

If the positioning of the successive layers is based on laying the next layer on top of the previous one, a build up of the errors takes place, which deteriorates the achievable precision.

This effect has been studied with a MonteCarlo simulation program described in ref [4].

The results in the case of round tubes with a dispersion of the radious, $\sigma = 5\,\mu$m, are reported in Table 1 [4]. A worsening of the precision in successive layers is evident.

The use of precision combs on the top layer may help in reducing, in part, such an effect. However it is not clear to us to which extent this procedure would be effective.

It has also to be taken into account that, even for large spacing of the tubes in the first layer, interferences can occur between tubes in the successive layers, as reported in Table 2 [4]. This causes a worsening of the precision and/or a deformation of the tubes, which implies an increased difficulty in the assembly.

More studies are beeing carried out to estimate the error propagation in the case of deviation of the tubes from the perfect circular shape. A larger effect can be expected.

It is clear that the best precision would be achieved if one could control the positioning of the tubes in each layer to the same extent as in the case of the first layer.

The main point is how to realize that. In the following a method is described which aims at achieving this goal.

3 The basic concept of the assembly

The master base of the jigging locates in the best way one layer of tubes. If we could freeze the relative positions of the tubes in that layer, as determined by the precision jigging, and rigidly displace the whole layer by precisely controlled amounts in the two directions perpendicular and parallel to the jigging plane, it would be possible to put another layer of tubes on the jigging and to position precisely, as a whole, the previous layer with respect to the jigging and therefore with respect to the new layer.

In that case, the following results would be achieved:

1. the precision of the first layer, as given by the jigging, would be maintained;
2. the new layer, sitting directly on the jigging, would have its precision determined by the jigging only and would not depend on the precision of the previous layer;
3. the relative position of the two layers would be precisely controlled.

The basic idea of the assembly method presented here is that by glueing onto the spacer a monolayer, as it is positioned on the jigging base, we "freeze" it. As a consequence of this we can precisely displace it by displacing the spacer+monolayer with the aid of a supplementary jigging: then we can proceed by putting a new layer on the jigging base and glueing it onto the spacer+previous layer.

The operation can be repeated until the required number of layers in a multilayer is complete.

At that point, the spacer+multilayer is turned over and layers of tubes are glued on the other side of the spacer in the same way.

The described assembly procedure produces directly a complete chamber (two multilayers glued on the spacer).

The spacer is used in an essential way during the assembly, in order to guarantee that the initial precision of the monolayer is preserved and in order to allow for precise positioning of the successive layers. In this way some spacing between tubes can be kept not only in the direction parallel to the jigging base plane but also in the perpendicular direction, avoiding any interference and deformation of the tubes.

The possibility to realize the described procedure must be studied by constructing a prototype.

The point concerning how the tubes are kept in close contact with the jigging all along their lenght is a delicate one.

The effect of tube sagging, due to gravity, in between the zones glued to the spacer, when the spacer is raised to insert a new layer, has also to be taken into account. It must be observed, however, that the extreme precision is needed only in correspondence of the wire locators, while it can be relaxed at the $\sigma = 100\ \mu m$ level for the rest of the lenght of the tubes.

The application of the assembly method described above for the construction of a prototype is discussed in the following and detailed drawings are showed.

4 Plans for the construction of a prototype

A prototype of an operational chamber with two multilayers of 4×16 wired [7,8] tubes on each side of a spacer, and a tube lenght of 80 cm is planned to be built in Frascati .The tubes will not be in contact, but an average spacing of 50 μm will be left between any pair of neighbouring tubes in the same layer or in successive layers . This spacing is enough to avoid any interference and, at the same time, is well below the $\sigma = 100\ \mu m$ level on the wall positioning precision.

The resulting multilayer structure is shown in FIG. 1.

The jigging base is a flat granite table.

Three "combs" are layed down on the reference surface of the table, to position at the required spacing the tubes of a monolayer, at the two ends and in the middle.

The combs could be realized in many ways. The way exploited here is to make use of very precise rods, layed down on a table, in close contact between them and positioned against a vertical precise surface [4]. In FIG. 1 the rod "comb" is represented as the first layer of circles.

The FIG. 2 - 13 show some views of the successive phases of the assembly.

The spacer - without or with layers glued on - is displaced by means of precise supports, both in the vertical and in the horizontal direction, as needed from layer to layer.

Once one multilayer is completed, the spacer is turned over and the operation is repeated for the second multilayer of the chamber. The reference is taken from the same side of the jigging on the same side of the spacer.

In this concept, the precision required to the spacer is limited (assumed here $\sim$0.5 mm).

The ultimate precision needed in the assembly is obtained from the jigging.

5 Conclusions

The ultimate assembly precision allowed by the tube tolerances can be achieved only if each layer can be positioned independently from the others, so that no build up of errors takes place.

Such a positioning could be less straightforward than just positioning the external tubes of a multilayer.

The assembly concept illustrated here is based on the idea that the control of the position of the monolayers by the jigging can be achieved if use is made of the spacer to hold and displace the monolayer. more easily than by trying to space two monolayers in a duolayer assembly.

The feasibility of the scheme presented in this note has to be explored by further analysis and mostly by prototyping work.

References

[1] ATLAS Technical Proposal

[2] B. Dulach . *Produzione di camere a muoni.*
ATLAS-Frascati Internal Technical Note 001.

[3] S. Cerioni, B. Dulach. *Rough Considerations about jigging tolerances* .
ATLAS-Frascati Internal Technical Note 002.

[4] M. Curatolo, B. Esposito, *A Monte Carlo study of the propagation of the positioning error in a multilayer of tubes.*
ATLAS-Frascati Internal Technical Note 003.

[5] A. Ceccarelli. S. Cerioni. B. Dulach. B. Esposito. *Precision rods for tube positioning,*
ATLAS-Frascati Internal Technical Note 005 (In preparation).

[6] R. Bonini, *Studi di metodi di incollaggio dei tubi delle camere MDT di ATLAS.*
ATLAS-Frascati Internal Technical Note 006 (In preparation).

[7] R. Bonini. C. Capoccia. M. Curatolo. B. Esposito. M. Meli. L. Passamonti. V. Russo. *Tube end-plugs for the MDT chambers*
ATLAS-Frascati Internal Technical Note 007 (In preparation).

[8] R. Bonini. M. Meli. *Attrezzatura pneumatica per il 'crimpaggio' meccanico dei tubi*
ATLAS-Frascati Internal Technical Note 008 (In preparation).

