
Clean coal technologies
for Russian Power industry
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Conventional coal fired steam Power Plants are commercially efficient now and will stay as such in future

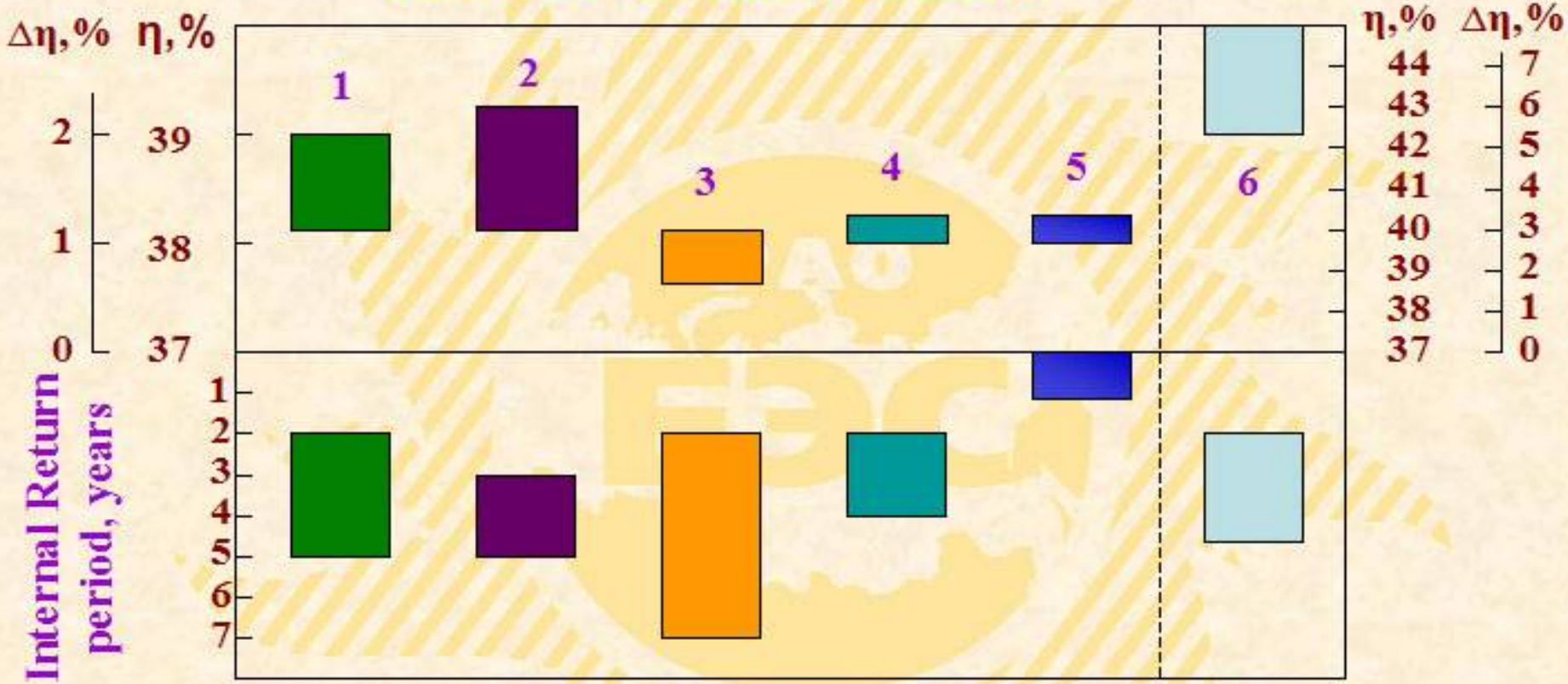
Energy Resources consumption in Power Plants, base variant

	2005		2030	
	bil. ton	%	bil. ton	%
Total	392	100	697,5	100
NPP	50.5	12.9	137	20
Hydro	63.8	16.3	89	12.9
Gas	191.9	49.0	240	34.9
Solid fuels	75.8	19.3	210	30.5
Fuel oil	10.0	2.5	11.5	1.7

Currently operated supercritical units
(ref. EPRI, USA, 2004)

