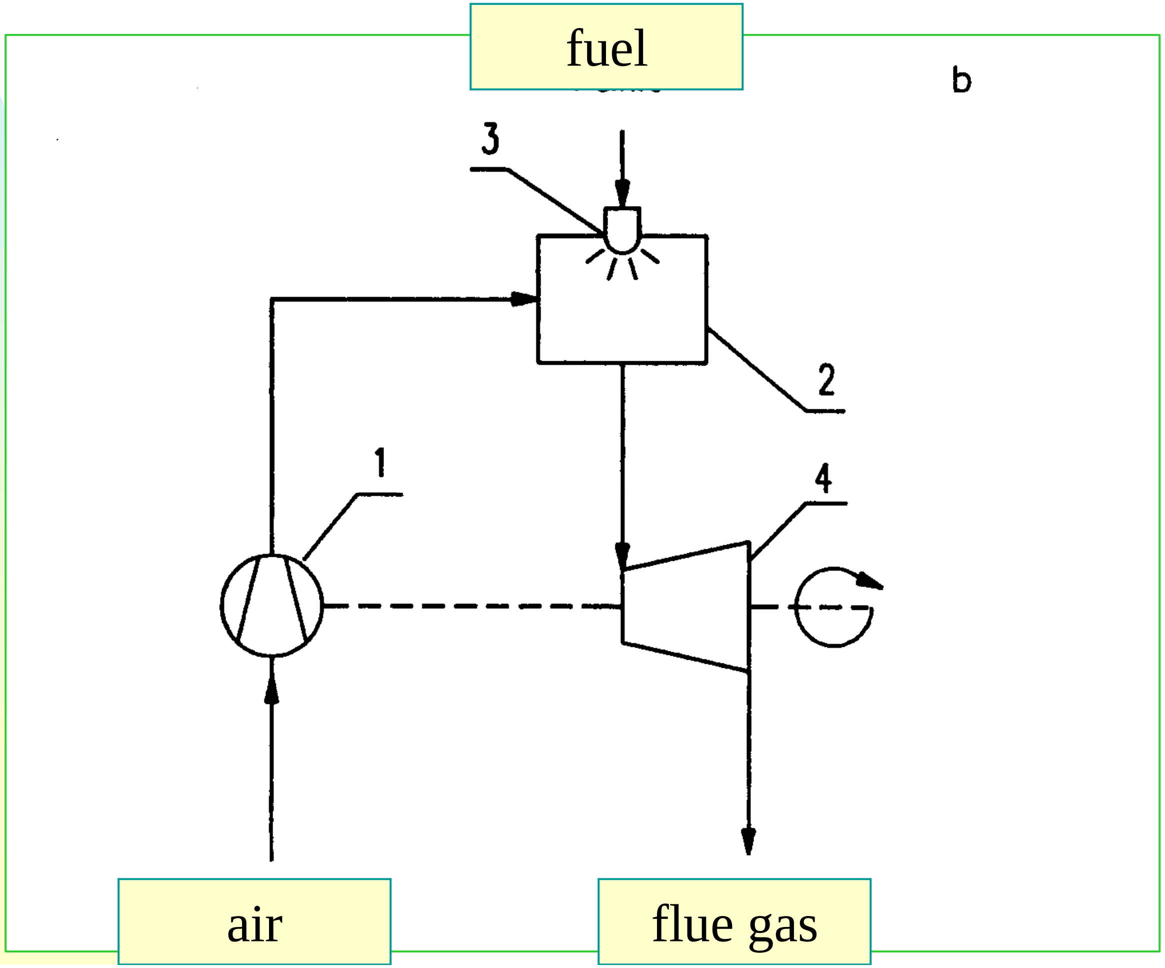
GAS TURBINE COMBUSTION

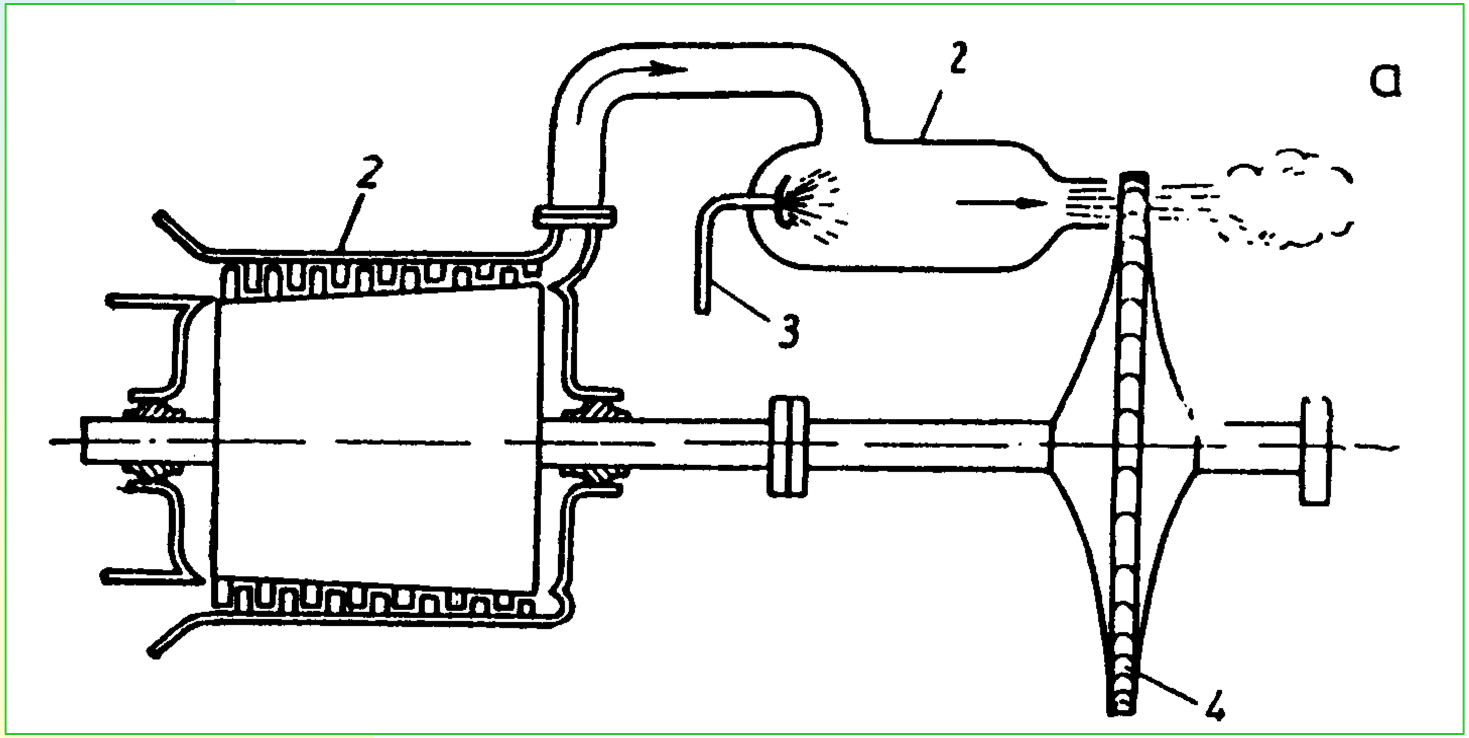
Scheme of gas turbine

Gas turbine (GT) is composed with turbine (4), compressor (1) and combustion chamber (2) (combustor)



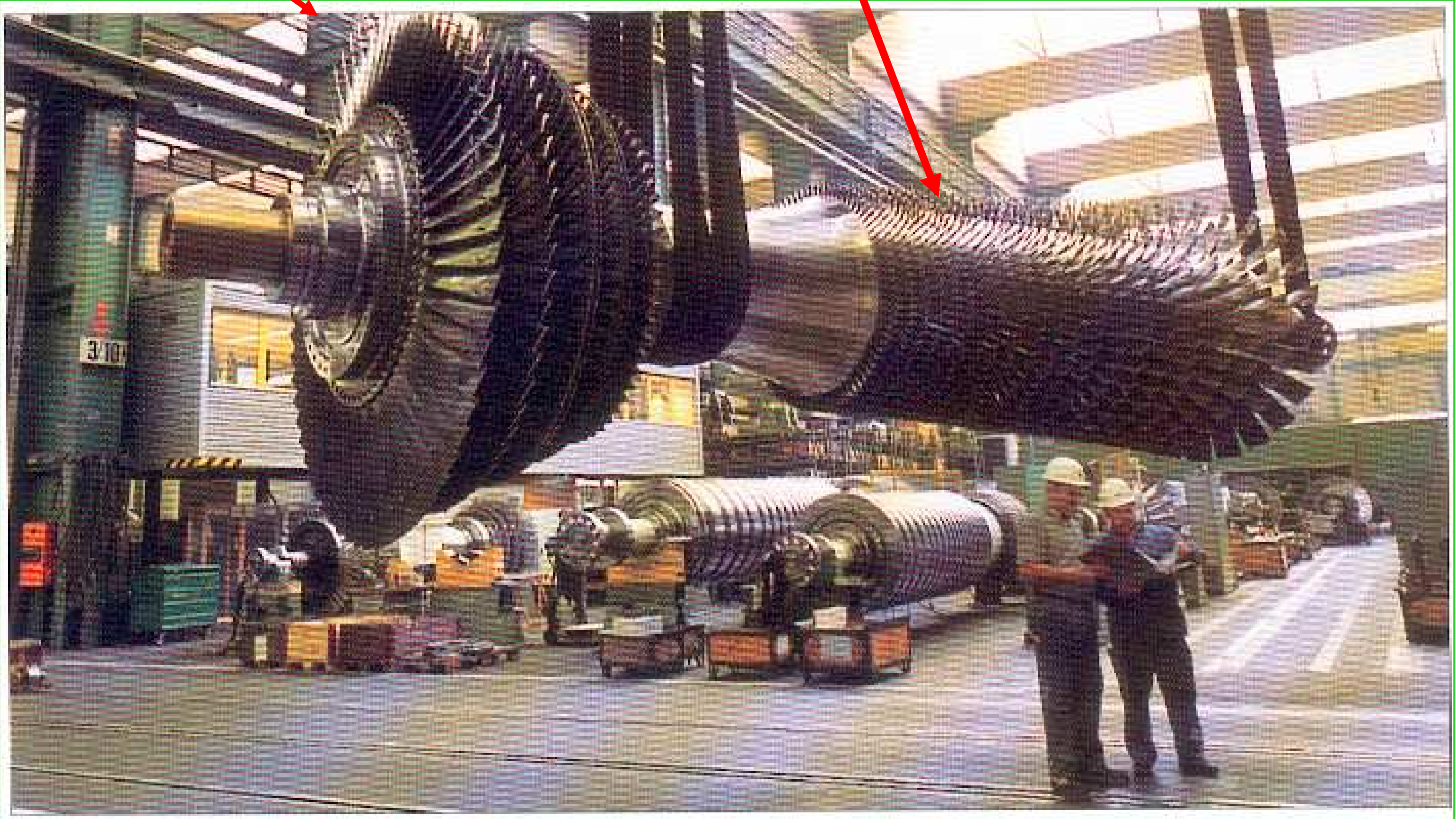
Principle of GT operation

Kinetic energy of flowing flue gas is converted into the turbine rotor, which shaft has a compressor supplying the combustor with air.



Gas turbines

Rotor of turbine and air compressor on a common shaft.



Rys. 5: Wirnik w fabryce 243 027

Types of GT combustors

There are two basic types of combustors:

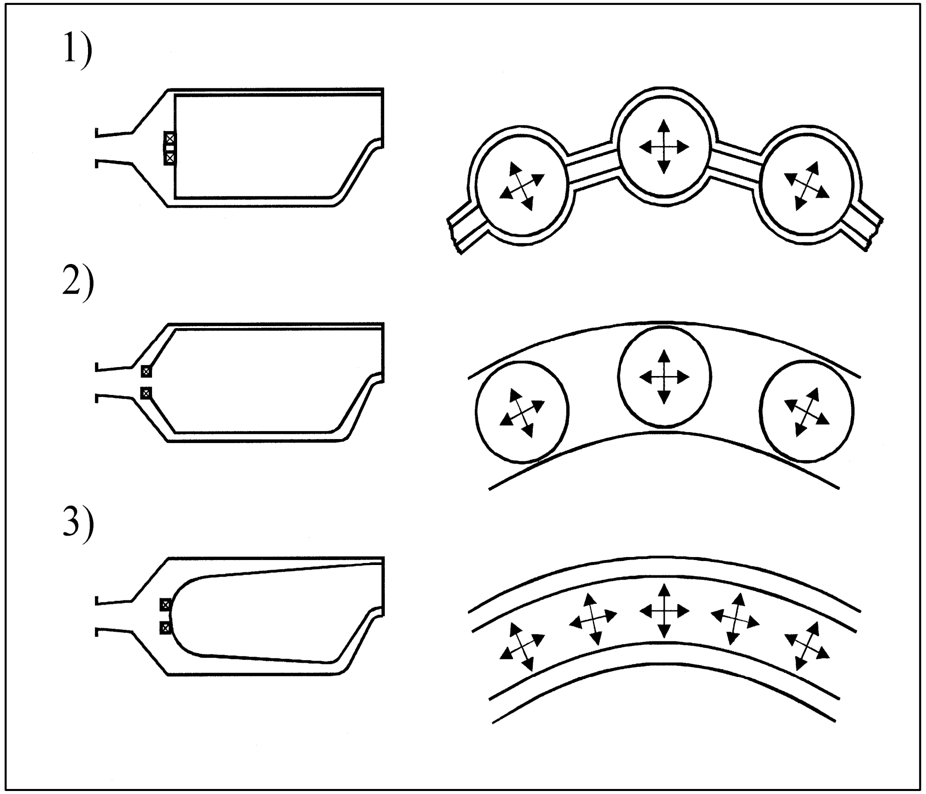
- **annular**
- **tubular.**

ANNULAR COMBUSTION CHAMBERS

Annular chambers

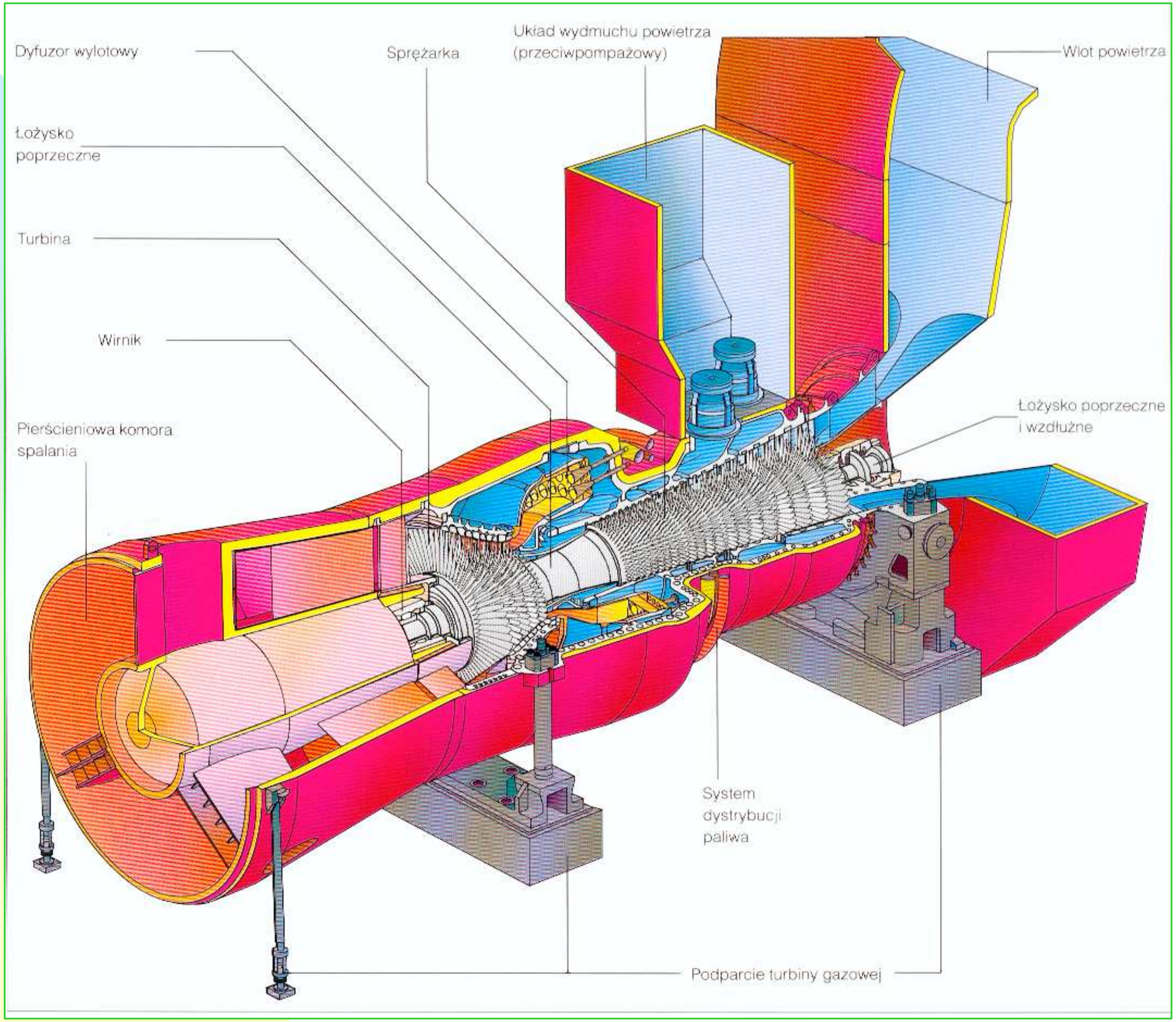
Gas turbines may have from 7 to 16 annular combustion chambers mounted concentrically. Each of combustor has his fuel supply and injection system.

There are three systems of annular combustors: **individual, sectional, annular**.



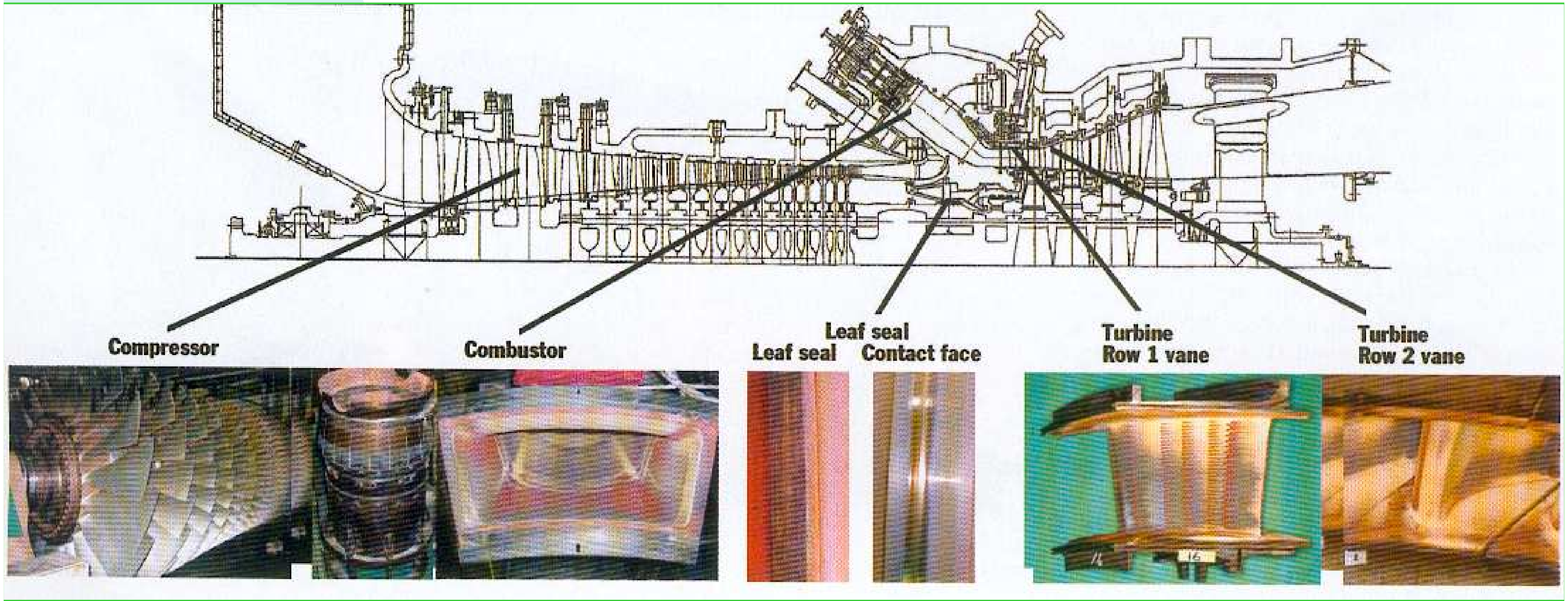
Types of combustors: 1 – individual, 2 – sectional, 3 – annular.

Example of GT with annular combustors

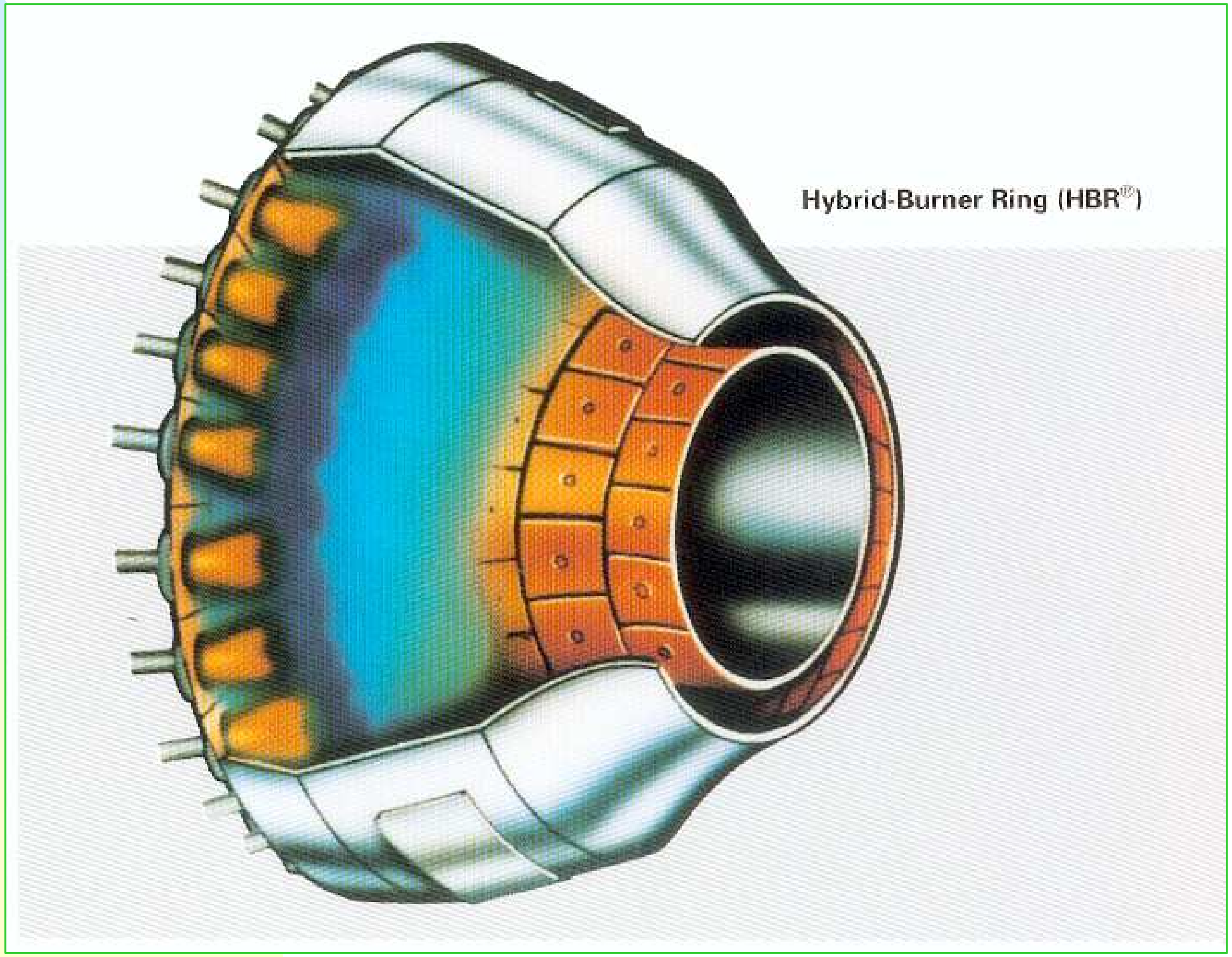


Scheme of GT with annular combustors

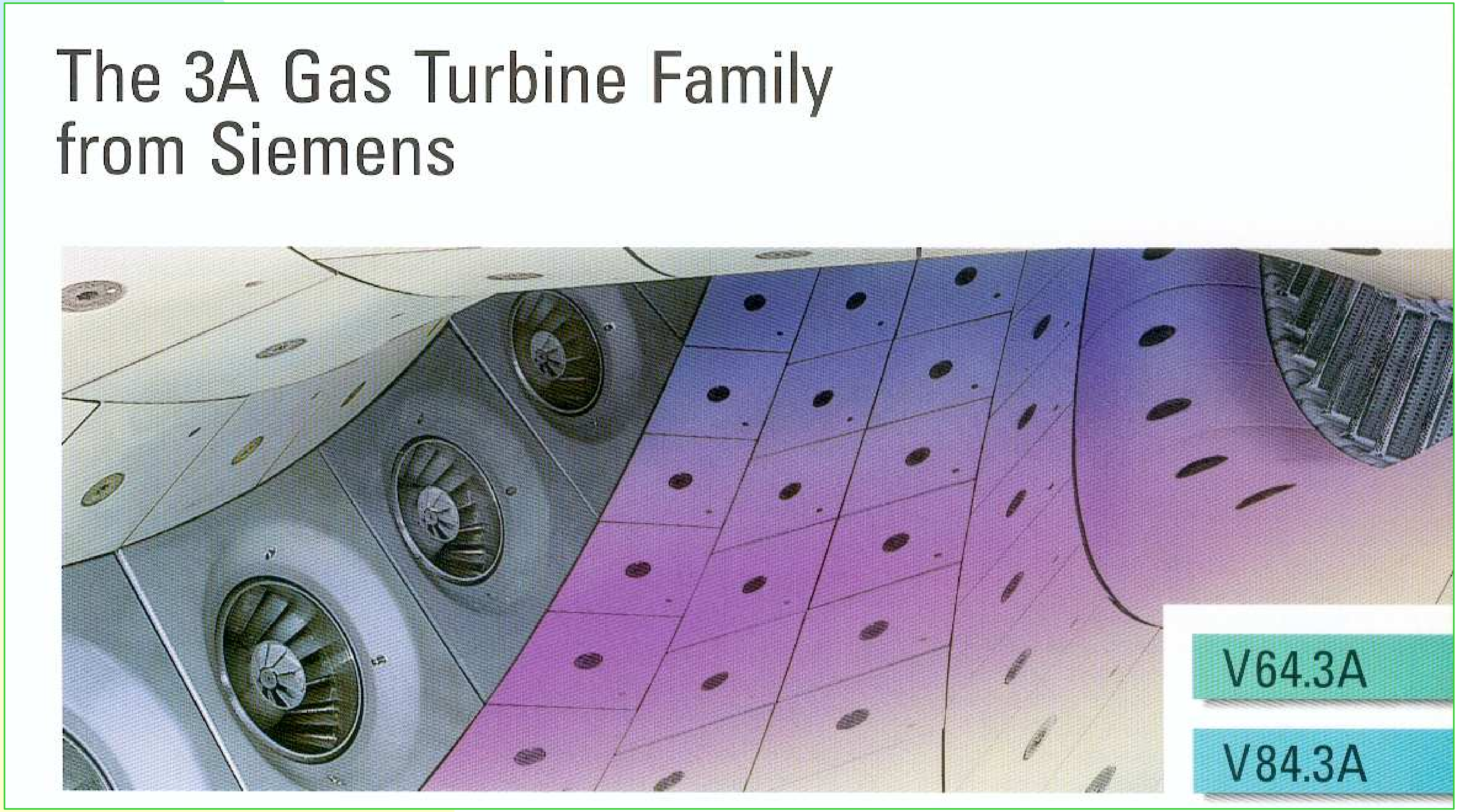
Temperature at the inlet of GT	1500 C
No. of combustors	16



