EXPERIENCE OF COGENERATION PLANT DESIGN TO OBTAIN POWER AND HEAT IN ORDER TO DECREASE FERROALLOY MANUFACTURE COSTS

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ABSTRACT

Pyrometallurgical processes in ore-smelting furnaces in the production of ferroalloys to obtain top gas associated with the determination of their calorific value, chemical composition and dust are presented. The schemes describe design solutions of cogeneration plants for heat and power in the gas and in the condensing turbines. Schemes of cogeneration plants for heat and electricity are presented in order to reduce the cost of production of ferroalloys.

The basic equipments of ferroalloy plant are known to be ore-thermal and refining furnaces.

Large-scale types of ferroalloys, such as ferrosilicomanganese, carbonaceous ferromanganese, high carbon ferrochrome, silicochrome, ferrosilicium of all grades 45%, 75%, 90%, carbothermic silicocalcium, crystalline silicon, crude ferronickel, are melted in electric ore-thermal furnaces.

Pyrometallurgical melting in ore-thermal furnaces is accompanied with release of large amounts of associated waste gas containing up to 75% of toxic carbon monoxide with calorific value of 2000-2500 kcal/Nm^3, those exhaust sometimes being quite significant.

One 63 MVA ferrosilicomanganese electric furnace gives 10000-12000 Nm^3 of waste gas every hour. These 12000 Nm^3/h of gas with calorific value of 2000-2500 kcal/Nm^3 are equivalent to:

2200x12000 = 26 400 000 kcal or 26,4 Gcal.

As 860 kcal are equivalent to 1 kWh:

26,4/0,86 = 30,697 MWh.

Considering eventual loss, even under 50% efficiency a single furnace which does not utilize this gas loses 15-16 MWh power every hour.

Annual loss comprises 8,600x15 = 129,000 MWh.

This is equivalent to 129,000 x 6 = 7,740,000 € per annum. Then a unit of 8 electric furnaces loses 8 x 7,740,000 = 61,920,000 € per annum.

Our first conclusion, from the economic aspect, is based on the above: this gas must be utilized in order to decrease manufacturing costs by investing in construction of cogeneration plants to obtain power and heat.

The next conclusion is based on the environmental aspect. If waste gas is not recovered and utilized, each 63 MVA low-hood open furnace emits above 550,000 Nm^3/h flue gas to the environment. It contains a substantial part of unburned carbon monoxide CO, as well as CO_2, NO_x, SO_2 and a lot of dust.

For chemical analysis of waste gas see Table 1.

Table 1: Chemical analysis of waste gas

Component	Content, mg/Nm^3	Exit gas temperature, ^oC	Waste gas temperature, ^oC
CO	16,4	200	170
CO_2	3,8		
NO_x	3,8		
SO_2	5,2		
H_2S	2,6		

Thus, one ferroalloy plant emits up to 740,000,000 Nm^3 waste gas per annum, and this costly product with calorific value of 2000 kcal is mostly burned in bleeders, which is considered totally unreasonable.

We have learned to reclaim 99,5% of dust, up to the content of 20 mg/Nm^3, in very costly and clumsy smoke filters, whereas we cannot recover gas.

That is an environmental aspect, and this issue must be resolved.

Proceeding from these two main tasks, in the course of the last 30-40 years ferroalloy industry has made attempts to resolve these problems by developing design solutions for electric furnacesand upgrading gas treatment plants of both wet and dry types.

This led to implementation of several designs of ore-thermal furnaces:

1. Open
2. Low-hood open
3. Funnel closed
4. Sealed

Open electric furnaces were installed at Chelyabinsk and Zaporozhye Ferroalloy Plants in the USSR in 1931-1933.

Funnel closed furnaces appeared at Stakhanov Ferroalloy Plant in 1963-1964, and later funnel closed furnace units were built at Nikopol, Aksu Ferroalloy Plants and at Chelyabinsk Electrometallurgical Combined Plant in 1968-1978.

In general, three specific features of the design of units equipped with sealed, low-hood open and funnel closed electric furnaces may be singled out.

Sealed furnaces are the most environmentally friendly as no exhaust is present under the crown, but they have strict requirements to charge sieve analysis and moisture content.

Sealed electric furnaces as an evolution of funnel closed furnaces appeared at Soviet Sibelektroterm in 1980-1988 and at Tanabe Kakoki in Japan in 1981-1983 following an order from Giprostal Institute, Kharkov.

