Institute of Power Engineering

Department of Nuclear and Thermal Power Plants

Turbines in NPP

Master’s program **140800 “Nuclear Physics and Technologies”,**
educational program specialization **“Operation of Nuclear Power Plant”**

Lecturer: Leonid Aleksandrovich Belyaev

Assistant Professor, DNTPP

Lectures: 48 hours
Independent learning : 60 hours
Test

Recommended reading:

1. *Leyzerovich*, *Alexander*. **Wet-Steam** Turbines for Nuclear Power Plants / *A. Leyzerovich*. — Tulsa : PennWell, 2005. — 456 p.
2. *Singh*, *Murari*. **Blade** Design and Analysis for Steam Turbines / *M. P. Singh*, *G. Lucas*. — New York : McGraw-Hill, 2011. — 364 p.
3. *H. P. Bloch*, *M. P. Singh*. **Steam** Turbines. Design, Applications and Rerating. -
4. **Паровые** и газовые турбины для электростанций. / *А.Г. Костюк, В.В. Фролов, А.Е. Булкин, А.Д. Трухний;* под ред. *А.Г. Костюка.* – М.: Издательский дом МЭИ, 2008. 556 с.
5. **Турбины** тепловых и атомных электрических станций. /*А.Г. Костюк, В.В. Фролов, А.Е. Булкин, А.Д. Трухний;* под ред. *А.Г. Костюка и В.В. Фролова.* – М.: Издательство МЭИ, 2001. 488 с.

Objectives of the course

Nuclear power plant is a station intended to produce **electrical energy** through conversion of **nuclear energy**

Law of conservation of energy:

energy does not disappear or reappear, it is converted

How is electrical energy generated?

Electrical energy is produced in a device called **Electric Generator**

Generator operating principle:

The First Law of Electromagnetic Induction:
EMF (electromotive force - electric current) is induced in the conductor which intersects magnetic field lines.

The Second Law of Electromagnetic Induction:
An oppositely directed force impacts the conductor through which an electric current moves and which intersects magnetic field lines.

I – current , *a*; *U* – voltage, *B*;

Power of the electric generator *(W):*

$$N_Э = IU = 2\pi r n R = \omega M$$

n – speed, s^{-1};

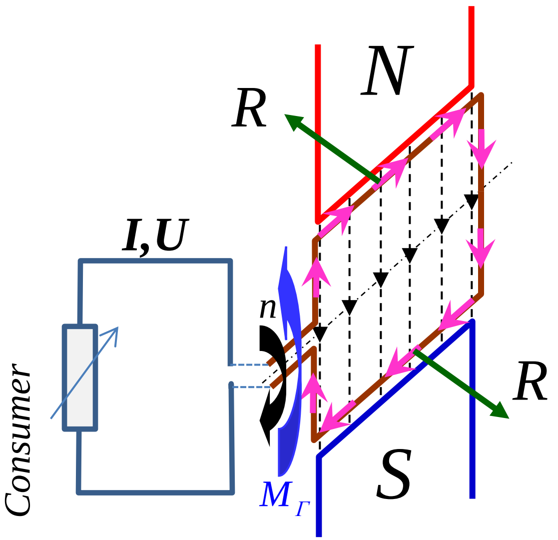
r – frame radius, *m*;

2πrn – distance per unit time, *m/s*;

R – force, N;

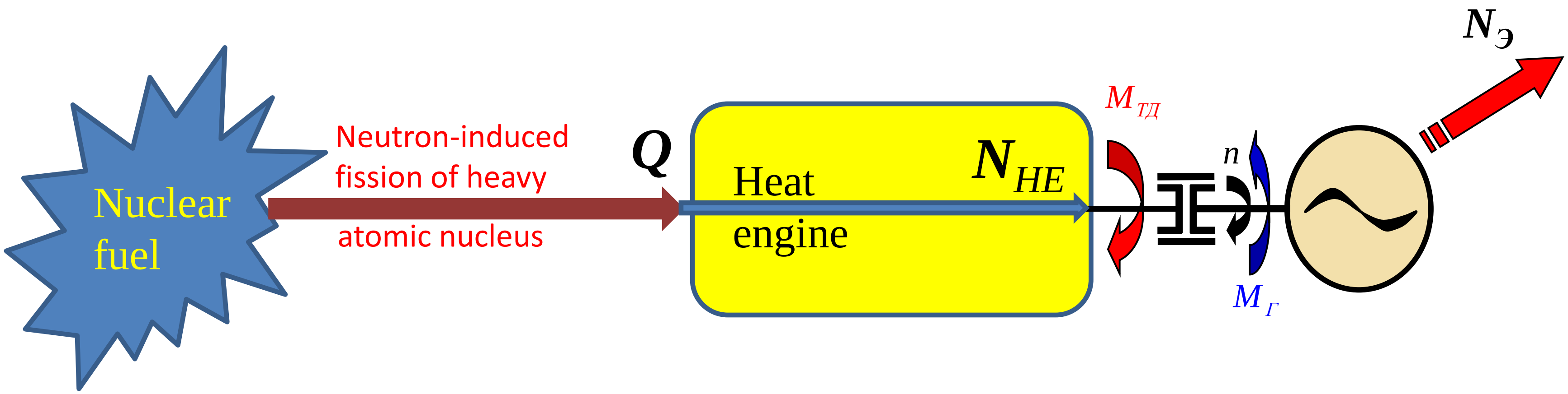
rR=M – torque, Nm;

2πn=ώ – angular velocity, s^{-1}.

