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ATLAS

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61-13-95-22

TILE CALORIMETER MODULE ASSEMBLY.

JINR-DUBNA GROUP PROPOSAL.

Abstract

An approach to constructing and assembly of TILECAL module is proposed. The basic idea is to use the hot-rolled steel with some selection criteria to fabricate good supermodule assembled from 1 meter long modules.

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Contents

1 INTRODUCTION.

In this paper we have considered the principal possibility of manufacturing in RUSSIA (via JINR, DUBNA) of the ATLAS hadron tile calorimeter.

When technology development we have taken into account JINR's experience in manufacturing by DUBNA of 5th prototype module ($1m$ long; 57 periods of $18mm$ thickness each and 2 flanges of $20mm$ thickness each).

As a basic design was taken "The standard Tilecal design", existing on the current stage of hadron calorimeter developing and manufacturing.

Were not changed the master plate's external dimensions : fully conserved the spacer geometry as well as that one for tiles and conserved spacer's connecting procedure with master plates by use of elastic bushings and studs going across the full module thickness.

For the module assembly convinience and to achieve the necessary demands to whole supermodule geometry we have CHANGED master plates base system (master plates locating) when assembling : we introduced in module design an additional KEY.

More detailed information on introduced changings and modifications in the module and supermodule design will be presented in sections 3,4 and 5.

2 MANUFACTURING OF STEEL.

2.1 Steel manufacturer choosing in RUSSIA.

Using our very recent (SDC/SSL connected) direct contact with different RUSSIAN steel producing plants, basing on our detailed knoweledge of their official (state) standards as well as on our direct experience with these producers and their steel quality we have choosen as a main steel producer the NOVOLIPETSK METALURGICAL COMBINATE, - the NLMK at the LIPETSK - city.

This world wide known gigantic plant has necessary technical possibilities to roll **all** hadron calorimeter steel during **one** shift on **one** rolling mill.

Technology proposed here is based on NLMK hot rolled steel using. Such a steel is an ordinary, regulary produced steel with no special or additional demands needed to be mentioned.

2.2 Material specification.

As a main hadron calorimeter structural steel we propose a hot rolled steel sheets : this is Russian standard "CT-10" steel, indicated in state standard as "ГОСТ 1050-78".

The CT-10 parameters are the following ones:

- The chemical composition (max. allowed):

$$C = 0.14\%;\ P = 0.035\%;\ S = 0.04\%$$

- the mechanical parameters:

$$R_e(\text{elastic limit}) = 190MPa$$

$$R_m(\text{crack limit}) = 340MPa$$

The hot-rolled ГОСТ 1050-78 $5mm$ and $4mm$ thick plates must be have tolerances within the limits $^{+0.1}_{-0.4}mm$ but in reality (our experience) the NMLK is able to have $^{+0.00}_{-0.15}mm$ tolerances for the thikness of one (15 tons "unit") serialy produced sheet banded in 15 tons heavy roll. Roughness of sheet surface corresponds to R_a value in microns:

$$R_a = (3.2 \div 6.3)\mu$$

When steel producing NLMK plant makes an authomatic steel thickness measurement and recording with 20 micron precision (value of scale gradation).

15 tons heavy roll will be cutted on single $3.3 \div 4m$ long sheets which will be then stacked in $4 \div 5$ packs each $3 \div 3.5t$ heavy. It is foreseen that for the first and last pack sheets their thickness will be measured and recorded. All packs will be marked . Measurement results will be used at futher plates production process.

2.3 Steel quality control.

All necessary kinds of control, necessary corresponding tooling, the volume of control as well as record formates can be described in future

QUALITY CONTROL PROGRAM . At current stage we do not consider this problem (comment: Dubna and NLMK have accumulated significant Q/A and Q/C experience including measurements stages when fabricating steel plates for SDC/SSC-Lab). We would add that we do not limit ourselves with Q/C and Q/A requirements at this moment.

2.4 Conditions of steel plates storage and of their transportation to modules manufacturer.

On all stages of material transportation from its manufacturer to final product producer all steel sheets must be surely protected from moisture, water acces to sheet surface.

When sheets transportation one must follow strictly slinging scheme, use slinging fixturings and use sheets packing fixtures as well as pack transportation fixturings.

Sheets must be stored stricktly horizontally. Storage place must be dry, warm and with no dangerous for steel admixtures in air.

To avoid overloading of storage it will be usefull to order that amount of steel which is corresponding to the hadron calorimeter components production schedule.

3 MODULE MANUFACTURING.

When disposing in RUSSIA the modules manufacturing order the final choice of producer will depend mainly on production schedule.

The potential manufacturers in Russia could be JINR's machine-shop, Savelovo machine tool plant, ATOMMASH-COMPLEX (VOLGODONSK-CITY, 1200 km off Dubna) ...SAVELOVO is 15 km off DUBNA.

The ATOMMASH is a unique plant able to fabricate any imaginable in modern industry size steel systems up to $\sim 10^2$ tons heavy.

Joint Institute for Nuclear Research has long term connections to ATOMMASH. The experience of cooperation is highly fruitfull... Good personal working contacts are established...

3.1 Steel storage. Incoming inspection.

When receiving of the steel (by spacer/master plates producer) from NLMK producer must make the incoming metal inspection.

For such a control the following information must be available for checking:

- heat number
- slab number
- sheet pack number
- sheets thickness measurement results
- other

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- other

The final list of items under control could be later described in quality control programme.

When sheets or packs transporting one must follow item 2.4 demands.

3.2 Master plates production.

For 5th hadron calorimeter prototype module fabrication we have obtained from NLMK $5^{+0.14}_{+0.10} mm$ thickness steel sheets for master plates.

These tolerances were valid for the full ordered set of metall with total weight of 8 tons.

In order to satisfy the shop-drawing requirements of thickness [5 ± 0.05 mm] we have decided to remove extra-thickness by chemical etching. After etching in SAVELOVO the NLMK steel sheets obtained the necessary thickness, indicated on drawing.

We have observed the following negative features of this method:

- some degradation of surface quality: we had $R_a \simeq 3.2$ microns and obtained $R_a \simeq 12.5$ microns.
- some increasing of of thickness nonuniformity of one masterplate precutted sheet ... The etching process is not going uniformly due to very large precutted plate area.
- it was necessary to clean chemically the plate surface to remove rust (ortophosphor 50% concentration acid was used).
- plate production time was increased.

Master plates production technology we propose here is based on use of the all purshased rolled metal with no plates thickness mechanical treatment (no machining). With such an approach we conserve good initial sheet flatness, surface quality on the $R_a = 3.2mkm$ level and achieve the necessary geometrical precision of modules production.

3.2.1 Billets preparation.

When preparing the master plates-billets from original sheet we do take into account the steel rolling technology. To be short it looks as follows:

- 15 tons heavy slab is passing through a set of a few pairs of the rolling shafts.
- What comes out looks like a steel roll with preliminary settled (known) thickness with $^{+0.00}_{-0.15}mm$ tolerances.
- In general case (phenomenological fact) steel thickness in roll is uniformly decreasing from begining to the end of roll.
- After roll was cooled down steel will be flattned by passing between rolling shafts (steel bobbin gets unrolled...).
- In such a way obtained long sheet will be cutted on given (fixed) length pieces.
- next step is a final sheet flattening by passing between rolling shafts.
- sheets stacking in a packs of given dimensions.

As a result we obtain smooth thickness decreasing from one to another sheet's end. In order to avoid the systematic thickness difference acumulation when module assembling it is necessary to introduce billets marking and use a'priory established sheet cutting scheme.

1. Billets marking "on sheet".

Before starting sheets precutting each sheet will obtain (by electric pencil) its identification number. In a special log-book we indicate to what purchasing (delivered) party of metal is given precutted sheet belonging to... To make marking simpler we use template.

2. Sheet blank lay-out.

To obtain precutted plates we use Guillotine shear. Scheme of original plate cutting is given on FIG.1. Template is used to contour the cutting lines... Some other (then Guillotine shears) methods are possible to obtain precutted plates.

3. Sheet rolling (straightening) if necessary.

Guillotine shear usually gives some flattness violations of precutted plate. Therefore such a plate needs to be straightend. Usually it can be achieved by additional rolling which is necessary before moving plate for further machining... When laser or gas cutting is used such a distortion does not appear, so there is no need to straighten precutted plates. What cutting procedure will be in reality used must be determined by master plates producer.

3.2.2 Precutted plates (billets) preparation for machining.

We propose master plates machining when they stacked in pack. Amount of plates in pack corresponds to quantity of plates in 1-m module plus some technological reserve. If this figure is fixed to be equal 120 (as in 5th prototype module), then each pack will contain plates numbers

- 40×10 key ways in narrow wedge side
- satisfy the $1550_{-0.3}$ dimension.

3.2.6 Holes drilling with drill jig.

We drill the plate holes using the drill jig. This operation is done with whole pack with $2 \div 5$ plates/pack. When placing of pack into drill jig the plates locating is done with use of $50mm \times 10mm$ and $100mm \times 10mm$ key ways. Drilling precission is illustrated by FIG.5.

3.2.7 Quality control.

The kinds, methods and amount of controls as well as report-forms can be described in special "Quality control program". At current stage the above mentioned operations are not prescribed.

3.2.8 Interoperational storage.

Master plate billets, plates under machining, when storaging between operation and ready plates must be kept in hiorizontally on solid support. Storage conditions for plates must be satisfied as item 2.4 indicated.

3.3 Spacers production.

When fabricating of 5th prototype module of h-cal we obtained the NLMK steel for spacers: $4^{+0.10}_{+0.01} mm$.

These figures (tolerances) were valid for the all ordered (4 tons) metal.

Spacer's thickness tolerances indicated on drawing were ± 0.1 mm.

As master plates were thicker then it was indicated on drawing and we decided to use chemical etching, so for some spacer plates we also used etching. Remaining spacer plates passed grinding.

After such a treatment (etching or grinding) all spacer plates thickness was not more then 4.05 *mm*.

Negative consequences of treatment:

- we were not able to obtain spacers which look (by eye) identically
- after grinding we had to do additional operation: straightening of some spacers

For spacers production now we propose the technology based on use of hot rolled steel but without spacer thickness machining. With such a technology we conserve excellent initial plates flattness, surface quality on the $R_a = 3.2 mkm$ level and keep the necessary module production geometry precision.

3.3.1 Billets preparation.

Steel sheets preparation technology for spacer and master plates is identical, see item 3.2.1. Therefore here is also necessary to have billet's marking and lay-out scheme.

1. Billets marking.

   Each billet must have its identification number done by electric-pencil. In a special log-book we indicate to what set of metal the given billet number is belonging to. For marking simplicity the template is used for lay out.

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1. Billets marking.

   Each billet must have its identification number done by electric-pencil. In a special log-book we indicate to what set of metal the given billet number is belonging to. For marking simplicity the template is used for lay out.

2. The sheet lay out.

To obtain billets one could use the Guillotine shears. The sheet thickness is allowing the horizontal knife cutting and it does not cause the billet's edge curving. The lay out scheme is given on the FIG.6. Some other methods of billets obtaining are possible provided they conserve the billets flatness.

3.3.2 Billets preparation for machining.

For machining the spacer plates are packed. When 5th prototype spacer producting pack had 5 billets. This figure could be noticably larger provided necessary technological preparation is done.

3.3.3 Holes drilling.

Originally in the pack of billets we drill two ⌀8*mm* base holes. These are holes which will be used for speacer clamping when assembling.

3.3.4 Contour machining.

The billets pack locating is achievedd by 2 holes in fixturing device. A possible spacer contour-surface machining sequence see on FIG.7. Machining: by milling or planing.

3.3.5 Quality control.

The kinds, methods and amount of controls as well as report-forms can be described in special "Quality control program". At current stage the above mentioned operations are not prescribed.

3.3.6 Interoperational storage.

Spacer billets, spacers when interoperational storage and ready spacers must be kept horizontally on solid basement. Spacer's storage and transportation must follow item 2.4.

4 MODULE ASSEMBLING.

4.1 Reference information.

Weight of one rolle of steel sheet .... $15t$

Weight of one meter of $5mm$ sheet $1520 \cdot 5 \cdot 1000 \cdot 7.8 \cdot 10^{-6}$ .... $60kg$

Weight of one meter of $4mm$ sheet $1520 \cdot 4 \cdot 1000 \cdot 7.8 \cdot 10^{-6}$ .... $48kg$

Length of $5mm$ sheet roll .... $250m$

Length of $4mm$ sheet roll .... $312m$

To fabricate $1m$ long module master plates

the needed amount of steel is $\frac{1.6m \cdot 120}{4}$ .... $48m$

To fabricate $1m$ long module spacer plates

the needed amount of steel is .... $25m$

One steel roll is enough to fabricate

master plates for .... 5 modules

spacer plates for .... 12 modules

Each roll (for master and for spacer plates) will be cutted and stacked in 5 packs each $3t$ heavy.

From one pack (with $5mm$ steel sheets) will be cutted 120 master plates for one 1 meter long module.

From one pack (with $4mm$ steel sheets) will be cutted the amount of spacers necessary for 2.4 module of 1 meter length.

4.2 Stacking.

After machining 120 ready master plates are stacked in one pack. As to spacer plates they also are stacked: 60 plates in one pack. Then for all master plates packs the pack height is measured under 20 tons pressure. Spacer plates pack height is measured under 2 tons pressure/pack.

When steel sheet rolling its thickness at the begining of roll (bobbin) is $4.0mm$ and at the end - $3.9mm$.

Correspondingly for $5mm$ sheets the thickness at the roll begining is $5.0mm$ and at the end - $4.9mm$.

Sheet thickness along the steel length in roll is given on FIG.8.

Thickness changing along the length gives as a result some difference in height of the first and the last pack of master plates: this difference is $0.02 \cdot 4 \cdot 120 = 9.6mm$.

For the $5mm$ uniformly thick steel in roll the expected master plates pack thickness would be $5.0 \cdot 120 = 600.0mm$ high. Due to steel thickness decreasing along the roll it will happen that the first pack height will be by $0.02 \cdot \frac{1}{2} \cdot 120 = 1.2mm$ smaller and equal to .... $598.8mm$.

For second pack .... $596.4mm$.

For third pack .... $594.0mm$.

For fourth pack .... $591.6mm$.

For fifth pack .... $589.2mm$.

Spacer plates first pack height will be $239.4mm$. Last spacer plates pack height is 234,6 MM

For the first module manufacture we take $598.8mm$ high first master plates pack and the last, 234,6 MM high, spacer plates pack.

As spacer plates location in module is a staggering one, it will double the module height and the last one is equal

$$H_{\text{module } 1} = 598.8 + 2 \cdot 234{,}6 = 1068 \quad mm$$

For the 5th module production we take last master plates pa 589,2 MM thick) and take first spacer plates pack 239,4 MM thick and as a result we obtain

By combining in this manner the packs of master plates and of the spacer plates we will get modules heights all equal to $1068mm$. In reality, due to some gaps between plates, the module's height could be bigger.

By having spacer plates of different height one can correct the module's height with $\pm 0.3mm$ precision (spacer plates thickness difference is within the $0.02 \div 0.1mm$ range).

To achieve necessary flatness of new period external surface when stacking of period into module, it is important to stack master and spacer plates accordingly their labeling (marking).

4.3 Module assembling in fixturing tool.

For 1-meter module assembly we use fixturing tool (FIG.9). This fixturing tool has two datum (base) surfaces. These surfaces are used for module master plates locating. Spacer plates necessary positioning in module will be determined by slotted bushings. Module assembling with using of hard base surfaces allowes one to achieve the module side surface nonflatness equal to $0.15mm$ (see APPENDIX 1).

After the necessary amount of master plates and spacers were stacked they must be compressed by studs acting through $20mm$ thick plate. The following action is module thickness measurement. If looks necessary, to obtain desirable module height and plates flatness some corrections could be undertaken with spacer plates exchanging. Studs then is placed on module and clamp it.

After necessary module height is achieved the two base surfaces must be removed from fixturing tool to get free acces to module. Then key is welded (on wide wedge side) to master plates. After that two $1000 \times 40 \times 10 mm^3$ plates must be welded to narrow wedge side. Now module is ready for assembling into supermodule (FIG.10; FIG.11).

5 SUPERMODULE ASSEMBLING.

Assembled module is rolled over its narrow side up and then placed on girder with help of rather special auxillary equipment able to move the module (FIG.12).

The module transverse positioning on to the girder is determined and fixed by module's key (was welded earlier). The key must be inserted in girder's key way.

Second module will be placed on girder close to first module. First/second modules distance is determined by module moving auxillary equipment.

Modules load on girder is transfered through key.The gap between girder and master plates surfaces is equal 0.5mm. Second module is moved towards the first one by jack.

By special auxillary tools the modules will be straped tightly. Then third module is positioned and same (as with 2nd module) operationes are repeated. Procedure is continued with IV,V,VI modules.

In the narrow wedge side key way will be inserted 5980mm long key. Key is fixing the modules relative positioning. Next step: all studs are inserted into supermodule. Temporary connecting (clamping) equipment removed.

Key (located in wedge narrow side) is welded to master plates. Wide wedge side master plates also were welded to the girder.

Now supermodule is prepared for the tiles to be inserted in.

The technology proposed allow one to achieve the assembly precision (along the supermodule length) equal to $\pm 2mm$; supermodules side

Then all six 6mm studs are removed out of modu sufaces ±0.25mm nonflatness is also technically achievable.

After tiles were inserted into supermodule (with fibers) the supermodule side surfaces are covered by 0.1mm thick, 300mm wide stainless steel foil. Foil strips are laying on along the supermodule and tightened by 750kg force for each strip.

Supermodule lifting, transporting and positioning will be done by standard lifting/rolling fixturings.

5.1 Quality control.

On current production stage needs no special regulation.

5.2 Packing and storage.

To avoid rust appearing on supermodule during storage period and transportation, each supermodule must be covered by polyethylen film case.

The case must be slightly vacuunized to prevent outside air moisture condensation inside case.

Supermodule storage must take place in dry, warm, closed building.

5.3 Transportation.

Rail-way supermodule transportation is supposed. For transportation period supermodule must be protected against damagings and moisture or water penetrating on supermodule details

6 CONCLUSION.

One of the realistic option of hadron calorimeter manufacturing in RUSSIA is considered here. The leading principles when (technology) choosing were the following ones:

- achievement of the required module and supermodule design parameters
- using of the ordinary, widely used equipment
- the most cheap steel using for the main components production
- module and supermodules assembly on the master and spacer plates production area
- achievement of the necessary modules and supermodules assembly rate.

7 APPENDIX 1

The module side surface nonflatness depends on the following parameters:

1. The nonaccuracy of the master plates side surfaces machinindg by planning; the achievable toleránces is $\pm 0.02mm$
2. The manufactured drill jig nonaccuracy: it affects when master plate surface machining; the achievable tolerance is $\pm 0.02mm$
3. The master plates key ways machining nonaccuracy. These key ways are the datum surfaces; the achievable tolerance is $\pm 0.02mm$
4. The gap between the key and the master plate key way; achievable tolerance is 0.04
5. Fixturing tool surfaces nonaccuracy; achievable tolerance is $\pm 0.02mm$.

The mean quadratic error of datum surfaces machining is:

$$\delta = \sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2 + \delta_5^2} = \sqrt{5 \cdot 0.04^2} \approx 0.1mm$$

If some of the plates will have more than $\delta = 0.15mm$ tolerances they will be grinded on the assemble module up to the required tollerance.

