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THE ASSEMBLY OF LARGE-SCALE TECHNO-
LOGICAL EQUIPMENT

P. Ya. Golovashchenko

Foreign Technology Division
Wright-Patterson Air Force Base, Ohio

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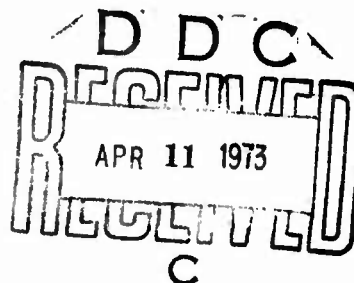
FOREIGN TECHNOLOGY DIVISION



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by

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*Translator's note: These pages were not translated.

THE TECHNOLOGICAL PRINCIPLES OF PREPARATION AND ERECTION

In the modern sense of the word, technology is the study concerning the processes of fabricating materials, of manufacturing parts from them, and assembling the parts into finished products. The parts which are fabricated in accordance with the working drawings are: plate elements of a vessel shell or piece of equipment; sections of girders, channel irons, angle brackets, bands or other forms of rolled metal. The sum of the parts assembled in accordance with the assembly drawing by any joining methods, that is, welding, riveting, soldering, bolting and others, into a structural part of the equipment or machine is called a subassembly. The sum of subassemblies assembled by any joining method in accordance with the assembly drawing into a larger structural part of the equipment or machine is called a unit. The test assembling, adjusting, fitting and stand testing of the units and subassemblies, and of the equipment, machine, etc., as a whole, creates the final product of production, that is, the manufactured article.

The manufactured article is the equipment delivered for construction jobs.

The modern erection of large technological equipment when certain standards are satisfied - that is, the complete and high-quality delivery of the finished products by machine building plants - is a technological process only involving the assembly of units, subassemblies and parts, and performing joining operations and testing in accordance with the erection drawings and instructions provided by the plant - equipment suppliers. It does not involve any kind of fitting or adjusting operations or any finishing of the units, subassemblies and parts.

When the basic finished state of the manufactured article is destroyed or disturbed, one is forced to perform, in the technological erection process, various additional fitting, adjusting, fabricating and assembling operations of the units, subassemblies, and parts.

The erection operation technology as an assembly process is divided into two main stages: assembling the units, subassemblies and parts manufactured by the plant-supplier into larger erection units which are within the maximum lifting capacity of the erection cranes available; and raising and installing the erection units in the design positions on the foundations.

The end product of the first stage is the erection units, and the end product of the second stage is the equipment, machine, pipeline complex, etc., depending on the accepted technical division of the object into individual sections of the overall equipment installation and its technological interconnections.

The main problem of the technological erection process is providing the most favorable technical-economic indexes which, in the final analysis, lead to the shortest erection time with the lowest labor cost. The essence of modern erection technology involves the rational assembly of units, subassemblies, and parts manufactured by the plant - equipment supplier into erection units. It also involves the use of efficient methods for raising and installing the erection units in the design position in order to create the final product - that is, the finished piece of equipment, apparatus, machine, or mechanism. Lastly, it involves the final adjustment of the facility and starting it up in order to place it in operation.

When it is necessary to perform finishing operations on the units, subassemblies, and parts at the construction site during the assembly process, in addition to the two main stages, the erection includes three additional groups of operations: lifting-transporting operations, adjusting or fitting operations, and assembly operations.

The operations in the last group include all kinds of joining operations which are carried out during the assembly process: welding, riveting, rolling, soldering, bolting and others. As erection experience has shown, the first two groups of operations are the most time consuming: the lifting-transporting operations and adjusting operations. The adjusting or fitting operations include, for example: bending under, trimming and dressing the edges of plate elements, shells

and the housing units of equipment; trimming the ends of pipes before setting them up for rolling; cutting, trimming and dressing the ends of various non-passive elements and parts associated with the unit or block assembly, drilling holes and threading them, etc. A large part of such operations is not included in the technology of assembling the finished products, but is included in the technology of fabricating the parts and is performed in the assembly area which must be provided for eliminating the imperfections of the plant-suppliers. When the adjusting or fitting operations are reduced, the lifting-transporting operations connected with the adjusting operations also are reduced - that is, the extent of the most laborious operations is reduced - and, consequently, the time required for the assembly process as well as the total time consumed in the erection operation is reduced. Thus, the main technical specifications for the delivery of large technological equipment must be: high-quality preparation of the machines, mechanisms and equipment, and the test assembling of them under factory conditions; a high degree of completeness of all the units, subassemblies and parts, which eliminates the necessity for fitting and adjusting operations at the erection site, and also completeness of the delivery which eliminates the necessity of preparing equipment parts which have not been supplied and of acquiring special materials.

Selection of the technological production process by the plant-manufacturer and by the equipment erector depends on a number of conditions. In machine building production, one of the conditions is the production scale, which depends on the production program.

Depending on the production scale, three main types of production are determined for machine building technology: individual production, volume production and mass production.

Individual production -- this is production which is so organized that the production program for the output of finished products is characterized by a nonrecurrent output, by the diversity of the list or nomenclature of the products being manufactured, and by the changing purpose of the technological operations. The most characteristic feature of the organization of an industrial enterprise is the diversity of the parts and subassemblies which pass through for fabrication or assembly. The technological indices of individual production are the fulfillment of all the assembly operations at a single stationary

working site by combined crews of qualified workers-assemblers.

Volume production is characterized by the recurrent, rhythmic output of uniform lots of finished products of the same nomenclature. Volume production is divided into large-volume production and small-volume production. With a great diversity of the nomenclature and an insignificant output of the lots of finished products, the production is considered to be small-volume. In the opposite case - that is, with a small number of finished products and a more or less considerable output of the lot of finished products - the production is referred to as large-volume. Small-volume production gravitates towards individual production, and large-volume production gravitates towards mass production.

Mass production assumes a continuous process for manufacturing a specific product in considerable numbers. The main index of this production is the constant performance of the same, continuously repeated operation at each working site. The continuity and relative rhythmic nature of the constant movement of parts and subassemblies creates a continuous-type operation for the technological process being used. Therefore, mass production is called assembly-line production. Maximum mechanization of manual labor, low qualifications of the production workers, and a high degree of interchangeability of the parts and subassemblies are characteristic features of mass production.

The erection of large technological equipment for modern large factories is a complex system of operations. Therefore, the creation of an orderly technological scheme for carrying out the erection operations is an important problem. In order to solve this problem and also for the convenience of technological planning and to simplify the organizational scheme for carrying out the operations, it is necessary that all the equipment which is to be used in the erection be concentrated at the individual subdivision sections of the operations. The equipment complex which provides, when it is in the assembled state, normal operation of the large production capacity which is being placed into operation is divided into sections erection. For example, the equipment complex of a large plant for sulfuric acid production is divided into the following sections: the furnace section; the wash section; the drying-absorption section; the contact compressor section;

TABLE 6

THE APPROXIMATE VOLUME OF ERECTION OPERATIONS FOR SECTIONS
OF A SULFURIC ACID PLANT

Sections	Volume, in tons		
	Equipment	Structures	Pipe System
Garage for thawing out pyrites	112	26	96
Receiving device	96	11	8
Open pyrite storeroom	600	-	-
Closed pyrite storeroom	465	34	28
Facility for removing pyrite cinders	562	23	34
Sections:			
Furnace	2288	61	484
Wash	745	12	238
Drying-absorption	1712	31	391
Contact-compressor	1324	43	272
Facility for collecting waste gases	210	12	89
Sulfuric acid storeroom	108	11	34

the facility for collecting waste gases; pyrites storerooms; trestles for removing pyrite cinders; galleries and conveyor loading units; technological piping-system scaffolding and neutralization stations. The approximate extent of the main mechanical-erection operations which are performed when erecting the sections of this plant are presented in Table 6. In erection operation technology, the finished product constitutes a part of the equipment complex being assembled for production. Thus, when planning the technological process of erecting the equipment complex for production, in order to best organize the erection operations, one should develop technological erection processes for the individual sections, starting from the distinctive features of the individual types of equipment constituting the produc-

tion complex.

Modern technology of erecting large-scale technological equipment is accomplished by two methods: individual assembly or assembly by "gradual depositing"; and large-block assembly. A characteristic feature of erecting large-scale technological equipment by the individual assembly method is the clearly expressed erection sequence of the units, subassemblies, and parts manufactured by the plant-supplier directly on the foundations after the construction and acceptance of the foundations under the equipment.

A characteristic feature of erection of large-scale technological equipment by the large-block assembly method is the prior consolidation of units, subassemblies, and parts delivered by the plant-manufacturer into larger erection units away from the foundations, independent of the degree of preparation of these foundations. The selection of the erection method in each specific case is determined by economic feasibility.

The method of large-block assembly assumes there will be a reduction in the amount of time-consuming work in high places, and thereby the work of the erectors-steelworkers will be facilitated. This method also reduces the need for scaffolds, temporary supports, and bracing. It provides the best possible combination of operations for erecting equipment while carrying out the building operations for completing the foundations under the equipment, and other general-construction jobs of the preliminary work. This method also increases the safety of the operations for erecting large-scale technological equipment.

Use of the large-block erection method enables one to carry out pre-erection assembly of erection units of many pieces of equipment, machines, mechanisms and pipe systems simultaneously. The preliminary partitioning of the equipment into large erection units when developing the design of large-scale equipment, machines and mechanisms facilitates this approach.

Preliminary partitioning of equipment into large erection units frequently is determined when developing a plan for carrying out the work of specialized erection. When planning the partitioning, the following are included in the large erection units of the equipment: small, metal, servicing areas; pipe systems; heat insulation; acid protection and fire-proof shielding. When planning the work, the main

part of the assembly and special operations is transferred to areas away from the equipment foundations, and away from the buildings in which the erection operations must be performed. Once beyond the building, one is able to carry out in parallel the assembly of many large erection units from various parts of the complete large-scale technological equipment. This is the first and most fundamental difference between the large-block erection method and the method of individual assembly.

The erection organization and the plant-supplier perform the consolidation operations for assembling the erection units. The construction organizations build the foundations under the building and equipment and perform the preliminary work connected with the construction of basements, tunnels, and passages. Specialized erection organizations simultaneously lay the technological and electric interconnections. State building organizations have the technical potential for completing the preliminary work in a normal manner by backfilling soil with the preparation of rough floors, and also they are able to produce large industrial sections under technological equipment without removing the soil and then afterwards performing any of the preliminary operations.

Because of the consolidation of the erection units, the number of small units, subassemblies, and parts manufactured by the plant-supplier and installed on the foundations in individual sequence is sharply reduced. In this way, organized repetition of the production operations is created in the main part of the work—that is, in the installation of the previously assembled large erection units on foundations. The organized repetition of large operations for installing the erection units is characteristic large-volume type production.

The main advantages of large-block assembly over the method of individual assembly by "gradual depositing" are the following:

The large-block assembly method enables one to carry out in parallel the erection operations of all the large-scale pieces of equipment, machines, and mechanisms in the initial construction period;

— the assembling of the large erection units is removed away from the foundation of the equipment, machine or mechanism, and even beyond the building where these items are being installed. Thus, it becomes

possible to carry out the construction work on the building and equipment foundations at the same time one is assembling the erection units. This shortens the total amount of time required for constructing the industrial section;

- carrying out the assembly operations in large open areas allows for the wide-spread efficient mechanization of the lifting-transporting operations by using various self-propelled cranes and other special cranes, railroad equipment and motor vehicles;

- the assembly of separate, relatively small units, subassemblies and parts of facilities, equipment, machines and mechanisms with the help of cranes in spacious assembly areas makes the work of the erectors similar to the conditions of plant and workshop assembly, which increases the labor productivity;

- the installation of large, finished erection units of the large-scale technological equipment on foundations opens a broad front for erection operations of auxiliary equipment, pipe systems, and structures, and for carrying out special construction operations;

- it significantly reduces the amount of the erector-steelworker work, due to which the time consumed in the erection operations is reduced, the working conditions are improved, and the operations can be performed more safely;

- in the assembly areas, one is able to perform acid-proofing and fire-proofing, to install thermal insulation, and other forms of protective coatings before installing the large erection units on the foundations;

- the amount of work involved in constructing scaffolds and temporary supports and braces is reduced, since a large part of the work which is normally done at heights is transferred to assembly areas and, in addition, permanent stairways and working areas are raised with the first large erection units. From the first days of the erection of large-scale equipment installations, machines and mechanisms, these stairways and areas are used for other erection operations and special construction jobs.

As a result of introducing large-block assembly the erection time for large-scale technological equipment and for the entire construction of the section is significantly reduced.

Improvement of the large-block assembly method has created a new form of organization for the production of the erection operations called the assemblyline erection organization.

Such an erection organization in which the production rhythm, established by a graph for carrying out the operations, is strictly maintained is called the assembly-line production of erection operations. This graph which is established for carrying out the operations is used for assembling the erection units and for installing them in the design site with compulsory continuity of the assembly and installation production processes.

The assembly-line erection methods shift the erection operations from the initial form of their organization, that is the individual type of production, to a higher stage of technical organization -- assembly-line production. The most efficient assembly-line methods for carrying out the operations must be used when simultaneously erecting several similar large-scale facilities, pieces of equipment, machines and mechanisms, shifting the separate production operations as established by the technological erection sequence according to a graph.

The principle of crew allocation of the working force and the prescribed production flow are based on a graph for the assembly-line erection of technological equipment, technological pipe lines, and other structures.

The rigidity of the technological production sequence of the operations allows one to organize specialized work crews of fixed composition which are engaged in recurring operations throughout the entire process of assembly and erection. With such an organization, a high quality of the operations which are performed, and the successful accomplishment of them by the assigned dates are achieved.

The production flow is determined by the length of time the specialized work crew must have in order to perform the assigned set of operations. The length of this time is constant. It is a multiple for all the specialized work crews which are engaged in the operations according to the assembly-line erection graph for the technological equipment, technological pipe lines and other structures. With an accepted amount of labor involved in the operations, the production

flow determines the size of the required work force. An increase in the time interval for completing the job, which is the same thing as a reduction of the production flow, reduces the size of the work force required for carrying out a prescribed set of assembly-erection operations. Conversely, a speed-up of the production flow increases the size of the work force which is needed for these operations.

THE TECHNICAL SPECIFICATIONS AND PRICE LISTS FOR DELIVERY

Machine building plants-manufacturers of large-scale technological equipment are obliged to deliver the equipment in accordance with technical specifications.

The price lists of the wholesale values of the production of machine building plants are developed and confirmed on the basis of the technical specifications.

The technical specifications for the delivery of large-scale technological equipment usually are a component part of the technical specifications pertaining to the type of equipment, independent of its dimensions. The technical specifications are based on the requirements for a high quality of the manufactured products which are being delivered and for their complete technical preparation. The industrial equipment and production organization of modern specialized machine building plants ensures fulfillment of the main requirements for the finished industrial products. Let us investigate the requirements for the delivery of large-scale welded steel vessels and equipment in accordance with the Interrepublic Technical Specifications MRTU 2-04-10-63 which took effect the 1st of January, 1964, and also in accordance with price list No. 23-03 (second part) for this type of equipment which took effect on the 1st of July, 1967.

In accordance with MRTU 2-04-10-63, standard containers and pieces of equipment are delivered in assembled, finished form; large-scale (non-standard) pieces of equipment are delivered both in assembled, finished form, and also in units in accordance with the instructions of the working drawings or engineering plan. The terms "standard"

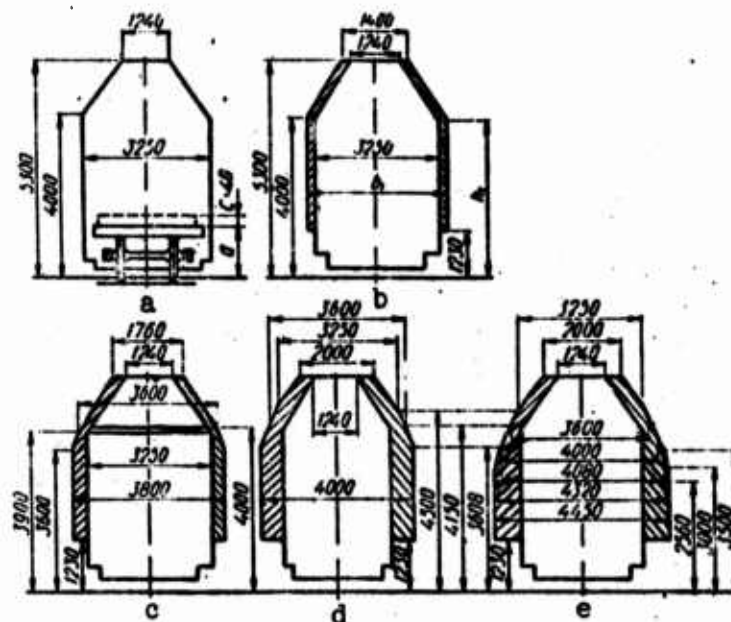


Fig. 10. Clearances of railroad rolling stock:

a. - clearance outline of a shipment; b.- non-clearance of degrees 0 and I; c.- non-clearance of degree II; d.- non-clearance of degree III; e. - non-clearance of degree IV.

and "non-standard" vessels and pieces of equipment are discussed in the MRTU as applied to the requirements of railroad transportation (Figure 10).

In accordance with the MRTU, vessels and pieces of equipment which are standard with respect to diameter but which, with respect to length, are not acceptable (according to the rules of the Ministry of Means of Communications) standard rolling stock when shipped via railroad are delivered in sections of maximum transportable length with provision for the necessary rigidity when transported. It is necessary to assemble each part of the equipment together with the internal

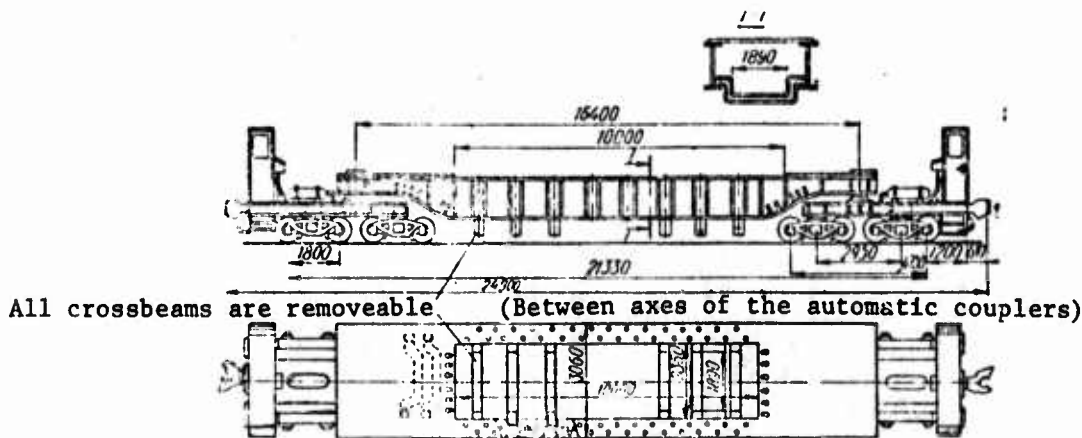


Fig. 11. Well-type railroad car.

devices at the plant-manufacturer and to hydraulically test the erection joint of adjacent parts, to draw guidelines, and to mark the parts with an indelible dye.

Vessels and pieces of equipment which are large in diameter should be transported by water routes or highways in completely assembled units. These fully assembled units, which include the internal devices, should be run and tested on a stand. They are transported by railroad in consolidated units which are prepared by the temporary deformation method developed by the Ye.O. Paton Electric Welding Institute. The units and rolls, the individual parts and subassemblies of the vessels and pieces of equipment which are large in diameter, are manufactured according to the technology developed by the plant-supplier in accordance with the erection plan. The technology must provide for the maximum consolidation of the units and individual parts of the vessels and pieces of equipment by the plant-manufacturer. It must call for the test assembly of the sections and for other operations which when performed ensure the erection of these large-scale vessels and pieces of equipment without unnecessary finishing or completing of the individual units, subassemblies and parts at the construction site. The plant-manufacturer must complete the preparation of large-scale vessels and pieces of equipment from the consolidation units, subassemblies and parts at the construction site. Special railroad cars (Figure 11) are used for transporting large-scale pieces of equipment by railroad. One of the devices designed for transporting large-scale pieces of equipment along highways is shown in Figure 12.

TABLE 7

TYPES OF TRANSPORTATION FACILITIES USED FOR TRANSPORTING
LARGE PIECES OF EQUIPMENT

Kind of transportation	Maximum size		
	Diameter, in mm	Length, in m	Weight, in Tons
Railroad:			
Flat car	3780	13	60
Railroad car	3780	13	90
" "	3450	45	110
" "	3840	34	240
" "	4050	32	110
" "	4232	9.8	55
Highway	5860	48.33	265
Barge	8000	50	400
By floating	10000	100	not limited

The kinds of transportation facilities used for transporting equipment are presented in Table 7.

The methods of shipping, and the designs for mounting large-scale pieces of equipment on railroad cars, on ships and when they are floated must be developed and coordinated by the plant-manufacturer in conjunction with the Ministry of Communications and the Ministry of the River Fleet.

The plant-manufacturer conveys the large-scale pieces of equipment to the shore for shipment by water transport. Large-scale bunkers, containers for condensers-coolers and other similar structures of large-scale equipment are delivered in units having maximum transportable dimensions. The bottoms of large-scale containers and of submerged condensers-coolers are finished in the form of welded strips folded into rolls.

Included in the equipment being delivered by the plant-manufacturers which contains the internal mechanisms of reactors, crystallizing

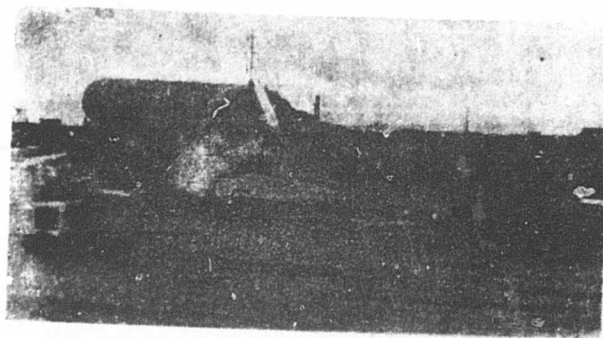


Fig. 12. Transporting a large piece of equipment along highway.

basins, vessels with immersible pumps and other devices, are the following: electric motors, reduction gears, pumps and other equipment. In the kit of delivered vessels, pieces of equipment and other manufactured articles are included: one set of gaskets and companion flanges together with fastening parts. For vessels and pieces of equipment manufactured from double-layer steel, connecting pieces are supplied instead of the companion flanges.

For the purpose of improving the production planning and delivery of large-scale pieces of equipment for the chemical, petroleum and petroleum refining industries⁽¹⁾, the enterprises under construction are obliged to deliver the orders for the manufacture and delivery of complete large-scale pieces of equipment with the necessary technical documentation no later than nine months before the beginning of the planning year to the Main Administration for Ensuring the Supply of Complete Sets of Equipment, Cables, and other Manufactures for High-Priority Construction Projects in the Coal Petroleum and other Branches of Industry.

In the contracts for the manufacture and delivery of large-scale equipment which are being concluded by the manufacturing enterprises

(1) Resolution by the USSR All-Union Council of Petroleum Refining and Chemistry of June 19, 1965, No. 41.

with the assembly organizations and clients, in addition to the conditions specified by the "Statement concerning the deliveries of the production of the industrial-engineering assignment", they must indicate⁽²⁾: the sequence of shipping the pieces of equipment, that is the separate units and subassemblies or the equipment in an assembled form; the dates for the delivery of the units and subassemblies; the mode of transport; the assembly sequence of the large-scale equipment on the client's construction site by the manufacturer's work force; the dates for starting and completing the assembly; the responsibilities of the client for providing, at the expense of the manufacturer, the assembly crews of this manufacturer which will be working at the client's construction site with lifting-transporting and welding facilities, with accessory materials, and with service and living quarters. The client is also responsible for rendering help to the assembly crews by assigning to them workers of the appropriate specialties. In the case when the manufacturer enlists the participation of construction-erection organizations and other organizations in preparing large-scale equipment, the manufacturer is responsible for communicating to the organization, using an established procedure based on their requirements, the appropriate restrictions on the labor, the task of reducing the cost of the construction-erection operations, and also the financial indicators if the indicated operations are not specified by the plan. Pieces of equipment which, because of their size exceed the load clearances for transportation by the railroad or are too long and therefore are shipped in the form of units and subassemblies, are included in the marketable production output of the manufacturer after the acceptance of the finished units and subassemblies suitable for welding by the technical control section of this manufacturer. The welding of the joints must be performed at the client's construction site by the work force of the manufacturer or by the work force enlisted by the manufacturer in the order established by the construction-erection organization. Payment for the cost of equipment which is too long and is manufactured and shipped in the form of subassemblies and units must be made by the client according to the price list approved by Gosplan (State Planning Commission of the USSR) in two installments: 93% of the cost is paid after completion of the shipment of all the units and

⁽²⁾ Resolution by the USSR Council of the Ministers of May 22, 1959, No. 539.

subassemblies by the manufacturer, and 7% is paid after the assembly and welding of the equipment at the client's construction site and the signing of the acceptance-surrender document.

The responsibility of the client-manufacturer for manufacturing and delivering pieces of equipment whose diameter is too large is considered to have been fulfilled after delivery to the client at the construction site with completion of the acceptance-surrender document. The manufactured pieces of equipment must be included in the marketable production output of the plant-manufacturer only after their assembly and welding at the construction site and their delivery to the client upon the completion of the document. Payment for the cost of equipment whose diameter is too large and is manufactured and shipped in the form of units and subassemblies must be made by the client for the equipment on the basis of the price list approved by the State Planning Commission of the USSR in two installments: 75% of the cost is paid after completion of the shipment of all the units and subassemblies by the plant-manufacturer, and 25% is paid after the assembly and welding of the equipment at the client's construction site.

The erection organizations are responsible for giving the equipment clients the necessary help with respect to showing the entire list of manufactured products which are distributed through the USSR Main Administration of Supply of Equipment in Complete Sets. When rendering this aid, they must keep in mind that an order for individual constructions and finished products which is not delivered in time leads to a delay in the construction and, in a number of cases, to a disruption of the dates for placing the object into operation. They are responsible for investigating, in conjunction with the clients, specifications for the equipment delivery as applied to the contracts, and for determining the dates for the equipment delivery on the basis of the length of time for the erection of the equipment and the established dates for introducing the objects. In connection with this, the erection organizations must be guided by the requirements laid down in MRTU 2-04-10-63, and take into account the fact that, because of the widening of the railroad cars, one can provide transportation

for equipment in the assembled form with a diameter up to 4.25 m. On the new railroad cars equipped with hydraulic unloading devices, they are able to transport equipment with a weight up to 120 tons, a length up to 32 m with a diameter up to 4 m. Devices for transporting even heavier pieces of equipment are available to the Ministry of Communications of the SSSR. The erection organizations must assign to the client, during the time when large-scale pieces of equipment are being completed at the construction site, rigging and other special equipment which the client does not have. The erection organizations beforehand, when preparing and signing with the clients the contracts for the delivery of large-scale pieces of equipment, must more precisely define the list of equipment to be supplied by these organizations during the period of finishing these pieces of equipment. They must render help to the client in unloading and transporting heavy large-scale equipment to the construction sites. Together with the client, these organizations must solve these problems beforehand, enlisting - in particularly complicated cases - the services of design and scientific-research organizations of the Construction Ministry of the State All-Union Trust of Specialized Operations of the Glavstroy (Minmonazhspeystroy) for the solution of these problems.

When accepting vessels and pieces of equipment for erection, the erection organizations must carefully check that the requirements for their delivery are satisfied in accordance with MRTU 2-04-10--63. These organizations are allowed to undertake the operations for finishing large-scale equipment with respect to the diameter only, when this will not cause a disruption of the main erection operations. In these cases, the finishing operations must be included by the client in the erection organization plan when the plant-equipment suppliers send the appropriate labor restrictions to the erection organization. This must be accomplished on the basis of a direct contract with the plant-equipment suppliers. The cost of the operations which are performed in accordance with the plan must be considered in the volume of contract operations performed. When determining the cost of the operations for the erection organizations to finish the equipment, one should be guided by the instructions of price list No. 23-03. The cost of

finishing the equipment when the subassemblies and units are delivered in accordance with the working drawings must be determined as the difference between the cost of equipment determined on the basis of the price list in accordance with Table 2, and 93% of the cost of the same equipment determined by the price list in Table 1.