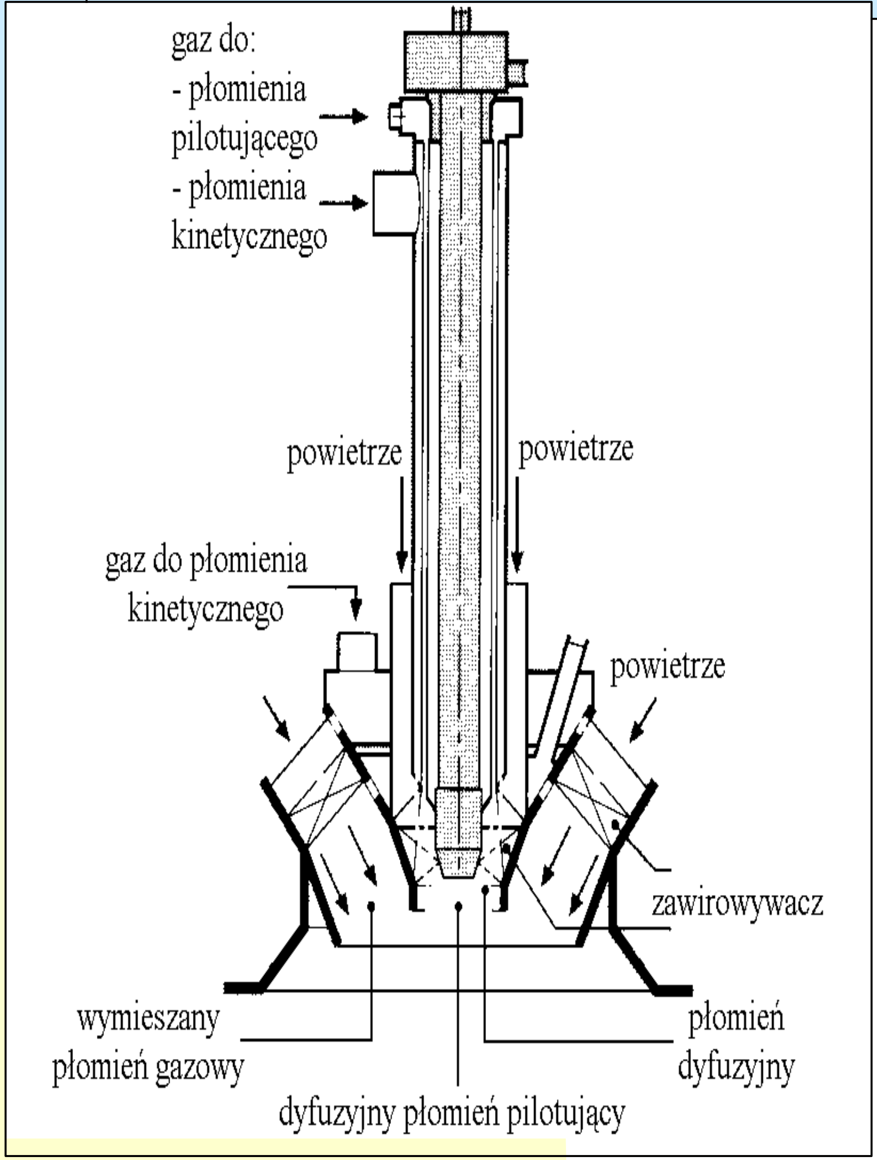
Annular combustion chambers of GT



Annular combustion chambers in GT

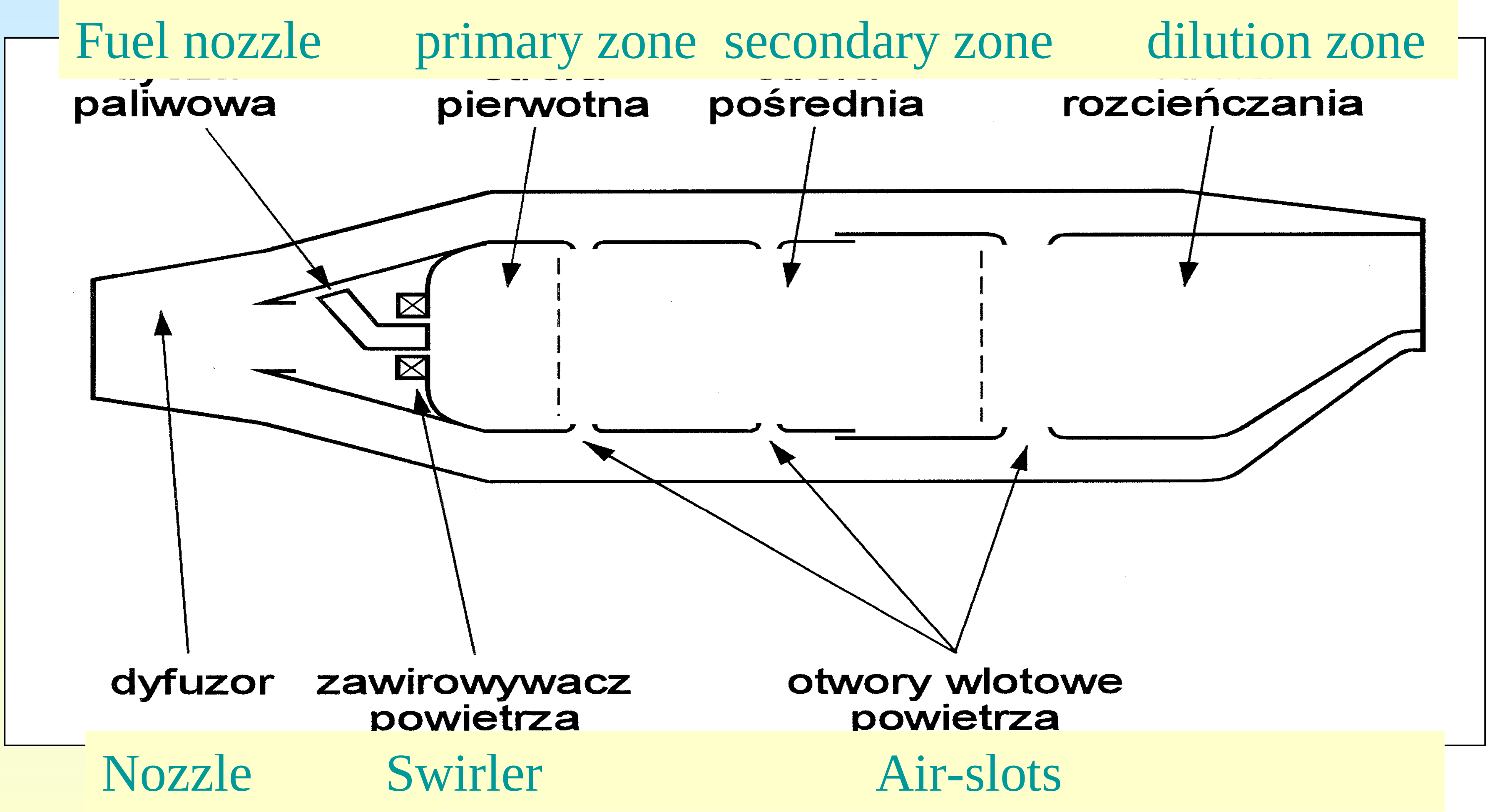


Combustor of annular system of combustion of GT



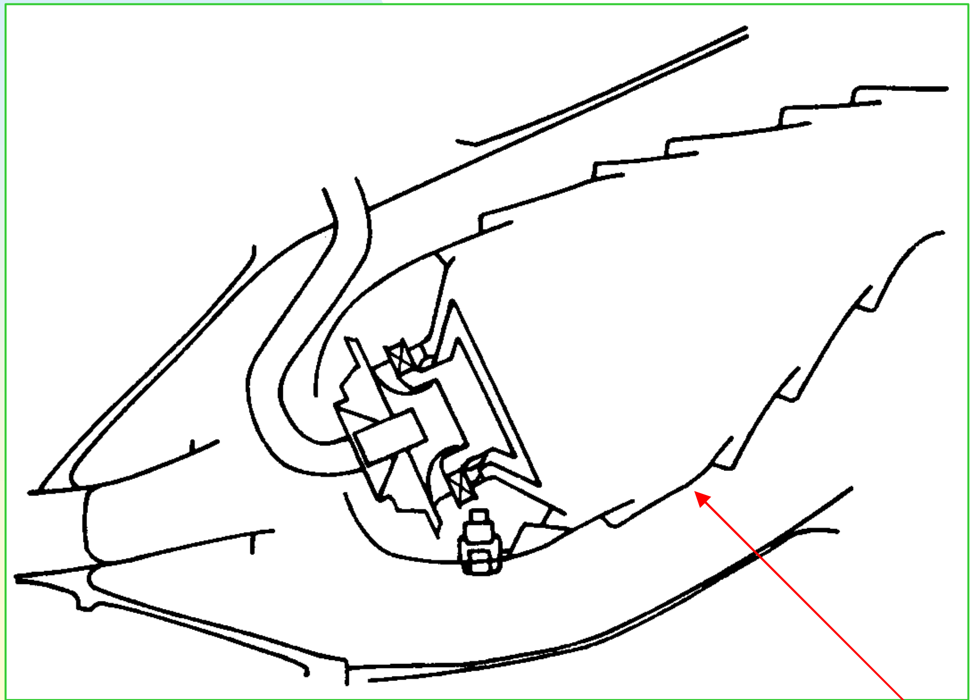
Low-NOx hybrid burner of V94.3 GT (Siemens)

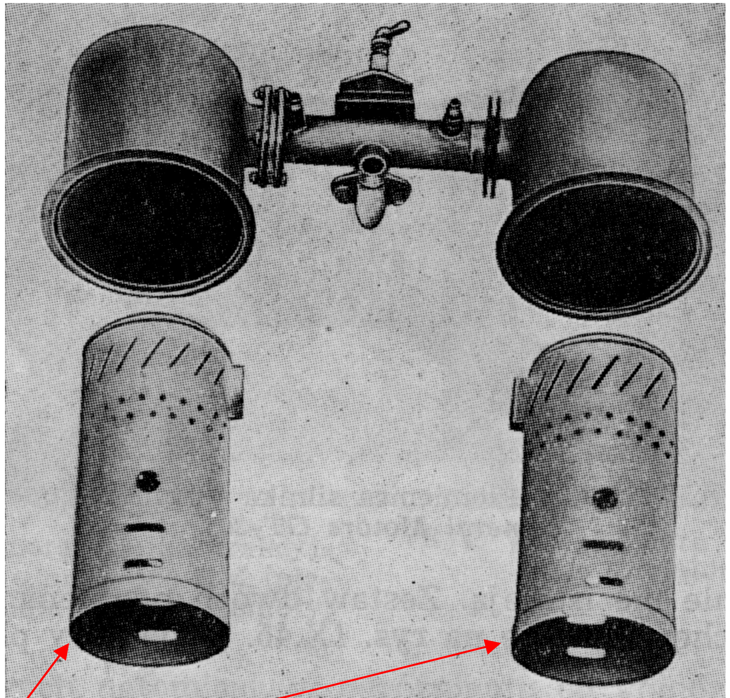
Scheme of GT combustion chamber



Single combustion chamber

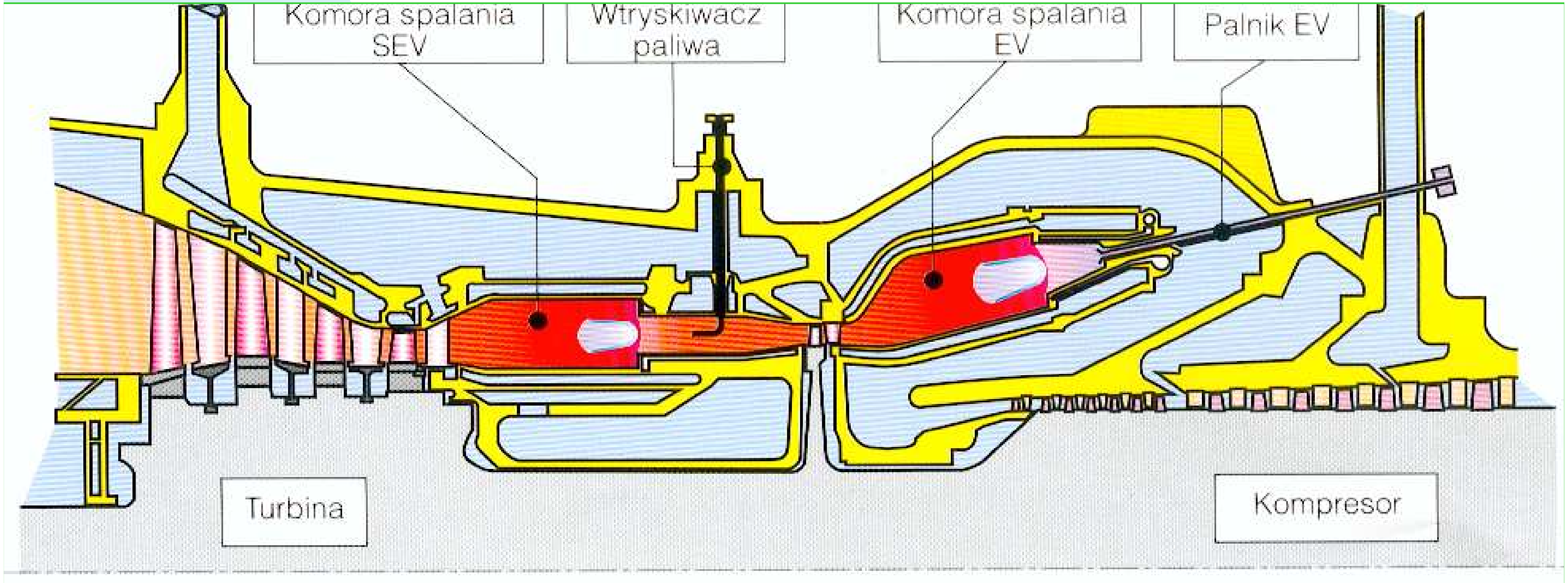
Furnace tubes (flame tubes)





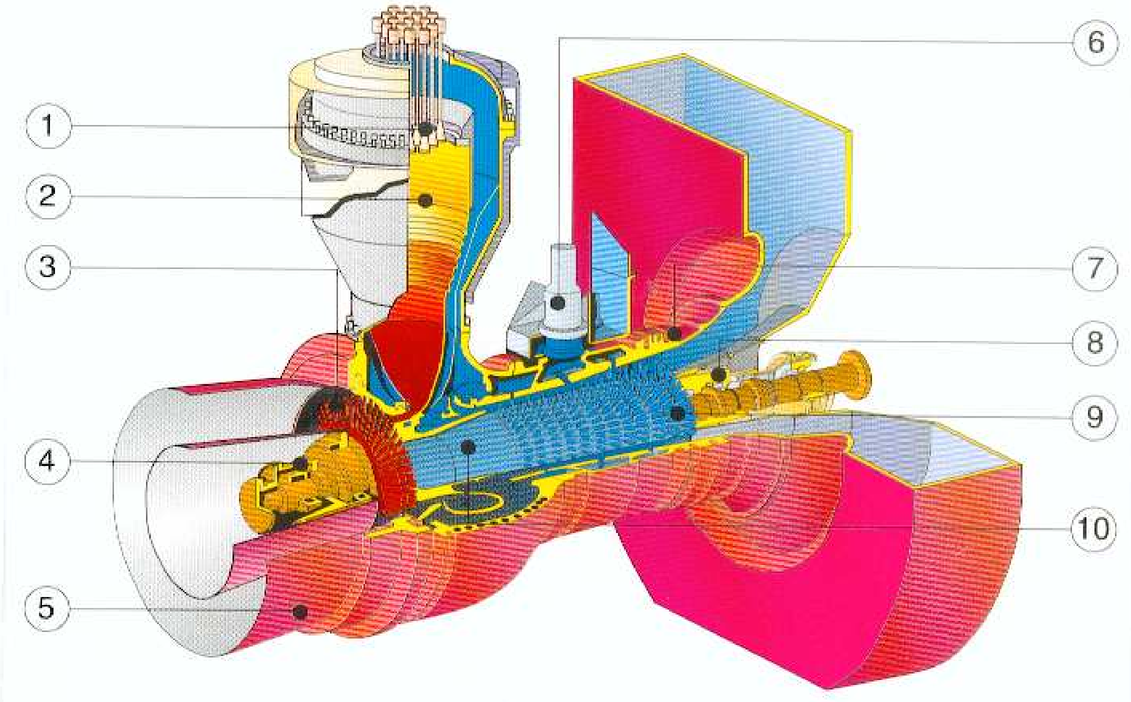
Flame tube

Sequential combustion system of GT26 (ABB)



