

# **“Cloud” service on properties of working mediums and materials in nuclear power engineering**

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*In this paper we consider problem of work with handbooks in modern conditions of Internet-society. 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.*

*More about “cloud” service on properties of substances – see <http://communities.ptc.com/groups/properties-of-substances-for-mathcad> (a user group on the PlanetPTC – <http://communities.ptc.com>)*

National research university Moscow power engineering institute (MPEI), Joint institute of high temperatures of RAS, “Trieru” company and Publishing house MPEI realize the complex project – “Handbook + Internet web-site” on thermophysical properties of working mediums and materials of nuclear power engineering.

The handbook, which will be published in traditional “paper” form, will also contain information concerning structure of the web-site and principle of its work. The web-site itself will be cardinally different from the similar sites, because it will contain 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 site also provides tools which allow user to generate needed functions and procedures, taking into consideration the required diapason of parameters – temperature, pressure etc. 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.

Publishing of “paper” version of any scientific-technical publication becomes a finance and technical challenge. The finance challenge – because after publishing the scanned version of the book becomes available in the Internet in mode of chargeable<sup>1</sup>, partly chargeable or free<sup>2</sup> access.

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<sup>1</sup> User of such site overlooks advertisement too and by this way he pays for access to the handbook. Owner of the site compensates his expenses for creation and technical support of the site with the payment from advertiser. It is important to make commercial context appropriate (commercial of power engineering companies, for example) and not irritating for user.

<sup>2</sup> Creators of such web-sites are guided with noble aim. They try to help teachers, engineers, students, which are not able to buy up-to-date scientific-technical literature – handbooks, textbooks, monographs. It is just impossible to find this literature in bookstores or libraries of provincial (and not only provincial) towns. If this novelty books become available, they still are very expensive for many potential readers. So the aim of creation of web-sites with scanned literature is constructive. But, on the other hand, such sites undermine traditional publishing-houses. This sites are called “piratical” not in vain! We don’t give addresses of these sites in this paper, first, not to make additional commercial for it, and, second, not to make ourselves supergrasses. Nowadays main control is realized for sites which provide non-licensed movies, music and fiction literature. Scientific literature is out of this process [4], but it is a temporary occurrence.

The libraries at educational institutions, which always were the main consumers of scientific-technical literature, nowadays reduced purchases of educational and scientific literature for many reasons<sup>3</sup>. All this circumstances lead to a situation when funds spent on publishing of new literature sometimes can be barely recompensed. Now publishing of scientific-technical publication can be profitable only with sponsorship support<sup>4</sup>. And, as it is known, such support can be rather limited. Dew to this fact many relevant handbooks, monographs and textbooks are not published and become out of date in manuscripts and minds of authors.

In soviet times the author (lecturer at institute of higher education) could write a textbook, republish it in general circulation and have a stable income which sometimes was even higher than regular lecturer's salary. Nowadays publishing of scientific-technical literature can not be a kind of material support for lecturers and scientific workers. Nowadays such books became published for reasons of prestige and career growth (for example, for status of professor among other requirements it is necessary to publish a textbook), or with sponsorship, which was mentioned above, or at the expense of the author. By the way, sponsorship has one negative consequence. The future author, who finally had got it, is absolutely sure that the book will be published and sometimes writes it carelessly. Dew to this fact low-quality literature is published in some cases. One of solutions in such situation is rigid selection of competent literature by expert association. By the way, this method is used by Publishing house of MPEI, which also relies on sponsorship of power engineering companies, such as Rosatom Nuclear Energy State Corporation, FSK (federal power supply network companies), MRSK (inter-regional power distributing companies), different OGK (generation companies of the wholesale electricity market), TGK (territorial generating companies) etc. This problem is discussed in [1].

The technical problem of publishing of "paper" handbooks consists in fact that such editions contain many formulas, graphs and tables, which are mean not only for reading but also for engineering work (designing, exportation, maintenance of technical equipment etc.). Modern computer technologies gave new fruitful impulse to this process.

Formula of an Internet-handbook can be "alive", i. e. it allows user to change input variables and see the result. On a graph which is presented in the Internet user can mark a point and inquire its coordinates, built additional isolines and etc. Internet-table can be sorted by any field (column), filtered (hide unnecessary lines) etc<sup>5</sup>. Internet-handbook with "alive" formulas, tables and graphs is almost unattainable for copying on the "pirate" web-sites. It completely stays at the disposal of its owner, who has a right to open it in chargeable, partly chargeable or free mode. But the main point is that the owner of the site is a creator at the same time which allows him to correct and improve the site. Moreover, the creator of the site is responsible for its content and can give certain guaranties that generated data correspond to the standards.