When the erection organization undertakes operations for assembling equipment which is very long and is delivered in the form of two or several sections, the erection organization should make certain that the plant-manufacturer has fulfilled the requirements of MRTU 2-04-10-63 specifying that a test assembly of adjacent parts of the equipment be conducted by the plant-manufacturer. Payment for the assembly of the joints of long-length pieces of equipment must be made on the basis of the contract with the plant-manufacturer in accordance with the decree of USSR Supreme Council of the National Economy of June 19, 1965, No. 41. The erection organizations must consider that the statements concerning the assembly and welding of vessels and pieces of equipment which are large in diameter do not extend to large-scale spherical containers, among them electric dehydrators. In connection with the fact that it is advisable to assemble these containers from large units delivered by the plant, directly on the foundation, the assembly and welding of the elements is combined with the erection. For spherical containers, all the operations for assembling and welding spherical containers with a volume of 600 m^3 and larger are computed by using the erection charts of price list No. 13, and the cost of their preparation without assembly is computed on the basis of the price list No. 01-09.

At present, price list No. 23-03 specifies the cost of preparing equipment by shellacking, polishing, grinding, tin-plating, brass plating, galvanizing, lead plating and using other protective coatings. The cost of performing these operations, except for painting, is not included in the wholesale prices on the price list. The payments for these operations are made over and above the wholesale prices on the price list at rates agreed upon by the plant-supplier and the client. At the same time it is also confirmed that the plant-supplier is responsible for performing these operations on large-scale equipment at the construction site.

In 1968, Gosstroy SSSR (The Office of State Construction of the USSR) approved for use starting January 1, 1969, the "General section for the rates for erecting equipment". General instructions are contained in this document for 35 rates used for all kinds of equipment. These rates are compulsory for all branches of industry when determining the estimated cost and when making calculations of the operations to be performed for erecting the equipment. The general section and the rates for erecting the equipment were developed on the basis of the requirements of the 3rd section of SNiP (Construction Specifications and Regulations) and the effective technical specifications for the delivery and erection of equipment. The rates depend on the completion and painting of the equipment arriving for erection. Large-scale equipment arriving for erection in a dismantled form or as maximally consolidated subassemblies (units) should not give rise to the need for carrying out adjusting operations during the erection. The equipment must be delivered for erection with companion flanges on the connecting parts and with mounting parts - that is, connecting studs, bolts and anchor bolts. These parts must have been partially or totally assembled at the plant-manufacturer and when necessary must have been burnished. Stand and other test must have been performed on the parts in accordance with the technical specifications for the equipment's manufacture and delivery. Rotating parts should have been statically and dynamically balanced.

Cases when the requirements for the quality and completeness of the deliveries of large-scale technological equipment by the machine-building industry have not been satisfied are one of the chief causes leading to an increase of the construction time, raising the cost of the construction, and reducing the quality of the equipment. This is the case because the conditions and facilities for the finishing, adjusting, and assembly of large-scale equipment at the construction site by the work force of the plant-supplier and by the erection organization or other organization enlisted for this purpose are considerably poorer than the conditions and facilities of the production shops fitted out at the plant-equipment manufacturers.

Experience in constructing and placing into operation modern large industrial facilities has confirmed the dependence of the quality

and completeness of the delivery of large-scale technological equipment on the attention paid to satisfying the specified requirements at all stages of designing, planning, manufacturing and completing large-scale technological equipment for each construction.

CHAPTER 2. PREPARATION FOR ERECTION AND ITS ORGANIZATION

THE MAIN REGULATIONS FOR THE ORGANIZATIONAL-TECHNICAL PREPARATION

A necessary condition for the proper preparation and organization of the erection operations for units with large technological equipment is the timely, before the start of the operations, delivery to the erection organizations of the complete design-estimate documentation.

The availability of the design-estimate documentation, its careful and comprehensive study, and the development of all the requirements for ensuring uninterrupted construction-erection operations, form the basis of a timely and high-quality preparation and organization of the operations. These operations include uninterrupted erection, testing and adjusting, and the operation of large-scale technological equipment.

The main regulations for the organizational-technical preparation for construction are the Construction Specifications and (SNiP) Regulations III-A. 6-62 which were approved by The Office of State Construction of the USSR and are effective at present. These regulations provide for and authorize the construction of new industrial enterprises and also the reconstruction and expansion of existing industrial enterprises only after the completion of the organizational-technical preparation for the construction. The organizational-technical preparation for the construction must ensure the systematic development and implementation of the construction-erection operations. These operations include the erection of large technological equipment by industrial assembly-line methods and placing the construction units into operation on the dates established by the plan (or the anticipated dates), while not exceeding the standards for the length of time for completing the construction. The preparation must also ensure that the goals are met for the construction-erection organizations with respect to increasing the labor productivity, reducing the cost of the operations, and high quality producing.

The organizational-technical preparation is accomplished in

three stages. In the first stage, organizational measures are developed and executed before starting the operations at the construction site. The second stage is the preparation period, when the construction-erection operations with respect to preparing the construction site for the main units are carried out. The third stage includes the preparation operations which must be performed before starting the construction of each actuating complex or separate main unit.

In the first stage, before the beginning the preparation period for the construction as a whole, the project assignment with summarizing financial-estimate calculations and the plan for the organization of the construction must be approved according to the established procedure.

PLAN FOR THE ORGANIZATION OF THE CONSTRUCTION

A plan for the organization of the construction (POC) is developed for conducting construction-erection operations, for shortening the construction time and increasing the quality of the construction, for increasing the organizational-technical level of the construction by using the newest achievements of science and engineering, and for increasing the economic effectiveness of the invested capital.

The plan for the organization of the construction should be developed assuming the following: delivery of the large-scale technological equipment with good factory preparation; maximum use of sub-assemblies and units; total mechanization of the operations using the most economical combinations of machines, and the maximum use of two or more shifts and also using small mechanization facilities; continuity and assembly-line production of the construction-erection operations with steady utilization of the resources and production capacities.

The project organization developing the project assignment, or a specialized project organization performing the construction part of the project assignment based on a contract with the general designer compiles the plan for the construction organization. For carrying out individual sections of the plan for the construction organization of large enterprises or complex objects and buildings -- the erection of

technological equipment and assembled structures, installing automatic equipment, communication facilities, remote control equipment and thermal insulation, and performing other operations -- the organization to which the compilation of the POC is entrusted enlists, at the beginning of the subprocedures, appropriate specialized project organizations.

For complicated objects (enterprises for initiating chemical reactions, workshops, factories, installations and buildings) a comprehensive network graph is developed as a part of the plan for the construction organization. The general project organization compiles this graph. The graph determines the length of time required for the main stages in designing and constructing items, the dates for the delivery of the technological equipment for erection, the time required for the equipment erection and for carrying out the starting-adjusting operations, and also for comprehensive testing of the equipment and for mastering the design. The comprehensive graph serves as the basis for planning the capital investments at the appropriate periods and for determining the material-technical equipment. The graph is coordinated with the client, with the organization completing the technological building, with the general contractor and the master erection organization.

The participation of the specialized project-technological organization of Minmontazhspetsstroy SSSR in the development of a plan for the construction organization ensures a good basic decision for the technology of erecting large technological equipment, for selecting the erection cranes, for determining the extent of the mechanical-erection operations, for establishing the technological interrelationship of the construction and erection operations for the objects. This part of the plan has the greatest influence on the basic decisions when constructing buildings and foundations under equipment and also in carrying out the electric installation operations and special construction operations.

And, conversely, a plan for the construction of objects with large technological equipment which has been developed without participation of the specialized project-technological organization of Minmontazhspetsstroy SSSR, as experience has shown, in the majority

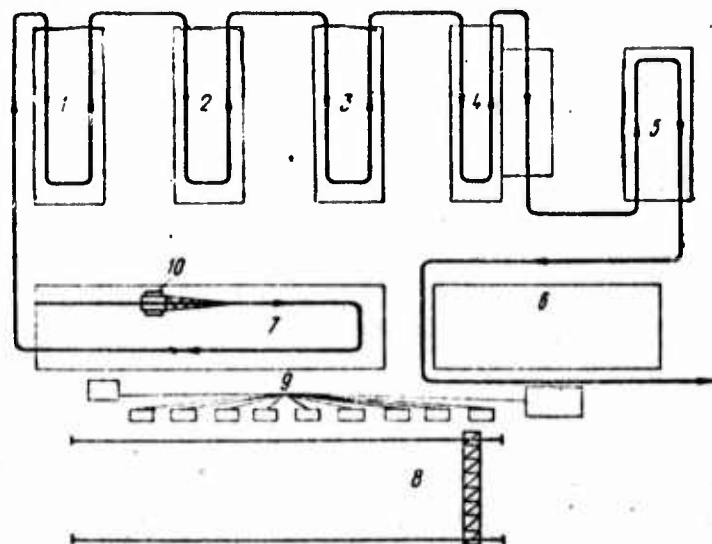


Fig. 13. General construction plan for the organization of the construction of a sulfuric acid plant for the Sumskiy Chemical Combine:

1 - furnace section; 2 - wash section; 3 - drying-absorption section; 4 - contact-compressor section; 5 - facility for collecting waste gases; 6 - sulfuric acid storeroom; 7 - closed pyrite storeroom; 8 - open pyrite storeroom; 9 - temporary buildings for the construction-erection organizations; 10 - caterpillar track crane SGK-30.

of cases does not correspond to the requirements of SNiP III-A. 6-62. It also does not ensure the finishing operations as provided by the Standards for Finishing the Construction of Enterprises, Chemical Actuating Complexes and Instructions for their Application (SN384-68) and The Standards for the Length of Time for the Construction of Enterprises, Lines, Chemical Actuating Complexes, Workshops, Factories, Installations, Buildings and Edifices (SNiP III-A. 3-66).

For example, the plan for the Construction Organization of the Actuating Complex for the Production of Sulfuric Acid by the Sumskiy Chemical Combine was drawn up by a branch of the project institute "Giprokhim" in 1968, without the participation of the specialized project-technical organization of Minmontazhspetsstroy USSR. In comparison with the erection of the large technological equipment which

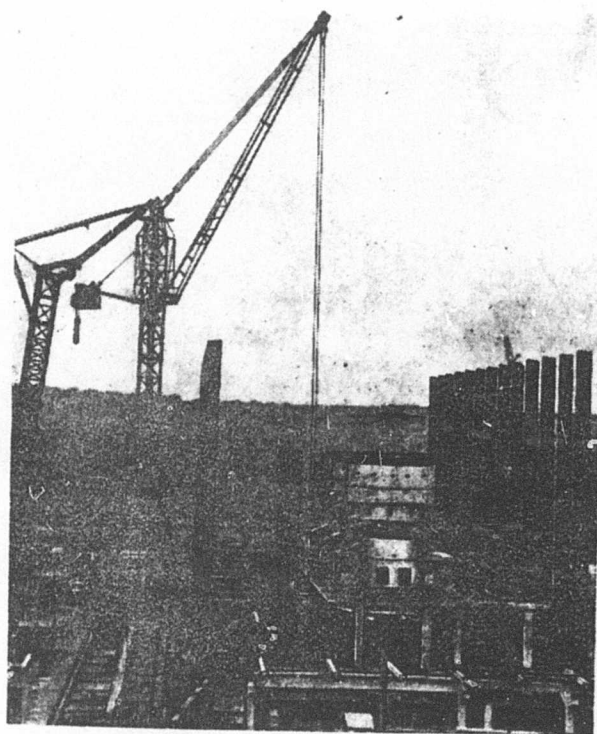


Fig. 14. The furnace section of the sulfuric acid plant at the beginning of erecting the furnaces and building framework.

was accomplished on the basis of the production plans (PPO) which were developed during the construction by the Ukrmontazhorgstroy Minmontazhspetsstroy Technological Institute, the former plan showed poor construction organization.

The general construction plan in the POC for the production of sulfuric acid by the Sumskiy Chemical Combine is presented in Figure 13.

In the furnace section the erection of the furnaces on 8-m high pedestals in accordance with the POC must be done using the SKG-30

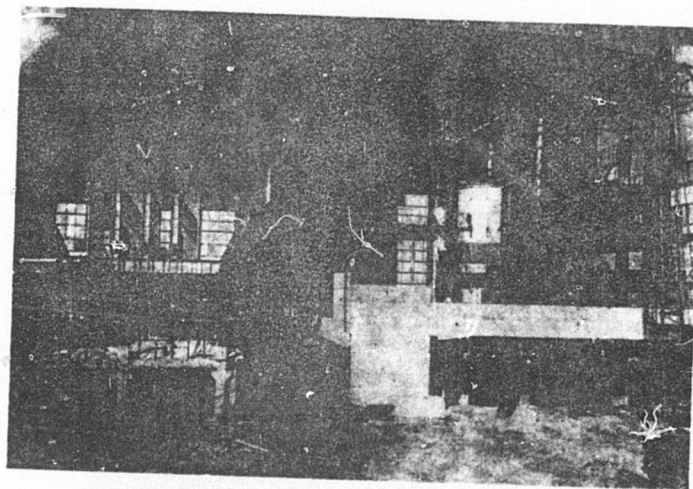


Fig. 15. The furnace section of the sulfuric acid plant during the erection of the building framework, furnaces, waste-heat boilers, cyclones and electric filters.

crane operating inside the building under the condition that the furnaces be erected at the same time as the building. Actually, the combined erection of the furnaces and building was carried out with a tower crane BK-300 (Figure 14). With high pedestals under the furnaces and waste-heat boilers, as is seen in Figure 14, the SKG-30 crane is not able to provide for the large-block erection. The large size of the waste-heat boilers, cyclones and dry electric filters (Figure 15) was not considered in the POC. The erection of the waste-heat boilers and gas conduits within the building also was performed using a BK-300 tower crane. The erection of the cyclones with sets of shelves outside the building was done with the crane MKG-25, and the dry electric filters with the gas conduits were erected using a tower-boom rigged crane SKG-40. Besides this, in the sorting and consolidation of the erection units, the pre-erection painting of the steel structures with a perchlorovinyl coating, in the assembly of the erection units of the equipment and gas conduits, and also in the pre-erection thermal insulation of the panels of the waste-heat boilers, five self-propelled boom cranes with a lifting capacity from 25 to 10 ton force were addi-

tionally engaged when carrying out the operations in two, and occasionally in three, shifts.

The average number of workers over a six month period was around 200 men with an average monthly output per individual worker-erector of 1,100 to 1,200 rubles.

In the wash and drying-absorption sections the erection of the large pieces of vertical equipment on pedestals around 9-m high according to the POC should be done using two SKG-30 cranes, moving the pieces of equipment to the design position with the help of rigging facilities. The erection of the spray coolers on 10-m high pedestals must be done with the help of K-51 cranes. Actually, the erection of the pieces of equipment was accomplished using a tower-boom rigged SKG-63 crane and a E2503 crane, and the erection of the spray coolers was accomplished with MKG-25 and MKP-25 cranes. In addition, when performing the work in two shifts the cranes MKG-25 and MKP-25 were used at the sites for assembling and welding the large erection units.

The average number of workers over a six-month period was around 280 men with a monthly average output per individual worker-erector of 900 rubles.

In the contact-compressor section the assembly and welding of the contact equipment should be performed according to the POC in the horizontal position, with its subsequent installation in the design position by the method of "rotation around a hinge" using two SKG-30 cranes. Then the erection of the internal devices of the equipment is carried out using a K-51 crane and small mechanization devices through an opening specially cut in the cover. The opening has dimensions of 2200 X 2200 mm, and is used for introducing the elements of the distribute lattices and plates. Actually, the erection of the contact equipment was accomplished using the crane SKG-40 and a tower-boom rigged crane SKG-63. In the assembly and welding of

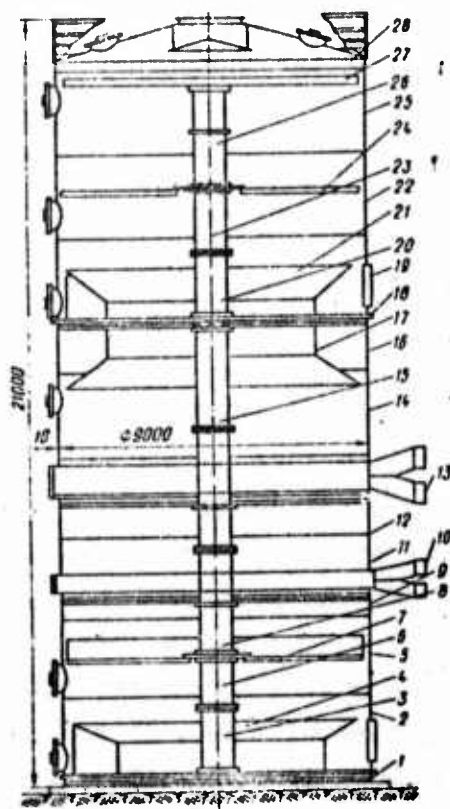


Fig. 16. Erection units in the assembly sequence for the contact equipment of the contact-compressor section of the sulfuric acid plant:

1 - 28 - sequence of the assembly.

erection units of the large-scale equipment, two MKG-25 cranes were used in addition when the work was carried out in two shifts.

Figure 16 shows 28 stages of the actual installation of the erection units of the contact equipment directly on the foundation in a vertical position.

The average number of workers over a six-month period was around 180 men with an average monthly output per worker-erector of 1000 rubles.

The POC recommended using K-51 cranes for erecting the gas conduits on the supports which were 23 m high. Actually, the erection of the gas conduits in large units was accomplished using tower-boom rigged SKG-63 cranes.

Erection of the large-scale technological equipment accomplished in accordance with the PPO was the main factor in reducing the standard erection time by more than a factor of three. If the erection had been accomplished in accordance with the POC, the time for erecting the large-scale technological equipment would have turned out to be considerably longer than the standard time.

More than half of the mechanical-erection operations actually performed on the projects and around half of all the construction-erection operations on the chemical actuating sections were not considered in the POC.

The complete consolidation graph with specific lengths of time for the main construction stages and dates for delivery of the technological equipment was missing from the POC. This information must serve as the basis for planning the capital investments and the material-technical construction equipment.

These most important decisions were not coordinated with the client, with the organization completing the delivery of the technological equipment, with the general contractor, or with the master building organization. Therefore, progress in the finishing and delivery of the equipment and the material-technical resources lagged behind the standards by 6-12 months.

As a result, when preparing to actually place the main technological equipment into operation in accordance with the standard length of time for the construction, the overall readiness of the construction-erection work for all the chemical actuating sections was only 65.86%, and the readiness completion with respect to capital investments was 71.24%. The delivery of the technological equipment for the waste gas collection section using wet-type electric filters was completed after the sulfuric acid plant was placed into operation.

CHAPTER 4. ERECTION OF CHEMICAL EQUIPMENT

ERECTION OF EQUIPMENT USING SELF-PROPELLED BOOM CRANES

In recent years, various self-propelled boom cranes have been ever more widely used for raising and installing large-scale pieces of chemical equipment.

With the increase in the production of heavy-duty self-propelled cranes in this country, the technology for raising and installing heavy pieces of equipment using one or several cranes has been perfected. With the paired use of two or more cranes, similar cranes having the same technical characteristics must be used in order to ensure synchronization of their operation. In a number of cases, special blancing crosspieces are also necessary in order to eliminate the possibility of overloading one of the paired cranes.

With the use of heavy-duty self-propelled cranes for erecting large-scale technological equipment and structures, the productivity of labor is increased and the cost of the erection operations is reduced in comparison with the case when rigging facilities are used for these same purposes.

For example, using cranes instead of rigging masts and supports for erecting heavy pieces of tower-type equipment increases the labor productivity by a factor of 3 - 4 [27].

As a result of conducting studies and design operations, tables have been compiled for the use of self-propelled cranes and boom cranes when they are used individually and with their paired operation, and also when moving with a load on the hook (Table 15). Standard schemes have been developed for raising and installing tower-type pieces of equipment by the method of rotating around a hinge (Figure 21) and by the skidding method with movement of the cranes

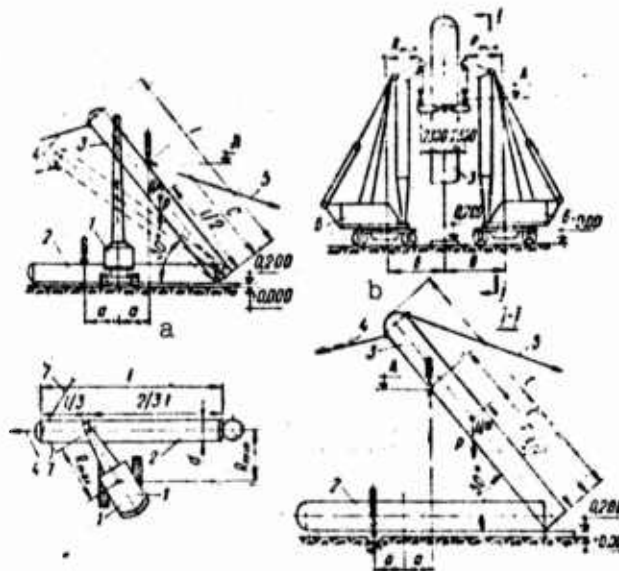


Fig. 21. Scheme for erecting tower-type equipment by the method of rotation when attaching the sling at a distance from the base of $\frac{2}{3}$ the tower length: 1 - caterpillar track crane; 2 - position of the piece of equipment before raising; 3 - position of the piece of equipment raised to its maximum degree; 4 - direction of the braking wire-braces; 5 - direction of the drawing-up cable; 6 - rubber-tired crane; 7 - lateral wire-braces.

and without movement of the cranes (Figure 22) [16].

For each scheme for carrying out the operations, they determined, by calculation, the maximum dimensions and weight of the pieces of equipment which may be raised by various self-propelled cranes with various boom lengths. The results of the calculation are listed in the tables. Data on the maximum lifting capacity of cranes under various operating conditions served as the basis for compiling the tables. The standard schemes were included as a supplement to Instructions for Raising Technological Equipment using Self-Propelled Boom Cranes MSN 124-66/MMSS SSSR.

The development of a tower-boom arrangement for self-propelled cranes by the Promstal'konstruktsiya Design Institute enabled them to considerably expand the field of application of these cranes by increasing the three-dimensional space serviceable by the boom. Now caterpillar track cranes of the SKG series are equipped with this

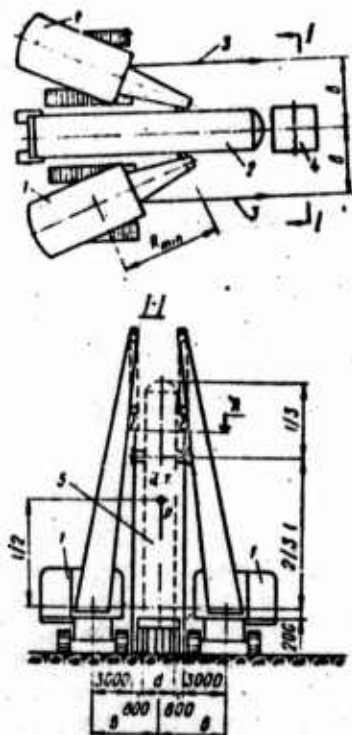


Fig. 22. Scheme for erecting equipment using two cranes by the skidding method when attaching the sling at a distance from the base of $2/3$ the length of the tower:

1 - caterpillar track crane; 2 - position of the equipment before raising; 3 - direction in which the cranes are moving; 4 - equipment foundation; 5 - position of the equipment before installing it on the foundation.

arrangement. The method of erecting equipment and structures using self-propelled cranes with temporarily braced booms has been widely introduced into industry. This technique was published in the Instructions for the Use of Caterpillar Track Cranes with Temporarily Braced Booms MSN 176-68. A-shaped supports have been developed for the crane booms to rest on. Data on these supports are published in Instructions for Using SKG-30 Cranes with the Boom Resting on an A-shaped Support for Erecting Equipment.

A method for the paired use of self-propelled cranes with booms connected by a crossbar has been widely disseminated. This method

Table 15.

MAXIMUM LIFTING CAPACITY OF CRANES UNDER VARIOUS
OPERATING CONDITIONS(1)

Crane designation	Individual Crane			Paired Cranes			
	no moving with the load (with any position of the boom) in percent	Moving with the load (boom position is in the direction of motion at an angle larger than 10°)		No moving with load		Moving with load without a balancing crosspiece (attaching the sling at the outermost point in respect to the equipment width)	
		Boom length in m	Percent of lifting capacity	With balancing cross- piece, in %	Without balancing cross- piece (attaching the sling at the outermost points in respect to the equipment width), %		
MKG-20	100	12.5	80	100	80	12.5	60
	100	22.5	60	100			
MKG-25	100	12.5	80	100			
	100	17.5 22.5	60	100	80	12.5	60
SKG-25, 30, 40	100	up to 25	80	100	90	up to 25	70
SKG-50	100	up to 40	80	100	90	up to 40	70
MKP-40, 50	100	not recommended		100	80	not recommended	

(1) Based on the data of VNIImontazhspestroy.

enables one to improve the load characteristics of cranes, and it may be used under restricted conditions where it is impossible to achieve bracing of the crane booms. In this case the booms of the

cranes, together with the crossbar, form a gantry system in which the crossbar equalizes the forces arising in the system from additional loading and counterbalances the forces arising in the ordinary scheme of crane operation which would cause it to lose stability.

The self-propelled boom cranes created in the Minmontazhspestroy SSSR system are equipped with diesel-electric drives which provide for independent operation and also for supplying the energy from a power line. The cranes have been designed to facilitate erecting, dismantling, repairing and transporting them. The load stability and support base make possible a considerable free boom overhang of the hook, and a considerable three-dimensional space can be served by the boom. Using these cranes, one can manipulate erection units with a considerable weight.

In 1965, three caterpillar track cranes erected a K-7 tower with a height of 41 m, a diameter of 2.8 m, and a weight of 100 tons by the method of rotating around a hinge. This erection, which was the first of its kind in the Soviet Union, was performed by the erectors of trust No. 7 for a catalytic refining installation of the Ryazanskiy Petroleum Refining Plant.

Before raising the tower, it was completely insulated and fitted out with the pipes and small service areas. The lower part of the tower was set on a hinge, and the upper part was set on trellis-like supports. The support-rotating hinge was welded to the lower part of the "skirt" installed on the foundation. Rotating corner plates were welded to the upper part. The erection was accomplished with two SKG-30 cranes and a E-2508 crane with 20-m booms.

Utilizing different lifting capacity, cranes having different hook raising speeds required the use of balancing crosspieces, fastened to the tower underneath. The crosspiece system consisted of a longitudinal tubular crossbar fastened under the piece of equipment by means of a hinge. The longitudinal crossbar which provides balancing of the two SKG-30 cranes was fastened to the

tubular crossbar at the point where the slings of the two cranes are attached.

Since the cranes have different hook raising speeds, crane E-2508 continuously raises the tower, but the cranes SKG-30 which have a higher hook raising speed only periodically raise the tower. During the raising process, all the cranes, based on a command, moved 6 m in the direction of the tower foundation.

After raising the tower to a position of 43° a drawing-up block and tackle with a lifting capacity of 100 ton force was put into use. When the entire load was transferred to the block and tackle, the crosspiece system came away freely from its engagement with the hinge and dropped to the earth. A container sunk in the ground and filled with water was used as an anchor for the block and tackle drawing up the tower. When the tower approached a neutral position, tension was taken on the braking wire-brace, and the tower was set down. The precise setting down of the tower was ensured by the corner plates (catchers) which were welded to the "skirt". The crew of riggers raised the tower in 3.5 hours.

