"CLOUD" SERVICE ON PROPERTIES OF WORKING MEDIUMS AND MATERIALS IN NUCLEAR POWER ENGINEERING.

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In this paper we describe the technology of Internet-access to scientific and technical information, particularly, to the functions on properties of working mediums and materials of nuclear power engineering on the remote server ("at clouds"). The examples of practical solutions of engineering calculation tasks are described.

Keywords: thermophysical properties, internet functions, nuclear power engineering

Introduction

Thermal engineering calculations demand knowledge of thermodynamic and physical properties of working substances. If such calculations are conducted manually, it is enough to have at hand corresponding tables [1] of properties of specific working substance. But computer calculations (which are conducted more often nowadays) demand special program functions, which return specific values of properties of working substances of power cycles depending on parameters of the cycle – temperature, pressure, specific enthalpy, specific entropy, density, etc.

2. On-line Reference Book "Properties and processes of working substances and materials of nuclear power engineering"

National research university Moscow power engineering institute (MPEI), "Trieru" company and Publishing house MPEI realized the complex project – "Handbook + Internet web-site" on thermophysical properties of working mediums and materials of nuclear power engineering.

The handbook, which is published in traditional "paper" form, also contains information concerning structure of the web-site and principle of its work. The web-site itself is cardinally different from the similar sites, because it contains not just formulas, tables, graphs and sets of formulas, which represent certain properties of materials (this illustration usually are presented in "paper" handbooks), but also "alive" calculation documents which allow to change parameters of working mediums and materials (temperature, pressure etc.) at on-line mode and to calculate its properties with representation of intermediate results. The site has one more distinction – it contains a set of functions and operations for calculation of thermophysical properties in popular calculation and engineering software: Excel, Mathcad, Matlab etc. Such use can be realized by download of the corresponding files from the web-site and its insert to the engineering software or by mechanism of links to the functions which are kept on the web-page. The user of the site can also get acquainted with examples of calculations of real technological processes at nuclear power stations with use of functional dependences and procedures which are kept in "alive" database.

During the creation of this complex we used data of leading world scientific centres connected with the problem of generation and storage of databases on properties of materials and working substances. The according links to these sources are presented on pages of the web-site.

Nowadays almost all engineers, scientists and students have access to the Internet and mainly they inquire information from Internet sources. All of these tendencies were described in the handbook which was already published in the Internet (http://twt.mpei.ac.ru/TTHB/NPP-en).

Below we describe typical pages of the site. Fig. 1 shows its headline.
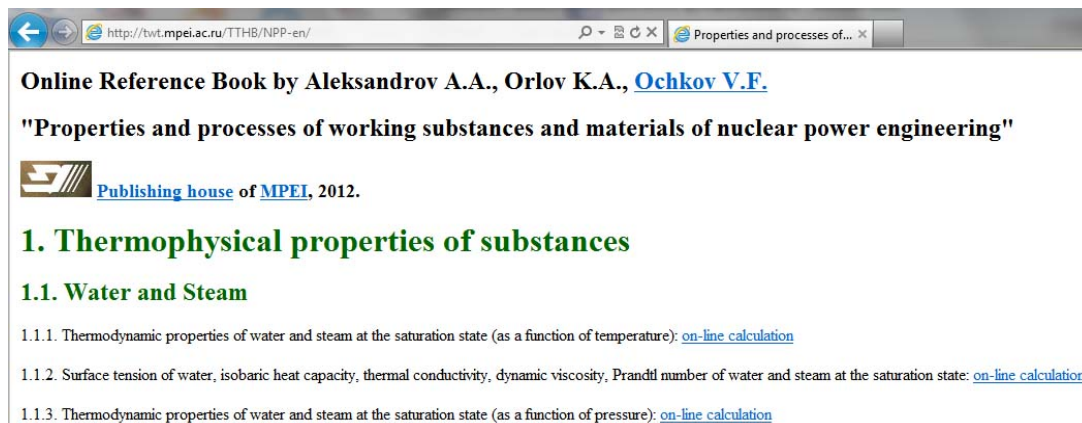
Fig. 1 The headline of the site.