Table 1

Rms of the distribution of the displacement of the tubes from the nominal position (1000 multilayers simulated)

SIGMA = 5 microns DJ = 30.140 mm

LAYER #	SIGX [microns]	SIGY [microns]
1	-	5.8
2	14.0	10.0
3	19.7	12.8
4	24.0	15.1

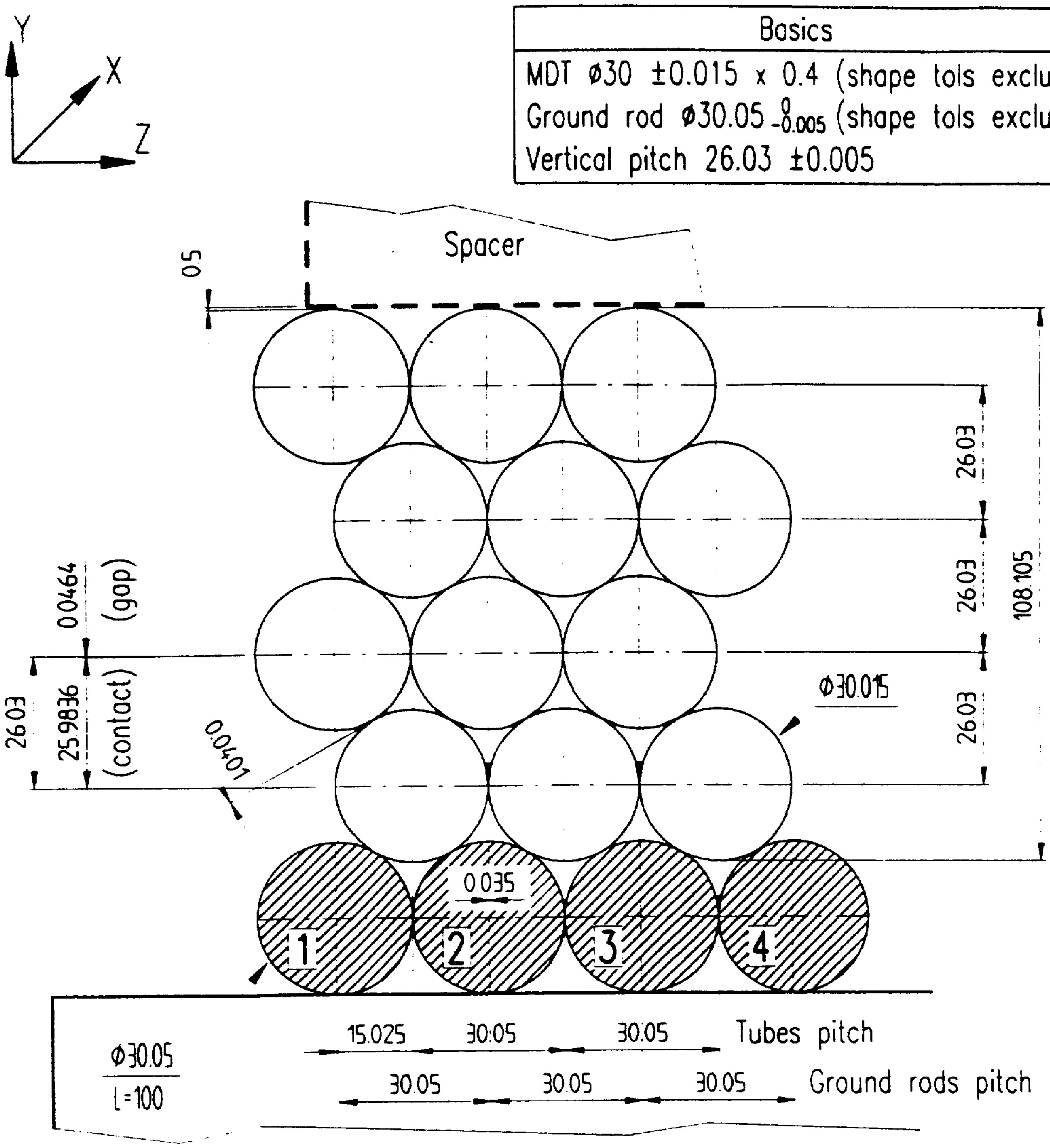
Table 2

Number of 'interfering' tubes (for 1000 multilayers)

SIGMA = 5 microns

lay #	DJ=30.060 mm	DJ=30.100 mm	DJ=30.140 mm
2	425	0	0
3	2106	42	0
4	3812	255	4

Basics
MDT Ø30 ±0.015 x 0.4 (shape tols excluded)
Ground rod Ø30.05 $^{0}_{-0.005}$ (shape tols excluded)
Vertical pitch 26.03 ±0.005



MAX/MIN Glue gaps (Worse cases)

MIN Gap (Z) = Min rods pitch − Max tube diam
= (30.05 − 0.005) − (30.015) = 0.030 mm

MAX Gap (Z) = Max rods pitch − Min tube diam
= (30.05) − (29.985) = 0.065 mm

MIN Gap (Y) = Min rods pitch Min vertical pitch Max tube diam
= 30.045 26.025 30.015 = 0.034 mm

MAX Gap (Y) = Max rods pitch Max vertical pitch Min tube diam
= 30.05 26.035 29.985 = 0.074 mm

