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PROCESSES AND DEVICES OF CHEMICAL MANUFACTURES

Classification of Nozzles of Mass Transfer Apparatuses

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Abstract—The detailed classification of nozzles of heat and mass transfer apparatuses is proposed. Examples of the constructive design of new types of domestic and foreign disordered and ordered nozzles are given.

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Nozzle apparatuses remain one of the most spread type of equipment for mass transfer. This is first of all due to relative simplicity of the production of elements of nozzle and also absence of necessity in devices for distribution of treated phases by each single element (in comparison, for example, with plate and film mass transfer apparatuses) [1, 2].

Despite quite big amount of existing nozzles there is quite active search of new designs of cheap and effective nozzle elements in recent years [3-6]. This is due to such advantages of nozzles in comparison with other types of contacting elements of mass transfer equipment as quite low price, possibility of its production from different materials, relatively high unification (possibility of use in apparatuses with different diameter) as well as other advantages.

The analysis of existing nozzles enabled making classification by following main groups of indices (Fig. 1):

– by method of laying in contacting part of apparatus;
– by equivalent diameter of the contacting element;
– by form of the element;
– by construction of the element;
– by type of the material of the element;
– by density of the material of the element;
– by parts density in contacting part of the apparatus;
– by motion freedom of elements relative to each other.

By the way of packing in apparatus there are disordered (irregular) and ordered (regular) packings. Irregular loading is used for nozzles of all dimensions, and regular is used in most cases for large and medium nozzles (equivalent diameter no less 50mm). Advantages of the regular packing are lower hydraulic resistance and higher velocities of light phase; main disadvantages are relative complexity of loading and unloading (especially for large apparatuses) and irregularity of flows of phases by cross-section of contacting part (up to by-pass of phases next to walls of the body caused by decreased hydraulic resistance [7]).

Recently quite many new kinds of regular packing are proposed; they have a form, for example, of ensemble of fixed to each other pipes, disposed at the angle to longitudinal axis of formed by them cylinder located in the contacting part of the mass transfer apparatus (Patent of Russian Federation no. 2397806, Fig. 2a). Also packing in a form of package of twisted by length polymer elements of cruciform cross-section (Patent of Russian Federation no. 2335724, Fig. 2b) is proposed.

By equivalent diameter elements of nozzles are divided into large, medium, small and granular (Fig. 1). With the decrease in the size of the nozzle the specific surface increases but simultaneously free volume decreases and consequently hydraulic resistance increases. Therefore small and granular nozzles are often used for carrying out of mass transfer processes at increased pressure when the loss of the pressure in apparatus is insignificant in comparison with operating pressure. It is necessary at selection of the size of the nozzle to follow ratio of equivalent diameters of apparatus and elements of nozzle which has to be no less 10 [8].

