Conveyor roasting machines (width of roasting car 3–4 m) are equipped with transfer collectors that transport the high-temperature gas from the cooling zone to the heating zone. No information is available on the successful installation of collectors in roasting machines for which the roasting-car width is 2 m. Moreover, initial experience in equipping OK-108 machines 9–12 at AO SSGPO with collectors proved unsuccessful, since the collectors and downpipes were clogged with dust and ultimately had to be dismantled.

In OK-306 machines (Severnyi and Lebedinsk enrichment facilities), cylindrical transfer collectors of the same diameter are employed (Fig. 1a). In the OK-520/536 machines (Mikhailovsk and Kostomukshsk enrichment facilities), the collectors consist of three cylinders, each with a different diameter (Fig. 1b). Collectors of such design have the following deficiencies [1]: nonuniform heating of the descending pipes and consequently uncontrollable accelerated heating of individual outputs; increased supply of high-temperature to the beginning of the hot zones (OK-306 machines); and the appearance of uncontrollable circulation loops for the combustion products in the system consisting of the intake chamber, the transfer collector, and the final chamber. This may be explained by the formation of reduced-pressure zones at points of sharp change in collector cross section (at the junctions of the cylinders with different diameters). As a result, the combustion products from the intake chamber under these zones are drawn to the transfer collector. These problems prevent optimal hot-gas distribution over the heating zones and hence lead to accidents and failure of the machines on account of overheating, melting, and failure of the downpipes and clogging of the burners with molten dust. Therefore, in the design of the transfer collector for the modernization of roasting machine 5, these problems must be resolved. They could be addressed by a familiar method [2]. In that approach, the transfer collector is divided in length by a transverse wall; each downpipe is equipped with a control gate and nozzles for flux ejection. However, that would complicate the design and operation of the system.

The transfer collector for modernized OK-124 roasting machine at AO SSGPO distributes gas at 850–950°C from the cooling zone to the heating zone [3]. To ensure uniform gas distribution over the hearth intake chambers in the correct quantities, with minimal aerodynamic drag, we adopt a conical profile, in accordance with the following design principles [4, 5]:

— the flow velocity in each cross section of the pipeline—including gas transfer from the collectors to the pipes or, conversely, from the pipes to the collector—must be the same, while the flows in and out of the pipes must follow the path of the primary flux;

—the pipeline diameter must be consistent with the quantity of hot gas, whose speed must not exceed the standard value (15–20 m/s). The selected collector profile is shown in Fig. 1c.

In developing the thermal system for the roasting machine, the quantity of hot gas supplied from the trans-
cer collector to the hearth through the downpipes in each gas-air chamber is calculated on the basis of the filtration rate of the gas in the bed and its temperature; the calculations take account of fuel combustion and the parameters of the primary air. This allows the designer to determine the necessary collector cross section after each hot-gas discharge through the pipe to the intake chamber.

The calculations also show that, for a roasting machine where the roasting-car width is 2 m, a single-flow transfer collector is best in terms of fuel consumption, on the basis of the characteristics of the coal batch and the required treatment-temperature curve, with minimization of the heat losses [6].

The transfer collector consists of two flanged conical selections. Lenticular compensators are provided to allow for thermal expansion of the casing. The refractory layer of the collector and downpipes consists of light wear-resistant BTIL concrete (operating temperature 1350°C), mounted on rivets. The heat-insulating layer consists of basalt fiber and MKRP-340 mullite—silica plate.

Drying of the refractory lining in the hearth and transfer collector is based on specially developed temporary instructions for the drying and heating of the lining in OK-124 roasting machine 5 at AO SSGPO, on the basis of OAO VNII MT technology [7]. The instructions include a drying graph adapted for the conditions of the heating system and take account of the use of new refractories and also automatic parameter regulation and interlocking of the automatic control system. The list of problems addressed by the control-system design ensures satisfactory drying and heating of the refractory lining in the hearth and transfer collector, as well as effective operation. In this technology, the hearth lining is dried by fuel combustion in primary burners. To dry the transfer collector and heat the diluting air, the conveyer is switched on, with the supply of a recirculating load of roasted pellets. As they pass through the heating and roasting sections, the pellets are warmed by the heat that filters through the combustion-product bed. The pellets are then sent to the cooling zone, where a fan forces air through the pellet bed from below. The pellets heat the air to the specified temperature; it is then sent to the dome of the cooling zone and to the transfer collector. As a result, the lining is dried. The instructions draw on experience at OAO VNII MT with the drying, startup, and operation of roasting machines at Russian pelletization facilities (Mikhailovsk and Kostomukshsk enrichment facilities) and experience with the 278-m² Lurgi roasting machine at Severnyi enrichment facility (Ukraine).

