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Contract No 95/2
UNIDO

PROJECT REPORT FOR ESTABLISHMENT OF SUPER PURITY ALUMINIUM PRODUCTION IN INDIA

Final Report

No DP/IND/84/002

Volume 1

General Explanatory Note

VAMI

V/O TSVETMETPROMEXPORT

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LENINGRAD
1986

PROJECT REPORT CONTENTS

Volume I — General Explanatory Note

Volume II, Book 1 — Drawings

Volume II, Book 2 — Basic Engineering Design of Main Technological Unit (Electrolyser)

Volume III — Specifications of Equipment

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3. Comparison of standards for high purity aluminium
4. Evaluation of EDU location in extended part of potroom No 78.

1. EXECUTIVE SUMMARY (RESUME)

1.1. General Initial Data and Conditions (Section 2)

The initiator of the project for construction of the experimental-demonstration unit (EDU) for production of high-purity aluminium (HPA) at one of the aluminium smelters in India is the Government of India undertaking, Bharat Aluminium Company Ltd., BALCO (India, New Delhi).

BALCO operates two aluminium smelters located in Korba (Madhya Pradesh) and Jaykaynager (West Bengal).

Preparation of the Feasibility study for construction of the EDU was awarded to the All-Union Research and Design Institute of Aluminium, Magnesium and Electrode Industry (VAMI) of the Ministry for Non-ferrous Metals USSR under the Contract No.85/2 dated 30.01.85 between UNIDO and V/O TSVETMETPROMEXPORT.

Implementation of this project in India will ensure:

- establishment of a new technology for manufacture of high-purity aluminium, the demand for which is ever growing;
- training of required personnel for future establishment of the high-purity aluminium production on a wide commercial scale;
- meeting of requirements for high-purity aluminium for capacitor manufacture at a level of 1989/90 demand, which will allow elimination of the need for imports of aluminium foil for this application.

1.2. Market and EDU Capacity (Section 3)

At present India produces no high-purity aluminium metal. All demand in products made of this metal is met fully by imports.

The main user of HPA metal at present is the electric capacitor manufacturing industry (over 95% of the total demand).

According to the available information a trend is developing in India towards a significant demand growth in this metal in the industry.

By the end of 80's the Indian demand in HPA is estimated to be at least 500 tpy, which is 1.9 times the 1984/85 demand equal to about 260 tpy.

Based on the analysis of Indian HPA demand, proposed capacity of a HPA cell and proposed number of cells, the normal production capacity of the EDU for the purpose of calculations is 540 tpy of HPA metal.

This capacity is ensured by installation of three 70 kA cells.

1.3. Materials and Utilities (Section 4)

The basic raw material for manufacture of HPA is a commercial-grade aluminium metal (crude metal from the electrolysis cell-rooms).

Besides, the use is also made of other industrial products (cryolite, aluminium fluoride, barium chloride, sodium chloride, graphitised electrodes, copper) and utilities (electric power and compressed air).

The annual requirements of the EDU for the basic raw material and energy is as follows:

- crude commercial-grade aluminium - 556 t
- process a.c. power - 10370000 kWh

1.4. EDU Siting (Section 5)

In conformity with the Contract the siting of the EDU was considered in connection with the aluminium smelters in Korba (Madhya Pradesh) and Jaykaynagar (West Bengal).

Based on the comparative assessment of the siting alternatives it is proposed for the purpose of the Feasibility study that the Korba aluminium smelter will be chosen as a construction site for the EDU installed in the cell-room-75 (Alternative II - Extension of the cell-room for location of HPA cells).

1.5. Engineering Concepts and Design Works (Section 6)

The main production units of the EDU are as follows:

- HPA process section consisting of three 70-kA cells;
- salt drying and salt mix preparation section;
- HPA casting section.

The transport, water supply, power supply, storage facilities of the EDU will use the existing units, service lines and tankage of the existing aluminium smelter.

The Feasibility study proposes the industrial HPA production technology by the method for three-layer electrolytic refining of commercial-grade aluminium metal.

The aluminium electrolytic refining process is carried out with the use of a chloride-fluoride electrolyte.

The major item of the process equipment is a HPA refining cell with amperage of 70 kA featuring the most favourable performance figures.

Construction of the EDU was considered in two alternatives:

Alternative I - installation of the HPA cells in place of three aluminium reduction cell to be removed in the existing cell-room-75

Alternative II - installation of HPA cell in the extension to this cell-room.

The following will also be provided for the both Alternatives:

- salt drying and salt mix preparation will be carried using the existing ingot soaking electric furnace and areas of the smelter foundry;

- HPA casting will be accomplished using the existing casting conveyor and DC casting machine, and areas of the smelter foundry.

The Feasibility study has been prepared on the basis of the indigenous equipment produced in India, except for a pneumatic anode alloy mixing machine and bimetallic strip to be supplied from the USSR. The cost of these supplies is Rs 90,000 (or 2% of the total equipment cost).

At the request of Indian side the variant of the EDU location in the extended part of potroom No 78 was additionally considered in the Feasibility Report (Annexure 4).

1.6. Establishment of EDU, Overheads and Other Expenses (Section 7)

Since the EDU is located in the existing aluminium smelter the economic calculations account for cooperation with the existing production facilities with respect to manning the EDU, performing maintenance and repairs, providing transport and other engineering services.

The overheads include general plant and non-production operating costs in connection with HPA production and sales.

1.7. Personnel (Section 8)

The overall labour requirements for the EDU operation are estimated at 15 persons with 10 production workers, 4 foremen, 1 engineer.

The functional management of the EDU is by the smelter management.

1.8. Project Implementation Time Schedule (Section 9)

The Feasibility study assumes the following:

- time of construction and installation of the equipment is 15 months;

- the basic engineering design and final specification are to be prepared before the start of construction;

- delivery and installation of the equipment will be within the period of 9 months, or 6 months after the start of construction.

The Feasibility study considers an additional alternative of siting the EDU directly in the cell-room-75 in place of three existing cells and in extention of potroom No 78.

The calculations show that this alternative, as compared with location of the EDU in the extended portion of the cell-room-75, is more capital intensive, since this requires extra capital investment connected with restoration of aluminium production capacity removed and increase of civil works.

1.9. Financial and Economic Evaluation (Section 10)

The financial and economic evaluation of the project has been prepared in prices as of the end of 1985 based on the capital and production costs, and financing conditions.

1.9.1. Total Investment Costs

The total investment costs for construction of EDU are estimated at Rs 22,670,000.

The breakdown of these costs in as follows (Rs 000):

- site preparation	- 46
- buildings and structures	- 3077
- technology (know-how with tax)	- 2960
- total equipment and installation cost	- 7484
Soviet-supplied equipment	- 140
Indian-supplied equipment	- 4457
supplied from third countries	- 1943
installation	- 944
- preliminary and preproduction costs (incl.contingency)	- 6368
- working capital	- 2735
Total	22,670

1.9.2. Financing Sources

The financing sources for the fixed capital are the government equity and long-term internal loan in ratio 1:1. The working capital (65 %) is financed by short-term bank loan. The remaining 35 % of working capital (margin money) is financed on the same conditions as the fixed capital.

Based on the above conditions the financing amounts are estimated as follows (Rs 000):

- government equity	- 10,446
- long-term internal loan	- 10,446
- short-term bank loans	- 1778
Total	22,670

1.9.3. Total Production Costs

The total production costs calculated for a normal year in average during the design period of operation at the full capacity of the EDU amount to Rs 23,765,000.

Breakdown of the annual production costs by cost items is as follows (Rs 000):

- materials and utilities	- 19983
incl.: commercial-grade aluminium	- 12457
electric power	- 5833
other	- 1693
- salary and wages	- 403
- general plant and non-production overheads	- 1197
Subtotal of operating costs	- 21588
- interest (in average during perios of operation)	- 804
- depeciation (in average during period or operation)	- 1373
Total of overall production costs	23,765

1.9.4. Financial Evaluation

To determine the financial impact of implementation of the EDU project the following calculations were made:

- cash flow:
- profit and loss account;
- estimate of internal rate of return.

The profitability of the project estimated on the basis of these calculations features the following indices:

- IRRI - 15,3%
- IRRE - 14,7%
- payback period - 5,5 years
- breakeven point - 65,2%
- breakeven capacity - 352 t
- minimum HPA price to ensure breakeven operation of EDU at 100 % capacity - Rs 44,000/t

1.9.5. Resume

The Feasibility study prepared for construction of the EDU for production of HPA at the Korba aluminium smelter (India) allows the following conclusions to be made.

1. Implementation of the project for establishment of the EDU, as a whole, will ensure:

- establishment of a new technology on an industrial scale in Indian conditions for production of high-purity aluminium and aquisition of required commercial experience;
- training of technical personnel and high-skilled indigenous work force;
- complete elimination of imports of HPA products for needs of Indian industries.

2. High economic profits attained by the EDU will improve, as a whole, financial and economic conditions of the Korba aluminium smelter.

3. The Feasibility study on the basis of International standards has been prepared in full scope and in conformity with the "Manual for preparation of industrial feasibility study" (UN, New York, 1978).

The financial evaluation of the project, including the sensitivity analysis, has been made by means of the computer and with the use of a complex of computer programmes developed in VAMI Institute.

2. GENERAL INITIAL DATA

2.1. Background History

2.1.1. Aim of Project

The aim of the project is to estimate the feasibility of construction of the Experimental Demonstration Unit (EDU) for high purity aluminium (HPA) production at one of aluminium smelters of Bharat Aluminium Company Ltd., in India.

At present, no HPA is manufactured in India, and all the local market demand is met by imported metal.

2.1.2. Essence of Project

At present, the developed countries, including the USSR, produce HPA by electrolytic refining the commercial-grade aluminium.

The most cost-effective solution involves the siting of the HPA facility at the existing aluminium smelters. This secures the use of molten aluminium and, with a low initial cost, an uninterrupted d.c. power supply to the HPA cells from the existing SCR station.

This project deals with the establishment of the HPA production facility (within the scope of the experimental demonstration unit) at one of the BALCO's existing smelters. This would allow the Indian experts to gain commercial experience in HPA production which later can be used at the other smelters in India, as well as, under UNIDO auspices, to familiarise with this technology the experts from other developing countries in this region.

2.1.3. Grade of HPA Produced, Scope of Application

The proposed EDU will ensure the manufacture of HPA in the following four grades: 99.995, 99.99, 99.97 and 99.95 cast in pigs 15 kg in weight and ingots upto 3 t in weight.

HPA is used for production of high-strength, corrosion-resistant alloys, electric capacitor and packaging foil, material for protection barrier against effects of sea water and atmospheric air, material for high-reflecting surfaces (reflectors, floodlights, etc.), protective sheathing for power and telephone cables, material of construction in the chemical industry, food industry, etc.

2.1.4. Capacity of EDU

The capacity of the EDU is set to meet the 1995 expected HPA demand in India, estimated at 500 to 550 tpy. To produce the above amount of HPA the EDU will be provided with three 70-kA cells with an average output of 180 tpy each.

2.1.5. Implementation Time Schedule

Based on the experience of the establishment of HPA production facilities in the USSR, the preparation of the engineering design and construction of the EDU may be completed within two years.

The attainment of the design figures will take one year.

2.1.6. Economic Impact

The establishment of the HPA facility in India will allow the saving of foreign currency otherwise required for imports of the metal, because it will totally eliminate the need for the same.

2.2. Initiator of the Project and Executor of the Feasibility Report

2.2.1. Initiator of the Project

The initiator of the project of the EDU construction is Bharat Aluminium Company Limited (BALCO),a Government of India undertaking. BALCO was founded in the year 1965. The head office is located in New Delhi (Punj House, 18 Nehru Place, New Delhi-110019).

The existing Alumina-Aluminium Complex at Korba under BALCO consists of:

- Bauxite mine,
- Alumina plant;
- Smelter;
- Fabrication Complex;

Besides this, the Company also manages the Jaykaynagar Smelter (Bidhan Bag Unit Smelter), located about 250-300 km from Calcutta. At present the alumina and aluminium production capacities of this plant are not utilised.

2.2.2. Role Played by BALCO in Project Implementation

BALCO is participating directly in the implementation of the Project of the EDU construction on behalf of the Government of India.

The Company has taken an active part and rendered assistance to the group of Soviet Experts which arrived in India in July-August, 1985 to collect the initial data in accordance with UNIDO terms of Reference.

2.2.3. Executor for the preparation of Feasibility Report

In accordance with contract between UNIDO (United Nations Industrial Development Organisation) and V/O TSVETMETPROMEXPORT the preparation of Feasibility Report of the RDU construction for HPA production has been assigned to All-Union Research and Design Institute of Aluminium, magnesium and Electrode Industry (VAMI) of the ministry of Non-Ferrous metallurgy of the USSR, Leningrad, V.O. Sredniy prospect, 86.

2.3. General conditions

2.3.1. Data on the Existing Aluminium Complex at Korba

The Plant Installed Capacity and its Utilisation.

The Plant has installed production capacity as follows:

- 100,000 tons annual production of primary Aluminium;
- 100,000 tons annual output of saleable products

Primary aluminium is produced by 100 kA V.S.Soderberg pots installed in 8 cell houses.

Cell-house dimensions are 624 x 18 m with one-row end-to-end pot layout. Processing of Primary Aluminium into saleable products is accomplished in Foundry, Profile-Tube and Sheet rolling shops of the rated capacity (tpy):

Ingots	18,000
Properzi Rods	35,000
Extrusions	7,000
Rolled Products	40,000

During 1984-85 the Plant production performance was 87,000 tons of Primary Aluminium and 83,358 tons of Saleable metal, comprising:

- Ingots	26,904 t
- Properzi Rods	36,509 t
- Extrusions	4,767 t
- Rolled Products	15,926 t
- Others	3,252 t

Against the Projected 99.5 % aluminium metal content in primary aluminium the actual value of it during previons year was found to be 99.54 % with 0.2835 % average content of iron and 0.114 % of silicon.

2.3.2. Climatic, Geographic and Social Conditions

The Plant is located in South-Eastern part of Madhya Pradesh State, in latitude 22°23' North and 82°44' longitude East, 9 km from Korba Railway Station, District Bilaspur.

The climate of the area is tropical. The average max. ambient temperature during 5 days of peak summer period is 43°C. The average minimum ambient temperature during 5 days of the peak winter months is 13.4°C.

The absolute maximum air temperature is 45°C. The absolute minimum air temperature is 6.1°C. Out-door air conditions are:

- for summer dry period, temperature 43 °C, relative humidity 22 %
- for summer damp season, temperature 33°C, relative humidity 100%.

The average annual value of atmospheric precipitation is about 1480 mm. The highest precipitation value is in august (about 460 mm). The region of Plant site is not exposed to seismic effect.

The Plant site ground is represented by sand loam and clay soils with 1.25-2.5 kg/sq.cm load carring capacity at 4-5 meters entry depth.

Integrated Township area is 900 acres. The Township has population of about 20,000 persons and has a Post office, Police Station, Hospital. The BALCO Township is within the TV reception range, it has a branched network of automobile roads, several schools, training centre and a few Cinema Halls.

3. MARKET AND INTERPRISE CAPACITY

3.1. HPA Demand and Supply

At present India produces no high-purity aluminium and all indigenous demand is satisfied by imports of the HPA-based foil.

The main end use of HPA is production of electrolytic capacitors accounting for over 95% of the overall imports.

According to the available information there is a sufficient potential market in India for HPA to justify establishment of an indigenous production facility in the scope of the proposed EDU.

At present demand for HPA in India is estimated at 260 tpy and expected to rise to at least 500 tpy by the end of 80's.

In addition to electric capacitor foil HPA can be used for manufacture of high-strength and corrosion-resistant alloys, packaging foil, protective barrier against effects of sea water and atmospheric air, reflecting material (reflectors, flood-lights, etc.), protective sheathing (for power and telephone cables), material of construction for chemical equipment, equipment in food industry, etc.

Thus, the proposed HPA production technology may have a significant impact on Indian economics. The establishment of the EDU will allow:

- acquisition of the experience in indigenous HPA production;
- assessment of introduction of indigenous HPA into the local market and expansion of its field of application;
- full elimination of need for imports of HPA foil.

3.2. HPA Sales

The feasibility study report assumes that the whole amount of HPA manufactured by the EDU will be consumed by the Indian indigenous market.

Since at present India produces no HPA and there is no local HPA price, according to BALCO's recommendations the HPA selling price is assumed, for the purpose of the feasibility study, at a level of Rs 45000 to Rs 50000 per tonne (the base variant - Rs.47750/t).

The above price level also takes into account the expected steps by the Government of India in readjustment of aluminium prices by the end of 1985 (price increase).

The financial-economic evaluation (Section 10) analyses the effects of HPA price variation on profitability of the project.

Based on the assumed price levels and production programme Schedule 3-1 below shows the calculation of the sales revenue.

Schedule 3-1

Sales Revenue

Item	HPA grade, % Al	Price, Rs/t	Years from start of operation			
			1st year		2nd year, etc	
			Qty t	Revenue Rs 000	Qty t	Revenue Rs 000
1	99.995	50000	4.3	215	5.5	275
2	99.99	49000	194.4	9526	243.0	11907
3	99.97	47000	194.4	9137	243.0	11421
4	99.95	45000	38.9	1750	48.5	2182
	Total:	47750	432	20628	540	25785

The sales expenses include the expenses connected with shipment of the finished product to clients and other overheads borne in connection with its sales.

Schedule 3-2 shows the estimate of these costs.

Schedule 3-2

Production cost estimate

Sales expenses

Item	Quantity, years from start of operation 1st	2nd	Unit	Cost item	Rate	Expenses, Rs 000, year from start of operation 1st	2nd
1	432	540	t	Shipment of product to clients	Rs 500/t	216	270
2	20628	25786	Rs 000	Sales expenses	1.5% of sales revenue	309	387
				Total		525	657

3.3. Production Programme

The proposed technology ensures the production of the following grades of HPA:

Sl. No.	Aluminium content, min	Percentage of impurities, max. Fe	Si	Cu	Zn	Ti
1	99.995	0.0015	0.0015	0.001	0.001	0.001
2	99.99	0.003	0.003	0.003	0.003	0.002
3	99.97	0.015	0.015	0.005	0.003	0.002
4	99.95	0.030	0.030	0.015	0.005	0.002

The following HPA production structure is assumed for the calculations of the Feasibility Report:

HPA grade	99.995	99.99	99.97	99.95
Percentage of production	1.0	45.0	45.0	9.0

The level of production capacity utilization is determined in accordance with the production schedule (start-up and commissioning of main process equipment-cells-for HPA production) given below:

Sl. No	Main process equipment	Quarters from beginning of start-up I	II	III	IV	I	II
1	Electrolyte preparation and cathode impregnation cell						
	- start-up						
	- commissioning and adjustment x)						
	- reaching capacity, %		22	46,5	70,0	100.0	100.0
2	Refining cell No 1						
	- start-up						
	- commissioning and adjustment						
	- reaching capacity, %	11.0	35.0	59,5	84,5	100.0	100.0
3	Refining cell No 2						
	- start-up						
	- commissioning and adjestment						
	- reaching capacity, %	5.0	29,0	53,5	78,0	100.0	100.0

x) During this period the cell produces electrolyte requirede for start-up of the refining cells Nos. 1 and 2.

On the basis of the HPA production structure and the production capacity utilization level the production programme assumed for the Feasibility Report calculations is determined in Schedule 3-3.

Schedule 3-3

Production programme

Sl No.	HPA grade (Al content p.c.)	Production at 100% capacity, t	Years from start-up of operation			
			1-st year		2-nd and following	
			Capacity utilization, %	Quantity, t	Capacity utilization, %	Quantity, t
1	99.995	5.5	80	4.3	100	5.5
2	99.99	243.0	80	194.4	100	243.0
3	99.97	243.0	80	194.4	100	243.0
4	99.95	48.5	80	38.9	100	48.5
	Total	540	80	432	100	540

3.4. EDU Capacity

The normal rated capacity of 540 tpy of HPA is adopted for the EDU. The above capacity is determined on the basis of following data:

- analysis of HPA market in India;
- unit capacity of refining cells to be installed;
- adopted number of cells.

For the EDU the 70 kA refining cells are adopted which are considered to be the most powerful cells used in the world at present for HPA production.

The average cell capacity is 180 tpy. This cell has the optimum technical and economical parameters. Three cells are adopted for installation.

The number of pots to be installed is justified by the fact that one of them will be used for refining of aluminium as well as for electrolyte preparation and cathode impregnetion and is not a typical refining pot for industrial production of HPA.

The EDU must contain not less than refining pots apart from this one for the performances of only one refining pot are not representative enough.

Besides the three pots arrangement offers one center pot typical for industrial HPA production for it has more favourable magnetic field than two other and allows for refining in optimum conditions.

4. MATERIALS AND OTHER PRODUCTION FACTORS

4.1. Characteristics of Raw Materials and Inputs

4.1.1. Classification of Materials

List of raw materials and inputs required for high purity aluminium (HPA) production:

- Technical grade (crude) aluminium,
- Barium chloride
- Cryolite
- Aluminium Fluoride
- Sodium Chloride (Table Salt)
- Copper
- Graphite
- Soda Liquor (used from the existing gas cleaning system)

4.1.2. Requirements to Raw Materials and Inputs

Taking into account that the refined aluminium is to be of high purity, there are certain requirements for raw materials and inputs relating to their impurity levels. Main impurities determining the purity of refined aluminium are copper, iron and silicon. The primary aluminium used for refining contains maximum 0.3% of Fe and 0.30% of Si.

The utilization of primary aluminium with higher impurity level as compared with above mentioned impurities results in contamination of HPA and increase of anode sediment, with respective higher specific consumption of crude aluminium.

The increase of copper content in HPA above the specified level (0.001 to 0.015% depending on HPA grade) depend upon the disturbed condition of refining process and incorrect operation of cells.

The contents of Zn and Ti in primary aluminium are not to exceed 0.06% and 0.03% respectively.

The utilization of such primary aluminium ensures the production of HPA with the following level of impurities:

Zn - 0.001% to 0.005% and

Ti - 0.001% to 0.002%

The salts (barium chloride, cryolite, aluminium fluoride and sodium chloride) charged into the cell for electrolyte preparation are to have minimum moisture content, Al_2O, Fe, Si and other impurities contents.

The salts moisture content is not to exceed 0.2% (to ensure this moisture content the salts are to be dried if required). The utilization of salts with higher moisture content will effect metal quality, increase specific power and salts consumptions as well as increase the labour requirements for sludge removal and ledge cutting.

Fe and Si contents in salts are also specified; they are not to exceed:

- for barium chloride ($BaCl_2.2H_2O$) - 0.003% Fe
- for cryolite - 0.08% of Fe (as Fe_2O_3) and 0.9% of Si (as SiO_2),
- for aluminium fluoride the sum of Fe_2O_3 and SiO_2 is 0.4%.

The utilization of salts with higher level of these impurities will deteriorate quality of the HPA.

Besides, the content of free alumina in aluminium fluoride is not to exceed 7.0%, and the contents of matters insoluble in water in barium and sodium chlorides - 0.12 and 0.45% respectively.

The graphitized electrodes are to have the electrical resistivity of 8.1 to 9.0 micro Ohm.m, the flexural strength of 70 kg/sq.cm.min and rupture strength of 35 kg/sq.cm.min.

When electrodes of poor quality are used the power and graphite consumption will increase as well as the cost of manufacturing, maintenance and repair of cathodes.

<u>Power:</u>

- AC current - 50 Herz, voltage - 220 V
  Amperage is determined by the characteristic of each power user.
- DC current - 70 kA
  Compressed air - 4 to 6 atm. pressure.

In accordance with the above requirements all materials for the HPA production are assumed of Indian supply for the Feasibility Report.

4.1.3. Characteristics of raw materials and inputs

4.1.3.1. Primary aluminium (crude)

Table

SNo	Description	Unit	Value
1	Aluminium content, min	%	99.6
2	Fe content, max	-do-	0.3
3	Si content, max.	-do-	0.13
4	Zn content, max.	-do-	none
5	Ti content, max.	-do-	0.02
6	Other impurities (Mn+Cr+Zr) each max.	-do-	0.01
7	Total impurities content	-do-	0.4

4.1.3.2. Barium Chloride

Table

SNo	Description	Unit	Value
1	$BaCl_2 \cdot 2H_2O$ content, min.	%	98.0
2	Matter insoluble in water, max.	-do-	0.2
3	Na content, max.	-do-	0.01
4	Ca content, max.	-do-	0.02
5	Fe content, max.	-do-	0.005
6	Total sulphur (S) content, max.	-do-	0.02

4.1.3.3. Cryolite

Table

SNo	Description	Unit	Value
1	F content, min.	%	53.0
2	Al content, max.	-do-	13 to 15
3	Na content, max.	-do-	31 to 34
4	SiO_2 content, max.	-do-	0.2
5	Sulphate content as SO_3, max.	-do-	0.6
6	Fe_2O_3 content, max.	-do-	0.2
7	Moisture content, max.	-do-	0.2
8	P_2O_5 content, max.	-do-	0.005 to 0.01
9	Cryolite ratio (molar)	-do-	3.0

4.1.3.4. Aluminium Fluoride

Table

SNo	Description	Unit	Value
1	L.O.I., max	%	1.0
2	AlF_3 content, min	-do-	90±1
3	Free Al_2O_3 content, max	-do-	8.08±1
4	(SiO_2 + Fe_2O_3) content, max	-do-	0.4
5	Sulphate content as SO_3, max	-do-	0.5
6	P_2O_5 content, max	-do-	0.02

4.1.3.5. Sodium Chloride (Common Salt):

Table

SNo	Description	Unit	Value
1	Sodium chloride, dry basis, min	%	99.5
2	Matters inso..ble in water, dry basis, max	-do-	0.05
3	Moisture content, max	-do-	5.0
4	Maximum content on dry basis:		
	Ca^{++}	-do-	0.03
	Mg^{++}	-do-	0.0005
	SO_4^{--}	-do-	0.02
	Fe	-do-	0.001
	Na_2SO_4	-do-	0.002
5	Grain size distribution, less then:		
	1.? mm	-do-	12.0 max
	1.2 to 0.5 mm		85.0 min
	2.5 to 4.5 mm		3.0 max

4.1.3.6. Electrolytic Copper

Table

SNo	Description		Unit	Value
1	Copper (Cu) content, min		%	99.9
2	Iron (Fe) content, max		-do-	none
3	Bismuth (Bi) content, max		-do-	0.001
4	Antimony (Sb) content, max		-do-	0.002
5	Arsenic (As)	-same-	-do-	0.002
6	Nickel (Ni)	-same-	-do-	0.002
7	Lead (Pb)	-same-	-do-	0.005
8	Tin (Sn)	-same-	-do-	0.002
9	Sulphur (S)	-same-	-do-	0.004
10	Oxygen (O_2)	-same-	-do-	0.06
11	Zinc (Zn)	-same-	-do-	0.04
12	Phosphorus (P)	-same-	-do-	-

4.1.3.7. Graphitized Electrodes

Table

SNo	Description	Unit	Value
1	Specific Electrical resistivity, max.	Micro-Ohm/m	9.5
2	Mechanical Strenth, min		
	- flexural strength	kg/sq.cm	85
	- rupture strength	-do-	75

4.1.4. Utilities

4.1.4.1. Compressed air

The compressed air is to be supplied periodically at a pressure of 4 to 6 atmospheres.

4.1.4.2. DC Power

The amperage of DC power is 70 kA. The permissible amperage fluctuation is ± 5 %.
The duration of emergency DC power cut-off is 2 hours maximum.

4.1.4.3. AC Power

Duration of emergency AC Power cut-off is 8 hours max.

4.1.5. Sources of Materials Supply

The indigenous materials will be provided for the operation of the EDU. The following sources of supply are assumed for the Feasibility study report:

4.1.5.1. Aluminium

Technical Grade (Primary) crude Aluminium is to be supplied to the EDU in molten form from the existing cellrooms of the Smelter at Korba.

4.1.5.2. Barium and Sodium Chlorides

Three Indian Chemical Companies have been identified as potential suppliers of Barium and Sodium Chlorides (Chemical Co. ICI, Sarabhai Chemicals and Bengal Chemicals with offices in Madras, Calcutta, Bombay and New Delhi). Barium and Sodium chlorides are supplied in polyethylene bags (50 kg. each) by truck or railway transport.

4.1.5.3. Cryolite and Aluminium Fluoride

Taking into account the low annual consumption of cryolite and aluminium fluoride as compared with the existing Smelter, it is assumed that these materials would be supplied to the EDU cells from the existing stocks of the Plant.

4.1.5.4. Graphitized Electrodes

The graphitized electrodes may be supplied from Bhopal in covered railway wagons or transported in covered trucks.

4.1.5.5. Copper

The copper may be supplied by the Company Hindustan Copper Limited, Ghatsila, near Tatanagar, Bihar.

4.1.5.6. Soda Liquor

Soda liquor is to be fed from the gas cleaning system of the operating Smelter.

4.1.5.7. Utilities

The existing services of the Smelter are to be utilized to supply the EDU with electric power and compressed air.

4.2. Supply Programme

4.2.1. Initial Data

To determine the supply programme with raw materials and inputs provision is made for a HPA grade range to be produced at the EDU as given in para 4.2.1.1. The HPA grades are selected to correspond to the USSR GOST 11069-74 "Primary Aluminium. Grades" and with consideration of their demand, optimum performance figures and composition of the raw materials in question.

The consumption rates of raw materials, inputs and utilities for production of HPA are listed in para 4.2.1.2. The annual production programme by grades is given in para 4.2.1.3.

4.2.1.1. Composition of HPA Grades to be Produced at EDU

Item	Percentage of aluminium, % min	Percentage of controlled impurities, % max					HPA grade, GOST USSR
		Fe	Si	Cu	Zn	Ti	
1	99.995	0.0015	0.0015	0.001	0.001	0.001	A995
2	99.99	0.003	0.003	0.003	0.003	0.002	A99
3	99.97	0.015	0.015	0.005	0.003	0.002	A97
4	99.95	0.030	0.030	0.015	0.005	0.002	A95

Note: The grade of aluminium is determined by subtracting from 100% the sum of controlled impurities (Fe, Si, Cu, Zn, Ti)

4.2.1.2. Consumption Rates for HPA Production (incl. losses and moisture content)

Item	Description	Unit	Rates per tonne of HPA
1	Crude commercial-grade aluminium	t	1.03
2	Hydrous barium chloride	t	0.034
3	Cryolite	t	0.0165
4	Aluminium fluoride	t	0.009
5	Sodium chloride	t	0.0045
6	Graphitised electrodes	t	0.015
7	Copper	t	0.014
8	D.C. power for refining cell	kWh	17000
9	D.C. power (overall demand)	kWh	18500
10	A.C. power (overall demand)	kWh	19200
11	Compressed air (at 4-6 bar)	Nm^3	600
12	Process wastes:		
	- anode sediments	t	0.04
	- crust	t	0.033
	- ledge and sludge	t	0.0165

4.2.1.3. Annual Production Programme by HPA Grades

Item	HPA grade	Output, tpy
1	A995	5.5
2	A99	243
3	A97	243
4	A95	48.5
	Total	540

4.3. Supply Programme Selection

4.3.1. Selection of the supply programme is determined by consumption of materials in the production process, continuity of operation, schedule of material consumption, availability of tankage and areas for storage, uniform load onto transport means and personnel responsible for handling operations.

4.3.2. The consumption rates of raw materials and inputs (para 4.3.2.1) during the first year of operation are estimated on the basis of HPA output attained by the end of this year.

The supply programme for the EDU operating at full capacity is given in para 4.3.3, stocks of raw materials and inputs - in para 4.3.2.4.

4.3.2.1. Annual Requirements for Raw Materials and Utilities for HPA Production

Item	Description	Unit	Years from start of operation	
			1st year	2nd year, etc.
1	Crude commercial-grade aluminium	t	450	556
2	Hydrous barium chloride	t	16.2	18.5
3	Cryolite	t	7.9	8.9
4	Aluminium fluoride	t	4.3	4.9
5	Sodium chloride	t	2.15	2.5
6	Graphitised electrodes	t	7.2	8.1
7	Copper	t	1.0	7.6
8	D.C. power (refining cell)	kWh	7.7×10^6	9.2×10^6
9	D.C. power (overall demand)	kWh	8.4×10^6	9.99×10^6
10	A.C. power (overall demand)	kWh	8.71×10^6	10.37×10^6
11	Compressed air (at 4-6 bar)	Nm^3	270000	324000

4.3.3. Supply Programme of Raw Materials and Inputs for EDU Operating at Full Capacity

Item	Description	Stock, t	Supply frequency	Supply batch	Transport means
1	Crude commercial-grade aluminium	-	every 2 days	3-3.2	cell room vehicles
2	Hydrous barium chloride	3.1	every 2 months	3.1	rail or motor transport
3	Cryolite	1.5	ditto	1.5	motor transport
4	Aluminium fluoride	0.8	ditto	0.8	ditto
5	Sodium chloride	0.42	ditto	0.42	rail or motor transport
6	Graphitised electrodes	1.35	ditto	1.35	ditto
7	Copper	0.21	every 10 days	0.21	ditto

4.3.4. Stocks of Raw Materials at EDU Operating at Full Capacity

Item	Description	Stock	
		tonnes	days
1	Crude commercial-grade aluminium	-	-
2	Hydrous barium chloride	3.1	60
3	Cryolite	1.5	60
4	Aluminium fluoride	0.8	60
5	Sodium chloride	0.42	60
6	Graphitised electrodes	1.35	60
7	Copper	0.21	10

4.4. Cost Estimate

The estimate of annual operating costs for raw materials and utilities used for the EDU are shown in Schedule 4-1.

The follosing basis was used for estimation:

- annual quantities of consumption of raw materials and utilities determined by the consumption rates;
- HPA production programme;
- prices of the raw materials and utilities used as of the end of 1985 (with price escalation ignored).

The electric power cost includes the cost of its transformation to DC (at 5%).

All raw materials and utilities will be indigenous.

The estimation has been prepared for the 1st year of operation of the EDU (start-up and attainment of the design capacity) and for the 2nd year (and all subsequent years) of its normal operarion.

Schedule 4-1

Production cost estimate

Materials and utilities

Project: EDU   Description: High-purity aluminium

Item	Qty, years from start of operation: 1st	Qty, years from start of operation: 2nd	Unit	Cost item	Unit cost, Rs	Total cost, Rs 000, years from start of operation: 1st	Total cost, Rs 000, years from start of operation: 2nd
1	2	3	4	5	6	7	8
1				Raw materials and utilities			
1.1	450	556	t	Crude commercial-grade aluminium	22,404	10,082	12,457
2				Inputs			
2.1	16.2	18.5	t	Barium chloride	35,000	567	648
2.2	7.9	8.9	t	Cryolite	20,233	160	180
2.3	4.3	4.9	t	Aluminium fluoride	22,562	97	111
2.4	1.0	7.6	t	Copper	50,000	50	380
2.5	7.2	8.1	t	Graphitised electrodes	40,000	288	324
2.6	2.15	2.5	t	Sodium chloride	20,000	43	50

1	2	3	4	5	6	7	8
2.7	15.0	-	t	Coal	360	5	-
				Subtotal of item 2		1,210	1,693
3				<u>Utilities</u>			
3.1	8710	10370	kWh 1000	A.C. power	562	4895	5828
3.2	270	324	Nm^3 1000	Compressed air	16	4	5
				Subtotal of item 3		4899	5833
				Total		16,191	19,983

5. LOCATION AND SITE

5.1. Location

In accordance with the UNIDO contract No.85/2 the following states for the EDU location were to be considered:

- Madhya Pradesh State, the operating BALCO's Smelter in Korba region;
- West Bengal State, the non-operational BALCO's Smelter in Jaykaynagar region.

5.1.1. Korba Aluminium Smelter

The capacity of the Smelter is 100,000 tpy of primary aluminium. 100 kA cells with vertical anode studs are installed at the Smelter. The Smelter consists of raw cells-lines with gas-cleaning plants. Each cell-line consists of four cell-rooms. Fifty one cells are installed in one cell-room, the cells being arranged in single row, end-to-end.

The cell-rooms are equipped with erection crane of 80/20 t capacity and two process operation cranes of 8/12.5 t lifting capacity.

The smelter is power supplied from the operating power plants (State sector) located in Korba region. In 1985 BALCO had started the construction of a captive power plant of 270 MW capacity, the first unit of 67.5 MW to be commissioned in 1987.

The cell-line (4 cell-room) is supplied with power from the Silicon Rectifier Sub-station consisting of 6 rectifier units (Outlet parameters of the rectifiered current : 950 V, 22 kA).

High skilled manpower is available at the Smelter.

5.1.2. Aluminium Smelter at Jaykaynagar

The Jaykaynagar Smelter was constructed and commissioned 40 years ago under the design of the Company Alusuisse Switzerland.

The Jaykaynagar plant consisted of alumina plant, Smelter and Fabrication Complex. The production of the Smelter was 9000 tpy. The cell-room No.1 is equipped with 24 KA horizontal stud cells, and the cell-room No.2 with 50 KA vertical studs cells.

During last 15 years the capacities of alumina and aluminium production have not been operated. The cell-rooms and the Rectifier Sub-stations are not used.

The structures and the equipment of cell-room No.1 have a high lovel of wear and high investment is required for their restoration.

The conditions of the cell-room No.2 and the Rectifier Sub-station are satisfactory. 56 cells are installed in cell-room No.2. The cells are arranged in two rows, end-by-end. The cell-room is equipped with E.O.T. cranes of 12.5 t capacity.

Four rectifier units are installed at the Rectifier Sub-station. The rectifier amperage is 16.8 KA, minimal possible voltage 78 V. At present the Fabrication Complex is power supplied from the State Electricity Board.

5.1.3. Main Factors for Selection of the EDU Location

The location of the EDU for high purity aluminium production was selected jointly with BALCO, taking into consideration the following factors.

- supply of primary aluminium in liquid form directly from the cell-room;
- possibility of utilization of the existing equipment;
- Transportation costs of raw materials and inputs;
- reliability of power supply;
- availability of skilled labour;
- required investment and production costs for construction and operation of EDU;
- Rate of return on total invested capital and loan repayment period.

5.1.4. Experimental Demonstration Unit (EDU) site selection

In order to evaluate and select the location of the EDU for high purity aluminium (HPA) production at one of the Aluminium Smelters of Bharat Aluminium Company Limited (BALCO), located in Korba (Madhya Pradesh State) and Support Study was prepared (Annexure No.1). As the analysis carried out had revealed the optimal EDU location site was Korba Smelter.

This variant of the EDU location (Korba Smelter) was adopted for the further consideration in the Feasibility Report.

5.1.5. Alternatives of EDU Location at Korba Smelter

The essential factors of the EDU location at Smelter site are as follows:

- the supply of molten primary aluminium directly from the cell-room
- minimum distance to the DC power supply source-main step-down substation;
- possibility to utilise the existing auxiliary equipment of the cell-room for the EDU.

Taking into consideration the above factors the following alternatives of the EDU location are assumed to be considered in the Feasibility Report:

Alternative I: The installation of refining cells for high purity aluminium production in the existing cell-room No 75. Three existing cells are to be dismantled and one- to be switched off. In this case the installed capacity of the Smelter will be decreased down to 99250 t/yea[r]

Alternative II: Expansion of the existing cell-room No 75 to 26 m for the installation of three refining cells for HPA production and switching off of four existing cells (temporarily). This will result in reduction of production capacity to 99000tpy before the additional voltage should be obtained due to the planned process improvements.

5.2. EDU Siting Conditions at Korba Aluminium Smelter

The experimental demonstration unit for production of high-purity aluminium consists of the following three process sections located in the existing cell-room:

- 1st section - three HPA cells in the cell-room No 75 in place of three existing cells to be removed (Alternative I) or on free area in the cell-room extension (Alternative II);
- 2nd section - salt drying facility located in the foundry;
- 3d section - HPA casting facility in the foundry.

Out of the above three EDU process sections only the siting of the 1st section requires coordination with the existing plot-plan, but the other two sections are easily sited in the foundry and in no way effect the existing service lines or roads.

Siting of HPA Process Section

Alternative I, dwg. 1367231 -ПП

Location of three HPA cells in place of three aluminium reduction cells to be removed in the western end of the existing cell-room - 75 will require to build at the plant only a new support racks for the busbar line between the SCR station - 85 and the cell-room 75 with total length of 72.2 m. No other measures like the moving of the existing service line or roads will be needed.

Alternative II, dwg. 1367232-ПП

Location of the HPA process section in the extended part of the western section of the cell-room - 75.

The extent of expansion of the western part of the cell-room - 75 is limited by the existing rail track running in parallel with the centre line 1 of this cell-room 29.494 m west of the cell-room. Based on the observance of the railway clearanc of 3.10 m, extention of the cell-room - 75 in the western direction will be 26.0 m long.

Extention of the cell-room - 75 by the above length will entail:

- moving the section of the existing motor road passing through the western ends of all cell-rooms because it interferes with HPA cells area;

- moving the section of the existing cable tunnel from within the limits of the building extention area;

- construction of a new section of the busbar rack 25.2 m long.

The overall area of the proposed motor roads is 560 m^2.

5.3. Cost Estimate

The cost estimate for construction of the EDU was prepared with reference to the existing Korba aluminium smelter site and so excludes any costs for acquisition of the land plot and expenses related to its use.

The cost for preparation of the site for construction of the EDU is included in the investment cost of the buildings and structures listed in Section 6.

5.4. Selection of the EDU Location Alternatives at Korba Smelter

The calculations carried out revealed that the most economically viable was the Alternative II - the location of three HPA production cells in the expanded part of the cell-room No 75.

Thus the financial and economic evaluation of the present Feasibility Report was prepared for Alternative II only.

The location of HPA cells as per the Alternative I requires the dismantling of four existing cells, that is cut-back of operating aluminium production capacity.

That is why this Alternative is not recommended for implementation.

5.5. Environmental Impact

5.5.1. Characteristic of Harmful Emissions from Process Equipment

Main harmful emissions of the EDU are HF gas, dust of fluoride solids, HCl and dust mainly containing $BaCl_2$.
These harmful emissions are emitted from the cells.
Out of three cells one cell (for electrolyte preparation and cathode impregnation) is equipped with gas exhaust system.
No gas exhaust systems are required for refining cells as their emissions are not important.

5.5.2. Quantities of Harmful Emissions

Maximum quantities of the EDU emissions into the air will make:

HF gas	- 0.26 kg/hour
HF solids	- 0.16 -same-
HCl	- 0.34 -same-
Dust ($BaCl_2$)	- 0.55 -same-

The above maximum quantities of the EDU harmful emissions should be generated only during the period of operation of one out of three cells for electrolyte preparation and cathode impregnation (once in 60 days during 3,5 days for salts melting).

Taking into consideration the short duration of the maximum emissions, the above quantities of HCl emitted to the air are admissible and the additional gas-cleaning is not required.

It is to be noted that emissions of the Smelter practically are not changed because during the EDU operation four existing cells in the cell-room No 75 are to be switched off.

5.5.3. Technical Concept

To clean the gases from the electrolyte preparation and cathode impregnation cell the provision is made for the utilization of the existing gas-cleaning system of the cell - line No 2 located between the cell-rooms Nos. 76 and 77.

6. ENGINEERING AND DESIGN WORKS

6.1. Engineering devision

6.1.1. Initial data

Initial data for elaboration of process estimations, erectio drawings and general lay-out of EDU are as follows:

- EDU capacity - 540 tonnes of high-purity aluminium (HPA) per year;
- production program;
- three-stage electrolytic process for HPA production;
- 70 kA electrolytic cell for HPA production;
- continuous operation of EDU pots (8760 hours per year)
- initial data for Korba aluminium smelter plant site.

6.1.2. Composition of engineering documentation for EDU

The major production units of EDU are:
- section of HPA pots,
- salt drying and salt charge preparation section,
- HPA casting section.

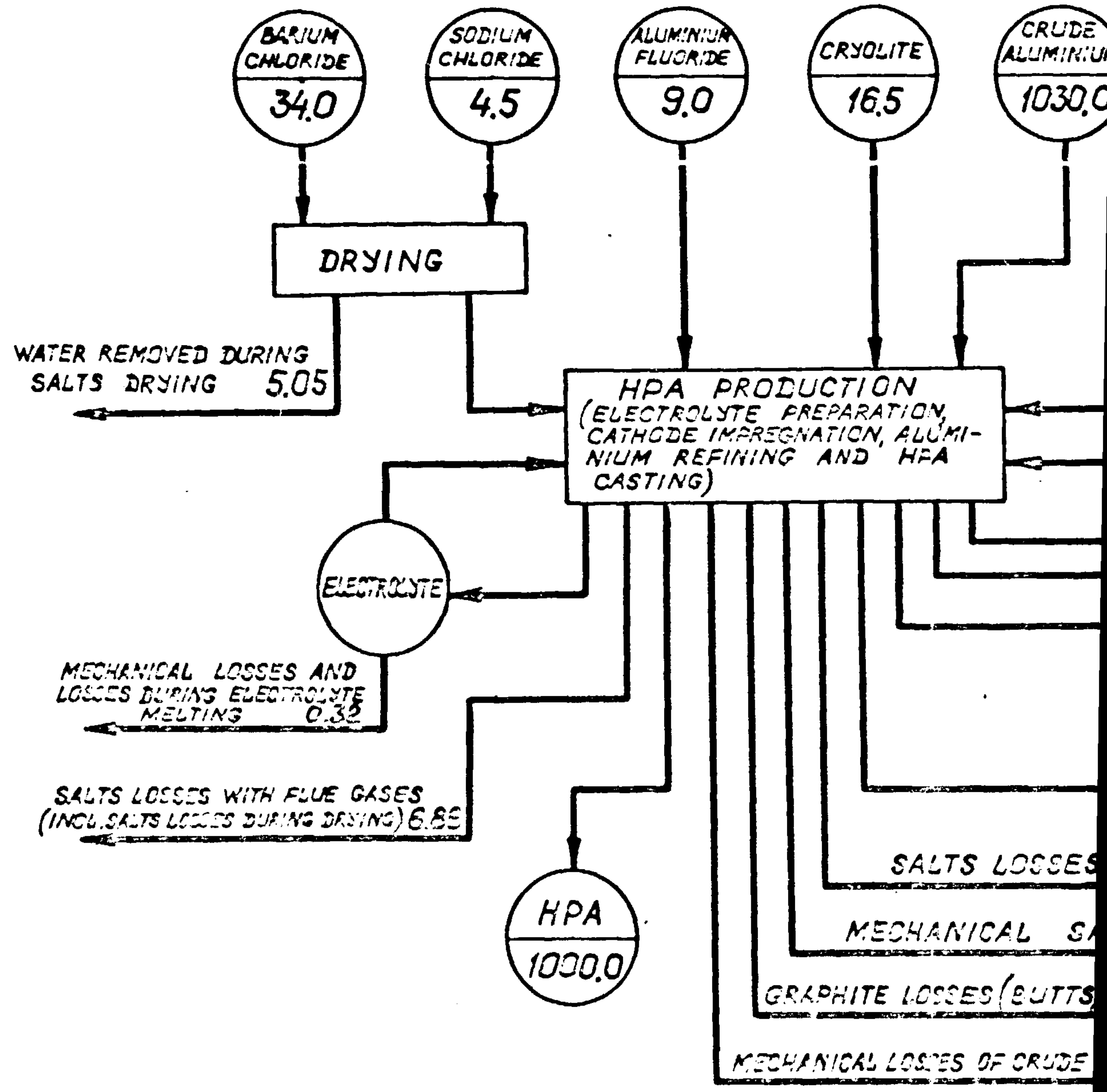
The determine optimum technical solutions and to provide for high technical and economical indexes of EDU for HPA production two variants of pot section location have been considered: in the first variant HPA pots are located at the end of potroom No 75 near SRSS with arrangement of three HPA pots instead of three existing aluminium pots; in the second variant three pots are installed in prolonged part of potroom No 75.

In the Feasibility Study the following documentation has been prepared for HPA pot section:

- line process diagram,
- general views of HPA pots,
- erection drawings,
- construction drawings,
- power supply diagrams.

The mentioned documentation is in volume 2. Calculations of hour material flows with EDU capacity of 540 t/year of high-purity aluminium and material flows per 1 tonne of commercial high-purity aluminium (diagrams 1 and 2) have also been made.

Specifications on equipment and materials are given in volume 3.



NOTE:

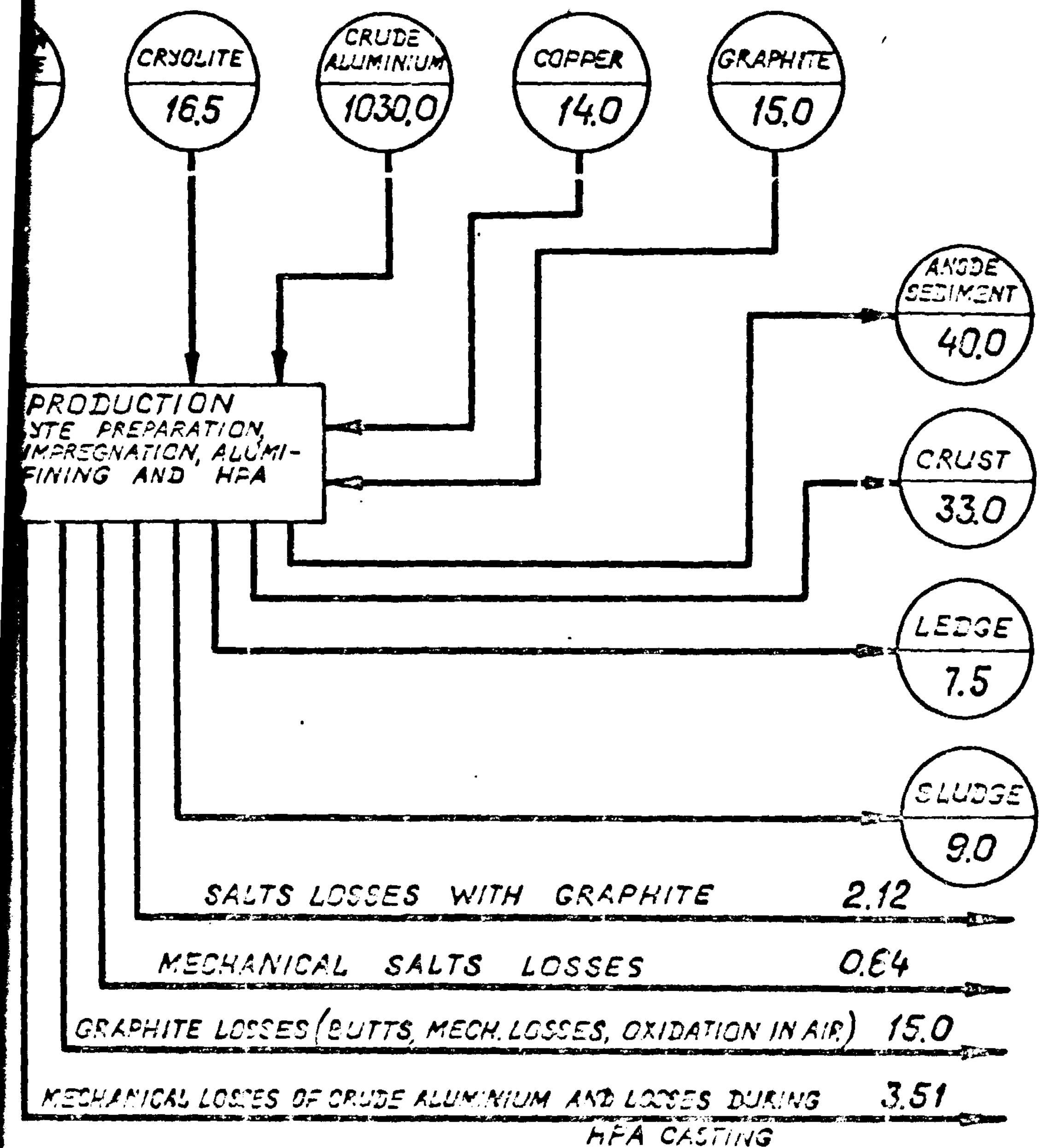
MECHANICAL LOSSES OF CRUDE ALUMINIUM AND LOSSES DURING HIGH PURITY ALUMINIUM CASTING ARE GIVEN WITH CONSIDERATION OF RECYCLING OF SLUDGE, METAL REST IN LADLES ETC.

FL

MATERIAL

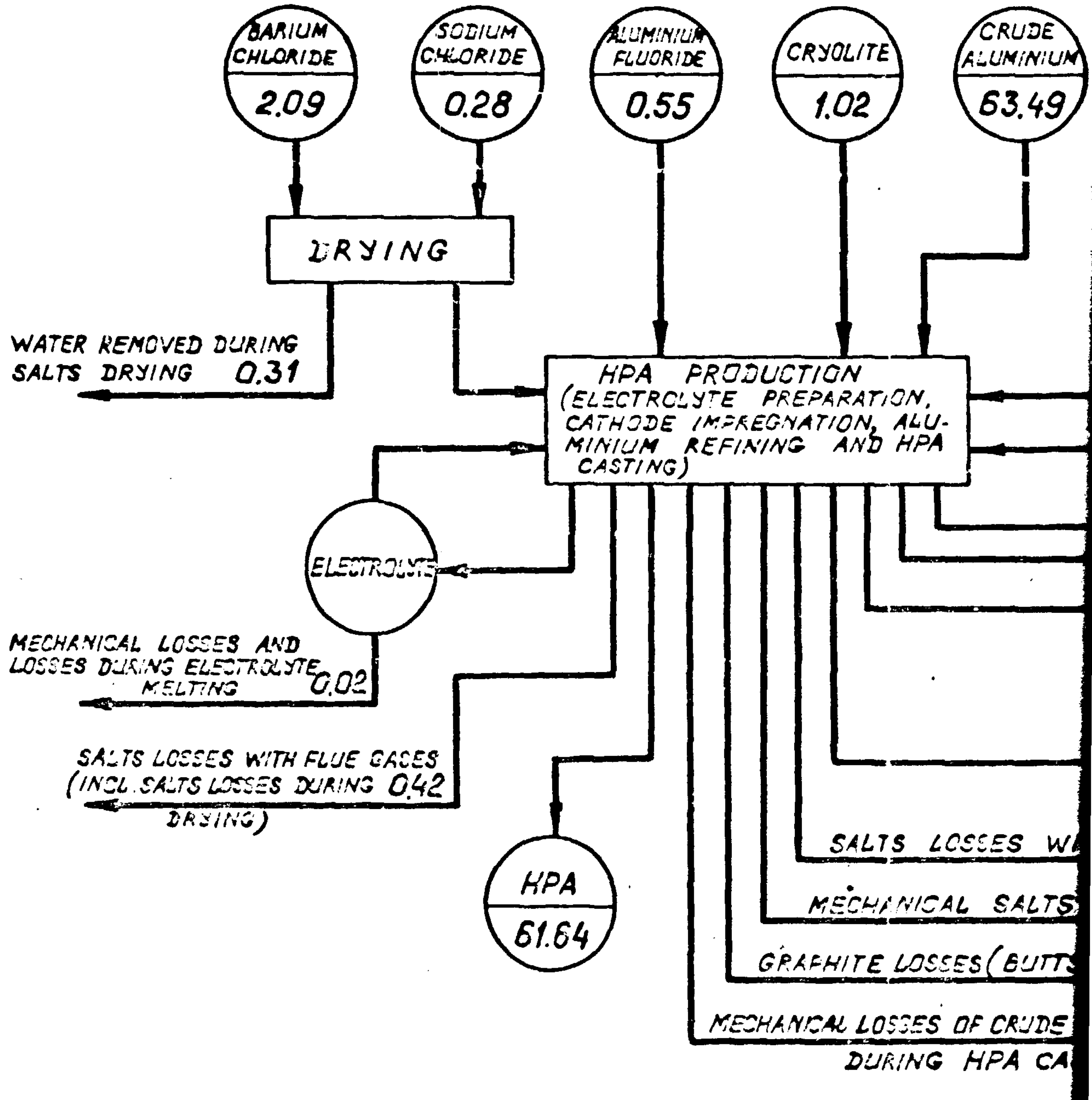
HIGH PO

SECTION 1



FLOWSHEET No 1

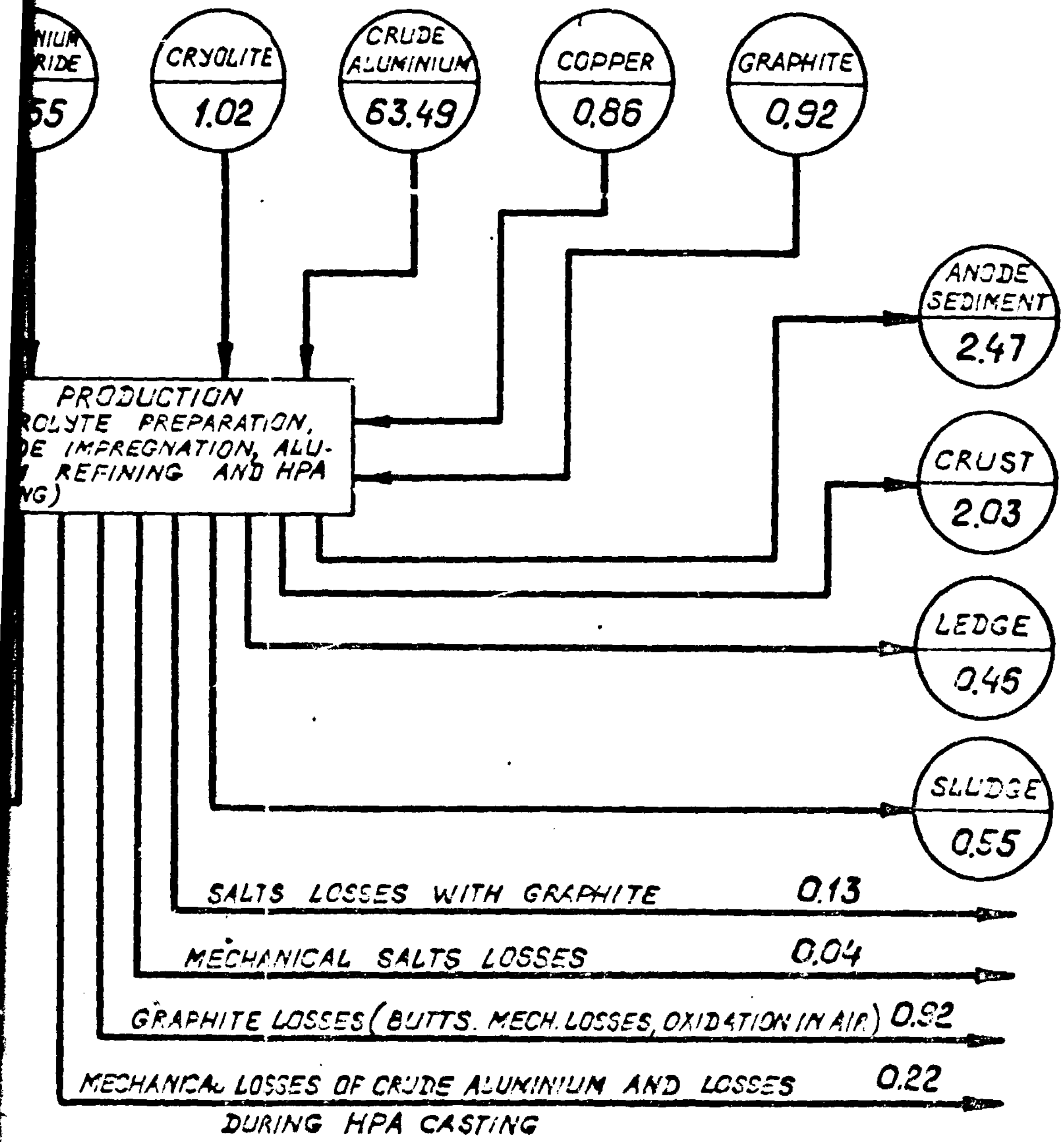
MATERIAL FLOWS PER ONE TONNE OF REFINED HIGH PURITY ALUMINIUM (IN KG).



FLOWSHEET

SECTION 1

HOURLY MATERIAL
UNIT OF 540 TP
CAPACITY (IN KG).



FLOWSHEET No 2

HOURLY MATERIAL FLOWS OF EXPERIMENTAL DEMONSTRATION UNIT OF 540 TPY HIGH PURITY ALUMINIUM PRODUCTION CAPACITY (IN KG).

6.2. Process description

6.2.1. Methods for HPA production

One of the commercial methods for high-purity aluminium production, in the present time, is an electrolytic method of commercial grade aluminium refining by three-stage method which is widely used in the USSR.

This method provides for HPA production of A 95 - A 995 grades. For high-purity aluminium production commercial-grade crude aluminium in liquid form is fed into HPA pots in which electrolytic refining process takes place.

Electrolytic refining process is performed with using of chloride-fluoride electrolite.

Together with three-stage method of HPA production other methods of this metal production have been developed and are under development (two-stage method, refining processes using water and organic solutions, electrolite of salts with low melting point, method of fracture crystallization, method of vacuum distillation and other). But all these methods of HPA production were not commercially used.

6.2.2. Selection of the technology. Major parameters of the process

For commercial production of high-purity aluminium there is only one method which can be recommended-tree-stage electrolytic method of commercial aluminium refining.

6.2.3. Major process parameters

6.2.3.1. HPA pots section

Cathode metal temperature		- 770+810 °C
Level of layers in the pot bath:		
cathode metal		- 15+22 cm
electrolyte		- 12+14 cm
anode alloy		- 33+40 cm
Electrolyte composition:	$BaCl_2$	- 57+58%
	NaF	- 16+17%
	NaCl	- ~4%
	AlF_3	- 21+22%
Content of elements in anode alloy:	Al	- 50-40 %
	Cu	- 33-40 %
Current density in electrolyte		- 0.6 A/cm^2

6.2.3.2. Salt drying and salt charge preparation section

Salt drying temperature	- 350÷400 °C
Moisture content in dried salts	- 0.2 %

6.2.4. Line process diagram of high-purity aluminium production (drawing No 1360970 TM, sheet 1)

Melted crude aluminium (in ladles) is transported from operated potrooms to the section of HPA pots.

Crude aluminium is fed into pots with the help of pouring machine.

The following materials are added to crude aluminium:

- copper to correct anode alloy composition,
- solid crushed electrolyte to compensate losses.

High-purity aluminium produced in the pot is periodically removed by vacuum ladle and then cast into pigs and ingots.

Anode sediments and electrolyte crust are periodically removed from the pots.

Off-gases from the pot where periodically electrolyte is prepared and cathode impregnation is performed are cleaned.

Electrolyte preparation

Electrolyte is prepared from $BaCl_2 \cdot 2H_2O$, cryolite, AlF_3 and NaCl.

Barium cloride and sodium cloride are preliminary dryid in electric furnace.

The charge of above mentioned materials is fed in one of the pots for high-purity aluminium production. Charge melting, sedimentation of solid impurities and electro-chemical cleaning of electrolyte take place in this pot.

Cathodes are also impregnated in this pot.

Thus prepared electrolyte is poured into sealed boxes and solidifies.

Before charging into pots for HPA production the electrolyte is crushed.

Impregnated cathodes are used in HPA pots.

6.3. Equipment

6.3.1. Basis for calculation and selection of equipment

Major process equipment is selected on the basis of selected technology for high-purity aluminium production. The major process equipment for HPA production is the pot for aluminium refining.

At present time 25-70 KA pots are used in the USSR for high-purity aluminium production.

Brief characteristics of the pot are given in the table below.

SRL Nos	Characteristics	Units	Amperage, kA		
			28	60	70
1	Pot capacity	tonnes per year	76.5	164.0	191.0
2	Specific material consumption	tonnes per 1 t of HPA per year	0.45	0.35	0.32
3	Specific production of HPA from 1 m2 of pot surface	tonnes per year	6.7	7.7	8.25

For the given EDU 70 kA pot is adopted, which provides the most favourable technical and economical indexes.

It should also be mentioned that this pot is the most powerful pot used in the world at present time.

Calculations of the equipment are made on the following basis:

- production capacity - 540 tonnes of high-purity aluminium per year;
- continuous mode of operation - 365 days per year (8760 hours)
- existing equipment at Korba aluminium smelter should provide for continuous mode of operation:
  - silicon rectifier substation,
  - cast house (electric furnace for ingot homogenization and casting equipment) and gas cleaning devices.

The following considerations were also be taken into account for selection of the equipment:

- standart size of the equipment must correspond to modern world practice and high efficiency of capital investment;
- the design of the equipment should fully provide for maximum reliability, convinience and simplicity of operation and maintenance of the equipment.

6.3.2. Pots section (drawing No 1360970 TM, sheets 2 and 3)

Pot section is designed for high-purity aluminium production.

Selection of the section location is made taking into account the following:

- transportation of liquid crude aluminium;
- minimum distance from DC power supply source (silicon rectifier substation - SRSS);
- posibility of using auxiliary equipment installed in the existing potroom for high-purity aluminium production.

Two variants for pots section arrangement at Korba smelter have been considered in the Feasibility Study:

I variant - arrangement of high-purity aluminium production pots at the end of potroom No 75 near SRSS. Three existing aluminium pots should be dismantled.

II variant- prolongation of potroom No 75 (at SRSS side) to arrange high-purity aluminium production pots.

Number of pots for high-purity aluminium production does not depend on the mentioned variants and is 3 (with amperage of 70 KA).

6.3.3. Calculation of high-purity aluminium production pots capacity

The following mode of operation for the three pots of the EDU is adopted:

- two pots will constantly operate at the mode of refining;
- the third pot will operate at two modes: at the mode of electrolyte preparation and cathode impregnation (periodically, once in two months during 3.5 days) and at refining mode (the rest time).

Production capacity of EDU pot section is determined by the equation:

$$Q = \left[q\,(n_{inst.} - 1) \times 365 + q\left(365 - \frac{13 \times n_{inst} \times 3.5 \times 12}{6 \times 13} - 0.5 \times \frac{13 \times n_{inst} \times 12}{6 \times 13}\right) - q\,\frac{n_{inst.} \times 25}{4.3} \right] \times 10^{-3},$$

where:

q - daily capacity of one pot, kg/day;
$n_{inst.}$ - number of installed pots;
13 - number of installed cathodes on one pot;
3.5 - time of cathode impregnation in the pot, days;
2.0 - stock of impregnated cathodes, months;
6.0 - cathode service life, months;
0.5 - duration of pot operation mode chending from electrolyte preparation and cathode impregnation to aluminium refining, days;
25 - duration of pot capital repair works including burning and start-up, days;
4.3 - average service life of pots, years.

The above equation can be transferred as follows:

$$Q = 351.2 \times n_{inst.} \times q \times 10^{-3}$$

Daily capacity of a pot will be:

$$q = 70000 \times 0.335 \times 0.93 \times 24 \times 10^{-3} = 523.4 \text{ kg/day}$$

where:

70000 - amperage, A
0.335 - electrochemical equivalent of aluminium, gr/A.h
93 - current efficiency, %
24 - number of hours in a day

So, $Q = 351.2 \times 3 \times 523.4 \times 10^{-3} = 551.45$ tonnes of crude HPA/y

Normal production capacity of the pot section will be:

$Q_N = Q \times K = 551.45 \times 0.98 = 540$ tonnes of commercial HPA per year

K - is a coefficient which takes into account some deviation of the process and losses of HPA during casting.

For servicing and reparing of the installed pots bridge cranes, vacuum networks and compressed air networks existing in potroom No 75 are used.

The existing 3 t ladles are used for transportation of crude aluminium to the pots.

Pouring machine is provided for pouring of crude aluminium into the pots.

High-purity aluminium is removed from pots by 3 t vacuum ladle.

Lining and preheating of EDU ladles are assumed to be made in ladle repair shop and manufacturing of cathodes and bottom blocks - in the auxiliary shops block of the aluminium smelter.

6.3.4. Salt drying and salt charge preparation section

Salt drying and salt charge preparation section is designed for:

- drying of $BaCl_2 \cdot 2H_2O$ and NaCl
- salt charge preparation
- short-time storing of salts.

For location of this section area of cast house is used in axes 80-84 of the span C-D at axis C. The required area is about 200-300 m^2 (see drawing CDO-KB-M10-431).

$BaCl_2 \cdot 2\,H_2O$ and NaCl are dried in electric furnace at 300-400 ^oC. Moisture content in dried salts is not more than 0.2 %.

Operating "Westerwerk" electric furnace is used for salt drying. The furnace is installed in ingot homogenization section of cash house in axes 78-77 (drawing CDC/KB/M10-431).

Characteristics of the furnace:

Installed power rating	- 1513.5 +10 % kW
Power of heating elements	- 1300 + 10 % kW
Maximum temperature	- 620 ^oC
Operating temperature	- 520 ^oC
Power supply	- 380 V
Number of phases	- 3
Frequency	- 50 hZ
Furnace dimensions	- 6.94 x 2.4 x 7.0 m

Temperature of the furnace will be controlled by instruments.

After drying $BaCl_2$, NaCl, cryolite and AlF_3 are metered and mixed in the mixer. Received charge is transported to HPA pots in special buckets.

Operation schedule of salt drying and salt charge preparation section depends on operation schedule of one of the three pots in the mode of electrolyte preparation and cathode impregnation.

SRL NOS	Description	Units	Value
1	Time of operation	days	1-2
2	Amount of salt to be dried:		
	$BaCl_2 \cdot 2H_2O$	tonnes	~3.0
	NaCl	-"-	~0.5
3	Amount of salt charge	tonnes	~5.3
4	Stock of all salts	months tonnes	2 ~5.8
5	Period of operation	-	once in 2 months

Taking into account salt hydroscopicity time for salt preparation should not exceed 2 days.

It is feasible partly to cooperate operation of salt drying section with pot operation in the mode of electrolyte preparation.

6.3.5. HPA casting section

HPA casting section is designed for casting of this metal into pigs and ingots.

The section is located in the existing cast house of the smelter.

HPA is transported to the section in 3 t vacuum ladle by existing vehicles once in two days. Amount of metal is about 3 tonnes.

To produce small pigs (~15 kg) a casting conveyor is used. The conveyor is installed in axes 87-91. Casting is performed from vacuum ladle with the help of existing bridge crane and special trough with a stand.

Flat ingots are also cast from vacuum ladle using the existing bridge crane on one of the casting machines in axes 60-69.

Ingot casting is performed according to the technology adopted for flat ingots casting on the given equipment.

6.3.6. Gas cleaning

The major harmful effluent from EDU are gaseous HF, dust of fluorides, HCl and dust which generally contains $BaCl_2$. Sources of these harmful matters are the pots. One of the three pots (the pot for electrolyte preparation and cathode impregnation) is equipped with gas suction.

When this pot operates in the mode of electrolyte preparation the amount of harmful effluents is increased.

Characteristics of effluents from EDU pots are given in the table below.

SRL Nos	Description of harmful matters	Units	Total amount
1	Refining pots - 2 pcs		
1.1	Gaseous HF	kg/hour	0.122
1.2	Dust of fluorides, as solid HF	- " -	0.034
2	Pot for electrolyte preparation and cathode impregnation - 1 pc x)		
2.1	Gaseous HF	- " -	0.8
2.2	Dust of fluorides, as solid HF	- " -	0.65
2.3	HCl	- " -	2.05
2.4	Dust ($BaCl_2$)	- " -	3.0

x) Period of pot operation with gas suction is 3.5 days once in two months.

Volume of gas suction of the pot for electrolyte preparation and cathode impregnation amounts to:

- 8000 m^3/h with closed shutters,
- 22000 m^3/h with open shutters (taking into account the volume of air which goes through untightness of gas suction system.

Quantity of harmful matters removed by gas suction and sent to gas cleaning of the second line amounts to:

HF_{gas}	- 0.[illegible]
HF_{solid}	- 0.5[illegible] -
HCl	- 1.75 -"-
Dust ($BaCl_2$)	- 2.[illegible]5 -"-

6.3.7. Brief description of major process equipment

Major process equipment of EDU on the pots section:

- refining pot - 2 pcs,
- pot for electrolyte preparation and cathode impregnation - 1 pc,
- pouring machine - 2 pcs,
- vacuum ladle - 3 pcs.

Refining pot (drawing No 1335338 EC)

The pot consists of anode and cathode units.

Anode unit is a welded steel case lined with red clay, fire clay and magnesite bricks.

Inside layer of the bottom is made of carbon material with inserted steel rod for power supply. In one of the end walls there is a charging pocket.

Cathode unit of the pot consists of cathodes, supporting steel structure, cathode aluminium busbars and cathode moving device.

Cathodes consist of cylinder graphite electrodes with embeded stubs and aluminium rods. Aluminium rod is connected with stub by special weld.

To meet the necessary requirements for electric contact provision is made for installation of eccentric clamps between aluminium cathode rods and cathode bus arrangement.

Working area of the pot is covered with aluminium covers and suspended roof.

Unlike the refining pot the pot for electrolyte preparation and cathode impregnation has more deep shaft and equipped by hood with gas suction.

The hood is of shutter type. End walls, part of side walls and upper part of cathode unit are protected by steel sheets.

Round-type shutters are equipped with electric drive and located on the sides of the pot. Gas suction of the pot is of upper-type.

For pouring of crude aluminium all the pots have charging pockets.

Technical characteristics of refining pot.

SRL NOS	Description		Units	Value
1	Amperage		kA	70.0
2	Current density		A/cm^2	0.6
3	Current efficiency		%	93.0
4	Pot production capacity		kg/day	523.4
5	DC power consumption		kw.h/t	17000
6	Number of cathodes		pcs	13
7	Shaft depth		mm	700
8	Shaft width		-"-	2450
9	Shaft length		-"-	4760
10	Pot outer dimensions:	width	-"-	3590
		length	-"-	6420
		height (of case)	-"-	2120
11	Pot service life ж)		years	5.0

ж) service life of the pot for electrolyte preparation and cathode impregnation - 3 years.

Pouring machine

Pouring machine is designed for pouring of crude aluminium into pot.

Pouring machine is a welded steel car with a ladle installed on it. This machine is equipped with oil hydraulic drive for turning of ladle. Crude aluminium is poured into pot through the ladle spout, chute and charging pocket of the pot.

Speed of crude aluminium pouring is controlled with the help of hydraulic drive of the ladle. The ladle is made of steel and lined with fire clay brick. Ladle capacity is 800-1200 kg.

Vacuum ladle

Vacuum ladle is designed for crude aluminium removal from the pots.

Vacuum ladle consists of welded steel case lined with fire clay brick, removable steel cover, intake pipe and graphite inlet.

For transportation of vacuum ladle with the help of bridge crane and for metal discharge a beam with ladle turning drive is provided for.

Capacity of vacuum ladle is 3 tonnes.

6.3.8. HPA quality control

Physical and chemical analysis to control the quality of raw materials, materials, HPA and composition of the EDU production wastes should be carried out by means and methods of the existing chemical and analytical services of the Smelter (shop and central laboratories).

6.4. Power supply

6.4.1. Existing power supply circuit

The energy for the plant is supplied from Thermal Power Plants using local coal extracted by open pit method and imported coal. The total rated capacity of public sector Power Plants in operation in the vicinity of Korba amounts 1340 MW.

The construction of new 270 MW Captive Power Plant was initiated in 1985, the first 67.5 MW unit due for commissioning in 1987.

Presently the plants maximum power demand is fixed at 225 MW the rated potroom power consumption being 184 MW (two sections 92 MW each).

The plant is supplied by power through two 220 kV feeders. The plent's substation has four transformers 220/33 KV 120 MVA each. By means of 220 KV outdoor switch-gear any one of transformers can be connected to feeders.

The 220 KV & 33 KV distribution is made by a double bus system to ensure reliable power supply to Rectiformer Stations.

Each Potline consisting of 204 pots is supplied with power through Silicon Rectifier Substation consisting of six rectifiers each rated at 22 KA 950 V, 22,9 MW. At least 5 of six are in operation feeding 100 KA at 950 V. Each group of rectifiers is provided with individual energy counter on AC side & amper hours & voltage hours controller on DC side.

6.4.2. DC Electrical power supply of HPA pots (for variants I & II)

The DC power supply is made from operating Silicon Rectifier Station located in the vicinity of potrooms 75 & 76 (second potline). The SRS contains 6 rectifiers of Indian company BHEL.

Specifications of the rectifier unit (annex 8):

- type OFB
- rated rectified current of one unit - 22 KA
- rated voltage - 950 V.

Presently each rectifier unit gives 20 KA current.

The following electric power supply circuit diagram for feeding potline N 2 producing HPA. Four rectifier units are feeding the EDU pots and operating pots of the second potline with the 70 KA current.

Two rectifier units are feeding the operating pots of the second potline with 30 KA make up current.

Arrangement of the EDU pots according to variant I requires:

- an additional minus busbar at SRS with two rectifier units
- an additional make up busbar between SRS and potroom N 75

Arrangement of the EDU according to variant II requires:

- an additional negative busbar with two rectifier units to be connected to existing negative external busbar; the existing negative busbar is switched off external busbar,
- an additional negative busbar between SRS and an extended part of the potroom N 75 and its connecting to existing negative SRS busbar.

Works related to the installation of busbar of HPA cells section, external busbar and modification of SRS busbars should be carried out without long shut-down of cell-line. This can be reached by utilisation of temporary by-pass and shunt busducts.

This method of new busbar installation and modification of existing busbar will require several short-term disconnection of the cell-line. The duration of each cell-line disconnection is 1 to 2 hours maximum.

Admissible DC amperage variation at the EDU is ± 5 % (average per hour).

The duration of an emergency power cut-off is not more that 2 hours.

Busbar diagrams and routes of busbars are indicated on the drawing 1247836-ЭС (variant I) and 1247837-ЭС (variant II).

Presently there is no vacant voltage at SRS in operation at the second potline.

Therefore four existing pots must be switched off to operate this EDU.

The calculation of the number of pots to be switched off is indicated in Annex 2.

6.4.3. Power equipment
(power supply of electrical equipment of EDU with AC)

<u>Variant I</u>

For control of cell drives for production of high purity aluminium control cabinets of dismantled cells of potroom N 75 with partial substitution of equipment in the cells. Additional equipment is given in the specification. For control of blinds drive for preparation of electrolyte and cathode impregnation a box for control of asynchronic reversive short-circuit motors type ШУ 5400 is used. Control boxes and cabinets for control of cells are fed from existing lines (voltage ~ 220 V) with insulated neutral.

For connecting of pouring machine to the line plug connector type A700/A701 is installed on cell control cabinet (CCC) and flexible cable type КРПТ I ($3x4\ mm^2$) is ordered. Circuits from CCC cabinets and box for blinds control to electric reciever at the cell are made of heat resistant copper wire type ПАЛ I30 ($1x1\ mm^2$). Running of wires along the cell is carried out in thin-walled steel pipes with protection of lead-in places to lead-in boxes of electric motors by flexible inlets made of metal flexible tube. For decreasing of number of wires coming to the cells clamp boxes type У 614 are installed on the cells.

Wiring from CCC cabinents and box to clamp boxes on the cell is rope suspended with necessary asbestos cloth protection of wires from radiation of spilled metal. Protection should be made in several layers. Rope should be insulated from earth potential.

Variant II.

In order to provide for the control of cells drives for production of high-purity aluminium cabinent for cells control (CCC) are foreseen which are installed at the elevation of cells service in the aperture between the columns on the insulators.

For control of blinds drive of one cell a box for control of asynchronic reversive short-circuit motors type ШУ 5400 is installed. For feeding of the CCC cabinets and the box it is necessary to prolong the existing line (220 V AC) with insulated neutral. For this additional sections of closed distribution busbar of 220 V AC type ШРА-73 for current 250 A are foreseen. For connection of pouring machine to electric circuit plug connector type A 700/A 701 is installed on the middle CCC cabinet and flexible cable КРПТI ($3 \times 4\ mm^2$) is foreseen. Circuits from CCC cabinet and box for blinds control to electric recievers on the cell are made of heat-resistant copper wire type ПАЛ-130 ($1 \times 1\ mm^2$).

Running of wires along the cell is carried out in steel thin walled pipes with protection of lead-in places to lead-in boxes by flexible inlets made of flexible tube.

For decreasing of number of wires coming to the cells clamp boxes type У 614 are installed on the cells.

Wiring from CCC cabinets and box to clamp boxes on the cell is rope suspended with necessary asbestos cloth protection of wires from radiation of spilled metal. Protection should be made in several layers. Rope should be insulated from earth potential.

For feeding of bridge cranes in wide part of potroom it is necessary to prolong trolley up to the end of crane jibs. For trolley steel angle with cross section 75 x 75 x 6 and trolley cantilevers should be foreseen. Period of emergency switch-off of AC power - not more than 8 hours.

6.4.4. Electrical lighting

Variant I

No additional lighting needed

Variant II

Calculated illumination of the pot site in extended part of the potroom is 200 lux, of zero level - 50 lux.

Lamps will be of gas-discharge tube type ДРЛ-700 and НСП II-20.

Lamps will be serviced from step-ladder and from bridge crane.

Lighting voltage will be 415/240 V (lamps 240 V).

Ordinary and emergency lighting system is fed from existing circuits.

Main lighting is controlled from the cabinet situated in the connecting corridor.

Lighting panels will be of type ЩС 5100 with automatic switches and magnetic starter for distant control of upper and lower platforms lighting.

Feeding and group circuits are made of cables type АВВГ, laid together with power cables across trusses, along trusses and along the walls fixed with supporting hooks.

6.5. Main infrastructure concepts

6.5.1. Due to small requirements the provision of the EDU with water supply and draining facilities, compressed air and air supplied at negative pressure as well as with transport and repair services to be from the corresponding networks and departments of the smelter.

6.6. Buildings and structure

6.6.1. Data for design of the buildings and structures

The following served as a basis for designing the buildings and structures:

- the technology adopted for production of high-purity alumirium at the existing electrolysis facilities;
- the process equipment selected for production of high-purity aluminium;
- the local climatic conditions and conditions of supplying the proposed unit with utilities;
- the configuration and size of the operating electrolysis facilities.

6.6.2. List of buildings and structures

According to the technology selected for production of high-purity aluminium the following sections to be organized in the operating electrolysis shop:

- a section for three HPA cells in the western end of the potroom No 75;
- a section of salt drying and salt feed preparation in the casting shop;
- a section of casting HPA ingots in the casting shop.

Design studies on layout of the equipment have shown the following:

- location of the salt drying and salt feed preparation sections as well as the HPA ingots casting section in the casting shop will not require its reconstruction;
- location of the HPA cells in the potroom No.75 will necessitate its reconstruction with volumes of work dependent on a cells arrangements considered in this Study in two variants:

Variant I

The three HPA cells to be located between the axes 5-9, in the western end of the potroom instead of three primary aluminium cells to be dismantled.

It this variant the R.C. cell supports to be rebuilt as well as the floor at el. 3.00 (partially). A new section of supports of the busbar conductor system to be built from the SRS to the potroom.

Variant II

The three HPA cells to be located in a section of the potroom to be extended. A layout of facilities in this area permits extending the potroom building by 26 m (max).

An extension of the existing building with a span of 18 m by an amount specified will require a removal of the existing end wall along axis I with removal of steel framed columns and dismantling the R.S. foundations for hese columns. A new section of supports of the busbar conductor system to be built from the SRS to the potroom.