When erecting the Kirov Voronezhskiy Synthetic Rubber Plant, the method was used of raising by rotating around a hinge using two SKG-30 cranes, to a position of $45 - 50^{\circ}$ and then drawing up the equipment using a block and tackle fastened to a stock anchor or to a previously erected piece of equipment - for installing the apparatus which weighed 50 - 60 tons on the foundation. During the erection process, the cranes periodically moved in the direction of the foundation, thereby maintaining the position of the loaded pulley block.

Equipment weighing up to 30 tons was erected using paired SKG-30 cranes by the skidding method. The SKG-30 cranes with a boom of 22.5 m were set up on two sides of the foundation. The equipment was laid down with the top in the direction of the foundation, and the sling was connected to dummy fittings slightly above the center of gravity.

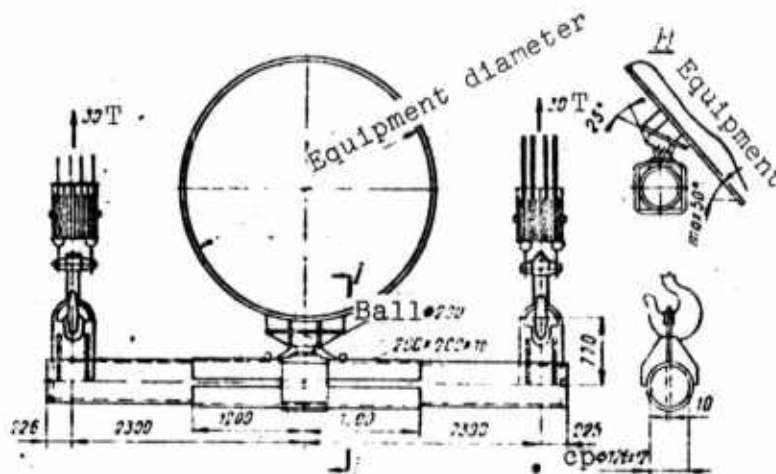


Fig. 23. Balancing crosspiece with a ball support.

The equipment was simultaneously raised by the two cranes. While this was being done, the base of the equipment was moved in the direction of the foundation by means of a pipe layer at such a rate that during the erection the loaded pulley blocks of the cranes were maintained in a vertical position.

When the equipment reached the vertical position, the pipe layer was disconnected, and the cranes raised the equipment to a height sufficient for lining it up on the foundation bolts. Then the equipment was lowered to the foundation by lowering the booms. The lifting capacity margin of the cranes in all cases was sufficiently large (20 -25%); therefore, no special measures of any kind were taken in order to ensure the uniform loading of the cranes. The possibility of a dangerous redistribution of the loads arose only in the last stage of the raising when the equipment reached the vertical position. At this stage a careful watch was maintained of the vertical position of the equipment. Any deviation from the vertical was easily detected long before dangerous values were reached, and the deviation was quickly eliminated.

Slings of the equipment was accomplished by means of a loop sling encompassing half the diameter of the equipment and passing

through the dummy fittings. This scheme ensured easy slinging and unslinging of the equipment.

Part of the equipment was erected using another scheme. This equipment was laid out with the base in the direction of the foundation, and the cranes were positioned close to the equipment's center of gravity. With this arrangement, the travelling part of the cranes was positioned parallel to the equipment axis.

Verticality of the loaded pulley blocks of the cranes was achieved by periodically moving the cranes along the equipment axis. After the equipment reached the vertical position, the cranes moved in the direction of the foundation. When in the immediate vicinity of the foundation, the equipment was raised to the necessary height, and it was installed on the foundation by a small rotation of the booms.

During a short period, the erectors erected 15 pieces of tower-type equipment with a total weight, including the framework and insulation, of around 400 tons. In the erection of this equipment 2,300 rubles were spent, of which 930 rubles was the cost for operating the cranes. But if the equipment had been raised using rigging masts, the erection of this equipment would have cost 7,800 rubles - that is, more than three times more.

Rules for the Arrangement and Safe Operation of Hoisting Cranes of the State Committee of the Council of Ministers for Supervision of Industrial Safety and for Mining Inspection (Gosgortekhnadzor) (p. 255) allow one to use several cranes for raising and moving a load under the condition that the load taken on each crane must not exceed its lifting capacity. One should give considerable attention to the problem of distributing the loads between several cranes during the process of erecting large-scale technological equipment.

Therefore, actual values of the loads acting on cranes when erecting pieces of tower-type equipment by the method of rotating around a hinge and by the skidding method were studied by the All-

Union Scientific Research Institute of Construction of the State
All-Union Trust of Specialized Operations of the Glavstroy (VNIImon-
tazhspetsstroy).

In order to conduct this study, tensometric pull bars were hung on the crane hooks, and the loads which arose were continuously recorded using an oscillograph. The studies were conducted while raising ten pieces of tower-type equipment using cranes of various designations and with the use of various slinging and raising methods.

The measurements of the loads on the crane hooks when raising the equipment showed that, when dummy fittings are used for the slinging, the overloading of the cranes may reach twice the balanced load value, especially with a rigid design of the hinge when there is not considerable play between the rotation axis and the support structure. In this case any misalignment arising with a synchronous operation of the cranes, even if the cranes are of the same type, is perceived by the hinge and the load nonuniformity coefficient of the cranes reaches a value of two. Therefore, when paired cranes raise pieces of tower-type equipment using the method of rotation around a hinge it is necessary to use balancing crosspieces. When using paired cranes, it is simplest to raise the equipment by attaching the sling to the equipment's top section. However, it is usually impossible to attach the sling to the top of very tall equipment.

Of the many proposed designs and tested constructions of crosspieces, the most promising balancing crosspiece is one with a ball hinge (Figure 23). A balancing crosspiece with a ball support has free movement in all planes, which significantly contributes to the maneuverability of the cranes and reduces the danger of overloading them as a result of possible deviation of the loaded pulley blocks from the vertical. The possibility of moving the crosspiece in the horizontal plane over a large range favorably distinguishes this ball support crosspiece from all previously existing crosspieces when raising equipment by the method of rotation around a hinge.

In a number of cases, balancing crosspieces are also used when raising horizontal pieces of equipment. When installing the atmospheric piping for the Ryzzanskiy Petroleum Refining Plant, it was necessary to install 24 horizontal heat exchangers with a length of 10.8 m, 12 of which weighed 32 tons and 12 of which weighed 22 tons, on 6-m high reinforced concrete pedestals.

In line with the pedestals, a chute ran below the cable under the heat exchangers. Because of this chute, the available SKG-63 crane with a 30-m boom and SKG-30 crane with a 25-m boom had to be set up at a distance of 7.2 m from the edge of the pedestals. When raising the heat exchanger with the sling attached to its end, without using a balancing crosspiece, the cranes did not have the necessary lifting capacity because of the large overhang of the booms. The use of masts would have considerably increased the time and cost for erecting the installation. A balancing crosspiece made from a pipe with a diameter 325 X 30 mm strengthened by three sections of pipe of the same diameter was used when erecting the heat exchangers. The spot for attaching the cable to the crosspiece was selected in such a way that the load did not exceed the permissible load for the cranes - that is, 12 tons for the crane SKG-30 and 20 tons for the crane SKG-63. The sling for the heat exchanger was located in the middle near the center of gravity.

Using the balancing crosspiece enabled them to safely carry out the necessary operations (raising, moving to the pedestal, installing on the semi-carriage, moving to the design position) using cranes with different lifting speeds.

Erection of the synthesizing towers at the Novolipetskiy Nitrogen Fertilizer Plant (Novolipetskiy azotno-tukovom proizvodstve) may serve as an example of the successful operation of paired cranes with a balancing crosspiece. The synthesizing towers which have a weight of 80 tons, a height of 20 m, and a diameter of 1.2 m were erected by the skidding method using a tower crane BK-1000 and a caterpillar

track crane SKG-50 with a 30-m boom. The towers were installed on a 1.2 m high metal support.

A variable-arm crosspiece with a lifting capacity of 80 ton-force which ensures distribution of the loads on the cranes in accordance with their lifting capacity was used for raising the towers. The lower part of the tower was set on a special hinge support which was dragged up during the raising process. Special attention was paid to the vertical position of the loaded pulley blocks of the cranes during the raising. After setting the tower on the metal support structure, the tower together with the support was moved along special guides to the design position and fastened by anchor bolts.

The defects of the method described include the complexity of ensuring the verticality and synchronous operation of the loaded pulley blocks. This requires special attention and the precise performance of the erection operations.

The presence at the erection site of a large amount of technological equipment whose weight exceeds the lifting capacity of the available self-propelled boom cranes compels designers to seek ways of increasing the lifting capacity characteristics of these cranes.

One of the methods enabling the lifting capacity of the cranes to be increased is the method of erecting the equipment using a crane with a temporarily braced boom. The basis of this method is the principle of equivalence of the stresses in the boom associated with the ordinary operating mode of the crane, and the stresses in the boom associated with operating with a braced boom. When operating a crane with a temporarily braced boom, the boom is supported by a brace running to an anchor. With this arrangement, the system supporting the crane boom is slackened.

The increase of the crane lifting capacity occurs as a result of an increase of the angle of the system supporting the boom. This enables one to reduce the loads acting on the boom and, consequently,

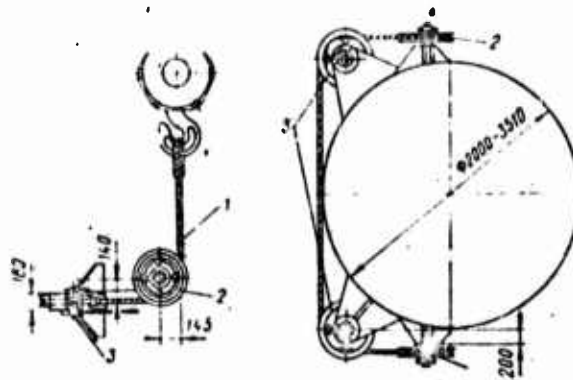


Fig. 24. Overall view of hoisting sling.

to increase the weight of the load being raised, while the stresses in the boom remain at the previous levels.

Two horizontal heat exchangers with weights of 17.5 tons and 10.7 tons was accomplished for the acetic acid facility of the Moscow Petroleum Refining Plant using this method. The heat exchangers were set on a metal set of shelves at the + 16 m mark. A SKG-30 crane with a 25-meter braced boom was used for the erection.

When installing the heat exchangers, it was necessary to change the overhang of the crane hook to 14 m. With such an overhang, the certified lifting capacity of the crane is altogether 7 ton force, but use of the braced boom method enables one to increase the load characteristic of the crane with this overhang by more than a factor of two. Before beginning the erection, the crane was set on a levelled area which was laid out using crossbars. The brakes were applied to the mechanism for moving the crane. A single-roller block was fastened by means of a cable to the haunch of the crane boom beyond the axis of the fixed block of the load pulley system. This single-roller block ensures uniform loading of the brace arms during the raising process. The brace arms are fastened to tractor winches which are used as ground anchors.

The heat exchanger was raised above the upper mark on the set

of shelves and then, by increasing the overhang of the crane boom (by turning on the tractor winch), the heat exchanger was lowered to the design position. The raising and installing of the heat exchanger was accomplished in three hours.

The defects of the method described include the impossibility of rotating the boom of a braced crane when erecting equipment, the necessity of rethreading the cables of the load pulley block, and the need to carefully check that the brace is horizontal and the brace axes are properly aligned.

In the Sterlitamakskiy Synthetic Rubber Plant tower-type equipment with a height of 26.5 m and a weight of 27.6 tons was erected on a 6.1 m high pedestal by paired cranes using the skidding method with the help of a sling.

The tower was laid alongside the foundation. Two cranes, a SKG-30 and a SKG-40, were used for raising it. When first starting, the cranes operated with a boom overhang of 10 m with a full load. During the raising process, the boom overhang was reduced and the loading was only 70%. The design of the sling (Figure 24) includes four rollers. The cable 1 passes around roller 2 to roller 3, and then around the same kind of roller located on the other side of the tower and then on to a second roller 2.

The loads are equalized between the cranes by movement of the cable. The rollers are welded to the casing of the equipment in such a way that the converging ends of the sling will meet on the axis of the tower.

The sling was made from a 7-strand cable. The ends of the cable were sealed into a pad-eye. The raising was accomplished in the same way as raising with two cranes using the skidding method.

In order to prevent the cable from coming off the roller at the moment the load is removed, guards made from a 10 mm diameter rod were welded to the roller holder when setting in the lower horizontal

part of the support.

The length of time for picking up the mechanisms is: for the crane MKG-6 — 2 hours; SKG-40 — 8 hours; SKG-30 — 12 hours; and the pipe layer TL-4 — 12 hrs.

The following factors were revealed during the raising process: the possibility of equalizing the load between the cranes using a sling; the absence of spontaneous movement of the sling in the rollers when the hook rests against a roller; the amount of labor used in installing and welding the rollers of the sling is somewhat more than the labor expended in installing ordinary dummy fittings; the angle brackets of the small rollers are small and the haunches of the booms rub against the equipment casing. Therefore, the angle brackets should be increased to 50 mm; use of the sling is very effective when the loads on the cranes constitute 80 - 100% of their capacities with the given boom overhang; the necessity of improving the design of the sling in order to make it more versatile, and it would be desirable to have it detachable.

When the booms of self-propelled cranes are connected by a cross-piece and the boom pulley cable system is slackened, a gantry system is formed. With this arrangement, the crosspiece balances the forces arising in the system, and the lifting capacity and stability of the cranes also are significantly increased.

Calculations of the lifting capacity of SKG-30 cranes when their booms are connected by a crosspiece have shown that their lifting capacity with minimum boom overhangs will be increased by a factor of 2-3, and with maximum boom overhangs it is increased by a factor of 7-8.

The lifting capacity of the cranes was calculated starting from the requirement for maintaining the strength assumed in the design of the booms and their haunches (including the axle of the load block of the crane boom). The maximum total lifting capacity of two SKG-30

cranes with 15-m booms connected by a crosspiece is 98 tons. This maximum lifting capacity is achieved by re-equipping the haunch of the crane booms by installing two additional rollers on the upper axle of the block of the load pulley systems, by replacing the hook blocks of the cranes with five-roller BM-50 blocks with a lifting capacity of 50 ton force, and appropriately rethreading the cables of the load pulley blocks.

Paired cranes with booms connected by a crosspiece may be used for raising technological equipment and installing it in the design position on foundations with a height up to 2 m under restricted conditions.

VNIImontazhspestroy developed sketches of crosspieces for the cranes SKG-30, SKG-40, MKG-20 and MKG-25 and also formulated Recommendations for Using Paired Cranes with Booms Connected by a Crosspiece.

One of the methods for increasing the certified lifting capacity of boom cranes is resting the crane boom on a support. In this case, the main load is absorbed by the support, and the crane mechanisms play the role of braces, anchors, and devices for raising the load and moving the support.

Verifying calculations for the cranes SKG-30 and SKG-40 show that their lifting capacity with all overhangs when the 30 m long boom rests on a support may be increased to 50 tons - that is, three times more than the certified lifting capacity when the crane is operating in the usual way. In order to re-equip the crane, it is necessary to replace the hook yoke with a BM-50 block, to install two additional rollers on the boom haunch, and to rethread the load cable.

When erecting the equipment for the dilute nitric acid installation of the Voskresenskiy Chemical Combine, three pieces of tower-type equipment with a weight of 75 tons, a height of 46.5 m, and a diameter of 3.2 were raised by SKG-40 cranes with supported booms.

There is a stock support with a weight of around 8.5 tons which is a tubular construction consisting of a welded upper crosspiece, two legs made from tubes with a diameter of 426 X 10 mm, and a horizontal tierod located at a distance of 1.5 m from the base. The support legs are made in sectional pieces so that the supports may be assembled for booms with a length of 20, 25 and 30 m. The supports are made in the form of A-shaped supports which have a spread of 5.5 m at the base along the axes of the tubes.

The supports are raised in the following way: the crane lowers the boom to a horizontal position, and the upper crosspiece of the support is fastened by means of a pin to the boom haunch. After this, the support crosspiece is slung on the hook of a second crane and is raised to an angle of 55° . From this position, the support is raised by the boom block and tackle system of the crane itself. The support for the second crane is raised by the first crane having the support suspended from its boom. The length of the load cable on the cranes was increased to 260 m.

Because of the restricted conditions of the erection area, the pieces of equipment were laid out at an angle to the axis of the foundations before raising them. The SKG-40 cranes were set up with their axes aligned. At the site where the cranes and supports were set up, the area was levelled by a bulldozer, and in order to prevent sinking of the ground crossbars, and reinforced concrete slabs were laid under the caterpillar tracks and supports.

Each crane with a supported boom was tested by loading 48 tons on the hook with a simultaneous deflection of its loaded pulley block from the vertical of 5° in the plane perpendicular to the boom, and 4° in the plane of the boom. Before starting to raise the load, the crane supports were raised a little so that there was a clearance of 30 mm between the support base and the plates under the supports. When the load was taken up, the supports settled down on the plates which ensured operation of the crane booms in a compression state.

After the tests, the equipment was slung from the dummy fittings and, with synchronous operation of the two cranes, simultaneously raising the equipment, the equipment was raised to 80°. When the equipment passed through the neutral position, the bottom of the equipment was smoothly lowered by the braking guy wire until the equipment was in the vertical position. After this, the equipment was set on the anchor bolts and fastened to them. After all three pieces of equipment were raised, the A-shaped supports were lowered to a horizontal position and disconnected from the crane booms.

About three machine-shifts of the pipe layers and 72 man-hours of work by the rigger crews was expended in re-equipping the two cranes, assembling and raising the two supports, and installing them in the design position. The length of time for raising each piece of equipment itself was around 1.5 hours. The amount of labor expended in the remaining preparation operations was insignificant.

In a number of chemical constructions, only self-propelled boom cranes were used for erecting the large-scale pieces of equipment. In particular, erection of the equipment for the large factories at Kryma, Rovno and Sumakh was accomplished using such cranes.

While there was a considerable number of self-propelled boom cranes at the sites, the lifting capacity of the SKG-63 cranes which were the heaviest duty cranes available was less than that required for raising and installing the equipment casings in an assembled form on the set of shelves with a height of around 9 m. This set of shelves is where the equipment was located in two rows, and for the second row the radius of action for the crane boom was 18 m. All the mechanical-erection operations for the technological equipment, the gas conduits and the technological pipe systems were completed at the Krymskiy and Rovenskiy plants in 9 months, and at the Sumskiy Chemical Combine the work was completed in 7 months instead of the 24 months based on the standard.

Moreover, in each construction they were obliged to complete the preparation of the 3,116 ton technological equipment which was large in diameter. This work was carried out at the concreted areas associated with the objects in parallel with the raising of the foundations and pedestals.

At the Krymskiy plant, the first job to be done was the construction of the units for sulfuric acid production with the finishing of pieces of equipment with a diameter from 4.5 to 6.5 m. At this stage, truck-mounted cranes were used for assembling the sheet-steel cylinders, and K-161 and MKG-25 cranes were used for assembling the erection units [21]. The erection of the large-scale technological equipment at the Krymskiy plant was accomplished for the individual sections under the following conditions.

The furnace section. The raising of the pedestals and the erection of the five KS-200 furnaces, five waste-heat boilers and ten dry electric filters OG-4-16 was carried out simultaneously from the first to the last axis before raising the building. In order to make optimum use of the SKG-63 crane, it was decided to delay the construction of the pedestals under No. 5 and 6 electric filters. Such an erection scheme made it possible to shorten the erection of the electric filters by 4 - 5 months. As the pedestals were completed, the large-block erection of the furnaces was carried out using the SKG-63 crane. The waste-heat boilers were assembled in parallel using the MKG-25 crane from panels of the boilers. Drums with a weight of 12 tons were installed in the upper area of these boilers. Following the erection of the furnaces and waste-heat boilers, the metal framework of the building was erected. The floors and ceilings, and the equipment inside the building, all were erected using a MKG-25 crane "by itself". In order to do this, completion of the foundations under the blowers was delayed. The metal structures, and grouped cyclones assembled in two units together with the insulation, were erected in the same way. The units of the dry electric filters, which were erected at the time the pedestals were completed, were erected using SKG-63 and MKG-25 cranes. The pieces

of the metal structure of the waste gas canopy and collector were erected last. Special attention was paid to preparing a front for the companion workers to work on: the cases of the furnaces and waste-heat boilers were sheathed, and then they were turned over to workers who lined them with brick.

Wash section. At the zero mark, on the design site, without waiting for the foundations to be finished, the acid collectors were installed, and then they were provided with chemical protection. The pedestals which were around 9 m high under the equipment and around 10 m high under the spray coolers were constructed simultaneously.

By the time the construction of the foundations reached the 9 m mark, the pieces of equipment had been completely prepared at a site near where the equipment was being installed. Eight ShMK-9.6 electric filters and four wash towers were installed on the pedestal and moved to the design position using a SKG-63 crane with a 30-m boom. The antegmite coolers were assembled in stacks. Non-standard inserts were manufactured for erecting the cast-iron acid piping: The gas conduits were erected by using reinforcing units.

The drying-absorption section. The anhydride coolers which are vertical heat exchangers with a diameter of 4.4 m were assembled to a lifting weight of 45 tons in order that one could complete the assembly and roll the bundles of tubes to the design site. After the chemical protection was applied to the pedestal, the drying towers, fuming sulfuric acid and monohydrate absorbers (diameter 6.5 m, height 14 m, and lifting weight 41.6 tons) were installed using paired SKG-63 cranes on the edge of the pedestal, and they were moved along special routes to the design foundations. The spray catchers with a diameter of 6.5 m and a height of 20 m, and also the anhydride coolers and blow-off towers were set up directly on the design site.

The large-block erection also enables one to shorten the time for the main pieces of equipment of the section to be given chemical protection.

The sections of the cast-iron spray coolers with dimensions of 9 X 4.5 X 0.5 m and a weight of 12 tons were erected after the builders completed the pans and the devices for chemically protecting them.

The equipment of the contact-compressor section was erected in large units using a SKG-40 crane which serviced the entire section.

The gas conduits were erected as large subassemblies which were assembled to include the accessories and lens compensators.

The erection cranes were secured to specific objects and carried out their operations in accordance with the graph. This expedited the maximum loading of the cranes. The cranes were used by the builder of the sulfuric acid plant at 20.6% above the standard loading.

It was necessary for the builder of the sulfuric acid plant at the Sumskiy Chemical Combine to complete the mechanical-erection operations in shorter times than those which were actually achieved when the Krymskiy plant was constructed. Therefore, it was necessary not only to increase the number of self-propelled boom cranes, but also to introduce substantial changes in the methods of finishing and erecting certain large-scale pieces of equipment.

In the furnace section the erection of the furnaces, waste-heat boilers, and gas conduits within the building, and also the erection of the metal structural members and the pre-cast reinforced concrete was carried out using a BK-300 tower crane instead of a SKG-63 caterpillar track crane. Using the tower crane enabled them to build all the pedestals and foundations within the building and in front of the building without any delays. This speeded up the completion of the construction and erection operations.

The erection of the cyclones and dry electric filters was handled

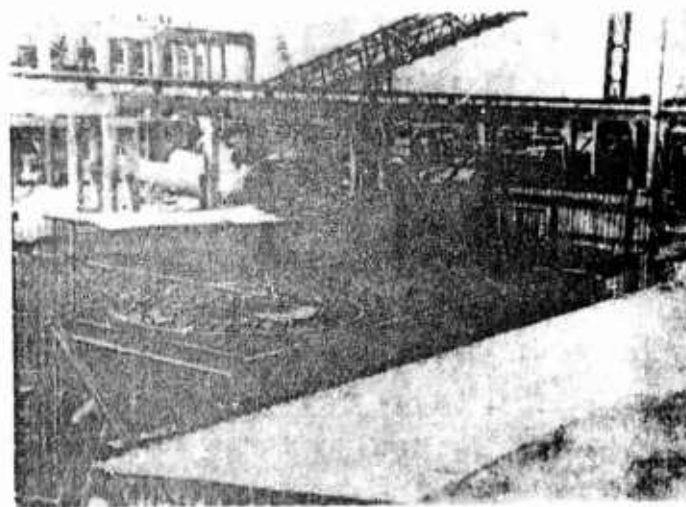


Fig. 25. Stands for assembling and soldering the units of the lead precipitator electrodes of ShMK-9.6 electric filters.

by caterpillar track cranes.

In the wash section, because the construction work on the pedestals which were around 9 m high was lagging way behind, it was proposed that the preparation and erection of the complicated and time-consuming systems of the lead precipitator electrodes of the eight wet ShMK-9.6 electric filters under the 12 large-scale pieces of equipment be accomplished in the form of completely finished erection units with a weight of 15 tons.

In order to put together the lead units, an area near the building for the living quarters of the wash section was concreted over. A temporary building was constructed for preparing the lead hemihexahedrons of the precipitation electrodes, and metal stands were set up for assembling and soldering the units (Figure 25). The finishing up of the hemihexahedrons was done as usual, manually on wooden templates with the edges framed by metal angle brackets.

The lattices were assembled from two halves on an open concrete area. The tightness of the lead lining and the soldering was checked in a tank.

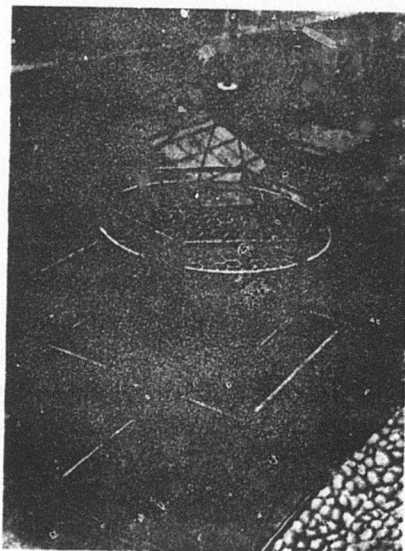


Fig. 26. The stand and lead precipitator electrode unit at the beginning of raising the unit.

The finished lattice was laid on the stand, and they began to assemble and solder the lead hemihexahedrons to the lattice and to each other.

The finished unit of the precipitator together with the stand was placed on a trailer and delivered to the site where it was to be raised. Then the stand together with the unit was lifted off the trailer and set down at the site where it was to be lifted by the SKG-63 crane (Figure 26).

The method of preparing and erecting the system of lead precipitator electrodes of the wet ShMK-9.6 type electric filters using completely prepared erection units speeded up the erection of each electric filter by 1.5 months. It also ensured the high-quality assembly and soldering of the units under conditions which were convenient for carrying out these operations on a stand. It lightened the labor

of the workers, it increased their productivity, and it reduced the cost of the operations.

In order to speed up the assembly of the steel casings of the electric filters and wash towers, they carried out the assembly of these elements not only on the concrete area used for the assembly of the equipment for the wash section, but also in the equipment storeroom. Large sections of the casings were sent from the storeroom to type T-30 welding stands which were being serviced by a welding gantry with a suspended cabin for the welder, the control panel for the stand, a welding tractor and a device for sucking up the flux. The height at which the cabin is suspended is adjusted depending on the diameter of the equipment.

The use of the equipment storeroom in the drying-absorption section for the assembly of the pieces of equipment also contributes to the speeding up of the operations.

All the casings of the equipment of the wash section and the drying-absorption section were welded on the welding drive stands simultaneously by two welding tractors TS-17r. One of the welding tractors is located in the cabin of the gantry, and the other welding tractor is located inside the unit being welded at the root of the seam being fused. Automatic welding from the outside is performed in two passes. The welding procedures were selected so that the welding from the outside and from the inside of the equipment could be conducted at the same speed. The welding process from the inside of the equipment is finished in half the time; therefore, the welder performing the welding inside the equipment proceeds to weld the bottoms which are assembled side by side at the site.

Monitoring the tightness of the welded seams is done at the same time the welding is done on the stand. This eliminates the need for expending additional time and money in constructing ladders and scaffolds. The welded casings of the equipment after testing for tightness are lowered by crane from the stand and are set up so that the

bottoms can be welded to them. This welding is done using a TS-17r welding tractor which is specially equipped for welding angular circular seams.

The automatic welding is done under a layer of flux using direct current with a reverse polarity. The power supply source for the welding arc is a PSM-1000 or a PSO-500 welding generator. The welding wire SV-08A with a diameter of 4 mm and the flux AN-348 A are used. The work is performed by four welders.