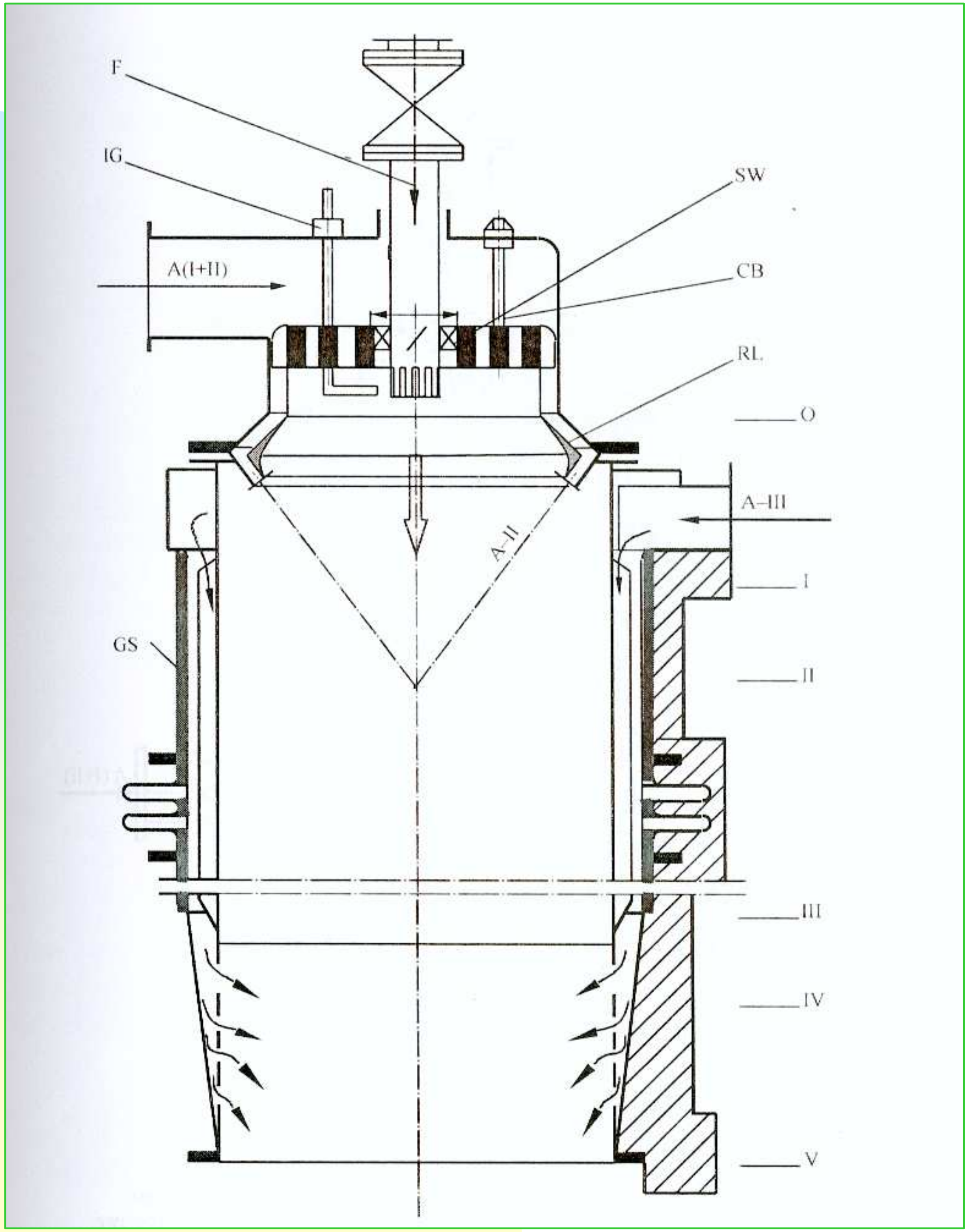
TUBULAR COMBUSTION CHAMBERS

TG with tubular combustor



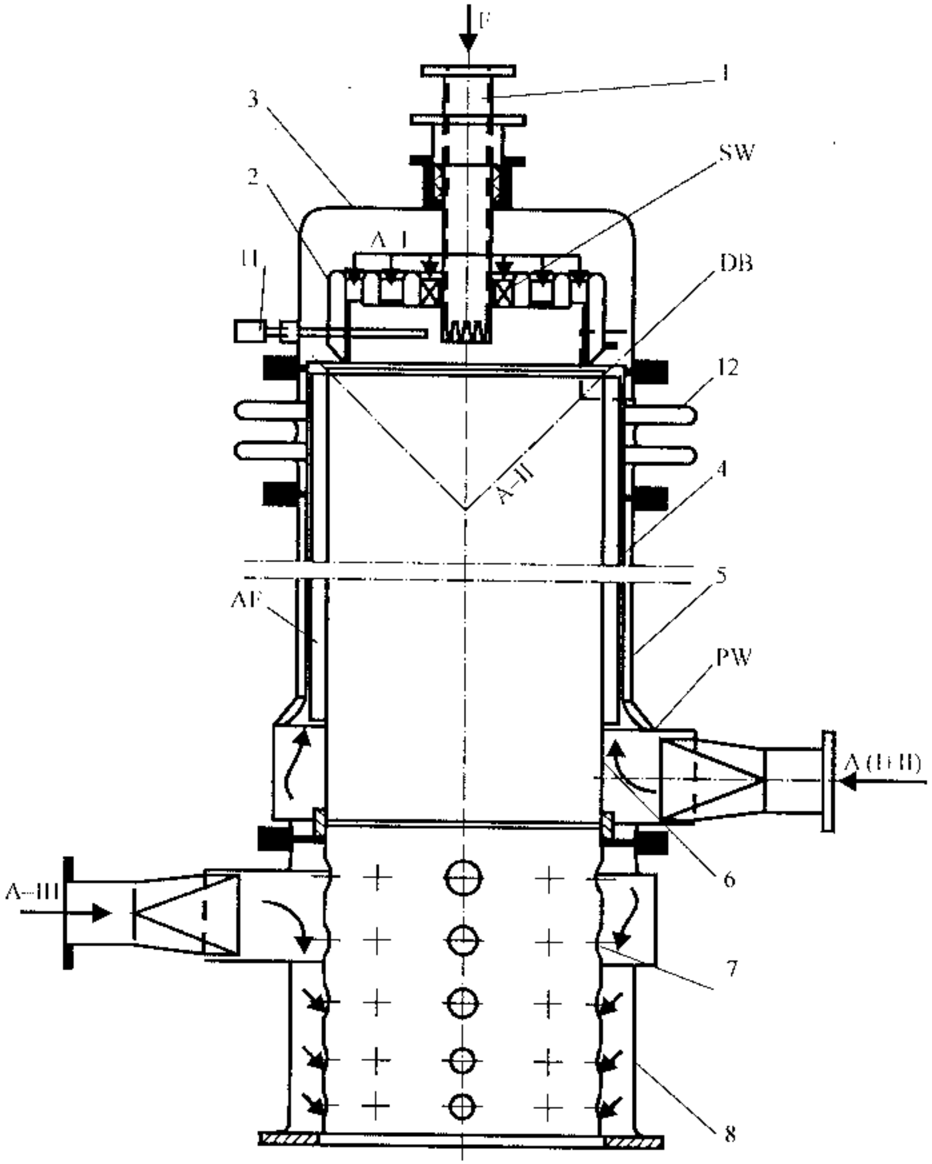
Turbina gazowa GT8C

1 – palniki, 2 – silos, 3 – wirnik turbiny, 4, 8 – łożyska, 5 – dyfuzor, 6 – zawór, 7 – sprężarka, 9 – wirnik sprężarki, 10 - wał



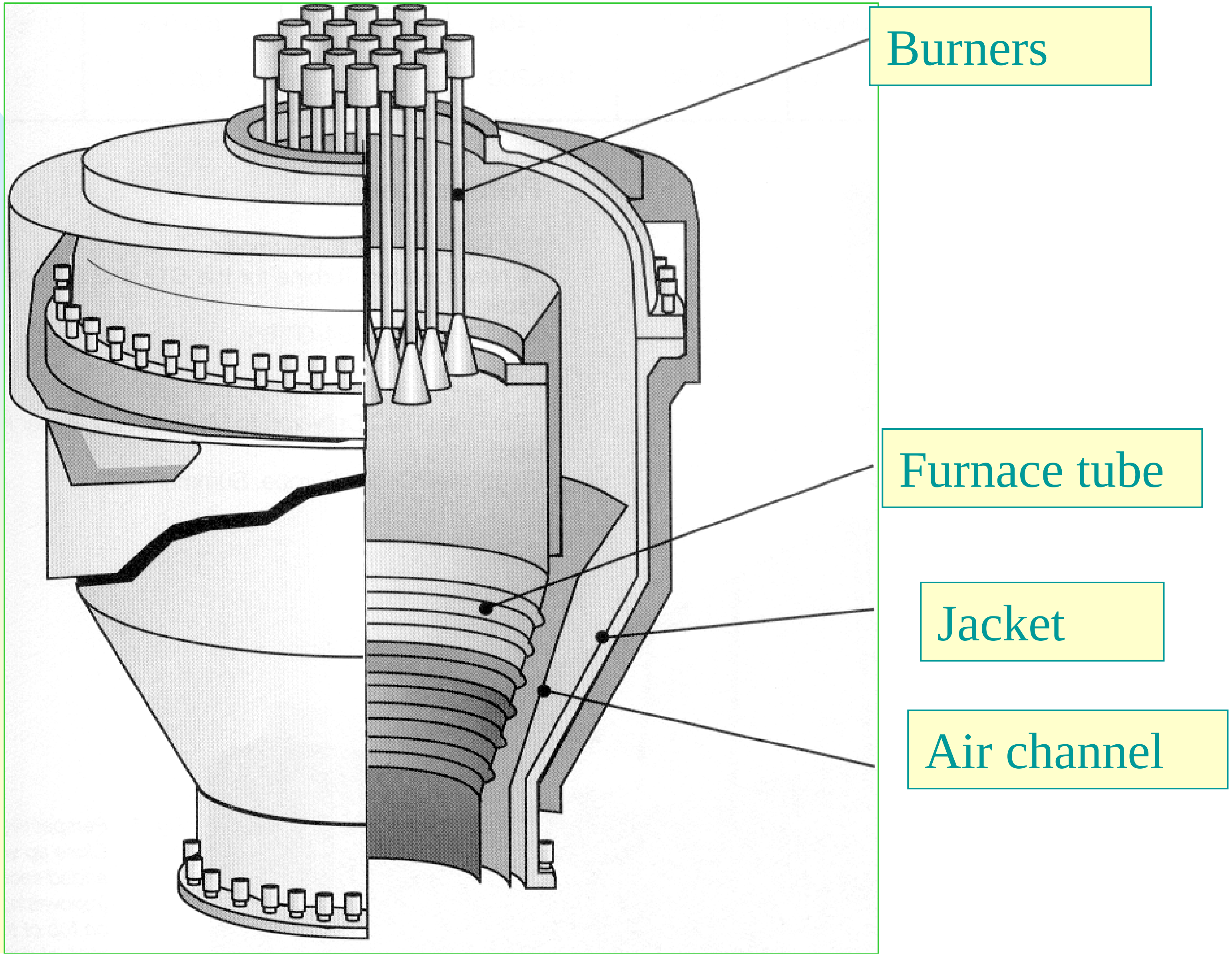
Parallel-flow tubular combustor

Tubular combustion chamber



Oposite-flow tubular combustor

Details of tubular combustor



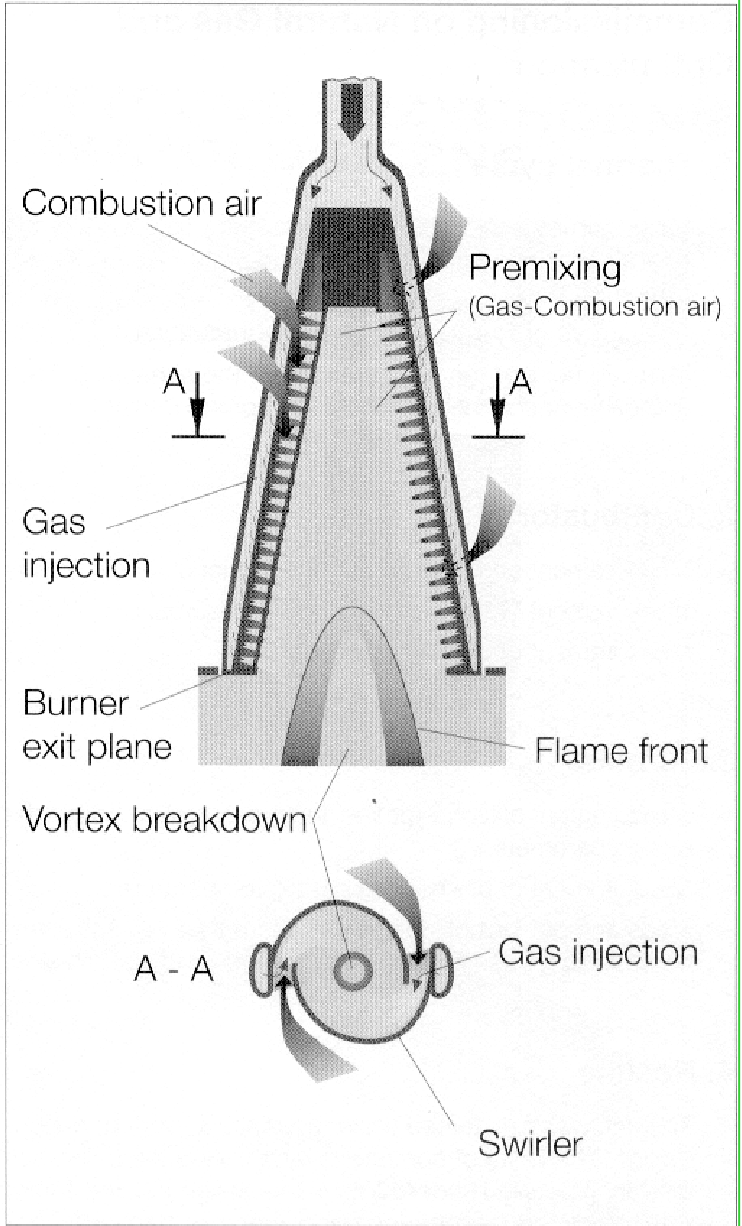
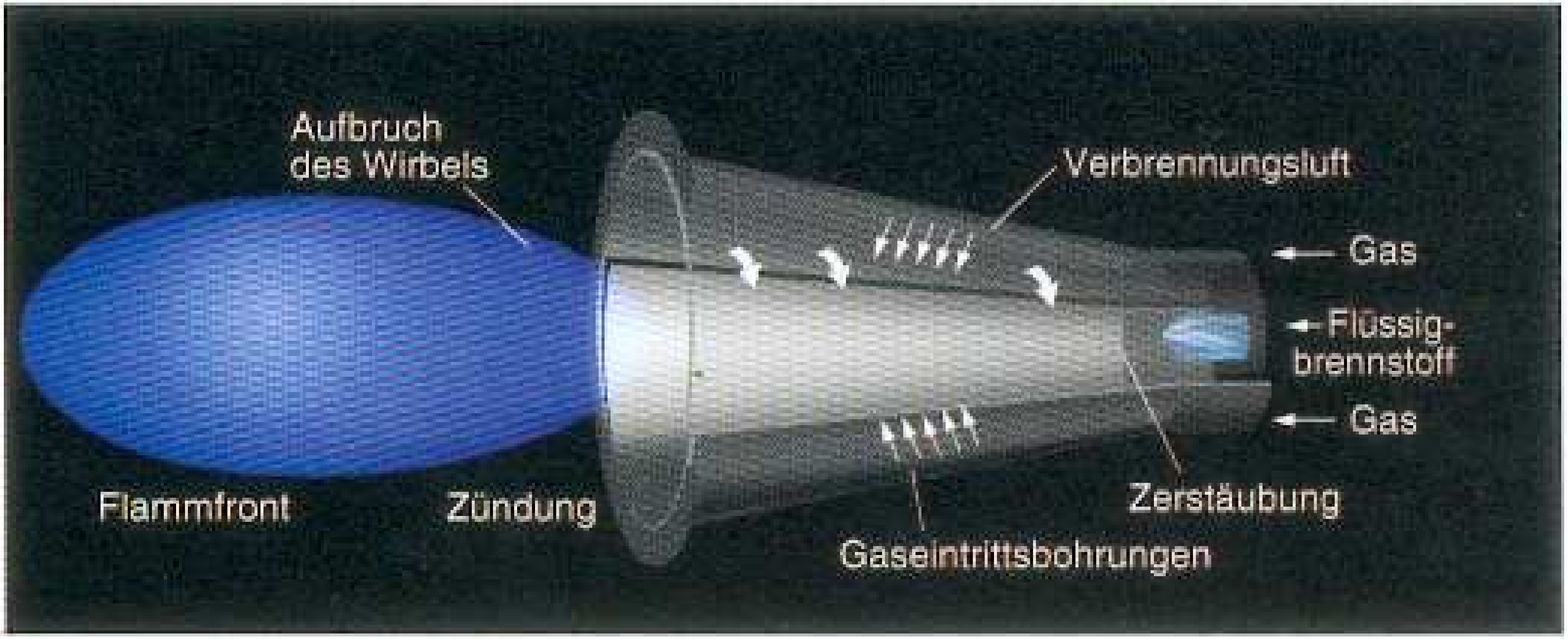


