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The Design of Cast Technological Equipment for Heat Treatment Furnaces

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Abstract

Various examples of the design of cast elements of the equipment used in furnaces for the heat treatment of machine parts are given. Shortcomings in their performance are indicated. Reasons for required stability of equipment are briefly discussed. Elements of equipment illustrate the possibilities of using a charge-carrying pallet with dimensions of 900×600×45 mm as a basis for multi-component technological equipment. Introducing additional elements, such as metal baskets, intermediate pallets or crossbars to the main pallet, it becomes possible to create different configurations of this equipment. The technological equipment presented and discussed here is offered to different plants which heat-treat a wide variety of produced parts. It was found that the reliability and durability of new designed equipment can be checked only during practical use. For large plants dealing with the heat treatment of bulk quantities of parts homogeneous or similar in shape is recommended to use the dedicated tooling.

Keywords: Innovative Foundry Technologies and Materials, Castings for Heat Treatment Plants, Grates

1. Introduction

In most general terms, the technological equipment for heat treatment furnaces can be described as "containers" that allow the formation of charge and its transport both inside and outside the furnace chamber.

Long-term observation of the equipment used for heat treatment [1-4] leads to the conclusion that there are many shortcomings in its performance system. These include, among others:

- low level of utilization of the effective work of the equipment in cases when it can not be used for the heat treatment of a large range of parts,
- high operating cost of the equipment, where an essential component of this cost is maintenance and repair,
- high failure rate of the equipment during operation, which also affects the extended downtime of the furnaces.

The possibilities of limiting the above shortcomings are searched mainly in the upgraded design of the equipment [1-4].

Tooling should be considered technological (properly designed), when it meets the basic demands of furnace operation, including its performance, functionality, environmental issues, etc. At the same time, tooling should also meet some other requirements listed below [1-4]:

- workmanship (easy and low-cost production, selection of best construction materials, etc.),
- operation (reliability, durability, ergonomics, maintainability, easy handling, etc.).

Technological equipment usually comprises from several up to several tens of elements of different shapes and sizes. The basic rule generally accepted and applied by manufacturers of this type of tooling is "the minimum weight with maximum strength and capacity". This stresses the importance and share of the tooling cost in the overall cost of the performance of a furnace for heat treatment.

The designer of the tooling is also expected to ensure that all heat treated parts loaded into the furnace chamber have the same conditions of the heat treatment.

This paper presents examples of the design of technological equipment using a pallet of basic dimensions of 900×600 mm. The pallet has been designed in such a way as to improve its versatility and enable various structural elements to be added to its construction thus allowing for a heat treatment of the widest possible range of machine parts.

2. The base pallet

The cast base pallet with dimensions of 900×600 mm is commonly used in chamber furnaces for heat treatment. Usually this is an openwork and thin-walled design.

Manufacturers of this type of tooling make as a rule their own designs of the base pallet (Fig. 1 and 2) [3,4].

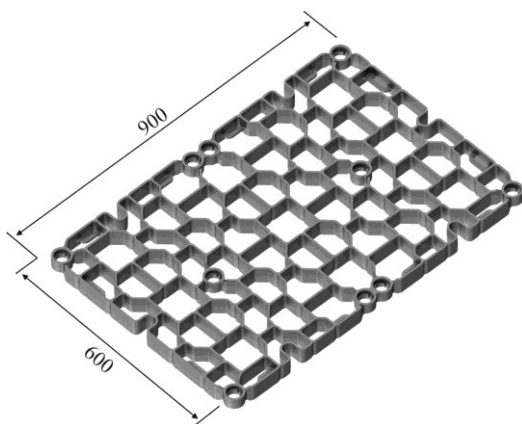


Fig. 1. The base pallet operating in a chamber furnace

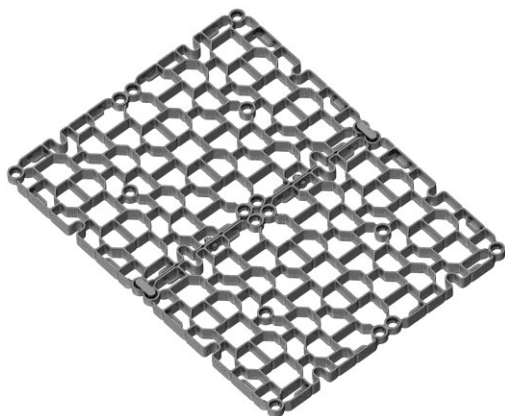


Fig. 2. Pallets (Fig. 1) assembled with screw joints and clamps in the corners

When designing the shape of the pallet it is assumed that:

- heat-treated parts with large weight and dimensions will be stacked on a pallet directly,

- small parts will be placed or suspended on a pallet using additional elements, which requires the design of proper mounting system.