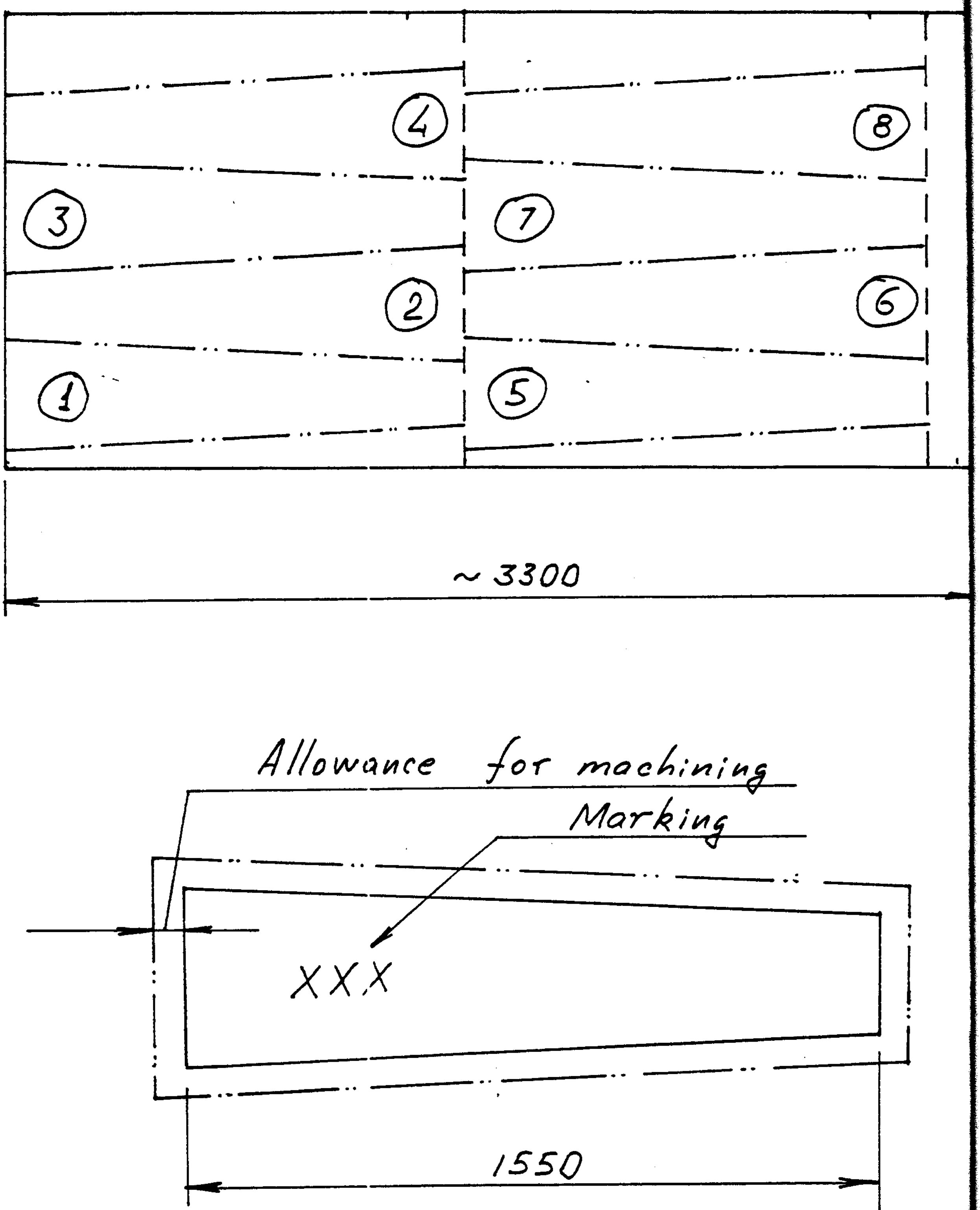


Fig. 1

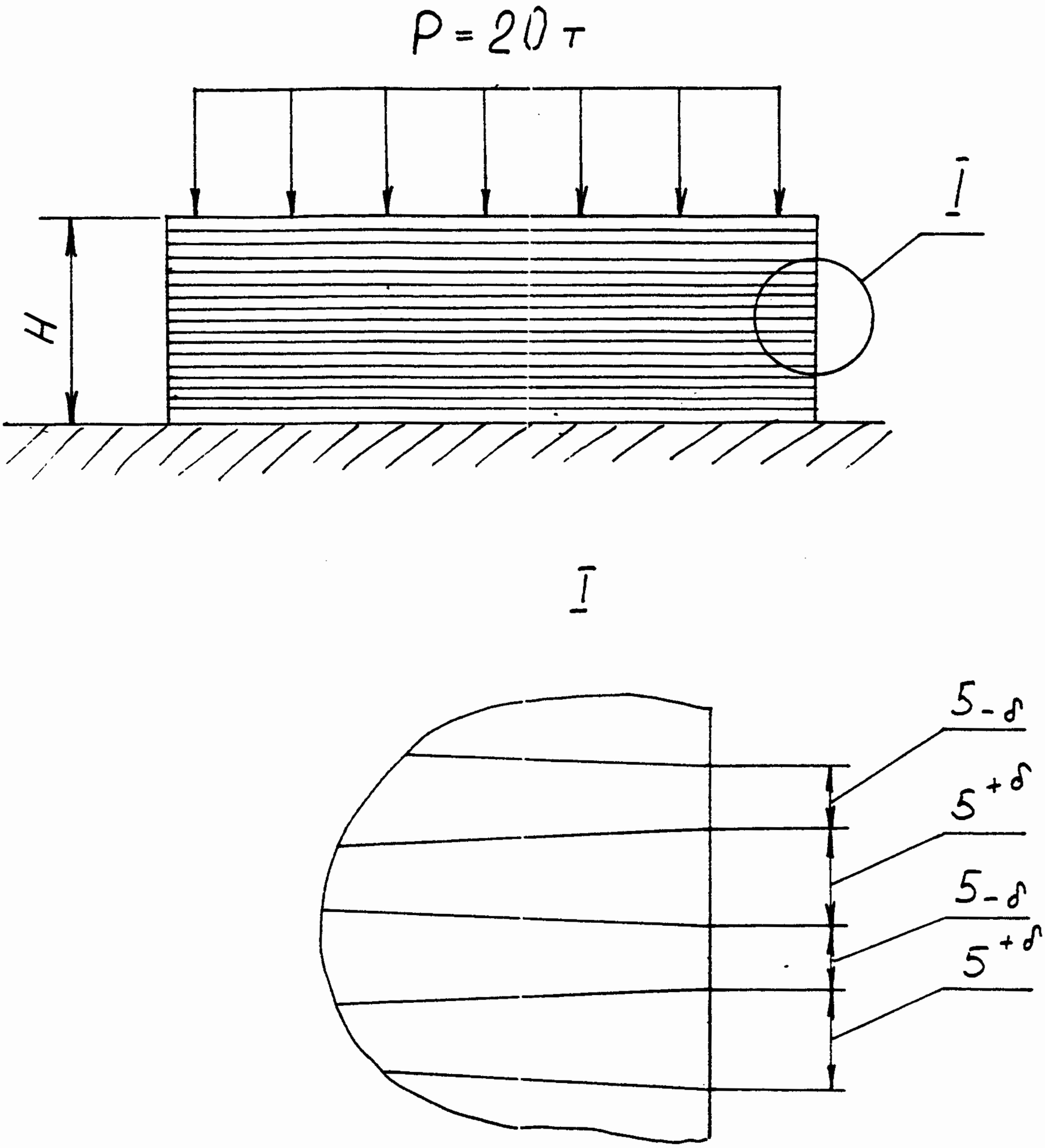


Fig. 2.

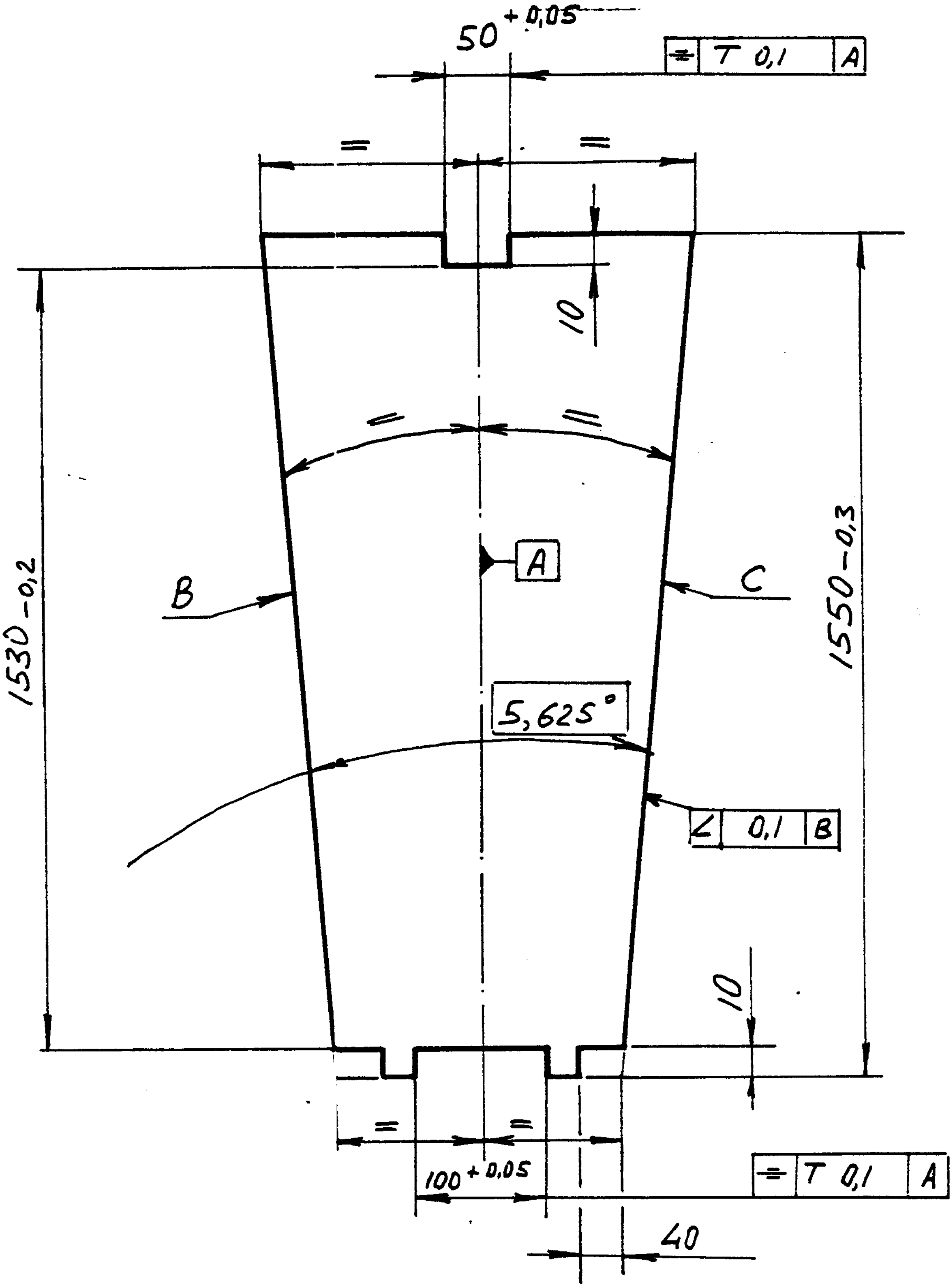
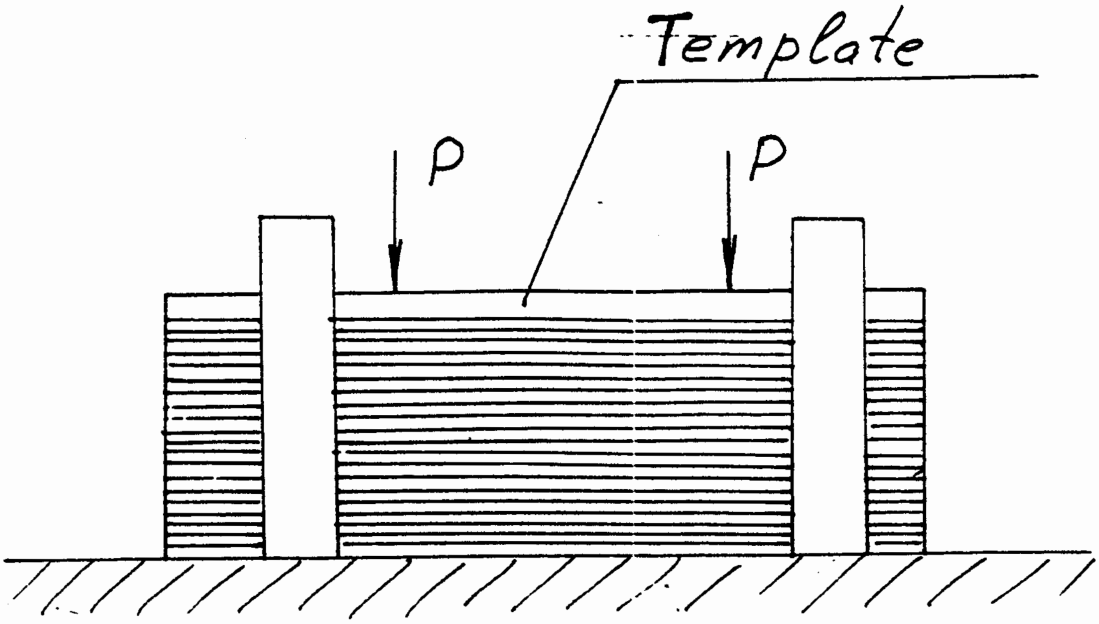


Fig. 3.



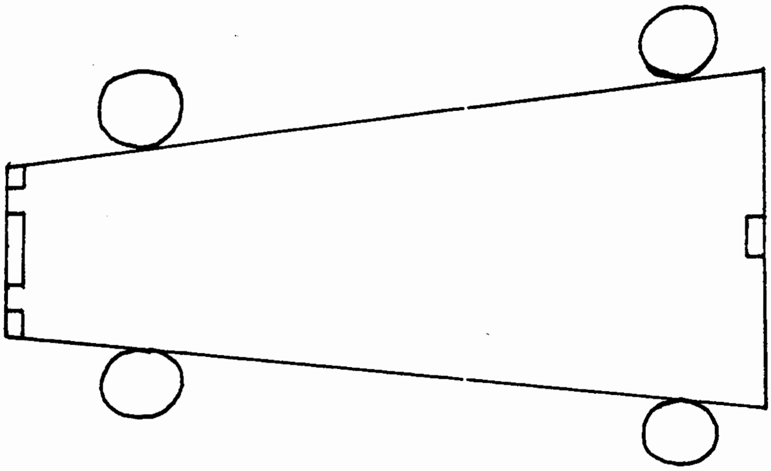


Fig. 4.

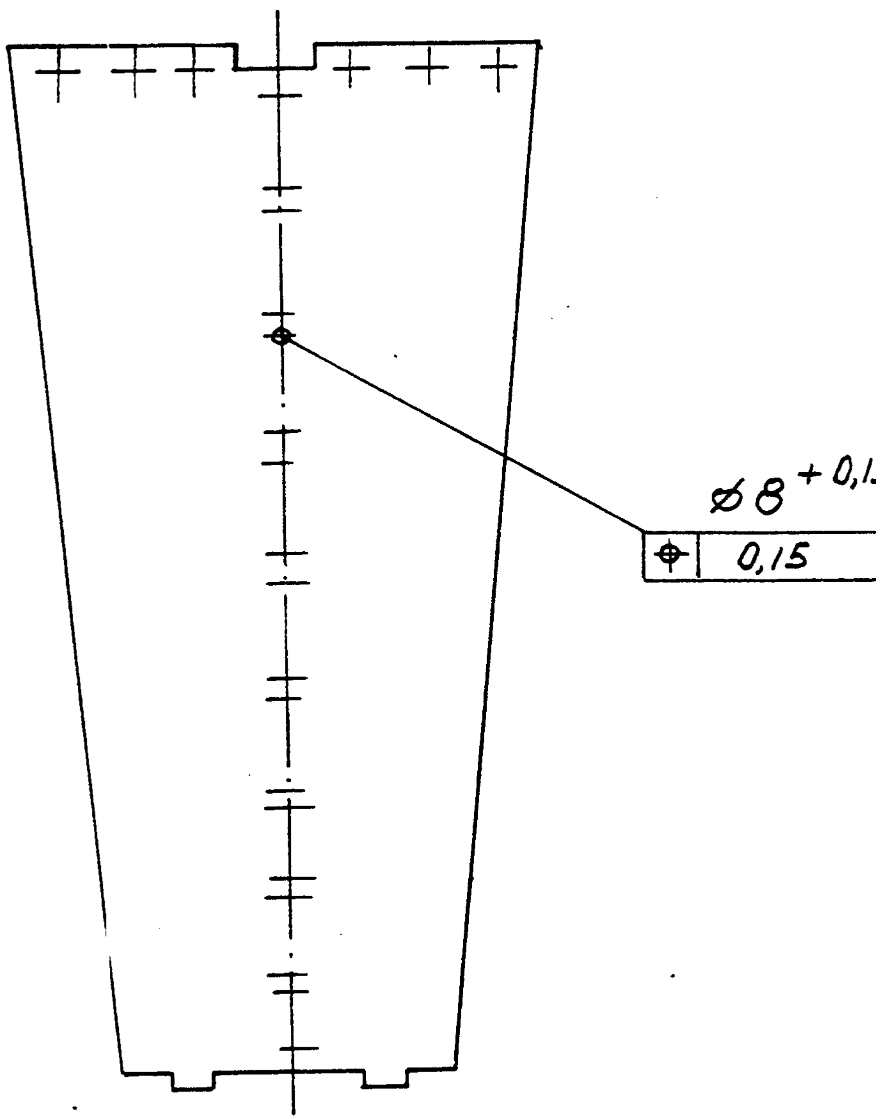


Fig. 5.

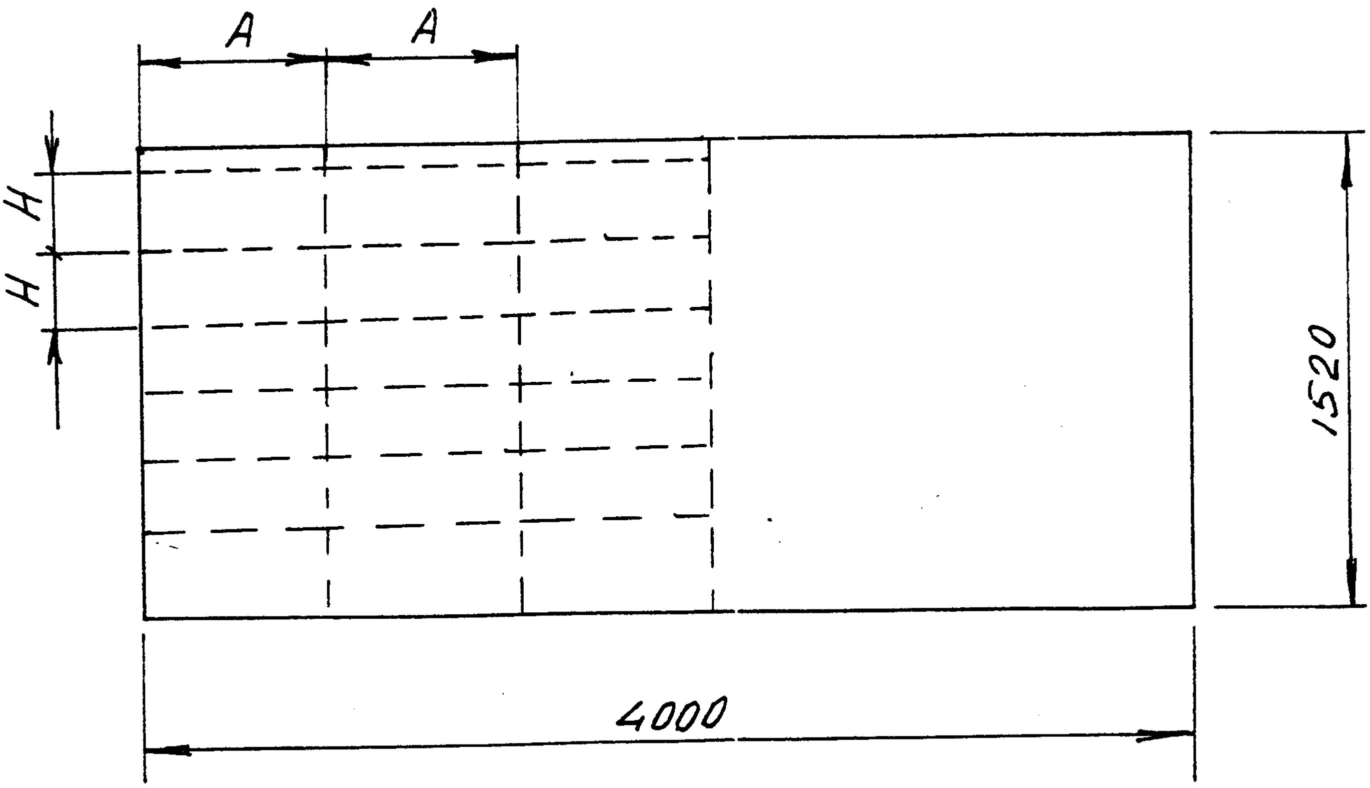


Fig. 6.

