UNIVERSITY OF CRAIOVA

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MODELING GAS-DYNAMIC THERMAL PROCESS IN HIGH POWER STEAM BOILERS WITH LOWER SOLID FUEL

THE ABSTRACT OF PHD THESIS

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Content

Foreword

Taking as a starting point 27 years professional experience in the operation, repair and maintenance of power installations, at Craiova Energy Complex Company, I proposed to combine practical experience with theoretical knowledge and develop scientific paper entitled " **Modeling Gas-Dynamic Thermal Process in high-power steam boilers with lower solid fuel".**

Modeling Gas-dynamic thermal process was performed on a power plant, the existing, well known in the national energy system, in the boiler type, Benson, 510 t/h of power plants (TPP) Isalnita, Dolj county.

The boiler belongs to a block of 315 MW put, into operation in 1967-1968 period. Energy block is served by two boilers of 510 t/h each, operating on lignite.

By carrying out this work have revealed some deficiencies in the design and execution of coal dust burners. Identified deficiencies have generated some problems in boiler operation with adverse consequences on fuel, boiler efficiency and emissions.

Aim of the study was to analyze primary and secondary air flow through the burner of coal dust, and modeling of combustion in the furnace, so that it can provide power management information in order to take immediate decisions for the promotion of investments, minimum cost and increase the competitiveness of energy per unit energy market.

Scientific paper was divided into 7 chapters as follows:

• Chapter 1, **Power generation plants with lower solid fuel**, offers an overview of the Romanian energy sector challenges, following Romania's accession to the EU from the potential national energy resources, the priority objectives of energy system development, identifying specific measures be taken in energy. We have presented briefly, clean technology, used worldwide for power generation based on coal. Made a presentation to the fuels that are used in conventional power plants in Romania.

• Chapter 2, **Formation noxious in steam boiler furnaces and technical solutions to reduce noxious emissions**, shows the formation mechanisms of emissions of sulfur oxides, nitrogen and carbon dioxide and their effect on human body and environment. It was presented technical solutions to reduce emissions of pollutants discharged into the atmosphere: denitrificaton, desulphurization, capture, transport and storage of carbon dioxide.

• Chapter 3, **High power steam boilers used in the national power system**, shows an analysis of solid fuel combustion in boilers, which were presented by the technical characteristics of high power steam boilers used in Isalnita TPP, Turceni TPP, Rovinari TPP and Craiova TPP.

• Chapter 4, **Modeling the flow process into coal dust burners and into furnace of the Benson boiler 510 t/h from Isalnita TPP, using F.E.M.**., the types of flow encountered in coal dust burners in the boiler furnace of 510 t/ h. Were determined by calculation, the input data used in analysis and modeling of primary and secondary flow air through the burner of coal dust. They presented the results and conclusions resulting from modeling flow fluid through the burner.

• Chapter 5, **Modeling combustion in the boiler furnace of 510 t/h from Isalnita TPP** presents a theoretical modeling of heat in the boiler field energy and thermal conditions were determined by ignition of coal dust in the boiler furnace. At the end of the chapter was modeled combustion process inside the boiler furnace of 510 t/h .

• Chapter 6, **Technical solutions for modernization of high-power steam boilers in framing the environment protection requirements.**
Were presented technical solutions for modernization of high-power steam boilers, were to detail the coal dust burners with low NOx and possible technical solutions organization stepped combustion furnace, at chapter ended.

• Chapter 7 **General Conclusions. Personal contributions** in this chapter have presented the general conclusions resulting from modeling of primary and secondary flow air through the coal dust burner and the boiler furnace of 510 t/h from Isalnita TTP. I said that personal contribution to developing scientific work and how to exploit the results and impact of work on the economic environment, the social consequences on the environment favorable.

• Selective Bibliography

Viorel Tudor

1. Electricity production in power plant based on rough coal

Introduction

Economic development cannot be ensured only through existence of a reliable base of primary energy, a reliable supply and an appropriate technological potential. All efforts to increase the economy can not materialize without providing power supply without rigorous measures to reduce energy consumption amid the sustainable development of national economy, efficiency and environmental protection activities. Strategic Energy is formulated in the context of Romania's EU accession. Energy policy must be able to support sustainable growth, based on harmonization of requirements for economic efficiency, social considerations and environmental objectives.

National potential of energetic resources

Romania has a wide range, but reduced the amount of primary energy resources: oil, natural gas, coal, uranium ore, and a significant potential for renewable resources, especially in the hydropower.

In Table 1.1 an overview of domestic primary energy resources.

Tab.1.1 Primary domestic energy resource situation

Primary domestic energy resource	Reserve					Annual production 2005	Estimated period of assurance	
	Geological			Exploitable (for which exist license)			Geological reserves	Exploitable reserves
	UM		Mil. tep	UM	Mil. tep	Mil. tone *)	Year	Years
1	2	3	4	5	6	7	8=3 / 7	6=5 /7
Coal								
- pit coal	Mil. tons	279	106	72	27	3	93	24
- lignite	Mil. tons	1490	276	719	133	28	53	25,7
Oil	Mil. tons	74	72			5,2	14,2	
Natural gase	Bil. mc	185	159			12,5	15	
Uranium **)	Mil. tons	1	14,27			0,061	16,4	

*) exclusive natural gase, in billion mc

**) coresponding of a single nuclear group consumption

In table 1.1 was noted with **tep**, ton oil equivalent,

1 tep= 1,5 t.c.c = 12.21 MWh = 10,5 Gcal.= 43,9 GJ, and t.c.c represent ton fuel conventional,
1 t.c.c. = 7 Gcal = 29,26 GJ.

Priority objectives of the Romanian energy sector development

The main policies of Romania's energy policy, convergent with the European Union energy policy are:

- increase security of energy supply;
- improving energy efficiency in the whole chain: resources - production - transmission - distribution - consumption to ensure sustainable development;
- reduce the negative impact of energy sector on the environment, achieving environmental protection and reduction of CO_2 emissions;

To ensure a balanced energy mix, priority will be given to investments in new production units that use electricity:

- renewable energy;
- clean coal technologies;
- safe nuclear energy-technology and low environmental impact

Specific measures in energy sector

In the actual stage of Romanian technology, the boilers use lower solid fuel, sprayed, and oil for start up and support combustion for the boiler flame stability.

The boilers are constructed for particular fuel combustion, with well defined characteristics that can vary within certain limits. Lower solid fuels features prove to have extremely large differences, even for fuel from the same pool, became so frequent cases of overcoming the characteristics of the fuel for a boiler is built. Because of these fluctuations appeared to sustain burning need to ensure flame stability, a fuel intake, mostly hydrocarbons.

Providing the hard oil and natural gas to the national economy and the growing needs of the population cannot, for a long time to be covered from internal resources, and imports in terms of today's complex international has become very expensive and unreliable.

It must therefore include the need to save oil in the production of electricity and heat based on solid fuels, namely that production will be limited by the fuel, the solid.

Clean technology to produce coal-based electricity

The most important clean technology for electricity generation in coal-fired power, worldwide, are classic burning pulverized coal (PC), coal combustion in boilers with supercritical steam parameters, coal combustion in circulating fluidized bed (CFB) combustion coal fluidized bed pressure steam-gas combined cycle (PFBC), integrated coal gasification combined cycle steam-gas (IGCC). Abbreviations listed in parentheses are the names abbreviated in English for that technology.

Benefits of innovative technologies for burning coal technology over traditional spray (PC) of coal is presented in Table 1.2:

Table 1.2 Analysis of technologies for clean electricity based on coal

Characteristic elements	**Classical burning spray of coal**	**Burning coal in boilers with supercritical parameters**	**Circulating fluidized bed coal (CFB)**	**Coal fluidized bed combined cycle steam pressure - gas (PFBC)**	**Integrated coal gasification combined cycle steam - gas (IGCC)**
Technology Maturity	Proven, available in terms of commercial guarantees	Proven, available in terms of commercial guarantees	Proven, available in terms of commercial guarantees	At the demonstration plant Coal	In the research phase - Development
Capacity Installed groups	Available all levels of commercial power including the power to 1,300 MWe	Available all levels of commercial power including the power to 1,300 MWe	Capacity to 460 MW	250 ÷ 300 MWe, in currently limited to high capacity gas turbines available	Capacity proposed demonstration plant is approx. 90 MWe
Flexibility fuel	Uses a wide range of fuels	Uses a range variety of fuels	Uses a range variety of fuels. It most suitable for coal with high content ash	Should use a wide range of fuels, but this was not yet demonstrated, not suitable for. coal lower content high ash	Should use a wide range of fuels, was designed efficient use of coal with lower high ash content

Net thermal efficiency cycle	Limited steam parameters; Around 41% modern projects	Today at least 45% and in view of development best materials, 50%	Currently approx. 44%, but may increase it in perspective and / or use of steam supercritical parameters	Currently approx. 43%, but possibly an efficiency of 50% for use advanced gas turbines ago results of research and development	Currently approx. 43%, but possibly over 50% efficiency due to results research findings development and use turbines advanced gas
Operating flexibility	Reduced performance at low loads	Can operate at low loads but reduced performance	Reduced performance at low loads	Can operate only under load curve	Studies suggest a satisfactory performance in low load

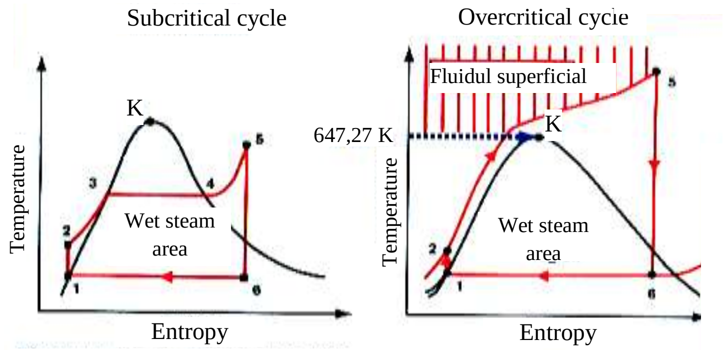
Technological development permit:
- Increasing the net yield, the value of 35-37% (of `70 years) to 40-41% in the 90s;
- Increasing the net yield of plants with computer technology, the value of 42% (from 90s) to 46-48% in the first years of the millennium;
- Use technology to reduce NO_X emissions (through reduced NO_X burners and catalytic equipment or non-catalytic)
- Use technology to reduce SO_X emissions (by installation of desulphurization).

Currently, worldwide, approx. 90% of thermal power plants using pulverized coal combustion technology (PC), approx. 10% coal combustion technology in circulating fluidized bed (CFB) and a very small number of central technology in fluidized bed coal combustion pressure steam-gas combined cycle (PFBC) and integrated coal gasification with steam-gas combined cycle (IGCC).

Coal combustion in boilers with supercritical parameters

Critical point coordinates are 221.2 bar and 647,27 K (fig. 1.1 - point K). At this critical point of water suddenly turns to liquid into vapor. Becoming "overcritical fluid", phases converge to a density without passing through the vapor phase subcritical wet specify cycle parameters.

The difference between these types of cycles is illustrated in the Ts diagram in fig. 1.1.



Ideal cycle Rankine Diagram

Fig. 1.1

Among the advantages of the technology with supercritical parameters lists the following:
- Technology is tested, used and perfected a long time;
- Scheme is more appropriate to use as partial loads

Circulating fluidized bed coal combustion (CFB)

Technology circulating fluidized bed combustion (CFB) has distinct advantages for combustion of solid fuels and energy recovery to produce steam.

Characteristic process consists of a mixture of particles suspended in an upward current of gas, leading to a fluid combination of good properties.