The possibility of combining pallets (Fig. 2) is also taken into account in the case of furnaces with large working chamber.

More information on the design of this type of openwork construction can be found in [1,2].

Pallets and other elements of the tooling are cast, mainly from the creep-resistant high-alloyed nickel-chromium steel. Occasionally nickel alloys are also used [5-9].

3. Design of the equipment

The technological equipment used in the heat treatment of small parts consists of a base charge-carrying pallet on which the following elements are set:

- basket / baskets (Figs. 3, 6, 8, 9, 11), or
- structure comprising pallet posts and intermediate pallets (Figs. 12 and 14), or posts and crossbars (Figs. 15 and 16).

In the solutions of tooling design discussed below, the matching elements are joined together with detachable connections. This allows for their easy replacement when changing the type of stock or removing the single worn out elements. Loose fit applied to these components ensures their free heat distortion in the range of operating temperatures.

3.1. The system including base pallet and basket/baskets

Baskets are used for the heat treatment of massive parts with small dimensions. Their treatment using other types of equipment is virtually impossible. Baskets are often used also for the heat treatment of parts with low requirements, i.e. when their arrangement in the basket does not affect the result of the heat treatment, e.g. during the stress relief annealing process. The use of the basket improves the furnace efficiency and facilitates loading and unloading of the charge. When the charge loaded into the basket is very small, the interior of the basket is covered with chromium-nickel wire mesh and/or perforated sheet made from heat-resistant steel. The interior of the basket can be complemented with compartments or nests where parts which have to be separated are placed [3,4].

The simplest solution is to add side walls to the base pallet (Fig. 3).

The stability of such structures (Fig. 3) during operation is ensured by the use of screws joining the walls in the corners and additional stiffening with a linking rod (Figs. 4 and 5).

Often the design of the basket also includes:

- mounting side walls on a pallet using posts (Figs. 6 and 8),
- setting the basket/baskets on a pallet (Figs. 9 and 11).

The use of long mounting posts allows the attachment of a large number of side walls (Fig. 8), which significantly raises the basket capacity (Fig. 6).

Sometimes baskets not attached to the base pallet are also used (Figs. 9 and 11) and then they can be operated independently. This mainly happens when the weight of the

charge is small. For the stock of a large weight, the basket should be protected against possible deformation by placing it on a base pallet (Figs. 9–11).

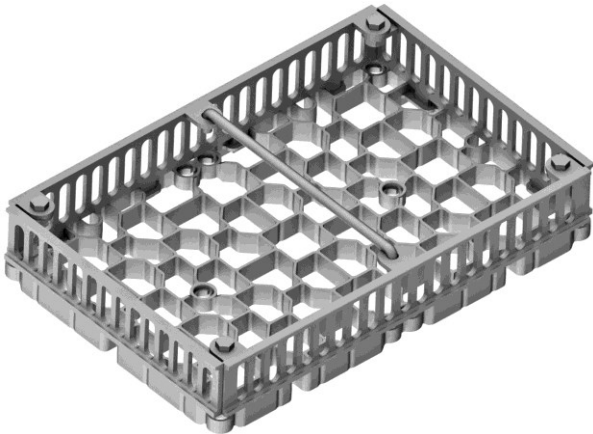


Fig. 3. Low basket built on a pallet using side walls (Fig. 1)