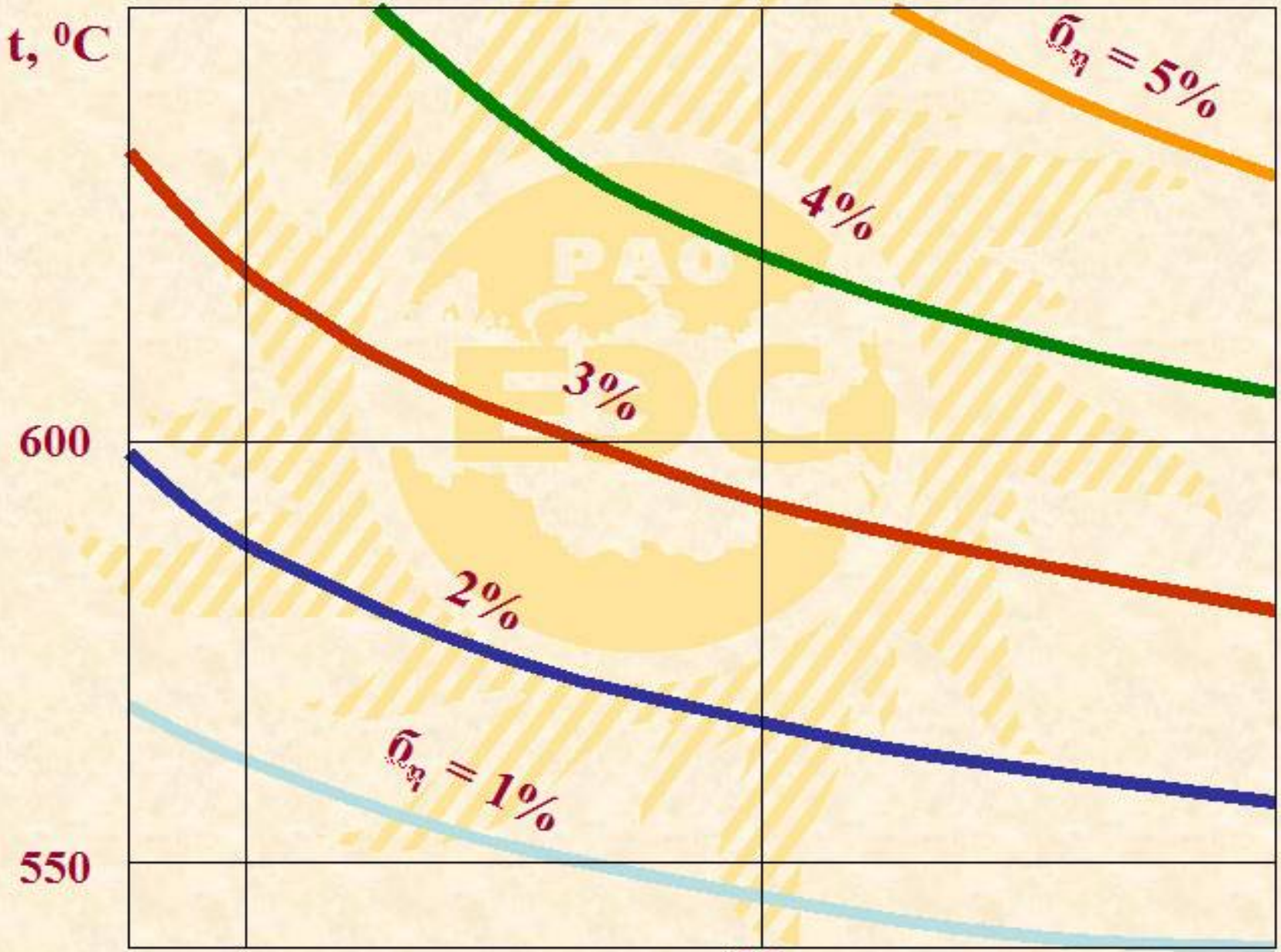
Region	Number of Units	Capacity, MW
USA	164	300–1100
Europe (Germany, Denmark, Holland, Finland)	60	200–1000
Japan	50	500–1000
Russia and NIS	~240	300–1200
Total	~520	200–1200

Prospects of efficiency improvement for 300MW units



η –efficiency (first – coal fired, second – natural gas fired), %;
Δη – total efficiency change, %; 1-turbine improvement; 2-boiler improvement and reduction of flue gas temperature; 3- reduction of pressure losses in steam ducts; 4-improvement of auxiliary equipment and reduction of the auxiliary power consumption; 5-increase of steam temperature; 6-total.