The site provides user with various thermophysical properties (specific volume, density, enthalpy, entropy, internal energy, speed of sound, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number, etc.) as a functions of different sets of input variables (temperature, pressure, density, enthalpy and entropy) for a wide range of substances (nuclear fuels, coolants, working mediums, absorbing and structural materials) used in nuclear power engineering such as: water and steam, heavy water, air, hydrogen, helium, argon, lead, bismuth, gallium, lithium, sodium, potassium, caesium, uranium, plutonium, thorium zirconium and so on.
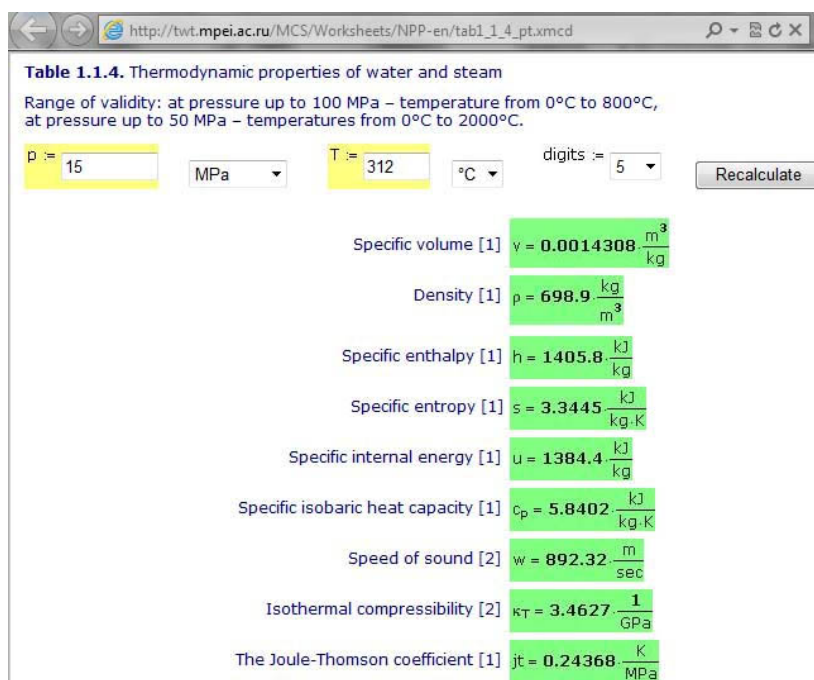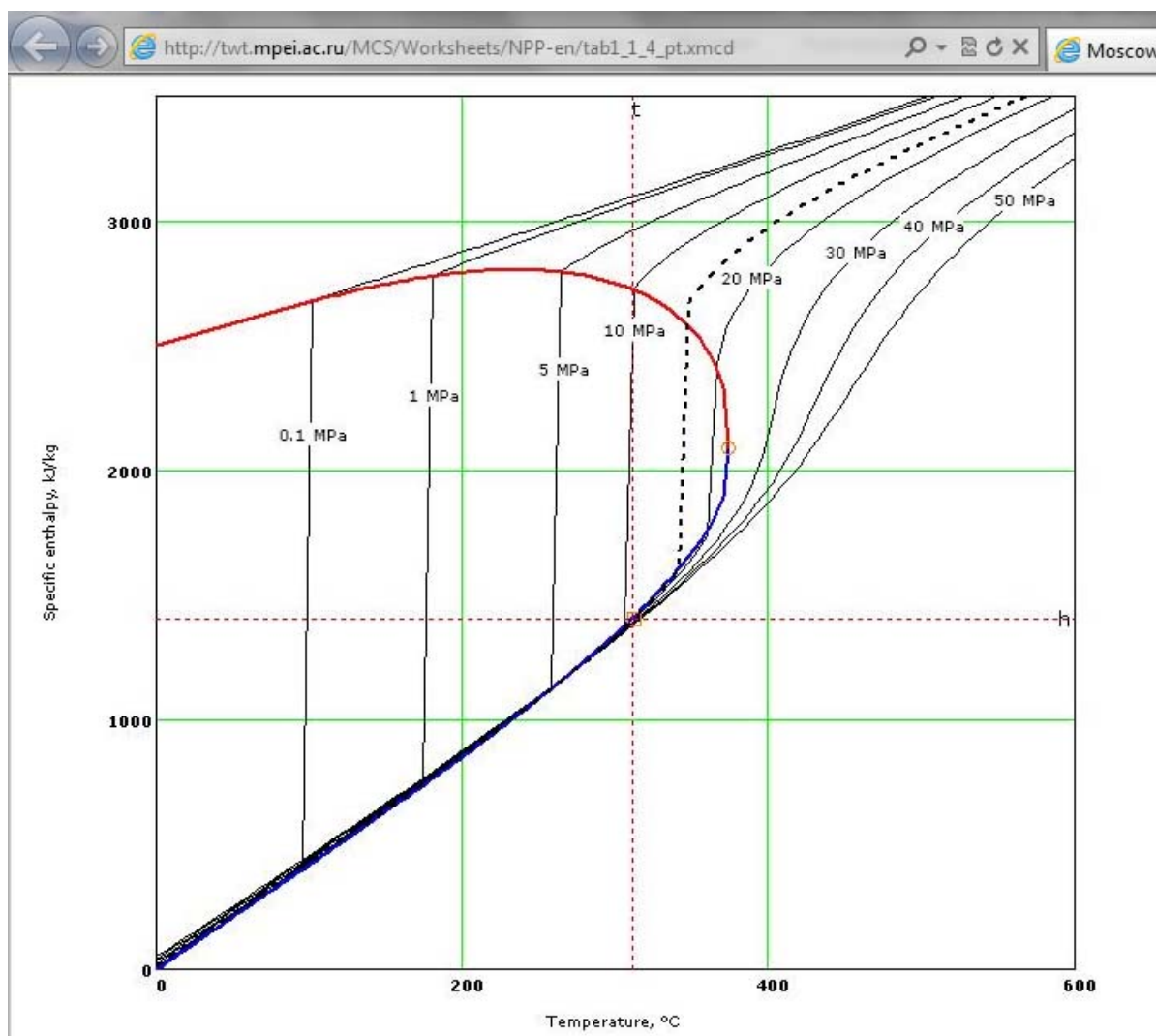
3. On-line calculations

