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"Cloud Computations" for Chemical Departments of Power Stations

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Abstract—The notion of "cloud computations" is defined, and examples of such computations carried out at the Moscow Power Engineering Institute are given. Calculations of emissions discharged into the atmosphere from steam and hot-water boilers, as well as other calculations presented on the Internet that are of interest for power stations, are shown.

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So-called "cloud computations," a term that denotes granting of access to remote computation resources, disk space ("clouds"), and communication channels to a customer, occupy the first place in the list of the most important IT-turnovers, events that will bring about serious changes in the lives of users of computers. "Clouds" are understood to mean computation centers the capacities of which are an order of magnitude more powerful than the infrastructures of users. Access to virtual servers deployed in a distributed network of computers with commercial-grade capacities is provided to customers instead of access to physical servers. The changeover for using "cloud computations" is connected, among other things, with such factors as a high cost of licenses for computer programs installed on individual workstations, high cost of renting premises, growing cost of electricity and combating computer piracy.

The website www.vpu.ru/mas (vpu is the transliterated abbreviation of the Russian term for "water treatment plant," and mas stands for Mathcad Application Server [1]) contains a collection of Internet pages with "live" calculations of the thermodynamic properties of pure water and aqueous solutions. For example, Fig. 1 shows a *transparent interactive network* calculation of the ionic product of water and water steam as a function of temperature and pressure carried out in accordance with a formulation approved by the International Association for the Properties of Water and Water Steam (IAPWS) in 2007 (www.iapws.org)[1]. A "network" visitor of this site is able, not only to change the initial values of temperature and pressure in different units of measurement (an interactive feature) and obtain the required value of ionic product, but also see all the formulas and intermediate calculation results (transparency), all without the need to install additional programs on his or her computer. These features enable the user to develop, if necessary, this calculation procedure by him- or herself and, most importantly, to quickly debug it. In addition, a calculation point is recorded on the p, T diagram, due to which a site visitor can see the region in which the process is located: the domain of subcooled water (the case shown in Fig. 1) or superheated steam, the saturation line, or the domain of supercritical parameters.

A calculation of the thermodynamic parameters of seawater as a function of pressure, temperature, and salinity (Fig. 2) has been published using the same principle, i.e., a transparent, interactive, and network one. The formulations for this calculation were approved at the last session of the IAPWS in 2008. The network calculation shown in Fig. 2 allows a user, not only to carry out calculations, but also to show certain dynamics, e.g., a pattern of change in the parameters of seawater when one of the input parameters is varied and the other two remain constant.

Some other network calculations of the properties of water and steam have also been published on the site http://twt.mpei.ru/ochkov/WSPHB [2].

Figures 3–5 show examples of routine calculations that have been opened on the Web for engineers and technicians of chemical departments at power stations.

(1) A database of sources of water supply for power stations (see Fig. 3), which is continuously upgraded and modified and takes into account seasonal variations of water quality.

(2) A dependence describing the concentration of an aqueous solution of sulfuric acid as a function of its density and temperature (see Fig. 4). Tables and graphs

[1] The Internet-based calculation shown in Fig. 1 contains a direct reference to the corresponding formulation placed at the site www.iapws.org