From the other side, 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://twf.mpei.ac.ru/TTHB/NPP-en>), and some extracts from this handbook will be published in "paper" form<sup>6</sup>. Authors hope that this creation can gain the acknowledgement.

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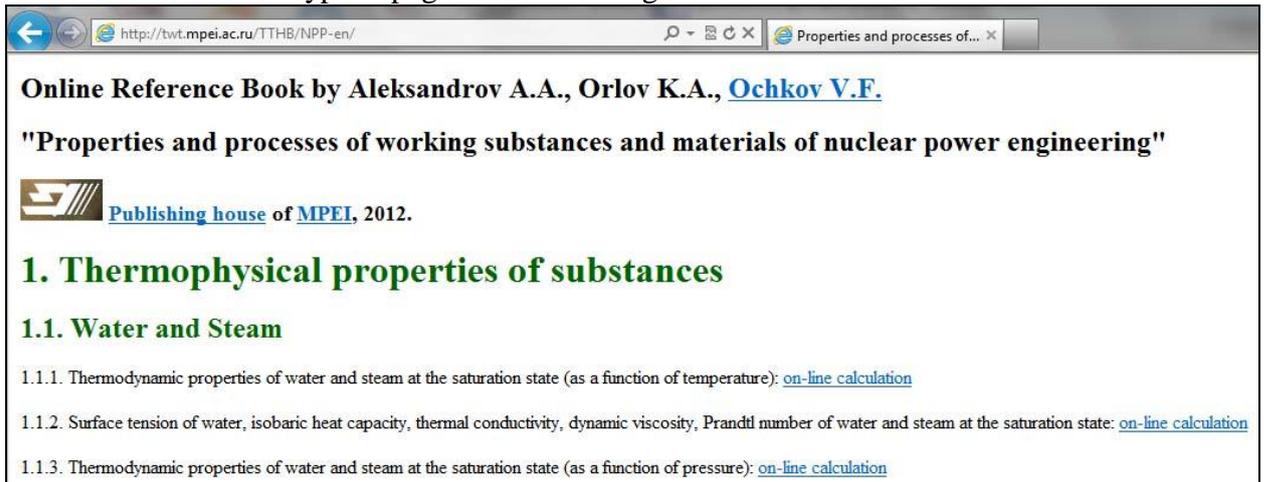
<sup>3</sup> One of such reasons is described in this paper – it is the Internet.

<sup>4</sup> The edition [2], for example, was published dew to funds of grant of Russian fund of fundamental research ([www.rffi.ru](http://www.rffi.ru)).

<sup>5</sup> In on-line version of the handbook it is possible to colour and animate if necessary. On-line version of the handbook can be equipped with hyperlinks which lead not only to needed fragments of the handbook itself, but to the other web-sites, which contain detailed information for the certain theme. All term and abbreviations of the handbook can be uncovered and user can receive exhaustive definition.

<sup>6</sup> The described handbook already exists in form of "paper" manuscript and is prepared for publishing. Here is one nuance: one can hold "paper" book in hands, "smell the charming fragrance of fresh-typed book", give it as a present to colleagues, and, the main – to include it in list of proceedings at applying for different grants, status etc. All these things can't be done with the web-site. So, there appears strange situation – "paper" books are necessary not for readers but for authors, publishers and booksellers. Some readers can say that "paper" book is indispensable. For example, it can be read during trip or in hammock. But today have appeared many electronic book readers