Fig. 2. On-line calculation of thermodynamic properties of water and steam.

Fig. 2 shows the example – on-line calculation of thermodynamic properties of water and steam. In all "paper" handbooks on properties of water and steam such dependences are shown in the form of tables, where temperature and pressure are independent parameters. At that, as a rule, step of change of pressure and temperature is rather big, which makes user to apply interpolation. If the step of change of temperature and pressure in smaller, the size of handbook is too big, which makes it inconvenient. Internet-version of the present handbook allows determining thermodynamic properties of water and steam depending on pressure and temperature (Fig. 2), pressure and specific enthalpy and specific enthalpy and specific entropy. If at setting of input variables the user will exceed the range of validity, he will receive the corresponding error message. The user of the site can also see his point on phase diagrams of water and steam. One of these diagrams is shown on Fig. 3.

Fig.3. h, T – phase diagram of water and steam

Fig. 4 presents an example of calculation of thermophysical properties for lead.
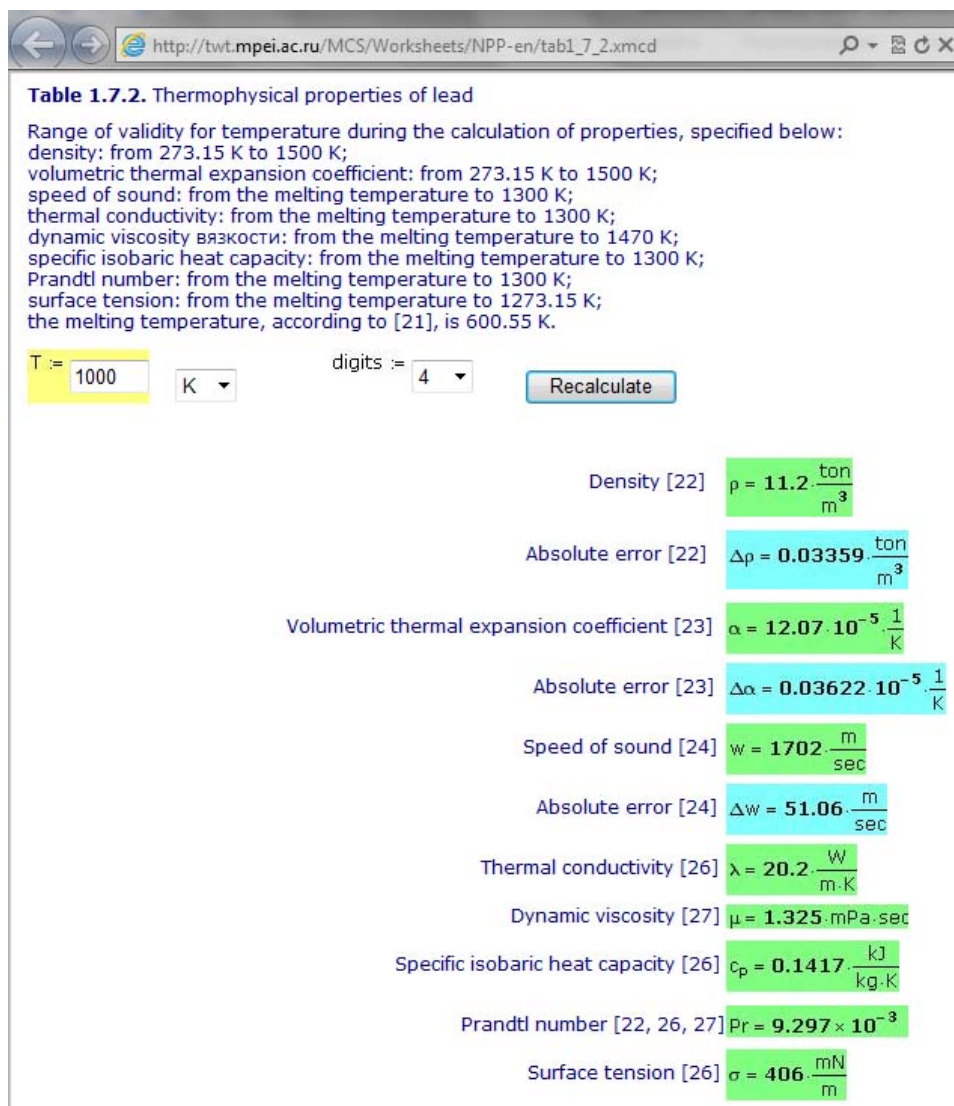
Fig. 4. On-line calculation of thermophysical properties of lead

4. User calculations

The essential difference of the present Internet-handbook is the possibility not only to fulfil the single on-line calculation, but to incorporate the appropriate functions into his own calculations which can be carried out in popular mathematical and engineering computer programs. For detailed explanation let us consider the calculation of the properties of lead (Fig. 4).

For example, if the user of our web-site works in engineering calculator Mathcad [2], he can download the functions which return thermodynamic properties of the given metal from the page of web-site and put it in his calculation.

Fig. 5. Page of the web-site for thermodynamic properties of lead.

