

STEAM TURBINES

Public lecture for students of Energietechnik (Jülich), FH Aachen

Prof., Dr. Eng. Cheilytko Andrii



Lecture plan



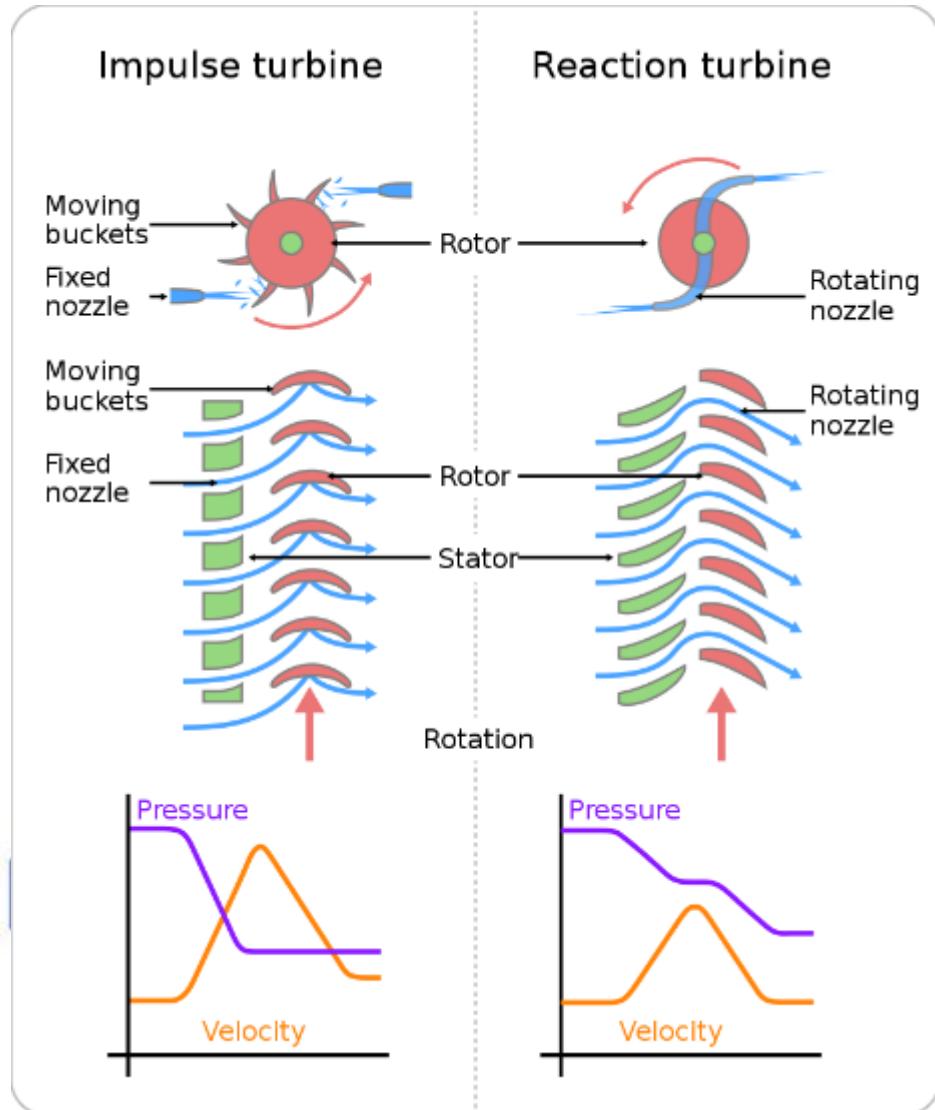
Introduction

1. Turbine stage calculation
2. The use of steam turbines in power plants
3. Steam turbine in Julich Solar tower

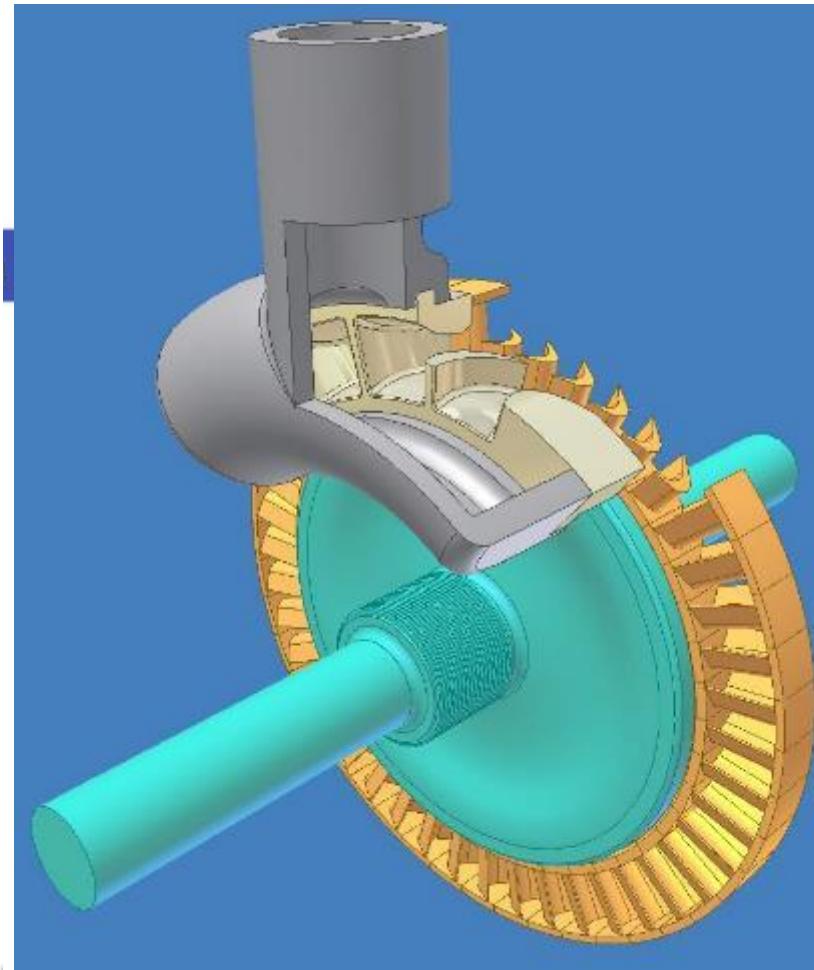
Literature and links

Impressum

What we remember from school...



<https://naukozavr.info/wp-content/uploads/2020/07/Shematichna-budova-parovoyi-turbiny.jpg>



<https://de.wikipedia.org/wiki/Dampfturbine#/media/Datei:Curtis-turbina.jpg>

Classification of steam turbines



active turbines

reactive turbines

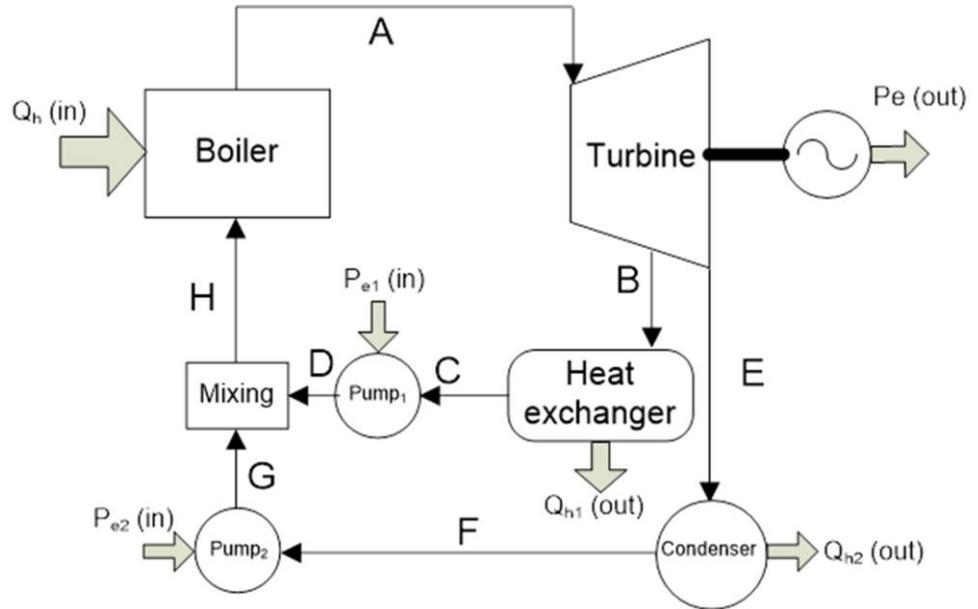
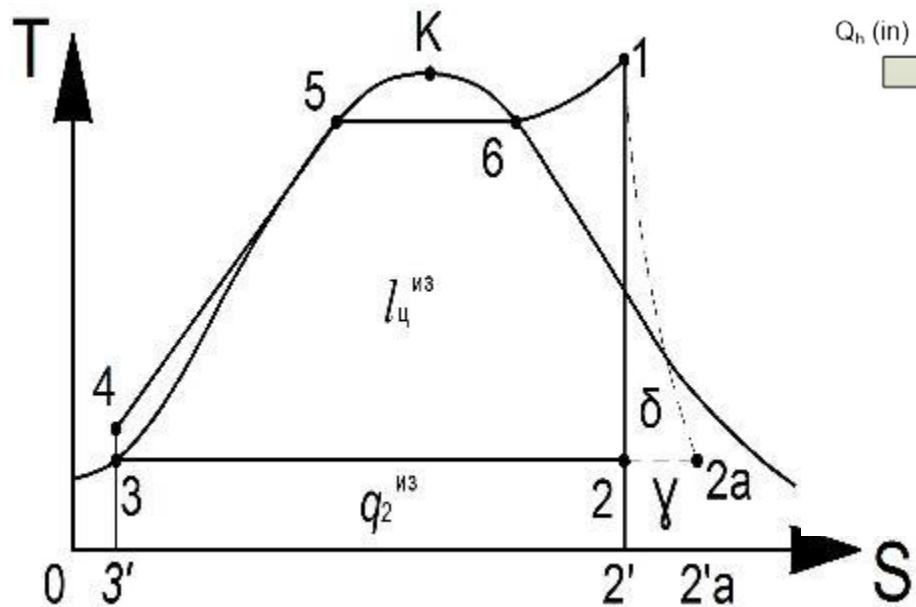
**Condensing
and Noncondensing
Turbines**