**DRYING AND HEATING OF REFRACTORY LINING AND BTIL CONCRETE**

Four steps are required:

1. Holding of the concrete for 20 days before drying;
2. Ventilation of the hearths and gas-air channels with air for 2 days, so as to remove the moisture from the refractory surfaces, and additional fan operation at high load;
3. Active drying of the hearth's brick lining for five days, by the combustion products of natural gas, while maintaining a pressure of 1–10 Pa in the hearth. As a result, there is a natural flow of combustion products into the adjacent zones (drying zone 2, cooling zone 1, the transfer-collector system), with partial drying of the concrete lining. Roasted pellets are loaded in the roasting machine (as the base), and the primary drive is turned on. As a result, the heat from the pellets is sent from the heating zone to the cooling zone;
4. Active drying of the concrete lining for eight days, by the forced supply of hot gas from cooling zone 1 to the transfer collector and drying zone 2. The lining of cooling zone 2 is dried analogously to the lining of cooling zone 1.

Thus, drying of the refractory lining begins in the period of air ventilation of the hearth and ends at 400°C. The drying of the concrete lining begins in parallel with active drying of the brick lining and continues (from 80 to 500°C) on heating the brick lining (from 400 to 900°C). Heating of the concrete lining above 450°C accompanies heating of the brick component from 900°C to the working temperatures.

**ACTIVE HOT DRYING OF THE HEARTH’S BRICK LINING**

This process begins with lighting of the ignition modules at all the burners (1–14) and drying of the intake chambers. On drying (for 3–4 h), burners 1 and 2 are ignited in heating zone 3; burners 9 and 10 are ignited in roasting zone 2. The initial natural-gas consumption at each burner is minimal (no more than 30 nm³/h), with a gas pressure of 0.5 kPa ahead of the burner.

The combustion products of natural gas, diluted with air, are supplied from the intake chamber to the hearth and are sucked through a bed of granular material on the charging car. Primary air for combustion and secondary air from the transfer collector are used to dilute the combustion products. On passing through the hearth, the combustion products surrender some of their heat to the lining, which is heated and dried.

The temperature and quantity of combustion products are regulated so as to strictly maintain the conditions specified by the drying graph: the rate of temperature rise must be no more than 10°C/h for the brick; steady temperatures should be no higher than 30°C above the rated value.

The rate of temperature rise and the holding temperature are regulated by adjusting the natural-gas and air flow rates at the working burners, switching burners on or off, and switching between burners.
Stationary instruments that measure the hearth-gas temperature are used to monitor the heating of the lining and to correct the drying process. To prevent local heating of the lining, the drying process is regulated as necessary by switching off some of the burners and switching on others.

**ACTIVE DRYING OF THE HEARTH'S CONCRETE LINING AND THE TRANSFER-COLLECTOR SYSTEM**

This process is as follows. The combustion products of natural gas are drawn through a granular layer on the roasting car and surrender some of their heat to the bed. The heat stored in the bed is transferred to cooling zones 1 and 2 by air blown through the bed. As it moves further in the hearth region of cooling zones 1 and 2 and the transfer-collector system, the air takes heat from the concrete lining and rises.

The drying graph for the concrete lining conforms to the following conditions: rate of temperature growth no more than 2–5°C/h on heating to 500°C and no more than 10°C/h subsequently; holding at 50, 100, 200, and 300°C for no less than 12 h and at 500°C for at least 40 h. The holding time may only be increased. The temperature is maintained constant to within ±10°C up to 100°C and ±20°C at higher temperatures.

The rate of temperature growth and the holding temperature are regulated by changing the speed of the car, the height of the pellet bed (where possible), the quantity of hot gas passed through the layer, and its temperature.

Stationary instruments that measure the hearth-gas temperature are used to monitor the heating of the lining and to correct the drying process.

Note that the drying and heating process incorporates forced delays, so as to eliminate the vibration of individual fan units (F1, F4), to adjust burner operation, or to adjust the gas-supply system. Nevertheless, inspection of the lining in the hearth and transfer collector during scheduled shutdown of the machine indicates that it is in satisfactory condition. The dust entrained from cooling zone 1 does not settle in the transfer collector. (This is very important.) The dust is carried with the air flux through the collector, the downpipes, and the intake chambers to the hearth and then to the hot pellet bed, where it settles on the surface of the hot granules.

If the forced air motion from cooling zone 1 to the transfer collectors, the downpipes, and the intake chambers of the burners and the hearths is monitored in a cold system, we find that there are no stagnant zones or backflow zones where dust could collect and penetrate into the gas fluxes.

**HEATING AND COOLING OF THE LINING AFTER PROLONGED SHUTDOWN**

In that case, the heating rate may be up to 50°C/h. The burners are ignited in pairs, in accordance with the instructions.

After reaching a hearth temperature of 700–800°C, the raw pellets are supplied, with an initial load of 20 t/h. After the machine reaches the working temperature, the automatic control system is switched on, and additional burners are turned on as the pellet load grows.

Subsequently, roasting conforms to the corresponding technological chart. It is found that raising the temperature in the transfer collector entails ignition and greater loading of burners closer to the cooling zone. Ignition of the burners proceeds from the tail of the machine to the head. The speed of the belt and the bed height are increased. The guide systems of fan units F6 and F4 in the recuperation zone are screened so that the pellets are not overcooled. Analysis of the actual temperatures in the hearth on heating machine 5 (Fig. 2) shows that the heating rate of the lining is 62°C/h above gas–air chamber 11, 48°C/h above gas–air chamber 15, and 56°C/h above gas–air chambers 11 and 17 during heating.
18 (Fig. 3). This is in complete agreement with the standard heating rates.