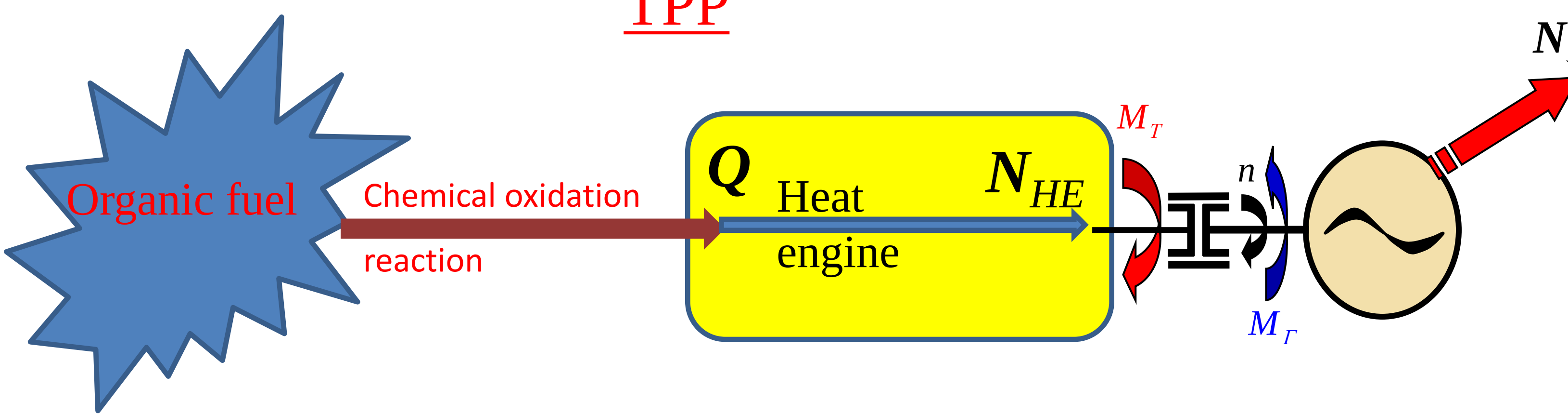


Conclusion: to produce electric current in the generator, the torque is to be **externally** applied to the generator rotor.

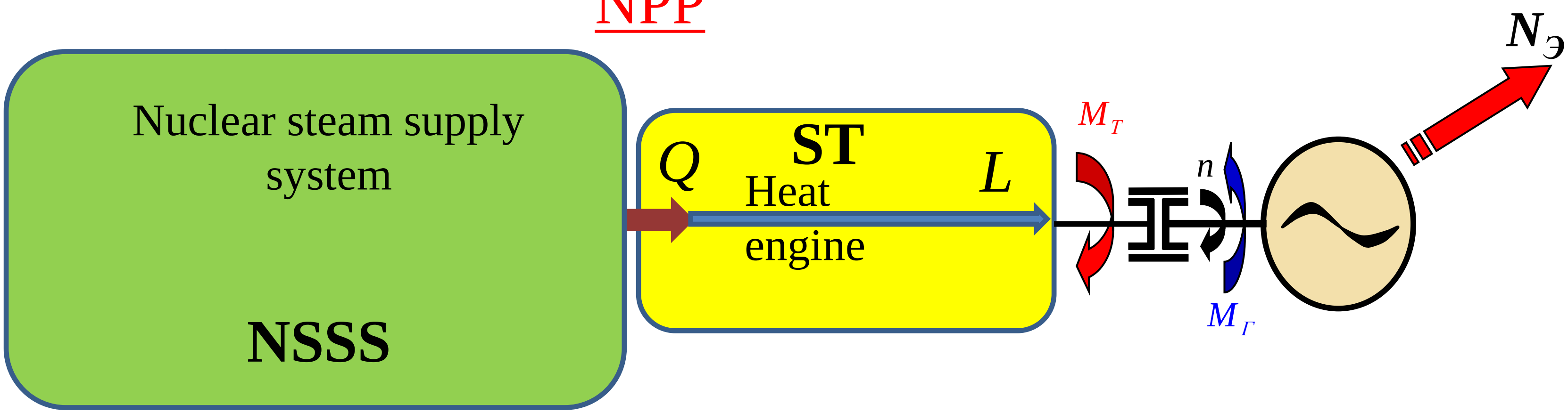
Nuclear Power Plant (NPP)