5. "Cloud" calculations

But downloading functions from Internet sites onto user's computer has one essential lack consisting in the following. Programs for computers, and in particular, programs for calculation of thermophysical properties of individual substances are continuously improved. It is connected with the development of new formulations that contain directions for calculating specific 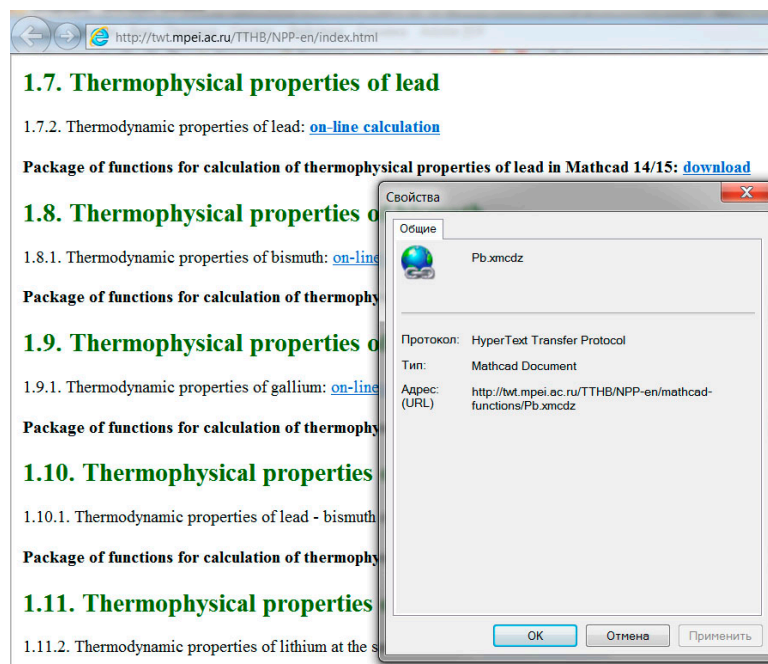properties of concrete substances[1] or that in existing programs errors and inaccuracies are corrected, and the area of their application extends, their characteristics (speed, volume of occupied memory of the computer, etc.) improve. Users of such programs often do not keep up with these changes and work with out-of-date versions.

In this connection, and also taking into account the fact that now almost all computers on which engineering, and in particular thermal calculations, are conducted, have a permanent access to the Internet, the new technology of work with functions on thermal and physical properties of working substances of power systems has been offered by the authors of the given article, based not on downloading, but on references to the functions, stored on different sites on the Internet such as the site of our handbook.

Mathcad has a command to insert the reference into a worksheet to another Mathcad document, which variables and functions become usable in the first one .It is possible to do such reference on Mathcad-documents (files with expansion *.mcd, *.mcdz, *.xmcd, *.xmcdz, *.mcdx and *.mcdxz) which can be located on a personal computer, on a local computer network or on an Internet server (at "clouds"). It opens ample opportunities for realization of a new technology of

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[1] For example if we speak about water and water steam, the basic working body of power engineering, such formulations are developed and approved by The International Association for the Properties of Water and Steam (IAPWS) – see www.iapws.org.

use of the functions stored on sites of the Internet without downloading them on the user's computer.

If, during the solution of thermal engineering problems in the environment of Mathcad, it is necessary, that the functions returning thermodynamic properties of working substance became usable in the user's document, it is necessary to execute several simple steps, displayed on Fig. 5 and 6.