Such a technological process for the welding operations ensures performance of 87% of the welding by the mechanized method. With automatic welding, 137 man-days (without manual welding which required 76.6 man-days) were required for the 26 pieces of large-scale equipment with a total length of the welded seams of 7,289 m. This was 34 calendar days using two work shifts instead of 1,001 man-days required with manual welding.

The productivity of the workers using automatic welding was increased in comparison with manual welding by a factor of 4.3. The automatic subwelding of the seam roots ensured a high quality of the welding and produced welded joints with a geometry suitable for lining the equipment with bricks without mechanical machining of the welded seams. Because of this, the time-consuming operation of dressing the 4,858 m welded seams, which would be required after manual welding, was eliminated. This resulted in a savings of 1,218 man-days. The economic savings resulting from introducing automatic welding was 27,000 rubles.

In order to more effectively use heavy-duty self-propelled boom cranes in industrial construction, many foreign firms have equipped their cranes with interchangeable working systems: a tower-boom; folding and telescoping booms; booms equipped with a travelling load carriage, with telescoping and hinging counterweights (counterbalances), with hydraulic outriggers, etc.

In order to shorten the time for moving the cranes around the construction site and for transporting them, their travelling speeds have been considerably increased. At present, travelling speeds of 60 km/hr are achieved for pneumatic-tired cranes.

The maximum lengths of booms being manufactured for cranes is 160 m, and the load hoisting speed is 30 - 40 m/min.

Extension booms, usually of a tubular construction, are made from high-strength steel. The sections of the boom are joined by means of connecting sleeves and joint pins. This provides convenient, rapid assembly, and high strength of the boom. The diagonal struts together with the boom sectional elements of tubular booms are connected by special connecting pieces.

Extension booms frequently have an intermediate countershaft fastened to the lower sectional elements of the middle part of the boom. This arrangement provides a more uniform distribution of the load between the sections, especially when raising the boom from a horizontal position. This arrangement also significantly attenuates the boom vibrations which arise during its operation.

Pneumatic-tired cranes, since they are the most maneuverable, have been ever more widely used for carrying out construction-erection operations in foreign countries. A number of firms manufacture pneumatic-tired cranes with a lifting capacity up to 500 ton force. Thus, the West German crane-construction firm "Paul Rosenkranz" manufactures pneumatic-tired cranes having a lifting capacity of 500 ton force with a main boom length of 25 m. The maximum height to which the hook can be raised when the crane is equipped with a tower-boom arrangement is 160 m, and the associated lifting capacity is 10 ton force. The crane has eight axles of which six are driving axles. These eight axles enable the load to be uniformly distributed over a large support surface. The large range of the load-height characteristics of the tower-boom arrangement enables the crane to be used for the construc-

tion of tall buildings, for erecting equipment on the floors of buildings under construction, and to raise metal frameworks for very tall pipes, radio towers, etc.

In England a truck-mounted crane with a lifting capacity of 250 ton force was created which has a main boom length of 21.5 m, and a radius of action of 5.5 m. When an extension boom with a length of 98 m is installed, the crane is able to lift a load with a weight of 1.4 tons in a radius of 91 m. The maximum lifting height when a 24.5-m long flute is used is 122 m. The lifting capacity of the new crane with a given radius of action or the radius of action with a given load is two times larger than for other existing truck-mounted cranes with a large lifting capacity. The crane mechanisms are driven by a six-cylinder diesel engine of 325 hp equipped with a hydraulic converter.

A 525 hp engine and a six-speed transmission with a servodrive for the shifting mechanisms is used for driving the truck.

In the construction of industrial enterprises, when it is necessary to erect individual large units whose weight exceeds the certified load characteristics of the available erection cranes, special devices are used which enable one to temporarily increase the lifting capacity of the cranes when they operate with long booms having long overhangs. The methods being used for increasing the load characteristics of cranes enable them to increase the lifting capacity of cranes with minimum boom overhangs by a factor of 1.8 - 2, and with maximum boom overhangs the lifting capacity is increased by a factor of 6-8 when the height of the boom arrangement is as much as 60 - 80 m.

The American erection firm "American Hoist & Derrick Co." in 1930 delivered, for the construction of the Magnitogorskiy Metallurgical Combine, the self-propelled cranes "Industrial". This crane with a lifting capacity of 45 ton force is based on a cater-

pillar track crane and was set on a railroad car. A self-propelled derrick-crane was created by installing an additional mast on the rotating platform of the crane at the point of the boom mounting. A boom-supporting system was fastened to the top of the additional mast. Such a system for suspending the main boom of the crane sharply reduced the compression loads in the boom, and by increasing the number of cables on the load-lifting pulley block system they were able to increase the lifting capacity of the crane by a factor of two. The additional mast was unfastened during the periods when they raised a load using four or six wire-braces which were fastened to ground anchors. The raising and installing of the additional mast was done by the main boom of the crane.

With such an operating scheme, the possibility was maintained for carrying out three operating movements using the crane: raising a load; changing the overhang of the hook; and rotating the crane platform. The possibility of rotating the crane platform was ensured by lining up the top of the mast with the axis of rotation of the crane and by the presence of a rotation haunch for the additional mast. The stability of the crane was increased, since the tilting loads are absorbed by the temporary guy wires. When the wire-braces are removed, the crane is able to travel.

The equipping of the self-propelled cranes with a mast-boom arrangement is possible because of the margin of strength which is available in the design of the rotating platform and in the travelling caterpillar track carriages of the cranes, and also by the power reserve and the cable capacity of the load winches of these cranes.

The American firm "Manitovok" incorporated the proposal of American erectors and manufactured heavy-duty cranes with a support device which enabled them to considerably increase the lifting capacity of a self-propelled crane by installing a special support-rotation ring on the travelling frame and by shifting the place where the crane boom is fastened to a frame which extends beyond the main section. A crane which has a maximum certified lifting capacity of 150 ton force with the main boom, when equipped with this device, has the load

moment of the crane increased by a factor of two with small overhangs and by a factor of four with significant overhangs. This enables the crane to lift 300 tons with a small overhang. When this crane is equipped with an 81-m long boom, its lifting capacity with a minimum overhang is 50 ton force. In connection with this, the crane can rotate through 360° . Using the support-rotation ring and the extended frame increases the angle between the crane boom and the boom supporting system which ensures a reduction of the compression forces in the boom. With this arrangement, the stability of the crane is increased, and the loads are transferred from the boom directly to the ground.

The increase of the crane stability is achieved by equipping it with an additional 25-ton counterweight, the lower part of which moves along the support ring.

The attempt by foreign firms to increase the lifting capacity of existing cranes was caused by the desire to make maximum use of existing crane equipment without investing considerable additional capital. By improving the load characteristics of the cranes, the West German firm "Bamag" manufactured pneumatic-tired cranes with an extended boom. A special extension support was fastened by a hinge to the rotating crane platform. The special extension support has a pad with a support-rotation device for the boom. The pad is set up on the ground on a prepared base. The boom is fastened to the upper part of the pad through a hinge which enables the boom overhang to be changed. The support-rotation device enables the crane boom with the raised load to be rotated through 360° . The rotation of the boom is accomplished by moving the crane with the platform on the radius around the support base. Because of this, the crane is able to perform three working operations: raising a load; changing the boom overhang; and rotating the boom. The operating scheme of the crane using outriggers provides an increase of its lifting capacity from 20 to 40 ton force. In order to increase the load moments of cranes with long booms, the firm "America" used an additional counterweight mounted on a pneumatic-tired

chassis and fastened to the rotating crane platform. The counterweight is a metal tank filled with water immediately before raising the load. After completing the work, the water is drained off and the counterweight is easily transported to the site of the new anchorage for the crane.

In order to improve the load characteristics of self-propelled caterpillar track cranes of the designation PH 670, another American firm manufactured a special caterpillar track carriage, the frame of which can be extended from 3.4 to 5 m. This ensures an increase of the support contour and load moment when the crane is operating. This operation is accomplished by raising one caterpillar track of the crane by means of jacks and sliding in a 0.8-m caterpillar track carriage by means of horizontal jacks. The same operation is repeated for sliding in a second caterpillar track carriage. Besides creating heavy-duty self-propelled cranes and special fittings for cranes of lesser lifting capacity, foreign firms have widely introduced various schemes for the simultaneous operation of several cranes in order to raise heavy large-scale equipment and structures. An analysis of modern, foreign crane building shows that the main crane improvements are:

- considerable expansion of the production of pneumatic-tired cranes with an increase of their lifting capacity;
- an increase of the mobility and maneuverability of pneumatic-tired cranes by increasing their travelling speed to 60 km/hr; creation of tires of increased carrying capacity and elasticity; the use of a hydraulic system for controlling the steering of the wheels and for setting up the extension supports;
- further expansion in the use of self-propelled boom cranes by equipping them with a variety of interchangeable operating attachments, among them those permitting one to temporarily increase the lifting capacity and to improve the load-height characteristics of the cranes;
- a further reduction of the weight and an increase of the reliability of the assemblies and units, including the boom, by using alloyed steels and special rolled shapes;

— broadening the support base of the cranes by using an elongated chassis for pneumatic-tired cranes which have from four to eight axles, and by using high-speed extension supports which provide a large support contour and high stability;

using new operating schemes for the cranes, including the combined simultaneous operation of 4 - 6 cranes for erecting large-scale heavy equipment and structures.

In technically advanced capitalistic countries, the raising of pieces of tower-type equipment and horizontal pieces of equipment which are being set up on low foundations or at high marks in the design position is mainly carried out by self-propelled boom cranes which are mounted on caterpillar tracks, pneumatic tires, or on trucks. In foreign operations, the same as in domestic practice, heavy pieces of equipment are raised by two or more cranes.

Some firms employ synchronous operation of both cranes with control of the drives from the cabin of one of the cranes, and sometimes they connect the travelling carriages of these cranes by a rigid frame. The availability of self-propelled erection boom cranes of large lifting capacity enables one to shift to more mobile erection methods. The recently constructed petroleum refining plant in Puerto Rico may serve as an example. All the technological equipment which had a diameter up to 5.5 m, a height up to 53 m, and a weight up to 200 tons was erected with the help of two boom cranes with a lifting capacity of 200 ton force.

A petrochemical complex was constructed at this same plant. The facilities for producing ethyl benzene include reactor towers with a height of 86.6 m, a diameter of 6 m, and a weight of 675 tons. Because of the large weight and the impossibility of delivering them to the installation site in a completely assembled form, the towers were erected from separate, finished, large units which were raised and installed in the design position by means of a caterpillar track crane.

The equipment with a diameter of 6.75 m, a height of 51.8 m, and a weight of 510 tons which is used for the cracking process with steam was designed for the production of ethylene at the Marafonskiy Chemical Plant in West Germany. This equipment was erected from large finished units. The large units were erected with the help of pneumatic-tired cranes.

However, examples of the erection of tower-type equipment in foreign countries using consolidated units are rarely encountered: all the firms tend to deliver to the construction site completely finished pieces of equipment independent of their overall size and weight.

In an American operation, towers with a weight of 109 tons and a height of 15 m were installed on a pedestal around 4 m high by one model 4,000 W "Manitovok" crane. This crane is noteworthy for its widely spaced caterpillar tracks, open-skeleton tubular boom, and high crane gantry. The load holding device of the crane is made in the form of a curved shackle. The slinging of the equipment is accomplished by means of cable slings through loops which are welded into the upper bottom.

If the equipment because of its height and diameter can not be raised by a single crane with a sling fastened to the top, then the raising is accomplished by attaching the sling to one side of the casing. In this case, the equipment at the final stage of the raising hangs with a certain inclination to the vertical, and it is more complicated to set it down on the foundation. In the same way as is done when the sling is attached to the top of the equipment, an auxiliary boom crane is used for moving the support part of the equipment to the foundation when the equipment is raised with the sling attached to the casing.

An attempt to expand the limits of the effective use of boom cranes led to the widespread use of several cranes simultaneously for the erection operations when raising and installing pieces of tower-

type equipment and other tall pieces of equipment. In the majority of cases, two boom cranes are used. In foreign operations, as distinct from domestic operations, when paired cranes are used for raising and installing equipment only the skidding method is used. With this method, a third additional crane is used in the majority of cases for moving the support part of the equipment to the foundation during the raising process.

In foreign countries, they do not use balancing crossarms when raising pieces of tower-type equipment using paired frames with the sling attached to the casing above the center of gravity. Therefore, uneven loading of the cranes occurs. In order to reduce this loading nonuniformity, in individual cases they increase the distance between the places for attaching the sling along the equipment diameter. In this respect, hoops, collars and cableless slings are of interest.

The method being used by Canadian erectors for using paired cranes when raising and installing tall structures being set up for equipment and pipe systems is of interest. A balancing crosspiece is used for attaching the sling to the set of shelves.

When erecting equipment by building up individual units, the sling is attached to the top of the equipment using a balancing crosspiece.

When raising equipment to a limited height, the sling for the equipment unit is attached to erection fittings on the casing just a little above the center of gravity, and the overhang of the fittings is sufficient for spacing the lower load blocks of the cranes. The load blocks are frequently fastened to the fittings without the use of cable slings by means of connecting release shackles.

THE ERECTION OF EQUIPMENT USING TOWER CRANES AND GANTRY CRANES

At the Voskresenskiy Chemical Combine local conditions (previously erected metal pliers for the pipe system and shelves and also the reinforced concrete pedestals for the heat exchangers which were in front of the large-scale pieces of equipment which were to be erected) did not permit them to use the standard plan for erecting equipment using rigging masts. Because of this, methods were developed for raising large-scale technological equipment and the metal structural units of the conversion, purification and ammonia synthesis sections with the help of a BK-1000 tower crane (lifting capacity 50 ton force with hook overhangs from 12.5 to 20 m) which was provided for operational needs. This enabled them to avoid the use of rigging devices as called for in the standard plan.

All the units of the technological equipment (around 150 pieces), with a total weight of more than 2000 tons, and also around 37 km of technological piping were erected using the BK-1000 crane. The large-scale pieces of tower-type equipment were erected mainly in the assembled form. Erection of the following units created the greatest difficulties: the two carbon monoxide converters with a height of 19.5 m, a diameter of 4 m and a weight of 50.3 tons; the two synthesizing towers with a height of 18.6 m, a diameter of 1.23 m and a weight of 73.4 tons; and the two copper ammonium scrubbers with a height of 15.8 m, a diameter of 1.28 m and a weight of 77.8 tons.

The complication in erecting the carbon monoxide converter involved the fact that the axis of the converter pedestal was located at a distance of 28 m from the crane axis. With such a hook overhang, the lifting capacity of the BK-1000 crane was only 34 ton force - that is, it was 1.5 times smaller than was necessary for raising the converter. A method was proposed which would allow one to raise and install the carbon monoxide converter in the design position with the help of the BK-1000 crane.

Before raising, the equipment was laid across the crane path,

the spot where it was to be installed. The equipment was slung by the "boa constrictor" method using a circular sling at a distance of 13.5 m from the base of the equipment. The location of the sling was determined by calculations based on the conditions for decreasing the hook overhang to 20 m. With such an overhang, the crane has a lifting capacity of 50 ton force. By slinging the equipment using the "boa constrictor" method at the selected site, they ensured that after the equipment was lifted from the ground it would hang at an angle of 35° to the vertical - that is, in connection with the deviation of the top of the equipment from the crane tower, the projection of the equipment base on the horizontal plane would be at a distance of 6 m from the projection of the spot where the sling was attached. In this way the overhang of the crane hook when installing the equipment on the pedestal was reduced to 8 m (6m because of the inclination of the equipment and 2 m because of the radius of the base). Using the BK-1000 crane, the equipment was raised from the initial position to the vertical position, then by extending the crane tower - the converter was raised above the pier of the metal structure which is located between the equipment pedestal and the crane tracks. When this is done, the converter is in an inclined position - that is, the base is towards the place where it is to be installed and the top of the converter is towards the crane tower. By increasing the hook overhang to 20 m, the base of the equipment was brought to a position over the pedestal in such a way that its lower rim was located above the support ring edge closest to the crane. This support ring had previously been installed on the pedestal. A catcher was prepared for making it convenient to install the equipment on the support ring. The catcher consisted of a horizontal 20-mm thick plate in the form of a dovetail which was fastened to the support ring, and a vertical plate welded to the lower part of the equipment casing. In lowering the equipment onto the pedestal, the vertical plate entered the slot of the dovetail and in this way the catcher was engaged. The catcher prevented the equipment from rolling along the support ring during the process of guiding the equipment to the design position. After the catcher locked, the equipment is turned to an angle of 70° to the horizontal by increasing the hook

overhang to 20 m, the base of the equipment was brought to a position over the pedestal in such a way that its lower rim was located above the support ring edge closest to the crane. This support ring had previously been installed on the pedestal. A catcher was prepared for making it convenient to install the equipment on the support ring. The catcher consisted of a horizontal 20-mm thick plate in the form of a dovetail which was fastened to the support ring, and a vertical plate welded to the lower part of the equipment casing. In lowering the equipment onto the pedestal, the vertical plate entered the slot of the dovetail and in this way the catcher was engaged. The catcher prevented the equipment from rolling along the support ring during the process of guiding the equipment to the design position. After the catcher locked, the equipment is turned to an angle of 70° to the horizontal by increasing the hook overhang of the crane. Further rotation on the support ring to the neutral position (an angle of 77° to the horizontal) is accomplished with a help of a tractor pulling on a guy wire fastened to the circular sling. When the equipment approaches the neutral position, a braking guy wire which ensures that it is set down smoothly on the pedestal comes into play.

The crew of erectors took about 1 hour in raising and installing each carbon monoxide converter in the design position. Around 12 man-days were expended altogether in the preparation operations for raising each piece of equipment. The labor productivity of the erectors was 4.15 tons/ man-days, that is, 6 - 7 times more than when rigging devices were used.

The erection of the synthesizing towers and copper ammonium scrubbers also presented substantial complications. The synthesizing towers are thick-walled pieces of high-pressure equipment which are subjected to heat treatment, therefore one is not allowed to weld the erection devices to them. When in the design position, each synthesizing tower stands freely on a support pan which is positioned on a welded, 4-arm support frame at a height of 2.7m.

The towers together with the support frame are raised by rotation around a hinge. The casing of the synthesizing tower is fastened to the support pan by means of a collar which is manufactured from two, flat, 20-mm thick rings. This collar is welded to the perimeter of the upper base of the support pan, and is precisely fitted to the tower casing.

The support frame was strengthened by welding on diagonal tie pieces made from 65 X 8 mm angle brackets. These diagonal tie pieces were located in the two planes of least rigidity. The hinge was made from a tube with a diameter of 273 X 10 mm, which was laid in half of a 325 X 10 mm diameter tube which was cut along the generating line. The support tube of a hinge was welded to a support plate laid on the tower foundation. The slinging of the tower was accomplished using a stock circular sling by the "boa constrictor" method at the place where the tower thickens for the upper cover. The equipment is raised to the neutral position (86° to the horizontal) by the BK-1000 crane without the use of a tractor. The tower is set on the anchor bolts with the help of a braking guy wire. The simplicity of the erection technology and fittings enables one to accomplish the preparation and raising of the synthesizing tower in a little more than 4.5 working shifts.

The raising of the two thick-walled copper ammonium scrubbers, which are set up in the design position on a cylindrical all-metal pedestal without fastening the tower to it, was also done by the BK-1000 crane using the method of rotation around a hinge.

The preparation for raising, and the raising of the two scrubbers was done in less than 5 working shifts by a crew of 4 erectors.

The erection of the technological equipment, structures, and pipe systems of the conversion, purification, and ammonia synthesis sections using a single BK-1000 crane proved the high effectiveness of its utilization.

The cost for erecting 1 ton of equipment was reduced from 30.1 rubles when erecting with rigging masts to 4.6 rubles when erecting with the help of the BK-1000 crane, and the labor productivity of the erectors was increased from 0.41 tons/man-days to 2.96 tons/man-days.

The method of increasing the lifting capacity of tower cranes which was proposed by the State Institute for the Planning of Chemical Machinery (Giprokhimmontazh) for erecting nitrogen fertilizer plants is of interest. A special stock device enabled them to increase the lifting capacity of tower cranes by a factor of 2 - 3.

The device consists of a lattice support stand and a crossbar of lattice construction with a span of 41.8 m. The weight of the device is 24.9 tons, and its lifting capacity is 130 ton force. The crossbar of the device is made fast to special hinge supports which have been fastened to the metal tower structure of the BK-1000 crane.

The device enables them not only to lift large-scale heavy equipment, but also to move it in the plane of the device. A tower crane is used for erecting the device and moving it in the erection area. The support (stand) of the device at the moment the equipment is raised is pulled over by guy wires running to stock anchors. Two 130-ton lifting capacity pulley blocks, and a hoisting crosspiece are used for raising and erecting equipment.

The proposed erection scheme enabled them to considerably shorten the erection times and to do away with a large amount of the rigging fittings and masts which are used when erecting nitrogen fertilizer plants.

One of the examples of the effective use of a gantry crane is the erection of technological equipment for the methane and carbon monoxide conversion section of the Shchekinskiy Chemical Combine. With the help of a specially redesigned K-18⁴ gantry crane, the erectors of the State All-Union Construction and Installation Trust of

the Ministry of Construction of Establishments of the Metallurgical and Chemical Industries, USSR (Soyuzprommontaz) erected the equipment for the section in a short time based on the plan of Giprokhimmontazh.

The conversion section is an open, metal set of shelves on which, at various marks, the technological equipment is installed. This technological equipment numbers 170 pieces with a total weight of 1,100 tons. The maximum weight of the heaviest piece of equipment of the methane converter is 48 tons.

The restricted conditions of the erection area and the large width of the set of shelves did not allow them to use self-propelled boom cranes, masts, or other rigging equipment for the erection. The erection of the equipment was carried out with the help of a commercial-type K-184 gantry crane with a lifting capacity of 18 ton force. The travel of the crane over the set of shelves is accomplished by means of a rigid stand at the ± 0.00 mark and by a flexible stand which travels along a fixed path under the crane. This path passes along the upper mark of the set of shelves. The reconstruction of the crane involved reducing the length of the span to 22 m, reducing the height of the flexible support to 8.84 m, and making certain other modifications which were made for the purpose of erection control.

The reconstruction of the crane made it possible for the gantry crane to cover the entire area for installation of the technological equipment and pipe systems, and to increase the lifting capacity (because of the reduction of the crane span and certain modifications of the support) to 45 - 50 ton force.

Use of the reconstructed K-184 gantry crane enabled them to completely mechanize all the operations for installing the technological equipment and the pipe systems tying the equipment together, to reduce the labor expenditure by 13,000 man-hours, to obtain an economic savings of 20,000 rubles, and to shorten the time for the erection by 40%.

THE ERECTION OF EQUIPMENT USING RIGGING DEVICES

The raising and installing of pieces of tower-type equipment on foundations is accomplished in the Soviet Union and in foreign countries using two methods: by cranes, and with the help of rigging devices - that is, masts, gantry hoists, A-shaped supports with block and tackle systems, and winches.

All kinds of modern equipment with a diameter up to 14 m, a height up to 100 m, and a weight up to 1000 tons are erected using rigging devices. With an increase in the dimensions and weight of equipment, the rigging devices were improved and they provide for the raising and installing in the design position of practically any, wholly-assembled, pieces of equipment independent of their weight and size.

Rigging devices are used in those cases when the weight of the equipment exceeds the lifting capacity of a crane. The increased lifting capacity of rigging devices creates, naturally, a margin of reliability and ensures a high degree of safety in the erection operations. However, it increases the cost of the erection. Rigging devices are very widely used in the Soviet Union and in foreign countries, and are constantly being improved. The raising of equipment with the help of rigging devices is accomplished, as a rule, in foreign countries by the skidding method while resting the bottom of the tower on special rollers or carriages.

In order to reduce the stresses when pulling equipment, the bottom of the equipment is moved with the help of a heavy-duty crane equipped with a short boom. The method of rotating around a hinge has not found widespread use in foreign countries, since the characteristics of the load-raising equipment which must be used are very high. If one traces the development of rigging devices in foreign countries, one can establish that the growth rate in the overall size, and especially in the weight, of pieces of tower-type equipment has

periodically outstripped the growth of the technical potential of erection masts. This explains the necessity for using four masts simultaneously, instead of the more efficient use of two masts with a large lifting capacity when raising heavy pieces of equipment.

In 1945 at Krivoy Rog, a complex consisting of two masts with a total lifting capacity of 200 ton force was designed and manufactured. With the help of these masts, tall, mine ram impact machines with a weight up to 200 tons, and their cantilevers with a weight up to 80 tons, were raised and installed in the design position for the first time in the construction of the Krivorozhskiy Mines. Blocks for a pulley with a lifting capacity of 200 ton force were simultaneously designed and manufactured. This pulley system was required for raising the load-transferring crane at the Krivorozhskiy Metallurgical Plant. The crane was raised by four paired 100-ton masts.

The complex of two masts with a total lifting capacity of 200 ton force was used for the first time in 1954 for erecting pieces of tower-type equipment at the Novokuybyshevskiy Petroleum Refining Plant. The equipment was raised together with its service platforms and the pipe systems for tying the equipment together.

When erecting fractionating towers, one of the most time-consuming operations is installing the plates. The labor expended in assembling the plates reaches 70 - 80% of the total labor expended in erecting the tower. The weight of the removable internal devices of the individual pieces of equipment reaches 50 - 60 tons, whereas the weight of the individual elements, based on the possibility of installing them through manholes, is only 50 - 100 k z . Assembling the plates after the tower has been installed on the foundation considerably lengthens the erection time.

In 1956 - 1957, innovators of the Moscow Petroleum Refining Plant, together with erectors, developed and introduced for the first time in this country a technology for assembling the plates in fractionating towers before raising them to the design position.

Experience in the operation of towers erected by such a method has proven the possibility of transferring the operations for assembling the plates and other devices inside the equipment to the manufacturing plants, and delivering the equipment to the construction site in the finished form. This pre-assembled erection method has been put into practice.

For the purposes of shortening the construction times, increasing the labor productivity, and generally reducing the amount of work which must be performed at heights, technology for applying the insulating coating to vertical equipment before raising the equipment to the vertical position has been widely introduced. The raising and installing of insulated vertical equipment was accomplished for the first time in 1956 at the Novokuybyshevskiy Petroleum Refining Plant. Experience in raising the equipment showed that the insulation coating which was made from diatomaceous brick and plaster was preserved completely intact. The expenditure of labor by the insulators was reduced by almost a factor of 2. The construction of vertical supporting structures around the equipment, which is one of the most time-consuming and dangerous operations, was avoided. The total time for constructing the equipment was considerably reduced, since the insulation operations were performed during the period when the foundation was being built. The raising of insulated equipment soon began to be used universally.

The method of erecting completely assembled pieces of tower-type equipment which have been insulated and fitted out with the working platforms and pipe systems is called the "complex" erection method. It has obtained widespread use. During the period 1962 - 1966, around 3,500 pieces of tower-type equipment were erected using this method.

In 1967 the raising of four fractionating towers with a diameter of 4.5 m, a height of 48.3 m and a weight of 300 tons was accomplished for the first time at the Tol'yattinskiy Synthetic Rubber Plant with the help of four lattice masts. These masts were built by the Tallinskiy Machine Building Plant and had a height of

60 m and a lifting capacity of 100 ton force. The towers were erected on 4-m high foundations. The towers were manufactured in a completely finished form in the building slips of the "Krasnoye Sormovo" Plant at Gorky. They were floated along the Volga River, set on pneumatic-tired trailers on the shore of the Kuibyshevskiy Sea, and then delivered along a highway to the erection site which was at a distance of around 10 km. The transport weight of each tower was 265 tons. The raising weight of the tower (300 tons) included the metal structure of the service platforms and the top-section piping which was somewhat spread out in the layout in order that it would not interfere with the free movement of the load pulley blocks. A concrete covering was laid down at the erection site before the towers arrived. Experience in erecting the towers confirmed the necessity of constructing such a foundation base, because such a base contributes to significantly improving the conditions and climate for carrying the lower part of the tower. The sleds were equipped with a hinge device for rotating the lower part of the tower when raising it. In connection with the restricted nature of the conditions at the site, the plane for raising the tower was positioned at an angle of 48° to the axis of the tower unit. The support plates for the masts were set up around the tower foundation on filled soil without any additional preparation. Experience in raising the tower confirmed the possibility of setting up the masts without any additional preparation of the base; during the raising of the tower, no settling of the mast support plates was observed after they received the maximum load.