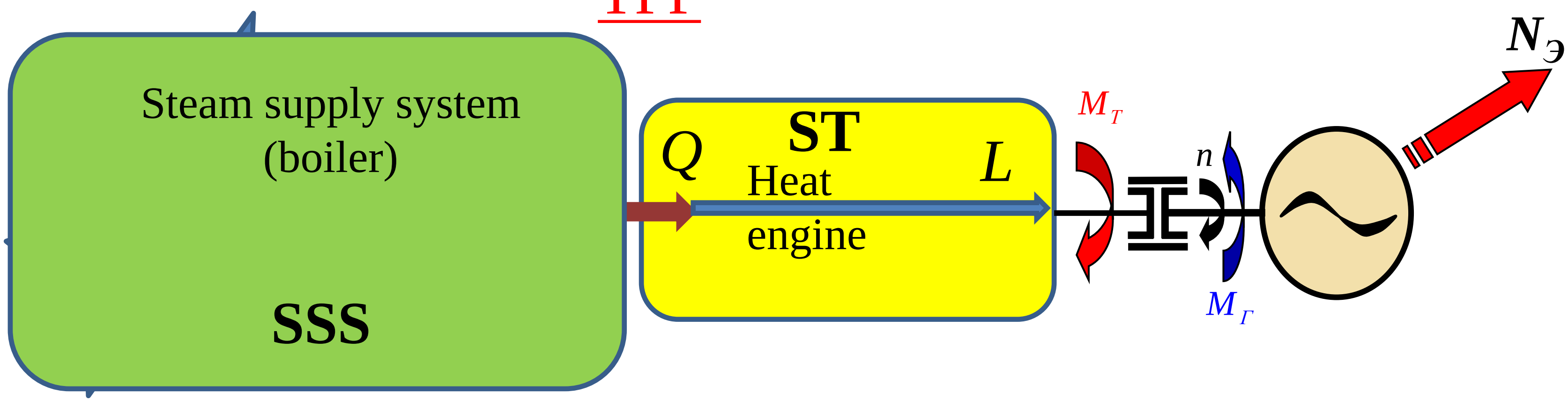
TPP



NPP



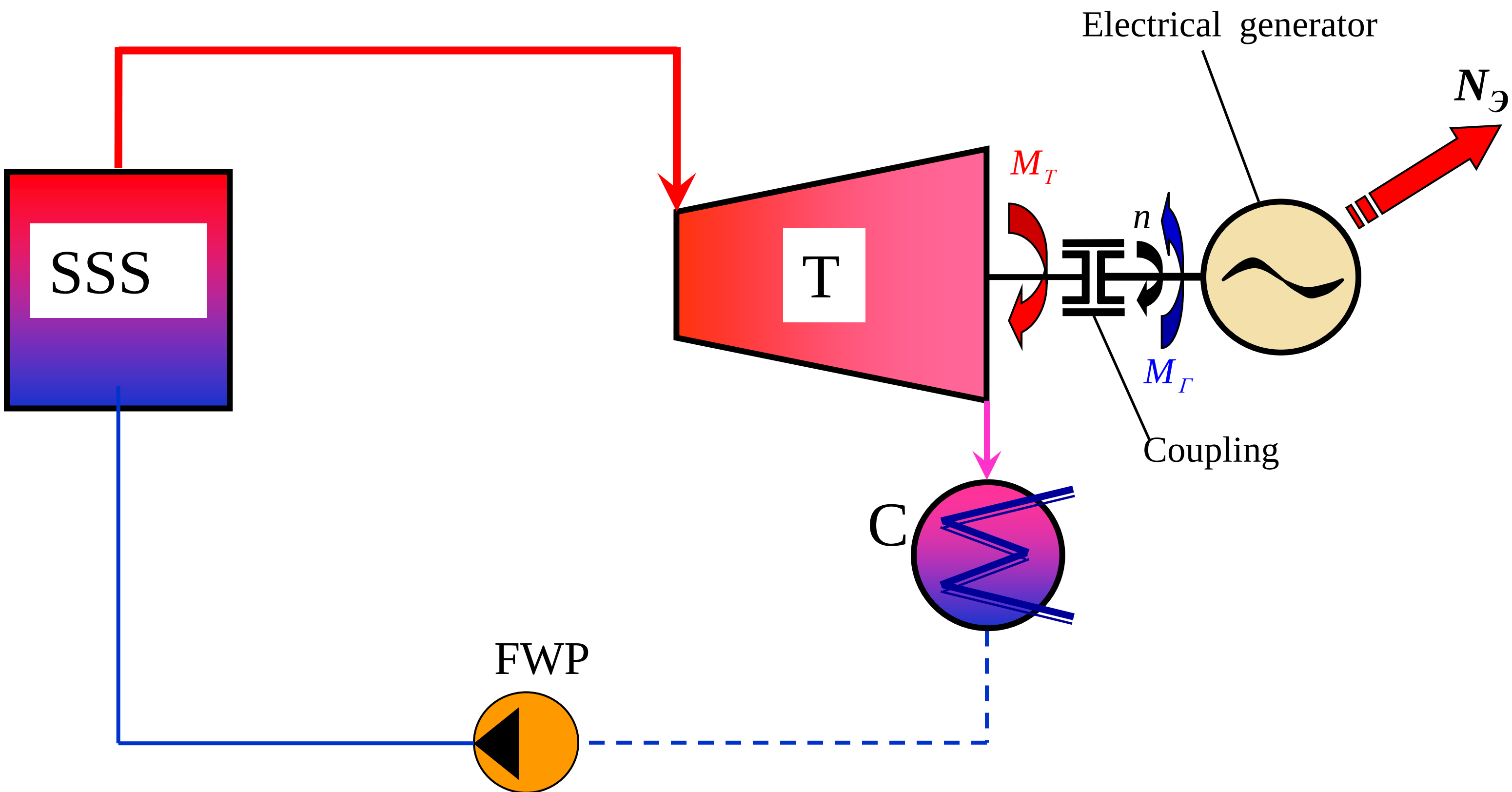
TPP



ST – steam turbine

SSS – steam supply system

Diagram of a simple steam turbine



Piping:

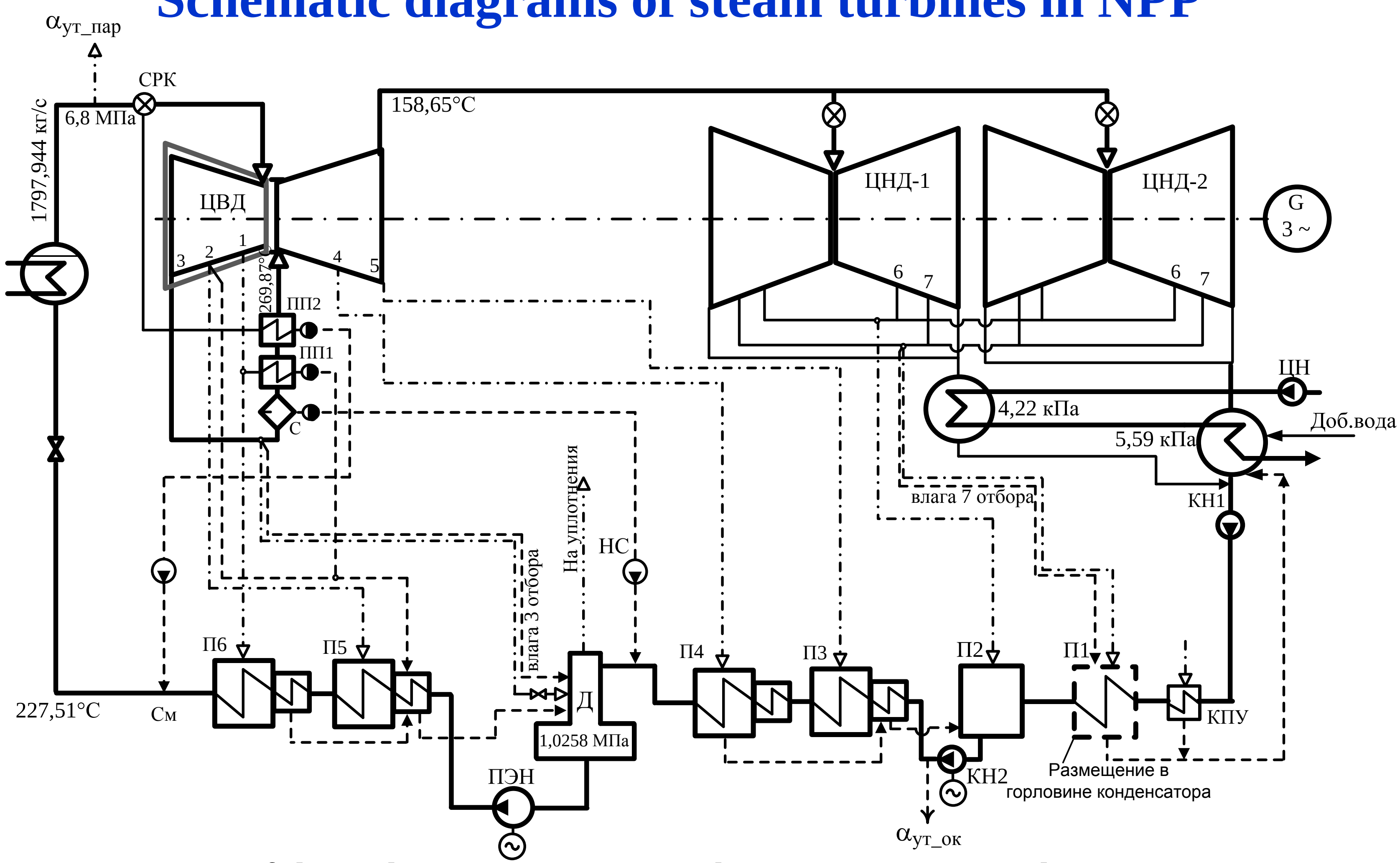
FWP	*feedwater pump*
SSS	*steam supply system*
T	*turbine*
К	*condenser*