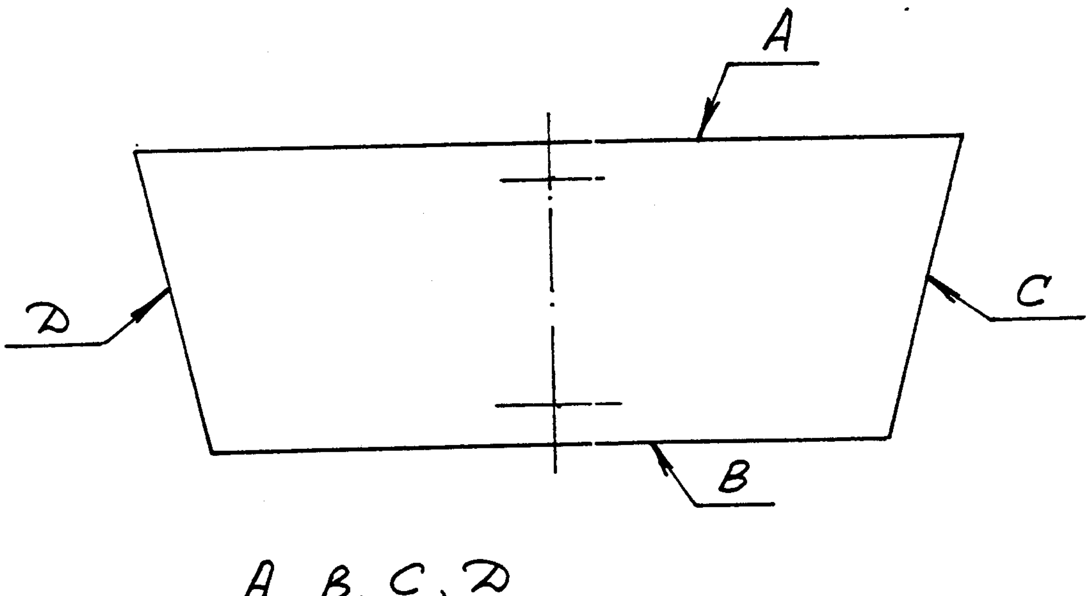


Fig. 7.

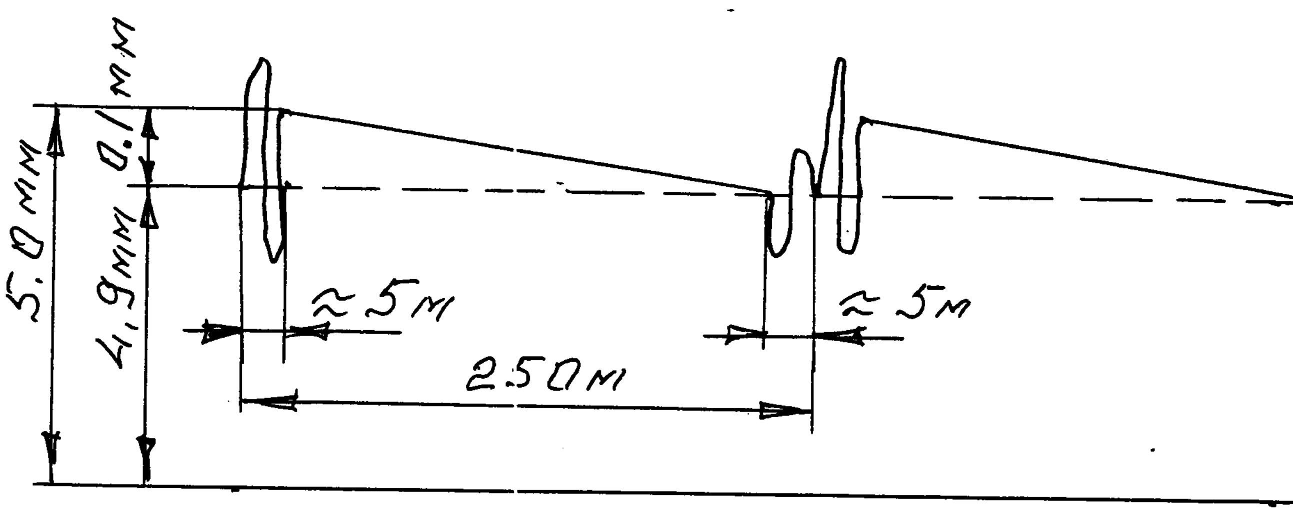


Fig. 8

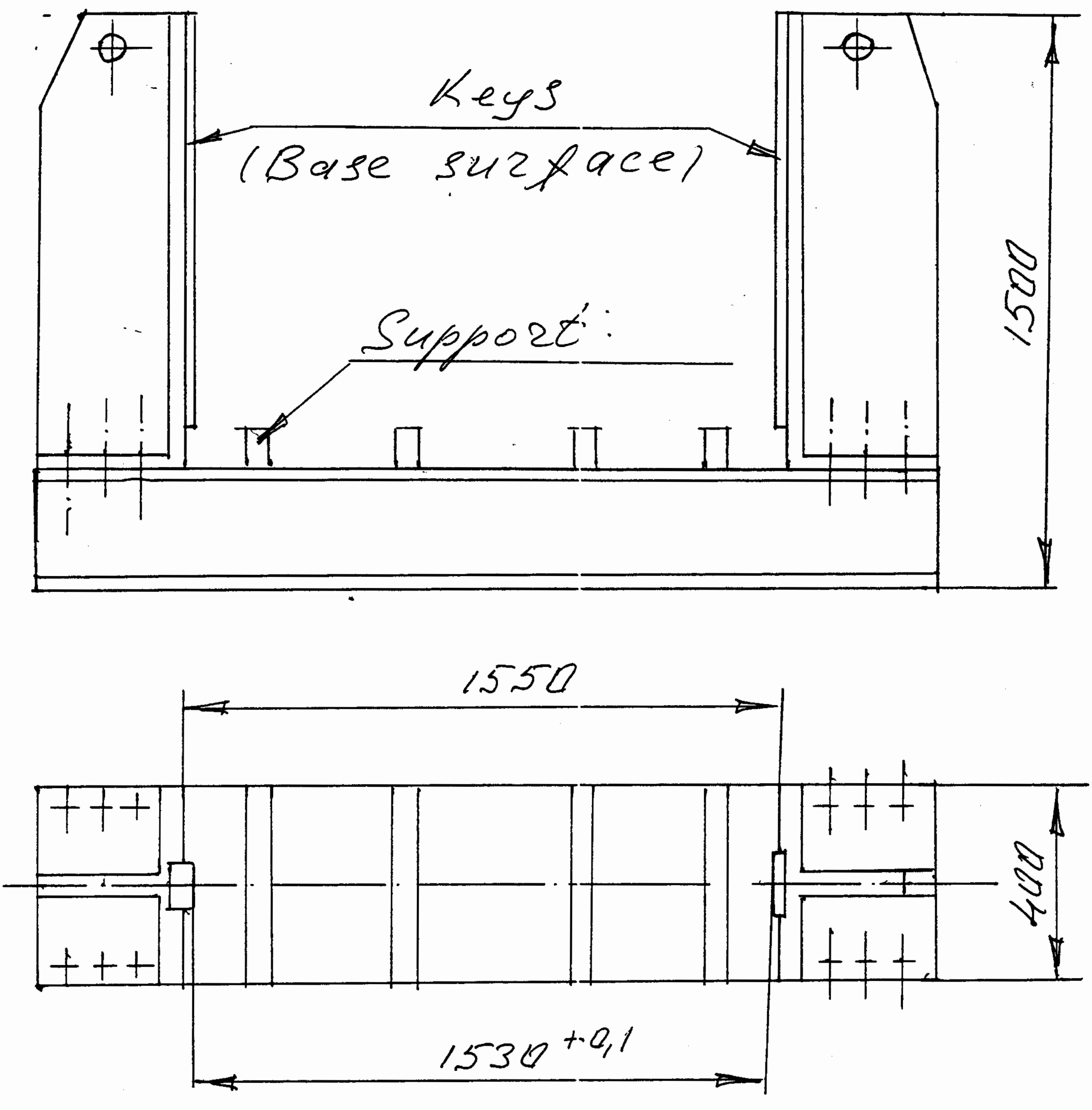


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Fig 9.

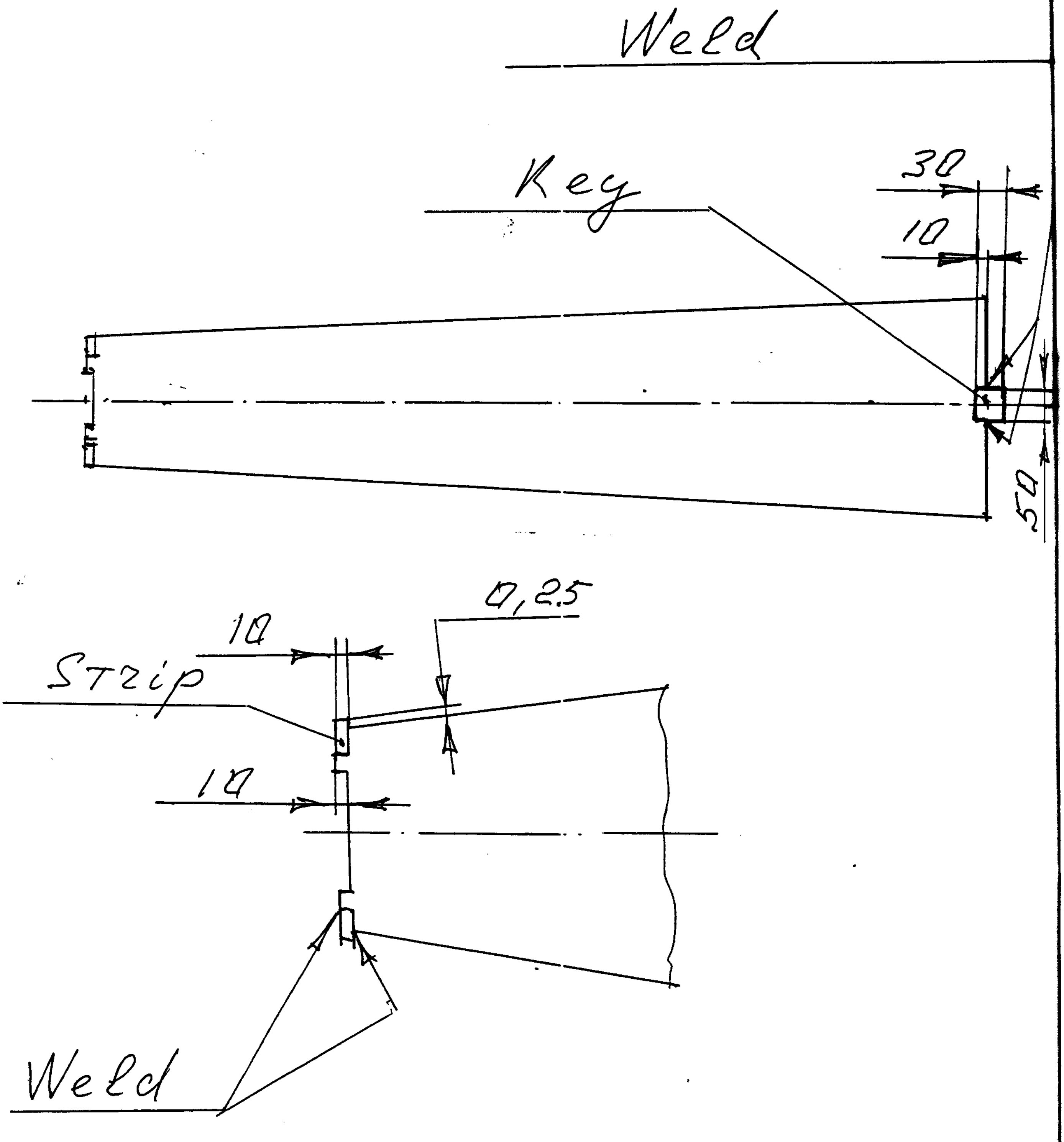

Fig. 10

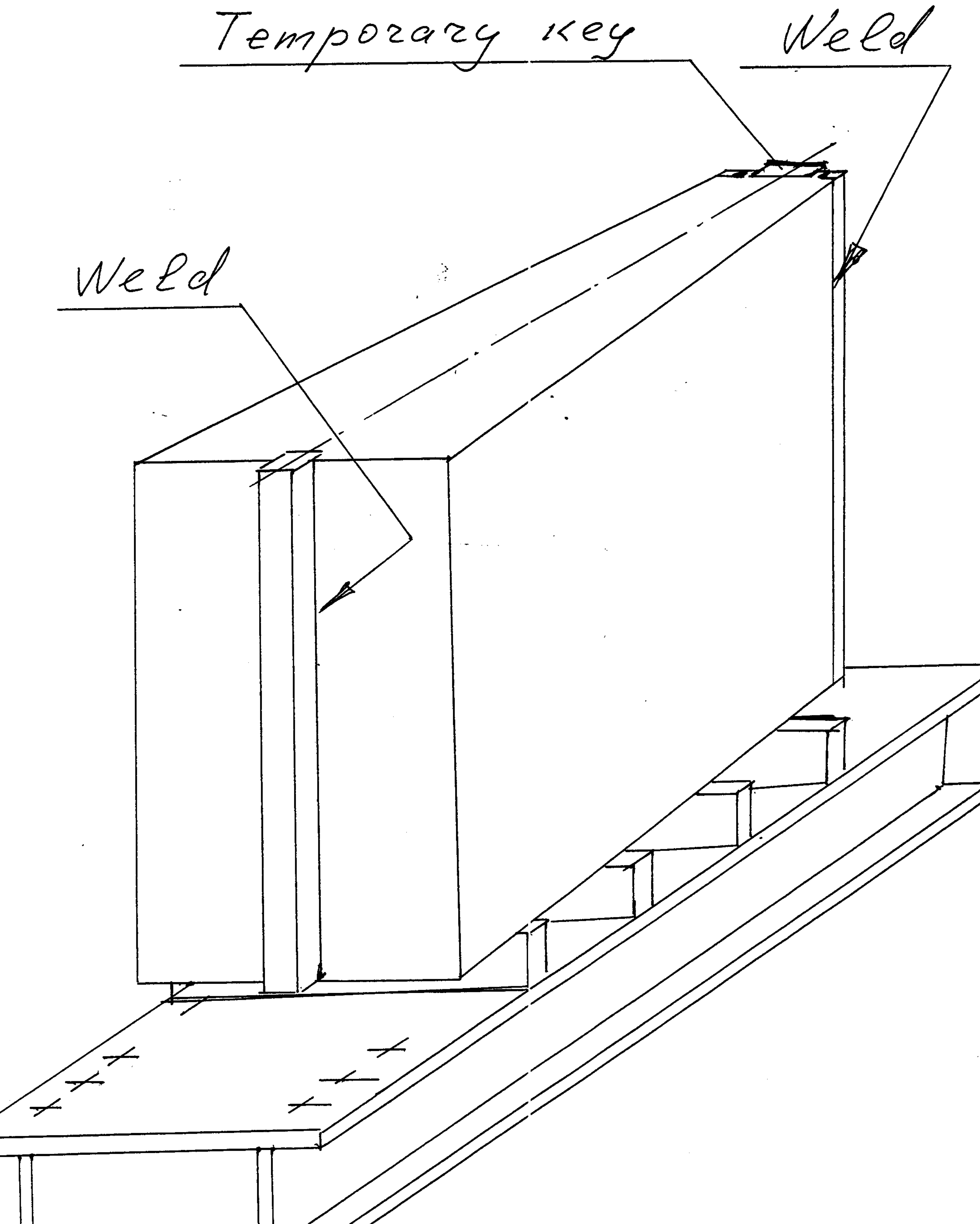

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Fig. 11

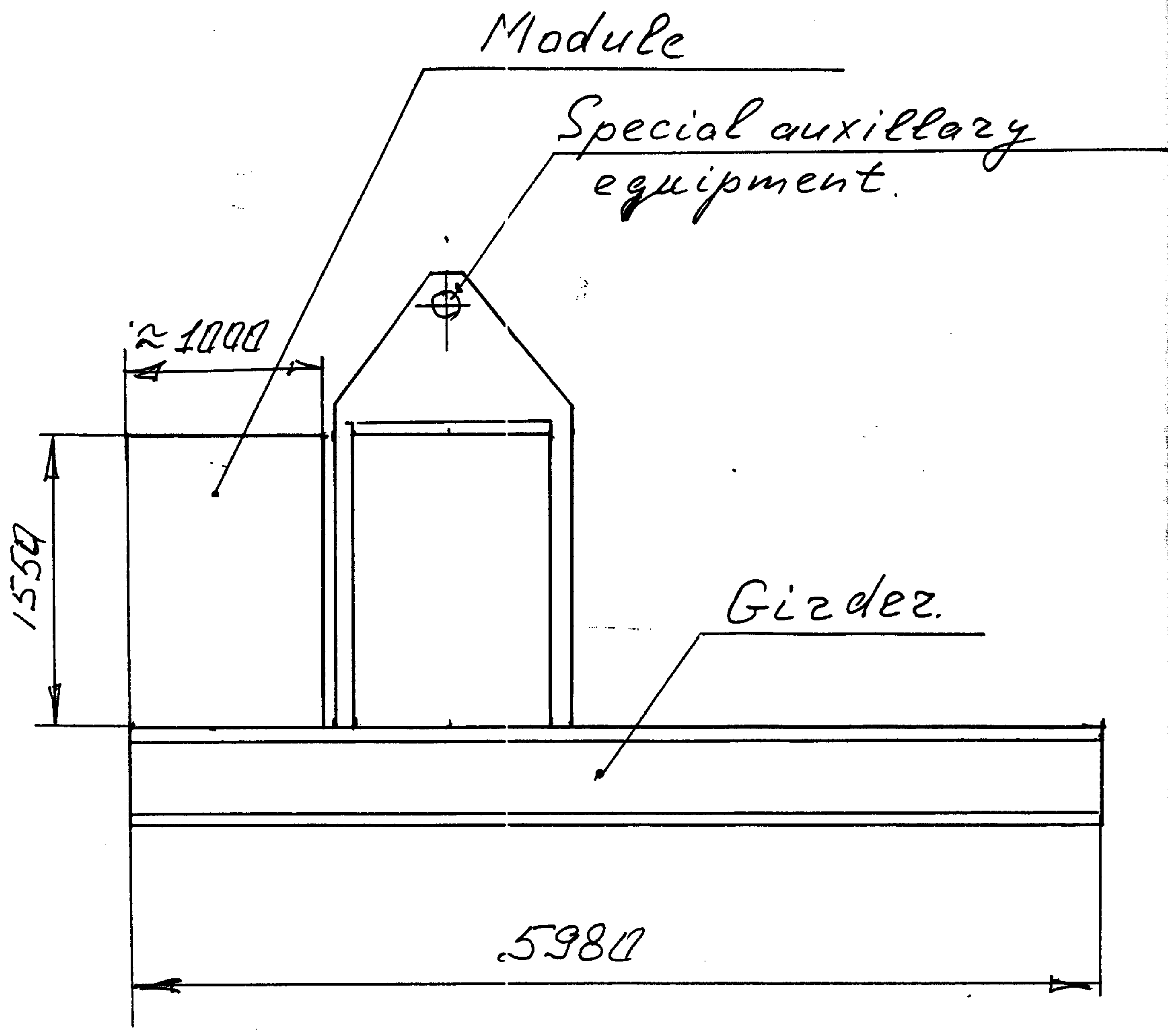

Fig. 12.