Power unit efficiency versus steam pressure and temperature



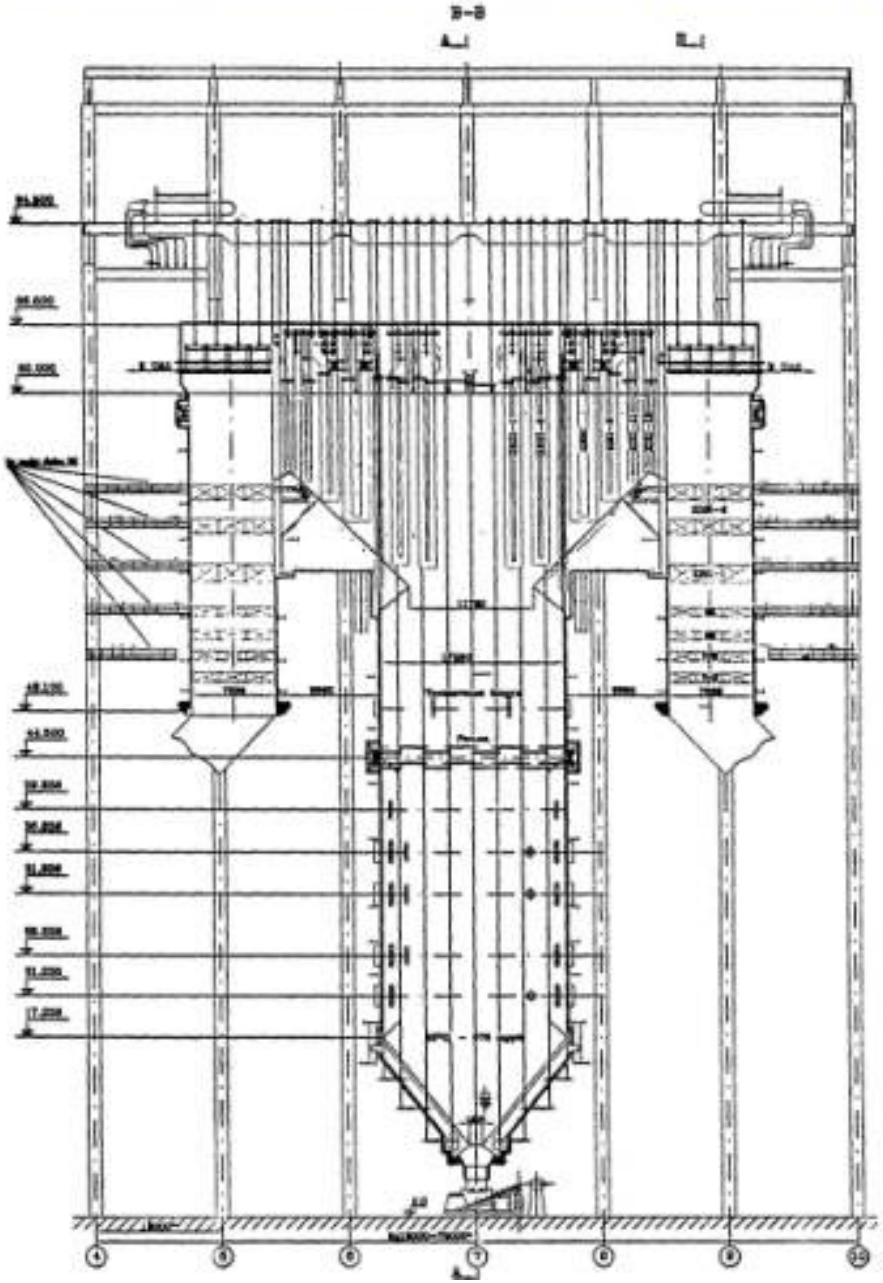
Boilers and units with supercritical steam parameters