Each mast was equipped with four main wire-braces and five auxiliary wire-braces. The auxiliary wire-braces were needed to ensure support of the masts when shifting them for raising the next tower.

The raising and installing of each tower took from 4 to 7 hours.

The erection of the tower-type atmospheric equipment with a diameter of 7 m, a height of 44.9 m, and a weight of 365 tons was accomplished at the Novopolotskiy Petroleum Refining Plant using the method of rotation around a hinge [3].

The tower was delivered to the construction site in the form of separate sheet-steel cylinders, whose dimensions satisfied the requirements for railroad clearance. The assembly of the tower units was

done by the work forces of the supplier, that is the Podol'skiy Machine Building Plant, named for S. Ordzhonikidz. Three units were assembled: a "skirt" for the tower with a weight of 19 tons, the lower part of the tower with a weight of 150 tons, and the upper part of the tower with a weight of 180 tons. The units were transported to the erection site on sleds pulled by caterpillar tractors. Each of the tractors developed a pulling force of 50 ton force. The units were rolled to the consolidation assembly site and were laid on a sand base.

Two standard lattice masts with a total lifting capacity of 200 ton force were used as the main load-hoisting devices during the assembly. The operations for joining the units and for fastening the piping systems and technological metal structures to the towers were performed by four crews with a total number of 29 men, among them 5 electric welders.

After completing the assembly, the towers were hydraulically tested. One should point out that testing equipment with such a capacity and length when it is resting on crossbars in the horizontal position entails the danger of causing bending deformations. Assembling the equipment on a compact sand base makes it convenient for completing the butt seams when welding the units, and it also eliminates the possibility of bending the equipment when filling it with water for tests in the horizontal position.

The towers were not thermally insulated before raising because, in order to install thermal insulation on equipment with a diameter of 7 m at the zero mark, one would be obliged to prepare complicated and cumbersome support structures. It is more reasonable to insulate the towers in the design position from the service platforms. For this purpose, they were obliged, before raising the tower, to erect in addition around 15 tons of metal structures, having converted the sector platforms specified in the plan to circular platforms.

In the absorption-compressor installation at the Omsk Petroleum Refining Plant, three heavy pieces of vertical tower-type equipment with a total weight of 280 tons were raised simultaneously. The raising was accomplished with the help of a lattice mast with a lifting capacity of 100 ton force by rotation around a hinge.

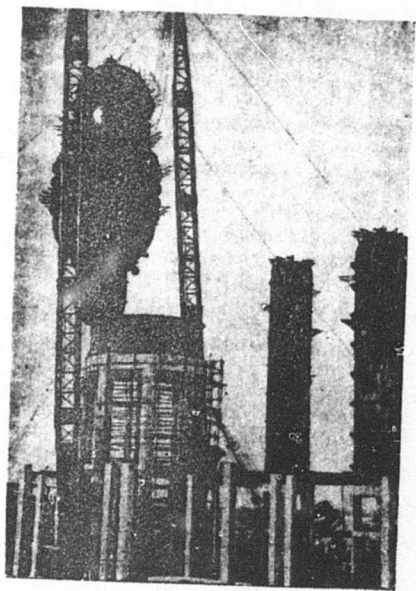


Fig. 27. Erection of thermal cracking equipment using two masts.

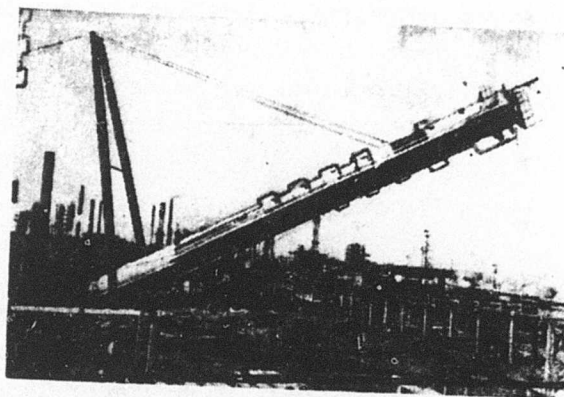


Fig. 28. Erection of equipment by rotation around a hinge with the help of a A-shaped falling support.

The metal structures of the service platforms, the piping tying the system together, and the thermal insulation were installed on the equipment beforehand. With such a raising method, the necessity of constructing two anchors with a large restraining force for the leading wire-braces was avoided. The chimney foundation and the foundation for the equipment of the central gas-fractionating installation were used as the supports.

In comparison with the usual erection method, the grouped raising of three towers enabled them to reduce the labor costs.

A thermal cracking tower with a weight of 180 tons (Figure 27) was raised and installed on a 15.4-m high pedestal at the Kremenchugskiy Petroleum Refining Plant in 1968. The raising was accomplished using two masts built by the Tallinskiy Plant with a total lifting capacity of 200 ton force; however, when the angle of inclination was 12° , the lifting capacity of the masts was 170 ton force.

According to the plan for the operations they proposed to raise the equipment in two halves, but a check based on calculations showed the possibility of raising the equipment in an assembled form. The erection operations were performed in this way with a reduction in the labor costs of 49.5%. The saving in wages was 2,147 rubles, and the saving in the cost of operating the mechanisms was 3,530 rubles. Thus, the total saving as a result of erecting the tower as a single unit was 5,677 rubles [22].

In 1963, for the first time in any erection operation in the world, two fractionating towers with a height of 56.5 m and weights of 250 and 300 tons were raised by the rotation method at the Moscow Petroleum Refining Plant. Before raising the equipment, it was completely assembled with the plates, tested, insulated, and equipped with the service platforms and pipe systems. The equipment was raised and installed with the help of a A-shaped falling support with a height of 36 m. The A-shaped support was made from tubular masts which were available at the site (Figure 28). Raising the equipment proved the possibility of constructing, at small costs, anchors with a holding force on the order of 200 tons which are made from partially sunken containers filled with water. The rotation method with simultaneous raising of two or more pieces of vertical equipment was also accomplished at Omsk and at Shchekino.

Even the first raising of vertical equipment using the rotation method proved that, in order for this method to be widely used, it would be necessary to prepare low (a height of from 1 to 2 m) foundations under the equipment with anchor bolts removable from the connecting pieces. The last requirement substantially reduces the costs for installing the hinge and, in a number of cases, eliminates the necessity of strengthening the support part of the equipment.

For raising and installing in the design position pieces of equipment with a weight up to 365 tons and a height up to 70 m, they usually use two lattice masts built by the Tallinskiy Machine Building Plant or similar masts with a height up to 62 m. Each mast is equipped with a 100 to 130-ton hoisting pulley system with a drive from an electric winch with a pull of 10 - 12 tons. Some erection organizations use for this purpose gantry hoists developed by TsPKO * Glavkhimmontazh or

*This may designate Central Design & Construction Section

similar gantry cranes with a height up to 60 m and a lifting capacity up to 200 ton force.

However, the growth of petroleum refining and the petrochemical industry have called for the use of larger technological facilities which operate at higher pressures and temperatures. The increase of the capacity leads to an increase in the dimensions and weight of the equipment and also in the number of pieces of equipment.

In order to install heavy pieces of equipment at ground level and on low foundations, one may very effectively use the method, developed in the USSR, of rotation around a hinge with the use of a A-shaped falling support. When raising grouped equipment, the equipment which has been previously erected is used as the erection masts. An outline study made by VNIImontazhspetsstroy of one variant for raising and installing equipment with a weight of 500 tons, a height of 30 m, and a diameter of 3 m with the help of an A-shaped, 30-m high, falling support and two block and tackle systems with a lifting capacity of 150 ton force, which were fastened to anchors, proved the effectiveness of such a solution [23].

Other variants for raising and installing heavy pieces of equipment are possible.

In both domestic and foreign operations, wide use is made of gantrys. Thus, when raising reactors with a height of 33 m, a diameter of 3 m, and a weight on the order of 500 tons for hydraulic cracking installations in California, gantry hoists were used which consisted of two masts connected by a crossbar which was part of the original construction. In order to prevent bending moments from arising in the gantry upright supports, the crossbar rested on the mast haunches on hinges. In order that the crossbar have a stable position on the mast haunches, the crossbar is given the shape of a broken line, so that the crosspiece member to which the blocks of the hoisting pulley system are fastened is positioned at a lower level than the crossbar hinge supports. Each upright support of the gantry is maintained in a vertical position by four wire-braces. The two load pulley systems were balanced using a crossarm. This crossarm is fastened by means of a hinge to a holding device connected by bolts to a fitting on the reactor neck. After the reactor has been installed, the holding device is removed and bolted to the reactor

which is to be raised next. Each load pulley system is threaded with a cable which has 16 working strands, and the pulley systems are fastened by links, with the block at one end linked to the gantry crossbar and the block at the other end linked to the balancing crossarm. The reactors are raised directly from the railroad cars.

A similar scheme for raising equipment with a weight up to 400 tons was developed by TsPKO Glavkhimmontazh. In order to raise and install such pieces of equipment with a height up to 30 m, one may use, as the gantry upright supports, Tallinskiy masts with a height up to 40 m, the upper sections of which are connected by a crossbar.

In order to avoid the effect of a bending moment acting on the masts, the Japanese firm "Chiyoda" uses masts with a hammer-type haunch which ensures their centered loading. Two load pulley systems balanced by a crossarm near the spot where the equipment is slung are fastened to the haunches. Using two such masts with a height of 40 m, equipment with a weight of 210 tons, a height of 52 m, and a diameter of 5.5 m was erected in Japan using the skidding method.

The American firm "Fluor" when erecting reactors for hydraulic cracking facilities has used, in a number of cases, a hoist made from four masts. Thus, the hydraulic cracking reactors with a height of around 30 m and a weight of 440 tons with a wall thickness of 175 m were installed by this method at a petroleum refining plant. The reactors were delivered from the manufacturing plant to the construction site by railroad. Four masts, each with a height of around 44 m, were used for raising the reactors. The masts were positioned in pairs along both sides of the equipment foundation. The tops of the masts were connected by tie rods. Eight wire-braces were used to hold the masts in the vertical position. The load pulley systems which are hung from each pair of masts arranged in a row were balanced with a crossarm. The two upper crossarms were fastened to the transverse crossarm. The middle section of this transverse crossarm was connected by a clamping device to the exposed end of the reactor. The weight of the load pulley systems and balancing crossarms was around 24 tons. When raising the reactor, its base was moved on sleds along rollers by means of a boom crane.

In another case, this same firm installed heavier reactors, with a weight of around 500 tons each, for a hydraulic cracking facility. The reactors were delivered from the machine building plant on two railroad flatcars with a lifting

capacity of 565 ton force. The reactor had a diameter of 3.6 m, a height of 30 m, and a wall thickness of 177 mm. Each of the four masts used for erecting the reactor had a height of 45 m, and was equipped with a 19-strand pulley system which was threaded with a 25.4-mm diameter cable. A holding device for the sling was fastened by bolts to the reactor neck. The masts were supported by wire-braces made from 32-mm diameter cable with an average length of 60 m. Four winches with internal combustion engines provided the drive for the load pulley systems. The boom crane which moved the base of the reactor had a lifting capacity of 110 ton force. Previously, American erection firms also resorted to using four masts for raising very heavy pieces of equipment. The firm "Fluor" recently used a complex consisting of two lattice masts, instead of four masts, for raising hydraulic cracking reactors with a weight up to 600 tons. In isolated cases, American firms have used two paired gantries. Thus when raising six reactors which were being installed in a row for the isocracking facilities at a petroleum refining plant of the "Bechtel", two tubular gantries were used. Two load pulley systems balanced by an equalizing roller were hung to the crossbar of each gantry. The haunches of the gantries were connected by a cable. The gantries were held in the vertical position by eight wire-braces.

A similar scheme for raising equipment with a weight of 600 tons using two gantry hoists was developed by TsPKO Glavkhimmontazh using four masts.

The firm "Ralph Parsons" (USA), in constructing a petroleum refining plant, raised and installed the isocracking reactors using two guy-wire derrick-cranes. The reactors had a height of 32 m with a wall thickness of 180 mm, and a weight of around 400 tons each. The lifting capacity of each 48-m tall derrick-crane was 200 ton force. The reactor was delivered by railroad directly to the operating area of the derrick-cranes. All the rigging devices were tested by lifting a reactor off the ground with a sling consisting of coiled cable slings near the center of gravity. The creation of heavy-duty derrick-cranes may be justified when erecting a large number of pieces of equipment and structures concentrated in a small area.

The operating experience of erection organizations has led them to recommend two methods for raising and installing vertical pieces of equipment with a weight of 400 - 600 tons: with low foundations, the method of rotation around a hinge;

with foundations of any height, the method of skidding using a gantry hoist with hinge supporting of the crossbar on the gantry upright supports.

To save expenses, one should use the available hoisting masts, rigging equipment, pulley blocks and winches.

A plan using erection masts with a total lifting capacity of 400 ton force has been developed for erecting pieces of tower-type equipment with a weight of 400 tons or more. An 11-roller pulley block with a pull of 280 tons has been designed for these masts. The pulley blocks are equipped with a universal shackle which enables them to use webbed slings and twisted slings, and also a cableless clamping device.

The required winches, with a pull of no less than 16 ton force and a cable capacity of 1,250 m using 35.5-mm diameter cable, were created by reconstructing type LPN-10/800 winches.

A new method has been introduced and can be better recommended for raising and installing, in the design position, pieces of tower-type equipment with a weight of 400 tons. This new method was proposed and developed by Spetsial'ny konstruktorskiy byuro VNIImontazhspetsstroya SSSR. This method uses special masts with a hydraulic drive system for raising the equipment and is called the "cableless hoist" (Figure 29). An experimental model of the "cableless hoist" was used in the erection of tower-type equipment with a weight of 150 tons at Sumgait in 1969. The economic and technical results proved completely satisfactory.

The principle of operation of the "cableless hoist" is based on the movement of hydraulic cylinders along rack supports. The lifting capacity of such hoists may reach 600 tons or more in keeping with the increase in the weight of tower-type equipment.

The comparative technical-economic characteristics of methods being widely used for raising pieces of tower-type equipment with the help of rigging devices are presented in Figures 30 and 31, using as an example equipment with a weight of 300 tons, a height of 48 m, and a diameter of 3.8 m, when it is being installed at ground level, and the number of pieces of equipment varies from one to five.

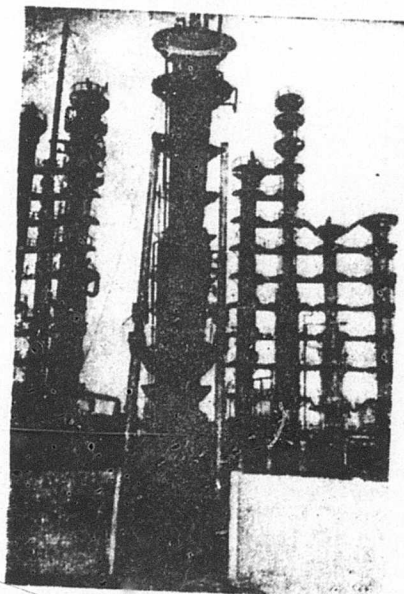


Fig. 29. The erection of equipment using a "cableless hoist".

For comparison, it was assumed that before raising the equipment was completely assembled, tested, and positioned near its foundation. Setting the equipment in the initial position for raising (placing it in the hinge, setting it on supports, setting it in sleds) is accomplished with the help of a special gantry hoist. With all the raising methods, one design of the rotating hinge without cutting and strengthening of the support part of the equipment is assumed. When raising the equipment by the skidding method, it is assumed that erection using masts is accomplished by dragging the support part of the equipment along the ground on sleds to the foundation using a 100-ton pulley system; raising the equipment using a gantry crane assumes a 30-ton pulley system is used for dragging the support part of the equipment to the foundation along the rail path. Ground-type anchors (a frame loaded with reinforced concrete blocks) are used with all erection methods. The following are used as the main technical-economic characteristics: the reduced costs (the cost with consideration of the capital expenses) in rubles; the labor productivity in tons per 1 man-day.

The graph presented in Figure 30 shows that when erecting a single piece of

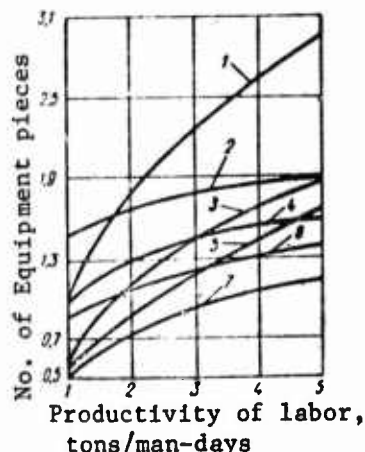


Fig. 30. Graph of productivity of labor when raising equipment with a weight of 300 tons using various methods when erecting from 1 to 5 pieces of equipment. 1- pressing method with rotation around a hinge; 2 - cableless hoist; 3- falling A-shaped support with rotation around a hinge; 4 - a support using the anchorless method; 5 - using a gantry (a skidding method); 6 - paired masts (the skidding method); 7 - a four-support hoist (the skidding method).

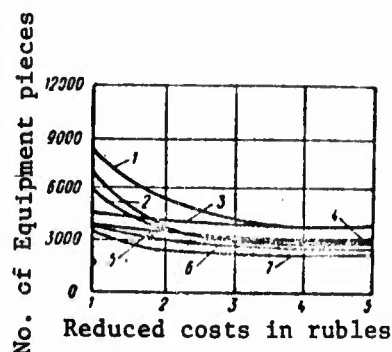


Fig. 31. Graph of the reduced costs for raising a single piece of equipment with a weight of 300 tons using various methods when erecting from 1 to 5 pieces of equipment are being erected: 1 - four-support hoist (the skidding method); 2 - paired masts (the skidding method); 3 - A-shaped support (anchorless method); 4 - gantry (skidding method); 5 - cableless hoist; 6 - falling A-shaped support with rotation around a hinge; 7 - pressing method with rotation around a hinge.

equipment the productivity increases most when the erection is done by the rotation method using a hydraulic hoist; however, when erecting two or more pieces of equipment the pressing method is most effective. The labor productivity with this method increases greatly with an increase in the number of pieces of equipment. Based on the reduced costs (see Figure 31), the pressing method gives the best characteristics with any number of pieces of equipment. A rigid gantry (Figure 32)⁽¹⁾ is used for the pressing.

Experience in raising equipment with a height of 33 m, a diameter of 2.5 m, and a weight of around 100 tons set up on a 4 m high foundation with the help of

⁽¹⁾ Author Certificate No. 195613. Official Bulletin of Committee for Inventions and Discoveries Associated with the USSR Council of Ministers "Izobreteniya, promyshlennyye obraztsy, tovarnyye znaki (Inventions, Commercial Models, Trade Marks)", 1967, No. 10.

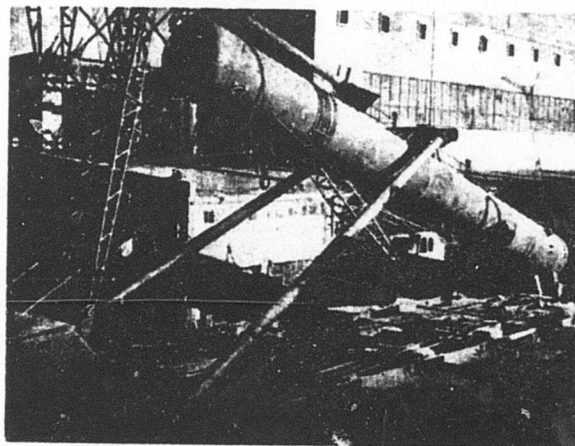


Fig. 32. The erection of equipment using the pressing method.

a rigid gantry under restricted conditions at the Kirov Voronezhskiy Synthetic Rubber Plant convinced us of the following merits of the pressing method: the erection may be performed under restricted conditions since the rigid gantry is set up within the clearances of the structure which has been prepared for raising; anchors and wire-braces are not needed; a rigid gantry has a small weight and a low height; the low position of the pulling block and tackle system makes it possible to watch the pulley blocks during the entire raising process and it facilitates setting them up and dismantling them; the horizontal loads on the foundation equal zero; it is possible to set up equipment on high foundations; there is a high degree of safety.

As a result of the experience of the Central Design-Construction Bureau of the Main Technical Erection, a new design has been developed for a device for raising equipment by the pressing method. When using this new design, the loads on the pulley systems do not exceed 50% of the weight of the equipment being raised. This additionally increases the effectiveness of this method [4].

THE PREPARATION AND ERECTION OF SPHERICALLY SHAPED EQUIPMENT

Welded steel spherically-shaped equipment has found wide application in various branches of industry, not only for storing various gases under pressure and for storing liquids, but also as technological equipment. In the Soviet Union spherical equipment is used in petroleum refining plants for compressing the gases of the propane-butane fraction, in cellulose plants for regeneration of sulfurous anhydride (SO_2), etc.

A spherical shape for equipment, in comparison with a cylindrical shape having the same volume, is more economical both from the point of view of the metal consumed in manufacturing it (up to 15%) and also in its operation. Recently spherical regeneration vessels made from double-layer steel have been installed in enterprises under construction and being reconstructed. The production of these double-layer steels has been mastered by our domestic metallurgy industry.

With the growth of the synthetic chemical industry, the horizontal cylindrical vessels with a capacity up to 200 m^3 which were previously used for storing liquid gases under pressure no longer meet the requirements for storage vessels, and they are the cause of unjustified overconsumption of metal. In connection with this, in both foreign and domestic practice, they have begun to widely use the more economical spherical vessels with a volume of 300 m^3 and more. At present, spherical vessels and equipment with a volume of $600 - 2,000 \text{ m}^3$ and more are most widely used.

When building spherical equipment and vessels, special importance is allotted to the correctness of the shape - that is, to ensuring a constant curvature in two directions. The West Germans customarily assume that, in order to main a practically uniform stress state in a spherical shell, it is necessary that the local deviations from the pattern in a length of 500 mm not exceed 5 mm, and the distortion of the sphere diameter must not be larger than 0.5%. However, these require-



Fig. 33. The layout of the shell of a spherical casing with a diameter up to 13 m.

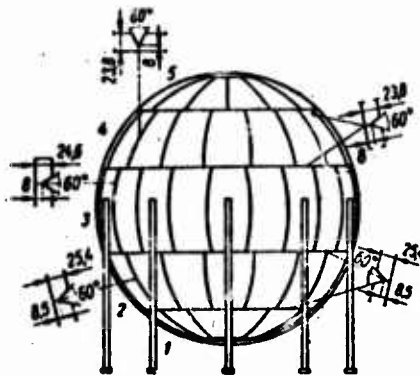


Fig. 34. The meridian-equatorial layout of spherical equipment and the recommended partitioning of the belts: 1, 2, 3, 4, 5 - equipment belts.

ments are not always fulfilled, and in a number of cases a distortion in the diameter dimensions up to 1.5 - 3% occurs. The shape of the sphere depends a great deal on the method of partitioning the shell into elements. From considerations of the least consumption of metal and duplication of one or two standard size plate blanks, the West Germans have reverted to a shell layout which was used earlier for riveted spherical gas holders (Figure 33).

Spherical containers with such a layout are also built at present with a diameter up to 13 m. However, the meridian-equatorial layout of the casing has obtained more widespread use. This method facilitates the erection and completion of the welding operations (Figure 34). The meridian layout "orange section" form creates the best conditions for assembly, and especially for welding, in the erection process. This layout scheme requires the smallest allowances when preparing the casing plate elements, and its erection elements better yield to consolidation and automatic welding.

Figure 35 shows five schemes for laying out the shell of a spherical tank. Table 16 gives the characteristics of spherical tanks with a capacity of 600 m³.

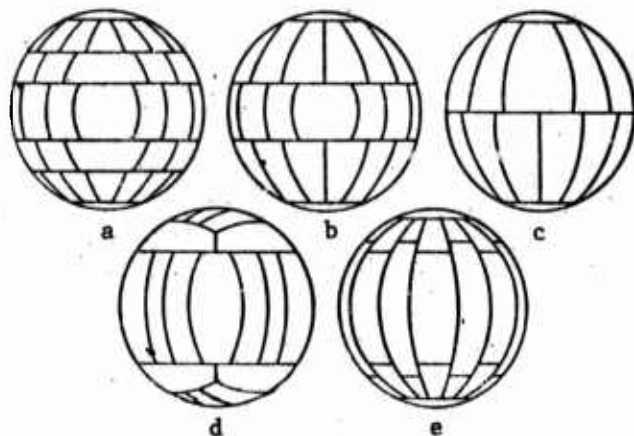


Fig. 35. Schemes for laying out spherical tanks which are manufactured by:
 a - Taganrogskiy Boiler Plant; b - in Czechoslovakia;
 c - Barnaul'skiy Boiler Plant; d - in France; e - Ural Chemical Machine Plant.

Both hot and cold stamping are used for manufacturing shell elements independent of the thickness of the plates. It is required that the steel being stamped not have a tendency to age harden. Cold stamping is also used after hot stamping for standardization to the design curvature. According to the data of the Ye.O. Paton Institute of Electric Welding of the Academy of Sciences of the Ukrainian SSR, method of manufacturing is widely used at present in European countries, the USA, and Japan [2].

Based on the data from the plant "Volgotsemmash", when developing the manufacturing technology for the shell of a spherical tank with a diameter of 10,500 mm and a volume of 600 m³, the plant studied the experiences in the manufacturing of spherical shells of the plant "Vitez na Upora" in Czechoslovakia, the Barnaul'skiy Boiler Plant, and the Ferganskii Erection Directorate. The elements of the spherical tanks made by the Czechoslovakian plant and by the Barnaul'skiy Boiler Plant were manufactured by hot stamping with subsequent cutting

TABLE 16

THE CHARACTERISTICS OF SPHERICAL TANKS WITH A CAPACITY OF 600 m³

Characteristics	Suppliers				
	Taganrogskiy Boiler Plant	Barnaul'skiy Boiler-Mechani- cal Plant	Uralkhimmashza- vod	Czechoslovakia	France
Diameter of the tank (internal), mm	10510	10550	10510	10500	10500
Thickness of the wall, mm	24-26	24	22	24	22
Weight of the casing, tons	61	65.1	60.1	62	60.2
No. of plates (elements)	114	26	18	50	30

according to patterns, machining of the edges, and test assembly. The overall dimensions of the individual stamped elements depend on the technological potential of the press equipment, that is, the size of the preheating furnace, the power of the press, and the distance between the upright supports of the press.

The shell of the Czechoslovakian spherical tank consists of 50 erection elements which are prepared in the plant. The length of the erection weld seams is 303 m. The spherical tank manufactured by the Barnaul'skiy Boiler Plant has 25 stamped elements, and the length of the erection weld seams is 296 m [15].

Erection Construction Trust using its own Seredina-Budskiy plant organized the hot stamping of 3,000 spherical elements from sheet steel with a thickness of 20, 30 and 40 mm using a 400-ton press which was spherically re-equipped for this purpose. These 3,000 spherical elements were used for decompressors with a diameter of 9 m, for

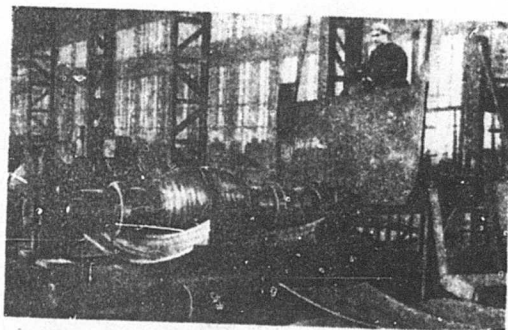


Fig. 36. A method of cold rolling using a three-roller sheet-bending rolling mill for short plates of blast heater domes of blast furnaces.

correction basins, and for equipment for roasting and reducing alunite in aluminum production.