Fig.1 – Multilayer structure

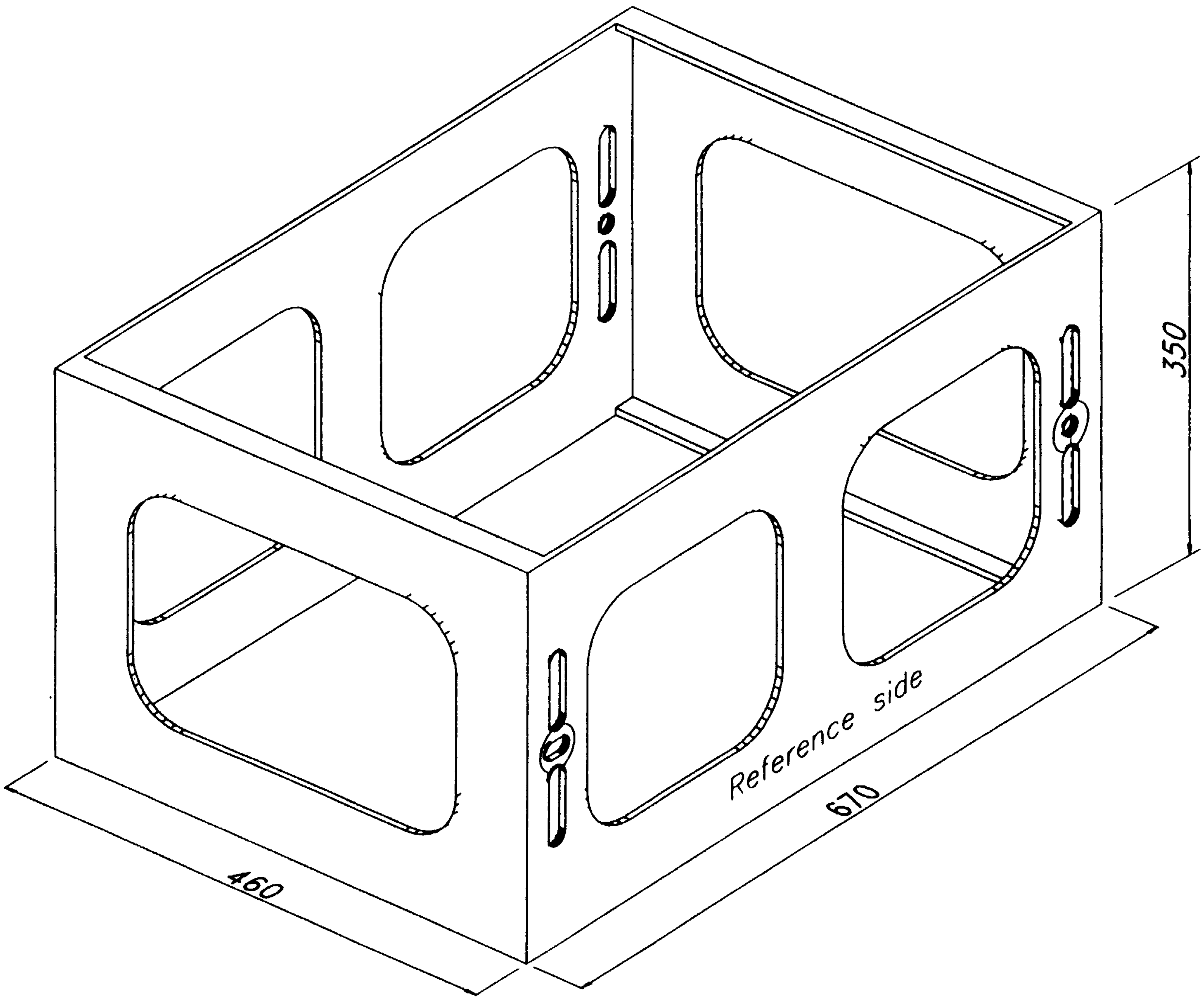


Fig.2 – Spacer

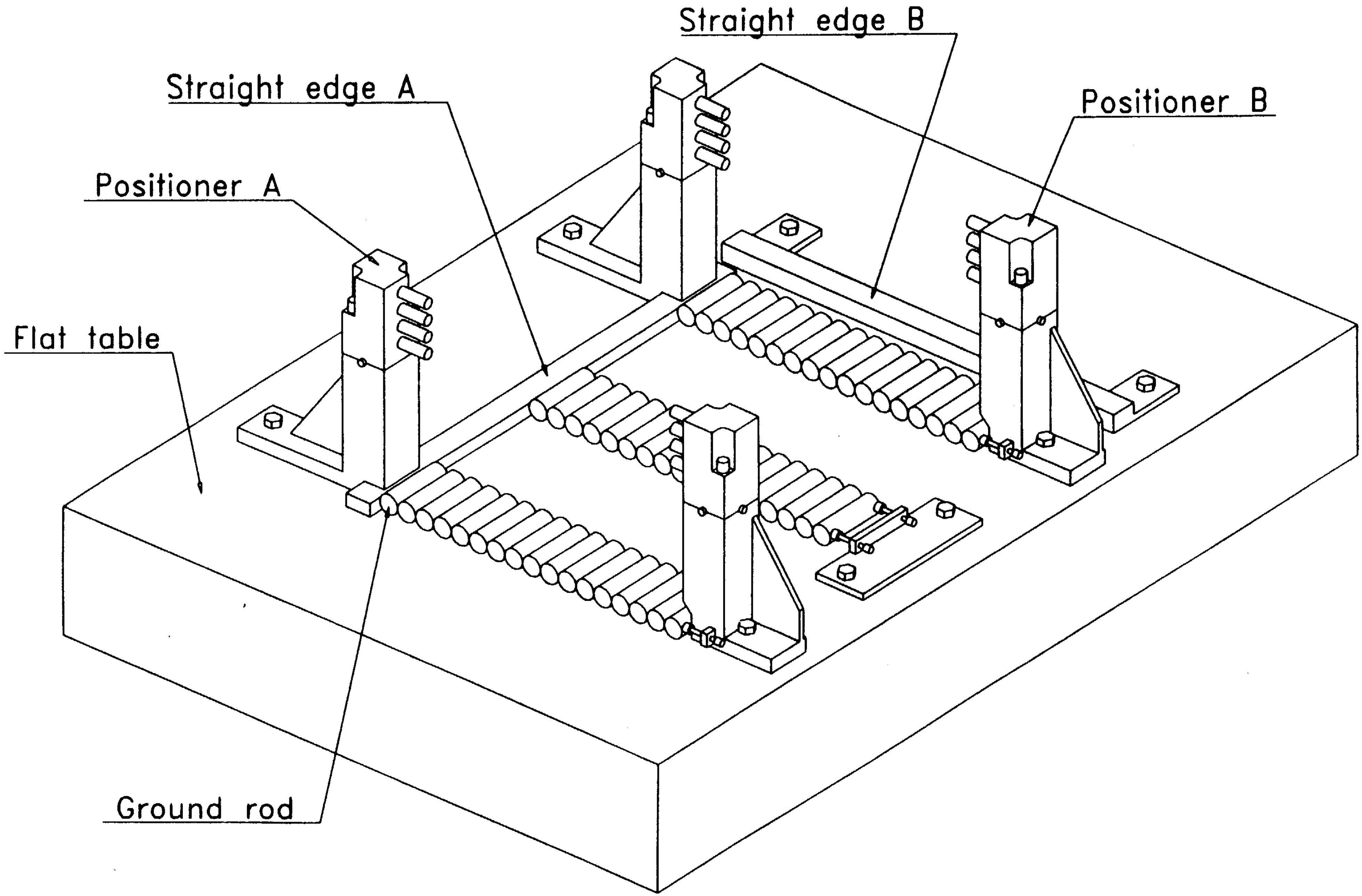


Fig.3 – Assembly equipment