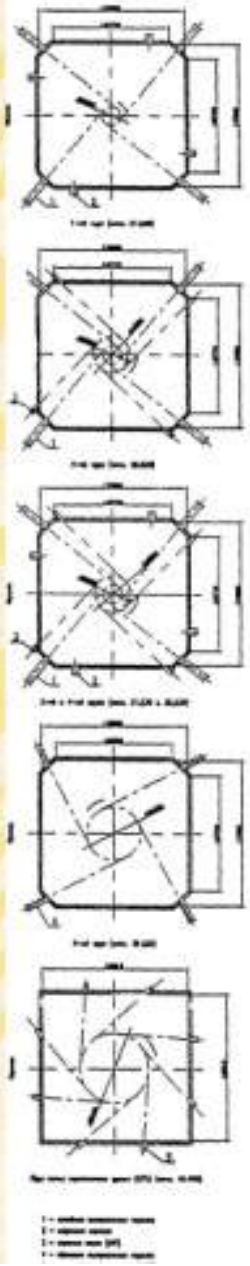
Parameters	Boiler 60-ОП (# 7)	Unit СКР-100	Prospective units
Location	VTI Cogeneration Plant	Kashira CHP	Kashira CHP, TroitskCHP, Refta CHP, BerezovoCHP
Comisioning year	1949 (600 °C) 1960 (650 °C)	1963	2005
Steam parameters	p=35 MPa t=650 °C	p=30 MPa t=650 °C	p=30 MPa t=600/600 °C
Steam capacity, ton/hr	15	710	up to 1500
Steel type	15 ХМ, ЭП17, ЭИ257, ЭИ695Р, ЭП184	12Х1МФ, ЭП184, ЭП17, ЭИ695Р	12Х1МФ, 14Х1ГМФ, ДИ82, ЭИ756, ДИ59, ЭП184
Operating time, thousand hour	>200	> 40	—

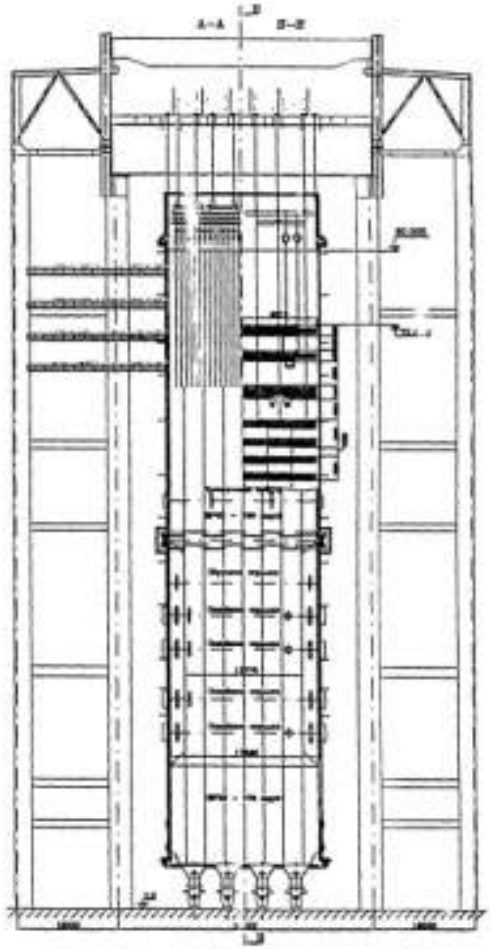
MAIN PARAMETERS OF A 500 MWe SUPERCRITICAL UNIT

Fuel	Power, MWe	Turbine power, MW	Pressure, MPa	Temperature, °C			Turbine efficiency %	Boiler efficiency %	Unit efficiency %
				Boiler exit	Re-heater exit	Feed water			
Kuznetsk coal Г or Д	550	575	30	600	600	302	49.0	93.6	46.3
Lignite. Kansk-Achinsk Region	550	575	30	600	600	293	49.0	93.0	46.0

Supercritical 550 MW boiler (Kuznetsk coal)