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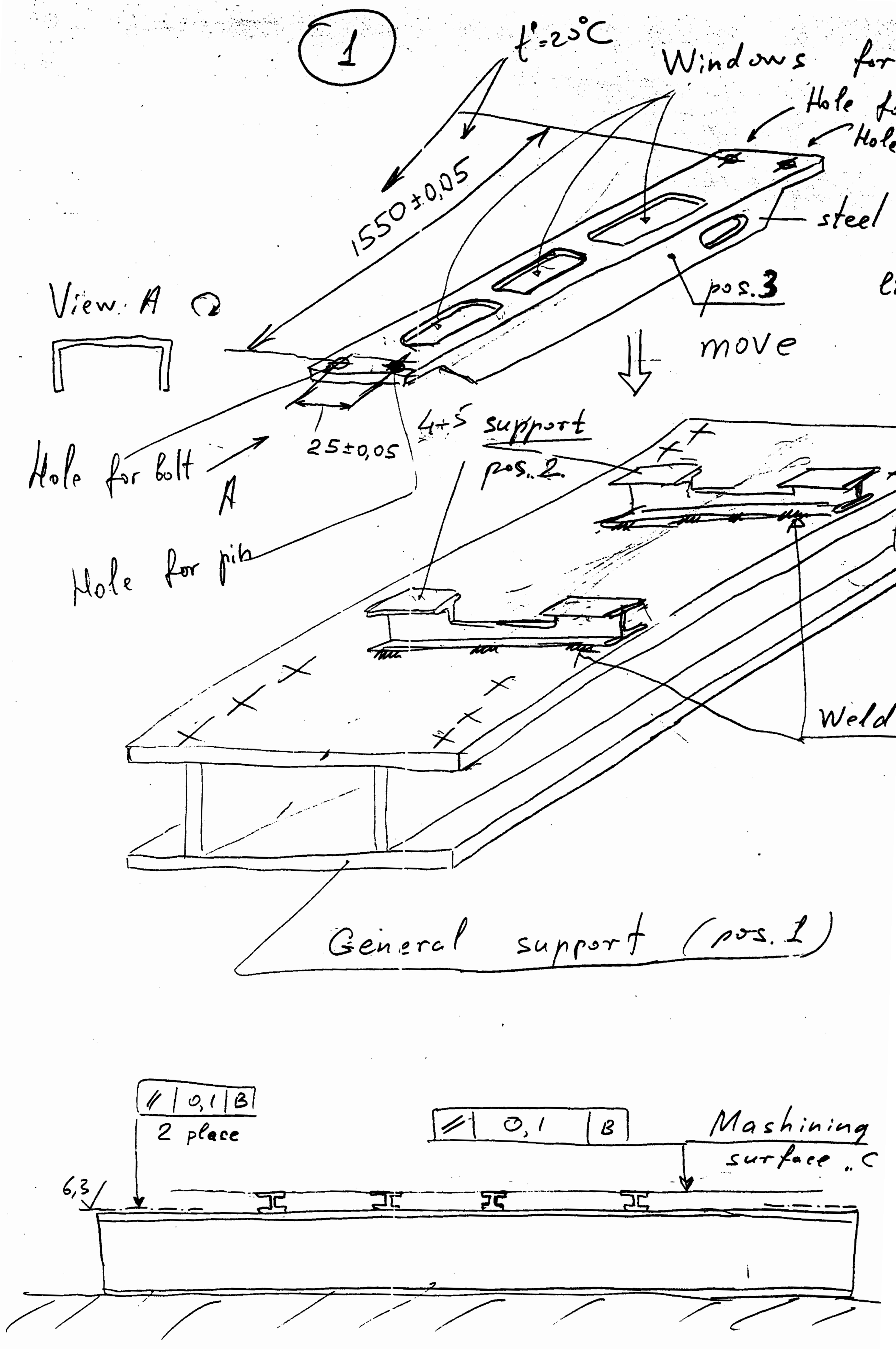
Appendix 2

Module and supermodule assembling

CERN

24 June 1994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Windows for
Hole f
Hole
1550±0,05
steel
pos.3
View A
move
25±0,05
4÷5 support
pos. 2.
Hole for bolt
A
Hole for pin
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General support (pos. 1)
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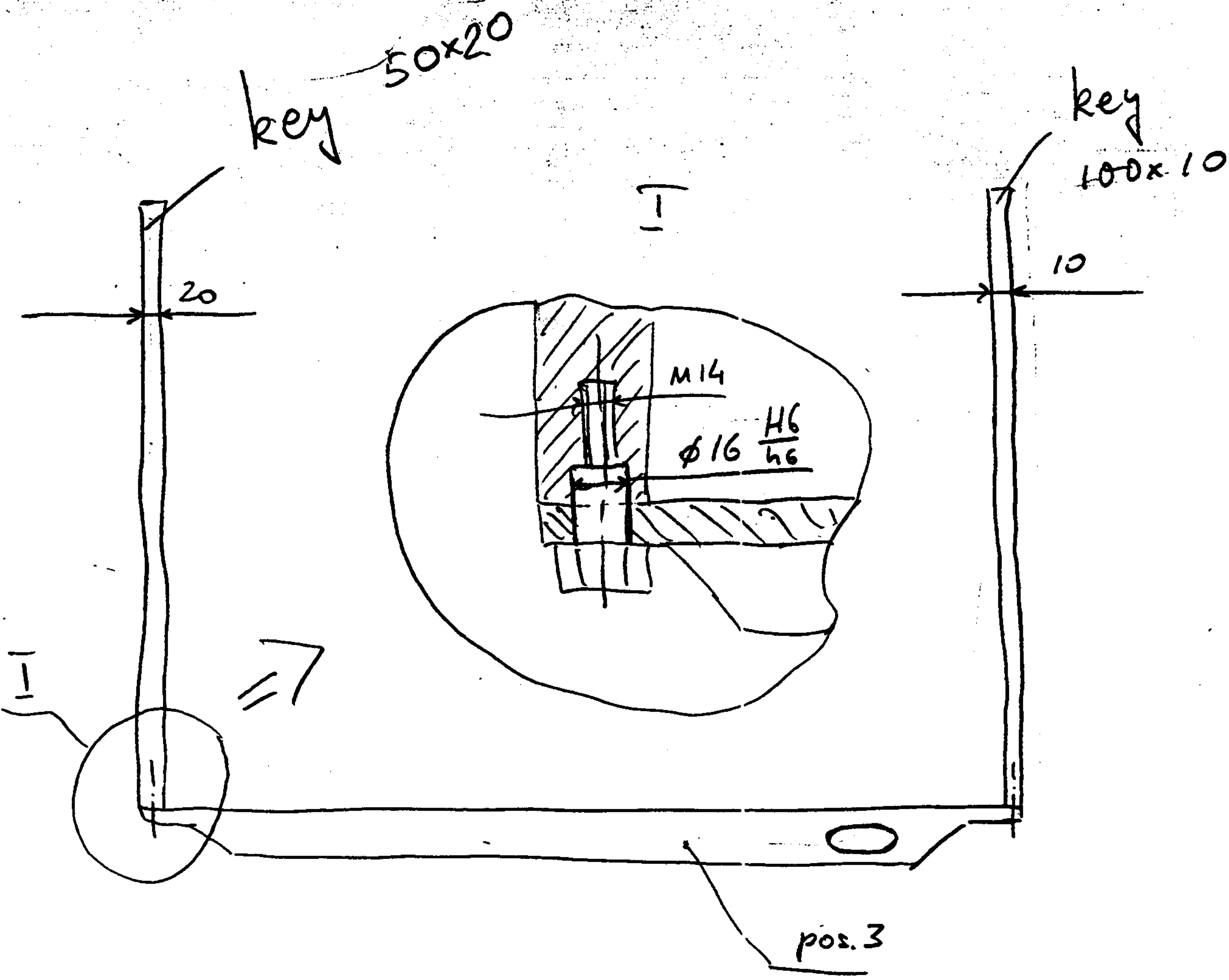
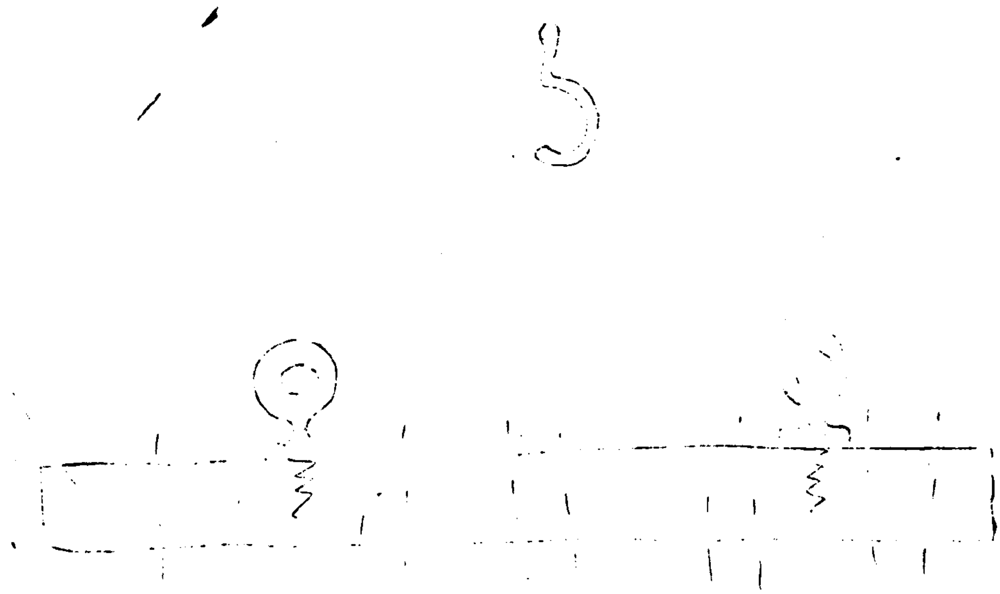
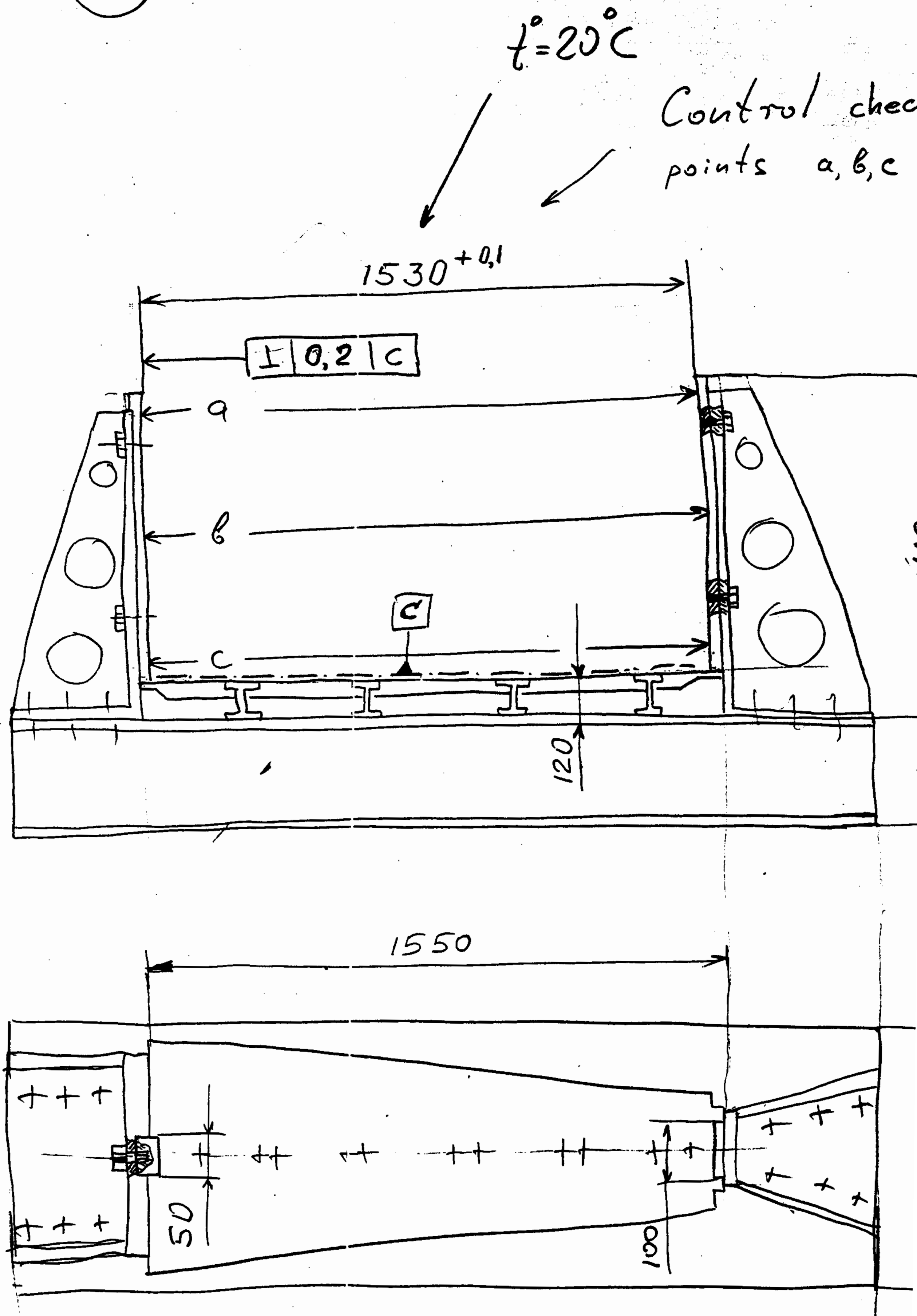
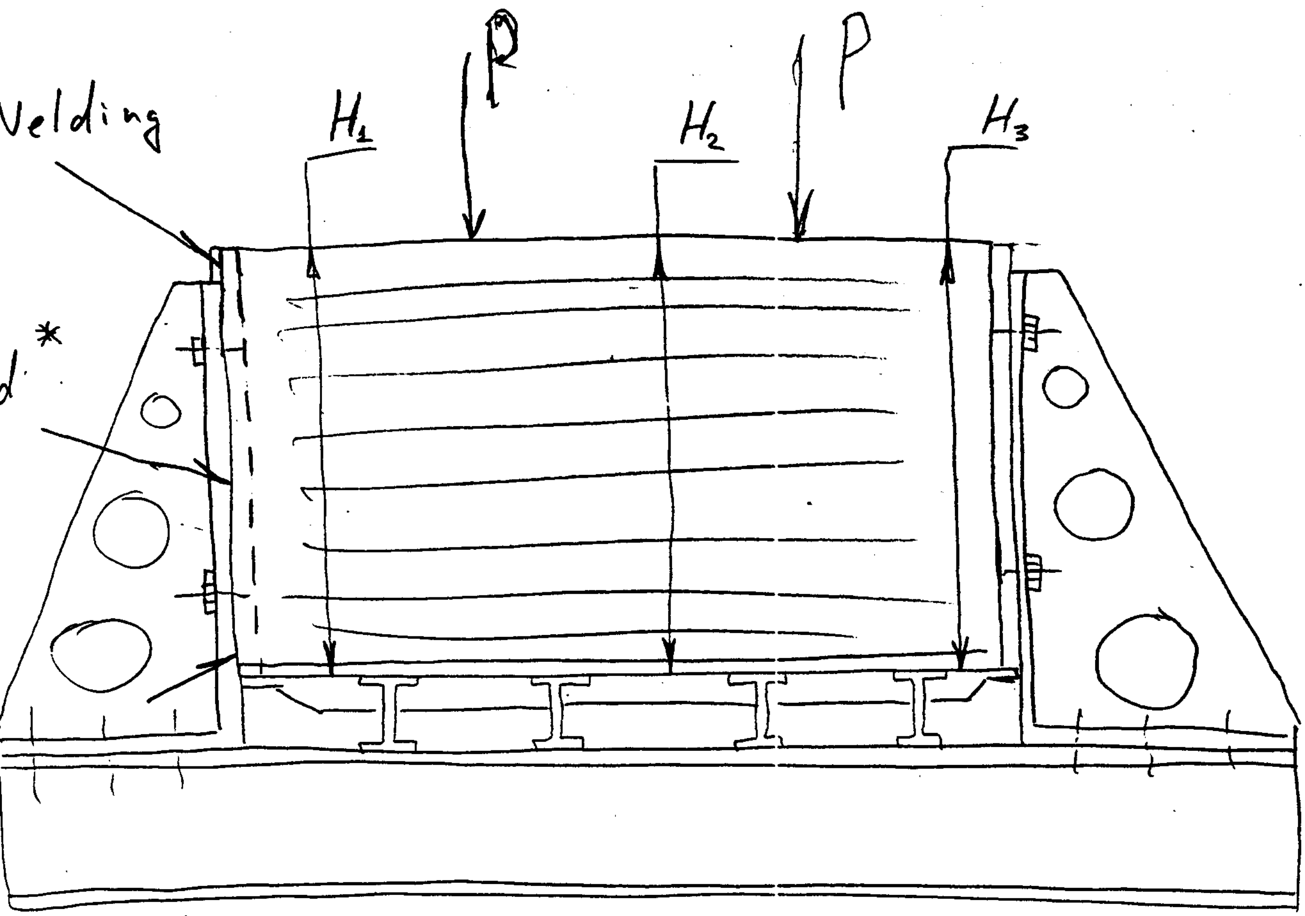




(3)



④



Checking

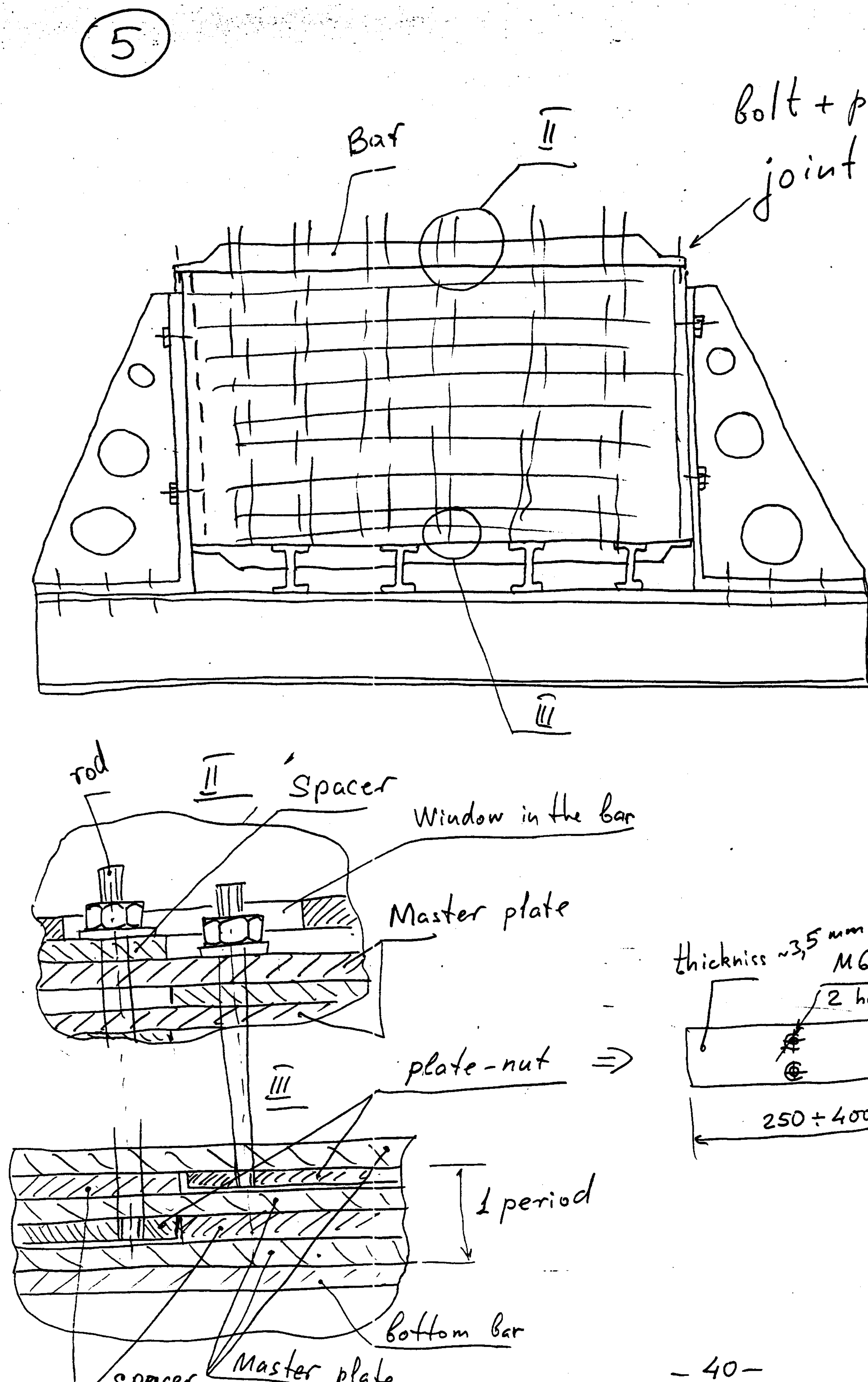
$$|H_i - H_j| \leq 0{,}2 \qquad i = 0, 1, 2, 3 \quad j = 0, 1, 2, 3$$