Combustion takes place in bed with a high heat transfer outbreak and low combustion temperatures.

The advantages of this process are:

- Greater flexibility in burning various fuels;
- Emissions reduction

Of CFB technology enumerates these features:

- Temperature of combustion in CFB boilers (1113.15 ÷ 1173.15 K), much lower than in boilers burning pulverized (1623.15 ÷ 1773.15 K), have the effect of reduced formation of NO_X and SO_2 can capture outbreak, by injection of limestone;
- Although in the CFB combustion temperature is lower, during the outbreak of the coal is stationary longer than the PC so that yields two types of boilers are similar;
- Experience has shown that in terms of achieving the same effective retention of polluting emissions (SO_2, NO_X and particulate) are recorded lower investment costs approx. 8 ÷ 15% and
- Lower operating costs by approx. 5 ÷ 10% in CFB boilers than pulverized coal boilers (PC) plant equipped with flue gas desulphurization (FGD) and installation of flue gas treatment Catalytic (SCR);
- CFB boilers allow startup faster than PC boilers, so cold and the hot, thereby reducing operating costs related to fuel.

Characteristic process consists of a mixture of particles suspended in an upward current of gas, leading to a fluid combination of good properties.

Combustion takes place in bed with a high heat transfer outbreak and low combustion temperatures.

Following figure (fig. 1.2) shows the technological scheme of a boiler with circulating fluidized bed coal combustion, related to a block with an output power of 250 MW thermal power plant belonging Gardanne - France (until now the largest heating technology CFB in the world).

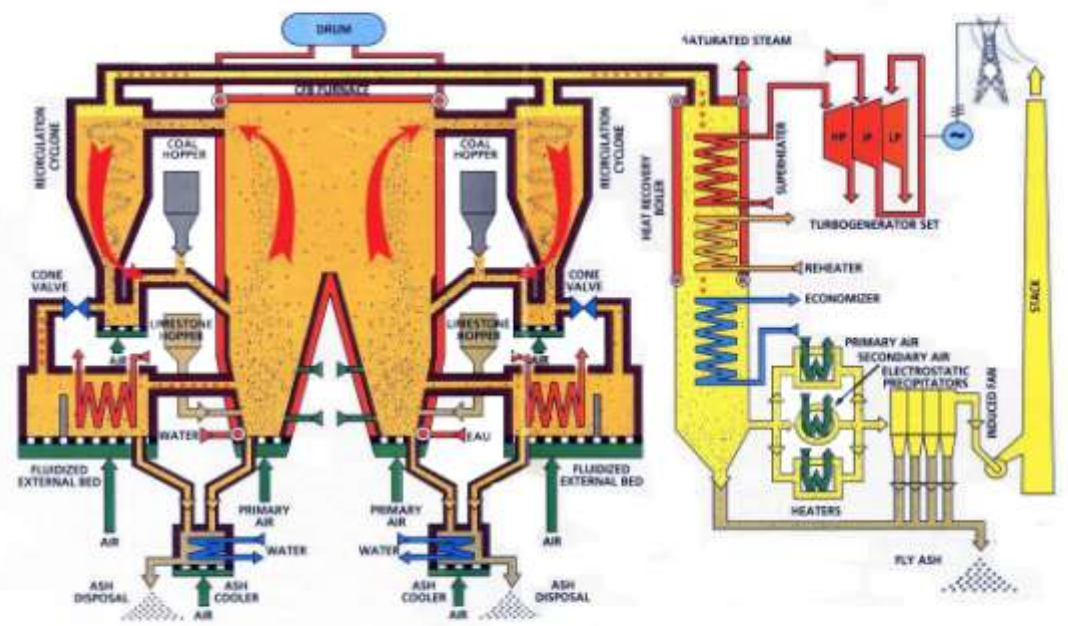


Fig. 1.2 Technological scheme of the boiler of 250 MW Gardanne - France

Fluidized bed coal combustion pressure steam-gas combined cycle (PFBC)

Plants that use coal combustion boiler technology fluidized pressure steam-gas combined cycle (PFBC) combined cycle used to achieve greater efficiency.

Gases from the combustion of coal into fuel, then get to cleaning gas turbine (which causes an air compressor and electric generator), then are used to preheat water used in the generation of steam. Generated steam train steam turbine, which in turn trains electric generator.

In fig. 1.3 is a schematic diagram of central PFBC technology.

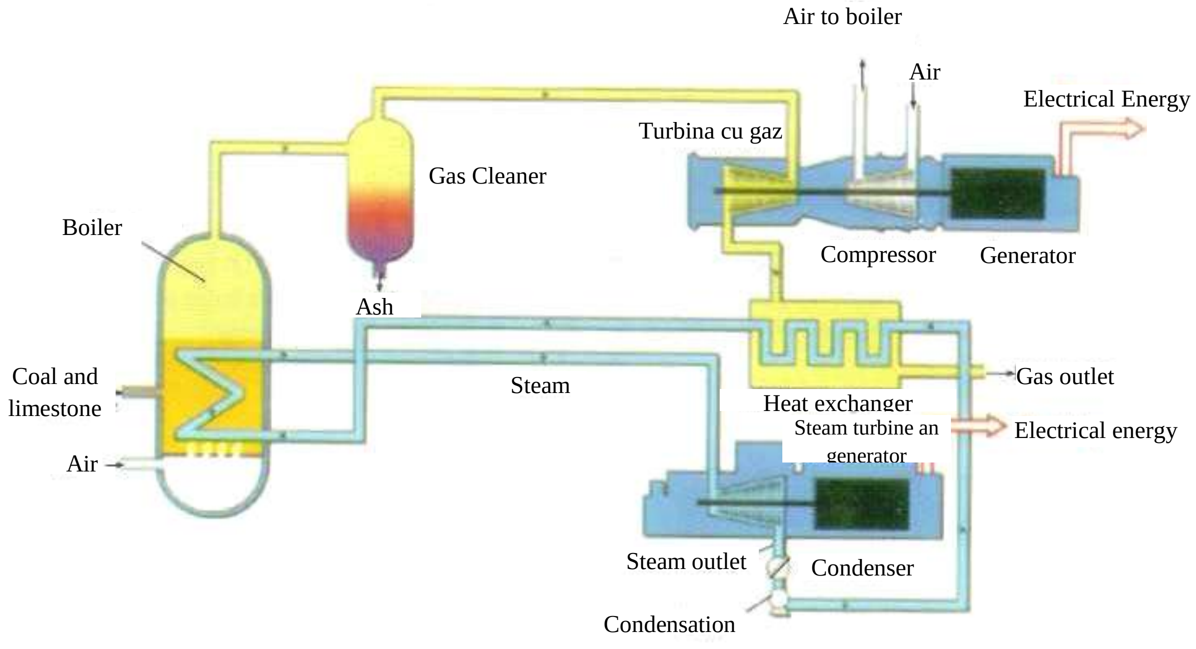


Fig. 1.3 Schematic diagram of a power plant with PFBC

Integrated coal gasification with steam-gas combined cycle (IGCC)

Coal gasification technology integrated with steam-gas combined cycle (IGCC) is in the stage of demonstration projects that various types of applications (number, power, countries), higher than PFBC system, but rather an investment cost high.

In terms of efficiency mention that IGCC technology for the gasification efficiency values of 80 ÷ 85% and combined cycle efficiency of 55÷56% for temperatures of 1573.15 ÷ 1373.15 K flue gas at the entrance gas turbine, can achieve a lower overall efficiency of IGCC technology 44÷46%.

Operating principle

IGCC technology type, the limit may be equated to a combined cycle, without post-combustion, who was attached to a coal gasification plant in which fuel prepare "clean" installation of necessary gas turbine operation. In fig. 1.4 shows a schematic diagram of IGCC plants.

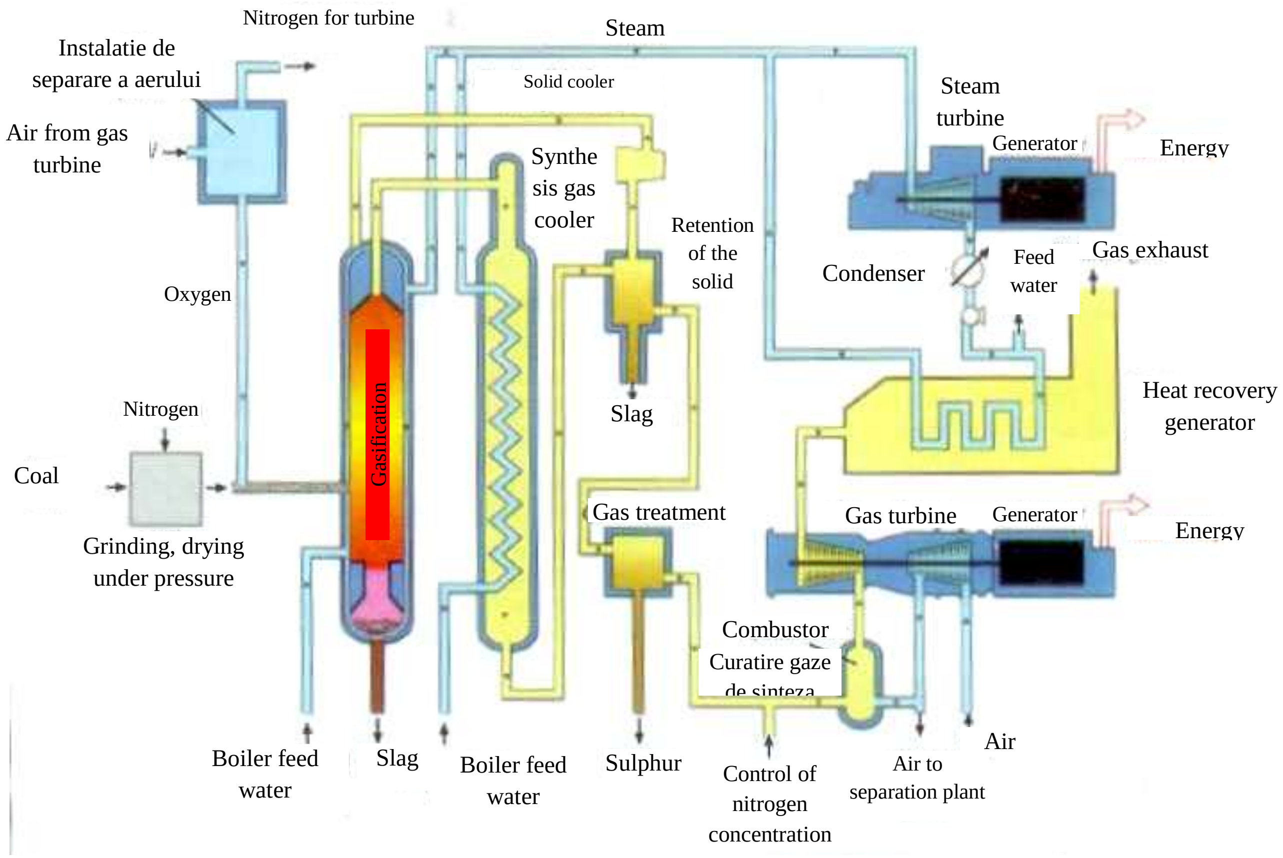


Fig. 1.4 Schematic diagram of a power plant with IGCC

Gasification is a process by which a solid or liquid fuel is converted into a fuel gas. fig.1.4 is apparent in a gas-producing coal that turns into synthesis gas, then are cooled, treated, cleaned and placed in the gas turbine (which causes an air compressor and an electric generator). Of gas turbine, after rebound, gas enter to heat recovery generator and then are discharged into the atmosphere. The generator heat recovery, flue gases convert water into steam. Steam generator product mix with heat recovery steam produced in gas-producing and entering the steam turbine, which train the electric generator.