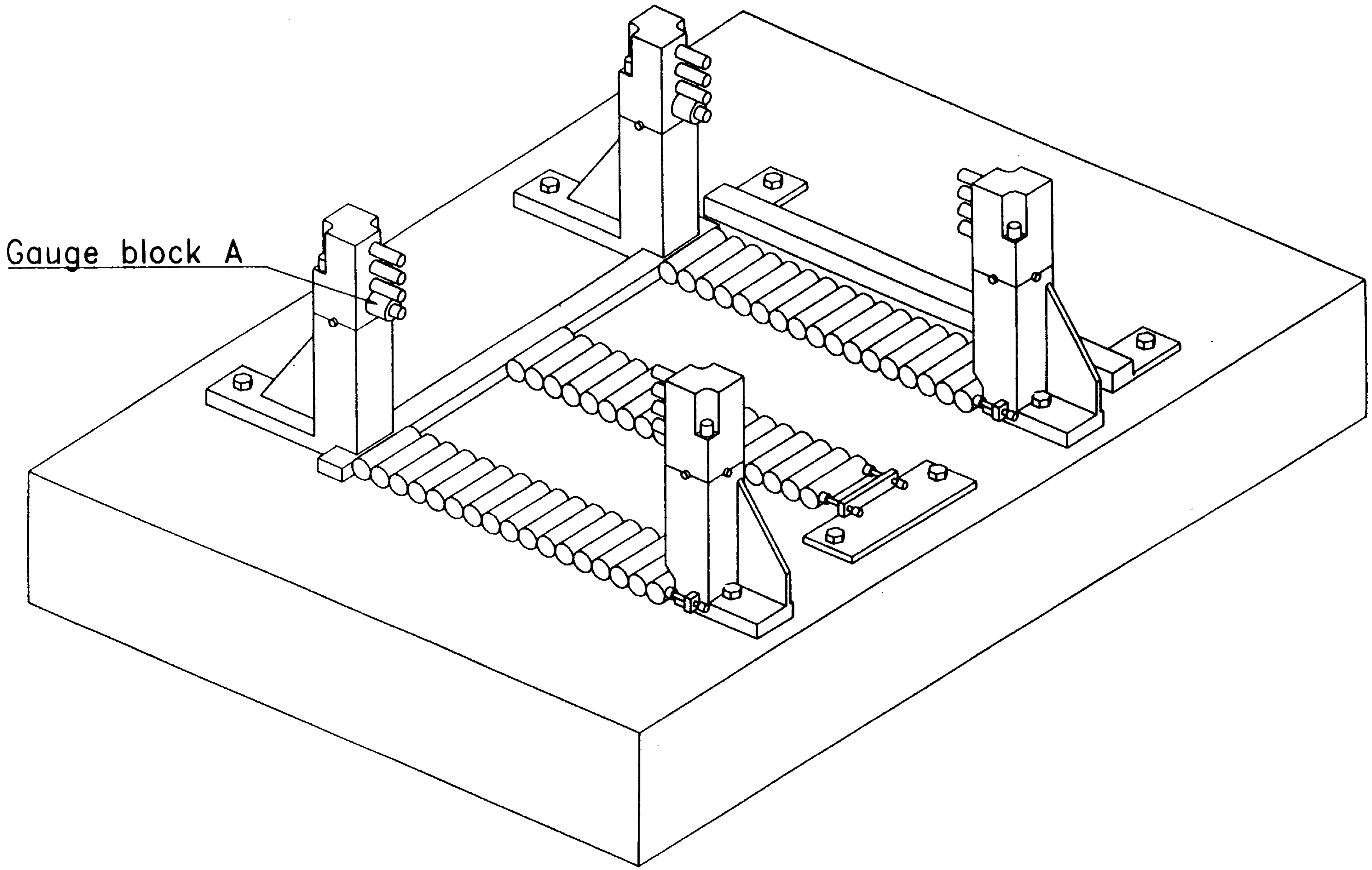


Fig.4 – Assembly equipment

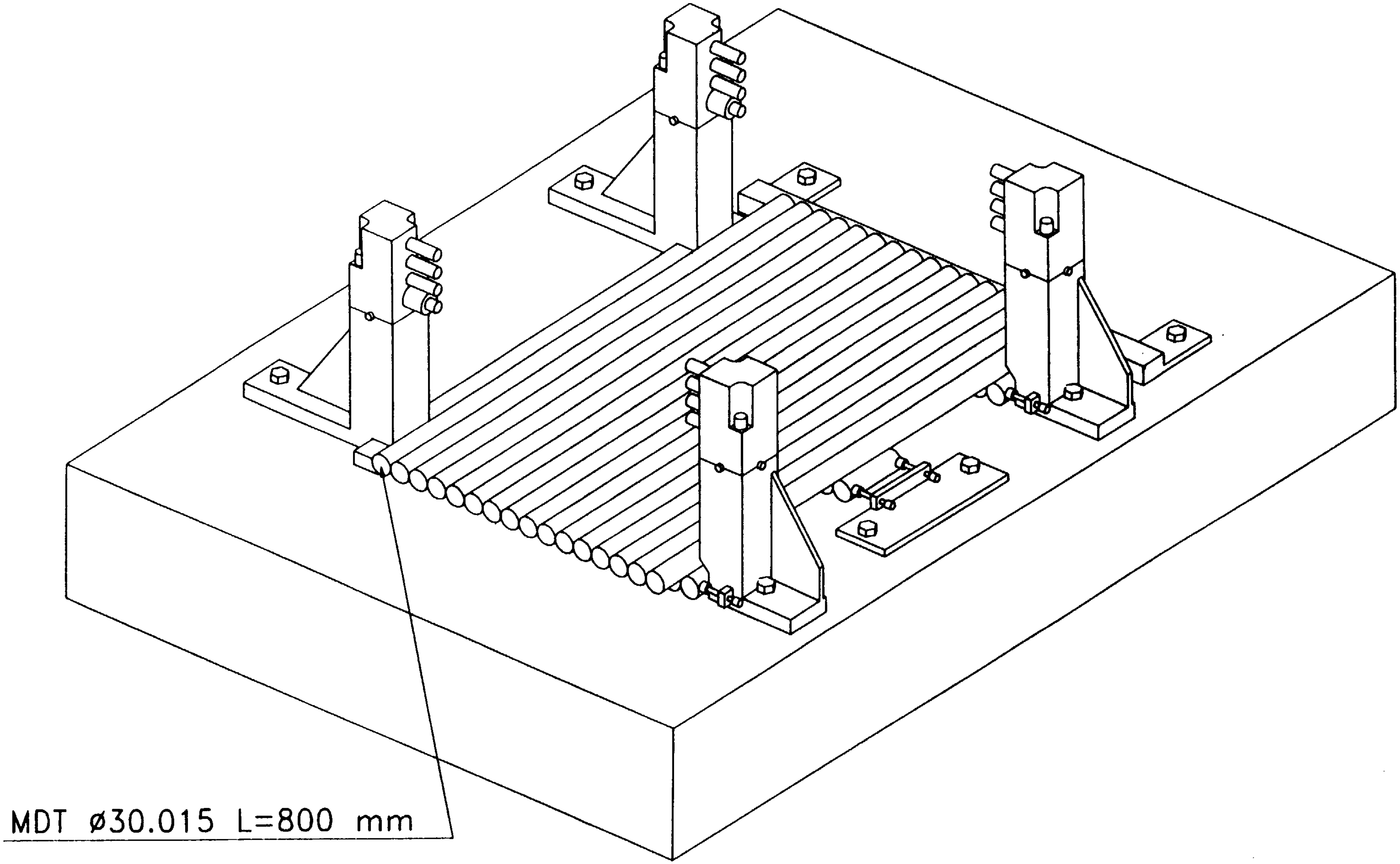


Fig.5 – First monolayer (16 tubes) positioning

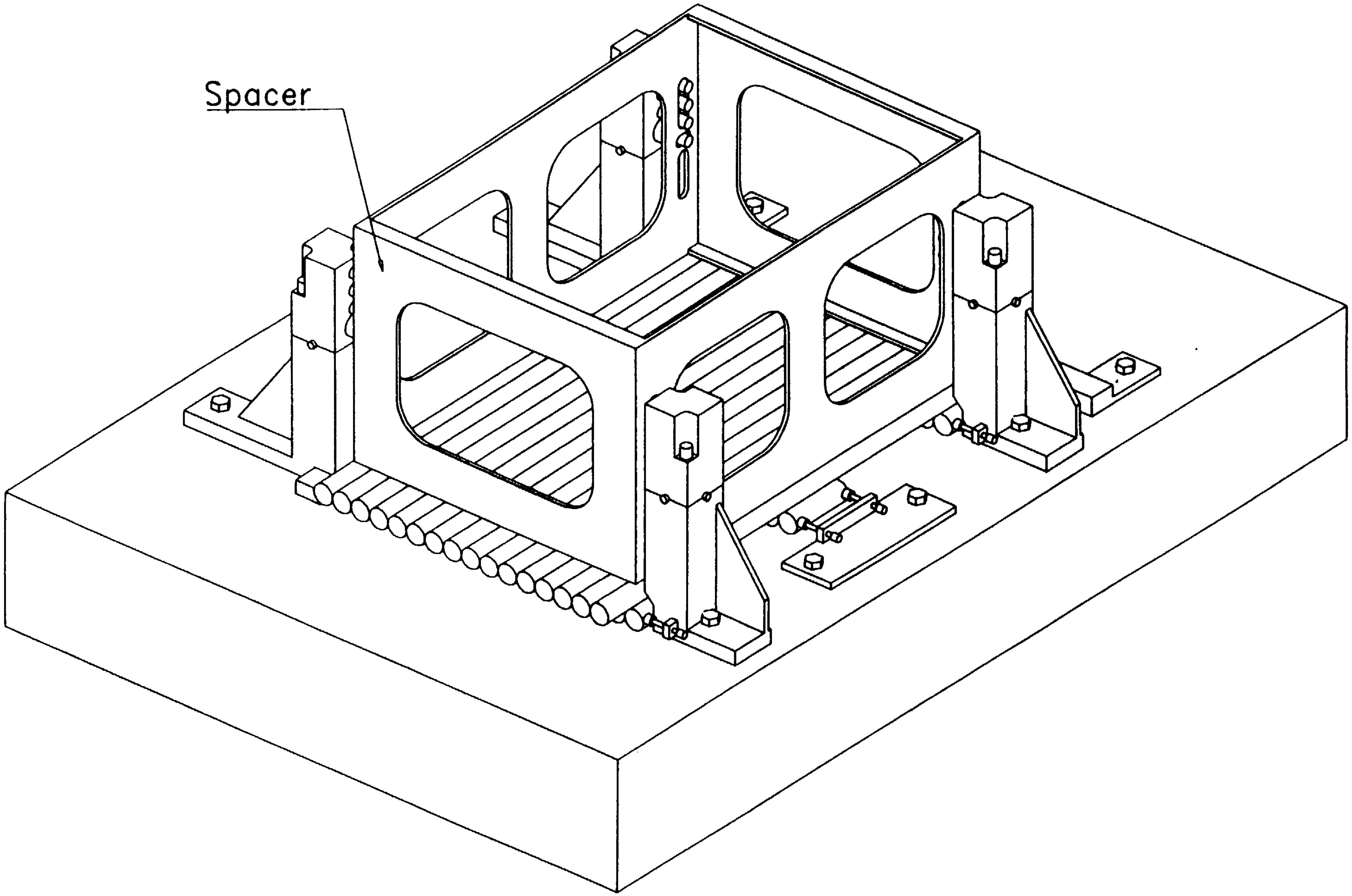