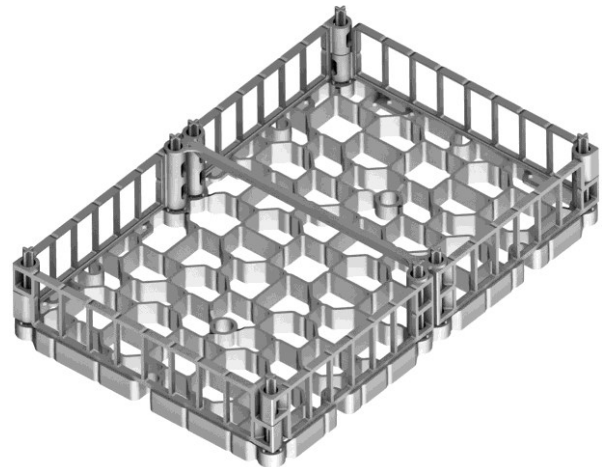


Fig. 6. Low basket built on a pallet using side walls and posts

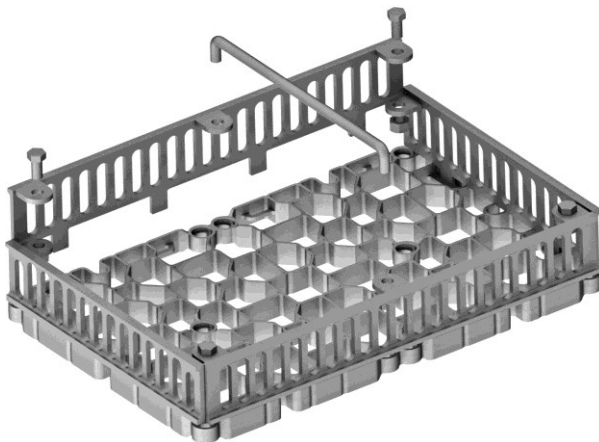


Fig. 4. Elements of the basket shown in Figure 3

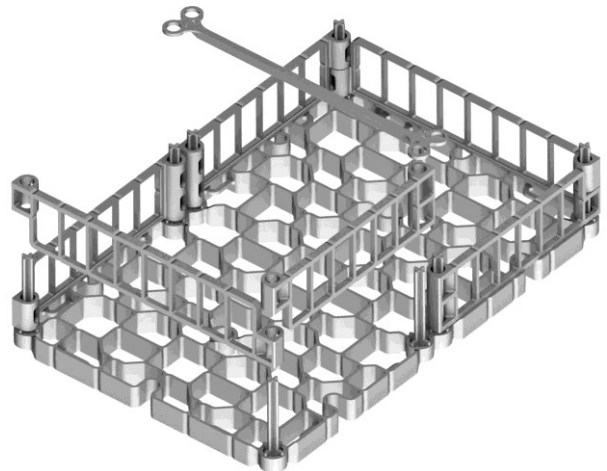


Fig. 7. Elements of the basket shown in Figure 6

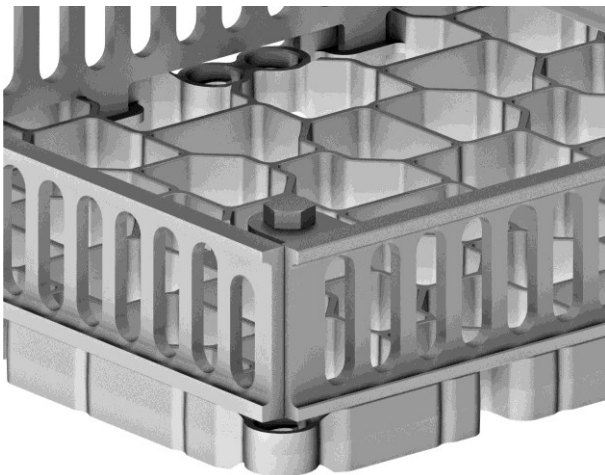


Fig. 5. The corner of the basket shown in Figures 3 and 4



Fig. 8. High basket compared to the low basket shown in Figure 6, built on a pallet with a large number of walls and long bars

Baskets (Figs. 9 and 11) are of low weight and modest rigidity. They can be stacked on each other and held in position

by the transport holders disposed in the middle of the short sides. Large baskets (Fig. 9) are usually raised by a crane. The size and weight of small baskets (Fig. 11) are such that their manual operation is not difficult, even when they are filled with charge.