Fig. 5: GT8C Dry low NO_x EV-Burner; cross section and function principle

Single EV burner (ABB)

Scheme of EV burner (ABB)



EV burner (ABB)

ORGANIZATION OF COMBUSTION PROCESS IN TG

Flame stabilization in GT

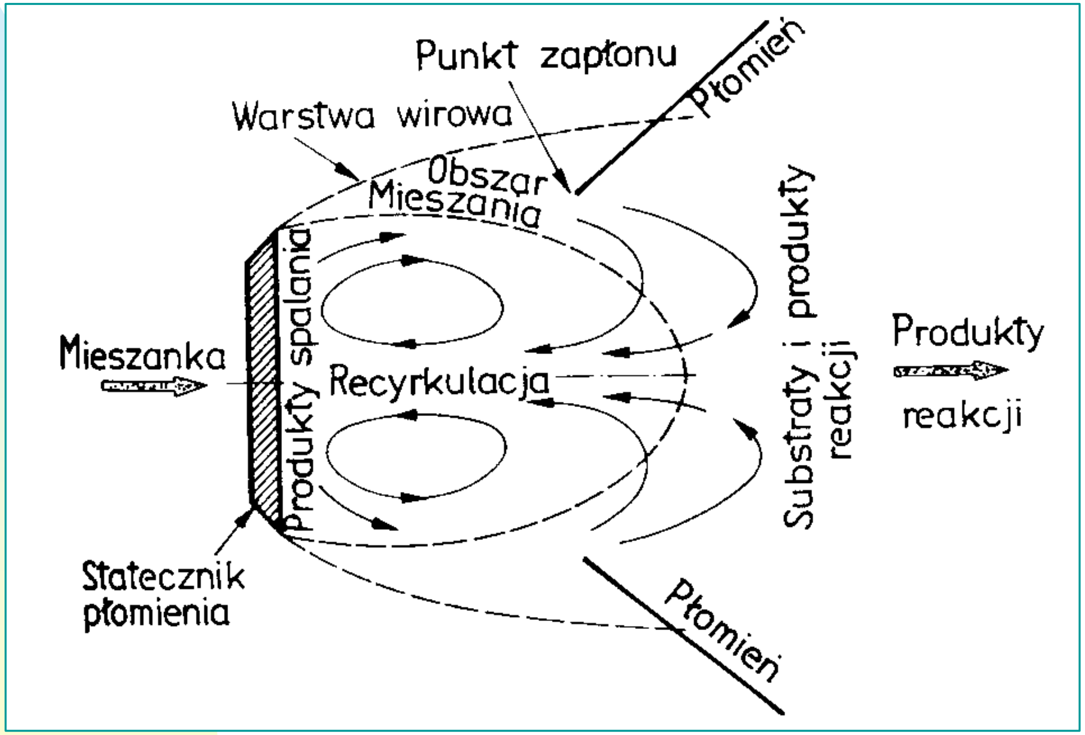
Combustion of lean fuels with preliminary evaporation and mixing - LPP
(lean, premixed, prevaporised)

a) The principle is complete evaporation of fuel and mixing with air, because of:

- avoid of droplets,
- Temperature of lean mixture flame is low.

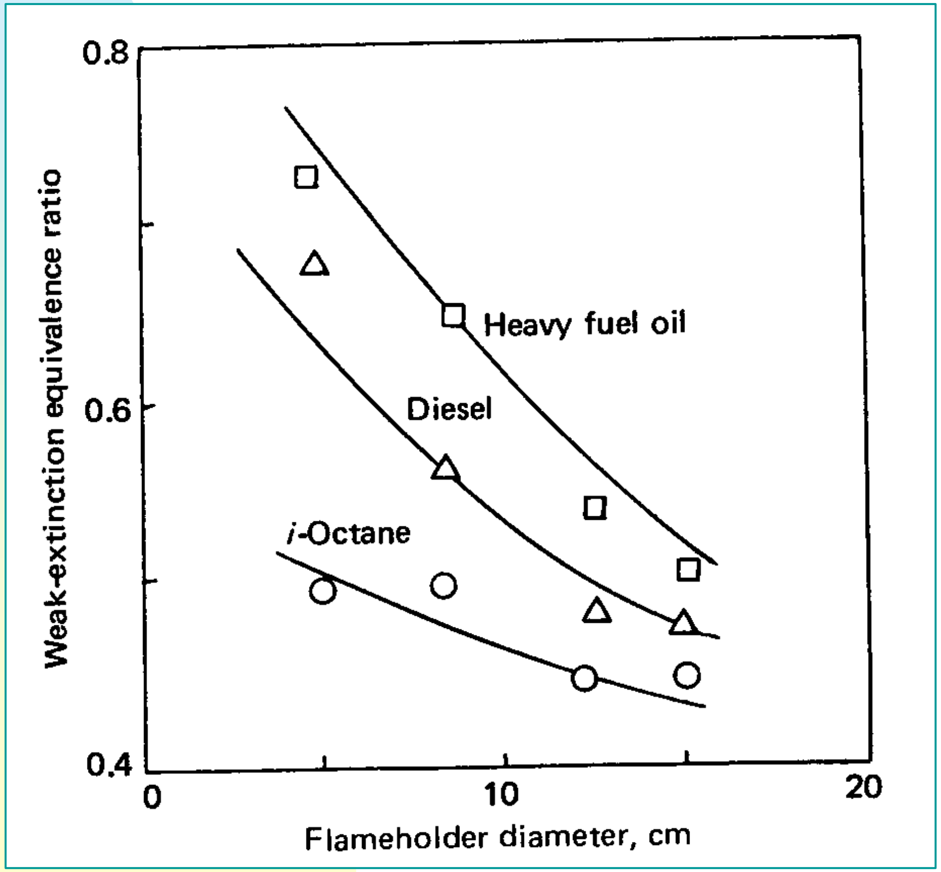
Combustion systems LPP should co-operate with the systems of variable geometry, tu avoid danger of extinction due to LEL for small load.

Flame-holder operation



Principle of stabilization with flame-holder

Influence of flameholder size on the lower limit of stability for different fuels



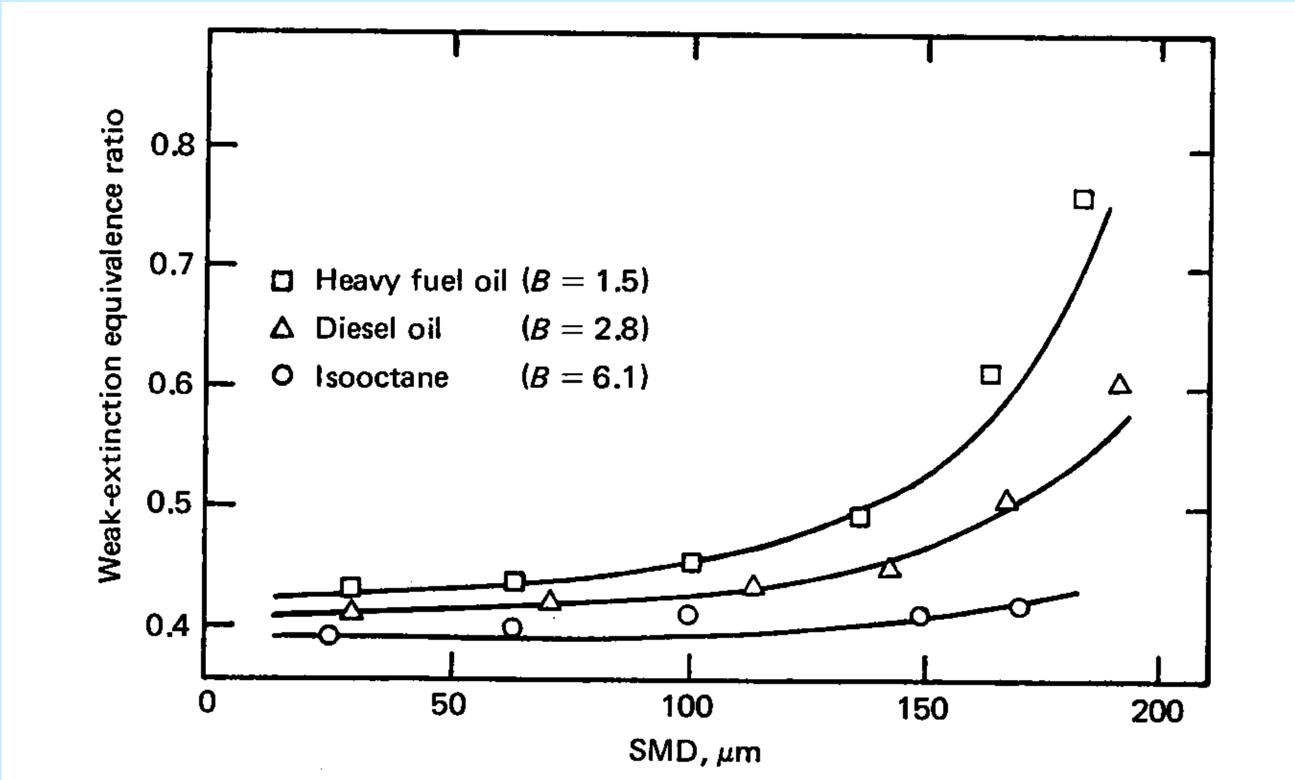
$P = 100$ kPa

$T_0 = 300$ K

SMD = 60 μm

$U = 30$ m/s

Influence of particle size on the lower limit of stability for different fuels



U=15 m/s, T_0=300K, p = 100 kPa

Counter-flow stabilisation effect

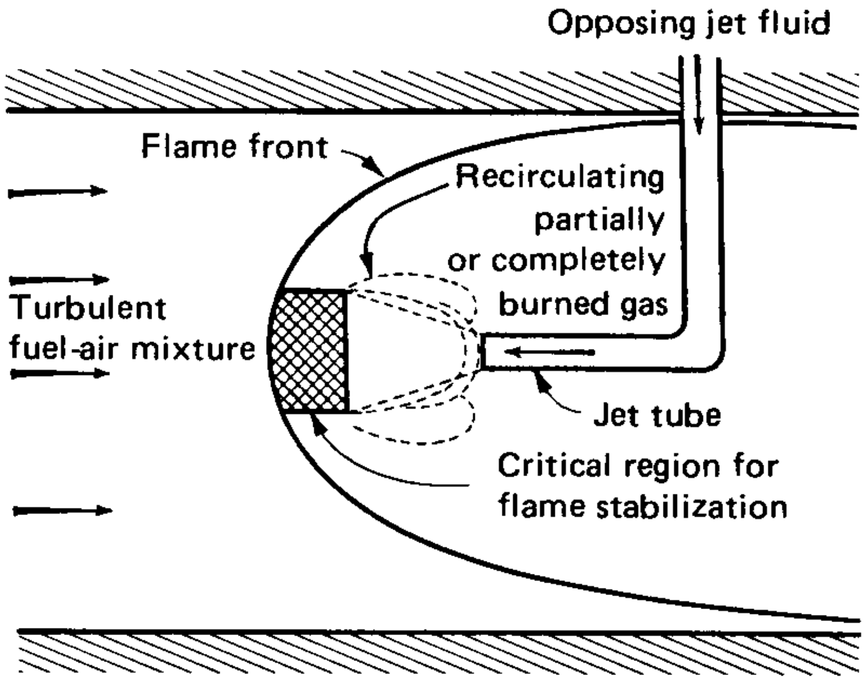
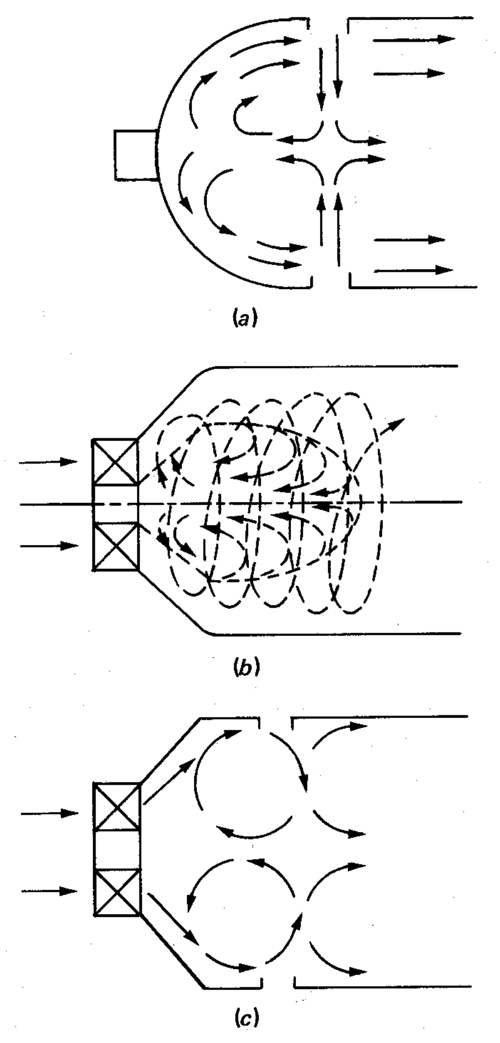


FIG. 6.34 Schematic diagram of opposing-jet flameholder [57].