Main buildings parameters

		Built up area, m^2		Usable area, m^2		Building volume, m^3	
		Variant I	Variant II	Variant I	Variant II	Variant I	Variant II
1	Section of HPA cells in the potroom No 75	-	516	-	722	-	10720

Architectural and civil concepts and structures design

The architectural and civil concepts and structures design for both variants of reconstruction of the potroom No 75 for construction of new sections of the busbar conductor system are assumed similar to those realized in the operating potroom No 75 and in the existing supports of the busbar conductor system.

The following building elements are assumed for reconstruction of the potroom No 75:

- foundations of the building columns and supports of the cells - of monolithic reinforced concrete;
- floor at el. 3.0 m - of monolithic reinforced concrete;
- columns of the building, framework, roof trusses, stairs - of steel;
- walls and roof covering - of A.C. sheets.

Elements of the busbar conductor system:

- foundations - of monolithic reinforced concrete;
- columns - of precast reinforced concrete.

6.7. Cost estimate

An estimated construction cost of the EDU (Variant II) was calculated according to the initial data compiled by a team of VAMI experts in cooperation with BALCO promoting the project.

A prices level is taken as at the end of 1985.

6.7.1. Cost of technology

A "know-how" cost is determined by the Supplier. Including the tax (48%) the total capital cost connected with purchasing the technology is Rs. 296 thous.

6.7.2. Cost of equipment

The process equipment is assumed according to the specifications.

In the capital cost calculations an equipment and materials cost is taken as follows:

- for the equipment and materials to be supplied by the Indian organizations - from the data by BALCO according to the initial data;

- for the equipment and materials to be supplied from the USSR (a pneumatic machine for mixing an anode alloy and the bimetal plates) according to the data of V/O "Tsvetmetpromexport";

- for the equipment and materials not included into a list of initial data to UNIDO contract N 85/2 (some kinds of electrical equipment) according to the initial data for preparing a feasibility study of modification of the calcination kilns for a gallium and special alumina production (1983) to be carried out at the same Korba facility. Conversion from the 1983 prices to those as at the end of 1985 is done with the use of an escalation factor on a 10 % annual price increase basis (K = 1.21).

An initial stock of spare parts is taken to be 4 % of the equipment cost.

For a summary of the equipment capital costs see Schedule 6-1.

The production costs connected with repair of the equipment are taken as a percentage of the equipment cost and are included into the general shop overhead costs (chapter 7).

6.7.3. Cost of erection works

The erection works take into account a cost of works on erection of the equipment, steel elements and cell linings, internal and external buswork, electric lighting system of a building which houses the EDU.

An erection works cost is determined on the Basis of an overall volume of works for erection of the equipment, process stell sections, lining, for running the cable networks and busbar conductors and estimated from parameters for determining an equipment erection cost given in the initial data.

6.7.4. Cost of buildings and structures

The civil works on constructing the buildings and structures take into account the following:

- site preparation and development;
- relocation of the engineering networks and distribution lines, including a steam pipeline;
- general civil works connected with an extension of No 75 potroom to accomodate the EDU.

A civil cost estimate is determined on the basis of an overall volume of works with the use of unit rates according to the initial data.

A summary cost estimate for constructing the buildings and structures is given in Schedule 6-2.

Annual maintenance costs are taken as a percentage of the civil works cost and are included into the general shop overhead costs (chapter 7).

Schedule 6-1

Estimate of investment costs

Equipment

Project: EDU

Item	Qty	Unit	Cost category	Unit cost, Rs.	Costs, 000 Rs.		
					foreign	local	total
1	2	3	4	5	6	7	8
1			<u>Production equipment</u>				
1.1	2	pcs	70 kA aluminium refining cell	112333*) / 442859	224.7	885.7	1110.4
1.2	1	pc	70 kA electrolyte preparation cell	112333* / 510412	112.3	510.4	622.7
1.3			<u>Process equipment</u>				
1.3.1	2	pcs	Aluminium pouring machine	119890	-	239.8	239.8
1.3.2	0.027	t	Pneumatic machine for mixing of anode alloy	97080	2.6	-	2.6
1.3.3	0.039	t	Pneumatic hammer	12000	-	0.5	0.5
1.3.4	2	pcs	Portable potentiometer with thermocouple	3500	-	7.0	7.0
1.3.5	2	pcs	DC millivoltmeter	1500	-	3.0	3.0
1.3.6	3	pcs	Vacuum ladle for aluminium	70 000	-	210.0	210.0
1.3.7	40	r.m	Rubber-canvas hose	50	-	2.0	2.0
1.3.8	2.1	t	Welded steel container for electrolyte	10 000	-	21.0	21.0
1.3.9	2.3	t	Welded steel container for dry salts	10 000	-	23.0	23.0
1.3.10	0.575	t	Process tools	12 000	-	6.9	6.9
1.3.11	16.8	t	Covering plates for busbar channels (including insulation of ACEID-0.3 t, and edged boards - 0.15 m^3	10048	-	168.8	168.8
1.3.12	4	%	Spare parts	329769	-	13.2	13.2
			Total of item 1.3		2.6	695.2	697.8

1	2	3	4	5	6	7	8
1.4			<u>Electrical equipment</u>				
1.4.1	10721	m^3	Electric lighting system	19.72	-	211.4	211.4
1.4.2	-	-	Electrical equipment	-	-	77.7	77.7
1.4.3	-	-	DC and AC measuring system	-	1000.0	-	1000.0
			Total of item 1.4		1000.0	289.1	1289.1
1.5			<u>Anode buswork</u>				
1.5.1	35.62	t	Aluminium busbars	35000	-	1246.7	1246.7
1.5.2	2.4	t	Aluminium strip	33100	-	79.4	79.4
1.5.3	0.43	t	Aluminium pad	25000	-	10.8	10.8
1.5.4	57	kg	Asbestos sheet mill-board	50	-	2.8	2.8
1.5.5	0.68	t	Asbestos cement plate	10000	-	6.8	6.8
1.5.6	0.34	t	Steel ВСт 3 кП 3	10000	-	3.4	3.4
			Total of item 1.5			1349.9	1349.9
1.6			D.C. buswork				
1.6.1	20.19	t	Aluminium busbar	35000	-	706.7	706.7
1.6.2	0.5	t	Welding wire	30000	-	15.0	15.0
1.6.3	0.5	t	Welded structural steel	10000	-	5.0	5.0
			Total of item 1.6			726.7	726.7
			Total of 1		1339.6	4457	5796.6
2			<u>Overheads for imported equipment and materials</u>				
2.1	1.5	%	Port charges and levies	1339.6	-	20.1	20.1
2.2	1.0	%	Bank charges	1339.6	-	13.4	13.4
2.3	50	%	Custom duty	1339.6	-	669.8	
2.4	3	%	Transportation to plant site	1339.6	-	40.2	40.2
			Total of item 2:			743.5	743.5

1	2	3	4	5	6	7	8
3			Installation				
3.1	10	%	Process structures and structural steel	2110470	-	211.0	211.0
3.2	20	%	Electrical equipment	3663545	-	732.7	732.7
			Total of item 3:	5774015		943.7	943.7
			Grand total		1339.6	6144.2	7483.8

* Cost of imported bimetallic plates and carbon blocks.

Schedule 6-2

Estimate of investment costs

Civil works

Project: EDU

Item	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. 000 foreign	local	total
1	2	3	4	5	6	7	8
1			SITE PREPARATION				
1.1	100	r.m.	Replacement of steam pipeline	150	-	15	15
1.2	-	-	Relocation of service lines and distribution lines	-	-	25	25
1.3	50	100 m^2	Site levelling	120	-	6	6
			Total of item 1			46	46
2			BUILDING AND STRUCTURES				
2.1	10721	m^3	Building for EDU (extension of potroom No 75)	270	-	2894.7	2894.7
2.2	-	-	Disassembly of end wall of existing potroom No 75	-	-	10	10
2.3	7.0	t	Installation of steel sheet piling (structural steel)	9000	-	63	63
			Total of item 2			2967.7	2967.7
3			OUTDOOR STRUCTURES				
3.1	560	m^2	Motor accessway to potroom No 75	192	-	107.5	107.5
3.2	4.0	100 m^2	Demolition of asphalt-concrete pavement	329	-	1.3	1.3
			Total of item 3			108.8	108.8
			GRAND TOTAL			3122.5	3122.5

7. ORGANIZATION OF EDU, OVERHEAD AND OTHER COSTS

7.1. Organization of EDU

Calculations for Feasibility Study are made taking into account EDU arrangement in potroom No 75 at existing Korba smelter. For this purpose potroom No75 is to be prolonged.

It is assummed that EDU is organized within the aluminium smelter. Manpower provision, routine and capital repair implementation, building and structures maintenance, outer transportation, watersupply, material storages provision and other problem connected with EDU are solved within the frame of aluminium smelter.

The major process section of EDU is the section consisting of three 70 KA electrolytic cells for high-purity aluminium production.

7.2. Overhead operating costs

7.2.1. Overhead operating costs include:

- expenses on buildings and structures maintenance at 0,5% of their cost;
- expenses on routine repair of equipment at 2.5 % of its cost (at the construction site);
- charges on capital repair of the cells at 17.5 % of their construction costs according to the depreciation charges on capital repair valid in the USSR;
- inderect overhead costs (drinking water, air conditioning, ventilation, lighting etc) are estimated on the basis of actual existing overheads at Korba smelter at 5 % of estimated overhead costs.

To provide stable power supply and taking into account existing power consumption balance, start-up of EDU can cause cut-off of four operating pots for primary aluminium production in the potroom No 75. But the resulting expenses will not be included into additional charges, because temporary losses of metal are very low (about 1% of designed capacity before the additional voltage should be available).

Estimation of overhead operating costs is given in Table [illegible]1.

7.2.2. Capital amortisation

Capital amortisation is included into production cost, by equal installment during the total operational period at average rate of 8.5 %.

Average amortisation rate is determined on the basis of the following rates as per initial data:

- for equipment - 10 %
- for building and structures - 3.5 %

Preliminary expenses are included into production costs for the given equipment at 10 % of its cost (according to UNIDO recommendations).

In calculations of amortisation interest during construction is added to the fixed capital.

Working capital is not depreciated but is taken into account in salvage value at the end of estimated operational period.

7.3. Income tax

Taking into account that the EDU for high purity aluminium production is to be set-up under the UNIDO and UNDP assistance and it is not a commercial unit, the income tax on finished product is not included for the financial elaluation of the EDU.

Schedule 7-1

Production costs estimate

Overhead operating costs

Object: EDU. Name: high purity aluminium

Nos.	Q-ty	Unit	Name of expenses	Cost, Rs thous.		Expenses, Rs thous		
1	2.5	% of eqpt cost	Routine repair of the equipment	1340	5200	33	130	163
2	[illegible].5	% of building and structures cost	Maintenance	-	3077	--	15	15
3	17.5	% of pot cost	Charges for capital repair of the pots	337	1583	59	277	336
			Sub-total			92	422	514
4	5	% of estimated expenses	Indirect overhead costs	92	422	5	21	26
			Total			97	443	540

8. MANPOWER

8.1. Manning table and organizational management layout

As the EDU is to be located at the existing smetler being a part of it, the costs for administration staff are not required.

To control the EDU operation one engineer is required during the working day. In addition, one supervisor per shift i.e. a total of 4 supervisors will be required, including 1 relief supervisor.

8.2. Availability and requirement of labour

The three shift continuous operation of the EDU is envisaged. Ten smelter workers are required. The maintenance works to be carried out by the existing maintenance personnel of the operating smelter.

8.3. Cost estimate

Labout costs (wages and salaries of personnel) are estimated on the basis of actual data from the smelter on the average monthly wages and salaries by categories of personnel taking into account fringe benefits and bonus.

For an estimate see Schedule 8-1

Schedule 8-1

Estimate of production costs

Wages and salaries

Project; EDU Product: high-purity aluminium

Item	Categories of personnel	Quantity	Average monthly wages & salaries Rs.	Annual wages & salaries Rs.	Costs, Rs. thous
1	Skilled workers	10	2,100	25,200	252
2	Supervisors	4	2,600	31,200	125
3	Management	1	2,600	31,200	31
	Total	15	-	-	408

9. PROJECT IMPLEMENTATION

9.1. Programme and schedule of the EDU implementation

The following project implementation stages are assumed for evaluating the EDU project:

- prior to construction a basic engineering (process) and assignment specifications to be prepared along with detailed civil drawing;
- construction of the EDU for 15 months prior to the start-up and commissioning;
- manufacture and erection of the equipment (9 months), 6 months after a start of construction;
- putting the EDU into operation on the third year after the basic engineering report has been prepared;

According to the above programme a project implementation schedule was developed (see the end of this chapter).

9.2. Estimate of project implementation costs

The project implementation costs being formed at the stage of a construction preparatory period, start-up and a build-up of production are determined of the basis of the "Initial Data".

The costs include the following:

- overheads (taxes, insurance)
- project management costs (management costs, control and coordination, Soviet experts costs, recruitment and training of staff and labour, design engineering).

In addition, the estimate includes start-up and commisioning operations costs determined according to Supplier's calculations.

Contingencies are calculated for all kinds of costs but the know-how cost, costs of the start-up and commissioning operations and of the design engineering to be carried out by the Supplier's organizations.

In the calculations the preparation stage costs to be written-off for a construction period.

For the project implementation costs see Schedule 9-1.

Schedule 9-1

Estimate of investment costs

Project implementation

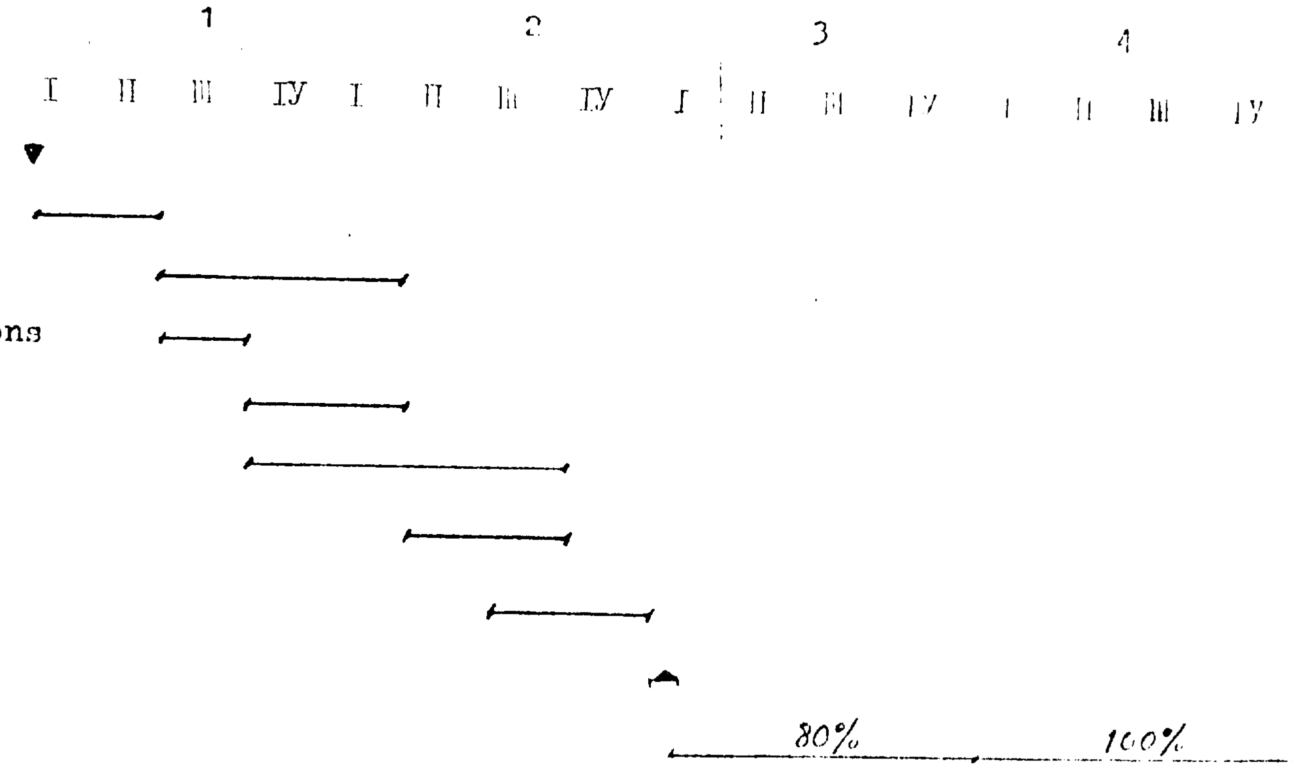
Project: EDU

Item	Qty	Unit	Cost category	Unit cost, Rs.000	Costs, Rs. 000 foreign	Local	Total
1	2	3	4	5	6	7	8
1			OVERHEAD COSTS				
1.1	1.8	%	Insurance of construction units and equipment	9862.8	-	177.5	177.5
1.2	4.8	%	Tax on turn-over of construction company	9862.8	-	473.4	473.4
			Total of item 1			650.9	650.9
2			MANAGEMENT FOR PROJECT IMPLEMENTATION				
2.1	1.8	%	Control, coordination	9862.8	-	177.5	177.5
2.2	24.5	%	Costs of Soviet specialists dispatched for start-up and adjustment work and approval of garanteed performances		492.5	175.0	667.5
2.3	48	%	Income tax on services of Soviet experts	492.5	-	236.4	236.4
2.4	-	-	Design engineering and preparation of working drawings	-	500	852	1352
2.5	48	%	Tax on design engineering	500	-	240	240
2.6	0.4	%	Management costs	9862.8	-	39.5	39.5

1	2	3	4	5	6	7	8
2.7	2.5	man/year	Recruitment of managerial staff, staff training	1.2	-	3.0	3.0
			Total of item 2		992.5	1723.4	2715.9
			Total preliminary costs (items 1+2)		992.5	2374.3	3366.8
3			START-UP AND ADJUSTMENT	-	-	1634	1634
4			CONTINGENCIES				
4.1	12	%	Civil works	3122.8	-	374.7	374.7
4.2	12	%	Equipment (exept for imported equipment)	4457.0	-	534.8	534.8
4.3	12	%	Installation works	943.7	-	113.2	113.2
4.4	12	%	Other costs	2866.8	59.1	284.9	344.0
			Total of item 4	11390.3	59.1	1307.6	1366.7
			GRAND TOTAL	-	1051.6	5315.9	6367.5

EDU Construction Implementation Schedule

S.No	Implementation Stages
1	Contract award
2	Basic engineering
3	Working (detailed) drawings
4	Supply of assignment specifications
5	Tendering
6	Construction
7	Manufacture & supply of equipment
8	Erection of equipment
9	Start-up and commissioning
10	Production



10. FINANCIAL AND ECONOMIC EVALUATION

In the present chapter an analysis of the EDU project is presented. A full capacity of the unit is taken as a basis of calculations.

The analysis includes the following:

- a cash-flow calculation starting from the first year of construction of the EDU;
- a calculation of profits and losses by years of operation;
- a calculation of an internal rate of return on investment and on equity;
- a calculation of a total project profitability based on determination of a simple rate of return on the total investment;
- a pay-back period calculation;
- a sensitivity analysis.

An economic evaluation consists of a determination, in a generalized form, of requirements in the capital investments, working capital, production costs, volumes of financing.

The evaluation is based on a determined construction cost, an acquisition and erection of the equipment (chapter 6), preliminary costs on realizing the project and technology purchasing costs (chapter 9), materials and utilities inputs, overhead and extraproduction costs, manpower costs, calculated in the chapters 3,4,7,8 as well as the data on financing, depreciation, taxation.

10.1. Total Investment Costs

The total investment costs are determined by adding a fixed capital and a working capital thus making Rs. 22,670 thous, the fixed capital being Rs. 19,935 thous and the working capital - Rs.2,735 thous.

A summary of the total investment costs is given in Schedule 10-5, and their break-down by years - in Schedule 10-6.

10.1.1. Fixed assets

The fixed assets include the initial investments (Rs.10,607 thous) and the preliminary capital costs (Rs. 9,328 thous).

The total fixed assets include the following:

- site preparation and development	- Rs.46 thous
- building and structures	- Rs.3,077 thous
- technology (know-how incl.tax)	- Rs. 2,960 thous
- equipment, total	- Rs.6,540 thous
including, indigenous	- Rs.4,457 thous
supplied from the USSR	- Rs. 140 thous
third countries supply	- Rs.1,943 thous
- equipment erection	- Rs. 944 thous
- start-up costs	- Rs. 1,634 thous
- preliminary costs	- Rs. 3,367 thous
- contingencies	- Rs. 1,367 thous
Total	Rs.19,935

When detemining the equipment costs, the port, bank and transport charges for delivery of the imported equipment and materials to the site as well as the customs duties are included into the total equipment costs.

The main capital costs are given in Schedule 10-1, and their break-down by years - in Schedule 10-2 (in the end of this chapter).

10.1.2. Working capital

A net working capital is determined as the required current assets minus current liabilities.

The following is included into the working capital:

- costs of the reserves of raw materials and supplies;
- debts receivable (cost of the product shipped but not paid for)
- product and in-process inventory;
- product in store;
- cash-in-hand.

An inventory of the raw materials is assumed on the basis of the process calculations, their costs are determined on the basis of a yearly operating costs estimate (for the estimate see Schedule 10-3).

An inventory of the finished product is calculated on the basis of the operating costs minus costs of selling the product, for a 7-days production (similar to the earlier projects).

In accordance with the UNIDO guidelines the sales of finished product and acquisition of materials is assumed on a deferred payment basis. The accounts are assumed payable within 7 days (similar to the earlier projects).

At the same time the receivables are determined on the basis of the total operating costs, and the accounts payable (current liabilities) on the basis of the materials and utilities costs.

As far as a product and in-process inventory is concerned assumed on the basis of the process calculations covering the volumes of the product and in-process inventory and costs of the materials and utilities involved an estimated reserve is 36 days.

The cash-in-hand is determined in an amount covering a two weeks requirement in salaries and wages to be paid and the operating overheads to be covered.

For a calculation of the working capital requirements see Schedule 10-4.

10.2. Project financing

A long-term internal loan and an equity capital in the ratio 1 : 1 are taken as the sources of financing a construction of the EDU.

65 % of a total working capital requirement will be covered by a short-term bank loan. The remaining 35 % of the working capital to be financed as a margin money on the same conditions as the fixed assets.

In a general form the total investment costs are as follows:

- an equity capital	- Rs.10,446 thous
- a long-term internal loan	- Rs.10,446 "
- a short-term bank loan	- Rs. 1,778 "
Total	Rs.22,670

For calculations according to the sources of financing and break-down of the amounts by years see Schedules 10-7 and 10-8.

The amounts for financing the total investment costs are offered on the following conditions:

Item	Financing source	Conditions of crediting	
		Annual interest rate	Period and conditions of repayment the deb
1	Equity	-	-
2	Long-term internal loan	12.5	10 years starting the next year after putting the EDU into operation
3	Short-term bank loan for working capital	17.5	taken into account in a salvage value at the end of the design operation period of the EDU

10.3. Total production costs

The production costs are determined as the total annual costs for production of high-purity aluminium by years of operation on the basis of an estimate of the operating costs, annual depreciation and the interests paid for the use of the credits.

The production costs in an agregated form and their breakdown by years of operation are given in Schedule 10-9.

10.4. Period of operation

For analysing the cash inflow and outflow in the financial-economic evaluation is assumed to be 17 years as follows:

- construction period - 2 years
- period of operation - 15 years

At the end of the 17-th year a salvage value of the project is included into the working capital.

10.5. Financial evaluation

For a financial evaluation of the EDU project the following calculations have been carried out: a cash flow, profits and losses by years of operation on the basis of the capital and operating costs, sales revenues, conditions of financing.
A financial analysis was performed on a computer using the programs developed at VAMI. The calculation results in basic prices are given in the following Shedules:

- cash flow (Schedule 10-10)
- net income statement (Schedule 10-11)
- calculation of an internal rate of return (Schedule 10-12)

On the basis of the above calculations the following profitability parameters of the EDU project were determined:

- an internal rate of return on investment	- 15,3%
- an internal rate of return on equity	- 14,7%
- a pay-back period	- 5,5 years
- a break-even point	- 65,2%(352t)
- a minimum price of one tonne of high-purity aluminium ensuring a break-even operation	- Rs.44,000/t

When determining a pay-back period of the total capital costs an interest and a depreciation were added to a net income.

The pay-back period is shown on a graph, Fig.1, at the end of this chapter.

When determining a break-even point the annual financial charges and depreciation calculated, as an average, for an operational period, are added to the fixed costs.

For a break-even point see a graph, Fig.2, at the end of this chapter.

10.6. Sensitivity analysis

A sensitivity analysis studies an impact of variation of the capital and operating costs on profitability parameters of the project in case a construction is delayed by 1 to 2 years at following levels of HPA price: low - Rs.45000/t (variants SAB/LP, SA1/LP, SA2/LP); basic - Rs.47750/t (variant SAB/BP, SA1/BP, SA2/BP); high - Rs.50000/t(variants SAB/HP, SA1/HP, SA2/HP)

For calculating escalation factors an increase in the construction capital costs is assumed to be 10% per year,(excluding know-how and Supplier's design works), working capital and in the operating costs - 6 % per year on the basis of the data available on variation of construction and operating costs of the industrial projects in India.

Below in the Table a summary is given of the project profitability parameters obtained by calculation with variations of the parameters studied. The calculations have been performed on a computer with the use of the corresponding programs.

An interdependence of all the parameters studied and their effect on the project profitability parameters are shown on Fig.3 at the end of the chapter.

The influence of all the parameters studied on the project profitability indices are shown in Table below and on Fig.3 at the end of the chapter.

Parameters of sensitivity analysis and parameters of project profitability	Unit of measure	Price of high-purity aluminium, Rs/t		
		45,000 (low level)	47,750 (basic level)	50,000 (high level)
1. Variant SAB - Basic				
IRRI	%	8,1	15,3	20,5
IRRE	%	3,9	14,7	22,5
BEP	%(t)	87,6(473)	65,2(352)	53,9(291)
PBP	years	9,0	5,5	4,3
2. Variant SA1 - Delay of construction by 2 years				
IRRI	%	0,0	7,9	13,5
IRRE	%	0,0	3,7	12,0
BEP	%(t)	0,0	88,2(476)	69,1(373)
PBP	years	21	8,0	6,2
3. Variant SA2 - Delay of construction by 3 years				
IRRI	%	0,0	0,0	6,0
IRRE	%	0,0	0,0	0,0
BEP	%(t)	-	-	97,0(524)
PBP	years	-	-	10,5

Note: IRRI - internal rate of return on investment; IRRE - internal rate of return on equity; BEP - break-even point; PBP - pay-back period.

Schedule 10-1

Fixed investment costs

Rs. 000

Item	Investment category	Foreign	Local	Total
1	Site preparation and development	-	46	46
2	Buildings and structures	-	3,077	3,077
3	Technology			
3.1	Know-how	2,000	-	2,000
3.2	Tax on know-how	-	960	960
	Total, technology	2,000	960	2,960
4	Process equipment			
4.1	Supplied from the USSR	90	50	140
4.2	Indigenous	-	4,457	4,457
4.3	Third countries supply	1,250	693	1,943
4.4	Erection	-	944	944
	Total, equipment	1,340	6,144	7,484
5	Pre-production	993	2,374	3,367
6	Start-up and commissioning	-	1,634	1,634
7	Contingencies	59	1,308	1,367
	Grand total, fixed investment costs	4,392	15,543	19,935

Schedule 10-2

Break-down of fixed investment cost by years

Rs.000

tem	Year of construction / Investment category	First Foreign	First Local	First Total	Second Foreign	Second Local	Second Total	Total Foreign	Total Local	Total Total
1	Site preparation and development	-	46	46	-	-	-	-	46	46
2	Buildings and structures	-	1,540	1,540	-	1,537	1,537	-	3,077	3,077
3	Technology	2,000	-	2,960	-	-	-	2,000	960	2,960
4	Equipment and its erection	-	-	-	1,340	6,144	7,484	1,340	6,144	7,484
5	Pre-production expenditure									
5.1	Overheads	-	651	651	-	-	-	-	651	651
5.2	Accomodation of Soviet experts dispatched for rendering technical assistance	-	-	-	493	411	904	493	411	904
5.3	Design engineering	500	1,092	1,592	-	-	-	500	1,092	1,592
5.4	Miscellaneous pre-production costs	-	110	110	-	110	110	-	220	220
	Total, item 5	500	1,853	2,353	493	521	1,014	993	2,374	3,367
6	Start-up and commissioning	-	-	-	-	1,634	1,634	-	1,634	1,634
7	Contingencies	-	322	322	59	986	1,045	59	1,308	1,367
	Total	2,500	4,721	7,221	1,892	10,822	12,714	4,392	15,543	19,935

Schedule 10-3

Estimate of annual operating costs

Rs. 000

Period	Start-up and production build-up			Full capacity		
Years, starting from beginning of construction	3			4-th and others		
Production programme	80			100		
Costs category	foreign	local	total	foreign	local	total
1 Raw and other materials, utilities						
1.1 Commercial-grade aluminium	-	10,082	10,082	-	12,457	12,457
1.2 Barium chloride	-	567	567	-	648	648
1.3 Criolite	-	160	160	-	180	180
1.4 Aluminium fluoride	-	97	97	-	111	111
1.5 Copper	-	50	50	-	380	380
1.6 Graphitized electrodes	-	288	288	-	324	324
1.7 Sodium chloride	-	43	43	-	50	50
1.8 Coal	-	5	5	-	-	-
1.9 Utilities	-	4,899	4,899	-	5,833	5,833
Total, item 1	-	16,191	16,191	-	19,983	19,983
2 Wages and salaries	-	408	408	-	408	408
3 Operating overheads	97	443	540	97	443	540
Total	97	17,042	17,139	97	20,834	20,931
4 Non-operating costs of selling the product	-	525	525	-	657	657
Total operating costs	97	17,567	17,664	97	21,491	21,588
Ditto, per 1 t of high-purity aluminium, Rs	-	-	40,889	-	-	39,978

Schedule 10-4

Calculation of working capital requirements

Rs. 000

Item	Cost category	Inventory days	Coefficient of turnover	Years starting fr[om] beginning of construction	
				3-d	4-th and others
1	Debts, receivable	7	51.4	344	420
2	Materials and utilities				
2.1	Commercial-grade aluminium, criolite, aluminium fluoride, coal	1	360	29	35
2.2	Barium chloride, sodium chloride, graphitized electrodes	60	6	150	170
2.3	Copper	10	36	3	12
2.4	Utilities	1	360	13	15
	Total, item 2	4.2	85	195	232
3	In-process inventory	36	10	1,619	1,998
4	Finished product, stored	7	51.4	333	407
5	Cash-in-hand	15	24	61	67
	Total, current assets			2,552	3,124
6	Accounts payable (current liabilities to be excluded)	7	51.4	315	389
	Total, net working capital			2,237	2,735

Schedule 10-5

Summary of total investment costs

Rs.000

Item	Cost category	Foreign	Local	Total
1	Initial fixed investment costs	1,340	9,267	10,607
2	Preliminary and pre-production capital expenditures	3,052	6,276	9,328
3	Working capital	-	2,735	2,735
	Total, investment costs	4,392	18,278	22,670

Schedule 10-6

Break-down of total investment costs by years

Rs. 000

Period	Construction						Start-up and build-up of production			Full capacity			Total		
Years	1			2			3			4					
Cost category	foreign	local	total	foreign	local	total	foreign	local	total	foreign	local	total	foreign	local	total
Fixed investment costs	-	1,586	1,586	1,340	7,681	9,021	-	-	-	-	-	-	1,340	9,267	10,607
Preliminary and pre-production costs	2,500	3,135	5,635	552	3,141	3,693	-	-	-	-	-	-	3,052	6,276	9,328
Working capital	-	-	-	-	957	957	-	1,280	1,280	-	498	498	-	2,735	2,735
Total	2,500	4,721	7,221	1,892	11,779	13,671	-	1,280	1,280	-	498	498	4,392	18,278	22,670

Schedule 10-7

Sources of financing the total investment costs

Rs.000

Item	Sources of finance	Foreign	Local	Total
1	Equity			
1.1	Major capital	-	9,967	9,967
1.2	Margin money	-	479	479
	Sub-total	-	10,446	10,446
2	Long-term national loan (at 12.5% rate of interest)			
2.1	Major capital	-	9,968	9,968
2.2	Margin money	-	478	478
	Sub-total		10,446	10,446
3	Short-term bank loan for working capital (at 12.5% rate of interest)	-	1,778	1,778
	Total		22,670	22,670

Schedule 10-8

Break-down of financing sources by years

Rs.000

Period	Construction		Start-up and build-up of production	Full capacity	Total
Years / Sources	1	2	3	4	
1. Equity	7,221	3,225	-	-	10,446
2. Long-term national loan	-	10,446	-	-	10,446
3. Short-term bank loan	-	-	1,280	498	1,778
Total	7,221	13,671	1,280	498	22,670

Schedule 10-9

Production costs

Rs.000

Years from start of construction	3	4	5	6	7	8
Production programme, %	80	100	100	100	100	100
1. Operating costs	17,664	21,588	21,588	21,588	21,588	21,588
2. Depreciation	1,750	1,750	1,750	1,750	1,750	1,750
3. Interest	1,499	1,516	1,421	1,282	1,144	1,005
Total	20,913	24,854	24,759	24,620	24,482	24,343

Rs.000

Years from start of construction	9	10	11	12	13	14
Production programme,%	100	100	100	100	100	100
1. Operating costs	21,588	21,588	21,588	21,588	21,588	21,588
2. Depreciation	1,750	1,750	1,750	1,750	1,750	1,338
3. Interest	866	727	589	450	311	311
Total	24,204	24,065	23,927	23,788	23,646	23,237

Rs.000

Years from start of construction	15	16	17	Total
Production programme,%	100	100	100	
1. Operating costs	21,588	21,588	21,588	319,896
2. Depreciation	-	-	-	20,588
3. Interest	311	311	311	12,054
Total	21,899	21,899	21,899	352,538

PLANT SITE : <<KORBA HPA-SAB/BP >>
FINANCING SCHEME : << >>

CASH FLOW
=========

DESCRIPTION	YEARS FROM THE BEGINNING OF					
	CONSTRUCTION		START-UP			
	1	2	3	4	5	
1. OUTFLOW						
1.1. CAPITAL COST INVESTMENT	7221.0	13671.0				
1.2. WORKING CAPITAL			1280.0	498.0		
1.3. DEBTS REPAYMENT						
1.3.1. LONG-TERM INTERNAL LOAN				1109.9	1109.9	11
1.3.2. WORKING CAPITAL LOAN						
1.3.3. SHORT-TERM DEBT						
TOTAL REPAYMENTS				1109.9	1109.9	11
TOTAL OUTFLOW	7221.0	13671.0	1280.0	1607.9	1109.9	11
2. INFLOW						
2.1. FINANCING						
2.1.1. EQUITY	7221.0	3225.0				
2.1.2. LONG-TERM INTERNAL LOAN		10446.0				
2.1.3. WORKING CAPITAL LOAN			1280.0	498.0		
2.1.4. SHORT-TERM INTERNAL LOAN						
TOTAL FINANCING	7221.0	13671.0	1280.0	498.0		
2.2. OPERATING CASH						
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS			-285.3	930.8	1026.0	11
2.2.2. DEPRECIATION			1750.0	1750.0	1750.0	17
TOTAL OPERATING CASH			1464.6	2680.8	2776.0	29
TOTAL INFLOW	7221.0	13671.0	2744.6	3178.8	2776.0	29
CASH BALANCE			1464.6	1570.9	1666.1	18
CUMULATIVE CASH BALANCE			1464.6	3035.6	4701.6	65

SECTION 1

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CASH FLOW

SCHEDULE 10-10

PAGE N 1

RS THOU

	YEARS FROM THE BEGINNING OF THE CONSTRUCTION								
TRUCTION		START-UP		FULL CAPACITY					
	2	3	4	5	6	7	8	9	10
0	13671.0								
		1280.0	498.0						
			1109.9	1109.9	1109.9	1109,9	1109.9	1109.9	1109.9
			1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
0	13671.0	1280.0	1607.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
0	3225.0								
	10446.0								
		1280.0	498.0						
0	13671.0	1280.0	498.0						
		-285.3	930.8	1026.0	1164.7	1303.5	1442.2	1580.9	1719.7
		1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0
		1464.6	2680.8	2776.0	2914.7	3053.4	3192.2	3330.9	3469.6
0	13671.0	2744.6	3178.8	2776.0	2914.7	3053.4	3192.2	3330.9	3469.6
		1464.6	1570.9	1666.1	1804.8	1943.5	2082.3	2221.0	2359.8
		464.6	3035.6	4701.6	6506.4	8450.0	10532.2	12753.3	15113.0

SECTION 2

PLANT SITE : <<KORBA HPA-SAB/BP >>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONS				
	FULL CAPACITY				
	11	12	13	14	15
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT					
1.2.WORKING CAPITAL					
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN	1109.9	1109.9	1109.9		
1.3.2.WORKING CAPITAL LOAN					
1.3.3.SHORT-TERM DEPT					
TOTAL REPAYMENTS	1109.9	1109.9	1109.9		
TOTAL OUTFLOW	1109.9	1109.9	1109.9		
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY					
2.1.2.LONG-TERM INTERNAL LOAN					
2.1.3.WORKING CAPITAL LOAN					
2.1.4.SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING					
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS	1858.4	1997.1	2135.9	2547.6	3885.8
2.2.2.DEPRECIATION	1750.0	1750.0	1750.0	1338.2	
TOTAL OPERATING CASH	3608.4	3747.1	3885.8	3885.8	3885.8
TOTAL INFLOW	3608.4	3747.1	3885.8	3885.8	3885.8
CASH BALANCE	2498.5	2637.2	2776.0	3885.8	3885.8
CUMULATIVE CASH BALANCE	17611.5	20248.7	23024.7	26910.5	30796.3

SECTION 1

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CASH FLOW

SCHEDULE 10-10

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION					
FULL CAPACITY					
12	13	14	15	16	17
1109.9	1109.9				
1109.9	1109.9				
1109.9	1109.9				
1997.1	2135.9	2547.6	3885.8	3885.8	3885.8
1750.0	1750.0	1338.2			
3747.1	3885.8	3885.8	3885.8	3885.8	3885.8
3747.1	3885.8	3885.8	3885.8	3885.8	3885.8
2637.2	2776.0	3885.8	3885.8	3885.8	3885.8
20248.7	23024.7	26910.5	30796.3	34682.2	38568.0

SECTION 2

PLANT SITE : <<KORBA HPA-SAB/BP >>
FINANCING SCHEME : << >>

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INCOME STATEMENT

DESCRIPTION	YEARS FROM THE BEGINNING				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1.PRODUCTION, MT			432.0	540.0	540.0
2.SALES QUANTITY, MT			432.0	540.0	540.0
3.SELLING PRICE, RS/MT	47750.0	47750.0	47750.0	47750.0	47750.0
4.SALES REVENUE			20628.0	25785.0	25785.0
5.OPERATING COST			17664.0	21588.0	21588.0
6.GROSS PROFIT			2964.0	4197.0	4197.0
7.INTERESTS ON:					
7.1.LONG-TERM INTERNAL LOAN			1387.4	1248.6	1109.9
7.2.WORKING CAPITAL LOAN			112.0	267.6	311.1
7.3.SHORT-TERM INTERNAL LOAN					
7.4.GROSS INTEREST			1499.4	1516.2	1421.0
8.PROFIT AFTER INTEREST			1464.6	2680.8	2776.0
9.DEPRECIATION			1750.0	1750.0	1750.0
10.PROFIT BEFORE TAX			-285.3	930.8	1026.0
11.INCOME TAX					
12.NET PROFIT AFTER TAX			-285.3	930.8	1026.0
13.RETAINED PROFIT			-285.3		

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONSTR				
	FULL CAPACITY				
	11	12	13	14	15
1.PRODUCTION, MT	540.0	540.0	540.0	540.0	540.0
2.SALES QUANTITY, MT	540.0	540.0	540.0	540.0	540.0
3.SELLING PRICE, RS/MT	47750.0	47750.0	47750.0	47750.0	47750.0
4.SALES REVENUE	25785.0	25785.0	25785.0	25785.0	25785.0
5.OPERATING COST	21588.0	21588.0	21588.0	21588.0	21588.0
6.GROSS PROFIT	4197.0	4197.0	4197.0	4197.0	4197.0
7.INTERESTS ON:					
7.1.LONG-TERM INTERNAL LOAN	277.5	138.7			
7.2.WORKING CAPITAL LOAN	311.1	311.1	311.1	311.1	311.1
7.3.SHORT-TERM INTERNAL LOAN					
7.4.GROSS INTEREST	588.6	449.9	311.1	311.1	311.1
8.PROFIT AFTER INTEREST	3608.4	3747.1	3885.8	3885.8	3885.8
9.DEPRECIATION	1750.0	1750.0	1750.0	1338.2	
10.PROFIT BEFORE TAX	1858.4	1997.1	2133.9	2547.6	3885.8
11.INCOME TAX					
12.NET PROFIT AFTER TAX	1858.4	[illegible]	[illegible]	2547.6	3885.8
13.RETAINED PROFIT					

SECTION 1

90

INCOME STATEMENT   SCHEDULE 10-11   RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION								
N	START-UP		FULL CAPACITY					
	3	4	5	6	7	8	9	10
	432.0	540.0	540.0	540.0	540.0	540.0	540.0	540.0
	432.0	540.0	540.0	540.0	540.0	540.0	540.0	540.0
0.0	47750.0	47750.0	47750.0	47750.0	47750.0	47750.0	47750.0	47750.0
	20628.0	25785.0	25785.0	25785.0	25785.0	25785.0	25785.0	25785.0
	17664.0	21588.0	21588.0	21588.0	21588.0	21588.0	21588.0	21588.0
	2964.0	4197.0	4197.0	4197.0	4197.0	4197.0	4197.0	4197.0
	1387.4	1248.6	1109.9	971.1	832.4	693.7	554.9	416.2
	112.0	267.6	311.1	311.1	311.1	311.1	311.1	311.1
...	1499.4	1516.2	1421.0	1282.3	1143.6	1004.8	866.1	727.4
	1464.6	2680.8	2776.0	2914.7	3053.4	3192.2	3330.9	3469.6
	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0
	-285.3	930.8	1026.0	1164.7	1303.5	1442.2	1580.9	1719.7
	-285.3	930.8	1026.0	1164.7	1303.5	1442.2	1580.9	1719.7
	-285.3							

FROM THE BEGINNING OF THE CONSTRUCTION					
	FULL CAPACITY				
2	13	14	15	16	17
0.0	540.0	540.0	540.0	540.0	540.0
0.0	540.0	540.0	540.0	540.0	540.0
0.0	47750.0	47750.0	47750.0	47750.0	47750.0
5.0	25785.0	25785.0	25785.0	25785.0	25785.0
8.0	21588.0	21588.0	21588.0	21588.0	21588.0
7.0	4197.0	4197.0	4197.0	4197.0	4197.0
8.7					
1.1	311.1	311.1	311.1	311.1	311.1
9.9	311.1	311.1	311.1	311.1	311.1
7.1	3885.8	3885.8	3885.8	3885.8	3885.8
0.0	1750.0	1338.2			
7.1	2135.9	2547.6	3885.8	3885.8	3885.8
7.1	2135.9	2547.6	3885.8	3885.8	3885.8

SECTION 2

PLANT SITE : <<KORBA HPA-SAB/BP >>
FINANCING SCHEME : << >>

CALCULATION OF INTERNAL RATES OF RE

DESCRIPTION	YEARS FROM THE BEGINNING				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1.CAPITAL COST INVESTMENT	7221.0	13671.0			
2.EQUITY CAPITAL	7221.0	3225.0			
3.WORKING CAPITAL			1280.0	498.0	
4.GROSS PROFIT			2964.0	4197.0	4197.0
5.DEPTS REPAYMENT				1109.9	1109.9
6.INTEREST PAYMENTS			1499.4	1516.2	1421.0
7.RESIDUAL VALUE					
8.INCOME TAX					
9.THE RETURN ON INVESTMENT	-7221.0	-13671.0	1684.0	3699.0	4197.0
10.THE RETURN ON EQUITY	-7221.0	-3225.0	184.6	1072.9	1666.1

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONSTR				
	FULL CAPACITY				
	11	12	13	14	15
1.CAPITAL COST INVESTMENT					
2.EQUITY CAPITAL					
3.WORKING CAPITAL					
4.GROSS PROFIT	4197.0	4197.0	4197.0	4197.0	4197.0
5.DEPTS REPAYMENT	1109.9	1109.9	1109.9		
6.INTEREST PAYMENTS	588.6	449.9	311.1	311.1	311.1
7.RESIDUAL VALUE					
8.INCOME TAX					
9.THE RETURN ON INVESTMENT	4197.0	4197.0	4197.0	4197.0	4197.0
10.THE RETURN ON EQUITY	2498.5	2637.2	2776.0	3885.8	3885.8

INTERNAL RATE OF RETURN
ON INVESTMENT : 15.27 P.C.
ON EQUITY : 14.67 P.C.

SECTION 1

CALCULATION OF INTERNAL RATES OF RETURN

SCHEDULE 10-12

PAGE N 1

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION								
TION	START-UP		FULL CAPACITY					
2	3	4	5	6	7	8	9	10
671.0								
225.0								
	1280.0	498.0						
	2964.0	4197.0	4197.0	4197.0	4197.0	4197.0	4197.0	4197.0
		1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
	1499.4	1516.2	1421.0	1282.3	1143.6	1004.8	866.1	727.4
671.0	1684.0	3699.0	4197.0	4197.0	4197.0	4197.0	4197.0	4197.0
225.0	184.6	1072.9	1666.1	1804.8	1943.5	2082.3	2221.0	2359.8

RS FROM THE BEGINNING OF THE CONSTRUCTION					
FULL CAPACITY					
12	13	14	15	16	17
197.0	4197.0	4197.0	4197.0	4197.0	4197.0
109.9	1109.9				
449.9	311.1	311.1	311.1	311.1	311.1
					2735.0
197.0	4197.0	4197.0	4197.0	4197.0	6932.0
637.2	2776.0	3885.8	3885.8	3885.8	6620.8

SECTION 2

DIAGRAM 1. PAY-BACK PERIOD

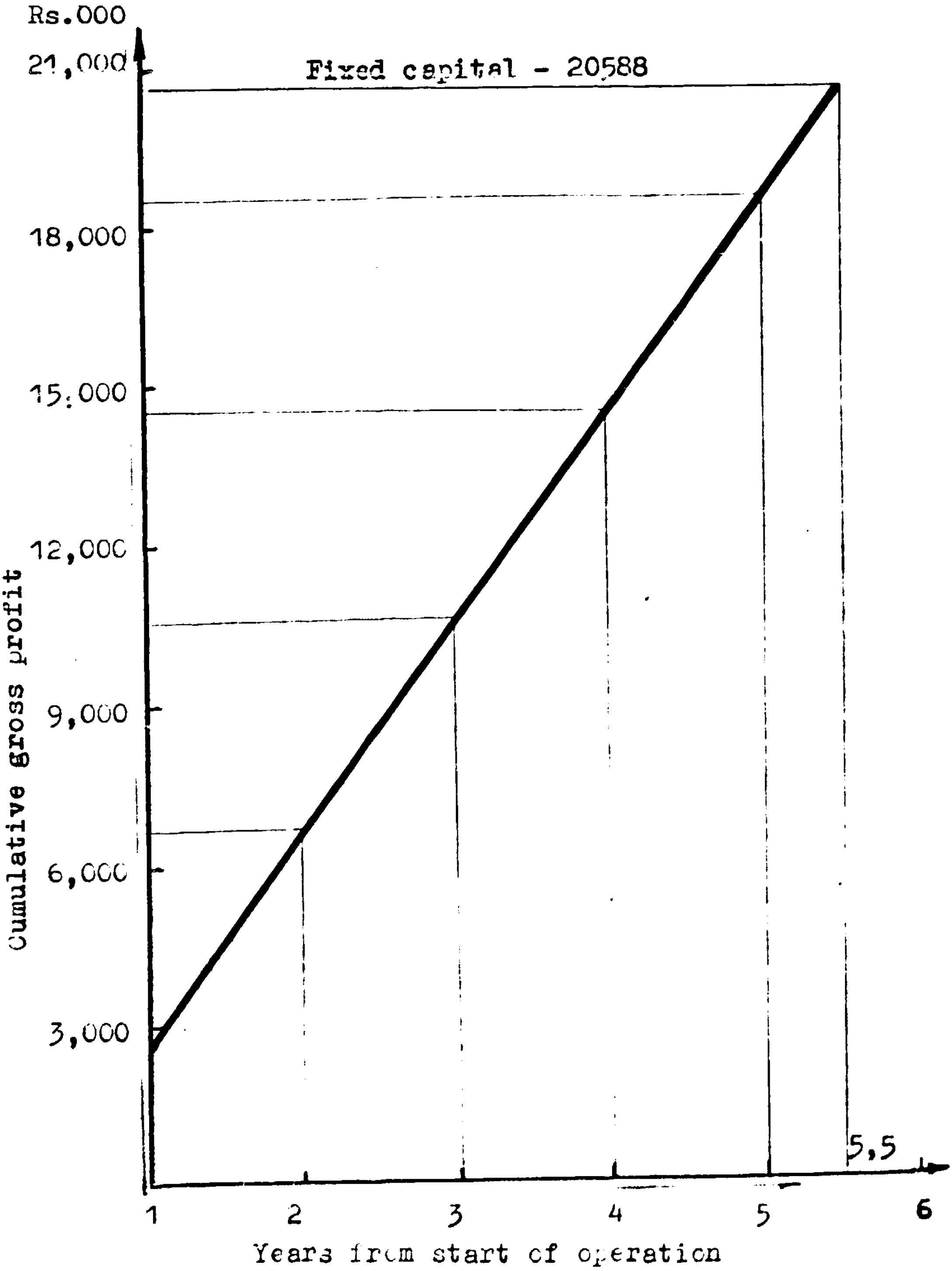


DIAGRAM 2. BREAK-EVEN POINT

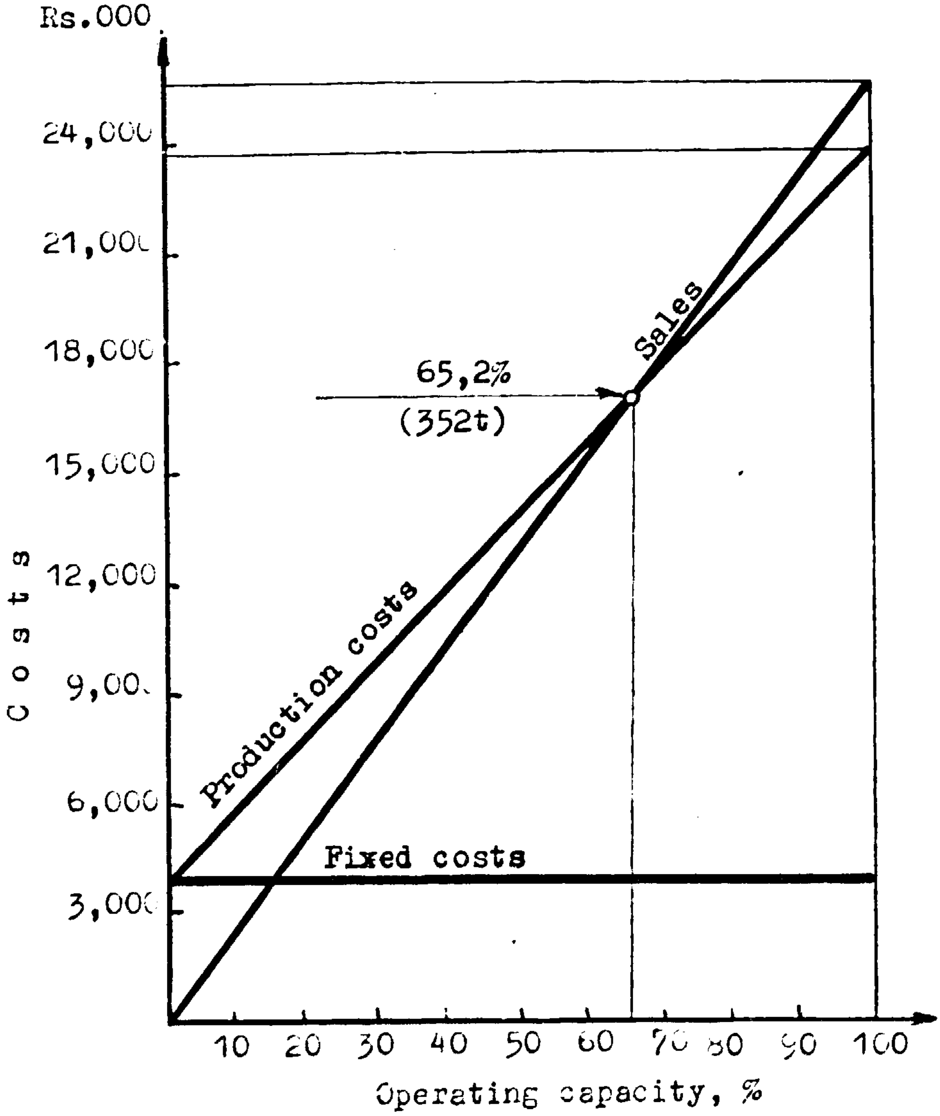
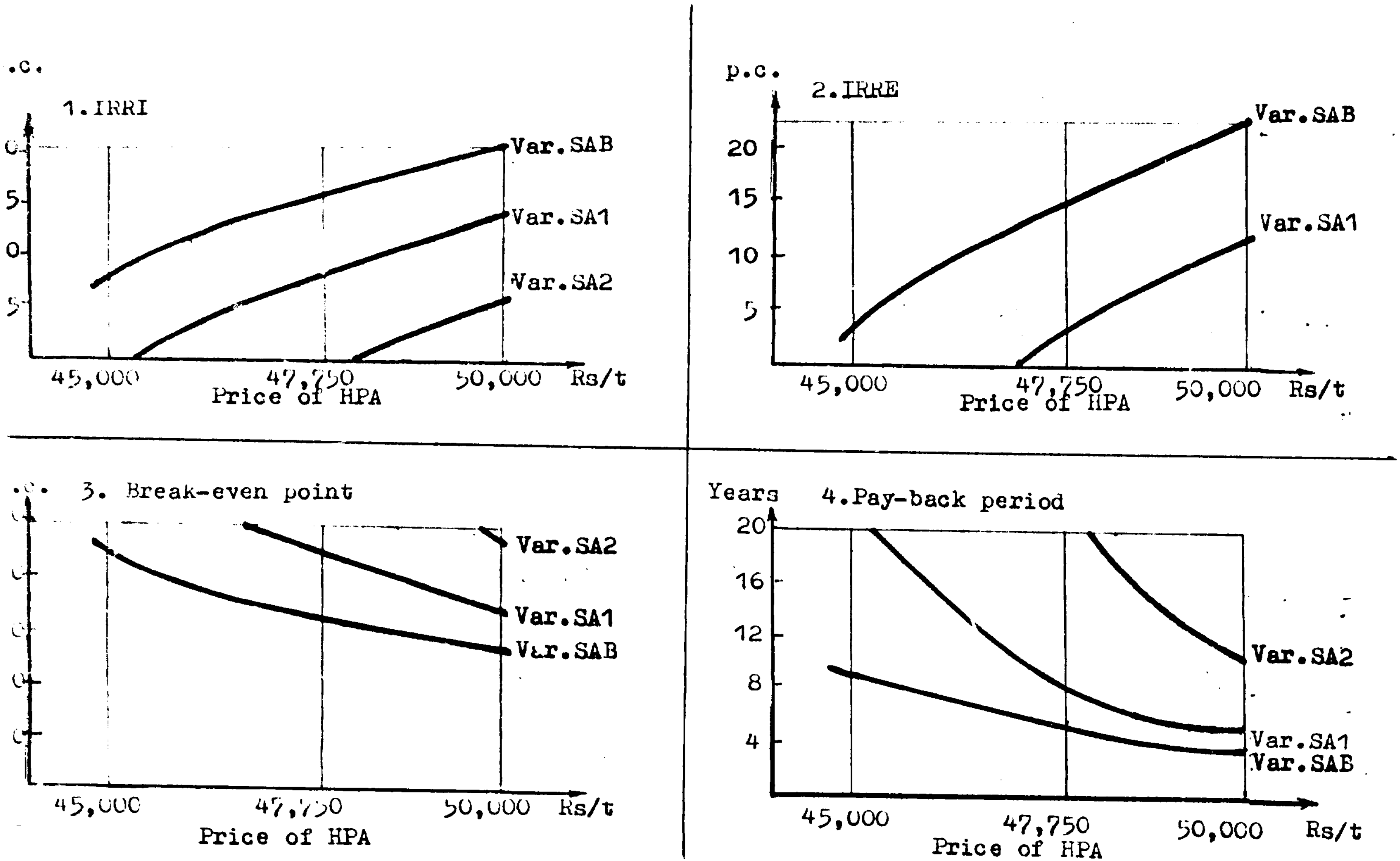


DIAGRAM 3. SENSITIVITY OF PROJECT TO COST INCREASE



SENSITIVITY ANALYSIS SCHEDULES

PLANT SIZE : <<KOOBA HPA-SAB/LP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGIN				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT	7221.0	13671.0			
1.2.WORKING CAPITAL			1280.0	498.0	
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN				1109.9	1109.
1.3.2.WORKING CAPITAL LOAN					
1.3.3.SHORT-TERM DEPT					
TOTAL REPAYMENTS				1109.9	1109.
TOTAL OUTFLOW	7221.0	13671.0	1280.0	1607.9	1109.
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY	7221.0	3225.0			
2.1.2.LONG-TERM INTERNAL LOAN		10446.0			
2.1.3.WORKING CAPITAL LOAN			1280.0	498.0	
2.1.4.SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING	7221.0	13671.0	1280.0	498.0	
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS			-1473.3	-554.2	-459.
2.2.2.DEPRECIATION			1750.0	1750.0	1750.
TOTAL OPERATING CASH			276.6	1195.8	1291.
TOTAL INFLOW	7221.0	13671.0	1556.6	1693.8	1291.
CASH BALANCE			276.6	85.9	181.
CUMULATIVE CASH BALANCE			276.6	362.6	543.

SECTION 1

CASH FLOW

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION								
...ION	START-UP		FULL CAPACITY					
2	3	4	5	6	7	8	9	10
671.0								
	1280.0	498.0						
		1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
		1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
671.0	1280.0	1607.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
225.0								
446.0								
	1280.0	498.0						
671.0	1280.0	498.0						
	-1473.3	-554.2	-459.0	-320.3	-181.5	-42.8	95.9	234.7
	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0
	276.6	1195.8	1291.0	1429.7	1568.4	1707.2	1845.9	1984.6
671.0	1556.6	1693.8	1291.0	1429.7	1568.4	1707.2	1845.9	1984.6
	276.6	85.9	181.1	319.8	458.6	597.3	736.0	874.8
	276.6	362.6	543.6	863.4	1322.0	1919.3	2655.3	3530.1

SECTION 2

PLANT SITE : <<KORBA HPA-SAB/LP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE				
	FULL CAPACITY				
	11	12	13	14	15
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT					
1.2. WORKING CAPITAL					
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN	1109.9	1109.9	1109.9		
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT					
TOTAL REPAYMENTS	1109.9	1109.9	1109.9		
TOTAL OUTFLOW	1109.9	1109.9	1109.9		
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY					
2.1.2. LONG-TERM INTERNAL LOAN					
2.1.3. WORKING CAPITAL LOAN					
2.1.4. SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING					
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS	373.4	512.1	650.9	1062.6	240
2.2.2. DEPRECIATION	1750.0	1750.0	1750.0	1338.2	
TOTAL OPERATING CASH	2123.4	2262.1	2400.9	2400.9	240
TOTAL INFLOW	2123.4	2262.1	2400.9	2400.9	240
CASH BALANCE	1013.5	1152.2	1291.0	2400.9	240
CUMULATIVE CASH BALANCE	4543.6	5695.8	6986.8	9387.6	1178

SECTION 1

CASH FLOW

...S FROM THE BEGINNING OF THE CONSTRUCTION					
FULL CAPACITY					
...2	13	14	15	16	17
...09.9	1109.9				
...09.9	1109.9				
...09.9	1109.9				
...12.1	650.9	1062.6	2400.9	2400.9	2400.9
...50.0	1750.0	1338.2			
...62.1	2400.9	2400.9	2400.9	2400.9	2400.9
...62.1	2400.9	2400.9	2400.9	2400.9	2400.9
...52.2	1291.0	2400.9	2400.9	2400.9	2400.9
...95.8	6986.8	9387.6	11788.5	14189.3	16590.1

SECTION 2

PLANT SITE : <<KOSBA HPA-SAB/HP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINN				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT	7221.0	13671.0			
1.2. WORKING CAPITAL			1280.0	498.0	
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN				1109.9	1109.
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT					
TOTAL REPAYMENTS				1109.9	1109.
TOTAL OUTFLOW	7221.0	13671.0	1280.0	1607.9	1109.
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY	7221.0	3225.0			
2.1.2. LONG-TERM INTERNAL LOAN		10446.0			
2.1.3. WORKING CAPITAL LOAN			1280.0	498.0	
2.1.4. SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING	7221.0	13671.0	1280.0	498.0	
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS			686.7	2145.8	2241.
2.2.2. DEPRECIATION			1750.0	1750.0	1750.
TOTAL OPERATING CASH			2436.6	3895.8	3991.
TOTAL INFLOW	7221.0	13671.0	3716.6	4393.8	3991.
CASH BALANCE			2436.6	2785.9	2881.
CUMULATIVE CASH BALANCE			2436.6	5222.6	8103.

SECTION 1

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CASH FLOW

PAGE N 1

RS THOU

	YEARS FROM THE BEGINNING OF THE CONSTRUCTION							
	START-UP		FULL CAPACITY					
	3	4	5	6	7	8	9	10
0								
	1280.0	498.0						
		1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
		1109.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
0	1280.0	1607.9	1109.9	1109.9	1109.9	1109.9	1109.9	1109.9
0								
0								
	1280.0	498.0						
0	1280.0	498.0						
	686.7	2145.8	2241.0	2379.7	2518.5	2657.2	2795.9	2934.7
	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0	1750.0
	2436.6	3895.8	3991.0	4129.7	4268.4	4407.2	4545.9	4684.6
0	3716.6	4393.8	3991.0	4129.7	4268.4	4407.2	4545.9	4684.6
	2436.6	2785.9	2881.1	3019.8	3158.5	3297.3	3436.0	3574.8
	2436.6	5222.6	8103.6	11123.4	14282.0	17579.3	21015.3	24590.0

SECTION 2

PLANT SITE : <<KORBA -PA-SAB/HP>>

FINANCING SCHEME . << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONS				
	FULL CAPACITY				
	11	12	13	14	15
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT					
1.2. WORKING CAPITAL					
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN	1109.9	1109.9	1109.9		
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT					
TOTAL REPAYMENTS	1109.9	1109.9	1109.9		
TOTAL OUTFLOW	1109.9	1109.9	1109.9		
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY					
2.1.2. LONG-TERM INTERNAL LOAN					
2.1.3. WORKING CAPITAL LOAN					
2.1.4. SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING					
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS	3073.4	3212.1	3350.9	3762.6	5100.9
2.2.2. DEPRECIATION	1750.0	1750.0	1750.0	1338.2	
TOTAL OPERATING CASH	4823.4	4962.1	5100.9	5100.9	5100.9
TOTAL INFLOW	4823.4	4962.1	5100.9	5100.9	5100.9
CASH BALANCE	3713.5	3852.2	3991.0	5100.9	5100.9
CUMULATIVE CASH BALANCE	28303.5	32155.7	36146.7	41247.6	46348.4

SECTION 1

RS THOU

CASH FLOW
=========

THE BEGINNING OF THE CONSTRUCTION				
FULL CAPACITY				
13	14	15	16	17
1109.9				
1109.9				
1109.9				
3350.9	3762.6	5100.9	5100.8	5100.8
1750.0	1338.2			
5100.9	5100.9	5100.9	5100.8	5100.8
5100.9	5100.9	5100.9	5100.8	5100.8
399[illegible].0	5100.9	5100.9	5100.8	5100.8
36146.7	41247.6	46348.4	51449.3	56550.1

SECTION 2

PLANT SI E : <<< 33% HPA-SA1/LP >>
FINANCIN SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT	7693.0	14999.0			
1.2. WORKING CAPITAL			1357.0	528.0	
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN				1205.5	1205.5
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT				199.4	590.5
TOTAL REPAYMENTS				1404.9	1796.1
TOTAL OUTFLOW	7693.0	14999.0	1357.0	1932.9	1796.1
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY	7693.0	3653.0			
2.1.2. LONG-TERM INTERNAL LOAN		11346.0			
2.1.3. WORKING CAPITAL LOAN			1357.0	528.0	
2.1.4. SHORT-TERM INTERNAL LOAN			996.9	1955.9	2569.4
TOTAL FINANCING	7693.0	14999.0	2353.9	2483.9	2569.4
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS			-2899.8	-2453.9	-2676.3
2.2.2. DEPRECIATION			1902.9	1902.9	1902.9
TOTAL OPERATING CASH			-996.9	-551.0	-773.4
TOTAL INFLOW	7693.0	14999.0	1357.0	1932.9	1796.1
CASH BALANCE					
CUMULATIVE CASH BALANCE					

SECTION 1

400

CASH FLOW
=========

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION							
START-UP		FULL CAPACITY					
3	4	5	6	7	8	9	10
1357.0	528.0						
	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
	199.4	593.5	1104.4	1764.0	2606.5	3479.1	4406.9
	1404.9	1796.1	2309.9	2969.5	3812.0	4684.6	5612.5
1357.0	1932.9	1796.1	2309.9	2969.5	3812.0	4684.6	5612.5
1357.0	528.0						
996.9	1955.9	2569.4	3297.7	4212.7	5359.7	6595.2	7955.5
2353.9	2483.9	2569.4	3297.7	4212.7	5359.7	6595.2	7955.5
2899.8	-2453.9	-2676.3	-2890.6	-3146.1	-3450.6	-3813.5	-4246.0
1902.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9
-996.9	-551.0	-773.4	-987.7	-1243.2	-1547.7	-1910.6	-2343.0
1357.0	1932.9	1796.1	2309.9	2969.5	3812.0	4684.6	5612.5

SECTION 2

PLANT SITE : << ?RBA HPA-SN/LP >>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CON				
	FULL CAPACITY				
	11	12	13	14	15
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT					
1.2.WORKING CAPITAL					
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN	1205.5	1205.5	1205.5		
1.3.2.WORKING CAPITAL LOAN					
1.3.3.SHORT-TERM DEPT	5484.2	6734.3	8174.2	9819.1	11489.3
TOTAL REPAYMENTS	6689.7	7939.8	9379.7	9819.1	11489.3
TOTAL OUTFLOW	6689.7	7939.8	9379.7	9819.1	11489.3
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY					
2.1.2.LONG-TERM INTERNAL LOAN					
2.1.3.WORKING CAPITAL LOAN					
2.1.4.SHORT-TERM INTERNAL LOAN	9548.1	11412.5	13584.5	14945.9	17599.2
TOTAL FINANCING	9548.1	11412.5	13584.5	14945.9	17599.2
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS	-4761.4	-5375.6	-6107.7	-6581.9	-6109.9
2.2.2.DEPRECIATION	1902.9	1902.9	1902.9	1455.2	
TOTAL OPERATING CASH	-2858.5	-3472.7	-4204.8	-5126.7	-6109.9
TOTAL INFLOW	6689.7	7939.8	9379.7	9819.1	11489.3
CASH BALANCE					
CUMULATIVE CASH BALANCE					

SECTION 1

CASH FLOW

RS THOU

THE BEGINNING OF THE CONSTRUCTION				
	FULL CAPACITY			
13	14	15	16	17
1205.5				
817..2	9819.1	11489.3	13418.0	15648.4
9379.7	9819.1	11489.3	13418.0	15648.4
9379.7	9819.1	11489.3	13418.0	15648.4
3584.5	14945.9	17599.2	20699.8	24326.6
3584.5	14945.9	17599.2	20699.8	24326.6
6107.7	-6581.9	-6109.9	-7281.7	-8678.2
1902.9	1455.2			
4204.8	-5126.7	-6109.9	-7281.7	-8678.2
9379.7	9819.1	11489.3	13418.0	15648.4

SECTION 2

PLANT SIZE : <<SOBA HPA-SA1/BP >>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINN				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT	7693.0	14999.0			
1.2.WORKING CAPITAL			1357.0	528.0	
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN				1205.5	1205.
1.3.2.WORKING CAPITAL LOAN					
1.3.3.SHORT-TERM DEPT					
TOTAL REPAYMENTS				1205.5	1205.
TOTAL OUTFLOW	7693.0	14999.0	1357.0	1733.5	1205.
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY	7693.0	3653.0			
2.1.2.LONG-TERM INTERNAL LOAN		11346.0			
2.1.3.WORKING CAPITAL LOAN			1357.0	528.0	
2.1.4.SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING	7693.0	14999.0	1357.0	528.0	
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS			-1624.5	-640.8	-536.
2.2.2.DEPRECIATION			1902.9	1902.9	1902.
TOTAL OPERATING CASH			278.4	1262.1	1366.
TOTAL INFLOW	7693.0	14999.0	1635.4	1790.1	1366.
CASH BALANCE			273.4	56.6	161.
CUMULATIVE CASH BALANCE			278.4	335.0	496.

SECTION 1

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CASH FLOW | PAGE N 1
RS THOU

ARS FROM THE BEGINNING OF THE CONSTRUCTION							
TART-UP		FULL CAPACITY					
	4	5	6	7	8	9	10
.0	528.0						
	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
.0	1733.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
.0	528.0						
.0	528.0						
.5	-640.8	-536.3	-385.6	-234.9	-84.2	66.5	217.2
.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9
.4	1262.1	1366.6	1517.3	1668.0	1818.7	1969.4	2120.1
.4	1790.1	1366.6	1517.3	1668.0	1818.7	1969.4	2120.1
.4	56.6	161.1	311.8	462.5	613.2	763.9	914.5
.4	335.0	496.1	807.9	1270.4	1883.5	2647.4	3561.9

SECTION 2

PLANT SITE : <<KORBA HPA-SA1/BP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONST				
	FULL CAPACITY				
	11	12	13	14	15
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT					
1.2.WORKING CAPITAL					
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN	1205.5	1205.5	1205.5		
1.3.2.WORKING CAPITAL LOAN					
1.3.3.SHORT-TERM DEPT					
TOTAL REPAYMENTS	1205.5	1205.5	1205.5		
TOTAL OUTFLOW	1205.5	1205.5	1205.5		
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY					
2.1.2.LONG-TERM INTERNAL LOAN					
2.1.3.WORKING CAPITAL LOAN					
2.1.4.SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING					
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS	367.8	518.5	669.2	1117.0	2572.1
2.2.2.DEPRECIATION	1902.9	1902.9	1902.9	1455.2	
TOTAL OPERATING CASH	2270.8	2421.4	2572.1	2572.1	2572.1
TOTAL INFLOW	2270.8	2421.4	2572.1	2572.1	2572.1
CASH BALANCE	1065.2	1215.9	1366.6	2572.1	2572.1
CUMULATIVE CASH BALANCE	4627.2	5843.1	7209.7	9781.8	12354.0

SECTION 1

CASH FLOW

RS THOU

BEGINNING OF THE CONSTRUCTION				
FULL CAPACITY				
	14	15	16	17
5.5				
5.5				
5.5				
...				
9.2	1117.0	2572.1	2572.1	2572.1
2.9	1455.2			
2.1	2572.1	2572.1	2572.1	2572.1
2.1	2572.1	2572.1	2572.1	2572.1
6.6	2572.1	2572.1	2572.1	2572.1
9.7	9781.8	12354.0	14926.1	17498.2

SECTION 2

CASH FLOW

PLANT SIZE : <<SOBA HPA-SA1/HP>>
FINANCING SCHEME : << >>

DESCRIPTION	YEARS FROM THE BEGINNING				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT	7693.0	14999.0			
1.2. WORKING CAPITAL			1357.0	523.0	
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN				1205.5	1205.5
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT					
TOTAL REPAYMENTS				1205.5	1205.5
TOTAL OUTFLOW	7693.0	14999.0	1357.0	1733.5	1205.5
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY	7693.0	3653.0			
2.1.2. LONG-TERM INTERNAL LOAN		11346.0			
2.1.3. WORKING CAPITAL LOAN			1357.0	523.0	
2.1.4. SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING	7693.0	14999.0	1357.0	528.0	
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS			-652.5	574.2	678.7
2.2.2. DEPRECIATION			1902.9	1902.9	1902.9
TOTAL OPERATING CASH			1250.4	2477.1	2581.6
TOTAL INFLOW	7693.0	14999.0	2607.4	3005.1	2581.6
CASH BALANCE			1250.4	1271.6	1376.1
CUMULATIVE CASH BALANCE			1250.4	2522.0	3898.1

SECTION 1

CASH FLOW
=========

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION							
START-UP		FULL CAPACITY					
3	4	5	6	7	8	9	10
1357.0	523.0						
	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
1357.0	1733.5	1205.5	1205.5	1205.5	1205.5	1205.5	1205.5
1357.0	523.0						
1357.0	528.0						
-652.5	574.2	678.7	829.4	980.1	1130.8	1281.5	1432.2
1902.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9	1902.9
1250.4	2477.1	2581.6	2732.3	2883.0	3033.7	3184.4	3335.1
2607.4	3005.1	2581.6	2732.3	2883.0	3033.7	3184.4	3335.1
1250.4	1271.6	137[illegible].1	1526.8	1677.5	1828.2	1978.9	2129.6
1250.4	2522.0	3898.1	5424.9	7102.4	8930.6	10909.4	13039.0

SECTION 2

PLANT SIZE : <<KORBA HPA-SA1/HP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE CONSTRU					
	FULL CAPACITY					
	11	12	13	14	15	
1.OUTFLOW						
1.1.CAPITAL COST INVESTMENT						
1.2.WORKING CAPITAL						
1.3.DEBTS REPAYMENT						
1.3.1.LONG-TERM INTERNAL LOAN	1205.5	1205.5	1205.5			
1.3.2.WORKING CAPITAL LOAN						
1.3.3.SHORT-TERM DEPT						
TOTAL REPAYMENTS	1205.5	1205.5	1205.5			
TOTAL OUTFLOW	1205.5	1205.5	1205.5			
2.INFLOW						
2.1.FINANCING						
2.1.1.EQUITY						
2.1.2.LONG-TERM INTERNAL LOAN						
2.1.3.WORKING CAPITAL LOAN						
2.1.4.SHORT-TERM INTERNAL LOAN						
TOTAL FINANCING						
2.2.OPERATING CASH						
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS	1582.9	1733.5	1884.2	2332.0	3787.1	3
2.2.2.DEPRECIATION	1902.9	1902.9	1902.9	1455.2		
TOTAL OPERATING CASH	3485.8	3636.4	3787.1	3787.1	3787.1	3
TOTAL INFLOW	3485.8	3636.4	3787.1	3787.1	3787.1	3
CASH BALANCE	2280.2	2430.9	2581.6	3787.1	3787.1	3
CUMULATIVE CASH BALANCE	15319.2	17750.2	20331.8	24118.9	27906.1	31

SECTION 1

105

CASH FLOW

RS FROM THE BEGINNING OF THE CONSTRUCTION					
	FULL CAPACITY				
2	13	14	15	16	17
05.5	1205.5				
05.5	1205.5				
05.5	1205.5				
3.5	1884.2	2332.0	3787.1	3787.1	3787.1
2.9	1902.9	1455.2			
6.4	3787.1	3787.1	3787.1	3787.1	3787.1
6.4	3787.1	3787.1	3787.1	3787.1	3787.1
0.9	2531.6	3787.1	3787.1	3787.1	3787.1
0.2	20331.8	24118.9	27906.1	31693.2	35480.3

SECTION 2

PLANT SITE : <<NOUBA HPA-S12/HP>>
FINANCING SCHEME : << >>

CASH FLOW 106

DESCRIPTION	YEARS FROM THE BEGINNING				
	CONSTRUCTION		START-UP		
	1	2	3	4	5
1. OUTFLOW					
1.1. CAPITAL COST INVESTMENT	8212.0	16459.0			
1.2. WORKING CAPITAL			1438.0	560.0	
1.3. DEBTS REPAYMENT					
1.3.1. LONG-TERM INTERNAL LOAN				1310.6	1310.6
1.3.2. WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEBT				2.4	78.3
TOTAL REPAYMENTS				1313.0	1388.9
TOTAL OUTFLOW	8212.0	16459.0	1438.0	1873.0	1388.9
2. INFLOW					
2.1. FINANCING					
2.1.1. EQUITY	8212.0	4124.0			
2.1.2. LONG-TERM INTERNAL LOAN		12335.0			
2.1.3. WORKING CAPITAL LOAN			1438.0	560.0	
2.1.4. SHORT-TERM INTERNAL LOAN			12.1	379.2	401.4
TOTAL FINANCING	8212.0	16459.0	1450.1	939.2	401.4
2.2. OPERATING CASH					
2.2.1. NET PROFIT AFTER TAX AND DIVIDENDS			-2083.3	-1137.3	-1083.8
2.2.2. DEPRECIATION			2071.2	2071.2	2071.2
TOTAL OPERATING CASH			-12.1	933.8	987.4
TOTAL INFLOW	8212.0	16459.0	1438.0	1873.0	1388.9
CASH BALANCE					
CUMULATIVE CASH BALANCE					

SECTION 1

RS THOU

YEARS FROM THE BEGINNING OF THE CONSTRUCTION							
START-UP		FULL CAPACITY					
3	4	5	6	7	8	9	10
1433.0	560.0						
	1310.6	1310.6	1310.6	1310.6	1310.6	1310.6	1310.6
	2.4	78.3	158.5	231.4	290.7	326.2	537.6
	1313.0	1388.9	1469.1	1542.0	1601.3	1636.8	1848.2
1438.0	1873.0	1388.9	1469.1	1542.0	1601.3	1636.8	1848.2
1438.0	560.0						
12.1	379.2	401.4	364.1	296.9	189.3	25.7	
1450.1	939.2	401.4	364.1	296.9	189.3	25.7	
2083.3	-1137.3	-1083.8	-966.2	-826.1	-659.1	-460.1	-223.0
2071.2	2071.2	2071.2	2071.2	2071.2	2071.2	2071.2	2071.2
-12.1	933.8	987.4	1105.0	1245.1	1412.1	1611.1	1848.2
1438.0	1873.0	1388.9	1469.1	1542.0	1601.3	1636.8	1848.2

SECTION 2

PLANT SITE : <<KORBA HPA-SA2/HP>>
FINANCING SCHEME : << >>

CASH FLOW

DESCRIPTION	YEARS FROM THE BEGINNING OF THE C				
	FULL CAPACITY				
	11	12	13	14	15
1.OUTFLOW					
1.1.CAPITAL COST INVESTMENT					
1.2.WORKING CAPITAL					
1.3.DEBTS REPAYMENT					
1.3.1.LONG-TERM INTERNAL LOAN	1310.6	1310.6	1310.6		
1.3.2.WORKING CAPITAL LOAN					
1.3.3. SHORT-TERM DEPT	43.6				
TOTAL REPAYMENTS	1354.2	1310.6	1310.6		
TOTAL OUTFLOW	1354.2	1310.6	1310.6		
2.INFLOW					
2.1.FINANCING					
2.1.1.EQUITY					
2.1.2.LONG-TERM INTERNAL LOAN					
2.1.3.WORKING CAPITAL LOAN					
2.1.4.SHORT-TERM INTERNAL LOAN					
TOTAL FINANCING					
2.2.OPERATING CASH					
2.2.1.NET PROFIT AFTER TAX AND DIVIDENDS	-8.3	159.3	323.2	810.5	2394
2.2.2.DEPRECIATION	2071.2	2071.2	2071.2	1583.8	
TOTAL OPERATING CASH	2062.9	2230.5	2394.4	2394.4	2394
TOTAL INFLOW	2062.9	2230.5	2394.4	2394.4	2394
CASH BALANCE	708.7	919.9	1083.8	2394.4	2394
CUMULATIVE CASH BALANCE	708.7	1628.6	2712.4	5106.7	7501

SECTION 1

CASH FLOW

…S FROM THE BEGINNING OF THE CONSTRUCTION

FULL CAPACITY

…2	13	14	15	16	17
…0.6	1310.6				
…0.6	1310.6				
…0.6	1310.6				
…9.3	323.2	810.5	2394.4	2394.4	2394,4
…1.2	2071.2	1583.8			
…0.5	2394.4	2394.4	2394.4	2394.4	2394.4
…0.5	2394.4	2394.4	2394.4	2394.4	2394.4
…9.9	1083.8	2394.4	2394.4	2394.4	2394.4
…8.6	2712.4	5106.7	7501.1	9895.4	12289.8

SECTION 2

A N N E X U R E

Annex 1

CONTRACT NO. 85/2

SUPPORT STUDIES
FOR EVALUATION AND SELECTION
OF LOCATION FOR EXPERIMENTAL
DEMONSTRATION UNIT(EDU) FOR
HIGH PURITY ALUMINIUM PRODUCTION AT
ONE OF EXISTING ALUMINIUM SMELTERS
OF BHARAT ALUMINIUM COMPANY LIMITED(BALCO)
IN INDIA.

(INTERIM REPORT)

UNIDO PROJECT NO. DP/IND/84/007

NEW DELHI- LENINGRAD

AUGUST-1985

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1. Brief Analysis for selection of EDU location.

In accordance with contract between UNIDO and V/o Tsvetmetpromexport No 85/2 the present support study is prepared in order to evaluate and select the location of the Experimental Demonstration Unit(EDU) for high purity aluminium production at one of the Aluminium Smelters of Bharat Aluminium Company Limited(BALCO), located in Korba (Madhya Pradesh State) and Jaykaynagar(West Bengal State).

The following main factors had been considered for evaluation of location sites:

- Supply of raw materials for the EDU;
- Possibility of utilization of existing equipment at Aluminium Smelters considered;
- Transportation costs for raw materials and inputs;
- Availability of skilled manpower;
- Investment and production costs for construction and operation of the EDU;

As the analysis carried out had revealed, the optimal EDU location site is Korba Smelter. In this case the following factors are ensured:

- Possibility to utilize the aluminium in liquid form from the operating cell-room;
- maximum utilization of process equipment of the Smelter as well as of auxiliary equipment of other units;
- Reliability of the EDU power supply and skilled manpower for commissioning, operation and maintenance of the EDU;
- Lower specific investment and production costs;

	Korba	Jaykaynagar
a) Investment costs R/t	28,309	46,935
b) Production costs, R/t	44,165	47,111
c) Rate of return, %	24	9.2

2.0 General Initial Data

2.1 Aim of Project

The aim of the project is to estimate the feasibility of construction of the Experimental Demonstration Unit(EDU) for high purity aluminium production at one of aluminium smelters of Bharat Aluminium Company Ltd., in India.