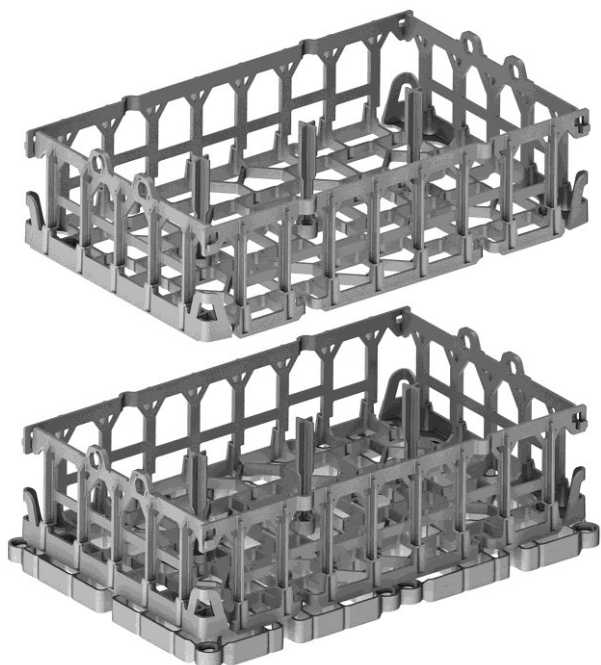


Fig. 9. Large basket set on a base pallet. The walls of the basket are mutually fastened and adjusted to the bottom of the basket

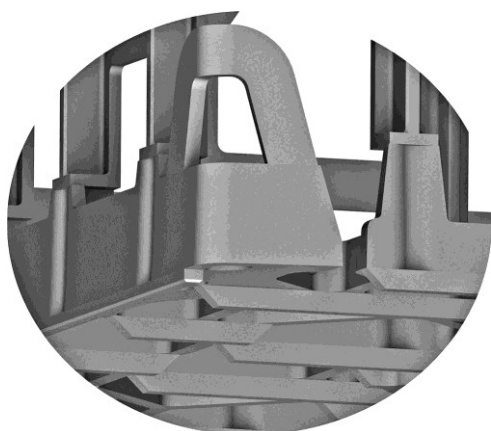


Fig. 10. The corner of the basket shown in Figure 9

In their upper corners, the walls of the basket are connected with clamps (Figs. 9 and 11). This combination enables frequent and relatively independent changes in the length of the walls caused by thermal deformation recurring in cycles during the heat treatment process. The corners of the basket are the parts most vulnerable to deformation during stand-alone operation (without the use of a base pallet), and therefore they are reinforced with horizontal ribs. The effect of dilatation (Fig. 10) allows for a relatively free change in the dimensions of the long and short edges of the basket bottom part. Three posts are introduced to the

central part of the basket (Fig. 9). Their task is to prevent deformation of the basket bottom when baskets are set on each other and when they are loaded with a heavy charge.

To make the basket movement along the furnace hearth easier when it is operated without a base pallet, transverse ribs are added to the design (lower than the longitudinal ribs). They play the role of slide elements – the bottom of the basket is "lifted" a few millimetres above the level of the stem (Fig. 10).

3.2. The system including base pallet and intermediate pallet

The technological equipment composed of intermediate pallets with posts and spacer sleeves is the most traditional and most commonly used structure (Figs. 12–14). The space between intermediate pallets can be further supplemented with various types of hangers facilitating distribution of the heat-treated parts.

The number of intermediate pallets depends on the shape and dimensions of the heat-treated parts, including the alignment of these parts. The distance between the pallets is determined by the length of the spacer sleeves used (Figs. 12–14).

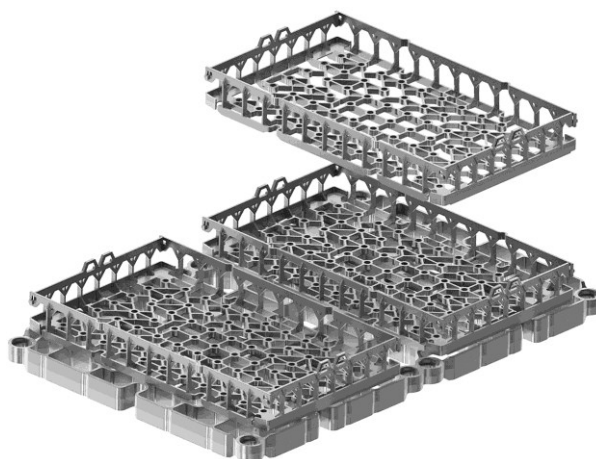


Fig. 11. Small baskets stacked on the base pallet

Two types of columns are used in the assembly of this type of tooling:

- slender columns with the same cross-section (Figs. 12 and 13a),
- two-stage columns (Fig. 13b) and multi-stage columns.

Columns with the same cross-section are generally used for the charge of a low weight placed on the upper level of equipment. With heavy charge it is recommended to use two-stage columns. The lower extended part of the column replaces the spacer sleeve. This solution offers many advantages such as:

- increased stability of the equipment, important for its horizontal movement inside and outside the furnace,
- reduced weight of the whole set,
- reduced thermal stress concentration in the area of the column seat in base pallet,
- increased heat transfer rates in the enlarged part of the column.