By the form of the element there are most spread

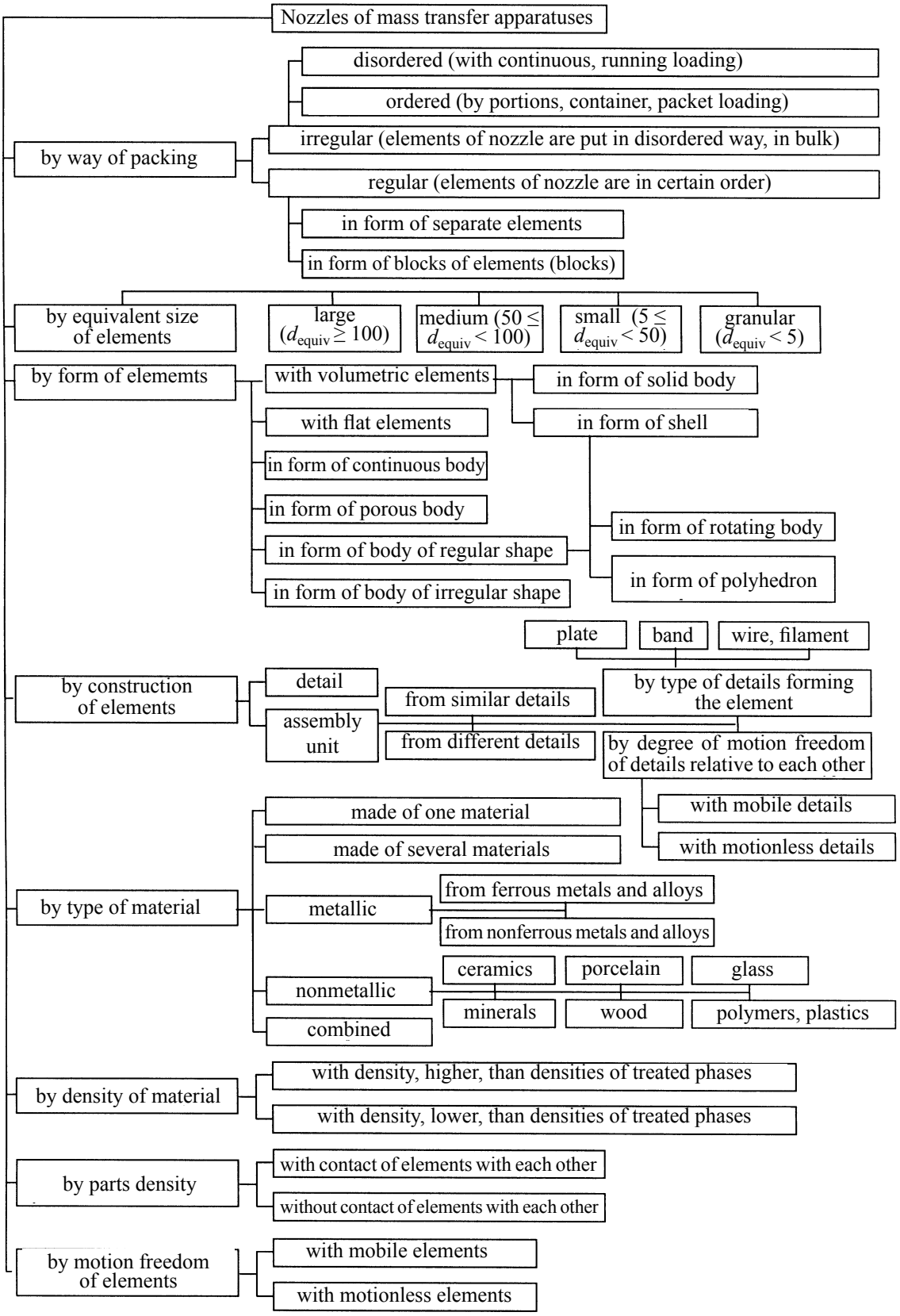


Fig. 1. Scheme of classification of nozzles of mass transfer apparatuses.

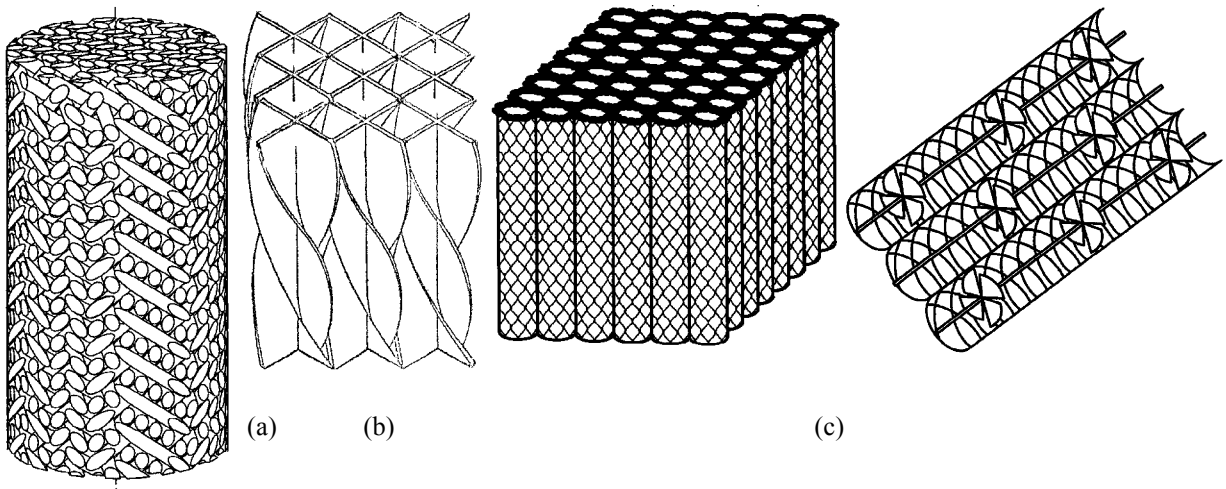


Fig. 2. Regular nozzle according to (a) RF Patent no. 2397806, (b) RF Patent no. 2350877, (c) RF Patent 2335724.

three-dimensional (volumetric) and two-dimensional (flat) nozzles (Figs. 1, 3). At that volumetric nozzles represent bodies of irregular shape (usually lumpy head) or done in a form of rotating bodies and polyhedrons (both solid and hollow, in a form of shells). At that nozzles of regular form are disposed in apparatus both disordered and ordered way.