The method for forming spheres by hot and cold stamping using presses emerged at the beginning of the 20th Century. It is based on imitating the ancient technology of boiler makers. This technology involves the fact that the spherical shape for the bottoms of steam boilers and for the blast heater domes of blast furnaces was achieved by manually hammering out the steel plate blanks which were heated in a fire. These steel plate blanks were laid on die-molds cast from steel or cast iron in a shape corresponding to the spherical profile and were hammered with sledge hammers. This technology is also used at present in plants manufacturing blast heater domes for blast furnaces.

In boiler construction, for example in the boiler construction plant "Krasnyy kotel'shchik" at Taganrog, the hot stamping of large-size bottoms with a spherical shape was accomplished for the first time in 1929 using a vertical hydraulic press with a pressure of 1,500 tons.

In the 1930's, boilermakers also created a sphere using steel

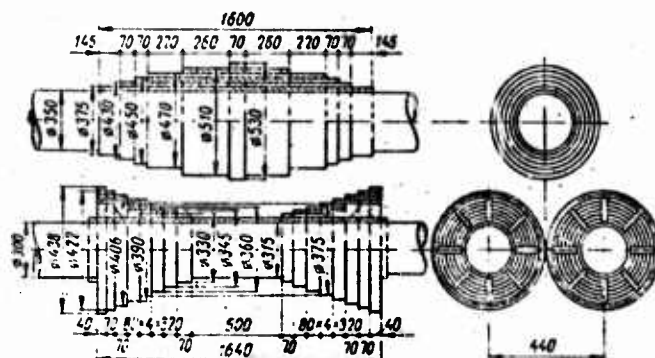


Fig. 37. Removable gauges for the cold rolling of long plates for the blast heater domes of Nos. 5 and 6 blast furnaces of the Magnitogorskiy Metallurgical Combine using a three-roller sheet-bending rolling mill in 1942 - 1943.

plate blanks of short length which were rolled without crimping the edge of the blank on a roll cylinder. This involved the method of cold rolling short blanks on a driven three-roller sheet-bending rolling mill with an adaption on the upper roller for interchangeable mandrel-rolls of the appropriate profile for the sphere, and an adaption on the lower roller for a support plate with a profile corresponding to the sphere (Figure 36). This method is also used at present in plants as being a more progressive method than hot stamping using presses. However, it is only suitable for short blanks.

In the days of World War II, during the construction of the No. 5 blast furnace at the Magnitogorskiy Metallurgical Combine, an attempt was made for the first time to cold roll long blanks for blast heater domes using an ordinary three-roller sheet-bending rolling mill which was available in the shop. This was done with the help of special removable gauges corresponding to the radius of the domes (Figure 37). The attempt was successful [6 - 7].

The gauges were manufactured from standard metal tubes with the

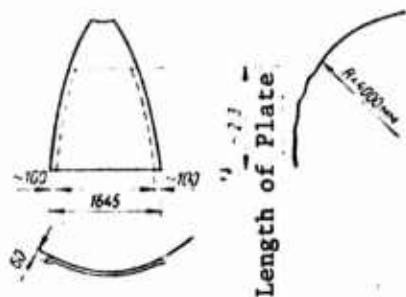


Fig. 38

Crimped edges with the first attempt at rolling long plates for the blast heater domes of No. 5 blast furnace of the Magnitogorskiy Metallurgical Combine using a three-roller sheet-bending rolling mill in 1942.

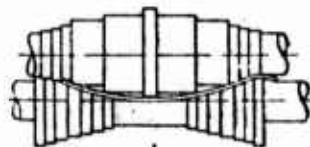


Fig. 39

The formation of crimped edges with the first attempt at rolling long plates for the blast heater domes of No. 5 blast furnace of the Magnitogorskiy Metallurgical Combine using a three-roller sheet-bending rolling mill.

help of a gas cutting torch and electric welding, but without machining on a lathe. In order that the gauges would freely fit on the shaft, the tubes were selected with an internal diameter 5 mm larger than the diameter of the shafts. The length of the gauges was determined by the width of the plate element at the base of the dome which consisted of 16 plates, and the profile of the gauges was determined by the radius of the dome's spherical shape which is 4000 mm. The first attempts to roll 48 plates for three blast heater domes of the No. 5 blast furnace gave results which were not completely satisfactory -- the 16 mm thick plates had crimped edges (Figure 38). Correcting these edges by heating them and manually straightening them using sledge hammers when assembling the plates presented considerable difficulties. When building the No. 6 blast furnace in 1943, changes were introduced which enabled them, when rolling, to obtain on the plate edges a surface precisely in accordance with the design radius, without any indications of crimping.

A study of the reasons for the formation of crimped edges showed that because of manufacturing errors the gauges pressed the plate unevenly across its width, and this led to a significant lateral shifting

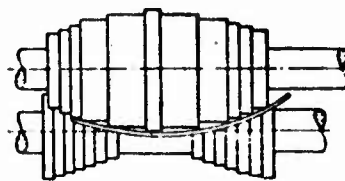


Fig. 40. Increasing the diameter of the upper gauge when improving the rolling of long plates for the blast heater domes of No. 6 blast furnace of the Magnitogorskiy Metallurgical Combine using a three-roller sheet-bending rolling mill in 1943.

of the plate with respect to the longitudinal rolling axis. The plate, having been shifted laterally, slid out from between the gauges, pressed against the upper shaft of the rollers and was bent in the opposite direction, thereby forming a crimped edge (Figure 39).

As a result of the study, the gauge of the upper shaft was manufactured anew from tubes of a larger diameter taking into consideration the maximum possible rise of the upper shaft which could be used. (Figure 40). However, when the length of the plates was around 6 m, the lateral shifting of the plates - starting from a point about one-third along its length - reached 300 mm at the end of the plate. This could not be compensated for only by raising the upper shaft.

A more precise mutual adjusting of the gauges, which was accomplished with the help of a gas cutting torch, and electric welding of the gauges directly on the shafts slightly reduced the lateral shift and turn of the plate. Therefore, rolling the plate along its entire length was replaced by rolling it in sections from one to one and one-half rotations of the shafts such that the lateral shifting of the plate did not exceed 10 mm. In order to control the shifting, the longitudinal rolling axis was marked beforehand with chalk on each

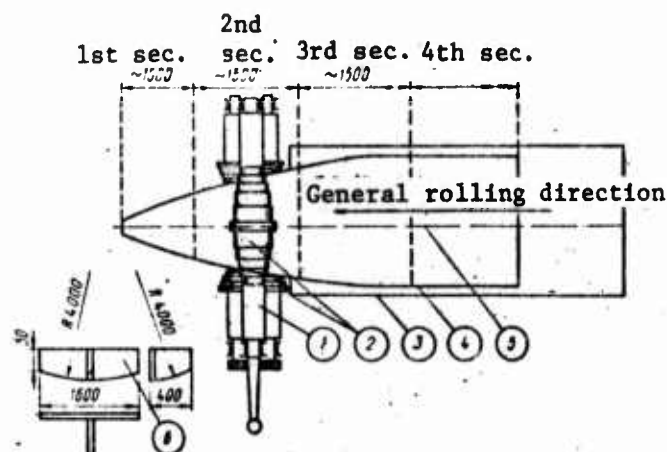


Fig. 41

Improved rolling of long plates for the blast heater domes of No. 6 blast furnace of the Magnitogorskiy Metallurgical Combine using a three-roller sheet-bending rolling mill in 1943:
 1 - rollers; 2 - removable spherical gauges of the upper and lower shafts; 3 - table; 4 - plate blank for the dome; 5 - rolling axis; 6 - control template.

plate and on the table before the rollers (Figure 41). When the rolling is done, one must make sure that the guideline marks on the plate line up with the center of the gauges and the guideline on the table. The rolling starts from the narrow end of the plate; thus each section of the plate during reverse rolling attains at once the design radius. In addition to this, the layout of the plate elements for the blast heater dome was changed. The new layout was divided into 18 plate elements instead of 16. The gradual, sequential rolling of the plate in small sections facilitates the rolling operation, it ensures high-quality rolling, and it significantly speeds up the work. The smooth plate edges, which are precisely maintained with respect to the radius, tightly join together and do not require any padding. The 54 plates for the three domes were rolled in 62 hours. In order to ensure precision and to speed up the assembly of the domes, a device was developed and used for holding the plate sections installed according to the design dimensions. (Figure 42).

With the help of this device, the assembly of three domes using sections made from two or three plates was carried out in 8 hours.

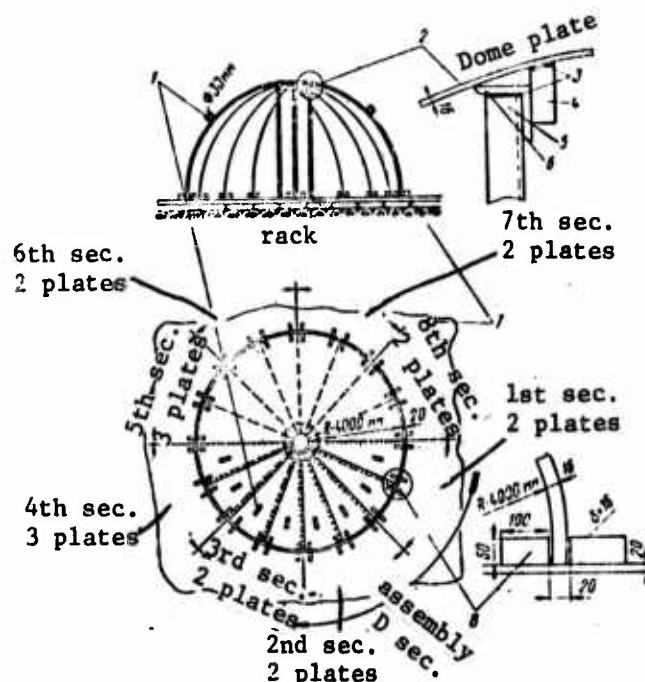


Fig. 42. A device using a rack for the precise assembly of the blast heater domes of No. 6 blast furnace of the Magnitogorskiy Metallurgical Combine in 1943:

- 1- strips (16 pieces) 100 X 100 X 16 mm for raising the plates when assembling them; 2 - detail of the support for two plates of the 1st section of the dome; 3- electrically welded seams; 4 - support strips 200 X 100 X 10 mm; 5 - upright supports under the support ring (4 pieces of No. 16); 6 - support ring L 100 X 100 X 10 mm with an internal diameter of 1000 mm; 7 - continuous flooring for the racks which is made from flattened plates $\delta = 20$ mm; 8 - detail of the support strips electrically welded to the flooring.

All the assembly holes lined up on the plates for the dome closing. The diameter of the holes was taken as 3 mm smaller than the design diameter to allow for drilling them in the assembled dome. On the edge of the plate which was to be fitted to the edge of the next plate assembly, holes are drilled only every 500 mm. The results which were achieved showed that one is able to drill all the holes in the plate elements with a diameter only 1 mm smaller than the design diameter.

The lifting capacity of the guy wire derrick which was used as the main mechanism when erecting the blast furnace enabled them, for the first time in blast furnace construction, to carry out the complete

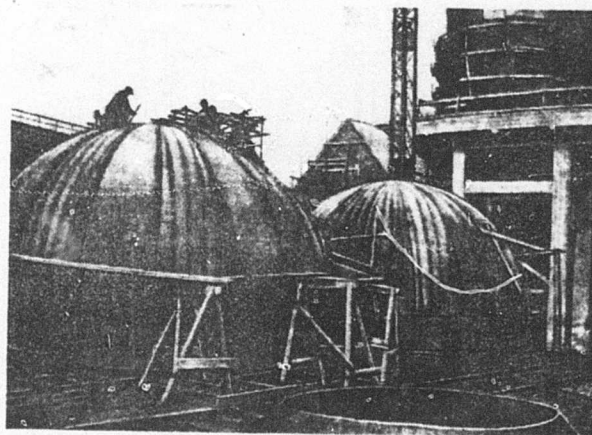


Fig. 43. The finishing-up erection assembly, drilling, riveting, caulking, and testing of the blast heater domes together with the upper sheet-steel cylinder of the No. 6 blast furnace for the Magnitogorskiy Metallurgical Combine.

assembly of the dome together with the upper sheet-steel cylinder down below on racks where the riveting, caulking, and testing for tightness of all the rivets and seams was conducted (Figure 43). The dome, together with the upper sheet-steel cylinder, was installed using one hoist (Figure 44). The new method of preparing and erecting the domes greatly speeded up the delivery of the blast heaters to the stack of refractory materials.

In commercial construction when welded joints replace riveted joints and the welded steel casings of blast heaters - that is, large-scale pieces of tower-type equipment for blast furnaces are manufactured from rolls of sheet metal - the manufacturing of the spherically shaped welded domes is most economically done by rolling the plate elements in a cold state using a three-roller sheet-bending rolling mill with removable gauges or with special rollers having a spherical profile.

At the "Volgotsemmash" plant specialists used their experience

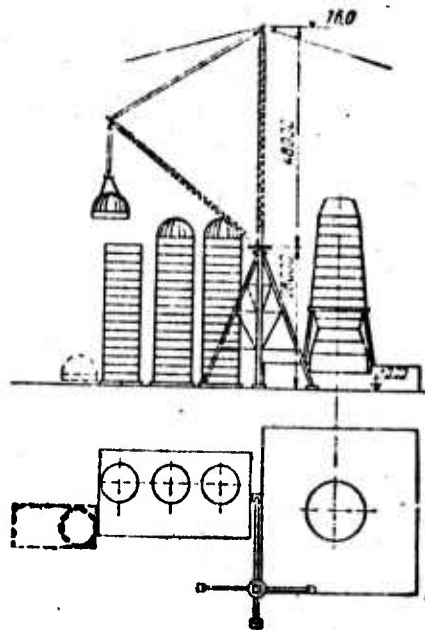


Fig. 44. Erection of the finished blast heater domes for the Nos. 5 and 6 blast furnaces at the Magnitogorskiy Metallurgical Combine.

in rolling plate elements on a multiple-roller rolling mill (Figure 45)⁽¹⁾ to manufacture a special rolling mill (Figure 46).

Comparative data on the layout of a spherical shell using the various technological methods are presented in Table 17.

To make maximum use of the available metal, a plate was manufactured by welding together pieces at the "Volgotsemmash" plant. This welded plate consists of three parts; a central plate with a length of 8000 mm and edge plates with a length of 3220 mm. The individual plates for the composite plates are cut at the factory along the contour using guillotines; the edges of the plates for the joints which are automatically welded are prepared with the help of a semiautomatic gas cutting torch. The individual plates for the composite plate which have been prepared for welding are assembled on a stand for automatic welding. The joint is held together by three tack wells made with UONI-13/55 electrodes; the clearance in the joint is 4 ± 1 mm. The displacement

(1) Author Certificate No. 201313. Official Bulletin of the Committee for Inventions and Discoveries Associated with the Council of Ministers of the SSSR "Izobreteniya, promyshlennyye obraztsy, tovarnyye znaki (Inventions, Commercial Models, Trade Marks)", 1967, No. 18.

TABLE 17

CHARACTERISTICS OF THE LAYOUT VARIANTS FOR THE SPHERICAL SHELL
OF A 600-m³ CAPACITY TANK

Manufacturing Plant	No. of plates	Plate size, mm	Plate wt., t (design wt. 42.9 tons)			Cost of metal, consid. wt.		Coefficient of metal utilization
			Weight according to order	Allowance (waste), %	Relative wt. %	Agreed, in rubles	Relative, in %	
Barnaul'skiy Boiler Plant:								
1st layout	26	2800×7000	63,9	46,6	127,0	5469	109,6	0,534
2nd layout	2	1800×7000						
Czech. Plant	24	2800×6600	58,9	35,0	95,8	5960	119,0	0,65
"Volgotsemmash" Plant	50	2300×4500	59,6	36,6	100	5016	100	0,634
	18	2100×8000	52,9	19	89,0	4311	96	0,81
		2100×7000						

of the plates with respect to the thickness in 1 mm. Strips with dimensions of 70 X 150 mm are welded to the ends of the joints for strating and terminating the seam.

The automatic welding under a flux is accomplished by an automatic welding maching ADS-1000-2. The power supply source is the converter ASO-2000. In order to obtain stable welding conditions, the excitation winding of the generator has an independent power supply from a P-52 motor-generator set. After welding the plate blank, it is lifted by a crane onto a stand for cutting with a gas torch along the contour in accordance with the curve evolute. In order to obtain precise measurements for the plate curve evolute, a special master template (Figure 47) is applied to the plate blank. The curve of the plate is cut out on both sides simultaneously according to the template using "Raduga" type semiautomatic cutters.

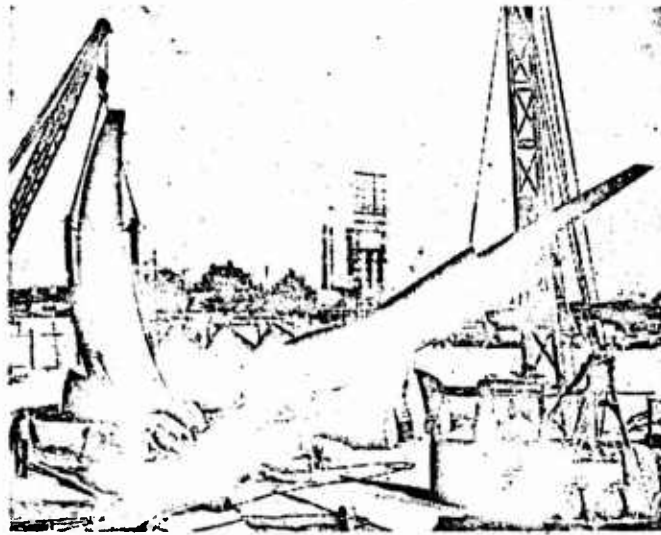


Fig. 45. Rolling plate elements for spherical containers using a multiple-roller spherical sheet-bending rolling mill.

It was experimentally established that the least distortion of the plate blank is produced if a specific cutting sequence is followed: the semiautomatic cutter moves along one side of the plate from the beginning to the end of the cut in one direction, and on the other side, the semiautomatic cutter moves in a direction opposite to the first cutter, starting from the uncut end.

Four folding layout brackets are provided in the master template design. These four brackets, which enable one to mark punch holes along the center and edge of the plate, are used when setting up the plate for the bending rollers. On each plate which has been cut out, a chart is drawn for measuring the main dimensions: the width of the central section and end sections, the length of the plate, a number of diagonals. The master template dimensions are adjusted to take into account the change in the length and width of the plate when the plate blank passes through the rolling mill. In making the calculation, it is assumed that the relative elongation is 0.02%.

The plate is bent on a multiple-roller rolling mill (See Figure 46), which was manufactured by the plant. The flat plate element which passes between nine rollers is bent in the shape of a sphere with a

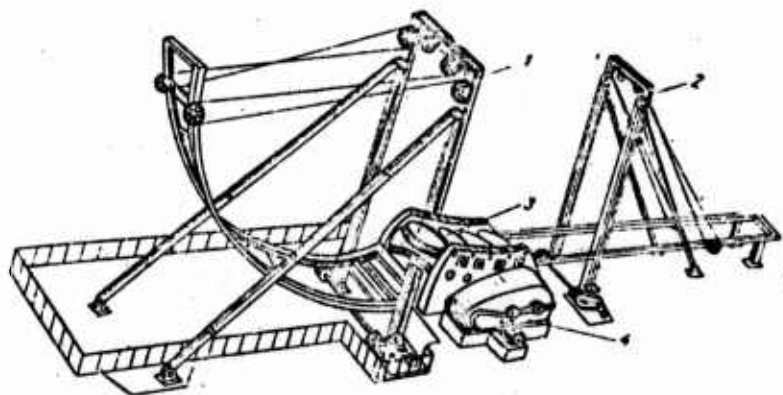


Fig. 46. A multiple-roller spherical rolling mill for the cold rolling of long plates for spherical tanks at the "Volgotsemash" plant:
 1 - receiving table of the rolling mill; 2 - feeding table of the rolling mill; 3 - multiple-roller spherical rolling mill; 4 - reduction gears.

radius of 5260 mm.

The rolling mill consists of a welded frame, four upper convex rollers with a diameter at the center of 550 mm which are not driven, and five lower concave rollers with a diameter at the center of 320 mm which are driven. The drive for the rolling mill is provided by a 14 kw electric motor. The rolling mill tables have individual drives for raising them to an inclined position, making it convenient to insert the blank between the first pair of rollers and for removing the bent plate element after it has been rolled. The maximum plate width which can pass through the rollers is 2100 mm. The bending is accomplished in a single pass. Water is poured on the plate while it is being bent.

The ends of the plate elements are cut along the radius on the receiving table of the rolling mill with the help of the applied master template. The master template is set up in respect to the control punch holes which were made when the plate blank was cut out. A "Raduga" instrument is used for the cutting. Rings are mounted on the

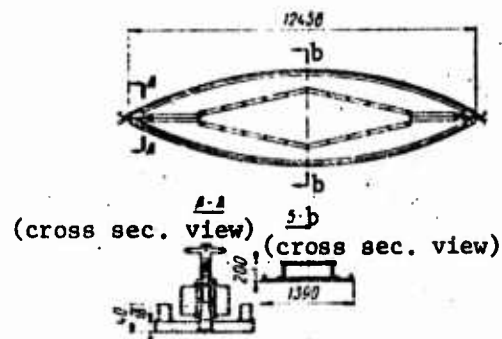


Fig. 47. Master template for cutting the curve evolute of a plate element for spherical tanks made by the "Volgotsemash" plant.

plates and welded to them on the receiving table of the rolling mill for hooking on to the plates when subsequently transporting them around the workshop and to the erection site.

A control chart for the measurements of the plate length and width is marked on each plate element after bending; in addition the bending radius must be checked with a template. Usually the plate edges have local deformations or crimps at two or three spots. The reasons for the formation of the crimps are: different plastic deformations of the edges in view of discrepancies in the plate thickness; a deflection of the curve evolute axis from the rolling mill axis; difficulties in making completely precise adjustments of the rollers. The local edge deformations are removed at the plant by using a special clamp with a screw jack. A complete test assembly of the sphere was made for the first tanks. In view of the good interchangeability of the plate elements, they were able to do away with the test assembly of the tank, and at present the assembly of two plates for checking the welding clearance and the radius of the sphere at the joint site is carried out only periodically. The clearance for the automatic welding which is performed during the erection is 2 - 3 mm.

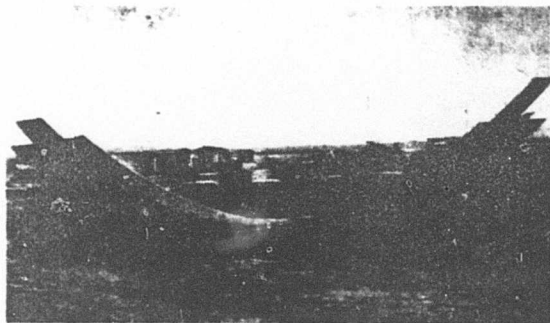


Fig. 48. Plate elements for a spherical tank resting in a plate holder.

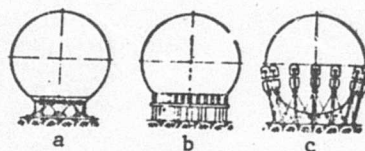


Fig. 49. Support structures for spherical tanks: a - metal pedestals; b - circular support; c - tubular up-right supports.

The bottom and dome of the tank are manufactured in the following way. Two semicircles with a radius of 1900 mm are cut, according to the layout, from a plate with dimensions of 7000 X 2100 mm. The central section of the plate blank is cut out according to the master template. Each part has a margin on one side for inserting the plate blank in the rolling mill. After bending on the rolling mill, both parts are joined together with tack welds along the central butt joint using a device with screw clamps. The final cutting is done by a "Raduga" instrument according to the marks of a pair of dividers. The finished plate elements are primed and packed in a special plate holder holding eight pieces of a hemisphere. This special plate holder is set on a railroad flatcar for shipping (Figure 48).

In order to erect the tank, the plate elements are assembled in units and then the tank is assembled from these units. The butt seams of the assembled sphere are automatically welded using a special manipulator which rotates the sphere at the appropriate welding speed. The inner seams are welded first by an automatic welding machine TS-17 using a circular flux submolding. Then the outer seams are welded. About 25% of the welded seams are checked with a gamma-ray defectoscope,

and after completing the assembly the sphere together with the accessories is hydraulically tested at a pressure of 9 absolute atmospheres.

Experience in manufacturing spherical tanks at the "Volgotsem-mash" plant by the method of cold rolling, using spherical rollers for the plates of the spherical shell, showed the considerable economic and technological advantages of this method in comparison with manufacturing the elements by stamping. The new method for manufacturing spherical shells enables one to produce interchangeable plate elements. This greatly improved the quality of the erection assembly and enabled them to use automatic welding under a flux. The coefficient of metal utilization is increased when this cold rolling method of manufacturing spherical shells is used. The productivity of the assembly-welding operations is significantly increased (by a factor of 5 - 6) when manufacturing spherical shells both under plant conditions and also at the erection sites.

Thus, there are obvious great economic and technological advantages in the cold rolling method using a bending rolling mill with rollers having a spherical profile corresponding to the radius of the manufactured sphere in comparison with the method which is widely being used at present in both domestic and foreign plants, that is, in comparison with the hot and cold stamping methods.

The investigated designs and methods of cold rolling long spherical plate elements using a sheet-bending rolling mill attest to the leading role of the Soviet Union in working out one of the most complicated technical problems encountered by machine building plants in manufacturing and in the assembly and welding, on upright supports, of large-scale spherical equipment and vessels which are being widely used in all countries in the world.

The spherical equipment and vessels are set up on support structures of various designs (Figure 49):

— metal pedestals supported on reinforced concrete foundation posts.

The upper part of these pedestals forms a circular surface on which the lower belt of the tank is supported by stiffening ribs and shims;

— a circular support consisting of a vertical cylindrical shell and a lower horizontal ring connected by anchor bolts to a circular reinforced concrete beam;

— tubular upright supports tangentially adjoining the vessel casing. This is the most progressive solution.

At the Nizhnekamskiy Chemical Combine (Nizhnekamskiy khimicheskiy kombinat) in 1966, for the first time in either domestic or foreign practices, somewhat under a hundred spherical tanks were erected over the course of a single year for one unit. These spherical tanks were set up in individual yards with 8 - 12 tanks in each yard. The tanks had a volume of 600 m^3 and a diameter of 10.5 m. They were manufactured from 09G2S(M) steel with a thickness of 16 mm for a pressure of 6 gauge atmospheres and a thickness of 34 mm for a pressure of 18 gauge atmospheres. The weight of the tank shells was 46 and 95 tons, respectively.

The 16-mm thick plate blanks were rolled on a multiple-roller spherical rolling mill in the cold state. There were 16 plate elements and 4 bottom halves for each tank which was designed according to a meridian layout and was supplied by the "Volgotsemmash" plant. The Barnaul'skiy Boiler Plant delivered tanks which had 24 plate elements and 4 bottom halves and were laid out according to the equatorial-meridian layout. The 34-mm thick plate blanks were stamped in the hot state.

The plate elements made by the plant-suppliers had significant deviations from the design dimensions and shape. Rectification of the plate elements was carried out over a 3.5 month period at the construction site by the combined forces of the plant-suppliers and erection management.

A special working area equipped with SKG-40, MKG-25, MKP-25 and KMK-120 cranes, automatic welding machines, manipulators, stands for

assembly, etc., was created for assembling and welding the spherical tanks. The combined crews, one for each yard, consisted of 10 - 12 men each, among them 4 - 5 metal work erectors, 2 gas cutting torch operators, 2 electric welders and 2 crane operators. The automatic assemblers worked in groups consisting of 2 - 3 men. For each set of operations, calculations were worked out for the labor costs of the consolidation standards.