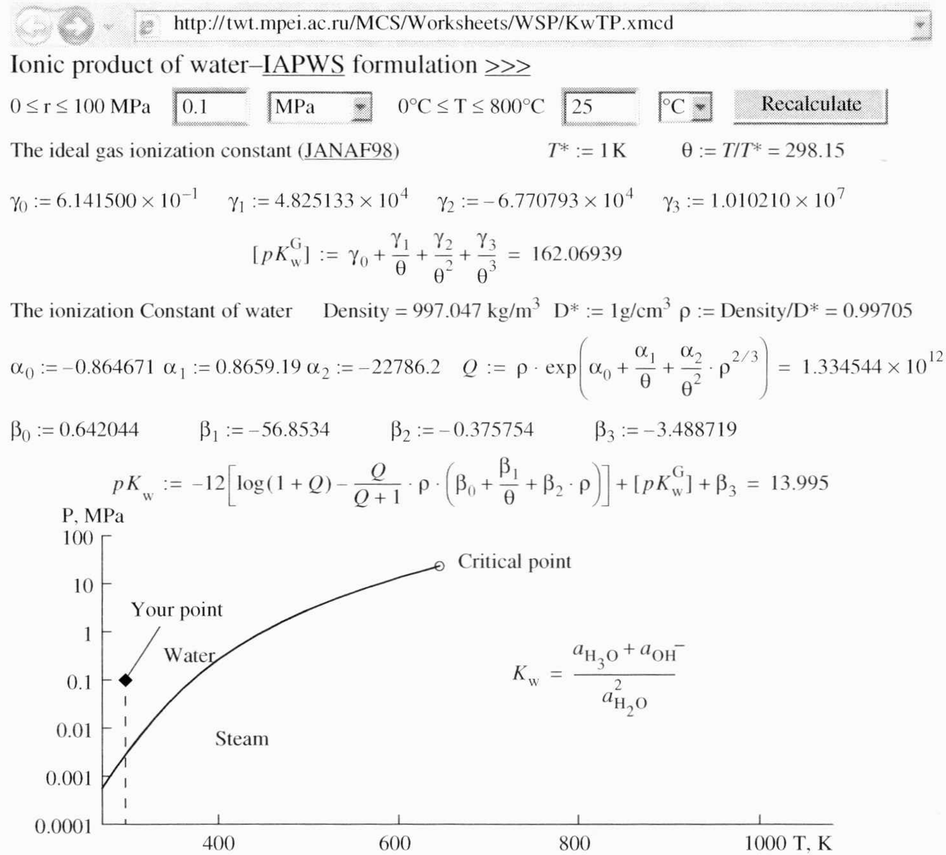


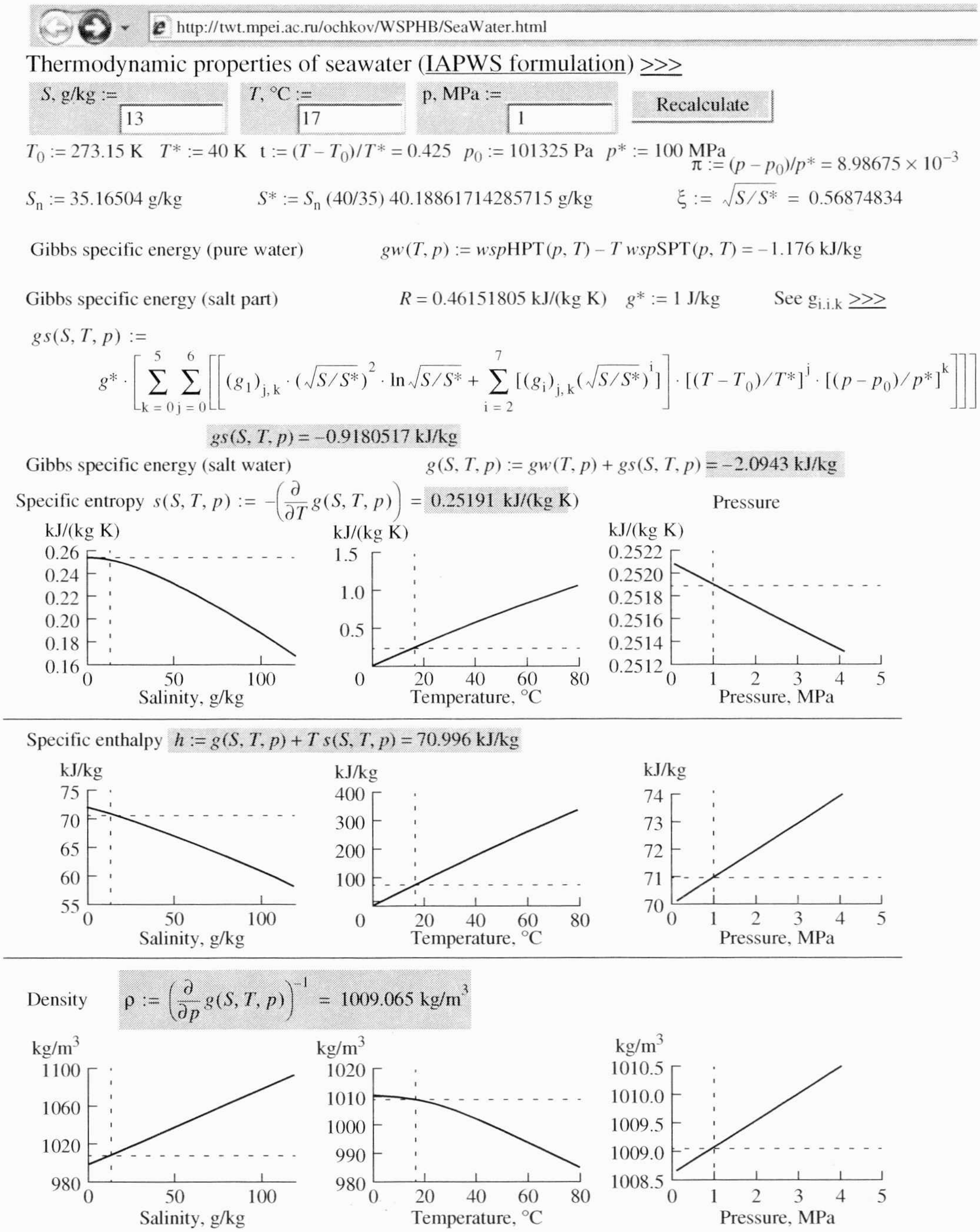
Fig. 1. Calculation of the ionic product of water as a function of temperature and pressure.