H_0 – true size of module

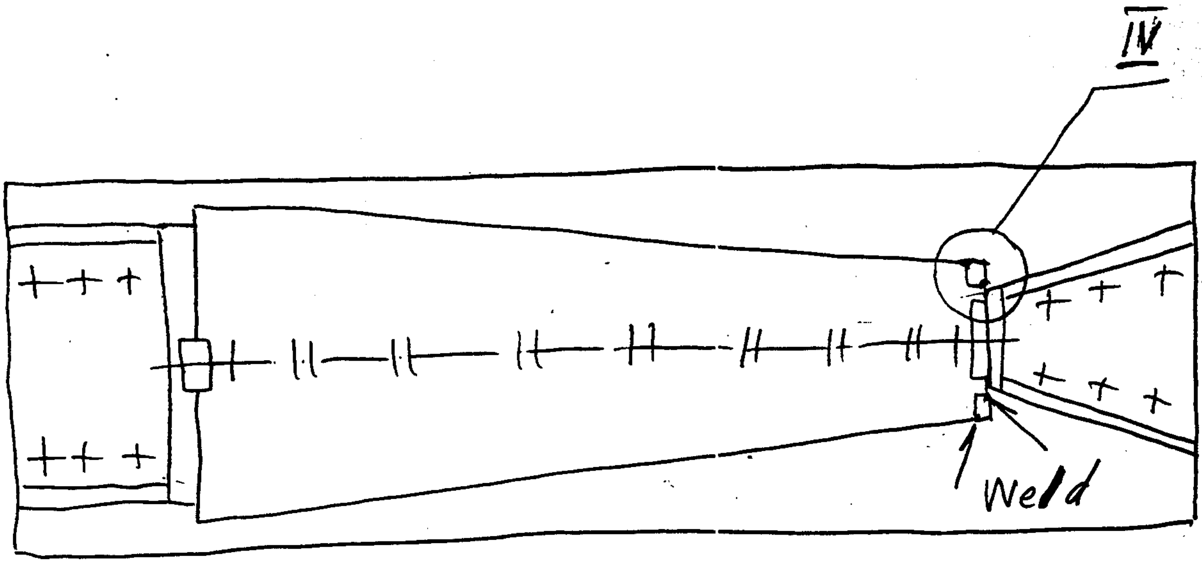
* Weld ** through windows in the suppor

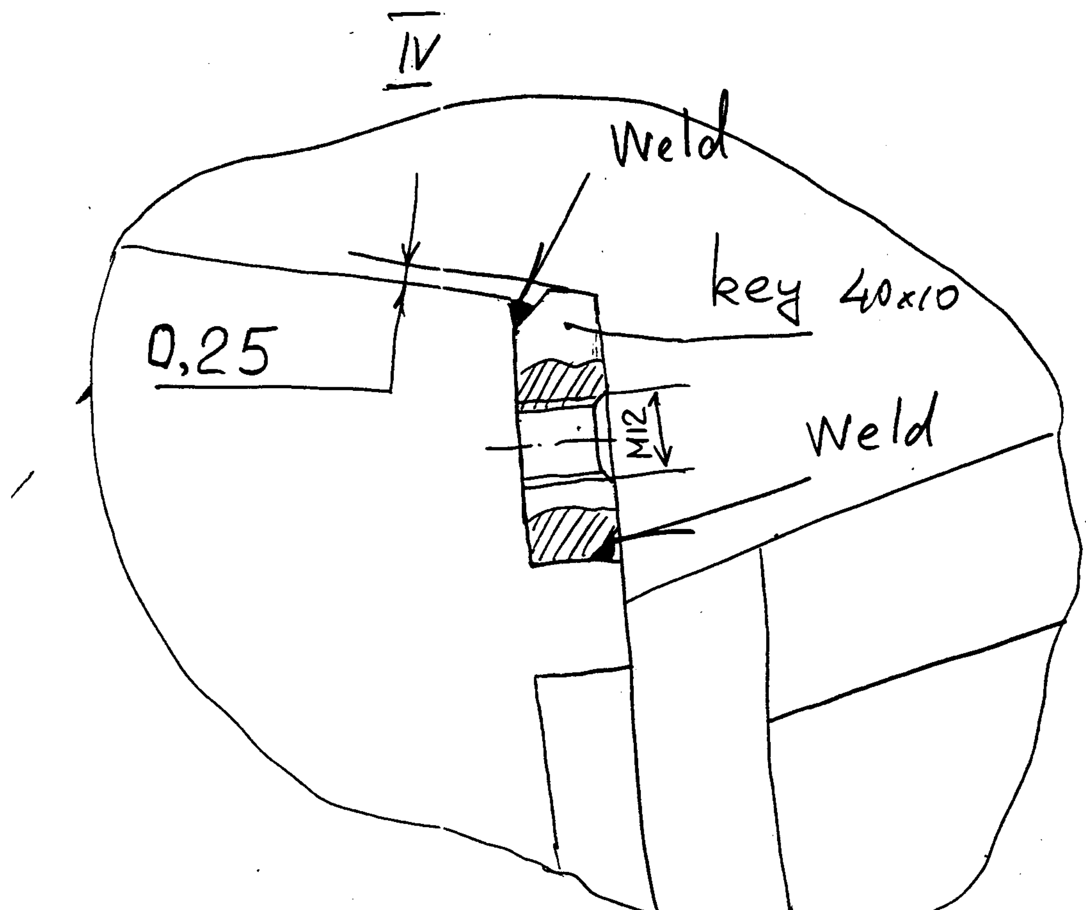
Adjust size „H_i" (change spacers or master plate)

** after procedure (see Fig. 5)


5
joint
Bar
II
III
rod
II
Spacer
Window in the bar
Master plate
thickniss ~3,5 mm
plate-nut
III
1 period
bottom bar

⑥





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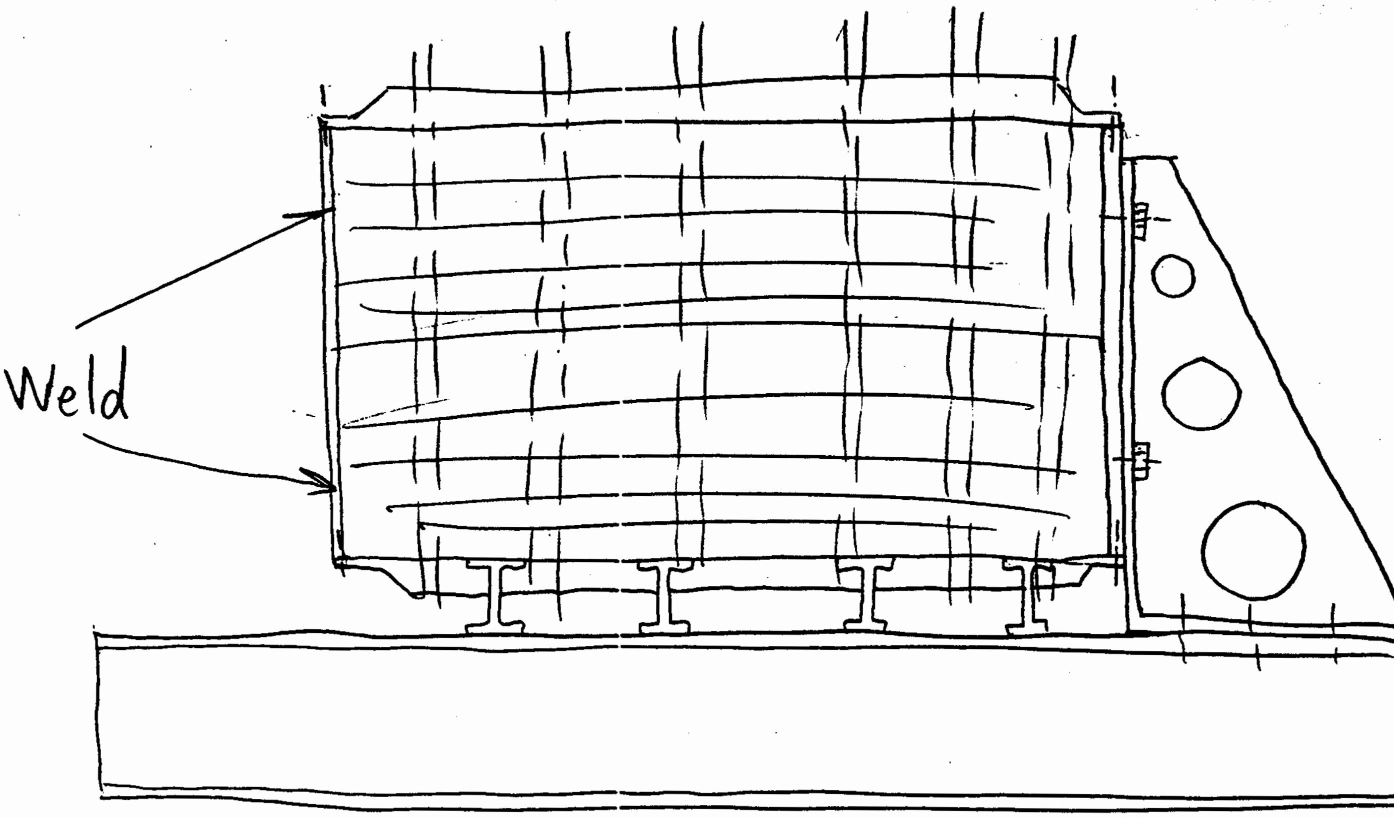