Solid fuels

Coal higher or lower lignite, continue to be for many years from now, the raw material for producing electricity. Although it is unfriendly to nature and the environment, thanks to emit pollutants by burning him with clean combustion technology, which implements the new electricity production capacity and upgrading existing ones continue to be widely used in all world countries.

Coal is composed of three components:

- Organic mass (o) - substances with complex structures consisting of carbon, hydrogen, oxygen, sulfur and organic nitrogen;
- Inorganic or mineral combustible mass (M) - minerals that ignition is turned to ash;
- Moisture (water)

Liquid fuels

Liquid fuels, almost entirely comes from oil known as inaccurate for "crude oil". Crude oil is first subjected to cleaning operations, desalination and stabilize, then go to primary distillation is performed at atmospheric pressure and finally the secondary distillation, performed under vacuum.

Products from the distillation or cracking oil are subject of refining operations, the components process which removes harmful compounds such as sulfur and oxygen or compounds which produce coke combustion process. Products of the distillation of petroleum and petroleum cracking can be categorized according to main use are given in the following groups:

- Gasoline
- Oil
- Diesel
- Hard Oil.

Hard oil is the most complex chemical product.

After more or less content of substances paraffin oil are grouped into two broad categories:
- Paraffinic oil,
- Non-paraffinic oil

Liquid fuels are used as support or start up fuels for burning in boilers for high power energy and can be used, moreover, as the basic fuel for power boilers designed for this purpose.

Gas fuels

Combustible gas used for energy purposes are divided into two main classes:

- Natural gas
- Gases

Natural gas is combustible gas which is naturally obtained by polling conducted in underground reservoirs. They consist of mixtures of saturated hydrocarbons with impurities like carbon dioxide, hydrogen sulphide, mercaptan, nitrogen oxides, etc.

Combustible gases are gases obtained by thermal processing of coal (gasification) and petroleum products. They get so of solid fuels in gas-producing, retorts and furnaces with fuel decomposition under the action of pressure. Gases are obtained as waste gases of different manufacture, such as: production of pig iron, coke coal production.

2. Forming pollutants in steam boiler furnaces and technical solutions to reduce exhaust emissions

A) The emission of sulfur oxides

Formation mechanism of sulfur oxides

Sulfur oxides are result of oxidation in the combustion process of fuel sulfur content.

Participation of sulfur in coal composition is generally comprised between 0.1-1.5% (for the Romanian lignite). Origin of sulfur in coal is diverse and can be grouped as follows: organic sulfur, sulfur in sulfides (pyrite), sulfur of sulfates and sulfur minerals.

Only a fraction of fuel sulfur was converted to sulfur trioxide, SO_3, most sulfur fuel, over 95% burns to form sulfur dioxide, SO_2.

$$2\,S + 3\,O_2 = 2\,SO_3; \tag{2.1}$$

$$S + O_2 = SO_2; \tag{2.2}$$

Conversion of SO_2 from flue gases into SO_3 is done both in combustion system and the atmosphere after flue gas evacuation

$$2\,SO_2 + O_2 = 2\,SO_3; \tag{2.3}$$

Atmospheric transformation is accomplished by the action of ultraviolet radiation (ruv), at a rate of 1 ÷ 2 ‰.

$$2\,SO_2 + O_2 + ruv = 2\,SO_3; \tag{2.4}$$

Sulfur oxides combine with water vapor (contents in the fuel) in the steam generator and the atmosphere resulting in sulphurous acid and sulphuric acid. In conditions of fog and very wet days, the atmosphere can reach a level of processing up to 15.7%

$$SO_2 + H_2O = H_2SO_3; \tag{2.5}$$

$$SO_3 + H_2O = H_2SO_4; \tag{2.6}$$

By oxidation the sulphurous acid pass into sulphuric acid:

$$2\ H_2SO_3 + O_2 = 2\ H_2SO_4\ ; \qquad (2.7)$$

Sulphur dioxide effects on human body

This sulfur dioxide odor is noticeable by irritating the mucous membranes and action effects are mainly related to impair respiratory function.

Repeated exposure to high concentrations of short-term, combined with long-term exposure to lower concentrations increases the risk of chronic bronchitis, especially smokers and long-term exposure to low concentrations is generally felt by people with asthma, elderly people and children

Sulphur dioxide effects on vegetation

Effect on plants is dependent on the concentration of sulfur dioxide, plant species and age of plant parts. Conifers are most affected during maximum activity of the plant, spring and early summer, the reddish lesions and partial or total discoloration. In winter, dark green color occurs in light green. Effect of fall foliage is needle, depending on the sensitivity of each species.

Sulphur dioxide effects on metallic materials

Corrosion affects both ferrous materials and ferrous ones, manifested primarily by loss of metal, but also by changing the electrical properties, magnetic and optical. It depends on the material metallic, aggressive nature and concentration of the substance, humidity and temperature. It is obvious that for a certain aggressive agent, in this case sulfur dioxide, increasing the concentration leads to increased corrosion. Metal buildings are affected by the phenomenon of corrosion, reducing the life of metal objects is 23 times in areas heavily polluted and of galvanized steel roofs are more affected in urban homes compared with those in rural areas, observations performed sustainability by showing a decrease of two to three times.

B) Emissions of nitrogen oxides

Formation mechanisms of nitrogen

Formation processes of nitrogen oxides in combustion plants are complex and until now not fully known.

Nitrogen oxides resulting from fuel combustion process from:

- Molecular nitrogen content in air combustion in high temperature conditions around the flame and flame and post flame, reacts with oxygen, forming the so-called thermal nitrogen monoxide, nitrogen monoxide promptly respectively. Genesis nitrous oxide flame nucleus is concomitant with combustion;
- Fuel nitrogen in the form of nitrogen compounds, which decompose in the combustion process, forming the so-called fuel nitrogen monoxide.

Nitric oxide thus formed, further reacts with oxygen to form a variety of nitrogen oxides in the literature note NO_X (NO_2, N_2O, N_2O_4).

Until now three ways are known, mechanisms of formation of nitrogen monoxide:

a) the formation mechanism of thermal nitrogen oxide existing nitrogen in the air to burn;

Formation of thermal nitrogen monoxide occurs at high temperatures, a mechanism that starts slowly in the flame, continuing in the post-flame combustion products (after the reaction).

$$N_2 + O => NO + N; \qquad (2.8)$$

$$N + NO => N_2 + O; \qquad (2.9)$$

b) nitrogen oxide formation mechanism prompt or early;

Nitrogen oxide formation occurs promptly flame zone of nitrogen from air, as a consequence of CN and CH radical reactions with molecules of H_2, H_2O and N_2.

$$CN + H_2 = > HCN + H; \quad (2.10)$$

$$CN + H_2O = > HCN + OH; \quad (2.11)$$

HCH above that resulting equation are then transformed into radicals such as IHN, which in the presence of atomic oxygen or OH radicals will generate nitric oxide.

c) the formation mechanism of nitrogen oxide, nitrogen exists in the fuel composition

Nitrogen is released from the fuel, which is in the form of aliphatic compounds (amine) or aromatic (pyridine, Pirol), while freeing the volatile material with an average rate equal to the particle mass loss of fuel. Nitrogen radicals in combination with fuel in the form of CH, forming compounds as HCN, CN and IHN, which reacts to form NO or N_2 according to oxidizing or reducing nature of the environment in focus. The quantity of NO formed is dependent on: the nitrogen content of fuel, oxygen concentration in the flame, the flame temperature and reaction time, having an important influence but only the first two factors.

Adverse effects of nitrous oxide on human body

Mixture of nitrogen oxides, among which is the highest concentration of nitrogen dioxide, potentially toxic gas is high, with multiple effects on the body, predominantly irritating character. Chronic and repeated action of certain toxic doses, can cause injuries but particularly pronounced deep respiratory tract..

Harmful effects of nitrogen oxides on the environment

Nitrogen oxides contribute to increased greenhouse effect, with a contribution estimated at between 4 and 6% and the degradation of the ozone layer.

Nitric acid formed by nitrogen dioxide with water under certain conditions, cause corrosion of metal structures and with different cations present in the atmosphere to form nitrates, electric and telephone networks degrades due to the corrosive action on copper, brass, aluminum, nickel. Due to strong oxidizing and nitride oxides of nitrogen and nitric acid to cause degradation of plastics, varnishes, paints generally used as protective materials.

C) Emission of carbon oxides

Mechanisms of formation of carbon oxides

Carbon dioxide (part of category greenhouse gas) is a natural component of air, is colorless and has an acid odor.

In the process of combustion of carbon containing solid fuel, training equations of carbon dioxide are:

$$C + O_2 = CO_2; \quad (2.12)$$

$$2\,C + O_2 = 2\,CO; \quad (2.13)$$

Effects of carbon dioxide

Carbon dioxide toxicity is manifested in its high concentrations in the air (above 5000 ppm). Sharp increase of the concentration of carbon dioxide than normal concentration in air, appear the first signs of poisoning, also known as carbonic drinking.

The most significant shortcoming related to the emission of carbon dioxide is a manifest influence on climate through the greenhouse effect.

Harmful effects of carbon monoxide

Risk of poisoning the population is generally reduced by industrial sources and discharges more frequently in connection with domestic and transport sources. Carbon monoxide poisoning occurs due to accumulation of gas in the inhalation air and breathes his presence felt without it, because gas is a colorless, inodorous and non-irritant. Presences of other gases like e.g. nitrogen oxides constitute an aggravating factor.

Technical solutions for reducing emissions of pollutants discharged into the atmosphere

A) Technical solutions for reducing NO_X emissions

NO_X emissions reduction may be achieved through two types of measures namely:

a) primary measures
b) secondary measures

When primary measures cannot achieve the required NO_X emission, are used the secondary measures which consist of two types of processes use:

b1) selective catalytic reduction process (SCR)
b2) non-catalytic selective reduction process (SNCR)

B) Technical solutions for flue gas desulphurization

Next is a brief technical solutions flue gas desulphurization:

a) Wet solution

This solution is most frequently used technique in the world, especially the large volumes of gases. Performance of this technical solution is 95%- 98% degree of desulphurization.

