APPROVED
at a meeting of the
Scientific Council
NJSC «Al-Farabi KazNU».
Minutes No.10 dated
May 23, 2022.

The program of the entrance exam for applicants to the PhD for the group of educational programs D098 – «Heat power engineering»

1. General provisions.

1. The program was drawn up in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 600 "On Approval of the Model Rules for Admission to Education in Educational Organizations Implementing Educational Programs of Higher and Postgraduate Education" (hereinafter referred to as the Model Rules).

2. The entrance exam for doctoral studies consists of writing an essay, passing a test for readiness for doctoral studies (hereinafter referred to as TRDS), an exam in the profile of a group of educational programs and an interview.

Block	Points
1. Essay	10
2. Test for readiness for doctoral studies	30
3. Exam according to the profile of the group of the educational program	40
4. Interview	20
Total admission score	100/75

3. The duration of the entrance exam is 4 hours, during which the applicant writes an essay, passes a test for readiness for doctoral studies, and answers an electronic examination. The interview is conducted on the basis of the university separately.

2. Procedure for the entrance examination.

1. Applicants for doctoral studies in the group of educational programs D098 – «Heat power engineering» write a problematic / thematic essay. The volume of the essay is at least 250-300 words.

2. The electronic examination card consists of 3 questions.

Topics for exam preparation according to the profile of the group of the educational program.

Discipline **«Superchargers and heat engines»**

Topic: Heat engines. Steam installations. Gas turbine installations. Jet engines. Diesel power plants. Working and thermal diagrams of jet engines. Compressors and compressor installations. Complete own operation of the gas turbine installation

Subtopics: Heat engine cycles; Generalized thermodynamic cycles of heat engines; Constant Volume Heat Transfer Cycle Graph; Scheme of heat transfer of the thermal cycle of a gas turbine installation at constant pressure and characteristics of each process; Single Stage Compressor Indicator Diagram; Multistage compressors. Minimum operation of multistage compressors; Complete own operation of the gas turbine installation; Centrifugal pump cavitation. Determination of the application of compressors depending on the speed and pressure; T, S diagram of a multistage compressor; Thermal diagrams of cycles of steam-gas power plants with a mixed working fluid

Discipline «Alternative energy»

Topic: Renewable energy sources. Renewable Energy Resources in Kazakhstan. Problems of using traditional energy sources.

Subtopics: RES resources; Converters manufacturing technologies; Problems of unconventional energy use; Energy saving using alternative energy sources;

Discipline **«Physical foundations of energy saving»**

Topic: Energy complexes. Energy sectors and dynamics of development of the Republic of Kazakhstan. Energy saving. Energy saving in heat generating plants. Energy saving in thermal technologies

Subtopics: Legal and regulatory framework in the Republic of Kazakhstan related to energy saving. Energy document of a manufacturing enterprise. The main directions of energy saving; Basic equations and laws of heat conduction. Differential equation of heat conduction. Convective heat transfer; Basic equations and theorems of thermal similarity. Fundamentals of combustion. Fossil fuel composition; Fundamentals of energy saving in the power supply system. Organization and technical basis for the provision of electricity. Measures to ensure the production of electricity. Fundamentals of energy saving in the design and operation of electrical installations. Energy audit basics. The main structure of an energy audit.

Discipline **«Viscous fluid flow»**

Topic: Basic concepts of the dynamics of a viscous fluid. Basic equations of viscous fluid mechanics. Incompressible fluid flow with constant properties. Energy equation. Stationary fluid motion. Divergent form of the energy equation. Layered flows. Boundary layer. Self-similar transformations of the boundary layer equations. Experimental methods for studying viscous fluid flows. Means and methods of physical experiment. Flat free jet (submerged).

Subtopics: An ideal and viscous liquid. Viscosity. Laminar and turbulent flow. Reynolds number. Continuity of the environment. Knudsen number. Compressibility of the medium. Mach number. The law of conservation of substance. Navier-Stokes equations. Continuity equation. Equations of motion. Viscous stress tensor. Translational motion. Rotational motion. Translational rotational motion. The law of conservation of momentum for an incompressible fluid with constant properties. Energy flux density. Poiseuille flow (dynamic and thermal problem). Plane Couette flow (dynamic and thermal problem). Dynamic boundary layer. Dynamic boundary layer properties. Boundary layer thickness. Boundary layer equations. Prandtl method. Mises method. Approximate

methods for solving the Blasius problem. Extrusion thickness. Impulse loss thickness. Iteration method.

Discipline **«Plasma technology in heat power engineering»**

Topics: Current state of the problem of combustion and processing of power-generating coals. Methods for improving fuel efficiency. Theoretical and experimental methods for studying plasma ignition processes, thermochemical preparation, combustion and gasification of coals. Allo-autothermal character of transformation of two-phase fuel flows. Physical and chemical characteristics of the investigated solid fuels. Method for determining the required amount of oxidant for fuel gasification. Method for calculating specific energy consumption for the fuel gasification process. Various options for using plasma gasification of solid fuels. Schematic diagrams of plasmatrons. Energy efficiency of the process of electrothermal chemical preparation of power-generating coals for combustion. Fossil fuel combustion methods: solid fuel combustion. Solid fuel combustion organization schemes.

Subtopics: The main sources of energy for heat generating plants. Fossil fuel classification. Analysis of fuel properties. Solid fuel classification. Coal brands. Size classes of high-quality coal. Legend symbols. Thermodynamic calculation for plasma ignition and combustion of pulverized coal. Classification of liquid fuels. Fuel oil. Fuel oil characteristics. Cracking. Relative density. Conditional viscosity. Flash point. Pour point. Classification of gaseous fuels. Dry Gases. Natural Gases. Artificial Gases. Solid fuel gasification. Water gas. Heavy hydrocarbons. OFA technology. Method of selective non-catalytic reduction of nitrogen oxides. "Sharp" blowing.

Discipline **«Numerical methods in heat power engineering»**

Topics: Classification of differential equations. Finite-difference methods (basic concept). Basic concepts and designations of the theory of difference schemes. Methods for representing differential equations in finite differences. Methods for the study of finite-difference schemes for stability and convergence. Explicit and Implicit Schemes.

Subtopics: Approximation of the first, second and mixed derivatives. Taylor series expansion. Polynomial approximation. Integral method. Integration method over the control volume. Small perturbation method. The von Neumann method. Practical sustainability method. Algorithm for calculating an explicit scheme. Examples of explicit schemas. Approximate or schematic viscosity. The principle of splitting into physical processes. Combined schemes. Algorithm of calculation of the wave equation. Heat conduction equations according to implicit schemes: Crank-Nicholson, Dufort-Frankel with different boundary conditions.

Discipline **«Computer simulation of reacting flows in combustion chambers»**

Topic: Basic concepts of modeling reacting flows in combustion chambers. Properties of numerical solution methods (consistency, stability, convergence, conservation, limitedness, feasibility, accuracy). Implementation of approaches to discretization (finite difference method, finite volume method, finite element method). Introduction to spectral methods (basic concept). Finite volume methods. Approximation of surface integrals. Approximation of volume integrals. Finite volume methods: an approximation of the original terms. 3D meshes. Block-structured grids. Unstructured meshes. Finite element methods based on control volume. Pressure Correction Equation. Axisymmetric problems. Nonlinear equations and their solution. Newtonian Techniques. Improving efficiency and accuracy. Analysis and evaluation of errors. Description of errors. Assessment of errors. Solution of Navier-Stokes equations. Discretization of convective and viscous terms. Discreteness of terms of pressure and bodily forces. Conservation properties. Choice of

variable location on the grid. Calculation of pressure. Boundary conditions for the Navier-Stokes equations. Introduction to turbulent flows. Direct Numerical Simulation (DNS). Large Eddy Simulation (LES). RANS models. Simulation of very large vortices. Heat and mass transfer. Flows with variable fluid properties. Free surface flows. Multiphase flows. Ignition.

Subtopics: The choice of the mesh. Step-by-step approximation by regular meshes. Overlapping meshes. Non-orthogonal meshes with boundary approximations. Mesh generation. Selection of speed components. Grid-Oriented Velocity Components. Components of Cartesian velocity. Fulfillment of boundary conditions. System of algebraic equations. Discretization errors. Approximation of convective and diffusion fluxes. Interpolation and Differentiation Practices (Upwind Interpolation (UDS), Linear Interpolation (CDS), Quadratic Upwind Interpolation (QUICK), higher order schemes). Introduction to the solution of systems of linear equations. Direct methods (Gaussian elimination, LU-decomposition, tridiagonal systems, cyclic reduction). Introduction to the solution of systems of linear equations. Iterative methods (basic concept, convergence, some basic methods, incomplete LU decomposition: Stone method, AD1 and other splitting methods, conjugate gradient methods, double-conjugate gradients and CGSTAB, multigrid methods). Parallel computing in CFD. Iterative schemes for linear equations. Decomposition of domains in space. Domain decomposition in time. The efficiency of parallel computing. Compressible stream. Pressure correction methods for an arbitrary Mach number. Methods designed for compressible flow.

Discipline «**Fundamentals of the theory of heat conduction**»

Topics: Thermal conductivity in solids. Mathematical description of the heat conduction process. Stationary thermal conductivity. Non-stationary thermal conductivity. Regular cooling (heating) of bodies. Convective heat transfer in a homogeneous medium. Differential equations for convective heat transfer. Theory of the similarity of convective heat transfer. Fundamentals of the theory of the laminar boundary layer. Foundations of the theory of a turbulent boundary layer. Heat and mass transfer under conditions of phase transition and chemical transformations. Heat transfer during boiling of a liquid. Heat transfer by radiation.

Subtopics: Heat transfer through a wall of various geometric shapes. Ways of intensification of heat transfer. Stationary thermal conductivity with a heat source. Stationary thermal conductivity of a multilayer wall of various shapes. Cooling (heating) of an unlimited plate (cylinder, ball). Cooling (heating) of bodies of finite dimensions. Approximate methods for solving problems of heat conduction. Reducing the differential equations of convective heat transfer to dimensionless form. Similarity criteria. Criterion equations. Heat transfer during forced flow around the plate. Heat transfer with free convection. Heat transfer of pipes in a forced flow of liquid and the features of heat transfer at the same time. Heat transfer in laminar, turbulent and transient modes of fluid flow in a pipe. Thermal calculation of heat exchangers. Foundations of the theory of thermal radiation. Basic laws of thermal radiation. Research methods of radiant heat transfer processes. Geometrical characteristics of a system of radiating bodies and properties of radiant fluxes. Heat transfer by radiation between heat and shell. Radiant heat transfer between two plane-parallel surfaces. Radiant heat transfer between gray bodies with high absorption coefficients. The action of heat shields. Determination of the slope coefficients of irradiation by the method of furnace algebra.

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