(red solid line)	*main steam*
(magenta solid line)	*Steam at the turbine outlet*
(blue dashed line)	*full-flow condensate*
(blue solid line)	*feed water*

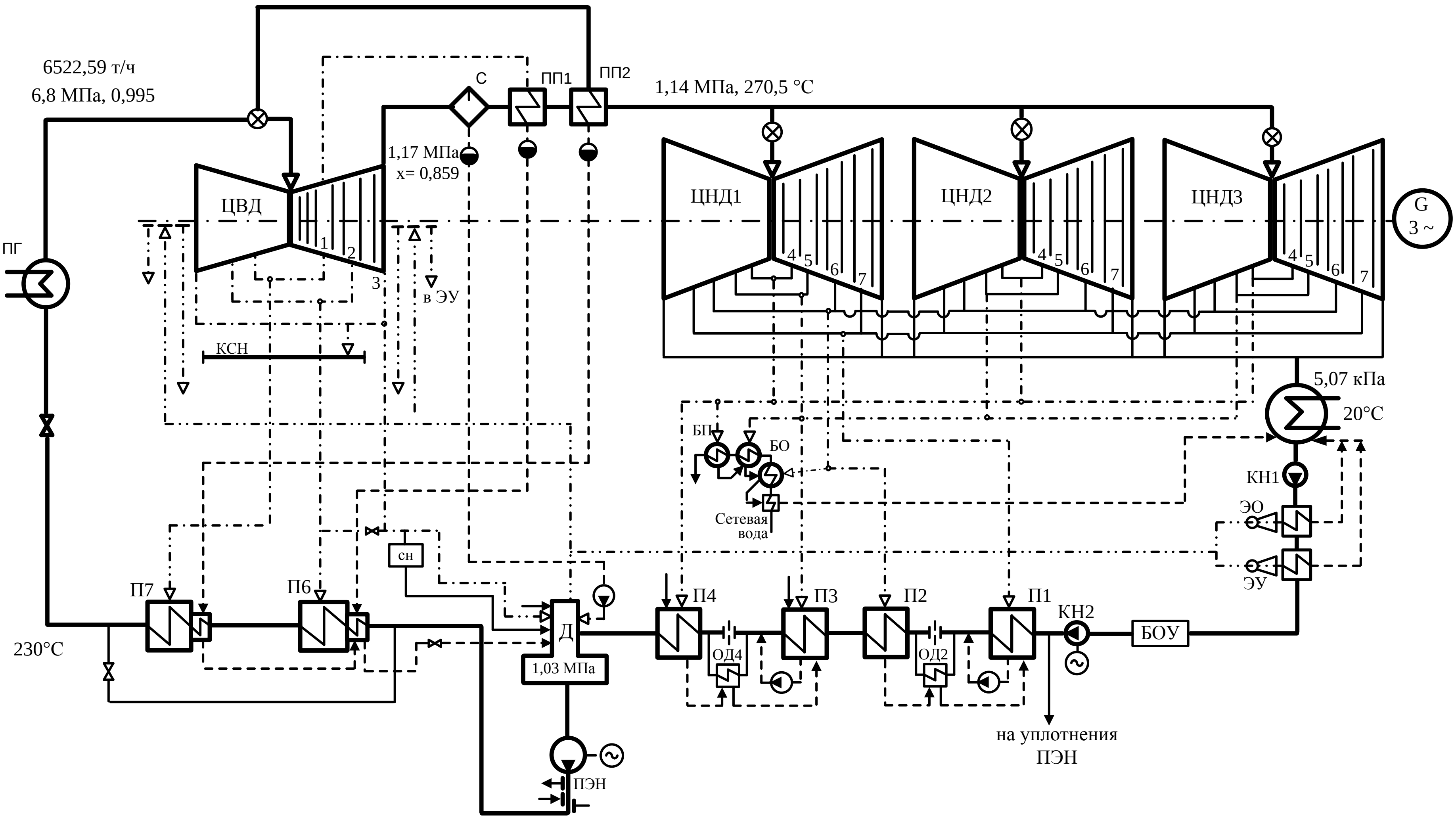
Basic requirements for steam turbines:

efficiency and reliability

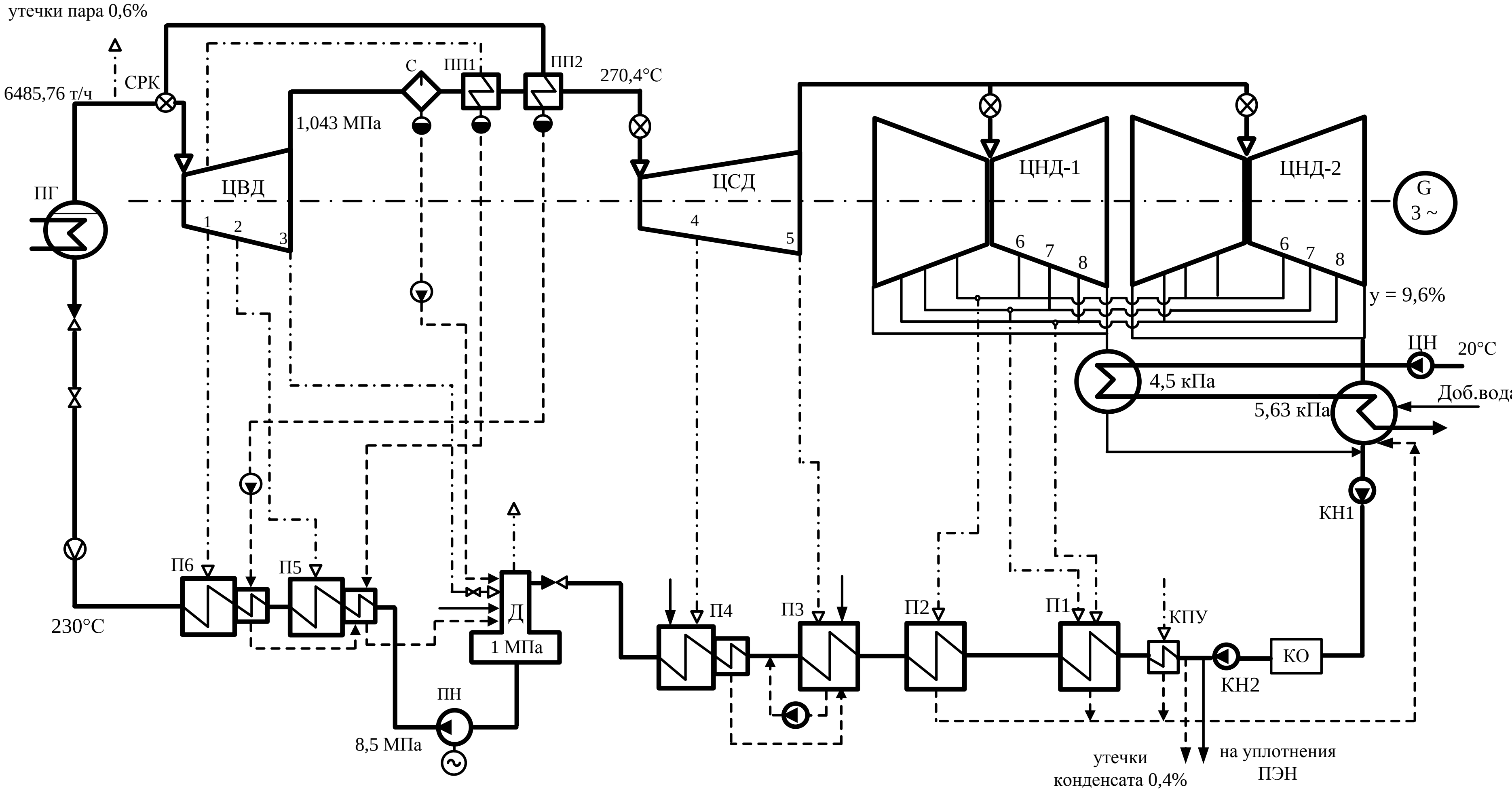
Schematic diagrams of steam turbines in NPP



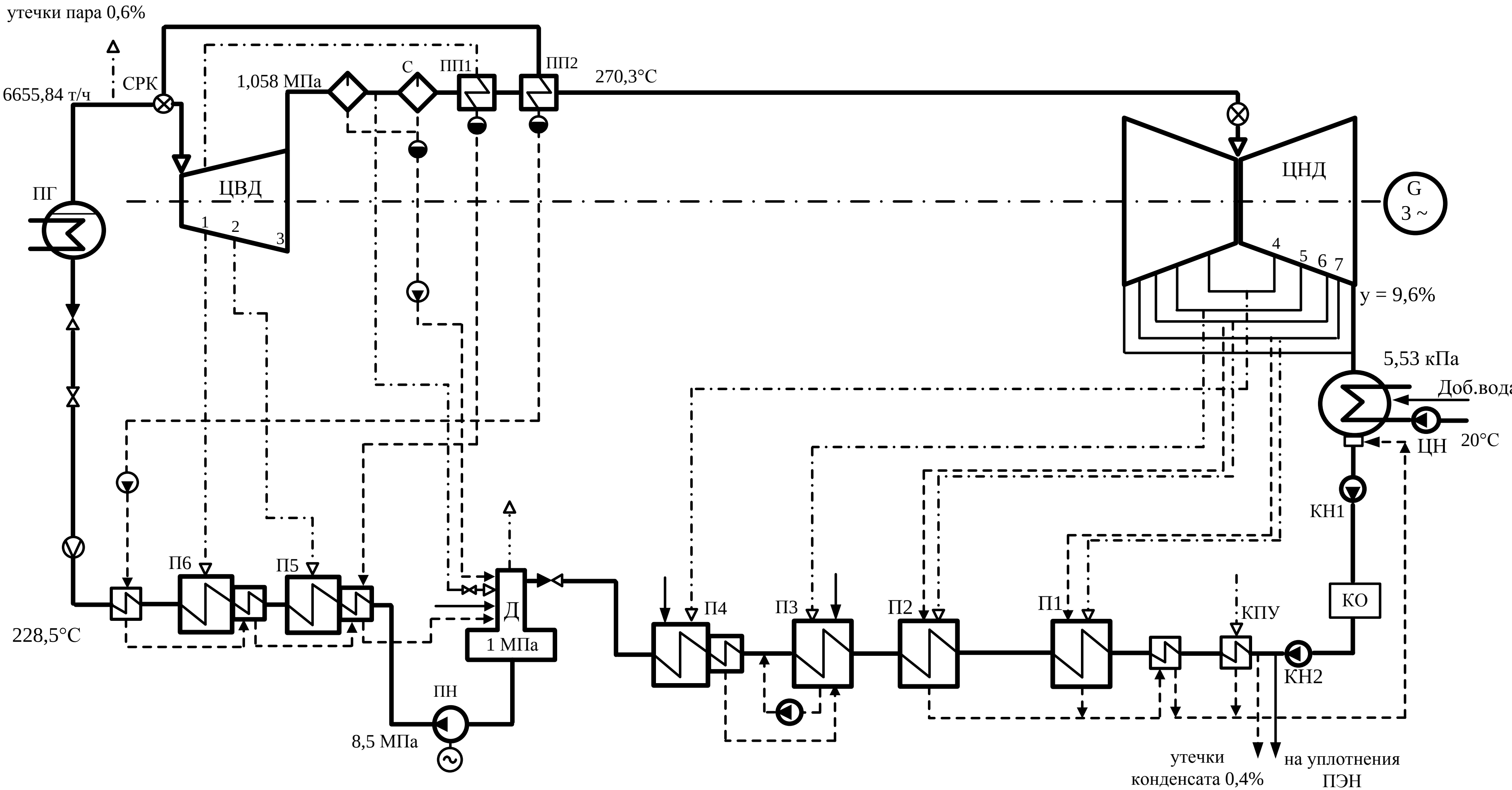
Cycle arrangement of the turbine K-1200-6.8/25 by JSC "Power Machines"