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



*Fig. 1 The headline of the site.*

1. Thermophysical properties of substances.
  - 1.1 Water and steam.
    - 1.1.1. Thermodynamic properties of water and steam at the saturation state (as a function of temperature).
    - 1.1.2. Surface tension, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number of water and steam at the saturation state.
    - 1.1.3. Thermodynamic properties of water and steam at the saturation state (as a function of pressure).
    - 1.1.4. Thermodynamic properties of water and steam: calculation as a function of pressure and temperature, pressure and specific enthalpy, pressure and specific entropy.
    - 1.1.5. Thermodynamic properties of metastable supercooled steam: calculation as a function of at pressure and temperature, pressure and specific enthalpy, pressure and specific entropy.
    - 1.1.6. Thermodynamic properties of wet steam.
    - 1.1.7. Dynamic viscosity, thermal conductivity, Prandtl number, negative logarithm of the ionization constant, static dielectric constant of water and steam.
  - 1.2. Thermophysical properties of heavy water.
    - 1.2.1. Thermodynamic properties of heavy water at the saturation state (as a function of temperature).
    - 1.2.2. Surface tension, isobaric heat capacity, dynamic viscosity, thermal conductivity, Prandtl number of heavy water at the saturation state.
    - 1.2.3. Thermodynamic properties of heavy water at the saturation state (as a function of pressure).
    - 1.2.4. Thermodynamic properties of heavy water: calculation as a function of pressure and temperature, density and temperature.
    - 1.2.5. Dynamic viscosity, thermal conductivity, Prandtl number of heavy water: calculation as a function of pressure and temperature, density and temperature. Package of functions for calculation of thermophysical properties of heavy water in Mathcad 14/15.
  - 1.3. Thermophysical properties of hydrogen.
    - 1.3.1. Thermodynamic properties of hydrogen: calculation as a function of pressure and temperature, density and temperature.

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which make reading more convenient. Also information on the web-site can be printed and turned into "paper" version. "Paper" book will not die in computer era, as theatre didn't die after appearance of cinema, and cinema didn't die after television.

1.3.2. Dynamic viscosity, thermal conductivity, Prandtl number of hydrogen: calculation as a function of pressure and temperature, density and temperature. Package of functions for calculation of thermophysical properties of hydrogen in Mathcad 14/15.

1.4. Thermophysical properties of helium.

1.4.1. Thermodynamic properties of helium: calculation as a function of pressure and temperature, density and temperature.

1.4.2. Dynamic viscosity, thermal conductivity, Prandtl number of helium: calculation as a function of pressure and temperature, density and temperature. Package of functions for calculation of thermophysical properties of hydrogen in Mathcad 14/15.

1.5. Thermophysical properties of argon (it is planned to add xenon and krypton).

1.5.1. Thermodynamic properties of argon: calculation as a function of pressure and temperature, density and temperature.

1.5.2. Dynamic viscosity, thermal conductivity, Prandtl number of argon: calculation as a function of pressure and temperature, density and temperature. Package of functions for calculation of thermophysical properties of argon in Mathcad 14/15.

1.6. Thermophysical properties of air.

1.6.1. Thermodynamic properties of air: calculation as a function of pressure and temperature, density and temperature.

1.6.2. Dynamic viscosity, thermal conductivity, Prandtl number of air: calculation as a function of pressure and temperature, density and temperature. Package of functions for calculation of thermophysical properties of air in Mathcad 14/15.

1.7. Thermophysical properties of lead.

1.7.1. Thermodynamic properties of lead. Package of functions for calculation of thermophysical properties of lead in Mathcad 14/15.

1.8. Thermophysical properties of bismuth.

1.8.1. Thermodynamic properties of bismuth. Package of functions for calculation of thermophysical properties of bismuth in Mathcad 14/15.

1.8. Thermophysical properties of gallium.

1.8.1. Thermodynamic properties of gallium. Package of functions for calculation of thermophysical properties of gallium in Mathcad 14/15.

1.10. Thermophysical properties of lead - bismuth eutectic alloy.

1.10.1. Thermodynamic properties of lead - bismuth eutectic alloy. Package of functions for calculation of thermophysical properties of lead - bismuth eutectic alloy in Mathcad 14/15.

1.11. Thermophysical properties of lithium.

1.11.1. Thermodynamic properties of lithium at the saturation state.

1.11.2. Isobaric heat capacity, thermal conductivity, dynamical viscosity, Prandtl number and surface tension of lithium at the saturation state. Package of functions for calculation of thermophysical properties of lithium in Mathcad 14/15.

1.12. Thermophysical properties of sodium.

1.12.1. Thermodynamic properties of sodium at the saturation state.

1.12.2. Isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of sodium at the saturation state. Package of functions for calculation of thermophysical properties of natrium in Mathcad 14/15.

1.13. Thermophysical properties of potassium.

1.13.1. Thermodynamic properties of potassium at the saturation state.

1.13.2. Isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of potassium at the saturation state. Package of functions for calculation of thermophysical properties of potassium in Mathcad 14/15.

1.14. Thermophysical properties of caesium.

1.14.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of caesium at the saturation state. Package of functions for calculation of thermophysical properties of caesium in Mathcad 14/15.

1.15. Thermophysical properties of uranium.

1.15.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of uranium at the saturation state. Package of functions for calculation of thermophysical properties of uranium in Mathcad 14/15.