Fig.6 – First monolayer/spacer glueing

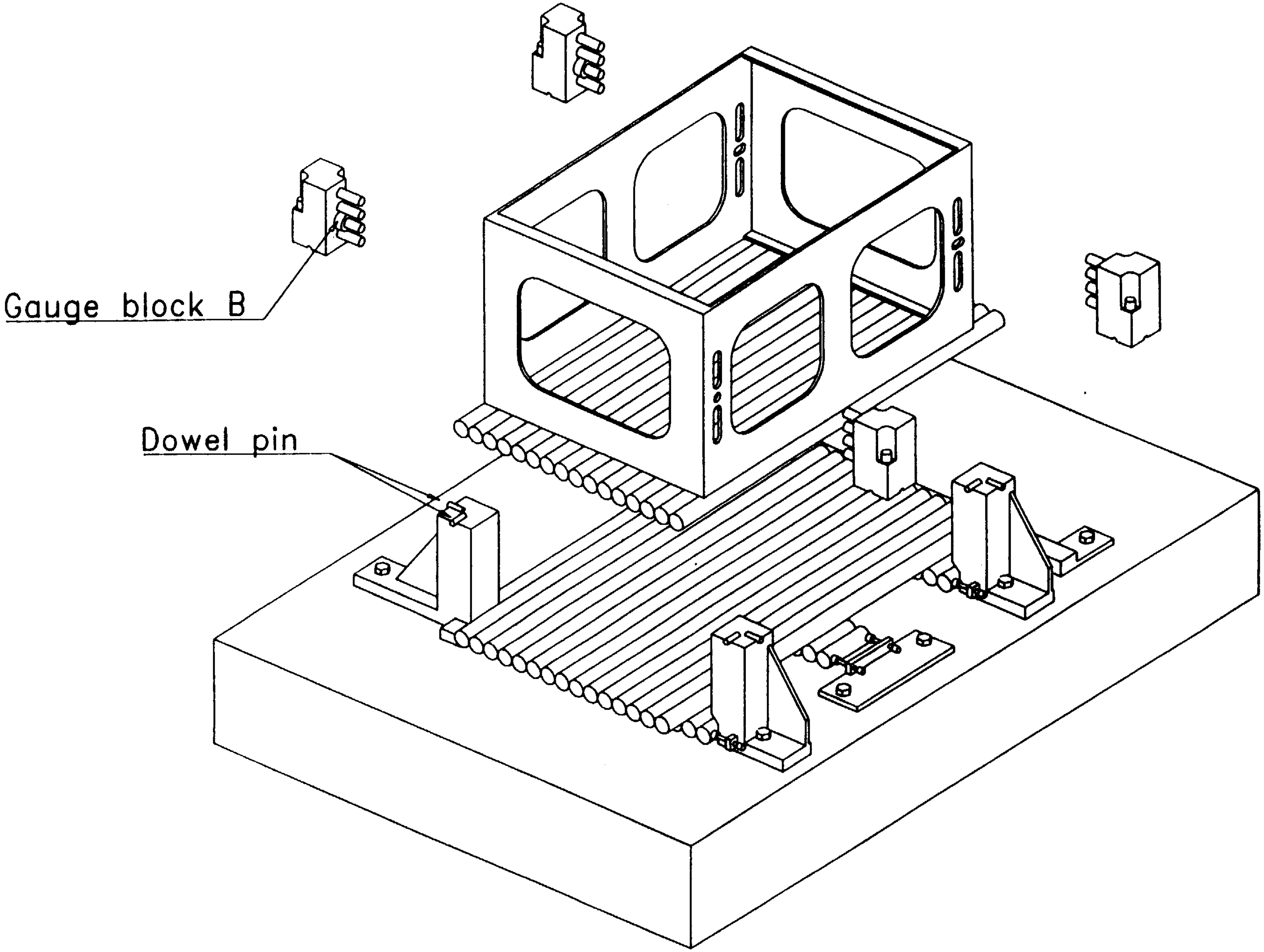


Fig.7 – Second monolayer (15 tubes) positioning

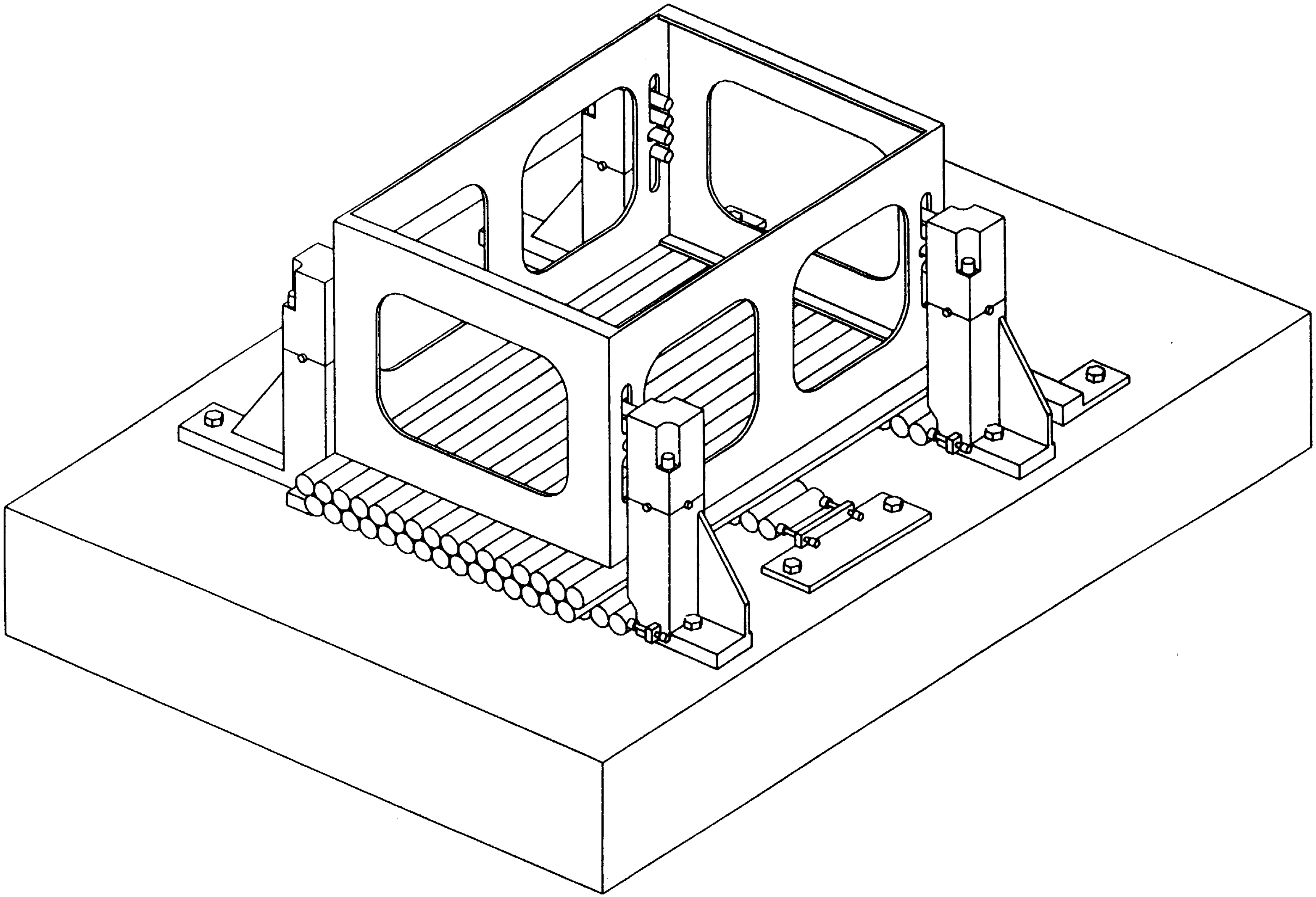