Chemical reaction is:

$$CaCO_3 + SO_2 + 2H_2O + (1/2)O_2 \rightarrow CaSO_4 \times 2H_2O + CO_2 \qquad (2.14)$$

In fig. 2.1 shows the scheme of an installation of flue gas desulphurization technology wet

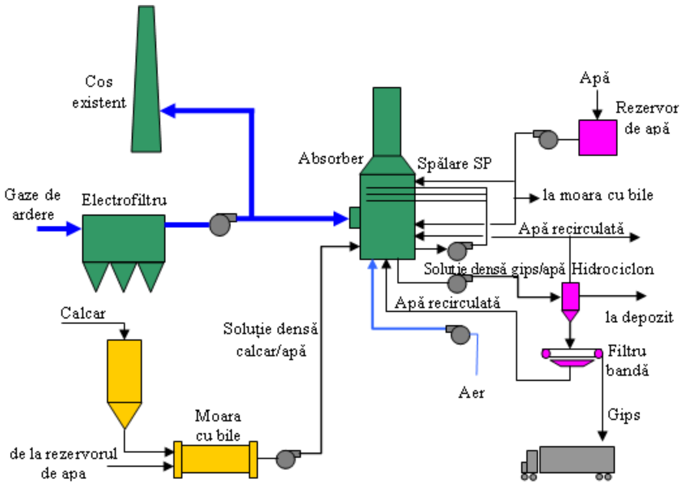


Fig. 2.1 Process diagram of wet desulphurization installation

b) Semi-dry solution

Reaction agent is lime, and the final product is calcium sulphite. The main reaction:

$$SO_2 + CaO + ½H_2O \rightarrow CaSO_3 \times ½H_2O \qquad (2.15)$$

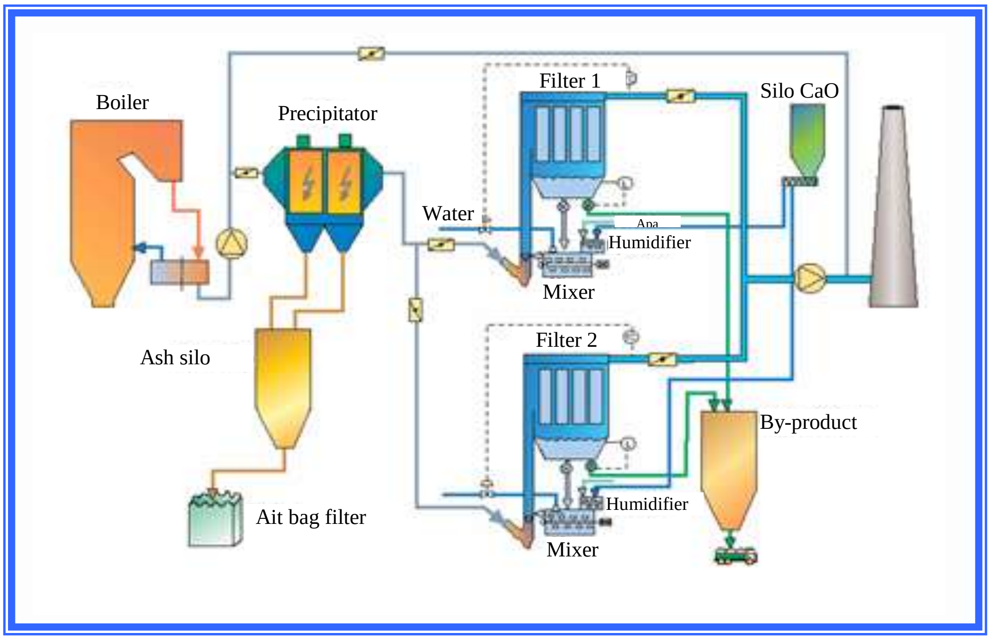


Fig. 2.2 Process diagram of semi-dry desulphurization installation

c) Solution with magnesium
d) Solution "CASOX" Catalytic Oxidation
e) Desulphurization system type OG
f) The "NKK LIMAR - Bag (dry type)
g) The "Blue Sky 2000
h) The semi desulphurization Lilac
i) The direct in the boiler desulphurization and denoxare
j) The "IHI in-line
k) drying system for removing hydrochloric acid and SO_2
l) The "Chiyoda Thoroughbred CT 121"
m) Forced oxidation system with ammonia
u) System with electro-catalytic oxidation (ECO ® Process)
a) Oxidation system with the flow of electrons (e-Scrub ® Process)

C) Technical solutions capture, transport and geological storage of carbon dioxide emissions in power stations

Technologies to capture carbon dioxide

Currently there are two technologies to capture carbon dioxide, whose stage of development is very close to scale demonstrations are:

- Oxy-combustion;
- Post-combustion

Carbon dioxide transport

To carry the CO_2 capture facility at possible storage site, technical and economical solution is feasible in the pipeline so-called natural state "dense phase". Dense phase CO_2 is physical condition in which fluid is overcritical, with a temperature of 304 K and pressure of 7.38 kPa.

This requires compression of CO_2 at high pressure (about 110 bar), so make sure that the entire length of route will not change the physical state of gas and also will cover related losses and pressure.

Possibilities for geological storage of carbon dioxide

Possible locations for injection of carbon dioxide are:
- Depleted oil fields possibly combined with increasing oil recovery;
- Former gas fields, possibly with additional gas production;
- Deep aquifers that contain non-drinking salt water;
- Deep layers of coal at large untapped methane that is exchanged with carbon dioxide absorbed by the simultaneous production of gas;
- Geothermal wells by extracting heat from the aquifer;
- Cavities left in the coal mines and salt depleted.

3. Steam boilers of high power used in national energy system

Burning solid fuels lower, in high power steam boilers

Organization of solid fuel combustion process in boilers

Organizing combustion technology includes the following phases:
1) Mechanical preparation of fuel through sorting and crushing;
2) Furnace fuel and air supply and ensuring their circulation;
3) Making intimate contact between fuel and air (oxidizer);
4) Preparation of gas heating and air necessary for combustion (air and fuel preheating, drying it in the boiler and release volatile substances);
5) resulted from ignition of gas to fuel thermal preparation;
6) Ignition volatile matter and coke;
7) Ensure traffic resulting from the combustion gases and their disposal;
8) Separation and disposal of the solid combustible (ash and slag).

In most large industrial boilers, burning time of coal particles until complete combustion is between one and two seconds, as shown in fig. 3.1

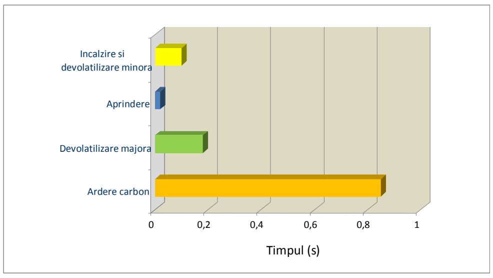


Fig. 3.1 Combustion Process Diagram times

This chart highlights the time spent by the particle of coal in the boiler. Smaller particles (higher fineness of milling) increases the amount of carbon as CO_2 and decrease the amount of fly ash particles which leaving the boiler.

Need support to sustain combustion of fuel: natural gas or hard oil

In conditions of low temperature gradient growth or stationary combustion process becomes unstable, specific thermal loads are reduced and grow much heat loss through incomplete combustion.

To overcome these adverse conditions and specific Romanian lignite, combustion plant must ensure continuity and stability of combustion in the range of 1173.15 ÷ 973.15 K by:

- Bringing a heat input of coke combustion zone;
- Maintenance in that area as big a part of the heat developed.

To ensure reliable ignition of volatile materials, which depends on the temperature, there must be an input of heat energy needed to provide maintenance process.

Failure conditions for igniting solid fuel is required to adopt the service of expensive measures to sustain the flame of solid fuel combustion, consisting mainly of higher fuel (gas or hard oil) to medium heat.

Steam boilers of high power used in national energy system

a) Steam boiler, Benson type of 510 t/h, used at Isalnita TPP

Isalnita TPP is composed of two 315 MW power blocks.

Each block of 315MW, is equipped with two steam boilers of 510 t/h, identical manufactured by MAN – Germany, a turbine manufactured by Rate – SCHNEIDER, France and one generator ALSTHOM-France.

Benson type boiler, the crossing point only variable forced evaporation, built in the shape of Π. Lignite used as solid fuel and natural gas for starting and sustaining flame

b) Steam boiler, Benson type of 525 t/h, used at Craiova CHPP

The steam boiler of 525t/h (146 kg/s) built by Vulcan, burning solid flue lignite, is mounted in the block diagram in Craiova CHPP, together with the 150/120 MW turbine group (774.5 GJ/h), built by IMGB.

Design is a steam generator, forced circulation single tower, with overheating Benson intermediate type, made in solution with membrane walls, vacuum circuit operating with combustion gases. Burning coal and hard oil / natural gas for starting and sustaining flame in the boiler.

c) Steam boiler, Benson type of 1035 t/h, used at Turceni TPP

The boiler used at Turceni TPP is a Benson forced tower type of 1035 t/h and use as base fuel lignite and natural gas as support fuel.

d) Steam boiler, Benson type of 1035 t/h, used at Rovinari TPP

Benson steam boiler is a tower type, built by Vulcan Bucharest under Babcock license, use lignite as fuel and hard oil as support fuel.

4. Modeling the flow process into coal dust burners and into boiler furnace of the Benson boiler 510 t/h from Isalnita TPP, using F.E.M.

Types of flow studies encountered into coal dust burner and into the boiler furnace of 510 t/h.

Results of analysis using F.E.M. were obtained based on specialized software **SolidWorks 2010**. and **COSMOSFloWorks 2010/PE.**

Flow Study can address two distinct categories:

a) The first study

<u>Distinguish the turbulent air flow into sections of plant unaccompanied by combustion processes</u>, the primary air (a mixture of polyphase form: free air + flue gases + coal dust) or secondary air.

a.1) Study of primary air flow turbulence

The concept of primary air, which will be used throughout, refers to a polyphase mixture consisting of coal dust particles carried by a stream of flue gases, water vapor (from the coal pre-drying tower for drying) and air atmospheric.

a.2) Study of secondary air flow turbulence

The secondary air is obtained from atmospheric air heated at T = 543.15 K.
Flow analysis is performed simultaneously by 9 flow channels as follows:

a.2.1) Study of turbulent secondary air flow (categorized as secondary air: lower, intermediate or higher) in five simultaneous channels with variable geometry (channels 1, 3, 5, 7 and 9, in fig. 4.2).

a.2.2) Study of turbulent secondary air flow in four channels with variable geometry (channels 2, 4, 6 and 8 in fig. 4.2)

b) The second study

Refers to turbulent polyphasic flow study within the furnace and accompanied by combustion process.

3D Modeling of the coal dust burner from the boiler of 510 t/h

Modeling the primary and secondary flow air into coal dust burner and furnace were determined input data such as: flue gas volume, mass and volume flow of flue gas components on thermodynamic parameters of calculation. The results of the input parameters were centralized in Tables 4.1, 4.2, 4.

Table 4.1 Volumetric flow rates of flue gases entering the burner to the thermodynamic parameters

	Components flue gases	**The thermodynamic conditions for calculation q_v [m^3 / s] in the input section T_p = 393.15 K, p_p = 101,030.7 [Pa]**		
		[m^3_N /kg fuel]	q_V [m^3_N /s]	q_V[m^3/s]
	Flue gases			
	CO_2	0,6119022	7,138859	4,305857787
Mixture primary air	SO_2	0,0095960	0,111953333	0,067525515
	N_2	2,6567189	30,99505383	18,69490543
	Superheaters vapors H_2O	0,6750659	7,875688333	4,750282074
	Total	**3,9532761**	**46,1215545**	**27,81857081**
		[m^3_N /kg fuel	q_V [m^3_N /s]	q_V[m^3/s]
	air	**1,0456130**	**12,1953125**	**7,355696659**
		[m^3_N /kg fuel]	q_V [m^3_N /s]	q_V[m^3/s]
	Total primary air	**4,9985890**	**59,3168670**	**35,17426747**

Table 4.2 Results obtained from the calculation, the volume flow of secondary air introduced into the burner

Secondary air	**The thermodynamic conditions for calculation q_v [m^3 / s] in the input section T_s = 542,50 K ; p_s = 101030,7 [Pa]**		
	[m^3_N /kg fuel]	q_V [m^3_N /s]	q_V[m^3/s]
	3,1359380	10,01757813	28.456998

Table 4.3 Results of calculation of primary air, secondary and tertiary introduced into the furnace

Type air	**The thermodynamic conditions for calculation q_v [m^3/s] in the input section**	**q_V [m^3/s]**
Primary air	T_p = 393,15 K; p_p = 101.030,7 [Pa]	35,17426747
Seconadry air	T_s = 542,50 K ; p_s = 101.030,7 [Pa]	28.456998
Tertiary air	T_t = 293,15 K ; p_t = 101.325 [Pa]	1,0941778
Total air		**64.725443**

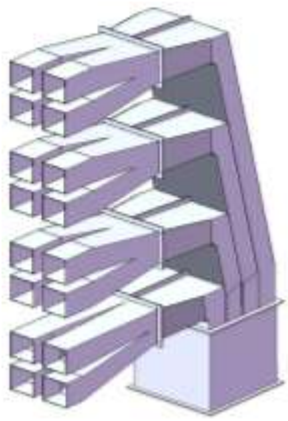


Fig. 4.1 Primary air flow channels

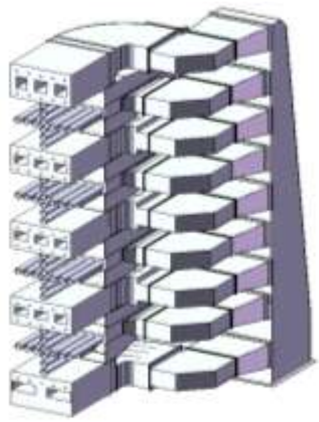


Fig. 4.2 Secondary air flow channels

Analysis of primary air flow inside the coal dust burner of boiler

The primary air flow channels through the coal dust burner appear in fig.4.1.