1.16. Thermophysical properties of plutonium.

1.16.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension for plutonium at the saturation state. Package of functions for calculation of thermophysical properties of plutonium in Mathcad 14/15.

1.17. Thermophysical properties of thorium.

1.17.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of thorium at the saturation state. Package of functions for calculation of thermophysical properties of thorium in Mathcad 14/15.

1.18. Thermophysical properties of uranium dioxide.

1.18.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of uranium dioxide at the saturation state. Package of functions for calculation of thermophysical properties of uranium dioxide in Mathcad 14/15.

1.19. Thermophysical properties of graphite.

1.19.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of graphite at the saturation state. Package of functions for calculation of thermophysical properties of graphite in Mathcad 14/15.

1.20. Thermophysical properties of zirconium.

1.20.1. Density, isobaric heat capacity, thermal conductivity, dynamic viscosity, Prandtl number and surface tension of zirconium at the saturation state. Package of functions for calculation of thermophysical properties of zirconium in Mathcad 14/15.

2. Working processes and cycles of nuclear powerplants.

2.1. Calculation of the flow of various substances through the convergent nozzle.

2.1.1. Calculation of the flow of steam through the convergent nozzle.

2.1.2. Calculation of the flow of wet steam through the convergent nozzle.

2.1.3. Calculation of the flow of metastable super cooled steam through the convergent nozzle.

2.1.4. Calculation of the flow of air through the convergent nozzle.

2.1.5. Calculation of the flow of helium through the convergent nozzle.

2.1.6. Calculation of the flow of hydrogen through the convergent nozzle.

2.2. Calculation of the flow of steam through the Laval nozzle.

2.2.1. Calculation of the flow of steam through the Laval nozzle.

2.3. The expansion of steam in the turbine.

2.3.1. Calculation of the expansion of steam in the turbine.

2.4. The compression of ordinary and heavy water in the pump.

2.4.1. Calculation of the compression of water in the pump.

2.4.2. Calculation of the compression of heavy water in the pump.

2.5. The temperature in the steam turbine condenser.

2.5.1. Calculation of the temperature in the steam turbine condenser.

2.6. The Rankine cycle with superheated steam.

2.6.1. Calculation of the Rankine cycle with superheated steam.

2.7. The regenerative Rankine cycle.

2.7.1. Calculation of the Rankine cycle with one regenerative heating stage.

2.7.2. Calculation of the Rankine cycle with two regenerative heating stages.

2.7.3. Calculation of the Rankine cycle with the pressure optimization in the regenerative bleed-off.

2.8. The cycle of the nuclear power plant with steam turbine and WWER (water - water energetic reactor).

2.8.1. Calculation of the cycle of the nuclear power plant with steam turbine and WWER.

2.9. The cycle of the nuclear power plant with steam turbine and high power channel-type reactor.

2.9.1. Calculation of the cycle of the nuclear power plant with steam turbine and high power channel-type reactor.

2.10. Coolant flow rate in the fast-neutron reactor BN-600.

2.10.1. Calculation of the coolant flow rate in the first circuit of the fast-neutron reactor BN-600.

2.11. Ratio of the coolant flow rate of the fast-neutron reactor BREST-1200.

2.11.1. Calculation of the ratio of the coolant flow rate of the first and second circuits of the fast-neutron reactor BREST-1200.

**Table 1.1.4. Thermodynamic properties of water and steam**  
Range of validity: at pressure up to 100 MPa – temperature from 0°C to 800°C,  
at pressure up to 50 MPa – temperatures from 0°C to 2000°C.