NO_x emissions from 300÷800 MW units

Coal	Furnace specific	NO_x emissions, mg/m^3
Lignite	Staged combustion, tangential furnace, dust pre-heating	200÷300
Anthracite	Staged combustion, low NOx burners	350÷450
Poor coal	Re-burning with natural gas, dust pre-heating burners, SNCR	550÷700 250÷350

Sulfur suppression technology for 300-500 MW units

Technology	Reduced sulfur in fuel, % kg/MJ	Power, MW	Reduced investments* rub./KW	Capturing price for 1 ton of SO_2, rub/t
Wet limestone	0.15	300 500	2900 2600	4600 3150
Ammonia-sulphate	0.15	300 500	1800 1600	2800 1900
Simplified wet-dry	0.03	300 500	75** 70**	3800 2500

* Calculated for prices as of Jan. 1, 1999
** Agent preparation not included.

Basic performance of the ЭГСЭ type ESP

- Exit dust emissions ≤ 30 mg/m^3;
- Electrode height ≤18 м;
- Collection area within the given housing 35-50 % larger than in commercial ESP;
- Active zone residence time 35-50 % longer than in commercial ESP;
- 20 % smaller metal consumption per a collection area unit.

Capacity range of typical coal fired supercritical steam units

	Capacity range					
Capacity, MWe	270–350				550–700	800–1000
Coal	Kuznetsk K-A Ekibastuz		Low-quality		Kuznetsk K-A Ekibastuz	
Combustion technology	Pulverized		CFB		Pulverized	
Steam parameters						
Pressure, MPa	28–30				30	
Temperature, °C	585–600				585–600	
Pre-heater, °C	585–620				600–620	
Turbine type	Cond.	CHP	Cond.	CHP		
Condensing mode efficiency, %	43–45	42–44	41–42	40–41	44–46	

Advantages of CFB technology

- Efficient combustion of low calorific, high ash and low volatile fuels without lighting-up;
- Combustion of different quality fuels in the same boiler;
- Deep unloading and quick hot re-start,
- High efficiency of sulfur oxide capture (combustion is at t=850–900 ^{o}C),
- Low NO_x emissions,
- NO DeSOx and DeNOx systems,
- Simple fuel preparation.