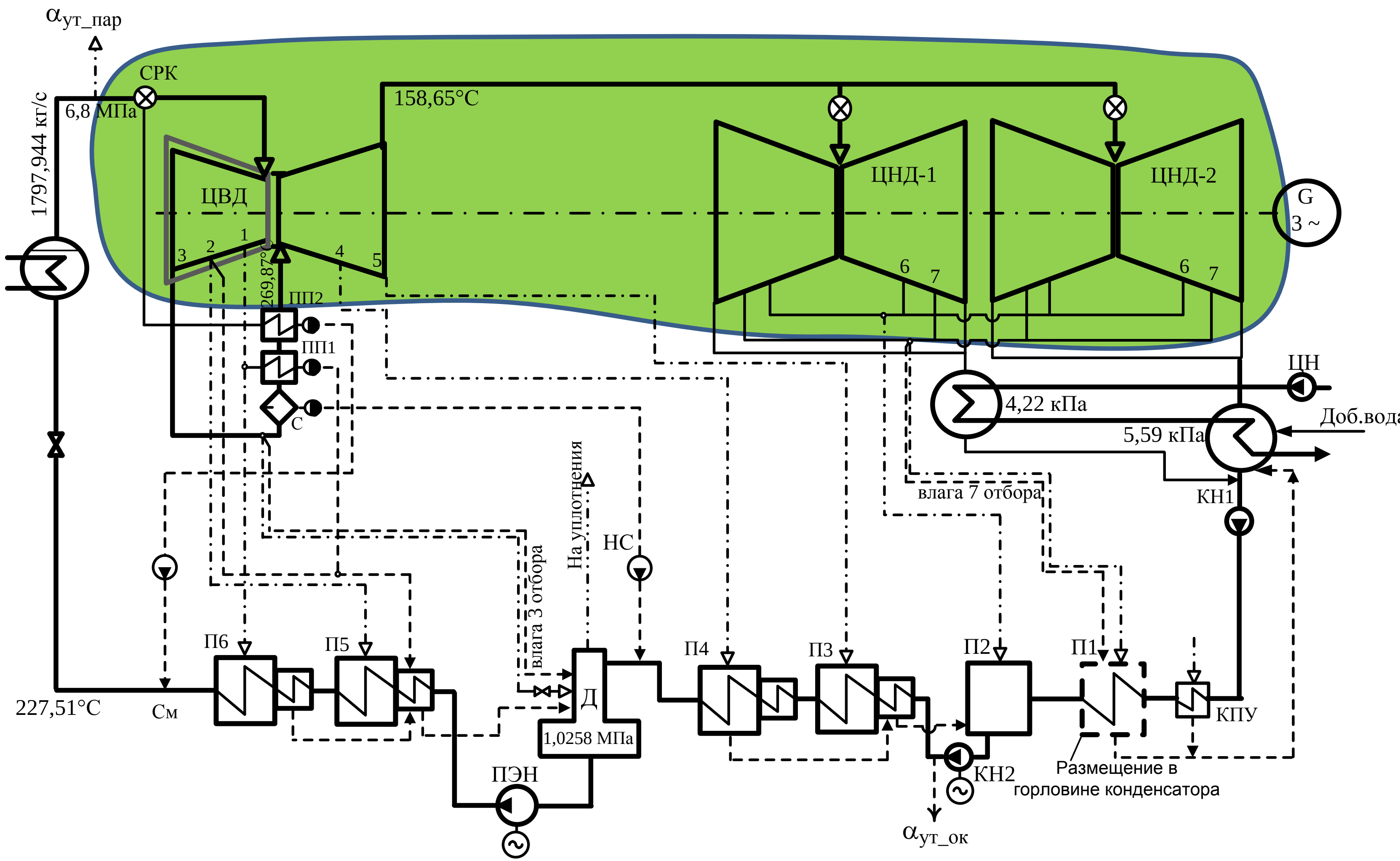
Cycle arrangement of the turbine К-1200-6.8/25 by JSC "Turboatom" (Kharkiv, Ukraine)



Cycle arrangement of the turbine by "ALSTOM"



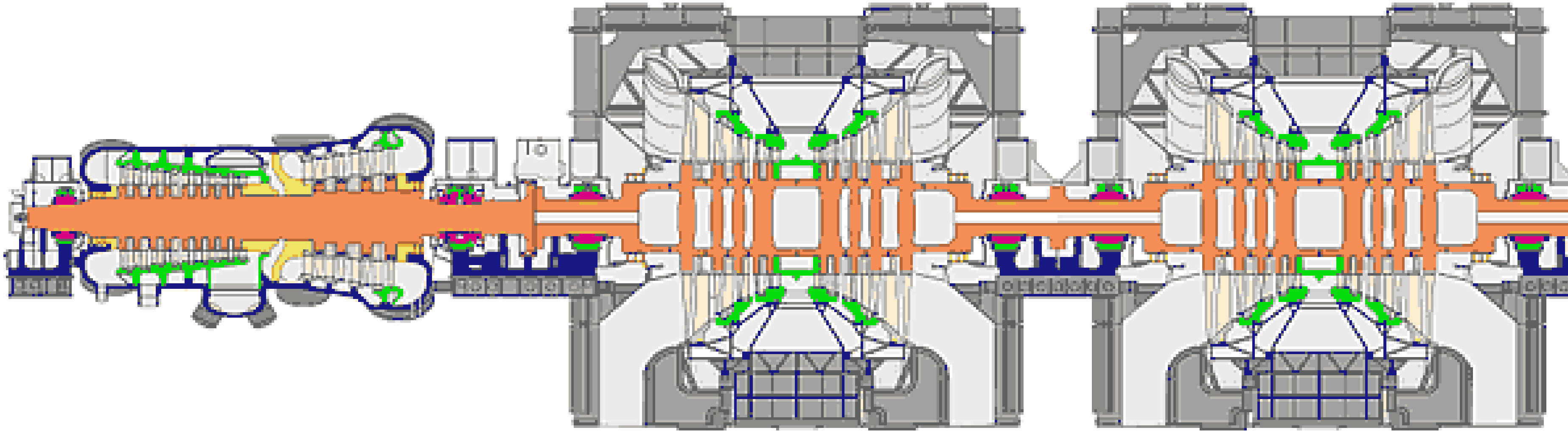
Information cycle arrangement of the turbine by "SIEMENS AG"