2.2 Initiator of the Project

The initiator of the project of the EDU construction is Bharat Aluminium Company Limited(BALCO), a Government of India undertaking. BALCO was founded in the year 1965. The head office is located in New Delhi(Punj House, 18 Nehru Place, New Delhi-110019).

The existing Alumina-Aluminium Complex at Korba under BALCO consists of:-

- Bauxite mine,
- Alumina plant;
- Smelter;
- Fabrication Complex;

Besides this, the Company also manages the Jaykaynagar Smelter([illegible] unit Smelter), located about 250-300 km from Calcutta.

Contd.....P/3

?.3 Executor for the preparation of Support Study (Interim Report)

In accordance with contract between UNIDO (United Nations Industrial Development Organisation) and V/o TSVETMETPROMEXPORT the preparation of Interim Report has been assigned to All-Union Research and Design Institute of Aluminium, magnesium and Electrode Industry (VAMI) of the ministry of Non-Ferrous metallurgy of the U.S.S.R, Leningrad, V.o Srednly prospect, 86.

Contd......P/4

3.0 Market and EDU capacity for production of high purity aluminium.

3.1 Brief survey of Indian market

At present, India is not producing high purity aluminium and the demand of the local market is totally covered by imported supplies.

The main field of high purity aluminium application is the production of aluminium capacitors. At present the demand for high purity aluminium is 250 tpy, and in the year of 1989-1990 it will grow to about 500 tpy.

3.2 Capacity of the EDU for high purity aluminium production.

The normal rated capacity of 540 tpy of high purity aluminium adopted for the Demonstration Unit. The above capacity is determined by the following factors :

- the analysis of demand for high purity aluminium in India;
- the unit capacity of the refining cell to be installed;
- the assumed number of cells

The 70 KA refining cell is adopted for the EDU, being the most powerful cell for high purity aluminium production in the world practice at present. The average annual cell production is 180 tpy. with the highest technical and economic parameters. Three cells are adopted for installation. This number is provided for the possibility to have a middle cell in the EDU composition. This middle cell is a typical cell for an industrial production, having the most advantageous magnetic field and current distribution by cathodes, as compared with end cells, ensuring the optimal conditions for the refining process.

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3.3 Production programme

High purity Al grades	99.995	99.99	99.97	99.95
Percentage of production	1.0	45.0	45.0	9.0

The quality of high purity aluminium is given in Table below :

Sl. No.	Aluminium content, min	Percentage of impurities maximum					Aluminium grade as per Soviet Standard
		Fe	Si	Cu	Zn	Ti	
1.	99.995	0.0015	0.0015	0.001	0.001	0.001	.995
2.	99.99	0.003	0.003	0.003	0.003	0.002	A99
3.	99.97	0.015	0.015	0.005	0.003	0.002	A97
4.	99.95	0.030	0.30	0.015	0.005	0.002	A95

Note: The grade of aluminium is determined by substraction of total content of specified impurities (Fe, Si, Cu, Zn and Ti) from 100%.

4.0 Materials and Utilities

4.1 Classification of materials

For the production of high purity aluminium the following materials are used :

- raw materials:primary aluminium (technical grade) produced by electrolysis of cryolite-alumina melt.
- industrial materials : electrolytic copper and graphite.
- auxiliary materials: barium chloride, cryolite, aluminium fluoride and sodium chloride (common salt)
- Utilities : power, compressed air, fuel oil, soda and water.

4.2 Supply programme and sources

Sl. No.	Description of material	Unit of measure	Annual requirement EDU location		Sources of supply
			at Korba smelter	at Jaykaynagar smelter	
1.	Primary aluminium (technical grade), liquid	t	556	-	Cell-rooms of Korba Smelter
2.	Primary aluminium, (technical grade), solid	t	-	559	Korba Smelter
3.	Barium chloride ($Ba\ Cl_2\ 2H_2O$)	t	18.5	18.5	Calcutta
4.	Cryclite	t	6.8	6.8	Bombay
5.	Aluminium fluoride	t	8.1	8.1	-same-
6.	Sodium chloride (common salt)	t	2.5	2.5	Calcutta
7.	Copper	t	8.7	8.7	Tatanagar
8.	Graphitized electrodes	t	8.1	8.1	Bhopal
9.	AC power	KW.h	10.2×10^6 - 10.37×10^6		Madhya Pradesh State Electricity Board.
10.	AC power Additionally	KW.h	-	10.2×10^6 - 10.37×10^6	West Bengal State Electricity Board.
	Additionally				
11.	Soda ($Na_2\ CO_3$)	t	-	45.0	Calcutta
12.	Fuel oil ($Q = 9,400$ K Cal/kg)	t	-	34.0	Calcutta

5. PROJECT ENGINEERING

5.1 List of industrial and auxiliary units of the EDU.

5.1.1 Industrial(technological)units;

- Installation of refining cells(with gas cleaning) for high purity aluminium production.

  On the basis of forecast evaluation of the high purity aluminium demand in India and the adopted EDU capacity three -70KA refining cells are to be installed;

  A 15t capacity bridge crane is required for the operation and repair of the refining cells.

- Section for high purity aluminium pigs and ingots casting.

5.1.2 Auxiliary units

- Section for salts drying and feed preparation. Composition of feed; dehydrated(dried)salts of $BaCl_2.2H_2O$, NaCl, as well as cryolite and aluminium fluoride;

- Taking into consideration that usually the high purity aluminium is produced only at operational aluminium smelters, the ladle lining and heating for the high purity Al.production and the manufacturing of cathodes and bottom blocks(for cell capital repairs) are carried out in the Smelter auxiliary service shops.

It is to be noted that the cupola melting furnace is required in composition of the Smelter Auxiliary Service shops for the production of liquid(melted) cast iron used for manufacturing of cathodes and bottom blocks.

Contd....P/9

5.2 Technology

At present the high purity aluminium is commercially produced by electrolytic refining of primary aluminium by triple-layer method. This method ensures the production of high purity aluminium of A95-A995 grades. For the high purity aluminium(HPA) production the liquid primary aluminium is fed to the cells where the process of aluminium electrolytic refining takes place. Periodically the copper is added into the cell with aluminium to correct the composition of anodic alloy. For the periodical preparation of electrolite one refining cell is selected. This cell is equipped with a hood and gasduct and its cavity is deeper. Electrolyte is profuced in this cell by melting of barium chloride, cryolite, aluminium fluoride and sodium chloride and by electrochemical refining of electrolyte. Cathodes are also impregnated in the electrolyte.

The high purity aluminium produced is transported for casting of pigs and ingots. The anodic sediment and electrolytic crust are removed periodically from the cells. The anodic sediment containing aluminium, copper, Iron and silicon, in accordance with the USSR experience can be used as a secondary raw material for copper smelting. The electrolytic crust containing aluminium, alumina and electrolyte is transported to the dump. The flue-gases from the electrolyte preparation and cathode impregnation cell are to be cleaned.

5.3 Brief Characteristic of EDU process equipment.

The main process unit of the EDU for high purity aluminium production is a refining cell. Brief technical characteristic of the cell is given in Table below:-

S.No.	Description	Unit of measure	Value
1.	Amperage	KA	70
2.	Current density	A/sq.cm	0.6
3.	Current efficiency	%	93-95
4.	DC power consumption for the refining cell	KW hour/t	17,000
5.	Duration of cell operation between overhauls (capital repairs)	Years	5.0

Contd.......P/11

6.0 Region of the EDU location

6.1 Considered location site

In accordance with the UNIDO contract No.85/2 the following states for the EDU location were to be considered :

- Madhya Pradesh State, the operating BALCO's Smelter in Korba region;
- West Bengal State, the non-operational BACC's Smelter in Jaykaynagar region.

6.2 Korba Aluminium Smelter

The capacity of the Smelter is 100,000 tpy of primary aluminium. 100 KA cells with vertical anode studs are installed at the Smelter. The Smelter consists of raw cells-lines with gas-cleaning plants. Each cell-line consists of four cell-rooms. Fifty one cells are installed in one cell-room, the cells being arranged in single row, end-to-end.

The cell-rooms are equipped with erection crane of 80/20 t capacity and two process operation cranes of 8/12.5 t lifting capacity.

The smelter is power supplied from the operating power plants (State sector) located in Korba region. In 1985 BALCO had started the construction of a captive power plant of 270 MW capacity, the first unit to be commissioned in 1987.

The cell-line (4 cell-room) is supplied with power from the Silicon Rectifier Sub-station consisting of 6 rectifier units (Outlet parameters of the rectifiered current : 950 V, 22 KA)

High skilled manpower is available at the Smelter.

6.3 Aluminium Smelter at Jaykaynagar.

The Jaykaynagar Smelter was constructed and commissioned 40 years ago under the design of the Company.Alusuisse Switzerland.

The Jaykaynagar plant consisted of alumina plant, Smelter and Fabrication Complex. The production of the Smelter was 9000 tpy. The cell-room No.1 is equipped with 24 KA horizontal stud cells, and the cell-room No.2 with 50 KA vertical studs cells.

During last 15 years the capacities of alumina and aluminium production have not been operated. The cell-rooms and the Rectifier Sub-stations are not used.

The structures and the equipment of cell-room No.1 have a high level of wear and high investment is required for their restoration.

The conditions of the cell-room No.2 and the Rectifier Sub-station are satisfactory. 56 cells are installed in cell-room No.2. The cells are arranged in two rows, end-by-end. The cell-room is equipped with E.O.T. cranes of 12.5 t capacity.

Four rectifier units are installed at the Rectifier Sub-station. The rectifier amperage is 16.8 KA, minimal possible voltage 78 V. At present the Fabrication Complex is power supplied from the StateElectricity Board.

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6.4 Main factors for selection of the EDU location.

The location of the EDU for high purity aluminium production was selected jointly with BALCO, taking into consideration the following factors.

- supply of primary aluminium in liquid form directly from the cell-room;
- possibility of utilisation of the existing equipment;
- Transportation costs of raw materials and inputs;
- reliability of power supply;
- availability of skilled labour;
- required investment and production costs for construction and operation of EDU
- Rate of return on total invested capital and loan repayment period.

Contd.....P/14

6.5 Evaluation of main factors for selection of EDU location;

Sl. No.	Factor description	Evaluation of factors by sites	
		Korba	Jaykaynagar
1.	2.	3.	4.
1.	Supply of primary aluminium for EDU	Liquid aluminium is supplied from cell-room	Supplied in pigs from Korba Smelter followed by remelting and additional expenditures for fuel oil for this purpose.
2.	Possibility of utilization of existing equipment and services.		
2.1	Process cranes for operation and repair of cells	Process and erection cranes is used.	Process crane is used after its inspection and restoration repair.
2.2	Gas-cleaning plant	Used	Is to be constructed.
2.3	Equipment of Rectifier Sub-station (Rectiformers)	Used	Installation of 4 new **rectifiers** is required including instruments for power consumption measurement.
2.4	Salts drying section	The existing furnace **in** foundry shop **is** used.	The purchase or installation of furnace for salts drying is required.
2.5	Ladle repair and cathodes manufacturing.	Is carried out in the existing service repair workshop	Setting-up of a special repair shop is required.

Contd...../15

1.	2.	3.	4.
3.	Transportation costs for raw materials and inputs	29,100 1) x 22 2) = Rs. 640,200	689,505 1) x 22 2) = Rs. 15,169,100
	1) Estimation of cargo turn-over quantities is given in Annexure-1. 2) Rs. 22- Railway tariffs calculated per 1 tonne/km of cargo to be transported.		
4.	Reliability of power supply	At present the power is supplied from Madhya Pradesh State Electricity Board. In 1985 the construction of Captive power plant was started to increase the reliability of Smelter power supply.	Power is supplied from West Bengal State Electricity Board. There is a shortage of power supply to the consumers.
5.	Availability of skilled manpower	High skilled labour and engineering staff are available.	Skilled manpower for operation and mainte- nance of the [illegible] is not available.
6.	[illegible] and production [illegible] for construction and operation of [illegible]		
6.1	[illegible]	. [illegible]	. [illegible]
6.2	[illegible]	[illegible] = [illegible]	[illegible] = [illegible]

[illegible] 16

1.	2.	3.	4.
6.3	Total production costs 3)	Rs. 23,349,000	Rs. 25,440,000
6.4	Specific production costs	Rs. 23,349,000 / 540t = = 44,165 Rs/t	Rs. 25,440,000 / 540t = = 47,111 Rs/t

3) Cost estimates are given in Annexure-2.

7.	Rate of return and loan repayment period		
7.1	Rate of return 4)	24%	9.[illegible]%
7.2	Repayment period 4)	3.3 years	6.[illegible] years

4) calculations are given in Annexure-2.

Contd......P/17

ANNEXURE- I

Calculations of cargo turn-over by the EDU location sites.

Sl. No.	Material description	Source of supply	Korba Distance km	Korba Annual quantities to be transported, t	Jagdalpur Distance km	Jagdalpur Annual qtys to be transported, t
1.	Aluminium	Korba	-	-	950	650
2.	[illegible] chloride and sodium chloride	Calcutta	700	24.5	250	24.5
3.	Cryolite and aluminium fluoride	Bombay	-	-	1650	17.5
4.	[illegible]	Bhopal	[illegible]	9.5	1050	9.5
5.	Copper	[illegible]	500	[illegible].7	[illegible]	[illegible].7
6.	Soda	Calcutta	-	-	250	45.0
7.	Fuel oil	Calcutta	-	-	250	34
	Total			[illegible].7		7[illegible]1.[illegible]
8.	Cargo turnover, in tonne-km			[illegible],100		[illegible],[illegible]5

Contd.......P/18

ANNEXURE-2

FINANCIAL ANALYSIS

Financial analysis of support studies was worked out in accordance with UNIDO manual for the preparation of Industrial Feasibility Studies, Annex-III, item A.9

A.9.1 INVESTMENT COSTS

Rs, 000/-

Sl. No.	Cost and unit description	Korba	Jaykaynagar
1.	2..	3.	4.
A.	INITIAL FIXED CAPITAL COSTS		
1.	Buildings and structures		
1.1	DDU	3,436 1)	3,273 2)
1.2	External bus-bar trestle	130	-
1.3	Internal bus-bar	1,292	-
1.4	Gas cleaning plant and salt preparation section,	-	1,800
1.5	Contingencies (10%)	4[illegible]9	507
	Total of 1	5,377	5,5[illegible]0
2.	Equipment and materials		
2.1	Main process equipment	2,442	2,442
2.2	Auxiliary equipment	49	269
2.3	Materials (including cell-room lining)	935	1,103
2.4	Gas cleaning equipment	-	1,015
2.5	Salt preparation section	-	660
2.6	Electrical equipment	120	4,9[illegible]0 3)
2.7	Instrumentation and DC power rectifying system	173	156
[illegible]	[illegible]	[illegible]7	[illegible]
[illegible]	[illegible] (10%)	[illegible]	[illegible]
	[illegible]	4,[illegible]	11,[illegible]
	[illegible]	[illegible]	17,[illegible]

......./19

(1)	(2)	(3)	(4)
B.	Fixed Capital (residual cost of existing assets)	-	905
C.	PRE-PRODUCTION COSTS	3,434	3,963
	Total of Initial Fixed Costs (A+B+C)	13,019	22,436
D.	MARGIN MONEY (35% of working Capital	648	756
E.	Interest during construction	427	698
	TOTAL INITIAL INVESTMENT COSTS	14,087	23,940
F.	Working Capital	1,200	1,405
	Total INVESTMENT COSTS	15,287	25,345

Note: 1) Extension of the operating cell-room No.5 for the EDU.

2) Capital repair and restoration works of the existing cell-room No.2 including dismantling of 14 cells for installation of the EDU at their place.

3) Four rectiformer units are to be installed at the Rectifier Sub-station.

A.9.2 Financing sources

Rs. 000

Sl. No.	Financing Sources	Korba	Jaykaynagar
1.	Equity capital	7,043	11,517
2.	Long-term national (@ loan 12.5% interest rate	7,044	11,518
3.	Short-term bank loan on working capital (@ 17.5% interest rate)	1,200	1,405
	TOTAL	15,287	24,440

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A.9.3 Annual PRODUCTION COSTS

Sl. No.	Cost Category	Unit of measure	Unit Cost Rs	Korba Quantity	Korba Cost, Rs.000	Jaykaynagar Quantity	Jaykaynagar Cost Rs.000
1.	2.	3.	4.	5.	6.	7.	8.
1.	MATERIALS						
1.1	Aluminium	t	22,404	556	12,457	559	12,524
1.2	Barium Chloride	t	22,000	18.5	407	18.5	407
1.3	Cryolite	t	20,233	6.8	138	6.8	138
1.4	Aluminium fluoride	t	22,562	8.1	183	8.1	183
1.5	Sodium chloride	t	14,000	2.5	35	2.5	35
1.6	Graphite	t	40,000	8.1	324	8.1	324
1.7	Copper	t	50,000	8.7	435	8.7	435
1.8	Soda	t	3,000	3,103	202	45	135
1.9	Fuel oil	l	3360	-	-	34	114
	Total of 1		-	-	14,131	-	14,295
2.	UTILITIES						
2.1	AC power	1000 KW.hr	536 / 520	10,370	5,558	10,370	5,392
2.2	Compressed air	ncu.m	1.6	324,000	518	324,000	518
	Total of 2		-	-	6,076	-	5,910
3.	Wages & Salaries		-	-	270	-	556
4.	Repair & maintenance						
4.1	of equipment (2.5%)	Rs.000	-	4,201	105	12,033	301
4.2	of buildings and structures (0.5%)	Rs.000	-	5,377	27	5,580	28
	TOTAL OF 4		-	-	132	-	329

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5.	Overhead costs (@ 5% of estimated costs)	Rs.000	-	-	1,033	-	1,035
6.	Sales costs	-do-	-	-	635	-	635
	TOTAL OPERATION COSTS	-do-	-	-	22,327	-	22,780
7.	Depreciation	-do-	-	-	984	-	1,894
8.	Interest	-do-	-	-	320	-	766
	TOTAL PRODUCTION COSTS	-do-	-	-	23,[illegible]	-	25,440
	SAME, Calculated per 1 t of high purity aluminium	Rs.	-	-	44,135	-	47,111

Notes: 1) At Korba site the soda liquor of the operating gas-cleaning plant is used.

2) The figure in numerator - the cost of soda liquor
the figure in denominator - the cost of soda

3) Numerator - the cost of power at Korba site, denominator - the cost of power at Jaykaynagar site.

9.4 COMMERCIAL PROFITABILITY

Sl. No.	Description	Unit of measure	Korba	Jaykaynagar
1.	Total investment costs	Rs.000	15,237	25,345
2.	Annual output of high purity aluminium	t	540	540
3.	High purity aluminium sales price	Rs/t	50,000	50,000
4.	Sales revenue (it.3xit.4)	Rs.000	27,000	27,000
5.	Operation costs	-do-	22,327	22,780
6.	Gross profit (it.4-it.5)	-do-	4,673	4,220
7.	Depreciation	-do-	994	1,894
8.	Interest	-do-	528	766
9.	Net profit (6-7-8)	-do-	3,151	1,560
10.	Rate of return $\left(\frac{\text{it } 9+8}{\text{it.} 1} \times 100 \right)$		24	9.2
11.	Loan repayment period	Years	3.3	6.0

Annex 2

Number of the switched off pots in potroom N 75

Initial data:

- Number of EDU pots	3 pcs
- Average voltage of the EDU refining pots	5.7 V
- Rated voltage at the transformer station	950 V
- Voltage drop at the transformer unit busbar and voltage reserve	15 V
- Average voltage drop at the aluminium pot	4,567 V
- Anode effect voltage	30 V
- Frequency of anode effects	1 per day
- Duration of anode effects	3,0 min

. Operating voltage at the pot is:

$$4{,}567 - \frac{30 \cdot 3}{24 \cdot 60} = 4{,}504 \text{ V}$$

. Voltage drop at the EDU pots is:

$$5.7 \cdot 3 = 17.1 \text{ V}$$

. Number of pots to be switched off is:

$$17{,}1 : 4{,}504 = 3{,}8 \cong 4 \text{ pieces}$$

Thus, according to the first version of the EDU pots arrangement 3 pots are dismantled and one is switched off, according to the second version 4 pots are to be switched off. In some short periods of the EDU pots operation general voltage drop increase will occur, namely:

- by 1÷4 V during 7 days once in 60 days when one of the pots is operating for the electrolyte preparation and cathodes impregnation,
- by 1÷8 V during 3-4 days at the start-up, once in 4,3 years,
- by 1÷5 V during 3-4 days once in 1÷1.5 at ledge removal etc.

This does not affect the operation of the pots.

Annex 3

Comparison of standards for high purity aluminium

Impurities in metal	COMECON standard ST SEV 950-78 "Primary Al. Grades"			USSR GOST 11069-74 "Primary aluminium. Grades"				GDR standard TGL 14712/01-80 "High purity Al and pure Al in ingots"			FRG DIN 1712 1977	
	Grades, %			Grades, %				Grades, %			Grades, %	
	A199,995	A199,99	A199,95	A995	A99	A97	A95	A199,99	A199,95	A199,9	A199,992	A199
Al, not less than	99,995	99,99	99,95	99,995	99,99	99,97	99,95	99,99	99,95	99,9	-	-
Impurities, not more than												
Fe	0.0015	0.003	0.03	0.0015	0.003	0.015	0.03	0.003	0.025	0.05	0.005	0.0
Si	0.0015	0.003	0.03	0.0015	0.003	0.015	0.03	0.003	0.02	0.04	0.006	0.0
Cu	0.001	0.003	0.015	0.001	0.003	0.005	0.015	0.003	0.015	0.03	0.003	0.0
Zn	0.001	0.003	0.005	0.001	0.003	0.003	0.005	0.003	0.005	0.005	0.005	0.0
Ti	0.001	0.002	0,002	0.001	0.002	0.002	0.002	0.002	0.002	0.01	0.002	0.0
Other impurities each not more than	0.001	0.001	0.005	0.001	0.001	0.002	0.005	0.001	0.005	0.01	0.001	0.0
Total impurities each not more than	0.005	0.010	0.05	0.005	0.010	0.03	0.05	0.01	0.05	0.1	0.01	0.1

2) The aluminium content is indicated as a part of 100 %

3) As other impurities are tolerated Mg, Mn, Cr, V, Zn, Pb, Ni

4) On agreement between producer and consumer in aluminium destinated for Al-Mg alloys with Mg content more than 3 %, the sodium content must not exceed 0,002 wt%

1) On agreement between producer and consumer in aluminium destinated for anodizing the iron content must not exceed 0.025 %, silicium - 0,020 wt%.

SECTION 1

Annex 3

[illegible]		FRG DIN 1712 1977 grades, %		Hungary Standard MSZ [illegible] "Primary aluminium, Ingots" (instead of MSZ [illegible]) grades, %						Japan JIS for refined aluminium [illegible]-1968 grades, %			Poland [illegible] "Primary aluminium. Grades" 2) grades, %		
,55	A199,9	A199.992	A199.9[illegible]	A199,995	A199,99	A199.99R	A199,97	A199,95	A199,9[illegible]	special class	class 1	class 2	A199,995[illegible]	A199,99[illegible]	A199,9[illegible]
5	99,9	-	-	99,995	99,99	99,99	99,97	99,95	99,9	99,995	99,990	99,950	99,995	99,99	99,95
25	0.05	0.005	0.035	0.0015	0.003	-	0.015	0.03	0.05	0.002	0.005	0.020	0.0015	0.003	0.030[1]
2	0.04	0.006	0.050	0.0015	0.003	-	0.015	0.03	0.04	0.002	0.005	0.020	0.0015	0.003	0.030[1]
15	0.03	0.003	0.005	0.001	0.003	-	0.005	0.010	0.03	0.002	0.005	0.010	0.0015	0.003	0.010
5	0.005	0.005	0.04	0.001	0.003	0.001	0.004	0.005	0.005	-	-	-	0.001	0.003	0.005
2	0.01	0.002	0.006	0.001	0.002	0.001	0.002	0.002	0.01	-	-	-	0.001	0.002	0.002
5	0.01	0.001	0.003	0.001	0.001	0.001	0.002	0.005	0.01	-	-	-	0.001[3,4)]	0.001	0.005
3	0.1	0.01	0.1	0.005	0.010	0.010	0.03	0.05	0.10	-	-	-	0.005	0.005	0.05

5,

ed

SECTION 2

E V A L U A T I O N

of the EDU location in extended part of cell-room N° 78

As per the request of Indian side the variant of the EDU location in extended part of cell-room N° 78 of Korba Smelter was also considered in the Feasibility Report.

In this case all technical concepts of the Unit will be similar to its location in cell-room N° 75.

Taking into consideration that the distance between the cell-room N° 78 and the SCR (silicon control rectifier) station is longer as compared with cell-room N° 75, the implementation of this variant results in additional consumption of aluminium bus-bars for positive buswork and DC power due to its higher losses in positive bussing.

The results of the techno-economic comparison of the EDU locations in cell-rooms Nos.75 and 78 are given in

SRL N°	Description	Unit	Variants of EDU location	
			cell-room N° 75	cell-room N° 78
1	2	3	4	5
1	DC power supply		From existing	SCR station N° 858
2	Additional bussing:			
	- length	m	20	59
	- weight of busbars	t	14	40
	- same, in percents	%	100	290
3	DC power consumption:			
	- specific	kWh/t	18500	
	- annual	kWh/year	$9.99x10^6$	$10.24x10^6$
	- same, in percents	%	100	102.5
4	Total capital cost	Rs.000	22670	23924

1	2	3	4	5
5	Annual operating costs	Rs.000	21588	21729
6	Internal rate of return:			
	- on investment	%	15.3	14.2
	- on equities	%	14.7	12.4
7	Break-even point	%(t)	65.2(352)	66.8(361)
8	Pay-back period	years	5.5	6.1

Contract No 85/2
UNIDO

PROJECT REPORT FOR ESTABLISHMENT OF SUPER PURITY ALUMINIUM PRODUCTION IN INDIA

Final Report

No DP/IND/84/007

Volume II, Book I

Drawings

VAMI

V/O TSVETMETPROMEXPORT

Leningrad
1986

Contract No 85|2
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1986

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Volume I — General Explanatory Note

Volume II, Book 1 — Drawings

Volume II, Book 2 — Basic Engineering Design of Main Technological Unit (Electrolyser)

Volume III — Specifications of Equipment

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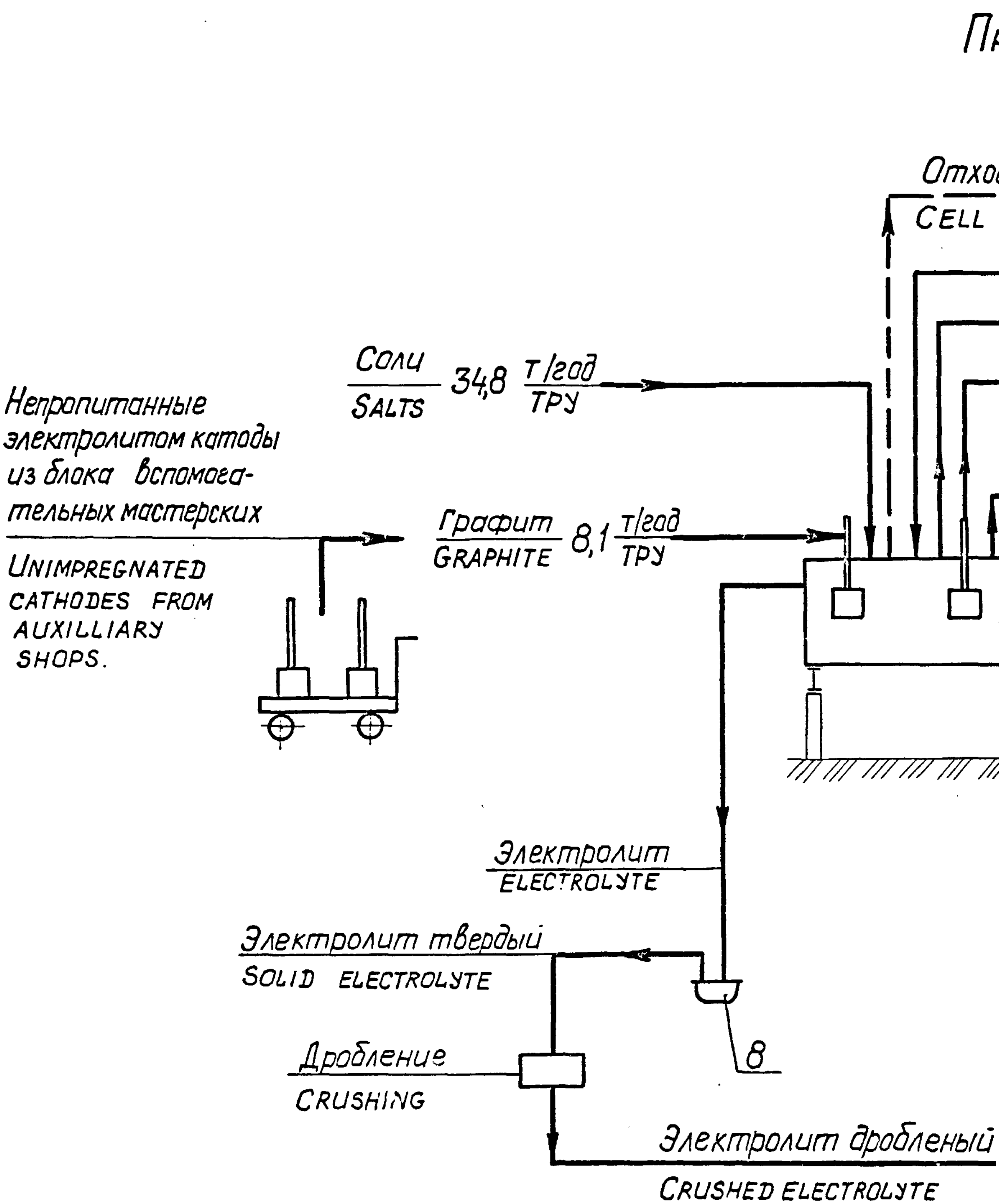
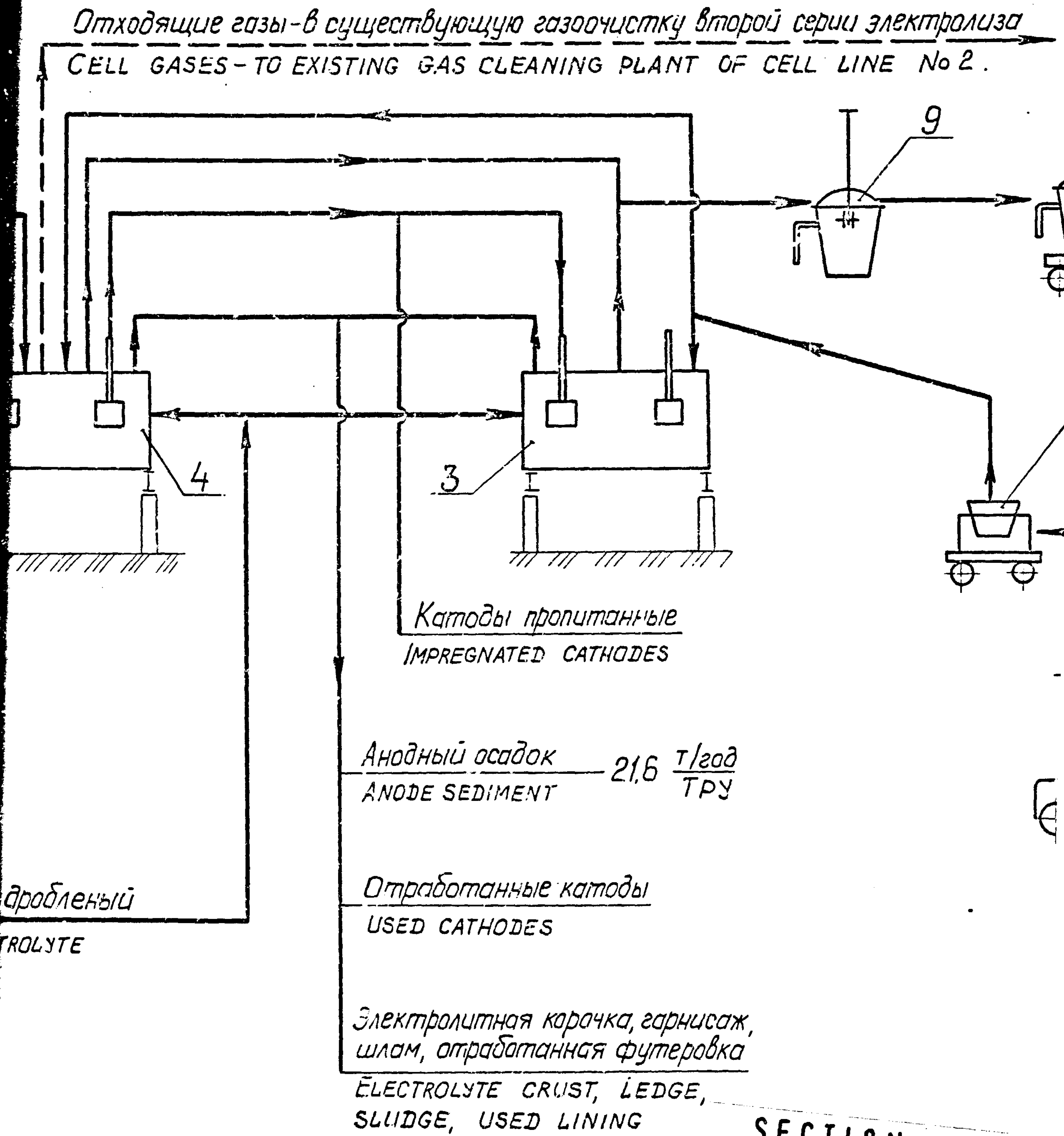
No	Drawing designation	Drawing No
	Technological drawings	
1	Process flowsheet of HPA production	1360970-TM sheet-1
2	HPA cells section (Variant I) Plans sections	1360970-TM sheet-2
3	HPA cells section (Variant II) Plans&sections	1360970-TM sheet-3
4	HPA cells section (Variant I) Busbar diagram	1360970-TM sheet-4
5	HPA cells section (Variant II) Busbar diagram	1360970-TM sheet-5
6	70 kA Cell for refining aluminium	1335338-BO
7	70 kA Cell for Electrolyte preparation and cathodes impregnation	1335339-BO
	Electrotehnical drawings	
8	Diagram and plan of busbar route (Variant I)	1247836-ЭС sheet 1
9	Diagram and plan of busbar route (Variant II)	1247836-ЭС sheet-2
10	Section of HPA cells (variant I) plans, section	1332639-AC sheet-1
11	Section of HPA cells (variant II), plans, section	1332639-AC sheet-2
12	General layout. Variant I	1367230-ГП sheet-1
13	General layout. Variant II	1367230-ГП sheet-2



SECTION 1

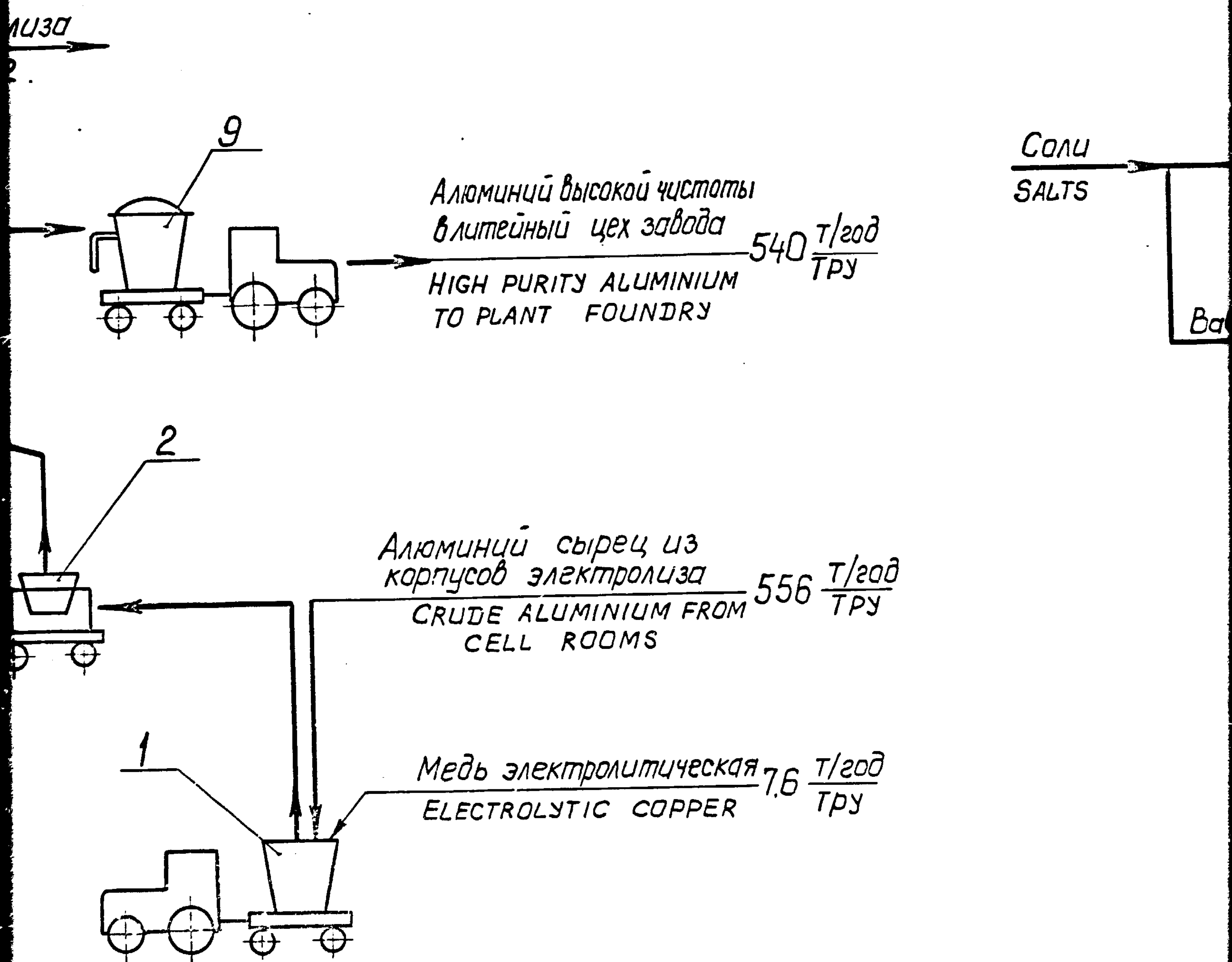
Инв. № подл. | Подп. и дата | Вз. инв. №

ПРИНЦИПИАЛЬНАЯ ТЕХНОЛОГИЧЕСКАЯ СХЕМА ПРОИЗВ
PROCESS FLOWSHEET OF HIGH PURITY AL



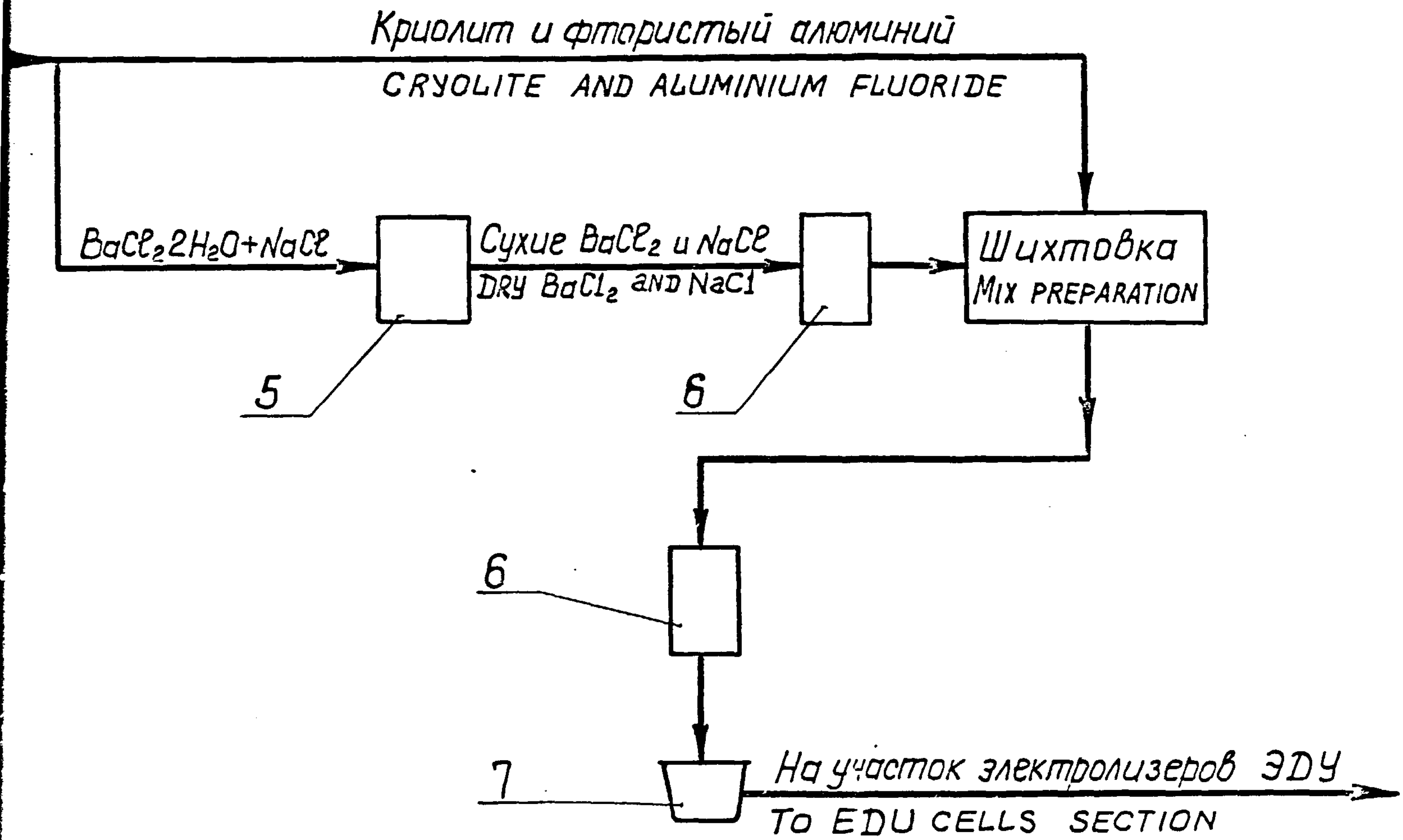
SECTION 2

РОИЗВОДСТВА АЛЮМИНИЯ ВЫСОКОЙ ЧИСТОТЫ
TY ALUMINIUM PRODUCTION



SECTION 3

Участок сушки солей и приготовления солевой шихты
SALTS DRYING AND SALT MIX PREPARATION SECTION



Примечание:
Расход катодов дан по графиту.

NOTE:

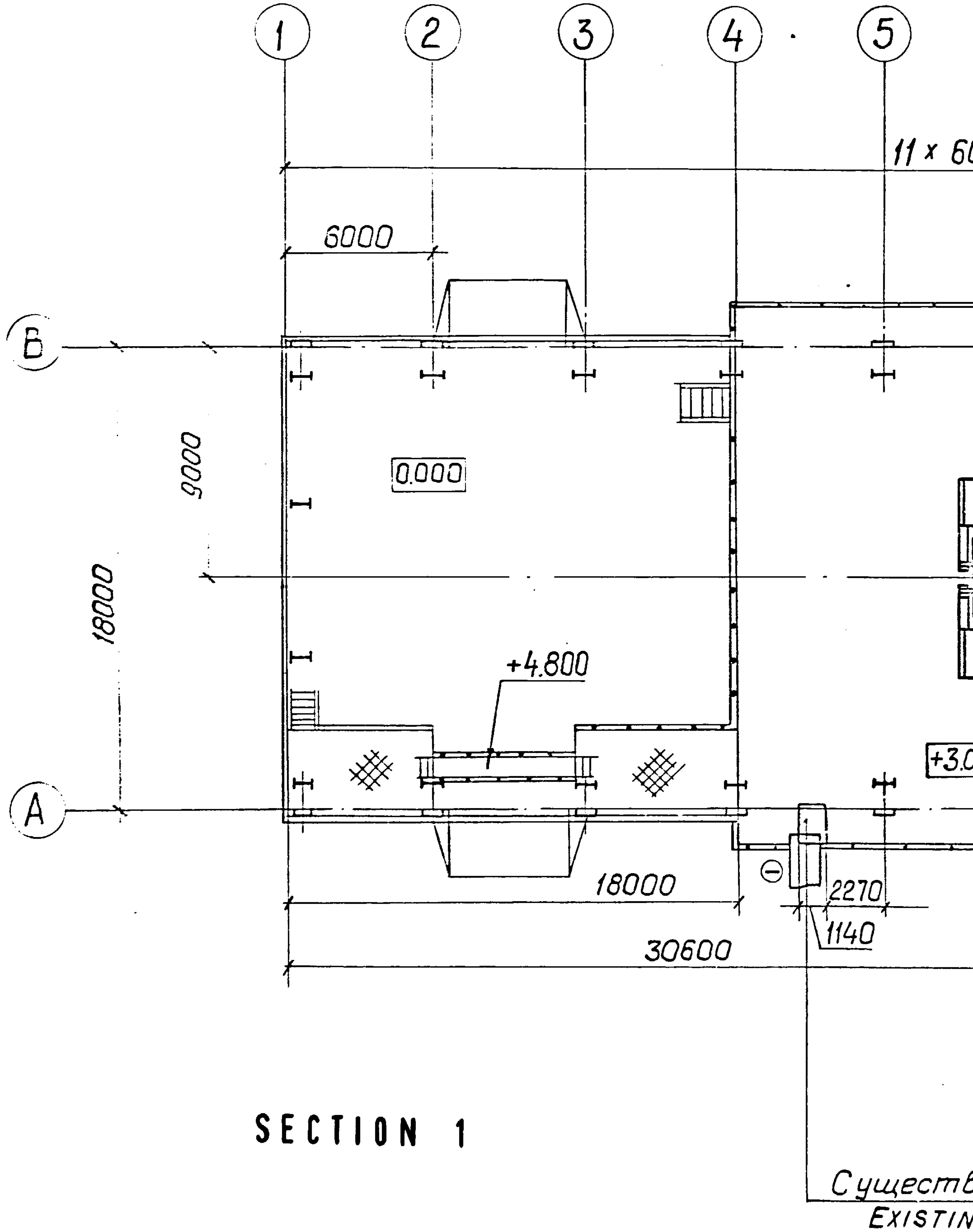
CATHODE CONSUMPTION IS GIVEN ON GRAPHITE BASIS.

SECTION 4

Поз. ITEM	Наименование DESCRIPTION	Техническая характеристика SPECIFICATIONS	Количество штук QUANTITY	Примечание REMARK
1	Ковш для алюминия-сырца LADLE FOR CRUDE ALUMINIUM	—	—	Существующий EXISTING
2	Машина заливочная POURING MACHINE	Вместимость ковша 1200 кг LADLE CAPACITY 1200 KG	2	На чертежах не показана NOT SHOWN
3	Электролизер рафинировочный REFINING CELL	Сила тока 70 кА AMPERAGE 70 KA	2	
4	Электролизер для приготовления электролита и пропитки катодов CELL FOR ELECTROLYTE PREPARATION AND CATHODE IMPREGNATION	Сила тока 70 кА AMPERAGE 70 KA	1	
5	Печь электрическая для сушки солей ELECTRIC FURNACE FOR SALTS DRYING	Электрическая мощность 1513,5 kW POWER RATING 1513,5 kW	1	Существующая EXISTING
6	Смеситель MIXER	Тип-лопастной PADDLE TYPE	2	На чертежах не показан NOT SHOWN
7	Кюбель для сухих солей BUCKET FOR DRY SALTS	Объем 1 м³ CAPACITY 1 cu.m	5	На чертежах не показан NOT SHOWN
8	Короб для электролита BOX FOR ELECTROLYTE	Объем 0,13 м³ CAPACITY 0,13 cu.m	15	На чертежах не показан NOT SHOWN
9	Вакуум-ковш VACUUM-LADLE	Вместимость 3 т CAPACITY 3 T	3	На чертежах не показан NOT SHOWN

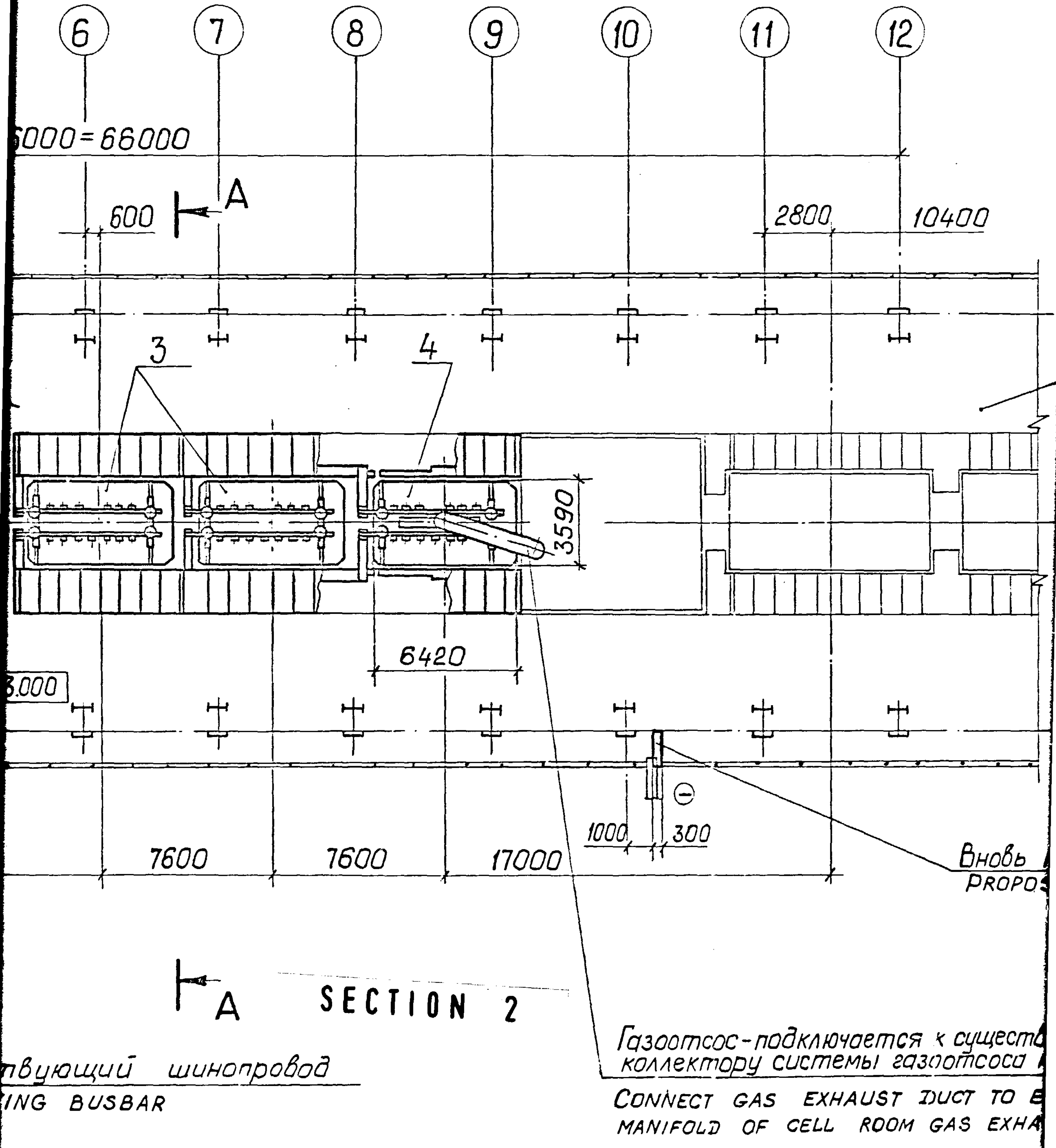
SECTION 5

ДАННЫЙ ЧЕРТЕЖ НЕ ПОДЛЕЖИТ РАЗМНОЖЕНИЮ ИЛИ ПЕРЕДАЧЕ ДРУГИМ ОРГАНИЗАЦИЯМ И ЛИЦАМ БЕЗ СОГЛАСИЯ ИНСТИТУТА ВАМИ THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	1360970-ТМ			
	Алюминиевый завод в г. Корба, Индия ALUMINIUM PLANT IN KORBA, INDIA			
	Экспериментально-демонстрационная установка для производства алюминия высокой чистоты EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
		ТЭО	1	5
	Принципиальная технологическая схема производства алюминия высокой чистоты PROCESS FLOWSHEET OF HIGH PURITY ALUMINIUM PRODUCTION	VAMI LENINGRAD		



SECTION 1

Вз. инв. №
Подп. и дата
Инв. № подл.



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коллектору системы газоотсоса
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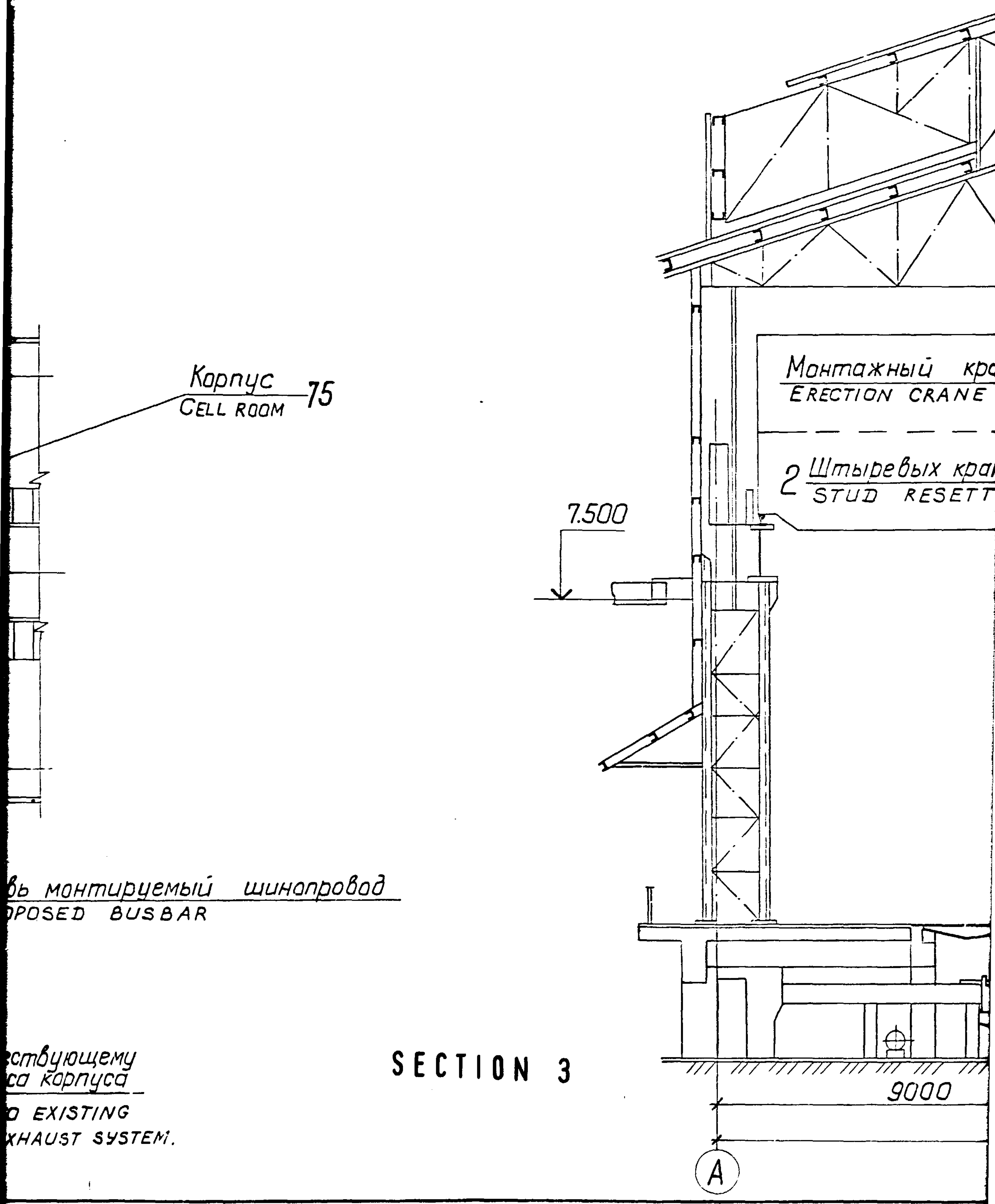
MANIFOLD OF CELL ROOM GAS EXHA
твующий шинопровод
ING BUSBAR

SECTION 2



Корпус
CELL ROOM
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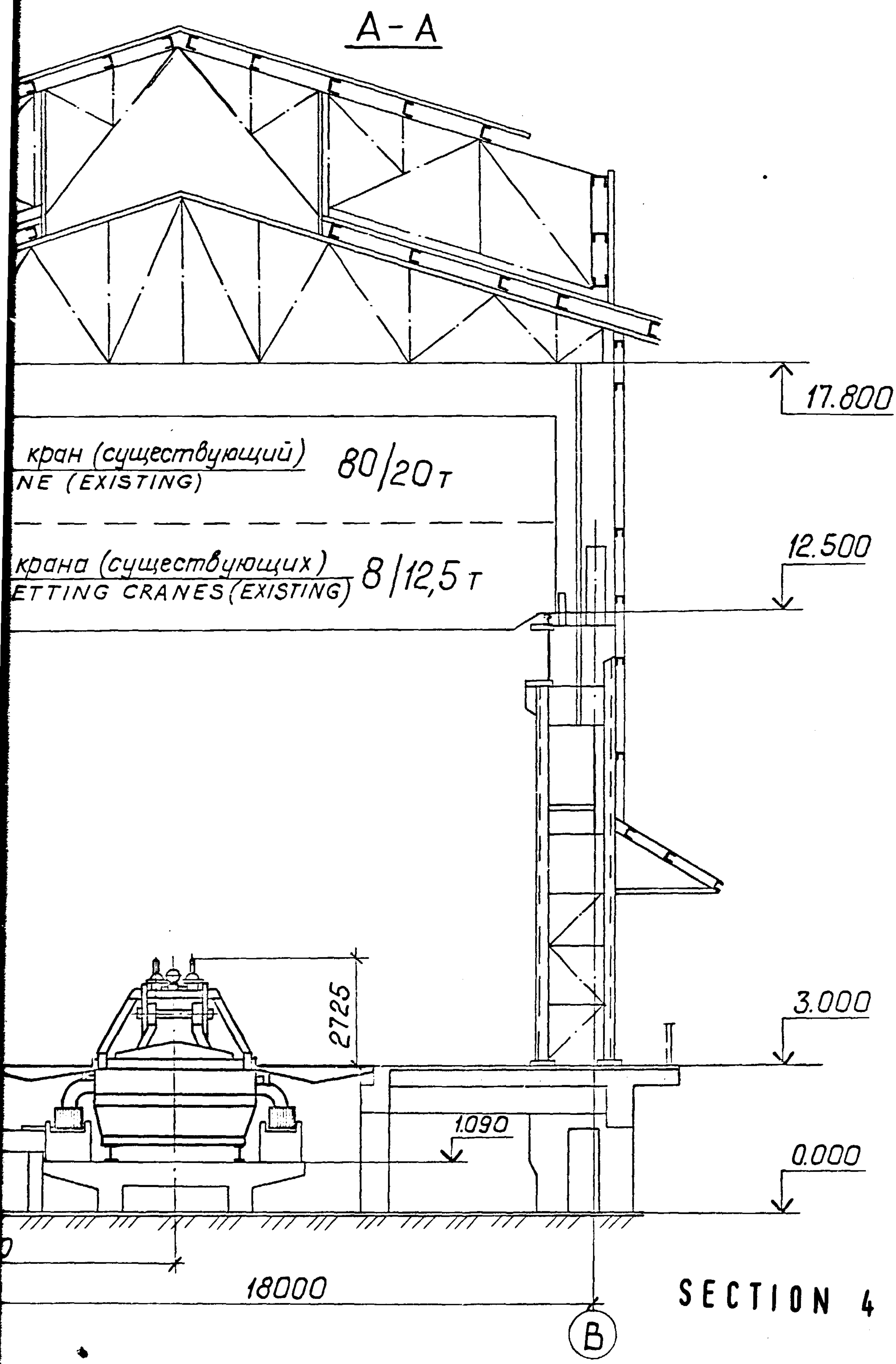
ERECTION CRANE
2 Штыревых кра
STUD RESETT
вь монтируемый шинопровод
OPOSED BUSBAR
ествующему
са корпуса
O EXISTING
XHAUST SYSTEM.
9000
A

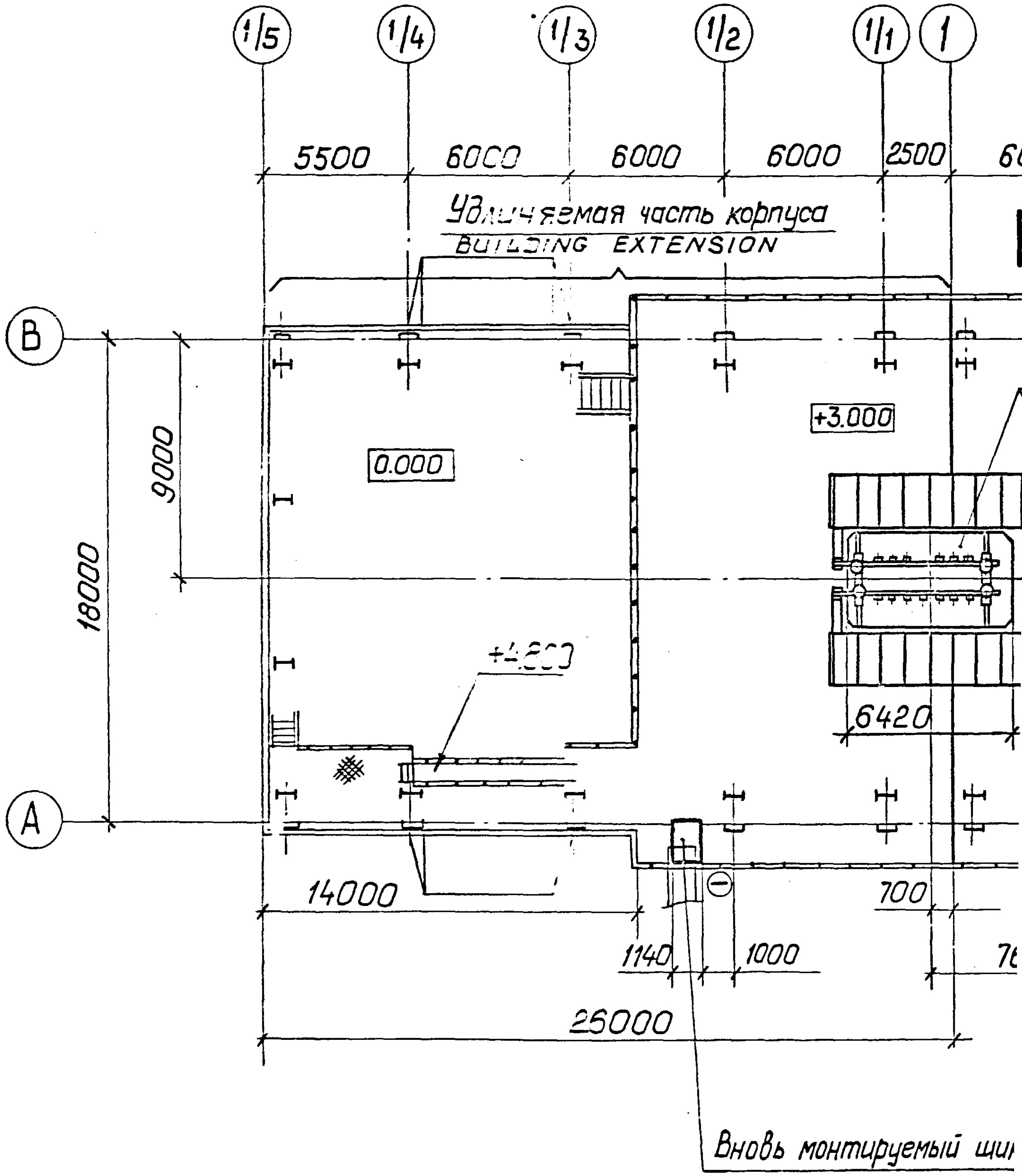
SECTION 3


A-A
17.800
кран (существующий)
NE (EXISTING)
80/20 т
12.500
крана (существующих)
ETTING CRANES (EXISTING)
8/12,5 т
2725
3.000
1.090
0.000
18000
B

SECTION 4

SECTION 5

ДАННЫЙ ЧЕРТЕЖ НЕ ПОДЛЕЖИТ РАЗМНОЖЕНИЮ ИЛИ ПЕРЕДАЧЕ ДРУГИМ ОРГАНИЗАЦИЯМ И ЛИЦАМ БЕЗ СОГЛАСИЯ ИНСТИТУТА ВАМИ	1360970-ТМ			
	Алюминиевый завод в г.Корба, Индия ALUMINIUM PLANT IN KORBA, INDIA.			
THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	Экспериментально-демонстрационная установка для производства алюминия высокой чистоты. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
		ТЭО	2	
	Участок электролизеров АВЧ. (Вариант 1). План и разрез. HPA CELLS SECTION. (VARIANT 1) PLAN AND SECTION	VAMI LENINGRAD		



SECTION 1

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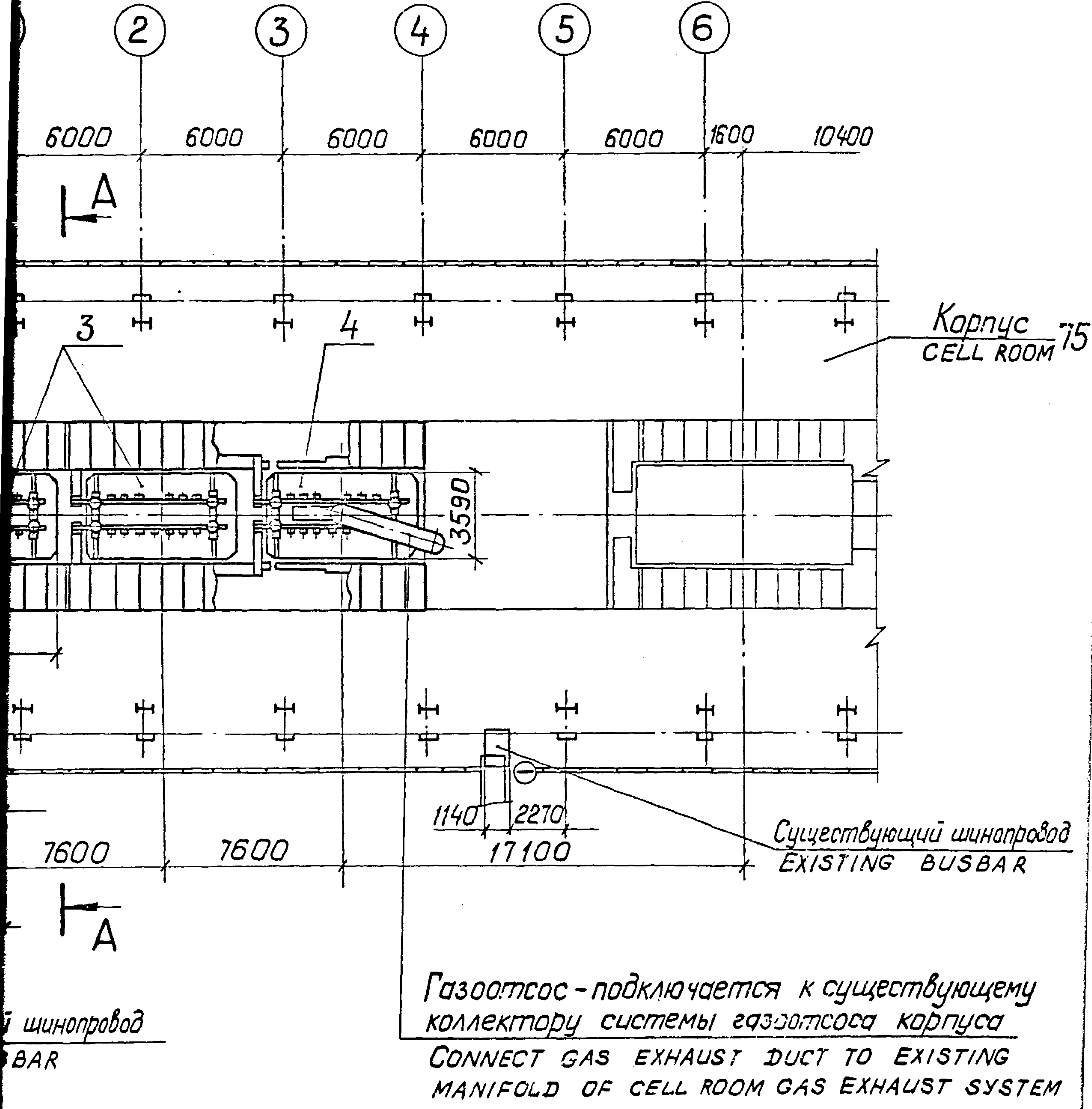
2
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6
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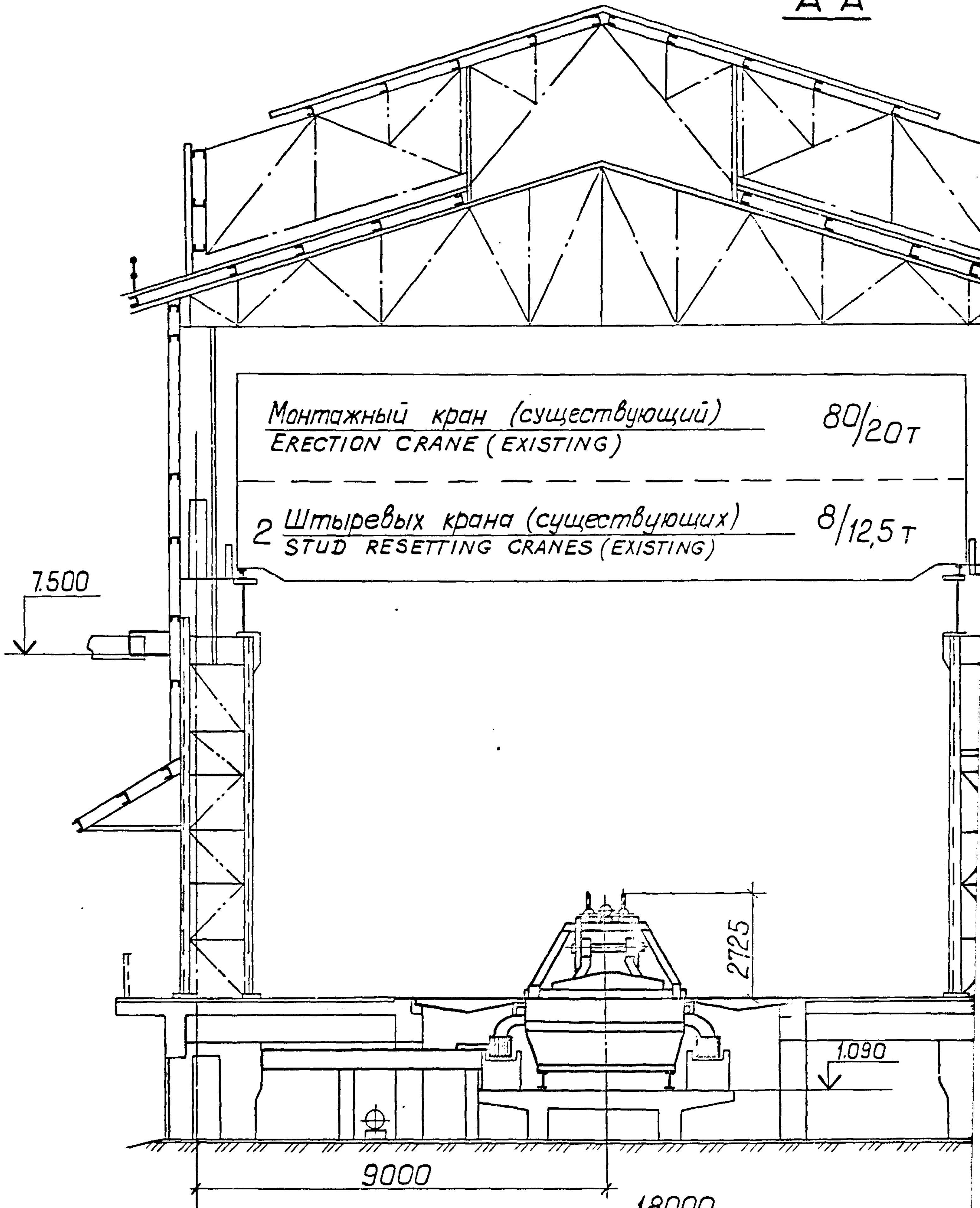
6000
6000
6000
6000
1600
10400
A
3
4
Корпус 75
CELL ROOM 75
3590
1140
2270
7600
7600
17100
Существующий шинопровод
EXISTING BUSBAR
A
й шинопровод
BAR
Газоотсос - подключается к существующему коллектору системы газоотсоса корпуса
CONNECT GAS EXHAUST DUCT TO EXISTING MANIFOLD OF CELL ROOM GAS EXHAUST SYSTEM

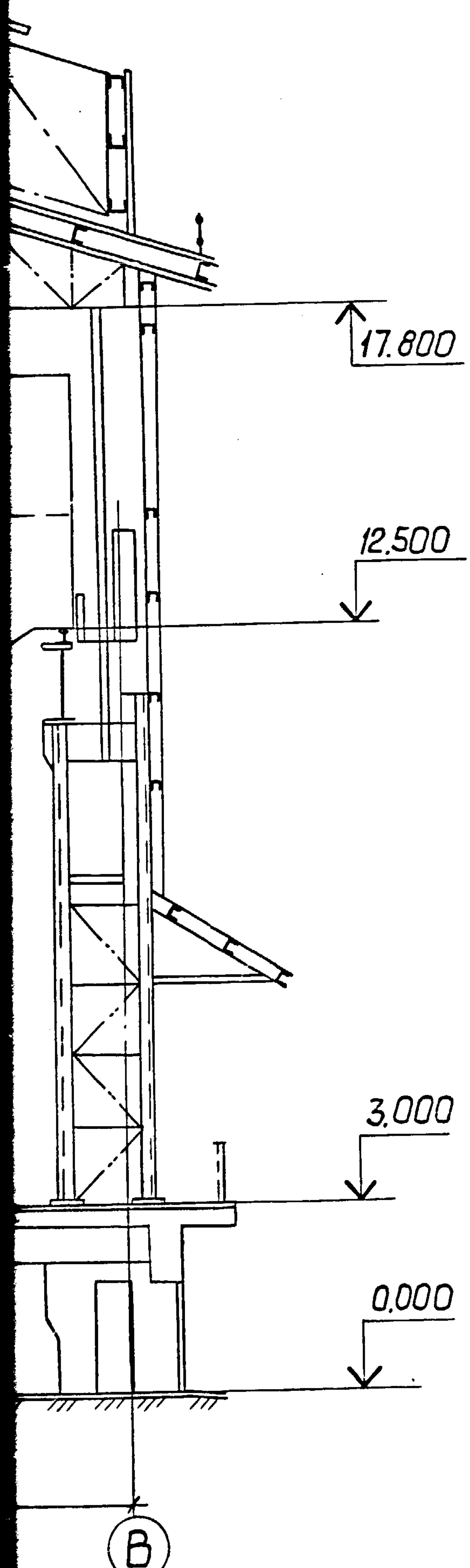
SECTION 2

A-A



Монтажный кран (существующий) 80/20т
ERECTION CRANE (EXISTING)
2 Штыревых крана (существующих) 8/12,5т
STUD RESETTING CRANES (EXISTING)
7.500
2725
1.090
9000
18000
A

SECTION 3

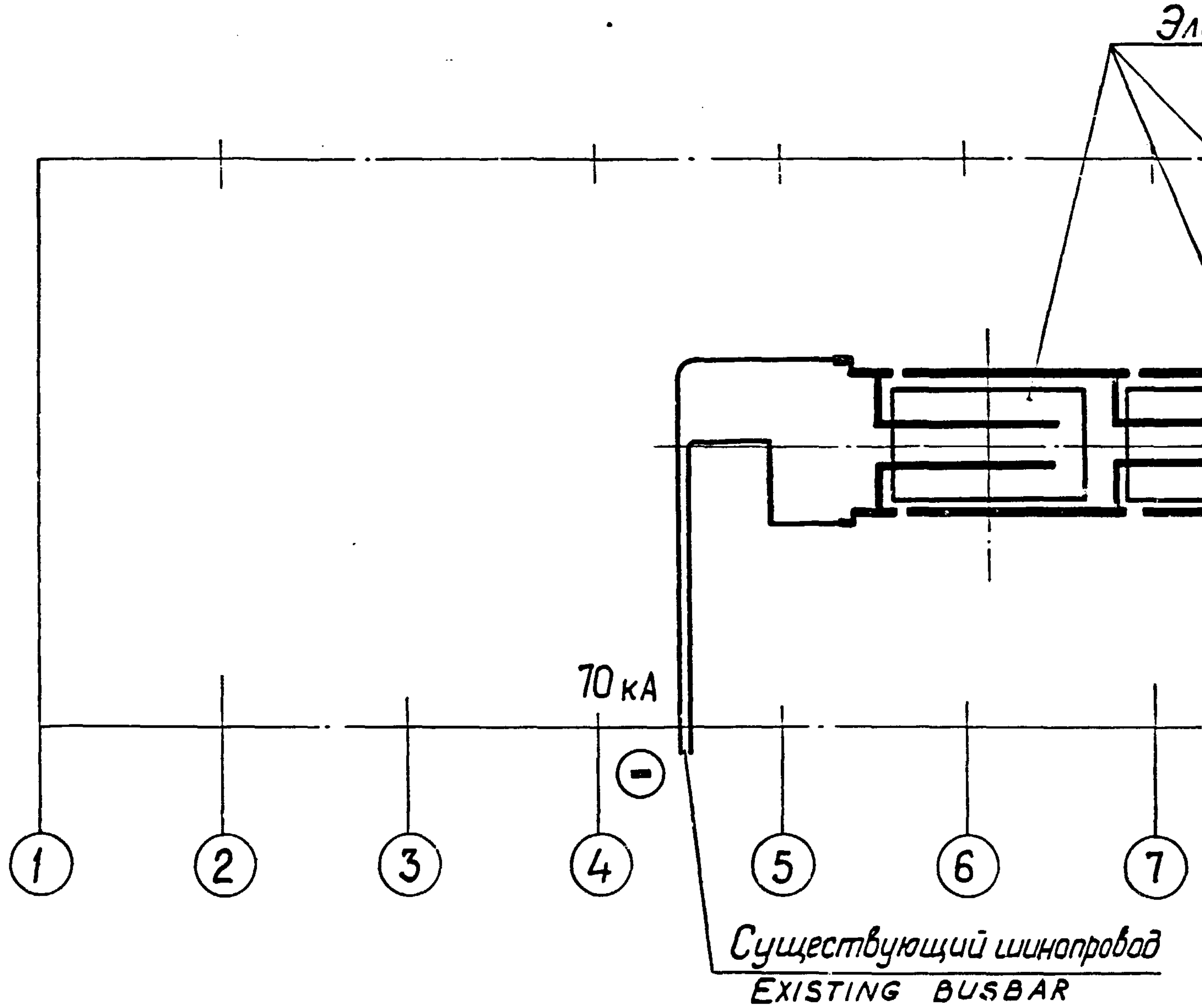


SECTION 4

SECTION 5

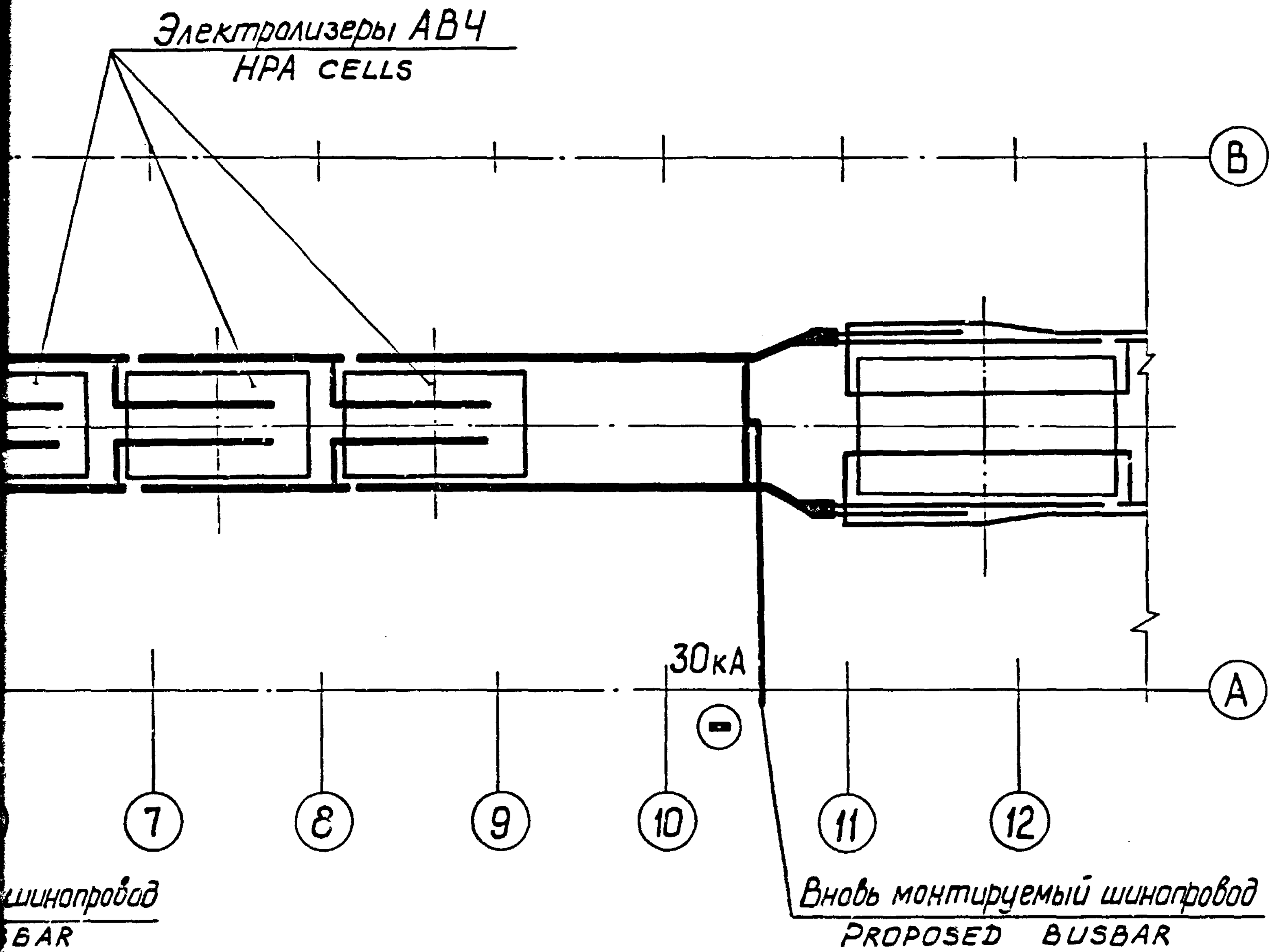
ДАННЫЙ ЧЕРТЕЖ НЕ ПОДЛЕЖИТ РАЗМНОЖЕНИЮ ИЛИ ПЕРЕДАЧЕ ДРУГИМ ОРГАНИЗАЦИЯМ И ЛИ 'АМ БЕЗ СОГЛАСИЯ ИНСТИТУТА В..МИ THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	1360970-TM			
	АЛЮМИНИЕВЫЙ ЗАВОД В Г.КОРБА, ИНДИЯ ALUMINIUM PLANT IN KURBA, INDIA.			
	ЭКСПЕРИМЕНТАЛЬНО-ДЕМОНСТРАЦИОННАЯ УСТАНОВКА ДЛЯ ПРОИЗВОДСТВА АЛЮМИНИЯ ВЫСОКОЙ ЧИСТОТЫ EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
		ТЭО	3	
	УЧАСТОК ЭЛЕКТРОЛИЗЕРОВ АВЧ (ВАРИАНТ 2). ПЛАН И РАЗРЕЗ HPA CELLS SECTION (VARIANT 2) PLAN AND SECTION	VAMI LENINGRAD		

Формат A4x5 Size A4x5



SECTION 1

Инв. № подл. | Подп. и дата | Вз. инв. №



SECTION 2

1360970-ТМ

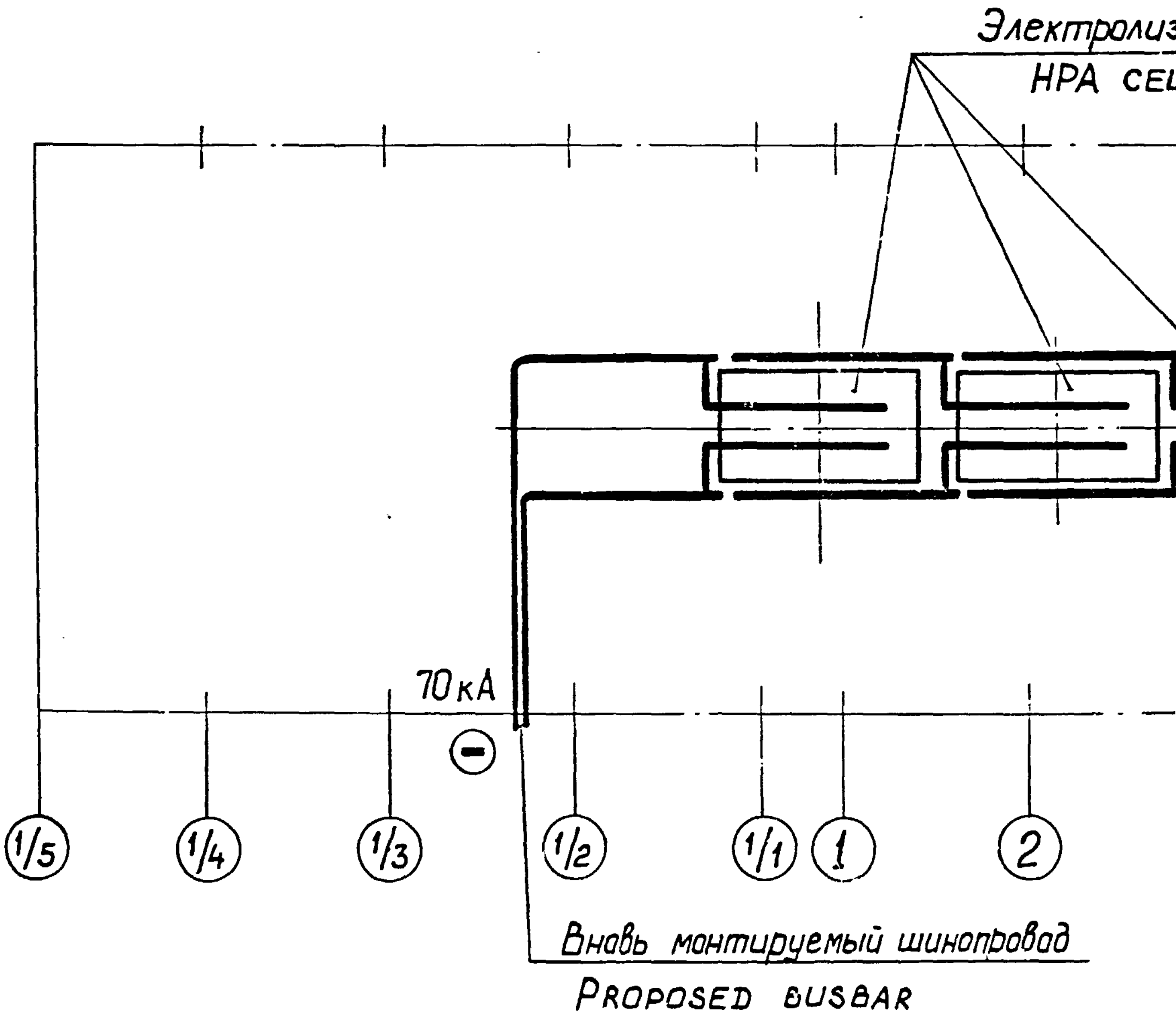
Алюминиевый завод в г. Корба, Индия
ALUMINIUM PLANT IN KORBA, INDIA.