On Fig. 5 it is shown, how by clicking of the mouse right button on the reference selected on Fig. 4, it is possible through the description of properties of the reference to receive the URL of the given function in the Internet and insert it (reference) into the thermal engineering calculation (Fig. 6). After this, functions purposed for the calculation of thermophysical properties of lead, for example density - ρ_{Pb_t} became usable, and returns the result of calculation depending on temperature. The technology of references to the "cloud" functions on properties of materials and working substances of nuclear power engineering provides fulfilling of more complicated calculations. Thus, on Fig. 7 we can see calculation of thermal efficiency of the Rankine cycle for wet steam in Mathcad.
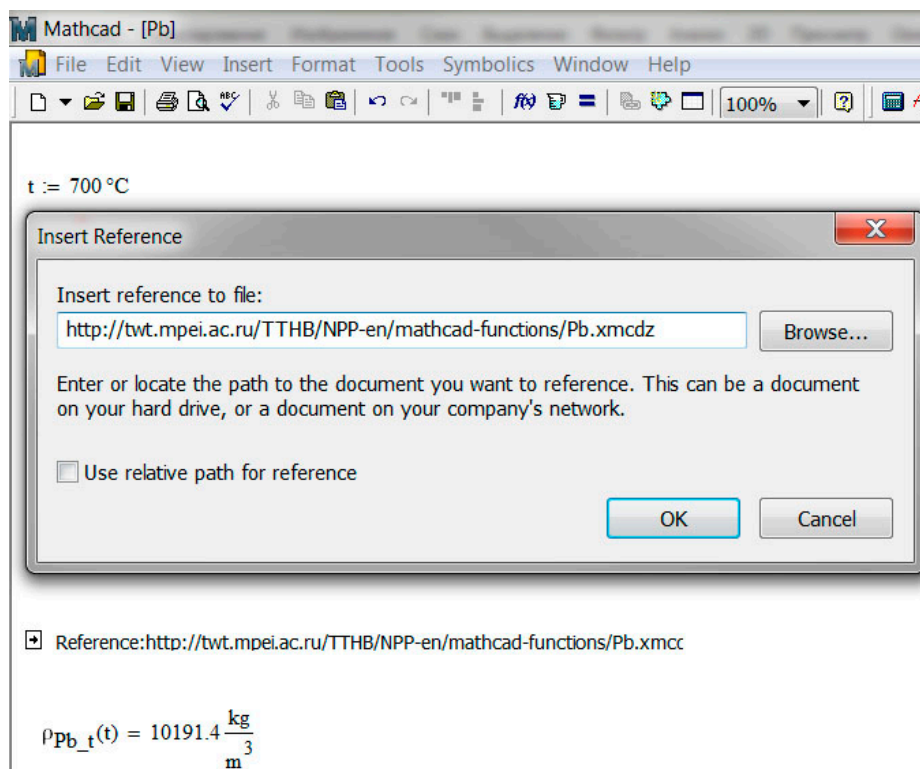
Fig. 6. Calculation of density of lead in Mathcad with link to the "cloud" function.
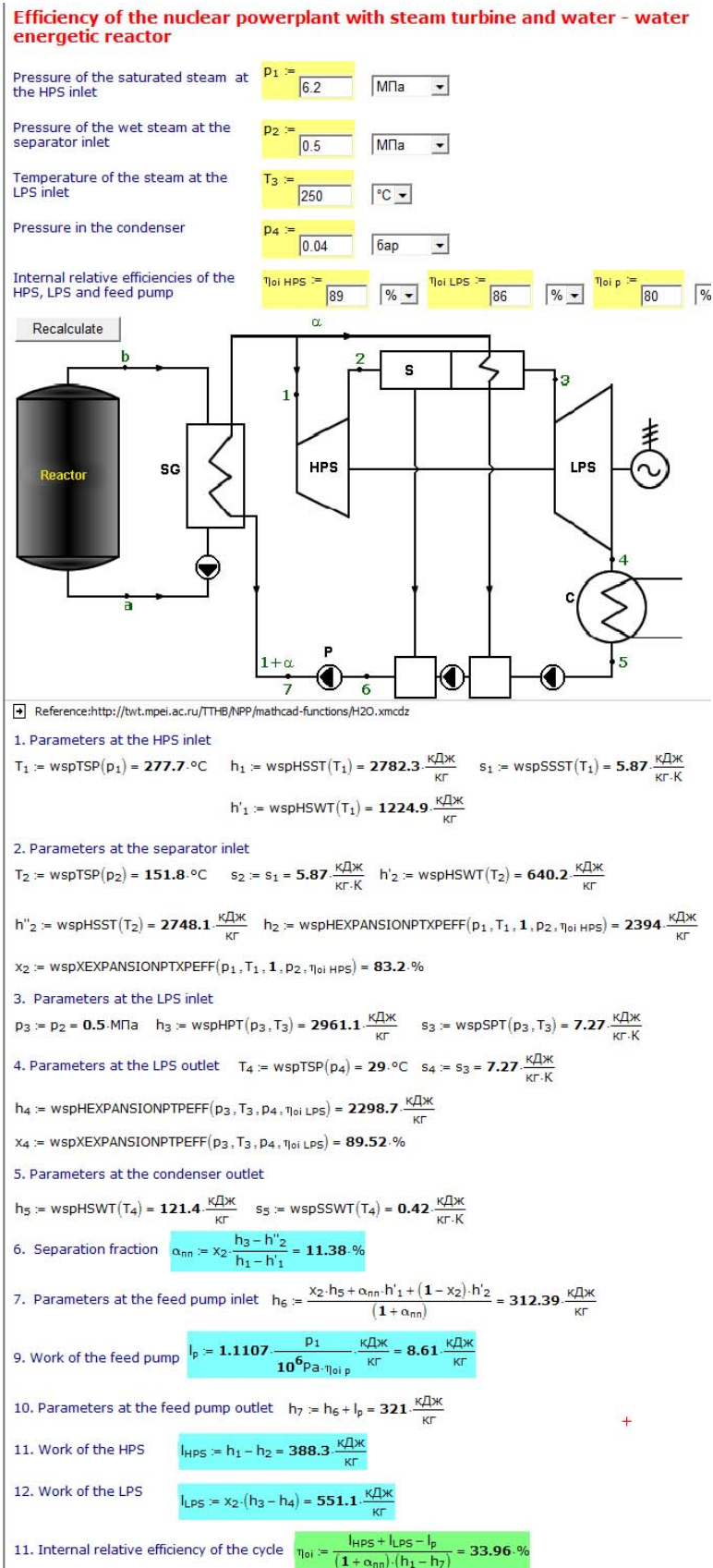
Efficiency of the nuclear powerplant with steam turbine and water - water energetic reactor

