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ATLAS Internal Note
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ATLAS Tile Hadron Calorimeter Module Assembly Design

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1 INTRODUCTION

In this note we describe the assembly procedure of a tile calorimeter module. Starting points for this investigation are the up to date dimensions of the tilecal design, including the more recent updates discussed in the mechnics meeting of 1994.

2 SUBMODULE DESIGN DESCRIPTION

The geometry of a submodule is presented on Fig. 1. Master and absorber plates are glued between themselves by epoxy glue. One module consists of 19 submodules. The total amount of periods in a barrel module is equal to 311.

12 submodules will have 16 periods and 288 mm of thickness; 7 submodules will have 17 periods and 306 mm of thickness.

Each submodule tickness tolerance is $^{+0.00}_{-0.25}$ mm. On the submodule's narrow side along its length 2 strips are welded (10×30 mm^2 in cross-section). Figure 2 shows also the key way which is foreseen.

All straps will have 4 holes M12 , which will allow to connect supports, needed to connect manipulation auxiliary equipment.

In the submodule wide side along its length the 30×47 mm^2 (cross section) strips are welded (Fig. 3) and also a 10×180 mm^2 cross-section key way is present. These strips will have 4 M20 holes for the submodule connection to the girder. The strips are 3 mm sank relatively to submodule's inclined surfaces and therefore do not disturb the fibers path in the final assembly.

3 MODULE DESIGN DESCRIPTION

The detailed module design is illustrated in Fig.'s 4 $\div$ 6.

The girder is the main module structural element. The edges of the girder are defined by 40 mm thick flanges plates (see Fig. 4). Plates are welded to the girder longitudinal elements by T-like welds. The weld's cathets are 10 mm. Total length of welds — for one plate — is 580 mm. The plates have on each side ø 50 mm half-holes (Fig. 5) for ø 50×40 mm^2 pins placing when barrel assembling. Along all its length the girder has 10×180 mm^2 cross-section projection (Fig. 6). During module assembling the submodules will be placed — by their key ways — on that projection and then fixed by M20 bolts to the girder.

In the module narrow side, into the submodules 10×125 mm^2 the key ways (the strip clamping) are inserted and after that welded (Fig. 7). At the module's ends two edge submodules are covered by end-plates. End-plates are attached to edge submodules by M12 bolts (Fig. 8) and then welded to the strip clamping. Each module is penetrated by ø 6 mm 11 tubes and by 11 studs of ø 6 mm in diameter. The tubes are needed for radiative source moving when tiles tests.

After a 6 m module is assembled the strips side surfaces are machining (Fig. 7) in order to obtain the flat contact surface. In the internal barrel volume the modules are in contact along the strips side surfaces. In the outside barrel part the modules are contacting through girder. There is no contact between the neighboring modules master plates.

4 MODULE ASSEMBLY GENERAL TOOLING DESIGN DESCRIPTION

The module assembling is done with dedicated tools (Fig. 9). This tooling consists of: 6 orthagonal I-beams 240 mm high; two structural channels 140 mm high; ribs of stiffness 6 mm thick and of supporting plates 20 mm thick.

All elements of the tooling are welded between themselves. The tooling's length is equal to the module's one. The bottom surfaces of the tool and the supporting surfaces of it are milled.

The top supporting surfaces have ø 27 mm holes to fix the girder when modules are assembled. The weight of tooling described here is about 1000 kG; production cost is of the order of 2000$ in material.

5 MODULE ASSEMBLY MAIN STAGES

Before assembling the tooling (Fig. 9) is located on a steel floor. The upper girder's supporting plane horizontality is not worse then ± 0.1 mm. The girder will be attached and fixed the assembly tool (Fig. 10).

The horizontality of the girder surface "K" (to place submodule on) is not worse that ± 0.1 mm. The submodule edge is placed on the girder together with the submodule flange plate (end plate). The submodule vertical position is checked by level gauge. Non perpendicularity of submodule positioning is allowed to be not worse than $\pm$ 20″ (or $\pm$ 0.15 mm).

If necessary the submodule's vertical position can be adjusted by insertion of shims between the girder and the submodule.

One by one the next submodules will then be position using the same procedure. The individual shim thickness will not be more than 0.5 mm. The total Z-direction shims thickness can not be more than 5 mm. When positioning, each submodule must be pressed to the previous one by 4 tons force by means of clamps and jacks (Fig. 10) and then submodules will be fixed by M20 bolts.

The verticality of each submodule is checked and corrected in the same way it was done for the first module.

After all submodules are positioned, a strip with 10×125 mm^2 cross-section and 5640 mm length, will be inserted in the upper key way.

By M12 studs the strip clamping through the cover plate (Fig. 11) is pressed to the submodules (Fig. 12) and is welded to the module. The welds on the strip clamping edges will be done alternatively on different sides each time with weld length $\simeq$ 50 mm. This method prevents significant deformations of the strip clamping and of the module.

After the module assembly is completed the strips side surfaces are machined (Fig. 7) in order to obtain the plane contact surface.

The module is grounded and painted to prevent corrosion.

6 THE MODULE SLINGING, PACKING AND TRANSPORTING

After assembling the module is removed from the assembly support. The cross rail and brackets are used for its lifting (Fig. 13). Each bracket is fasten to a submodule by four bolts M12 (Fig. 14). The weight load of the module is distributed uniformly between all brackets and bolts.

After lifting and moving the module is installed vertically on two supports (Fig. 15, 16). In such position it can be stored, assembled and transported by rail or car.

To turn a module around the Z-axis two brackets are installed on a girder (Fig. 13). The module is connected by two axles to a support (Fig. 17). After lowering of a crossrail the module is rotated and installed on the support in a horizontal position. For the subsequent lifting of a module two additional brackets are installed on it (Fig. 13, 18). The use of such scheme of slinging makes possible to assemble the first half of a barrel.

For the assembly of the second half of barrel the angular bracket is installed on the module along all its length (Fig. 19, 20). The angular bracket are fastened by bolts M24 to a girder. Such scheme of a slinging permits us to install the modules in barrel after the installation of a cryostat.

The bend of a module along its length is absent when such angular bracket is used for the lifting and moving of the module. This is due to the fact that the angular bracket takes the module's load uniformly along its length.

Changing the installation place of the mobile brackets we get the necessary rotation angle of the module around of the Z-axis (Fig. 21, 22). In all cases mentioned above the tensions and deformations of the module will be much less than allowable ones.

7 STRENGTH CALCULATION

CASE ONE

The module has special brackets for lifting and moving (Fig. 13, 14).

Each bracket is jointed to the submodule with four M12 bolts and due to traverse the module's weight load is distributed uniformly over all brackets and bolts.

Load on one bolt is:

$$F_b = \frac{G \cdot K}{4 \cdot n} = \frac{20 \cdot 1.33}{4 \cdot 20} = 333\ kG,$$

where G — module's weight, K — load factor, n — submodule's quantity.

This load is considerably less than allowable one for bolt:

$$F_b = 333 \ll [F_b] = 2000\ kG.$$

CASE TWO

In the below described process of barrel mounting the same brackets and cross rail are used (Fig. 18). Module's load in its narrow part is uniformly distributed over all brackets, which are joined to each submodule.

It is assumed that only two of four bolts will take shearing force and the center of gravity of section is in the middle module's section.

Than

$$F_s = \frac{G \cdot K}{2 \cdot 2 \cdot n} = \frac{20 \cdot 10^3 \cdot 1.33}{2 \cdot 2 \cdot 20} = 333\ kG,$$

Symbols are the same as in the case 1.

This load is considerably less than allowable one for bolt:

$$F_s = 333 < [F_s] = 1400\ kG.$$

CASE THREE

In the process of barrel's upper half mounting, after cryostat is placed, it is impossible to use brackets with four bolts. In this case possible to use lifting screws which set into holes M12 and steel plates 2 mm thickness. Lifting screws and plates stay in the module after its assembling (Fig. 23, 24).

Module's weight load will be uniformly distributed over the lifting screws.

Every submodule has two lifting screws.

Shearing force

$$F_s = \frac{G \cdot K}{2 \cdot 2 \cdot n \cdot \cos 30^\circ} = 385\ kG,$$

This load is less then allowable one

$$F_s = 385 < [F_s] = 1400\ kG.$$

PLATE CALCULATION

Maximum stress in the plate will be in the hole cross-section (Fig. 24).
The stress:

$$\sigma = \frac{F_s}{S} = \frac{385}{2 \cdot 0.2 \cdot 1.4} = 688\ kG/cm^2,$$

CASE FOUR

Module is placed on the supports as shown on Fig. 25. In this position module can be transported and stored. Shear forces and bending stresses are taken by girder.

Stress will be

$$\begin{aligned}
\sigma &= \frac{1}{W}(M_1 - M_2) = \\
&= \frac{1}{W}\left(\frac{P_1 \cdot L_1}{8} - \frac{P_2 \cdot L_2}{2}\right) = \\
&= \frac{1}{5447}\left(\frac{14 \cdot 10^3 \cdot 400}{8} - \frac{3 \cdot 10^3 \cdot 80}{2}\right) = \\
&= 106,5\ kG/cm^2,
\end{aligned}$$

This stress is considerably less than allowable.

CASE FIVE

Module is placed as shown on Fig. 26.

Maximum bending stress is in the plate of 10×125 mm² cross-section:

$$\sigma = \frac{q \cdot l^2}{8 \cdot W} = \frac{17 \cdot 563^2}{8 \cdot 24} = 28065\ kG/cm^2,$$

It is considerably more than allowable, that is why the transportation and storing in this position are inaccessible.

This operation can be carried out only as shown on Fig. 25.

CASE SIX

Module is placed in the barrel.

Pressing stresses which are acting in the inner part of barrel will be taken by stripes with contact surface 10×5640 mm².

Pressing stress in this case is:

$$\sigma = \frac{N}{S} \cdot \cos 2.8125° = \frac{376000}{564} = 666\ kG/cm^2,$$

it is less than allowable.

CASE SEVEN

Module is placed in the barrel. The friction forces and influence of pins are not taken into account.

Shearing forces will be taken by forty M24 bolts.

Then the load on one bolt:

$$\begin{aligned} F &= \frac{G}{3 \cdot n} \cdot \sin 30^\circ = \\ &= \frac{1400 \cdot 10^3}{3 \cdot 40} \cdot \sin 30^\circ = \\ &= 5833 \; kG, \end{aligned}$$

it is less than allowable for such bolt.

The equal load is acting on M20 bolt too, and it is less than allowable for M20 bolt as well:

$$F = 5833 \; kG \; < [F] = 10000 \; kG.$$

CASE EIGHT

For to module's turning around Z-axis the support is used as shown on Fig. 17.