for fixed temperatures can be found in the reference literature. The above-mentioned site for the first time shows processing of these data taking into account differences in temperature. In addition, it contains similar dependences for other chemical reagents that are used in water treatment plants at power stations.

(3) A "live" nomogram for calculating the working exchange capacity of ion-exchange resin (see Fig. 5). Manufacturers of water-treatment equipment often hand over closed and frequently nonlocalized the computer programs for calculations of water treatment plants to customers or furnish technical documentation with nomograms similar to that shown in Fig. 5. The nomogram given at the above-mentioned site is "live" in the sense that the user can change the initial data and obtain, not only the required answer, but also the corresponding curves on the diagram. Calculations for almost all ion-exchange resins produced in and outside Russia have been opened in a similar way. In particular, this made it possible to place "transparent interactive network" calculations of technological circuits containing ion-exchange filters and reverse-osmosis membranes on the site.

Work on creating "cloud" computation servers for specialists in thermal engineering and thermal power engineering is part of an innovative educational program (http://inedu.mpei.ru) that is being conducted at the Moscow Power Engineering Institute (MEI) (www.mpei.ru) for development of an Electronic Encyclopedia for Power Engineering (www.trie.ru). The server developed at the MEI is constantly augmented with new calculations for different fields of industry. Among the new computer programs relating to chemical and environmental laboratories, we should mention calculations of the quantity of harmful substances emitted into the atmosphere with flue gases from steam and hot-water boilers.

These calculations were carried out in the course of developing a multimedia simulation system intended for studying the effect of the production and technological processes used at power-generating facilities of RAO Russian Railways on the environment. These calculations allow a user to study atmospheric emissions of such pollutants as nitrogen and sulfur oxides, ash and unburned fuel, and fuel-oil ash containing vanadium and benz(a)pyrene generated during the operation of



$$gs(S,T,p) := g^* \cdot \left[\sum_{k=0}^{5}\sum_{j=0}^{6}\left[\left[(g_1)_{j,k}\cdot\left(\sqrt{S/S^*}\right)^2\cdot \ln\sqrt{S/S^*} + \sum_{i=2}^{7}\left[(g_i)_{j,k}\left(\sqrt{S/S^*}\right)^i\right]\right]\cdot\left[(T-T_0)/T^*\right]^j\cdot\left[(p-p_0)/p^*\right]^k\right]\right]$$

$$s(S,T,p) := -\left(\frac{\partial}{\partial T}g(S,T,p)\right)$$

$$\rho := \left(\frac{\partial}{\partial p}g(S,T,p)\right)^{-1}$$

Fig. 2. Thermodynamic properties of seawater as a function of salinity, temperature, and pressure.

KV-14GM and KV-TS hot-water boilers with a thermal power output of 17–84 GJ/h, as well as DB-14GM and DE-14S steam boilers with a steam output of 2.5–25 t/h. The calculations of atmospheric emissions of pollutants make it possible to estimate both maximal (g/s) and gross (t/yr) emissions, as well as to determine the sum of charges for emissions taking into account the fill-in factors of yearly and daily load curves.

The problems of environment protection and rational use of natural resources are crucial at the modern stage of development of power engineering and industry as a whole; therefore, matters concerning emissions into the atmosphere of harmful substances able to upset its chemical composition during combustion of organic fuels in industrial and heating boiler houses are of great importance.