Экспериментально-демонстрационная установка для производства алюминия высокой чистоты.
EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM

Стадия PHASE	Лист SHEET	Листов SHEETS
ТЭО	4	

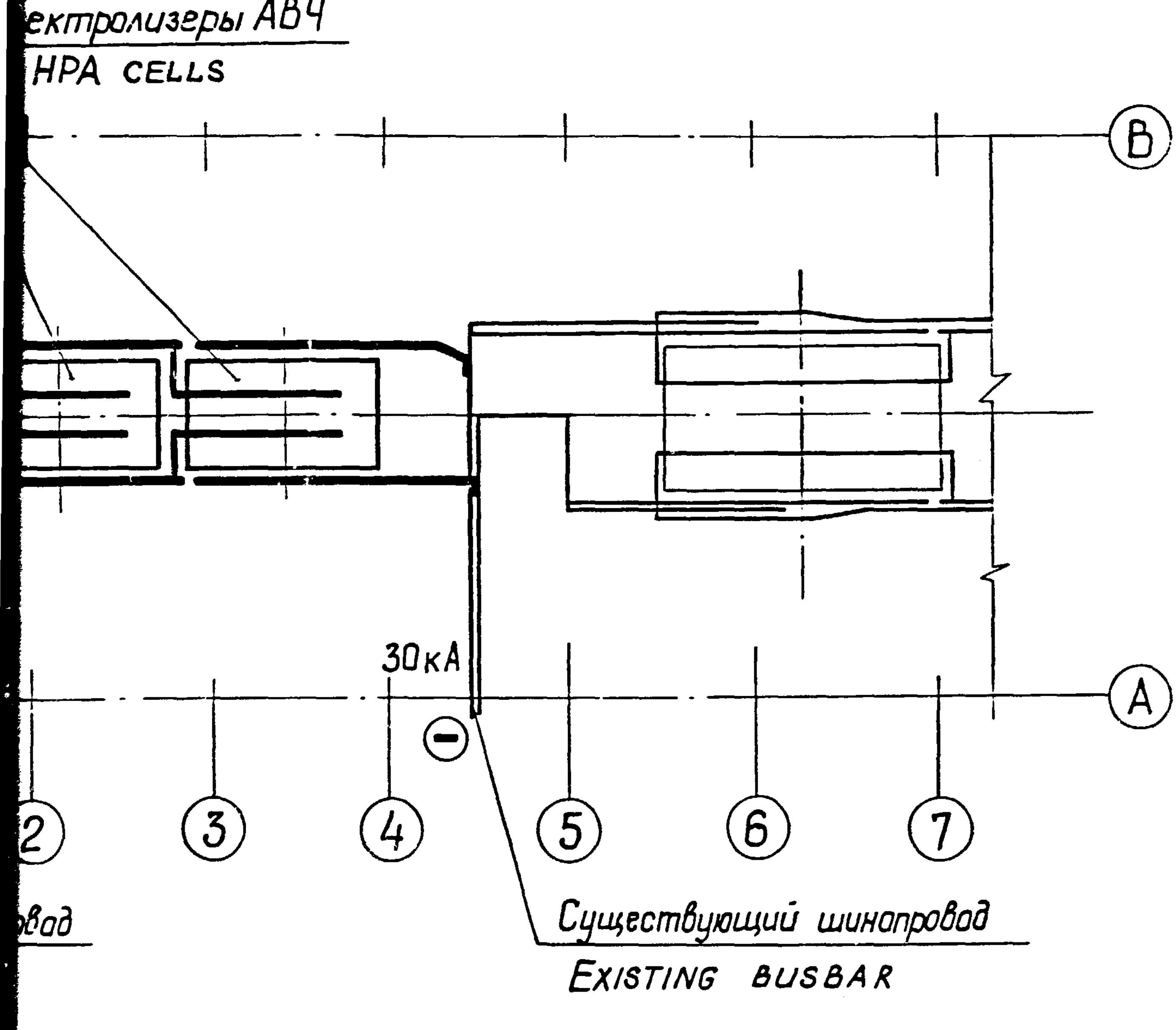
Участок электролизеров АВЧ (вариант 1). Схема ошиновки
HPA CELLS SECTION. (VARIANT 1) BUSBAR DIAGRAM

VAMI
LENINGRAD



SECTION 1

Инв. № подл. | Подп. и дата | Вз. инв. №



SECTION 2

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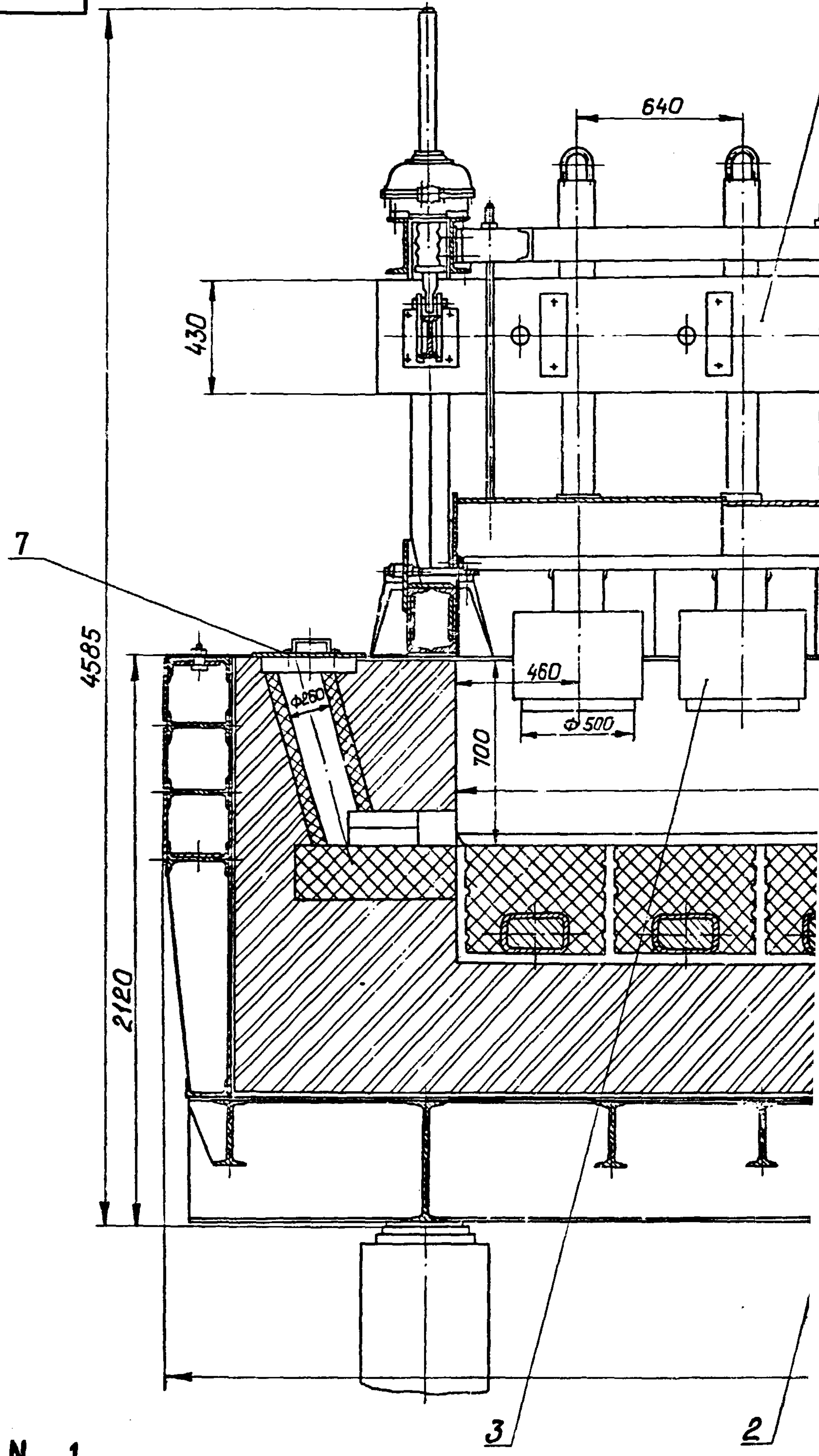
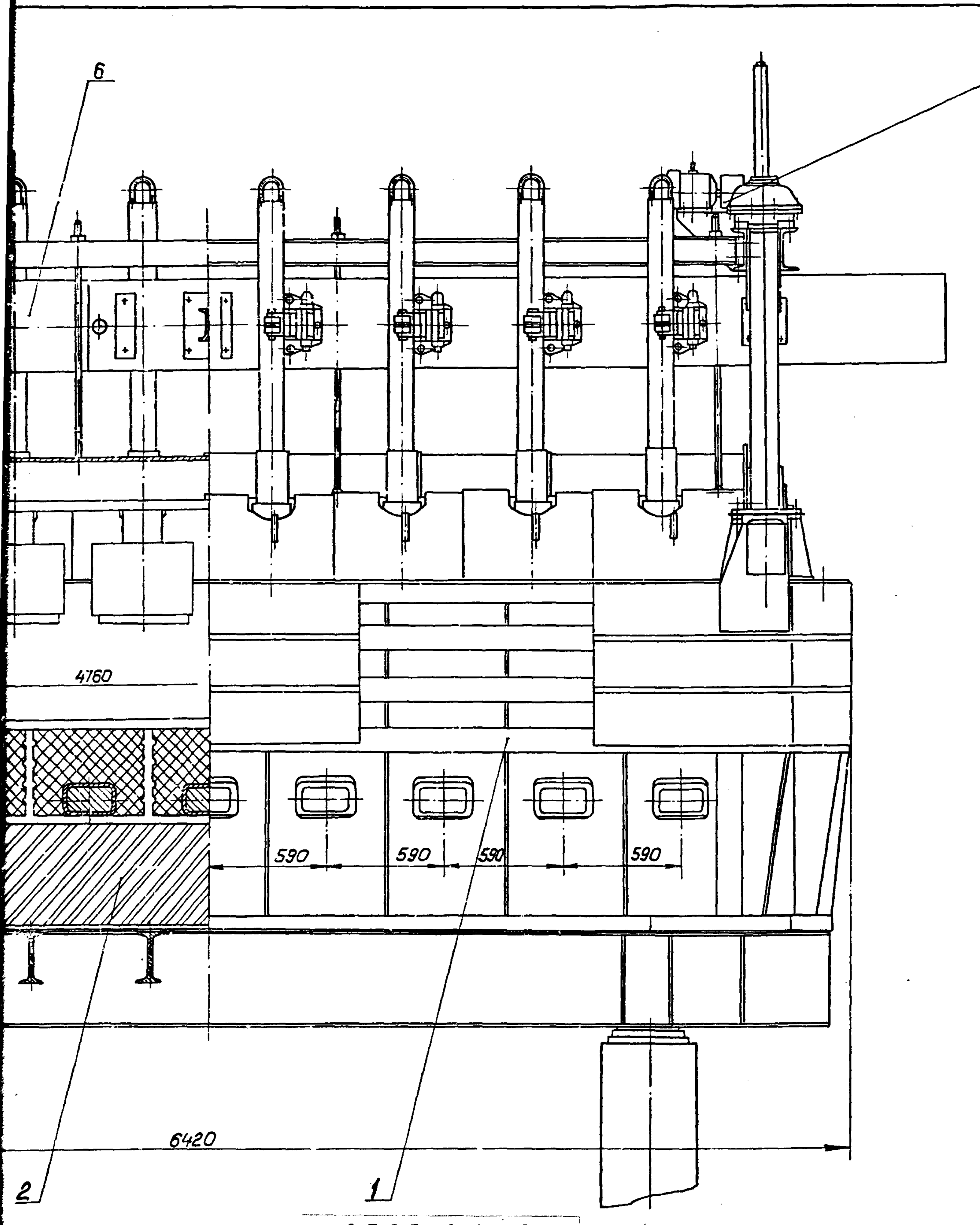
	Алюминиевый завод в г. Корба, Индия ALUMINIUM PLANT IN KORBA, INDIA			
THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	Экспериментально-демонстрационная установка для производства алюминия высокой чистоты EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
		ТЭО	5	
	Участок электролизеров АВЧ (вариант 2) схема ошиновки. HPA CELLS SECTION. (VARIANT 2) BUSBAR DIAGRAM	VAMI LENINGRAD		

1335338 B0

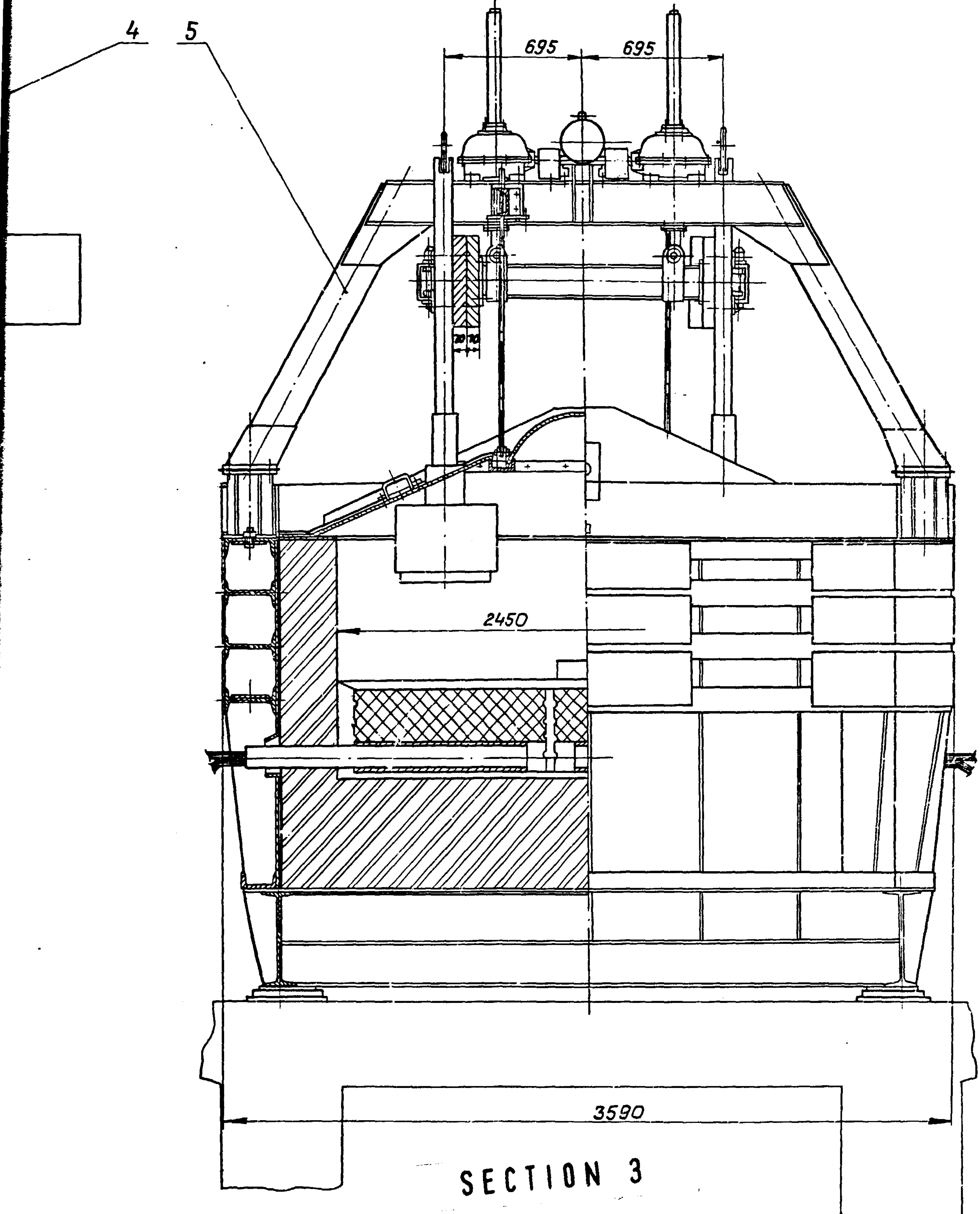


SECTION 1

Инв. № подл. | Подп. и дата | Взам. инв. №



SECTION 2



SECTION 3

№ поз. Item №	Наименование Name	Техническая характеристика Technical characteristics	Кол. Quantity	Примечание Remarks
1	Кожух металлический STEEL SHELL	Рамного типа FRAME TYPE	1	
2	Футеровка анодная ANODE LINING	Магнезит, шамот, угольные блоки. MAGNESITE, FIRE-CLAY, CARBON BLOCKS	1	
3	Катод CATHODE	Диаметр графита 500мм DIAMETER OF GRAPHITE CATHODE	13	
4	Механизм подъема катодов CATHODES RAISING MECHANISM	Мощность привода 0,75кВт. DRIVE POWER RATING	2	
5	Металлоконструкция электролизера CELL STEEL STRUCTURES	—	1	
6	Ошиновка катодная CATHODE BUSWORK	Алюминиевые шины 430x70мм ALUMINIUM BUSBAR	1	
7	Крышка COVER	—	1	

SECTION 4

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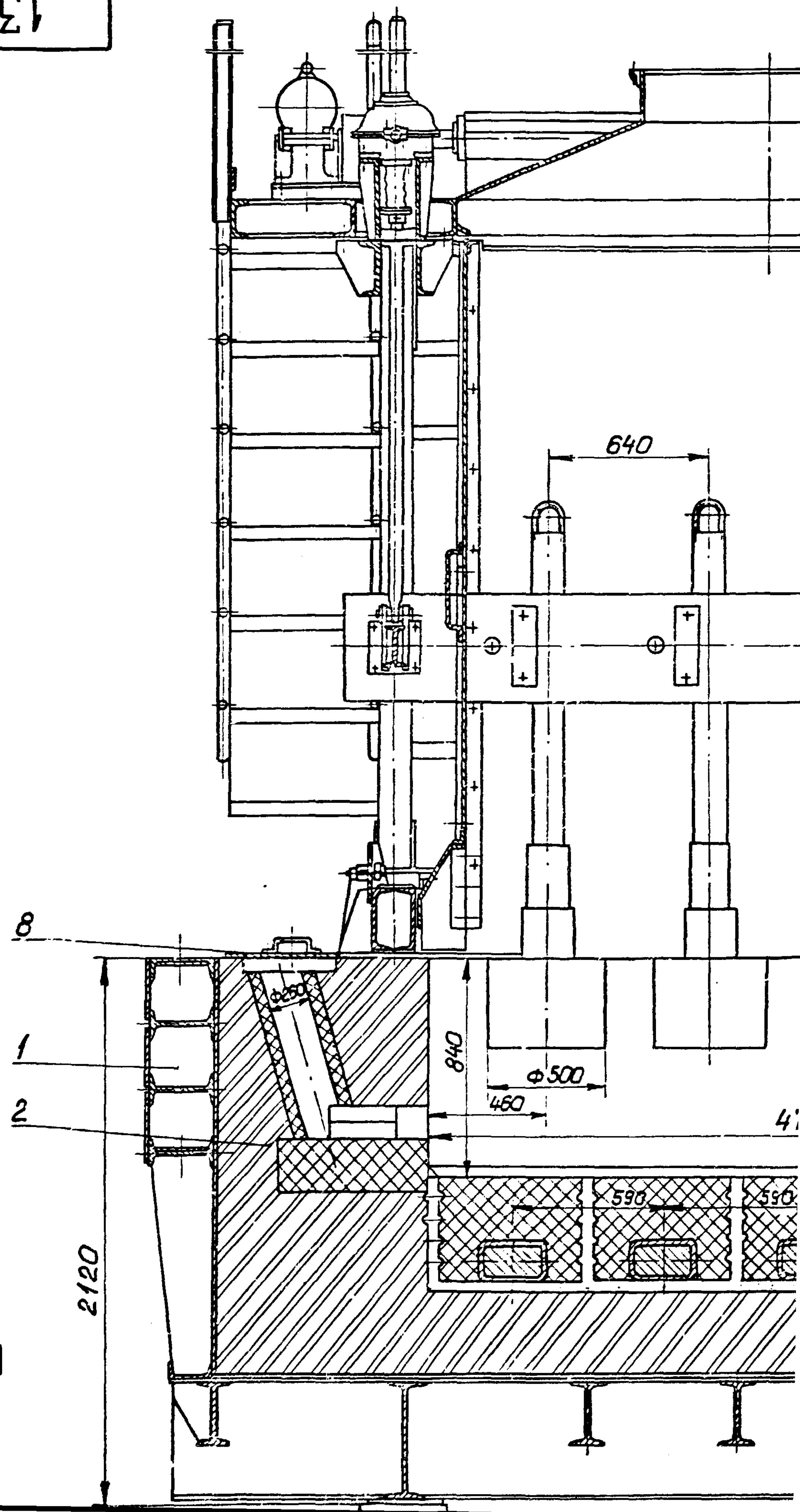
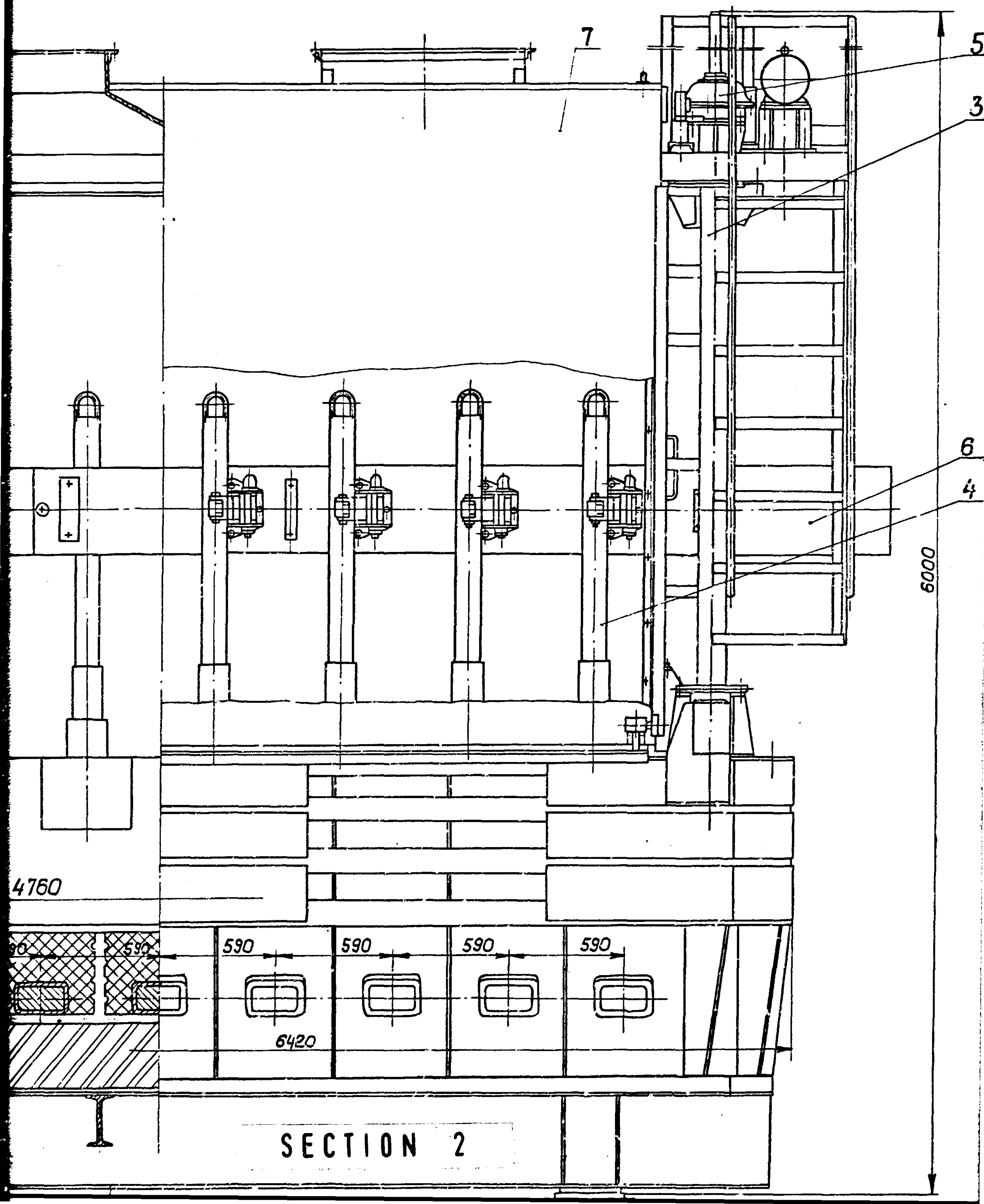
	ЭЛЕКТРОЛИЗЕР ДЛЯ РАФИНИРОВАНИЯ АЛЮМИНИЯ НА СИЛУ ТОКА 70 КА 70 KA CELL FOR REFINING ALUMINIUM	Стадия Phase	Масса Mass	Масштаб Scale
		П	—	—
		Лист Sheet	Листов Sheets 1	
		VAMI Leningrad		

13353980

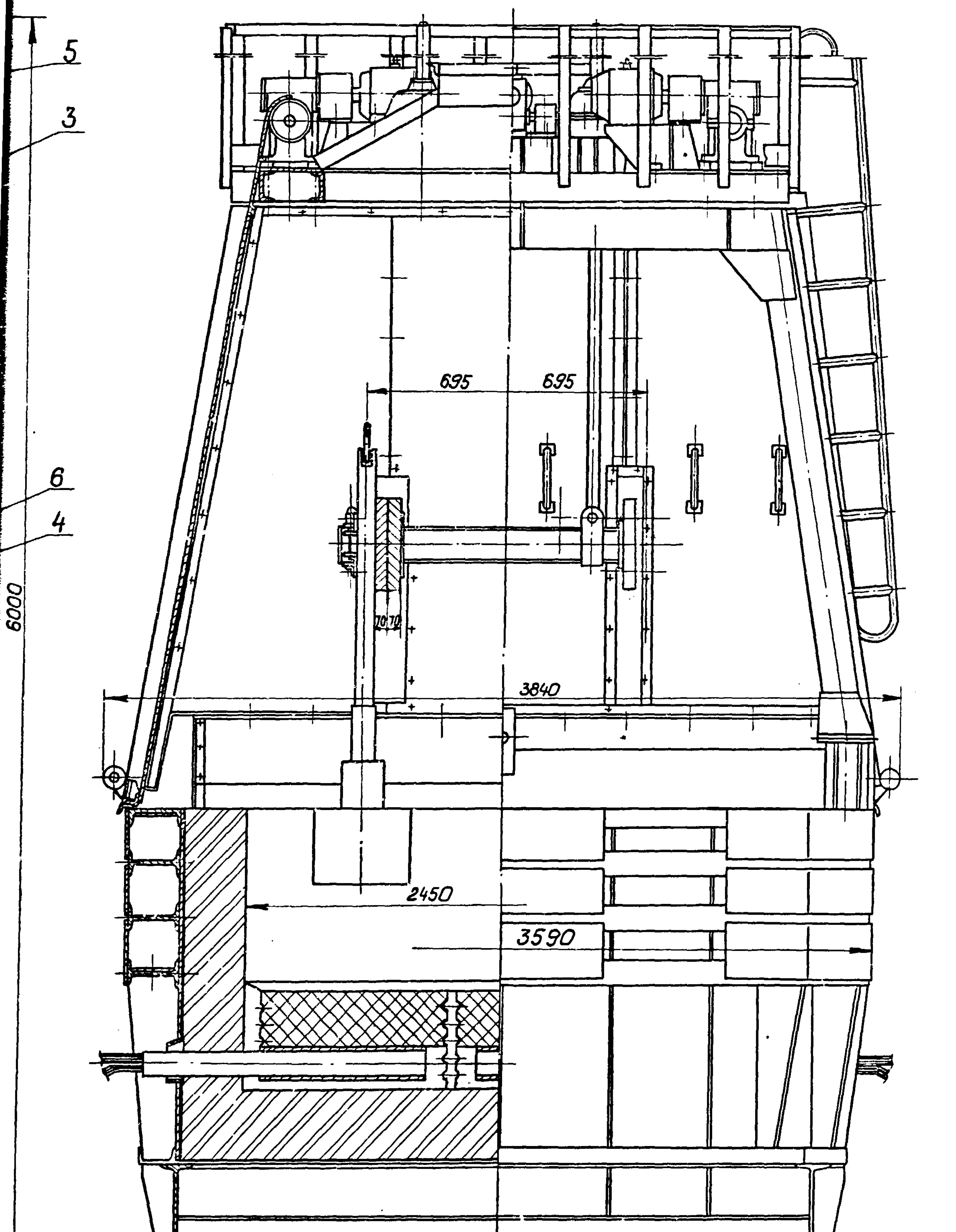


SECTION 1

Взам.инв.N°	Подп. и дата	д. N° подл.



SECTION 2



SECTION 3

№ поз. Item No
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Да
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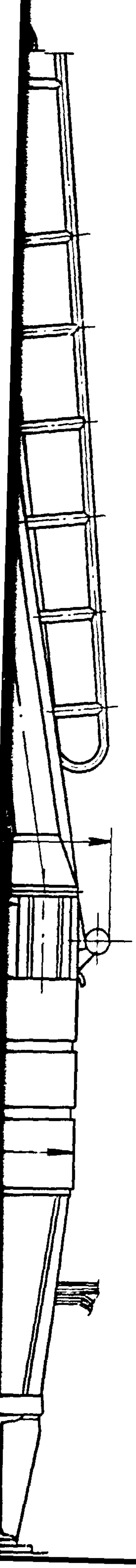


№ поз. Item No	Наименование Name	Техническая характеристика Technical characteristics	Кол. Quantity	Примечание Remarks
1	Кожух металлический STEEL SHELL	Рамного типа FRAME TYPE	1	
2	Футеровка анодная ANODE UNING	Магнезит, шамот, угольные блоки MAGNESITE, FIRE-CLAY, CARBON BLOCKS	1	
3	Металлоконструкция электролизера CELL STEEL STRUCTURES	—	1	
4	Катод CATHODE	Диаметр графита DIAMETER OF GRAPHITE CATHODE 500мм	13	
5	Механизм подъема катодов CATHODES RAISING MECHANISM	Мощность привода DRIVE POWER RATING 0,75кВт	2	
6	Ошиновка катодная CATHODE BUSWORK	Алюминиевые шины ALUMINIUM BUSBAR 430x70мм	1	
7	Штора В=4500 с приводом SHUTTER B=4500 WITH DRIVE	Мощность привода DRIVE POWEP RATING 2,2кВт	2	
8	Крышка COVER	—	1	

1335339 BO

ЭЛЕКТРОЛИЗЕР ДЛЯ ПРИГОТОВЛЕНИЯ ЭЛЕКТРОЛИТА И ПРОПИТКИ КАТОДОВ НА СИЛУ ТОКА 70КА.
70KA CELL FOR ELECTROLYTE PREPARATION AND CATHODES IMPREGNATION

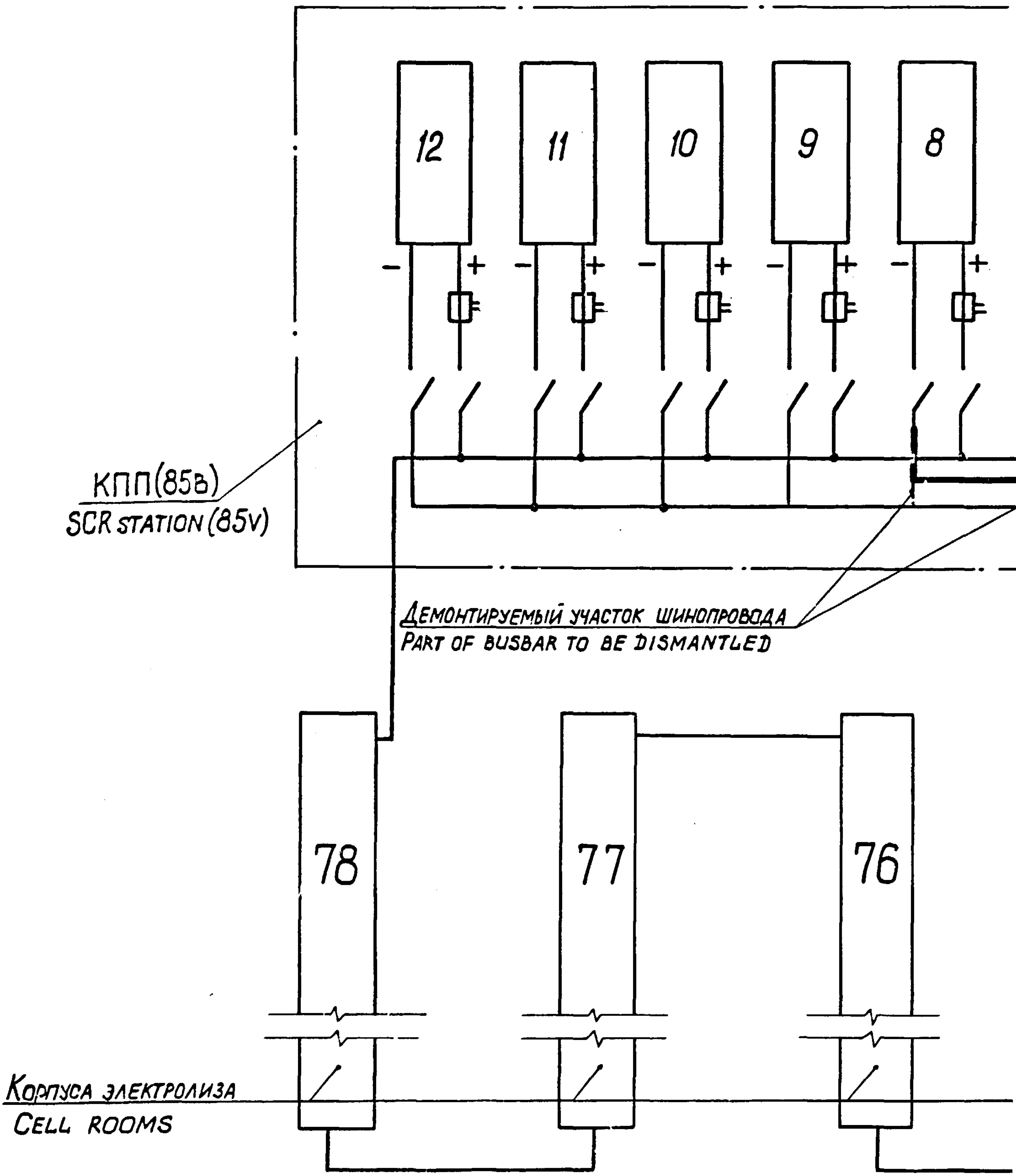
Стадия Phase	Масса Mass	Масштаб Scale
П	—	—

Лист Sheet | Листов Sheets 1

SECTION 4

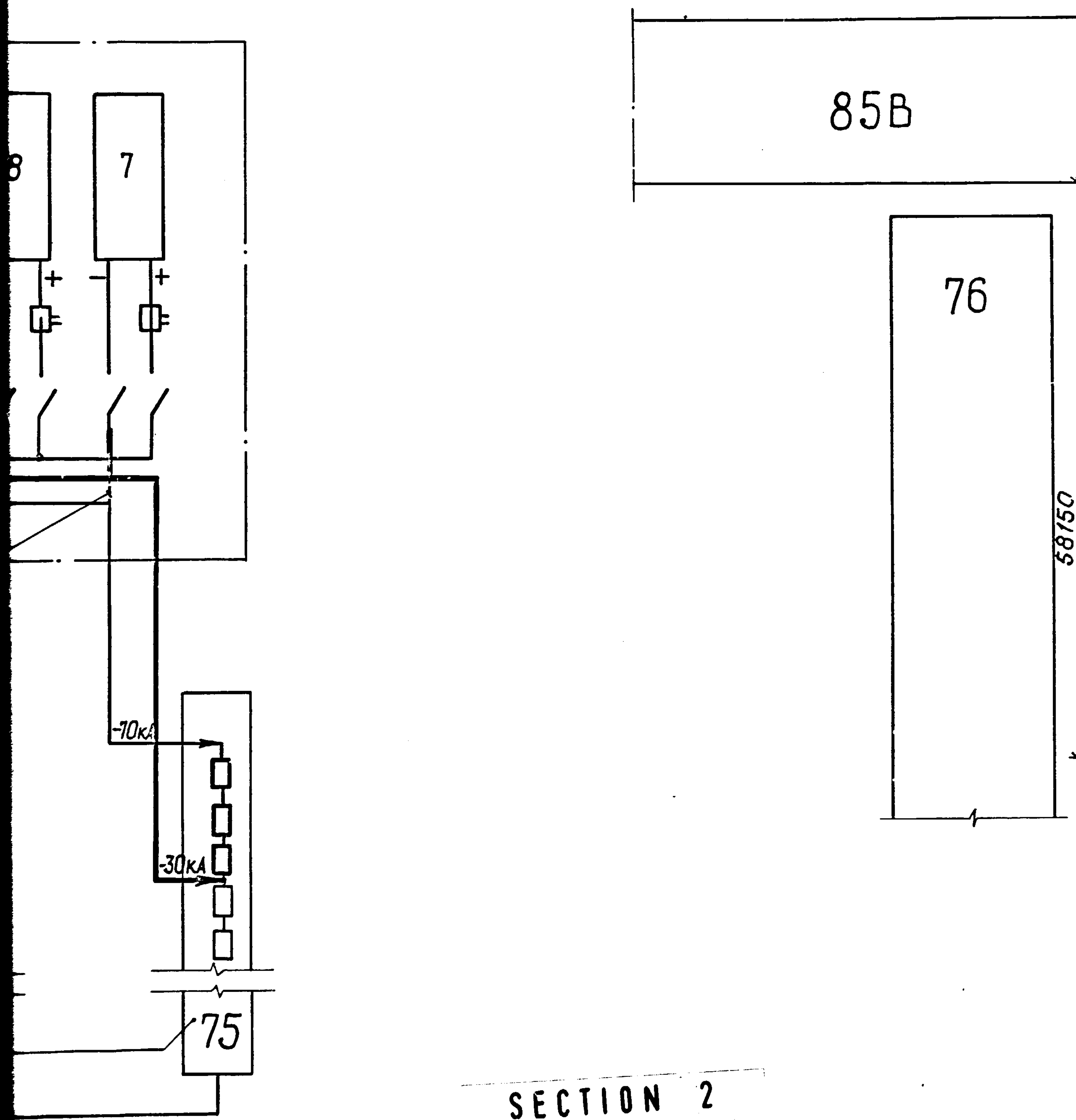
VAMI Leningrad

Схема
Diagram



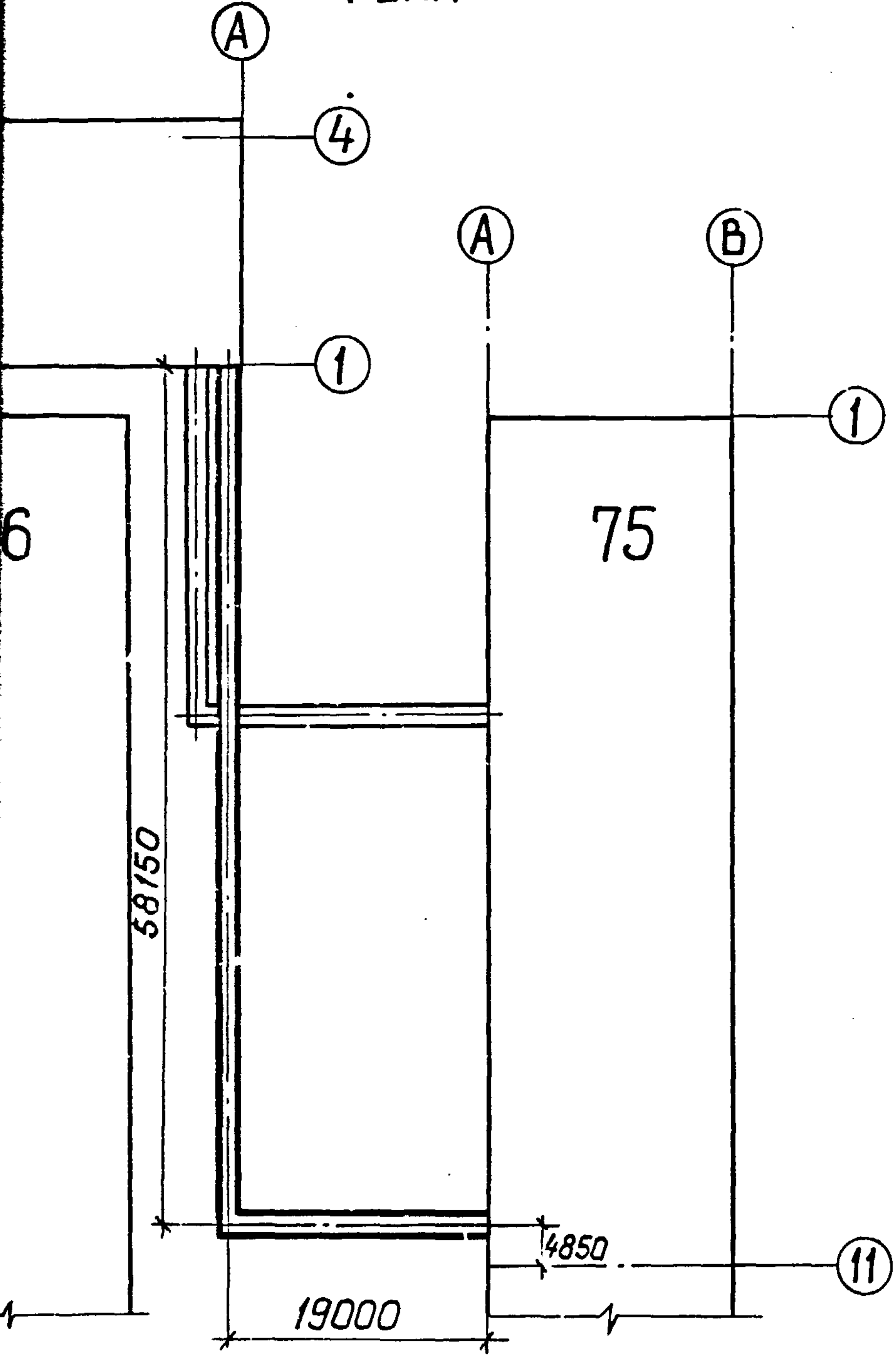
SECTION 1

Инв. № подл. | Подп. и дата | Вз. инв. №



SECTION 2

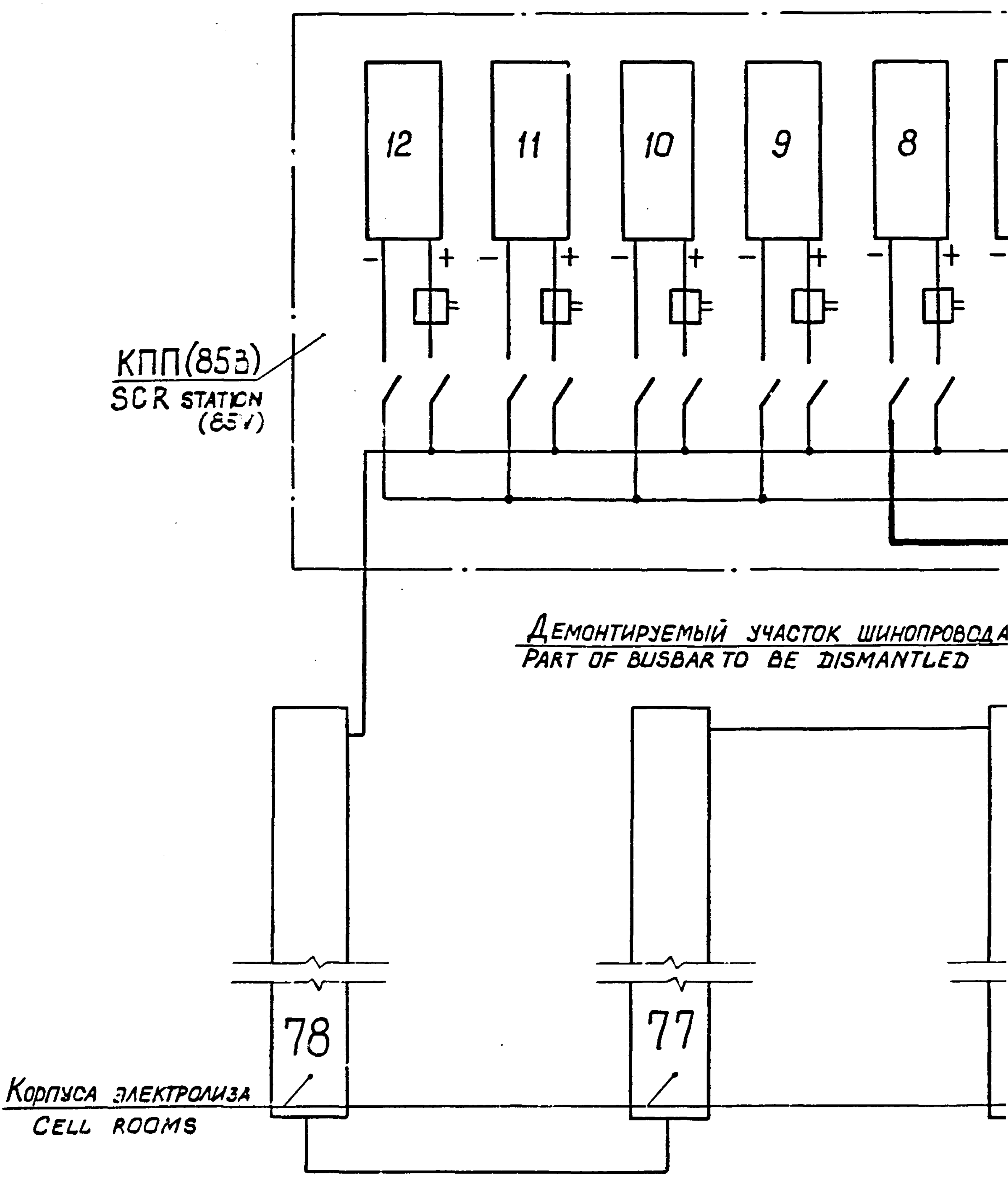
ПЛАН
PLAN



SECTION 3

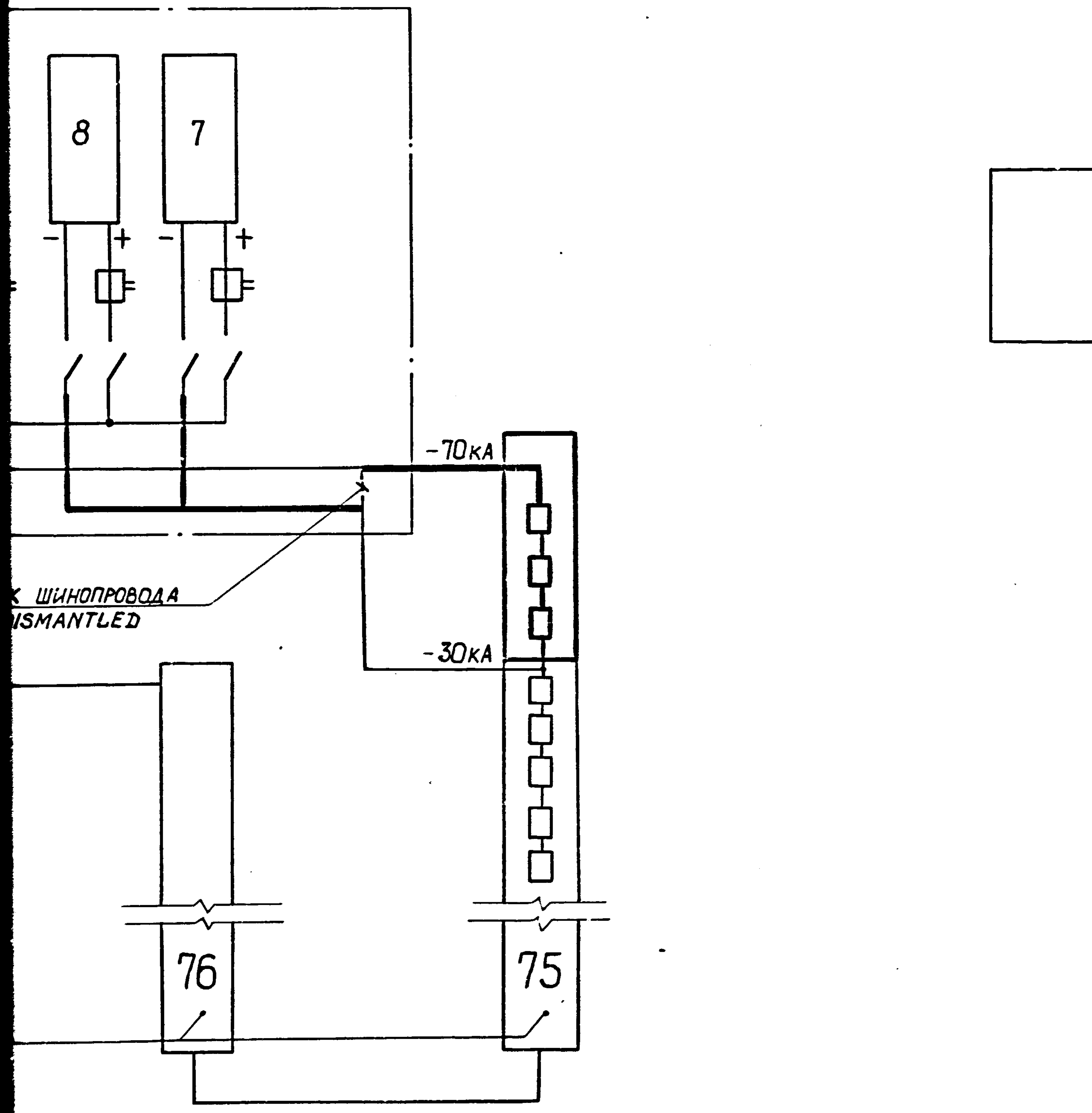
ДАННЫЙ ЧЕРТЕЖ НЕ ПОДЛЕЖИТ РАЗМНОЖЕНИЮ ИЛИ ПЕРЕДАЧЕ ДРУГИМ ОРГАНИЗАЦИЯМ И ЛИЦАМ БЕЗ СОГЛАСИЯ ИНСТИТУТА ВАМИ THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	1247836-ЭС			
	Алюминиевый завод в г. Корба, Индия Aluminium plant in Korba, India			
	ЭКСПЕРИМЕНТАЛЬНО-ДЕМОНСТРАЦИОННАЯ УСТАНОВКА ДЛЯ ПРОИЗВОДСТВА АЛЮМИНИЯ ВЫСОКОЙ ЧИСТОТЫ. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
			1	2
	СХЕМА И ПЛАН ТРАССЫ ШИНОПРОВОДА (ВАРИАНТ I). DIAGRAM AND PLAN OF BUSBAR ROUTE (VARIANT I).	VAMI LENINGRAD		

СХЕМА
DIAGRAM



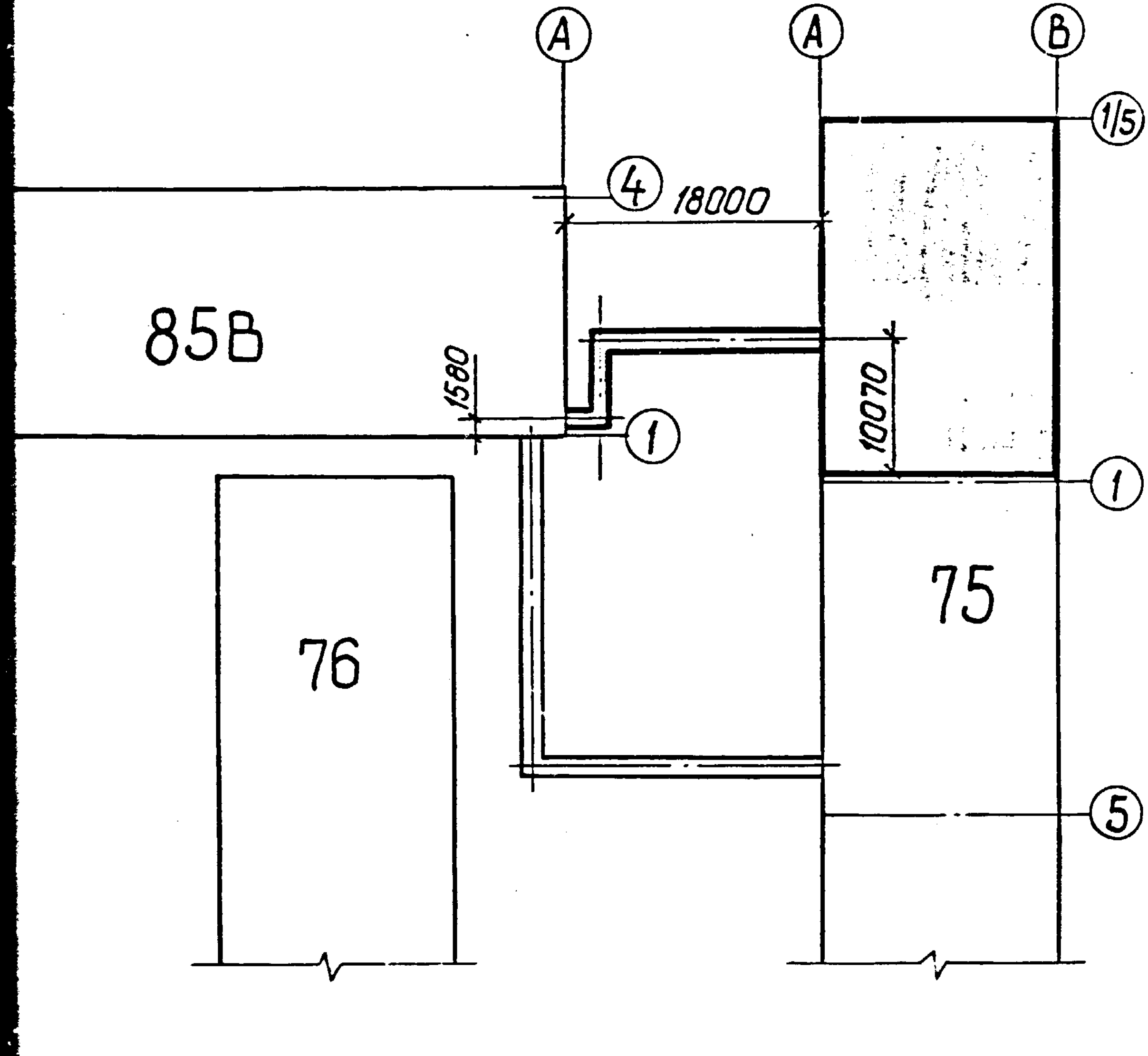
SECTION 1

Вз. инв. №
Подп. и дата
Инв. № подл.



SECTION 2

ПЛАН
PLAN

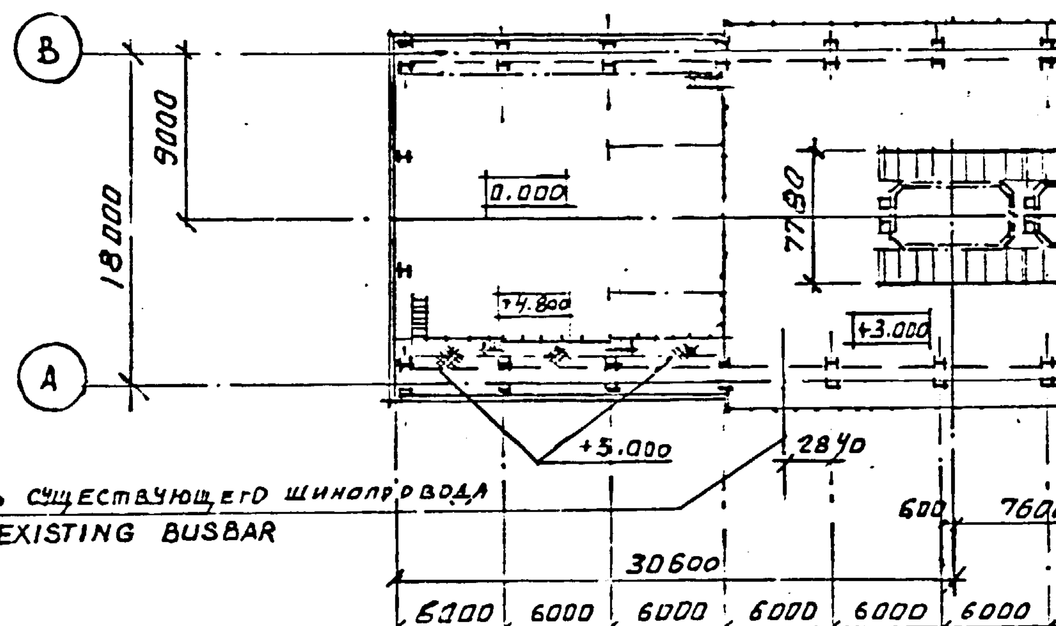


SECTION 3

ДАННЫЙ ЧЕРТЕЖ НЕ ПОДЛЕЖИТ РАЗМНОЖЕНИЮ ИЛИ ПЕРЕДАЧЕ ДРУГИМ ОРГАНИЗАЦИЯМ И ЛИЦАМ БЕЗ СОГЛАСИЯ ИНСТИТУТА ВАМИ THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI	1247836-ЭС Алюминиевый завод в г. Корба, Индия ALUMINIUM PLANT IN KORBA, INDIA			
	ЭКСПЕРИМЕНТАЛЬНО-ДЕМОНСТРАЦИОННАЯ УСТАНОВКА ДЛЯ ПРОИЗВОДСТВА АЛЮМИНИЯ ВЫСОКОЙ ЧИСТОТЫ. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM	Стадия PHASE	Лист SHEET	Листов SHEETS
		FS	2	
	СХЕМА И ПЛАН ТРАССЫ ШИНОПРОВОДА (ВАРИАНТ II). DIAGRAM AND PLAN OF BUSBAR ROUTE (VARIANT II)	VAMI LENINGRAD		

План на...

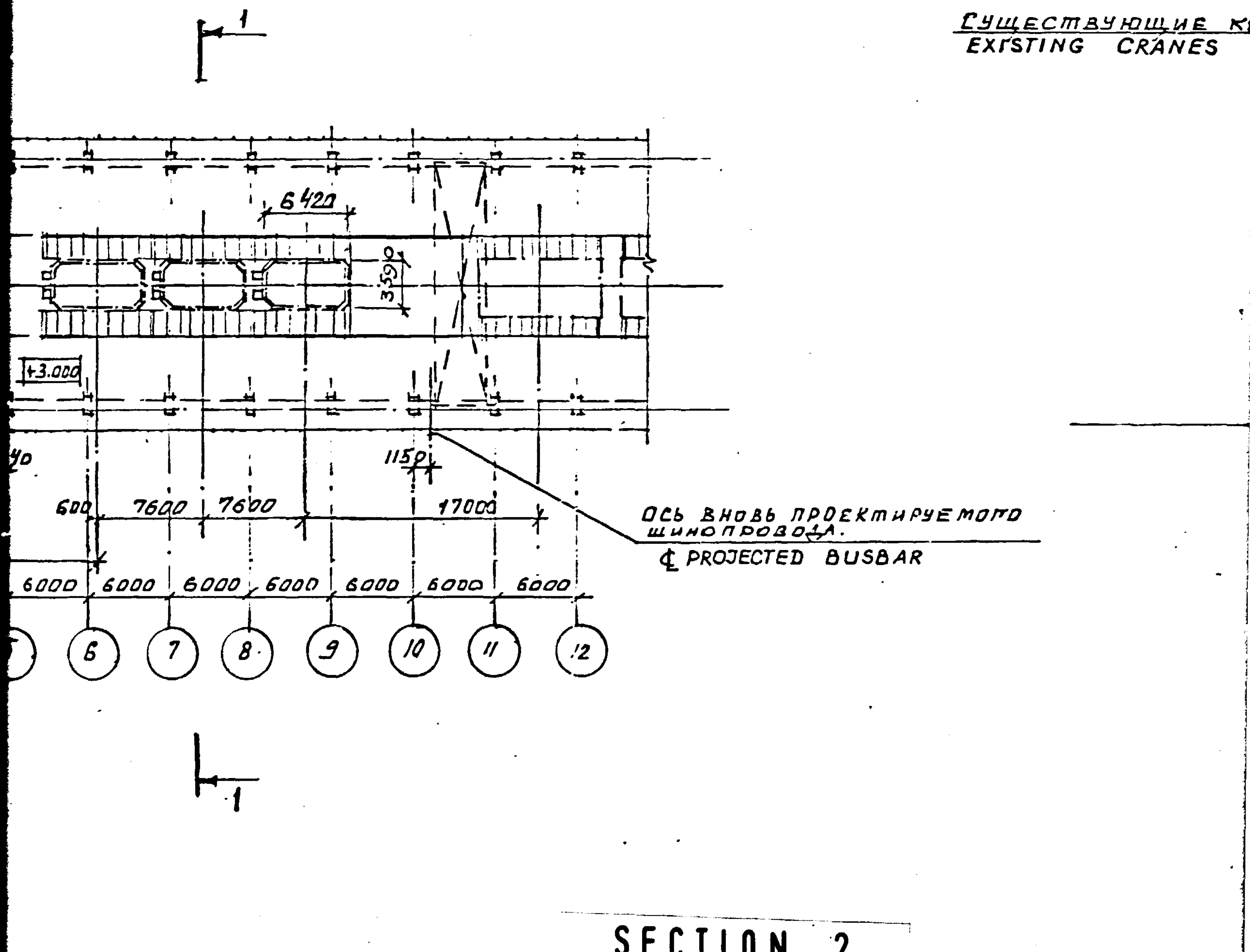
PLAN AT EL. 3.(...)



SECTION 1

Н НА ОТМ. 3.000

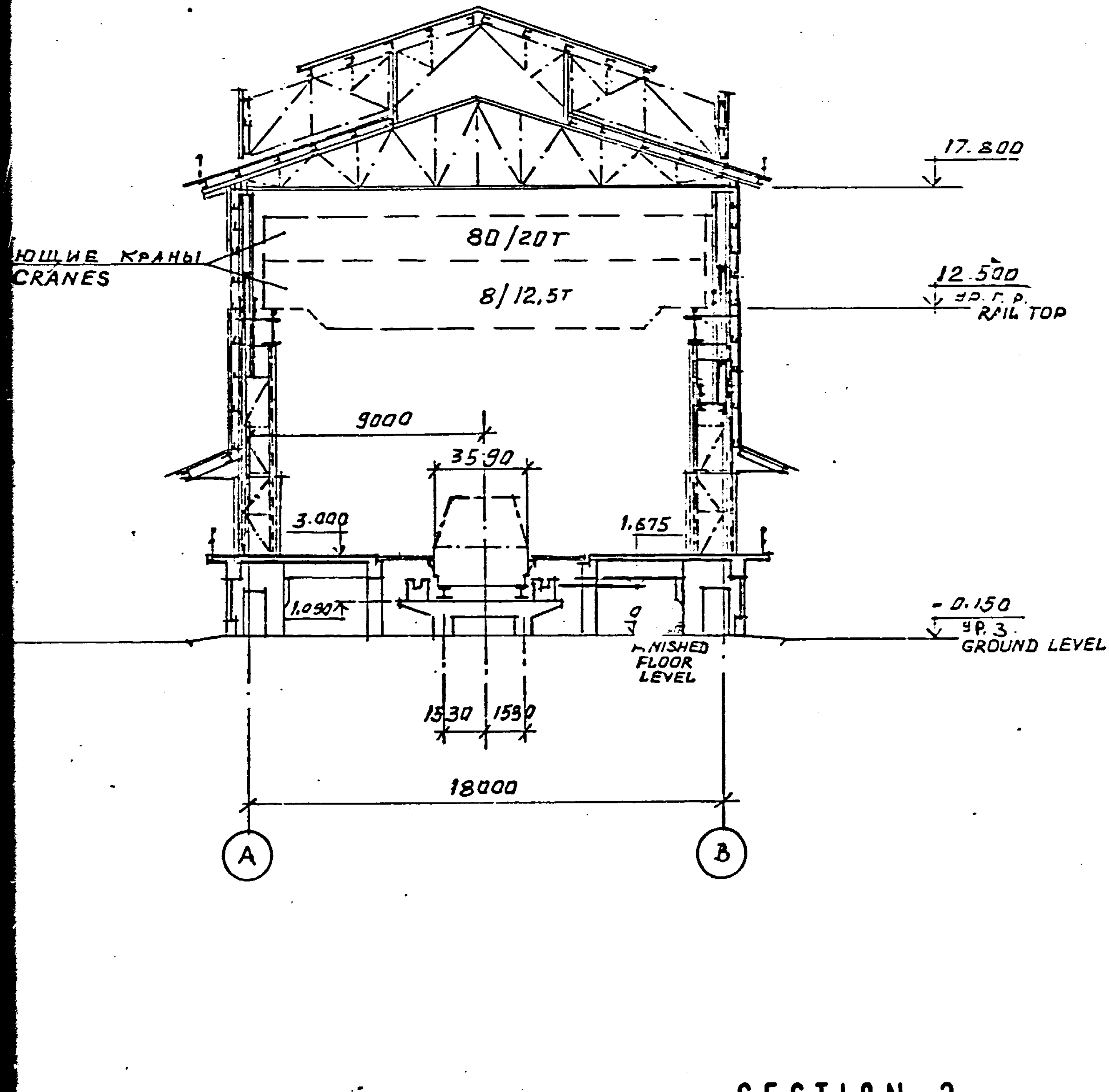
AT EL. 3.000



SECTION 2

Разрез 1-1

SECTION 1-1



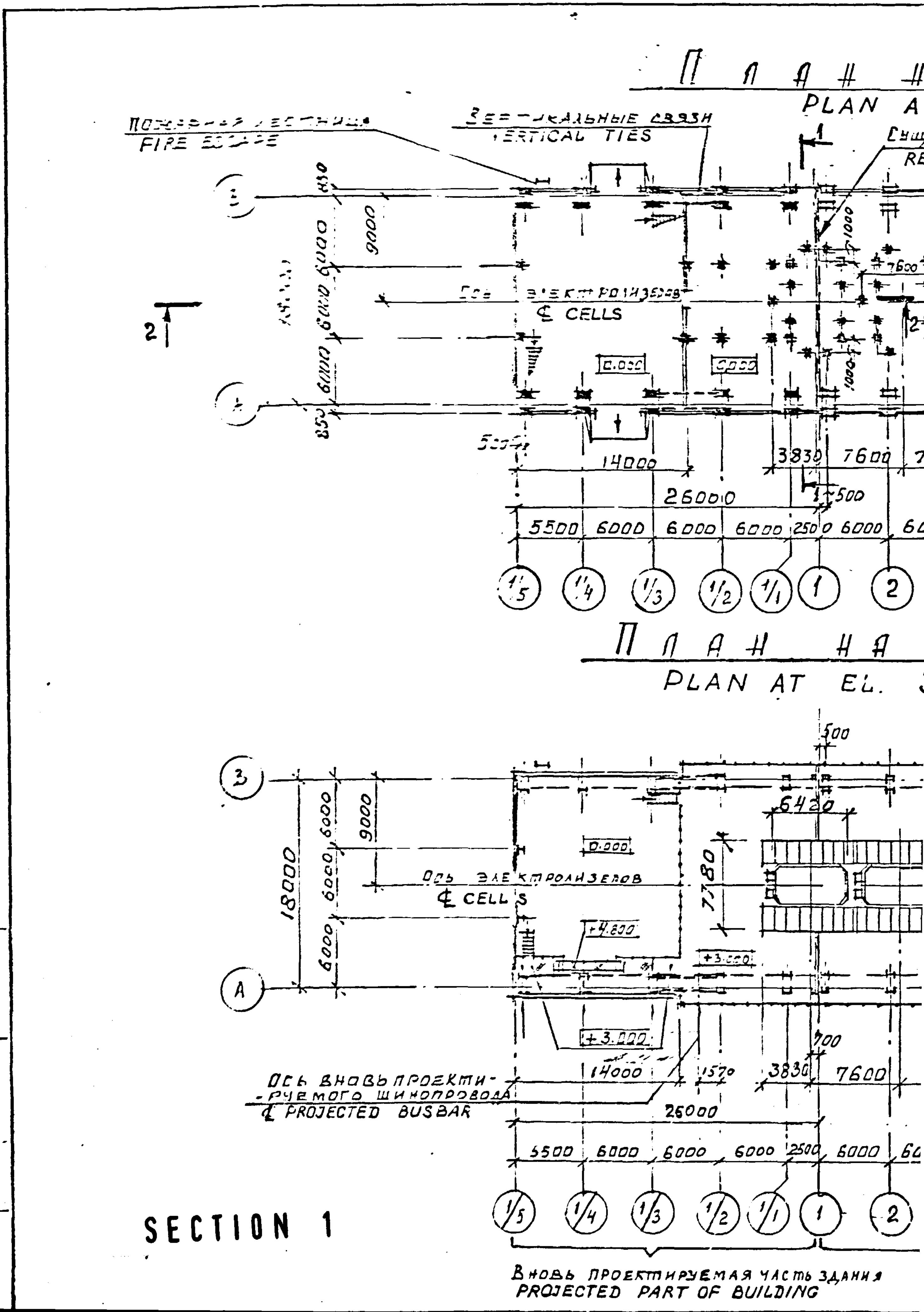
SECTION 3

SECTION 4

1332639-AC

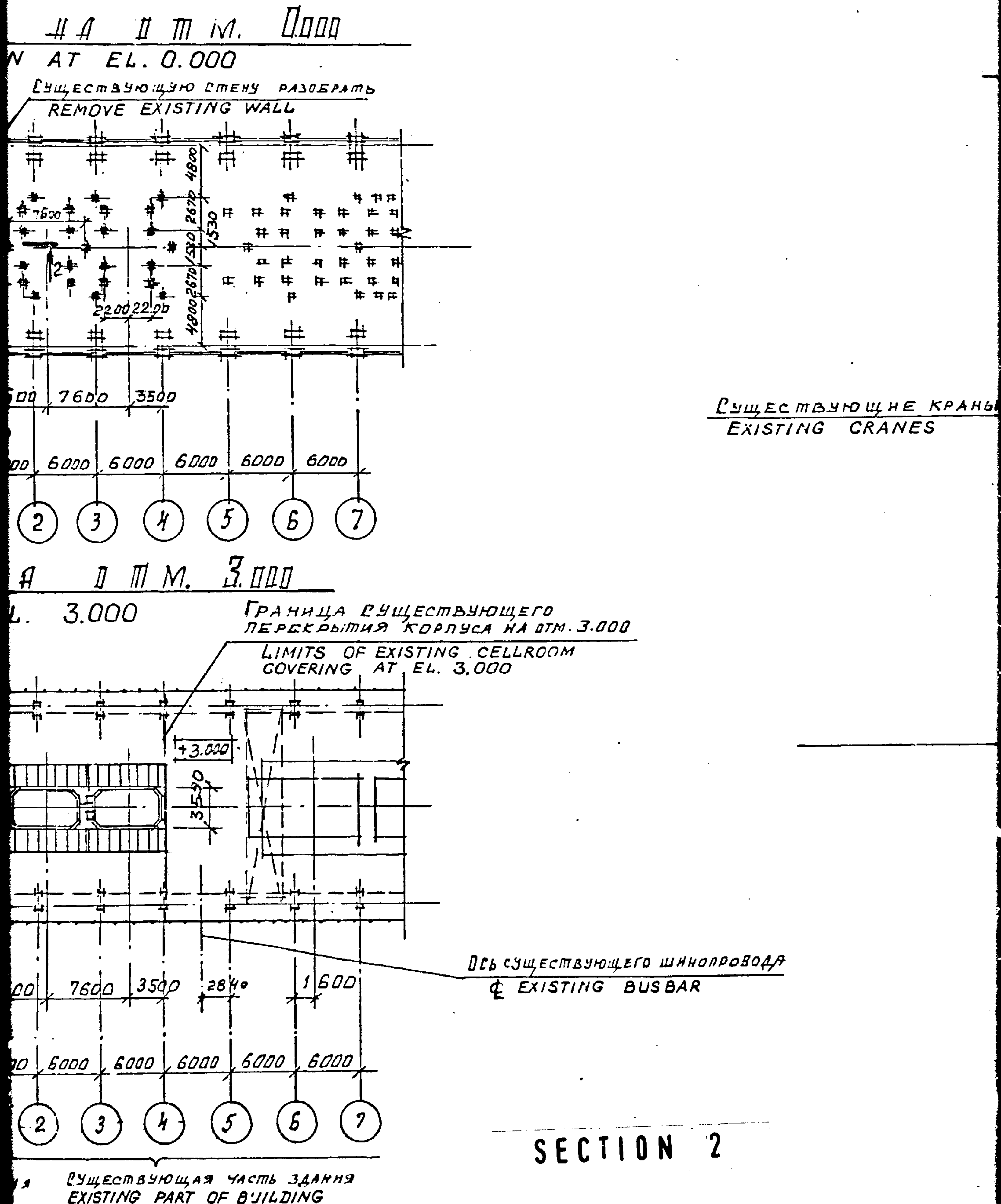
Алюминиевый завод в г. Корба, Индия.
ALUMINIUM PLANT IN KORBA, INDIA.