In erecting tanks designed for a pressure of 18 gauge atmospheres, the plate elements were assembled into hemispheres on radial stands. The bottom of the tank was set up in the center of the stand on a temporary upright support in the form of a mushroom; the plate elements (or pre-consolidated two-plate units) were installed by a crane along the limiting clamps of the stand, the upper edge of the plates rested on catchers which were welded to the bottom; the correctness of the assembly was checked with the help of templates and a measuring tape. When assembling hemispheres from assembly units, the difficulty of fitting the joints was increased because of the somewhat larger deviations from the correct spherical shape. Therefore, in the following units they assemble individual plates. Before installing the last plate, the central upright support was removed and then a strengthening crosspiece made from tubes and the closing plates were installed. After completing the assembly and tack welding all the assembly devices were cut off using an oxygen cutting torch. The welding spots were carefully dressed using emery wheels, and temporary connecting pieces were installed for assembling the shell.

The manual subwelding was done from the dressing side using UONI-13/45 electrodes. At the spots where the joints had increased clearances, a subwelding seam was applied in 2 - 3 layers in order to avoid breaking through with the automatic welding. Then the hemisphere is inverted by two SKG-40 cranes and set on a temporary support ring. This hemisphere is covered with the second hemisphere, stock scaffolding is set up, the equatorial butt joint is fitted, the scaffolding is taken down, one temporary upright support of the support ring is removed, and the manipulator is installed under the tank by

TABLE 18

WELDING CONDITIONS

Seams	Thick- of the metal in mm	Welding wire		Flux Brand	Welding current in amps.	Arc volt- age in volts	Welding speed in m/hr
		Dia- ter, in mm	Brand				
TANKS FOR 18 GAUGE ATMOSPHERES							
1st and 2nd from the outside					600-650	36-38	21
3rd inside	34	4	Sv-08GA	An-348A	700-750	36-38	19
4th and 6th from the outside					750-800	38-40	19
TANKS FOR 6 GAUGE ATMOSPHERES							
1st from the inside	16	4	Sv-08GA	An-348A	700-750	34-36	21
2nd from the outside					750-800	36-38	19

going through the opening which has been formed. A cabin for the welder is installed on the tank, and automatic welding of the shell is performed using the manipulator. Assembling the tanks on the temporary support rings enabled them to do the assembling and fitting of the equatorial butt joints beforehand. This reduces the manipulator lost time. In another yard where it was not possible to use the SKG-40 cranes, since the tanks were set up here at the + 3 m mark on reinforced concrete columns, a gantry crane KMK-120 was used. An area for assembling and welding the shells was organized close to the yard. While the crane was erected, four shells were welded and prepared for erection. The shells made from hemispheres, in this case, were assembled directly on the ground with their subsequent installation on the manipulator. The welded shell was towed by two tractors to the operating zone of the KMK-120 crane, and by means of this crane the shell was installed on the temporary ring of the assembly jig. Here tubular metal supports were welded to the shell, and the shell was installed using the KMK-120 crane on its foundation. After installing the six tanks of the first row, the crane moved along the perpendicularly positioned rails to the second row. Using the KMK-120 crane enabled them to erect eleven tanks in 3.5 months with a considerable reduction in the labor for the operations.

The technology for welding the shells was developed by the Ye.O. Paton Institute of Electric Welding. The welding was done by the welding tractor TS-17m which was supplied with a direct current of reverse polarity from a PSM-1000 converter. For the purpose of decreasing the deformations and reducing the magnitude of the residual internal stresses, the welding was performed in the following sequence: two layers of the seam were welded from the dressing side on the outside using manual subwelding; then from the blunting side a channel with a depth of 10 - 15 mm is blown out using a RVD cutting torch; the surface of the cut is dressed; the inner seam is welded using the TS-17m welding tractor; the outer seams are welded in 2-3 layers, until the dressing is completely filled. The welding conditions are indicated in Table 18.

At the Nizhnekamskiy Chemical Combine, for the first time in the USSR, spherical shells with a wall thickness of 34 mm were welded. Therefore, in this erection process they were obliged to work out an original welding technology, to study the causes for the appearance of defects and to develop methods for eliminating them. Transverse cracks, both showing up on the inner surface and also hidden, appeared in individual sections of the inner seams of the shells after completing the welding. Defective spots were revealed during the visual inspection process and during ultrasonic testing. These defective spots were removed with the cutting torch RVD. The surface of the cut was carefully dressed using grinding wheels. The cutting surface was etched in order to determine whether the defect was completely removed. Then, using preliminary and accompanying heating, they completed the welding using UONI-13/45 electrodes. After this, they recommended the required dressing of the cutting surface to a depth of 0.3 - 0.5 mm before welding using grinding wheels, in order to eliminate the carbonized zone.

The plates are assembled on an assembly stand. The stand consists of eight sections which are bolted together and two arched support frames. Index pins are installed on the stand for fastening the plates. Four methods for assembling shells were tested. Experience proved the unfavorable effect of the assembly of two plates in regards to maintaining the correct shape of the hemisphere. Additional expenditures of time also were required for manipulating and reslinging the plates. The variant of assembling a hemisphere plate by plate on stands which are convex upwards is the most feasible; the subwelding seam was welded from the outside; one of the hemispheres was turned over and the sphere was assembled. The welding was first done on the inside of the tank, and then from the outside using direct current of a reverse polarity from a PSM-1000 welding converter.

The welded and checked shell of the tank was set up at the design mark with the help of two MKG-25 cranes. For this purpose, a temporary support was set up inside the circular foundation. It was removed

after seven supports were welded to the casing, and then the eighth support was welded. A cross-pull strain was taken on the support using turnbuckles.

An ultrasonic monitoring method using the instruments UDM-IM and DUK-131M was used for revealing fine defects such as hidden cracks.

In 1967-1968, at the Nizhnekamskiy Chemical Combine, 14 spherical tanks with a volume of 2000 m^3 were erected. These tanks were designed for a working pressure of 2.5 cm^2 and had a diameter of 16 m with a wall thickness of 16 mm. The weight of the shell was 101.2 tons. Eight shells for the tanks were built from plates which were manufactured by cold rolling using a multiple-roller rolling mill (see Figure 45) by the Ferganskiy Erection Directorate of the Petroleum Plant Erection Trust. Six of the tanks were made from plates manufactured by the Ural Chemical Machinery plant using the same method. The meridian layout of the tanks made by the Ferganskiy Directorate contained 28 plates, and the layout by the Ural Chemical Machinery plant contained 24 plates. There were 12 upright supports. The plates of the shells supplied by the Ferganskiy Directorate were laid out and welded from 1800 X 7000 mm sheets. The plates were 20 m long. For convenience in transporting these rolled plates, they were cut into two elements with a length of 11 and 9 m. This enabled them, when consolidating these elements into a single unit, to avoid an equatorial seam and to join the support to the equator zone. Since the seam is above the equator, it is shorter than an equatorial seam, and therefore lower labor costs are required for welding it. The plates of the bottoms and dome were manufactured from 1800 X 5500 mm sheets. All the plates were test assembled at the plant, and they were packed in a special container for transporting them.

The tanks were erected by the vertical method. The plate elements were spread out in the erection area, and their edges were dressed. In order to consolidate the elements into units consisting of two plates, an assembly-disassembly stand was manufactured from shaped metal with plan dimensions 15.6 X 6.1 m. This stand was set up in an exactly horizontal plane. The radius of curvature of the

guides holding the plate elements during the assembly was 8000 mm. Limiting angle brackets were installed along the generating line on the stand.

The long plate element was placed on the stand by a SKG-40 crane and then the short plate element. Using wedges and screw clamps, the elements were joined with a clearance of 2 mm and then fastened together by tack welds. A short element was laid from above on the long element, and then a long element was laid on a short element. The angularity of the adjoining elements in the assembly unit was checked using a 1000-mm long template. A displacement of the edges of no more than 10% of the metal thickness was allowed. The elements of the second plate were fastened together, and then this plate was fastened to the first plate by 100-mm long tack welds every 250 mm with a welding penetration depth of 4 mm. Then the unit was removed from the stand and set on ribbing in a smooth area. Connection pieces were welded to one of the plates at a distance of 250 mm from the edge and stiffening tubes (159 X 6 mm) were bolted on. The length of the stiffening tubes (in respect to the axes of the bolt holes) was 11360 mm.

The plate elements were welded together by a continuous, manual, subwelding seam. The welding was done from the inside of the unit. First, the vertical seams were welded and then the meridian seams between two plates were welded. The subwelding seam was welded using UNOI-13/55 electrodes with a diameter of 4 mm. The seam leg (4 - 6 mm) depends on the clearance between the plates. Disks for installing coupling devices used during the erection were welded to the inside and outside of the units. Disks for hoisting the unit were welded on the inside of the unit at a distance of 600 - 700 mm from the end. Plates for the support part of the fixed upright supports of the tank were welded to the equatorial zone. The weight of the unit was 7 tons. A crew of 3 men assembled during one shift up to two units consisting of two plates each. The bottom and dome were assembled on a special flat stand. The assembled plates were tack welded, and then manual welding of the subwelding seam was done from the inside. Manholes were marked out on the bottom and dome sections. Along the perimeter of the edges of the bottom and dome, they marked the spots for the joints of the units

consisting of two plates each.

The central upright erection support was manufactured from two tubular elements of different lengths which were connected by flanges using bolts. The upright support was laid in a horizontal position resting on temporary supports. The bottom and dome were fastened to the ends of the upright support, being careful to align them with respect to the support axis. Plates (catchers) were welded to the outside of the bottom. These plates are used for installing the bottom on the manipulator and preventing the bottom from rotating on the stationary support of the manipulator. Plates (catchers) for installing the assembled units were welded to the outside of the bottom along its edge. A hole with a diameter of 430 mm was cut in the bottom and dome at the spots where the design manholes with a diameter of 500 mm are located. The upper end of the central upright support passes through this hole. A ring with braces made from shaped metal was welded from the inside to the central upright support, dome and bottom. These shaped braces provided strong rigidity to the erection connections when installing the units of the eight tanks in the first yard. When erecting the six tanks in the second yard innovators suggested that the stiffening ring with braces be installed above the dome from the outside of the shell. This facilitates dismantling the ring with the braces and does not disturb the stiffness of the erection joints. On the bottom and dome they mark off the layout for installing the ends of the units with consideration of the required clearance in the butts between the units. A fully-rotating hoisting cradle was installed on the upright support. A circular guard was erected on the dome. An adjustable erection ladder was fastened to the guard. The upright erection support with the bottom, dome, circular guard and ladder fastened to it was set up vertically, using a SKG-40 crane, on the fixed support of the manipulator. It was carefully aligned and made secure by three steel wire braces.

The units made from two plates were transported to the erection area and laid out in the order of their installation. Using a SKG-40

crane, the units were raised to the vertical position and with the help of assembly slats and wedges they are fastened together and to the bottom and dome.

The first unit is set on the catchers of the bottom and is secured to the dome section. Then the following units are erected clockwise. After installing and fastening the unit, upright supports for the tank are temporarily placed under the unit from the outside. The weight of the unit being installed is transferred to the support and foundation. The units are fastened together from the inside by 100-mm long tack welds every 250 mm. The tack welds have a fusion penetration depth of 4 mm. The work is carried out from a cradle which is able to move along an arc with a radius of 8 m in the vertical and horizontal planes. The vertical movement of the cradle is provided by an electric winch and the cradle is moved in the horizontal plane manually.

The units which have been installed are checked by meter-long templates. Thanks to the stiffening rings with angle braces attached to the bottom and dome and to the design upright supports which have been installed, the geometric shape of the shell is not distorted. The units are welded together and are welded to the dome and bottom from the inside from a cradle with a manual subwelding seam having a leg of 3 - 6 mm.

When erecting the first tank the stiffening tubes of the units were removed after completing the shell assembly. Subsequently, after carrying out experimental checks using strain gauges at all stages of the erection, because of the use of a pneumatic-tired manipulator with a "soft" system for supporting the shell, it became possible to remove the stiffening tubes during the erection process. After completing erection of the shell the central support and cradle were disassembled, the upright supports were disconnected from the shell, the erection ladder was removed, the cradle was dismantled and removed through the lower manhole. The central support was removed through the manhole in the dome.

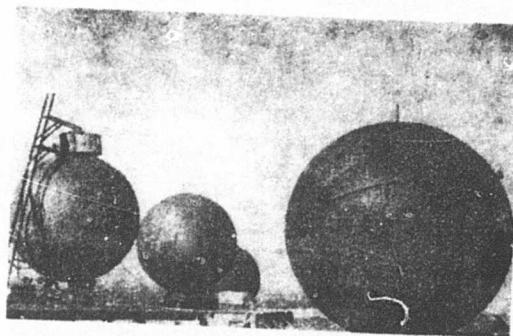


Fig. 50. A tank on the manipulator with the welding cabin and ladder.

After dismantling all the erection devices under the shell the moving support of the manipulator was erected using a pipe layer. The inside of the tank foundation was lined with crossties beforehand. The stationary circular support and the circular rail path were installed on these crossties. The moving support was installed in two sections through the opening between the two design upright supports. One section of the moving support consisted of three upright supports and the other section had one upright support. A mining ladder and welding cabin were installed on the tank (Figure 50).

The automatic welding of all the meridian and circular seams of the tank was performed on the manipulator. First all the meridian seams were welded and then the circular seams. During the welding process a superficial inspection of the welded seams was conducted in order to reveal and eliminate cracks, burn-throughs, beading and other defects. A crew of two - three men welded all the seams of the tank from the inside and outside in 20 work shifts. After completing the welding the quality of all the welded seams was checked using the ultrasonic method.

After the seams of the tank were checked the tank was installed in the design position using the jacks of the manipulator. The design position called for a distance of 3 m from the zero mark to the lowest point of the tank. The upright supports (except for two of them)

were installed, the haunches on their support ends were adjusted, the diagonal braces for the upright supports were installed, the nuts on the anchor bolts were tightened, and the haunches of the upright supports were welded to the shell. On the manipulator the flange connection at one of the driven roller supports was disconnected at four places (two places on the central support and two places on the carriage). Using a crane and winch, they pulled out from under the tank, through the opening between the two upright supports which had not been installed, the driven roller support for the carriage with its connecting tubing and the remaining three roller supports. Then they installed the two remaining upright supports. A crew of four men dismantled the manipulator in half a working shift and they erected it in one shift under the next tank which was prepared for assembly.

The assembly of a spherical tank with a volume of 2000 m^3 using the vertical method was performed in 6 - 7 calendar days (around 2 working shifts or 640 man-hours). This included the manual welding of the subwelding seam in the tank. With this method scaffolds and hanging platforms are not required. The automatic welding of the tank using the manipulator designed by the Construction and Design Bureau of the All-Union Scientific Research Institute for the Erection of Special Construction was performed in 20 shifts by a crew of 2 - 4 men with a welding speed of 16 - 19 m/hr.

The deviation in the shape of a shell from the design geometric shape did not exceed 10 mm (2% of the total number of measurements). The greatest number of deviations did not exceed 4 mm.

The geometric shape of the shell was measured when making hydraulic tests of the tank. With an excess pressure of 5 kgf/cm^2 the greatest external fibrous stresses in the zone where the shell rests on the upright supports did not exceed 1800 kgf/cm^2 ; in the zones of the erection seams which have local deviations from the design geometric form, the stresses did not exceed 2000 kgf/cm^2 , and the greatest stresses in the upright supports did not exceed 1500 kgf/cm^2 .

The design of the manipulator and the vertical method of erection enabled them to organize an assembly-line type method of assembling and welding the spherical tanks and ensured high quality of the welded joints [17].

SPECIAL ERECTION GANTRY CRANES

During 1958 - 1961, progressive technology for the erection of rotating furnaces with the dimensions 4.5 X 170 m was developed and introduced for the first time in the construction of the Belgorodskiy Cement Plant. In the plan for carrying out the operations for erecting the furnaces with dimensions of 4.5 X 170 m, the clearances of the main erection gantry crane were determined. As a result of the analysis of the possible variants for consolidation of the elements being erected, an optimum lifting capacity of the crane was selected. The crane had a lifting capacity of 120 ton force with a hoisting height of 18.5 m, a rail track width of 20 m, a hoisting speed of 0.995 m/min, a load carriage moving speed of 7.55 m/min, and a crane moving speed of 11 m/min. The total weight of the KMK-120 crane with its fittings was 114.3 tons (Figure 51).

The KMK-120 crane which had an assembly-disassembly design and used four load winches was manufactured by the Tuapsinskiy Plant named for the XI Anniversary of the October Revolution. The maximum weight of a unit in the erection of the rotating furnaces at the Belgorodskiy Cement Plant reached 126 tons.

In 1960, at the Achinskiy Alumina Plant the lifting capacity of the KMK-120 crane, as a result of strengthening the metal structures, was increased to 140 ton force for the purpose of erecting rotating furnaces with dimensions of 5.8 X 175 m. The maximum weight of an erection unit at the Achinskiy plant was 143.5 tons.

During 1961 - 1965, at Balakleye they constructed and put into operation the first modern standard cement plant with rotating furnaces

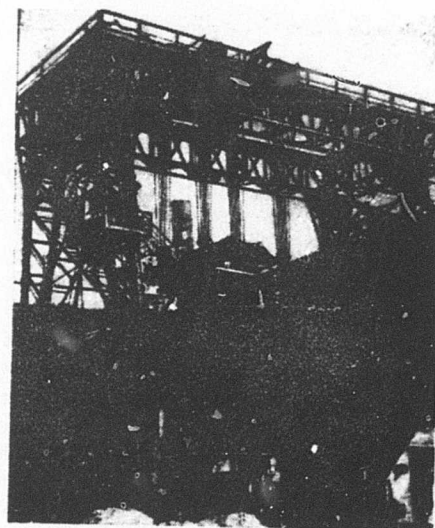


Fig. 51. The KMK-120 crane as seen when a platform is hung on the crane for automatic welding of the casing butt joints of a rotating furnace with dimensions of 5 X 185 m at the Balakleyskiy Cement Plant.

having dimensions of 5 X 185 m. The erection of these rotating furnaces was accomplished with the help of KMK-120 crane without increasing its lifting capacity to 140 ton force. The maximum weight of the erection units in the erection of four furnaces at Balakleye reached 140 tons. Based on the experience in erecting the Balakleyskiy Cement Plant, all the rotating furnaces with dimensions of 5 X 185 m were erected in the Ukraine using such cranes with a lifting capacity of 120 ton force. For erecting furnaces with dimensions 5 X 185 m, in the other Republics of the country, a gantry crane was used which had a lifting capacity of 140 ton force and a hoisting height of 21 m.

For erecting the test-experimental rotating furnace with dimensions of 7 X 230 m at the Balakleyskiy Cement Plant, they used an erection gantry crane with a lifting capacity of 320 ton force (four carriages with a lifting capacity of 80 ton force). This gantry crane had a hoisting height of 30 m, a gantry width of 35 m, a hoisting speed of 1.85 m/min, a travelling speed for the load carriages of

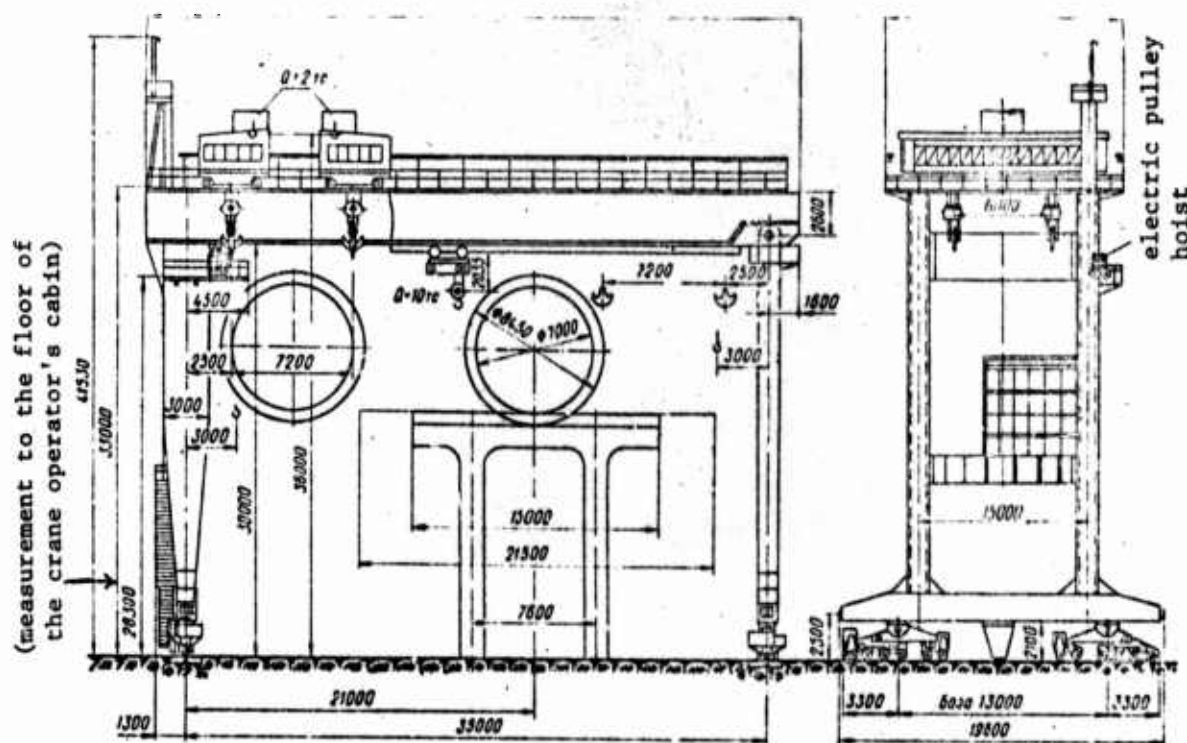


Fig. 52. Crane with a lifting capacity of 320 ton force for erecting a rotating furnace with dimensions of 7 x 230 m at the Balakleyskiy Cement Plant.

12.5 m/min and a crane travelling speed of 20 m/min. In addition, the crane was equipped with an electric pulley hoist with a lifting capacity of 10 ton force and a hoisting height of 30 m. It also was equipped with repair crane-beams on the cabs of the carriages with electric pulley hoists, with a lifting capacity of 2 ton force and a hoisting height of 36 m. These crane beams with electric pulley hoists also were designed to be used in part for technological purposes, that is, for delivering chains to the furnace when hanging a chain curtain. The total weight of the crane with its fittings was 574 tons (Figure 52).

In creating the heavy-duty erection crane, they reflected the modern requirements with respect to ensuring high-quality erection of multiple-support rotating technological equipment which is long and

TABLE 19. CHARACTERISTICS IN THE DEVELOPMENT OF FURNACES AND
ERECTION TECHNIQUES IN CEMENT PRODUCTION

Main Stages of the Development		Furnace daily productivity, tons	Total weight of erected equipment, tons	Av. labor expended in erecting equipment, man-days	Spec. labor of erection operations, man-days	
Furnaces in Cement Production	Erection Techniques				Per ton of cement output	Per ton of erected equipment
1	2	3	4	5	6	7
Hand-operated shaft furnaces (before 1930)	Erection from small elements with hand-operated winches & masts with installation of solid scaffolding	up to 20				
Mechanized shaft furnaces (1926 - 1930)	the same	20 - 80				
Rotating furnaces with dimensions of 1.8 x 40 m; 2.5 x 100 m (1930-1945)	Erection from small elements using winches, masts, & jacks with wooden trestles & scaffolding	100-250	1010	4625	18.5	4.6
Rotating rivetted furnaces with the dimensions 3x100 m; 3.6x150 m (1945 - 1958)	Erection using winches, masts, and jacks with wooden trestles and scaffolding	500-600	3560	10300	17.2	2.89

TABLE 19. CHARACTERISTICS IN THE DEVELOPMENT OF FURNACES AND
ERECTION TECHNIQUES IN CEMENT PRODUCTION

continued

1	2	3	4	5	6	7
Rotating riveted furnaces with the dimensions 3x100 m; 3.6x150 m (1955 - 1965)	Erection using metal scaffolding with a load-hoisting carriage	500-600	3560	8700	14.5	2.44
Rotating welded furnaces with the dimensions 3x100 m; 3.6x150 m (1955 - 1965)	the same	500-600	3284	7670	12.6	2.38
Rotating riveted furnaces with the dimensions 3.6x150 m; (1948 - 1966)	Erection of units with a weight up to 50 tons with the help of gantry cranes	600	3560	6950	11.6	1.95
the same - but welded furnaces	the same	600	3284	6140	10.2	1.87
Rotating welded furnaces with the dimensions 4.5x170 m; (1959 - 1967)	Erection of units with a weight up to 120 tons using the gantry crane KMK-120. Automatic welding	1000-1200	7646	9100	8.3	1.17
Rotating welded furnaces with the dimensions 5x185 m; (1963 - 1971)	Erection of units with a weight up to 140 tons using the gantry crane KMK-140. Automatic welding	2000-2300	9020	10200	4.7	1.13
Rotating welded furnaces with the dimensions 7x230 m; (1971)	Erection of units with a weight up to 320 tons using a gantry crane with a lifting capacity of 320 TS. Automatic welding.	3000-3500	12200	11000	3.4	0.9

heavy. The general characteristics in the development of furnaces for cement production and the main facilities for erecting the furnaces are presented in Table 19.

When erecting furnaces for a cement plant, two general construction plan variants are used. In the first variant, an assembly-welding area is laid out in the operating zone of the main erection crane. The assembly of the shells and units, and the erection of the furnace are carried out using a single gantry crane. In the second variant, the area for the preliminary operations is located outside the erection zone, and this area is serviced by separate cranes. When operating according to the first variant, it is necessary before starting the assembly operations to complete a large part of the construction with respect to building the foundations. In the second case, large erection mechanisms are required, but at the same time it is possible to integrate the construction operations with the assembly which shortens the construction time. The time the gantry crane remains in the erection area is shortened, and therefore the degree of its utilization is increased.

The assembly and welding of hoops, shells, and erection units for the furnace are complex, demanding and time-consuming operations. It is impossible to transport by railroad large-scale hoops, shells and units for furnaces with the diameter 4.5 - 5 and 7 m. The design plan for these furnaces provides for finishing the hoops, shells, and units at the erection sites.

ERECTION OF A ROTATING FURNACE WITH THE DIMENSIONS 7 X 230 m AT THE BALAKLEYSKIY CEMENT PLANT

The assembly and welding of the 18 erection units of the furnace casing (Figure 62), as was suggested by the erectors and the equipment supplier which was the "Volgotsemmash" plant, was carried out with the help of two KMK-120 gantry cranes. These KMK-120 gantry cranes were

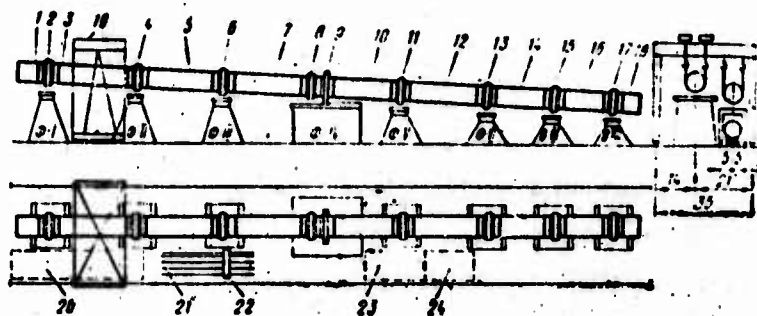


Fig. 62. Scheme for petitioning the casing of a rotating furnace with dimensions of 7 X 230 m into 18 erection units:

1 - 18 --- erection units; 19 --- gantry crane 4 X 80 TS; 20 --- preparation of the shells; 21 --- stand for assembling the units; 22 --- welding gantry; 23 --- stand for assembling the crown gear with the shell; 24 --- stand for assembling the hoops with the shells.

erected and placed into operation in a special area for the assembly.

Data on the length and weight of the erection units are presented in Table 23.

The riveting of the 24 shoes of the crown gear to the sub-crown shell was replaced by bolting the shoes to the shell (Figure 63). In order to perform this operation, the "Volgotsemmash" plant had to deliver to the erection area a special portable heavy-duty radial drill for drilling 744 holes with a diameter of 32 mm in the shell through the holes in the shoes which were drilled at the plant with a smaller hole diameter. However, it was also decided to replace the bolted connections with electric welding.

The erection organization carried out the assembly and welding of the 18 erection units for the furnace casing directly on a stand.