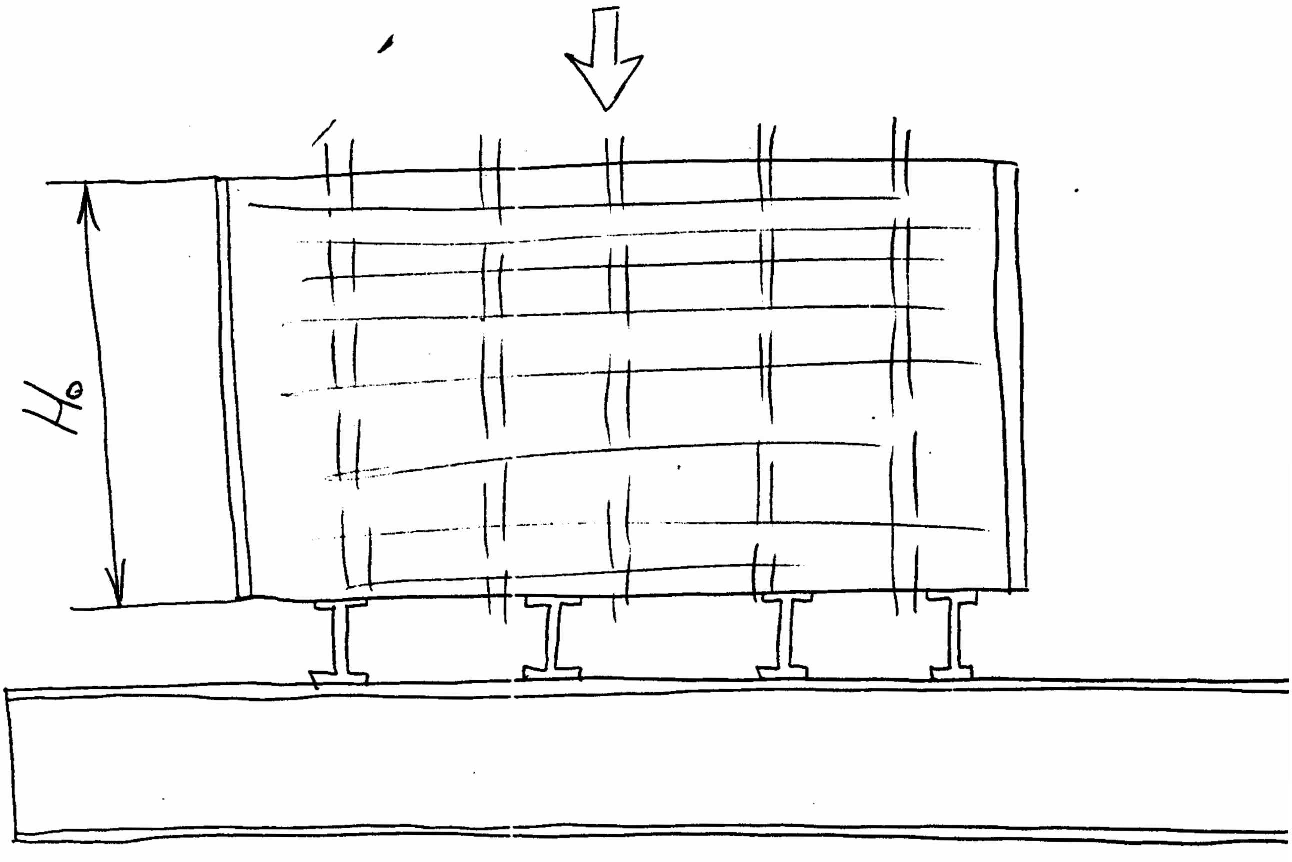

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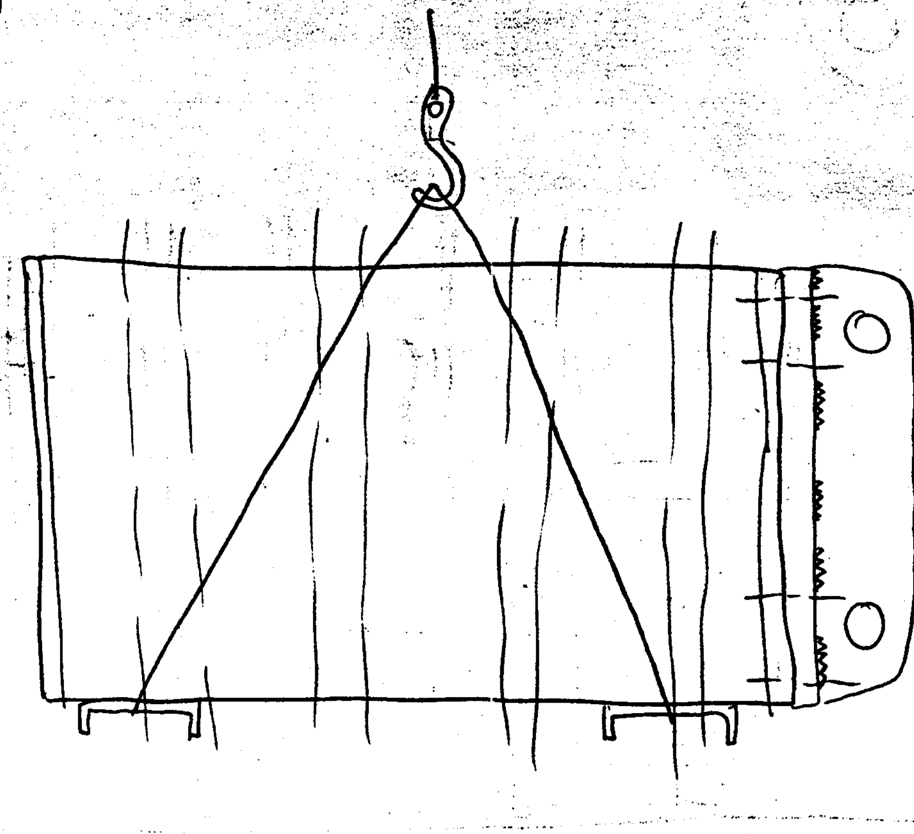
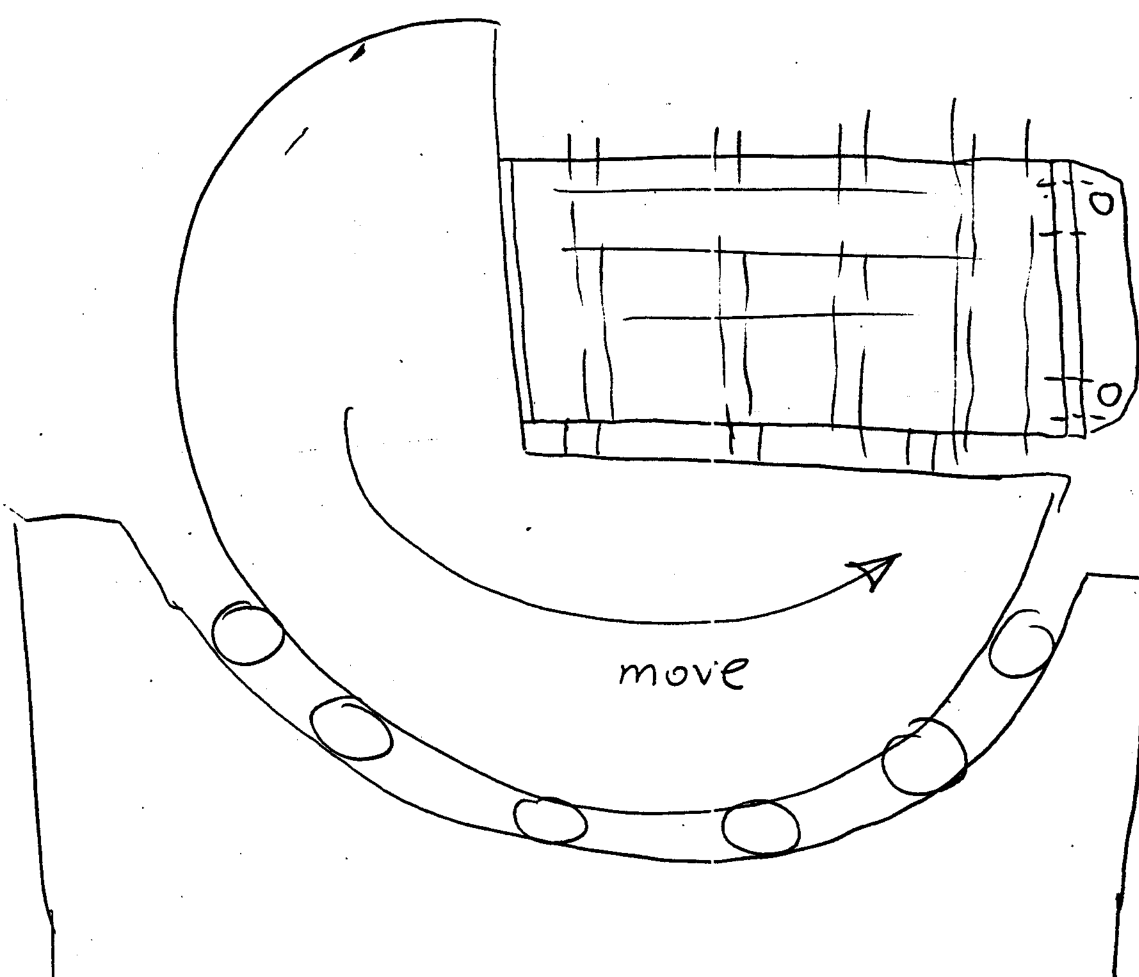
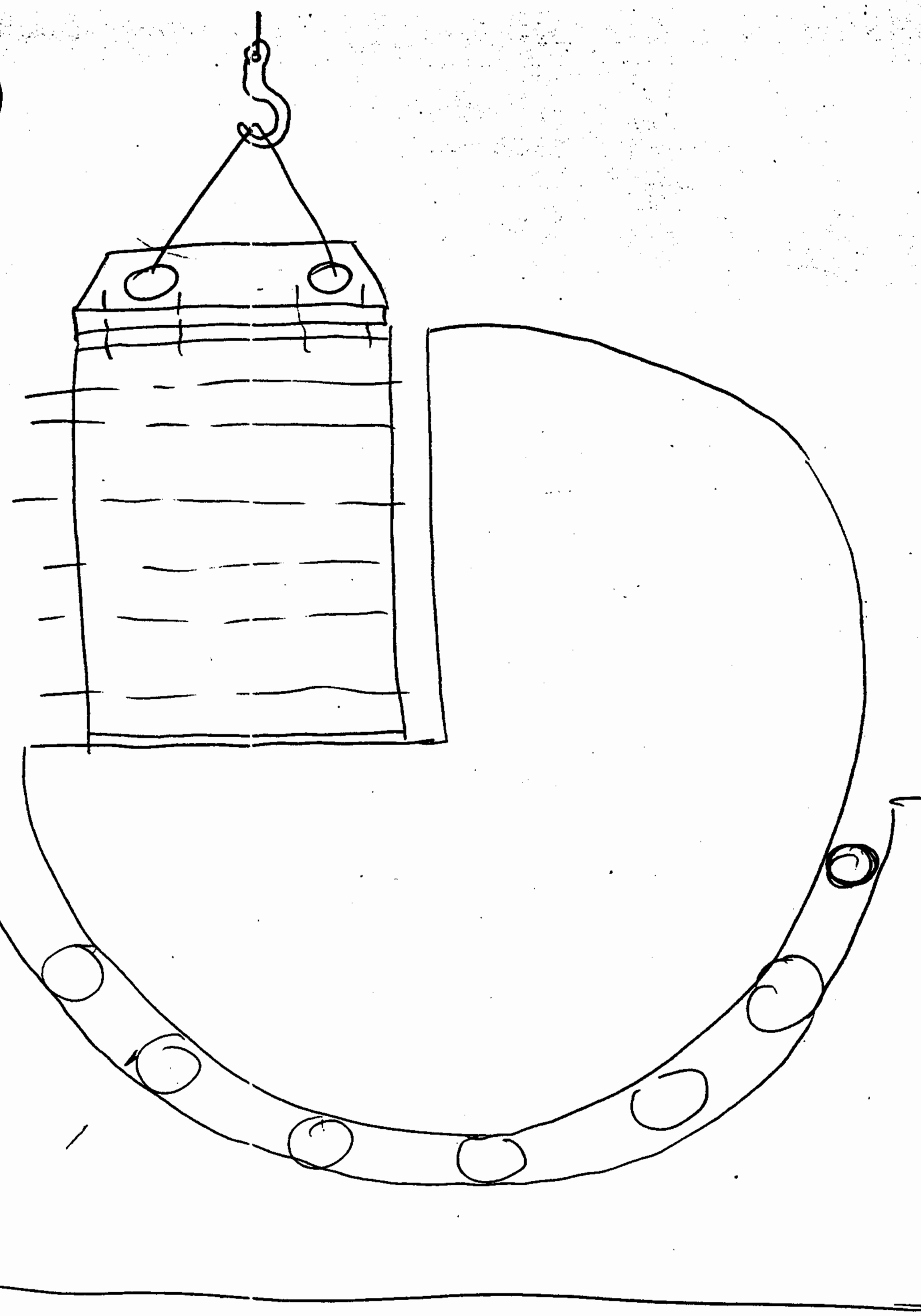
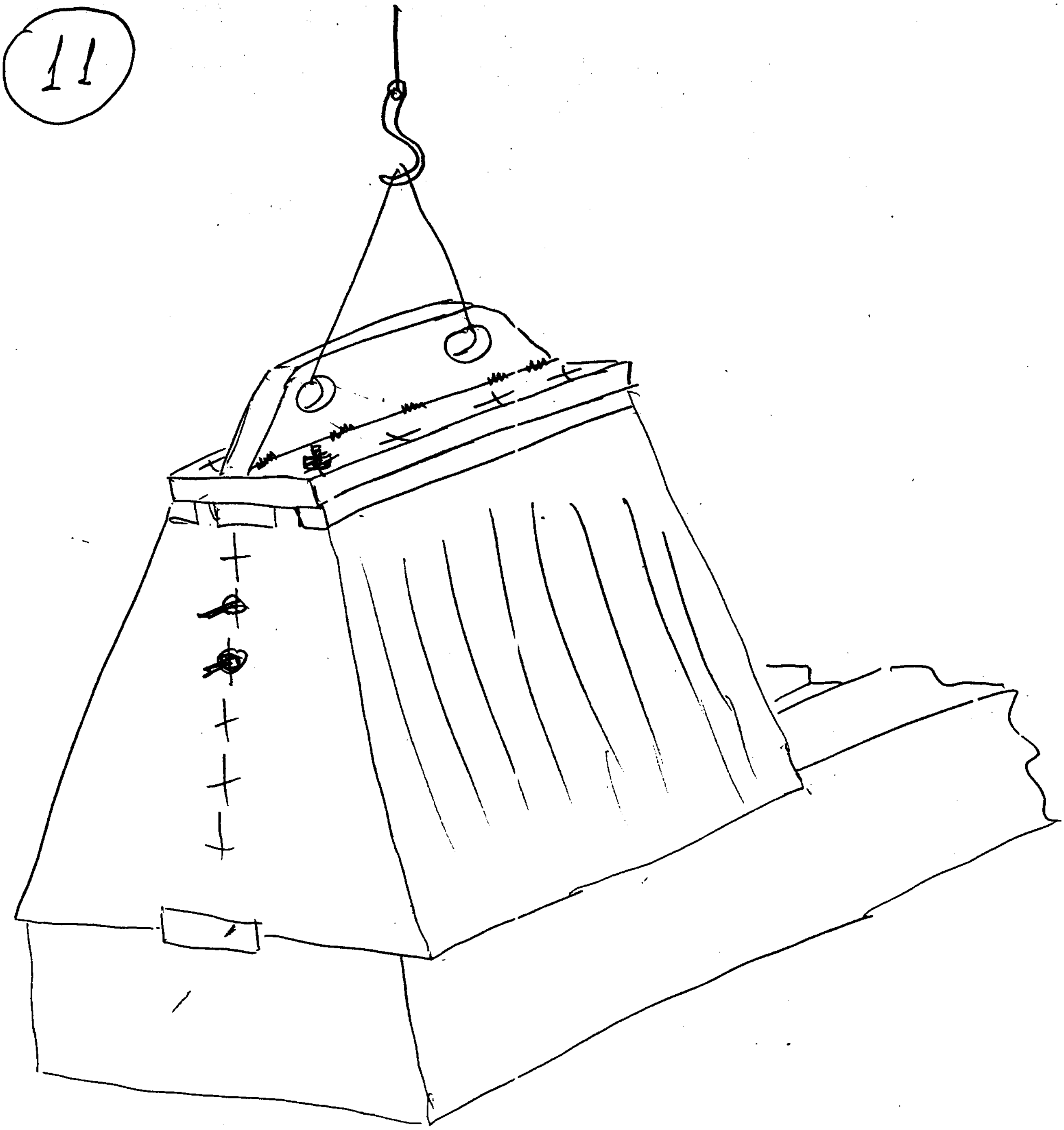




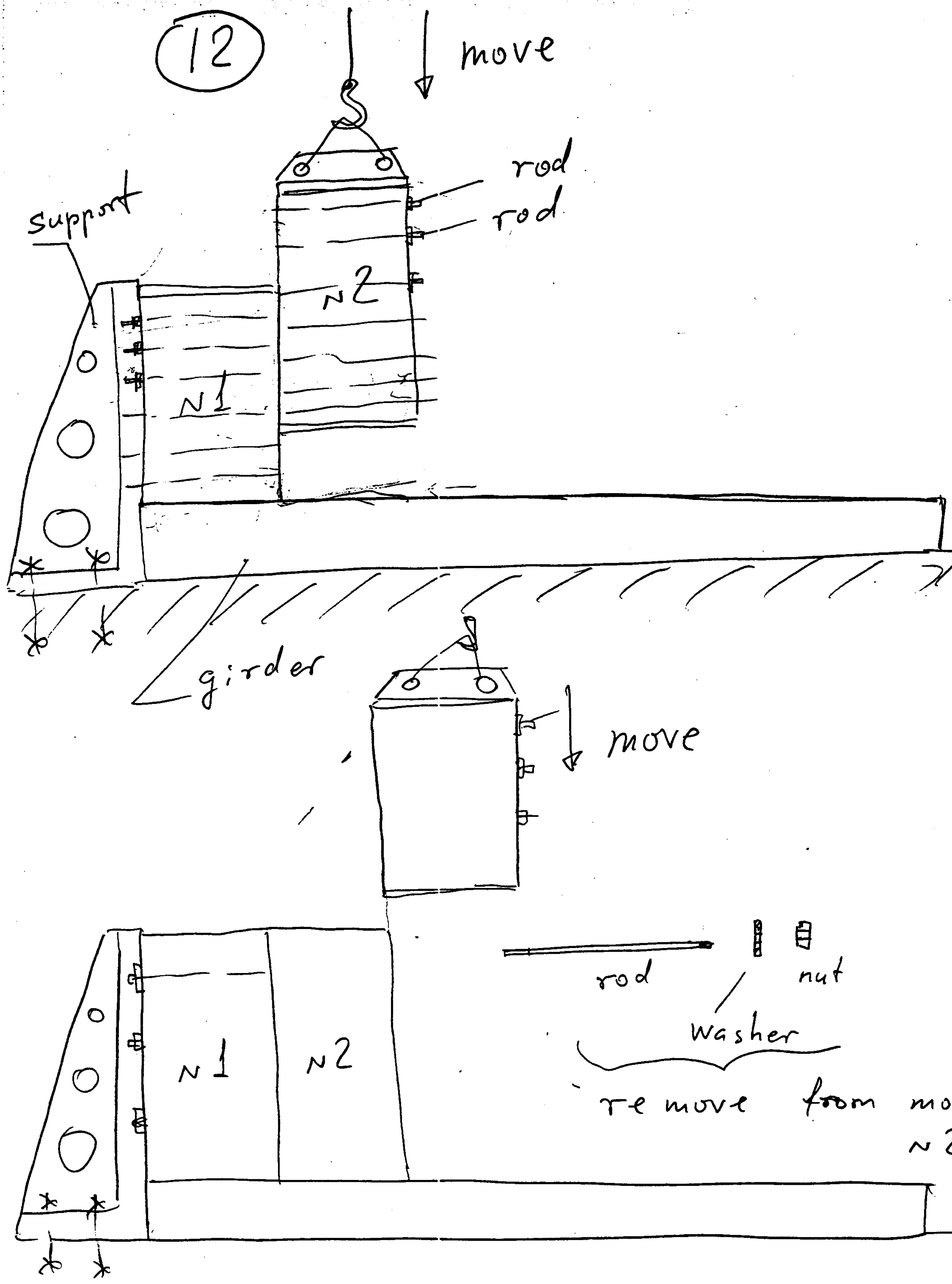
(10)



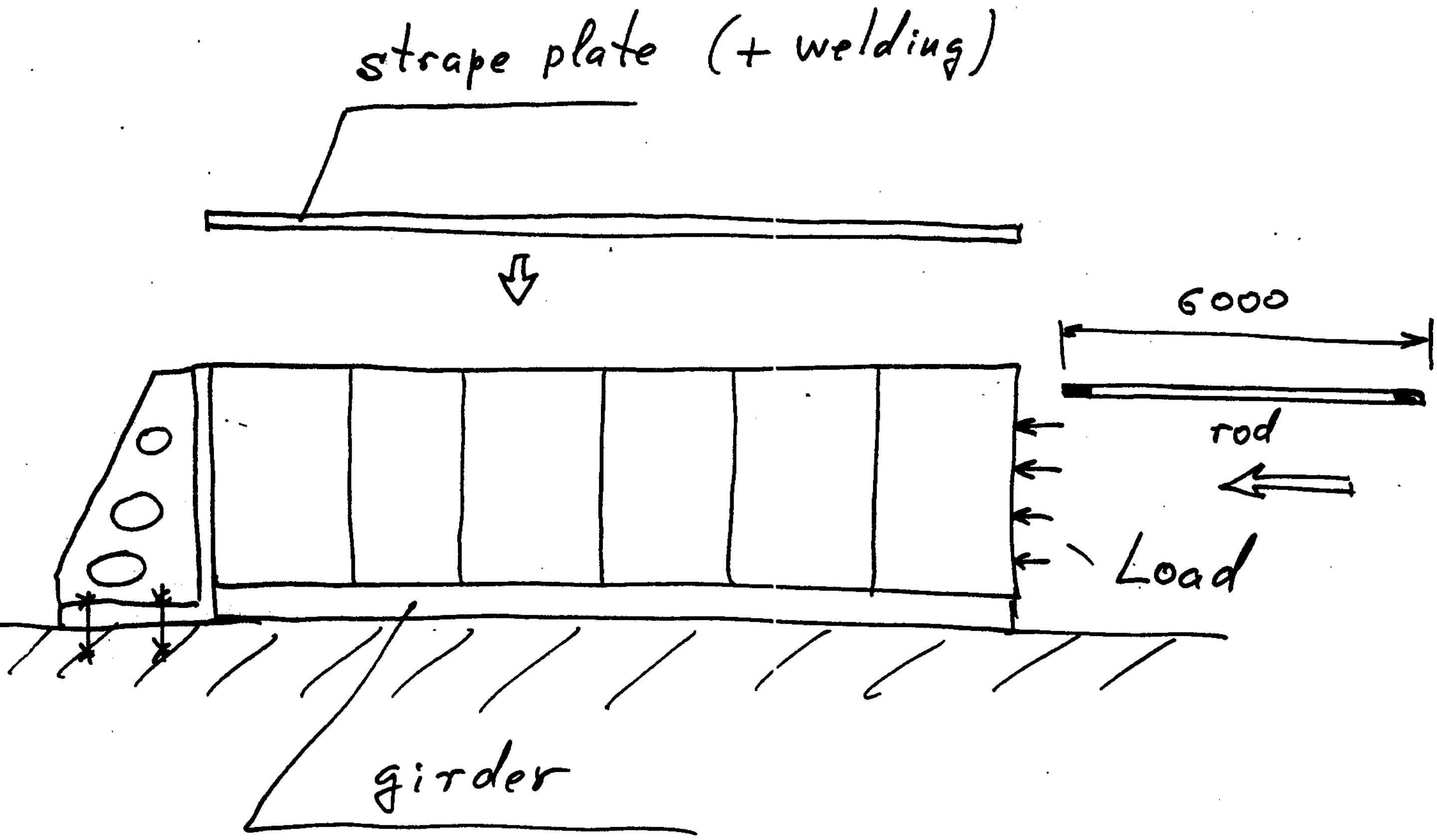
11



(12)


move
rod
rod
support
N2
N1
girder
move
rod
nut
washer
N1
N2
remove from mo
N 2

(13)



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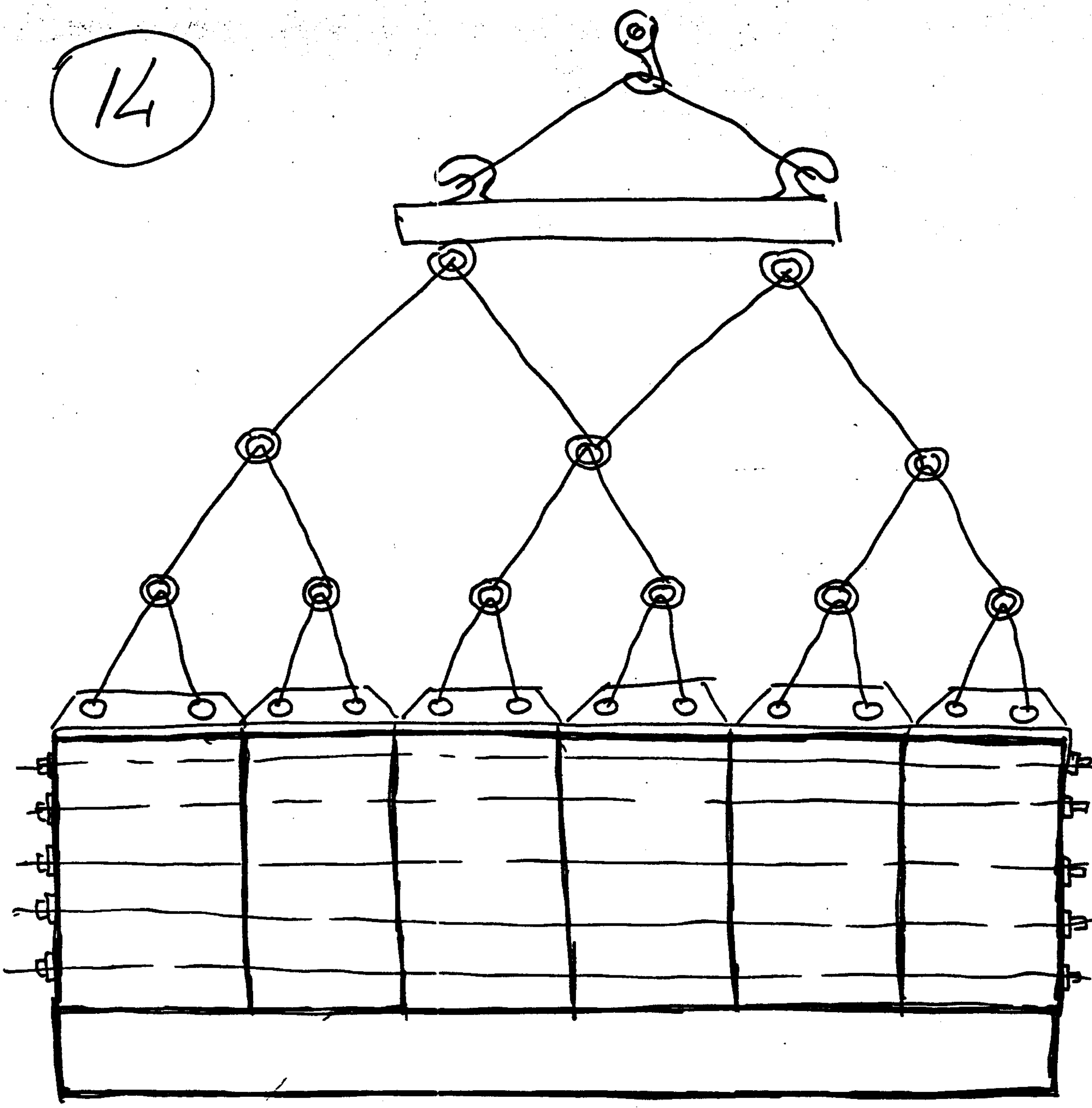
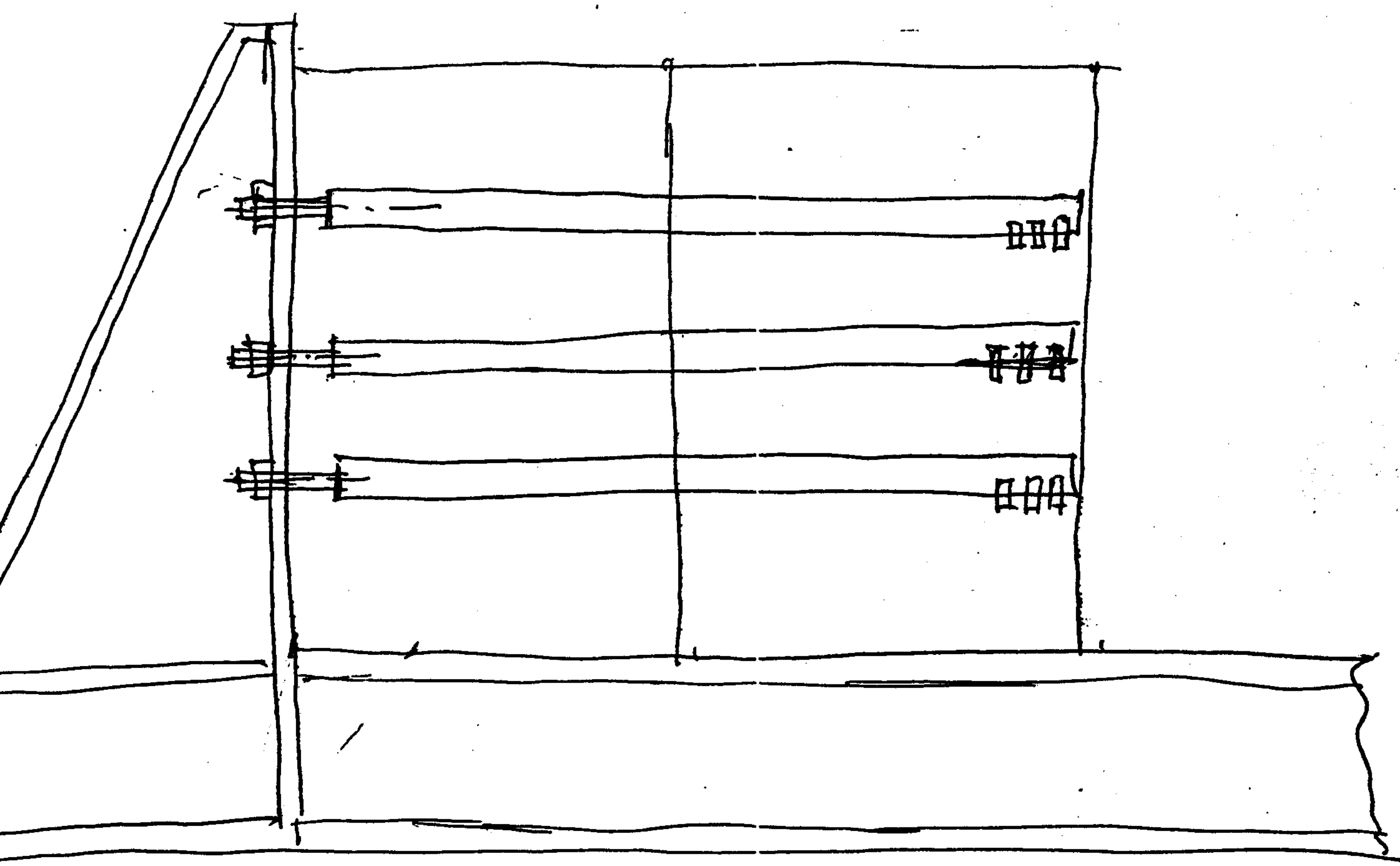