**Back-Pressure
Steam Turbines**

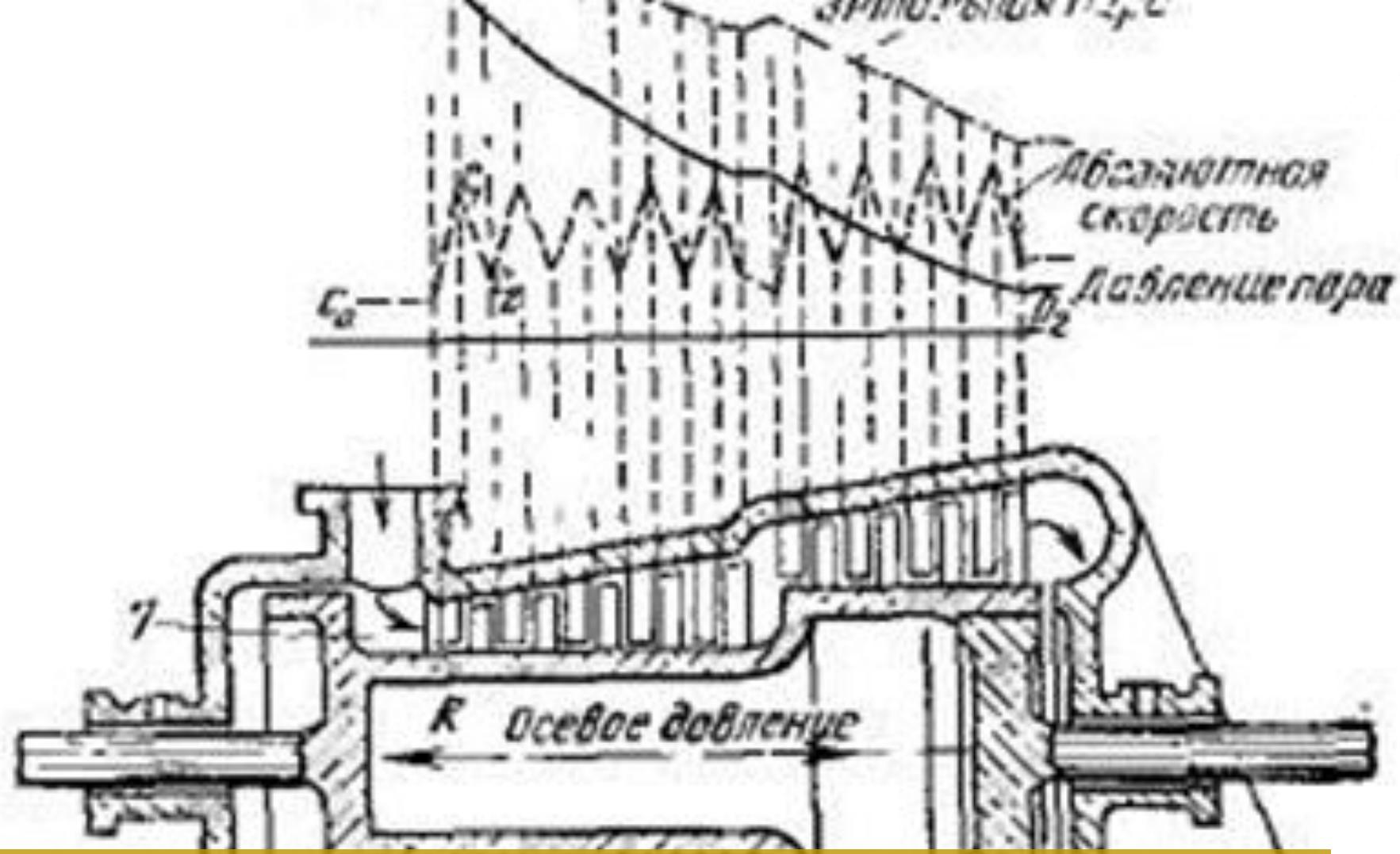
**Extraction Steam
Turbine**

Combined cycle of a steam turbine unit

$$l_{\text{u}} = q_1 - (q_2^{\text{u3}} + \gamma)$$

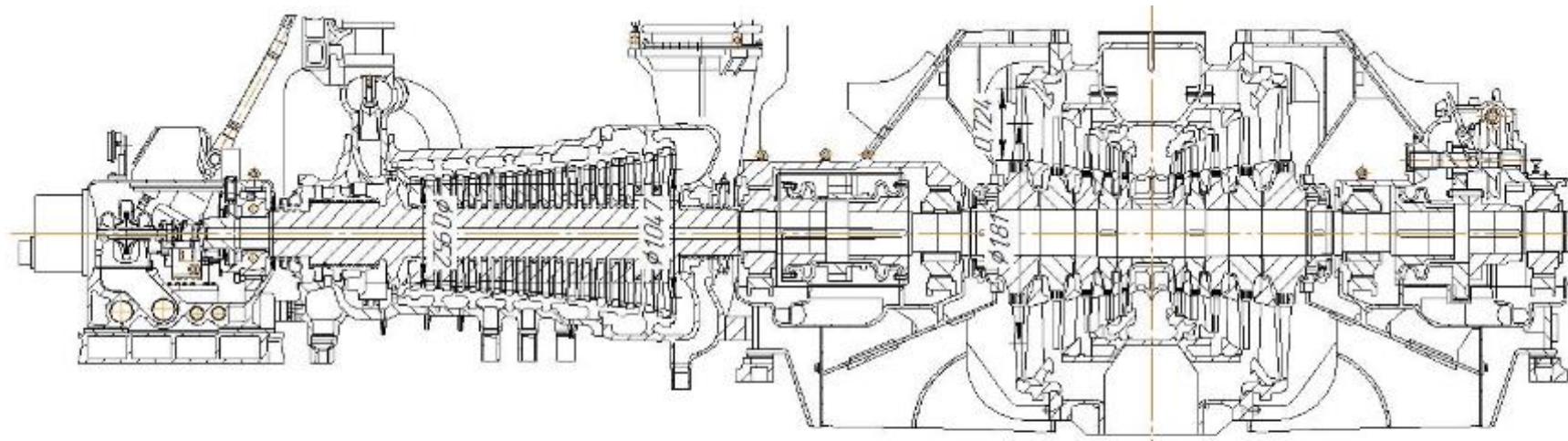


<https://electricala2z.com/electrical-power/combined-heat-power-plants-steam-gas-micro-turbine-fuel-cell/>

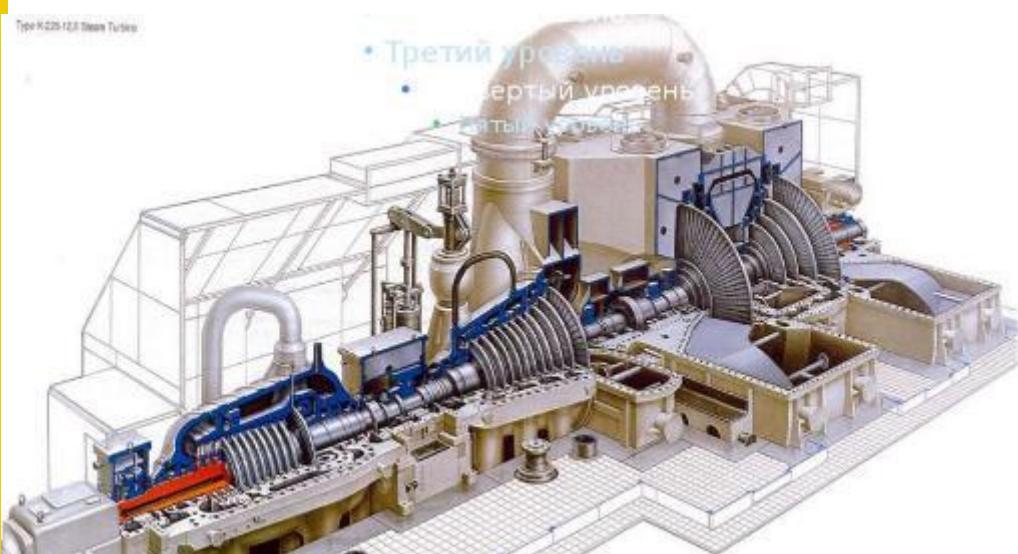


TURBINE STAGE CALCULATION

Longitudinal section of a condensing turbine



Type K-225-12/7 Steam Turbine



<https://svitppt.com.ua/fizika/parovi-ta-gazovi-turbini.html>

ФЕЕІТ ТГЕ ДРМ 18. 015 02 01 001			
Лист	№ Документ	Підпіл	Дата
Розроб	Джуринюк КС		
Проб	Бакотин ВІ		
Технічн.			
Инженер	Кузьменко А.А		
Учеб	Бакотин ВІ		

Послідовність ефективності когенераційної конденсаційної системи енергопостачання в порівнянні з КЕС

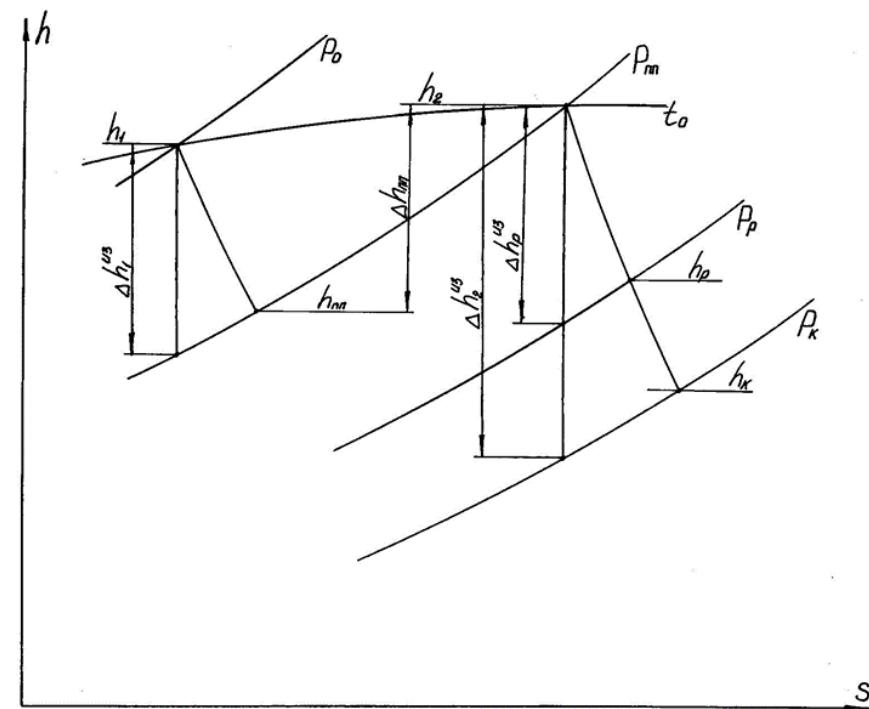
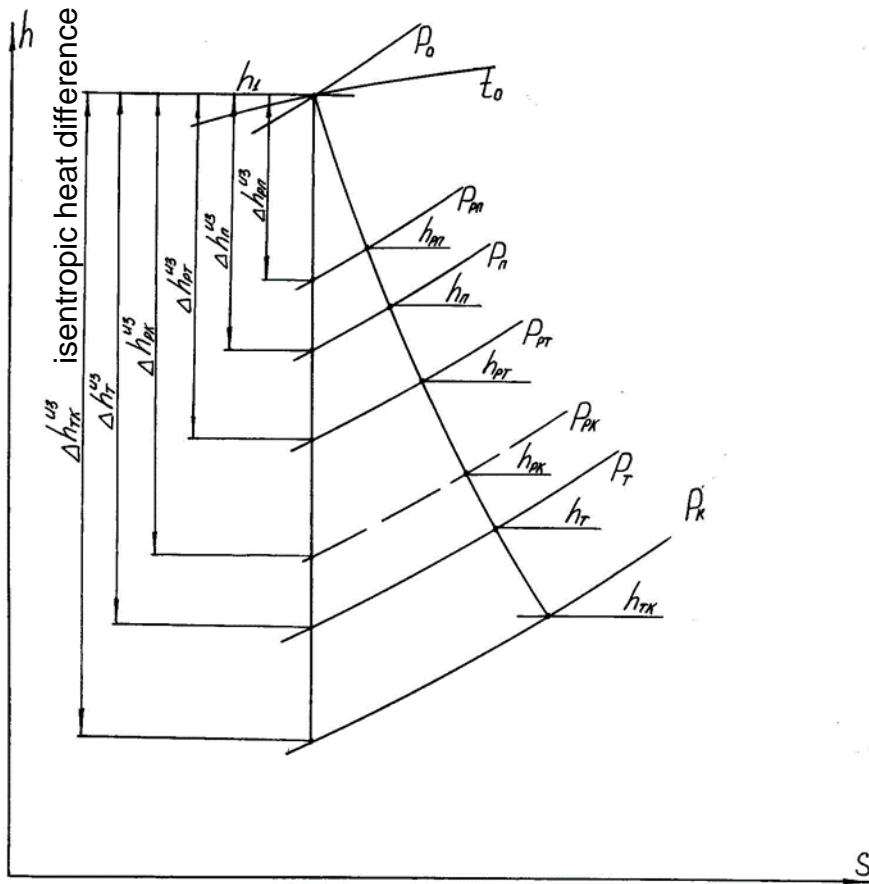
ЗДА коф. ТГЕ
гр. ТЕ-17 м3