Recirculation induced stopping of flow

Organisation of the 1-st zone of combustion

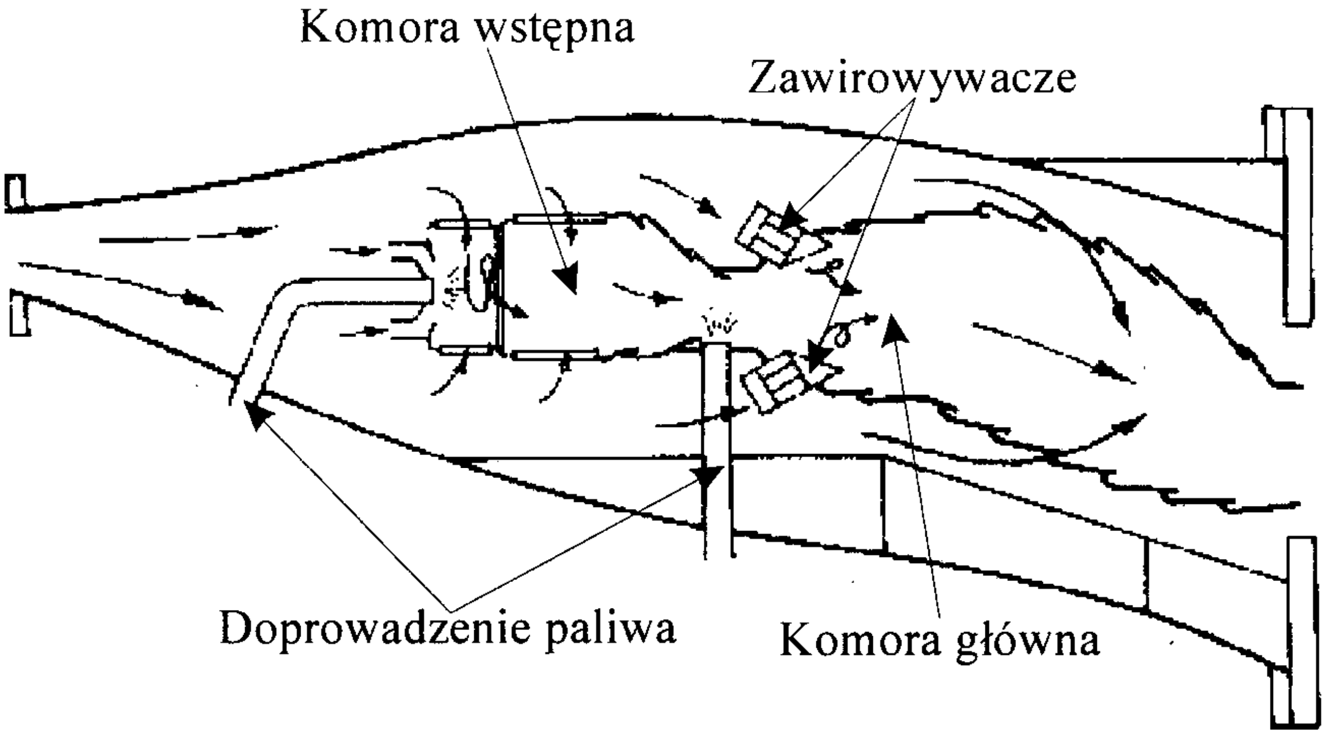


Stabilisation by jets collision (counter-flow)

Stabilisation by swirling

Stabilisation by combination of swirling and counter-flow

Fuel staging – design example



Rys. 15. Schemat komory spalania typu VORBIX [13]

COOLING OF FLAME TUBE

Methods of cooling of flame tube

A) Warstwowe

- polega na przenikaniu powietrza na stronę wewnętrzną płomienicy przez rząd otworków o małej średnicy. Strugi powietrza tworzą kurtynę oddzielającą wewnętrzną stronę płomienicy od gorących spalin.

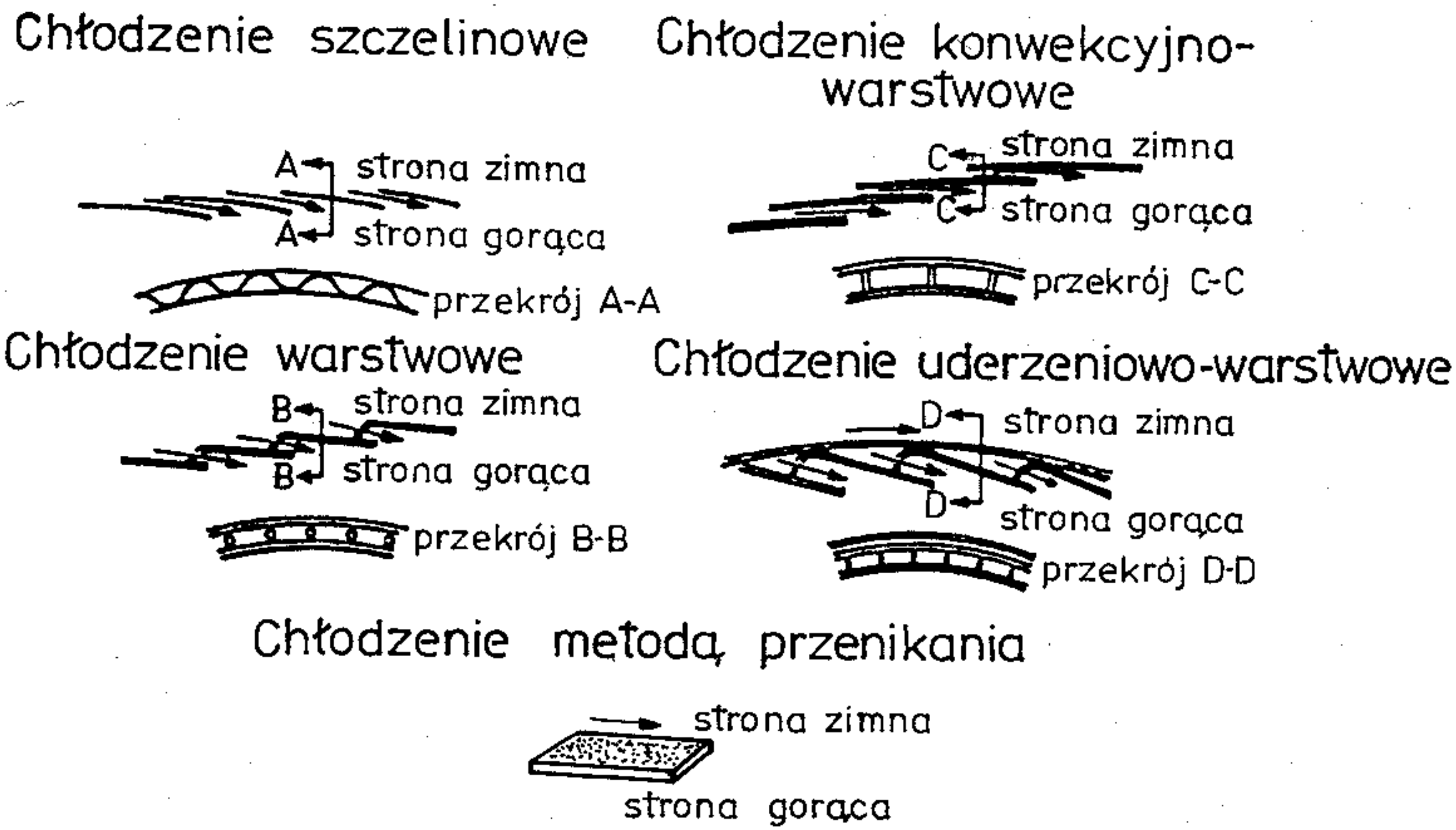
B) Konwekcyjno-warstwowe

- polega na przedłużeniu kanalików doprowadzających powietrze do wnętrza płomienicy. Dzięki temu poprawia się efektywność chłodzenia płomienicy, ale zwiększa się jej ciężar.

C) Transpiracyjne (z porowatą ścianą)

- polega na przenikaniu powietrza przez porowatą ścianę płomienicy i tworząc kurtynę powietrzna od gorących spalin.

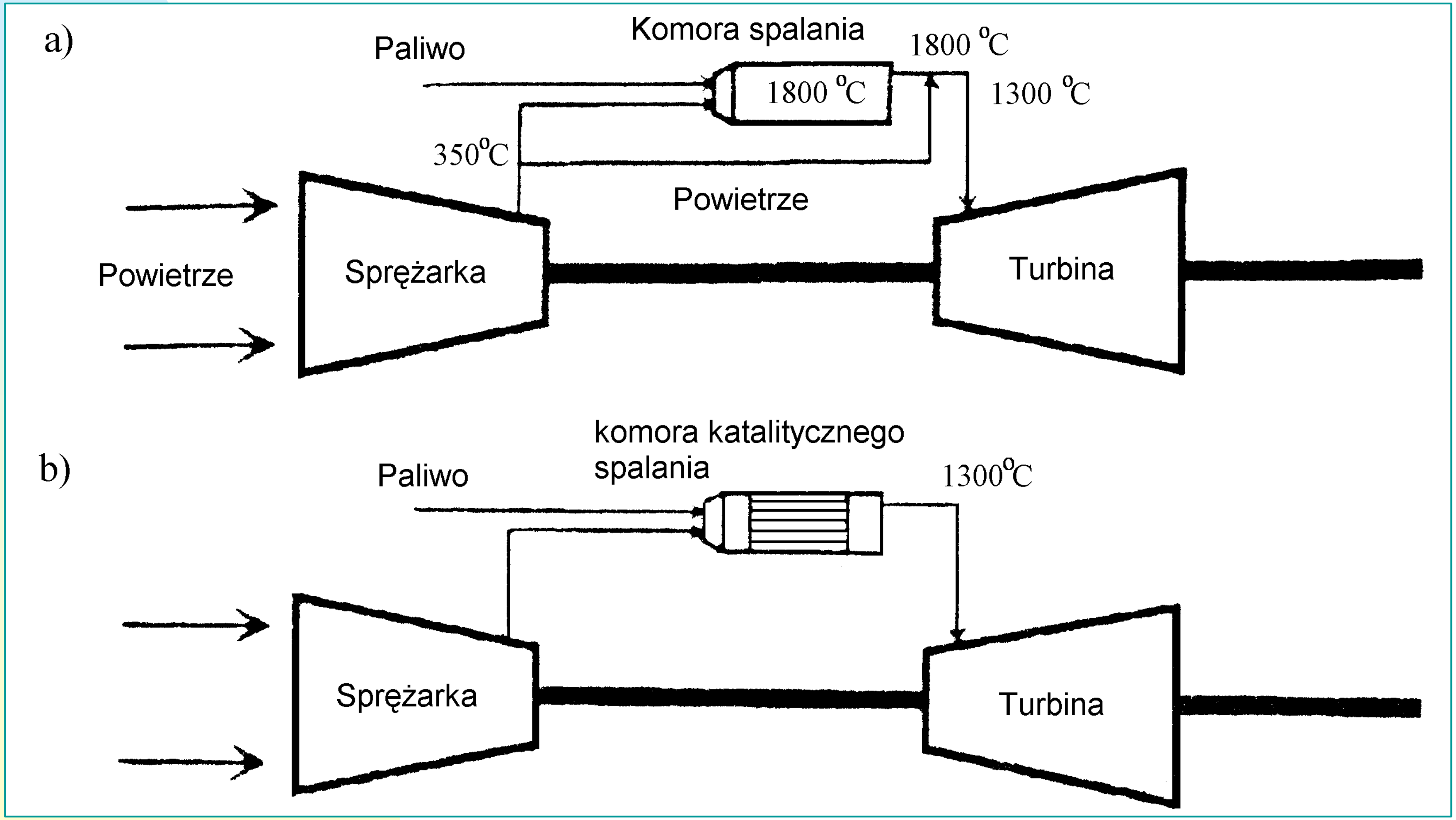
Cooling of flame tube



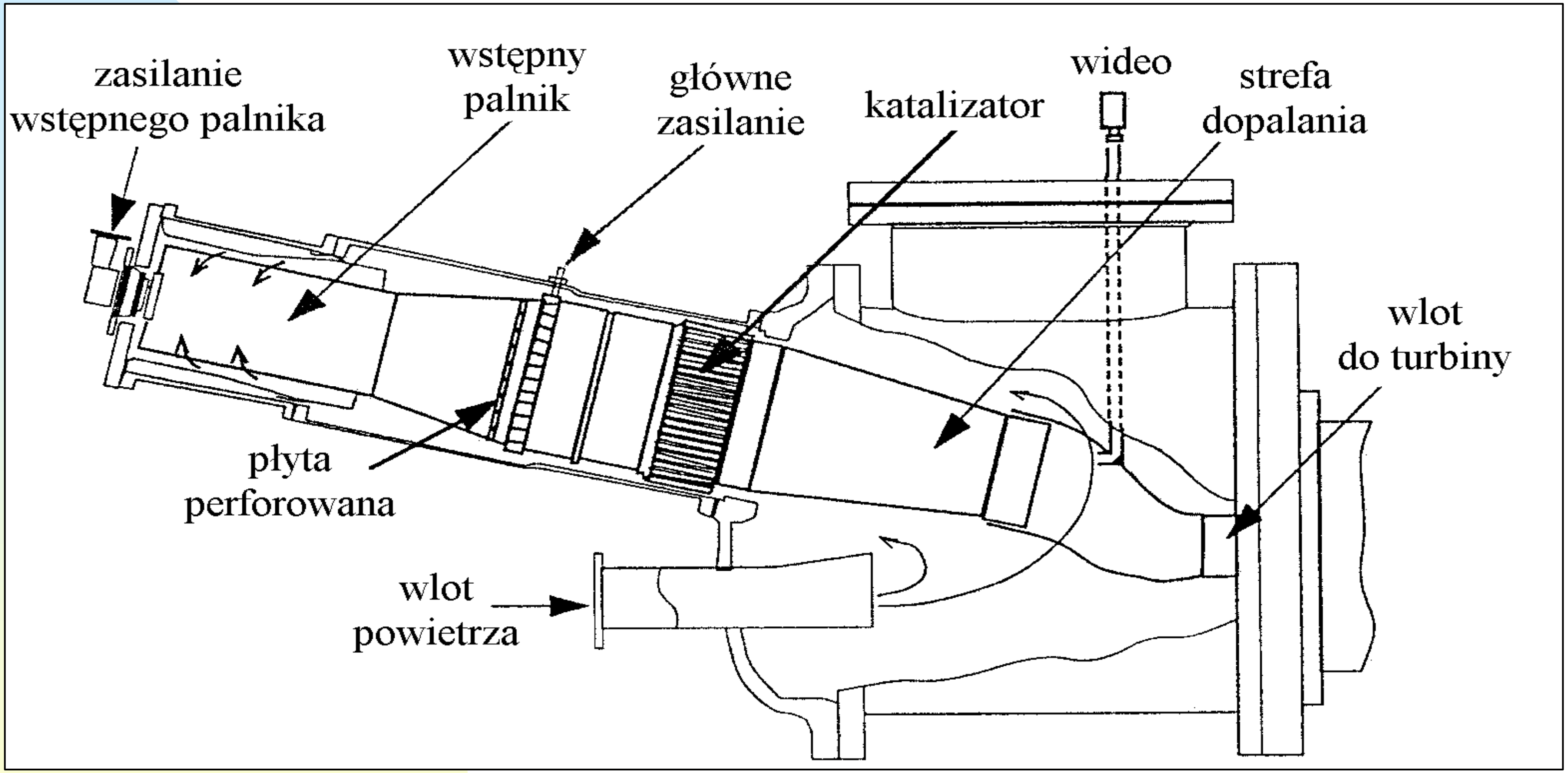
Rys. 11.41. Techniki chłodzenia rury żarowej [2]