Funnel closed electric furnaces require, along with wet gas treatment from under the crown, dry treatment of funnel gas (17-20%) in bag filters, which makes this ferroalloy production line more expensive as compared to sealed furnaces.

In this case for power manufacture gas must be compressed to 22 bar, gas turbine generators and condensing turbines installed for gas from under crown (furnace top gas) and dry gas treatment unit for furnace hood gas.

Low-hood open furnaces make a forced solution for melting high-silica ferroalloys (FS-75 and FS-90) as well as SiCa and crystalline silicon. Installation of heat recovery boilers and condensing turbines is a must here (Fig.1).

Our company develops such schemes and can offer them for implementation at ferroalloy plants.

In ferronickel manufacturing process tubular rotary furnaces are used to burn nickel ore and obtain cinder at temperatures of 850-1000^{o}C.

Tubular rotary furnaces emit 55-60 Nm^{3}/h of exhaust gas with temperature of 300-400^{o}C.

We develop some schemes which allow to use exhaust gas heat received from tubular rotary furnaces which in turn allows to obtain 12,5 MW power from two furnaces (see Fig.2).

If a ferronickel plant has sealed furnaces, top furnace gas treated at wet Venturi unit may be used for additional heating.

Comparison of open and sealed furnaces.

Fig.1. Flue gas removal from PKO-45 electric furnace with heat utilization

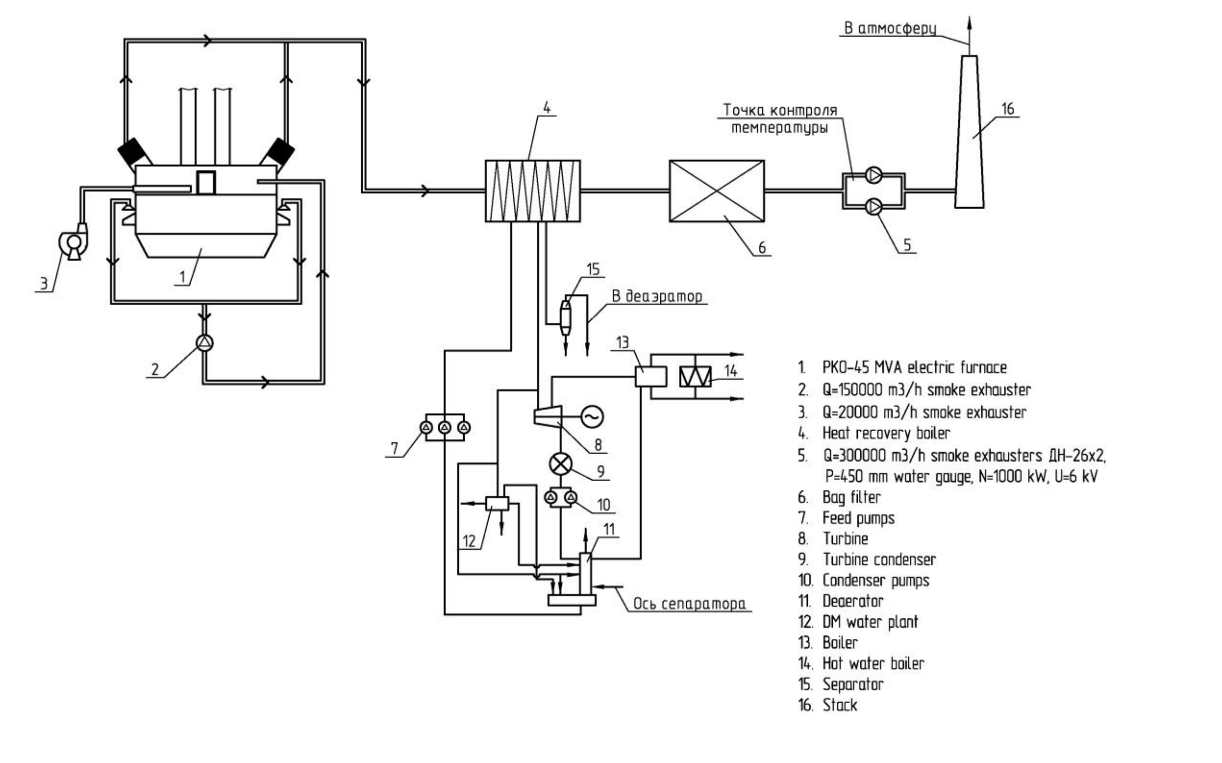
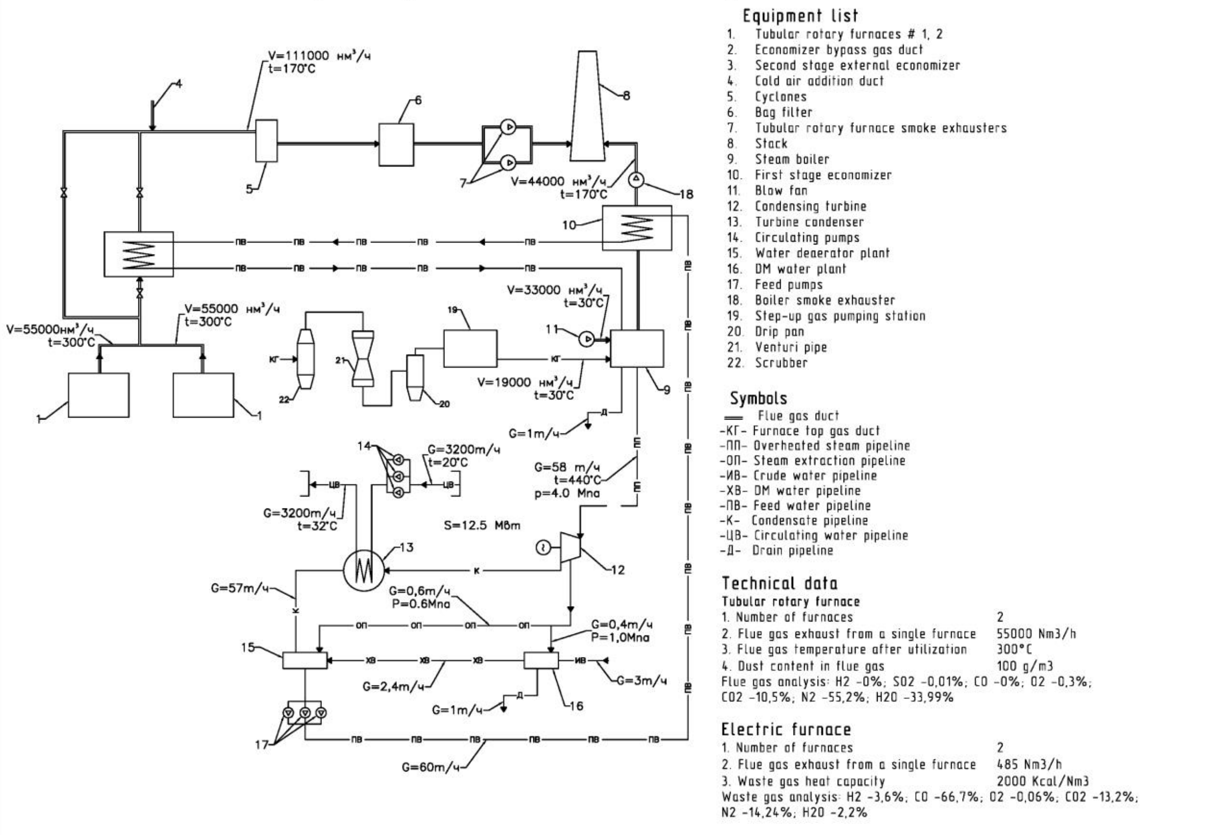