Following implementation and simulation using F.E.M. analysis, solving differential equations with partial derivatives to study the flow process, modeling the spatial distributions was obtained for velocity, pressure, density and temperature field of the flow paths of fluid elements, presented in fig .4.3; 4.4; 4.5; 4.6.

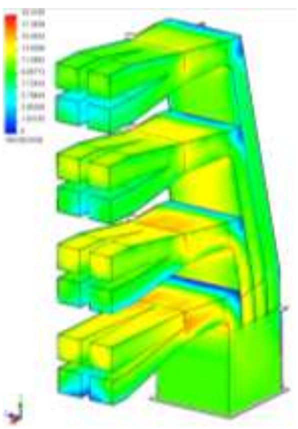


Fig.4.3 Velocity distribution

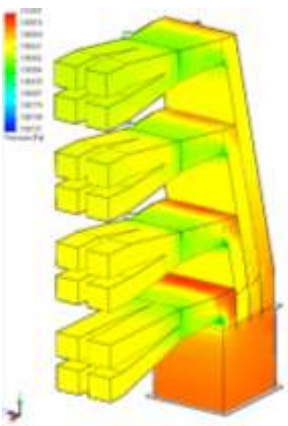


Fig.4.4 Pressure distribution

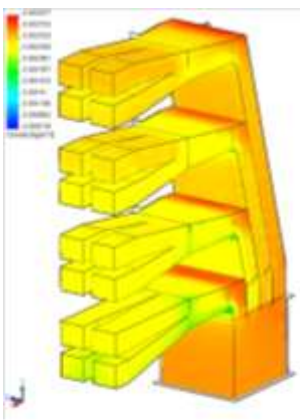


Fig.4.5 Density distribution

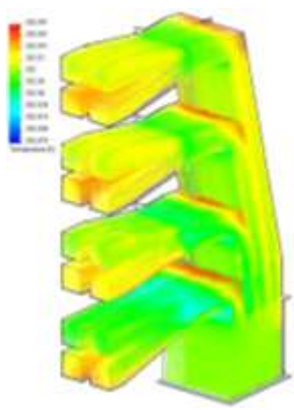


Fig.4.6 Temperature distribution

Variation of the mass flow of coal dust through the burner slots and coal dust burner pipelines are shown in fig. 4.7 and fig.4.8.

In fig. 4.9 is shown turbulence intensity into burner, and fig.4.10 profile exit velocities in sections of pipelines slots.

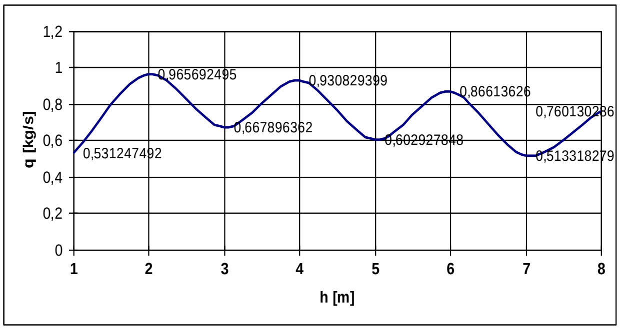


Fig. 4.7 Variation of the mass flow of coal dust through burner slots

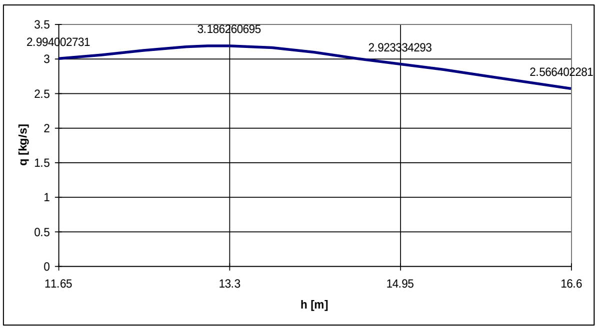


Fig. 4.8 Variation of the mass flow of coal dust through burner pipeslines

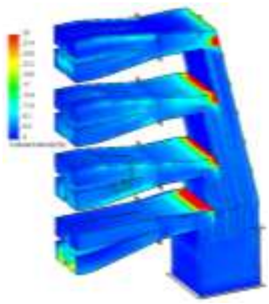


Fig. 4.9 Turbulence intensity

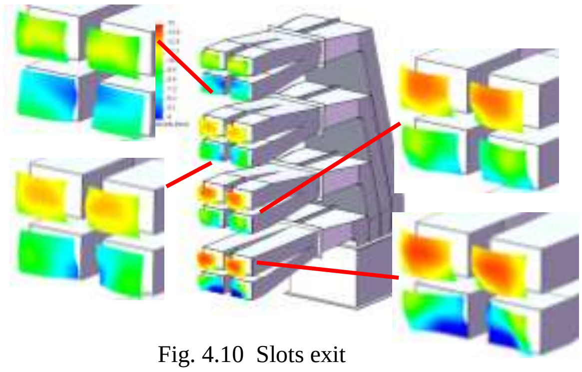


Fig. 4.10 Slots exit velocities

Conclusion:

- Primary air flow has a turbulent character, turbulence intensity has maximum values of external connections of pipe elbows broken dust, fig. 4.9; the output slot sections turbulence intensity is max. in a pipeline slots (1.3p and 1.4p) and descending to lower pipeline slots: 4 (4.3p, 4.4p), 2 (2.3p, 2.4p) and 3 (3.3p, 3.4p);
- Flow velocity is elevated in a pipe flow paths of upper slot (1.1p, 1.2p, 2.1p, 2.2p, 3.1p, 3.2p, 4.1p, 4.2p), but it decreases with increasing rate horizontal meaning (pipe $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$), fig. 4.3.
- 3D pressure distribution is uniform and decreases the output slot sections, with the maximum amount of dust into the outer pipe, also has high value in areas of high turbulence broken elbows, fig. 4.4.
- Density decreases the slots out of the dust ducts from a high density in the box, oblique sections of pipe and elbows broken external connection, fig. 4.5.
- Air heating due to partial transformation of the fraction of energy lost during air flow, generating a maximum increase of approx. T = 0.2 K, located in particular areas of turbulence at the elbows up, the external connections and pipe channels lower slot, after the bifurcation at pipe 1 (1.1p, 1.2p), up to 4 pipe (4.1p, 4.2p), fig. 4.6.
- Exit slot at maximum speeds are confirmed average surface profile slots attached 1.1p, 1.2p and 2.1p, 2.2p, which oppose the lowest wind resistance of air, fig. 4.10.
- Pipelines 1,..,4 is inspired: 25.67%; 27.35%; 25.05% and 21.93% of total coal dust flow entered into burner; flows with the highest values sent to furnace corresponding output slots, which have average speeds in the largest section, pipe no.2 brings maximum mass coal flow.

Analysis of secondary air flow inside the coal dust burner

Secondary air flow channels through the coal dust burner, are presented in fig.4.2.

The study of secondary air flow through the burner was done with F.E.M. and differential equations with partial derivatives associated fluid flow process.

It obtained spatial modeling of velocity, fig. 4.11, temperature, fig. 4.12; pressure fig.4.13, density, fig.4.14, turbulence intensity, fig. 4.15; turbulence energy, turbulence dissipation fig.4.16 and the secondary air flow through the burner, fig.4.17.

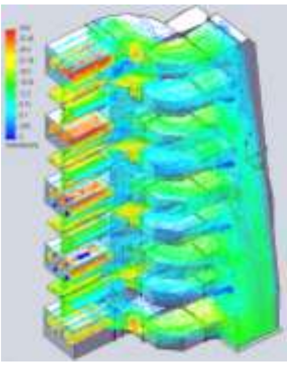


Fig. 4.11 Velocity distribution

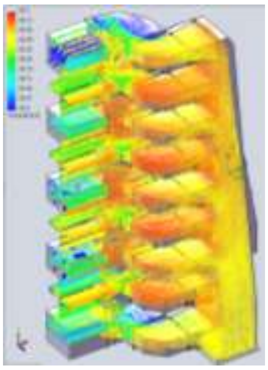


Fig. 4.12 Teperature distribution

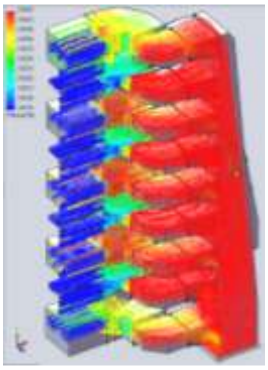


Fig. 4.13 Pressure distribution

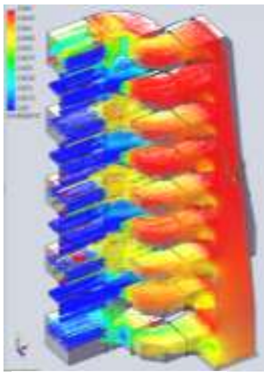


Fig. 4.14 Density distribution

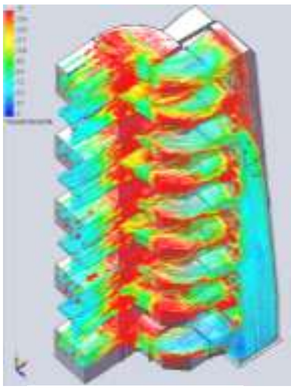


Fig. 4.15 Turbulence intensity

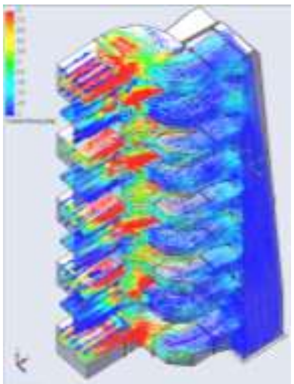


Fig. 4.16 Turbulence energy

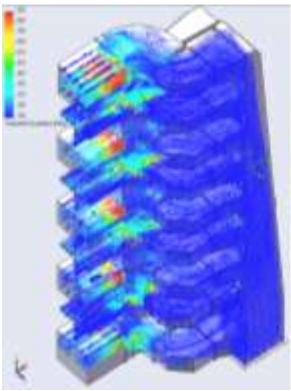


Fig. 4.17 Turbulence dissipation

Conclusion:

- In the secondary air pipes there is a turbulent flow. Flow velocities, the largest are found in channels upstream end of the rectangular openings of the pipes 7 and 9, fig. 4.11; intense vortex is in the relevant areas of internal and external connections or broken elbows secondary air ducts connected, speed is v = 30.5 m/s.
- Spatial distribution of temperature field shows that the inner pipe 2,..,8 shall receive heat by convection and radiation from adjacent lines (by moving the primary air), which takes them, increasing their temperature. To external lines 1 and 9, the temperature is lower, because they lose an additional amount of heat by convection, they are in contact with ambient air whose temperature is much lower compared to the secondary air passing through pipes. Maximum temperature difference, overall, is approx. $\Delta T = 0.7$ K. The extreme values of temperatures are recorded in areas where the highest losses occur pneumatic energy (which is partially converted into heat), these extreme temperatures are located in particular areas and broken elbows or variations confuzoarelor sudden section: fig. 4.12, reaching the maximum temperature T = 543.2 K.
- Secondary air pressure is higher in the input column, confused and broken elbows of pipes 2,...,9, and round elbows of pipe 3, 5, 7, value reaching $p \rightarrow$ 100 450 Pa; For sections output slot, which brings into focus the pressure reaches the value $p \rightarrow$ 100 150 Pa; It also notes that we have a variation of pressure field at the exit slot to center, both horizontally and vertically: fig. 4.13.
- Field distribution densities vary within $\rho = 0.643 ... 0.6445$ kg/m^3, with higher values to input and lower to output, reflecting the variation dependence density with temperature: fig. 4.14.