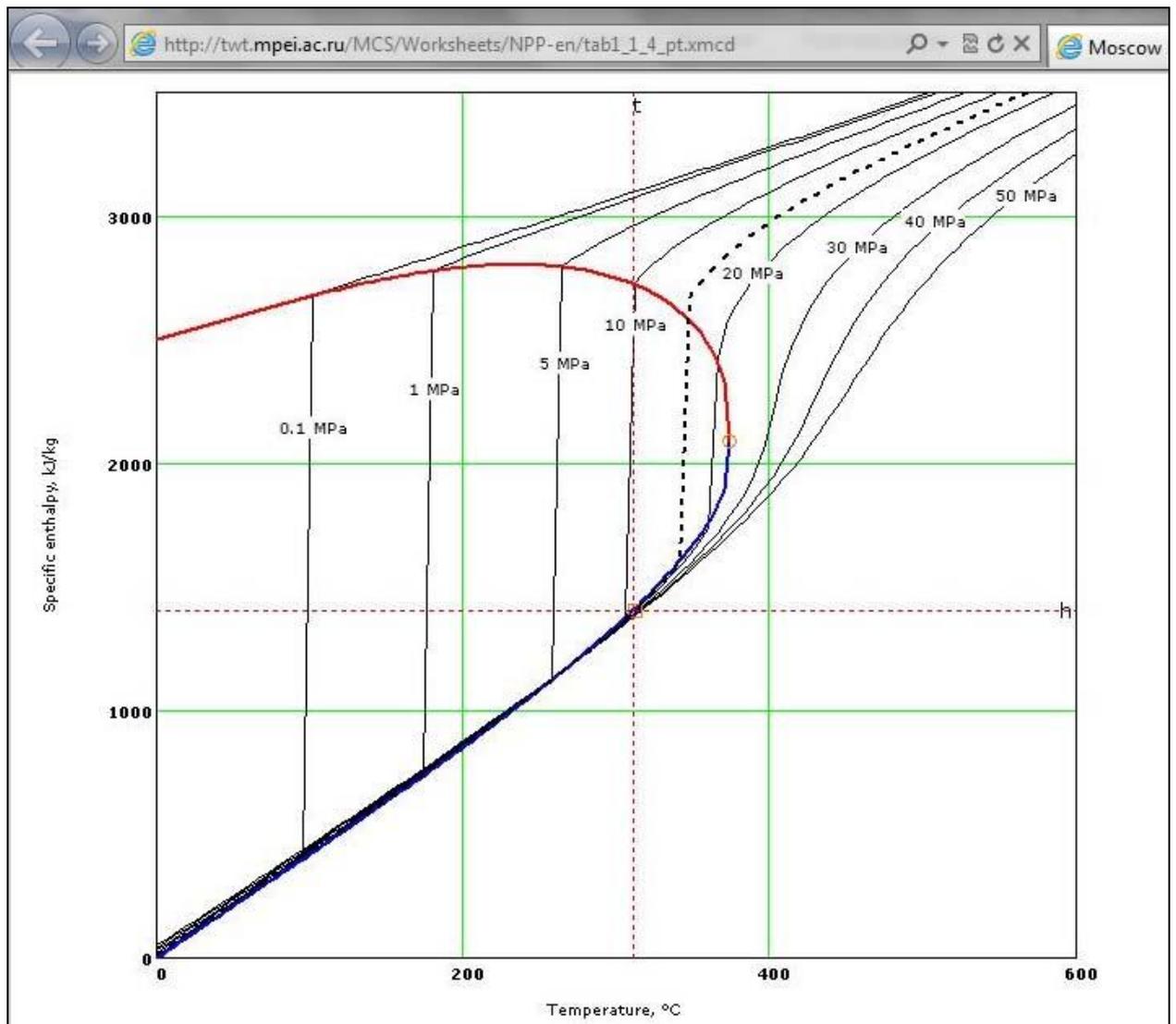
p := 15 MPa      T := 312 °C      digits := 5      Recalculate

Specific volume [1]	$v = 0.0014308 \frac{\text{m}^3}{\text{kg}}$
Density [1]	$\rho = 698.9 \frac{\text{kg}}{\text{m}^3}$
Specific enthalpy [1]	$h = 1405.8 \frac{\text{kJ}}{\text{kg}}$
Specific entropy [1]	$s = 3.3445 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$
Specific internal energy [1]	$u = 1384.4 \frac{\text{kJ}}{\text{kg}}$
Specific isobaric heat capacity [1]	$c_p = 5.8402 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$
Speed of sound [2]	$w = 892.32 \frac{\text{m}}{\text{sec}}$
Isothermal compressibility [2]	$\kappa_T = 3.4627 \frac{1}{\text{GPa}}$
The Joule-Thomson coefficient [1]	$jt = 0.24368 \frac{\text{K}}{\text{MPa}}$

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 (p. 1.1.4 of the list, shown above). 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 is 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.

http://twi.mpei.ac.ru/MCS/Worksheets/NPP-en/tab1\_7\_2.xmcd

**Table 1.7.2.** Thermophysical properties of lead

Range of validity for temperature during the calculation of properties, specified below:  
 density: from 273.15 K to 1500 K;  
 volumetric thermal expansion coefficient: from 273.15 K to 1500 K;  
 speed of sound: from the melting temperature to 1300 K;  
 thermal conductivity: from the melting temperature to 1300 K;  
 dynamic viscosity вязкости: from the melting temperature to 1470 K;  
 specific isobaric heat capacity: from the melting temperature to 1300 K;  
 Prandtl number: from the melting temperature to 1300 K;  
 surface tension: from the melting temperature to 1273.15 K;  
 the melting temperature, according to [21], is 600.55 K.