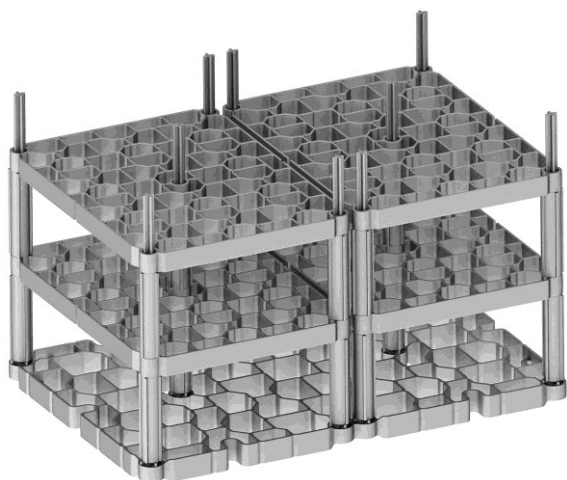


Fig. 12. Three-level technological equipment composed of intermediate pallets

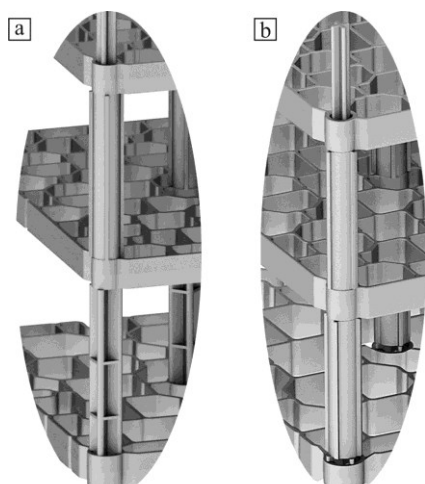


Fig. 13. The corner of three-level technological equipment. The distance between pallets is determined by the length of: a) the post and spacer sleeves, b) spacer sleeves (as shown in Fig. 12)

The number of levels in the technological equipment on which the heat treated parts are placed or suspended can be increased by introducing the additional intermediate pallets (e.g. of various widths – Fig. 14) and spacer sleeves of the desired length.

3.3. The system including base pallet and crossbars

The heat treatment of parts with compact shape, high symmetry and a hole in the centre of symmetry is often carried out in the technological equipment, in which the intermediate pallets are replaced by crossbars (Fig. 15). One can also use a mixed type of tooling including the base pallet and intermediate pallet or the base pallet and crossbar (Fig. 16).

The shape of the crossbar depends on the system of mounting the posts in the base pallet and crossbars on the posts; it is also determined by positioning of individual elements on crossbars, depending on their shape [3,4].

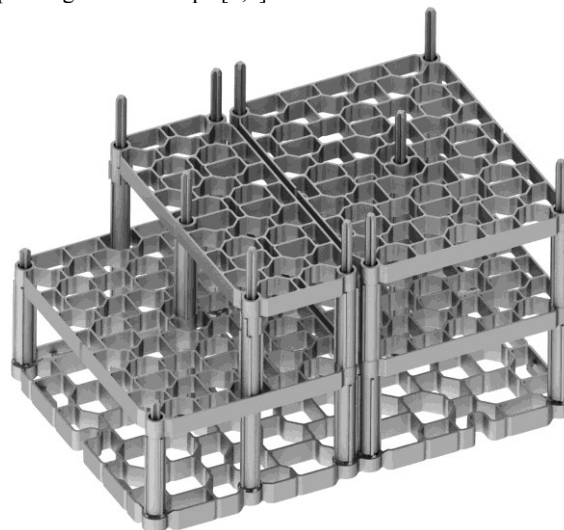


Fig. 14. Multi-level technological equipment composed of intermediate pallets with different widths