Design performance of CFB boilers for 300 – 330 MW units

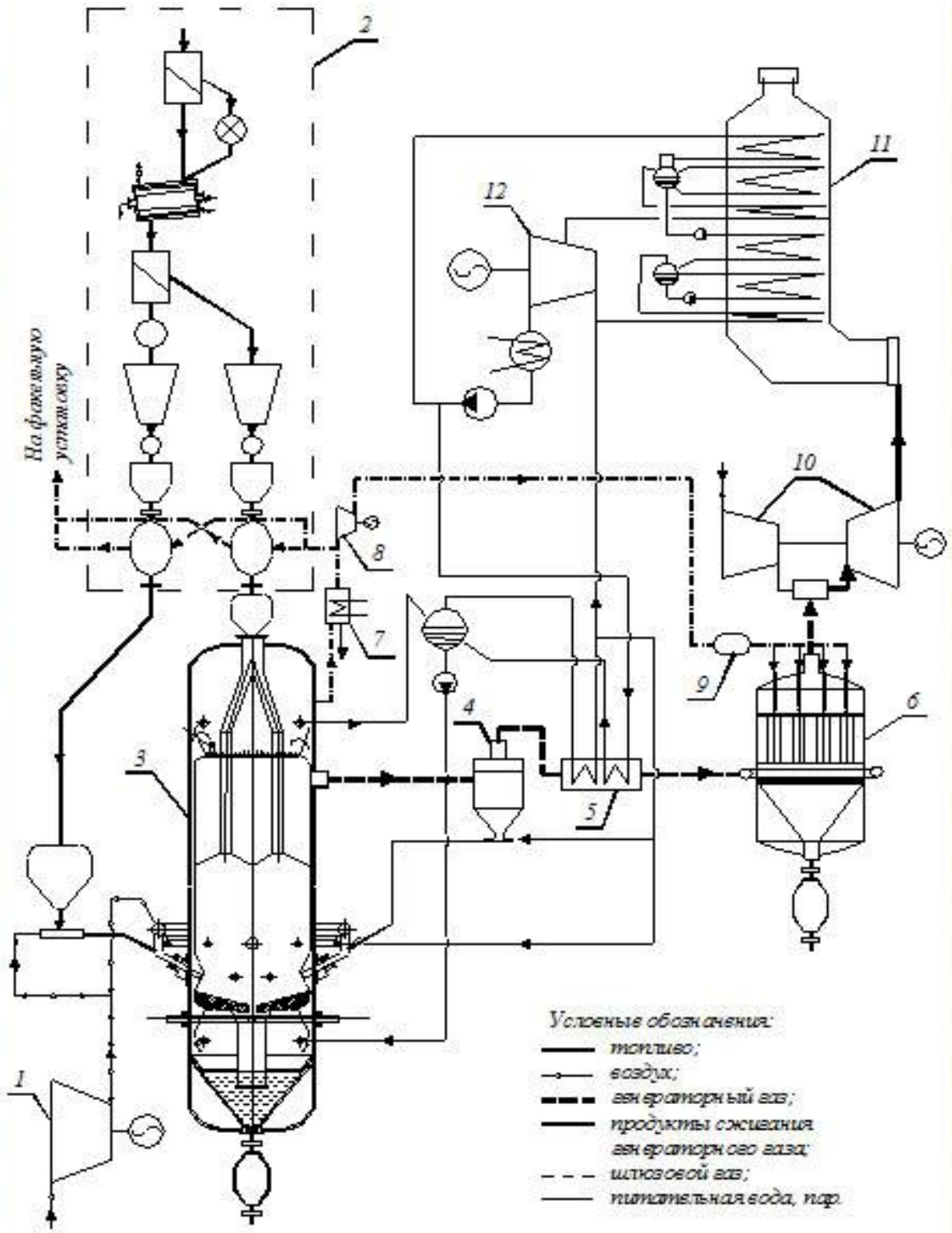
	Ryazan' CHP		Novo-cherkassk CHP	Kuznetsk poor coal firing unit	Troitsk CHP
	Berezovo	1/2 Berezovo + 1/2 Moscow	Culm		Ekibastuz
Fuel consumption, Bp, t/hr	176	227	120	171	118
Boiler efficiency η, %	92,0	91,0	91,0	92,0	92,1
Limestone consumption, t/hr	-	9,0	13,2	6,2	2,0
SO_2 emissions at α=1.4, mg/m^3	<100	<300	<400	<300	<200
Dust content before ESP, g/nm^3	5	23	26	40	20

Flue gas temperature 130 °C.

