The necessity of equipping the casting industry with modern apparatus for heat treatment of castings is due to several factors. One of them is the growing volume of production. For example, for heat treatment of cast iron with spheroidal graphite [1] it was noted that the production of castings in England increased more than 20 times in 15 years (10,000 tons in the mid 1950s, 10,000 tons in the mid 1960s, and over 200,000 tons in 1971).

All the requirements (high output of high-quality castings with consistent properties, low labor costs, improvement of working conditions) are met at the present time by continuous furnaces of the pusher type with an artificial atmosphere which are fired mainly by gas with radiant tubes.

The characteristics of these furnaces are as follows:

- parts in trays evenly distributed;
- the heat-treatment cycle is carried out in succession in independently controlled zones into which the furnace is divided;
- the desired artificial atmosphere is maintained automatically, being either protective, oxidizing, or decarburizing, depending on the requirements;
- all processes and operations are mechanized;
- the heating process and the operation of the mechanisms are automatically controlled.

An additional advantage in using continuous furnaces as compared with batch furnaces is the lower energy costs.

One-Row Pusher Furnace for Heat-Treating Castings of Ferritic and Pearlitic Cast Iron with Spheroidal Graphite. The furnace is installed at the John Harper and Co., Ltd. Albion Works, Willenhall, Staffordshire, England. The output is 700 kg/h of castings of pearlitic cast iron with spheroidal graphite. The length of the furnace is over 21 m, divided into six zones, two of them equipped with controlled devices.

Two-Row Pusher Furnace for Decarburizing Castings of White Heart Malleable Cast Iron. It is installed at the Bedford Works of George Fischer Castings, Ltd. [2]. The output of the furnace is 500 tons/month. The furnace is manufactured by Salen Engineering Ltd. under license from Mattias Ludwig of Essen (West Germany).

The furnace is gas-fired by means of 61 blind recuperative radiant tubes. The operating temperature is 1050–1060°C. One row accommodates 40 trays, each holding 500 kg of castings. Completely full, each row accommodates 20 tons of castings [1]. The castings are heated to 1150°C, held at this temperature at least 40 h, and cooled in the furnace to 650°C, at which temperature they are unloaded.

The furnace is divided into five zones.

Before the castings are loaded in the furnace they are heated by the exhaust gases to 400–500°C (US Patent No. 981139).

The overall dimensions are 38 × 5 × 4 m.
Apparatus for Annealing Black Heart Malleable Cast Iron [3]. The apparatus is manufactured by Salem Engineering Ltd. under license from Mattias Ludwig of Essen and is installed at the firm of William Lee and Sons (Malleable) Ltd. of Dronfield, Sheffield, England. The apparatus consists of a two-row high-temperature pusher furnace with artificial atmosphere (nitrogen), two-row low-temperature pusher furnace, and device for quenching in air. The apparatus is arranged in a U shape, which makes it possible to load and unload parts from the same position.

The first stage of graphitization is conducted in the high-temperature furnace, which has four zones and is heated by gas-fired recuperative radiant tubes arranged above and below the trays. The low-temperature furnace is divided into three zones. As in the furnace described above for heat-treating cast iron with spheroidal graphite, two heat sources are used. The first zone is heated by means of 12 gas-fired radiant tubes and the second and third zones, for the best control of the heating process at low temperatures, by electric heaters.

The trays (net load of each 320 kg) are placed on a table with a roller conveyor and pushed into position manually. After the trays are picked up by the pusher the entire process is automatic.

In the high-temperature furnace the trays move along carborundum guides and arrive at the loading end of the low-temperature furnace, the castings of ferritic malleable cast iron directly and castings of pearlitic cast iron after hardening in air. At the exit from the low-temperature furnace and extractor removes the trays. A small fan cools the trays before they are unloaded.

The input of hot gas in the high-temperature furnace is 95 m$^3$/h; the recommended nitrogen input is 28 m$^3$/h. In the low-temperature furnace the input of hot gas is 34 m$^3$/h in the first zone, with 100 kW electric heaters in the second and third zones.

Apparatus at the Firm of Renault in Lorient [4]. In place of previously used furnaces with moving trays, seven pusher furnaces with artificial atmospheres are used — two for normalization of steel castings, three for annealing of pearlitic malleable cast iron, and two for annealing ferrite malleable cast iron. The furnaces for normalization of steel castings are single-row, the others double-row. The furnace are placed in pairs (with a place reserved for a fourth furnace for annealing of pearlitic malleable cast iron if the necessity arises). All furnaces are of the same type and equipped with the same trays. The trays are plates $800 \times 800$ mm with perforated walls $300$ mm high; the overall height of the trays is $380$ mm.

All the furnaces are serviced from one end. In furnaces for normalization of castings and furnaces for annealing of pearlitic malleable cast iron this is achieved as follows: the trays are ejected from the furnace onto a cart which moves to the tripper. The tripper rotates the tray 180°C, after which the castings and empty trays are returned separately to the loading end of the furnace by a conveyor mechanism plated between each pair of furnaces (the castings are cooled with fans as they move). The furnaces for annealing of ferritic malleable cast iron are not equipped with a conveyor mechanism to return the castings and trays to the service end of the furnace. Annealing of ferritic malleable cast iron takes twice as long as annealing of pearlitic malleable cast iron, and therefore the furnaces for ferritic malleable cast iron have two decks — a lower deck for graphitization and an upper deck — with trays moving toward the service end of the furnace for ferritization.

The furnaces are heated by means of U-shaped gas-fired radiant tubes made of heat-resistant 35/15 alloy. To prevent combustion products from entering the furnace when holes occur in the radiant tubes the tubes are evacuated, for which purpose tubing in the shape of a Venturi tube is placed at the outlets.

The furnace for normalization of steel castings has 38 radiant tubes and is divided into seven zones. The inside width of the furnace at the exit is $0.95$ m, the length of the working chamber $20.3$ m, the overall length with pushers and loading tables is $26$ m. The furnace takes 24 trays.

The furnace for annealing ferritic cast iron has 56 radiant tubes and is divided into eight zones on each deck. The overall length of the furnace is $34$ m, the height $6$ m. The output of the furnace in a six-day week with operation for three shifts is given below (the operating coefficient is 0.8 on the basis of calendar time):

<table>
<thead>
<tr>
<th>Furnace</th>
<th>Output, tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>For normalization of steel castings</td>
<td>70</td>
</tr>
<tr>
<td>For annealing of pearlitic cast iron</td>
<td>70</td>
</tr>
<tr>
<td>For annealing of ferritic cast iron</td>
<td>58</td>
</tr>
</tbody>
</table>