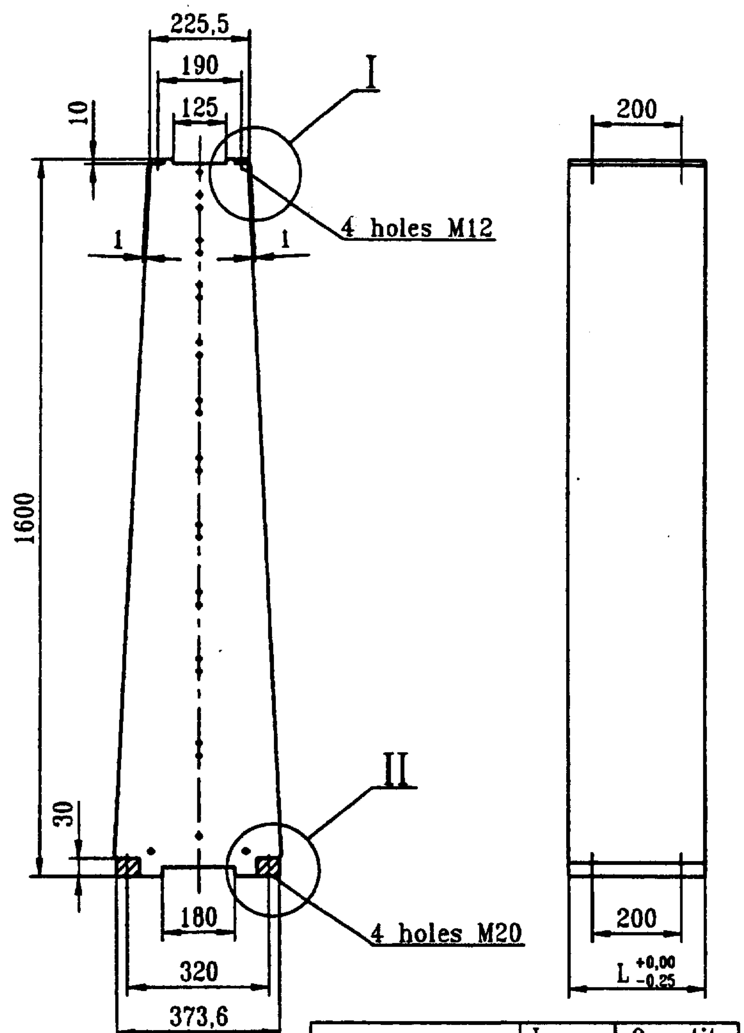
Module's narrow part takes the distributed load in the same way as in the cases one and two. The bolt's stress is less than allowable.

Girder is stiff and strong. It can perceive such concentrated loads during module's lifting and turning.

8 CONCLUSION

The 6 meter module design presented here allows one to fabricate the module by any of the participating institutions.

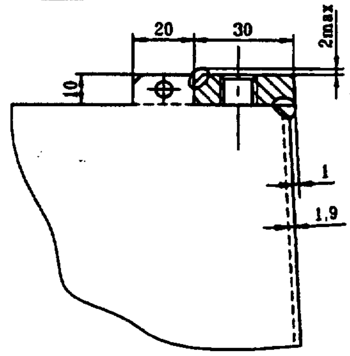
Auxiliary equipment and tooling are simple and unexpensive. They can be manufactured in one place (necessary amount of sets) and distributed between potential 6 meter modules manufacturers.



	L,mm	Quantity
Submodule N1	288	12
Submodule N2	306	7
Total	5598	19

Figure 1:

I



II

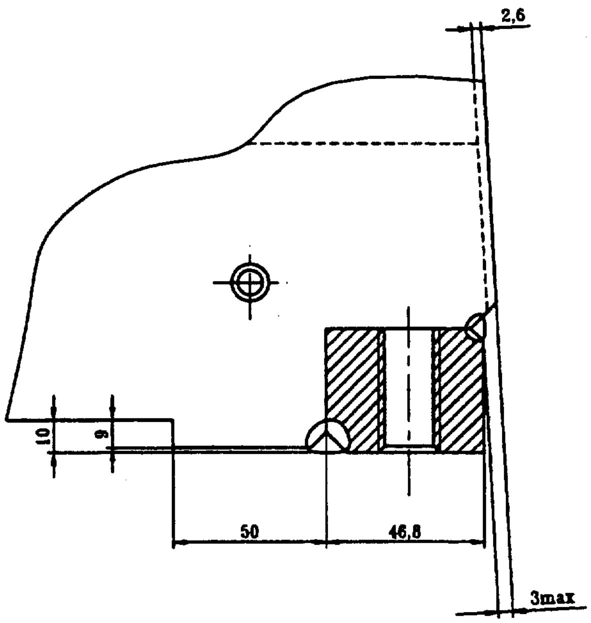


Figure 2 & Figure 3:

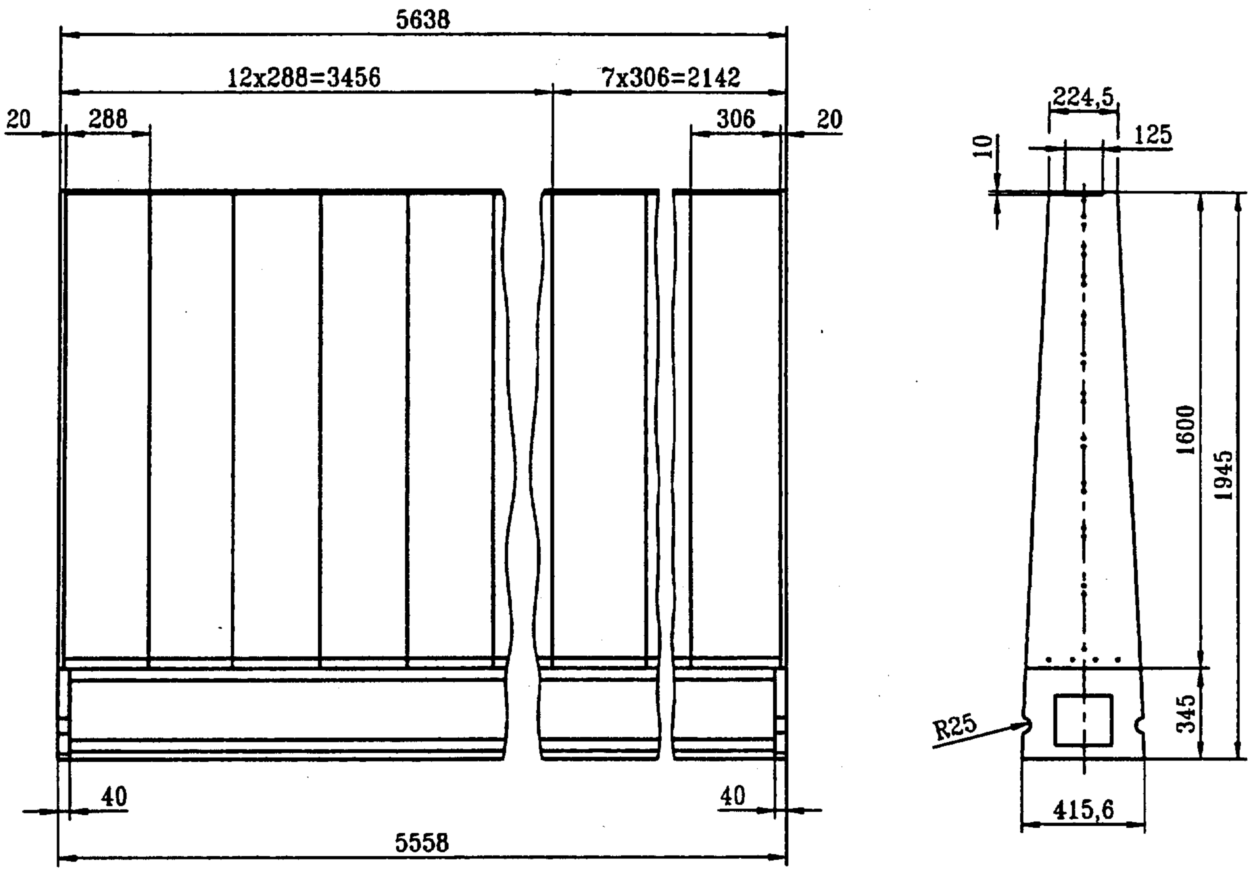
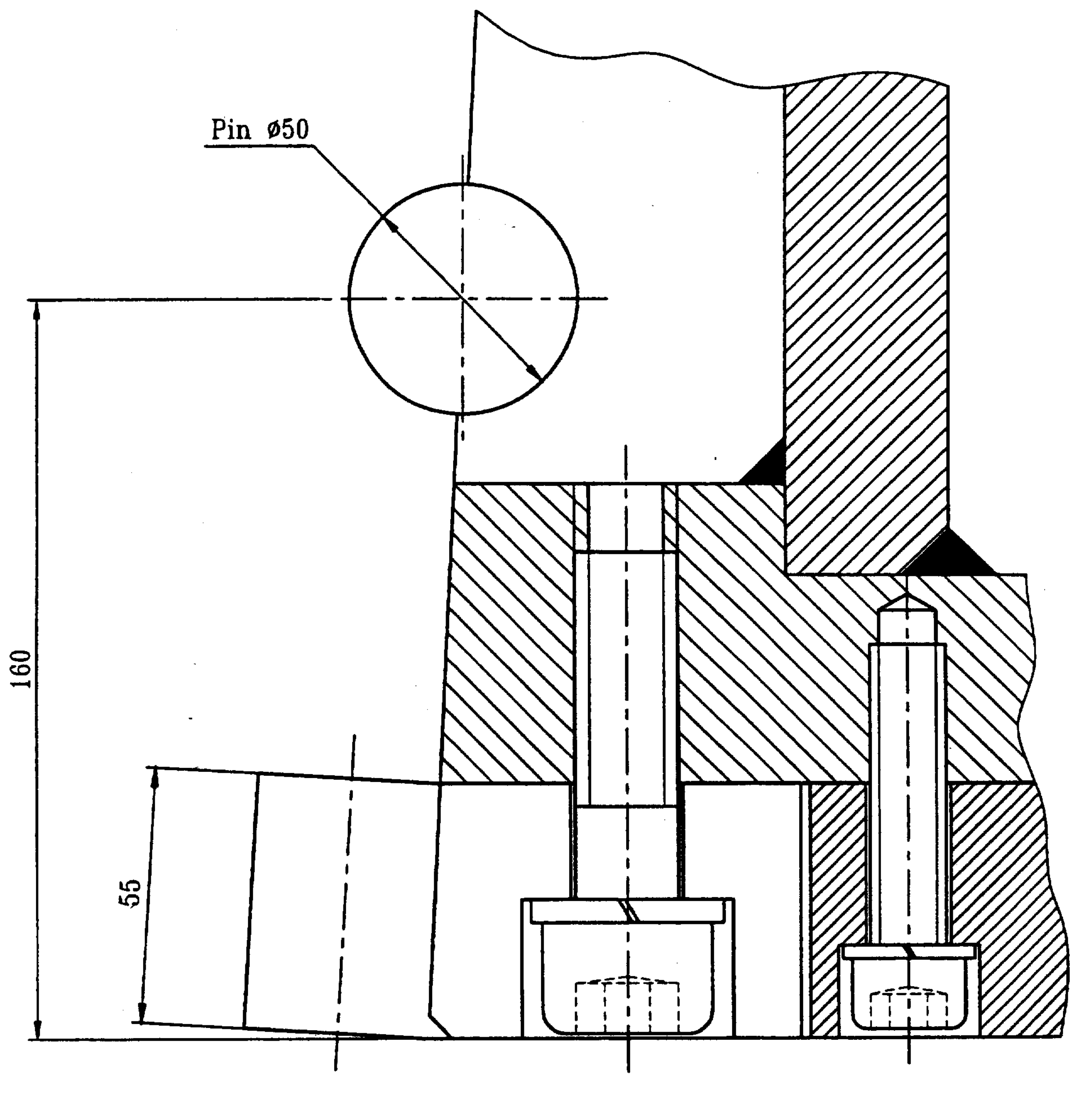

5638
12x288=3456
7x306=2142
20
288
306
20
224,5
125
10
1600
1945
345
R25
415,6
40
40
5558

Figure 4:



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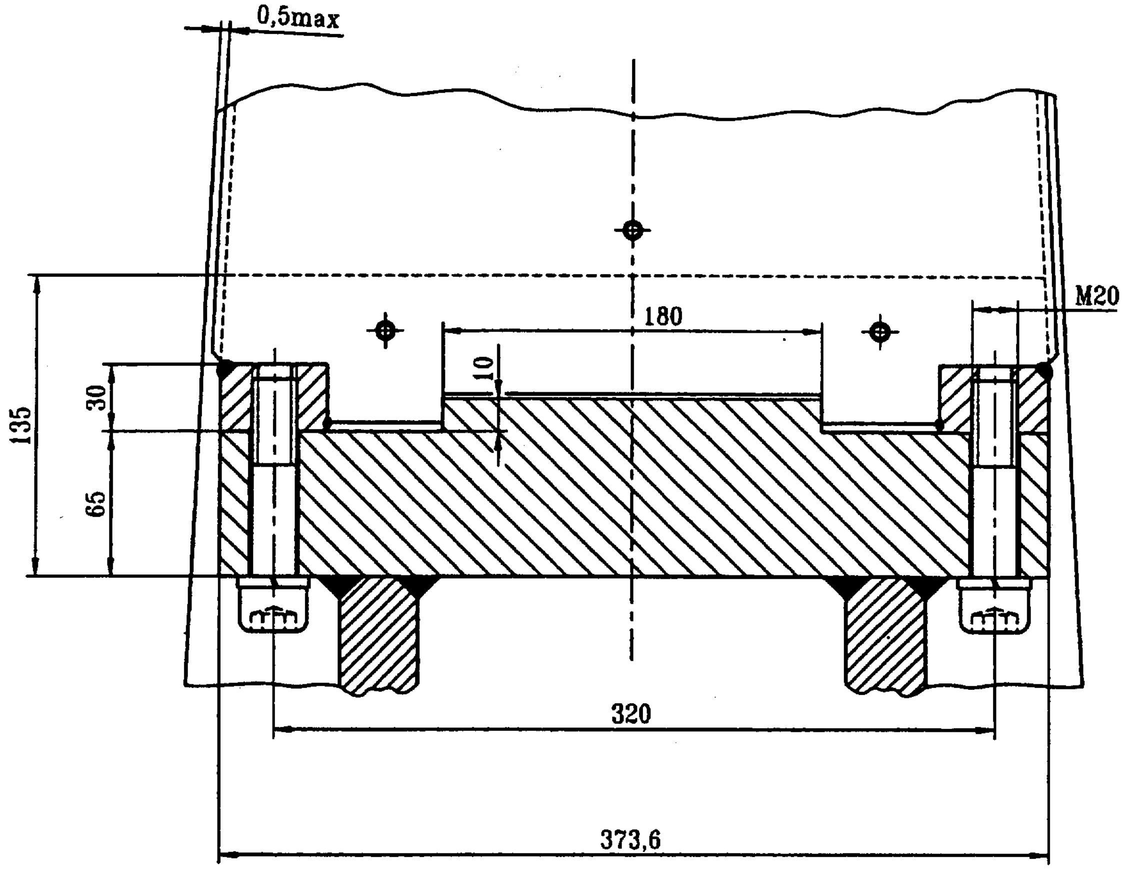

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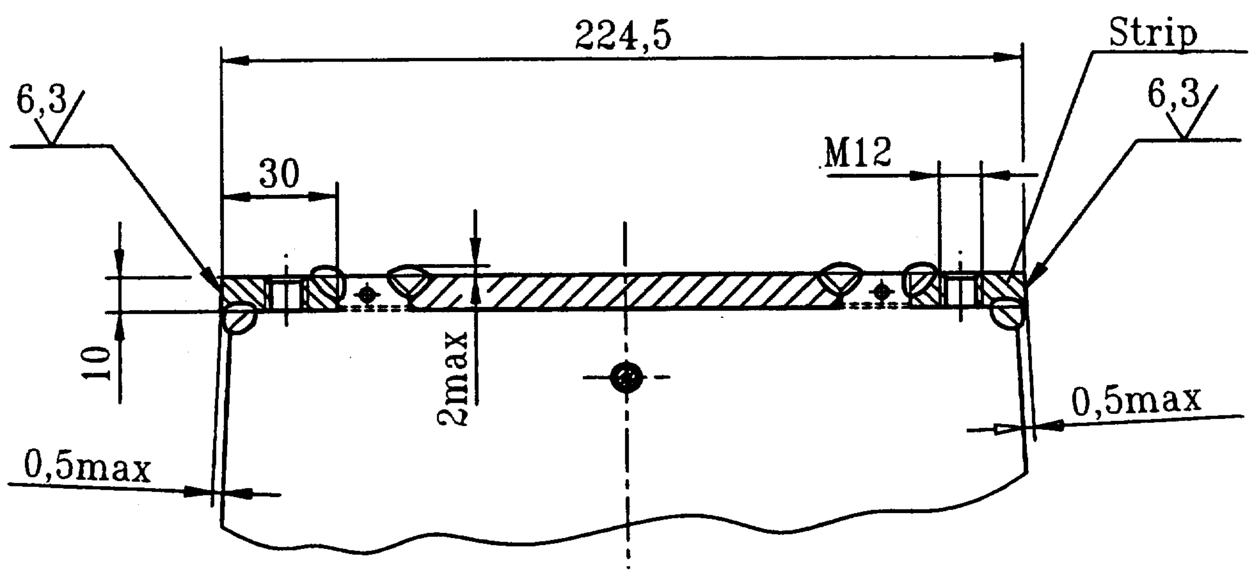

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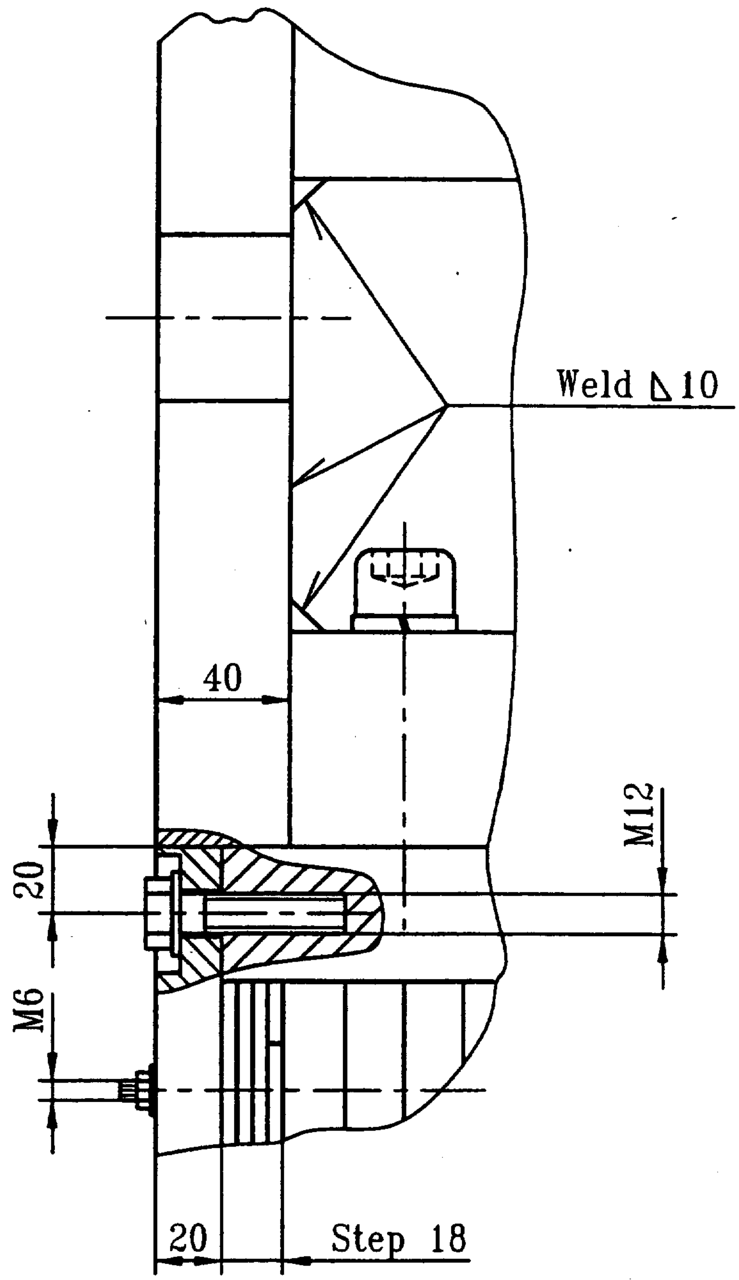

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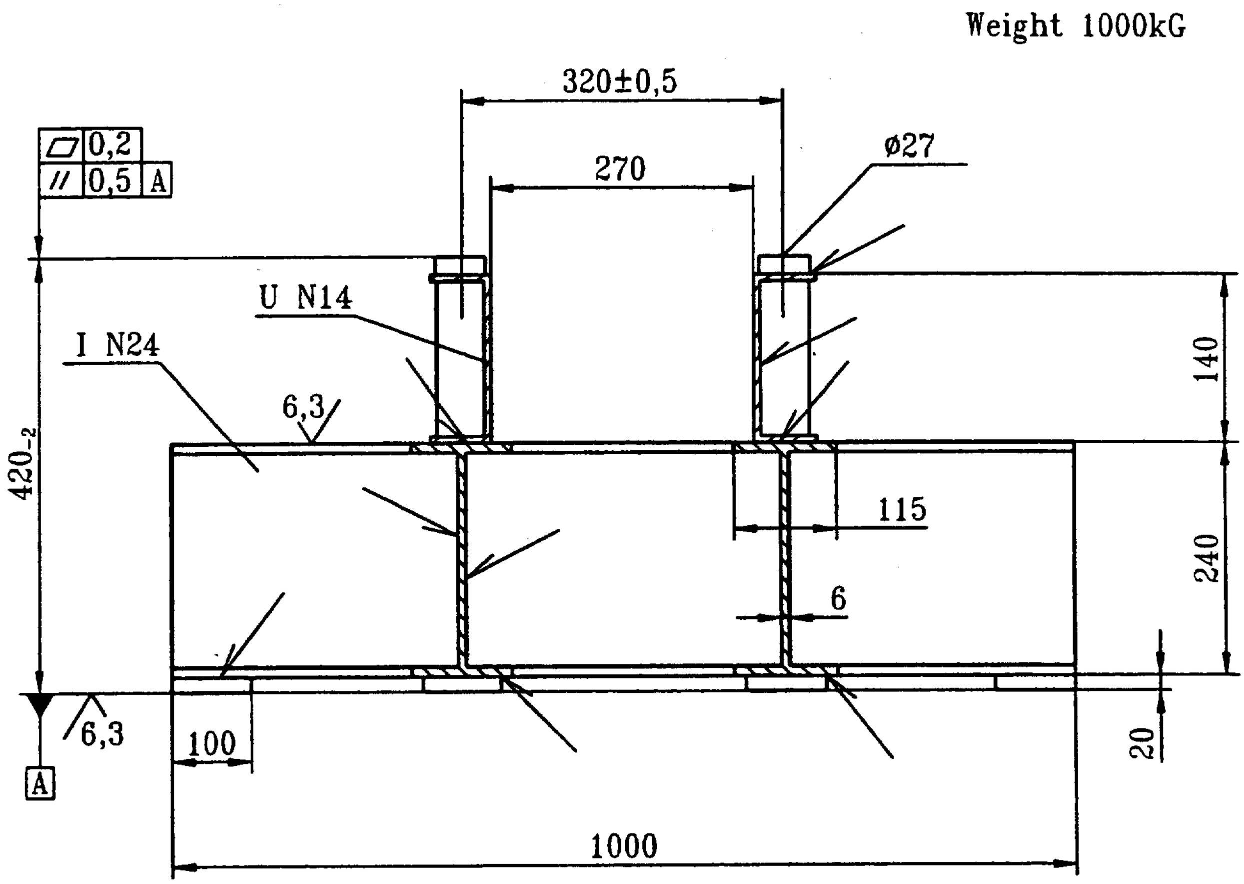


Weight 1000kG
320±0,5
270
ø27
0,2
0,5 A
U N14
I N24
6,3
420-2
140
115
240
6
6,3
100
A
20
1000

Figure 9:

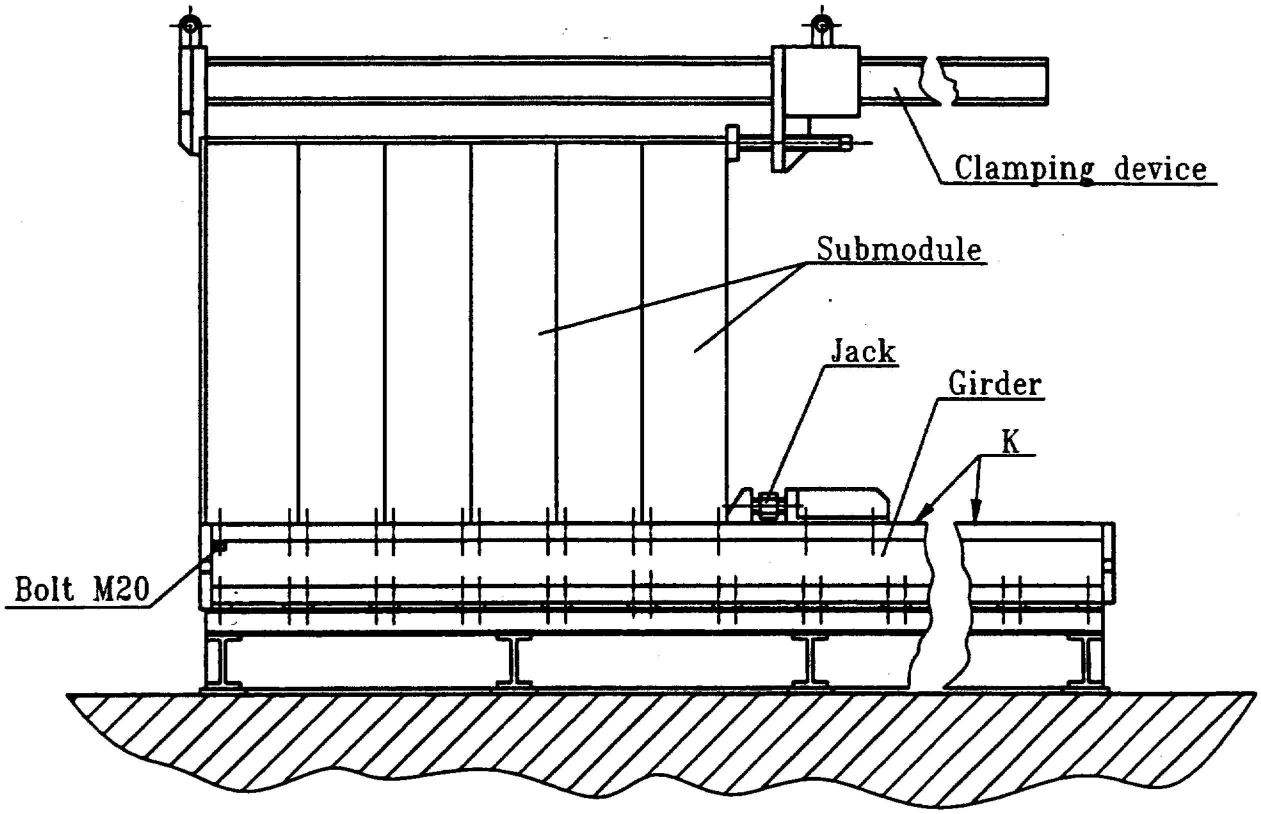


Figure 10:

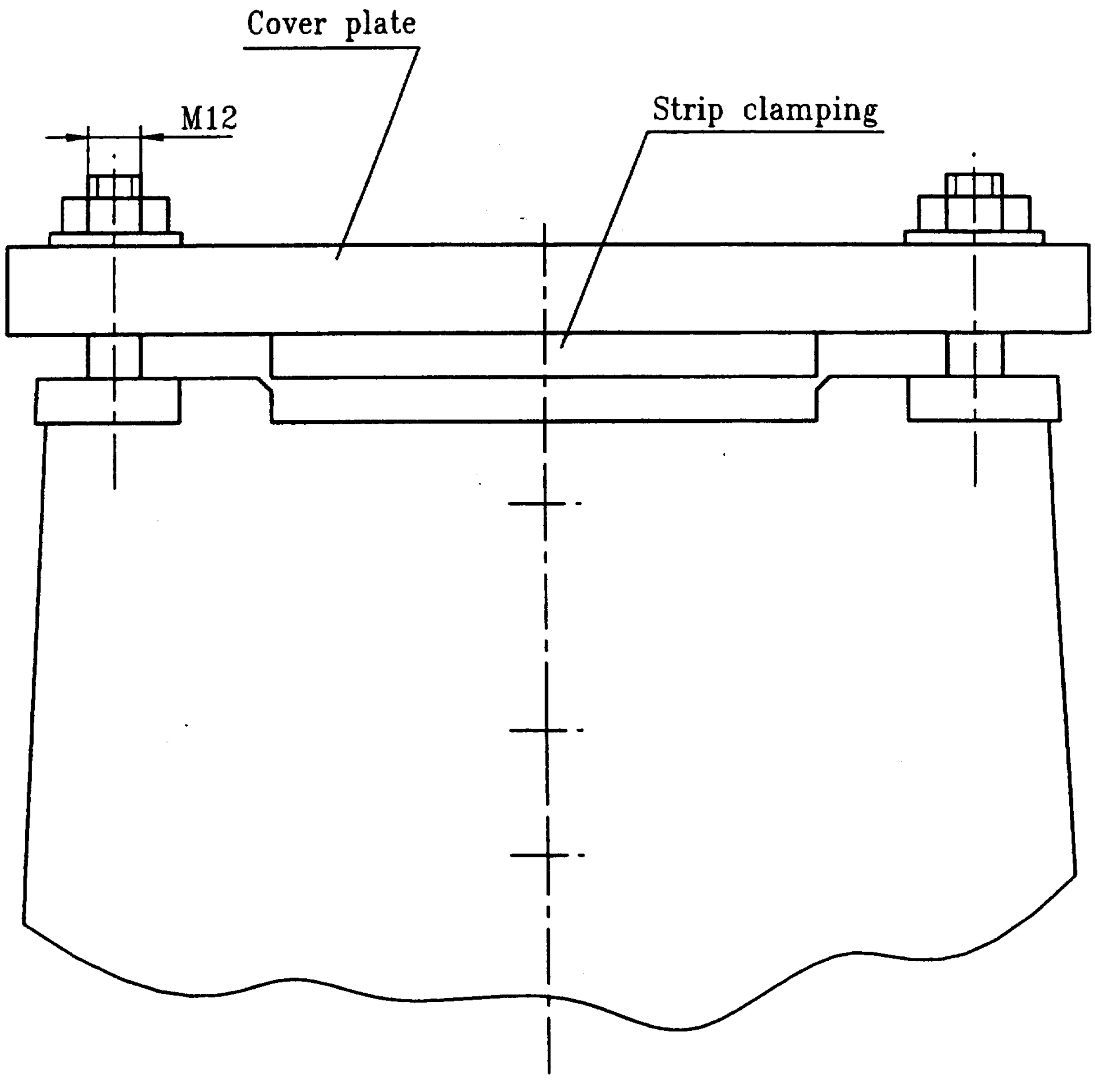


Figure 11:

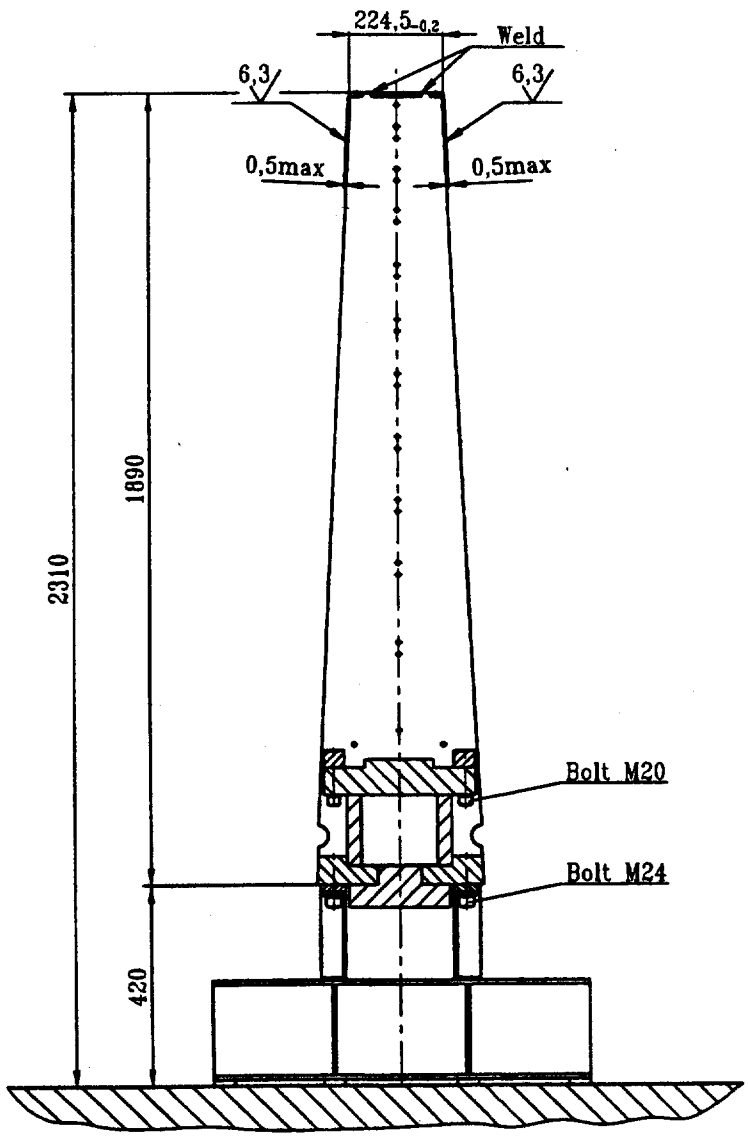


Figure 12:

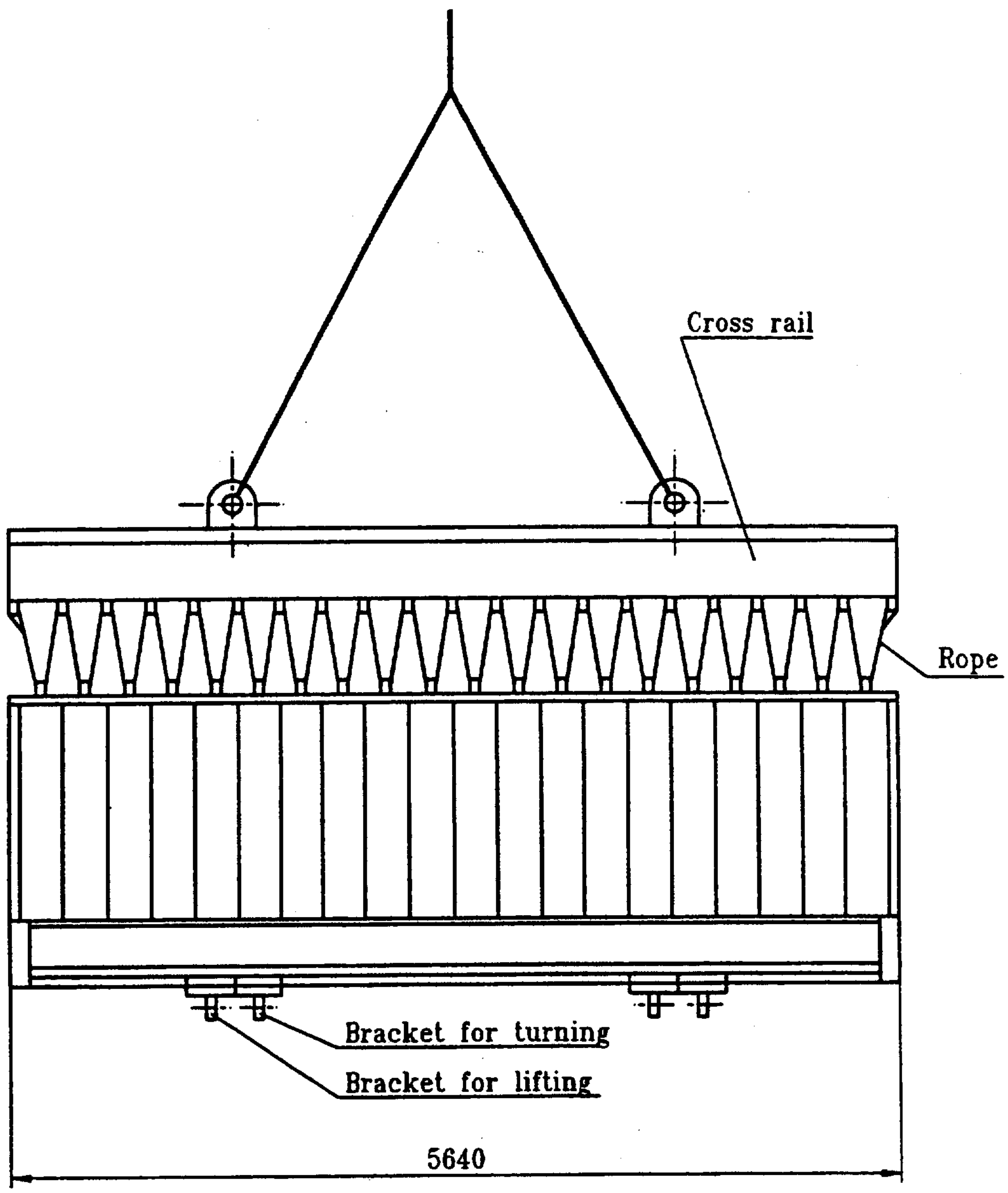

Cross rail
Rope
Bracket for turning
Bracket for lifting
5640

Figure 13:

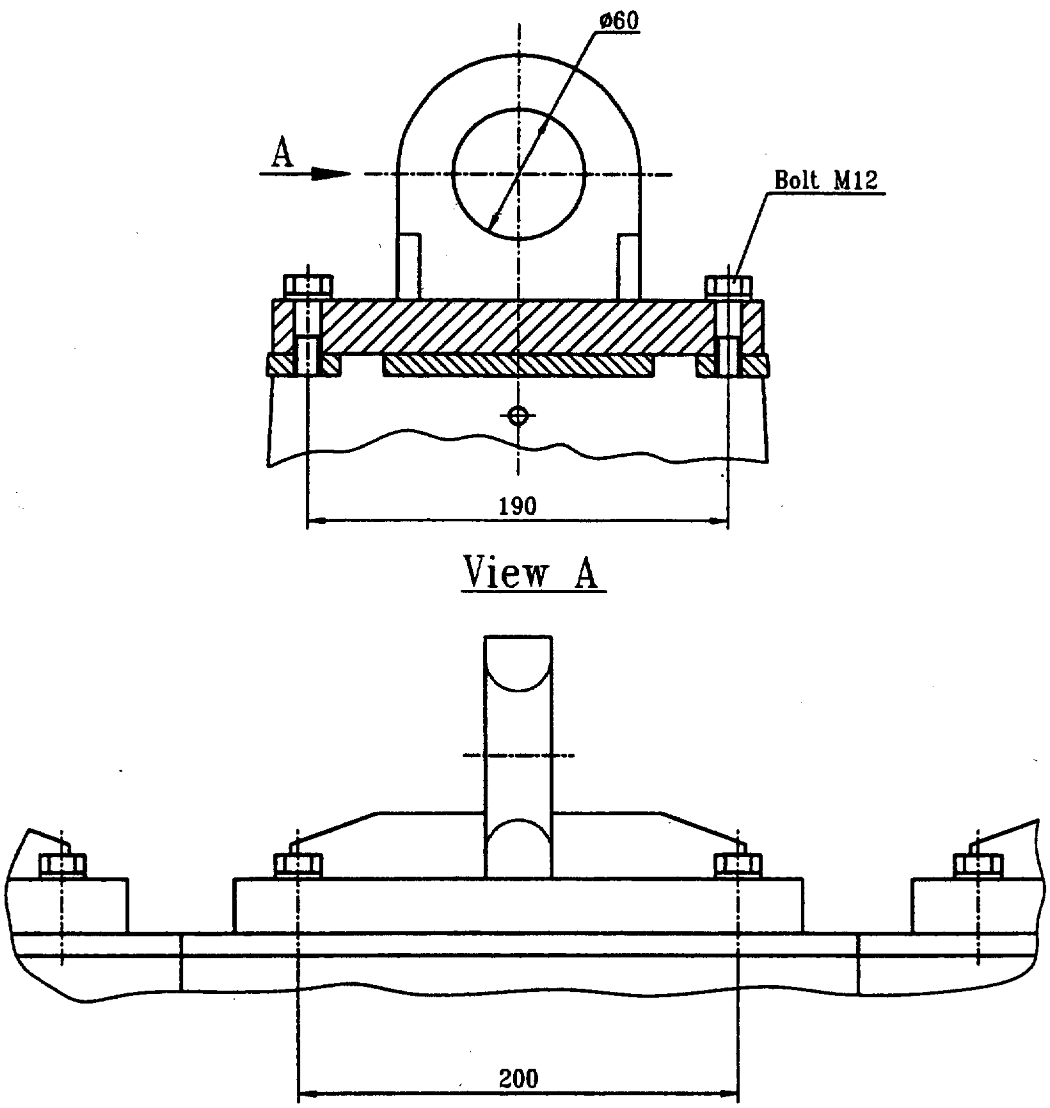


Figure 14:

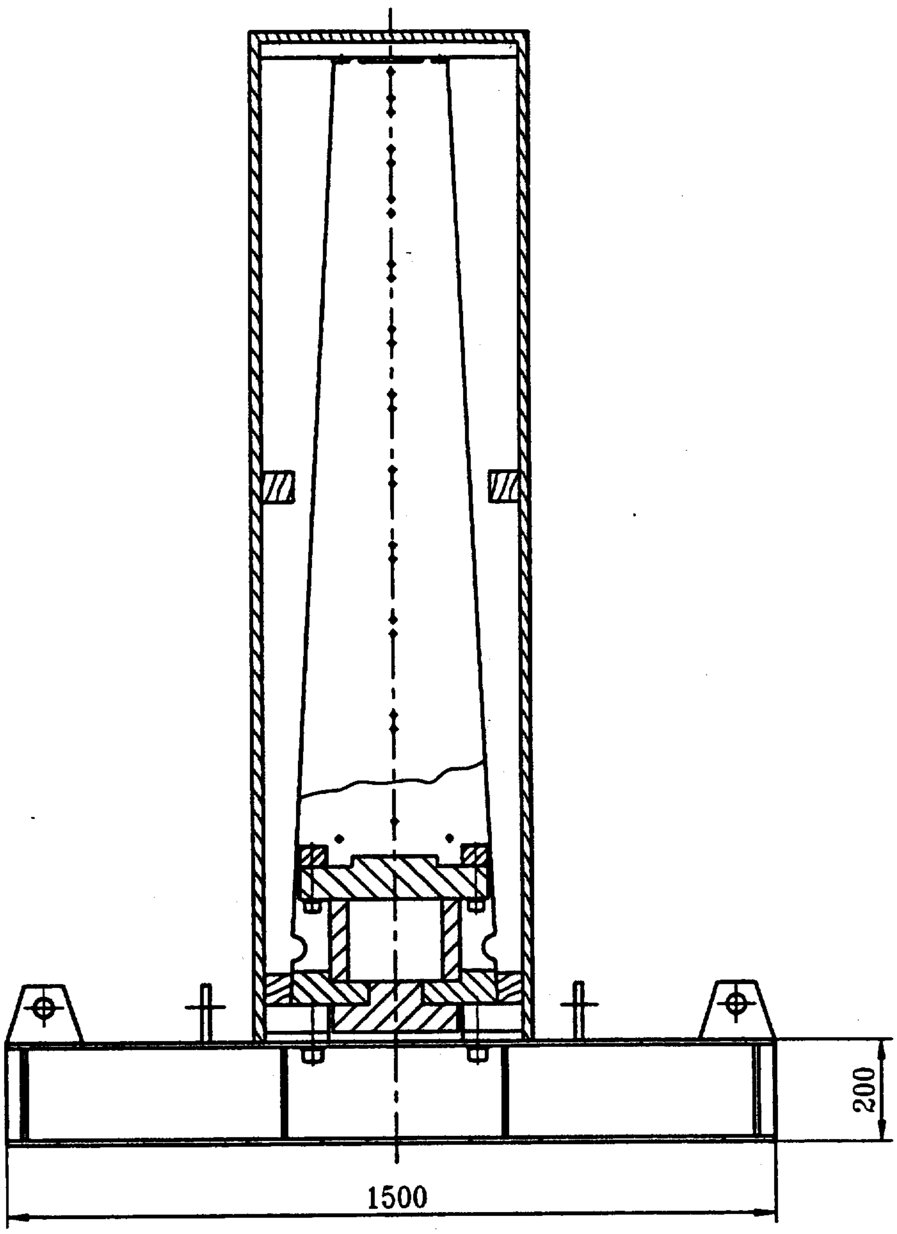
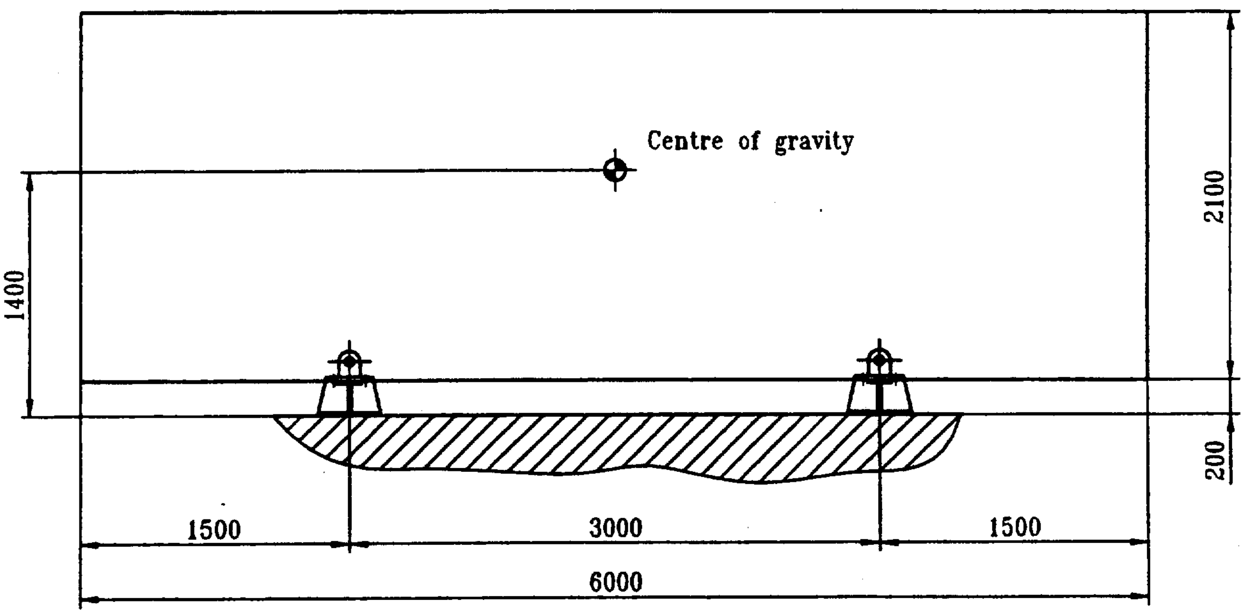


Figure 15:



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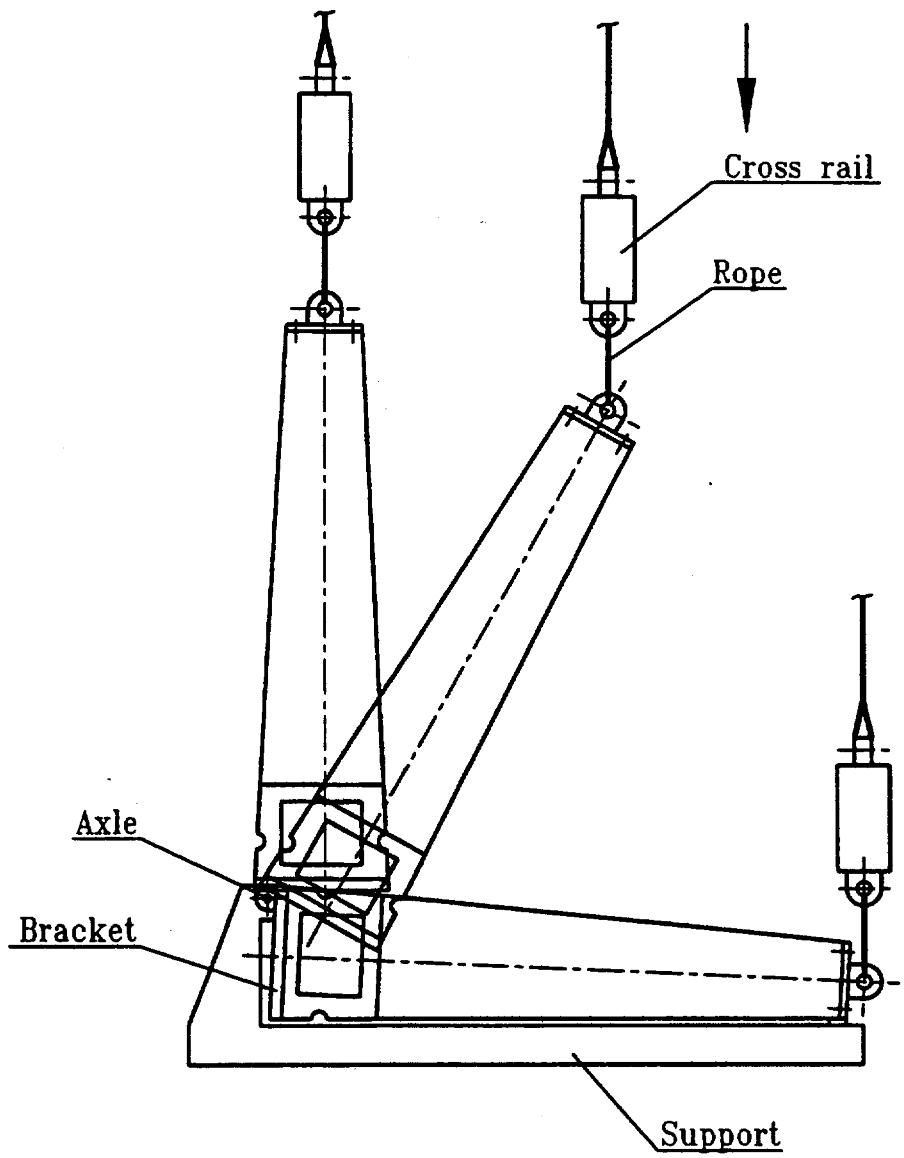


Figure 17:

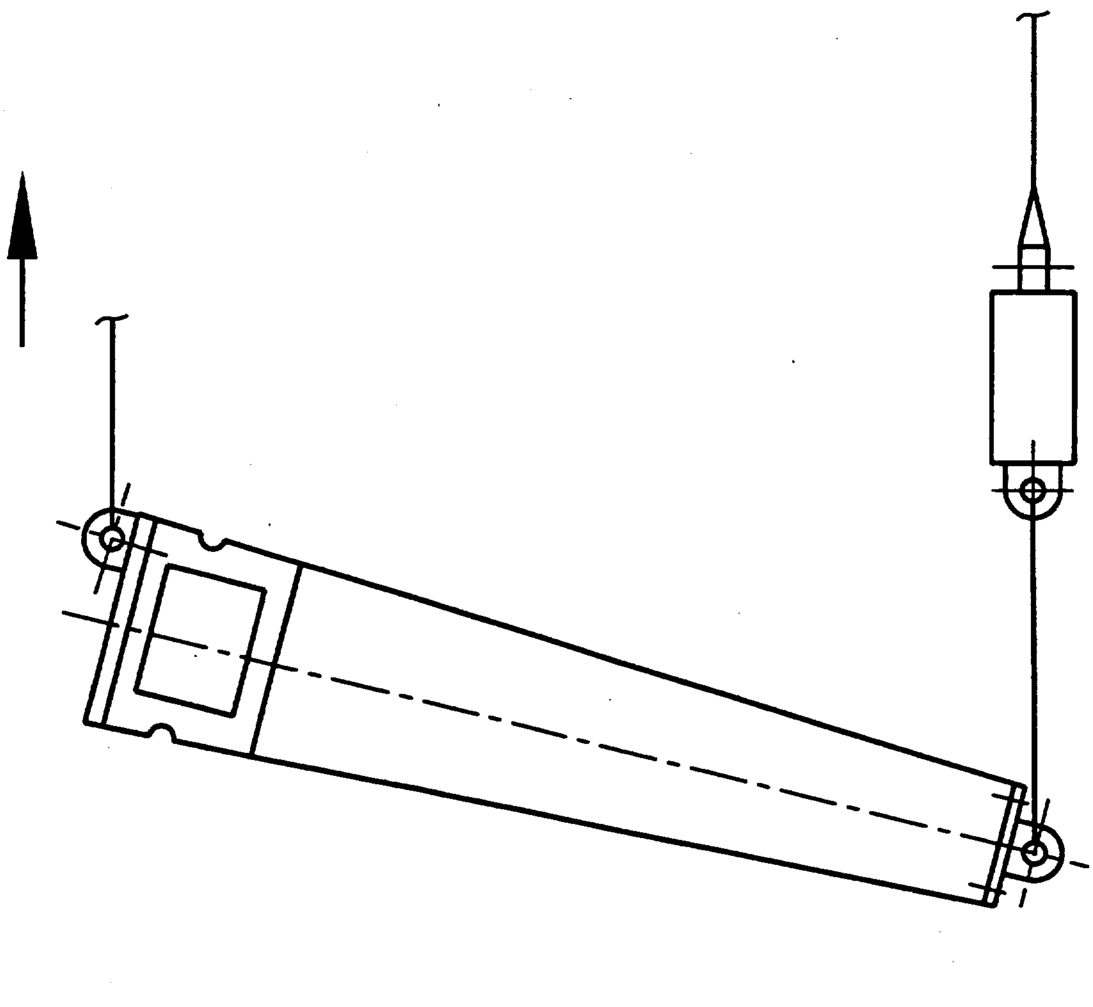


Figure 18:

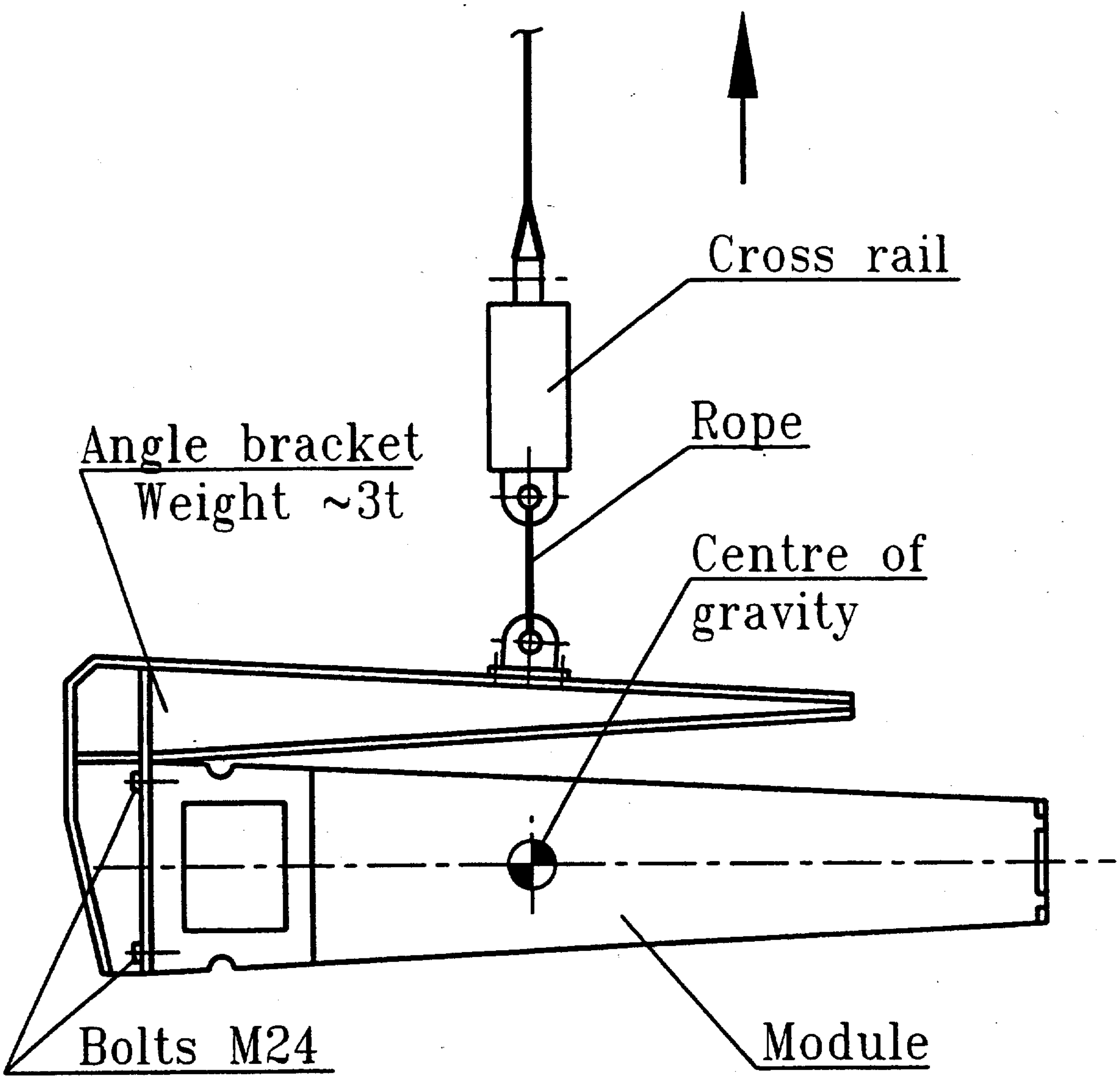

Cross rail
Rope
Angle bracket
Weight ~3t
Centre of
gravity
Bolts M24
Module

Figure 19:

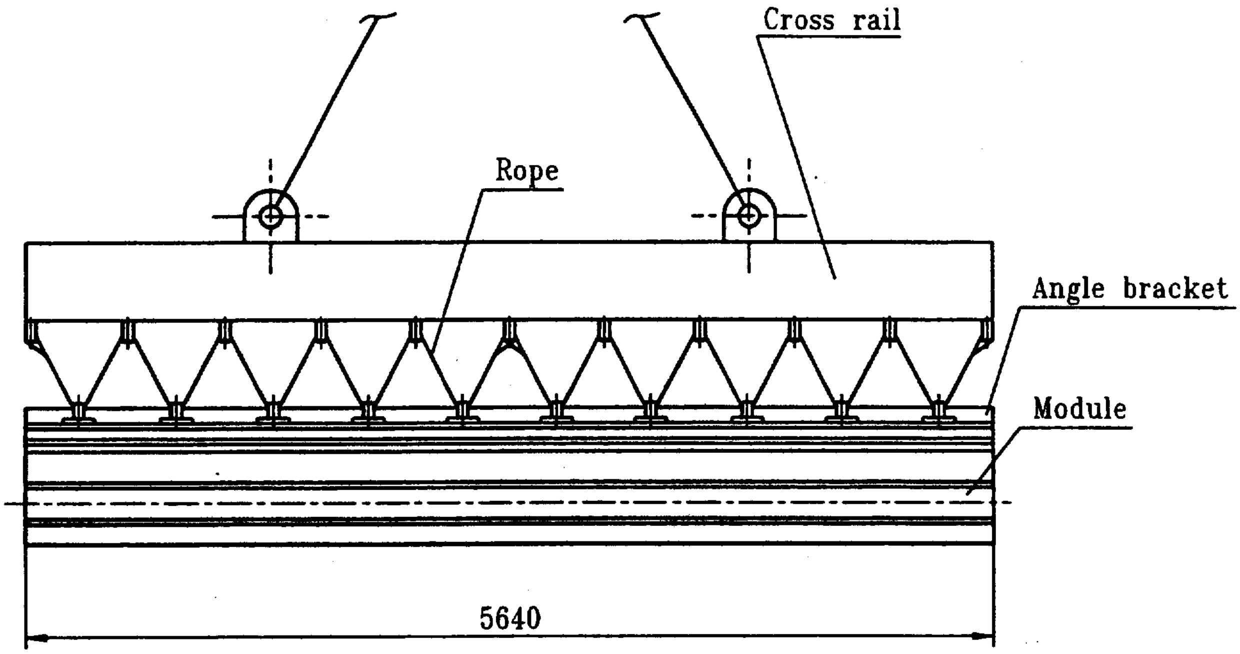


Figure 20:

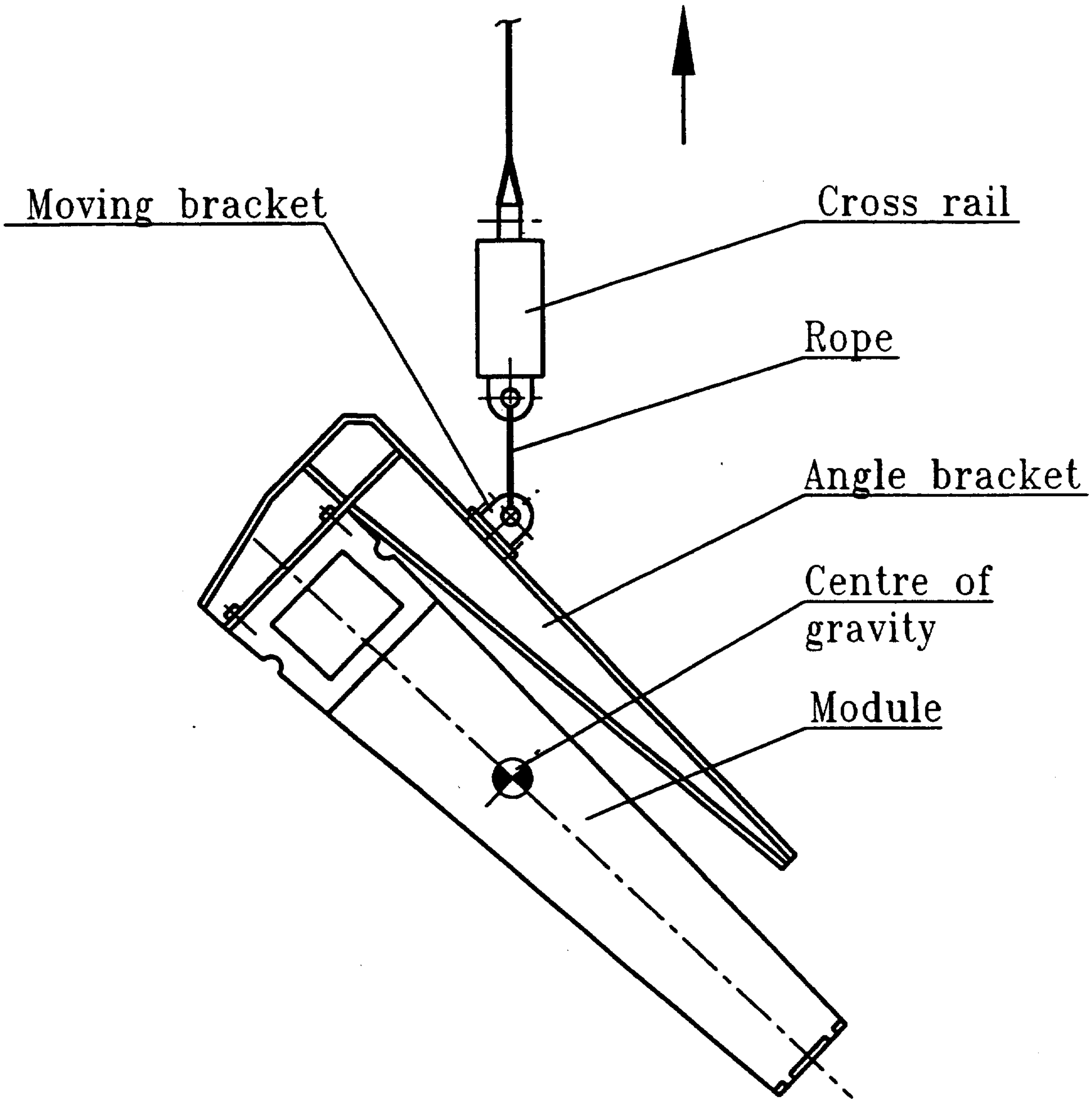
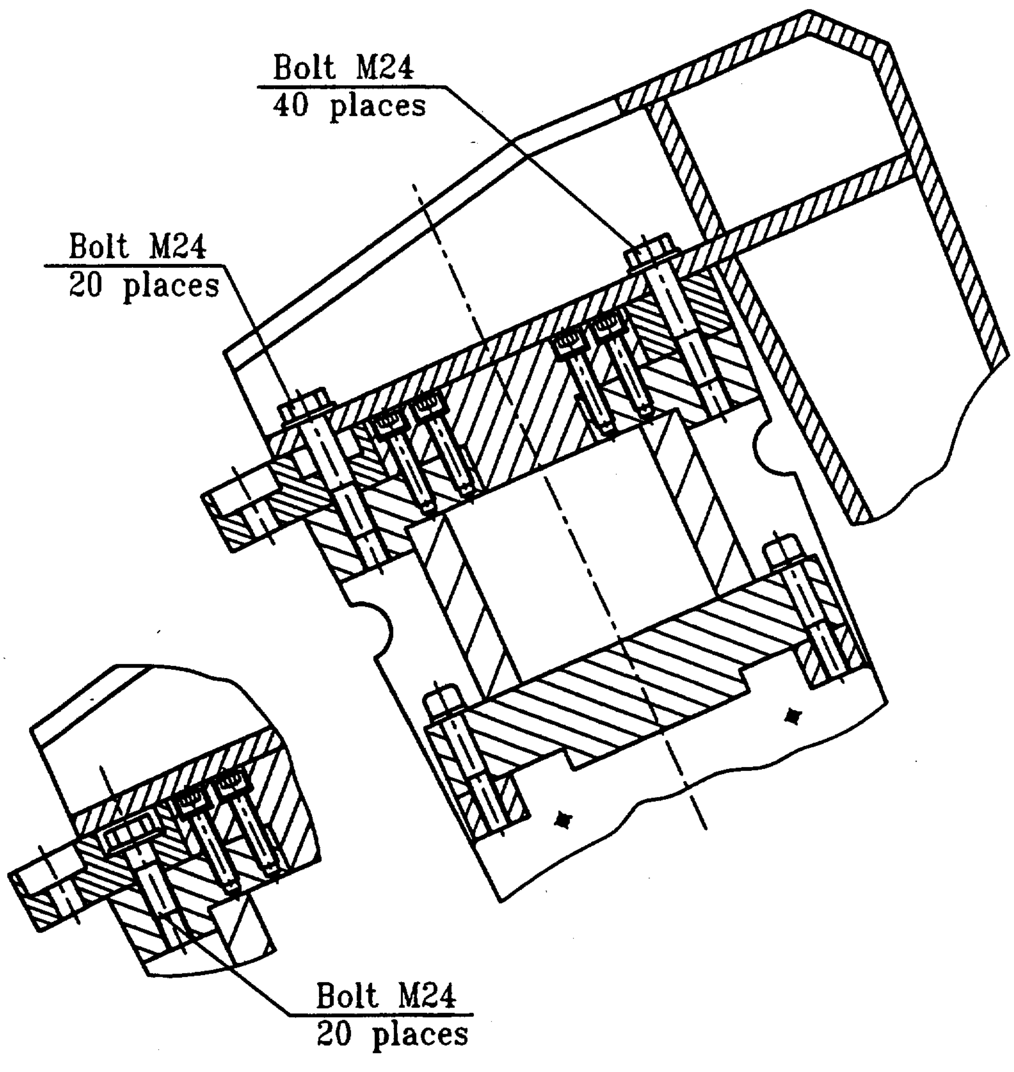

Moving bracket
Cross rail
Rope
Angle bracket
Centre of gravity
Module

Figure 21:



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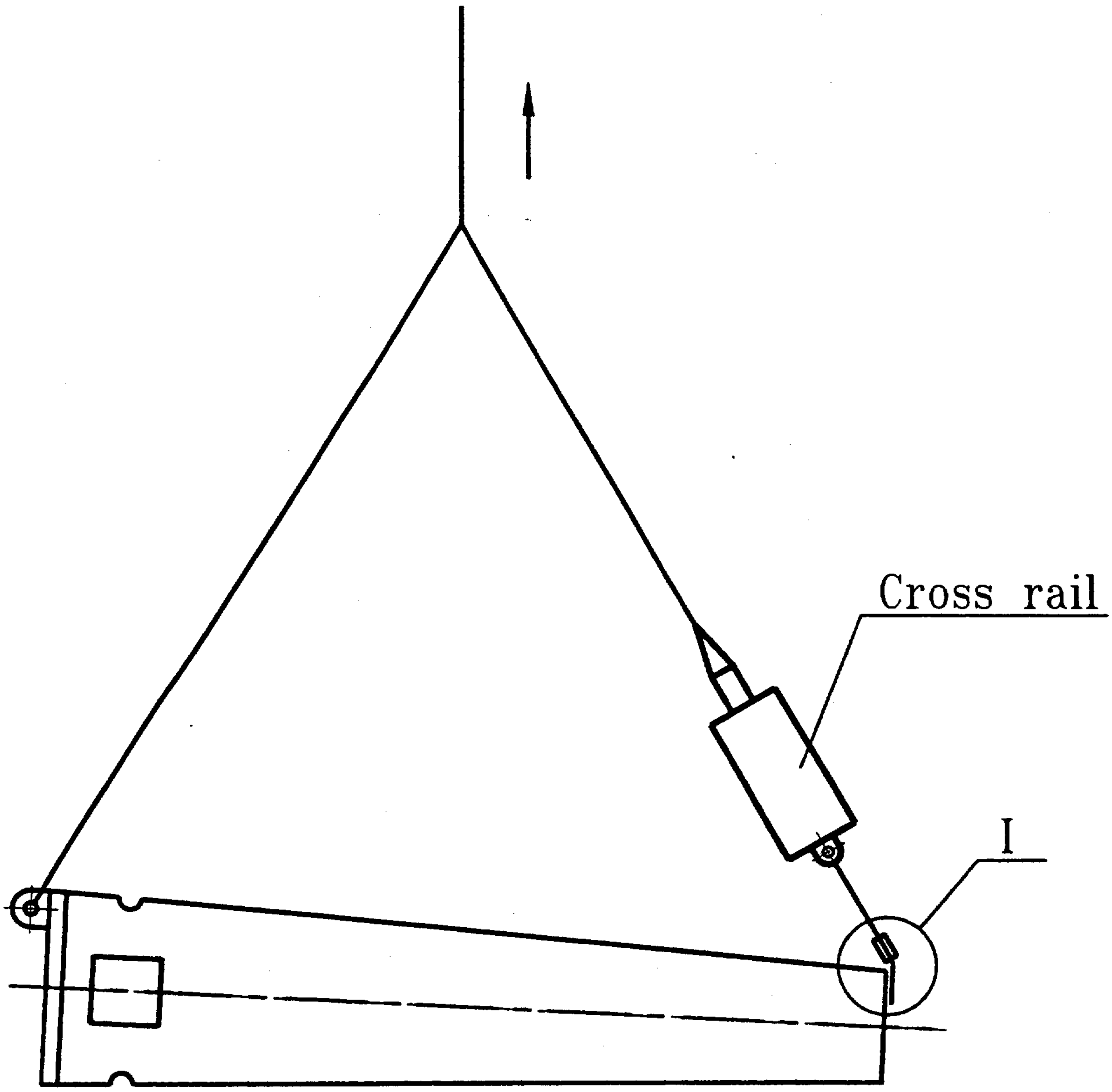