Экспериментально-демонстрационная установка для производства алюминия высокой чистоты. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM.	Стадия PHASE	Лист SHEET	Листов SHEETS
	ТЭО	1	2
Участок электролизеров АВЧ (Вариант I) План на отм. 3.000 Разрез 1-1 SECTION OF HPA CELLS (VARIANT I) PLAN AT EL. 3.000 SECTION 1-1	VAMI LENINGRAD		



П Л А Н
PLAN A
Пожарная лестница
FIRE ESCAPE
Вертикальные связи
VERTICAL TIES
Ось электролизеров
℄ CELLS
0.000
14000
26000
5500
6000
6000
6000
2500
6000
3830
7600
500
9000
6000
6000
П Л А Н Н А
PLAN AT EL.
500
6420
18000
7780
0.000
Ось электролизеров
℄ CELLS
+4.800
+3.000
+3.000
700
14000
1570
3830
7600
Ось вновь проектируемого шинопровода
℄ PROJECTED BUSBAR
26000
5500
6000
6000
6000
2500
6000
Вновь проектируемая часть здания
PROJECTED PART OF BUILDING
Инв. № подл.
Подп. и дата
Взам. инв. №

SECTION 1

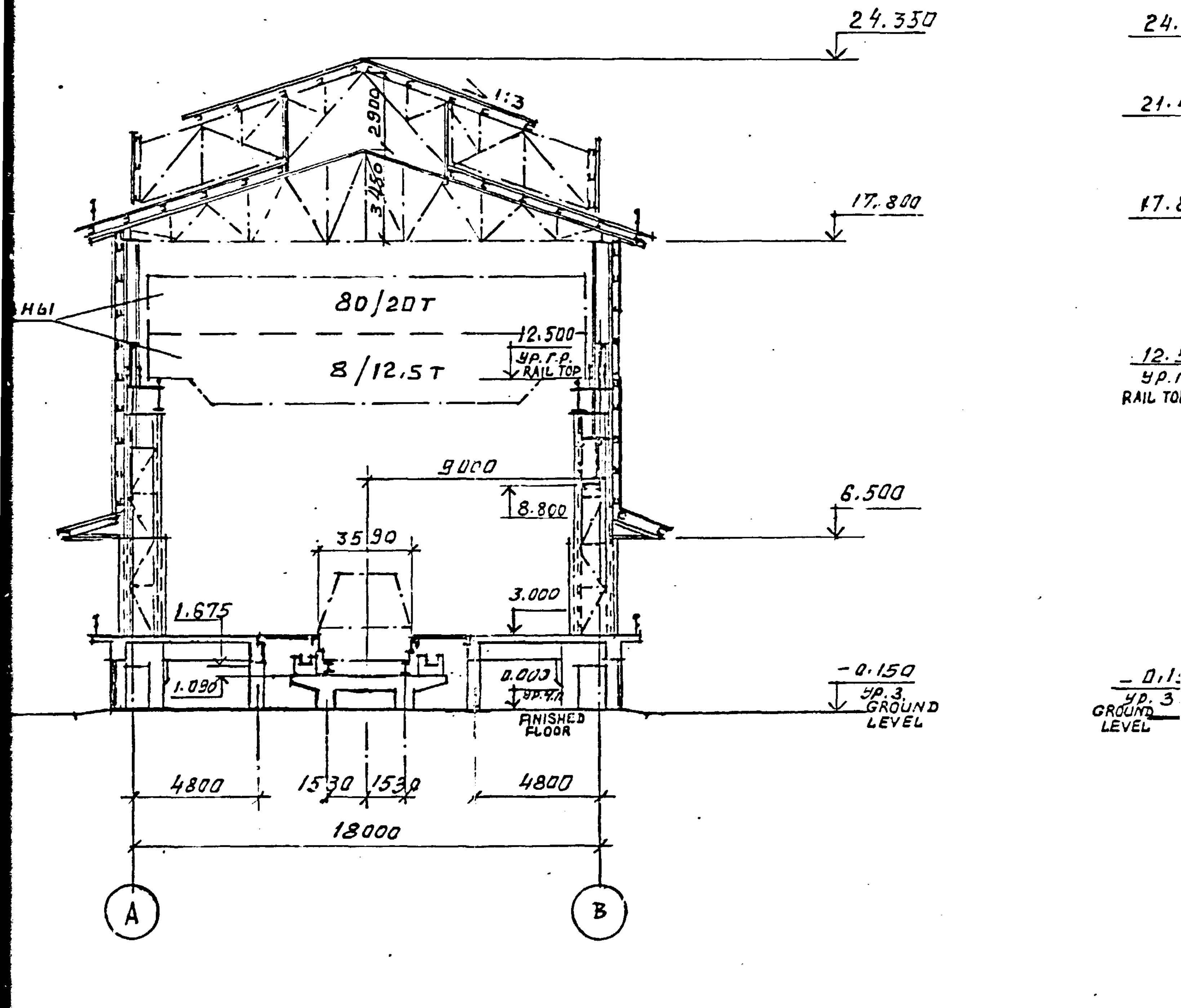


НА ОТМ. 0.000
N AT EL. 0.000
Существующую стену разобрать
REMOVE EXISTING WALL
7600
2200 2200
4800
2670
530
7600
3500
6000 6000 6000 6000 6000
2
3
4
5
6
7
А ОТМ. 3.000
L. 3.000
Граница существующего перекрытия корпуса на отм. 3.000
LIMITS OF EXISTING CELLROOM COVERING AT EL. 3.000
+3.000
3530
7600
3500
2840
1600
6000 6000 6000 6000 6000
Существующие краны
EXISTING CRANES
Ось существующего шинопровода
℄ EXISTING BUSBAR
Существующая часть здания
EXISTING PART OF BUILDING

SECTION 2

Разрез 1-1

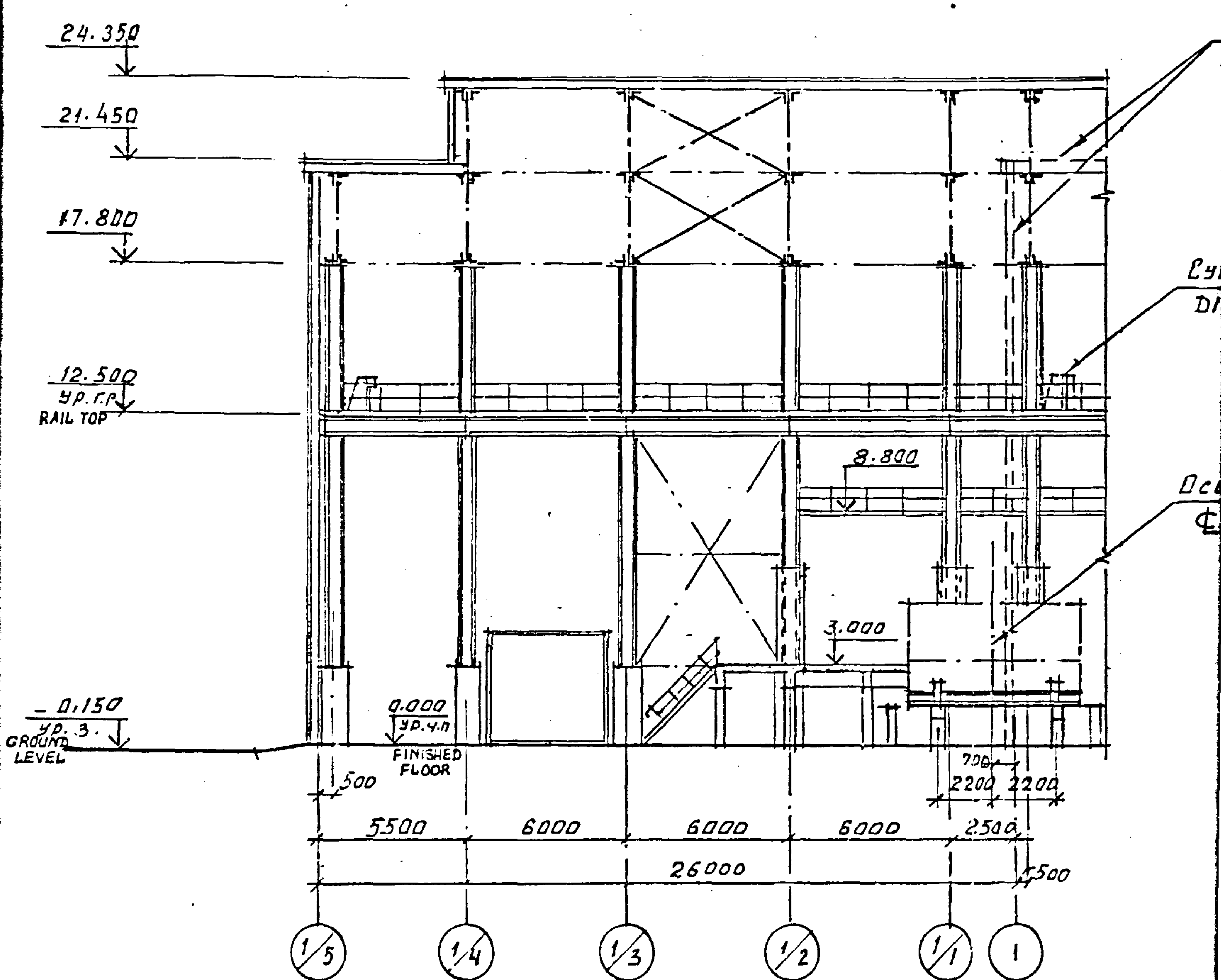
SECTION 1-1



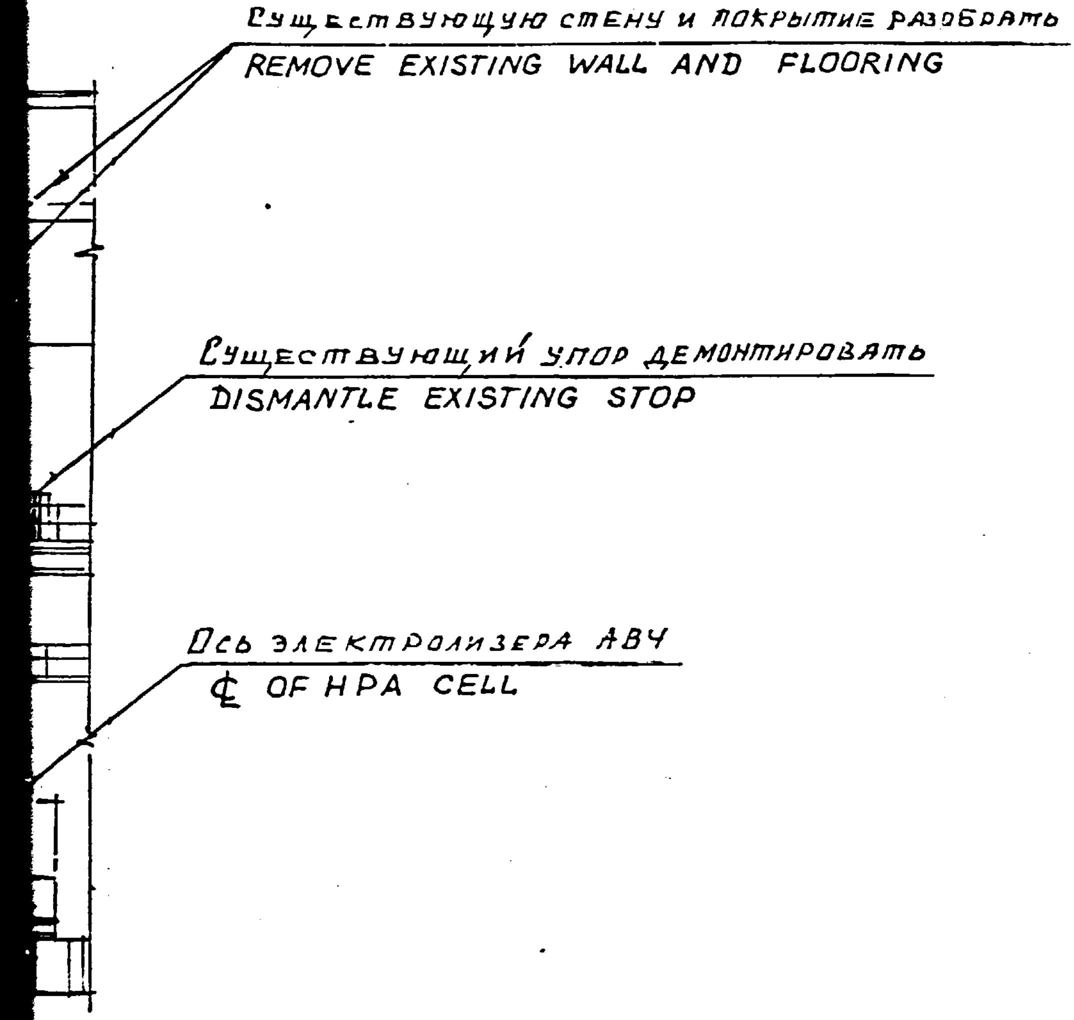
SECTION 3

Р А З Р Е З 2-2

SECTION 2-2



SECTION 4



SECTION 5

Данный чертеж не подлежит размножению или передаче другим организациям и лицам без согласия института ВАМИ

THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI.

1332639-АС

Алюминиевый завод в г. Корба, Индия.
ALUMINIUM PLANT IN KORBA, INDIA.

Экспериментально-демонстрационная установка для производства алюминия высокой чистоты.
EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM.

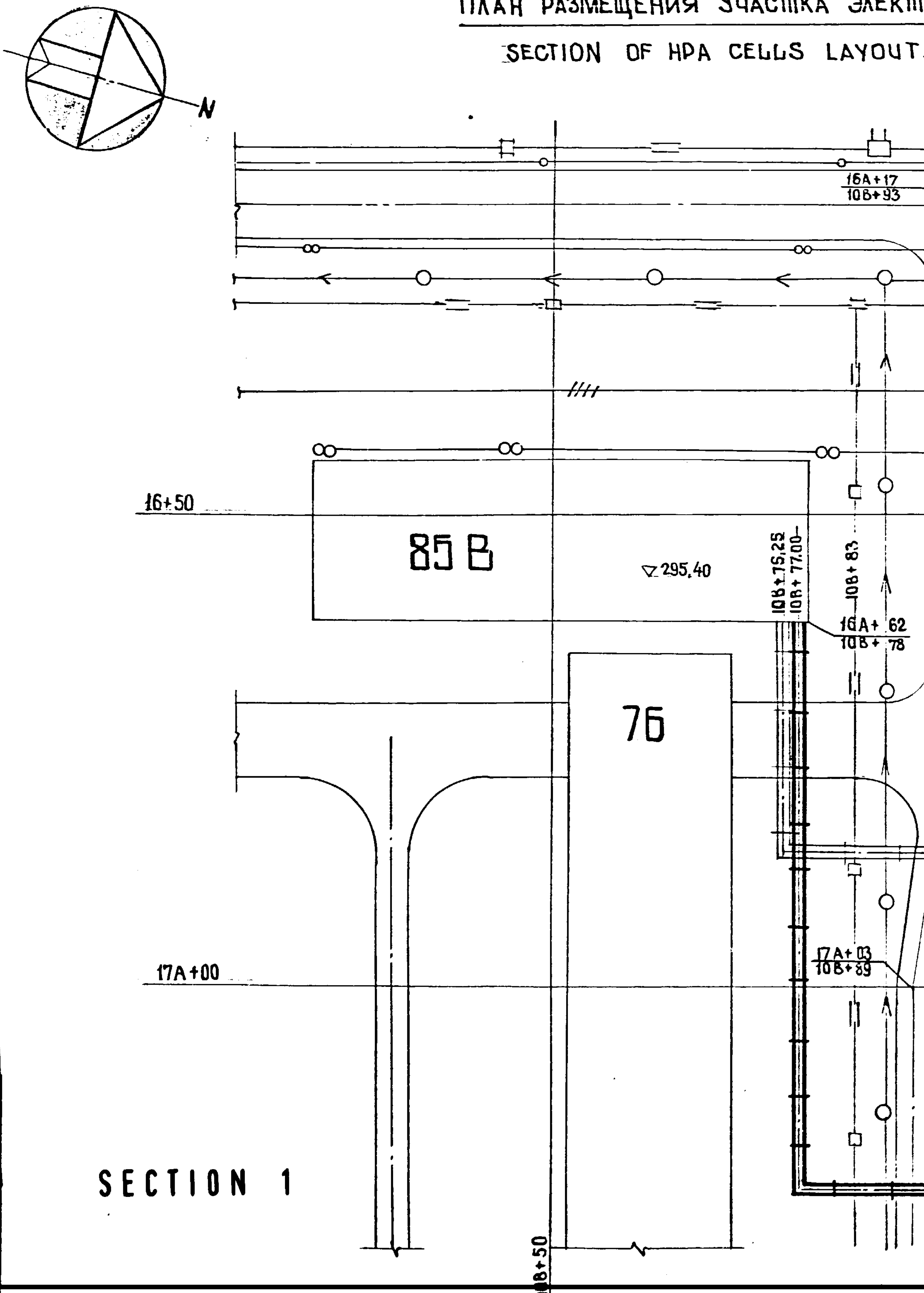
Стадия PHASE	Лист SHEET	Листов SHEETS
ТЭО	2	

Участок электролизеров АВЧ (вариант II) планы, разрезы
SECTION OF HPA CELLS. (VARIANT II) PLANS. SECTIONS

VAMI
LENINGRAD

ПЛАН РАЗМЕЩЕНИЯ УЧАСТКА ЭЛЕКТ

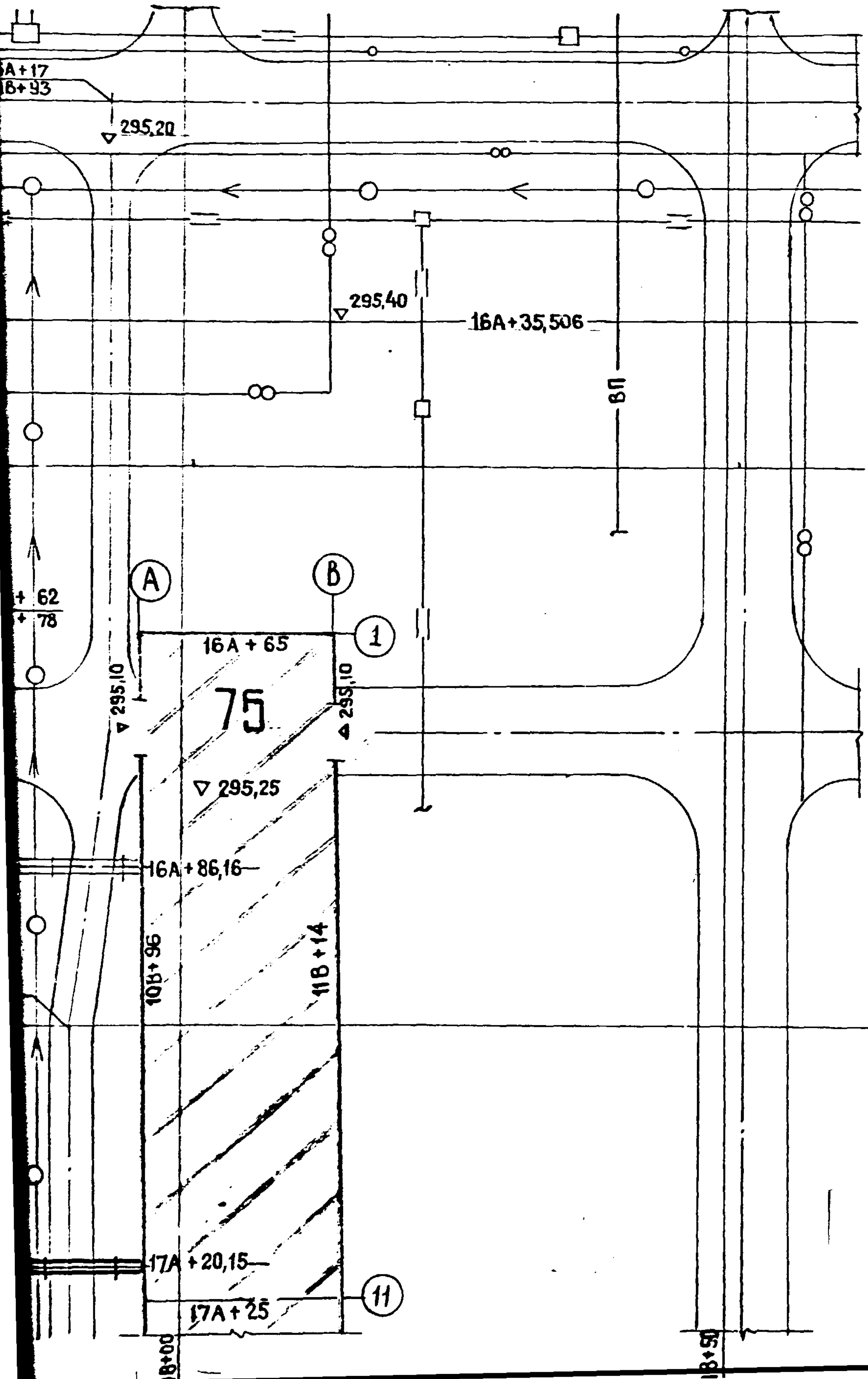
SECTION OF HPA CELLS LAYOUT



SECTION 1

ЭЛЕКТРОЛИЗЕРОВ. ВАРИАНТ I М 1:500.

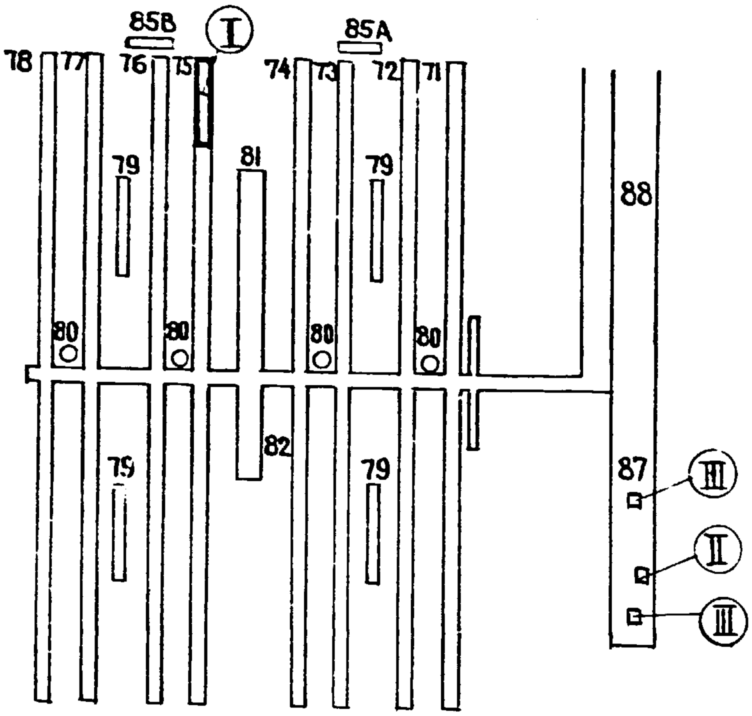
YOUT. VARIANT I SCALE 1:500.



SECTION 2

Схема размещения участков ЭДУ.

EDU SECTIONS LAYOUT.



(I) Участок электролизеров АВЧ.
SECTION OF HPA CELLS.

(II) Участок сушки солей и приготовления солевой шихты.
SALTS DRYING AND SALT MIX PREPARATION SECTION.

(III) Участок разливки АВЧ.
HPA CASTING SECTION.

SECTION 3

Экспликация существующих зданий и сооружений (для справок).

LIST OF EXISTING BUILDINGS AND STRUCTURES (FOR REFERENCES).

71-78 Корпуса электролиза.
CELL ROOMS.

79 — Газоочистные сооружения.
GAS CLEANING INSTALLATION SHOP.

80 — Силос глинозема.
ALUMINA SILO.

81 — Блок вспомогательных отделений цеха электролиза.
AUXILIARY DEPARTMENT FOR ELECTROLYTIC SHOP.

82 — Цех регенерации криолита.
CRYOLITE REGENERATION SHOP.

85 А— Преобразовательная подстанция N 1.
RECTIFORMER SUBSTATION №1.

85 Б— Преобразовательная подстанция N 2
RECTIFORMER SUBSTATION N 2.

87 — Литейное отделение.
FOUNDRY SHOP.

88 — Профильно-трубный цех.
PROFILE TUBE SHOP.

Примечания.

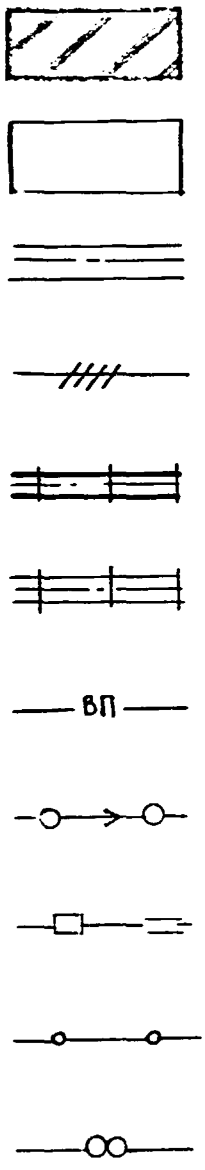
Данный чертеж выполнен на основании материалов, представленных фирмой Балко чертеж N COB/KB/121/C/10/0001
N COB/KB/121/C/10/0004.

NOTE.

THIS DRAWING IS BASED ON INFORMATION RELEASED BY BALCO
DWG. N COB/KB/121/C/10/0001
N COB/KB/121/C/10/0004.

SECTION 4

Условные обозначения
LEGEND.



Реконструирумые участки зданий
MODIFIED PARTS OF BUILDINGS.

Существующие здания и сооружения.
EXISTING STRUCTURES AND BUILDINGS.

Автодороги существующие.
EXISTING ROADS.

Железнодорожные пути существующие.
EXISTING RAILWAYS.

Эстакада шинопроводов проектируемая.
PROJECTED BUSBAR RACK.

Эстакада шинопроводов существующая.
EXISTING BUSBAR RACK.

Водопровод производственный.
INDUSTRIAL WATER PIPELINE.

Канализация фекальная.
FECAL SEWERAGE.

Канализация ливневая.
STORM WATER SEWERAGE.

Дренаж заглубленный.
BURIED TUNNEL.

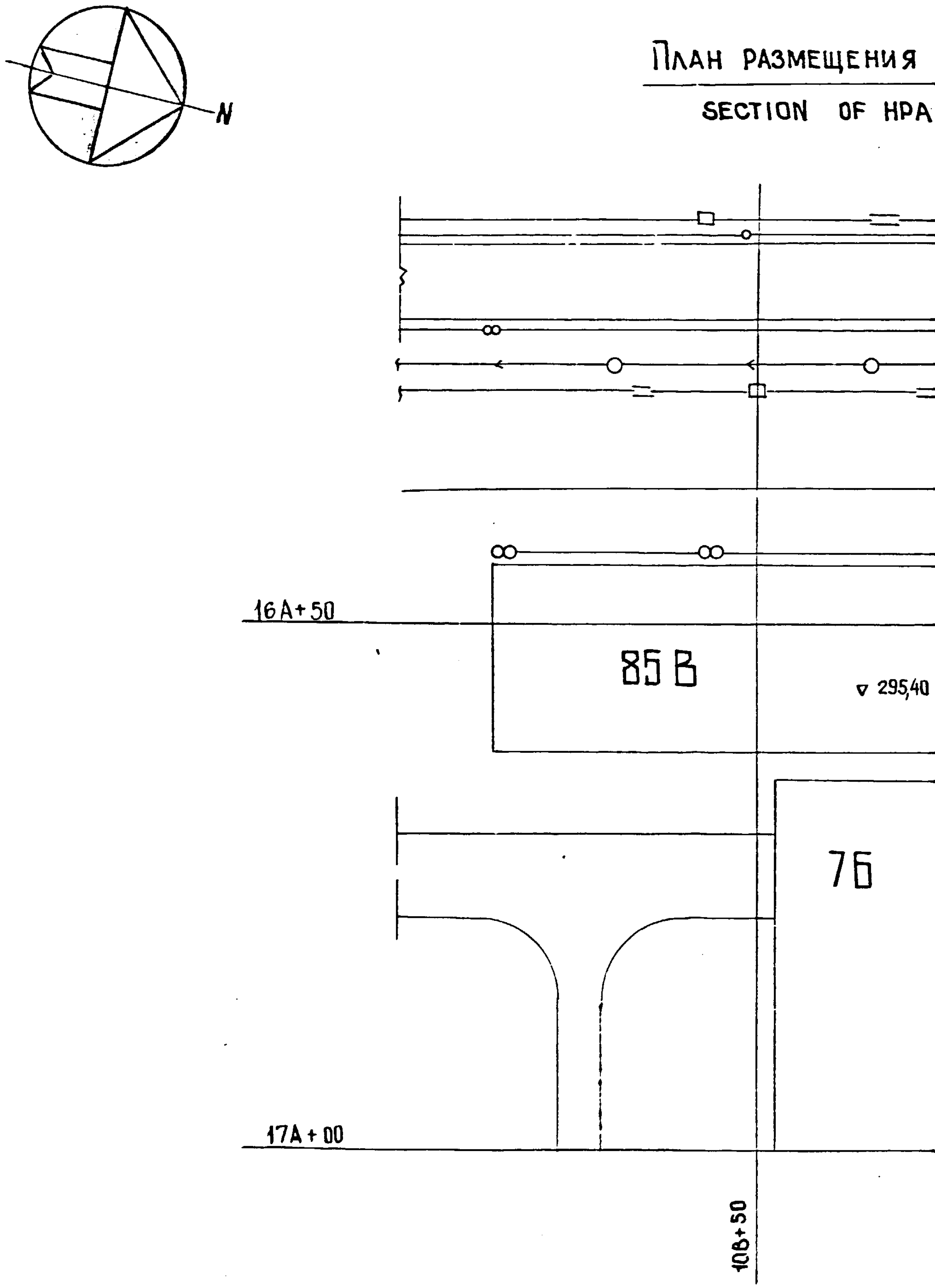
Кабельный туннель.
CABLE TUNNEL.

SECTION 5

Данный чертеж не подлежит размножению или передаче другим организациям и лицам без согласия института ВАМИ	1367230-ГП			
	Алюминиевый завод в г. Корба, Индия. ALUMINIUM PLANT IN KORBA, INDIA.			
THIS DRAWING IS NOT TO BE REPRODUCED OR TRANSFERRED TO OTHER ORGANISATIONS OR PERSONS WITHOUT AGREEMENT WITH VAMI.	Экспериментально-демонстрационная установка для производства алюминия высокой чистоты. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM.	Стадия PHASE	Лист SHEE	Листов SHEETS.
		Т30/FS	1	2
	Генеральный план. Вариант I.	VAMI		

План размещения

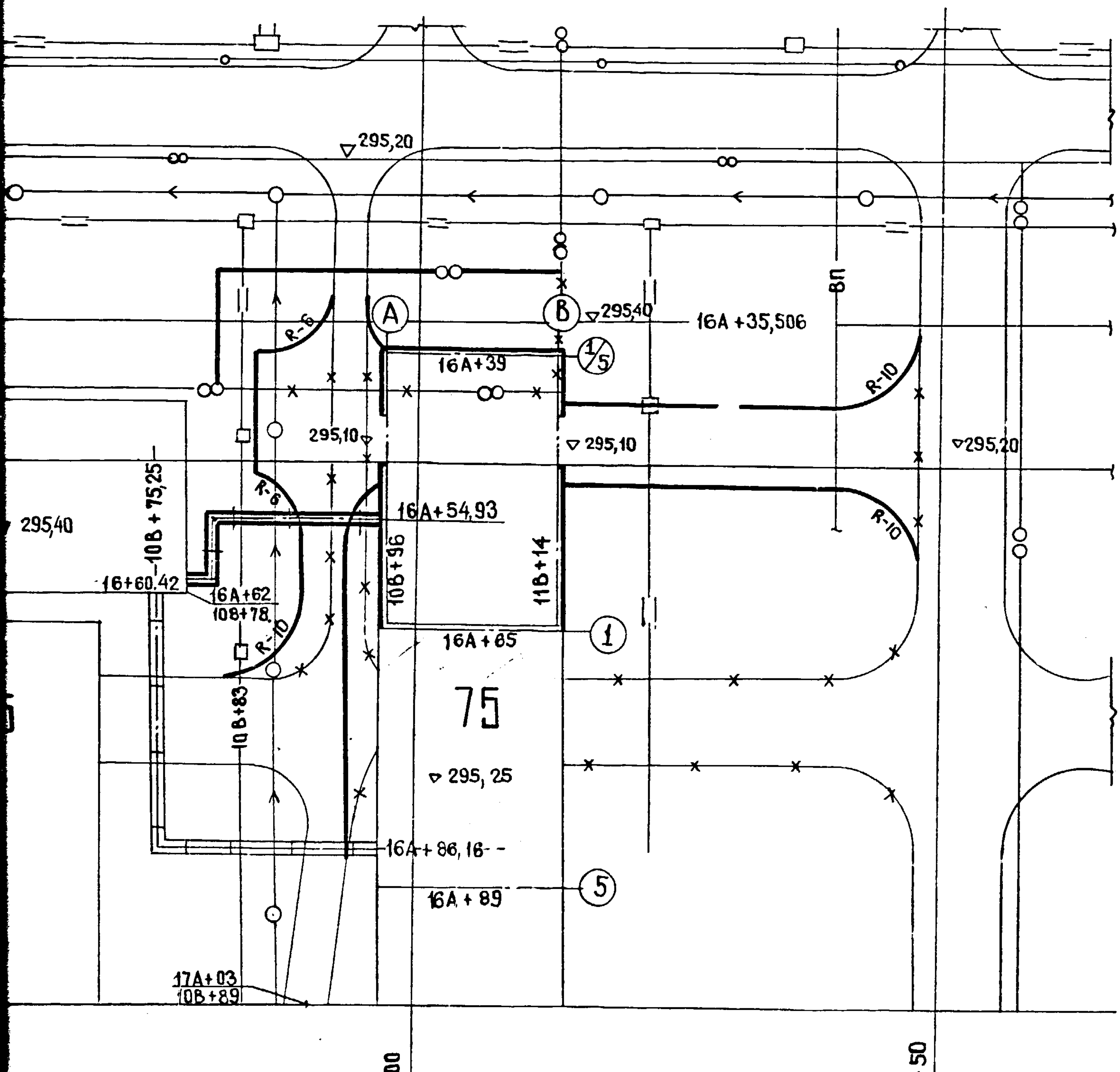
SECTION OF HPA



SECTION 1

НИЯ УЧАСТКА ЭЛЕКТРОЛИЗЕРОВ. ВАРИАНТ II М 1:500.

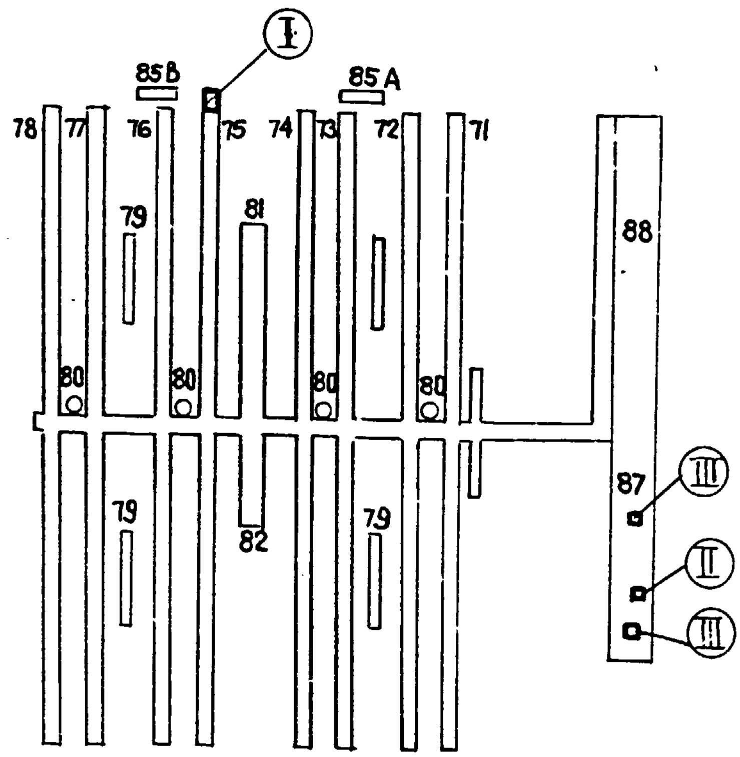
HPA CELLS LAYOUT. VARIANT II SCALE 1:500.



SECTION 2

Схема размещения участков ЭДУ.

EDU SECTIONS LAYOUT.



(I) — Участок электролизеров АВЧ.

SECTION OF HPA CELLS.

(II) — Участок сушки солей и приготовления солевой шихты.

SALTS DRYING AND SALT MIX PREPARATION SECTION.

(III) — Участок разливки АВЧ.

HPA CASTING SECTION.

SECTION 3

Экспликация существующих зданий и сооружений (для справок).

LIST OF EXISTING BUILDINGS AND STRUCTURES (FOR REFERENCES).

71–78 Корпус электролиза.
CELL ROOMS.

79 — Газоочистные сооружения.
GAS CLEANING INSTALLATION SHOP.

80 — Силос глинозема.
ALUMINA SILO.

81 — Блок вспомогательных отделений цеха электролиза.
AUXILIARY DEPARTMENT FOR ELECTROLYTIC SHOP.

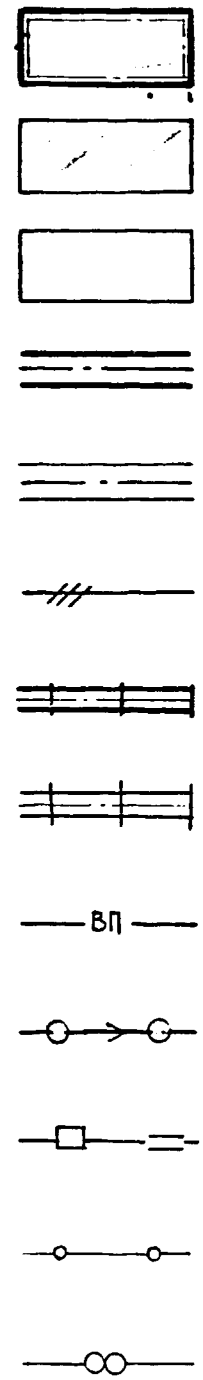
82 — Цех регенерации криолита.
CRYOLITE REGENERATION SHOP.

85A — Преобразовательная подстанция N 1.
RECTIFORMER SUBSTATION №1.

85B. — Преобразовательная подстанция N 2.
RECTIFORMER SUBSTATION №2.

87 — Литейное отделение.
FOUNDRY SHOP.

88. — Профильно-трубный цех.
PROFILE TUBE SHOP.



Примечания.

Данный чертеж выполнен на основании материалов, представленных фирмой Балко чертеж N COB/KB/121/C/10/0001.
N COB/KB/121/C/10/0004.

NOTE.

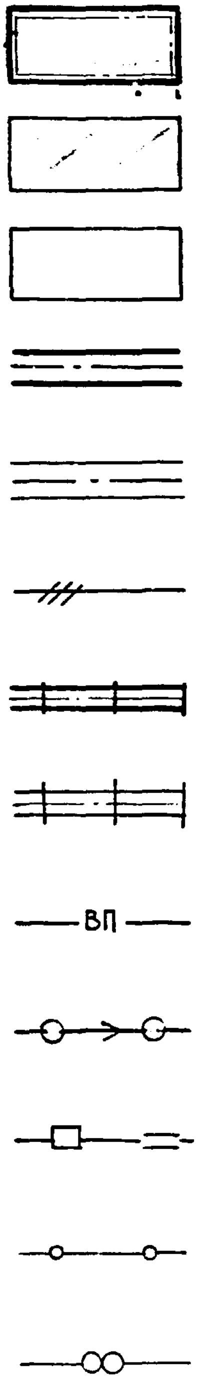
THIS DRAWING IS BASED ON INFORMATION RELEASED BY BALCO

DWG. N COB/KB/121/C/10/0001
N COB/KB/121/C/10/0004.

SECTION 4

NCES).

Условные обозначения.
LEGEND.



Проектируемые здания и сооружения.
PROJECTED STRUCTURES AND BUILDINGS.

Реконструируемые участки зданий.
MODIFIED PARTS OF BUILDINGS.

Существующие здания и сооружения.
EXISTING STRUCTURES AND BUILDINGS.

Автодороги проектируемые.
PROJECTED ROADS.

Автодороги существующие
EXISTING ROADS.

Железнодорожные пути существующие.
EXISTING RAILWAYS.

Эстакада шинопроводов проектируемая.
PROJECTED BUSBAR RACK.

Эстакада шинопроводов существующая.
EXISTING BUSBAR RACK.

Водопровод производственный
INDUSTRIAL WATER PIPELINE.

Канализация фекальная.
FECAL SEWERAGE.

Канализация ливневая.
STORM WATER SEWERAGE.

Дренаж заглубленный.
BURIED TUNNEL.

Кабельный туннель.
CABLE TUNNEL.

SECTION 5

01.
04.
CO

1367230-ГП

Алюминиевый завод в г. Корба, Индия.
ALUMINIUM PLANT IN KORBA, INDIA.

Экспериментально-демонстрационная установка для производства алюминия высокой чистоты. EXPERIMENTAL DEMONSTRATION UNIT FOR PRODUCTION OF HIGH PURITY ALUMINIUM.	Стадия PHASE	Лист SHEET	Листов SHEETS
	ТЭО/FS	2	

Генеральный план. Вариант II.
GENERAL LAYOUT. VARIANT II

VAMI
LENINGRAD

Contract No 85|2
UNIDO

PROJECT REPORT FOR ESTABLISHMENT OF SUPER PURITY ALUMINIUM PRODUCTION IN INDIA

Final Report

No DP|ID|84|007

Volume II, Book 2

Basic Engineering Design of Main Technological Unit (Electrolyser)

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Volume II, Book 2 — Basic Engineering Design of Main Technological Unit (Electrolyser)

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1. EXECUTIVE SUMMARY (CONCLUSIONS)

1.1. General Initial Data (Chapter 2)

The aim of the project is to work-out the cell for establishment of high purity aluminium (HPA) production in India taking into consideration the climatic conditions and utilization of Indian materials and equipment.

1.2. Assumed Capacity of the Refining Cell (Chapter 3)

The 70 kA refining cell was adopted for preparation of the present Basic Engineering Design. This cell is the most powerfull in the world practice and it ensures the high techno-economic indices of the HPA production.

1.3. Characteristics of Materials and Equipment Assumed for Elaboration of Basic Engineering Design of Refining Cell (Chapter 4)

Major materials for fabrication of the refining cell are magnesite, fireclay, light weight fireclay and clay bricks; carbon blocks and plates; graphite; aluminium bars.

Indian equipment and materials are selected for the cell (exept for bimetallic plates and bottom carbon blocks, imported to India from the third countries).

1.4. Location (Chapter 5)

The 70 kA refining cell is designed with due consideration of Indian climatic conditions and it can be installed in any State.

1.5. Technology and Equipment (Chapter 6)

The refining cell is designed for the technology of the HPA production by three-layer electrolytic refining of commercial grade aluminium.

Electrolytic refining process is performed with use of chloride-fluoride electrolyte. The cell consists of anode and cathode assemblies. Anode assembly is a steel welded bath lined from inside with magnesite, fireclay and clay bricks. The dimensions of the lined cavity:

2,450 x 4,760 x 700 mm

The inside bottom layer is made of carbon materials (anode blocks with inserted steel bars for current supply). The loading (feeding) compartment for pouring of raw aluminium is set in one of the end walls. The cathode assembly is a support steel structure installed on the anode shell. The cathode buswork, cathodes, cathode lifting mechanism and cell enclosure are installed on the steel structure. The cathode buswork consists of four aluminium busbars with cross-section of 430 x 70 mm and it is manufactured in form of two packs (with two busbars in each pack). The number of installed cathodes is 13 pcs. The cathode consists of a cylindric graphitised block with inserted stub with aluminium bar. The cathode lifting mechanism consists of two electric motors, two gears and four jacks. The cell enclosure is fabricated of aluminium sheets. Total weight of the cell is about 62 tonnes.

Total dimensions: anode shell - 6440 x 3610 x 2120 mm

cell - 6950 x 3610 x 4575 mm

For this cell the following has been prepared: calculation of cell energy balance, voltage drop in the buswork and electrical balance. The calculations revealed that in Indian climatic conditions and considering the fabrication of the cell of Indian materials the following performance figures should be ensured:

- Amperage - 70 ± 1 kA
- Current density - 0.6 A/cm^2

- Maximum capacity (for continuous operation during a year - 8760 hrs) - 191 tpy
- Cell voltage drop (including cell buswork voltage drop) - 5.5 V
- Specific DC power consupmtion (excluding power required for electrolyte preparation and losses in the buswork) - 17,650 kW.hr/t

The major requirement for the refining cell fabrication is to comply with the Specifications for Cell Installation during the manufacture of the cell assemblies.

The lining of the anode shell is to be carried out specifically carefull, as its quality effect the purity of aluminium produced and the cell service life.

Conclusions

1. The utilisation of the refining cell designed with consideration of Indian conditions for the establishment of high purity aluminium production in India will ensure the most favorable techno-economics.

2. Indian side has a great experience in fabrication and installation of aluminium cells, so the fabrication and installation of high purity aluminium production cell can be executed with the required quality.

2. GENERAL INITIAL DATA

2.1. Aim of the Project

The aim of the Project is to work-out the cell for high purity aluminium production in India. The cell is to be designed:

- with due consideration of Indian climatic conditions;
- with utilization of Indian materials and equipment.

3. ASSUMED CAPACITY OF THE REFINING CELL

3.1. Refining Cell capacity

At present HPA is commercially produced by electrolytic three-layer method for refining of primary (Commercial grade) aluminium, which is widely used in the USSR and other countries.

For HPA Production 25-70 KA Cells are used in the USSR, and 14-60 KA Cells in other countries (for example - 18 KA in France, 14 KA in Switzerland, about 40 KA in GDR and Hungary and 60 KA in USA). The 70 KA refining cell is adopted for design of the present project.

The normal (rated) annual cell capacity is 188 tpy. Maximum cell production capacity is 191 tpy (for the contineo-us operation of the cell during a year 8,760 hours).

3.2. BRIEF CHARACTERISTICS OF REFINING POT

Sl No	Description	Unit	Value
1	Amperage	KA	70
2	Current efficiency	%	93
3	Number of cathodes	pcs	13
4	Pot service live	years	5.0

4. CHARACTERISTICS OF MATERIALS AND EQUIPMENT ASSUMED FOR ELABORATION OF BASIC ENGINEERING DESIGN OF REFINING CELL

List of main materials and equipment for refining cell manufacturing.

- magnesite brick
- light-weight firebrick
- fireclay brick
- ordinary clay brick
- carbon blocks and plates
- bottom (ramming) paste
- graphite
- Steel
- aluminium sheets 1 x 150 mm
- cast aluminium bus-bars 430 x 70 mm
- extruded aluminium bus-bars 430 x 70 mm
- 0.75 KW electric motor, covered
- worm reduction gear
- 5 t screw jack

4.1. Requirements for main materials and equipment for manufacturing of one refining Cell

Sl. No.	Description	Unit	Value	Density, Gm/cc
1	Magnesite brick	m^3	3.16	2.63
2	Light-weight fire-brick	-do-	4.40	0.9
3	Fireclay brick	-do-	4.00	2.0
4	Ordinary clay brick	-do-	3.45	1.90

Sl. No.	Description	Unit	Value	Density, Cm/cc
5	Carbon blocks and plates	T	5.25	-
6	Bottom paste	-do-	2.36	-
7	Graphite	-do-	1.43	Including graphite for cathodes
8	Steel	-do-	18.92	-
9	Aluminium Sheets 1 x 150 mm	-do-	0.23	-
10	Cast aluminium bus-bars 430 x 70 mm	-do-	0.98	-
11	Extruded aluminium bus-bars, 430x70 mm	-do-	0.98	-
12	0.75 KW electric motor	Pcs.	2	-
13	Worm gear	-do-	2	-
14	5t screw Jack	-do-	4	-

4.2. Material requirements

Refractory & thermoinsulation materials to be utilised for set-up of the cell should comply with the following requirements so that:

- to ensure the required heat resistance of anode Jacket walls & hearth to obtain optimum heat conditions for refining process;
- to ensure the cell guaranteed service - life;
- to ensure production of high quality refined aluminium.

4.2.1. Magnesite brick is used for the Cell inside lining layer being in contact with electrolyte, liquid aluminium and anode alloy. In this case magnesite brick should meet the following requirements:

- refractoriness and resistance to electrolyte, liquid aluminium and anode alloy.

- dimensions of magnesite bricks are to be specified (380 x 150 x 75 mm, 300 x 150 x 75 mm and 300 x 150 x 65 mm).

- required mechanical strength (600 kg/cm^2 minimum).

The above requirements allow:

- to prevent the impurities (in general silicon and iron) to polute the Cathode metal;

- to line the cell with such magnesite brick work, which prevent the location of horizontal beams in most agressive layer-electrolyte. Thus, electrolyte is prevented to attack the fireclay lining, reducing the impurity level of cathode metal;

- to make the lining with less number of beams (the utilisation of large dimension bricks), which also reduce the impurity level of cell working media;

- to ensure the required cell lining service life period (5 years minimum).

4.2.2. Fireclay brick

The fireclay brick is used for the lining layer located directly after the magnesite layer. The fireclay bricks are to meet the following requirements:

- refractoriness relatively high resistance to cell working metals;

- mechanical strength should be not less than 230 kg/cm^2;

- thermal conductivity should be in a range of 0.8-0.9 Kcal,· m hour·degree

The above requirements allow to ensure

- the necessary service life of lining (not less than 5 years).
- the cell heat operation conditions.

4.2.3. Light-weight fireclay bricks

The light-weight firebrick is used for the lining layer between fireclay brick layer and fire brick lining.

The light-weight firebrick should meet the following requirements:

- density of 0.9 g/cm^3
- thermal conductivity 0.4-0.5 W/m^0K minimum

These requirements of lining materials shall ensure the heat operation mode of the refining cell.

4.2.4. Graphitised electrodes

Graphitised electrodes are used as a graphite part of the cell cathodes being in contact with cathodic aluminium.

The graphitised cathodes are to meet the following requirements:

- Specific electrical resistance should be 8.1-9.0 mc ohm.maximum.
- Flexural strength - not less than 70 kg/cm^2.
  rupture strength - not less than 35 kg/cm^2.

The lower quality of electrodes will result in increased graphite and power consumption, as well as increased costs of cathodes manufacturing, repair and maintenance.

4.3.0 Characteristics of material and equipment

4.3.1. Ordirary clay brick

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Brick size	mm	250x120 x65	230x115 x65	Standard size may be ordered
2	Compression strength, minimum	kg/cm^2	100	75	Average for 5 samples
3	Flexural strength min.	-do-	22	-	-same-

4.3.2. Fireclay brick

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Brick Sizes	mm	230x114 x65	230x115 x65	General purpose
2			230x114 x40	230x115 x40	Semi-acid fireclay
2	Al_2O_3 content. min.	%	30	30-32	
3	Refractoriness, min.	^0C	1670	1670	
4	Porosity, max.	%	23	23	
5	Compression strength, min.	kg/cm^2	230	230	

4.3.3. Light-weight fireclay brick

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Brick sizes	mm	250x124 x65	250x124 x65	
			230x114 x40	230x115 x 40	
2	Density	g/cm^3	0.9	0.8-1.29	
3	Compression Strength, min	kg/cm^2	25	20-30	
4	Max. Thermal conductivity at average temperature:	W/m.°K			
	$350 \pm 25^{\circ}C$		0.4	0.27	
	$650 \pm 50^{\circ}C$		0.5	0.4	

4.3.4. Compacted magnesite brick

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Brick dimensions	mm	380x150x75	380x150x65	
			300x150x75	300x150x75	
			300x150x65	300x150x65	
2	Magnesium oxide content	%	91	91 min.	
3	Calcium oxide content in calcined product, max.	%	3	2.5 max.	
4	Silica content in calcined product	%	2.5	1.0 max.	
5	Porosity, max.	%	11-18	16-20 max.	
6	Compaction strenght, minimum	MPa (kg/cm^2)	60 (600)	40-60 (400-600)	

4.3.5. Graphitized electrodes

Sl. No.	Description	Unit	Value		Remarks
			Soviet	India	
1	Sizes: Outside dia	mm	350	350	
2	Specific electrical resistance, max.	mc.Ohm.m.	8.1-9.0	9.5	
3	Mechanical strength bending strength	kg/cm^2	70	85	
4	Rupture strength	-do-	35	75	

4.3.6. Carbon Plate

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Plate Sizes	mm	200x450 x 630	200x450 x 630	Can be manufactured of Carbon block for cells at Korba Plant
2	Compression strength, min.	kg/cm^2	230	230	Average for a batch.
3	Stability factor		15		

4.3.7. Carbon block

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Block sizes	mm	400x550x x 900	400x550x x 900	
			400x550x 1340	400x550x 1340	
2	Average compression strength, min.	kg/cm^2	230	220 min.	Value of individual measurements should be not less than 80% of average value
3	Porosity, max.	%	22	24 max.	Value of individual measurements should not exceed the average value by more than 10%
4	Specific electrical resistance, max.	Ohm.mm 10^{-6}	90	70 max.	
5	Stability factor		8	-	

4.3.8. Bottom Paste

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Mechanical strenght	kg/cm^2	240	200 min.	
2	Binding factor, min.	kg/cm^2	16	25	
3	Yield of volatiles	%	6-12	-	
4	Porosity, max. (Baked)	-do-	22	23 max.	

4.3.9. Sodium Sulphate Water glass

Sl. No.	Description	Unit	Value		Remarks
			Soviet	India	
1	Silicate modulus		2.31-2.6	2.1	SiO_2-30% Na_2O-14.4%
2	Density	kg/cm^3	1.43-1.5	1.48-1.52	

4.3.10. Cast Iron.

Chemical Composition: Si 3.2-3.6, max. 0.3% Mn
P - 0.12% max. S - 0.03% max.

4.3.11. Collector Bars

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Strip Steel with cross-section	mm	230x115	230x115	
2	Steel Grade	-	$BC_T1K\Pi$	IS 1875-1978	
3	Carbon Content	%	0.1	0.1	
4	Strength	kg/mm^2	31-50	37-45	

4.3.12. Product mix of materials for anode casing (welded structure)

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	I-beam		No.45 No.24	Nos: 45, 25	
2	Channel		No.16 No.22 No.24 No.34	Nos: 15, 22.5, 25,35	
3	Strip-thickness	mm	60-80	60-80	
	Width	-do-	130-180	130-180	
4	Sheet, thickness	-do-	5-15	5-15	
5	Steel grade (items 1, 2, 3)	-do-	$BC_T3\Pi C5$	IS:226	

4.3.13. Support Steel structure of cell

Sl No.	Description	Unit	Values		Remarks
			Soviet	Indian	
1	Channel, height		Nos.12.14	Nos.12.5, 15	
2	Sheet thickness	mm	5-10	5-10	includes cell enclosure
3	Steel Grade	-	BC$_T$3ПC5	IS: 226	
4	Aluminium sheet thickness (enclosure)	-do-	0.5-3	0.5-3	
5	Fabric-bases laminate sheet, thickness	-do-	5-10	5-10	

4.3.14. Cathode Lifting mechanism

Sl. No	Description	Unit	Values		Remarks
			Soviet	Indian	
1	Channel	-	Nos.6.5-10	Nos: 7.5;10	
2	Sheet, thickness	mm	5-10	5-10	
3	Steel Grade	-	BC$_T$ 3Kп2	IS: 226	

4.3.15. Cathode bussing

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Cast Aluminium bus-bars				available
1.1	Bus-bar sizes	mm	430x70	430x70	
1.2	Chemical composition;				
	Al, max.	%	99.5	99.5	
	Fe, max.	%	0.35	0.35	
	Si, max.	%	0.12	0.12	

Sl. No.	Description	Unit	Value Soviet	Value Indian	Remarks
	Cu, max.	%	0.02	0.02	
	Zn, max.	%	0.04	0.04	
	Ti, max.	%	0.015	0.015	
2	Extruded aluminium busbars				
2.1	Bus-bar sizes	mm	430x70	430x70	
2.2	Chemical composition	-	-		See item 1.2
2.3	Ultimate rupture strength	Kg/mm^2	7	9-10	
2.4	Relative elongation	%	15	10-12	
3	Steel				
3.1	Product mix : I - beam height		No.16	No.17.5	
3.2	Sheet, thickness	mm	10-20	10-20	
3.3	Steel grade	-	BC_T3кп2	IS: 226	

4.3.16. Eccentric clamp

Sl. No.	Description	Unit	Value Soviet	Value Indian	Remarks
1	Casting (steel casting)	mm	290x200x 170	290x200x 170	
2	Steel grade	-	25Л	18/8 SS	

4.3.17. Cathode

Sl. No.	Description	Unit	Value		Remarks
			Soviet	Indian	
1	Aluminium rod	mm	80x120	80x120	
2	Material (item 1)		Aluminium	Aluminium	For aluminium composition see section 4.3.15 item 1.2
3	Steel stubs, dia	mm	180	180	
4	Steel grade (it.3)	-	$BC_T3K\Pi2$	IS: 226	
5	Bimetallic plates	steel / aluminium			Soviet supply

4.4. Utilities

4.4.1. DC power

- Amperage of DC power - 70 KA
- Permissible amperage fluctuation - ± 5%
- Duration of emergency DC power cut-off - 2 hours maximum

4.4.2. AC power

AC power voltage - 220 V

Duration of emergency AC power cut-off - 8 hours maximum.

5. LOCATION

70 KA refining cell is to be designed with due consideration of Indian climatic conditions and can be installed in any state.

The setting up of the Experimental Demonstration Unit (three 70 KA refining cells) is planned at BALCO Aluminium Smelter in Korba.

6. TECHNOLOGY AND EQUIPMENT

6.1. Brief process description

One of the commercial methode for HPA production at present is an electrolytic method of commercial grade aluminium refining by three-layer method which is widely used in the USSR.

This method provided for production of aluminium grade A95--A995.

For HPA production commercial grade crude aluminium (aluminium in liquid form) is fed into refining cells in which electrolytic refining process takes places. Electrolytic refining process is performed with use of chloride-fluoride electrolyte.

Crude aluminium (primary Al) is fed into pots by the pouring machine.

The following materials are added periodically to crude aluminium:

- Copper to correct anode alloy composition
- Crushed solid electrolyte to make for losses.

HPA produced in the pot is periodically removed by vacuum ladle and then it is casted into pigs and ingots. Anode sediments and electrolyte crust are periodically removed from the cells.

The flue-gases from the cell where electrolyte is prepared and cathodes are impregnated periodically are to be cleaned.

6.2. Refining Cell

(dwg. No 1335873)

The cell consists of two major parts: a cathode and anode.

6.2.1. Cathode

The cathode consists of:

- support steel structure;
- cathode buswork;

- cathodes proper;
- cathode lifting mechanism;
- cell enclosure.

6.2.1.1. Support Steel Structure

The support steel structure is made of two welded steel semi-frames interconnected by two longitudinal beams.

The longitudinal beams are to be electrical insulated of semi-frames. The support structures for jacks and electric motors of cathode lifting mechanism are installed in the upper part of steel structure.

The steel structure is installed on appropriate pillars of anode shell and is fixed to the pillars with bolts.

The provision is made for the electric insulation in places of steel structure contacts with anode shell.

6.2.1.2. Bathode Buswork

The cathode buswork consists of two packs of busbars interconnected by three spacer beams. Eyes are provided on two outer beams for suspension of the cathode buswork from the screws of the cathode jacks.

Each pack consists of two interlocked aluminium busbars with cross section of 70 x 430 mm.

Fitted from the outside of the buswork packs are the eccentric clamps designed to ensure electrical contact between the cathode bars and busbar packs.

6.2.1.3. Cathode
(dwg. No 1335875)

The cathode consists of:
- graphitised block 500 mm dia and 340 mm high;
- steel stub;
- aluminium bar with cross section of 120 x 80 mm
- steel - aluminium bimetallic plates.

The graphitised block is provided with a stub hole.

The cathode assembly procedure is as follows: two vertical bimetallic plates are welded to the aluminium bar, then a horizontal bimetallic plate is welded to two vertical bimetallic plates.

A steel stub is welded to the horizontal bimetallic plate. Then an aluminium bar (together with bimetallic plates and a stub) is inserted into the stub hole. The gap between the stub and graphite is filled with cast iron.

The assembled graphitised block is impregnated with electrolite. To protect the graphite block from oxidation it is mantled with high-purity aluminium metal.

6.2.1.4. Cathode Lifting Mechanism

The cathode lifting mechanism (2 pcs. for one cell) is designed to ensure the required positionning of cathode graphite part into the cathode metal pad.

The cathode lifting mechanism consists of:

- two screw jacks 5 t capacity each;
- worm gear;
- electric motor 0.75 kW

Maximum stroke of jack screws is 500 mm. The electrical insulation is provided for between the jack screws and cathode buswork.

6.2.1.5. Cell Enclosure

The enclosure is designed to reduce the cell heat losses and to protect the operating personnel from radiation heat.

The enclosure consists of:

- central hood,
- side removable covers.

Central hood is fabricated of aluminium sheets installed on steel frame suspended on ties to the support steel structure of the cell.

Side covers close the openings between the longitudinal rows of cathods and longitudinal walls of anode casing. Special cutouts to pass the cathode bars are provided for in the covers.

6.2.2. Anode assembly

Anode assembly consists of

- anode shell
- skirting
- lining

6.2.2.1. Anode shell

Anode shell is a welded rectangular bath. The vertical walls and the bottom of the bath are reinforced with I-beams and channels.

Four pillars for installation of support steel structure of the cell are welded to the upper horizontal belt of the bath. Framed openings for the installation of anode section collector bars are provided for on the longitudinal walls of shell.

6.2.2.2. Skirting

The provision is made for the skirting to cover the upper horizontal surfaces of the lining side walls. The side skirting is fabricated of steel sheets fixed to the upper horizontal belt of anode shell.

The skirting sheets of end walls are also fixed by the cross beams. By wedges the cross beams are fixed into the sockets of the anode casing support pillars (see drawing No. 1335873). The bracket for installation of the pneumatic device for the loading to the feeding compartment (for mixing of anode alloy) is provided for on the cross beam with the feeding compartment.

6.2.2.3. Lining (dwg. No 1335874)

The following is used for lining of anode shell:

- asbestos sheets,
- alumina
- brick (clay, fireclay, fireclay light-weight and magnesite),
- anode carbon sections.

Anode sections consists of carbon block with groove and steel bar (collector bar), located in this groove and iron casted. The lining of anode shell bottom consists of:

- layer of alumina fill,
- layer of asbestos sheets,
- two layers of clay bricks,
- three layers of fireclay lightweight bricks,
- two layers of fireclay bricks.

The layer of bottom paste is applied on the surface of fireclay lining. After that the anode carbon sections are laid. The lining of anode casing walls consists of:

- layer of asbestos sheet,
- one layer of lightweight fireclay bricks,
- two layers of magnesite bricks.

The joints between anode sections as well as between anode sections and the wall lining are to be filled with bottom paste.

The feeding compartment is provided for in one of the end walls. This feeding compartment consists of an inclined graphite tube and a horizontal channel connecting the tube with the anode casing cavity. The angles of this wall are lined with clay bricks.

6.3. Energy balance of the cell (Annexure No 1)

Energy balance of the cell has been made on the basis on Indian climatic conditions and its location in two-storey cell room.

The following basic data has been used in the energy balance calculation:

- electrolyte temperature - 810°C
- current efficiency - 93%
- raw aluminium specific consumption - 1.03 t/t
- thickness of layers: electrolyte - 13 cm
  cathode metal - 18.5 cm
  anode alloy - 36.0 cm
- electrolyte composition - chloride-fluoride
- abmient temperature in the cellroom:
  above + 3.0 m - 32°C
  under + 3.0 m - 25°C

The results of the calculations are given in the table below:

SRL Nos.	Description	Units	Values
1	Amperage	KA	70±1
2	Current density	A/cm²	0.6
3	Production rate: *)		
	- annual	t/year	191
	- daily	kg/day	523.4
	- hourly	kg/hour	21.8

*) with continuous cell operation

SRL Nos.	Description	Units	Values
4	Cell heating voltage (cathode bar-anode flexible)	v	5.32
5	Voltage drop across bus work	v	0.18
6	Cell operating voltage	v	5.5
7	Specific DC power consumption	kWH/t	17650

Calculations of the energy balance have shown that:

- the designed refining cell with electrolyte layer of 13 cm and amperage of 70 kA will be in a heat equilibrium;

- the cell will operate at optimum heat condition, which ensures technical and economical indices adopted for the project and also power, raw and other materials consumption.

6.4. Calculation of voltage drop in cell buswork (Annexure No 2)

In accordance with calculations carried out the voltage drop in cell buswork is 0.18 V. The average current density of the bussing was assumed equal to 0.29 A/mm^2. The economically feasible current density for Indian condition is in the range of 0.27-0.29 A/mm^2.

6.5. Operating voltage drop and specific DC power consumption of the refining cell

Refining cell operating voltage drop is:

$5.318 + 0.18 = 5.498 \approx 5.5$ V (see Annexures Nos. 1 & 2)

where: 5.318 - heating cell voltage drop, V,

0.18 - voltage drop of cell buswork, V.

Thus, the specific DC power consumption is:

$$W = \frac{5.5 \times 10^3}{0.335 x 0.93} = 17,650 \text{ KW.hr/t}$$

where: 0.335 - Aluminium electrochemical equivalent, g/A.hr

93 - current efficiency, %.

6.6. Summary Table of Cell Electrical Balance

(see Annexures Nos. 1 and 2)

SRL. No	Description	Unit	Value
1	Voltage drop in cathode assembly	V	0.475
2	Ohmic voltage drop in electrolyte	-do-	4.066
3	Polarization voltage at electrodes	-do-	0.38
4	Voltage drop in anode assembly	-do-	0.38
5	Voltage drop in anode flexibles	-do-	0.017
	Total, heating voltage	-do-	5.318
6	Voltage drop of cell buswork	-do-	0.18
	Total, cell operating voltage	-do-	$5.498 \simeq 5.5$

6.7. Major Specifications for Cell Installation

To construct the cell use the materials with physico-chemical properties as stated in Section 4 of this Basic Engineering Design.

Install the cell in conformity with the following specifications:

6.7.1. Installation of Anode Shell

6.7.1.1. The fabricated anode shell shall have the following tolerances of dimensions:

- inside length ± 20 mm max
- inside width ± 20 mm max
- inside depth ± 10 mm max
- departure from straight line:
  - long wall 30 mm max
  - short wall 20 mm max

6.7.1.2. To set the anode shell check that departure of longitudinal and cross axes of the cell from the appropriate axes of the support structures is 10 mm max.

6.7.1.3. Difference between the elevations of the corners of the shell mounted on the supports shall not exceed 15 mm. To level the shell use steel plates inserted under the corners of the shell.

6.7.2. Anode Shell Base Lining

6.7.2.1. Width of joints of the brickwork of the shell base shall not exceed the following:

- clay brick 7 mm
- lightweight fireclay brick 2 mm
- fireclay brick 2 mm

All brickwork except for top layer of fireclay brick is laid without any mortar. Fireclay mortar is used for top layer of bricks.

6.7.3. Installation of Bottom Blocks

6.7.3.1. Bottom blocks will be laid with a special bond as provided in the Basic Engineering Design.

6.7.3.2. Width of joints between the carbon blocks in the sections shall be between 35 and 50 mm.

6.7.3.3. Allow no gaps or cavities between carbon blocks. To eliminate the gaps fill them with hot carbon paste and pour with pitch.

6.7.3.4. See that the surface of the anode shell bottom is horizontal with absolute difference between the individual points not exceeding 20 mm.

6.7.4. Anode Shell Lining Curb

6.7.4.1. The lining curb is made using fireclay brick on refractory mortar, bonded joints and carefull fitting of bricks to each other and to the anode collector bars. Width of joints between the anode bars and bricks shall not exceed 0.5 mm.

6.7.4.2. Fill the gaps between the shell and the curb with building gypsum mortar.

6.7.5. Laying Side Lining (long and short walls)

6.7.5.1. According to the Basic Engineering Design the first and second layers of magnesite brickwork are laid along the whole perimeter of the cell cavity except for area of the loading compartment.

The first layer of magnesite lining is laid on gypsum mortar, the second layer is laid dry.

6.7.5.2. All magnesite brickwork is carefully fitted and bonded. Fill all joints facing the inside cavity of the cell with gypsum mortar.

6.7.5.3. Check that width of joints for the first layer of magnesite brickwork facing the inside cavity is 0.3 mm max., that of other layers - 0.5 mm. If necessary machine the faces of bricks to meet the above specifications.

6.7.5.4. Lightweight fireclay brickwork is laid dry and bonded, the joints are later filled with alumina. Width of joints is not to exceed 2 mm.

6.7.6. Bottom Joint Ramming

6.7.6.1. Before ramming the bottom joints:

- clean the cell cavity from gypsum, brick debris, solidified putty, etc.

- heat the bottom joints to 110-150 °C, do not allow overheating of the carbon blocks to over 180 °C. Having heated the joints clean them with wire brushes.

6.7.6.2. See that ramming mix (bottom paste) is at least 160 °C when placed into joints.

6.7.6.3. Check that ramming mix is loose and free from lumps.

6.7.6.4. Heat ramming mix so that to prevent any paste coking.

6.7.6.5. Ram the bottom without interruptions in one operation.

6.7.6.6. Ram using 8-10 fills 40-60 mm thick. Cross-hatch the previous layer before each next fill and ram.

6.7.6.7. The surface of the rammed joint should be slightly raised to a height of 5 mm above the block surface.

6.7.6.8. Use pneumatic rammers preheated before the use to a temperature of 100-120 °C.

6.7.6.9. The ramming workers should wear clean boots.

6.7.7. Loading Compartment Brickwork

The main component of the compartment is a graphite tube impregnated with electrolyte and set at an angle of abt 15 deg. of the vertical.

6.7.7.2. The loading compartment channel is made of magnesite brick and the graphite tube is lined with magnesite and fireclay bricks. Width of joints between bricks is 0.3 mm max.

A N N E X U R E S

1. CALCULATION OF CELL ENERGY BALANCE

BASIC DATA FOR PREPARATION OF ENERGY BALANCE

SRL No	Description	Unit	Value
1	Electrolyte temperature	°C	810
2	Current efficiency	%	93
3	Raw aluminium consumption per 1 t of HPA	t/t	1.03
4	Average estimated level of:		
	- electrolyte	cm	13
	- cathode metal	-do-	18.5
	- anode alloy	-do-	36.0
5	Electrolyte composition:		
	- barium chloride	%	57-58
	- cryolite	-do-	16-17
	- aluminium fluoride	-do-	21-22
	- sodium chloride	-do-	~4.0
6	Air temperature in cell-room at elevation higher than +3.0 m	°C	32
7	Air temperature in cell-room at el. lower than +3.0 m	-do-	25

2. CALCULATION OF CELL ENERGY BALANCE

The energy balance of refining cell can be represented by the following equation:

$$Q_1 + Q_2 + Q_3 = Q_4 + Q_5$$

where Q_1 = energy required to compensate heat losses;

Q_2 = energy used for electrochemical processes, in this case - for electrode polarization;

Q_3 = quantity of heat entering the cell with poured raw aluminium;

Q_4 = heat losses with HPA removed from the cell;

Q_5 = heat losses from cell heat-transfer surfaces.

Heat consumption for melting and heating of electrolyte and copper charged to the cell are neglected due to insignificant values of these heat output items.

2.1. HEAT INPUT

2.1.1. Quantity of electric power required for compensation of heat losses.

$$Q_1 = \frac{I^2R}{1000} \quad \frac{kW.hour}{hour}$$

where I - current intensity, A

R - cell electric resistance, Ohm

Cell electrical resistance can be represented by the following formula:

$$(1)\ R = R_1 + R_2 + R_3 + R_4$$

where: R_1 - electrical resistance of cathode assembly,

R_2 - electrical resistance of electrolyte,

R_3 - electrical resistance of anode assembly,

R_4 - electrical resistance of anode flexibles.

The calculation of electrical resistance of individual construction units and total electrical resistance of a cell are given below.

The data of electrical balance registered at commercial refining cell (analogue cell) with construction units analogue to the cell assumed for the present Basic engineering has been used for the calculation. The electrical balance of the analogue cell was enregistred at current intensity of 70 kA.

The electrical resistance of the cathode assembly was determined by formula:

$$R_1 = \frac{R_6 + R_7}{n}$$

where R_6 - electrical resistance of cathode aluminium bar,

R_7 - electrical resistance at section "stub-graphite-cathode metal",

n - number of cathodes installed.

Electrical resistance of cathode bar will be:

$$R_6 = \frac{\Delta V_1}{I_1} = \frac{0.08}{5385} = 14.9 \cdot 10^{-6} \text{ Ohm}$$

where ΔV_1 = 0.08 V - voltage drop at section "cathode bar - stub" of analogue cell cathode, including voltage drop of the clamp "cathode bussing - cathode cathode collector bar" and the clamp "cathode collector bar - stub"

I_1 = 5,385A - current intensity through one cathode of analogue cell.

Electrical resistance at section "stub-graphite-cathode metal will be:

$$R_7 = \frac{\Delta V_2}{I_1} = \frac{0.396}{5385} = 73.5 \times 10^{-6} \text{ Ohm}$$

where: $\Delta v_2 = 0.396V$ - voltage drop at section "stub-graphite-cathode metal" of analogue cell.

Thus, electrical resistance of cathode assembly of estimated cell will be:

$$R_1 = \frac{(29.7 + 58.7)\ 10^{-6}}{13} = 6.8 \times 10^{-6}\ \text{Ohm}$$

where: 13 pcs - number of cathodes installed at the cell.

Electrical resistance of electrolyte will be:

$$\frac{\Delta V_3 \times 1}{I \times 1_1} = \frac{4.7 \times 13}{70 \times 10^3 \times 15} = 58.2 \times 10^{-6}\ \text{Ohm}$$

where $\Delta V_3 = 4.700V$ - voltage drop of electrolyte of analogue cell,

$1 = 13$ cm - electrolyte level of estimated refining cell,

$1_1 = 15$ cm - electrolyte level of refining analogue cell,

$I = 70 \times 10^3 A$ - current intensity of estimated refining cell and analogue cell.

Electrical resistance of anode assembly will be:

$$R_3 = \frac{\Delta V_4}{I} = \frac{0.381}{70 \times 10^3} = 5.44 \times 10^{-6}\ \text{Ohm}$$

where $\Delta V_4 = 0.381V$ - voltage drop at anode assembly of analogue cell;

$I = 70 \times 10^3 A$ - current intensity at refining cell.

Average electrical resistance of anode flexibles will be:

$$R_4 = \frac{\Delta V_5}{I} = \frac{0.017}{70 \times 10^3} = 0.24 \times 10^{-6}\ \text{Ohm}$$

where $\Delta V_5 = 0.017V$ = voltage drop at anode flexible of analogue cell;

$I = 70 \times 10^3 A$ - current intensity at refining cell.

Further substituting into the formula (1) the corresponding resulting values of electrical resistance we'll get the resistance of the refining cell:

$$R = (6.8+58.2+5.44+0.24)\ 10^{-6} = 70.68x10^{-6}\ \text{Ohm}$$

The electric power required to compensate the heat losses amounts to

$$Q_1 = \frac{70.68 \times 10^{-6} \times I^2}{1000}\ \text{kW hour/hour}$$

2.1.2. Electric power consumed for polarization of electrodes

$$Q_2 = \frac{Ep \times I}{1000} = \frac{0.38 \times I}{1000}\ \text{kW-hour/hour}$$

where: Ep = 0.38 - E.M.F. of polarization, V

2.1.3. Heat input with raw (primary) aluminium poured to the cell.

$$Q_3 = \frac{0.335x0.93xIx292x1.16x1.03x10^{-3}}{1000} = \frac{0.109I}{100}\ \frac{\text{kWhr}}{\text{hour}}$$

where: $0.335x0.93x10^{-3}xI$ - hourly capacity of cell, kg/hour

292 - specific aluminium heat content at 810°C, kcal/kg

1.03 - consumption of raw aluminium per 1 tonne of HPA, t

2.2. HEAT CONSUMPTION

2.2.1. Heat losses with HPA removed from cell.

$$Q_4 = \frac{0.335x0.93xIx292x1.16x10^{-3}}{1000} = \frac{0.106I}{1000}\ \frac{\text{kWhr}}{\text{hour}}$$

where $0.335x0.93x10^{-3}xI$ - hourly capacity of cell, kg/hour

292 - specific heat content of HPA at 810°C

2.2.2. Heat losses through convective heat transfer surfaces of cell

The convective heat losses and heat losses by radiation are calculated in accordance with conventional heat transfer laws.

The convective heat losses are calculated using the criterion formula:

$$Nu = 0.135 (Gr \times Pr)^{1/3}$$

where: Nu - Nusselt number;

Gr - Grashof number;

Pr - Prandtl number.

In detailed form this relationship can be represented in the following way:

$$Q_c = \alpha \times S \times (t_2 - t_0) = 0.135 \times \lambda \times \sqrt[3]{\frac{9.81 \times \beta \times Pr\,(t_2 - t_0)}{\nu^2}} \times S(t_2 - t_0)$$

where: Q_c - convective heat losses, kcal/hour;

α - coefficient of convective heat transfer, $\frac{kcal}{m^2 \times hour \times degree}$

λ - thermal conductivity of air, $\frac{kcal}{m \times hour \times degree}$

β - air volumetric expansion, $°K^{-1}$

9.81- free fall acceleration, m/sec^2

Pr - Prandtl number for air

ν - air viscosity ratio, m^2/sec

t_0 - ambient air temperature, °C

t_2 - convective heat transfer surface temperature, °C

S - area of convective heat transfer surface, m^2

For horizontal down turned surfaces α is reducing by 30%, for up-turned surfaces α is increasing by 30%.

The heat losses by radiance are calculated in accordance with known formula:

$$Q_{rad} = \varepsilon_{red} \times \varphi_{av} \times C_0 \times S \left[\left(\frac{t_2+273}{100}\right)^4 - \left(\frac{t_0+273}{100}\right)^4 \right]$$

where Q_{rad} - heat losses by radiation, kcal/hour

C_0=4.96 - radiation factor of perfect radiator, $\frac{kcal}{m^2 \times hour \times °K^4}$

ε_{red} - reduced emissivity factor;

φ_{av} - average angle factor;

S - area of convective heat transfer surface, m^2;

t_2 - heat transfer surface temperature, °C;

t_o - ambient air temperature, °C

Thus, total heat losses of cell surfaces may be represented by the general formula:

$$Q=Q_c+Q_{rad} = \left\{\alpha(t_2-t_o)+ \mathcal{E}_{red} \times \varphi_{av} \times C_o \left[\left(\frac{t_2+273}{100}\right)^4 - \left(\frac{t_o+273}{100}\right)^4\right]\right\} \times S$$

2.2.1. Heat losses of hood central covers.

Surface area of central covers - 7.31 m^2

$\mathcal{E}_{red} = 0.6$ $\qquad \alpha = 7.09 \dfrac{\text{kcal}}{m^2 \times \text{hour} \times \text{degree}}$

$\varphi_{av} = 0.9$

$t_2 = 340°C$

$$Q = \left\{1.3x7.09(340-32)+4.96x0.6x0.9 \left[\left(\frac{340+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} x$$

$$x\ 7.31 = 46750 \frac{\text{kcal}}{\text{hour}} \quad \text{or } 54.36 \frac{\text{kW x hour}}{\text{hour}}$$

2.2.2.2. Heat losses of side removable covers. Surface area of side removable covers - 8.41 m^2

$\mathcal{E}_{red} = 0.6$ $\qquad \alpha = 7.08 \dfrac{\text{kcal}}{m^2 \times \text{hour} \times \text{degree}}$

$\varphi_{av} = 0.9$

$t_2 = 336°C$

$$Q = \left\{1.3x7.8(336-32)+4.96x0.6x0.9 \left[\left(\frac{336+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} x8.41=$$

$$= 52690 \frac{\text{kcal}}{\text{hour}} \quad \text{or } 61.27 \frac{\text{kWhour}}{\text{hour}}$$

2.2.2.3. Heat losses through openings.

Openings area - 2.24 m^2

$\mathcal{E}_{red} = 0.8$ $\qquad F = 0.85$ - f-stop

$t_2 = 770°C$

$$Q = \left\{4.96x0.8x0.85 \left[\left(\frac{770+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} x2.24 =$$

$$88770 \frac{\text{kcal}}{\text{hour}} \quad \text{or } 103.22 \frac{\text{kW.Hour}}{\text{hour}}$$

2.2.2.4. Heat losses though cathode holder bars surfaces.

Area of cathode holder bar - 6.03 m^2

$\mathcal{E}_{red} = 0.56$ $\alpha = 5.58 \frac{kcal}{m^2 \times hour \times degree}$

$\varphi_{av} = 0.55$

$t_2 = 128°C$

$$Q = \left\{5.58(128-32)+4.96x0.56x0.55 \left[\left(\frac{128+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\}6.03 =$$

$$= 4820 \frac{kcal}{hour} \text{ or } 5.6 \frac{kw.hour}{hour}$$

2.2.2.5. Heat losses through cathode stubs.

Area of sub heat transfer surfaces - 1.65 m^2

$\mathcal{E}_{red} = 0.8$ $\alpha = 7.34 \frac{kcal}{m^2 \times hour \times degree}$

$\varphi_{av} = 0.8$

$t_2 = 430°C$

$$Q = \left\{7.34(430-32)+4.96x0.8x0.8 \left[\left(\frac{430+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\}1.65 =$$

$$= 17170 \frac{kcal}{hour} \text{ or } 19.96 \frac{kW.hour}{hour}$$

2.2.2.6. Heat losses during crust removal.

Area of cell open surface during crust removal - 7.65 m^2

$\mathcal{E}_{red} = 0.8$

$F = 0.7 - f - stop$

Fraction of time when bath is open - 0.02083

$$Q = \left\{4.96x0.8x0.7 \left[\left(\frac{770+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\}7.65x0.02083 =$$

$$= 5200 \frac{kcal}{hour} \text{ or } 6.05 \frac{kW.hour}{hour}$$

2.2.2.7. Heat losses through anode casing.

2.2.2.7.1. Sides, including:

a) longitudinal side

Area of heat transfer surfaces - [illegible].74 m^2

$\mathcal{E}_{red} = 0.8$ $\alpha = $ [illegible].05 $\frac{kcal}{m^2 \times hour \times degree}$

$\varphi_{av} = 0.9$

$t_2 = $ [illegible]°C

$$Q = \left\{1.3 x 6.05\ (155-32) + 4.96 x 0.8 x 0.9 \left[\left(\frac{155+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 4.74 =$$

$$= 8810\ \frac{\text{kcal}}{\text{hour}} \text{ or } 10.24\ \frac{\text{kW.hour}}{\text{hour}}$$

b) end side, without compartment

Heat transfer are - 1.3 m^2

$\mathcal{E}_{red} = 0.8$ $\quad \alpha = 5.85\ \frac{\text{kcal}}{m^2 \text{ x hour x degree}}$

$\varphi_{av} = 0.9$

$t_2 = 140°C$

$$Q = \left\{1.3 x 5.85 (140-32) + 4.96 x 0.8 x 0.9 \left[\left(\frac{140+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 1.3 =$$

$$= 2020.0\ \frac{\text{kcal}}{\text{hour}} \text{ or } 2.35\ \frac{\text{kW.hour}}{\text{hour}}$$

c) short side with compartment

Area of heat transfer surface is 3.38 m^2

$\mathcal{E}_{red} = 0.8$ $\quad \alpha = 5.19$ kcal/m^2h deg.

$\varphi_{av} = 0.9$

$t_2 = 99°C$

$$Q = \left\{1.3 x 5.19 (99-32) + 4.94 x 0.8 x 0.9 \left[\left(\frac{99+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 3.38 =$$

= 2800 kcal/hr or 3.25 kW.hr/hr

Sides of the shell:

a) long sides

Area of heat transfer surface is 3.16 m^2

$\mathcal{E}_{red} = 0.8$ $\quad \alpha = 5.11$ kcal/m^2h deg.

$\varphi_{av} = 0.85$

$t_2 = 95°C$

$$Q = \left\{5.11 (95-32) + 4.96 x 0.8 x 0.85 \left[\left(\frac{95+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 3.16 =$$

= 2050 kcal/hr or 2.38 kW.hr/hr

b) short side without compartment

Area of heat transfer surface is 0.76 m^2

$\mathcal{E}_{red} = 0.8$ $\quad \alpha = 5.56$ kcal/m^2h deg

$\varphi_{av} = 0.8$

$t_2 = 120°C$

$$Q = \left\{5.56(120-32)+4.96 x 0.8 x 0.8 \left[\left(\frac{120+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} x\ 0.76 =$$

= 740 kcal/hr or 0.86 kWhr/hr

c) short side with compartment

Area of heat transfer surface is 0.76 m^2

$\mathcal{E}_{red}$ = 0.8 α = 5.17 kcal/m^2h deg
φ_{av} = 0.8
t_2 = 98°C

$$Q = \left\{5.17(98-32)+4.96 x 0.8 x 0.8 \left[\left(\frac{98+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 0.76 =$$

= 510 kcal/hr or 0.59 kWhr/hr

Cross beams

Area of heat transfer surface is 5.7 m^2

$\mathcal{E}_{red}$ = 0.8 α = 6.45 kcal/m^2h deg
φ_{av} = 0.9
t_2 = 205°C

$$Q = \left\{6.45(205-32)+4.96 x 0.8 x 0.9 \left[\left(\frac{205+273}{100}\right)^4 - \left(\frac{32+273}{100}\right)^4\right]\right\} 5.7 =$$

= 15230 kcal/hr or 17.71 kWhr/hr

2.2.2.7.2. Cathode shell below working floor level

Bottom:

a) shell

Area of heat transfer surface is 18.0m^2

$\mathcal{E}_{red}$ = 0.8 α = 4.58 kcal/m^2h deg
φ_{av} = 0.75
t_2 = 65°C

$$Q = \left\{0.7 x 4.58 x(65-25)+4.96 x 0.8 x 0.75 \left[\left(\frac{65+273}{100}\right)^4 - \left(\frac{25+273}{100}\right)^4\right]\right\} 18.0=$$

= 5070 kcal/hr or 5.9 kWhr/hr

b) beams

Area of heat transfer surface is 38.33 m^2

$\mathcal{E}_{red}$ = 0.8 α = 4.21 kcal/m^2h deg
φ_{av} = 0.70
t_2 = 55°C

$$Q = \left\{4.21(55-25)+4.96 \times 0.8 \times 0.7 \left[\left(\frac{55+273}{100}\right)^4 - \left(\frac{25+273}{100}\right)^4\right]\right\} 38.33 =$$

= 8770 kcal/hr or 10.2 kWhr/hr

Long sides:

a) shell

Area of heat transfer surface is 16.87 m^2

ε_{red} = 0.8 α = 5.25 kcal/m²h deg

φ_{av} = 0.85

t_2 = 91°C

$$Q = \left\{5.25(91-25)+4.96 \times 0.8 \times 0.85 \left[\left(\frac{91+273}{100}\right)^4 - \left(\frac{25+273}{100}\right)^4\right]\right\} 16.87 =$$

= 11350 kcal/hr or 13.2 kWhr/hr

b) beams, channels, gusset plates

Area of heat transfer surface is 10.5 m^2

ε_{red} = 0.8 α = 5.05 kcal/m^2 h deg

φ_{av} = 0.70

t_2 = 82°C

$$Q = \left\{5.05(82-25)+4.96 \times 0.8 \times 0.7 \left[\left(\frac{82+273}{100}\right)^4 - \left(\frac{25+273}{100}\right)^4\right]\right\} 10.5 =$$

= 5360 kcal/hr or 6.23 kWhr/hr

Short side without compartment:

a) shell

Area of heat transfer surface is 4.24 m^2

ε_{red} = 0.8 α = 4.82 kcal/m^2h deg

φ_{av} = 0.8

t_2 = 73°C

$$Q = \left\{4.82(73-25)+4.96 \times 0.8 \times 0.8 \left[\left(\frac{73+273}{100}\right)^4 - \left(\frac{25+273}{100}\right)^4\right]\right\} 4.24 =$$

= 1850 kcal/hr or 2.15 kWhr/hr

b) channels, I-beams, etc.