- Field distribution of turbulence intensity, shows that there highest values located in elbows where direction of change of flow and sudden changes of section, found on the route of flow: fig. 4.15.
- Dissipation of turbulence is more intense at the end of the secondary air ducts odd, out of round elbows and connected into a rectangular section channels: fig. 4.17.

5. Modeling combustion in the boiler furnace of 510 t/h from Isalnita TPP

Modeling thermal field

Modeling the combustion process is complex and can be achieved by addressing all data and fundamental physical phenomena governing the combustion.

In modeling should be considered:

- Modeling the physical properties of substances,
- Fundamental physical modeling,
- Turbulent flow modeling,
- Modeling of heat exchange by radiation,
- Production and transport modeling of chemical species,
- Modeling of pollutant formation.

Thermal conditions of ignition

Ignition temperature is directly influenced by fuel characteristics. Therefore, it is strongly dependent on the content of ballast since he is greatly ignition period is longer. Ignition is also influenced by other parameters, the order-functional design, which involved the design of a boiler, including: the fineness of grinding of the fuel, excess air ratio, the proportion of primary air and its temperature, instead of introducing secondary air , thermal regime of the furnace.

Equations representing the conditions of ignition are:

$$Q_{primit} \geq Q_{cedat}$$
$$\frac{dQ_{primit}}{dT_p} \geq \frac{dQ_{cedat}}{dT_p} \qquad (5.1)$$

Where T_p is the temperature of fuel particles, [K].

Solving this system of inequality is numerically using a program which determines the pair of temperatures (T_p, T_g) at time τ_i (T_g is the temperature of the gas phase), which carries the ignition conditions, namely:

- Heat flux received by the particle is less than that assigned;
- Growth rate of heat flow received by the particle is greater than the speed of the particle gives off heat.

Modeling the combustion process inside the boiler furnace of 510 t/h

Inside the Benson boiler at 510 t/h, coal dust burners brings in furnace a mixture of primary air + secondary, undergo combustion (in coal dust particles are suspended). Unhomogeneity fuel mixture sent in the furnace and the turbulent nature of flow process, carried the torch at different rates, are the inspiration of coal dust in the furnace, the exit slots of dust to be uneven lines and primary air, secondary and tertiary related pipelines, which leads to a process flow and spatially uneven combustion in the furnace.

This will be highlighted in the paper by analyzing the combustion process with finite element using a specialized software **Fluent 6.3** and software **Gambit 2.2.30** (used for modeling and mesh flow field). Finite element analysis results showing evolution of flow and combustion process existing in the furnace, which are determined appropriate spatial distribution of fields: temperature, speed, density, pressure, etc.

In fig. 5.1 a, b, c is presented spatial modeling of the boiler and a number of spatial sections in the furnace, and the furnace geometry.

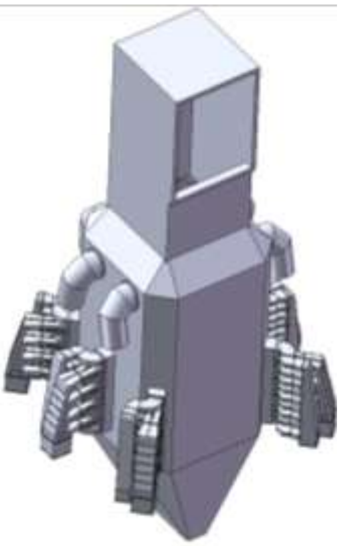


Fig. 5.1 a

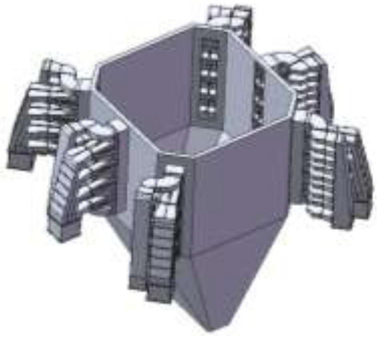


Fig. 5.1 b

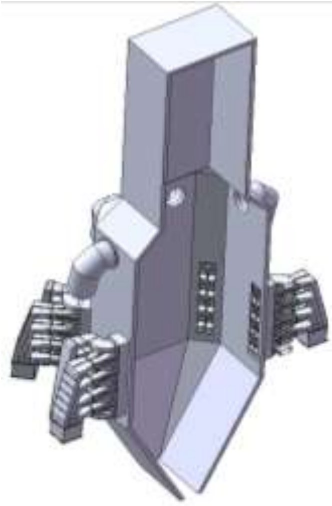
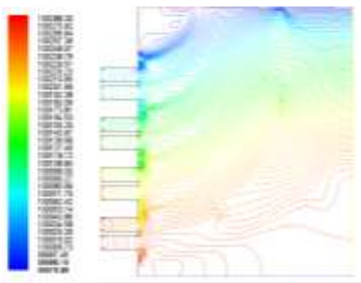


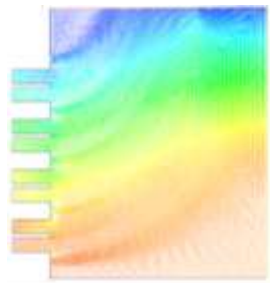
Fig. 5.1 c

In fig. 5.2,...,fig. 5.7, noted by a), b), c) are represented:
a) - contour lines (contours) for the specified physical size has constant values, such as e.g. at
p = ct., v = ct., ρ = ct., T = ct.
b) - vectors velocity fields, corresponding color point value attached to the point that the module size (Colored by velocity vectors ...)
c) - flow trajectories, colored according to the value that is attached to the physical size.

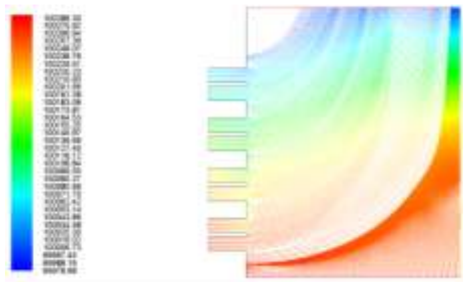
In fig.5.2,..., fig.5.9 distributions are the results of calculations and modeling of air flow measurements associated with primary, secondary and tertiary in the furnace.