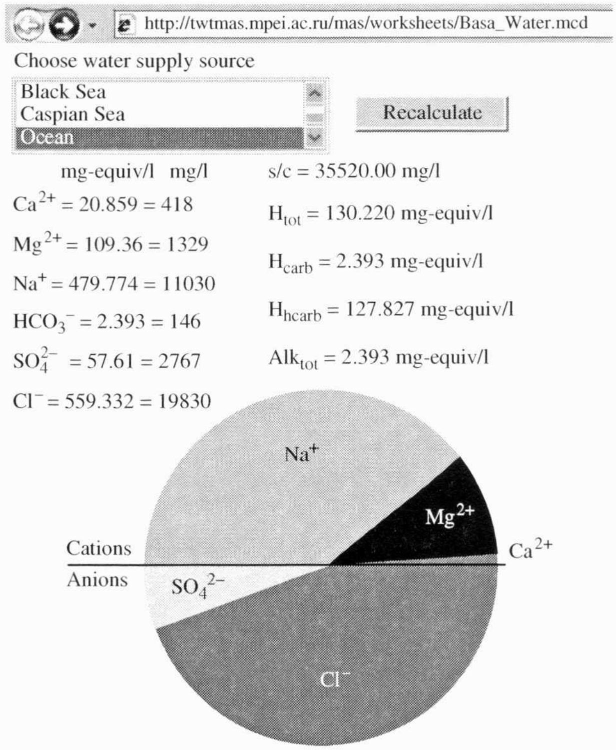


Fig. 3. Database on sources of water supply for power stations.

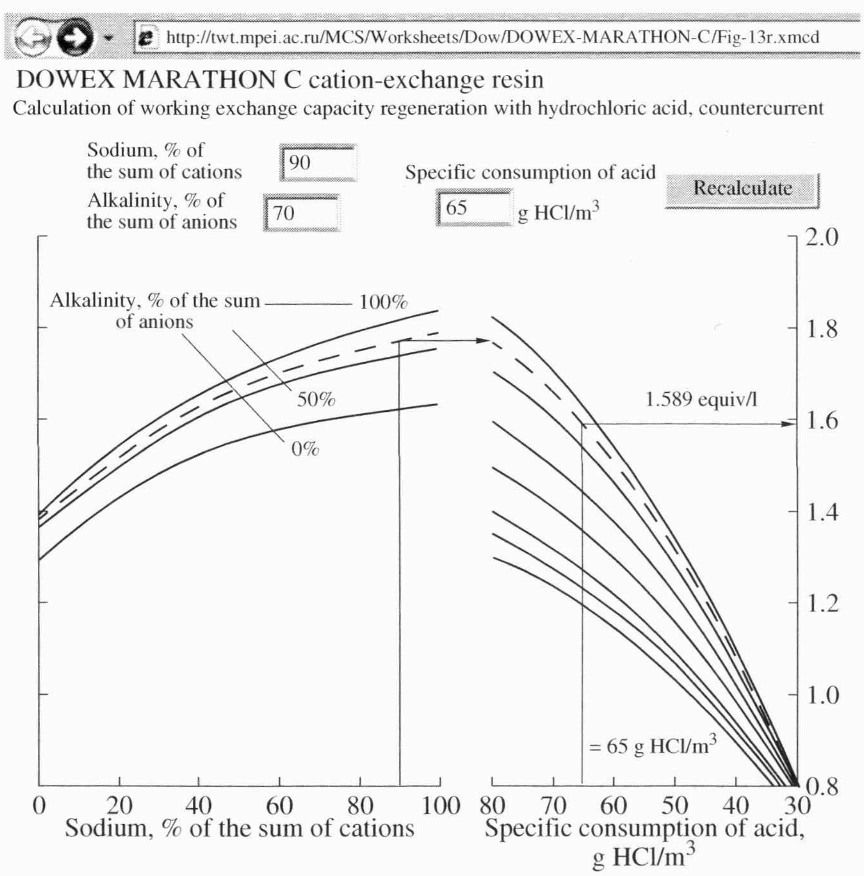


Fig. 4. Live nomogram for calculating the working exchange capacity of ion-exchange resin.