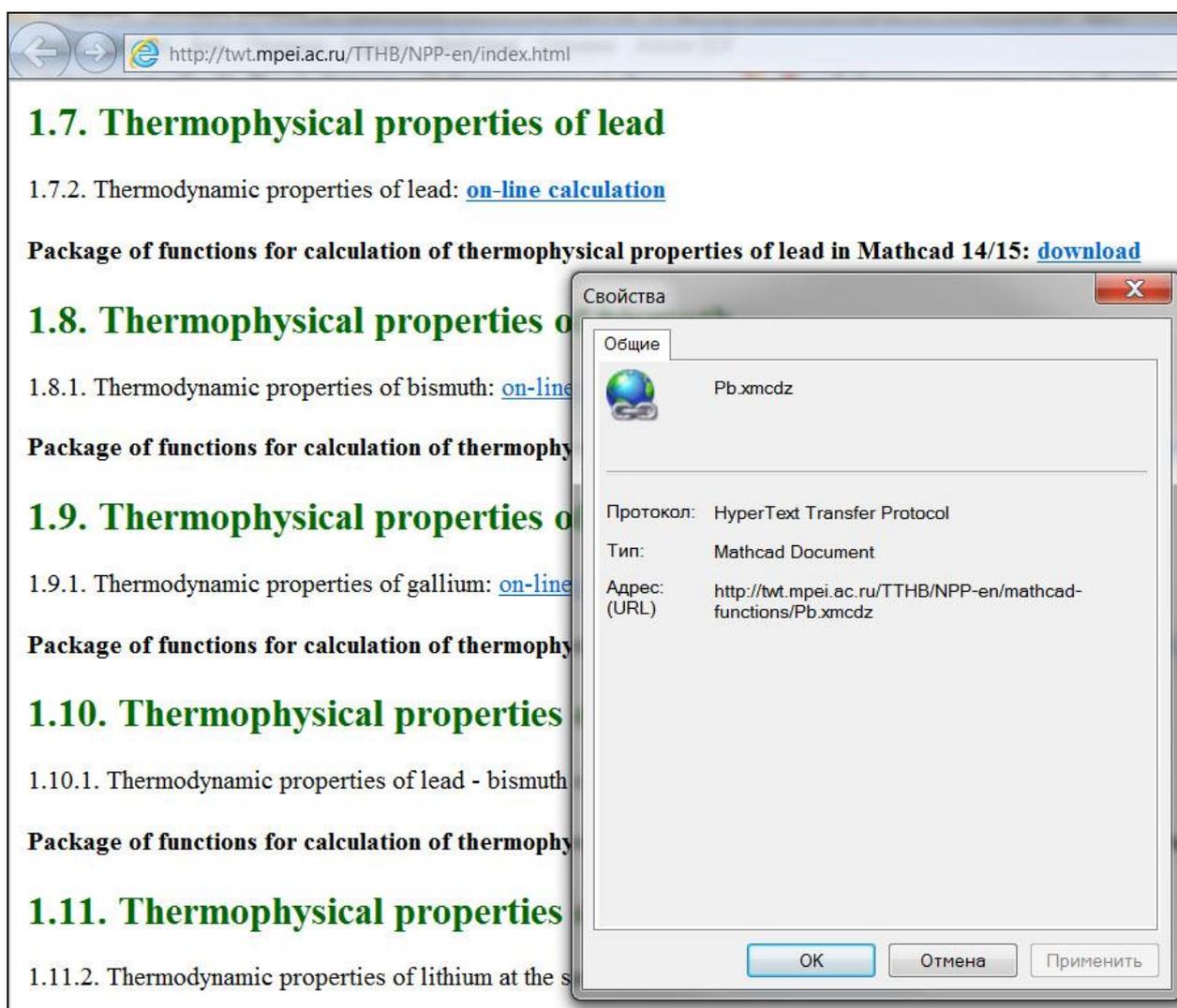
T :=  K    digits :=    

Density [22]	$\rho = 11.2 \cdot \frac{\text{ton}}{\text{m}^3}$
Absolute error [22]	$\Delta\rho = 0.03359 \cdot \frac{\text{ton}}{\text{m}^3}$
Volumetric thermal expansion coefficient [23]	$\alpha = 12.07 \cdot 10^{-5} \cdot \frac{1}{\text{K}}$
Absolute error [23]	$\Delta\alpha = 0.03622 \cdot 10^{-5} \cdot \frac{1}{\text{K}}$
Speed of sound [24]	$w = 1702 \cdot \frac{\text{m}}{\text{sec}}$
Absolute error [24]	$\Delta w = 51.06 \cdot \frac{\text{m}}{\text{sec}}$
Thermal conductivity [26]	$\lambda = 20.2 \cdot \frac{\text{W}}{\text{m} \cdot \text{K}}$
Dynamic viscosity [27]	$\mu = 1.325 \cdot \text{mPa} \cdot \text{sec}$