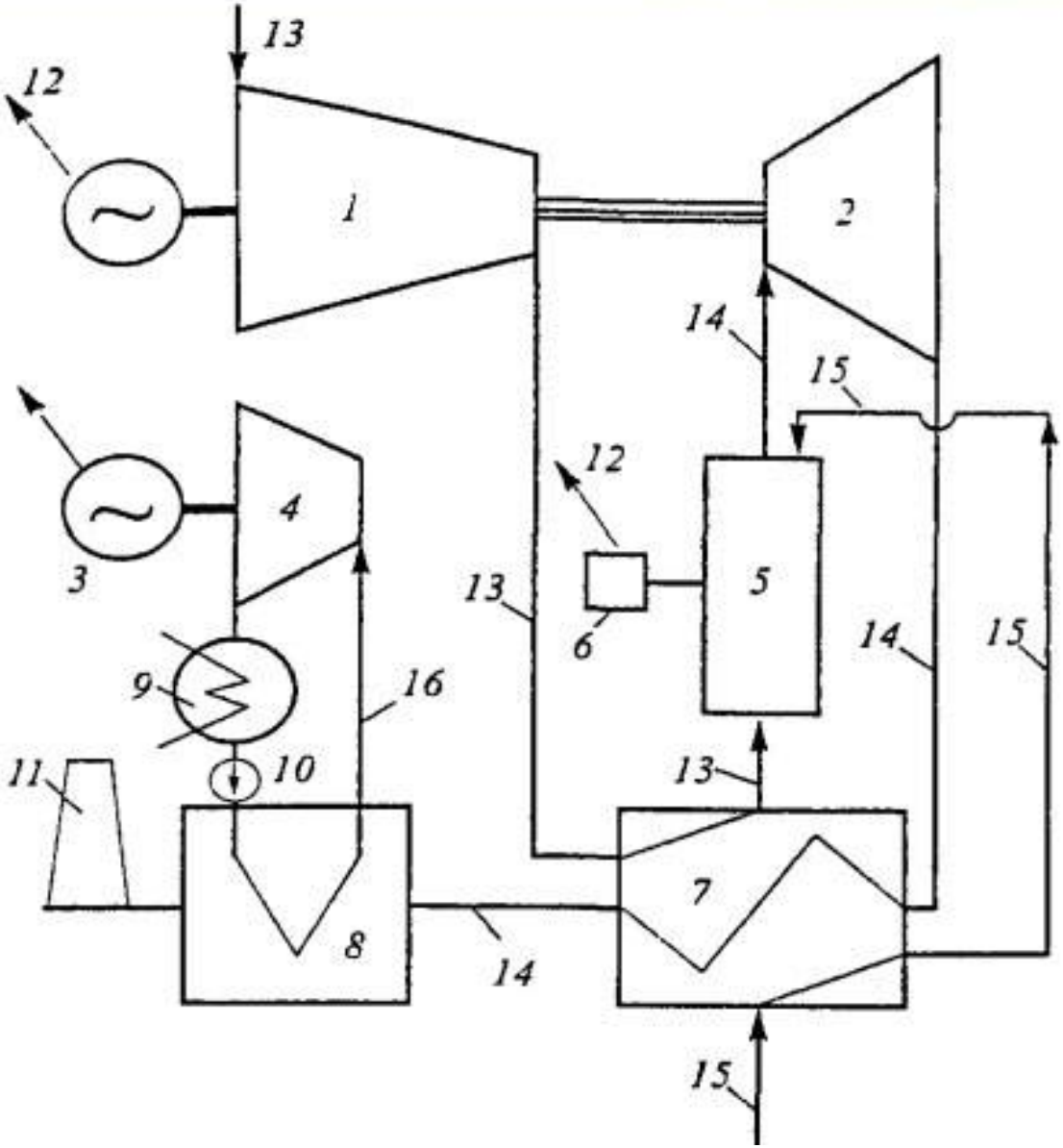
NOx emissions (at α=1.4), mg/nm^3 $\leq$ 300

250 MW Combined Cycle plant with gasification of Berezovo coal

1 – air supply compressor;
2 – fuel preparation and sluicing;
3 – gas producer;
4 – lined cyclone;
5 – convective heat exchanger;
6 – metal fabric filter;
7 – sluicing gas cooler;
8 - supercharger;
9 –gas receiver;
10 – Gas Turbine;
11 – heat recovery boiler;
12 – steam turbine



Experimental Hybrid unit at VTI Cogeneration Plant using fuel cells



1 – Compressor;
2 – Turbine;
3 – Generator;
4 – Steam turbine;
5 – Fuel cells;
6 – Inverter;
7 – Heat exchanger;
8 – Heat-recovery boiler;
9 – Condenser;
10 – Pump;
11 – Chimney;
12 – Power to network;
13 – Air;
14 – Fuel oxidation products;
15 – Cleaned natural gas;
16 – Steam

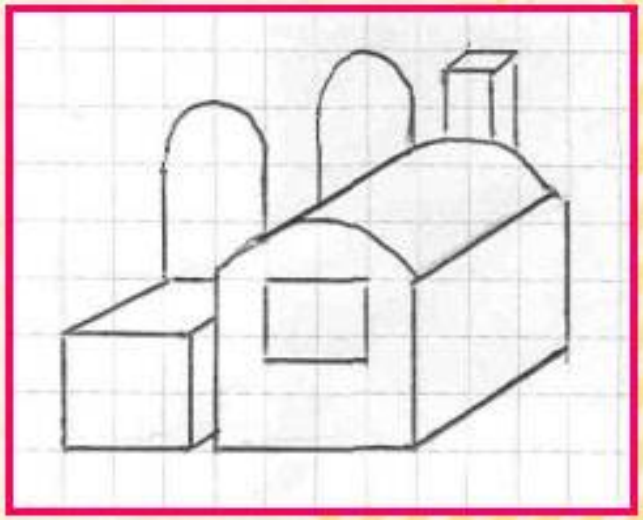
Production of Combined Heat and Power remarkably reduces CO_2 emissions. This technology is widely used in Russia and the respective reduction of fuel consumption is assumed as ~20 mil. ton of standard fuel per year.