Fig.8 – Second monolayer (15 tubes) glueing

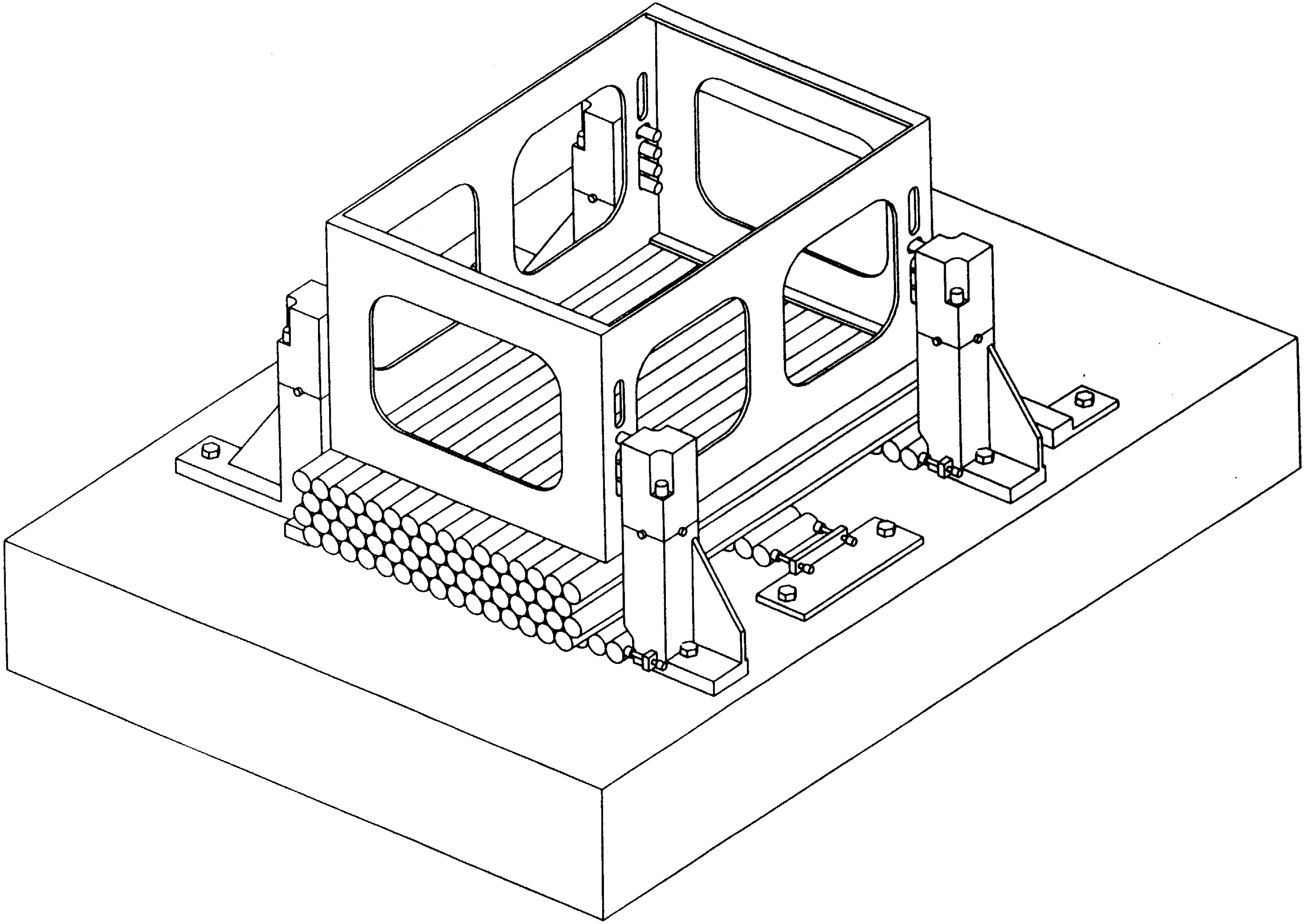


Fig.9 – Fourth monolayer (15 tubes) glueing

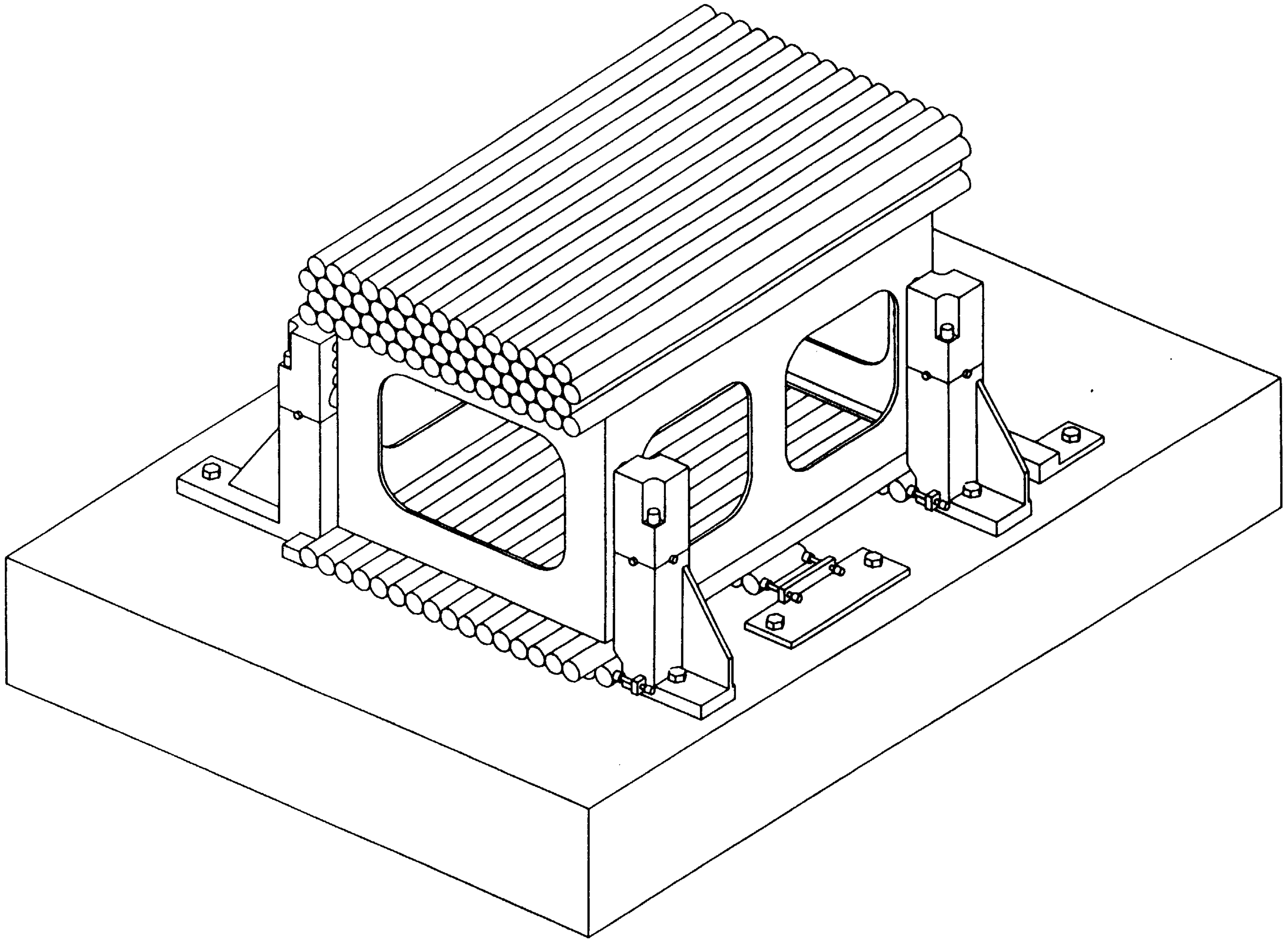