a

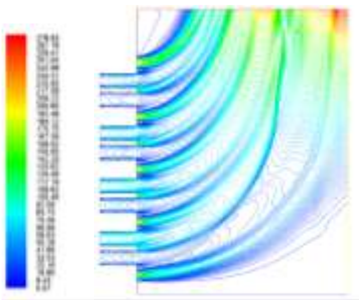


b

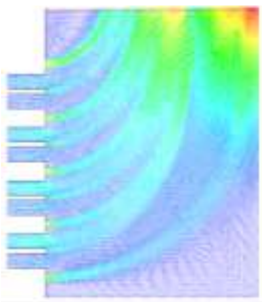


c

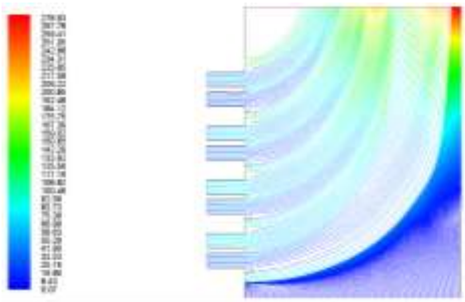
Fig.5.2 Staic pressure



a

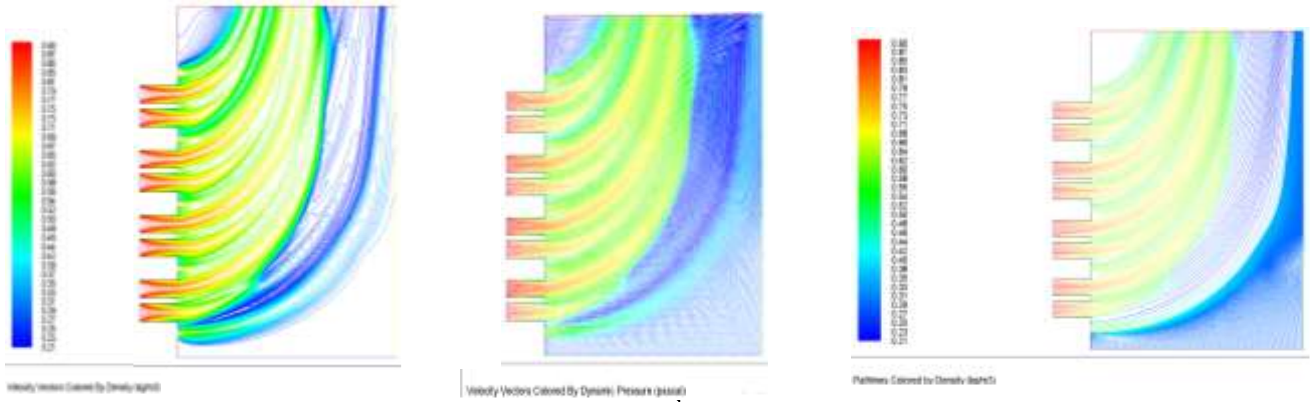


b



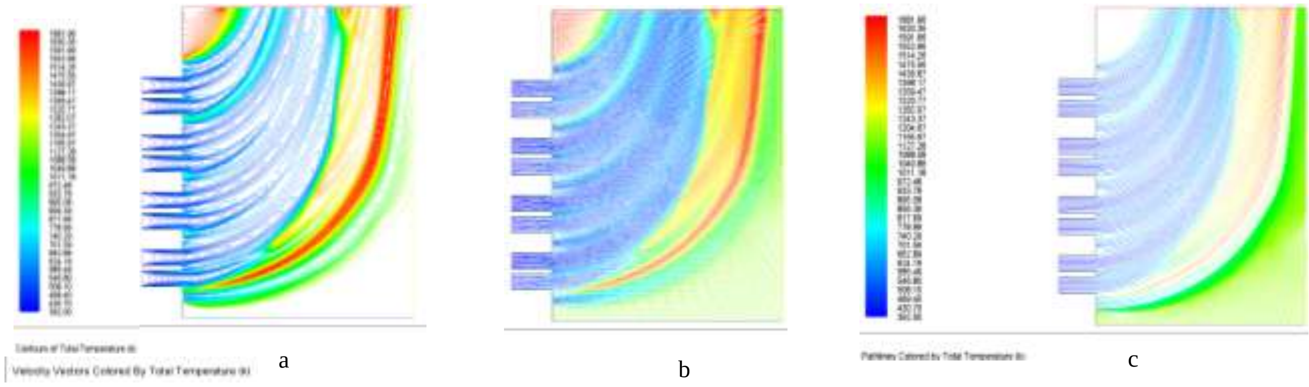
c

Fig.5.3 Dynamic pressure



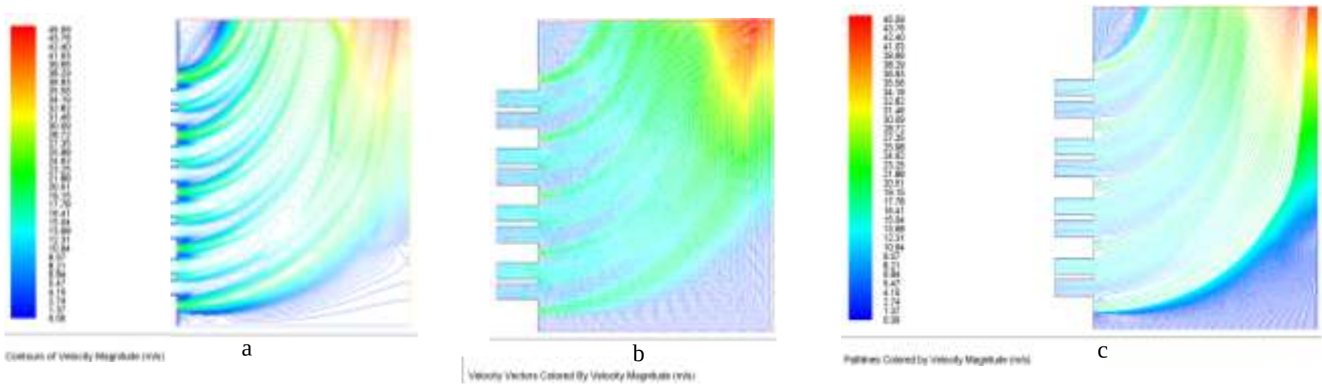
a b c

Fig.5.4 Density



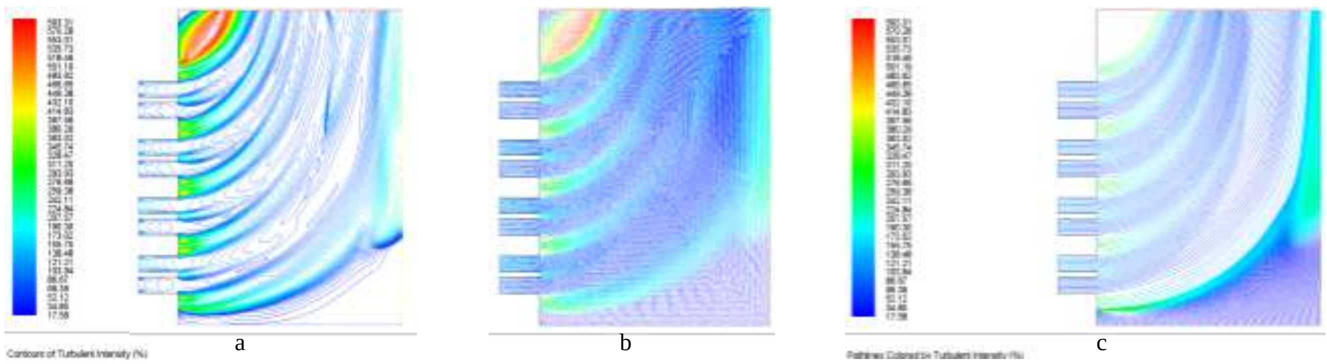
a b c

Fig.5.5 Temperature



a b c

Fig.5.6 Velocity size



a b c

Fig.5.7 Turbulence intensity

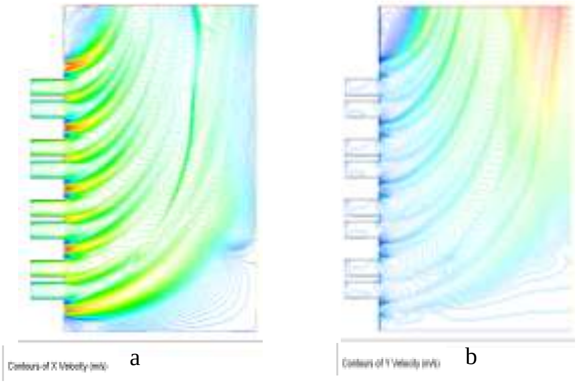


Fig.5.8 Velocity along the x axis and y

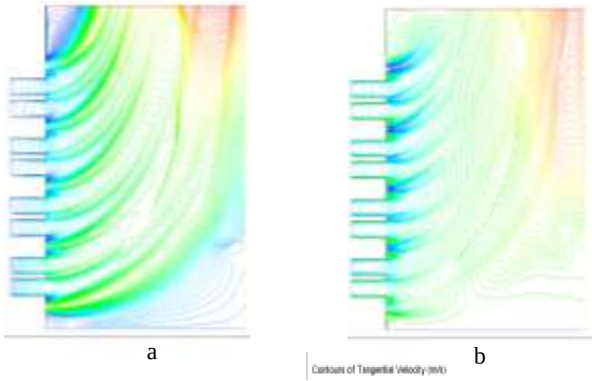


Fig.5.9 Radial and tangential velocity

Conclusion:

- 3D model of the boiler furnace is relatively simple with an octagonal section horizontally and coal dust burner design inspired mix of primary and secondary air in furnace at the imaginary cylinder tangent fig. 5.1 a, b, c.
- Distribution of flow velocity trajectory results show a significant disruptive influence of tertiary air, which is adjacent lower wall (where the flow velocity of primary and secondary air blast in furnace is higher) and increased toward the center of the boiler combustion chamber where its influence is more significant, fig. 5.6 a, b, c.
- - Spatial distribution of velocity v, x component, fig. 5.8 a, presents the extreme values in the adjacent wall furnace, with curved trajectories of these jets on the flow upstream, where the radius of curvature is less for higher quotas, accompanied by a decrease in flow rate to chamber axis combustion.
- Spatial distribution of velocity v, y component (which is approx. 1.77 times the x component of velocity v) to achieve maximum middle chamber, fig. 5.8 b, is curved upper flow paths.
- There is also an intense vortex flow in the imaginary cylinder, which brings coal dust burner fuel tangential, tangential flow velocity confirmed the presence fig. 5.9 b, which overlap and further over a radial flow speed, fig. 5.9 a.
- The total pressure drops in focus as share increases, tending to $p \rightarrow 100\ 000$ Pa, the dynamic pressure increases towards the center of the boiler combustion chamber fig. 5.3 a and the static pressure is greater than the bottom and toward the center of the chamber fig. 5.2 a and fig. 5.2 c, the share of the total load dynamic pressure is max. 0.28%.
- Total temperature of the mixture reaches the max. T = 1682 K, fig. 5.5 a, b, c, the radiation temperature is an important input, high temperature values are reached by the central furnace.
- Turbulence intensity distribution in focus, shows a greater value adjacent furnace wall, where primary and secondary air jets interact directly with the whirlwind forming recirculation zones due to a significant speed difference inspired jets, fig. 5.7 a, b, c.
- Mixture density decreases with development of the combustion of coal particles, fig. 5.4 a, b, c, decreasing to near the center of the furnace and the growth rate in the furnace.

In fig. 5.10, 5.11, 5.12, 5.13 presents an analysis related to a number of physical quantities, which characterizing coal dust during movements inspired in the trajectories, with the starting point of the primary air injection slots as: resistance while the particle velocity, density, temperature.

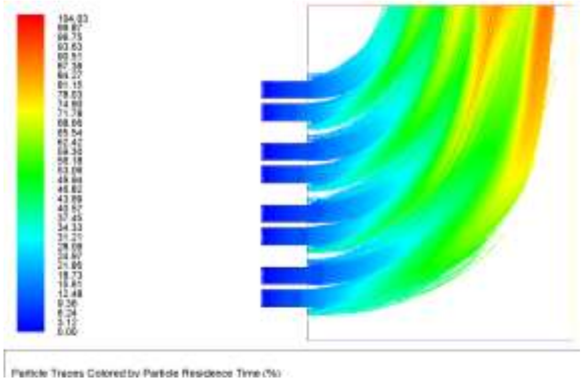


Fig.5.10 Resistance particle coal dust

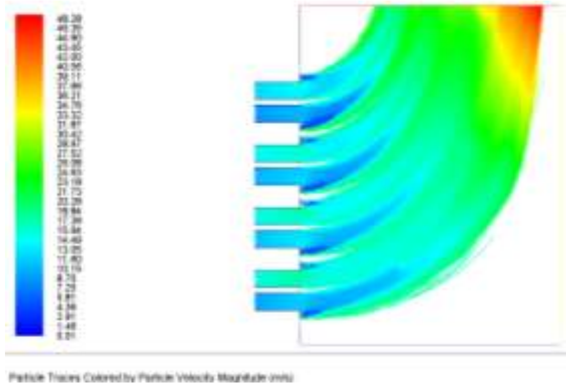


Fig.5.11 Resultant velocity dust particle

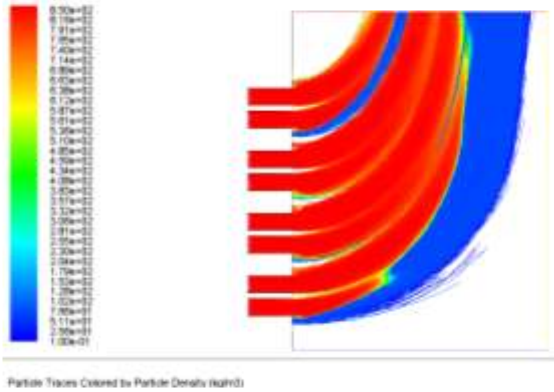


Fig.5.12 Dust particle density

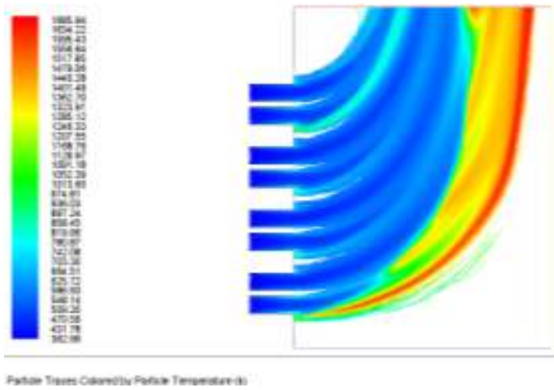


Fig.5.13 Dust particle temperature

Conclusion:

- In fig. 5.10, while resistance is found that coal dust particles, expressed as a percentage, the highest value, one has particles that reach the middle chamber of the boiler, the max. their being 99.87%;
- Resultant particle velocity increases with increasing level to the furnace, reaching a peak of v = 45 m/s fig. 5.11;
- Density per unit volume of coal dust particles, reduces the combustion process is completed, in moving towards the center of the chamber, fig. 5.12;
- Particle temperature rise near the center of the chamber, fig. 5.13.

6. Technical solutions for upgrading high-power steam boilers with framing environmental requirements

The technical possible solutions for modernization of boilers and to achieve the environmental protection requirements, which will be implemented by the end of 2012 will be:

- Replacement of gas burners and coal dust with some upgraded with reduced levels of NO_X emissions;
- Improving combustion by implementing management systems and combustion control;
- Replacement of heat exchange surfaces;
- Replacement of control and isolation valves;
- Bringing a boiler operating with excess air design values;
- Automation modernization of energy block;
- The installation of flue gas desulphurization plants, etc.