Area of heat transfer surface is 3.93 m^2

ε_{red} = 0.8 α = 4.51 kcal/m^2h deg

φ_{av} = 0.70

t_2 = 63°C

$$Q = \left\{4.51(63-25)+4.96\times0.8\times0.7\left[\left(\frac{63+273}{100}\right)^4-\left(\frac{25+273}{100}\right)^4\right]\right\}3.93 =$$

= 1200 kcal/hr or 1.4 kWhr/hr

Short side with compartment:

a) shell

Area of heat transfer surface is 4.24 m^2

$\mathcal{E}_{red}$ = 0,8 α = 4.76 kcal/m^2h deg

φ_{av} = 0.8

t_2 = 71°C

$$Q = \left\{4.76(71-25)+4.96\times0.8\times0.8\left[\left(\frac{71+273}{100}\right)^4-\left(\frac{25+273}{100}\right)^4\right]\right\}4.24 =$$

= 1750 kcal/hr or 2.04 kWhr/hr

b) channels, I-beams, gusset plates

Area of heat transfer surface is 3.93 m^2

$\mathcal{E}_{red}$ = 0.8 α = 4.29 kcal/m^2h deg

φ_{av} = 0.7

t_2 = 57°C

$$Q = \left\{4.29(57-25)+4.96\times0.8\times0.7\left[\left(\frac{57+273}{100}\right)^4-\left(\frac{25+273}{100}\right)^4\right]\right\}3.93 =$$

= 970 kcal/hr or 1.13 kWhr/hr

Collector bars

Area of heat transfer surface is 1.64 m^2

$\mathcal{E}_{red}$ = 0.8 α = 6.59 kcal/m^2h deg

φ_{av} = 0.71

t^2 = 205°C

$$Q = \left\{6.59(205-25)+4,96\times0.8\times0.71\left[\left(\frac{205+273}{100}\right)^4-\left(\frac{25+273}{100}\right)^4\right]\right\}1.64 =$$

= 3990 kcal/hr or 4.64 kWhr/hr

Thus, calculated heat losses of the electrolytic cell are as follows:

54.36+61.27+103.22+5.60+19.96+6.05+16.24+2.35+3.25+2.38+0.86+0.59+

+17.71+5.9+10.2+13.2+6.23+2.15+1.4+2.04+1.13+4.64 = 334.73 kWhr/hr

2.2.3. Summary Table of Heat Losses of Electrolytic Cell

S/N	Heat loss items	Surface temperature t_2	Convection factor of heat transfer to air α	Normalised degree of blackness ε_{red}	Mean angle factor of radiation φ_{av}	Area heat transfer surf... S
		°C	$\frac{kcal}{m^2.hr.°C}$	-	-	m^2
1	2	3	4	5	6	7
1	Central covers	340	7.09	0.6	0.9	7.3
2	Removable covers	336	7.08	0.6	0.9	8.4
3	Holes	770	-	0.8	F=0.85	2.2
4	Cathode holder bars	128	5.58	0.56	0.55	6.0
5	Cathode stubs	430	7.34	0.8	0.8	1.6
6	Crust removal	770	-	0.8	F=0.7	7.6
7	Sheel above working floor level:					
	sides:					
	a) long sides	155	6.05	0.8	0.9	4.7
	b) short side w/compartment	99	5.19	0.8	0.9	3.3
	c) short side w/o compartment	140	5.85	0.8	0.9	1.3
	Shell walls:					
	a) long sides	95	5.11	0.8	0.85	3.1
	b) short side w/o compartment	120	5.56	0.8	0.8	0.7
	c) short side w/compartment	98	5.17	0.8	0.8	0.7
	Cross beams	205	6.45	0.8	0.9	5.7
8	Shell below working floor level					
	Bottom:					
	a) shell	65	4.58	0.8	0.75	18.

mary Table of Heat Losses of Electrolytic Cell

	Surface temperature	Convection factor of heat transfer to air	Normalised degree of blackness	Mean angle factor of radiation	Area of heat transfer surface	Heat losses		
	t_2	α	ε_{red}	φ_{av}	S	Q		
	°C	$\frac{kcal}{m^2.hr.°C}$	-	-	m^2	$\frac{kcal}{hr}$	$\frac{kW.hr}{hr}$	%%
	3	4	5	6	7	8	9	10
	340	7.09	0.6	0.9	7.31	46750	54.36	14.62
	336	7.08	0.6	0.9	8.41	52690	61.27	16.47
	770	-	0.8	F =0.85	2.24	88770	103.22	27.75
	128	5.58	0.56	0.55	6.03	4820	5.60	1.51
	430	7.34	0.8	0.8	1.65	17170	19.96	5.37
	770	-	0.8	F =0.7	7.65	5200	6.05	1.63
floor								
	155	6.05	0.8	0.9	4.74	8810	10.24	2.75
part-								
	99	5.19	0.8	0.9	3.38	2800	3.25	0.87
om-								
	140	5.85	0.8	0.9	1.3	2020	2.35	0.63
	95	5.11	0.8	0.85	3.16	2050	2.38	0.64
om-								
	120	5.56	0.8	0.8	0.76	740	0.86	0.23
part-								
	98	5.17	0.8	0.8	0.76	510	0.59	0.16
	205	6.45	0.8	0.9	5.7	15230	17.71	4.76
floor								
	65	4.58	0.8	0.75	18.0	5070	5.9	1.59

SECTION 2

1	2	3	4	5	6	7
	b) beams	55	4.21	0.8	0.70	38.
	Long sides:					
	a) shell	91	5.25	0.8	0.85	16.
	b) channels, I-beams, gussets plates	82	5.05	0.8	0.70	10.
	Short side w/o compartment:					
	a) shell	73	4.82	0.8	0.8	4.2
	b) channels, I-beams, gusset plates	63	4.51	0.8	0.7	3.9
	Short side w/compartment					
	a) shell	71	4.76	0.8	0.8	4.2
	b) channels, I-beams, gusset plates	57	4.29	0.8	0.7	3.9
9	Collector bars	205	6.59	0.8	0.71	1.6
10	Unaccounted losses	-	-	-	-	-
	TOTAL	-	-	-	-	-

SECTION 1

3	4	5	6	7	8	9	10
55	4.21	0.8	0.70	38.33	8770	10.2	2.74
91	5.25	0.8	0.85	16.87	11350	13.2	3.55
82	5.05	0.8	0.70	10.5	5360	6.23	1.67
73	4.82	0.8	0.8	4.24	1850	2.15	0.58
63	4.51	0.8	0.7	3.93	1200	1.4	0.38
71	4.76	0.8	0.8	4.24	1750	2.04	0.55
57	4.29	0.8	0.7	3.93	970	1.13	0.30
205	6.59	0.8	0.71	1.64	3990	4.64	1.25
-	-	-	-	-	31980	37.19	10.00
-	-	-	-	-	319850	371.92	100.00

SECTION 2

Taking into account unaccounted heat losses (those from surface of the cell cathode structures, and those with electrolyte crust, anode deposits, etc) assumed equal to 10% on the basis of measurements, the total heat loss of the cell will be:

$$Q_5 = 334.73 + \frac{334.73 \times 0.1}{0.9} = 371.92 \text{ kWhr/hr}$$

2.3. Determination of Amperage and Heating Voltage Drop

Substituting the calculated value in the expression of the cell energy banace we get:

$$\frac{70.68 \times 10^{-6} \times J^2}{1000} + \frac{0.38 \times J}{1000} + \frac{0.109 \times J}{1000} = \frac{0.106 \times J}{1000} + 371.92$$

or $70.68 \times 10^{-6} \times J^2 + 0.383 \times J - 371.92 \times 10^3 = 0$

Amperage:

$$J = \frac{-0.383 + \sqrt{0.383^2 + 4 \times 70.68 \times 10^{-6} \times 371.92 \times 10^3}}{2 \times 70.68 \times 10^{-6}} = 69880 \cong 70000 \text{A}$$

Heating voltage:

$$V_{heat} = 69880 \times 70.68 \times 10^{-6} + 0.38 = 5.318 \text{ V}$$

Taking into account accuracy of calculation of the cell energy balance and fluctuation of ambient air temperature over a year, the calculated amperage of the cell is adopted equal to 70 ± 1 kA.

Calculated output of the cell:

$70000 \times 0.335 \times 0.93 \times 8760 \times 10^{-6} = 191$ tpy (continuous operation, 8760 h/year)

where: 0.335 - electrochemical Al equivalent, g/A.h

93×10^{-2} - current efficiency, %

2.4. Summary Table of Cell Energy Balance

Energy Input					Energy Output	
S/N	Item	kcal/hr	kWhr/hr	%	S/N	Item
1	Electric power to compensate heat losses (Q_1)	296830	345.15		1	Heat loss with Super-Puri minium tapped from cell (
2	Electric power to polarise electrodes (Q_2)	22850	26.56		2	Heat loss by heat transfe surfaces (Q_5):
3	Heat content of crude aluminium fed to cell (Q_3)	6550	7.62		2.1	Central covers
					2.2	Removable covers
					2.3	Holes
					2.4	Cathode holder bars
					2.5	Cathode stubs
					2.6	Crust removal
					2.7	Shell above working floor
					2.7.1	Sides:
						a) long sides
						b) short side w/compartme
						c) short side w/o compart
					2.7.2	Shell walls:
						a) long sides
						b) short side w/o compart
						c) short side w/compartme
					2.7.3	Cross beams
					2.8	Shell below working floor
					2.8.1	Bottom:
						a) shell
						b) beams
					2.8.2	Long sides
						a) shell

SECTION 1

ry Table of Cell Energy Balance

r/hr	%	S/N	Item	kcal/hr	kWhr/hr	%
			Energy Output			
		1	Heat loss with Super-Purity aluminium tapped from cell (Q_4)	6370	7.41	1.95
.15		2	Heat loss by heat transfer surfaces (Q_5):	319850	371.92	98.05
		2.1	Central covers	46750	54.36	14.33
56		2.2	Removable covers	52690	61.27	16.15
		2.3	Holes	88770	103.22	27.21
		2.4	Cathode holder bars	4820	5.60	1.48
2		2.5	Cathode stubs	17170	19.96	5.26
		2.6	Crust removal	5200	6.05	1.59
		2.7	Shell above working floor level:	32160	37.38	9.87
		2.7.1	Sides:	13630	15.84	4.18
			a) long sides	8810	10.24	2.70
			b) short side w/compartment	2800	3.25	0.86
			c) short side w/o compartment	2020	2.35	0.62
		2.7.2	Shell walls:	3300	3.83	1.02
			a) long sides	2050	2.38	0.63
			b) short side w/o compartment	740	0.86	0.23
			c) short side w/compartment	510	0.59	0.16
		2.7.3	Cross beams	15230	17.71	4.67
		2.8	Shell below working floor level:	36320	42.25	11.14
		2.8.1	Bottom:	13840	16.10	4.24
			a) shell	5070	5.9	1.55
			b) beams	8770	10.2	2.69
		2.8.2	Long sides	16710	19.43	5.12
			a) shell	11350	13.2	3.48

SECTION 2

Energy Input					Ener	
S/N	Item	kcal/hr	kWhr/hr	%	S/N	Item
						b) channels, I-beam gusset plates
					2.8.3	Short side w/o comp ment
						a) shell
						b) channels, I-beam gusset plates
					2.8.4	Short side w/compar
						a) shell
						b) channels, I-beam gusset plates
					2.9	Collector bars
					2.10	Unaccounted losses
	TOTAL	326220	379.33	100		TOTAL

SECTION 1

		Energy Output				
kWhr/hr	%	S/N	Item	kcal/hr	kWhr/hr	%
			b) channels, I-beams, gusset plates	5360	6.23	1.64
		2.8.3	Short side w/o compartment	3050	3.55	0.94
			a) shell	1850	2.15	0.57
			b) channels, I-beams, gusset plates	1200	1.4	0.37
		2.8.4	Short side w/compartment	2720	3.17	0.84
			a) shell	1750	2.04	0.54
			b) channels, I-beams, gusset plates	970	1.13	0.30
		2.9	Collector bars	3990	4.64	1.22
		2.10	Unaccounted losses	31930	37.19	9.80
379.33	100		TOTAL	326220	379.33	100

SECTION 2

Annexure No 2

CALCULATION OF VOLTAGE DROP ACROSS CELL BUSWORK

1. Basic Data

Cell amperage, kA	- 70
No of cathode buswork packs, pc	- 2
No of busbars in one pack, pc	- 2
No of anode buswork packs, pc	- 2
No of busbars in one pack, pc	- 5
Cross-section of busbars: cathode buswork, mm	- 430 x 70
anode buswork, mm	- 420 x 60
Working temperature of cathode buswork, °C	- 80
Working temperature of anode buswork, °C	- 50

2. Voltage Drop A~~c~~cross Cathode Buswork

Amperage distribution per cathode:

$$J = \frac{70}{13} = 5.385 \text{ kA}$$

where: 13 - number of cathodes per cell

Aluminium resistivity at 80 °C

$$\rho_{Al}^{80} = \rho_{Al}^{20}\left[1 + \alpha(t - 20)\right] = 0.028\left[1+0.0049(80-20)\right]=0.036\,\frac{\text{ohm.mm}^2}{\text{m}}$$

$\rho_{Al}^{20} = 0.028$ - aluminium resistivity at 20 °C $\frac{\text{ohm.mm}^2}{\text{m}}$

$\alpha = 0.0049$ - temperature coefficient of aluminium resistivity

First buswork pack (see Fig.1)

The first cathode buswork pack is connected to 7 cathodes.

Voltage drop in the first pack is calculated from the expression:

$$V_1 = \rho\left[\ell d + \ell_1(d_1 + d_2 + d_3 + d_4 + d_5 + d_6)\right]$$

where: $d, d_1, \ldots, d_6$ - current density in appropriate sections of first cathode buswork pack, A/mm^2

Current density in buswork sections is calculated by the formula:

$$d = \frac{J_1 \cdot n}{k \cdot a \cdot b} \quad A/mm^2 \qquad (2)$$

K - number of busbars in a pack

a x b - cross-section of busbars, mm

h - number of cathodes connected to cathode buswork at appropriate sections

Substituting the appropriate solution in the expression (2) we will get:

$$d = \frac{5385 \cdot 7}{2.430.70} = 0.626 \ A/mm^2 \qquad d_3 = \frac{5385 \cdot 4}{2.430.70} = 0.358 \ A/mm^2$$

$$d_1 = \frac{5385.6}{2.430.70} = 0.537 \ A/mm^2 \qquad d_4 = \frac{5385 \cdot 3}{2.430.70} = 0.268 \ A/mm^2$$

$$d_2 = \frac{5385 \cdot 5}{2.430.70} = 0.447 \ A/mm^2 \qquad d_5 = \frac{5385 \cdot 2}{2.430.70} = 0.179 \ A/mm^2$$

$$d_6 = \frac{5385 \cdot 1}{2.430.70} = 0.089 \ A/mm^2$$

Thus, voltage drop in the 1st pack of the cathode buswork will be:

$$V_1 = 0.036 \left[1.31 \times 0.626 + 0.64 \ (0.537+0.447+0.358+0.268+0.179+0.089)\right] = 0.0728 \approx 0.073 V$$

The second buswork pack (Fig.1)

The second pack of the buswork is connected to 6 cathodes.

Voltage drop in the second pack is determined by the formula:

$$V_2 = \rho\left[\ell d' + \ell_1 (d_1' + d_2') + \ell_2 d_3' + \ell_1 (d_4' + d_5')\right]$$

Current densities in the respective sections will be:

$$d' = \frac{5385 \cdot 6}{2.430.70} = 0.537 \ A/mm^2 \qquad d_3' = \frac{5385 \cdot 3}{2.430.70} = 0.268 \ A/mm^2$$

$$d_1' = \frac{5385 \cdot 5}{2.430.70} = 0.447 \ A/mm^2 \qquad d_4' = \frac{5385 \cdot 2}{2.430.70} = 0.179 \ A/mm^2$$

$$d_2' = \frac{5385 \cdot 4}{2.430.70} = 0.358 \ A/mm^2 \qquad d_5' = \frac{5385 \cdot 1}{2.430.70} = 0.089 \ A/mm^2$$

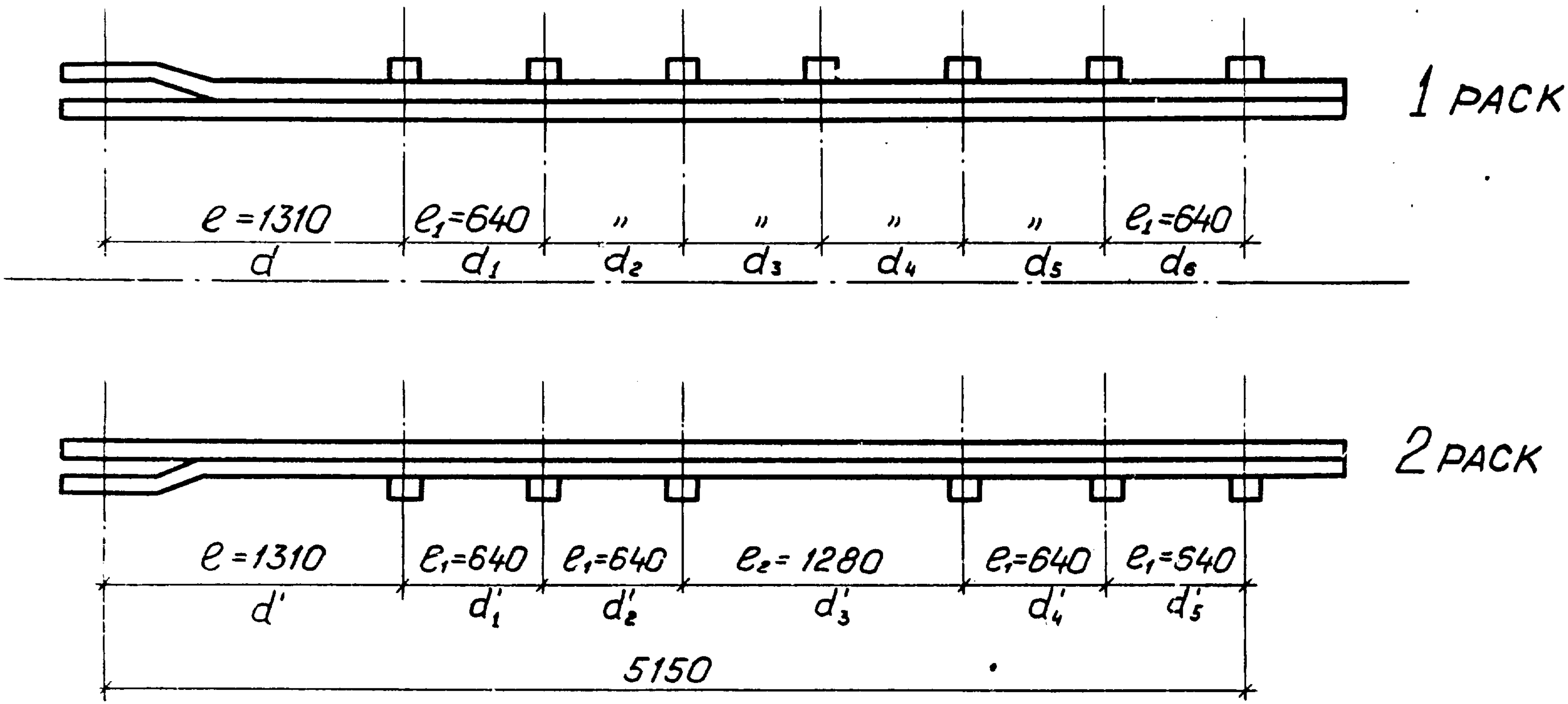


FIG 1. CATHODE BUSWORK

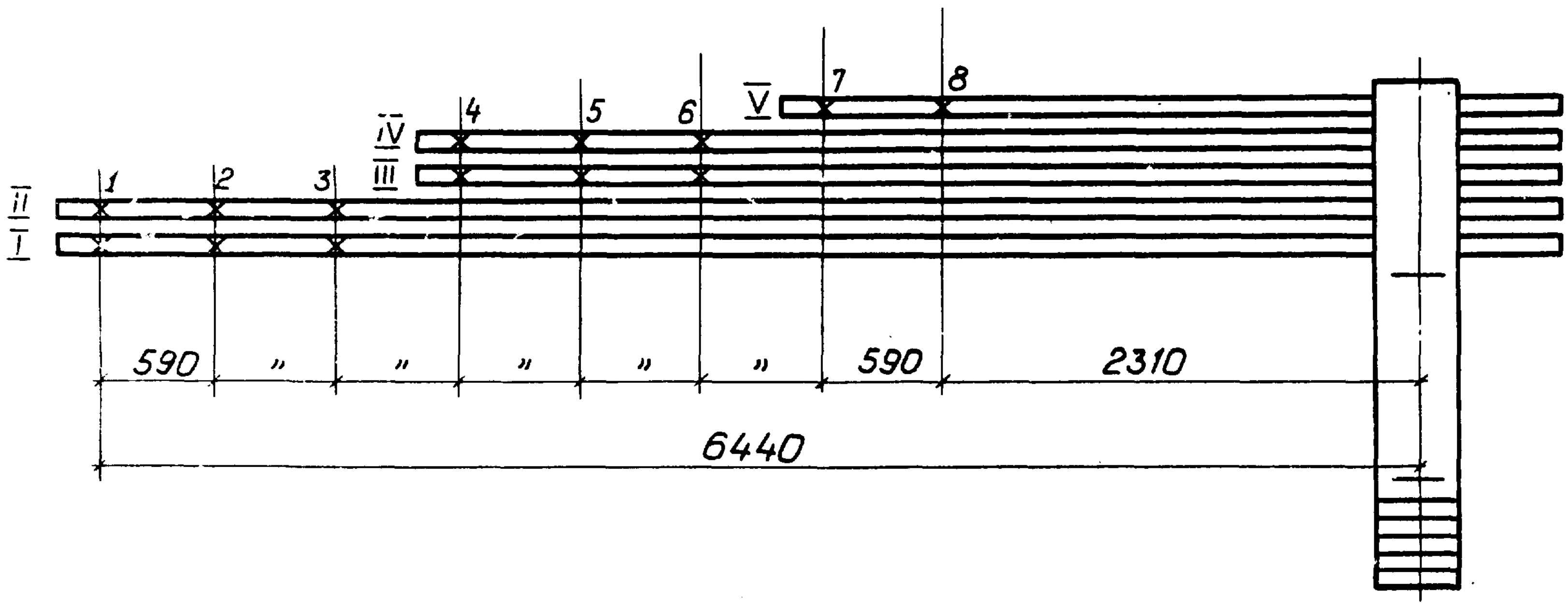


FIG 2. ANODE BUSWORK

Then, voltage drop in the second pack of the cathode buswork is as follows:

$$V_2 = 0.036\left[1.31\times0.537+0.64\,(0.447+0.358)+1.28\times0.268+0.64(0.179 + 0.089)\right] = 0.0624 \approx 0.062\ \text{V}$$

Thus, voltage drop in the cathode buswork will be:

$$V_{cath.bus.} = \frac{0.073 + 0.062}{2} = 0.0675 \approx 0.068\ \text{V}$$

3. Voltage drop in Anode Buswork

3.1. Voltage Drop in Anode Riser

Aluminium resistivity at 50 °C is as follows:

$$\rho_{Al}^{50} = \rho_{Al}^{20}\left[1+\alpha(50-20)\right] = 0.028\left[1+0.0049(50-20)\right] = 0.032\ \frac{\text{ohm.mm}^2}{\text{m}}$$

Voltage drop in the anode riser will be:

$$V_{a.r.} = J\cdot\rho_{Al}^{50}\,\frac{\ell}{n\cdot a\cdot b} = 35\times10^3\times0.032\ \frac{4.0}{3\times420\times60} = 0.059\ \text{V}$$

$n = 3$

$\ell = 4.0$

3.2. Voltage Drop on Horizontal Packs of Anode Buswork

Resistance of busbars No.1 and 2 (Fig.2) is as follows:

$$R_{1,2} = 0.032\,\frac{2.31 + 0.59 \times 7}{2 \times 420 \times 60} = 4.09 \times 10^{-6}\ \text{ohm}$$

Resistance of busbars No.3 and 4 is as follows:

$$R_{3,4} = 0.032\,\frac{2.31 + 0.59 \times 4}{2 \times 420 \times 60} = 2.97 \times 10^{-6}\ \text{ohm}$$

Resistance of busbars No.5 is as follows:

$$R_5 = 0.032\,\frac{2.31 + 0.59}{420 \times 60} = 3.68 \times 10^{-6}\ \text{ohm}$$

Hence, resistance of the horizontal pack of the anode buswork:

$$R = \frac{1 \times 10^{-6}}{\frac{1}{4.09} + \frac{1}{2.97} + \frac{1}{3.68}} = 1.17 \times 10^{-6}\ \text{ohm}$$

Voltage drop in the horizontal pack of the anode buswork:

$$V_{a.p.} = J \cdot R = 35 \times 10^3 \times 1.17 \times 10^{-6} = 0.041 \text{ ohm}$$

Voltage drop across the anode buswork will be

$$V_{a.b.} = V_{a.r.} + V_{a.p.} = 0.059 + 0.041 = 0.100 \text{ ohm}$$

And total voltage drop across the cell buswork:

$$0.068 + 0.100 = 0.168 \text{ ohm}$$

Considering voltage drop in the welded connections the total voltage drop across the cell buswork is adopted equal to 0.18 V.

Annexure No 3

SUMMARY TABLE OF INVESTMENT COSTS FOR MANUFACTURING AND INSTALLATION OF 70 KA REFINING CELL

At I trimester of 1986 price level

SRL No	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. Foreign	Local	Total
1	2	3	4	5	6	7	8
1			Anode Assembly				
1.1	11.935	t	Welded steel anode shell	12000	-	143220	143220
1.2			Anode Lining				
1.2.1	560	kg	Asbestos sheet mill board 10 mm thick	50	-	28000	28000
1.2.2	2.010 (6560)	1000 pcs. (kg)	Ordinary clay bricks: 250 x 115 x 65	450	-	905	905
1.2.3	8305 (3.16)	kg (m^3)	Magnesite bricks: 725 pcs - 380 x 150 x 75 15 pcs - 300 x 150 x 75 4 pcs - 300 x 150 x 65	3.41	-	28330	28330
1.2.4	7940 (3.97)	kg (m^3)	Fireclay bricks: 2152 pcs - 230 x 115 x 65 255 pcs - 230 x 115 x 40	0.91	-	7225	7225

SRL No	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. Foreign	Local	Total
1.2.5	3960 (4.4)	Pcs (m^3)	Light weight fireclay bricks: 2154 pcs - 250 x 124 x 65; 95 pcs - 230 x 115 x 40	3.09	-	12236	12236
1.2.6	0.32	t	Alumina, filling	3000	-	960	960
1.2.7	0.016	t	Fireclay paste	3000	-	48	48
1.2.8	2.31	-do-	Ramming mix (bottom paste)	7500	-	17325	17325
1.2.9	0.16	-do-	Building gypsum	1500	-	240	240
1.2.10	0.075		Sodium suplhate water glass	3000	-	225	225
1.2.11	0.057		Chrisolyte asbestos	1500	-	85	85
1.2.12	0.055		Graphitized electrodes, dia 350 mm	40000	-	2200	2200
1.2.13	0.076	t	Carbon plate: 200 x 370 x 625 mm	29000	-	2204	2204
			Total of item 1.2			99983	99983
1.3			Anode Sections				
1.3.1	0.096	t	Bottom paste	7500	-	720	720
1.3.2	5.28	-do-	Strip steel (collector bar) cross-section 230 x 115 mm	9000	-	47520	47520
1.3.3	1.320	-do-	Cast iron	3000	-	3960	3960

SRL No.	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs.		
					Foreign	Local	Total
1.3.4	5.176	t	Carbon block, section 400 x 550 mm	14148	73230	-	73230
1.3.5	0.23	-do-	Aluminium strip, section 1 x 150 mm	20000	-	4600	4600
			Total of item 1.3		73230	56800	130030
			Total of item 1		73230	300003	373233
2			Cathode assembly				
2.1		t	Cell steel structure (support structure):				
2.1.1	0.852	t	- steel	12000	-	10224	10224
2.1.2	0.16	t	- aluminium	30000	-	4800	4800
	1.012		Total of item 2.1			15024	15024
2.2	0.005	t	Fasteners (bolts, nuts, washers split pins)	10000	-	50	50
2.3	0.67	kg	Fabric based laminate	150	-	101	101
2.4	6.5	kg	Asbestos sheet mill board	50	-	325	325
2.5			Cathode lifting mechanism				
2.5.1	2	pcs.	Motor N = 0.75 kW, 1000rpm.	1200	-	2400	2400

SRL NO	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. Foreign	Local	Total
2.5.2	2	pcs	Worm reduction gear, reduction number i = 63, permissible torque on slow-speed shaft – – 120 kgf/m	7500	-	15000	15000
2.5.3	4	pcs	Screw jack, capacity 5 t	15000	-	60000	60000
2.5.4	0.032	t	Support structure	12000	-	384	384
			Total of item 2.5			77784	77784
2.6			<u>Cathode buswork</u>				
2.6.1	0.982	t	Cast aluminium busbars, section 430 x 70 mm	35000	-	34370	34370
2.6.2	0.982	-do-	Extruded aluminium busbars, section 430 x 70 mm	35000	-	34370	34370
2.6.3	0.175	t	Beams, cross-beams, etc.	10000	-	1750	1750
2.6.4	0.036	-do-	Fasteners	10000	-	360	360
			Total of item 2.6			70850	70850
2.7	13 (286)	pcs. (kg)	Eccentric clamp	5000	-	65000	65000

SRL No.	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. Foreign	Local	Total
2.8			<u>Cathode</u>				
2.8.1	0.442	t	Aluminium bar, section 80x120 mm	30000	-	13260	13260
2.8.2	0.152	t	Bimetallic plate (Aluminium - steel)	108760	16532	-	16532
2.8.3	0.101	t	Steel	9000	-	909	909
2.8.4	0.738	t	Stub, dia 180 mm	8000	-	5824	5824
			Total of item 2.8		16532	19993	36525
			Total of item 2		16532	249127	265659
			Grand total (it. 1 + 2)		89762	549130	638892
3			<u>Fabrication and Installation</u>				
3.1	1	pc.	Anode assembly lining	10500	-	10500	10500
3.2	2.175	t	Fabrication of cathode buswork	550	-	1196	1196
3.3	10	%	Installation (anode steel shell, anode sections, cathode assembly)	538909	-	53891	53891
			Total of item 3			65587	65587

SRL No.	Qty	Unit	Cost category	Unit cost, Rs.	Costs, Rs. Foreign	Local	Total
			Overhead costs				
4.1	1.5	%	Port charges and levies	89762	-	1346	1346
4.2	1.0	%	Bank charges	-do-	-	898	898
4.3	50.0	%	Custom duty	-do-	-	44881	44881
4.4	3.0	%	Transportation costs from port to plant site	-do-	-	2693	2693
			Total of item 4			49818	49818
			GRAND TOTAL		89762	664535	754297

Формат Size	Зона Zone	Поз. Pos.	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
		I	–	Кожух металлический **Steel casing**	I	11935kg
				В том числе: **Including**		
				Швеллер ISLC150 **channel**	–	25[illegible] kg
				Швеллер ISLC250 **channel**	–	918 kg
				Двутавр ISMB250 **I – beam**	–	22[illegible]1 kg
				Двутавр ISMB450 **I – beam**	–	1340 kg
				Лист δ = 4 **Sheet**	–	176 kg
				–"– δ = 6	–	157 kg
				–"– δ = 8	–	532 kg
				–"– δ = 10	–	5708 kg
				–"– δ = 12	–	232 kg

Сборочных единиц Assembly units		Деталей Parts		Вновь разработанных Newly designed	8,25
				Примененных Applied	
				Всего листов Totally sheets A1	

Алюминиевый завод в г.Корба, Индия
Экспериментально-демонстрационная установка для производства алюминия высокой чистоты.
Aluminium Smelter in Korba, India
Experimental demonstration unit for high purity aluminium production

I335873

Электролизер рафинировочный на 70 кА
70 kA Aluminium refining

Стадия Phase	Лист Sheet	Листов Sheets
П	I	6

VAMI

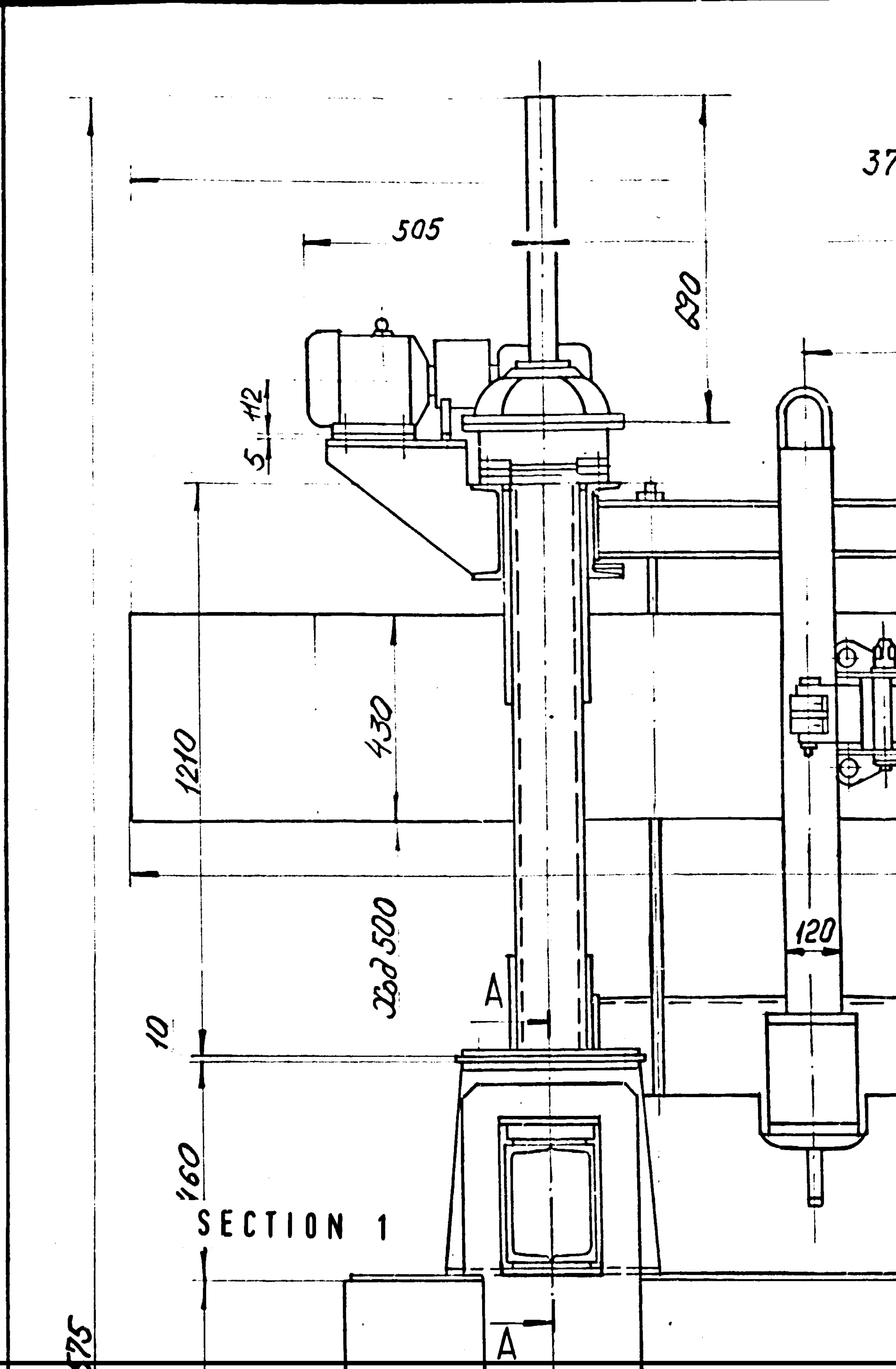
Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Лист δ = 15 Sheet	-	44 kg
				-"- δ = 20	-	46 kg
				Полоса 5 x 160 Strip	-	178 kg
				Поковка Forging	-	108 kg
				Крепеж Fasteners	-	7 kg
				Марка стали IS:226 Steel grade		
A4		2	I335874	Футеровка анодная Anode lining	1	42500 kg
A4		3	I335875	Катод Cathode	13	3510 kg
		4	-	Механизм подъема катодов Cathode lifting mechanism	2	400 kg
				В том числе: Including		
				Редуктор червячный трансформируемый тип R I с червяком над колесом, типоразмер 30 передаточное число 60, входная мощность 0,9 лошадиных сил	2	35 kg

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Transforming worm gear, type RI with worm above the wheel, standard size 30, gear ratio 60, input power 0.9 h.p.		
				Двигатель трехфазный Three-phase motor	2	38 kg
				Серии OR 29c-6 type N = 0.75 kW, 1000 rpm		
				Домкрат винтовой грузоподъемностью Screw jack, capacity 5 t	4	280 kg
				Муфта кулачково-дисковая Double-slider coupling	4	10.5kg
				Муфта упругая втулочно-пальцевая Elastic coupling with rubber-bushed studs	2	4,5 kg
				Металлоконструкция Steel structure	-	32 kg
		5	—	Металлоконструкция электролизера Cell steel structure	1	1012kg

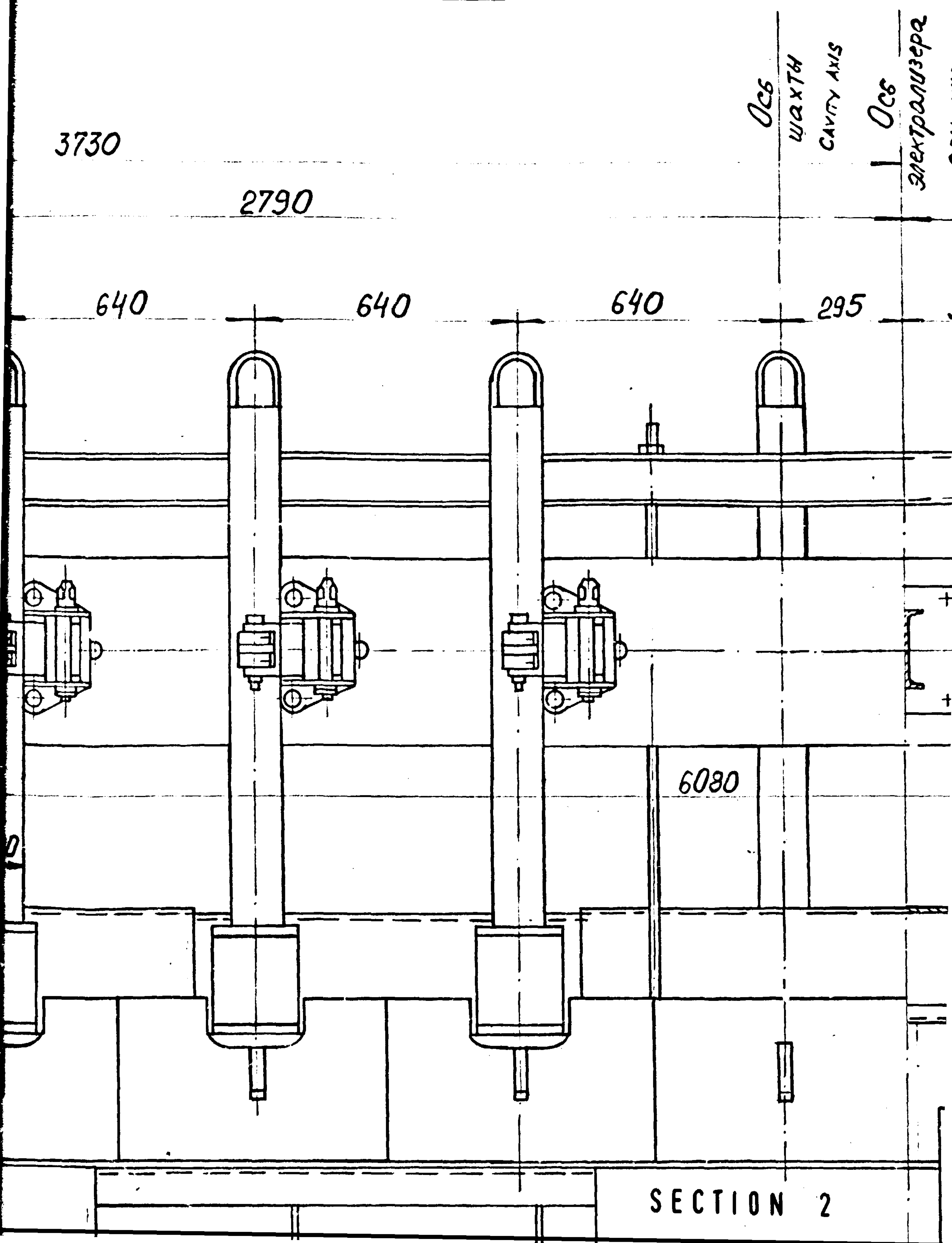
Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				В том числе: Including		
				Швеллер ISLC 125 Channel	-	220 kg
				Швеллер ISLC 150 Channel	-	210 kg
				Швеллер ISLC 225 Channel	-	212 kg
				Лист δ = 3 Sheet	-	3 kg
				-"- δ = 5	-	27 kg
				-"- δ = 8	-	5 kg
				-"- δ = 10	-	106 kg
				Лист δ = 15 Sheet	-	42 kg
				Полоса 10 x 120 Strip	-	5 kg
				Угольник 50x50x5 Angle	-	7 kg
				Круг ø 12 Rod	-	10,5 kg
				Крепеж Fasteners	-	4,5 kg
				Марка стальных деталей Steel parts grade as per IS : 226		

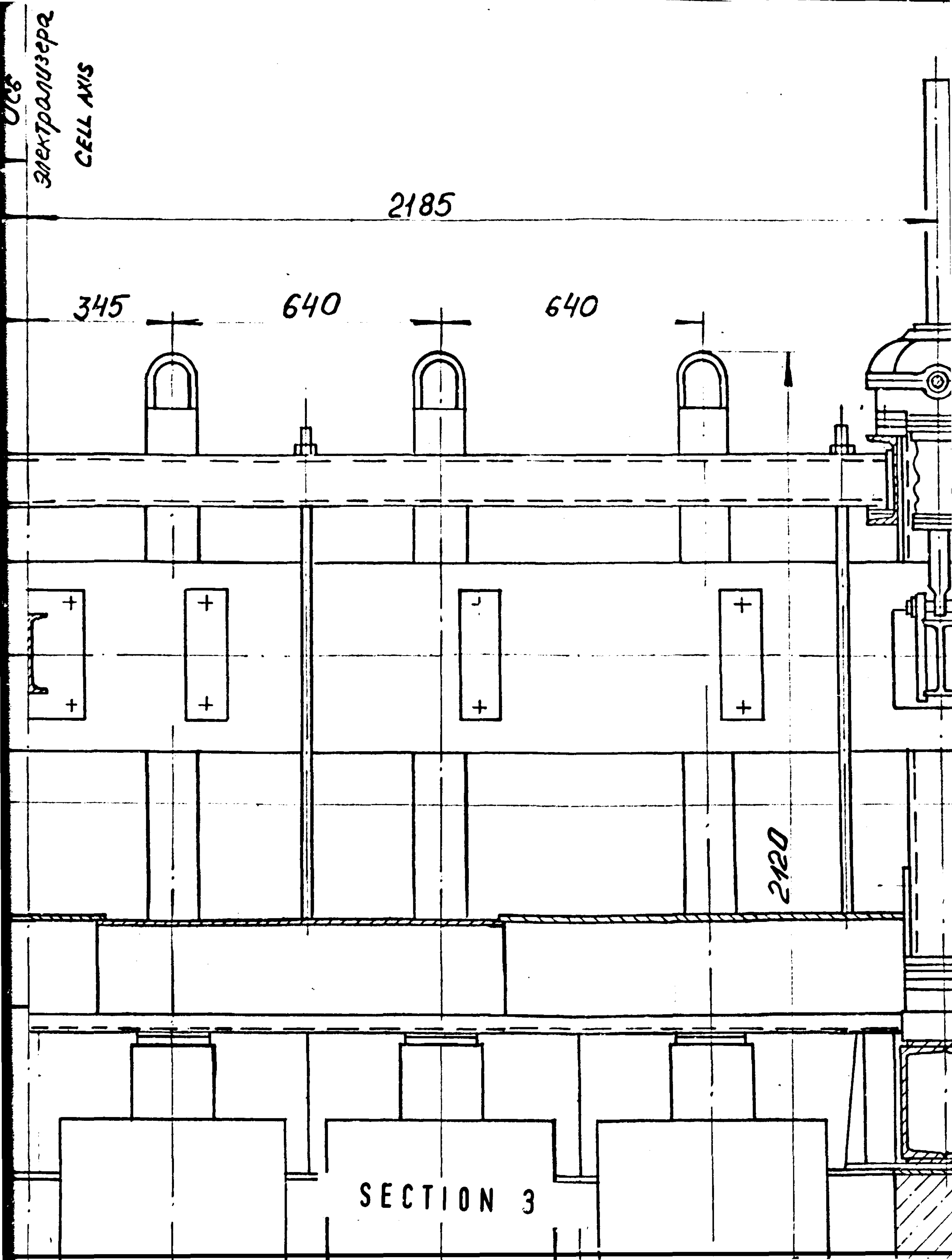
Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Лист алюминиевый δ = 3 Aluminium sheet	-	~~60 kg~~
				Лист алюминиевый δ = 8 Aluminium sheet	-	~~100 kg~~
				Характеристика алюминия: Aluminium characteristics		
				Предел прочности Strength		
				6 kg/mm^2		
				Относительное удлинение Elongation		
				20 ... 28%		
				Текстолит Fabric-based laminate	-	0,67 kg
				Картон асбестовый Asbestos sheet mill board	-	6,5 kg
		6		Ошиновка катодная Cathode buswork	1	2461kg
				В том числе: Including		
				Шина алюминиевая литая сечением Cast aluminium bar, section 430 x 70	-	982 kg
				Шина алюминиевая прессованная сечением Extruded aluminium bar, section 430 x 70	-	982 kg

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Химический состав материала шин индийский стандарт фирмы "Балко" Chemical composition of busbar material as per BALCO standard No 19501		
				Зажим эксцентриковый Eccentric clamp	13	286 kg
				Сталь 18/8SS Steel		
				Двутавр ISMB 175 I - beam	-	66 kg
				Лист $\delta = 10$ Sheet	-	43 kg
				Лист $\delta = 15$ Sheet	-	34 kg
				Полоса 20 x 100 Strip	-	32 kg
				Крепеж Fasteners	-	36 kg
				Марка стали IS:226 Steel grade		
		7	-	Крышка Cover	1	3 kg
				Лист алюминиевый Aluminium sheet $\delta = 3$		

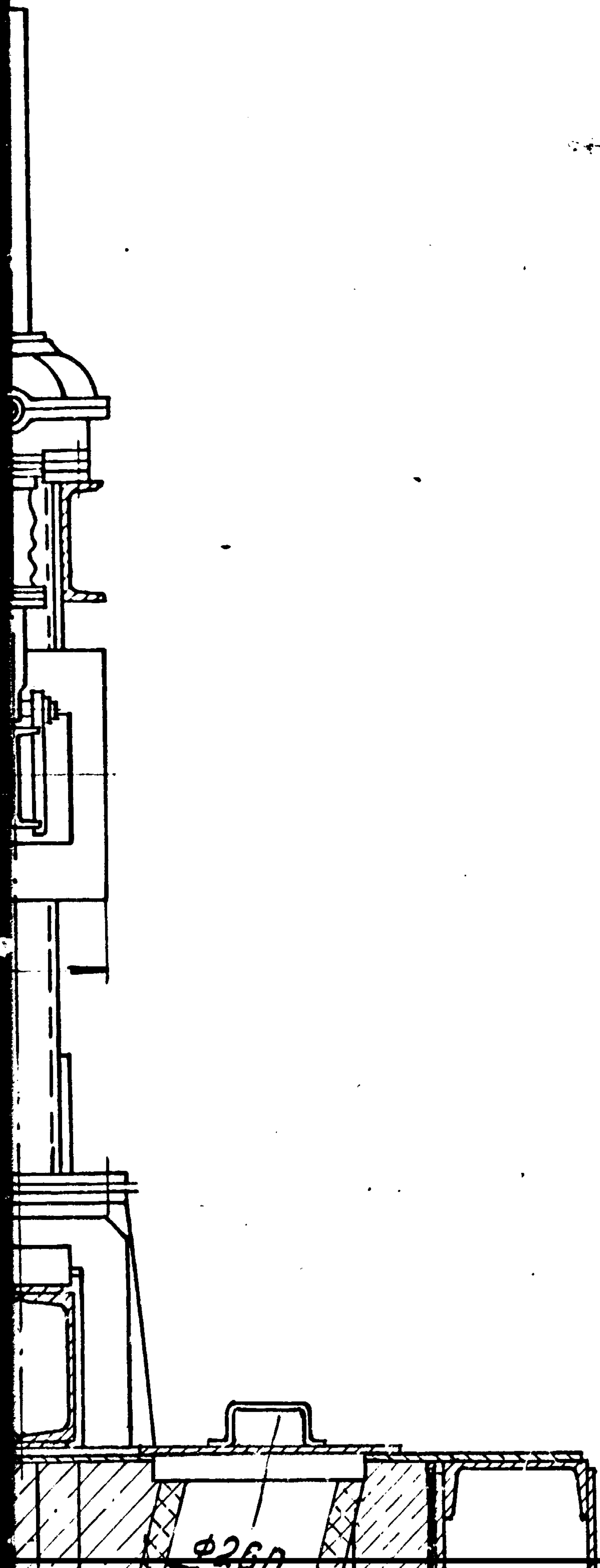


37
505
290
112
5
1210
430
Ход 500
120
A
10
160
SECTION 1
A
575

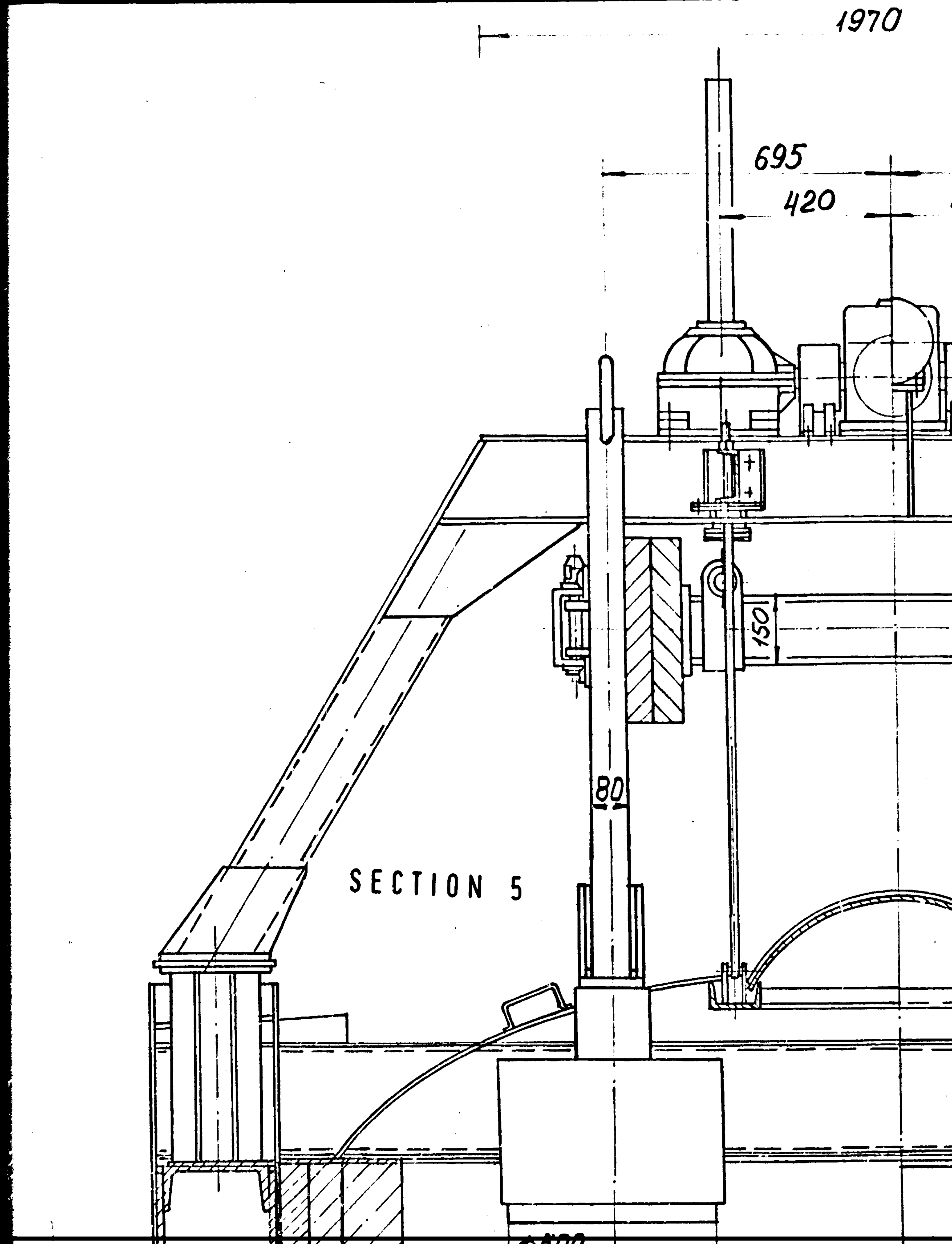

3730
2790
640
640
640
295
Ось шахты
CAVITY AXIS
Ось электролизера
6080
SECTION 2



Ось электролизера
CELL AXIS
2185
345
640
640
2120
SECTION 3

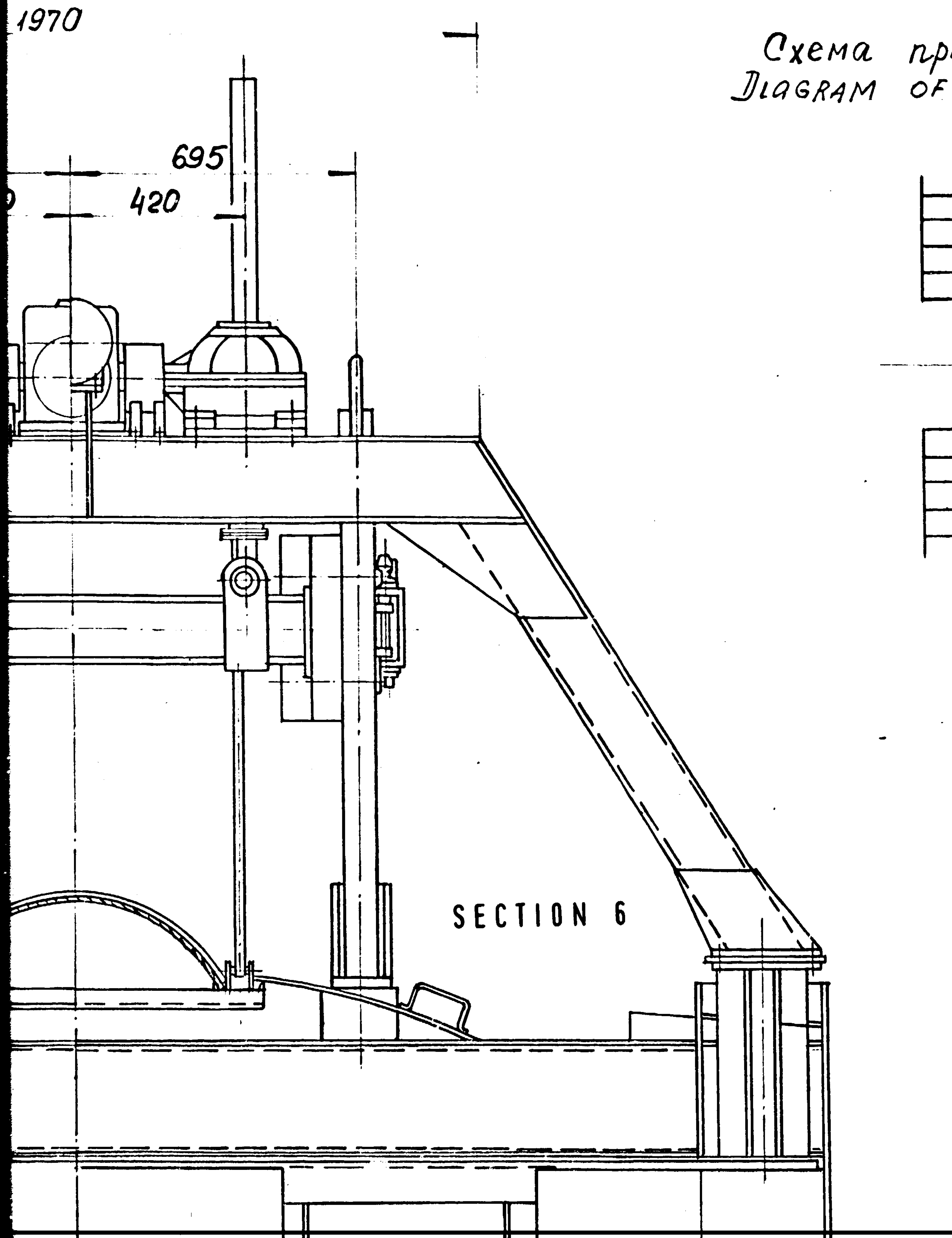


SECTION 4

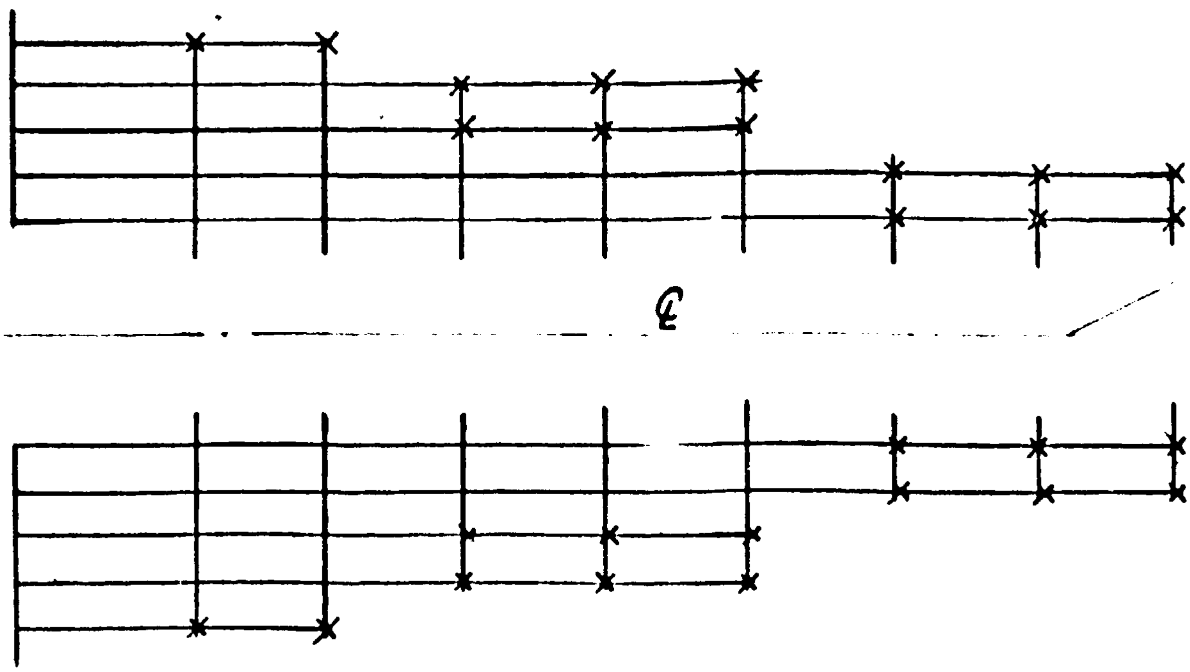


1970
695
420
150
80
SECTION 5

Схема пр
DIAGRAM OF



приварки анодных спусков
OF ANODE FLEXIBLES WELDING



Техническа
TECHNICAL

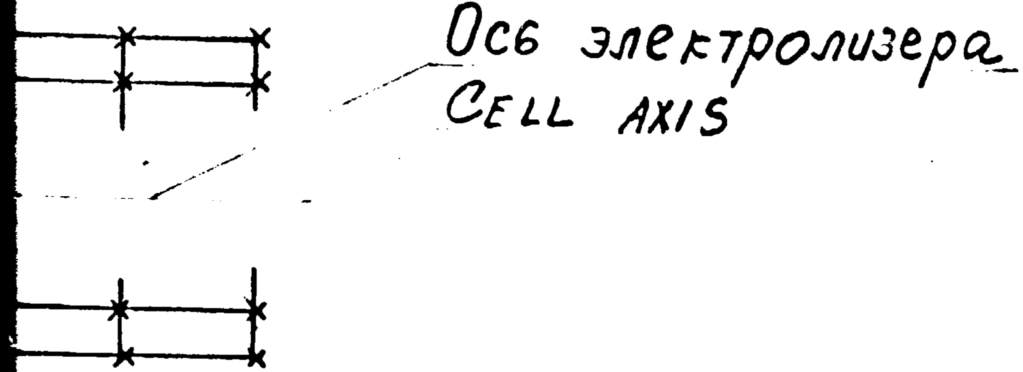
Расчетная си
1. ESTIMATED

Плотность т
2. CURRENT DEN

Размеры шах
3 CAVITY DIME

Глубина ш
4 CAVITY DE

SECTION 7



Техническая характеристика
TECHNICAL CHARACTERISTICS

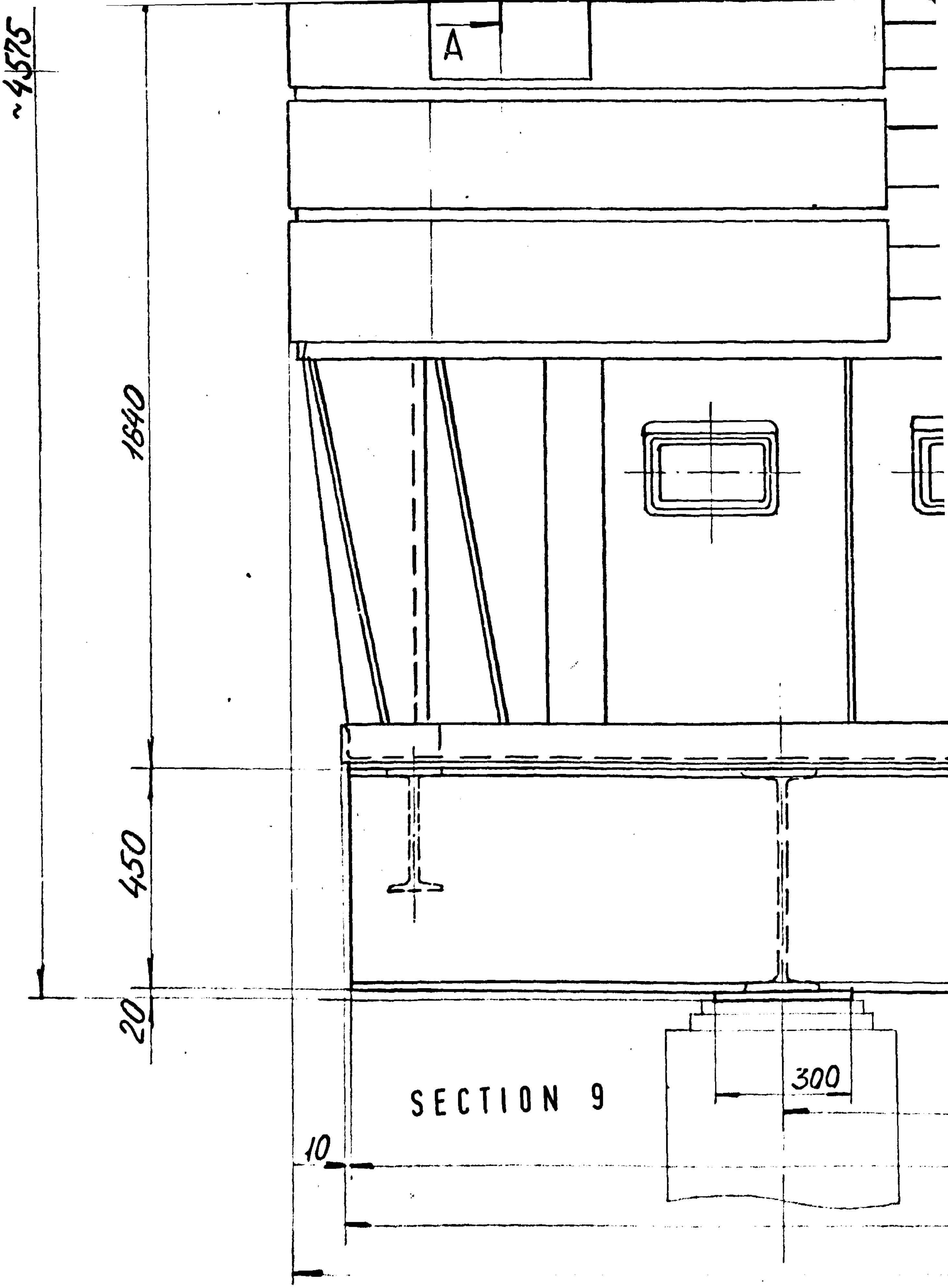
1. Расчетная сила тока
ESTIMATED AMPERAGE — 70kA

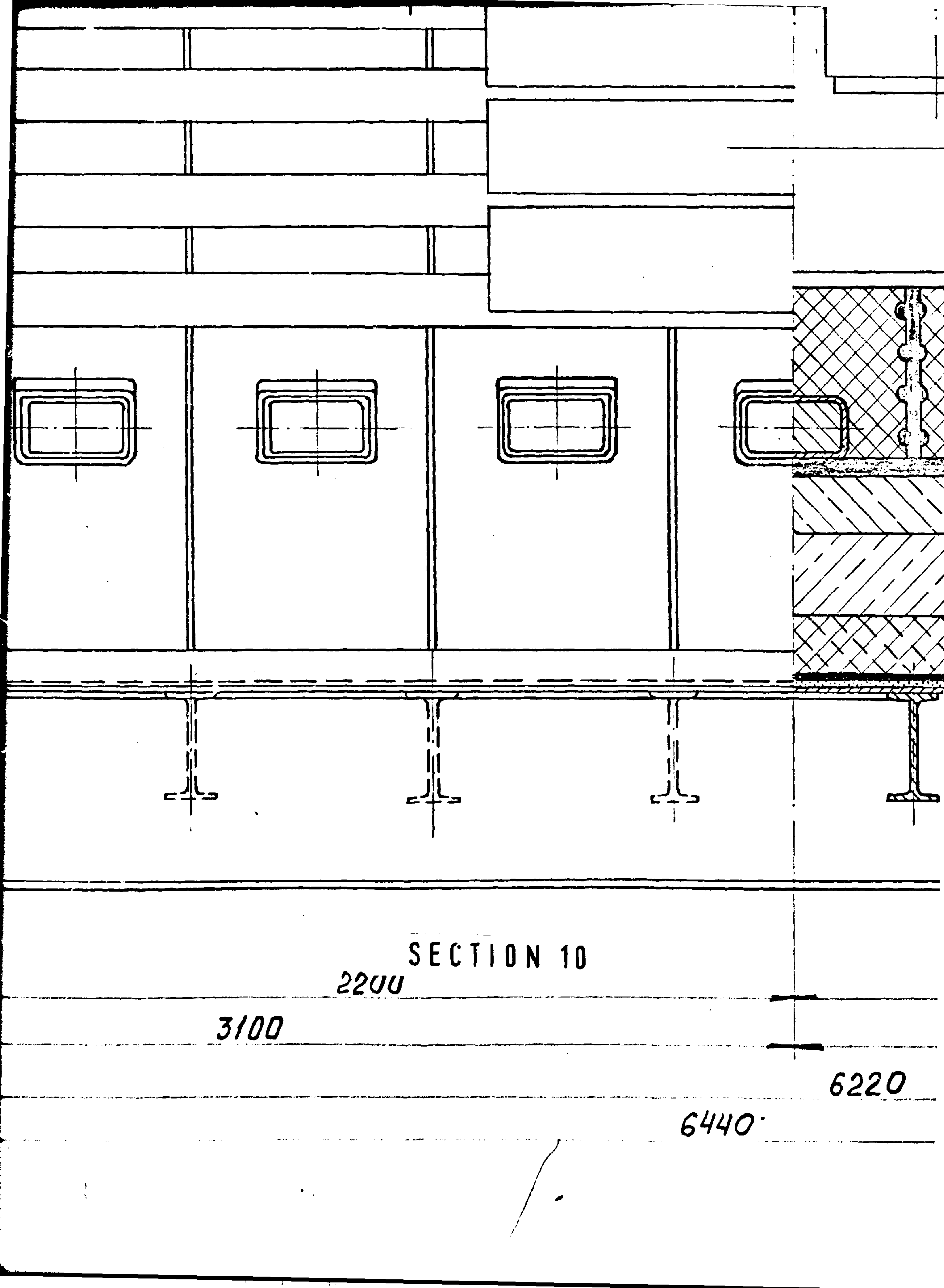
2. Плотность тока в электролите
CURRENT DENSITY in ELECTROLYTE — 0,6 A/cm²

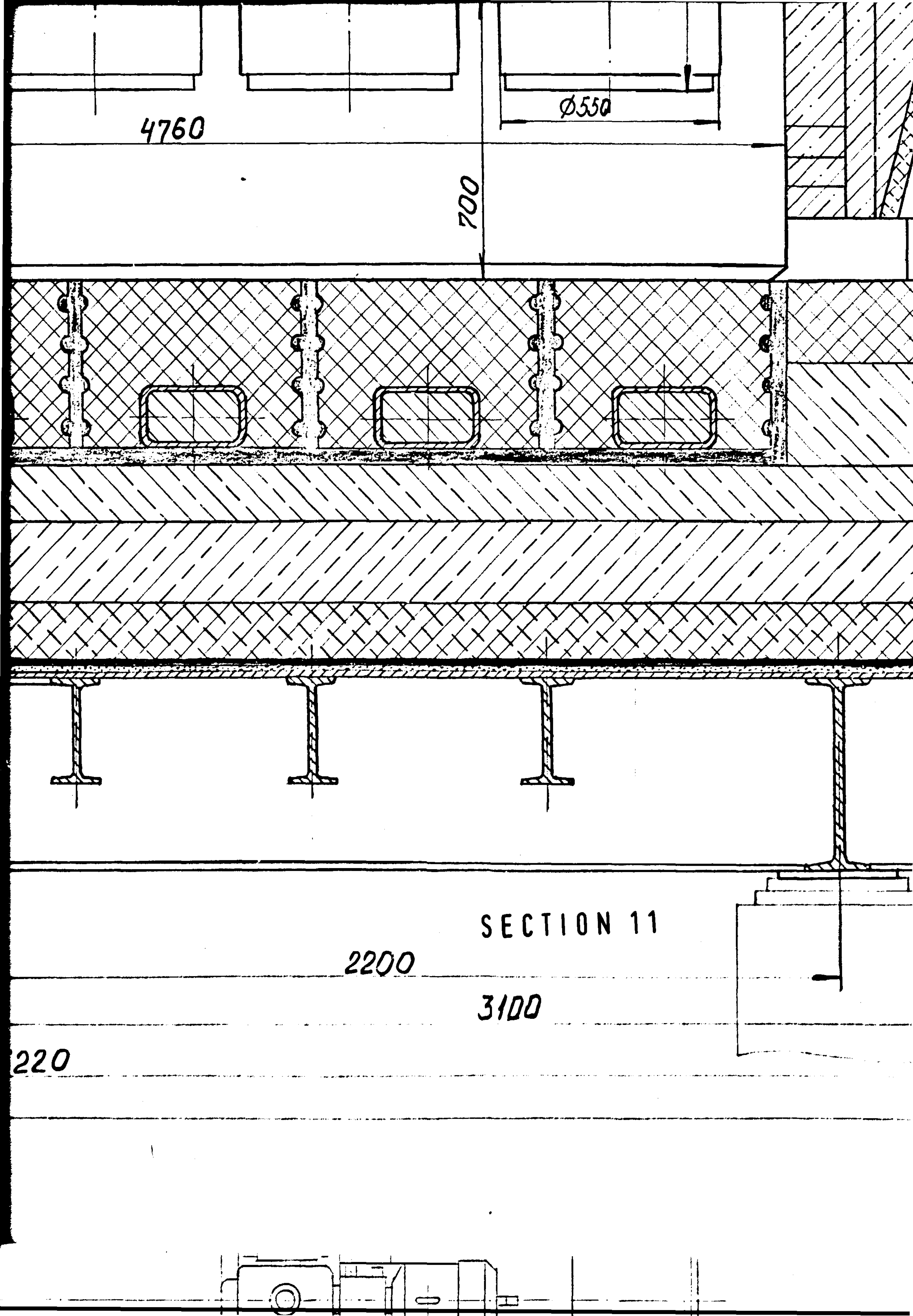
3. Размеры шахты в плане
CAVITY DIMENSIONS in PLAN — 2450 × 4760mm

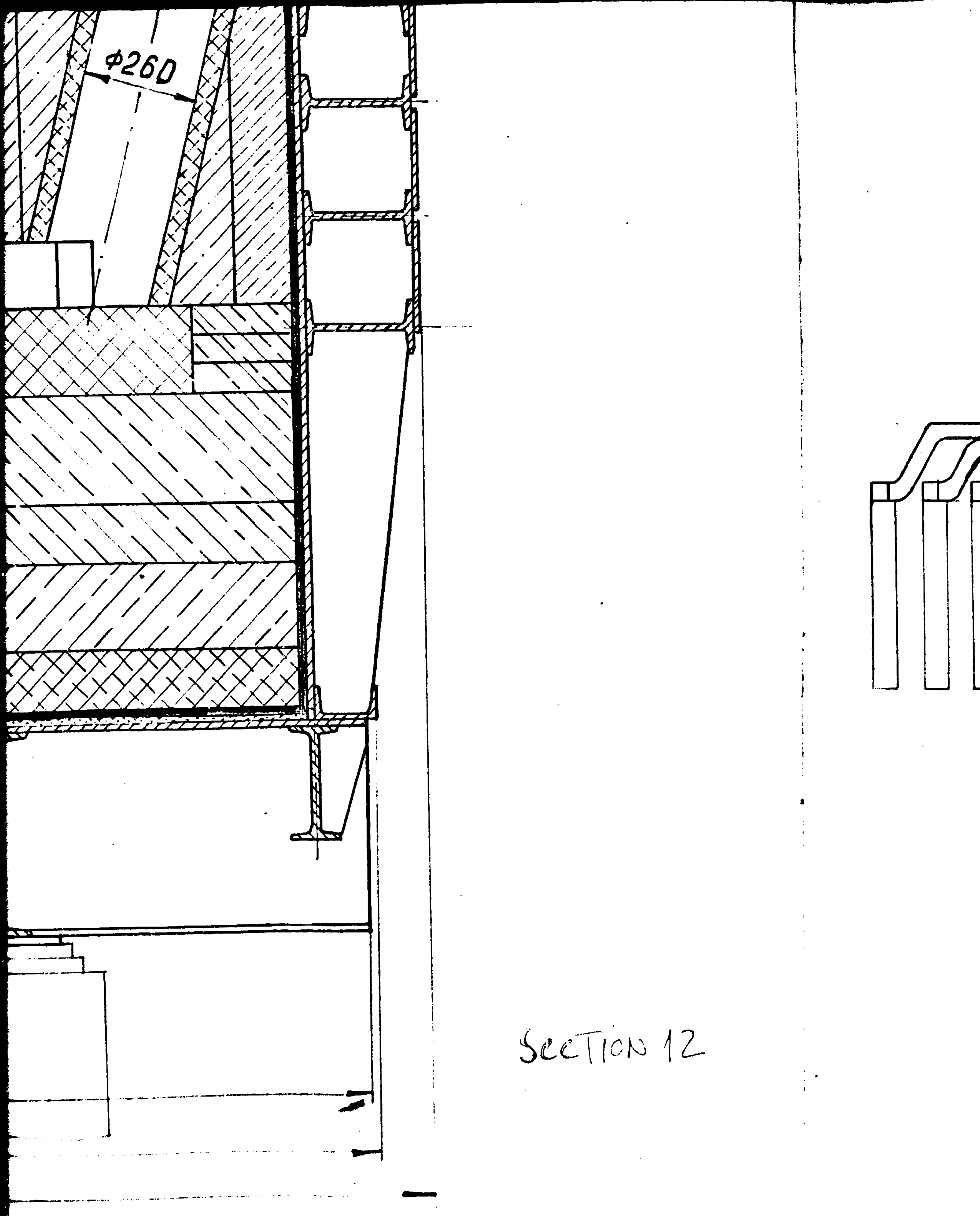
4. Глубина шахты
CAVITY DEPTH — 700mm

SECTION 8

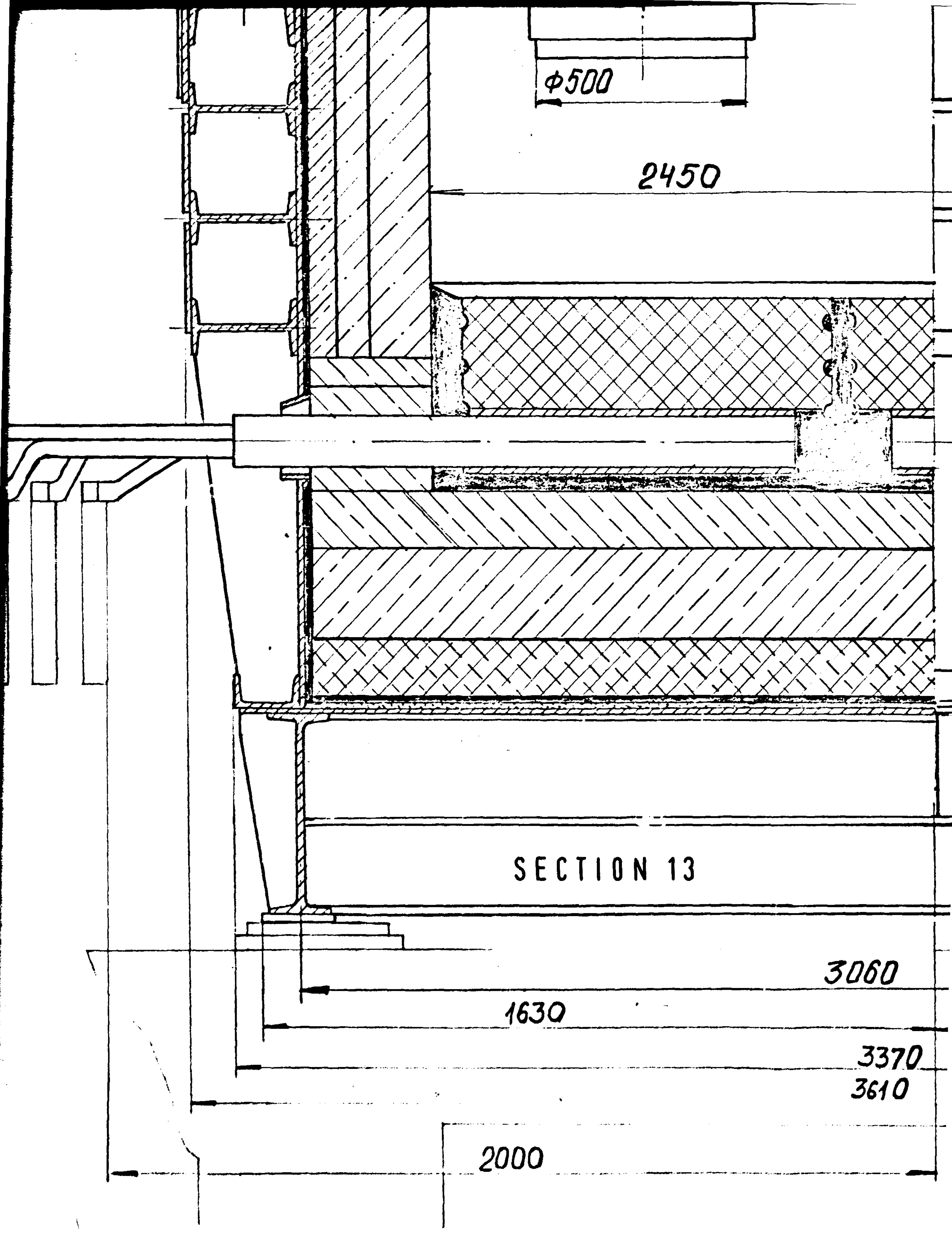

~4575
A
1640
450
20
300
SECTION 9
10


SECTION 10
2200
3100
6220
6440

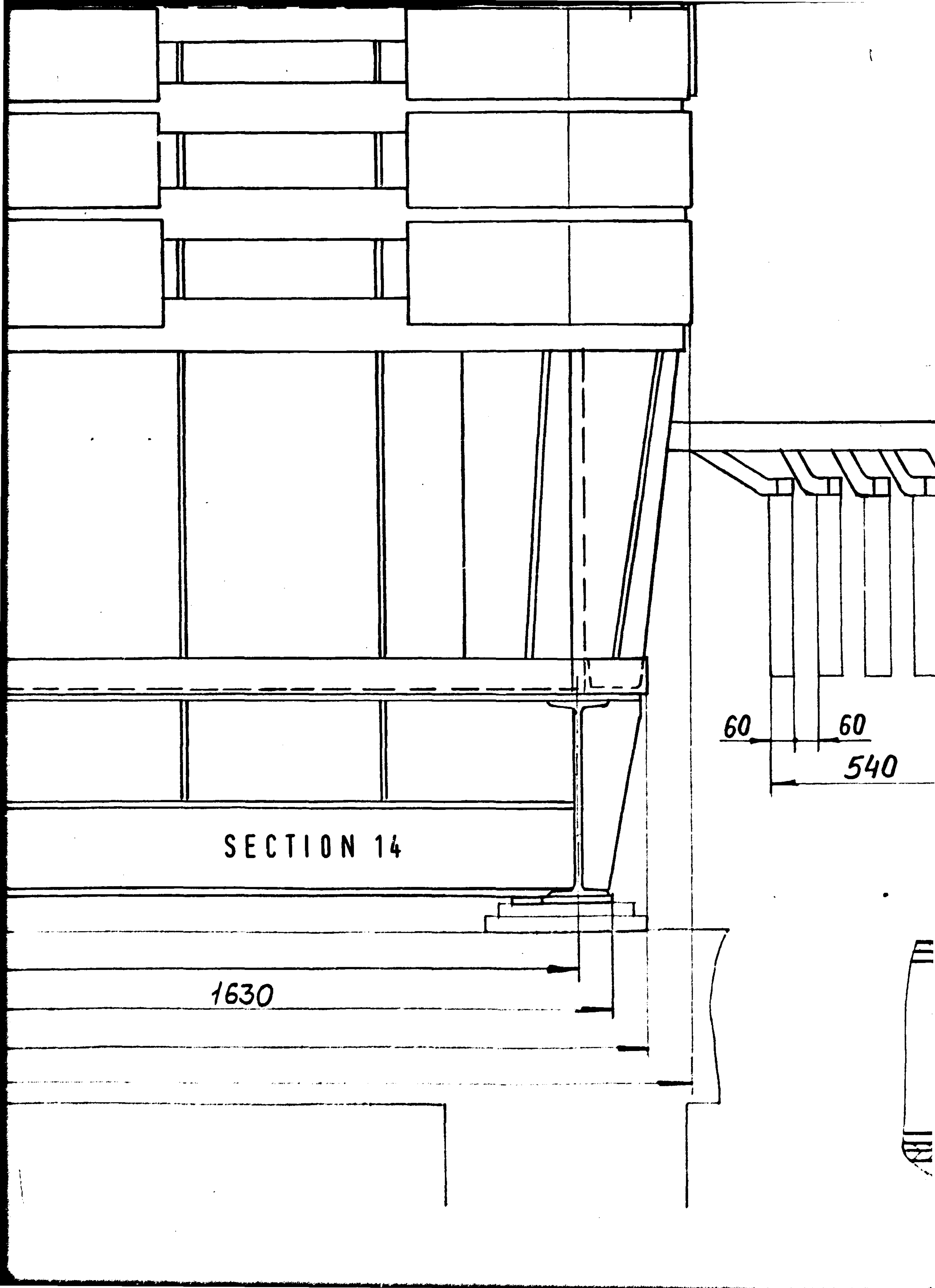

4760
Ø550
700
SECTION 11
2200
3100
220



SECTION 12



?at		?ion	Обозначение	Наименование	Кол.	Примечание


SECTION 14
60
60
540
1630

Глубина шахты

4 CAVITY DEPTH

5. Количество катод

NUMBER OF CATHO

6 Диаметр графитированн

DIAMETER OF CATHODE

7 Количество анодны

NUMBER OF ANODE SE

8 Количество загрузо

NUMBER OF FEEDING

9 Скорость перемеще

CATHODE MOVEMENT

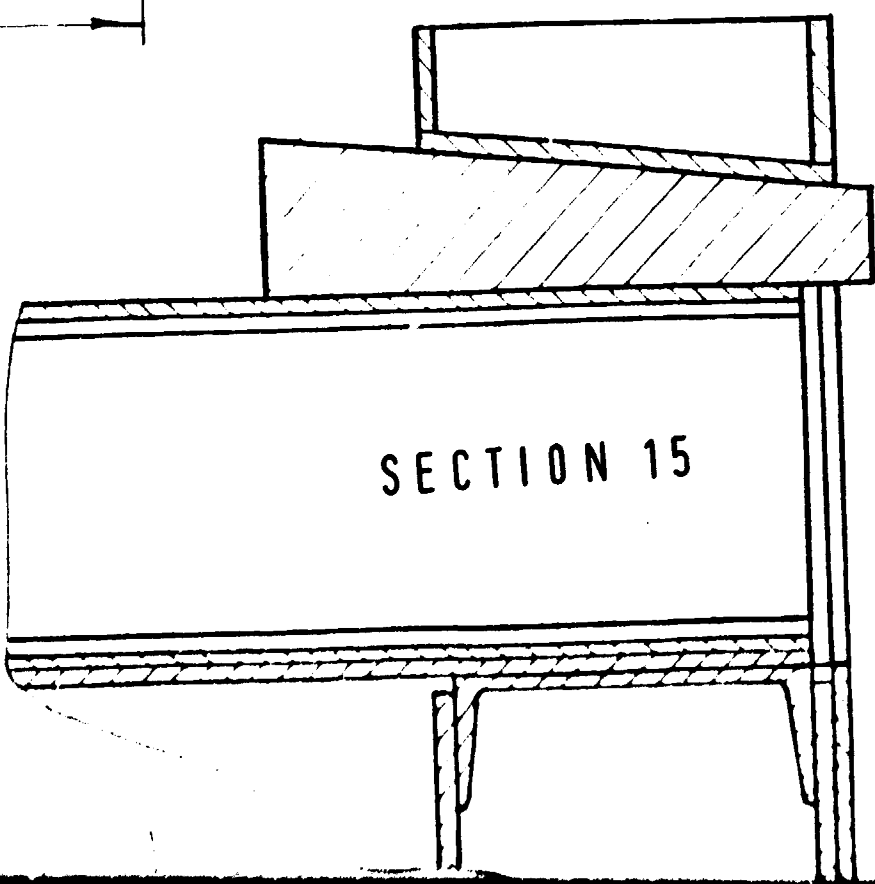
10. Максимальный ход

MAXIMUM BUSWORK

11. Грузоподъемность подъема катодов

LOAD CAPACITY OF 2 MECHANISMS

A – A
M 1:5



Алюминиевый завод в г

Экспериментально-демострацио производства алюминия

ALUMINIUM SMELTER IN KORB

EXPERIMENTAL DEMONSTRATION

ALUMINIUM PRODUCTION

Эле
во

70

4 Глубина шахты — 700 mm
CAVITY DEPTH

5. Количество катодов — 13 шт. PCS
NUMBER OF CATHODES

6 Диаметр графитированного блока катода — ϕ 500mm
DIAMETER OF CATHODE GRAPHITE BLOCK