CATALITYC GAS TURBINES

Conventional and catalytic GT

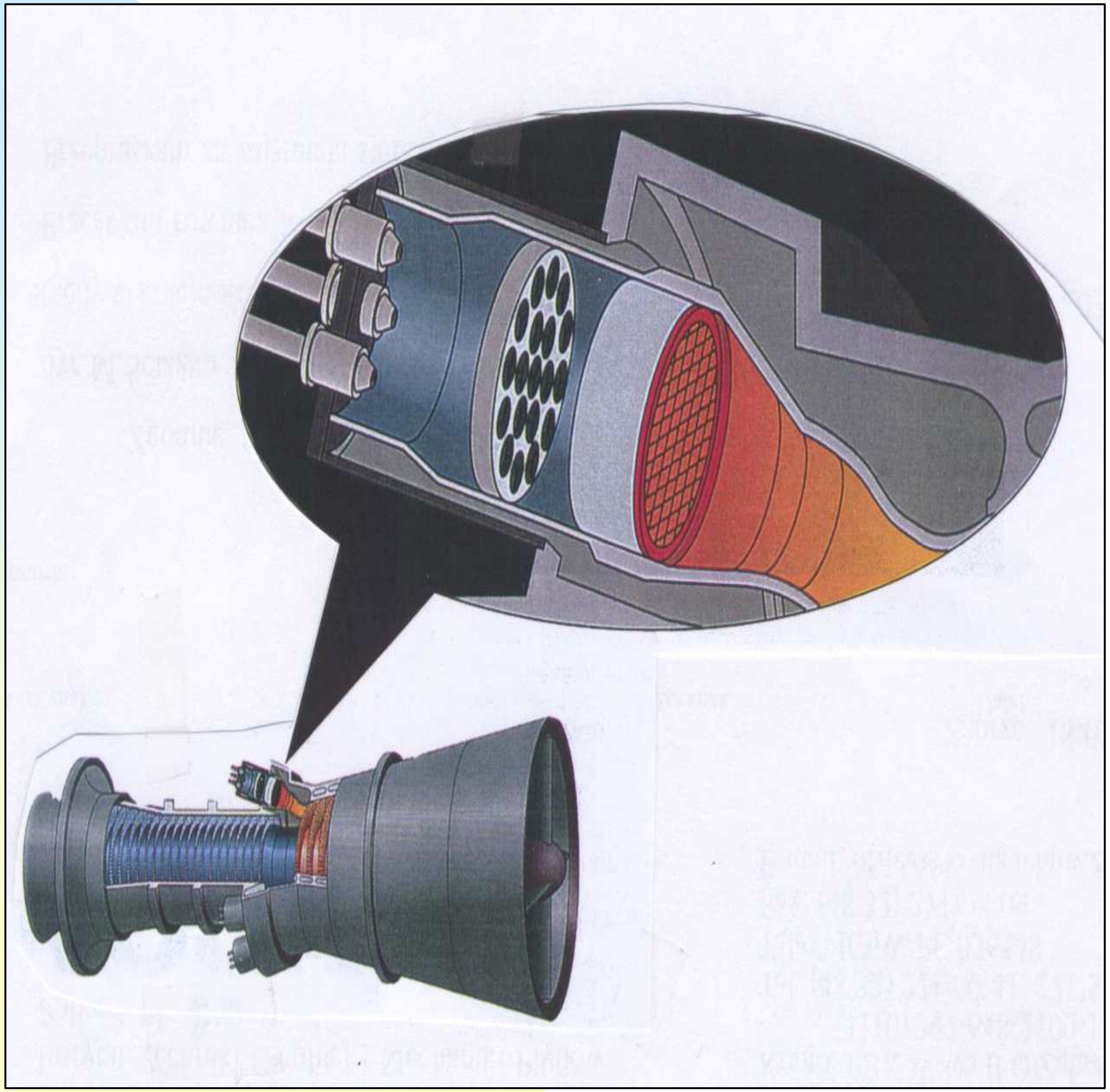


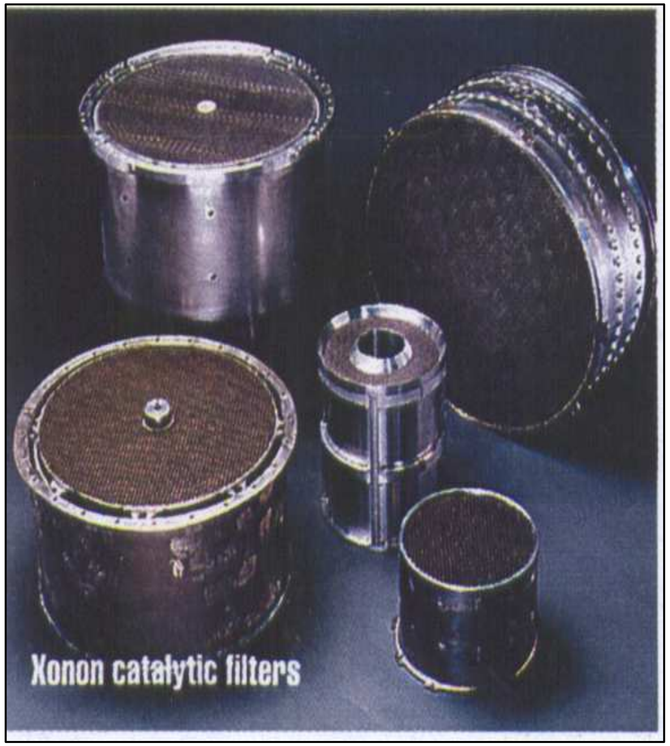
Catalytic combustion chamber (combustor)