αут_пар
СРК
6,8 МПа
1797,944 кг/с
158,65°С
ЦВД
ЦНД-1
ЦНД-2
G
3 ~
3
2
1
4
5
6
7
6
7
269,87°С
ПП2
ПП1
С
ЦН
4,22 кПа
5,59 кПа
Доб.вода
КН1
влага 7 отбора
На уплотнения
НС
влага 3 отбора
П6
П5
П4
П3
П2
П1
Д
1,0258 МПа
227,51°С
См
ПЭН
КН2
КПУ
Размещение в горловине конденсатора
αут_ок

Longitudinal cross section of the turbine K-1200-6.8/25, JSC "Power Machines”

$L_{last\ stage}$ = 1740 mm



State of matter

State of aggregation of matter: solid, liquid, gaseous, plasma.

Heating level: cold, warm, hot ...

Other characteristics...

? How to quantify the state of matter?

The state of matter is unambiguously determined if we know two ***independent*** thermodynamic properties…

Thermodynamic properties:

- temperature – heating level of the body, t [°C], T [K]
  - internal energy $u=f(t)$ [kJ/kg] is related to the temperature
- pressure is the exerted force of gas (or liquid) per unit area normal to this surface, *p [Pa = N/m²], kPa, MPa; bar; ATA; ATG ;*

  total, static, dynamic pressures are considered for the flow
- density is mass per unit volume, ρ [kg/m^3]

  - specific volume is the volume of unit mass, $\upsilon=1/\rho$ [m^3/kg]
- enthalpy is stored energy per unit mass of the substance, h [kJ/kg]
- entropy is the probability of the state of matter, s [kJ/$kg\cdot K$]
- dryness fraction is the proportion of vapor in the wet steam volume .

$$ds = \frac{\delta q}{T}$$

Equations of state:

$$p\upsilon = RT$$ Clapeyron equation

$$h = \frac{k}{k-1} p\upsilon + const$$ enthalpy equation,

where k is specific heats ratio $k = \frac{c_p}{c_\upsilon}$

- ✓for superheated steam $k = 1,26 \ldots 1,33$

  For estimations, it can be taken $k_{nn} = 1,3$

- ✓for dry saturated steam $k_{вn} = 1,135$
- ✓for air $k_{возд} = 1,4$

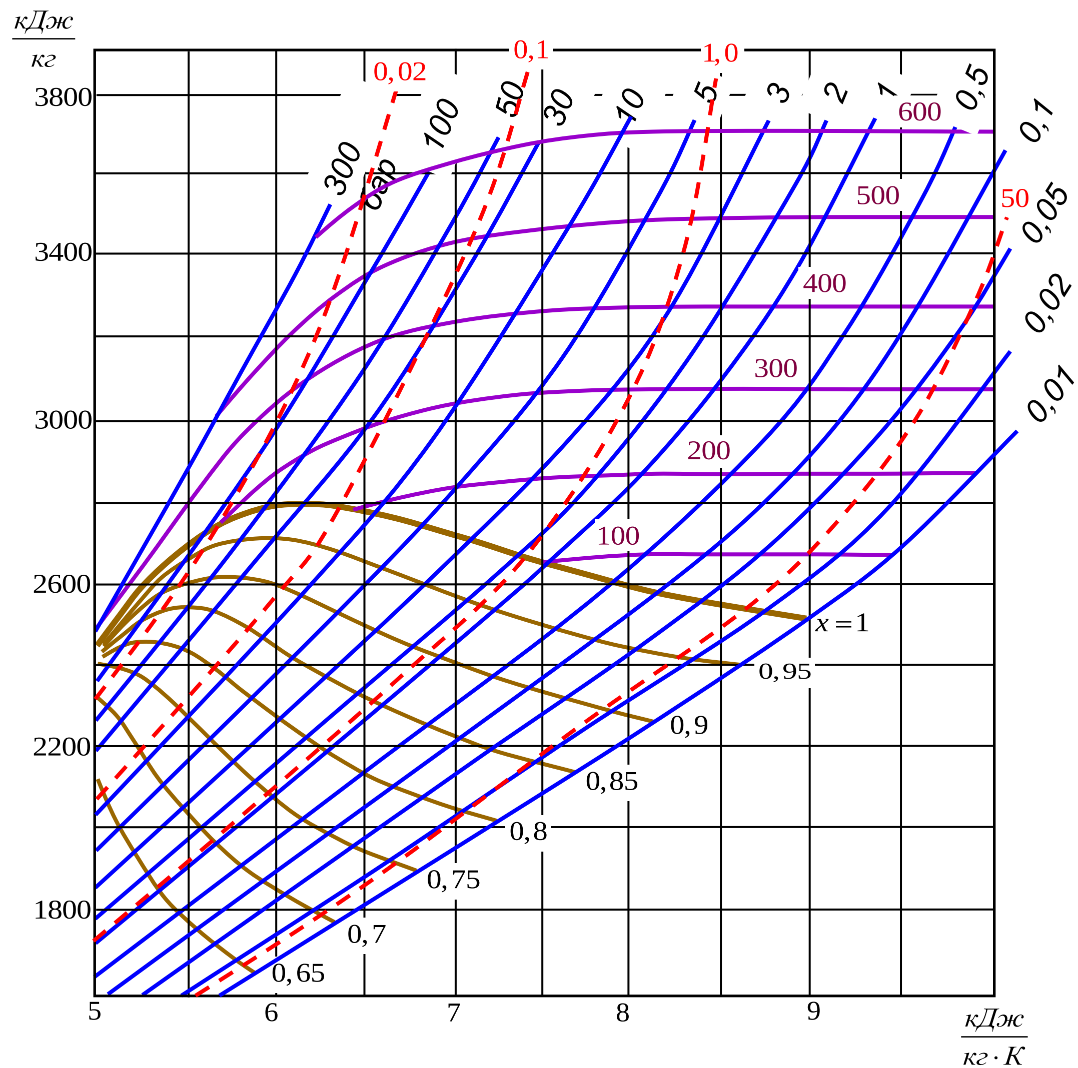
The equations of state as formulas are used for **analytical description of processes**

For calculations, we use:

- **tables of thermodynamic properties;** (discrete ratios of parameters)
- **charts** based on tables