Pressure of the saturated steam at the HPS inlet $\quad p_1 :=$ `6.2` МПа

Pressure of the wet steam at the separator inlet $\quad p_2 :=$ `0.5` МПа

Temperature of the steam at the LPS inlet $\quad T_3 :=$ `250` °C

Pressure in the condenser $\quad p_4 :=$ `0.04` бар

Internal relative efficiencies of the HPS, LPS and feed pump $\quad \eta_{oi\ HPS} :=$ `89` % $\quad \eta_{oi\ LPS} :=$ `86` % $\quad \eta_{oi\ p} :=$ `80` %

[Recalculate]

Reference:http://twt.mpei.ac.ru/TTHB/NPP/mathcad-functions/H2O.xmcdz

1. Parameters at the HPS inlet

$T_1 := wspTSP(p_1) = 277.7 \cdot °C \qquad h_1 := wspHSST(T_1) = 2782.3 \cdot \frac{кДж}{кг} \qquad s_1 := wspSSST(T_1) = 5.87 \cdot \frac{кДж}{кг \cdot К}$

$h'_1 := wspHSWT(T_1) = 1224.9 \cdot \frac{кДж}{кг}$

2. Parameters at the separator inlet

$T_2 := wspTSP(p_2) = 151.8 \cdot °C \qquad s_2 := s_1 = 5.87 \cdot \frac{кДж}{кг \cdot К} \qquad h'_2 := wspHSWT(T_2) = 640.2 \cdot \frac{кДж}{кг}$

$h''_2 := wspHSST(T_2) = 2748.1 \cdot \frac{кДж}{кг} \qquad h_2 := wspHEXPANSIONPTXPEFF(p_1, T_1, 1, p_2, \eta_{oi\ HPS}) = 2394 \cdot \frac{кДж}{кг}$