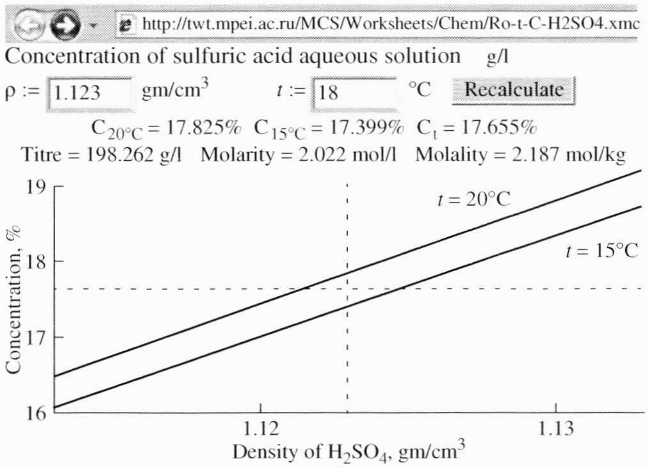


Fig. 5. Density, temperature, and concentration of sulfuric acid.

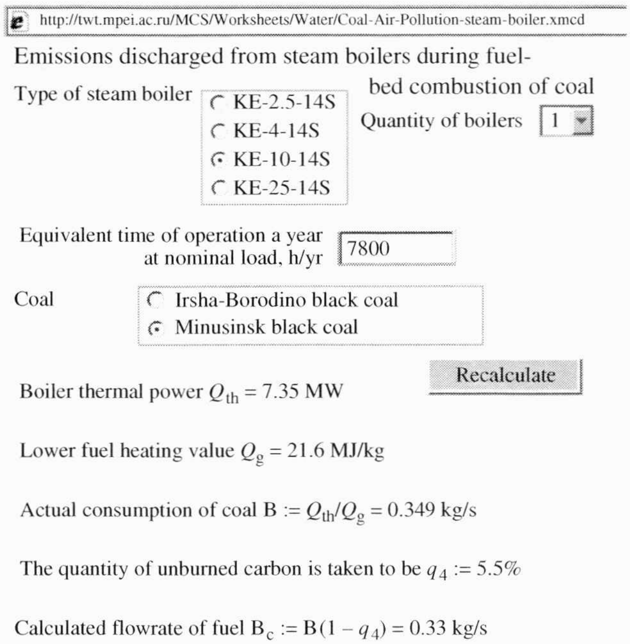


Fig. 6. Entering of initial data for calculating the emissions discharged from steam boilers during coal combustion.

The list of substances that enter into the atmosphere during combustion of solid fuel includes, along with oxides of carbon and hydrogen (CO_2 and H_2O), which are the main combustible elements, fly ash with particles of unburned fuel, sulfurous and sulfuric anhydrides (SO_2 and SO_3), nitrogen oxides (N_2O, NO, and NO_2, denoted generally as NO_x), and some quantity of fluorides, as well as gaseous products from incomplete combustion of fuel (CO, H_2S, and others). A quantitative assessment of these processes using a computer program on the Internet is shown in Fig. 6.

The composition of flue gases emitted into the atmosphere during combustion of sulfur-containing fuel oils includes sulfurous and sulfuric anhydride, nitrogen oxides, gaseous and solid products of incomplete combustion, and vanadium compounds (oxides with different valences, including V_2O_5). Most of these components are toxic and have a detrimental effect on the natural environment and human beings even in low concentrations. Carcinogenic substances can be generated during incomplete combustion of fuel, the most dangerous of which are polycyclic aromatic hydrocarhttp://twt.mpei.ac.ru/MCS/Worksheets/Water/Oil-Air-pollution-water-boiler.xmcd

Benz(a)pyrene emission

Factor taking into account the fuel oil atomization method for mechanical steam-atomizing burners

$$R_m := 0.75$$

Air excess factor in combustion products at the furnace outlet $\alpha'' =: 1.2$

Furnace volume heat density $q_v := 260$ kW

Since the design of the boiler types being considered does not incorporate the possibility of recirculation, the dimensionless factor that takes into account the influence of flue gas recirculation on the generation of benz(a)pyrene is taken to be $K_{rec} := 1$

Factor depending on the relative boiler load K_d [1.5]

Air is not fed in bypass of boilers in the considered types of boilers; the dimensionless coefficient that takes into account stagewise admission of air $K_{st} := 1$