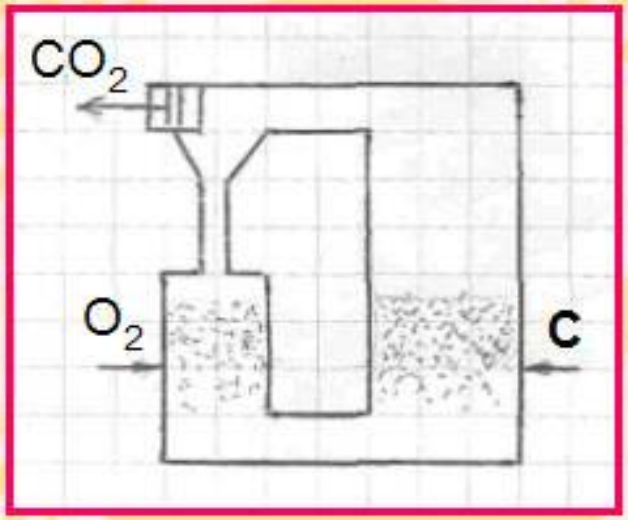
Improvement of coal fired units efficiency can reduce CO_2 emissions more than by 20%.

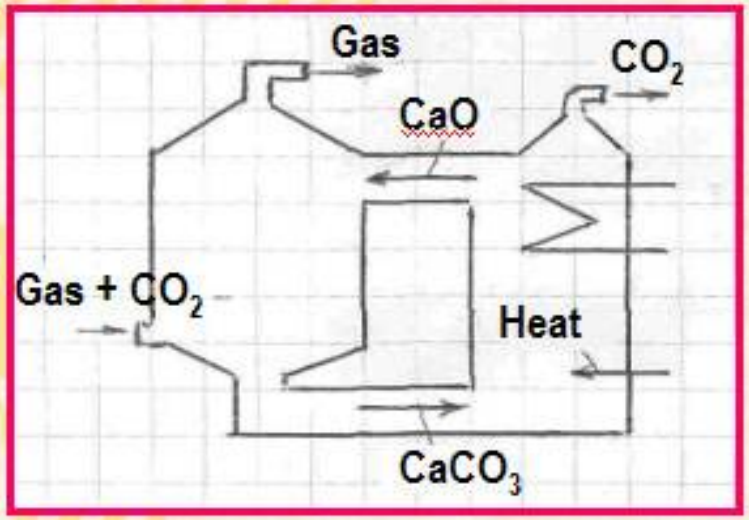
The principal technology is CO_2 capture and storage based on:

- **Combined Cycle with coal gasification, reforming $CO+H_2O$ into H_2+CO_2 and remove of CO_2 from the unit;**
- **CO_2 capture from steam units flue gas;**
- **Fuel combustion in pure oxygen with CO_2 addition.**

Development of CO_2 capture technology







GT with CO_2 capturing before combustion

$2MO_{n+1} + C \rightarrow 2MO_n + CO_2$

$2MOn + O_2 \rightarrow 2MO_{n+1}$

$CO_2 + CaO \rightarrow CaCO_3$

$CaCO_3 \rightarrow CaO + CO_2$

Conclusions:

- **Wider use of coal requires:**

  - Development and commissioning of 600-700 MW supercritical coal fired units,

  - 300 MW CFB units,

  - Efficient cleaning of flue gases from ash particles, NOx and SO_2.

- **There is a need of investigations, technology and equipments development for advanced coal firing technology: gasification, hybrid units with fuel cells, CO_2 capture and storage.**

Thank you for your attention

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