Fig.2. Flue gas removal from tubular rotary furnaces



Large-scale manganese alloy and carbonaceous ferrochrome production takes place at sealed-type furnaces from Tanabe Co., Japan. Along with increased dimensions and capacity, sealed furnaces allow to use utilities most efficiently and to prevent environmental pollution.

At the same time, as Japanese and our experts admit, high capacity sealed and closed furnaces suffer certain operational difficulties:

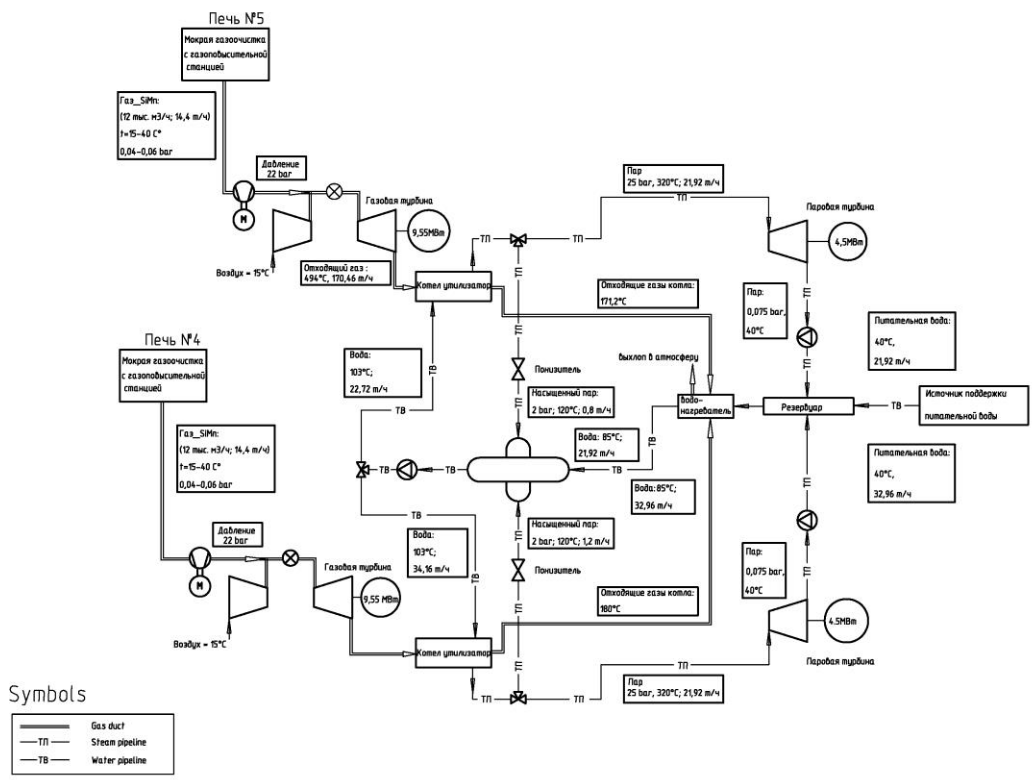
- strict requirements to the quality of raw material (max.10% fraction under 8,0 mm and max 5% moisture content in charge), that is, more thorough charge preparation is required.

Nevertheless, those difficulties are overcome with excess if cogeneration units are constructed and exhaust gas is used to produce power and steam. Charge moisture content is quite acceptable if it includes sinter, then the total charge may contain up to 8% moisture.

All those difficulties have been successfully, though in different ways, overcome in all countries, including Japan, as substitution of two or three electric furnaces by one of higher capacity substantially saves investment and operation costs; besides, exhaust gas from closed and sealed electric furnaces compensates for the complicated design, and in general this solution is cost-effective. We must also take into consideration that sealed and closed furnaces are environmentally friendly and at the same time provide for better work safety and protection of personnel from hazardous effect of high temperatures as compared to low-hood and open-type furnaces.

Our calculation for a European plant showed that investment cost of a sealed electric furnace is approximately 30-40% less than that of a low-hood furnace. This calculation did not include waste gas utilization at the plant instead of bought natural gas or fuel oil as well as power obtained by burning waste gas at recovery boilers and condensing turbines, or compressing waste gas to 22 bars and installation of gas generator turbines using special equipment, thus increasing even more cost effectiveness of sealed electric furnaces (see Fig.3). Such designs with calculation and equipment procurement may be obtained from TOPAZ LTD and UKRFERRO Research Entity with their partners in Ukraine, China and Germany.

Fig.3. Ferroalloy waste gas utilization using gas and condensing turbines



What tasks, in our opinion, is ferroalloy industry in Ukraine and elsewhere facing?

We see the main tasks as follows:

1. Environmental problems: protection of aqueous and air environment.

2. Energy saving: obtaining of steam, hot water and power from furnace waste gas, i.e. usage of secondary utilities, in particular, with equipment from MAN DIESEL & TURBO, Germany.

3. Process improvement: development and detailing of precision alloy technology, including liquid melt mixing, DC, plasma and induction furnaces, development of ferroalloy manufacture technologies in such furnaces.

4. Improvement of furnace unit designs as regards simplicity, environment acceptability, waste absence, process mechanization and automation.

5. Improvement of mud and slag treatment processes in order to recover additional metal from slag as well as introduction of patented technologies such as mud, dust and ore fines pelletizing for subsequent pyrometallurgical recovery of primary element.

Together with its partners TOPAZ LTD develops and suggests installing lump sorting modules for additional recovery of metal from slag.

6. Process and equipment development for alloy casting (casting machines) in order to minimize the content of fines (-5 mm) as well as finalization of metal fines remelting technology after crushing with the use of induction furnaces.

TOPAZ LTD together with specialists of a Ukrainian ferroalloy plant has developed a ferrosilicon fines remelting process technology in induction furnaces of OTTO JUNKER, Germany.