The basic concept of powdered coal burner with reduced NOx emissions

Burner description

Coal dust burner with multiple slits levels, existing burners will be replaced with RS (fig.6.1 and fig.6.2), a new concept. These burners are circular type and are equipped with flame stabilizing ring to ensure initiation of ignition near the burners (fig.6.2), even changing the fuel quality.

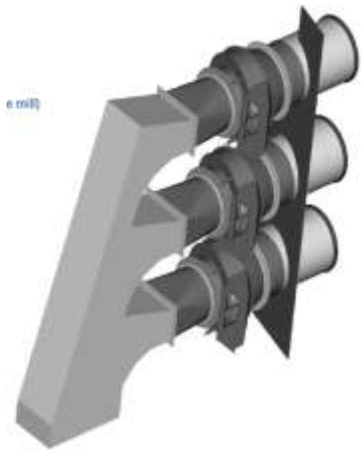


Fig. 6.1 Architecture of coal burners, RS type

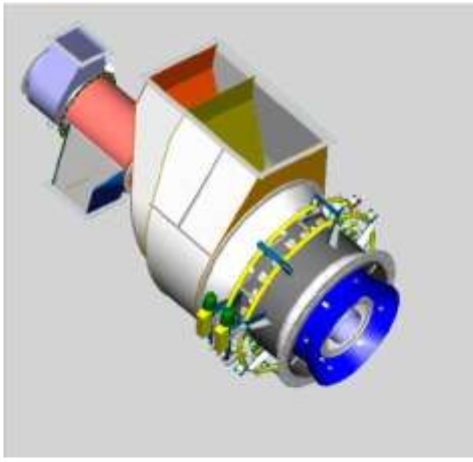


Fig. 6.2 Coal dust burner with low NO_X , RS type

Organizing the stepped combustion at furnace level

Most common variants of the method of organizing the furnace stepped combustion as shown schematically in fig. 6.3 a, b and c.

In fig. 6.3 is sketched the "Over Air threads"- the air above the burning zone, characterized by installing over coal dust burners, of nozzles, which inject tertiary air.

Main burners operate under substoichometric and therefore, production of NO_X is broken by a lack of oxidizer in the vicinity of burners. For completion of combustion breathe air and rest to burn so-called finalization of the combustion air. Injection nozzles are located at the top of the outbreak, aiming at the percentage of unburned to remain below 5%.

If the modernization of older plants, it is advantageous to use the "**Burners Out of Service**", sketched in fig. 6.3 b.

This method is expected decommissioning of existing burners before modernization or change their operating procedure. Under this principle, the main burners (from the base of furnace) run with no air, and the secondary burners, higher mounted, running with excess air.

A great way to capitalize on the burning speed is so-called reduction of NO_X in combustion space. The method is known as the **"In-furnace NO_X reduction"**, presented in fig. 6.3

At the bottom of the furnace burners are mounted special low-NO_X, what produce a small amount of NO_X. Above them is well-determined quantity of injected fuel to create a reducing atmosphere

As a result, the furnace, are the three areas of combustion:

- The main combustion zone (ZPA), the excess air coefficient λ has values between 1.13 and 1.15 and of the gases will go out with a content of NO and unburned;

- The (gas) reducing (ZR), conditions are substoichiometric and compounds like HN_i, HCN and CO (substoichiometrica produced in combustion process due to fuel injection) will help reduce the (chemical) NO existing;
- Finalization of the combustion area (ZDA), in which breathe air through nozzles mounted on a surface area sufficient for the heating furnace roof in order to ensure appropriate reaction time and consequently reduce oxidation of unburned from fly ash 5%.

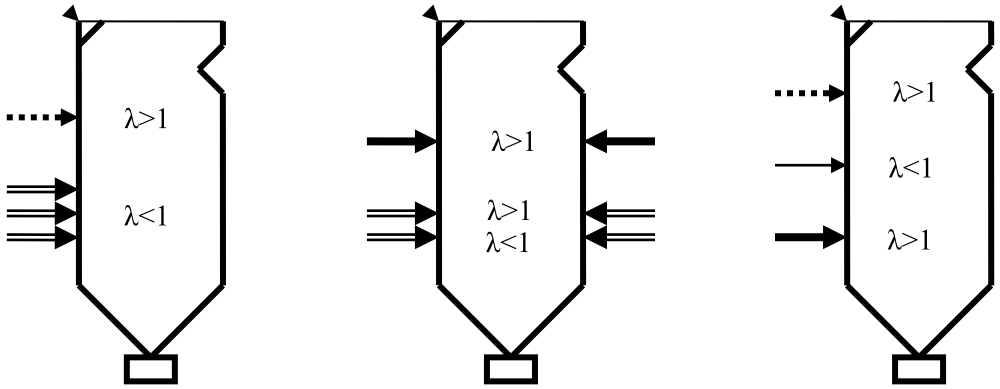


Fig. 6.3 a Fig. 6.3 b Fig. 6.3 c

Fig. 6.3. Variants of stepped combustion method, the height of the furnace

LEGEND

Burner with little air ($\lambda>1$) — combustible

burner with great air ($\lambda<1$) — air

λ - excess air coefficient

a- principle method: **Over fire air;**

b- principle method: **Burners out of service;**

c- principle method: **In furnace NO_X -reduction.**

7. General conclusions. Personal Contributions

After modeling poly-phase flow and secondary air mixture through the burner of coal dust were found following:

a. For poly-phase mixture (primary air) air, flue gases and coal dust

- The flow of coal dust on the trajectories of dust particles moving initially on flow path direction, which opposes the lowest air resistance.
- There is uneven distribution of flow rates of coal dust in the entrance section of the burner box, due to turbulent flow generated by the route above the pipeline connection between the mill and coal burning. Turbulent flow is further reinforced by the variation of coal dust channel geometry and flow direction changes, which lead them inside and out on sections of the burner slot, uneven distributions of: flow, pressure and density of particles in unit volume coal;
- Is an injection of different mass flow of coal dust in the furnace boiler outlet slots;
- Pressure distribution is uneven, meaning flow through the burner. and decreases the output slot sections, with maximum value at the entrance pipe cleaner box. Pressure in output slots vary depending on position in the burner pipe, decreasing the value of the order of $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$.

- Pipelines 1, … 4 are different flows instill: 25.67%; 27.35%; 25.05% and 21.93% of the total flow of coal dust got into the burner;
- Density drops out of the vents dust pipes, starting with a high density in the input box on the burner, oblique sections of the outer connecting pipe and elbows broken

b. For secondary air

- An overall secondary air ducts finds a turbulent flow, flow rates are common in most channels of rectangular slots preceding terminal valves 7 and 9.
- Secondary air pressure is higher in the Input column, confusion and broken elbows of pipes 2,...,9, rounded elbows of the pipes 3, 5, 7 with value $p \rightarrow 100\ 450$ Pa. For out of the slot sections, which infuse the outbreak, the pressure tends to $p \rightarrow 100\ 150$ Pa, as we shall also find a variation of pressure field in the output slot to center both horizontally and vertically.
- Field distribution densities vary within $\rho = 0.643 ... 0.6445\ kg/m^3$, with higher values at entry and lower exit, this variation reflects the density and temperature dependence.
- Field distribution of turbulence intensity show the existence of the highest values in the elbows; place where the flow changes direction and abrupt changes of section common flow path.
- Izopotentiale surfaces look like covered velocities in the range v = 7-12 m/s are the most extensive areas of secondary air column, confuzoarelor and elbows, and once the upper limit speed increases $v \rightarrow 30$ m / s and they are shrinking withdraw the final sections of pipe

In the paper the modeling was done and **burned in the boiler furnace** of 510 t / h, you should see these:

- 3D model of the boiler furnace is relatively simple with an octagonal section horizontally, and from constructive point of view the coal dust burners inject the air mixture in the primary and secondary to furnace, tangential as an imaginary cylinder.
- Velocity distribution of flow paths results show a significant disruptive influence of tertiary air, which is adjacent lower wall (where the air flow velocity in the primary and secondary blast outbreak is greater) and more elevated toward the center of the boiler combustion chamber where its influence is attenuated
- There is also an intense vortex flow in the imaginary cylinder, which breathe coal dust burner fuel tangential, tangential flow velocity confirmed this, further than that overlaps and a radial flow.
- Total temperature of the mixture reaches the max. T = 1682 K, the temperature of the radiation makes an important contribution. High temperature values are attained by the furnace center.
- Confirm that there inside the furnace along the axis y-y, cutting plan, a complex movement whose membership includes: a whirlwind of inspiration generated by the four fuel burning plane and an imaginary circle (called the circle of fire) whose intensity increases with the order, for which there is a tangential velocity, a magnitude vortex)and a radial velocity.
- The resultant particle velocity increases with increasing heart rate and to the outbreak with a maximum value of v = 45 m / s.
- Density in unit volume of coal dust particles, reduces the combustion process is completed, in moving towards the center of the chamber.
- Particle temperature increases with proximity to the center chamber and growth rate

Thesis contribution to knowledge development in the field, the ways to exploit the results - potential beneficiaries

Solution modeling the flow of coal dust burners and combustion in the furnace, boilers using solid fuel, can be successfully applied to the rehabilitation and modernization of power boilers, available, with costs much lower than the value of investments would require Full replacement of the combustion system. By correlating coal dust burners redesign using advanced materials and implementing a management system and combustion control, integrated automation system operating the power unit can obtain technical advantages - economic implications.

Flow Modeling (poly-phase mixture, secondary air and tertiary), the burners and combustion of coal dust in the furnace, aims to increase boiler efficiency and to decrease specific fuel consumption by improving and optimizing the combustion, reduction of unburned slag and ash, reducing NO_X emissions. Reducing specific fuel consumption and reduce emissions of SO_2 and CO_2 levels discharged into the atmosphere.

Analysis of flow through the coal dust burners, highlight areas in which flow measurements produce physical changes that characterize the fluids moving through the burner and can also be so, to redesign and coal dust burners to eliminate all initial design deficiencies.

Analyses and modeling done in this paper, results and conclusions obtained, can be applied to other existing power boilers using solid fuels in Romania.

Potential beneficiaries of the proposed solutions will be Isalnita TPP, Craiova II CHPP, Turceni TPP and Rovinari TPP or any other heating system that uses lignite as a fuel base.

Thesis impacts

Economical impact of thesis results

The results from research and application of optimization in boilers burning high-power in Romania can bring an improvement in combustion boilers implied yield will be easier to control parameters of boiler operation by facilitating the automation system by block operator’s energy. This is focused on lowering production costs and increasing flexibility of energy producers, coal, to meet the demands of increasingly stringent competitive market for electricity and heat.

Social impact of thesis results

Social impact is not one of neglect; one can get out all activities from design, construction, installation and commissioning staff in the country, without resorting to expensive technologies and solutions from abroad. This will allow power producers falling prices of electricity and heat, so that end users, industry and households will benefit from cheaper energy.

Thesis results impact on the environment

Environmental impact is a major, reduces emissions of NO_X, SO_2 and CO_2 which are discharged into the atmosphere. Impact of coal power operation on the environment will be diminished significantly.

By increasing efficiency and optimizing boiler combustion, reduces fuel consumption, reducing the effect on exhaust emissions levels, with positive effects on ozone layer protection, the environment and population.

Observe also the principles of sustainable development of the Romanian energy sector, with framing the evolution of global trends and European

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