Fig.10 – Rotation and first monolayer (16 tubes) glueing

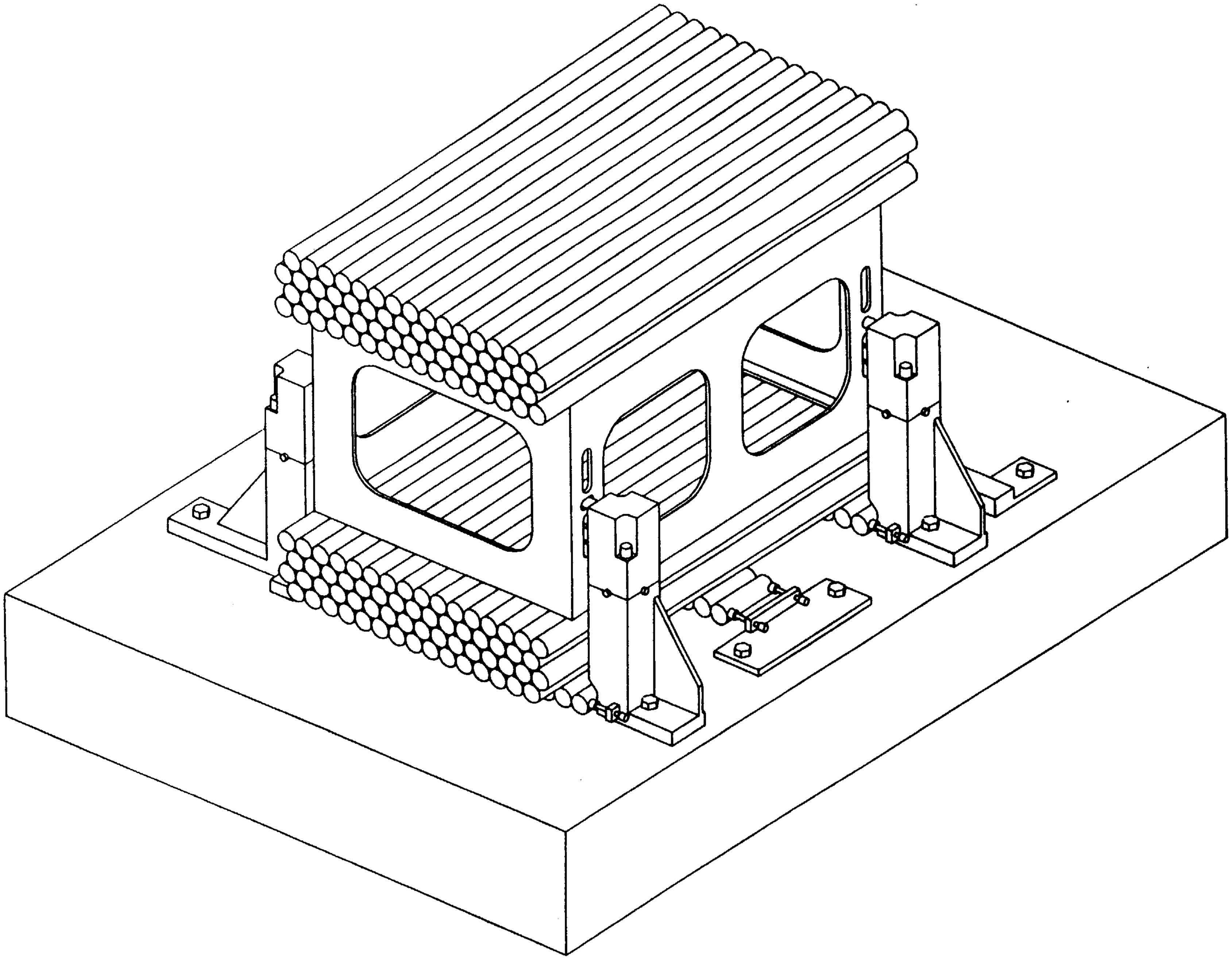


Fig.11 – Fourth monolayer (15 tubes) glueing

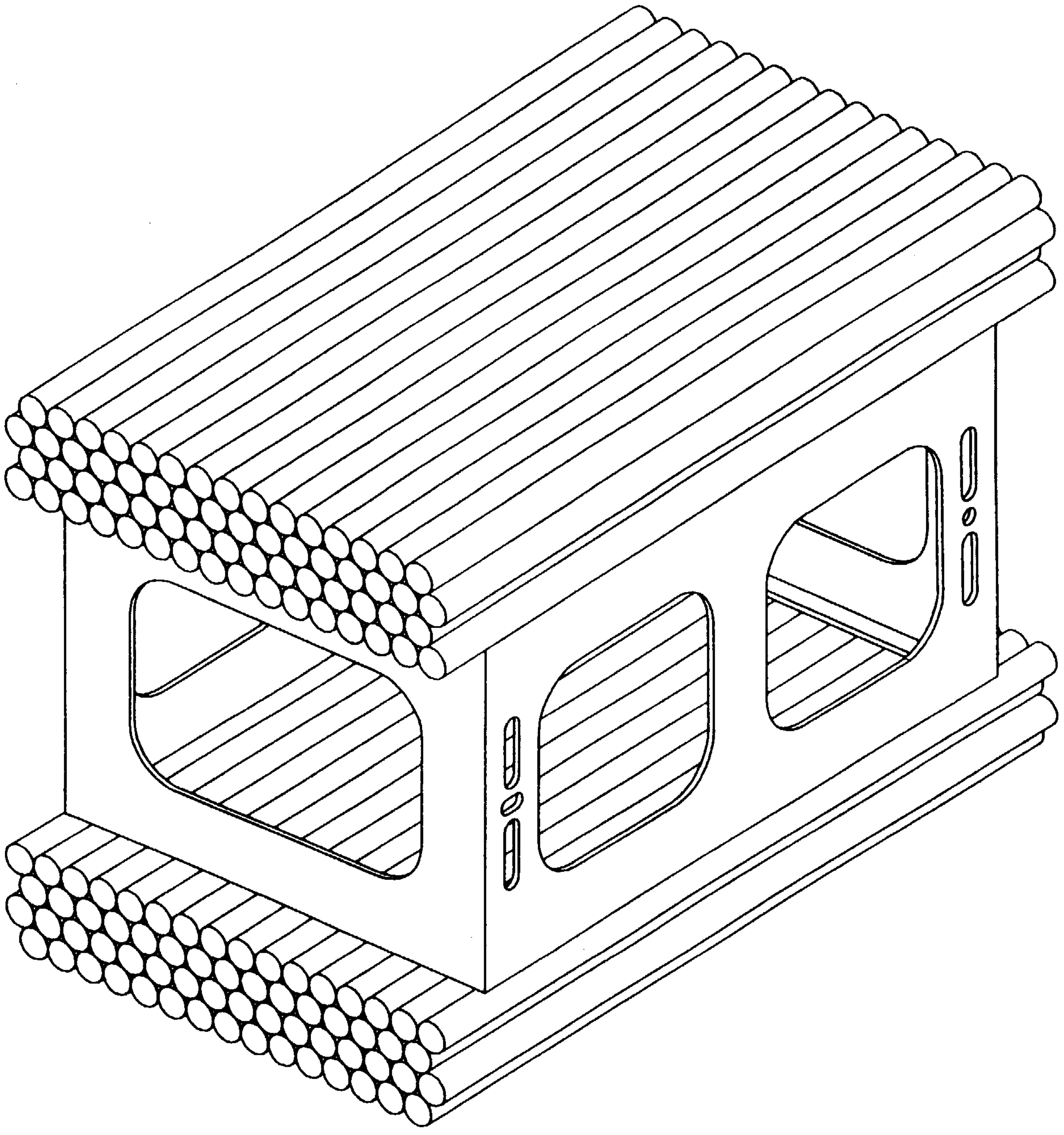