Формат А3

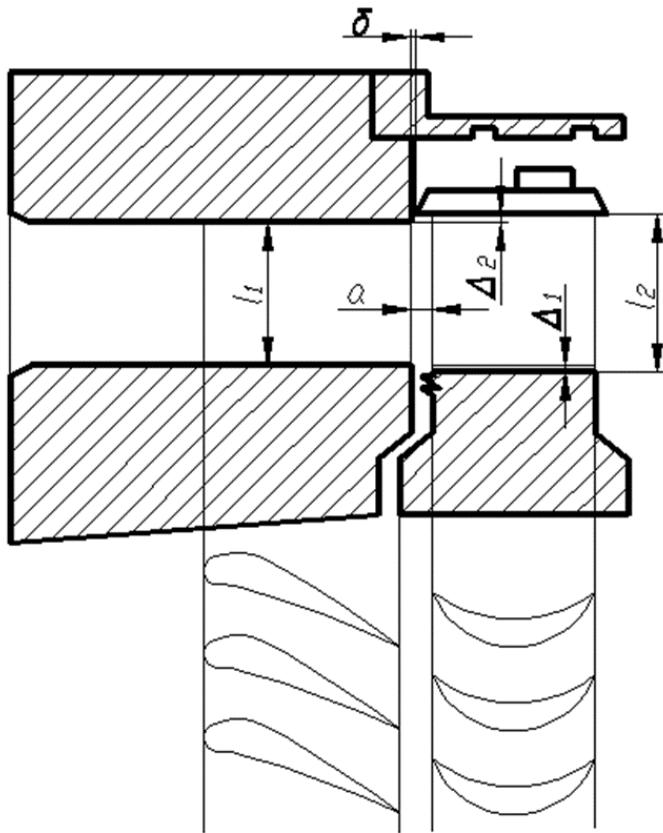
The process of steam expansion in the turbine flow path



- Cogeneration operation of the turbine
 - With intermediate overheating

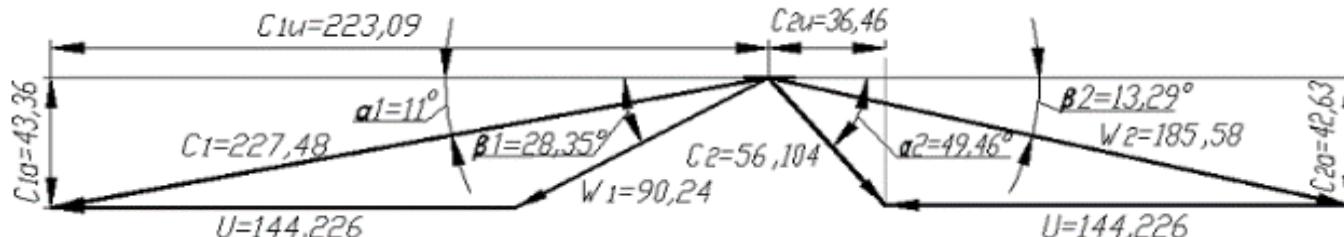


Sketch of the flow part of the intermediate stage.



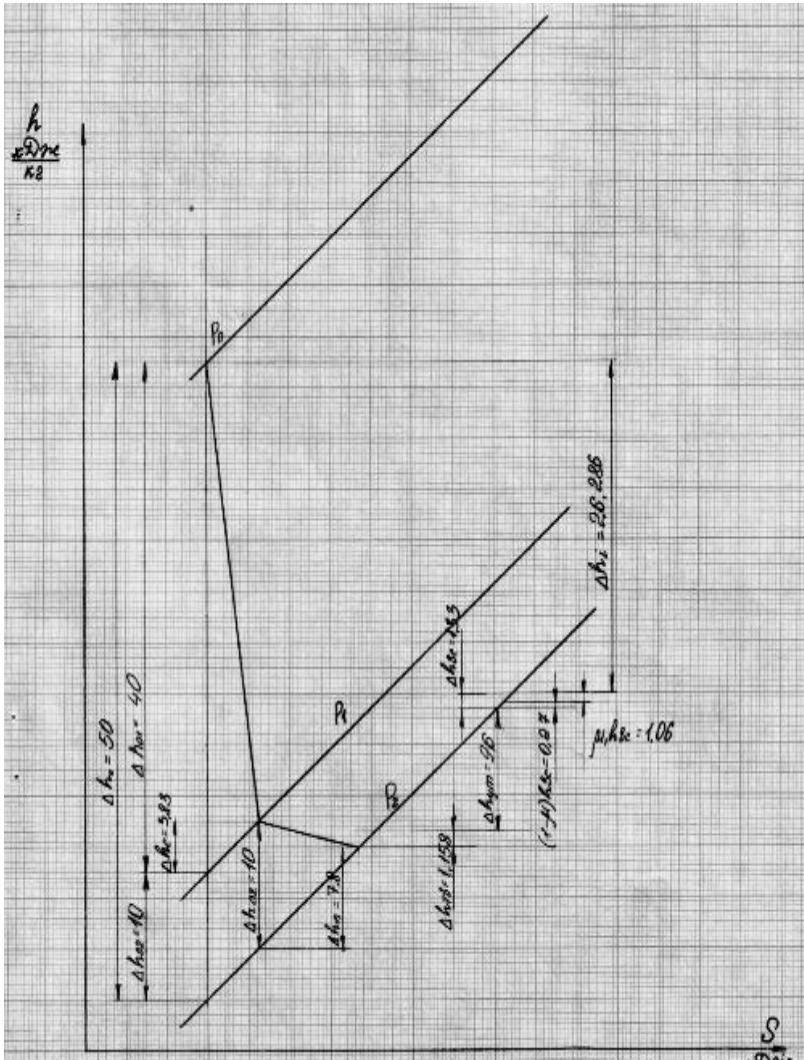
Step 1 Calculation of the steam turbine stage

- I. the heat drops
- II. dummy velocity of steam flow
- III. average diameter of the stage skirting
- IV. actual steam velocity at the outlet of the nozzle channels
- V. nozzle grille height
- VI. steam exit angle from the working blades
- VII. actual relative velocity of steam at the outlet of the blades
- VIII. Also we find the velocity projections $C_{1\text{circum},\text{axial}}$ and $C_{2\text{circum., axial}}$



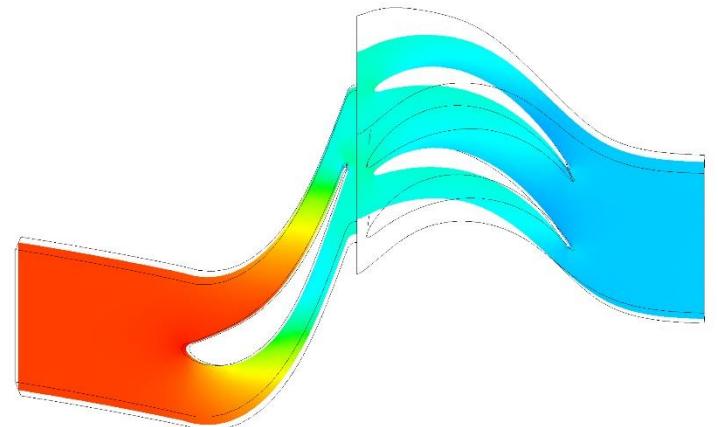
Speed triangles of the turbine stage

The thermal process of the unregulated stage in the $h-s$ diagram



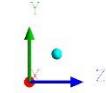
Step 2

DETERMINATION OF LOSSES AND
EFFICIENCY OF THE TURBINE STAGE

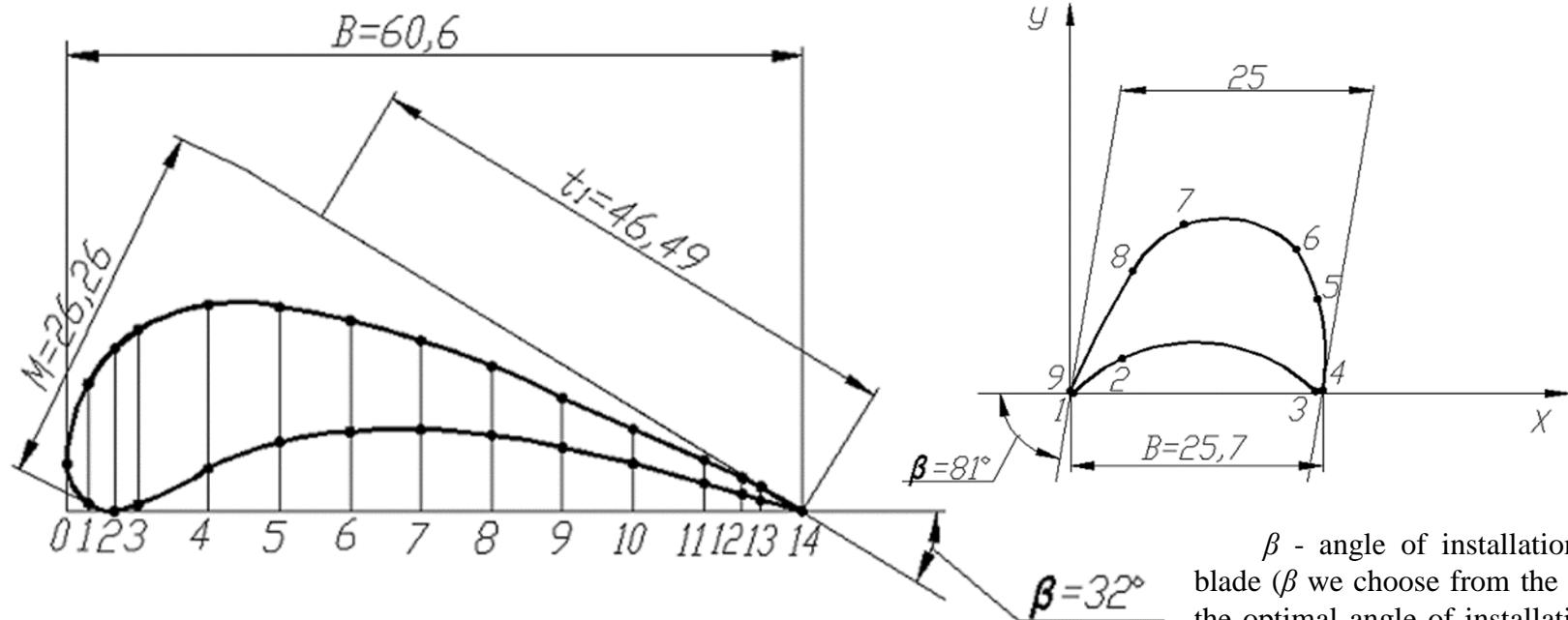


<https://www.fetchcf.com/view-project/78>

0 0.025 0.050 0.075 0.100 (m)



Sketch of the profile of the nozzle and impeller blades



β - angle of installation of the blade (β we choose from the range of the optimal angle of installation). We take the optimum angle $\beta = 80^\circ$, draw a sketch of the blade.

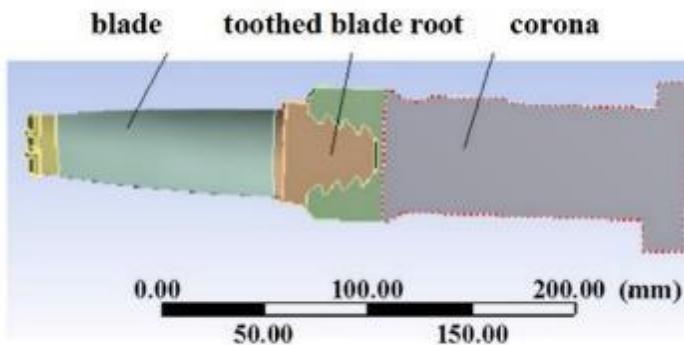


Figure 1. Final blade and wheel geometry

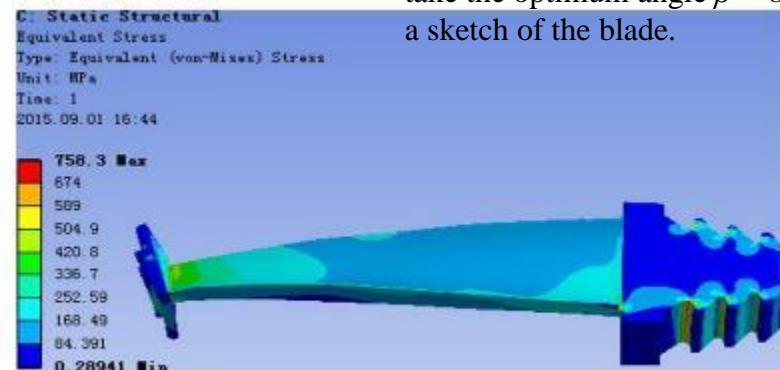
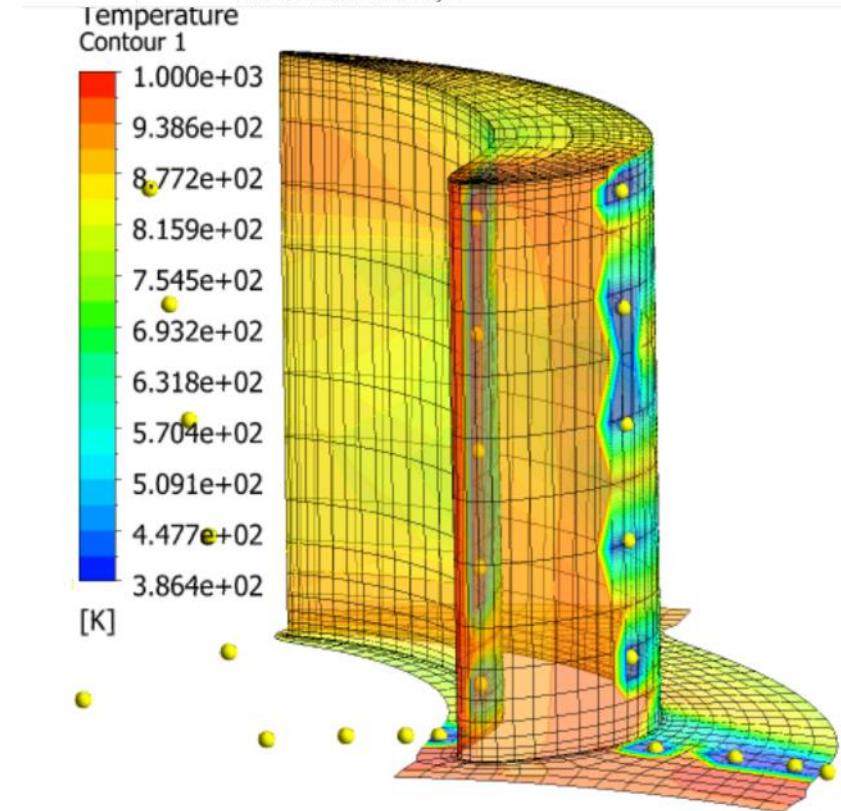
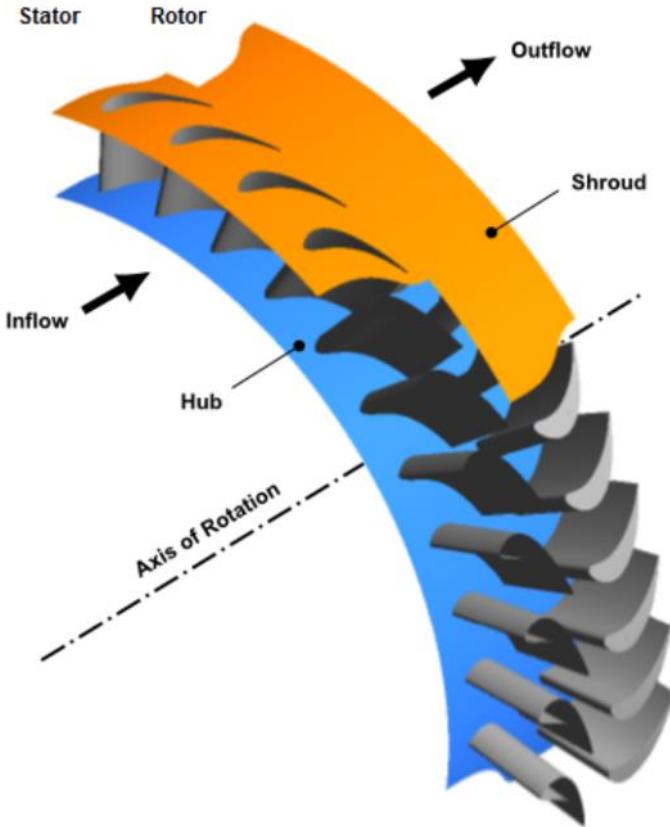


Figure 4. Blade stress distribution cloud map

Fig1, Fig4: Zhu, M. Y. (2019). Design and analysis of steam turbine blades. 3rd International Conference on Fluid Mechanics and Industrial Applications, 1300.

Cooling hole locations inside the modeled passage (as well as many outside the passage)



Ansys_CFX_Tutorials_2022_R2

THE USE OF STEAM TURBINES IN POWER PLANTS

Types of energy

Thermal

Electric



Source: <http://wikimapia.org/1470585/Maritsa-Iztok-Mining-And-Electricity-Complex>

Source of power supply

Split circuit

Combined circuit



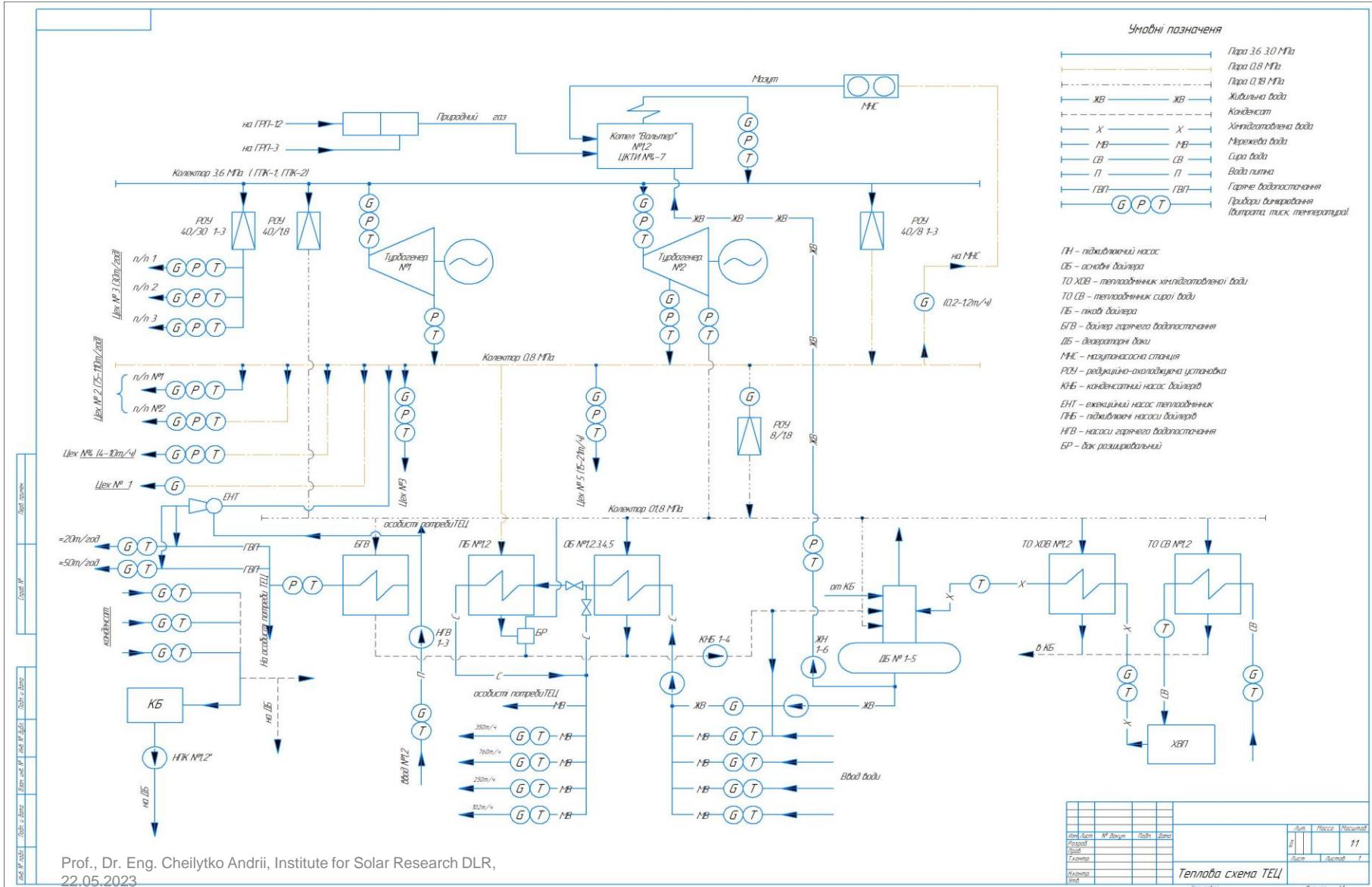
Electricity is produced at the power plant TPP and transmitted to the consumer via power lines

Heat energy is produced in district boiler houses and transmitted through heating networks in the form of steam or hot water to the consumer.

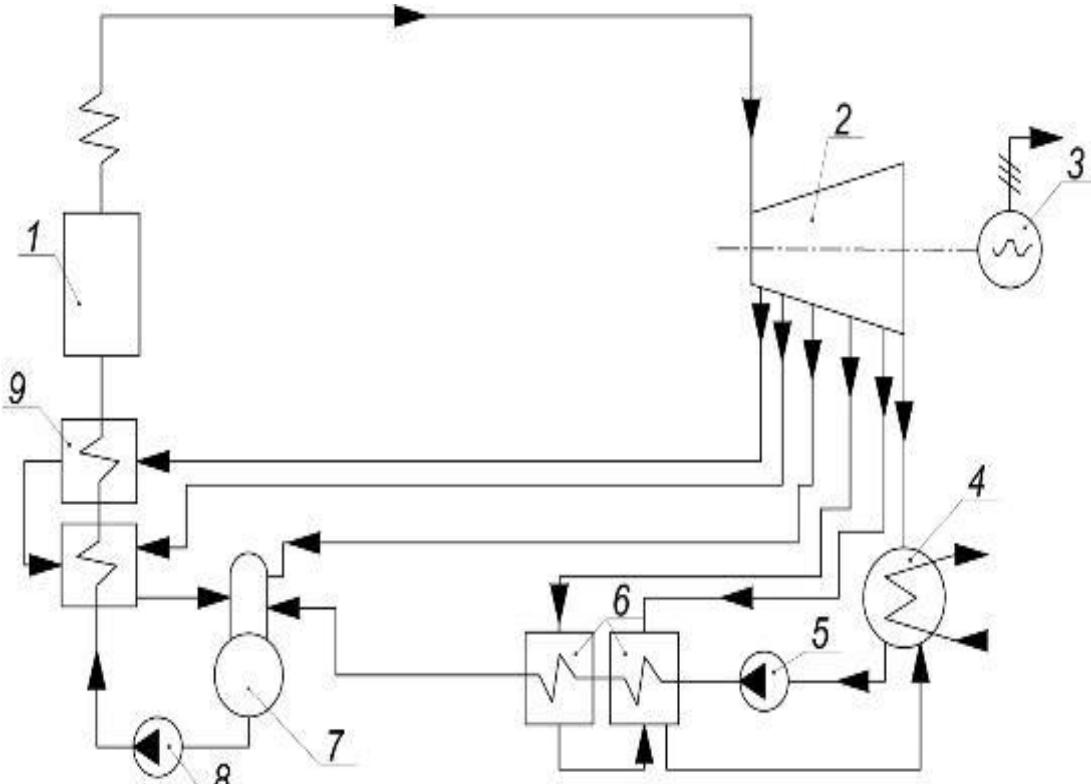
Heat and electricity are generated at the **CHPP**. The combined system is electrically connected to the energy system of the region, which makes it possible to compensate the imbalance between the production and consumption of electricity at any time.

The combined system requires additional capital costs, but is more economical in terms of fuel consumption.

Real scheme of cogeneration plants with back-pressure turbines



Schematic diagram of a separate power supply



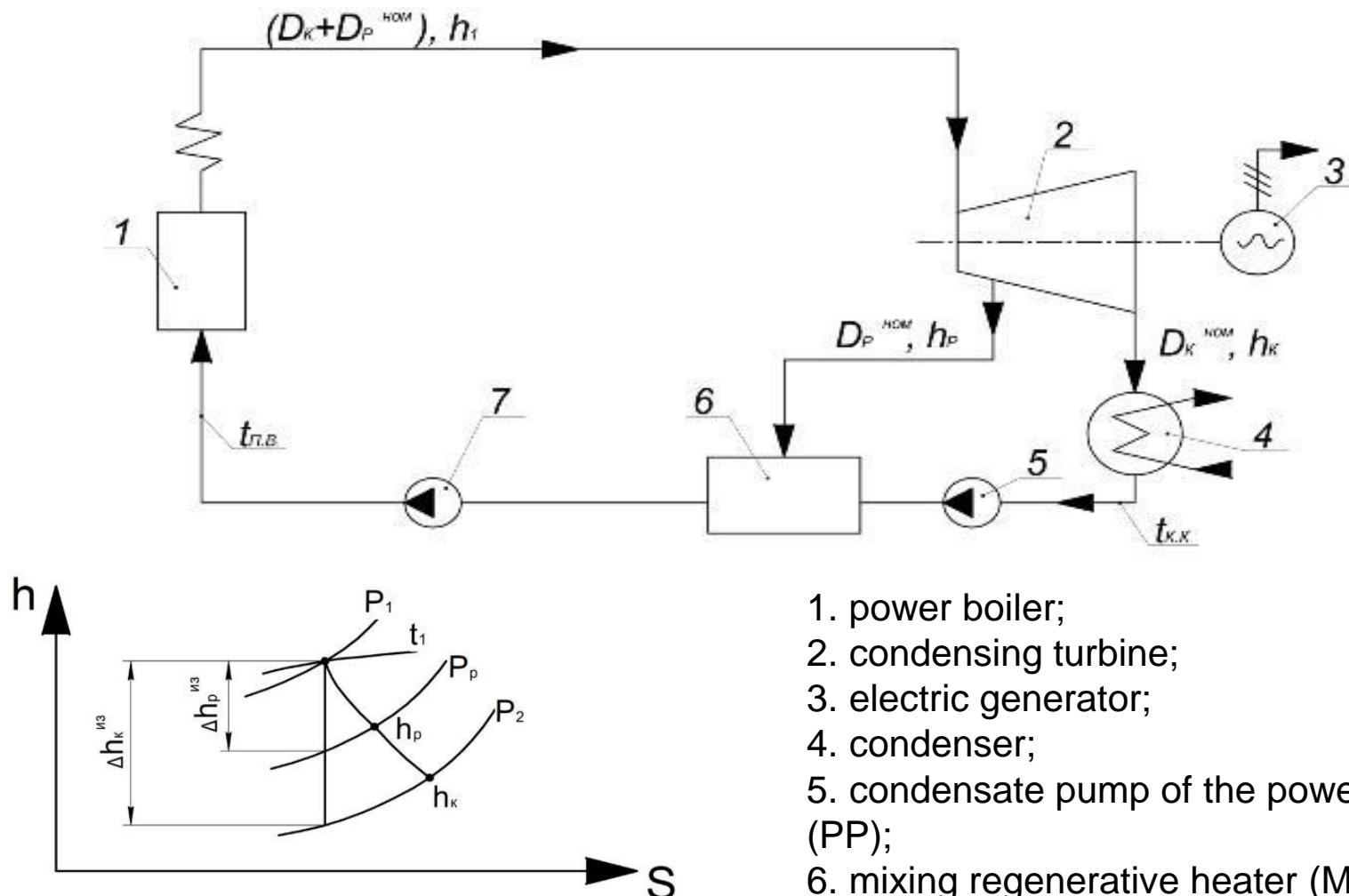
Prydniprovska TPP, Ukraine

1. power boiler;
2. condensing turbine;
3. electric generator;
4. condenser;
5. condensate pump of the power plant;
6. low pressure heaters (LPH);
7. deaerator;
8. feed pump of the CPS;
9. high pressure heaters (HPH);

Fig from

Cheilko A. Design and optimization of heat supply systems: a study guide for students of ZGIA specialty 144 "Heat Power Engineering" full-time and part-time. Zaporizhzhia: ZGIA, 2016. 200 p

Dummy scheme of a separate power supply system



1. power boiler;
2. condensing turbine;
3. electric generator;
4. condenser;
5. condensate pump of the power plant (PP);
6. mixing regenerative heater (MRH);
7. feed pump of the PP;
8. steam boiler of an industrial boiler house;

Fig.from

Cheilytko A. Design and optimization of heat supply systems: a study guide for students of ZGIA specialty 144 "Heat Power Engineering" full-time and part-time. Zaporizhzhia: ZGIA, 2016. 200p

Fictitious scheme of cogeneration plants with back-pressure turbines

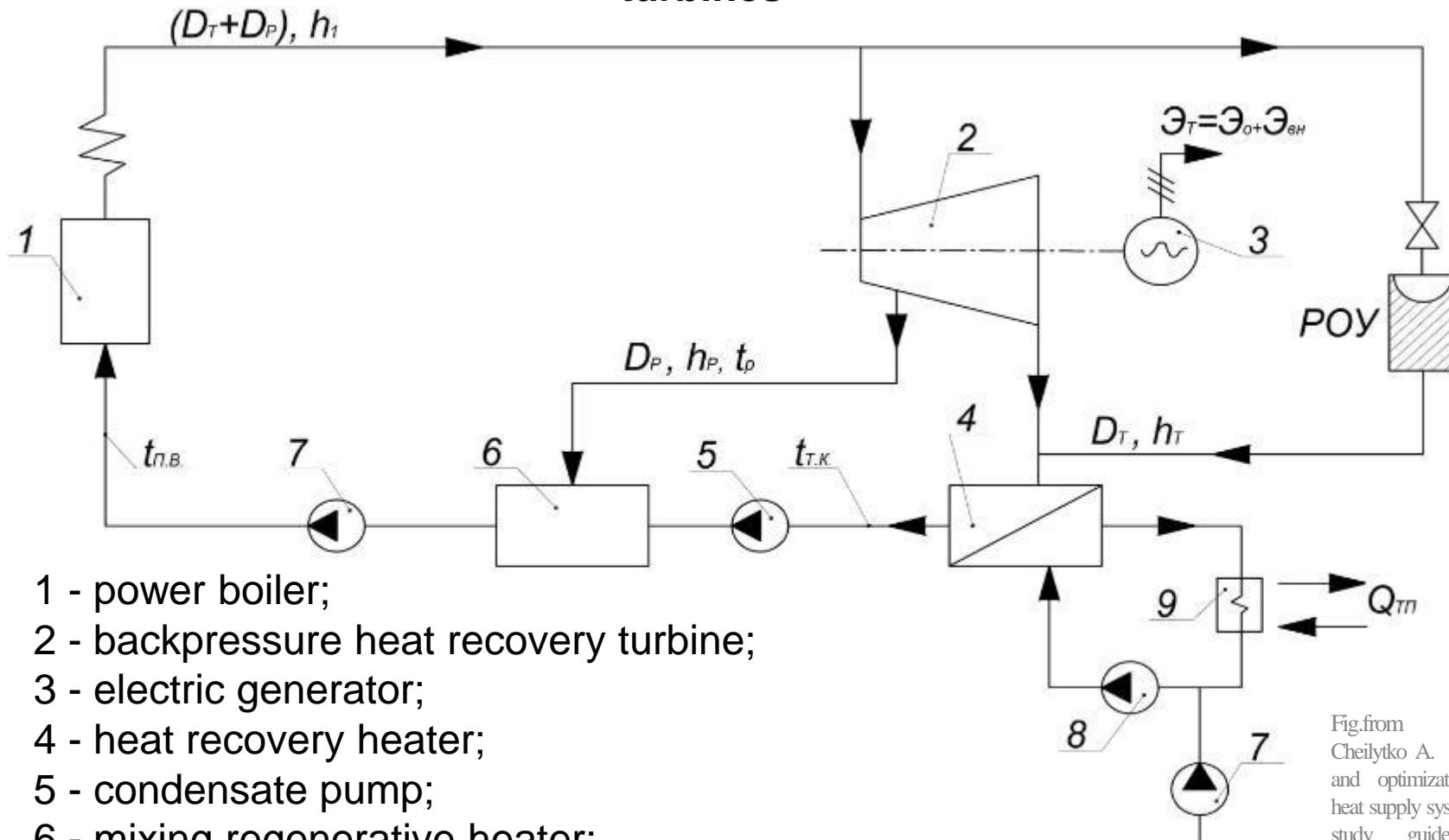


Fig.from
 Cheilytko A. Design
 and optimization of
 heat supply systems: a
 study guide for
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 specialty 144 "Heat
 Power Engineering"
 full-time and part-time.
 Zaporizhzhia: ZGIA,
 2016. 200 p

Advantages

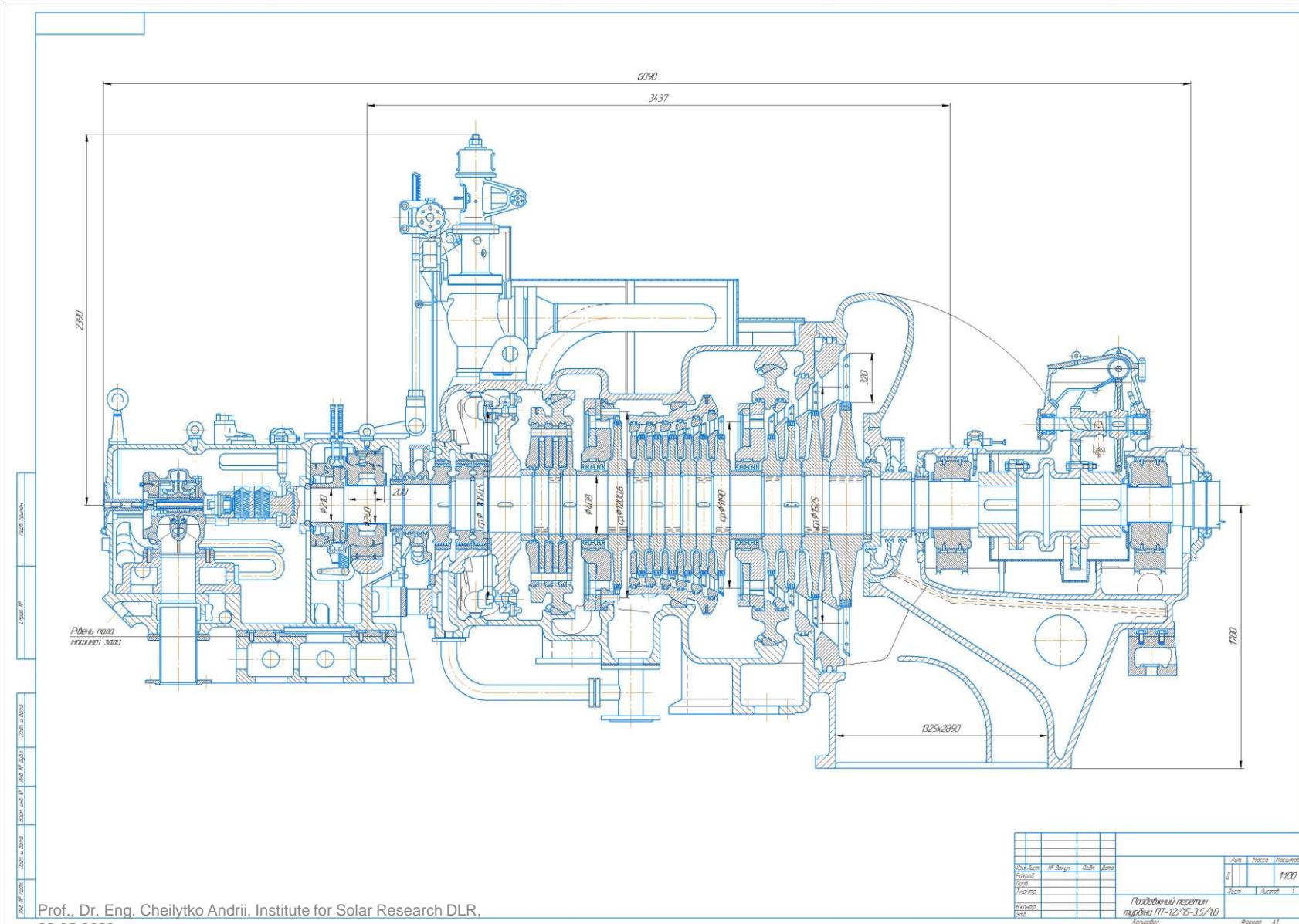
- Operation is possible with various fuels (gaseous, liquid, solid). High thermal efficiency.
- Unlimited unit power.
- High speed and possibility of non-serial connection to the generator shaft

Disadvantages

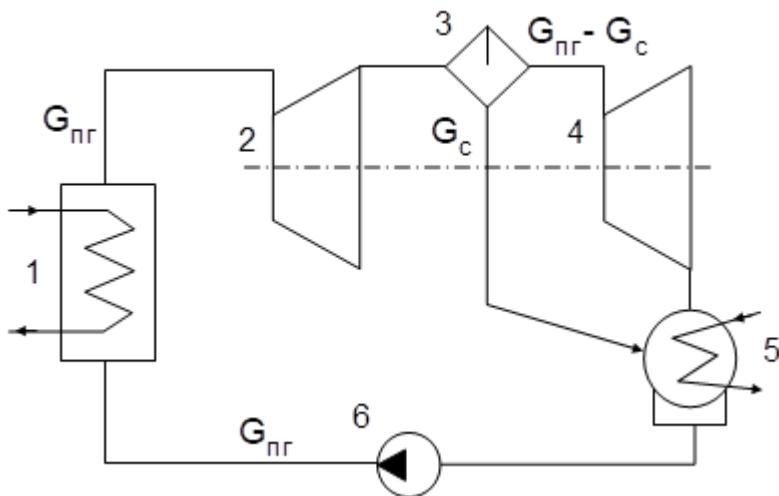
- Large dimensions and weight.
- Impossibility of creating a highly efficient steam turbine of low power.
- The need for a large amount of cooling.

Longitudinal section of the turbine

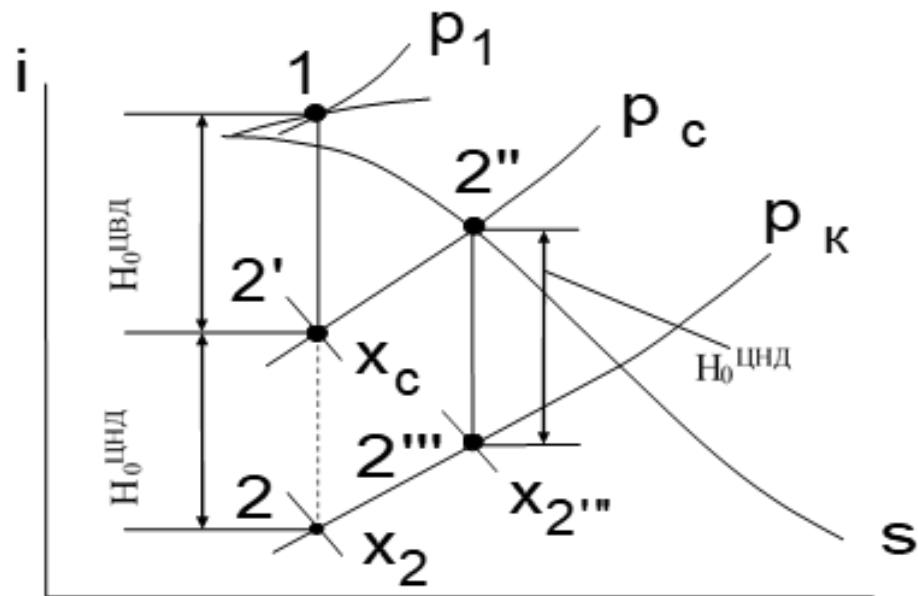
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ST with intermediate separation



- Functional diagram of a steam separation unit with intermediate steam separation

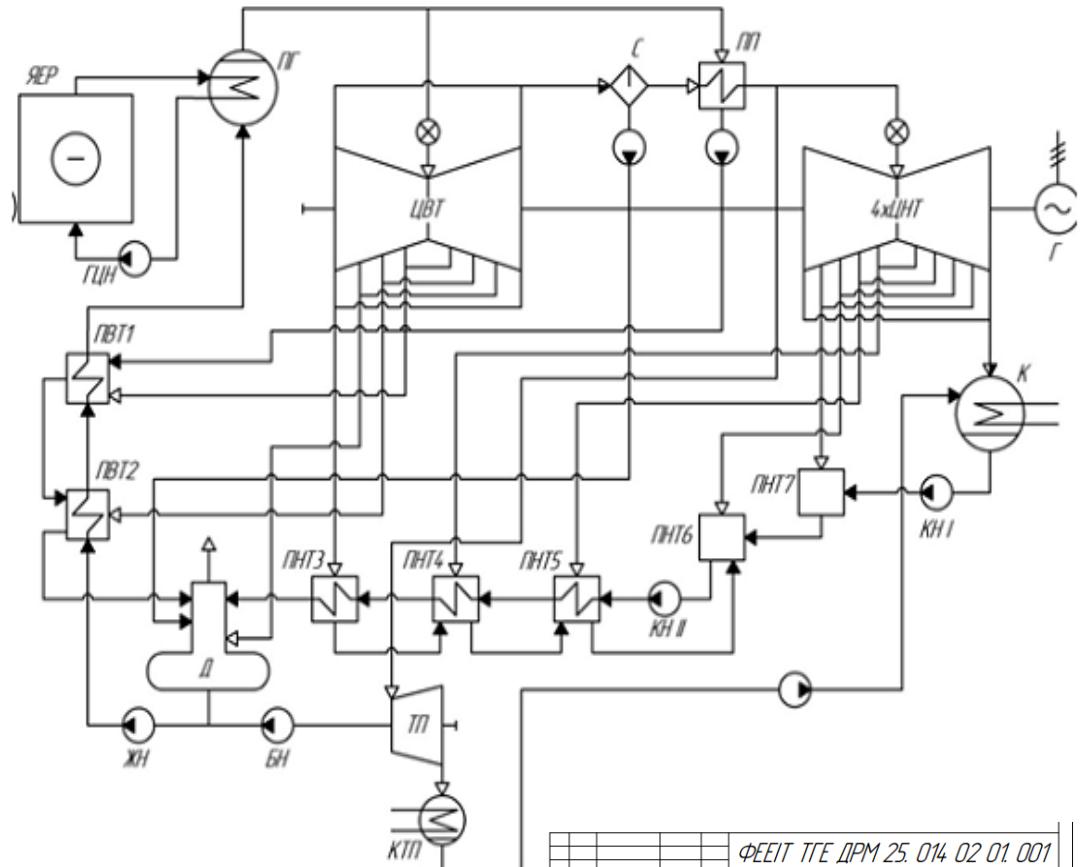


- Vapor expansion in a steam generating unit with intermediate separation on an *i-s* diagram

Schematic diagram of the steam turbine unit K-1000-60/3000



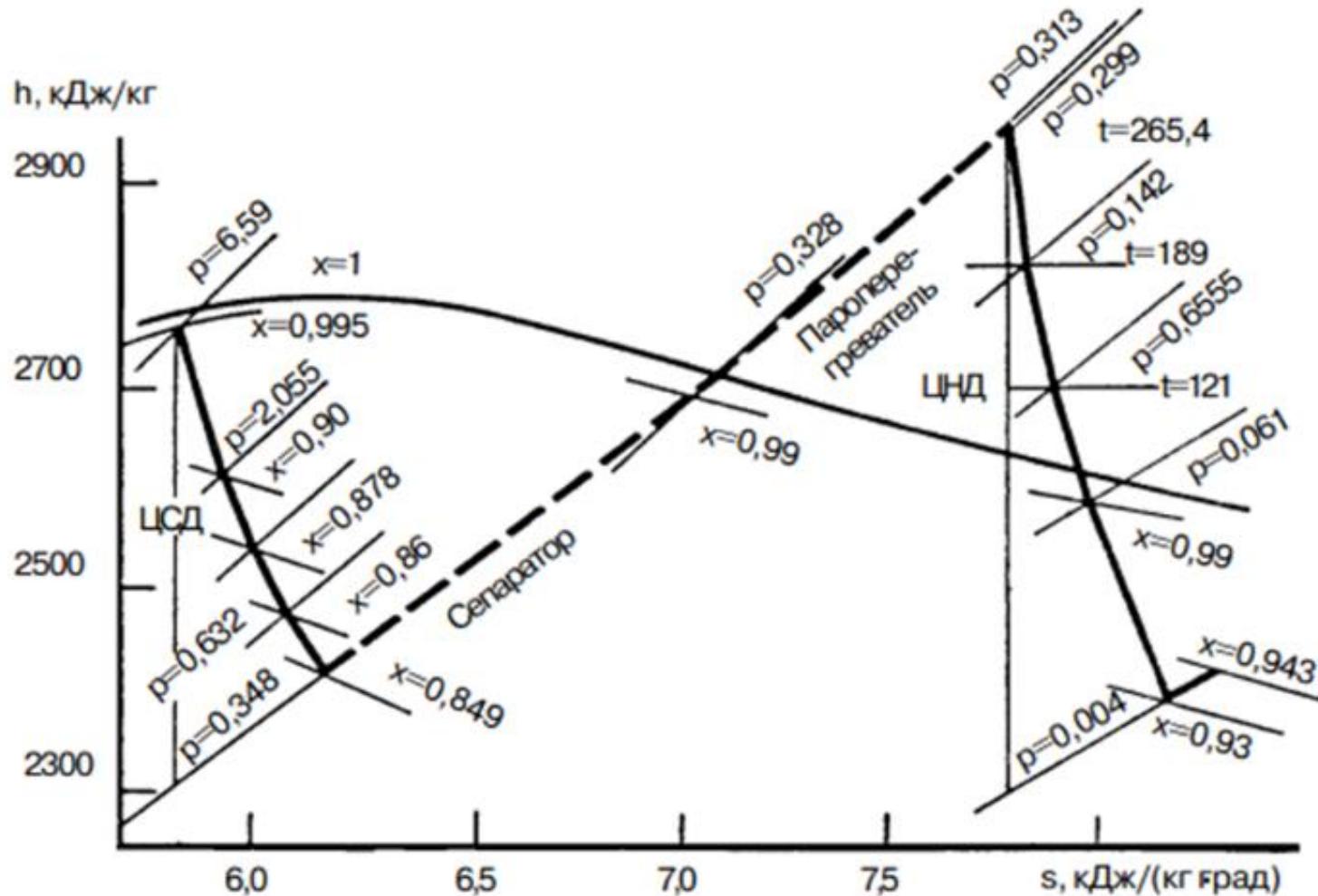
Source: Dampfturbine Montage01 - Парова турбіна — Вікіпедія
(wikipedia.org)



ФЕІТ ТГЕ ДРМ 25.014 02.01.001		
Ім'я/Локація	№ документу	Підп. /Ім'я
Розмір:	Насіння ОІ	
Підп.	Чечілікто А.О.	
Ім'я/Локація	Аналіз ефективності застосування проміжного перегорювача в паротурбінних установках АЕС	
Івандр.	Каркіш О.І.	Літність
Ччч	Чечілікто А.О.	Маса
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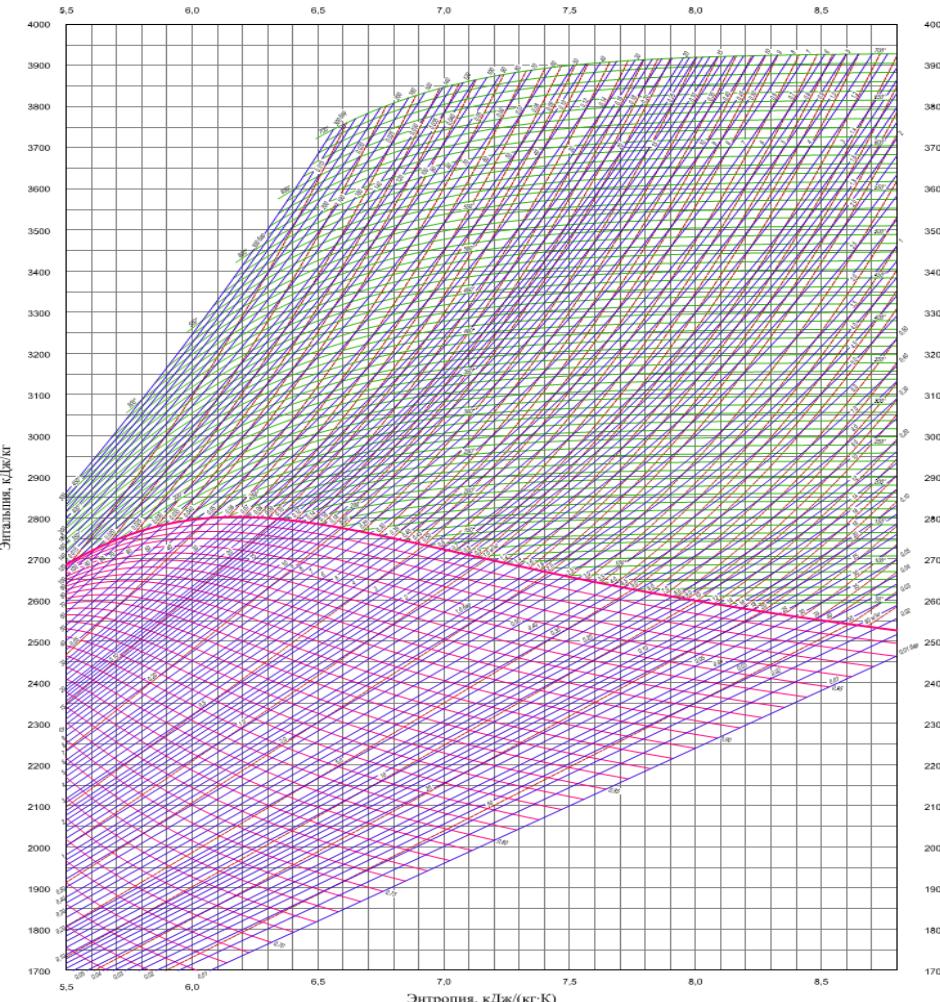
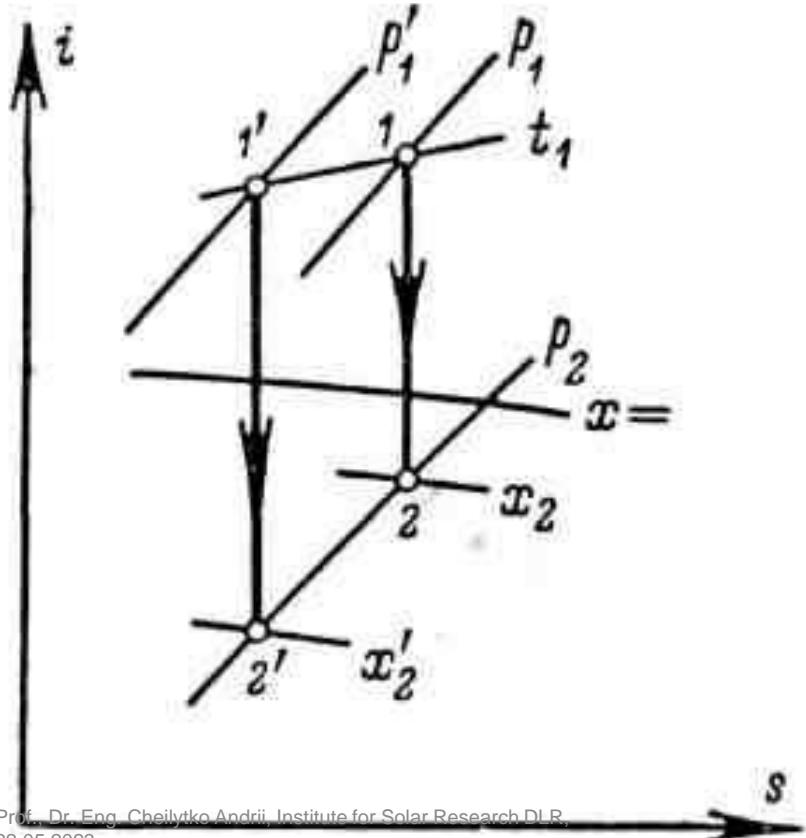


Actual process in a steam turbine plant with intermediate separation and superheating

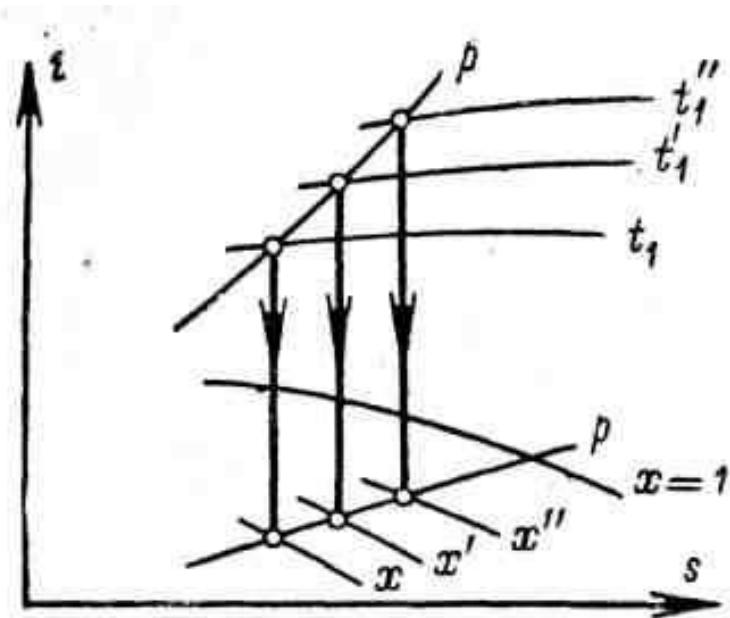
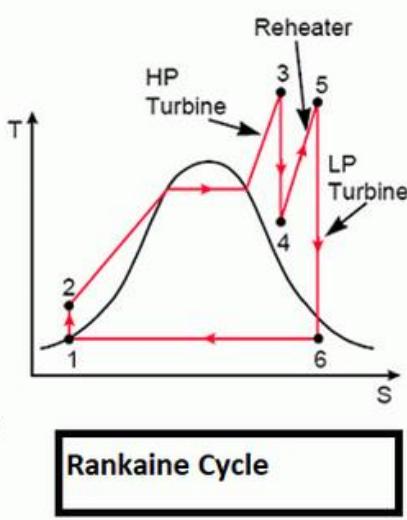
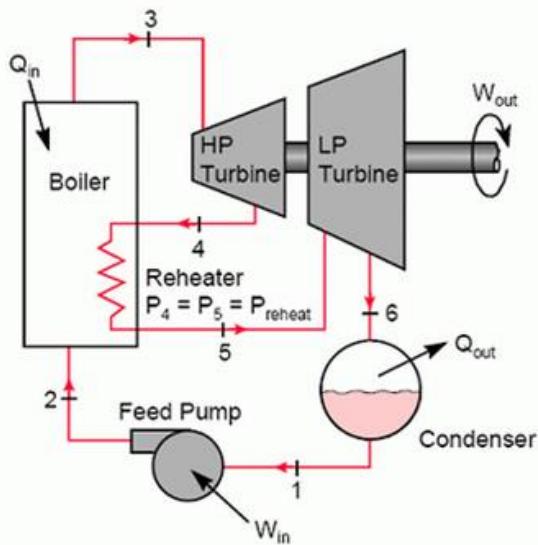


Effect of increasing the initial pressure on the efficiency of the Rankine cycle

- If increase P , $T=\text{const}$, then H value will slightly decrease, but the thermal difference $h_1 - h_2$ will increase, which increases the thermal efficiency, and the specific consumption will decrease. Accordingly, with an increase in the initial P , the cycle efficiency increases.
- A negative consequence of the P increase is an increase in steam humidity at the end of its expansion, as can be seen from the hs-diagram



Effect of increasing the initial temperature on the efficiency of the Rankine cycle

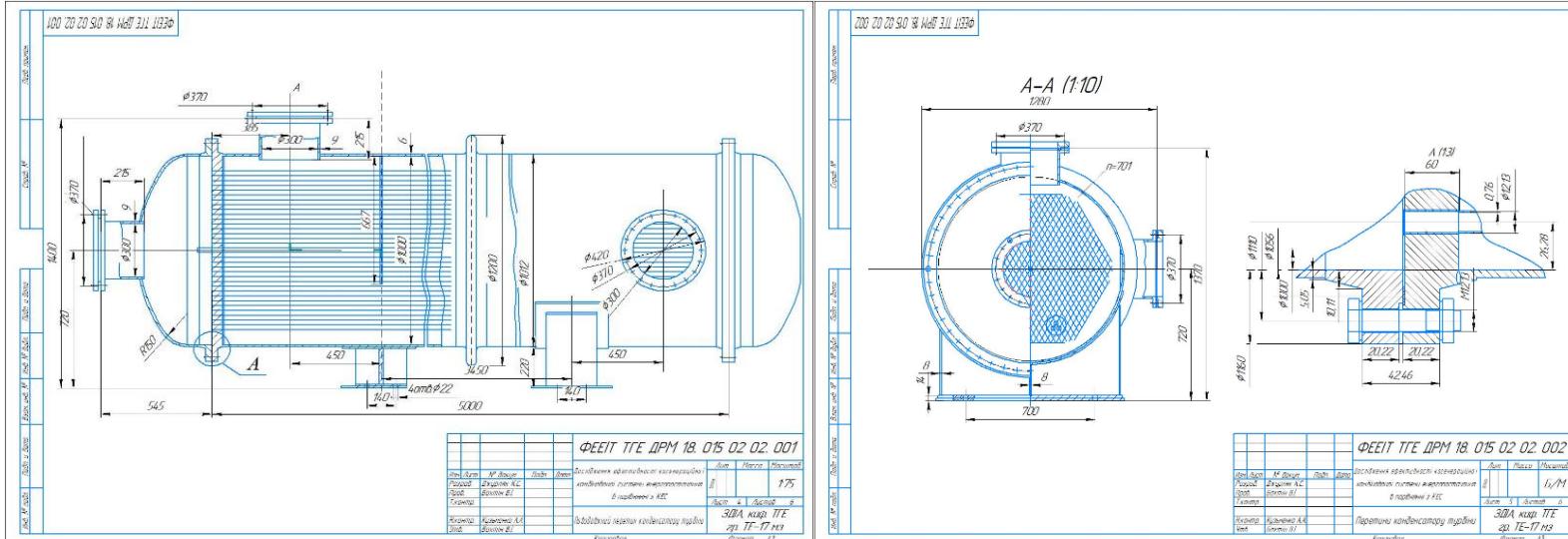


Supercritical Boiler circuit Diagram

<https://medium.com/@ashwinpalohow-to-calculate-thermal-efficiency-of-rankine-cycle-37a7dbcadc12>