(15)



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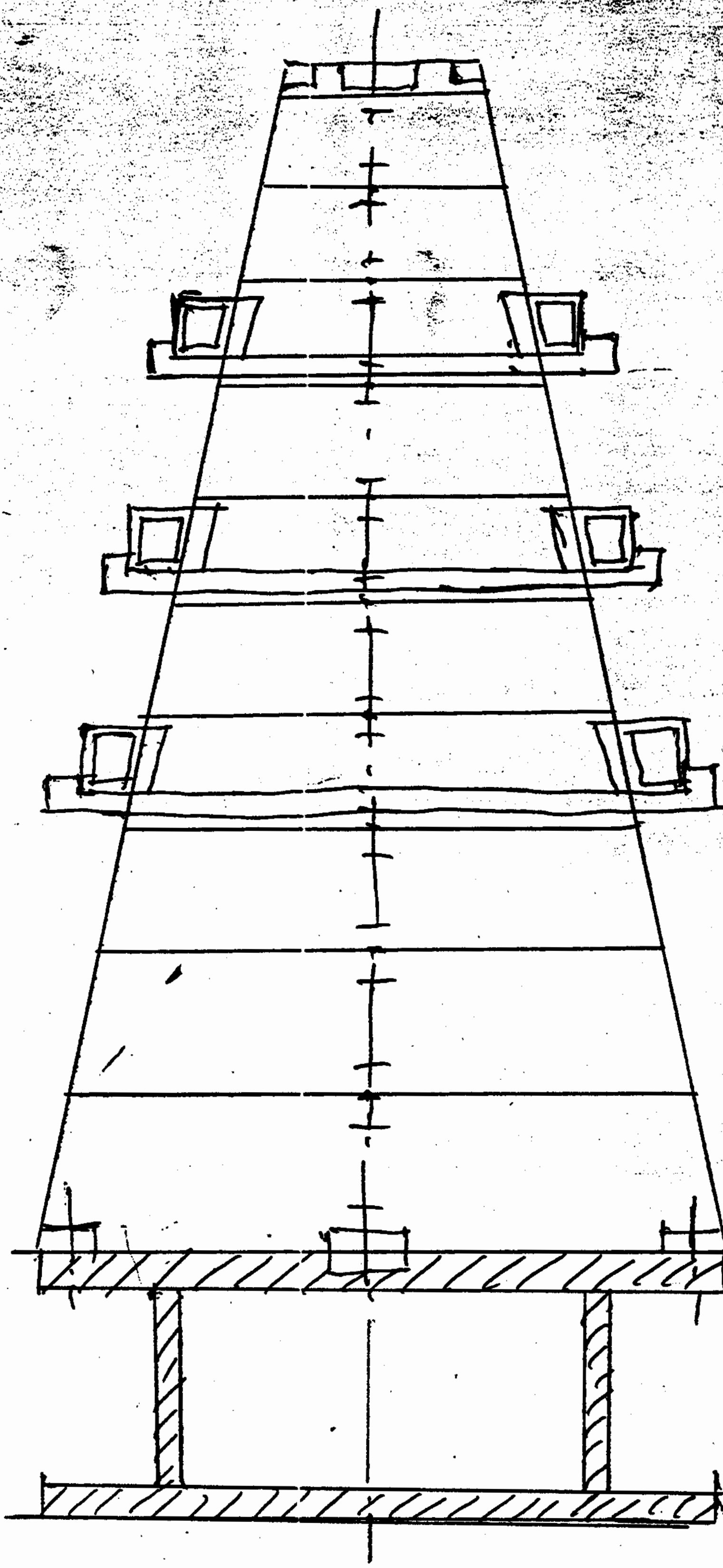


28 june, 1994

9. Appendix 3

his part is a summary of „ questions, discussi-
s and answers" accumulated by all groups
olved in TILE CAL\ during the last days discussions.
ppendix 3 reflects our \Dubna-Erevan\ current
derstanding of possible design and assembling
rategy. Important starting position accepted
all of us (TILE CAL team) is that we
art any assembling scenario with a
ood(!) rolled steel sheets. Quality of
eel arrived from factory determines
rately all following technological actions,
sembly methods: Both for 1m and 6m
les.

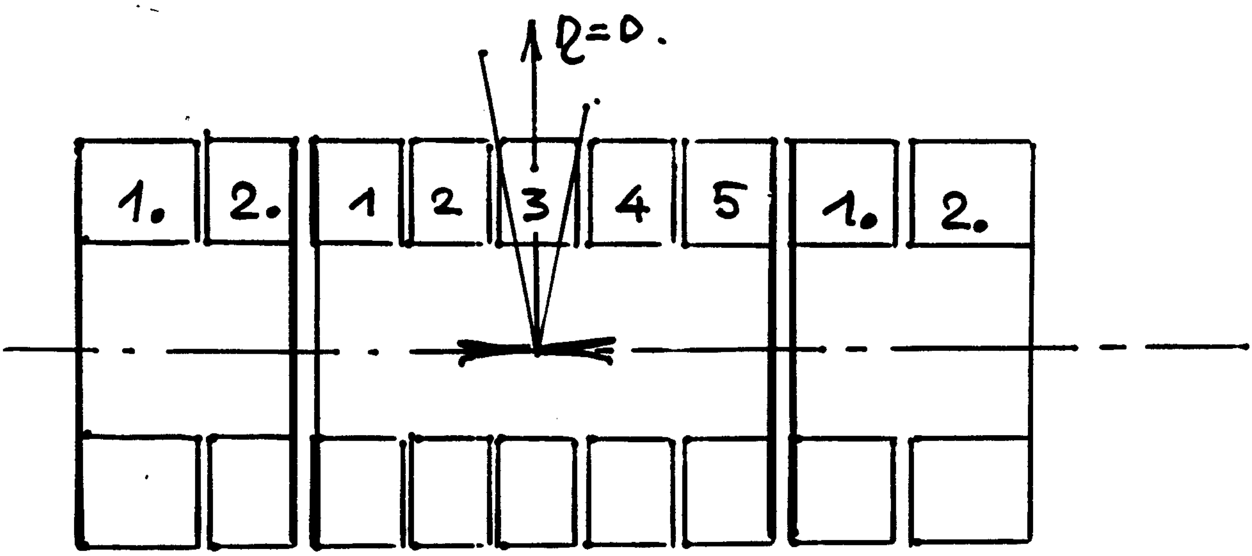
DESIGN: CRITERIA & STEPS

Report
28 June 9

N. TOPILIN, V. ROMANOV, J. BUDAGOV

Level 1

- Cooperative production by particip. institutes
- Production by compatible (additive) components
- „High" components identity / by diff. manufacturers /
- Identical modules structure
- φ cracks ≤ 0.5mm (design param) (wedges self support)
- Possibility of assembly at „destination point" (CE



COMMONLY ACCEPTED STARTING COND's TO FABRICATE IDENTICAL MODULES (1M?)

1. Ready module dimensions meet design tolerances
2. " " is stiff and ∴ transportable
3. " " studs (strips) not overloaded

START. 4 Originally purchased st. sh DO meet tolerances

Comm. a: independent manufacturing of (1/M) modules

Comm b: production cooperation is foreseen: exchange by toolings, auxil. equipment, dies, ...

Report on 28 June 94

Main features of our (D+E) procedures were reported. 2

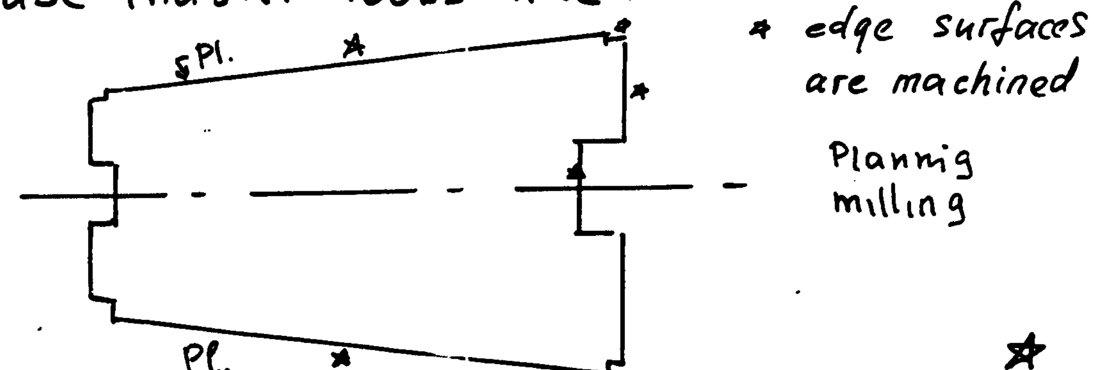
On previous meetings many questions were common for all presentations.

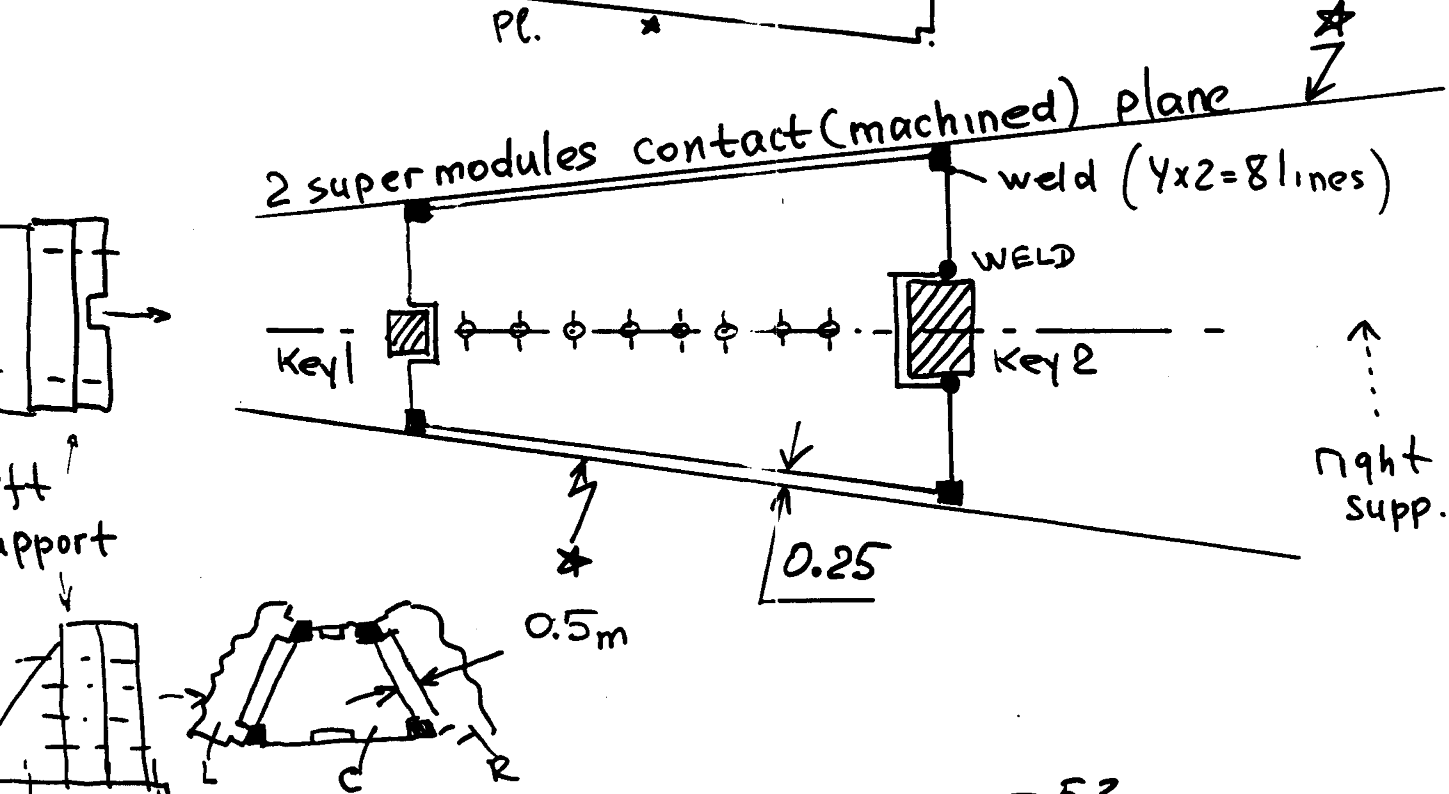
Therefore we do not repeat our designing, manufact., assembling procedures..

But important points mentioned

- it is really important for purchased st. sheets to meet tolerances... Agreed: it is achievable (in our industries.)
- Using these st.sh's collaborotion makes masters, spacers, which meet desigh tolerances (remember: this is a common starting point!)

In our case master looks like:





Report on 28J

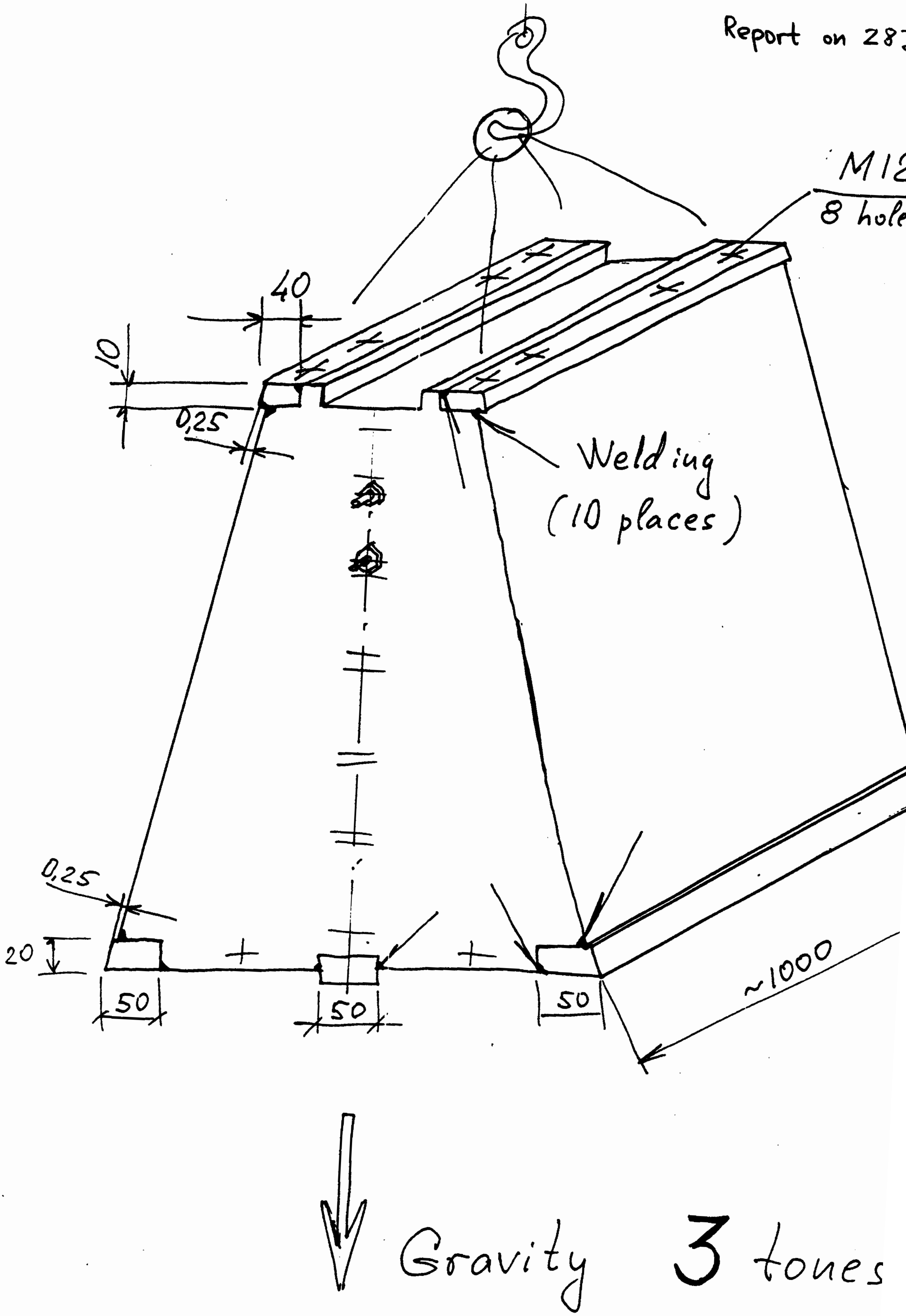


Fig. 1

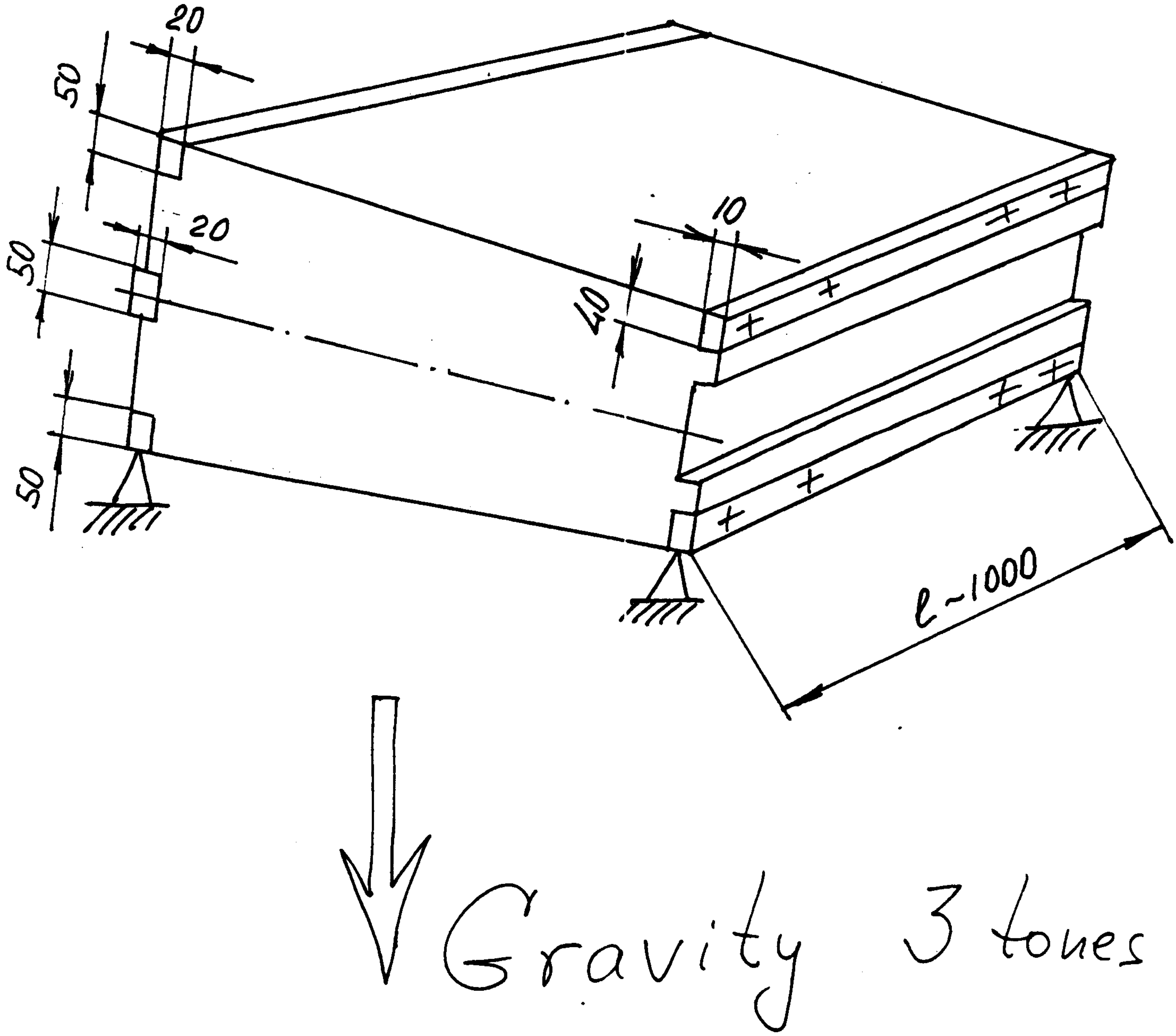


Fig. 2.