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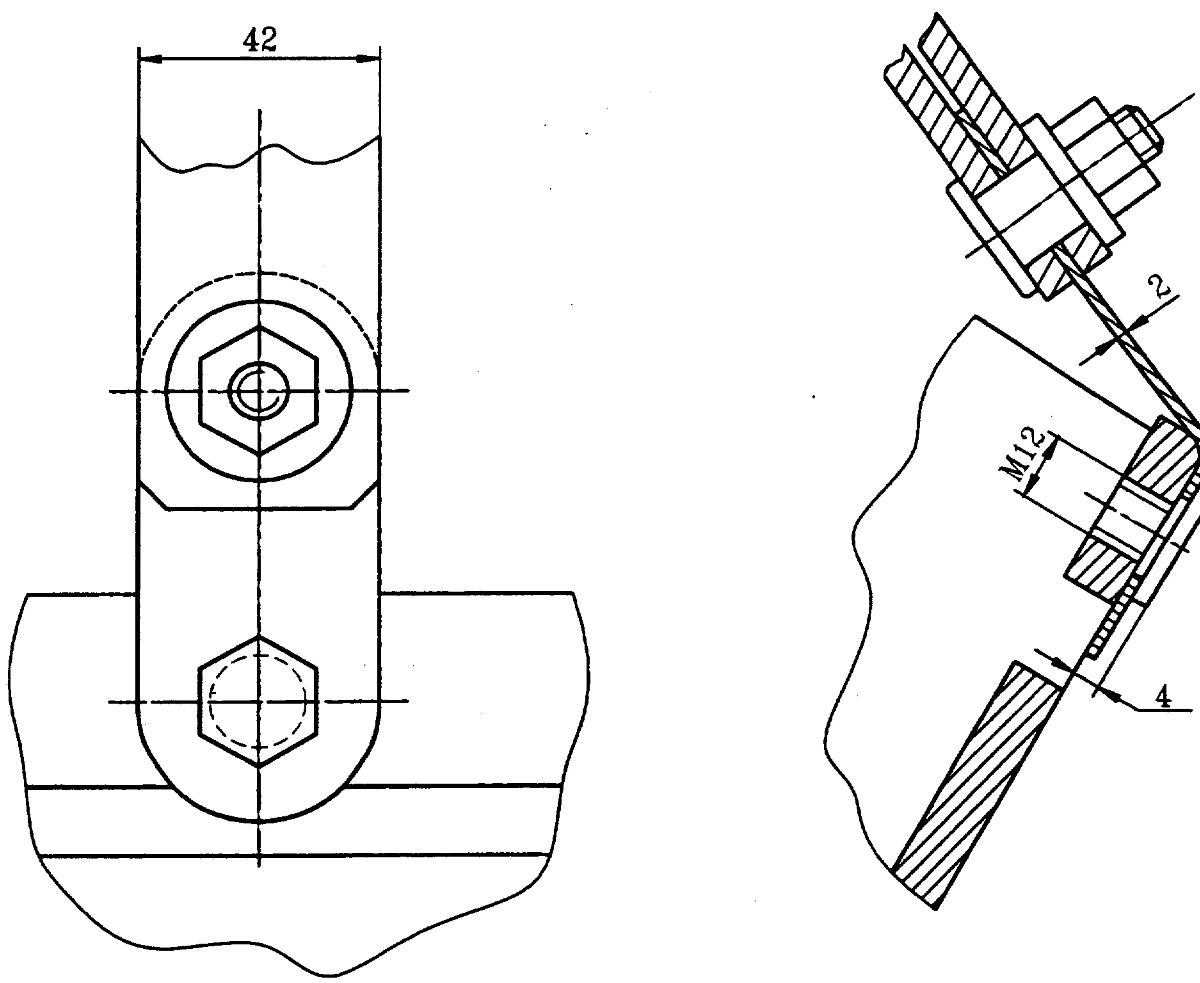

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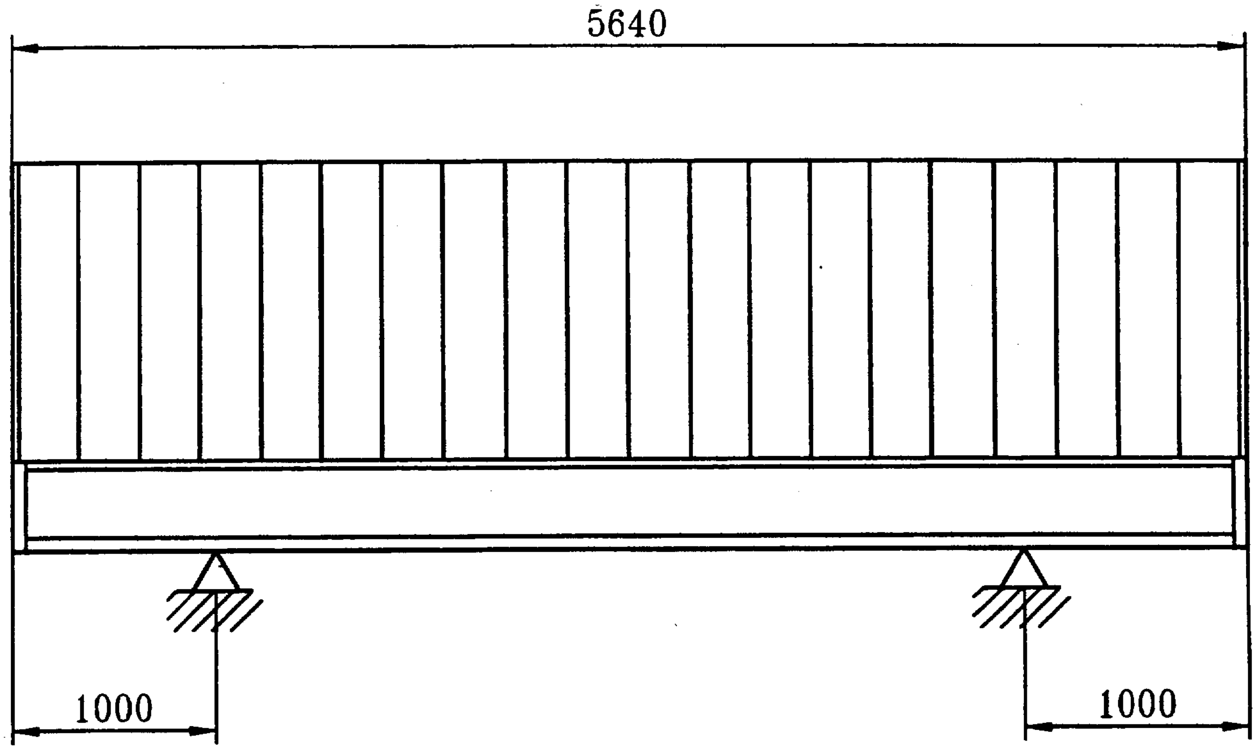

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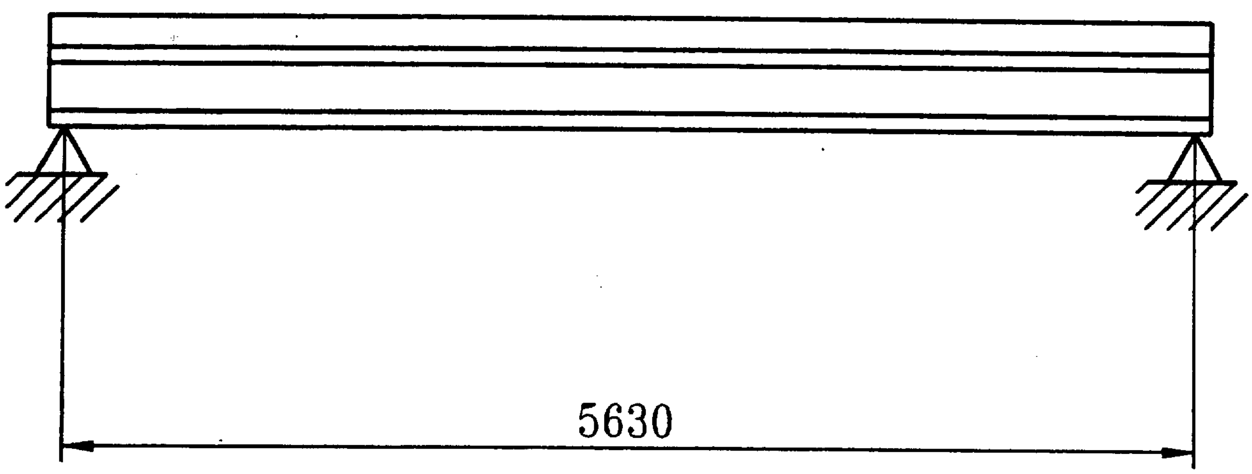

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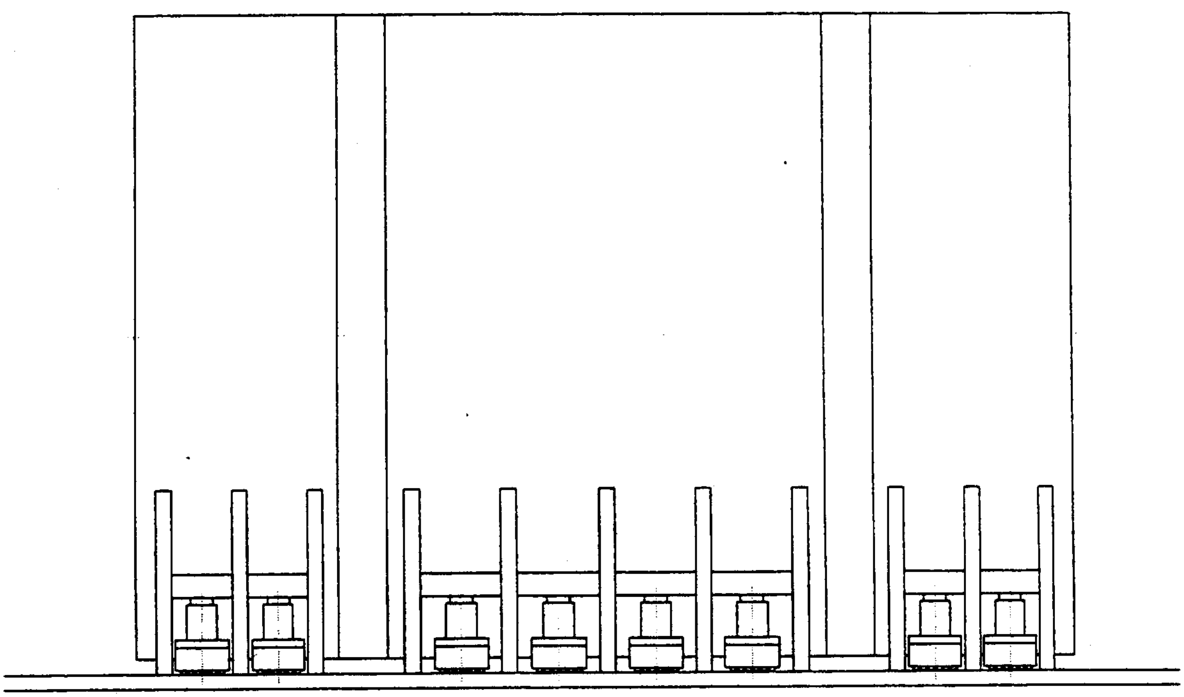

Figure 27: