Федеральная служба
по экологическому, технологическому и атомному надзору
(Ростехнадзор)
Федеральное бюджетное учреждение
«Научно-технический центр по ядерной и радиационной безопасности»
(ФБУ «НТЦ ЯРБ»)
Экспертный совет по аттестации программ для ЭВМ при Ростехнадзоре

АТТЕСТАЦИОННЫЙ ПАСПОРТ ПРОГРАММЫ ДЛЯ ЭЛЕКТРОННЫХ ВЫЧИСЛИТЕЛЬНЫХ МАШИН

«Программный комплекс «dPIPE 5»

регистрационный №	265 от 20.10.2019
выдан	Обществу с ограниченной ответственностью «ЦКТИ-Вибросейсм» (ООО «ЦВС»). Юридический адрес: 195220, г. Санкт-Петербург, ул. Гжатская, д.9, лит. А
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(FBI SEC NRS)
Expert Board on certification of computer software at Rostechnadzor

CERTIFICATION PASSPORT FOR COMPUTER SOFTWARE

Software package dPIPE 5

registration number	265 issued on 20.10.2019
to	CKTI-Vibroseism Ltd. (CVS) Legal address: 9 A, Gzhatskaya Street, Saint Petersburg 195220, Russia
validity	23.09.2019 (subject to the conditions specified in paragraph 5 of this certification passport)

Deputy Director FBI SEC NRS,
Chairman of the Expert Board
on certification of computer software
at Rostechnadzor, Candidate of Technical Sciences

S.N. Bogdan

1. Overview

1.1. Owner of computer software

Owner: CKTI-Vibroseism Ltd. (state certificate of registration for computer software N 2010611497).

1.2. Authors of computer software

Alexey Berkovsky, Petr Vasilyev, Oleg Kireev, Igor Popovich, Grigory Yudin

1.3. Registration and testing details of computer software and its components

dPIPE 5 was tested and registered in the nuclear industry fund for software programs and algorithms (OFAP YR): reg. no 638 issued on 25.12.2008.

1.4. Information about previously issued certification passports for computer software

This certification passport was issued in substitution of a certification passport for computer software dPIPE 5 (reg. no 265 issued on 23.09.2009) upon its expiration. Experts which were testing computer software in 2009 are V.S. Rubtsov (Candidate of Science (Engineering), head of the department of SEC NRS), V.V Tkachev (Candidate of Science (Engineering), senior researcher of INR RRC “Kurchatov Institute”), and A.M. Belostotsky (Doctor of Science (Engineering), CEO of R&D Center StaDiO).

1.5. Experts responsible for analyzing computer software

V.S. Rubtsov, Candidate of Science (Engineering), SEC NRS

2. Purpose and field of application of computer software

2.1 Purpose of the computer software

dPIPE 5 program is intended for piping flexibility and stress analysis under following loads and load combinations:

- internal pressure;
- concentrated and distributed weight load;
- loads from thermal expansions of piping and attached equipment;
- seismic loads applied in the form of acceleration response spectra;
- seismic loads applied in the form of accelerograms;
- dynamic transient loads applied at nodes of piping finite-element (FE) model.

The program allows to perform piping analysis (calculation of stresses of categories $(\sigma)_2$, $(\sigma)_{RK}$, $(\sigma_{aF})_K$) for static and seismic loads according to Annex 5 of Standards PNAE G-7-002-86. Comparison of design stresses with allowable stresses (strength evaluation) is carried out according to paragraphs 5.4 (static strength analysis), 5.9 (long-term static strength analysis), 5.6 (cyclic strength analysis), and 5.11 (seismic analysis) of Standard PNAE G-7-002-86.

For piping working at the creep range (high-temperature piping), the software takes into account reduction of the elements forces and moments due to relaxation of thermal expansion loads according to the approaches adopted from RD 10-249-98 “Strength analysis code for land-based boilers and steam and hot water pipelines”.

2.2 Types of nuclear facilities for which the program may be utilized

Any NPP pipes covered by part 1.1 of PNAE G-7-002-86

2.3 Operation modes of a nuclear facility

Static loads (weight, pressure, temperature, predefined movements of piping supports) under normal operating conditions (NOC) and beyond normal operating conditions (BNOC). Dynamic loads under beyond normal operating conditions, earthquake, plane crash, industrial explosions.

2.4 Limitations for the application field of the program

Parameters range: small elastic deformations. Nonlinear behavior of piping supports is considered both in the static analysis: consideration of friction forces in sliding supports, one-way supports, deflection of hangers from the vertical position, and in the time history analysis (THA): restraints with gaps, mechanical and hydraulic dampers. For dynamic analyses, the number of natural mode shapes included in the response should be complete enough to correctly describe the motion of the system in the area of nonlinear piping restraints.

For static analyses, the degree of discretization of a finite-element model reflects the basic geometry of the piping system, location of cross-section changes, supports, and lumped parameters. To determine locations of maximum displacements and stresses, it is recommended to assume the distance between the nodes of the computational model as at least five diameters of the current piping cross-section.

For dynamic analysis, in addition to the above requirements, the criterion of ensuring minimal partial frequency of the created model is added to determine the exact frequency within the range of up to the maximum frequency (FMAX) considered in the analysis. It is recommended that the minimum partial frequency of the model is 2.5 – 3 times higher than FMAX. For this, the maximum length of the pipeline span shall be selected accordingly.

The time-integration step for dynamic calculations using THA is set to be smaller or equal to one-twentieth of the minimum natural period of the system, which guarantees the unconditional convergence of the solution.

Both static and dynamic analysis assumes the work of a piping within the elastic range. Stress analysis of bends and tees is to be performed per paragraph 2.3.1 of Annex 5 of Standards PNAE G-7-002-86. Refined methods of paragraphs 2.8 and 2.9 of the same document are not implemented in the program.

Model size limitations are determined by available RAM and disk space. Computer software operating experience demonstrated the ability to solve problems with the following maximum sizes:

- maximum number of elements: 2000;
- maximum number of spring hangers: 300;
- maximum number of anchors: 300;
- maximum number of supports: 300;
- maximum number of concentrated weight loads: 300.

Computer software is not designed to simulate wave propagation effects in shock processes.

2.5 The admissible error provided by computer software in its intended field of use

Accuracy of the practical calculations is determined by the following:

- accuracy of the problem's solution for small deformations and displacements;
- uncertainty in physical and mechanical properties of materials;
- uncertainty in geometric parameters, weight characteristics of a structure, and loading parameters;
- time-integration step size in calculations using the time history analysis method;
- number of natural mode shapes included in the analysis using response spectrum method or modal integration method.

A maximum permissible error of the solution based on a comparison of calculation results with theoretical and experimental data should not exceed 15% for stress-strain state parameters.

3. Information on the calculation methods implemented in computer software

The finite element method is implemented in computer software in the form of displacements. The main unknowns are nodes' displacements of a computational model.

Three main types of finite elements are used in computer software: a straight beam of circular and arbitrary cross-section, a curvilinear beam of circular cross-section, and a spring element. Each of these elements is a two-noded element having six degrees of freedom in each node.

For modeling and corresponding displaying of specific nodes and components of piping, computer software uses a set of service elements, presentation of which within a computational model is reduced to the described above types of finite elements. Using these service elements the following components can be modeled: straight pipe, bend/elbow/miter, reducer, fixed support, valve, expansion joint, spring element, beam, cold spring.

To account for nonlinear supports, static analysis is carried out using an iterative procedure.

The Lanczos method is used for determining natural frequencies and mode shapes of a piping.

Seismic analysis can be performed using the time history analysis method or response spectrum method.

When performing calculations using the response spectrum method, combination of response modal parameters for one spatial direction of seismic excitation can be performed using the following methods: the SRSS (Square-Root-of-Sum-of-Squares) rule, ten-percent summation, CQC (Complete Quadratic Combination) rule. In case of independent support motion (a multiple-support excitation), a combination of responses for groups of supports can be done using either SRSS rule or absolute summation. A combination of response parameters from seismic excitation applied in different spatial directions is carried out using the SRSS rule. Static correction is used to account for the modes above the cut-of-frequency.

Time History Analysis is implemented by the procedure of modal integration of the equations of motions of a piping system with account for damping supports (including non-proportional damping), mechanical and hydraulic snubbers, as well as one way supports or restraints with gaps. The total damping in the system is considered as modal damping, uniform for all modes of vibration. The account for nonlinear properties of supports for an uncoupled system of modal equations is made using a vector of nonlinear modal forces.

4. Information on the databases and built-in constants used in computer software

All input parameters required for analysis should be specified by the user. Computer software does not contain built-in databases or constants.

5. Special conditions

This Certificate for computer software is valid until the date of release of the order of Rostechnadzor on the cancellation of Standards PNAE G-7-002-86.

6. Additional information

Minimum system requirements:

- operating system WINDOWS 2000/XP;
- available disk space – at least 64MB;
- RAM – at least 128 MB.

7. List of organizations whose specialists have been trained to use computer software:

- ATOMPROEKT JSC;
- Atomenergoproekt JSC;
- Zarubezhenergoproekt JSC;
- Afrikantov OKBM JSC;
- Severnoye DB JSC;
- ASE EC JSC;
- OKB GIDROPRESS JSC;
- KALUGA TURBINE WORKS OJSC;
- AAEM LLC;
- Petro-Metall LLC ;
- Resource LLC;
- STIKO LLC;
- CVS;
- Kompensator SPE JSC;
- Power Machines PJSC;
- Turboatom JSC.

8. List of documents provided for the computer software expertise

- Appeal from CKTI-Vibroseism Ltd. for renewal of the certification passport (reg. no 265 issued on 23.09.2009) upon expiration of its validity (letter from 03.04.2009 no VS-005/93).
- Software package for strength calculations of piping systems under operational and seismic loads dPIPE 5. Verification report, revision 4, CKTI-Vibroseism Ltd., arch. no VR01-07/A, Saint Petersburg, 2017.

- Decision of Section no 4 “Strength and durability of elements, equipment, and systems” of Expert Board on certification of computer software at Rostechnadzor with a group of experts (record of the meeting from 26.09.2019 no 6/s4-2019) on renewal of the certification passport for computer software dPIPE 5 (reg. no 265 issued on 23.09.2009) upon expiration of its validity.
- Decision of the Presidium of Expert Board on certification of computer software at Rostechnadzor (record of the meeting from 20.11.2019 no 76).

Academic Secretary of Expert Board on certification of computer software at Rostechnadzor,

Candidate of Technical Sciences

S.A. Shevchenko

Chairman of Section no 4 “Strength and durability of elements, equipment, and systems” of Expert Board on certification of computer software at Rostechnadzor,

Candidate of Technical Sciences

V.S. Rubtcov