7. Количество анодных секций — 16 шт PCS
NUMBER OF ANODE SECTIONS

8. Количество загрузочных карманов — 1 шт PC
NUMBER OF FEEDING COMPARTMENTS

9. Скорость перемещения катодов — V=62 m/min
CATHODE MOVEMENT VELOCITY

10. Максимальный ход ошиновки — H=500mm
MAXIMUM BUSWORK TRAVEL

11. Грузоподъемность 2^х механизмов подъема катодов — Q=10 t
LOAD CAPACITY OF 2 CATHODE LIFTING MECHANISMS

Алюминиевый завод в г. Корба. Индия
Экспериментально-демострационная установка для производства алюминия высокой чистоты
ALUMINIUM SMELTER IN KORBA, INDIA.
EXPERIMENTAL DEMONSTRATION UNIT FOR HIGH-PURITY ALUMINIUM PRODUCTION

SECTION 16

1335873 В0

Электролизер рафинировочный на 70 КА
70 KA REFINING CELL

Стадия Phase	Масса Mass	Масштаб scale
П	61830	1:10
Лист Sheet 1	Листов Sheets 2	

VAMI

5. Количество катодов — 13 шт.
NUMBER OF CATHODES — PCS

6 Диаметр графитированного блока катода — ф 500[illegible]
DIAMETER OF CATHODE GRAPHITE BLOCK

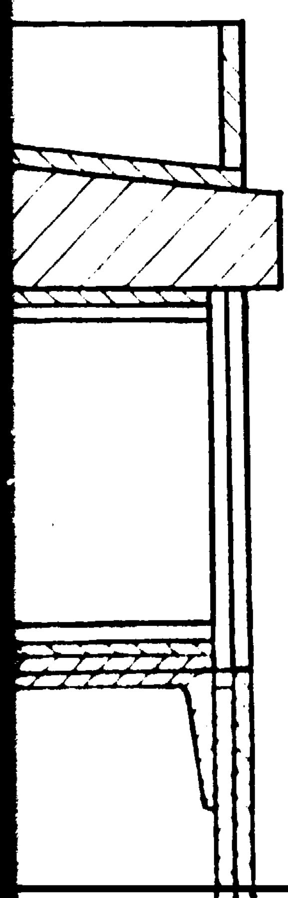
7. Количество анодных секций — 16 шт
NUMBER OF ANODE SECTIONS — PCS

8. Количество загрузочных карманов — 1 шт
NUMBER OF FEEDING COMPARTMENTS — PC

9. Скорость перемещения катодов — V=62 m/m[illegible]
CATHODE MOVEMENT VELOCITY

10. Максимальный ход ошиновки — H=500m[illegible]
MAXIMUM BUSWORK TRAVEL

11. Грузоподъемность 2^{x} механизмов подъема катодов — Q=10 t
LOAD CAPACITY OF 2 CATHODE LIFTING MECHANISMS



Алюминиевый завод в г. Корба. Индия
Эксперементально-демострационная установка для производства алюминия высокой чистоты
ALUMINIUM SMELTER IN KORBA, INDIA.
EXPERIMENTAL DEMONSTRATION UNIT FOR HIGH-PURITY ALUMINIUM PRODUCTION

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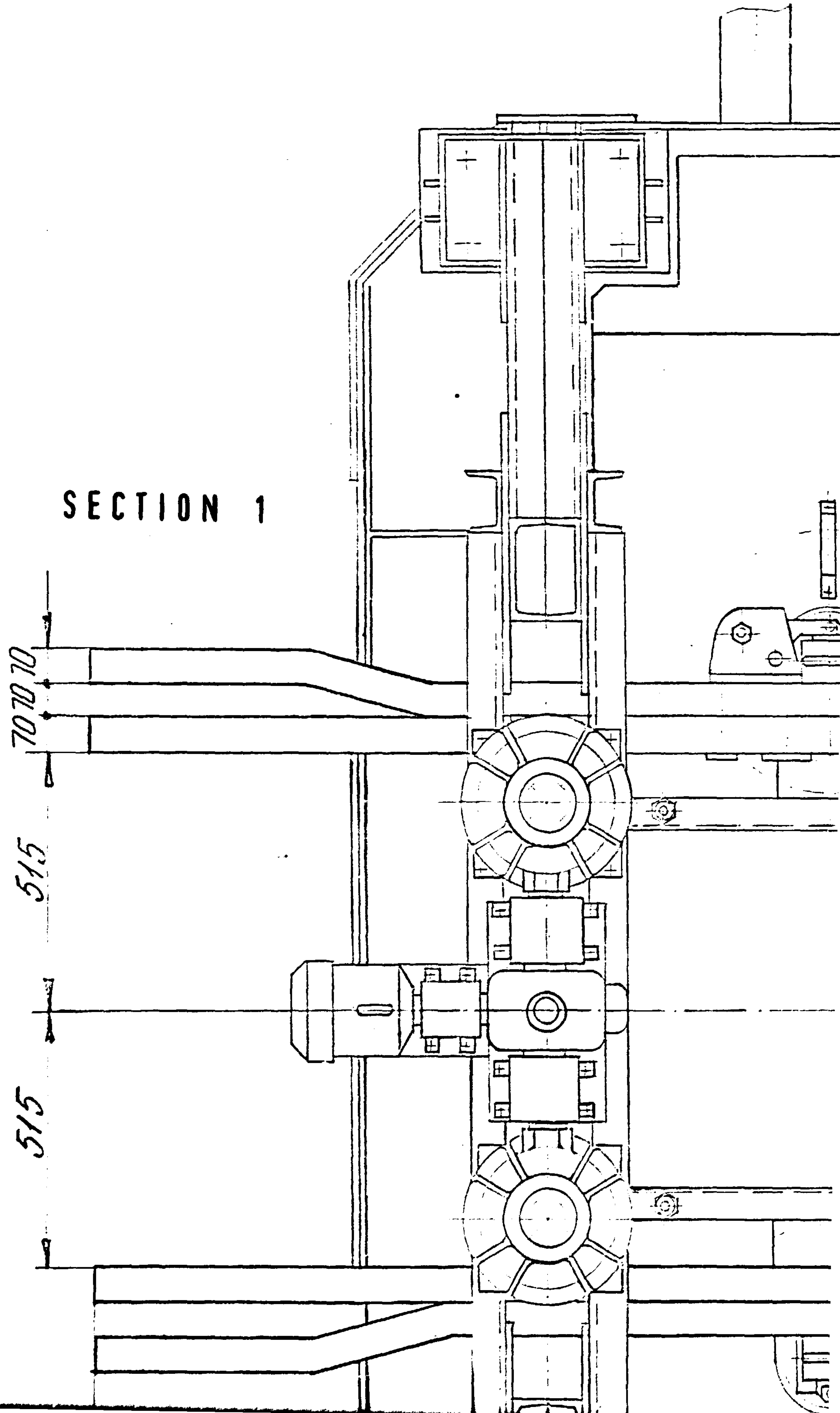
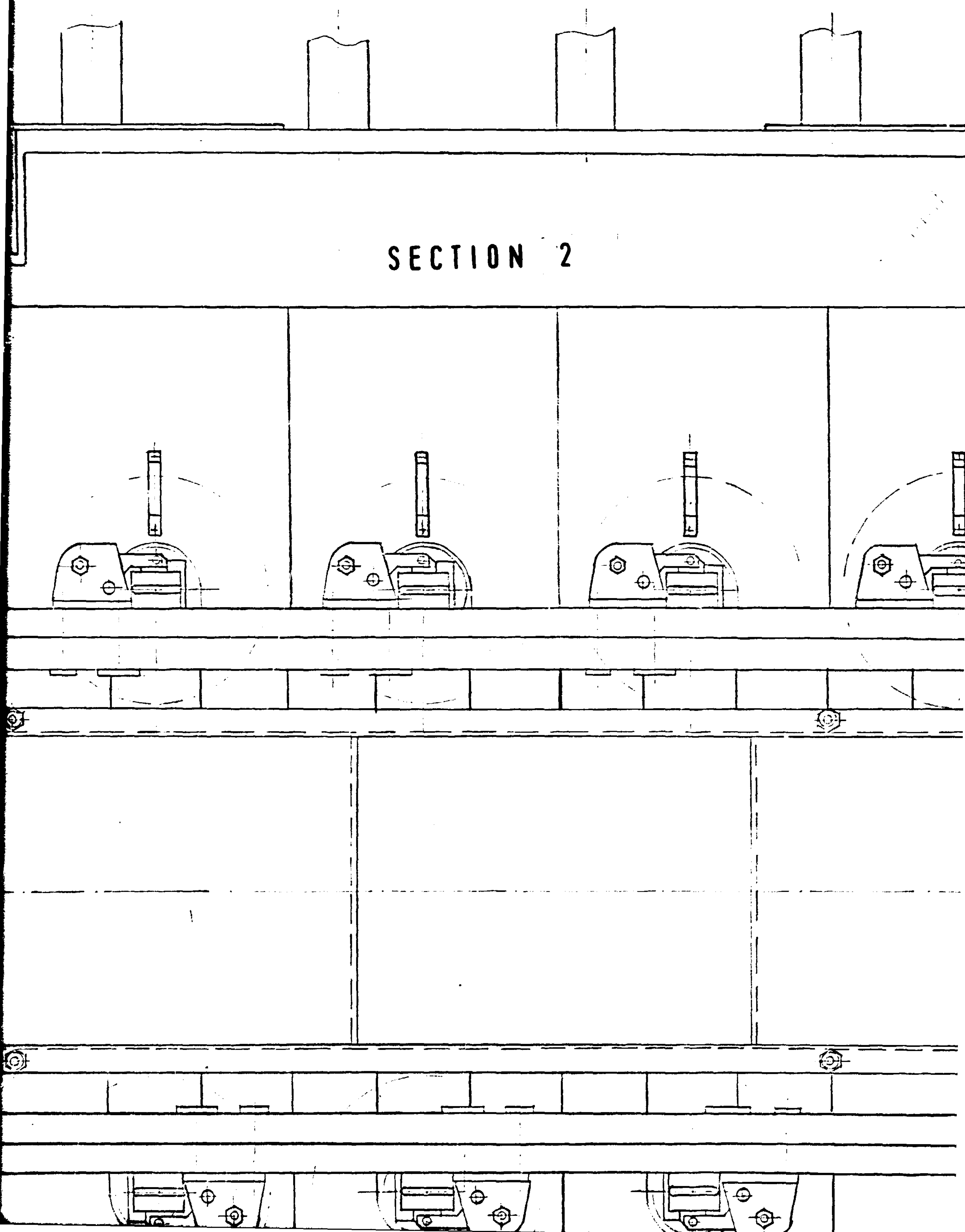
	Электролизер рафинировочный на 70 КА 70 KA REFINING CELL	Стадия Phase: П	Масса Mass: 61830
		Лист Sheet 1	Листов Sheet[illegible]
	SECTION 17	VAMI	

SECTION 1

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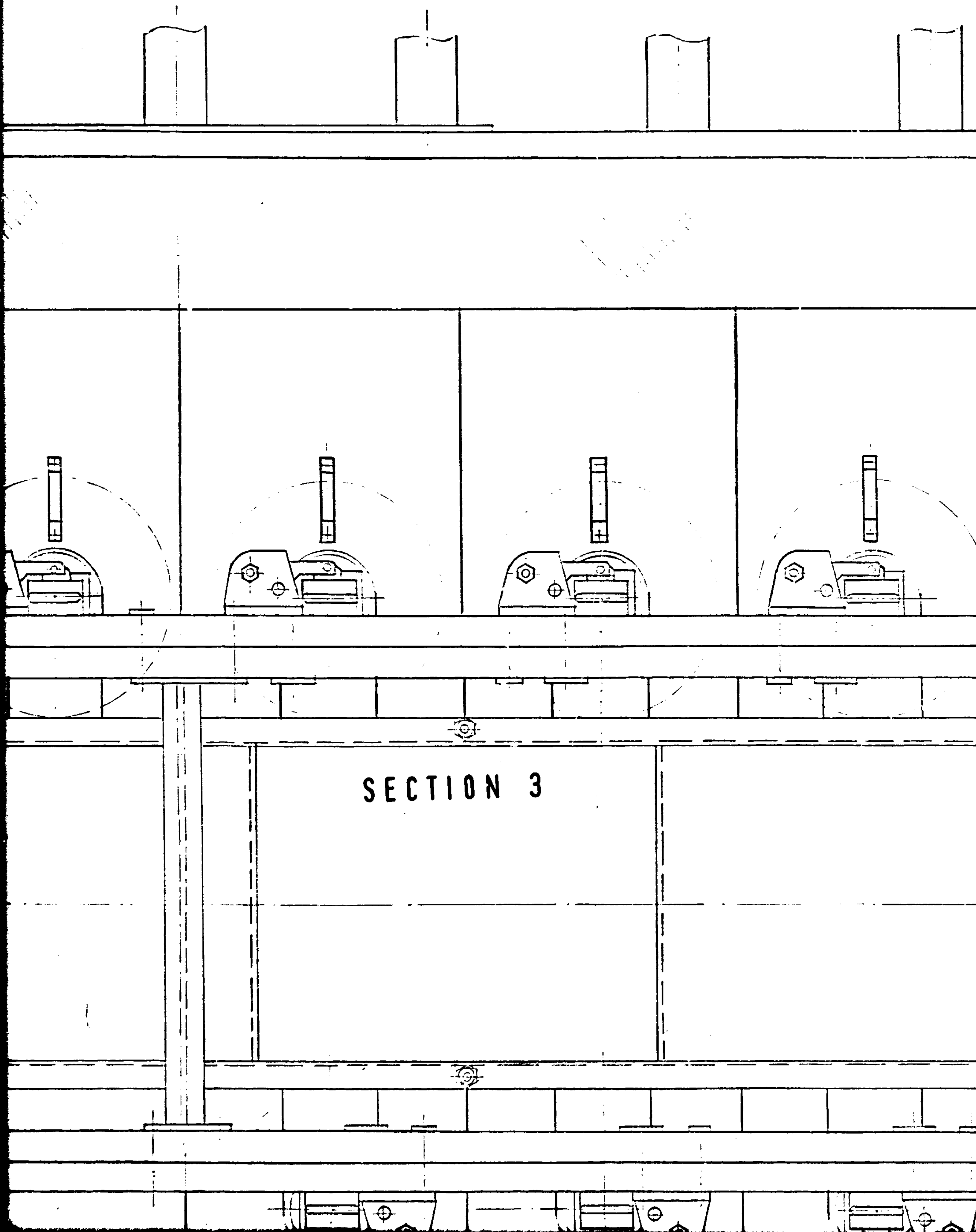
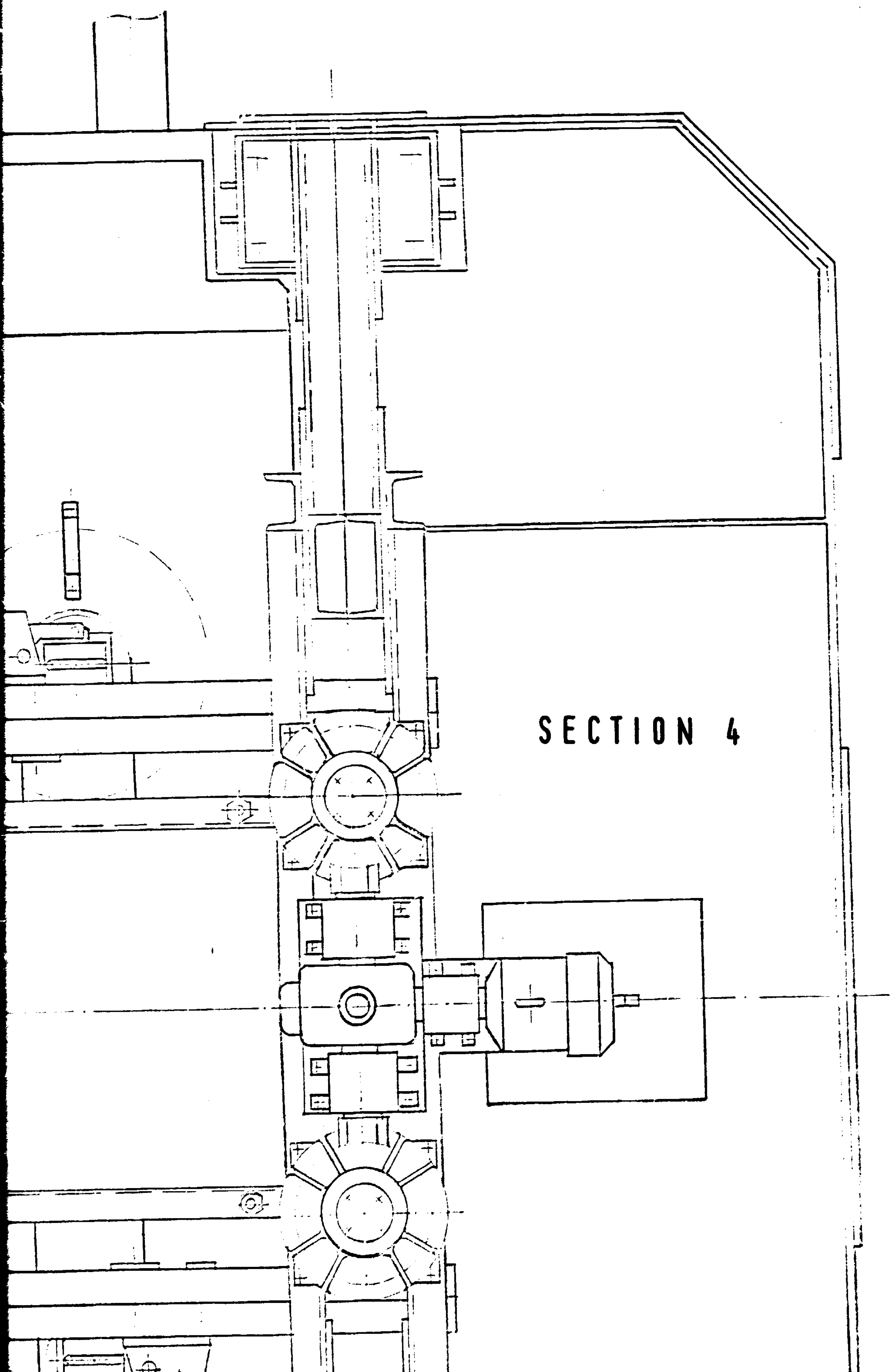

SECTION 3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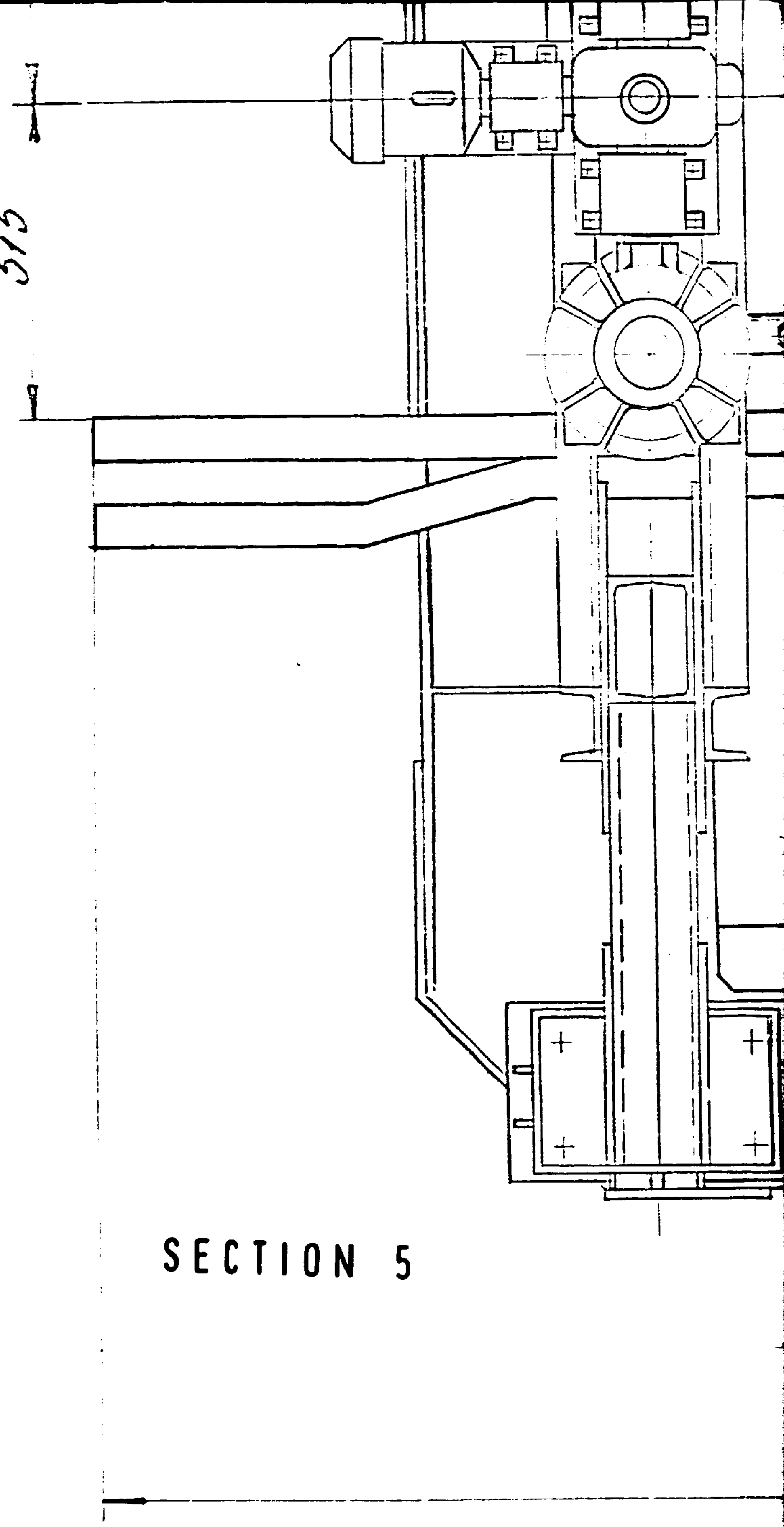
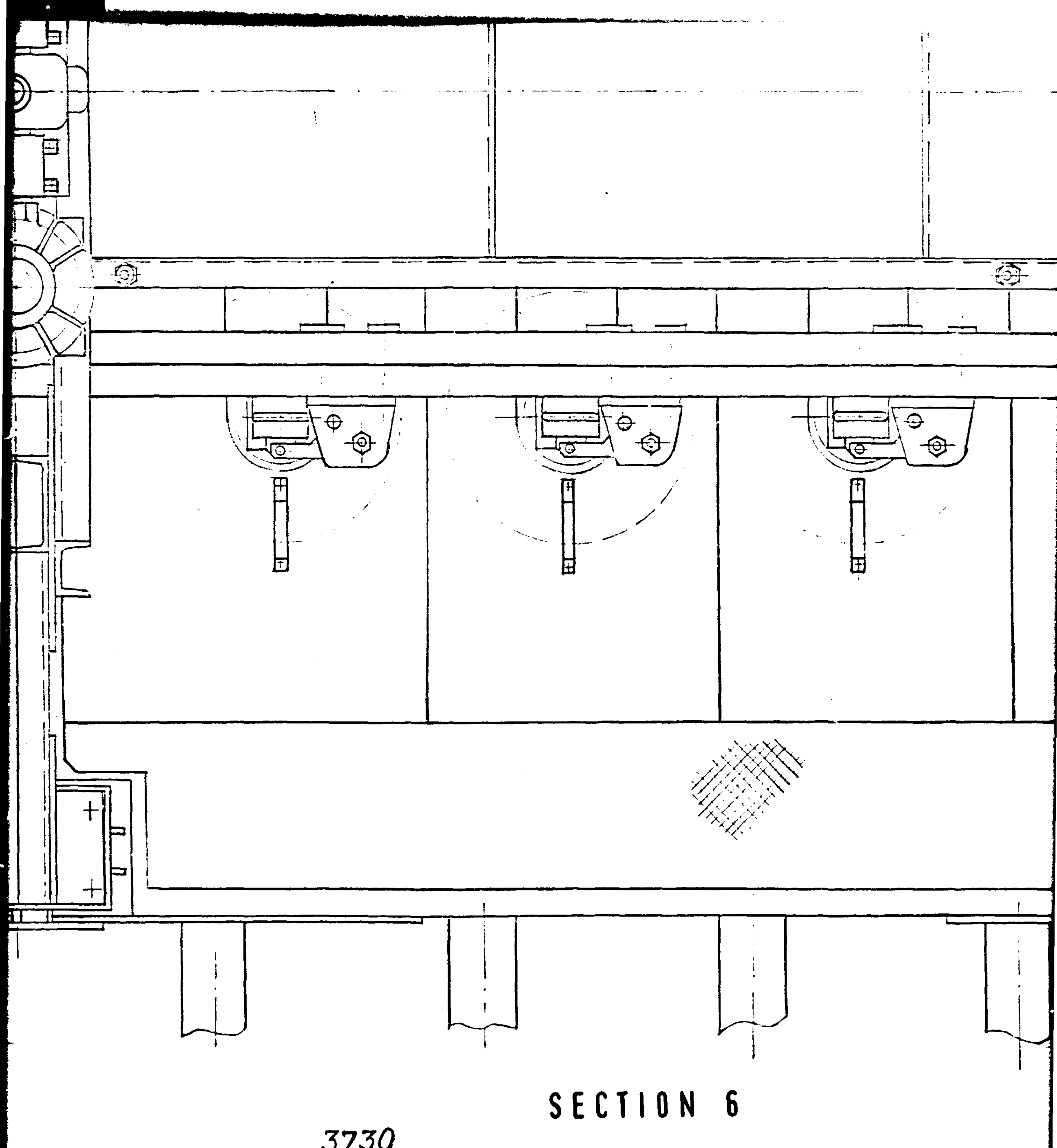


SECTION 5

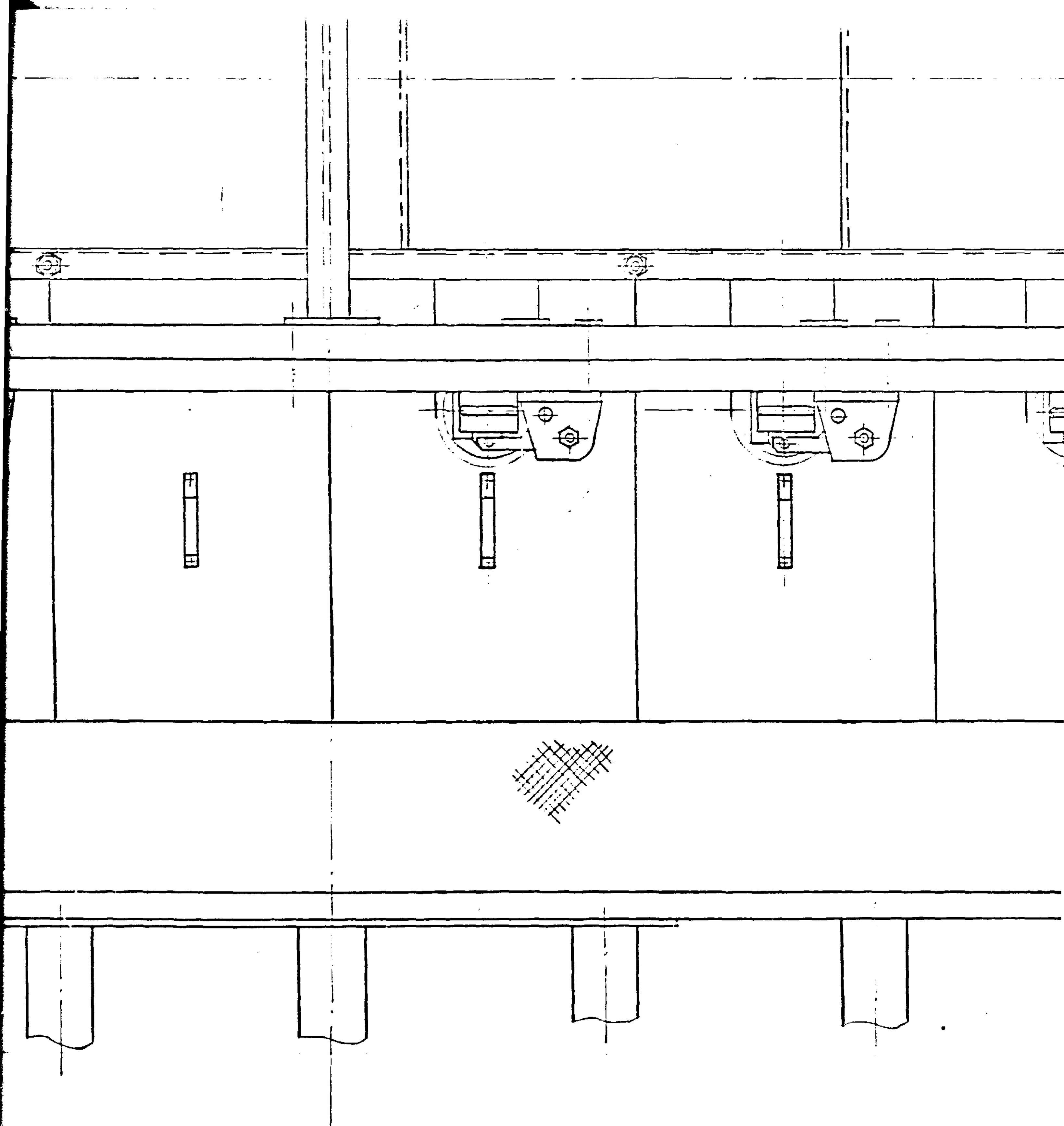
Перв. примен.
1335873
Справ. №

A – A лист 9

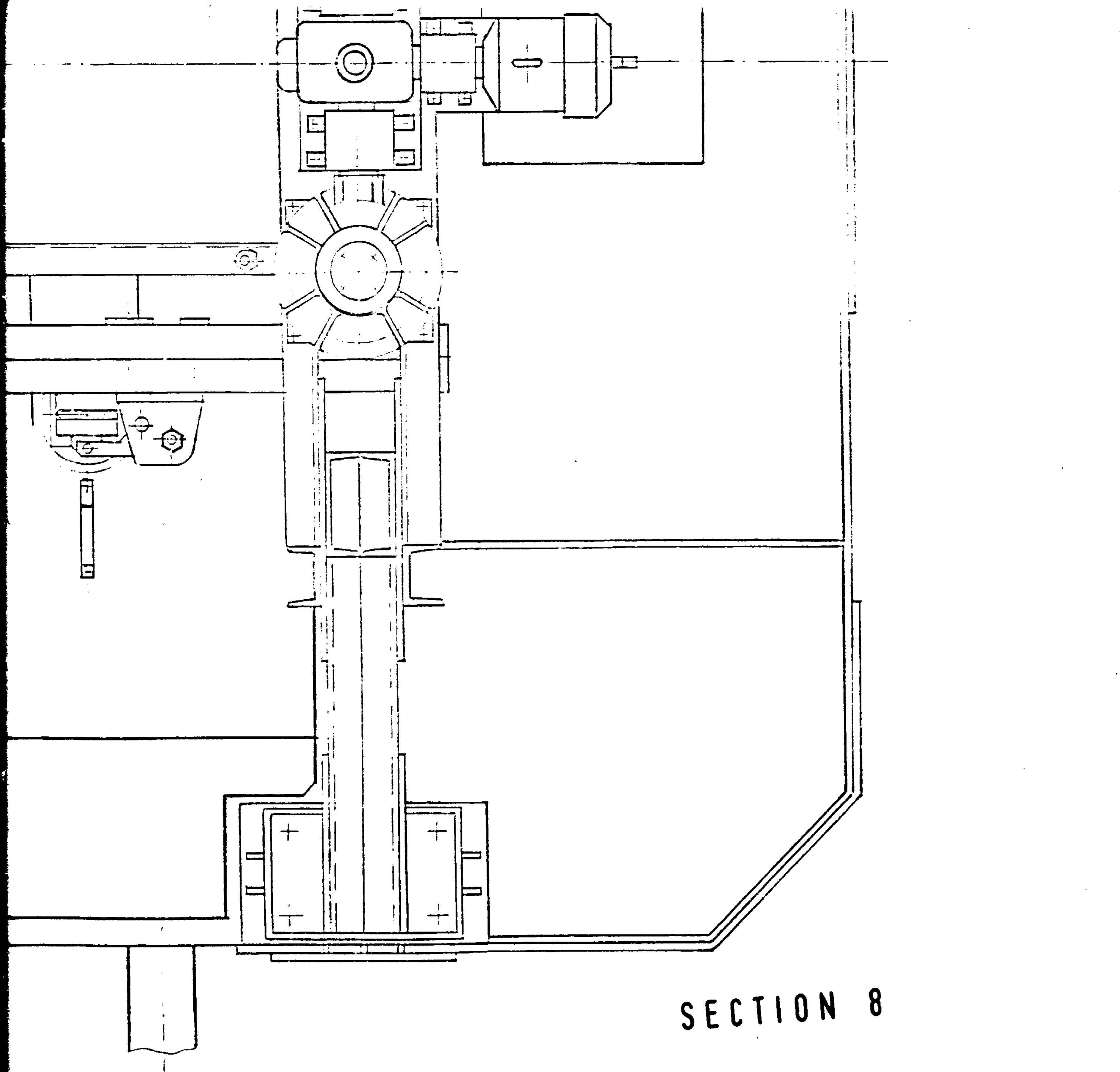


SECTION 6

3730



SECTION 7



SECTION 8

1335373 ВО

Электролизер рафинировочный на 70 кА

70KA REFINING CELL

Стадия Phase	Масса Mass	Масш. scal…
П	—	1:…

Лист Sheet	Листов Sheets

VAMI

Leningrad

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
			Поставка по импорту Imported	Блок угольный	-	2088kg
				¢Carbon block		
				400 x 550 x 900		
				Средний предел прочности		
				на сжатие не менее		
				Average compressive		
				strength minimum		
				220 kg/cm^2		
				Пористость, не более		
				Porosity		
				24 %		
				Удельное электросопротив-		
				ление не более		
				Electric resistivity		
				maximum		
				70 μohm.mm мкОм.мм		
				Заливка		
				Casting		
				Чугун литейный	-	520 kg
				Cast iron		
				Химический состав:		
				Chemical composition		
				Si 3,2 ...3,6 %;		
				Mn ≤ 0,3%; P ≤ 0,12 %;		
				S ≤ 0,03%		

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Набивка Ramming	-	48 kg
				Масса подовая Ramming mix		
				Предел механической прочности, не менее Mechanical strength, 20 kg/cm^2, min		
				Коэффициент связи, не менее Coupling coefficient 25 kg/cm^2		
				Пористость, не более Porosity 23 %		
		2		Секция анодная Anode section	8	7051 kg
				В том числе: Including		
				Блюмс - сталь полосовая сечением Collector bar, strip steel, section 115x230 IS 1875-1978	-	3000 kg
				Лента алюминиевая сечением Aluminium strip section 1 x 150	-	115 kg
			Поставка по импорту Imported	Блок угольный Carbon block 400 x 550 x 1340	-	3088kg

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Заливка Casting	–	
				Чугун литейный Cast iron	–	800 kg
				Набивка Ramming		
				Масса подовая	–	48 kg
				Характеристики материалов см.позиция I For material characteristics see item 1	–	
		3	–	Труба заливочная Pouring tube	–	55 kg
				Графитированный электрод Graphitized electrode Ø 350		
				Удельное электрическое сопротивление, не более Electrical resistivity, maximum 9,5 mk.ohm.m мк.Ом.м		
				Предел механической прочности: Mechanical strength При изгибе, не менее bending strength 85 kg/cm^2, min.		

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				При разрыве, не менее		
				Breaking strength		
				75 kg/cm^2, min		
		4	-	Плита угольная	-	74 kg
				Carbon plate		
				200 x 370 x 625		
				Механическая прочность		
				на сжатие, не менее		
				Mechanical compressive		
				strength 230 kg/cm^2		
		5	-	Кирпич глиняный обыкно-венный одинарный	3,45m^3	6560kg
				Ordinary clay brick		
				230 x 115 x 65		
				Прочность при сжатии,		
				не менее		
				Compressive strength		
				75 kg/cm^2, min.		
				γ = 1,9 G/m^3		
				Кирпич шамотный		
				Fireclay brick		
				Al_2O_3-30 ... 32%		
				Огнеупорность, не ниже		
				Refractoriness 1670°C, min		
				Пористость, не более		
				Porosity		
				23 %		

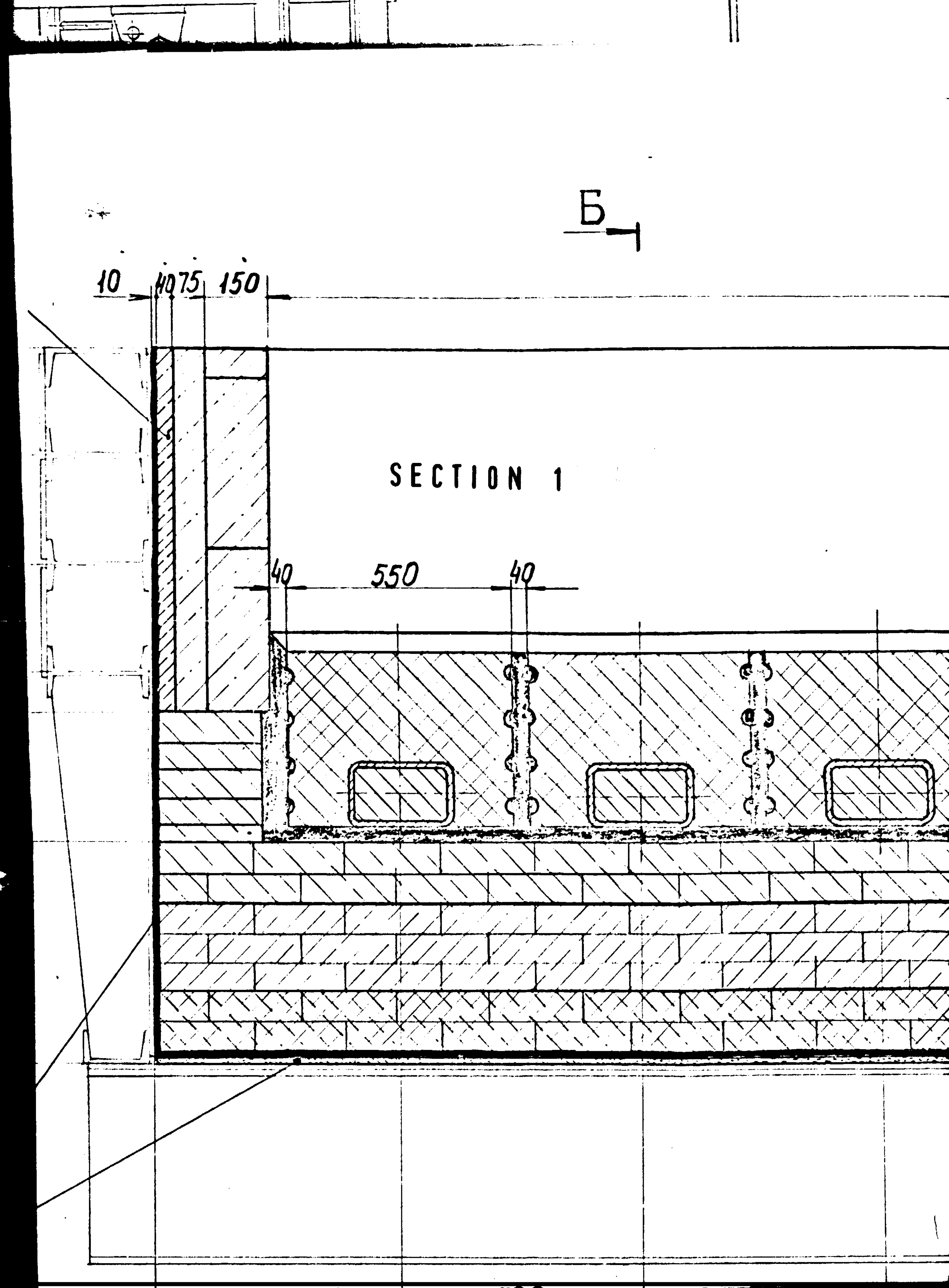
Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Предел прочности при сжатии, не менее		
				Compressive strength, 230 kg/cm², min		
				γ = 2 G/cm³		
		6	–	Кирпич 230 x 115x65 Brick	3,7m³	7400kg
		7		Кирпич 230 x 115 x 40 Brick	0,27m³	540 kg
				Кирпич шамотный легковесный		
				Light-weight fireclay brick		
				Предел прочности при сжатии, не менее		
				Compressive strenght 25 kg/cm², min		
				Теплопроводность, не более, при средней температуре:		
				Heat conductivity, max., at average temperature		
				350±25°C-0,27 W /m°K		
				600±50°C-0,4 W /m°K		
				γ= 0,9 G/cm³		
		8	–	Кирпич 250x124x65 Brick	4,3m³	3870kg
		9	–	Кирпич 230x115x40 Brick	0,1m³	90 kg

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Кирпич магнезитовый уплотненный		
				Compacted magnesite brick		
				Содержание окиси магния на прокаленное вещество, не менее		
				Magnesium oxide content, on calcined basis 91 % min.		
				Содержание окиси кальция на прокаленное вещество, не более		
				Calcium oxide content, on calcined basis 2,5 % max.		
				Содержание двуокиси кремния на прокаленное вещество, не более		
				Silica content, on calcined basis, 1 % max.		
				Пористость, не более		
				Porosity, 20% max.		
				Предел прочности при сжатии, не менее		
				Compressive strength, 500 kg/cm^2 min.,		
				γ = 2,63 G/cm^3		

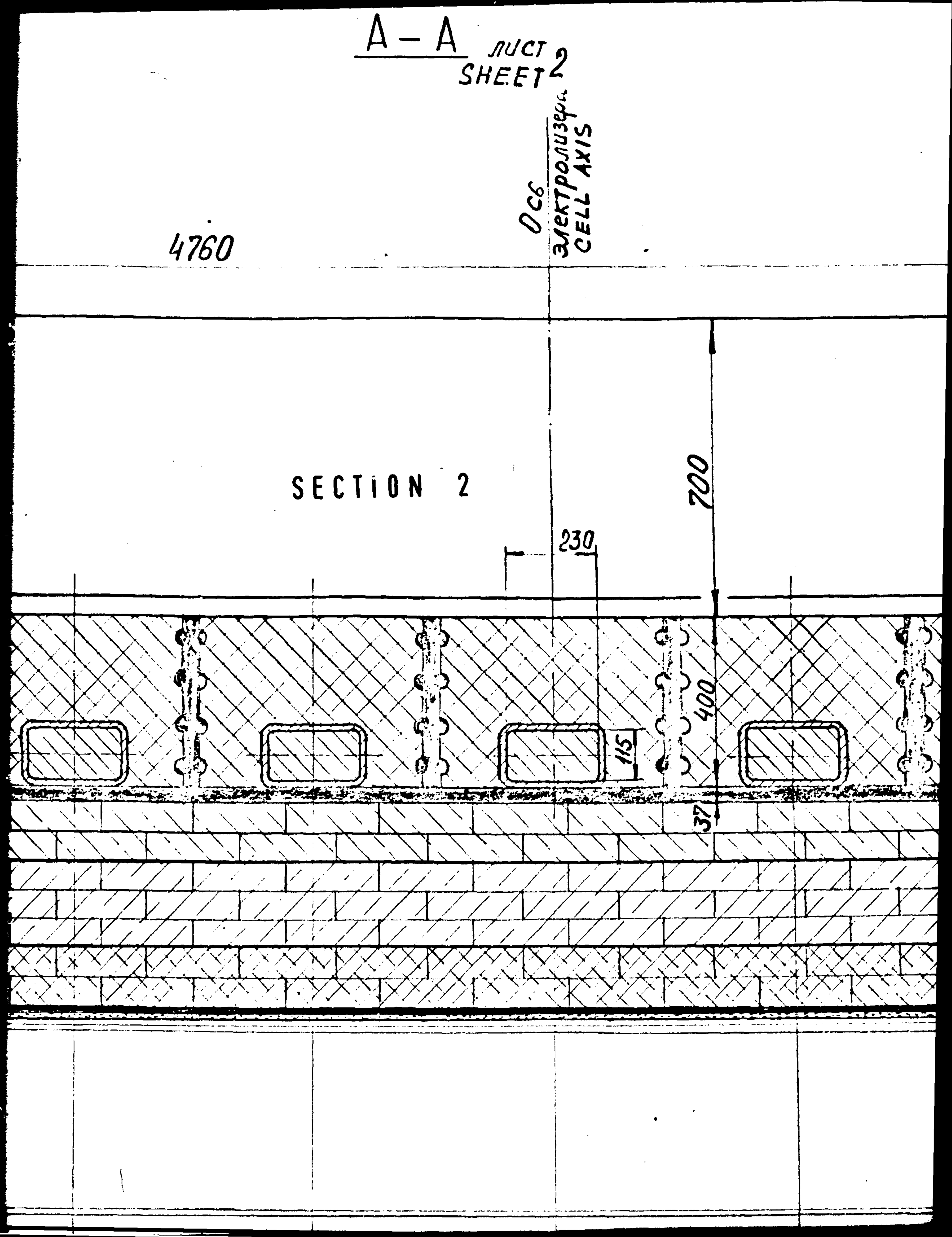
1335874

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
		I0	–	Кирпич 380x150x75 Brick	$3,1m^3$	8150 kg
		II	–	Кирпич 300x150x75 Brick	$0,05m^3$	132kg
		I2	–	Кирпич 300x150x65 Brick	$0,01m^3$	26 kg
		I3	–	Картон асбестовый Asbestos sheet mill board	–	560 kg
				$\delta = 10$		
		I4	–	Набивка Ramming	$1,4m^3$	2310kg
				Масса подовая Ramming mix.		
				Предел механической прочности, не менее Mechanical strength 200 kg/cm^2, min.		
				Коэффициент связи, не менее Coupling coefficient 25 kg/cm^2, min.		
				Пористость, не более Porosity 23 %, max.		
		I5	–	Замазка Putty	$0,11m^3$	132kg
				Асбест на жидком содово-сульфатном стекле Asbestos based on sodium-sulphate water glass		

Формат Size	Зона Zone	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Силикатный модуль 2,1 Silica modulus		
				Плотность 1,48...1,52G/cm^3 Density		
		I6	-	Замазка шамотная Fireclay putty	-	16 kg
		I7		Промазка Spreading	-	~~160 kg~~
				Гипс строительный Building gypsum		
		I8		Засыпка Filling	0,27m^3	320kg
				Глинозем Alumina		



Б
10
40
75
150
SECTION 1
40
550
40



A – A
лист
SHEET 2
Ось электролизера
CELL AXIS
4760
SECTION 2
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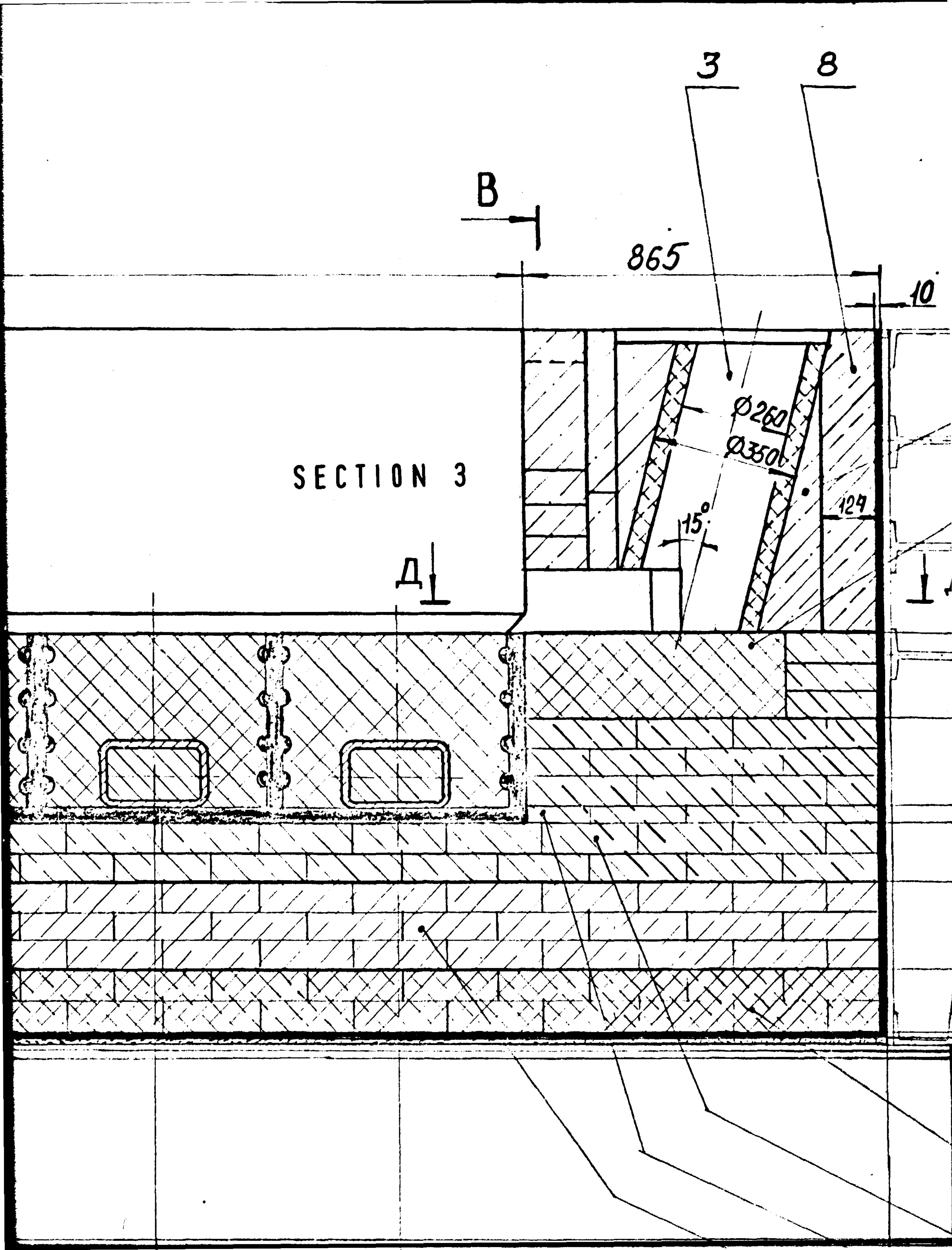
230
400
115
37



3
8
B
865
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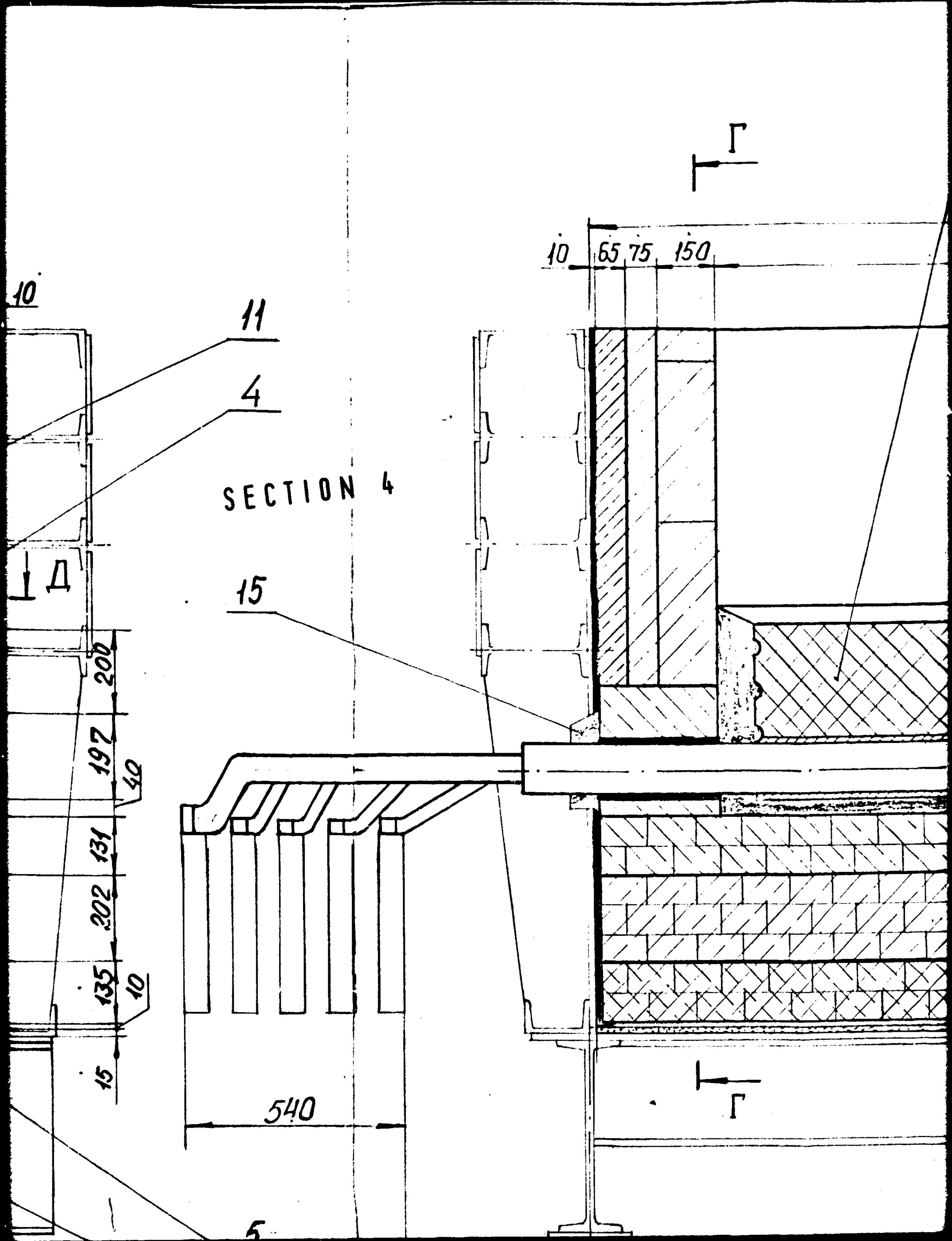
Ø260
Ø350
124
15°
SECTION 3
Д



SECTION 4
Г
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65
75
150
10
11
4
Д
15
200
197
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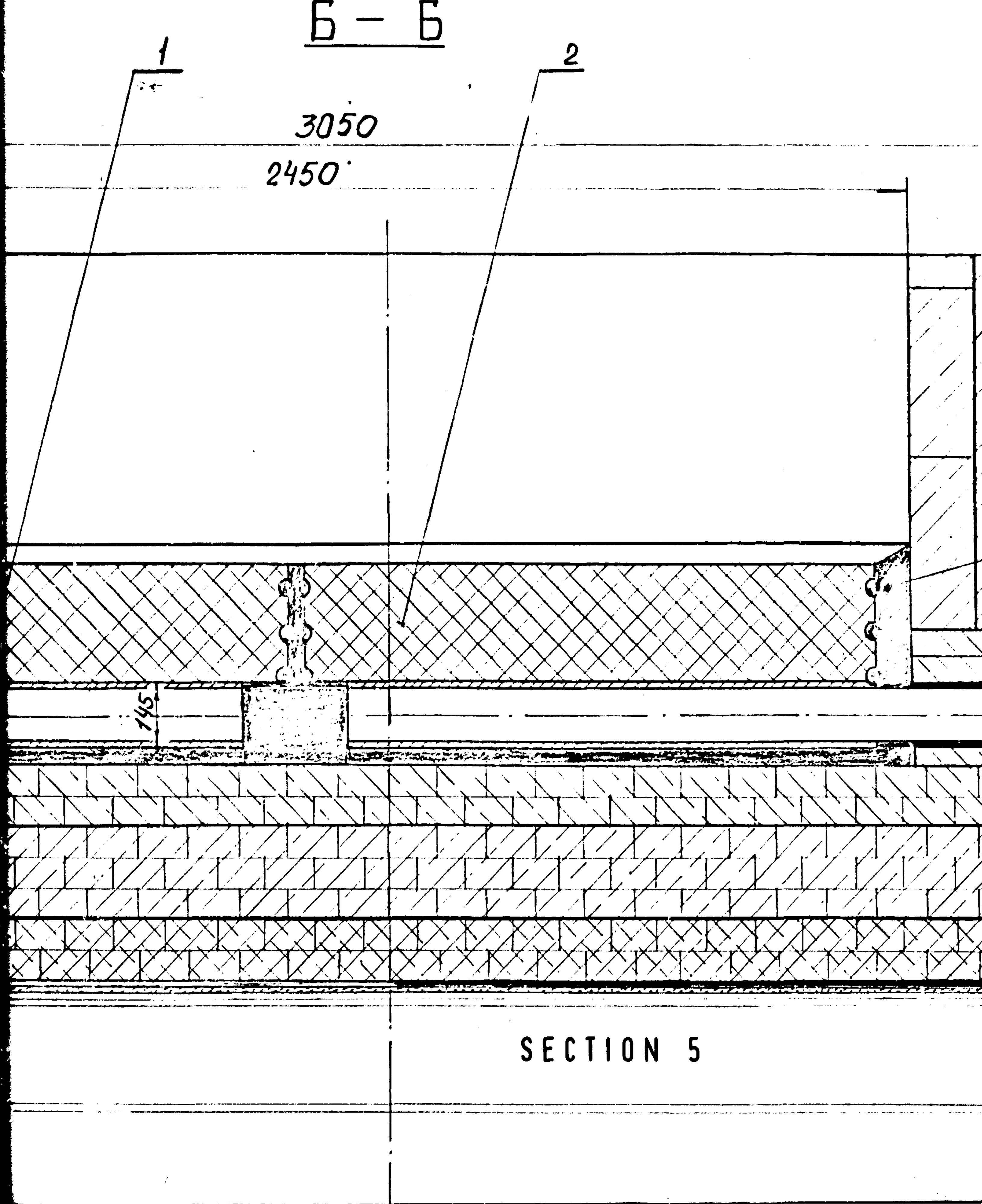
131
202
135
10
15
540
Г
5



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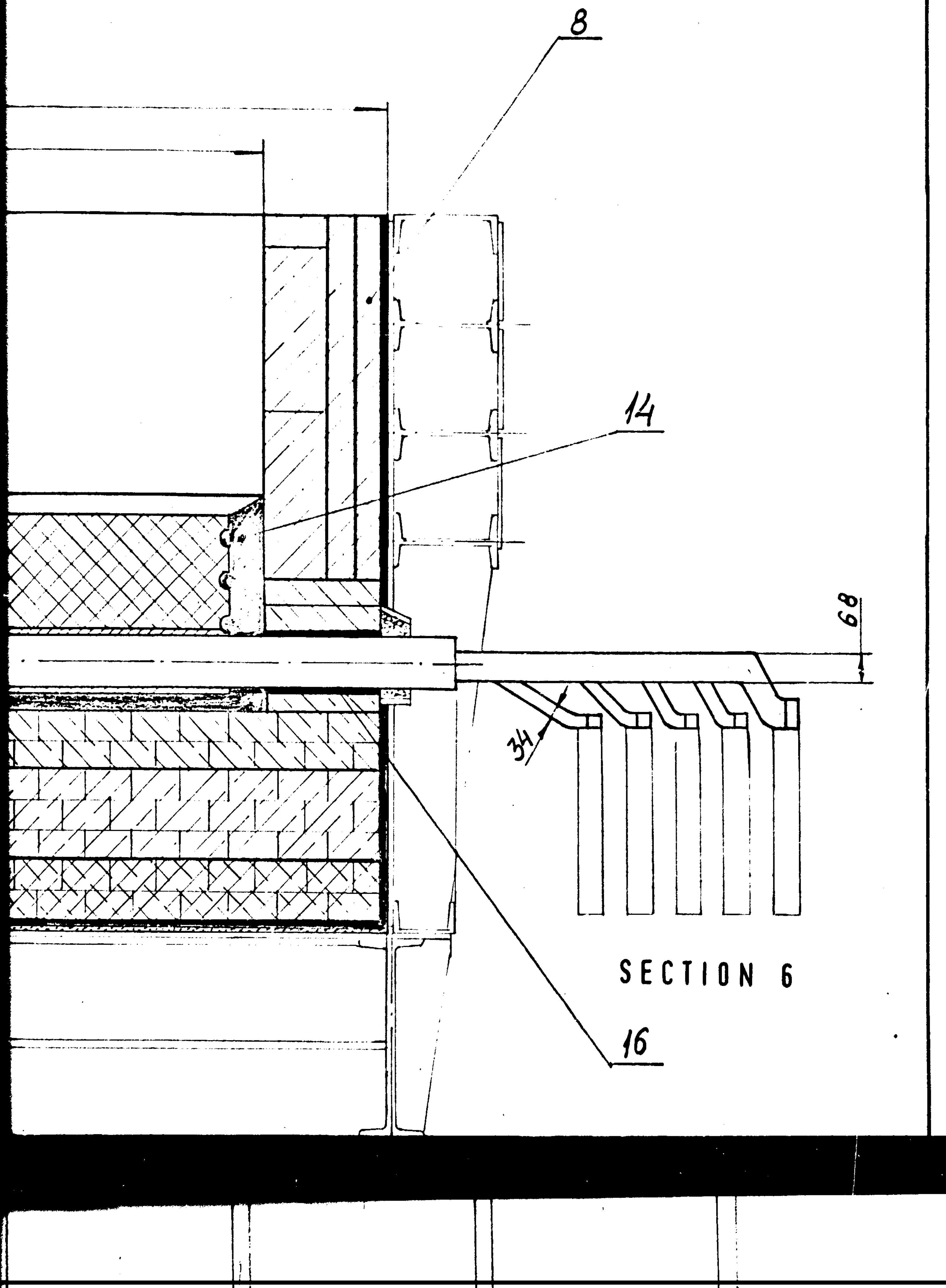

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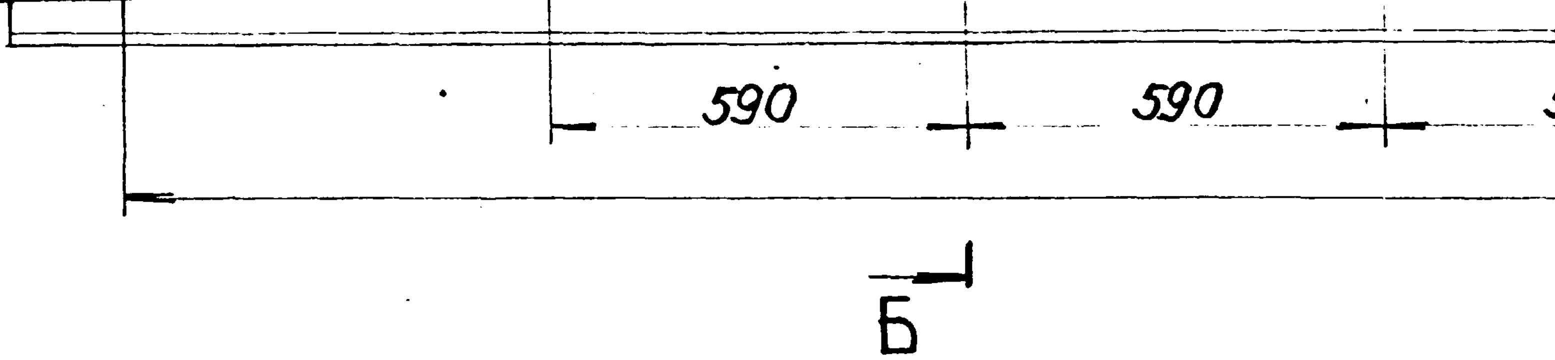
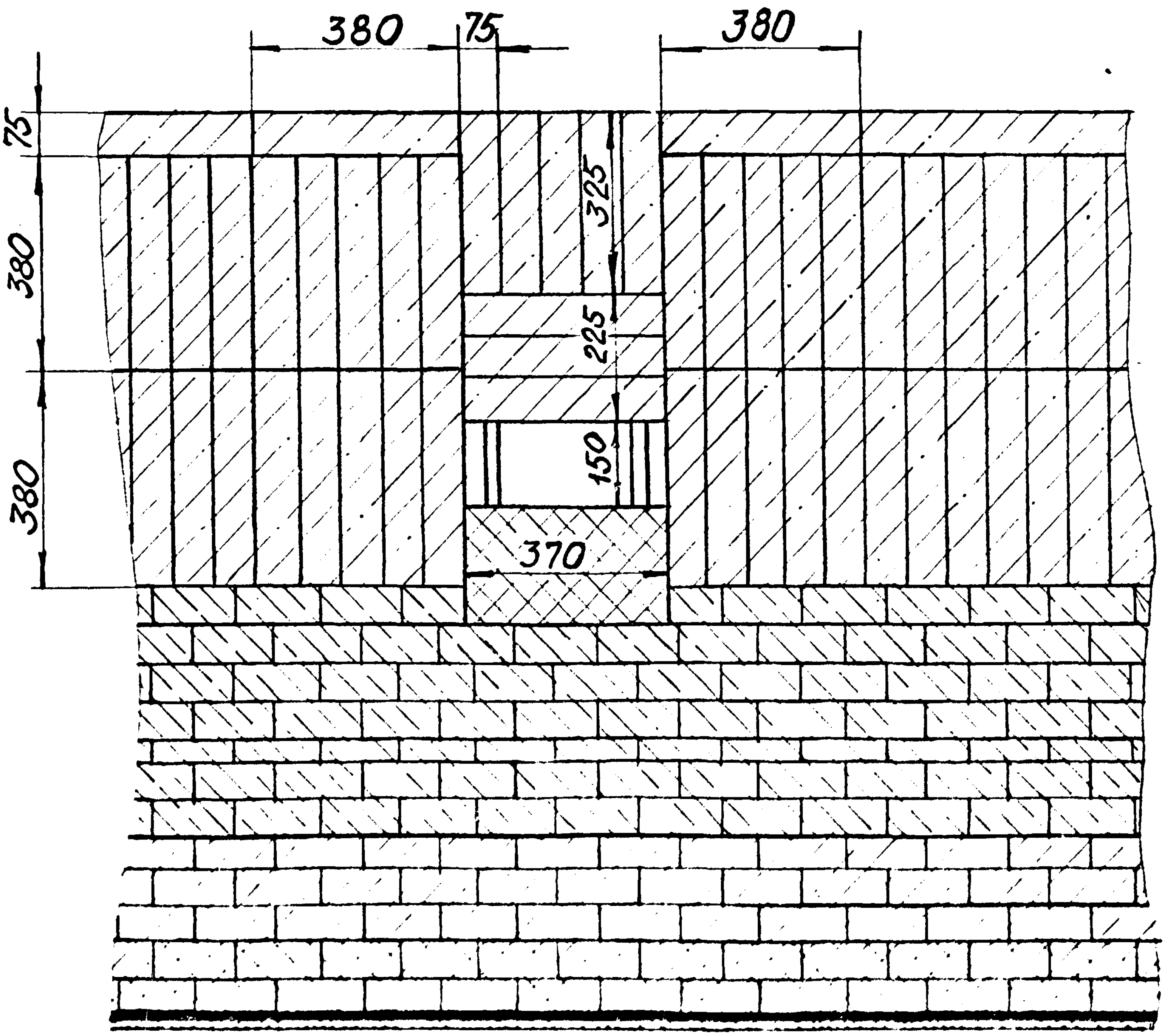
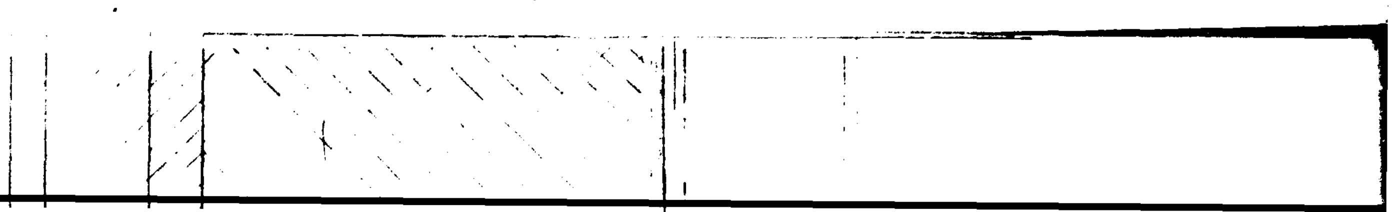
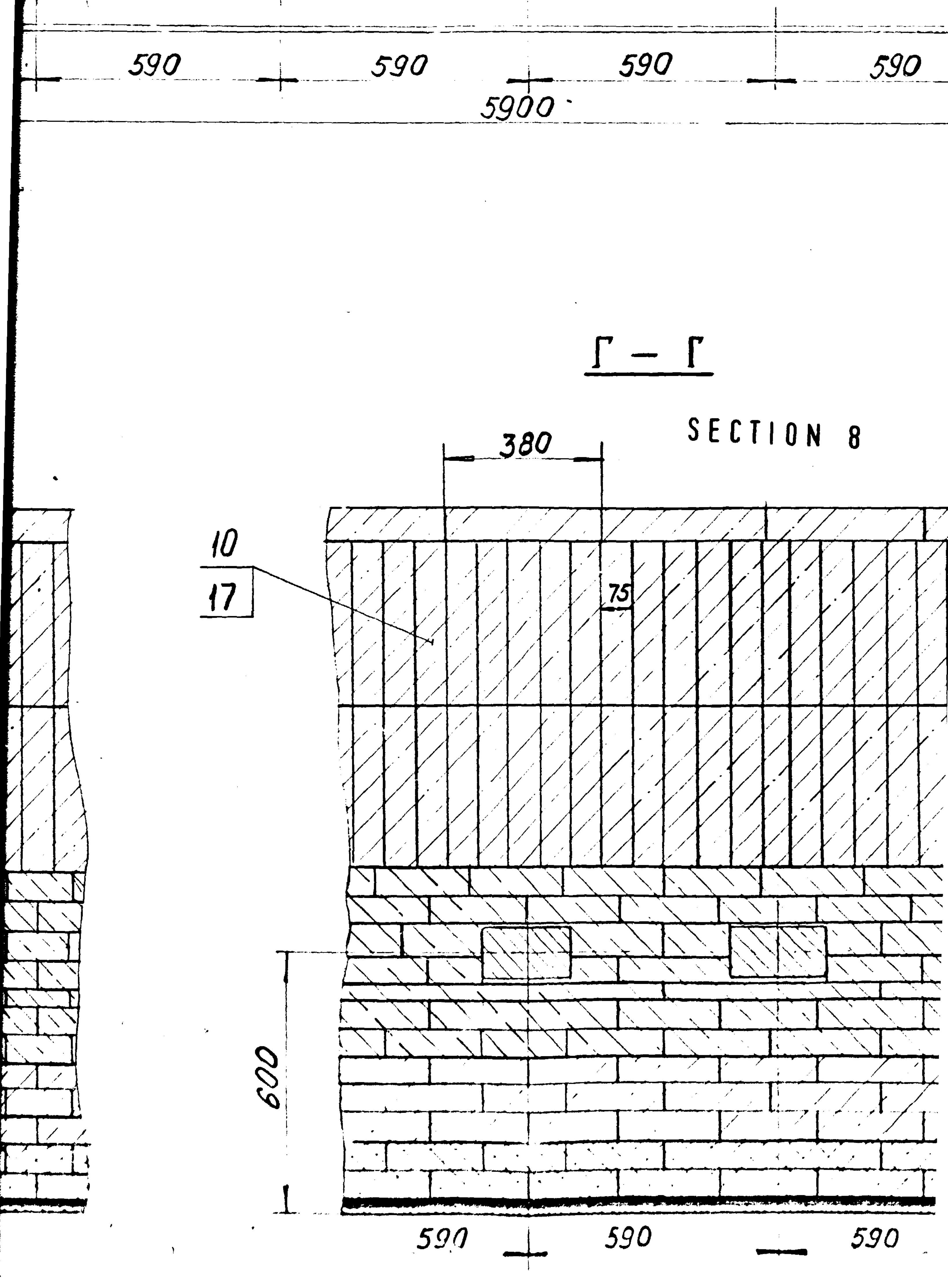


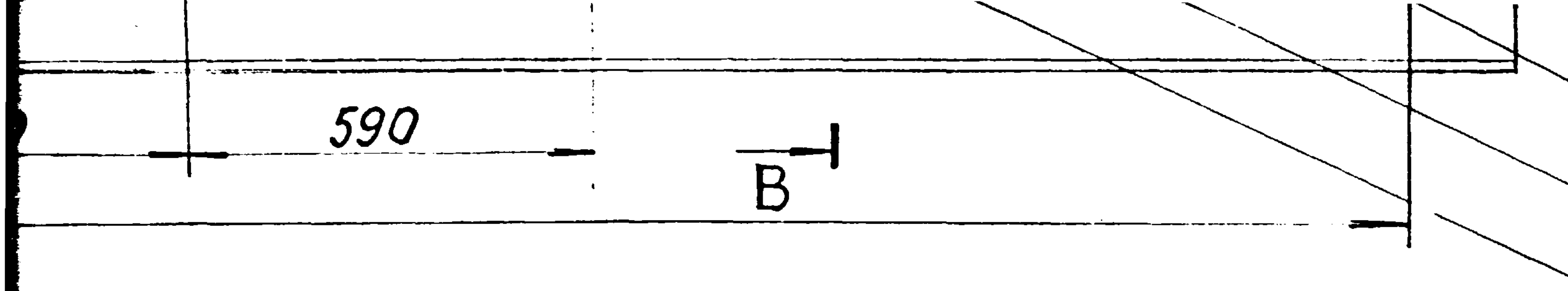
B – B

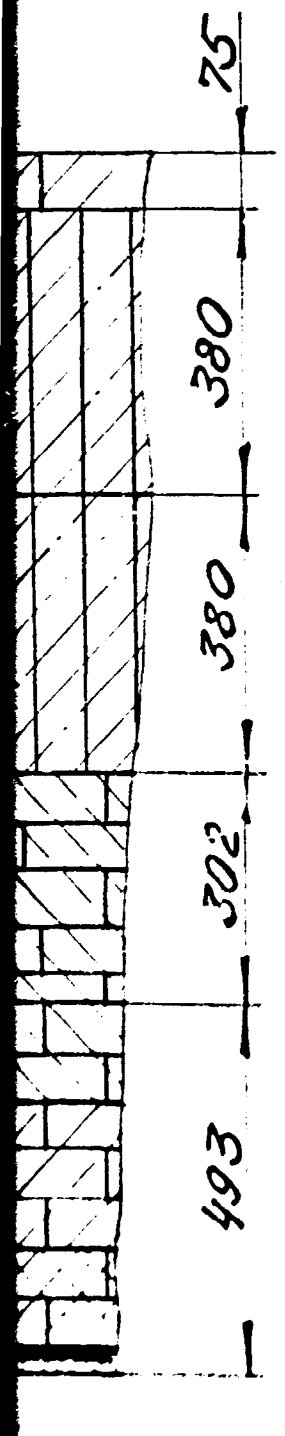
SECTION 7

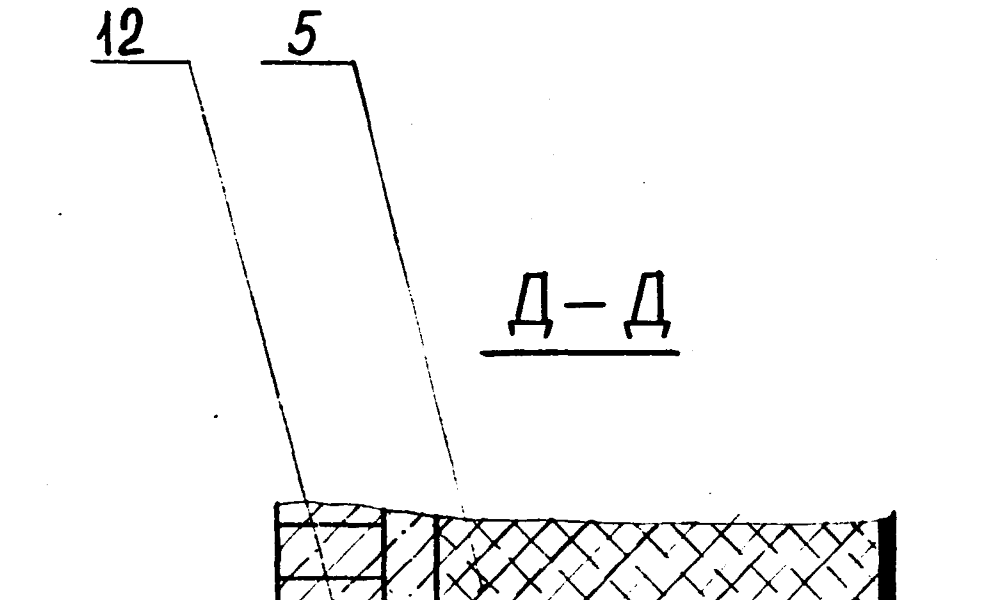





590
590
590
590
5900
Г – Г
SECTION 8
380
10
17
75
600
590
590
590







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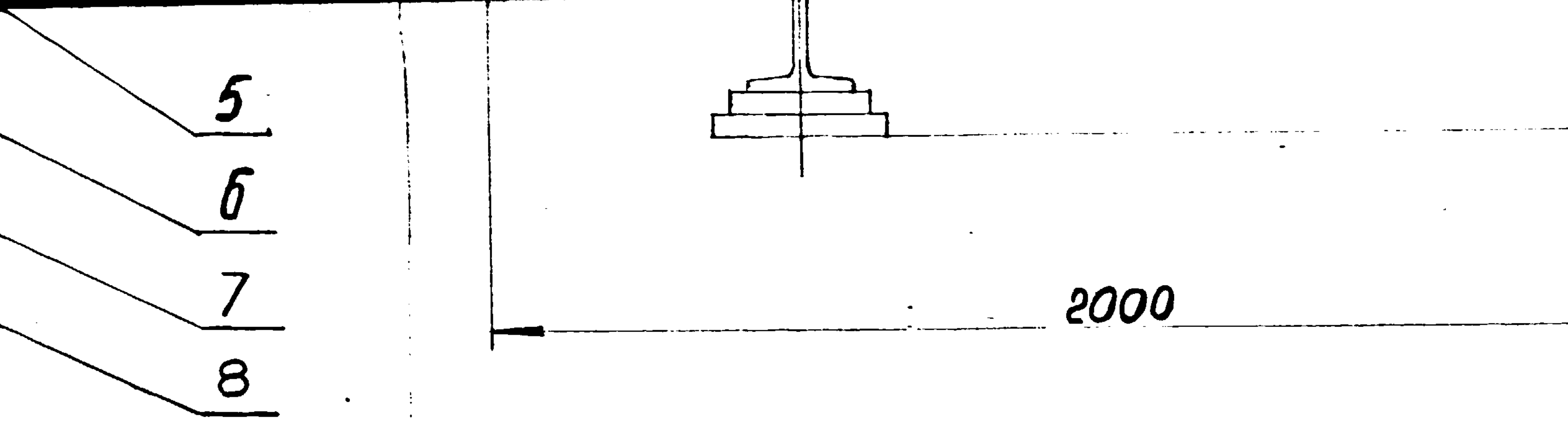
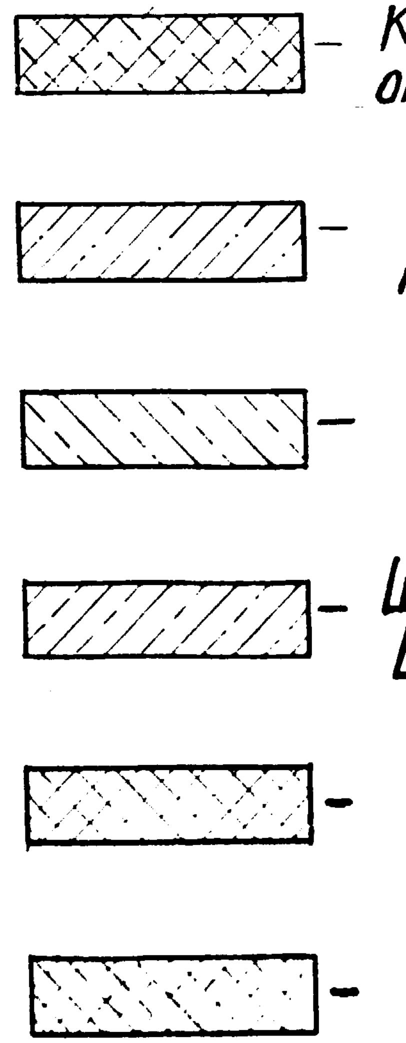


Условные обозначе

LEGEND



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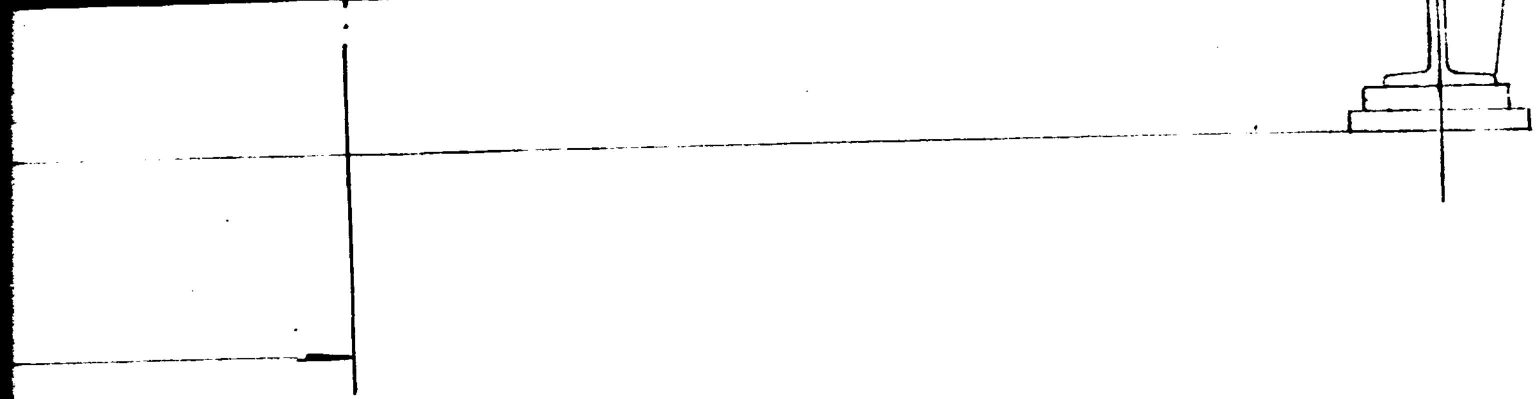


ения

Кирпич глинянный обыкновенный
ORDINARY CLAY BRICK

Магнезит
MAGNESITE

Шамот
FIRECLAY

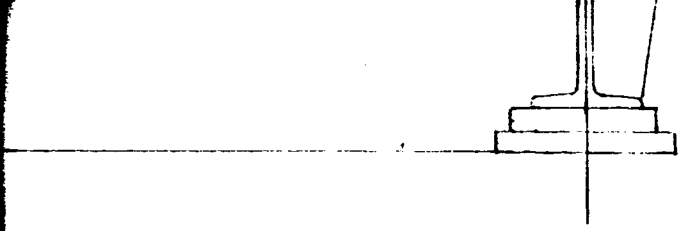
Шамот легковесный
LIGHT-WEIGHT FIRECLAY

Уголь
CARBON

Графит
GRAPHITE

Алюминиевый завод в
Эксперименталько- демон
для производства алк
ALUMINIUM SMELTER IN KORBA
EXPERIMENTAL DEMONSTRATION U
ALUMINIUM PRODUCTION

SECTION 11



ий

Алюминиевый завод в г. Корба, Индия.
Экспериментально-демонстрационная установка для производства алюминия высокой чистоты.