Catalytic combustion system applied to gas turbine

Parts of catalytic combustion chamber

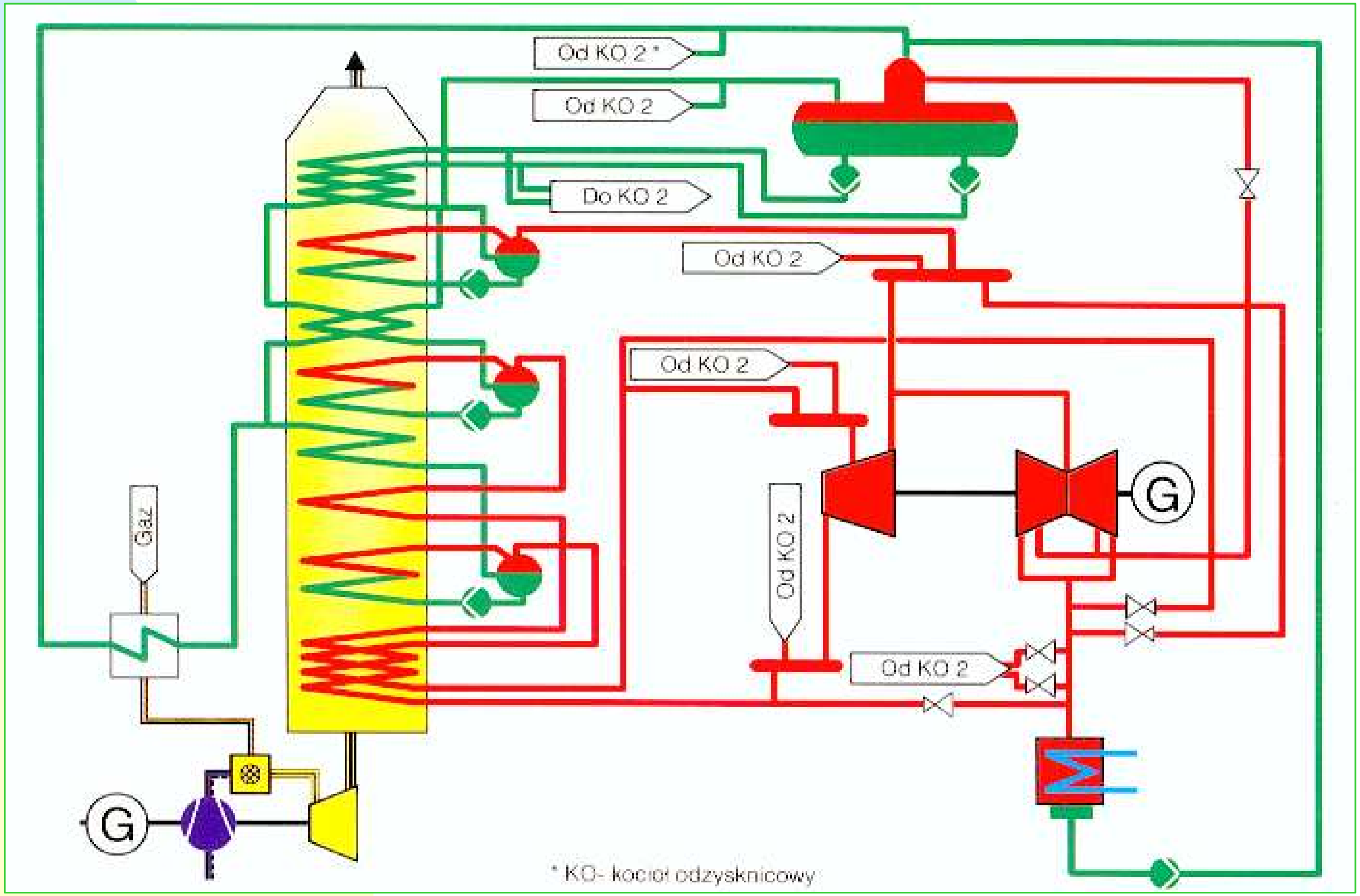


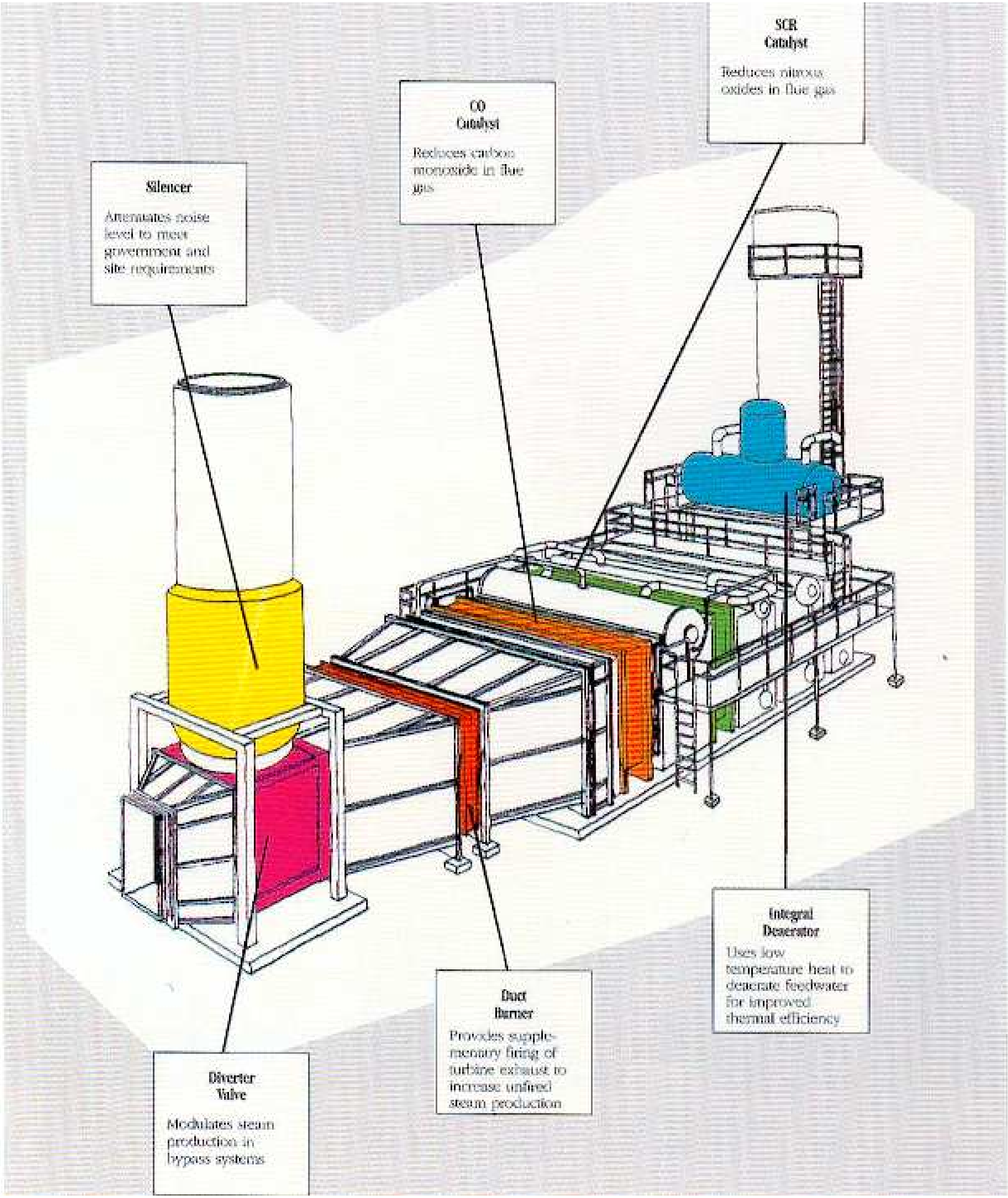


Catalysts

HEAT RECOVERY STEAM GENERATORS

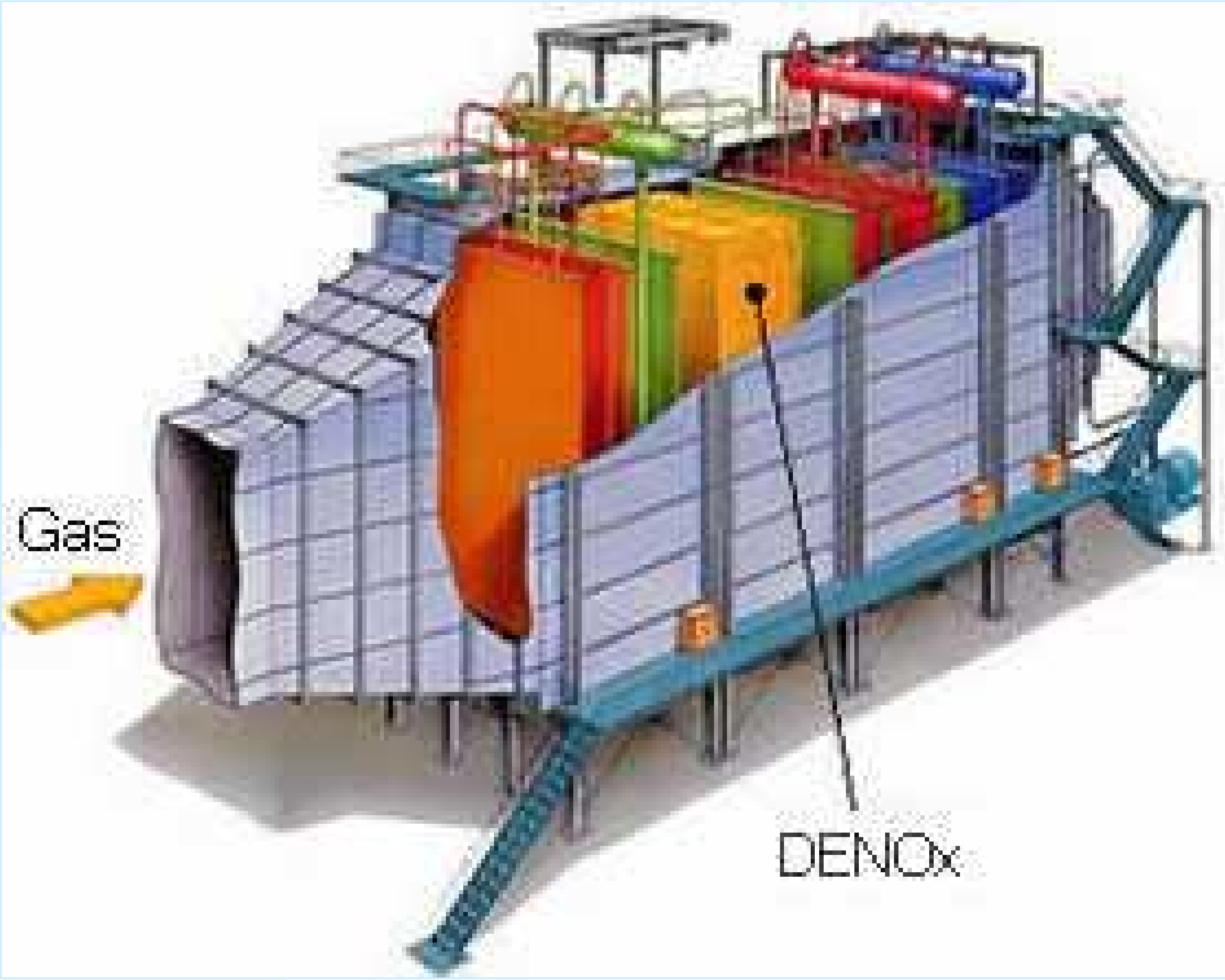
Combined cycle power plant
Gas turbine combined cycle CTCC





Heat recovery steam generator

Heat recovery steam generator



Scheme of channel burner

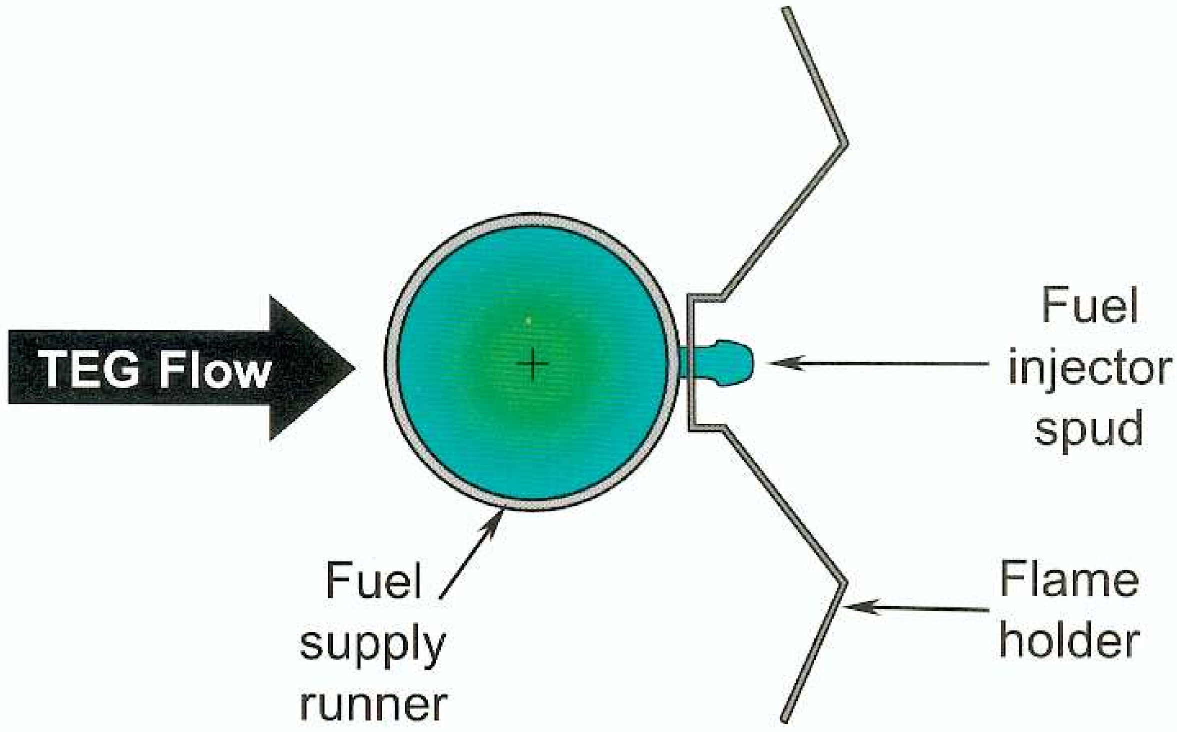


FIGURE 18.8 Linear burner elements.

Channel burner operation

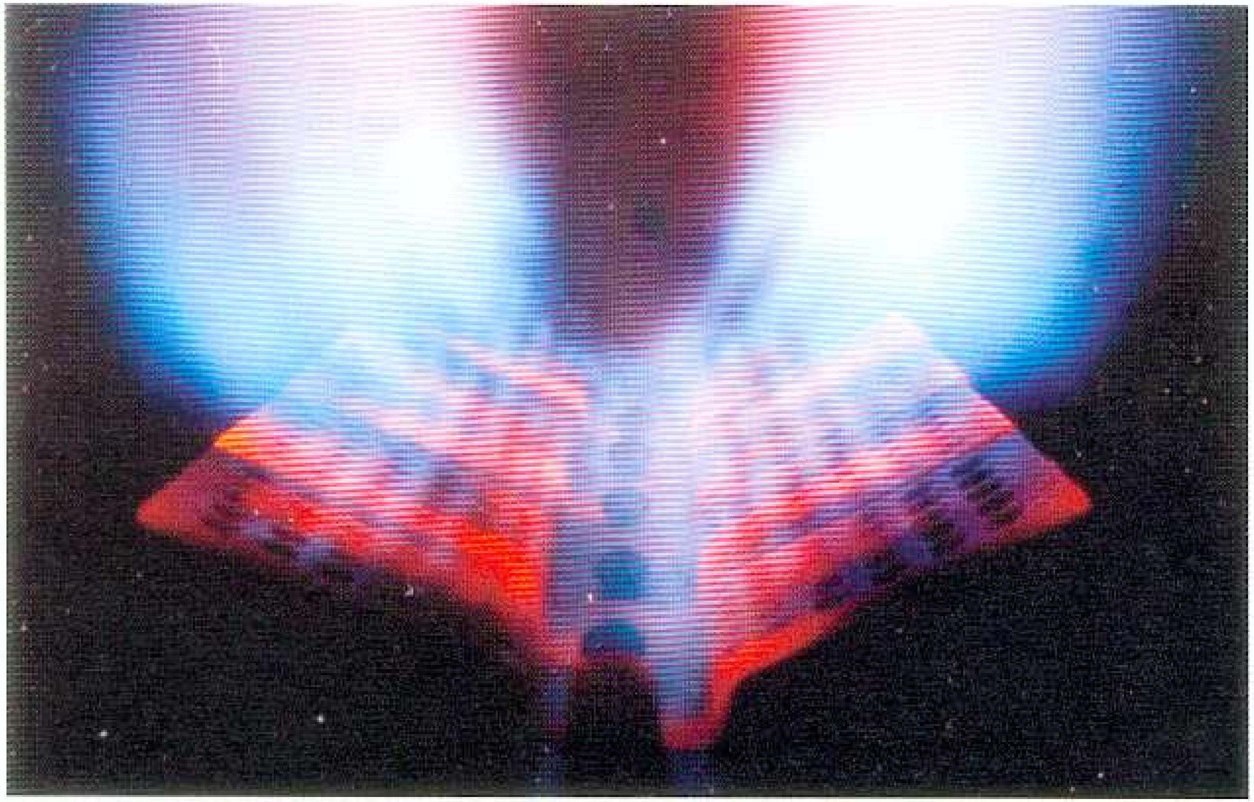
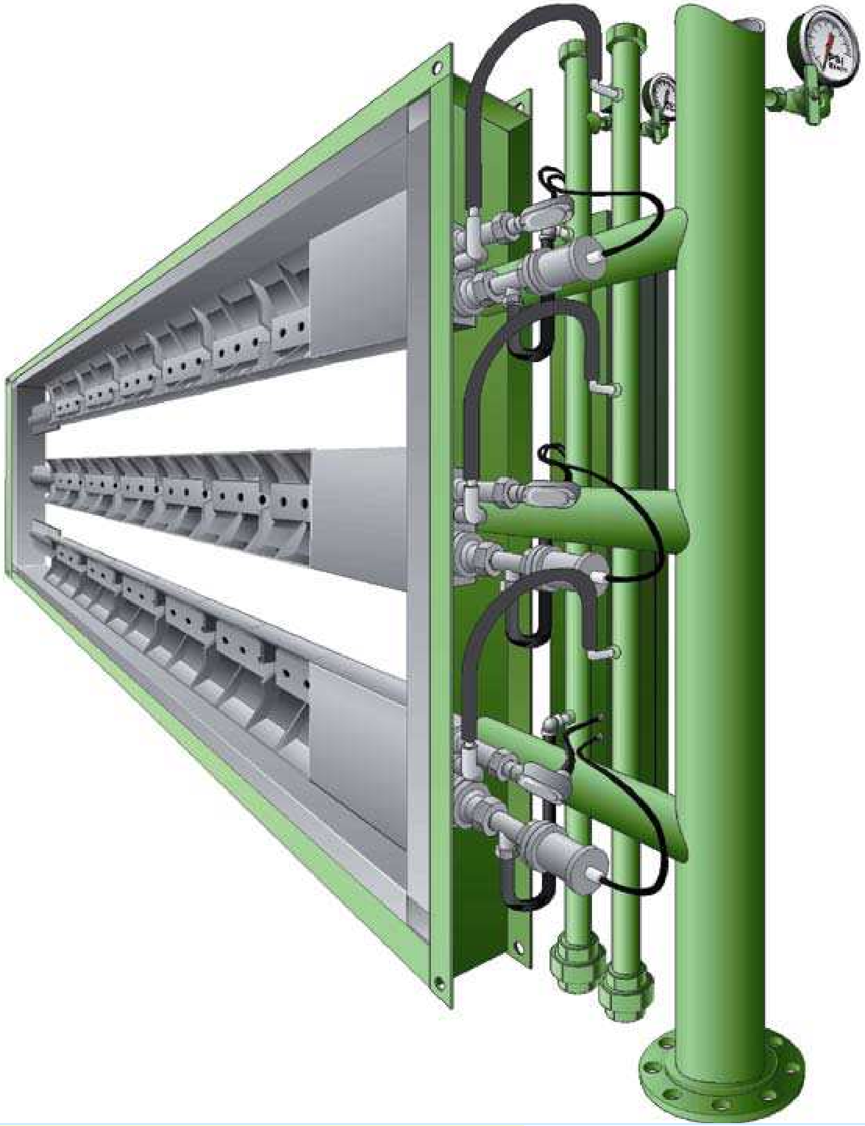


FIGURE 18.9 Gas flame from a grid burner.

Channel burners for HRSG's



FUEL GAS	HEAT RELEASE	O_2 PPM	NOx PPM	CO PPM
Natural	Unfired	15.4	49	7.0
Natural	425 mmBtu/hr	13.1	53	5.0
Refinery	Unfired	15.3	47	7.7
Refinery	425 mmBtu/hr	13.1	52	4.5

GT 100 MW

GAS TURBINE FUELS

GT fuels – general requirements

1. Low cost and easy excess.
2. Low risk of fire.
3. High HCV.
4. High thermal stability..
5. Low pressure of evaporation.
6. High specific heat.

Types of gas turbine fuels

1. Gasoline
2. Kerosines
3. Diesel oil
4. Heating fuel oil
5. Natural gas
6. Syngas
7. Others (H_2, NH_3, C_3H_8, C_4H_{10}, alcohols,..)

Selected parameters of GT fuels

Parameter	Gazoline	Kerosine
Relative density at 311 K	0.793	0.82-0.88
Viscosity 311 K, cSt	1.4	2-4
Temperature of ignition (Flash point), K	311-344	339-367
Temperature of freezing (Pour point), K	228	253-273
LHV, MJ/kg	42.8	42-43
Sulfur, % mas.	0.01-0.1	0.1-0.8

Non-conventional GT fuels

TABELA 2

Właściwości niektórych paliw rozważanych jako alternatywne paliwa lotnicze[29]

Paliwo / Parametr	Nafta lotnicza A-1	Alkohole		Metan	Wodór	Pentaboran
		metylowy	etylowy			
Skład	H/C 0,16	CH_3OH	C_2H_3OH	CH_4	H_2	B_3H_8
Ciężar cząsteczkowy	~ 120	32,04	46,06	16,04	2,016	63,17
Wartość opałowa, kJ/kg	42 800	19 985	29,750	49 080	119 890	64 300*)
Gęstość, kg/m^3	753	785	817	425	71	633
Temp. wrzenia, K	470÷560	337	352	112	20,5	332
Temp. krzepnięcia, K	220	175	158	90,8	14	226
Ciepło parowania, kJ/kg	244÷256	1103	853,6	581,5	449	507
Ciepło właściwe, kJ/kgK	2,01	2,55	2,59	3,44	9,29	2,4
Gęstość paliwa / Gęstość nafty lotniczej	1	1,04	1,08	0,56	0,094	0,84
Wartość opał. z 1 kg pal. / Wartość opał. z 1 kg nafty lotn.	1	0,47	0,70	1,15	2,80	1,50
Wartość opał. z 1 m^3 paliwa / Wartość opał. z 1 m^3 nafty lotn.	1	0,49	0,75	0,65	0,26	1,26

*) z uwzględnieniem ciepła kondensacji B_2O_3