Combustion and the Air Pollution

Anthropogenic activities discharge various pollutants into the atmosphere, and especially, industrial activities combining the combustion have the possibilities to be the causes of the air pollution.

1. Fuel Types

Fuels for the industry are categorized to **gaseous-fuel**, **liquid-fuel**, and **solid-fuel**.

a. Gaseous Fuels

Gaseous Fuels for the industry, especially for the **power generation** are:

- **Natural gas**: produced from the gas field using gas wells, from the oil field associating the oil production, and from the coal field. Main element of the natural gas is **methane**, but contains **little sulfur**. The LNG (Liquefied Natural Gas) is liquefied gas at the temperature of -162 C degree. Because the LNG volume becomes 1/600 of former gas state, it is convenient to transportation.
- **LPG** (Liquefied Petroleum Gas) : produced in the process of oil refining. The LPG is the one of butane-, butylene-, propane-, propylene-gas, or mixture of these gases, but contains **little sulfur**. The LPG can be liquefied easily and used for home use, for fuel of the car, etc.
- **Coal gas**: produced by the dry distillation of coal in the process of coke. In recent years, the coal gasification is aimed to produce high-calorie gas instead of LNG, and partial oxidation process was developed that is intended to apply for the **IGCC** (Integrated Gasification Combined Cycle) power generation. The main components of gases for IGCC are **H_2** and **CO**.

b. Liquid- Fuels

Liquid- Fuels for the industry are heavy-oil, light-oil, kerosene, and naphta (coarth gasoline). These fuels are produced from the **crude oil** by the distillation process. The crude oil includes sulfur (Arabian: 0.8~2.7 %, Southeastern: 0.1~0.2 %), and sometimes includes less amount of sulfur than in the heavy-oil enough for the direct combustion in the thermal power plant.

- **heavy oil**: used for diesel engine and thermal power plant, and classified **A, B, and C** with the viscosity. Each oil includes the sulfur as: 1.0 %(A), 2.0 %(B), and 2.7 %(C). The A-heavy-oil is used for the small diesel engine or for the burner burning. C-heavy-oil is required the preheating for the combustion and used for the large scale diesel engines and boilers.
- light oil: used for the diesel fuel.
- kerosene: used for the home heater and small engines.
- naphta: raw materials of the gasoline.

NOTE 1: The price of the crude oil was under the control of the oil major, however, after the "oil shock" in 1973 and 1979, the price was affected by the contraction between the oil production countries, OPEC, and users, and was jumped up. Following the high-priced oil, oil consuming countries policies were changed to the aiming for "energy saving" and for the development of "alternative energy," and to the aiming the development of new oil field such as the North sea oil field. The non-OPEC countries oil production introduced the relaxation of oil demand and supply. The relaxation of demand and supply relation brought up the "Spot transactions" in the oil market. In 1986, after the change of policy of Saudi Arabia that had the oil price decide by the market, oil price fell down suddenly. Then, the OPEC countries had started reducing the oil production.

NOTE 2: OPEC (Organization of Petroleum Exporting Countries) involving, Saudi Arabia, Venezuela, Iran, UAE, Kuwait, Nigeria, Libya, Indonesia, Algeria, Qatar.

c. Solid- Fuels (coal)

Solid- Fuels for the industry are mainly coal and coal induced fuel (coak). The coal composing atoms are C, H, O, and S. In general (imported to Japan), the coal is composed of water (called as total water: 10 %), volatiles (30 %), fixed carbon (50 %), ash content (10~15 %), and sulfate (less than 1 %). The ratio between the fixed carbon and the volatiles is called **fuel ratio**.

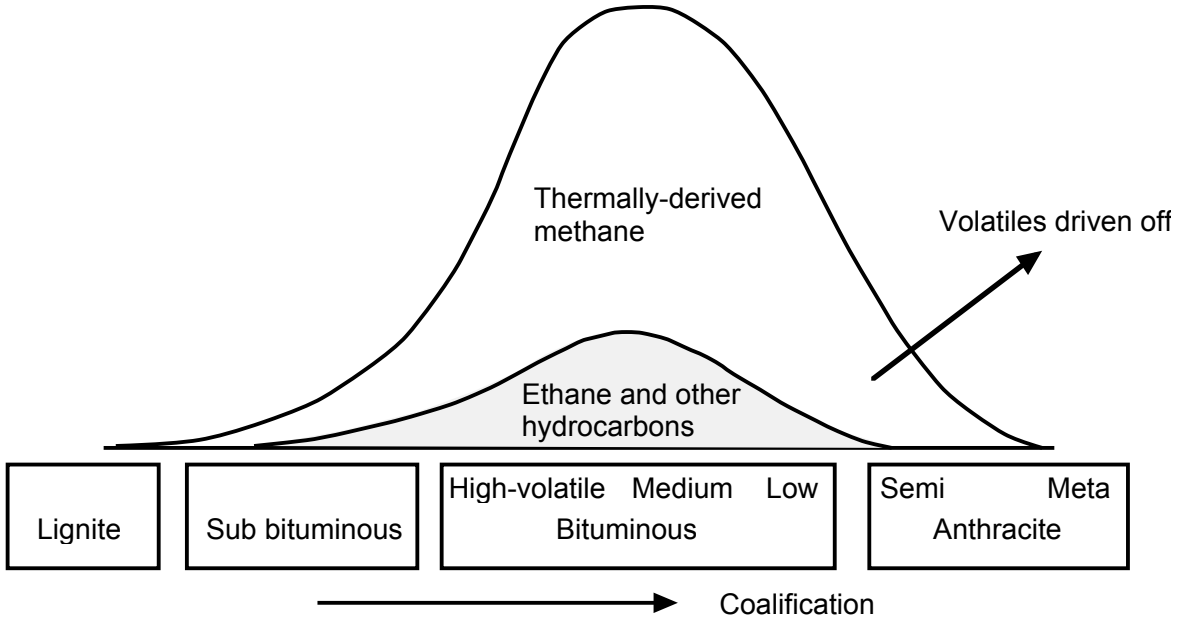
The coal fuels are classified in usage as:

- coking coal: used for coak production and coal gasification: bituminous coal, anthracite
- general coal: used for the boilers and thermal power generation: lignite, brown coal, bituminous coal

The coals are classified also by the coalification level as the following table,

	coalification (C %)	fuel ratio
anthracite	90 ~	> 4
bituminous coal	78 ~ 90	1 ~ 4
brown coal	70 ~78	~ 1
lignite	~70	

d. coal and coal bed methane



Coalification and the production of gases

Peat lignite bituminous anthracite

http://www.scsc.k12.ar.us/2000backeast/Trip/Members/ReynoldsJ/Coal/CoalQuestions.htm4

2. Combustion and Air

- **Theoretical air requirement** : Minimum amount of the air to burn the fuel. For example, the complete combustion of methane is represented as,
  $CH_4 + 2O_2 = CO_2 + 2H_2O$.
  The equation shows the required oxygen for the 1 m^3N of methane is 2 m^3N. Because the oxygen ratio in the atmosphere is 21 %, the theoretical air requirement become 2/0.21= 9.5 m^3N for the 1 m^3N of methane combustion.

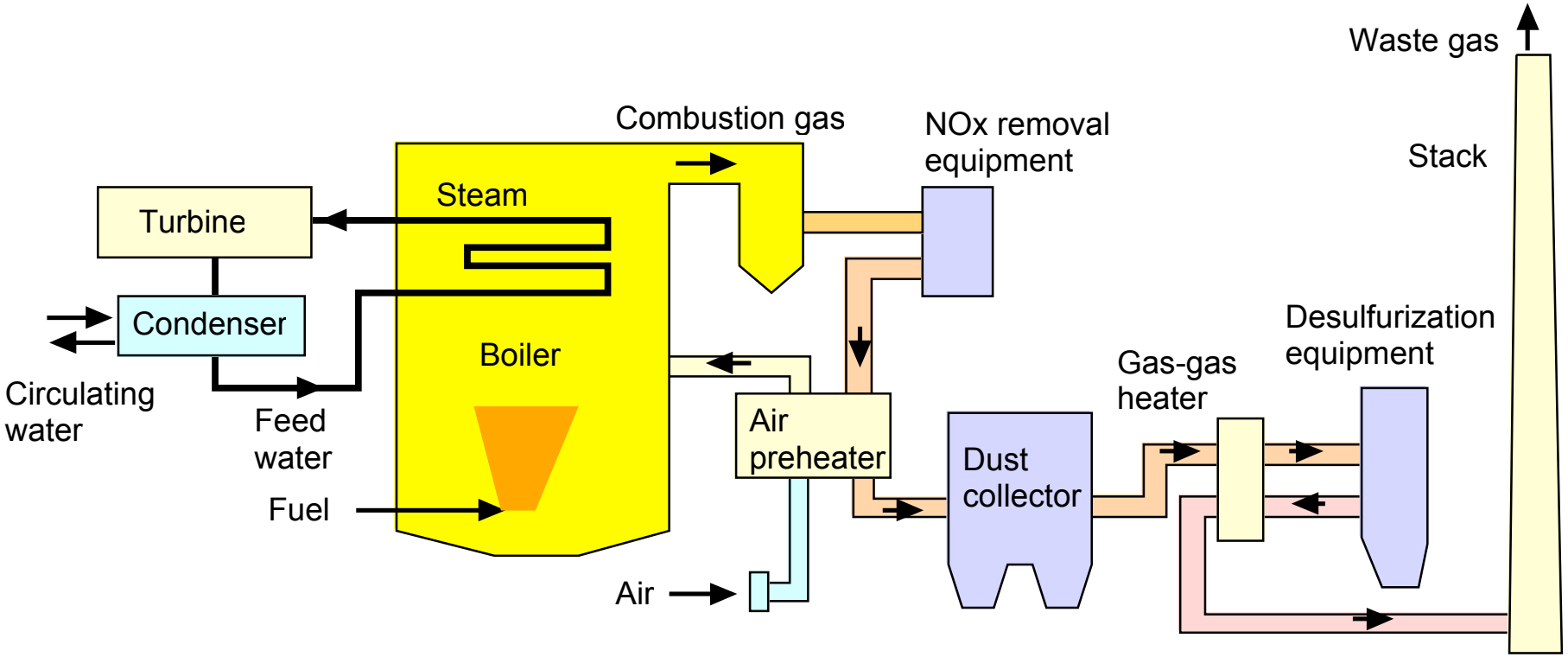
- **Excess air ratio** : Generally, the perfect combustion does not occur by the theoretically amount of air, then, the ratio between the really required air and "theoretical air requirement" is defined as "excess air ratio." For the heavy oil, the excess air ratio is 1.1 ~ 1.3.

NOTE: 1 m^3N (1 normal cubic meter : 1 cubic meter of the gas at the state of 1 atm. and 0 degrees Celsius)

3. Thermal Power Plant and Air Pollutants

a. Coal/ oil combustion power plant

Following is the combustion and waste gas control system schematics of the thermal power plant. In the case of coal combustion, coal is pulverized.



The **combustion gas** from the boiler includes **dust**, **sulfur oxides**, and **nitrogen oxides**. The nitrogen oxides produced in the boiler are:

- **Fuel NOx** :nitrogen in the fuel oxidized
- **Thermal NOx** : nitrogen in the air oxidized at the high temperature,

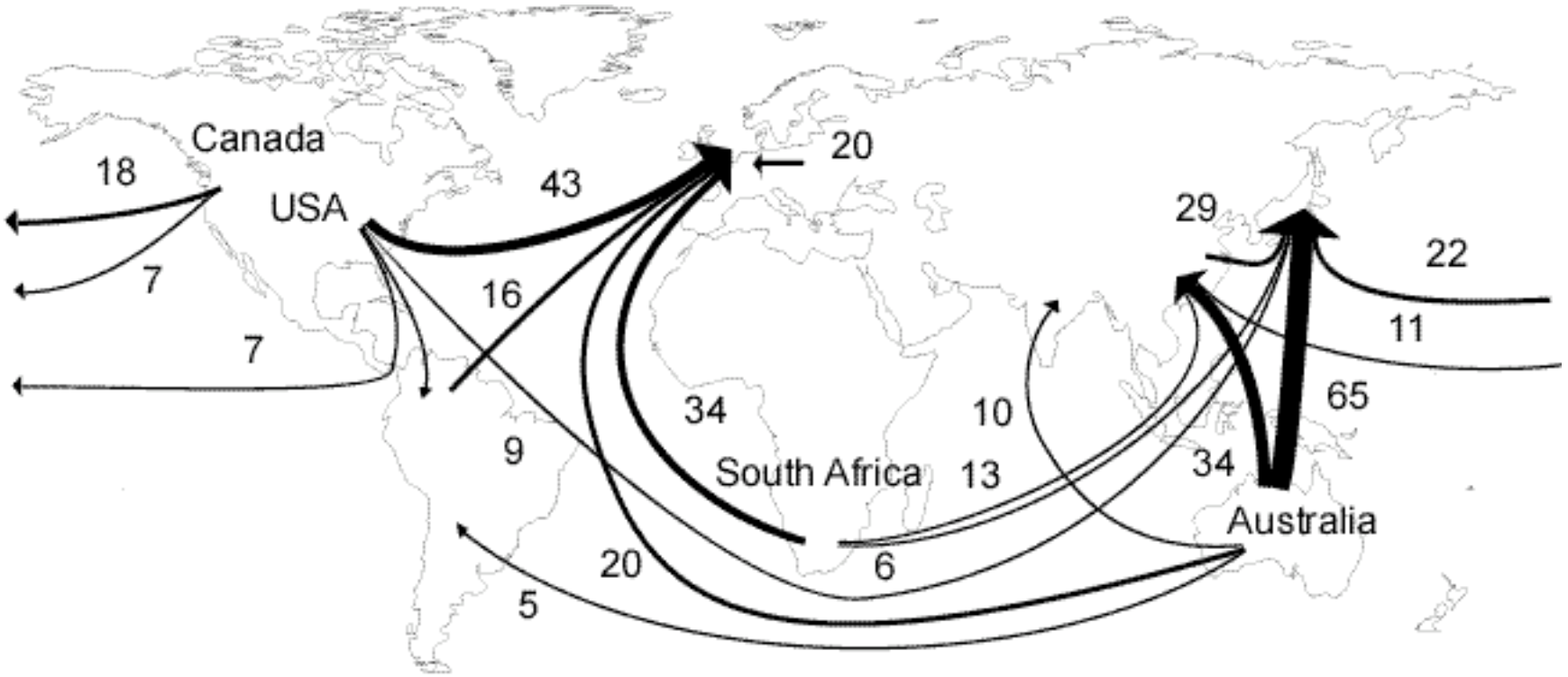
and the ratio of thermal NOx is:

- 10 ~ 20 % for the coal combustion boiler
- 30 ~ 40 % for the heavy-oil combustion boiler
- 100 % for the LNG combustion boiler.

The nitrogen oxides in the combustion gas from the boiler are composed of **NO** (95 %) and **NO_2** (5 %).
The characteristics of the boiler combustion gases are as follows,

		coal	heavy oil
	calorific value (kcal/kg)	6,000 ~ 7,000	10,500
Fuel characteristics	nitrogen (%)	1.0 ~ 2.0	0.1 ~ 0.3
	ash content (%)	10 ~ 25	< 0.1
	sulfur (%)	0.2 ~ 2.0	1 ~ 2
Combustion gas characteristics	**NOx** (ppm)	100 ~ 200 (O_2=6 %)	60 ~ 100 (O_2=4 %)
	dust (g/m^3N)	**10 ~ 25**	0.1 ~ 0.2
	SOx (ppm)	200 ~ 1,600	500 ~ 1500

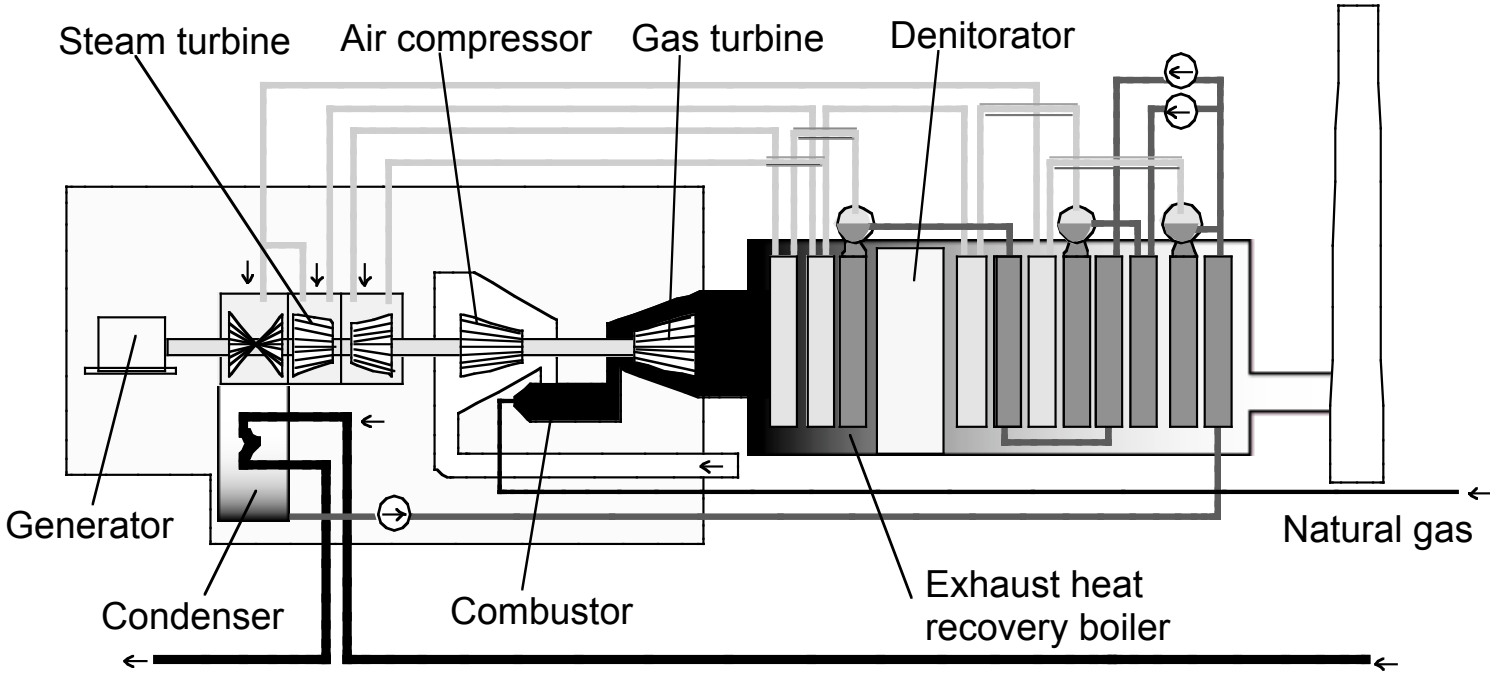
NOTE: The atmospheric pollutants of waste gases from the stack of the latest coal combustion plant are suppressed to: less than 10 mg/m^3N for the dust, less than 50 ppm for the sulfur oxides, and 45 ppm for the nitrogen oxides.



Coal trading flow in 1995 (M metric tonnes)

b. Natural gas combustion power plant

The natural gas combustioning thermal power plant adopting the **combined cycle** can achieve the **high thermal efficiency** comparing conventional coal/oil combustion power plant, and is not required desulfurizaition facilities.

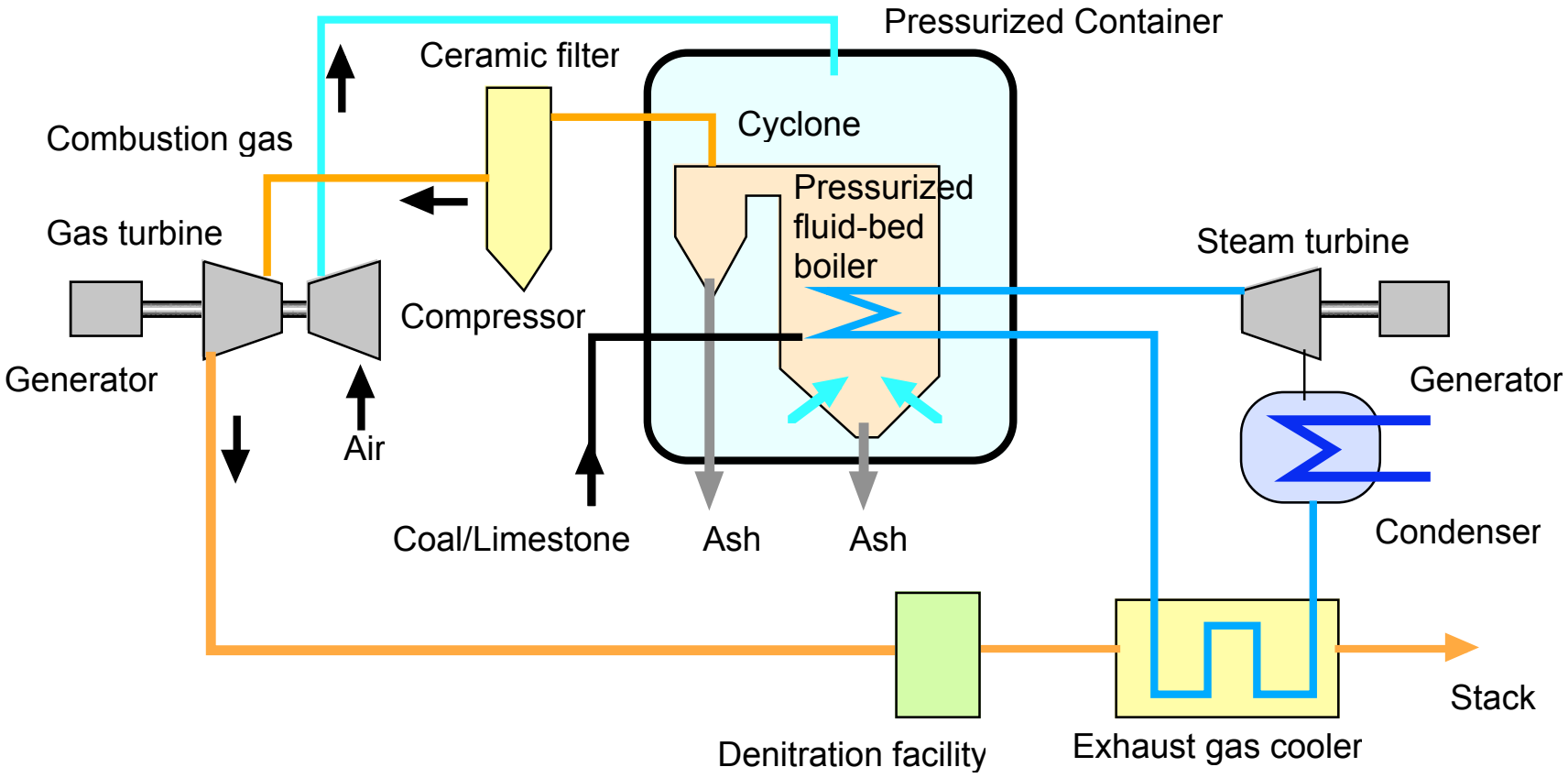


Energy flow diagram for advanced combined cycle power plant

NOTE: The latest plant, advanced combined cycle, achieved the efficiency of 46 % at 1100 ！ class combustion temperature.

c. Pressurized Fluid-bed Combustion Combined Cycle Generation System (PFBC)

PFBC power generation system can raise the **generation efficiency** (41~ 42 %), broadening the range of applicability to **different types of coal**.



Pressurized Fluid-bed Combustion Combined Cycle Generation System