Period of time between cleaning operations

- ○ 12 h
- ○ 24 h
- ◉ 48 h

[Recalculate]

Factor taking into accountthe effect of shot cleaning of convective surfaces in the operating boiler $K_{cl} = 2.5$

Emission of benz(a)pyrene in combustion products from a fuel-oil-fired hot-water boiler

$$C_{BP} := 10^{-6}\frac{R_m\left(0.445\frac{q_v}{\text{kW}} - 28\right)}{e^{3.5(\alpha''-1)}} \cdot K_{rec} \cdot K_d \cdot K_{st} \cdot K_{cl} \cdot \frac{\text{mg}}{\text{m}^3} = 1.225 \times 10^{-4}\,\frac{\text{mg}}{\text{m}^3}$$

Fig. 7. Calculation of benz(a)pyrene emissions discharged from hot-water boilers during fuel oil combustion.

http://twt.mpei.ac.ru/MCS/Worksheets/Water/Gas-Air-Pollution-steam-boiler.xmcd

Gas fuel

- ◉ Saratov–Moscow
- ○ Serpukhov–St. Petersburg

Gas fuel heating value $Q_g = 28.64$ MJ/m^3

Actual thermal power $Q_{th} := B_c Q_g = 7.383$ MW

Specific emission of NO_2 during gas fuel combustion

$$K_{NO_2} := \left(0.01\sqrt{\frac{D}{t/h}} + 0.03\right)\text{g/MJ} = 0.062\ \text{g/MJ}$$

Dimensionless factor for rotary-type burners $\beta_k := 1$

Temperature of air fed for combustion $t_{c.a}$, °C [30]

Dimensionless factor taking into account the temperature of air supplied for combustion

$$\beta_T := 1 + 0.002(t_{c.a} - 30) = 1$$

Dimensionless factor taking into account the effect of air excess factor onhe generation of nitrogen oxides β_a [1.225] [Recalculate]

Dimensionless factor taking into account the effect of flue gas recirculation through the burners on the generation of nitrogen oxides without recirculation $\beta_{rec} := 0$

Dimensionless factor taking into account stagewise admission of air into the furnace chamber in he absence of air fed to the flame's intermediate zone $\beta_{st} := 0$

Total quantity of nitrogen oxides NO_x emitted into the atmosphere with flue gases

$$M_{NO_x} := B_c \cdot Q_g \cdot K_{NO_2} \cdot \beta_k \cdot \beta_T \cdot \beta_a \cdot (1 - \beta_{rec}) \cdot (1 - \beta_{st}) = 0.562\ \text{g/s}$$

Recalculation of the obtained value of NO_x emission for nitrogen dioxide and nitrogen oxide

$$M_{NO_2} := 0.8 M_{NO_x} = 0.45\ \text{g/s} \qquad M_{NO} := 0.13 M_{NO_x} = 0.073\ \text{g/s}$$

Total quantity of NO_x emitted into the atmosphere with flue gases a year

$$M_{NO_{x\_yr}} = 15.778\ \text{t}$$

Fig. 8. Calculation of nitrogen oxide emissions discharged from steam boilers during gas combustion.

bons, especially benz(a)pyrene ($C_{20}H_{12}$), which is the most active of them. A quantitative assessment of these processes carried out using a computer program on the Internet is shown in Fig. 7.

Various nitrogen oxides also enter into the environment as pollutants. Being toxic to human beings, they feature a pronounced irritating effect, especially on the mucous membranes of the eyes, and degrade respiratory functions, resulting in a larger number of respiratory diseases. A quantitative network assessment of these processes is shown in Fig. 8.

The calculations of emissions available on the server can be used, not only for educational purposes, but for engineers and researchers working in this branch of industry, and the technology of "cloud" computations makes these calculations accessible for all interested specialists.

CONCLUSIONS

(1) "Cloud computations" are an advanced technology, the use of which makes it possible to avoid errors in engineering and scientific calculations provided that certified computer programs are available; in addition, it allows less money to be spent for purchasing software.

(2) The calculations of emissions discharged from KV-14GM and KV-TS hot-water boilers and DB-14GM and DE-14S steam boilers during their operation on coal, fuel oil, and gas that have been developed at the Department for Thermal Physics of High Temperatures of the Moscow Power Engineering Institute (Technical University) are accessible for use at the website www.vpu.ru/mas.

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