The technology for erecting a furnace with dimensions of 7 X 230 m

TABLE 23

THE LENGTH AND WEIGHT OF THE ERECTION UNITS
OF THE ROTATING FURNACE WITH DIMENSIONS OF
7 X 230 m

No. of Erection Units	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Length, m	8,5	7,0	25,0	7,0	25,0	8,1	23,9	8,1	2,9	23,0	7,0	25,0	7,0	17,0	7,0	15,0	7,0	6,5
Weight, tons	76	295	204	295	204	307	233	307	178	188	295	204	295	173	295	140	295	79

differs substantially from the technology for erecting the four Balakleyskiy furnaces with dimensions of 5 X 185 m.

The first difference involves the fact that the hoop units consist not only of hoops and sub-hoop shells, but also of shells adjacent to these sub-hoop shells along both sides (Figure 64).

An increase in the length of the hoop units enabled them to install at the ends of the hoops special stock saddle supports directly on the foundation, outside the roller supports. This created conditions for speeding up the erection of the intermediate erection units.

The second difference involves the fact that, to increase the quality of the machining on lathes, the assembly on the stand, and the erection on the foundations, the furnace casing was considered to be a multiple-support shaft with a straight rotation axis which operates in bearings. Thus, each hoop unit appears as a base with a precisely fixed position both with respect to the longitudinal axis of the furnace rotation and also with respect to the transverse axis of the roller supports. Consequently, the allowances for the deviations of the erection units from the nominal length were determined solely on

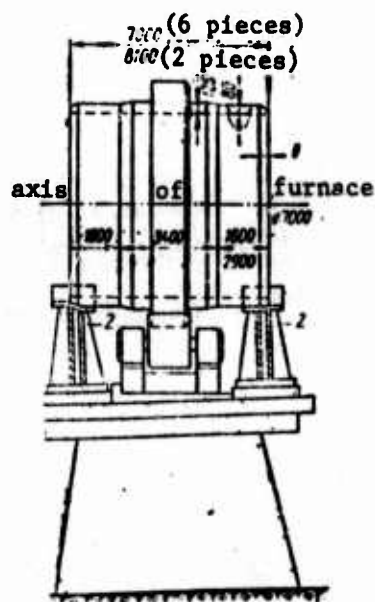


Fig. 64. Erection unit of a casing with a hoop:

- 1 - erection unit;
2 - saddle-like supports.

The fully-welded casing of the rotating furnace with dimensions of 7 X 230 m was assembled from 112 shells manufactured from sheet steel with a thickness of 125 mm (8 sub-hoop shells), 80 mm (19 shells), 50 and 40 mm (85 shells).

The nominal dimensions of the clearances at the butt joints of the shells and the allowances for the increase of the clearances, as is seen from Figure 65, determine the actual dimensions of the shell lengths when their edges are processed under the weld. When connecting the

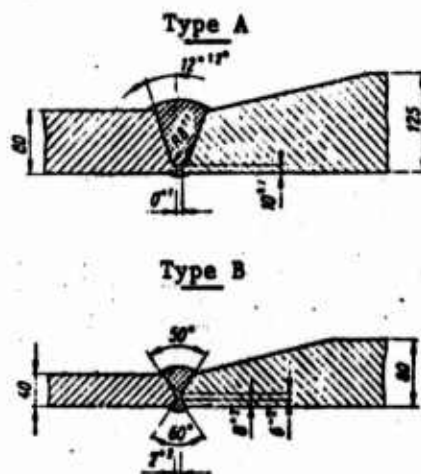


Fig. 65. Dressing of the butt joints for welding the casing of a furnace with the dimensions 7 X 230 m.

shells and erection units with an A-type weld seam, the following should be observed. The actual length of the shells and units, obviously, must not be longer than the nominal length of the shell and unit along the axes of their weld seams. Also, the allowance of the deviation from nominal dimensions must only be minus and be within 1 mm. For joining shells with a B-type welded seam, the following must be observed. The actual length of the shells must be shorter than the nominal dimensions by 2 mm, and the minus allowance must be within 2 mm. For connecting erection unit No. 9 with erection unit No. 10 using a B-type weld seam, the following must be observed. The actual length of No. 9 erection unit must be shorter than the nominal dimension by 1 mm, and the minus allowance must be within 2.5 mm.

Table 24 presents the dimensions of the clearances and the allowances for the increase of the clearances in all the circular butt joints in the furnace casing and the actual lengths of each shell and their assembly in each erection unit. The actual length of shells in the

TABLE 24. CLEARANCES FOR WELDING THE CIRCULAR SEAMS OF THE CASING OF A ROTATING FURNACE WITH THE DIMENSIONS 7 X 230 m, AND THE REQUIRED LENGTH DIMENSIONS OF THE SHELLS FOR WELDING THEM INTO ERECTION UNITS

Erection Unit No.	Shells					Welded Seams			Required length of shells, mm			
	Sheet thickness, mm	No. of pieces	Type	No. of Pieces		Nominal Clearance, mm	Allowance for increase of clearance, mm	Total, in mm	Based on limiting allowances	to the allowable deviation	For machining on lathe	For assembly into erection units
				On the stand	In erection							
1	40	4	B	3	1	2	+2	7	+7	-2	-7	-7
2	80	1	B-A	2	-	1	+1.5	1	+1.5	-1.5	-2	-4
	125 80	1	A-A-B	-	-	1	+1.5	1	+1.5	-1.5		
3	40	13	B	12	1	2	+2	26	+26	-2	-26	-26
4	80	1	B-A	2	-	1	+1.5	1	+1.5	-1.5	-2	-4
	125 80	1	A-A-B	-	-	1	+1.5	1	+1.5	-1.5		
5	40	13	B	12	1	2	+2	26	+26	-2	-26	-26
6	80	1	B-A	2	-	1	+1.5	1	+1.5	-1.5	-1	-3.5
	125 80	1	A-A	-	-	0	+1	0	+1	-1		
7	80	1	A	1	1	0	+1	0	+1	-1	-19	-20.5
	80 40	9	A-B-B	9	-	2	+2	18	+18	-2		
8	80	1	B-A	2	-	1	+1.5	1	+1.5	-1.5	-1	-3.5
	125 40	1	A-A	-	-	0	+1	0	+1	-1		

TABLE 24. (Continued)

10	40	12	6	11	1	2	+2	24	+24	-2	-24	-21
11	80 125 80	1 1 1	B-A A A-B	2 - -	1	1 0 1	+1.5 +1 +1.5	1 0 1	+1.5 +1 +1.5	-1 -1 -1	-1.5 -2 -1.5	-4
12	40	13	B	12	1	2	+2	26	+26	-2	-26	-26
13	80 125 80	1 1 1	B-A A A-B	2 - -	-	1 0 1	+1.5 +1 +1.5	1 0 1	+1.5 +1 +1.5	-1 -1 -1	-1.5 -2 -1.5	-4
14	50	9	B	8	1	2	+2	18	+18	-2	18	-18
15	80 125 80	1 1 1	B-A A A-B	2 - -	-	1 0 1	+1.5 +1 +1.5	1 0 1	+1.5 +1 +1.5	-1 -1 -1	-1.5 -2 -1.5	-4
16	50	8	B	7	1	2	+2	16	+16	-2	-16	-16
17	80 125 80	1 1 1	B-A A A-B	2 - -	-	1 0 1	+1.5 +1 +1.5	1 0 1	+1.5 +1 +1.5	-1 -1 -1	-1.5 -2 -1.5	-4
18	50	4	B	3	1	2	+2	7	+7	-2	-7	-7
Altogether . .				112	2	0	+1	0	+19		-184	-203
			B	77	15	2	+2	184	+184			
				94	17			184	+203			

furnace casing, as is seen from the Table, is 184 mm shorter than the nominal dimension of 230 m. When adding the limiting minus allowance for the increase of the clearances, the actual length may be shorter than the nominal dimension by 387 mm.

The necessary precision which has been indicated above for the actual length of the shells and erection units is fully ensured by the precision of the lathes on which the profiles of the circular edges of the shells are machined. More precisely, it is ensured by the carousel lathe on which the circular edges of the shells are machined from sheet steel with a thickness of 125 and 80 mm, and by the gas cutter which is used for cutting the edges of the shells which are made from sheet steel with a thickness of 50 and 40 mm.

The actual lengths of shells which are obtained when the edges are processed by a carousel lathe or by a gas cutting torch must be indicated in the processing log for the set of shells for a furnace casing. Accurate assembly of the shells on the drive stand according to the appropriate marking of the paired half-shells enables them to complete, at the construction site, all the shell connections with a precision of the dimensions of the clearances under the weld, the flatness of the ends, and the perpendicularity of the circular edges to the axis of the shells and erection units which have been achieved by the lathe or torch. With this technology and quality of the shell processing, technically the need should not arise for carrying out additional operations for processing the edges under the weld either in the stand assembly or in the assembly of the casing at a height on the foundations. Also the need should not arise for shifting the hoops with respect to the transverse axis of the sub-hoop shells.

Special care is required when aligning the permanent casing connections, since an error leads to the appearance of cracks after the furnace has been placed into operation. The welding-up of such cracks only worsens the alignment errors. Therefore, the only method for eliminating these errors is the removal of a casing section with its subsequent alignment and connection.

A multiple-support shaft - that is, the casing of a rotating furnace - can not operate normally if its axis of rotation is not straight. Significant bends of the furnace rotation axis at the connections of each pair of shells, when there are a large number of pairs, create abnormal operating conditions for the furnace casing, accelerates the destruction of the internal refractory lining, and produces significantly higher dynamic impacts on the roller supports which are transmitted to the foundations and destroy them.

The third difference in the erection technology of a furnace with dimensions of 7 X 230 m involves the fact that the riveted connection of the crown gear shoes to the sub-crown shell is replaced by a bolted connection. Normal riveting of rivets of such a size either manually using a hammer or with a pneumatic hammer is not possible -- it does not ensure complete seating of the rivet stem along the entire length of the hole. In order to drill holes for the bolts, it is necessary to use a heavy-duty portable radial drill which is part of the basic equipment of the workshop of the plant-supplier.

The fourth difference involves the fact that the welding of the 17 erection butt joints of the furnace casing after alignment and centering is done with new high-productivity two-arc welding tractors of the Ye.O. Paton Institute of Electric Welding. These new welding tractors bear the designation DTS-38 and operate with the TSD-2000 power supply sources.

The fifth difference involves the fact that the span of the erection gantry crane with a lifting capacity of 320 ton force enables them to arrange, under the crane, a driven assembly stand for assembling the shells of the furnace casing into erection units, and a welding gantry. This arrangement is shown in Figure 62. In this way, the possibility is provided for eliminating considerable costs in the construction and equipping a special area for the assembly and welding of the shells and erection units of furnaces with dimensions of 7 X 230 m. The maintenance conditions of the furnace during the operating period

are improved also.

When integrating the operations performed by the plant-supplier work forces for the assembly and welding of the erection units and by the erection organization work forces for the erection of the finished units of the furnace casing on the foundations, the operations must be regulated by using a graph detailing the hourly round-the-clock use of the crane.

THE CONCEPT OF PRECISION

Precision designates the degree to which the actual values of the geometric, operational and other parameters approximate their design values which determine the quality of the technological equipment operation. In the given case, only the precision with respect to the geometric parameters of the rotating furnace is investigated: the precision in the dimensions of the parts, shells, erection units, furnace casings, support rollers, hoops and crown gear; the precision of their shape and the precision of the relative alignment of their surfaces.

As the qualitative criterion for the precision, we use the largest deviation of the geometric parameter of the finished product - that is, of the rotating furnace - from the design value. Such a deviation is caused by an error in the processing, assembly, or erection. Not every error is allowable. The errors may be divided into allowable errors and intolerable errors - that is, into permitted errors and forbidden errors. A permitted error is ruled to be an allowance.

The allowances are determined on the basis of the technological and operational requirements imposed on the part, unit, casing, or finished rotating furnace. The allowances which satisfy the operational requirements are called functional allowances; the allowances which satisfy the requirements of the achievable precision of manu-

facturing, assembly, and erection associated with modern technological processes are called technological allowances.

The principle of the engineering design of technological processes for manufacturing parts, for assembly and erection, assumes connection between the technological and functional allowances. In the first case, the technological allowances are smaller or equal to the functional allowances; then the allowances are completely linked and the method of full interchangeability is used. In the second case, the technological allowances of the parts, shells, and sub-assemblies in the intermediate stages of the technological manufacturing and assembling process are larger than the functional allowances. In this case, the allowances are partially corrected, and they use adjustment of the parts, shells, and units during the process of assembly and erection of the rotating furnace.

When designing the technological processes, the selection of one of these two methods is determined by the given level of precision. This specified precision level is determined from the optimum economic calculation of the cost of manufacturing and erection.

A properly performed engineering calculation of the precision of the technological manufacturing processes should ensure high-quality erection and guarantees that the technological and functional allowances correspond on the basis of the most favorable economic solutions.

When determining the allowances, it is necessary to base them not only on the precision of the manufacturing and erection, but also on the condition for maintaining the operating efficiency of the rotating furnace over a specific operating time - that is, ensuring the reliability and longevity. In order that the operational characteristics of the rotating furnace at the end of its service time are within the prescribed limits, it is necessary to establish a guaranteed precision margin. The numerical values of the precision margin coefficient must serve as a guarantee that, during the time of manufacturing,

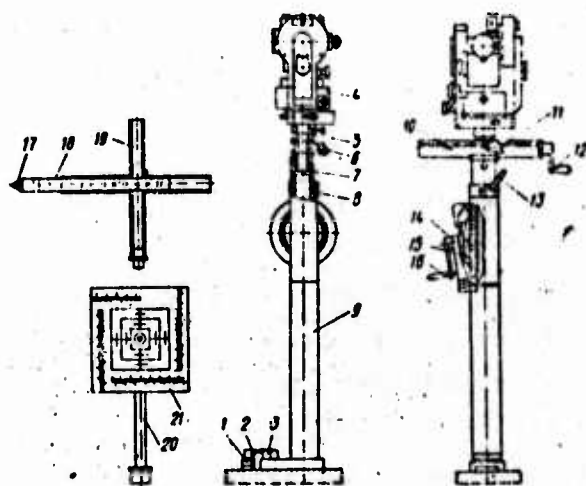


Fig. 66. The schematic diagram of the IGTs0-3 instrument:

- 1 - π - shaped base; 2 - screw; 3 - nut;
- 4 - theodolite; 5 - slide guide; 6 - reference level; 7 - rack for the vertical motion mechanism; 8 - measurement system of the vertical motion mechanism 9 - tubular upright support;
- 10, 11, 12 - transverse motion mechanism; 13 - lock of rack 7; 14 - bracket holder; 15 - spiral checking device; 16 - handle of the vertical motion mechanism; 17, 18, 19 - geometric center locator; 20, 21 - target.

erection, and operation of the unit, there is no possibility that any of the intolerable limiting situations will occur. A precision margin is necessary for all manufactured articles which have a long operating period, among them rotating furnaces.

METHODS FOR ALIGNING AND CENTERING ROTATING FURNACES

Modern optical instruments enable one to obtain a high degree of precision and to create new methods for checking the straightness of the rotation axis of the furnace. A new method based on the use

of the optical instruments IGTsO-3 (Figure 66)⁽¹⁾ was developed for checking the straightness of the individual units or of the furnace casing as a whole. This new method also enabled them to check the perpendicularity of the end planes of the units to their axes [19]. The method involves finding the centers of gravity of the transverse cross sections of the shells and then subsequently checking their relative position. In the upper part of the IGTsO-3 instruments, one may interchangeably set up the center of gravity locator for the cross-section, a telescope or a target, whichever is appropriate. When replacing the locator with the telescope or target, their centers coincide. It is advisable to have up to five IGTsO-3 instruments in the set of instruments. However, it is also possible to align the shells with only two instruments. When aligning the straightness with the help of IGTsO-3 instruments, it is necessary first of all to establish which cross sections one should use as the base cross sections and which cross sections one should adjust to correct the alignment.

When assembling the shells into erection units, the outermost shells are used as the base cross sections, and the other or intermediate shells are aligned with respect to the outermost shells. For example, for aligning five shells it is desirable to use five instruments. These five instruments are arranged on the single axial plane of the unit. Having set up the first instrument in the cross section of one of the outermost shells its center of gravity is found and then the center of gravity locator is removed. Then the theodolite is installed on the slide guide in place of the locator. A similar procedure is followed in the cross section of the other outermost shell; however, the center of gravity of the locator in this case is replaced by the target. The theodolite telescope is sighted on the center of the target, and the telescope is locked in this position. In a similar way, the instruments are installed in the cross sections of the inter-

(1) Author Certificate No. 248259. Official Bulletin of the Committee of Inventions and Discoveries Associated with the Council of Ministers of the USSR "Izobreteniya, promyshlennyye obraztsy, tovarnyye znaki (Inventions, Commercial Models, Trade Marks)". 1969, No. 23.

mediate shells, and after finding their centers of gravity targets are installed in place of the locators. By looking through the telescope eyepiece, one can determine the distortion of the axis of the units in a given cross section, for example, the first intermediate shell, at once in two mutually perpendicular planes. For the purpose of simplifying the deciphering of the image, one should conventionally assume that the target grid is a fixed coordinate system and the telescope crosshair grid is the moving system. If the targets installed in the cross sections of the first, second and third intermediate shells have identical dimensions, then the checking is performed sequentially, remembering to check in the interval between two measurements the correctness of the telescope sighting. It is desirable, however, to select the dimensions of all the targets and to position their grids in such a way that all of them would fall in the telescope's field of view. In this case, the very substantial advantage of IGTsO-3 instruments is more fully used. This advantage is the possibility of conducting a continuous observation of the position of the unit axis during the process of assembling the unit and even during its welding. This is possible, since the fastening and design of the instruments allows them to rotate together with the unit on the stand, or together with the casing of the rotating furnace on its roller supports.

After the casing rotates, one only has to check the sighting of the telescope on the center of the target installed in the cross section of the second outermost shell.

With the help of IGTsO-3 instruments, the effect of solar radiation on the position of the axis of rotation of a furnace with the dimensions 5 X 185 m was determined. This solar-effect checking was performed when erecting the No. 7 furnace at the Sebyakovskiy Cement Plant. The bend of the rotation axis turned out to be so substantial that after this, all the alignment operations were conducted only at night. The other operating rotating furnaces which were positioned alongside also may have a similar effect on the unit being aligned. Based on the measurement data, a graph was constructed for the position of the unit axis in two mutually perpendicular planes.

When rectifying the unit axis, it is necessary to remove part of the casing at the butt joints of the shells - that is, to cut out a wedge, the dimensions and position of which are determined analytically or graphically.

When the casing of a rotating furnace, rotates, loads arise which differ in their direction and the character of their action. These loads are transmitted to the roller supports through the hoops. It is necessary to point out that the universally used method of fitting hoops with a hot clearance is not fully justified. In fact, it is well known that fastening such hoops on the furnace casing is a very imperfect solution, and it requires special and very time-consuming repairs. Rigid fitting of the hoops to the casing was used for the first time in the designs for the rotating furnaces with the dimensions 3, 3/3, 6 X 150 m. These furnaces and their rigidly fitted hoops provided very durable operation. Therefore, the studies of the Ye.O.Paton Institute of Electric Welding for creating special hoops which are rigidly connected with the furnace casing took on great importance. These special hoops had a box-like cross section and contained a coolant.

The established allowances for the relative position of the hoop surfaces and its wobble when installed on the furnace casing are as follows:

- non-concentric nature of the cylindrical surfaces of the hoop (internal and external) — 1 mm;
- non-parallel nature of the end planes of a hoop of rectangular cross section — 1 : 5000 of the hoop's external diameter;
- ovality with respect to the external diameter — 0.0005 of the diameter;
- breakdown (bend) of the end plane — 1 mm per 1 m of the hoop radius;
- lateral wobble of the hoop with furnace rotation — up to 3 mm.

Studies showed that large errors are introduced into the align-

ment of the axis of rotation of a rotating furnace by hoops which have an incorrect circular shape. Therefore, it is necessary to check the shape of the welded hoops, and when possible to mechanically machine them after welding the half-rings.

After the furnace is placed into operation, the stresses smooth out, and spacers of the same thickness ensure minimum vibrations of the center of gravity of the shell cross section at the hoop installation site during rotation of the section. In order to align the hoop in the axial direction, one should use a circular line which is easily drawn with the help of IGTsO-3 instruments when they have a special optical attachment. In order to establish the magnitude of the hot clearance, it is necessary to know the operating temperature of the hoop and the sub-hoop shell associated with the steady-state thermal conditions of the furnace. However, these temperatures fluctuate depending on the condition of the lining and lubrication, the distribution of the temperature zones, and the temperature of the surrounding air.

The methods of aligning and centering rotating furnaces which were developed by the laboratory for instrumental alignment of the United Cement Repair Trust enabled them to conduct all the erection operations without rotating the furnace and enabled them to achieve maximum integration of the assembly operations.

A laser beam directed precisely along the furnace rotation axis is used as the control base. A commercially manufactured OKG-11 laser (Figure 67), which is installed during the erection in the dust chamber serves as the beam source.

During the entire period for erecting the rotating furnace, the instrument is set up altogether two times: the first time for monitoring the erection of the support frames, roller supports and furnace drive; the second time for monitoring the erection of the casing and crown gear.

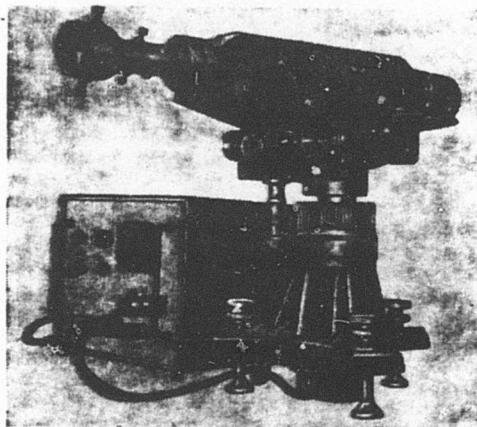


Fig. 67. Optical quantum generator (laser) OKG-11.

The first setup of the instrument (Figure 68) enables them to erect the support frames and roller supports simultaneously on all the foundations, and additional calculations and measurements are not required in order to maintain the design slope. Using these devices for monitoring the position of the support rollers enables them to simultaneously establish rollers in the vertical and horizontal planes.

Monitoring the erection of the support frames is done with the help of a device consisting of a reference ruler which is fastened to a magnetic base. The precision with which the device is installed in the horizontal plane is checked by using a level which is located in the base of the device.

The position of the frame is checked at once both in the projection on the horizontal plane and with respect to the slope, and its position in the transverse direction (with respect to angles) is revealed with the help of a control ruler and level.

Monitoring the erection of the support rollers is done with the help of a device which is mounted on the generating surfaces of the rollers. The device consists of a moving target which moves with

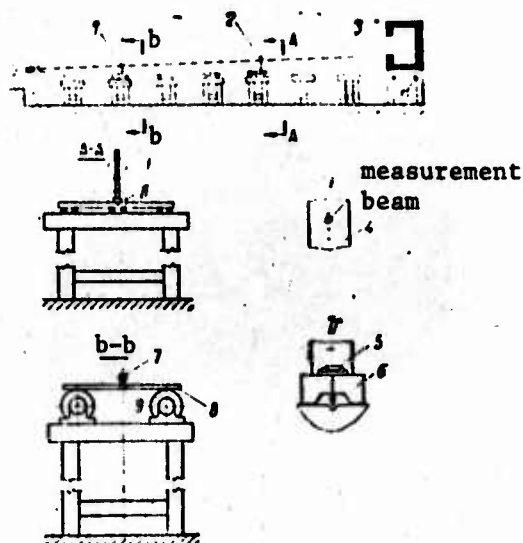


Fig. 68. The first setup of the OKG-11 instrument:
 1 - device for monitoring the erection of
 the support rollers; 2 - device for monitoring
 the support frames; 3 - laser; 4 - reference
 ruler; 5 - level; 6 - magnetic base; 7 - moving
 target; 8 - control ruler; 9 - level.

respect to the control ruler. A level which monitors the height of the rollers with respect to one another also is fastened to the control ruler.

By checking the position of the support rulers on the basis of the generating surfaces, one is able to achieve maximum precision in installing the rollers.

Having completed the erection of the support rollers and having added the support frames, they begin to erect the furnace casing. For this purpose, it is necessary to set up the OKG-11 generator in the second position (Figure 69).

Before starting the erection, the units are marked off beforehand with respect to their centers of rotation. The marking is accomplished by drilling 8-mm diameter holes in the protective spacers

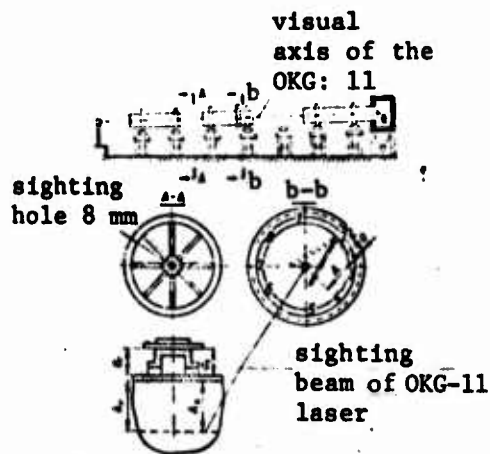


Fig. 69. Second setup of the OKG-11 instrument:
1 - 8 -- partition points for the measurement.

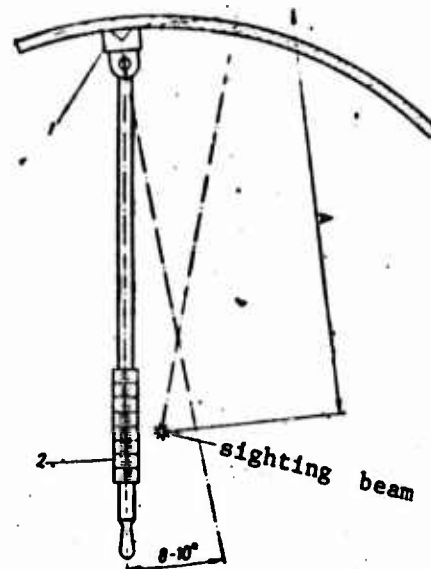


Fig. 70. Device for determining the displacement of the shell center from the center of the rotating furnace:
1- magnetic base; 2 - reference ruler.

which are set up inside the shells. The units are considered to have been correctly joined together when the laser beam passes through all the marking holes. Data on the marking are presented in Table 25.

In order to center the crown gear, a device was used for determining the displacement of the center of the shell from the center of rotation of a furnace (Figure 70) - that is, an inside gauge with a magnetic base. In addition to the magnetic base, the inside gauge has a reference ruler fastened to the base by means of a hinge.

The shell is marked off along the perimeter in eight sections. The inside gauge base is set at each of the partition points; the swinging of the reference ruler measures the quantity A which is the distance from the center of rotation of the furnace to the marked-off point of the sub-crown shell. The data obtained are recorded in a table of measurements, after which they determine the quantity a, which is the distance from the shell to the trough of the teeth of the crown gear:

$$a = R - A - S,$$

TABLE 25

SCHEME FOR PERFORMING THE MEASUREMENTS

Partition Points ¹	1		2		3	
	Kh	G	Kg	G	Kh	G
S - casing thickness . . .	60	60	60	60	60	60
A	2505	2504	2495	2496	2500	2500
a	805	806	815	814	810	810
Control	3370	3370	3370	3370	3370	3370

¹The partitioning points are seen in Figures 69 and 70.

where $R = \frac{D}{2}$ is a constant which is the same for all eight points;

D is the diameter of the crown gear with respect to the troughs of the teeth.

In order to eliminate the axial wobble of the crown gear, these measurements must be made twice, once from the side of the cold end of the furnace and once from the side of the hot end of the furnace. These measurements are made on a base of 1.5 m.

The suggested methods for instrumental aligning are simple. They eliminate mathematical calculations, and the alignment itself makes it possible to shorten the length of time required for performing the erection operations because of maximum integration of the erection operations and because of the change of the technology for performing many of the operations.