Specific isobaric heat capacity [26]	$c_p = 0.1417 \cdot \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$
Prandtl number [22, 26, 27]	$Pr = 9.297 \times 10^{-3}$
Surface tension [26]	$\sigma = 406 \cdot \frac{\text{mN}}{\text{m}}$

Fig. 4. On-line calculation of thermophysical properties of lead

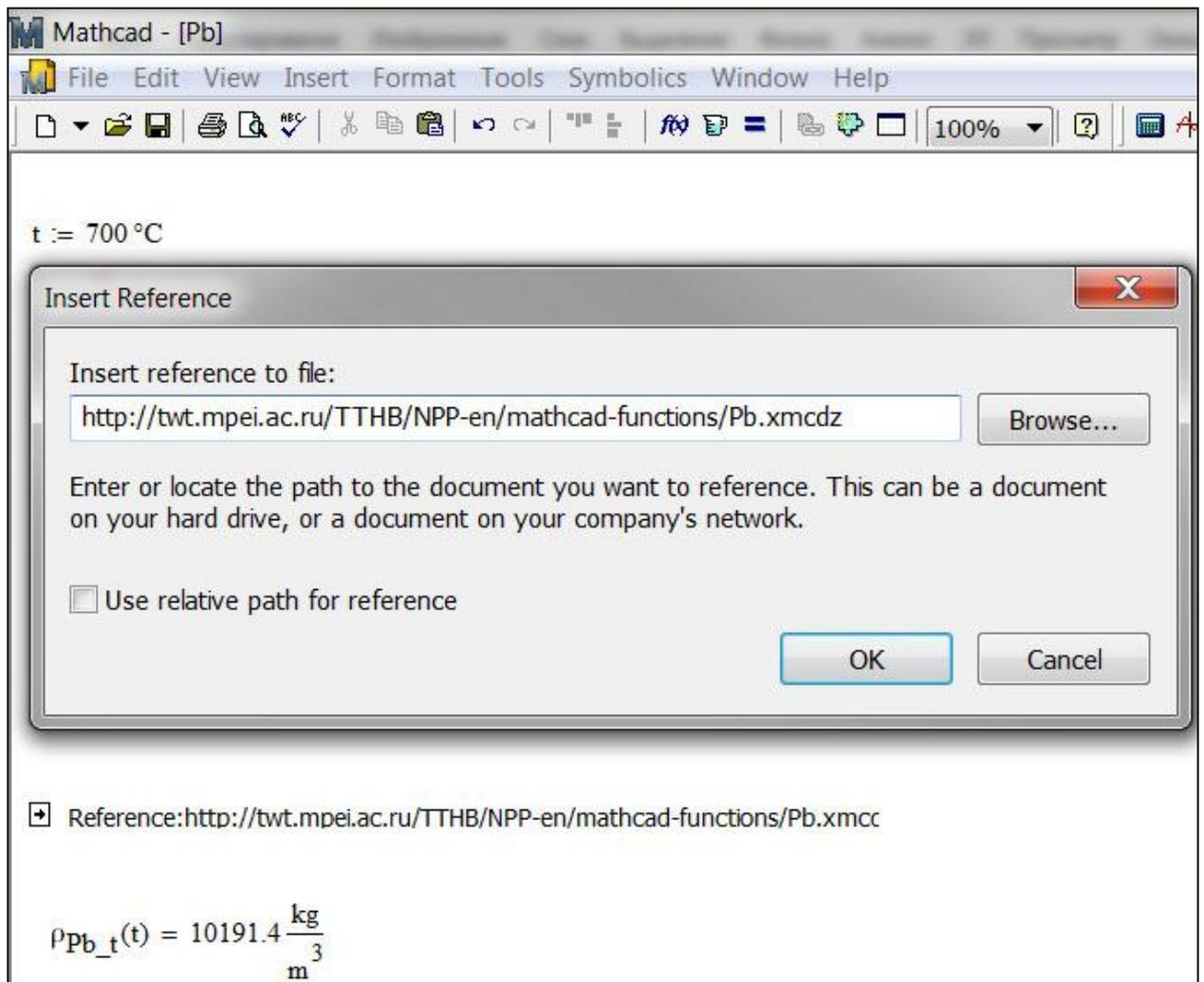
The essential difference of the present Internet-handbook is the possibility not only to fulfil the single on-line calculation, but to incorporate the appropriate functions into his own calculations which can be carried out in popular mathematical and engineering computer programs. For detailed explanation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