ALUMINIUM SMELTER IN KORBA, INDIA.

EXPERIMENTAL DEMONSTRATION UNIT FOR HIGH-PURITY ALUMINIUM PRODUCTION

SECTION 12

Данный чертеж не подлежит размножению или передаче другим организациям и лицам без согласия института ВАМИ	1335874В0			
	Футеровка	Стадия Phase	Масса Mass	Масштаб Scale
This drawing is not to be reproduced or transferred to other organizations	LINING	П	1/2500	1:10
		Лист Sheet 1		Листов Sheets 2

ННЫЙ

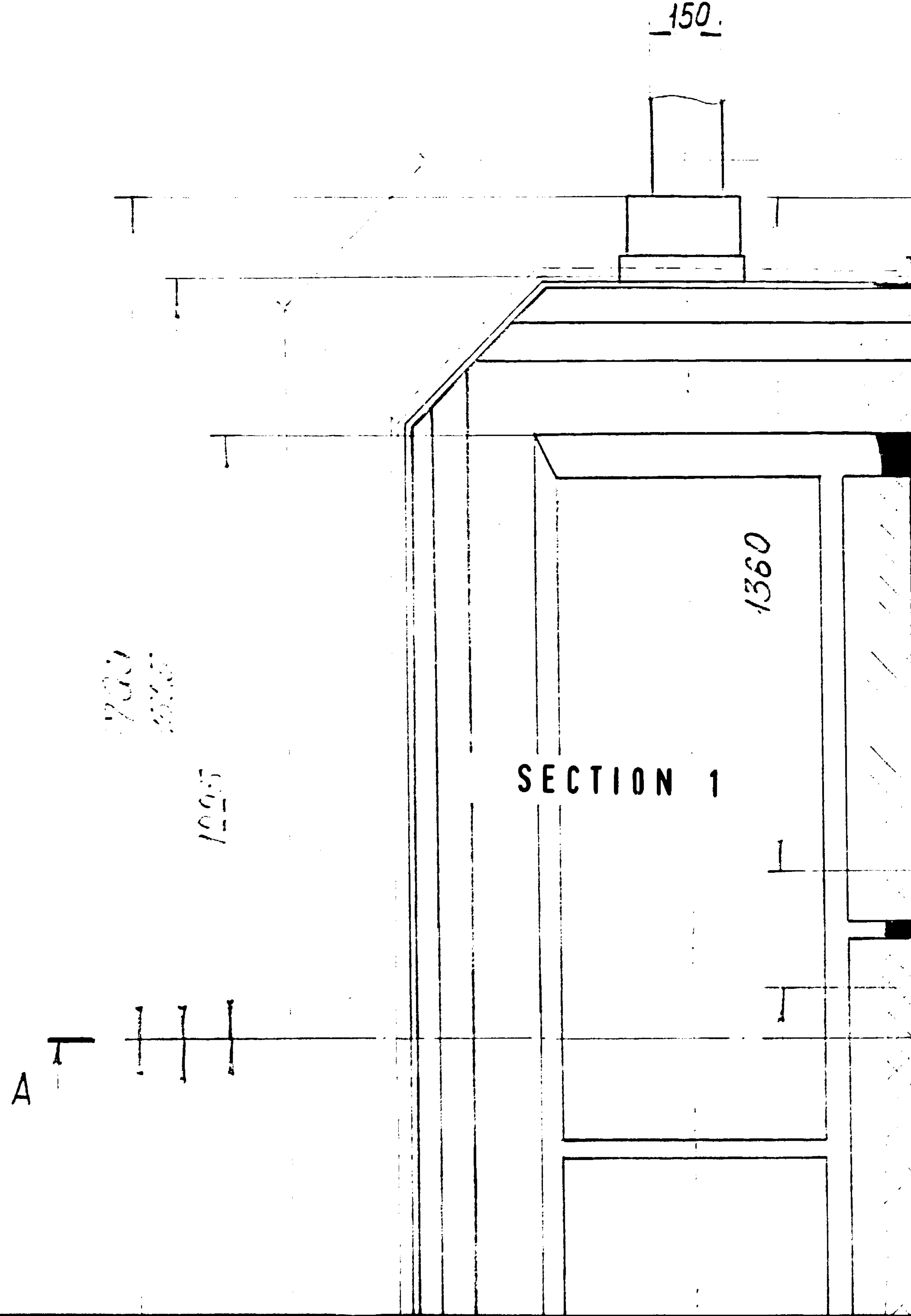
Алюминиевый завод в г. Корба, Индия.
Экспериментально-демонстрационная установка для производства алюминия высокой чистоты.

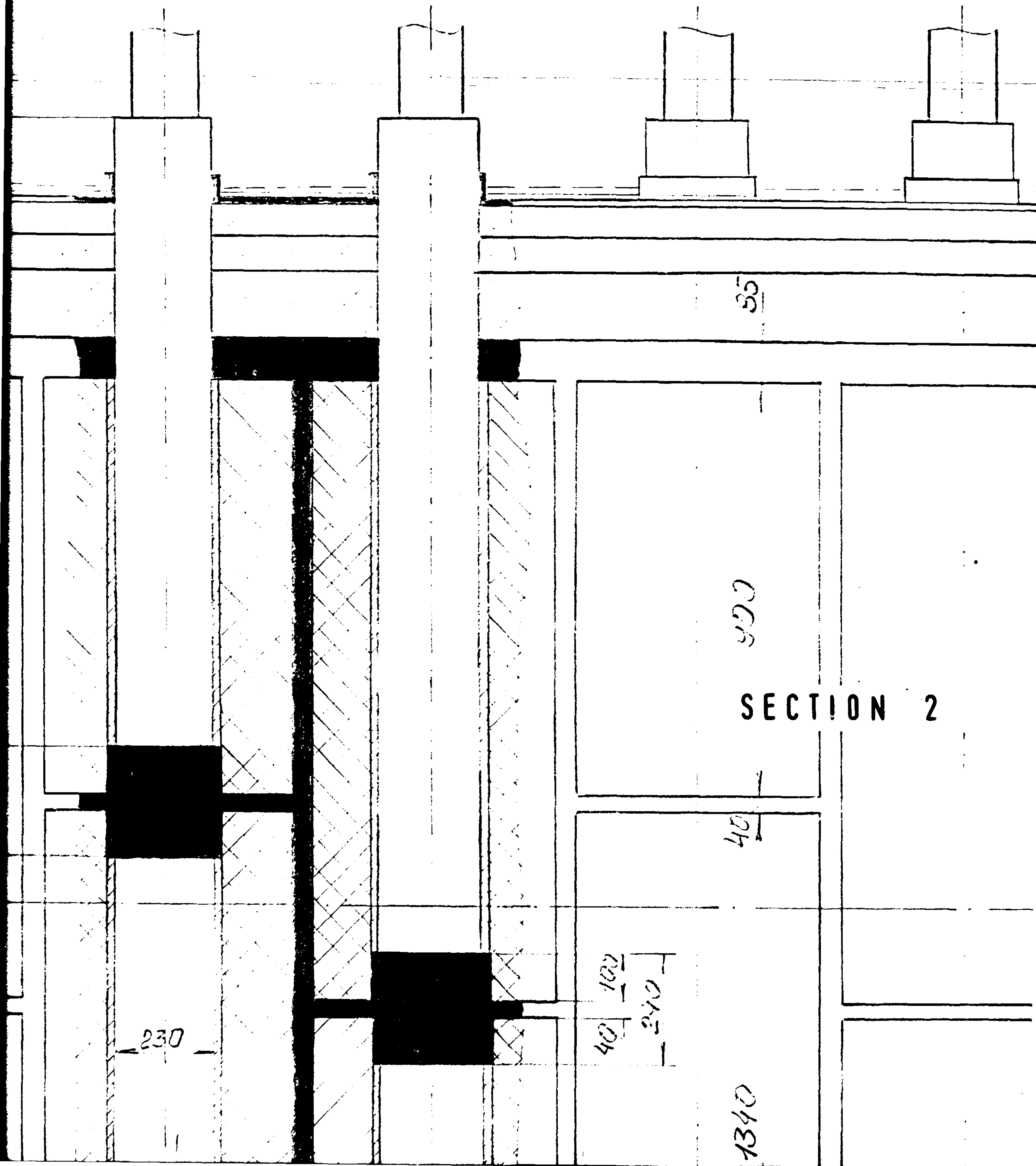
ALUMINIUM SMELTER IN KORBA, INDIA.

EXPERIMENTAL DEMONSTRATION UNIT FOR HIGH-PURITY ALUMINIUM PRODUCTION

SECTION 13

Данный чертеж не подлежит размножению или передаче другим организациям и лицам без согласия института ВАМИ	1335874ВО			
This drawing is not to be reproduced or transferred to other organizations or persons without agreement with VAMI	Футеровка LINING	Стадия Phase П	Масса Mass 1/2500	Масштаб scale 1:10
		Лист Sheet 1		Листов Sheets 2
		VAMI		


150
1360
SECTION 1
A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230
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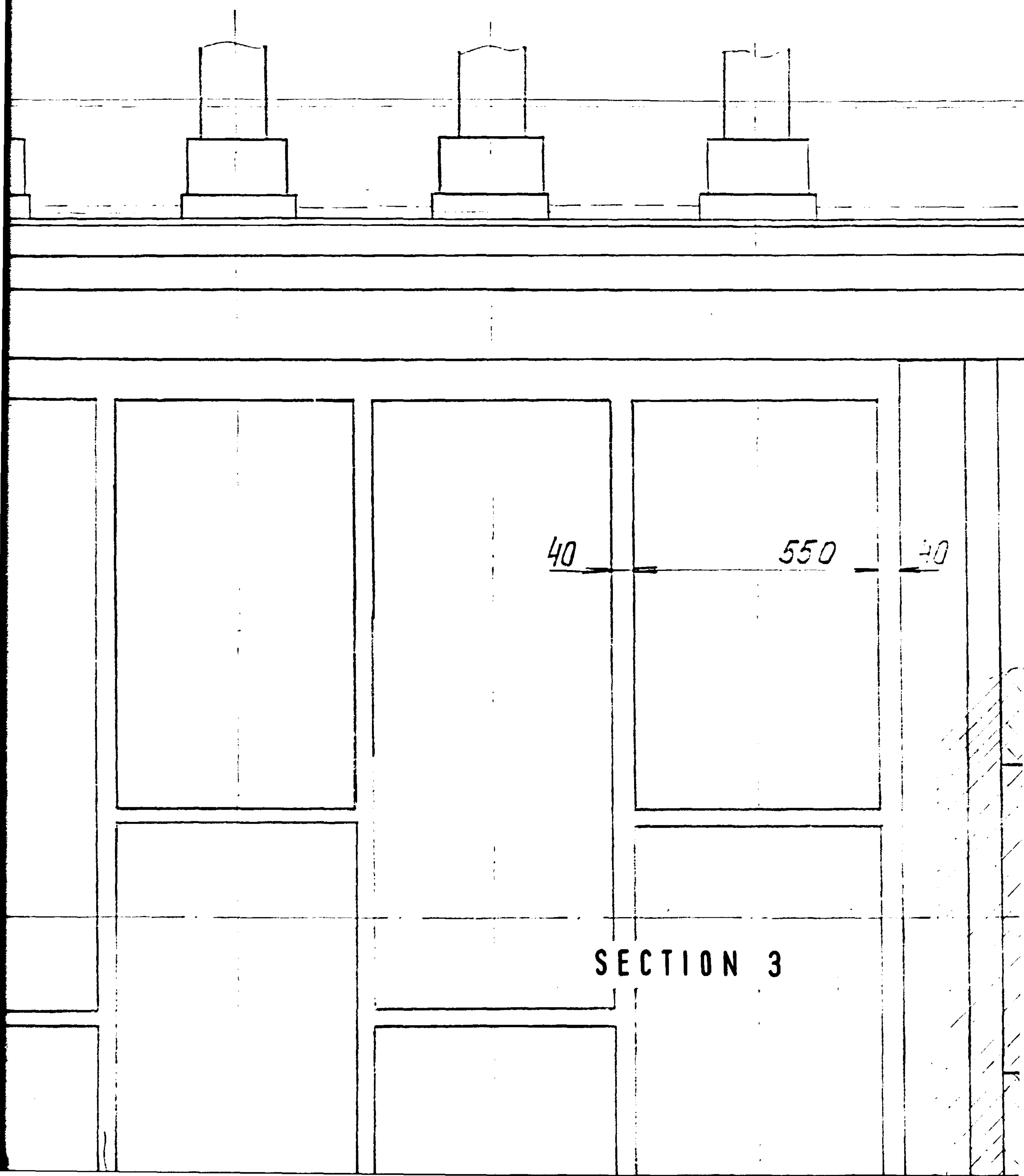

40
550
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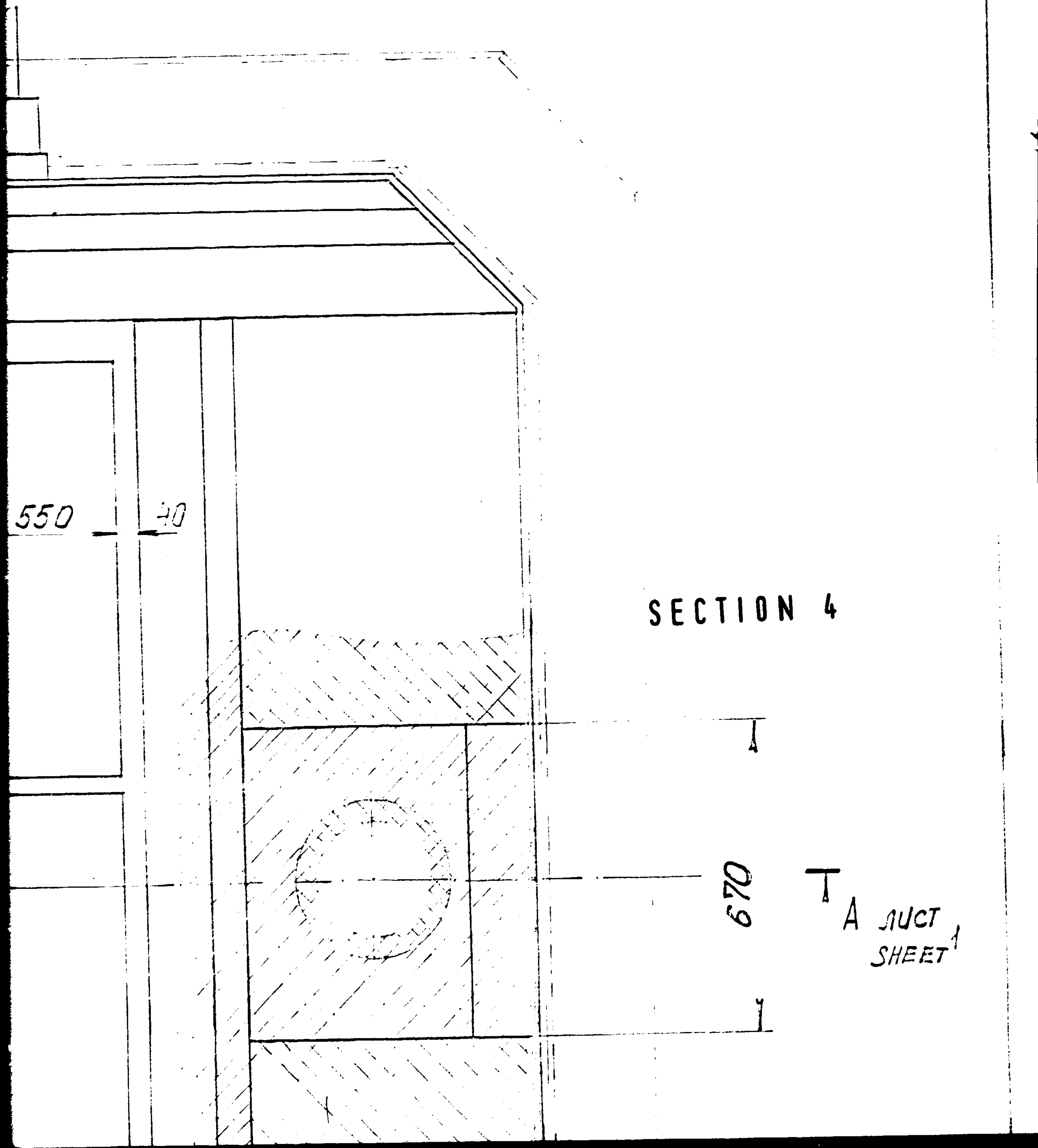
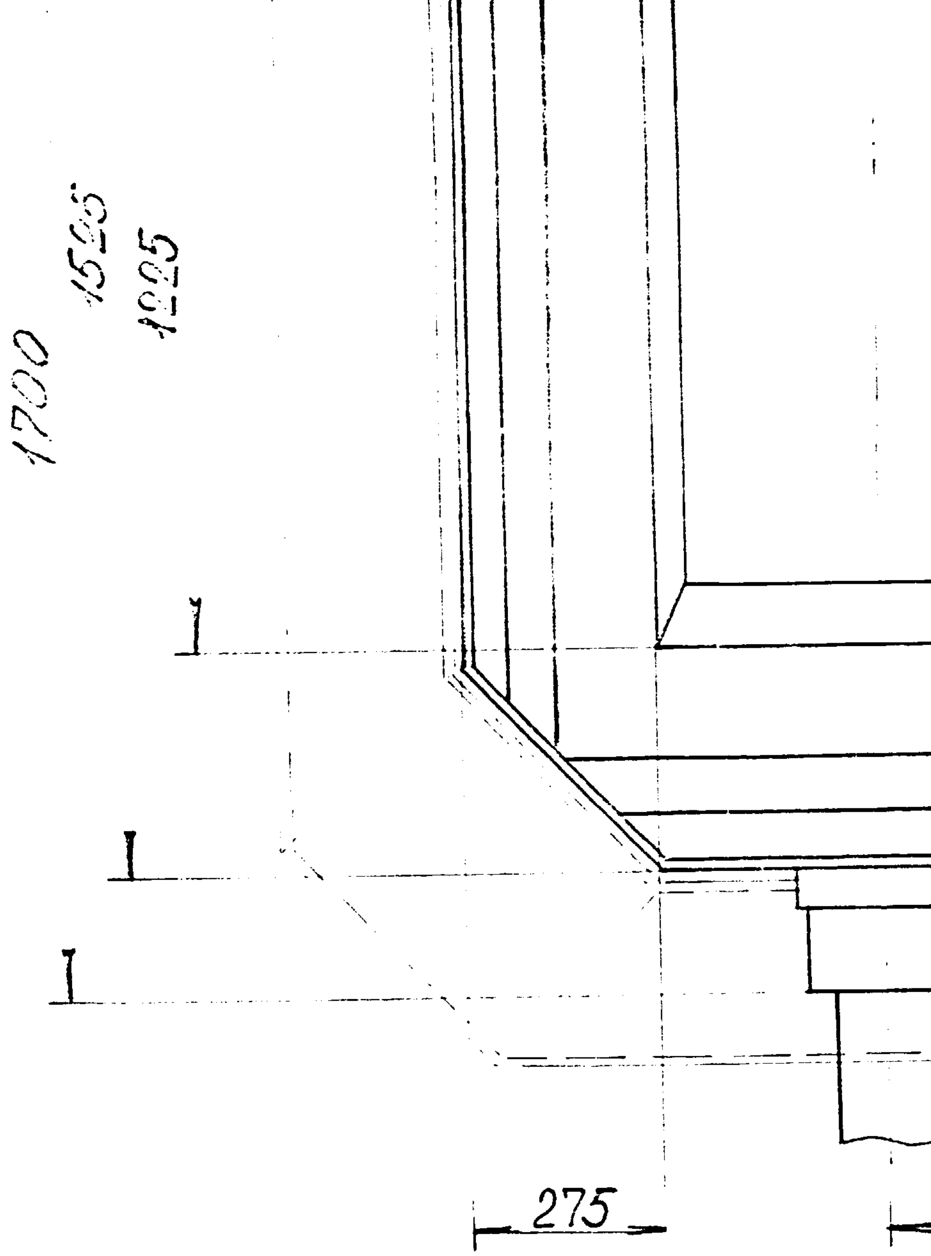
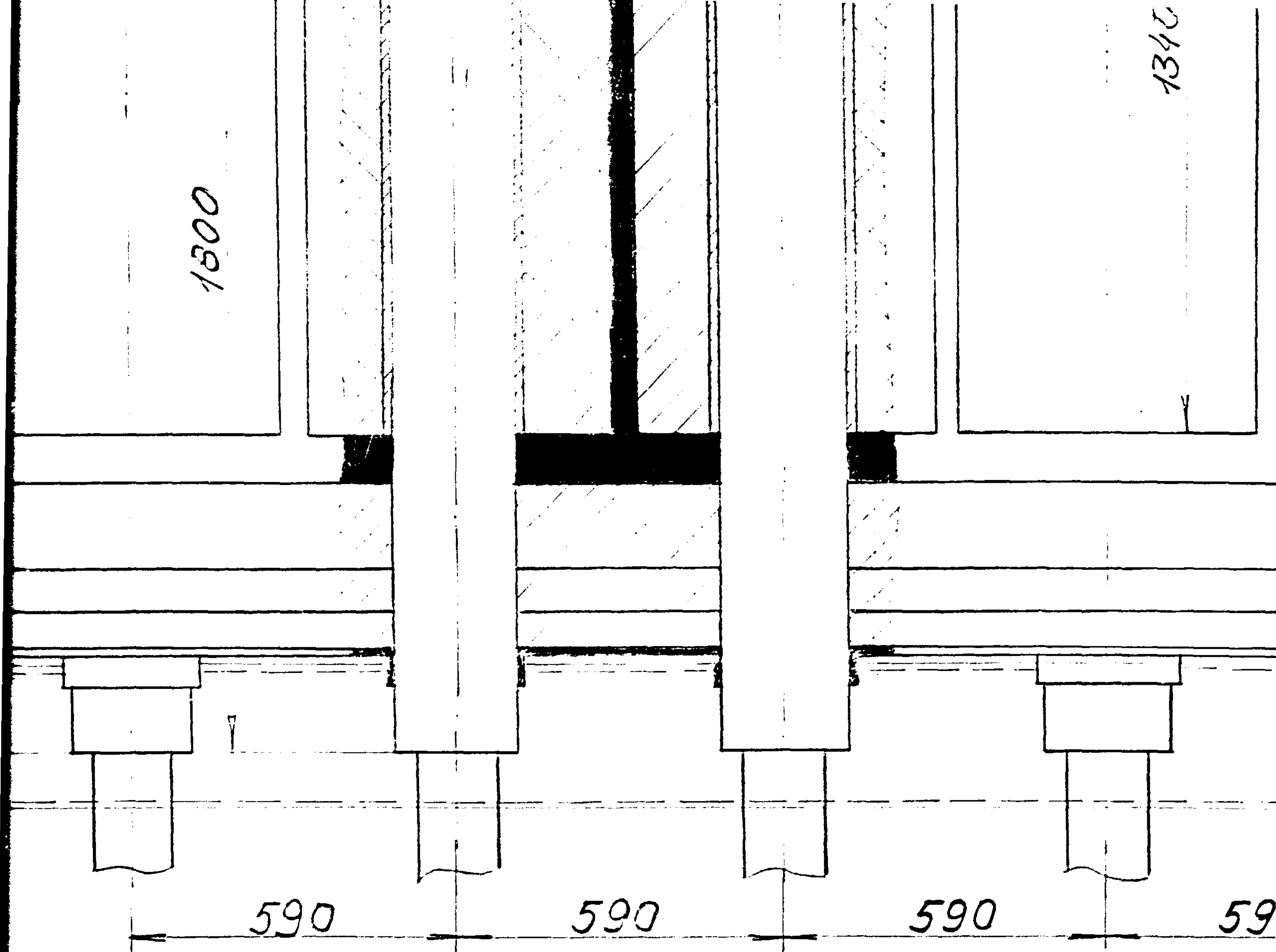
SECTION 3


550
SECTION 4
670
A
ЛИСТ
SHEET 1



Перв. примен.
1335874
Справ. №

SECTION 5



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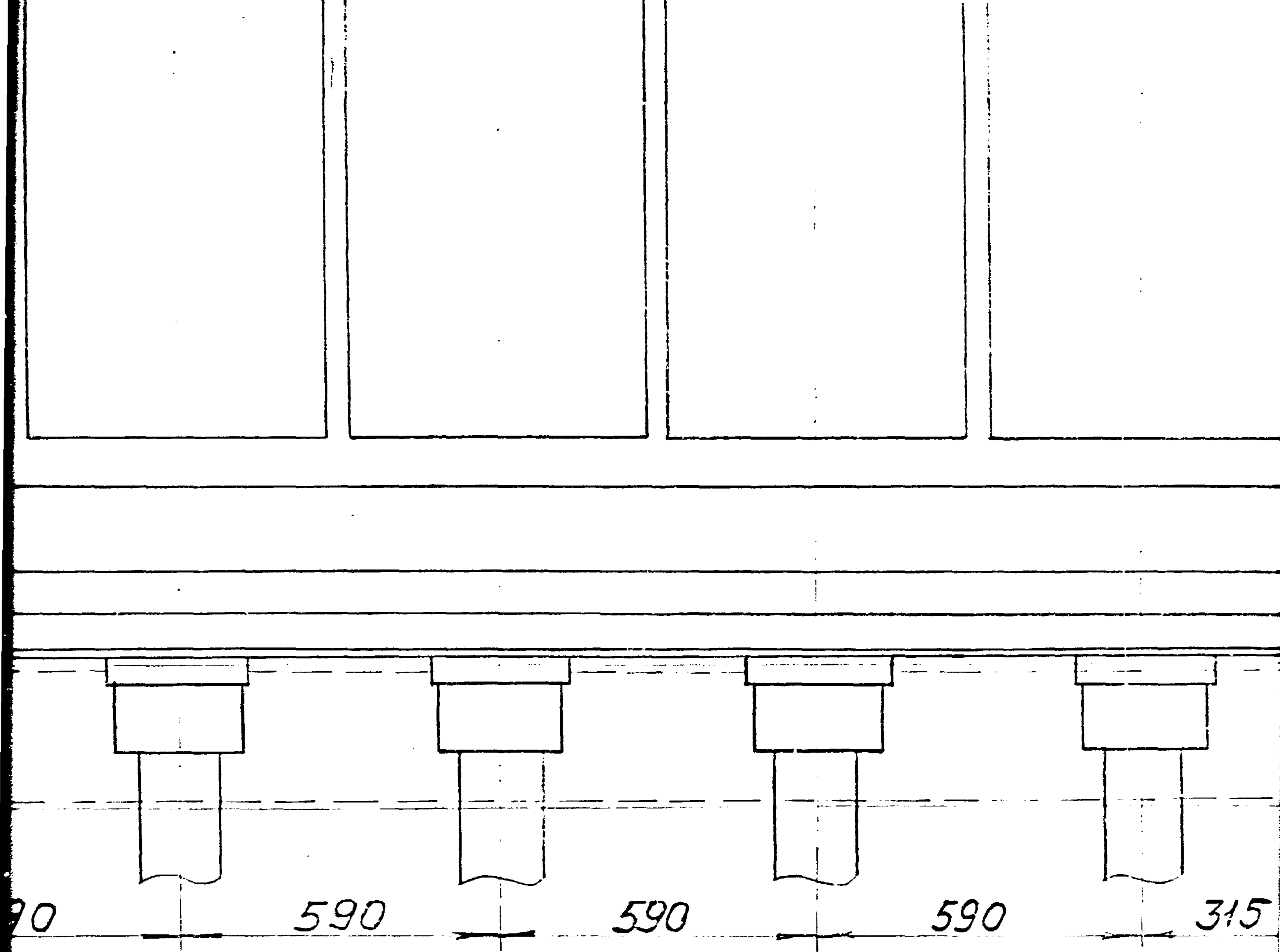

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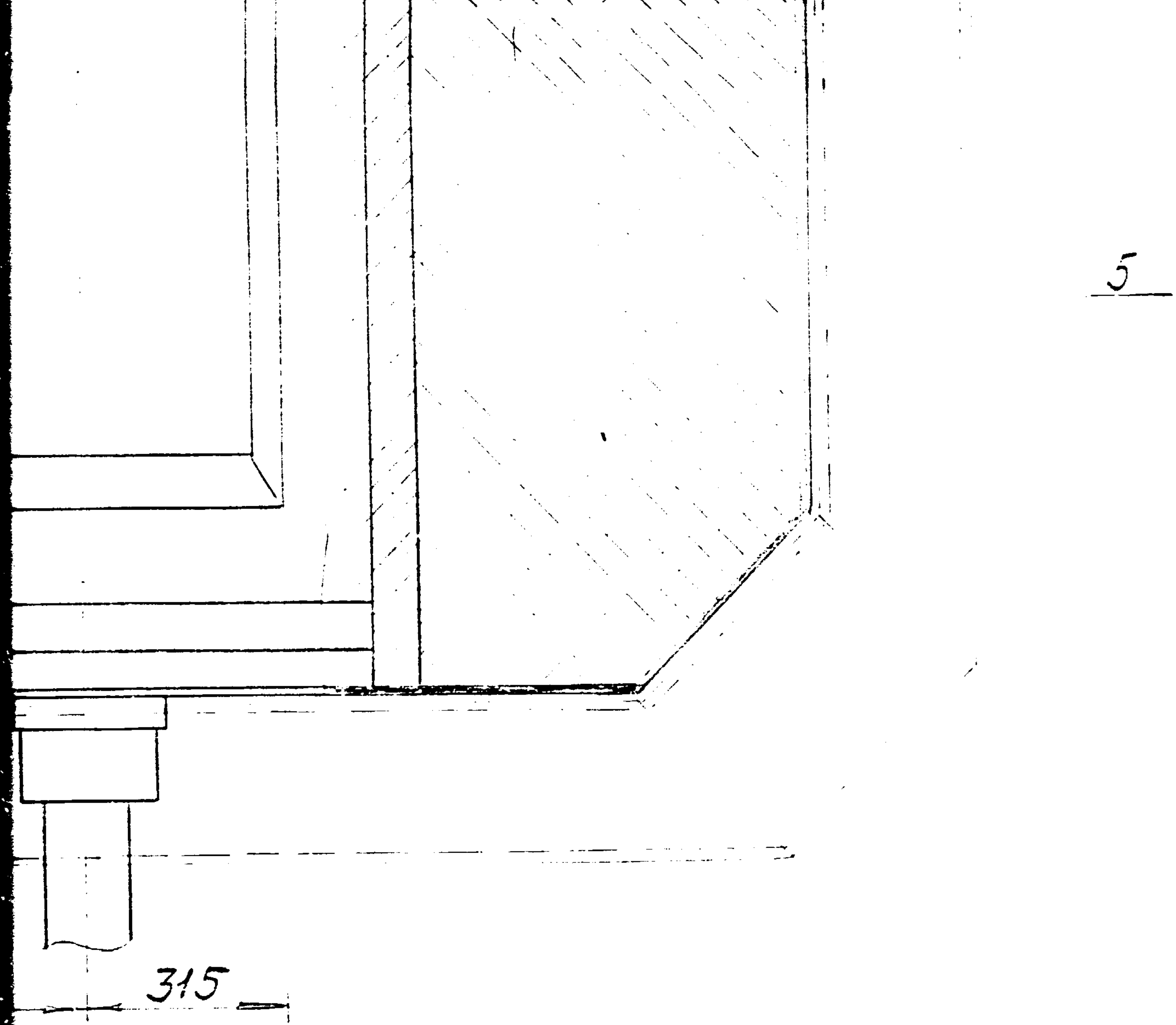

SECTION 8

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	Футеровка LINING	Стадия Phase	Масса Mass	Масштаб scale
		П	—	1:10
		Лист Sheet	Листов Sheets 2	
		VAMI Leningrad		

Формат Format	Зона Zone	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
		I	-	Штанга алюминиевая сечением Aluminium bar, Section 80 x 120	1	34 kg
				Химический состав - индийский стандарт фирмы "БАЛКО" Chemical composition as per BALCO Indian Standard N 19501		
		2	-	Ниппель-круг Ø 180 Stub-rod	1	56 kg
				Сталь IS:226 Steel		
		3	-	Серьга Shackle	1	1,2 kg
				Круг Ø 20 Rod		
				Сталь IS:226 Steel		
		4	-	Накладка Strap	1	6,6 kg

Сборочных единиц Assembly units		Деталей Parts		Вновь разработанных Newly designed	0,375
				Примененных Applied	
				Всего листов Totally sheets A1	

Алюминиевый завод в г.Корба, Индия
Экспериментально-демонстрационная установка для производства алюминия высокой чистоты
Aluminium smelter in Korba, India
Experimental demonstration unit for high purity aluminium production

I335875

Катод
Cathode

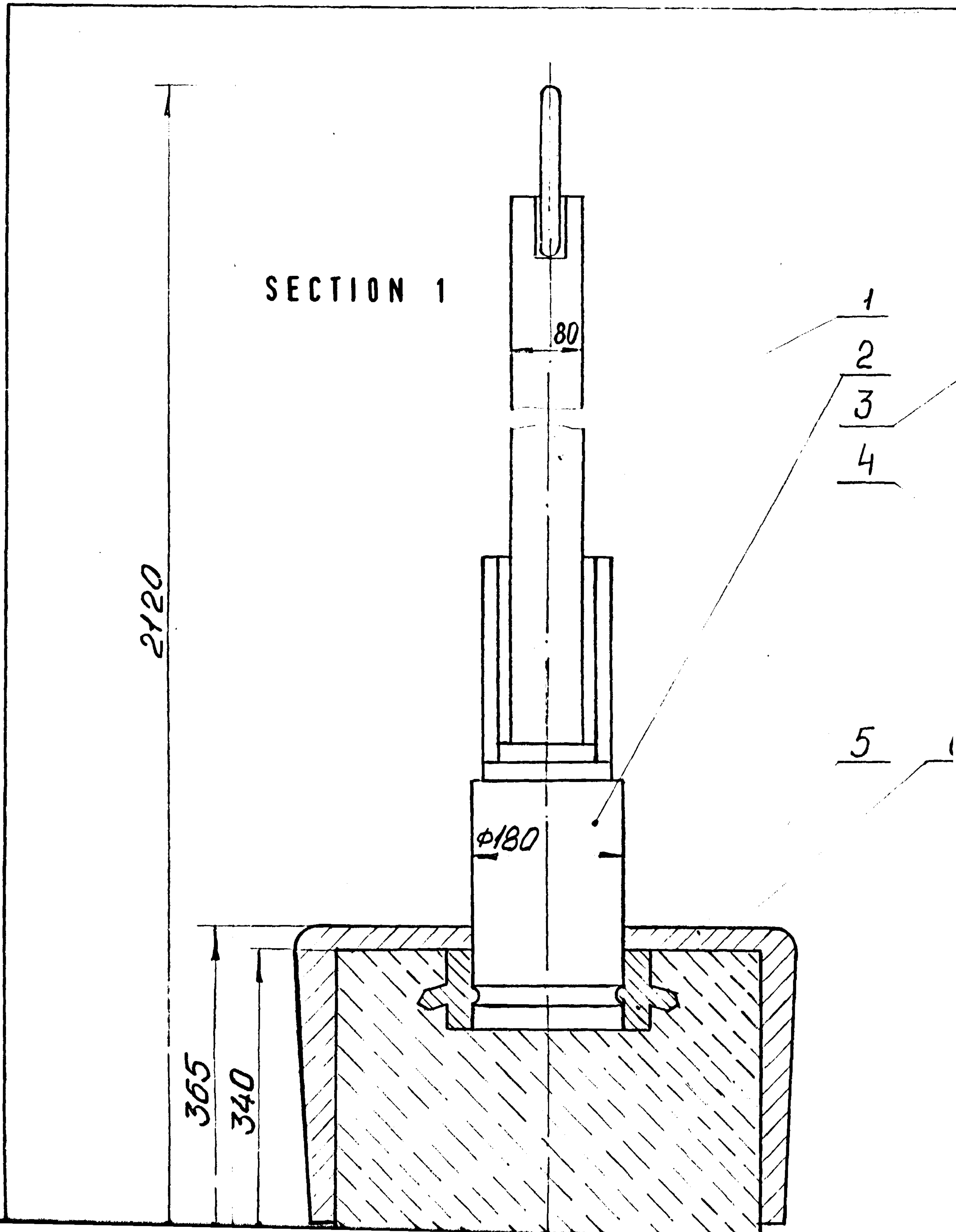
Стадия Phase	Лист Sheet	Листов Sheets
П	I	3

VAMI
LENINGRAD

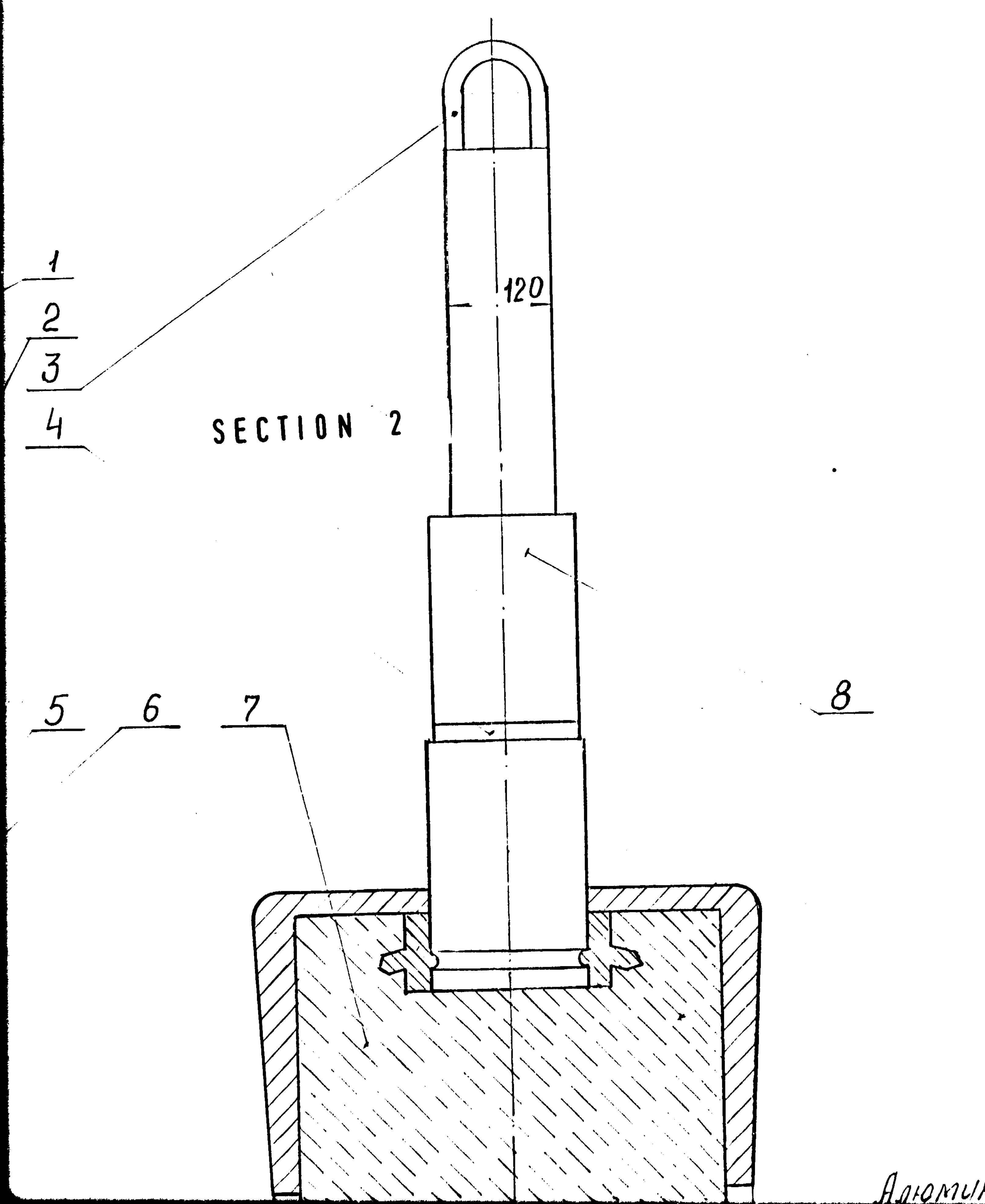
I335875

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				Лист δ=18		
				Sheet		
				Сталь IS:226		
				Steel		
		5	–	Рубашка защитная	–	46 kg
				Protective jacket		
				Алюминий высокой чистоты		
				High purity aluminium		
		6	–	Заливка	–	7,7 kg
				Casting		
				Чугун литейный		
				Cast iron		
				Химический состав:		
				Chemical composition		
				Si 3,2...3,6%; Mn ≤ 0.3%		
				P ≤ 0.12%; S ≤ 0.03%		
		7	–	Блок катодный	1	106 kg
				Cathode block		
				Графитированный электрод		
				Graphitized electrode		
				Ø 500		
				Удельное электрическое		
				сопротивление, не более		
				Electrical resistivity		
				9,5 мк Ом.м (mk.ohm.m) max		
				Предел механической		
				прочности:		
				Mechanical strength:		

Формат Size	Зона Zona	Поз. Position	Обозначение Designation	Наименование Name	Кол. Q-ty	Примечание Remark
				При изгибе, не менее: Bending strength		
				85 kg/cm², min.		
				При разрыве, не менее Breaking strength		
				75 kg/cm², min.		
		8	Поставка СССР USSR supply	Пластина биметаллическая Bimetallic plate	2	11,7kg
				Алюминий Aluminium		2,8 kg
				Сталь Steel		8,9 kg



SECTION 1
80
Φ180
2120
365
340
1
2
3
4
5



1
2
3
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SECTION 2
120
5
6
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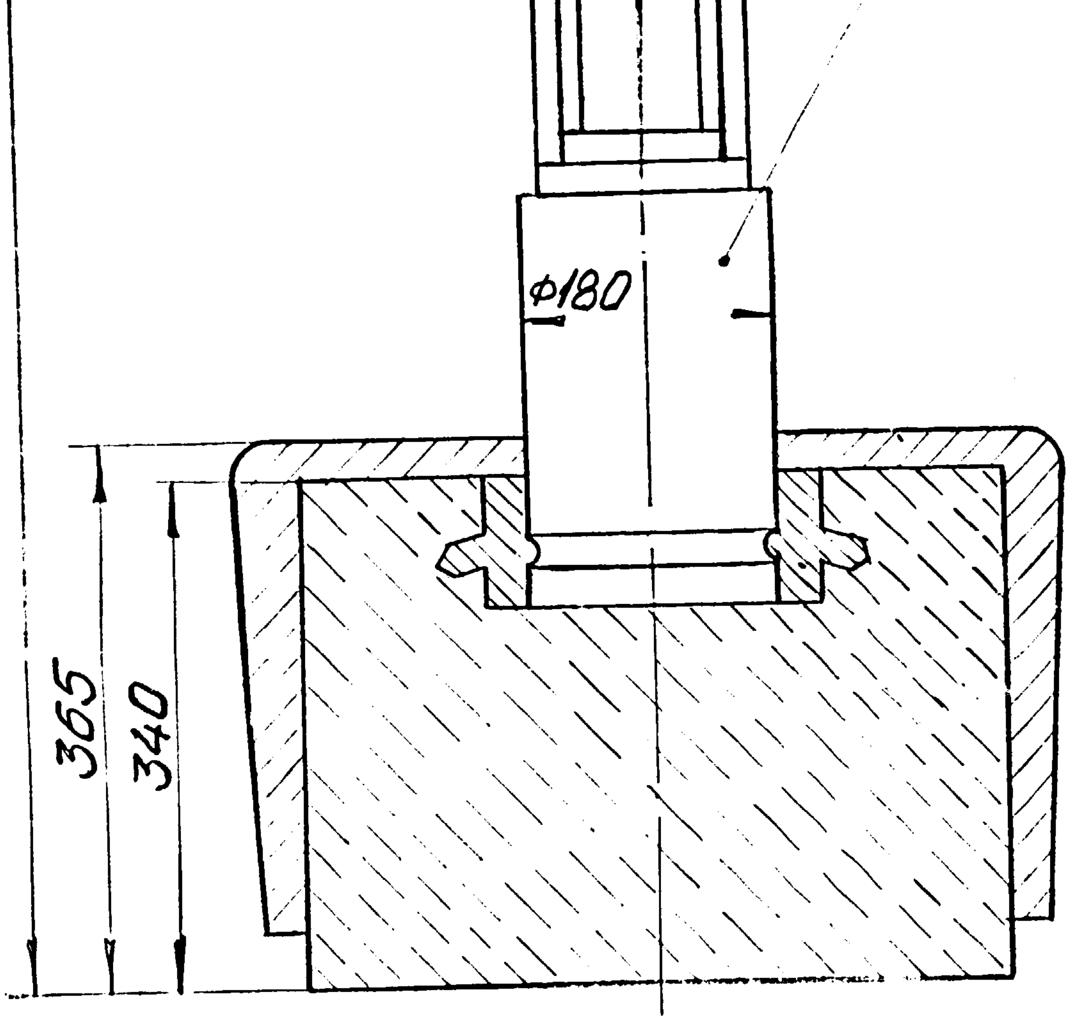
8



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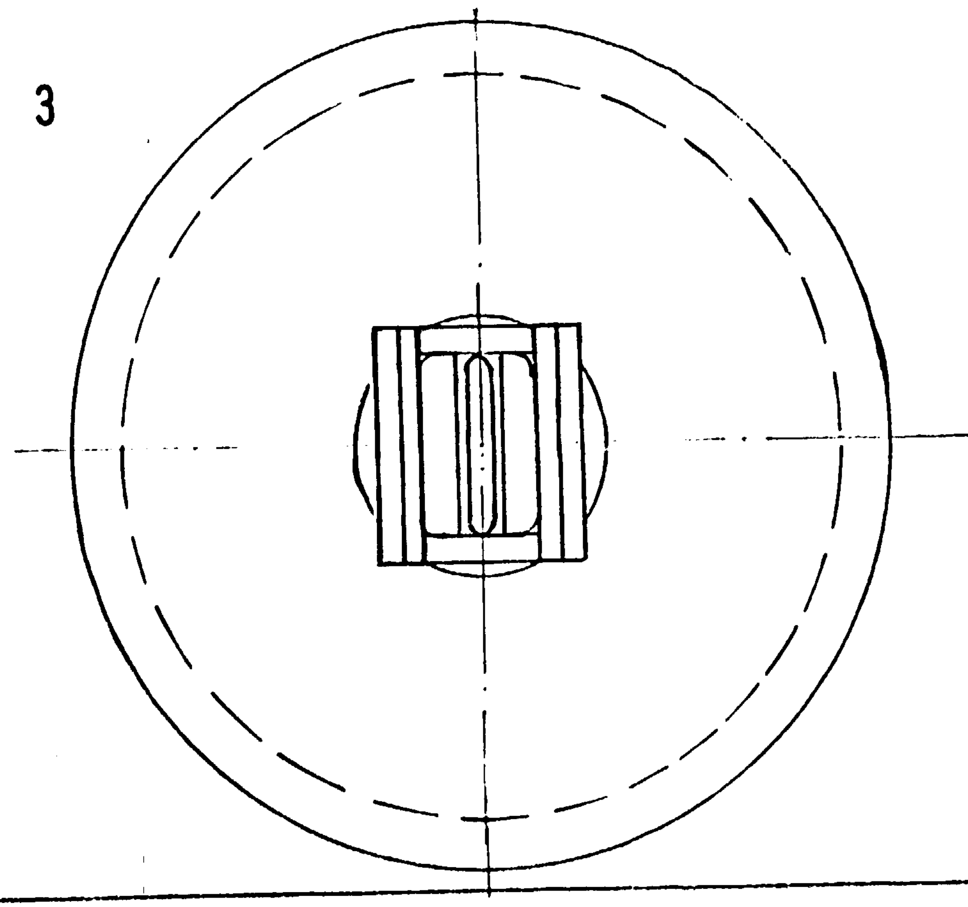

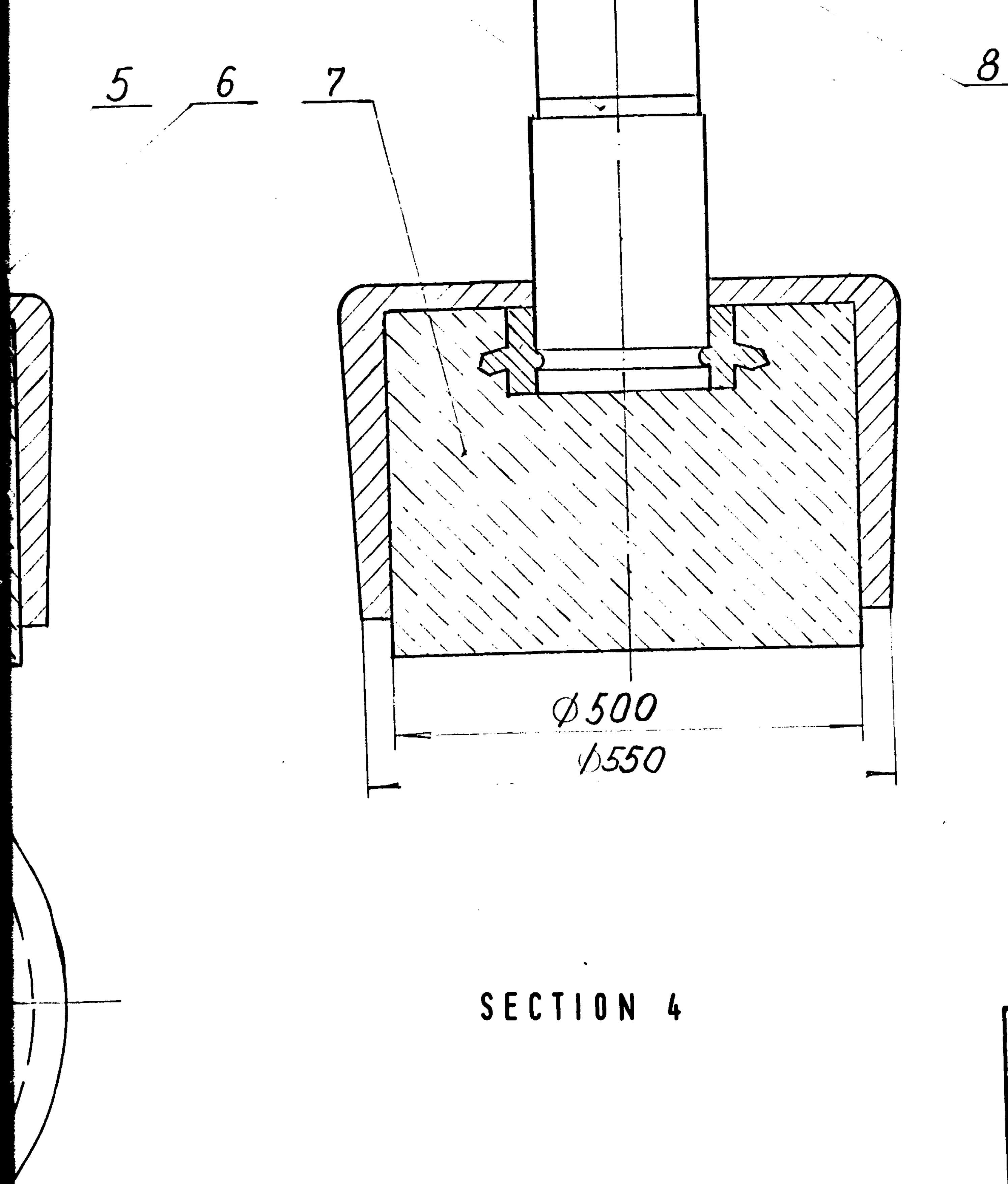

SECTION 4

Алюм
Экспе
для
ALUMI
EXPERIN
ALUMIN

Алюминиевый завод в г. Корба. Индия.
Экспериментально-демонстрационная установка
для производства алюминия высокой чистоты.

ALUMINIUM SMELTER IN KORBA, INDIA.
EXPERIMENTAL DEMONSTRATION UNIT FOR HIGH-PURITY
ALUMINIUM PRODUCTION

SECTION 5

1335875В0

Катод
CATHODE

Стадия Phase	Масса Mass	Масштаб scale
П	270	1:5

Лист Sheet	Листов Sheets
	1

VAMI
Leningrad

Формат A2 Size A2

Contract No 85/2
UNIDO

PROJECT REPORT FOR ESTABLISHMENT OF SUPER PURITY ALUMINIUM PRODUCTION IN INDIA

Final report
No DP IND 84 007

Volume III

Specifications of equipment

VAMI   V/O TSVETMETPROMEXPORT

LENINGRAD
1986

PROJECT REPORT CONTENTS

Volume I	General Explanatory Note
Volume II, Book 1	Drawings
Volume II, Book 2	Basic Engineering Design of Main Technological Unit (Electrolyser)
Volume III	Specifications of Equipment

C O N T E N T S

	Page
1. Introduction	1
2. Equipment and materials specifications for experimental-demonstration unit (EDU)	3
3. Equipment and materials Specifications for 70 kA aluminium refining cell (per one cell)	9
4. Equipment and materials Specifications for 70 kA cell for electrolyte preparation and cathode impregnation (per one cell)	15
5. Specification on electric equipment, materials, cables and other articles	22
6. Specification on materials	30

1. INTRODUCTION

The Equipment and Materials Specifications for the Feasibility Study of construction of the Experimental-Demonstration Unit (EDU) for production of high-purity aluminium (HPA) have been prepared with reference to the siting at the BALCO's Korba Aluminium Smelter (India).

The siting of the EDU at this smelter is considered in the Feasibility Study in two alternatives of arrangement of the HPA cell process section:

- Alternative I - the HPA cells are arranged in the cell-room-75 in place of three aluminium reduction cells to be dismantled:
- Alternative II - the HPA cells are arranged in the extended part of the cell-room-75.

Since the both alternatives differ but little, the difference in weights of the equipment and materials, if any, is in the form of a fraction with a top figure referring to Alternative I and a bottom one - to Alternative II.

The overall requirements for the equipment and materials in the summary table below are given with breakdown by the sources of supply.

SUMMARY TABLE

of Equipment and Materials Requirements for EDU for HPA Production

Item		Supply quantities, t		Remarks
		Alternative I	Alternative II	
1	Equipment:			
	Soviet	0.03	0.03	
	Indian	115.07	117.97	
	Total of equipment	115.10	118.0	
2	Materials:			
	Soviet	0.80	0.80	
	Indian	183.0	188.4	
	Total of materials	183.8	189.2	
	Grand total of equipment and materials			
	Soviet	0.83	0.83	
	Indian	298.07	306.4	

For convenient use of the Specifications in this book please bear in mind:

- the equipment and materials without reference to the supply source will be supplied from India;
- the equipment and materials to be imported from the USSR will be marked as such.

2. EQUIPMENT AND MATERIALS SPECIFICATIONS FOR EXPERIMENTAL-DEMONSTRATION UNIT

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	total	Whom to be supplied by
		EXPERIMENTAL-DEMONSTRATION UNIT						
		I. PROCESS EQUIPMENT						
1		70-kA refining cell		pcs	2			
2		70-kA electrolyte preparation and cathode impregnation cell		pcs	1			
3		Aluminium vacuum crucible, lined, capacity 3 t		pcs	3	3930	11940	
		including:						
		- steel				2775	8325	
		- lining for crucible, including:			3	1205	3615	
		a) asbestos board 10 mm thick				35	255	
		b) brick No.3, ШБ, grade 1				1120	3360	
4		Unit for pouring aluminium into refining cell compartment, complete with hydraulic tipping drive, capacity 1200 t including:		pcs	2	2170	4340	
		- electric motor, N = 1 kW 1500 RPM		pcs	2	22	44	
		- asbestos-cement board, S20				4.18	8.6	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg		Whom to be supplied by
						of one piece	total	
		- asbestine				30	60	
		- light-weight fire clay ШЛ-0.9, brick No.8				395	790	
		- fire clay, ШБ grade 1, brick No.6				310	620	
		- chrysotile asbestos, GOST 12871-67				65	130	
		- plastics				0.014	0.03	
		- felt				0.018	0.04	
		- rubberised asbestos				0.45	0.9	
		- oilproof rubber				0.115	0.23	
		- cast iron C415				190	380	
		- steel 45				1110	2220	
		- gear pump w/motor, bedplate РШ-I2		pcs	2	58.7	117.4	
		- oil cup IV-Б-I2		pcs	4	0.11	0.44	
		- leaf filter Г4I-II-08		-"-	2	2.1	4.2	
		- pressure gauge, type 1, Ø 100, $P_{max} = 16$ kg/cm^2		-"-	2	0.8	1.6	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
5		Anode alloy pneumatic mixing unit		pcs	2	14	28	USSR
6		Pneumatic jack hammer, type TO-XO PCHB-I		-"-	3	13	39	
7		Portable potentiometer w/thermo-couple, immersible part 200 mm long, measurement range 700-1100°C		-"-	2	0.9	1.8	
8		D.C. millivoltmeter, scale 0-300 mV		-"-	2	0.5	1.0	
9		Fabric-reinforced rubber hose, O.D. 25		r.m.	40		24	
10		Welded steel box for electrolyte, capacity 0.13 m3		pcs	15	140	2100	
11		Welded steel bucket for dry salts, capacity 10 m3		pcs	5	460	2300	
12		Cover plates for busbar channel span (in total weight a top figure refers to Alternative I and a bottom one - to Alternative II)					17200 / 17200	
		- fabrication and installation of new cover plates, steel 30Л-I, castings		pcs	48		16800 / 16800	

NOS: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		- insulation of channel span						
		a) accid 400 (micanite)					300 / 300	
		b) edged board, 3 grade, pine					100 / 100	
1[illegible]		Process tools (crowbars, shovels, scrapers, electrolyte preparation cup)		set.	1	575	575	
		II. MATERIALS						
		Buswork						
		- cast aluminium busbar, 420x60 A5E		kg			29570 / 35620	
		- aluminium strip 420 x 1		-"-			2400 / 2400	
		- built-up aluminium A5E		-"-			380 / 430	
		- asbestos board S10 mm		-"-			50/57	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		- asbestos-cement board, 20 mm thick		kg			600/680	
		- steel DCN3K 3		kg			300/340	
2		Miscellaneous structural steel,		kg			18100 / 19100	
		Including HPA casting section (11500 kg)						
		Total Equipment-Alt.-I					56649	
		Materials-Alt.-I					33300	
		Equipment-Alt.-II					57649	
		Materials-Alt.-II					39527	

3. EQUIPMENT AND MATERIALS

SPECIFICATIONS FOR 70 KA ALUMINIUM REFINING CELL
(PER ONE CELL)

NOs: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		Anode lining						
		Including:						
		- asbestos board, 10 mm thick		m^2	46		560	
		- commercial clay brick M100		m^3	3.3		5940	
		- magnesite brick MY-91						
		including: N 3 (300x150x65 mm)		m^3	0.6		180	
		N 4 (300x150x75 mm)		m^3	0.4		1200	
		N 5 (380x150x75 mm)		m	2.6		7800	
		- fireclay brick						
		including: N 5 (230x114x65 mm)		m^3	4.1		8200	
		N 6 (230x114x40 mm)		m^3	0.26		520	
		- light fireclay brick						
		including: N 6 (230x114x40 mm)		m^3	0.1		90	
		N 8 (250x124x65 mm)		m^3	4.3		3870	
		- alumina - filling		m^3	0.27		270	
		- bottom paste (ramming paste)		m^3	1.3		2150	

)

x) for characteristics of materials see Appendix

NOS: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		- water sodium glass, soda-sulphate		kg			75	
		- chrysotile asbestos		kg			57	
		- building gypsum		kg			160	
		- built-up aluminium		kg			25	
		- electrode tube		pce	1		55	
		- carbon plate 200x450x630		pce	1		91	
		- anode sections, including:		pce	16		12126	
		a) bottom paste					96	
		b) collector bars, steel strip for cells 230x115 mm [illegible]					5280	
		c) cast iron					1320	
		d) carbon block 400x550 mm					5180	
		e) aluminium sheet 1 x 150 mm					250	
2		Steel shell						
		steel [illegible] пс 5		pce	1		11530	
3		Side hood						
		steel [illegible]3 пс5		pce	1		1000	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
4		Cell steel structures		pce	1		939	
		including: steel ВСт3 пс5					860	
		- aluminium					236	
		- textolite					1	
		- asbestos board					7	
		- fasteners					15	
5		Cathodes raising mechanism		pce	2	244	488	
		Including:						
		- electric motor 4А80А6У3 N = 0,75 kW, n = 1000 R.P.M.		pce	2	17.5	35	
		- worm gearbox 24-80-63		pce	2	14.5	29	
		gear ratio i = 63, permissible torque on low-speed shaft 20 kgf.m						
		- jack Q = 5 t		pce	4	56	224	
		- steel structure, steel ВСт3кп2					200	
6		Cathode buswork		kg			2170	
		Including:						
		- aluminium busbar 430 x 70 mm					980	
		- aluminium busbar 430 x 70 mm					980	

NOs: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		- built-up aluminium					8	
		- steel ВСт3 пс5					125	
		- steel Ст3 пс2					50	
		- fasteners					30	
7		Eccentric clamp		pce	13		290	
		Including:						
		- steel casting, steel 25					160	
							-	
		- steel ВСт3 пс5					130	
8		Cathode		pce	13		1663	
		Including:						
		- aluminium rod, A5E					490	
		- steel 20					16	
		- steel ВСт3 пс2					890	
		- bimetal plate		pce	39		267	USSR
		- aluminium - steel, including:						
		a) aluminium					67	
		b) steel					200	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		Total: equipment					18080	
		materials					43370	

4. EQUIPMENT AND MATERIALS

SPECIFICATIONS FOR 70 KA CELL FOR ELECTROLYTE PREPARATION AND CATHODES IMPREGNATION

(PER ONE CELL)

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg		Whom to be supplied by
						of one piece	total	
		Anode lining						
		Including:						
		- asbestos board, 10 mm thick		m^2	46		560	
		- x) commercial clay brick N 100		m^3	1.2		2200	
		- magnesite brick MY-91,						
		including: N 3 (300x150x65 mm)		m^3	2.6		7800	
		N 5 (380x150x75 mm)		m^3	0.9		2700	
		- fireclay brick HB-I, including:						
		N 5 (230x114x65 mm)		m^3	4.06		8120	
		N 6 (230x114x40 mm)		m^3	0.14		280	
		- light fireclay brick		m^3	0.12		100	
		including:						
		N 6 (230x114x40 mm)		m^3	0.12		100	
		N 8 (250x124x65 mm)		m^3	4.3		3900	
		- bottom paste (ramming paste)		m^3	1.5		2500	
		- water sodium glass, soda-sulphate		kg			75	

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x) for characteristics of materials see Appendix

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		- chrisolite asbestos		kg			57	
		- building gypsum		kg			160	
		- built-up aluminium		kg			25	
		- electrode tube		kg			55	
		- carbon plate [illegible]00x450x[illegible]50					91	
		- alumina - filling		m^3	0.18		180	
		- anode sections		pce	16		12126	
		including:						
		a) bottom paste		kg			96	
		b) collector bars, steel strip for cells 230x115 mm ВС$_т$ I пс		kg			5280	
		c) cast iron		kg			1320	
		d) carbon block		kg			5180	
		i) aluminium sheet 1x150 mm		kg			250	
2		Steel shell steel ВС$_т$3 пс5		pce	1		11530	
3		Side [illegible] steel ВС$_т$3 пс5		pce	1		1000	

NOS: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
4		Cell steel structures		kg			3280	
		Including:						
		- steel ВСт3 пс5					3130	
		- steel Х18Н10Т		"			133	
		- asbestos board δ = 10 mm		"			7	
		- paronite		"			4	
		- glass fabric		"			5	
5		Cathodes raising mechanism		pce	2		488	
		Including:						
		- electric motor [illegible] N = 0,75 kW, n = 1000 r.p.m.		pce	2	17.5	35	
		- worm gearbox Ч-[illegible]0-63 gear ratio i = 63, torque on low-speed shaft [illegible]0 kgf.m		pce	2	14.5	29	
		- jack Q = 5 t		pce	4	56	224	
		- steel structure, steel ВСт3пс2		kg			200	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
6		<u>Cathode buswork</u>		kg			2173	
		Including:						
		- aluminium busbar A5E, 430x70 mm		-"-			980	
		- aluminium busbar ADO, 430x70 mm		-"-			980	
		- built-up aluminium		-"-			8	
		- steel ВСт3 пс5		-"-			125	
		- fasteners		-"-			30	
		- steel ВСт3 кп2		-"-			50	
7		<u>Eccentric clamp</u>		pce	13		290	
		Including:						
		- steel casting 25Л		kg			160	
		- steel ВСт3 пс5		-"-			130	
8		<u>Cathode</u>		pce	13		1663	
		Including:						
		- aluminium rod, A5E		kg			490	
		a) steel 20		-"-			16	
		b) ВСт3 кп2		-"-			890	

NOS No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		- Bimetal plate aluminium-steel Including:		pce	30		267	USSR
		a) aluminium		kg			67	
		b) steel					200	
2		Curtain B = 4500 with drive		pce	2		1511	
		Including:						
		- electric motor 4A100 L6УЗ N = 2.2 kW, n = 1000 R.P.M.		pce	2		84	
		- worm gearbox РЧН-120-30 gear ratio i = 30, N = 1,47 kW		pce	2		120	
		- radial spherical ball bearing d = 55 D = 110; b = 21 mm		pce	4		3	
		- cast iron СЧ15		kg			5	
		- paronite		kg			4	
		- steel45Л		-"-			20	
		- steel Ст3		-"-			1230	

NOS	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg		Whom to be supplied by
No according to technological flowsheet						of one piece	total	
		Total equipment					21935	
		materials					40929	

3. SPECIFICATION

OF ELECTRIC EQUIPMENT, MATERIALS,

CABLES AND OTHER ARTICLES

[illegible]	[illegible] No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		Section I. DC BUSWAY AT SRSS AND BETWEEN SRSS AND POTROOM No 5. Variant 1						
1		Aluminium alloy busbar 30 x 450 mm^2	AD31T	km	0.3		21000	
2		Aluminium strip 0.5 x 450 mm	ACM	km	1.285		750	
3		Welded wire dia 2 mm	CBAK-5	kg	-		500	
4		Steel structure		kg	-		500	
			Total materials				22750	
		DC busway at [illegible] and [illegible] and between [illegible] No 5. Variant II						
1		Aluminium alloy busbar 30x430 mm^2	AD31T	km	0.265		18600	
2		Aluminium alloy busbar 25 x 305	AD31T	km	0.075		1500	
3		Aluminium strip 0.5x430 mm^2	ACM	km	0.15		90	
4		Welded wire dia 2 mm	CBAK-5	kg	-		500	
5		Steel structure	-	kg	-		500	
			Total materials				21190.	

№ [illegible]	[illegible] №	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		Section II. [illegible] EQUIPMENT, CABLES AND OTHER ARTICLES Variant I						
		1. Electric devices and motors [illegible]					211	
		- AC induction motor 220 V with short-circuited rotor, close type, ventilated with power rating 0.75 kW	4A80A	pc	6	22.0	132.0	
		1.1 kW	4A80A4Y3	pc	1	22.0	22.0	
		2.2 kW	4A100L6Y3	pc	2	28.6	57.0	
		2. Electric devices up to 1000 V					21	
		- AC three-pole circuit breaker 50 A	A150D-[illegible]	pc	3	1.0	3.0	
		- 1st magnitude magnetic starter	[illegible]-II4	pc	3	0.6	1.8	
		- DC voltmeter	M369	pc	3	1.0	3.0	
		- Pilot relay 220 V, type [illegible]	[illegible]	pc	10	1.0	10.0	
		- contactor A 700/A 701		pc	3		3.0	
		3. [illegible] control devices for [illegible] drives						
		- control cabinet	[illegible]540I-05B2A	pc	1		20.0	

NOS: No according to technological flowsheet	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		4. Cables					35	
		- Portable flexible power cable with copper cores 3 x 4 mm2	KPHT	km	0.05		20.0	
		- Copper wire with inforced asbestos isolation 1 x 1.0mm^2	HAI-I30	-"-	0.6		15.0	
		5. Mounting hardware						
		- Terminal box for 10 terminals	V6I4	pc	10		20	
		- Flexible bushing	K968	pc	30		60	
		6. Galvanized steel pipes						
		- Thin-walled steel pipe 25x2 mm		km	0.06		20.0	
			Total:	equipment			367	
				materials			20	

Nos [illegible]	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg: of one piece	Net weight, kg: total	Whom to be supplied by
		POWER EQUIPMENT, MATERIALS, CABLES AND OTHER ARTICLES						
		Variant II						
		1. Electric devices and motors up to [illegible] kW						
		- AC induction motor 220 V with short-circuited rotor, close type, ventilated with power rating:					211	
		0.75 kW	4A80A	pc	6	22.0	132.0	
		1.1 kW	4A80A4 У3	pc	1	22.0	22.0	
		2.2 kW	4A100L 6У3	pc	2	28.6	57.2	
		2. Packaged distribution devices up to [illegible]						
		- AC single-sided box 380 V with 3-pole knife switch and safety device	ЯБ3-32	pc	2		30.0	
		3. Packaged control devices for electric [illegible]					260	
		- Control cabinet	ШУ5401 -03В2А	pc	1		20	
		- Control cabinet 600x350x300	dwg. VAMI	pc	3		240.0	

[illegible]	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg		Whom to be supplied by
						of one piece	total	
4		4. [illegible]						
		- Portable flexible power cable with copper cores 3 x 4 mm2	КГНТ	km	0.05		8.0	
		- Power cable with aluminium cores without protection for 660 V:						
		3 x 16 mm²	АВВГ	km	0.1		56.0	
		3 x 4 mm²	-"-	-"-	0.5		150.0	
		- Copper wire with informed asbestos isolation 1 x 1 mm²	ПАЛ-I30	km	0.6		18.0	
		5. [illegible]						
		- Terminal box for 10 terminals	У6I4	pc	10		50.0	
		- Flexible bushing	К968	pc	30		30.0	
		- Aluminium [illegible] busway [illegible], 250 A	ШРА-73	set.	10		100.0	
		- Trolley brackets for main trolley [illegible] up to 660 V for bridge cranes	К03ЕУТ	pc	30		60.0	
			К03ЕСУТ	pc	2		10.0	
		6. [illegible]						
		Equal angle 75 x 75 x 6		kg	800		800	
			Total:	equipment			983	
				materials			800	

[illegible]	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg of one piece	Net weight, kg total	Whom to be supplied by
		Section III. ELECTRIC LIGHTING Variant II						
		1. [illegible]					22	
		- Circuit breakers	[illegible]- [illegible]	pc	1	1.0	1.0	
		- Control cabinet	[illegible]	pc	1	20.0	20.0	
		- Pilot relay 220 V	PII-I2	pc	1	1.0	1.0	
		2. [illegible]						
		- Control cabinet	by VAM[illegible] drawing	pc	1	80.0	80.0	
		3. [illegible]					185	
		- Lighting fixtures with lamps	[illegible]-700	pc	20		100.0	
		- Lighting fixtures with incandescent lamps	[illegible]-[illegible]	pc	2		10.0	
			[illegible]-[illegible]	pc	12		75.0	
							945	
		. [illegible]						
		- Power cable with aluminium cores in [illegible]	[illegible]					
		up to 6 mm - 2,5 and 4 - cores		km	0.2		80.0	
		up to 25 mm - 4-cores		km	0.3		250.0	

[illegible]	Trans. No	Name and technical characteristics	Type, brand, model, cipher	Unit of measurement	Quantity	Net weight, kg		Whom to be supplied by
						of one piece	total	
		- up to 95 mm - 4-cores		km	0.2		400.0	
		- 660 V wire with aluminium cores 2.5 mm2	АПВ	km	0.5		10.0	
		- wire with copper cores 1.0 mm^2	ПВ-3	km	0.15		5.0	
		- Control cable 660 V with aluminium cores 5x2.5+19x2.5 mm^2	АКВБГ	km	0.3		200.0	
			Total.	equipment			1232	

6. SPECIFICATIONS OF MATERIALS

1. LINING

1.1. Clay ordinary bricks, 230 x 120 x 65 mm, strength 100 kgf/sq.cm

1.2. Compressed magnesite bricks with magnesium oxide mass portion 91 % min and open porosity 14 to 18 %, 300 x 150 x 75 mm, 300 x 150 x 75 mm, 300 x 150 x 65 mm

1.3. Tube of graphitized electrode, inner diameter 260 mm, wall thickness 45 mm, graphite specific electrical resistivity 8.1 to 9.5 micro Ohm.m, mechanical strength limit, miniumum:

- Flexural strength - 70 kgf/sq.cm
- Raptural strength - 55 kgf/sq.cm

1.4. Ordinary fire bricks, semi-acid, Al_2O_3 mass portion 30% min, refractoriness 1670°C, open porosity 25 % max, compression strength limit 230 kgf/sq.cm, sizes 230 x 114 x 65 mm, 230 x 114 x 40 mm.

1.5. Sodium-sulphate water glass, silica modulus 2.31-2.6, density 1.43-1.5.

1.6. Carbon plate - manufactured of carbon side blocks for cells.

1.7. Collector bars - strip steel, section 230 x 115 mm. Rimming steel, carbon content 0.1 %, strength 34-50 kgf/sq.mm.

1.8. Cast iron, Si content 3.2-3.6%, Mn - 0.35 max, P - 0.12% max, S - 0.03 % max.

1.9. Carbon block, electrical resistivity 90 ohm.mm 10^{-6}, stability coefficient - 8, porosity - 21 % max, compression strength limit 230 kgf/sq.cm.

1.10. [illegible] clay bricks with apparent density 0,9 g/cm^3 and compressive strength not less than 25 kgf/sq.cm

2. STEEL SHELL

2.1. Semi-killed steel [illegible], with mechanical properties and chemical analysis as follows: ultimate strength 38-49 kgf/sq.mm, yield point 25 kgf/sq.mm, elongation 26%. C content - 0.14-0.22%, Mn - 0.4-0.65%, Si 0.05-0.17%, P - 0.04% max, S - 0.05 max, Cr - 0.3% max, Ni - 0.3% max, Cu - 0.3% max, As - 0.08% max.

3. SIDE HOOD

Ref. to item 2.

4. CELL SUPERSTRUCTURE

4.1. Steel [illegible] – C content – 0.12%, Mn 1.0–2.0%, Cr 17–19%, Ni – 9–11% (only for electrolyte preparation and cathode impregnation cell)
4.2. Aluminium AD0 (hood). Strength limit 6 kgf/mm^2, elongation 20–28%.
4.3. [illegible] – ref. to item 2.1.

5. CATHODE LIFTING MECHANISM

5.1. Structural steel [illegible]
Rimming steel, with mechanical properties and chemical analysis as follows: ultimate strength 37–47 kgf/sq.mm, yield point 24 kgf/sq.mm, elongation 27%, C content – 0.14–0.22%, Mn – 0.3–0.6%, Si – 0.07% max, P – 0.045 max, S – 0.05 % max, Cr – 0.3% max, Ni – 0.3% max, Cu – 0.3 % max, As – 0.8 % max.

6. CATHODE BUSSING

6.1. Cast aluminium bus-bars A5E. Al content 99.5 % max.
Impurities, max.(%): Fe – 0.35, Si – 0.12, Cu – 0.02, Zn – 0.04, Ti – 0.01
6.2. Aluminium bus-bars AD0 – pressed aluminium busbar, non-heat treated rupture ultimate strength 7 kgf/sq.mm, elongation 15 %.
6.3. [illegible] – ref. to item 2.1.
6.4. [illegible] – mechanical properties of steel – ref. to item 5.1.

7. ECCENTRIC CLAMP

7.1. Steel [illegible] – foundry steel, C content – 0.22–0.3%, Si – 0.17–0.37%, Mn – 0.5–0.8%.
Yield point 25 kgf/sq.mm.

8. CATHODE

8.1. Aluminium A5E - Ref. to item 6.1 (bar.).
8.2. Steel 20. C content 0.17-0.24%, Si - 0.17-0.37%, Mn 0.35-0.65%, P - 0.04 % max, Cr - 0.25% max.
8.3. 30 [illegible] - Ref. to item 5.1 (stub).

Additionally for electrolyte preparation and cathode impregnation cell.

9. (CURTAIN) SHUTTER TYPE HOOD B-4500 WITH DRIVE

9.1. Cast iron C4-15 - tensile strength - 15 kgf/sq.mm, bending strength - 32 kgf/sq.mm
9.2. Steel 45Л. C content 0.42-0.5%, Si - 0.17-0.37%, Mn - 0.5-0.8%. Yield point 36 kgf/sq.mm.
9.3. Steel 20 - Ref. to item 8.2 (curtain leaf).