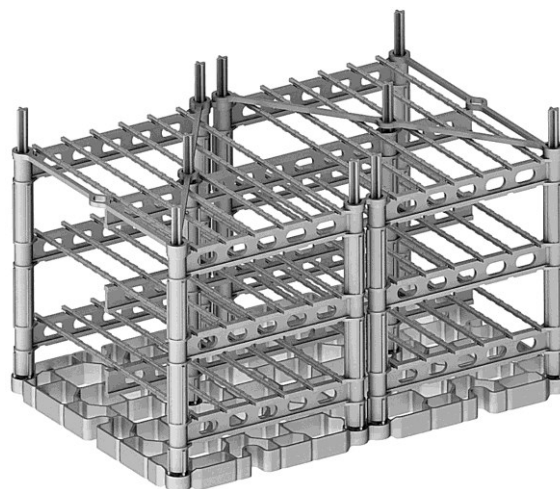


Fig. 15. Technological equipment composed of posts, sleeves, toothed racks, horizontal bars, as well as lateral and/or diagonal clamping yokes

The design of tooling should ensure its stability, which is required for several reasons. For example:

- it is necessary for proper functioning of automatic manipulator performing tasks related with tooling operation,
- "warping" of the equipment may damage the walls of the furnace chamber during loading/unloading of the furnace.

This is most likely to happen in the case of high structures.

An improvement of the tooling stability is achieved through the use of clamping yokes (Fig. 15). The use of clamping yokes lateral and/or diagonal is desired especially in all those cases when the charge has holes with small diameters to string the

pieces on bars. For such cases, notches on bars positioning the charge are of low height. During transportation without the stiffening system, the vibrations can move the charge along the bars or can make the bars slide off from the toothed racks.

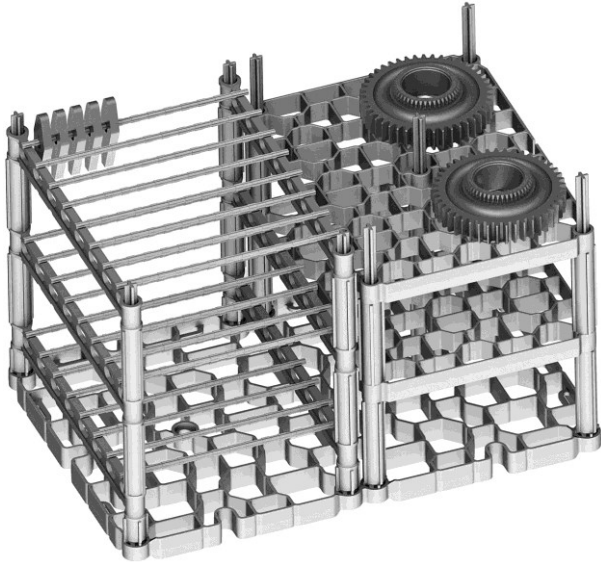


Fig. 16. Mixed type of technological equipment composed of the two different types of tooling (see Figs. 12 and 15)

4. Final remarks

The durability and reliability of the presented designs of the technological equipment assembled from pallets with dimensions of 900×600×45 mm used for the heat treatment of machine parts were verified under real operating conditions. The data obtained from users have confirmed the expectations. It should be noted, however, that in the case of newly designed tooling both the user and the designer know that the reliability and durability can be checked and defined more precisely only during practical use of the equipment. This fact stems from the multiplicity of factors determining the durability of equipment of this type [3,4].

The user is usually determined to bear the possible higher costs of heat treatment in the first phase of production, knowing that in the case of mass production it will be certainly more economical to use tooling well adapted to the specific heat treatment operations and to the specific nature of charge, allowing for the diversity of its shapes, dimensions and weight.

There are large plants dealing with the heat treatment of bulk quantities of parts homogeneous or similar in shape. These can be, for example, gears, bearing rings and drive shafts. In such cases it is recommended to use the dedicated tooling precisely adjusted to the type of the heat treated products. This gives the opportunity to maximize the potential of the furnace and provides stability of the heat treatment conditions.

User benefits arising from the selection of technological equipment best adjusted to the given range of heat-treated parts include:

- lower cost of the purchase of new/additional tooling elements (the cost is lower because it is reduced by the cost of, for example, patterns),
- reduced tooling OFF periods (as a result of shorter service time),
- increased efficiency of tooling,
- improvements in furnace operation,
- increased reliability and coefficient of the tooling technical readiness.

The same knowledge is also guiding the tooling designer and manufacturer. Including multi-purpose equipment in the offer makes this offer much more competitive, allowing the user to choose the most rational design solution, well adapted to the current production requirements.

In short, it can be concluded that the use of universal and multi-task equipment in large heat treatment plants creates the opportunity for easier and cheaper adaptation of this equipment to perform a variety of processes and technological activities. One can easily make different types of tooling in configurations tailored to the specific shape and weight of the heat treated charge.

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