CONCLUSIONS

The transfer-collector system designed by OAO VNIIMT for OK-124 roasting machine 5 at AO SSGPO (width of roasting car 2 m) is characterized by operational efficiency and ensures an optimal distribution of high-temperature gas over the length of the machine. The effectiveness of the measures adopted, the selected materials, and the drying and heating technologies adopted is confirmed by operational experience with the modernized roasting machine for a year and a half and by inspection of the refractory lining.

REFERENCES

OJSC Scientific-Research Institute of Metallurgical Heat Engineering (VNIIMT) established in 1930 as Ural Division of All-Union Heat Engineering Institute is widely known in Russia and the CIS. The Institute focuses on development of high-technology heat engineering units, energy efficient and ecologically friendly technologies in ferrous and non-ferrous metallurgy, machine-building and other fuel-consuming branches of industry.

Highly-qualified academic researchers, unique experimental and production facilities and own research and design centre enable efficient scientific-and-research, design-and-experimental, engineering and project works, delivery of equipment, designer's supervision and commissioning works including execution of turnkey contracts in the following areas:

**Sintering:**
- development of techniques and modes of metal raw material heat treatment;
- design of energy-efficient agglomeration hearths and agglomeration gas heat recovery circuits allowing to reduce energy consumption and dust and gas emissions.

**Pellet production:**
- optimal traveling grate pelletizing furnaces for heat treatment of iron-ore pellets from various concentrates (hematite, magnetite, etc.) with optimal automatic process control system.

**Preparation of metallic and nonmetallic raw materials:**
- technique of iron-ore raw material dephosphorization by roasting and leaching;
- installations for drying high-moisture dispersive materials of various designs;
- efficient techniques of magnetizing roasting and subsequent dressing;
- technique of rare-earth element extraction (for example, germanium from germanium iron ores).

**Blast-furnace ironmaking:**
- explosion-proof near-furnace systems of blast furnace slag granulation giving a high-quality product for cement production;
- optimal control system for hot blast stoves;
- an innovative bench for drying hot metal and steel-smelting ladles;
- copper coolers and tuyeres of blast furnaces.

**DRI (direct reduction of iron)**
- improvement of the reduction technique in shaft furnaces for radical improvement of technical and economic indicators of their operation (productivity is increased twice);
- technique of raw material reduction in rotary furnaces using coal as the reductant.

**Lime production:** development of the technique and increase of lime production process efficiency:
- in shaft furnaces;
- in double-shaft furnaces;
- in rotary furnaces;
- in “stacked-tower preheater - rotary furnace” installations;
- in “shaft calciner - rotary furnace” installations (VNIIMT innovative technology).

**Granulation of metal melts:**
- development of technologies and designs of explosion-proof plants for near-furnace granulation of metallurgical slag, molten metal, etc., including heat recovery;
Reheating furnaces:
• development of new and update of the existing designs of furnaces for stock heating;
• high-performance systems of reheating furnace firing with recovery and regeneration firing systems based on the innovative burner units designed by VNIIMT;
• switching the furnace firing systems to cheaper fuel types;
• development and implementation of optimal furnace operating parameters.

Heat-treatment furnaces development of techniques and equipment for heat treatment of roll stock and metal products including those with protective atmospheres:
• thermochemical treatment conditions ensuring retention or directional change in chemical composition of metal surface;
• gas dampers for heat-treatment furnaces;
• spray quenching units and other elements of convective cooling systems;

Furnaces with protective atmosphere and gas treatment units:
• development of the furnace structure, design, manufacture, delivery and commissioning works;
• development of a technology for treatment of articles and devices for protective gas generation;
• calculation, development and manufacture of endogas and exogas atmosphere generators for metal product thermochemical treatment units;
• gas analysis systems for monitoring and control of physico-chemical properties of protective process atmospheres.

Reheating, heat-treatment and drying furnaces with convection heat transfer:
• development, design and manufacture using industrial heat-resistant (up to 900 °C) furnace fans designed by VNIIMT.

Rolled products:
• techniques and units for controlled high-speed air-to-water cooling (quenching) of rolled ferrous and non-ferrous metal products including thick plate on mill 5000;
• replacement of oil quenching technology with VNIIMT’s eco-friendly air-to-water technique;
• innovative technique of oily mill scale processing;
• line of wire rod accelerated air cooling with process improvement.

Manufacturing manufacture and delivery of:
• high-performance burner units;
• heat-resistant (furnace) fans (up to 900 °C);
• copper coolers for blast furnaces and nonferrous furnaces based on VNIIMT technology;
• Pitot tubes for measuring flow rates and pressures.

OJSC VNIIMT developments are widely used in metallurgical enterprises of Russia, Ukraine, Kazakhstan, China, India and others.

For detailed information on institute developments, please visit OJSC VNIIMT site at www.vniimt.ru

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