Fig.12 – Chamber's prototype

Total weight = 45 daN

N.124 MDT ø30 ±0.015 mm
L = 800 mm

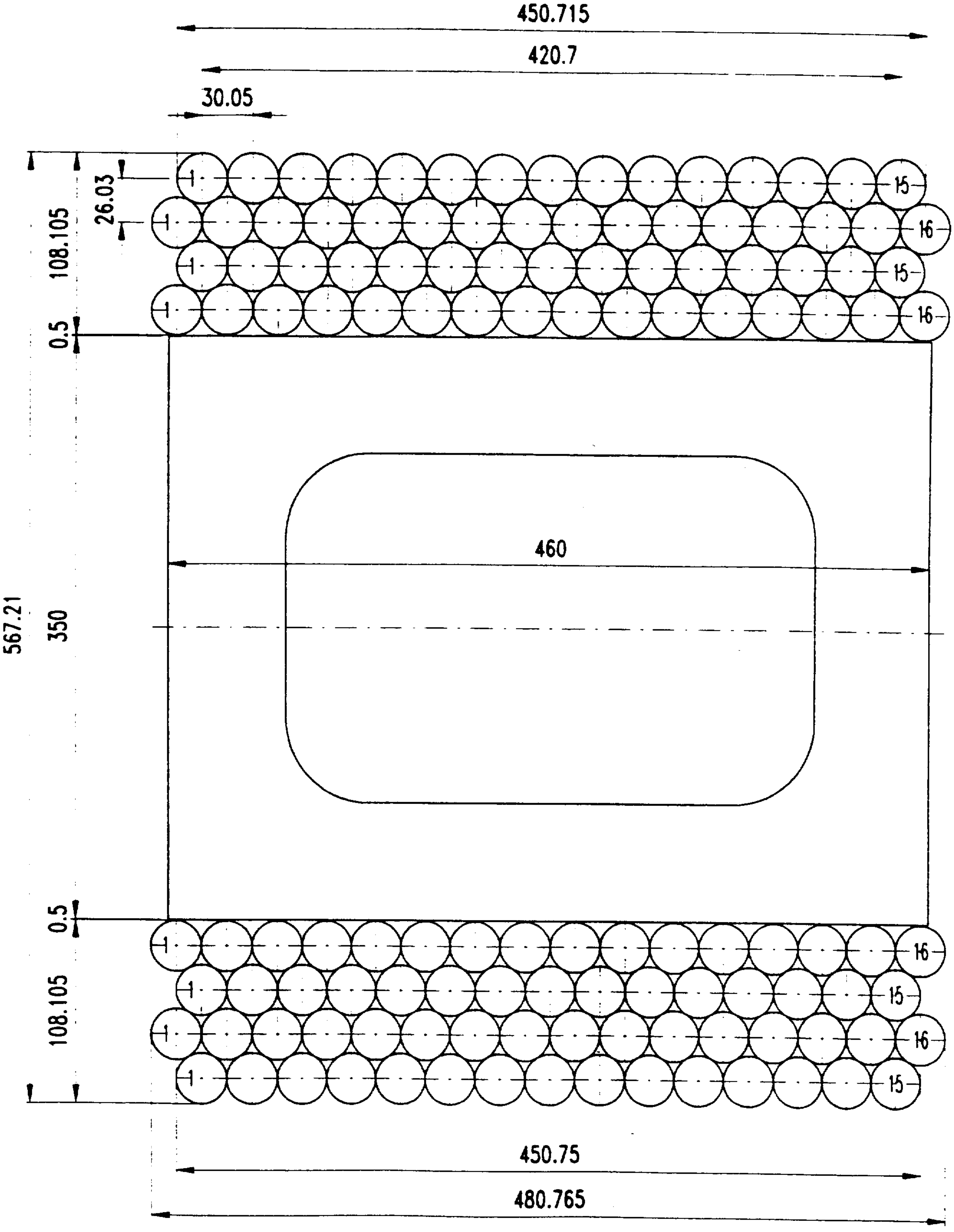


Fig.13 – Chamber's prototype front view