Report on 28 June

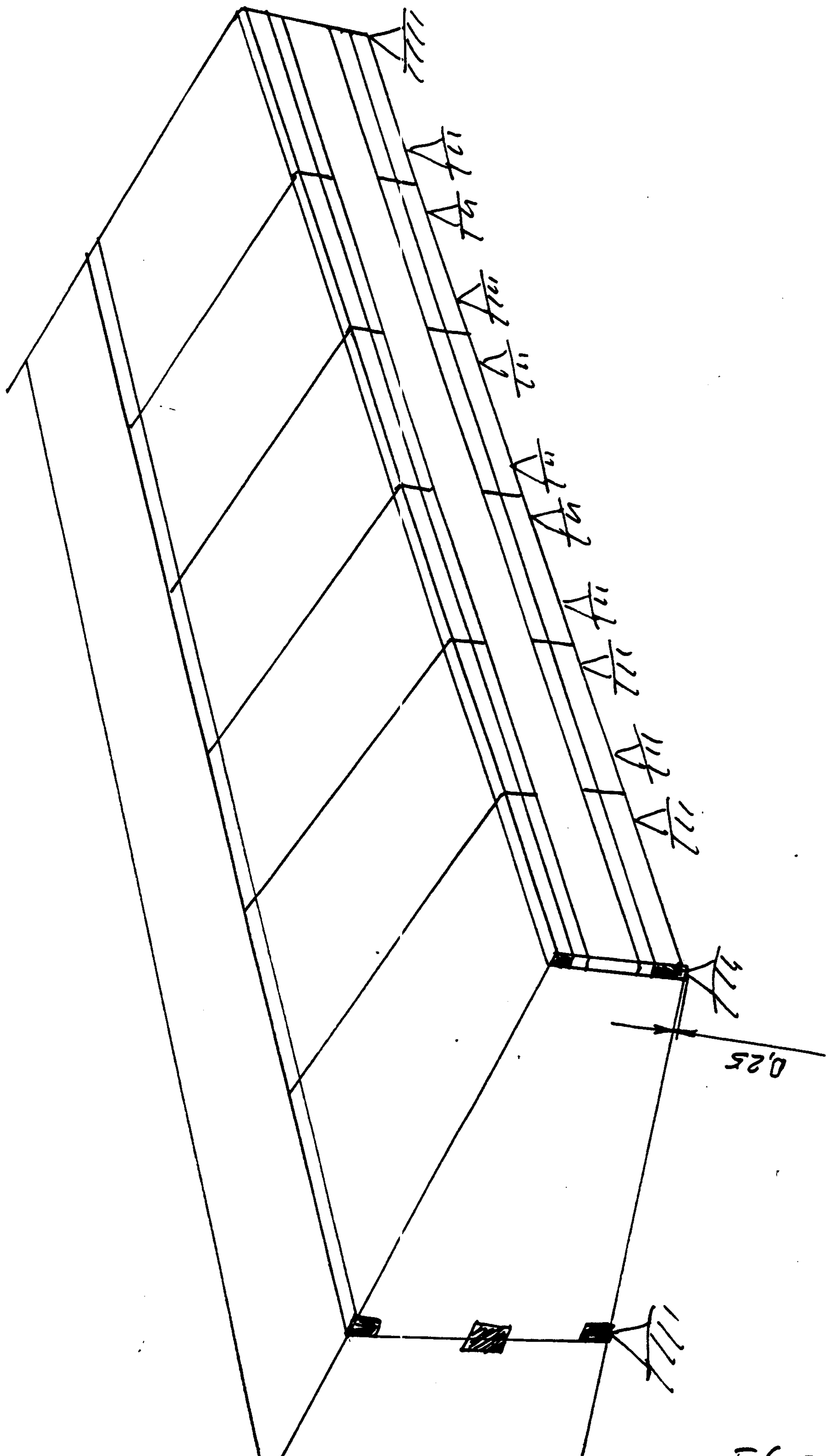


Fig 3

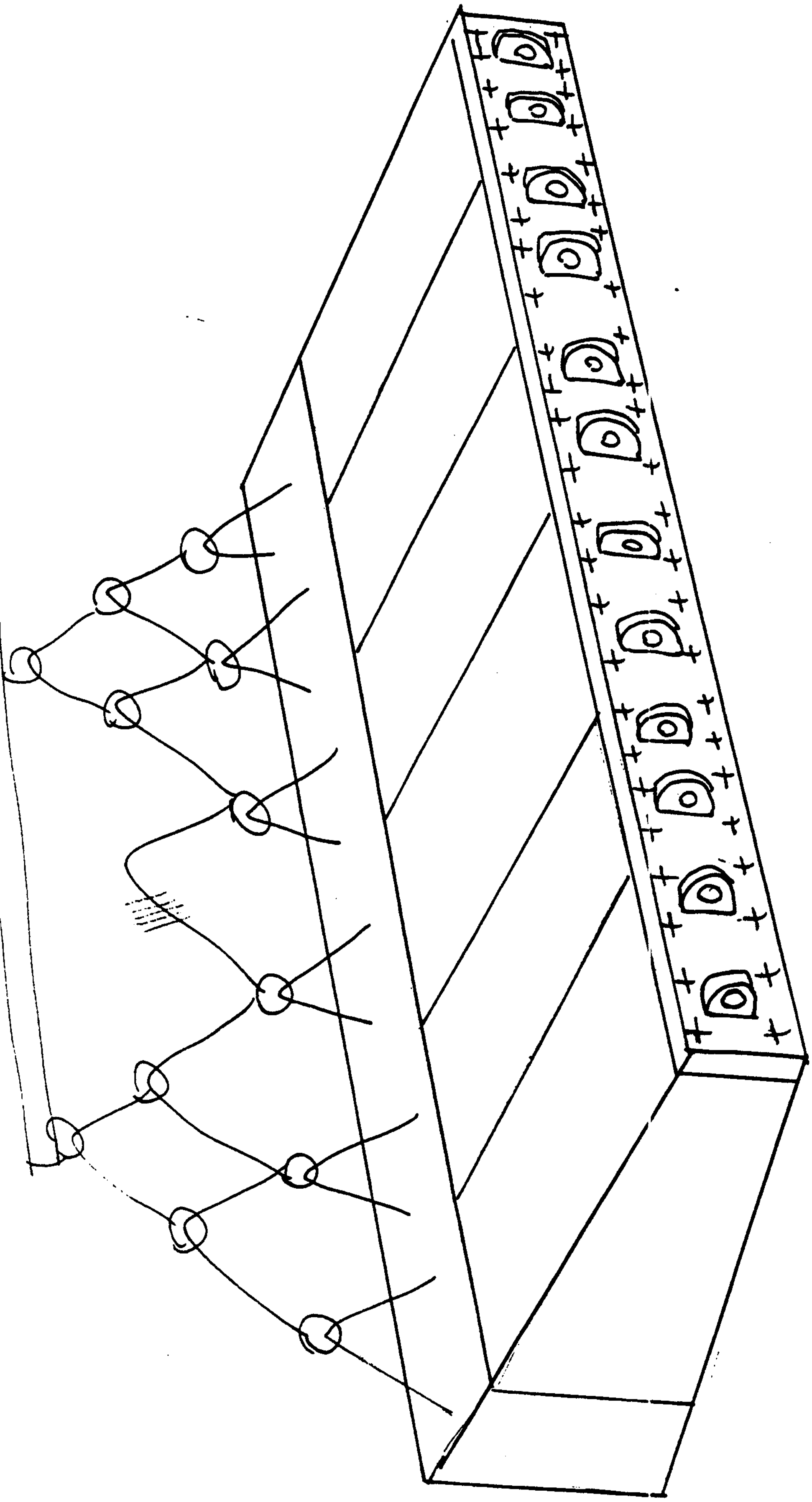
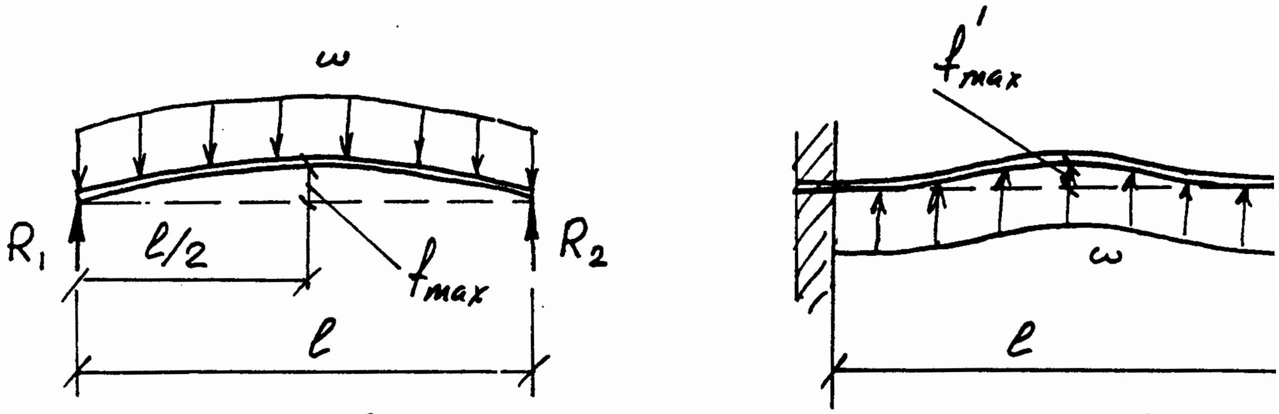


Fig 4

Report on 28 June 94



$$W = \omega \ell \qquad\qquad W = \omega \ell$$

$$f_{max} = \frac{W}{EI}\,\frac{5\ell^3}{384} \qquad\qquad f'_{max} = \frac{W}{EI}\,\frac{\ell^3}{384}$$

$$f'_{max} = \frac{1}{5} f_{max}$$

Fig 5

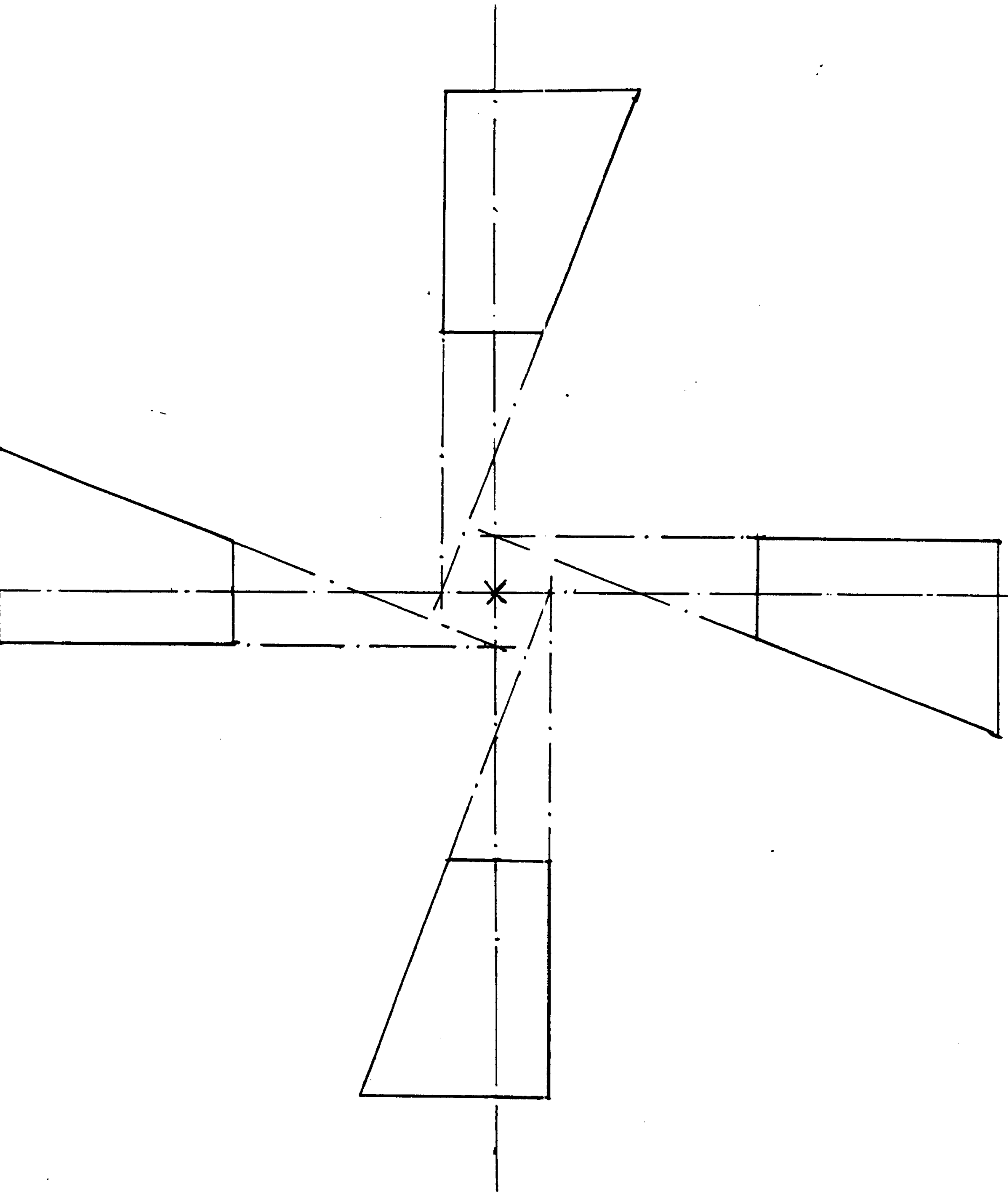


Fig 6

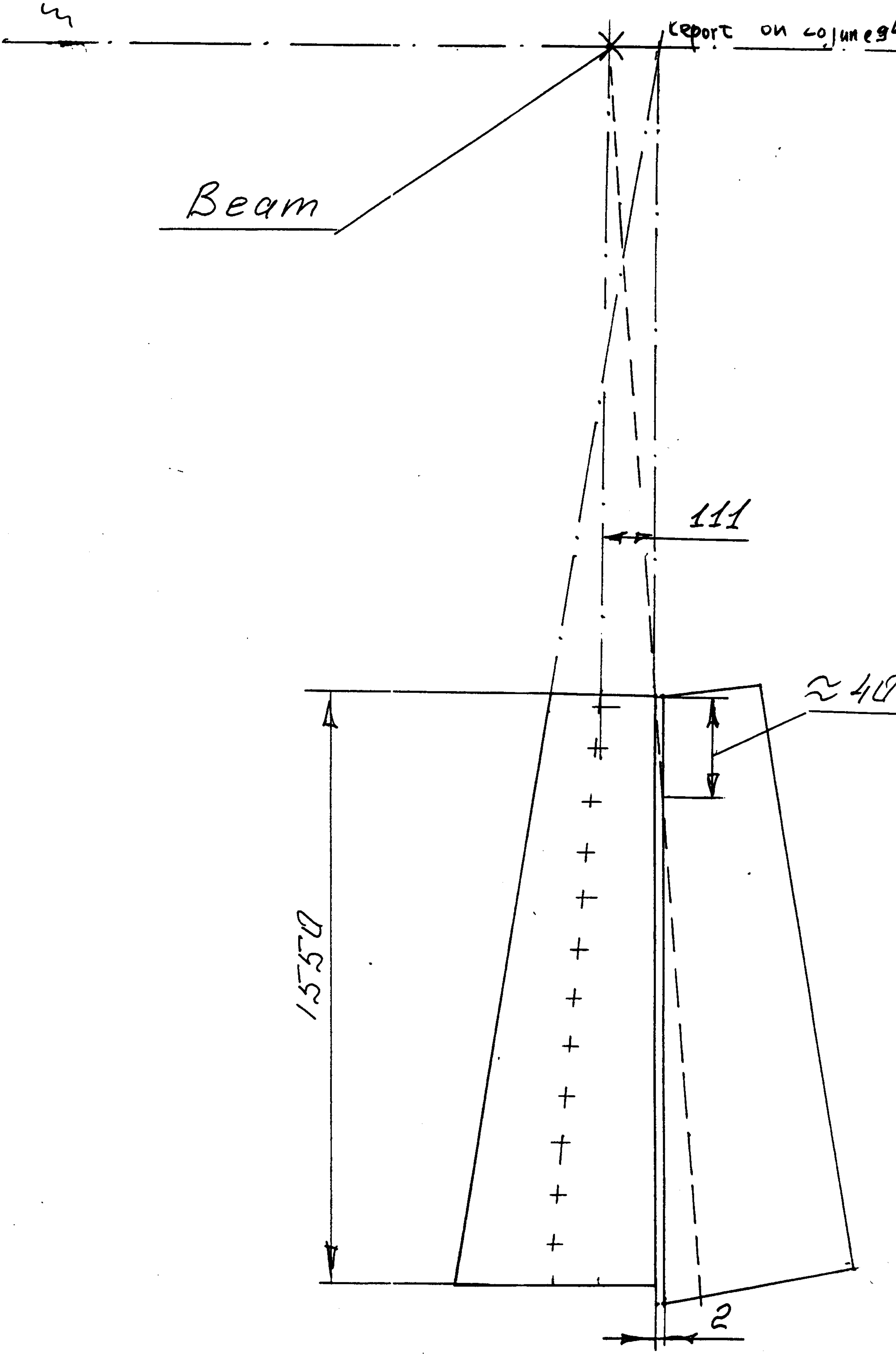


Fig 7