For example, if the user of our web-site works in engineering calculator Mathcad [3], 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.*

It is also possible not to download functions from the site but to create a link to the site in the work document. This operation is shown on fig. 6.



*Fig. 6. Calculation of density of lead in Mathcad with link to the “cloud” function.*

Mathcad has a command to insert the reference into a worksheet to another Mathcad document, which functions and variables will be usable in the first one. The linked document can be located on a personal computer, on a local computer network or on an Internet server. In calculation, shown on fig. 6, there was made a link to the document which address is presented on fig. 5. After this link in calculation shown on fig. 6 the function named  $\rho_{Pb,t}$  became usable, and it returns the result of calculation of lead’s density 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.

## Efficiency of the nuclear powerplant with steam turbine and water - water energetic reactor

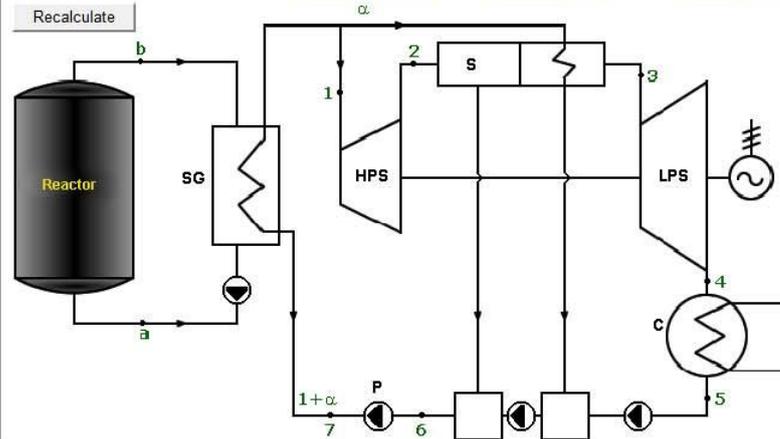
Pressure of the saturated steam at the HPS inlet  $p_1 :=$   МПа

Pressure of the wet steam at the separator inlet  $p_2 :=$   МПа

Temperature of the steam at the LPS inlet  $T_3 :=$   °C

Pressure in the condenser  $p_4 :=$   бар

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



Reference: <http://bwt.mpei.ac.ru/ТТНБ/НПП/mathcad-functions/H2O.xmcdz>

1. Parameters at the HPS inlet

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

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

2. Parameters at the separator inlet

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

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

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

3. Parameters at the LPS inlet

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

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

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

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

5. Parameters at the condenser outlet

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

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

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

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

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

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

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

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

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, namely:

- `wspHSST` — specific enthalpy of saturated steam as a function of temperature;
- `wspSSST` — specific entropy of saturated steam as a function of temperature;
- `wspHSWT` — specific enthalpy of water at the saturation line as a function of temperature;
- `wspHEXPANSIONPTXPEFF` — specific enthalpy of steam at the end of the process of expansion in a turbine as a function of starting pressure, temperature and steam dryness fraction, end pressure and internal relative efficiency of the turbine;
- `wspHPT` — specific enthalpy of water or steam as a function of pressure and temperature;
- `wspSPT` — specific entropy of water or steam as a function of pressure and temperature;
- `wspTSP` — temperature at the saturation line as a function of pressure;
- `wspHEXPANSIONPTPEFF` — specific enthalpy of steam at the end of the process of expansion in a turbine as a function of starting pressure and temperature, end pressure and internal relative efficiency of the turbine;
- `wspSSWT` — specific entropy of water at the saturation line as a function of temperature.

Names of these functions have prefix `wsp`. This is abbreviation of program package WaterSteamPro, which is available on the web-site [www.wsp.ru](http://www.wsp.ru). On fig. 6 it is shown how these functions can become available in Mathcad. 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, fortran 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.

### References

The addresses of Internet-versions (in Russian) are mentioned in brackets.

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