$x_2 := wspXEXPANSIONPTXPEFF(p_1, T_1, 1, p_2, \eta_{oi\ HPS}) = 83.2 \cdot \%$

3. Parameters at the LPS inlet

$p_3 := p_2 = 0.5 \cdot МПа \qquad h_3 := wspHPT(p_3, T_3) = 2961.1 \cdot \frac{кДж}{кг} \qquad s_3 := wspSPT(p_3, T_3) = 7.27 \cdot \frac{кДж}{кг \cdot К}$

4. Parameters at the LPS outlet $\quad T_4 := wspTSP(p_4) = 29 \cdot °C \qquad s_4 := s_3 = 7.27 \cdot \frac{кДж}{кг \cdot К}$

$h_4 := wspHEXPANSIONPTPEFF(p_3, T_3, p_4, \eta_{oi\ LPS}) = 2298.7 \cdot \frac{кДж}{кг}$

$x_4 := wspXEXPANSIONPTPEFF(p_3, T_3, p_4, \eta_{oi\ LPS}) = 89.52 \cdot \%$

5. Parameters at the condenser outlet

$h_5 := wspHSWT(T_4) = 121.4 \cdot \frac{кДж}{кг} \qquad s_5 := wspSSWT(T_4) = 0.42 \cdot \frac{кДж}{кг \cdot К}$

6. Separation fraction $\quad \alpha_{nn} := x_2 \cdot \frac{h_3 - h''_2}{h_1 - h'_1} = 11.38 \cdot \%$

7. Parameters at the feed pump inlet $\quad h_6 := \frac{x_2 \cdot h_5 + \alpha_{nn} \cdot h'_1 + (1 - x_2) \cdot h'_2}{(1 + \alpha_{nn})} = 312.39 \cdot \frac{кДж}{кг}$

9. Work of the feed pump $\quad l_p := 1.1107 \cdot \frac{p_1}{10^6 Pa \cdot \eta_{oi\ p}} \cdot \frac{кДж}{кг} = 8.61 \cdot \frac{кДж}{кг}$

10. Parameters at the feed pump outlet $\quad h_7 := h_6 + l_p = 321 \cdot \frac{кДж}{кг}$

11. Work of the HPS $\quad l_{HPS} := h_1 - h_2 = 388.3 \cdot \frac{кДж}{кг}$

12. Work of the LPS $\quad l_{LPS} := x_2 \cdot (h_3 - h_4) = 551.1 \cdot \frac{кДж}{кг}$

11. Internal relative efficiency of the cycle $\quad \eta_{oi} := \frac{l_{HPS} + l_{LPS} - l_p}{(1 + \alpha_{nn}) \cdot (h_1 - h_7)} = 33.96 \cdot \%$

Fig. 7. Calculation of thermal efficiency of Rankine cycle for wet steam with references to cloud functions.

On Fig. 7 right below the scheme of steam turbine block of nuclear power-station with water-water energetic reactor there is a reference to the Mathcad document which contains functions for calculation, such as wspHPT, wspSPT and so on. Names of these functions have prefix wsp. This is abbreviation for water and steam properties. Similar abbreviation is used in the program package WaterSteamPro [3, 4], which is available on the web-site www.wsp.ru. Technologies of references and downloading, described in given article, have their advantages and disadvantages. The compromise (intermediate) technology is an installation on the computer or a local network of the program WaterSteamPro and its regular updating. If thermal engineering calculations are conducted on computers with a reliable connection to the Internet it is possible to apply the technology of the references described in this article. The technology of references to Internet functions opens to users a wide set of other useful thermal engineering functions placed on MPEI (TU) calculation server. These and other functions of properties of working mediums of power engineering, including nuclear power engineering, become available practically in all computer programs, which are used in engineering and scientific calculations: Excel, Matlab, C, Pascal, etc.

Conclusion

The described web-site provide operative calculations and effective use of data on the properties of materials and working mediums for engineers and scientific researchers, who work in the sphere of nuclear power engineering and industry.

Literature

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