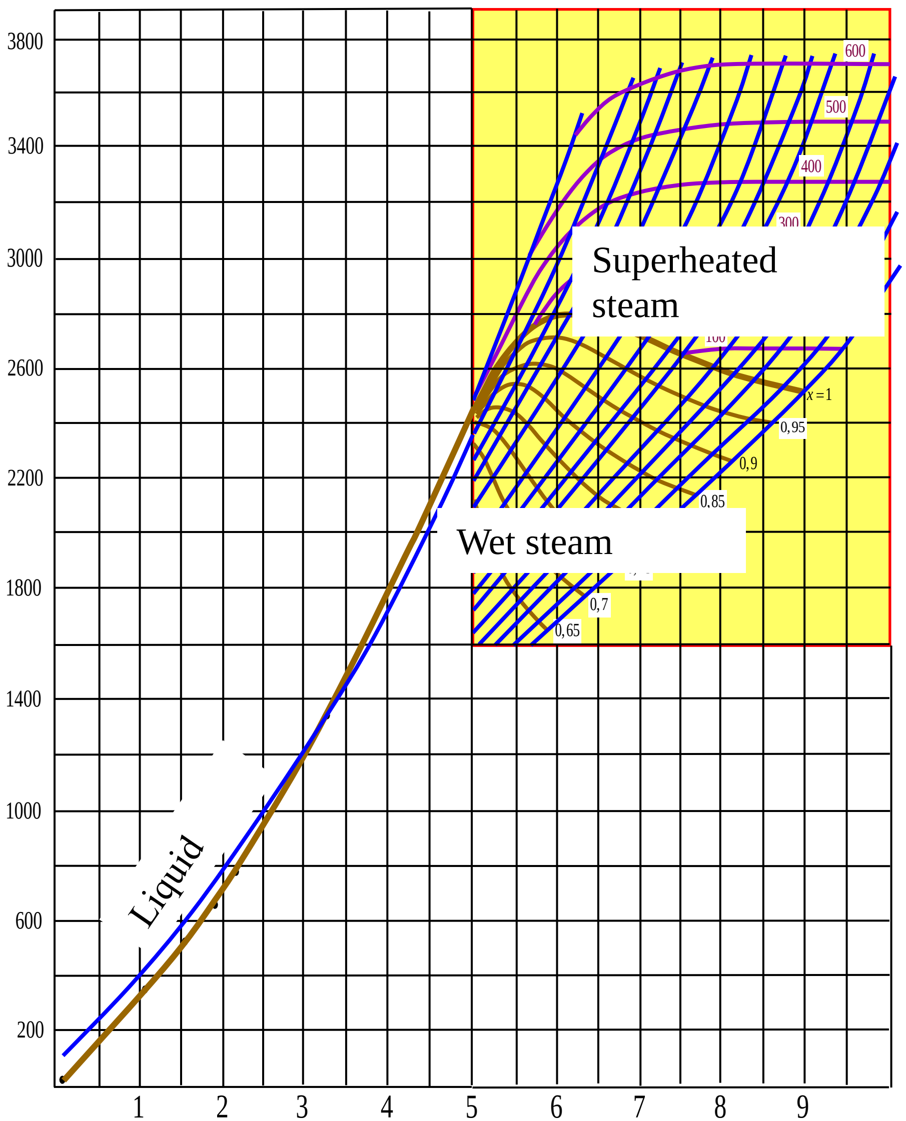
A. *hs* Mollier chart

suggested in 1904 for calculation of steam turbines



The disadvantage is low accuracy of parameter determination

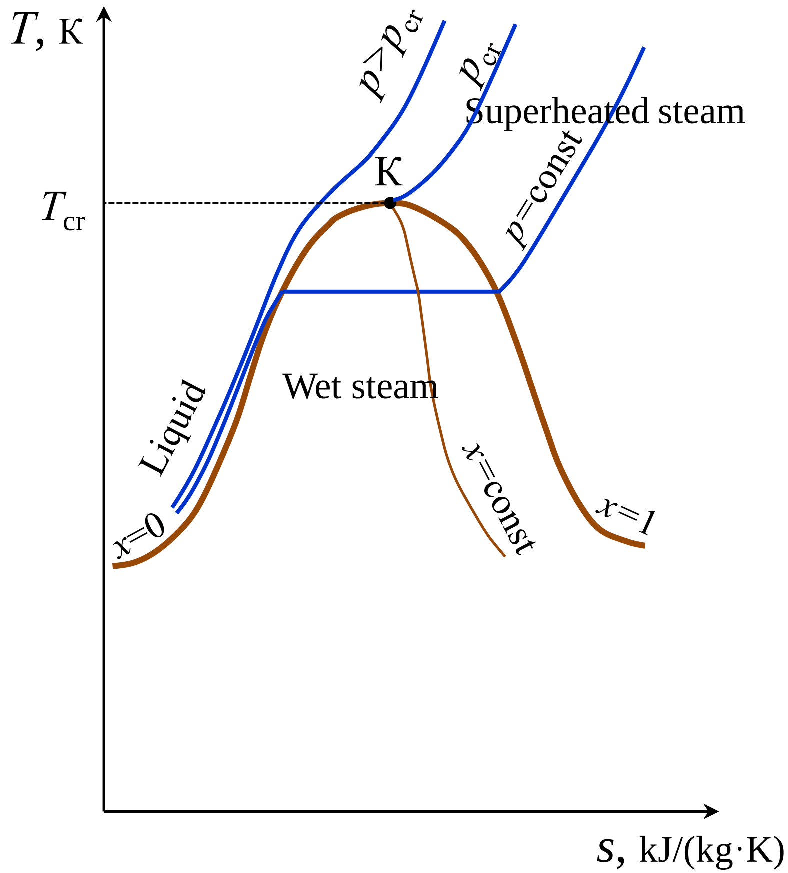
It is convenient in terms of process visualization


3800
3400
3000
2600
2200
1800
1400
1000
600
200
1
2
3
4
5
6
7
8
9
600
500
400
300
100
x = 1
0,95
0,9
0,85
0,7
0,65
Superheated steam
Wet steam
Liquid

Б. *Ts* chart

p. K is critical point

T_{cr}=375°C; p_{cr}= 22.5 MPa



➢electronic work sheets which are made based on approximation of thermodynamic properties

Change in the state occurs as a result of the process