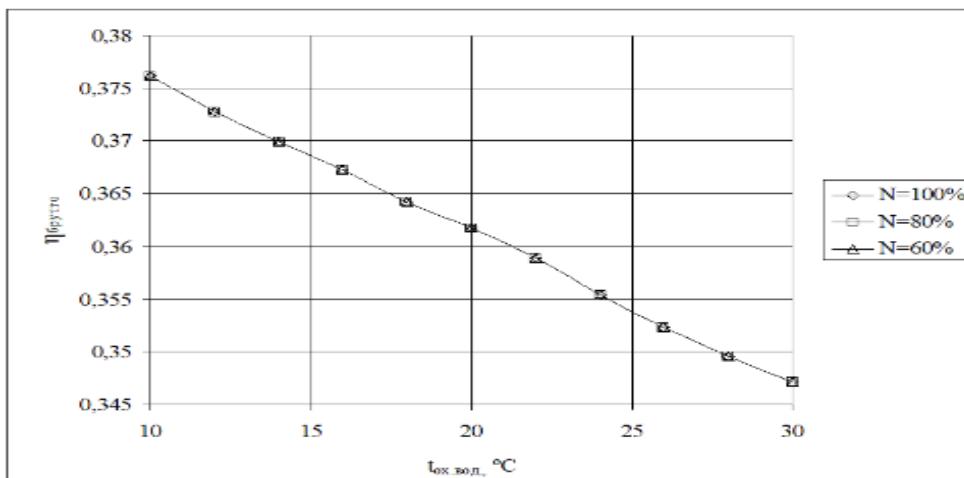
- Increasing the thermal efficiency can be achieved by increasing the initial steam temperature, $P=\text{const}$

efficiency from temperature cooling



Longitudinal section of the turbine condenser

Turbine capacitor cross sections



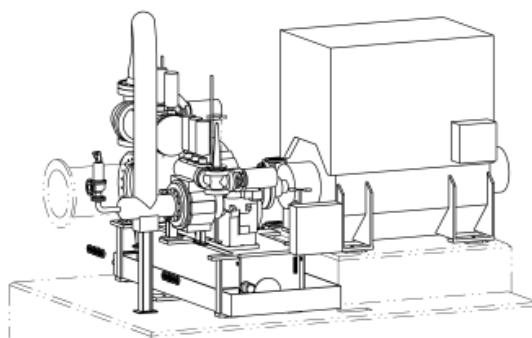
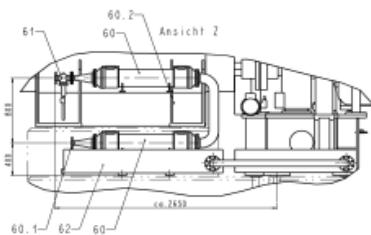
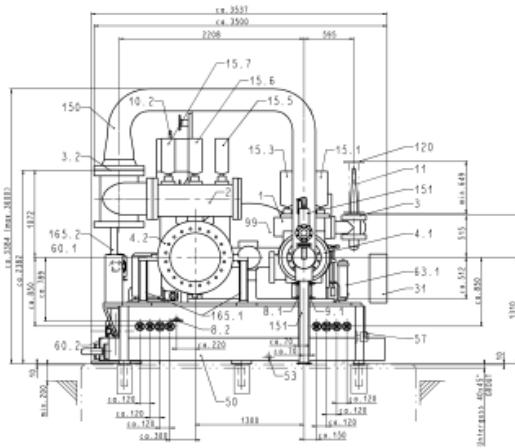
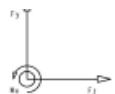
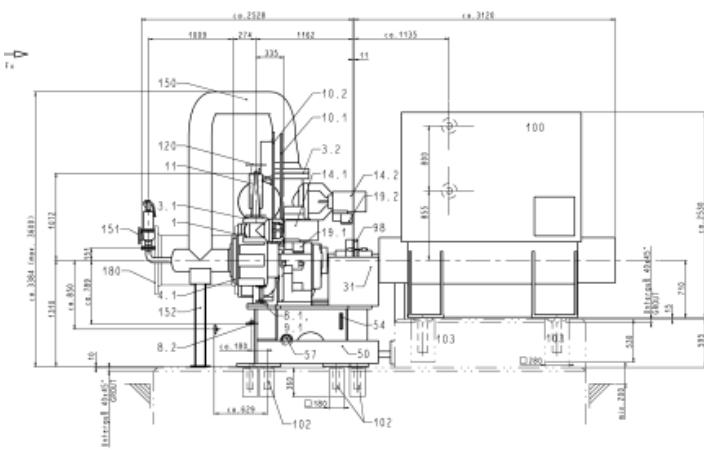


STEAM TURBINE IN JULICH SOLAR TOWER

Steam turbine in Julich solar tower

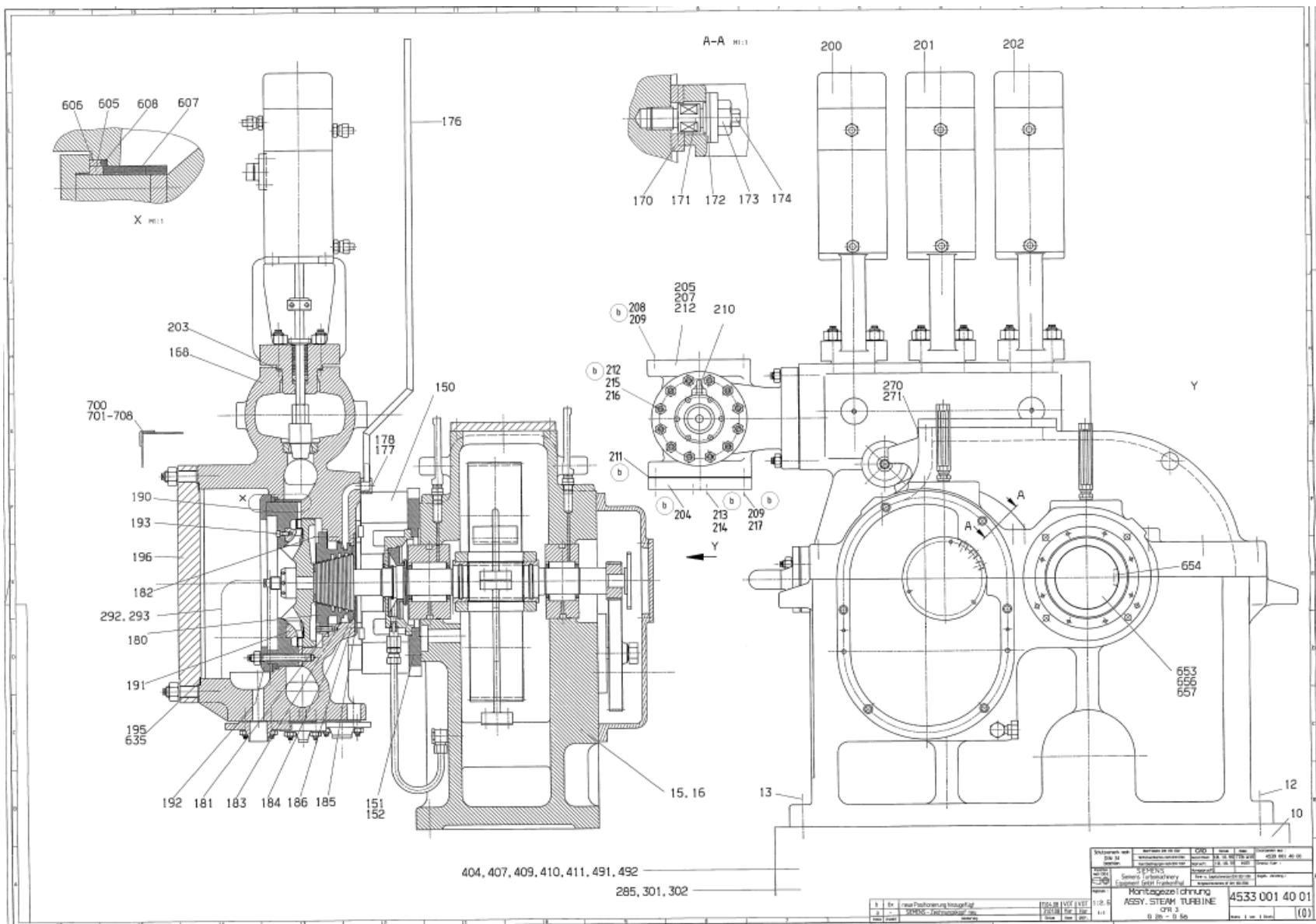


DLR



Büro		Telefon	Fax	E-Mail
1. Nachschub eingetragen				
2. Nachschub gegeben				
3. Nachschub abgenommen				
4. nach Kundenkartei gebucht				
Rechnungszeitraum:		Stand:	Empfänger:	
Revision e		02.07.08		
Beschriftung:				
 Stadtwerke Jülich GmbH		 Münchener Gas- und Wasserwerke Münchener Gas- und Wasserwerke Betriebsgesellschaft mbH 80533 München Tel.: 089/5444-0 Fax: 089/5444-120		
Generationsanlagen:				
 Kraftanlagen München <small>GAS & WERKE</small>		Kraftanlagen München GmbH Betriebsgesellschaft mbH 80533 München Tel.: 089/5444-0 Fax: 089/5444-120 Mobil: 0171/2000000		
Name/Ort:		Preisgruppe:		
Sicherheitsabstandsstelle Jülich		9. 112. 1. 612		
Abrechnungszeitraum:				
01.07.08 - 06.07.08		Von 01.07.08 bis 06.07.08 sind keine Abrechnungen mehr möglich.		
07.07.08 - 12.07.08		Von 07.07.08 bis 12.07.08 kann nur noch die Abrechnung für den Monat August erfolgen.		
Bemerkung:				
Einbuzezeichnung:		 Plausibilisierung Kraftanlagen München Betriebsgesellschaft mbH 80533 München Tel.: 089/5444-0 Fax: 089/5444-120		
NEU-Kennzeichen:		Lokalkennz. (MB) Karte Nr.:		
		91121612-BA-1105 5		
Kam.: 4. 736 029				
 Eine weitere Leistung erhält der Kunde im System der Energieversorgung nach § 10 (1c) REGG, wenn er die Forderung des Energieversorgers nicht erfüllt. Dies ist der Fall, wenn der Kunde die Forderung des Energieversorgers nicht erfüllt, obwohl er dies kann oder soll. Dies gilt auch für die Forderung des Energieversorgers, die er nicht erfüllen kann oder soll, wenn er dies kann oder soll.				
 SIEMENS				

Steam turbine in Julich solar tower



Turbine strapping



Literature and links



1. Cheilytko A. Design and optimization of heat supply systems: a study guide for students of ZGIA specialty 144 "Heat Power Engineering" full-time and part-time. Ukraine: ZGIA, 2016. 200 p
2. Sauerhering, J., Angel, S., Fend, T., Brendelberger, S., Smirnova, E., & Pitz-Paal, R. (2008). Characterisation of Flow and Heat Transfer in Sintered Metal Foams. Proceedings of the 6th International Conference on Nanochannels, Microchannels, and Minichannels, Pts a and B, 121-127.
3. <https://svitppt.com.ua/fizika/parovi-ta-gazovi-turbini.html>

Impressum



Thema: Steam turbine. Public lecture for students of Energietechnik
(Jülich), FH Aachen

Datum: 22.05.2023

Autor: Prof., Dr. Eng. Andrii Cheilytko

Institut: DLR, Institute for Solar Research

Bildcredits: Cheilytko A. Design and optimization of heat supply systems: a study guide for students of ZGIA specialty 144 "Heat Power Engineering" full-time and part-time (2016). Zaporizhzhia, Ukraine: ZGIA, 200 p.