The nozzle in a form of cylindrical pipe, Raschig

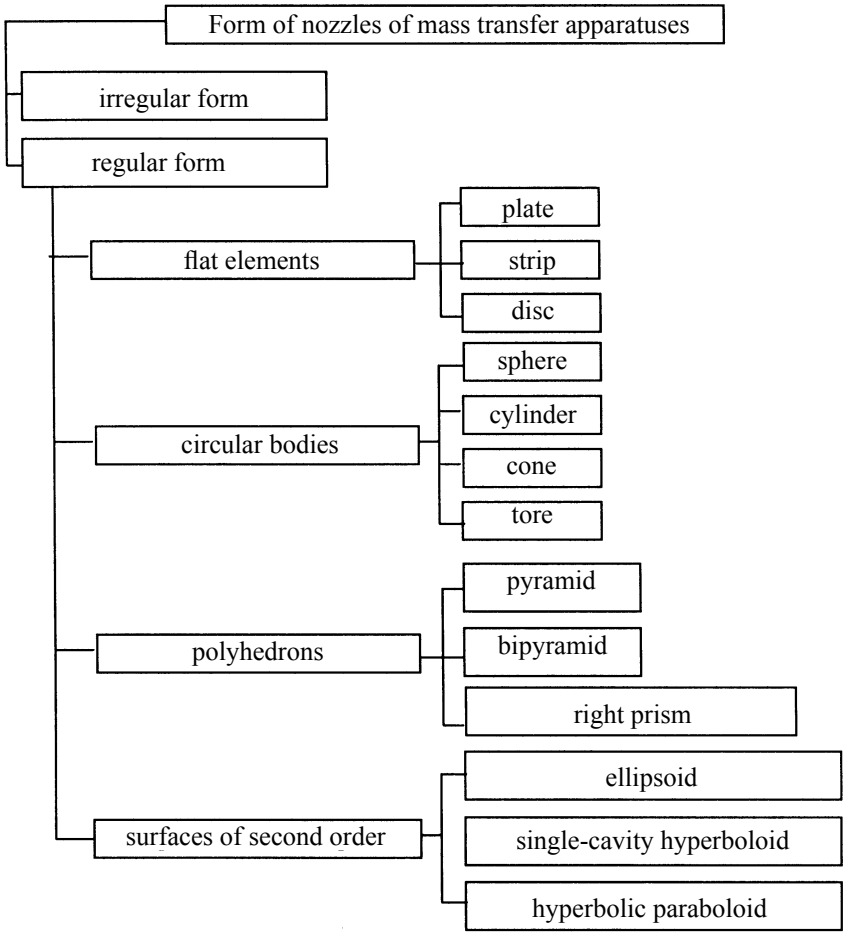
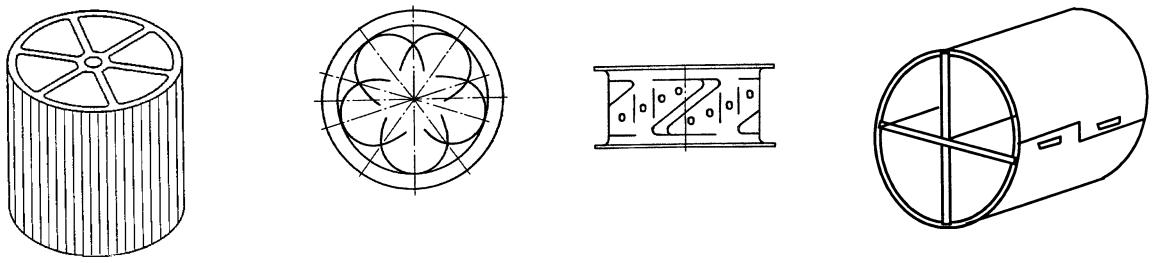


Fig. 3. Scheme of classification of nozzles by geometry.



(a) (b) (c)

Fig. 4. Construction of tubular nozzle: (a) US Patent no. 5730916; (b) Nazim ring (RF Patent no. 20027504); (c) UA Patent no. 28581.

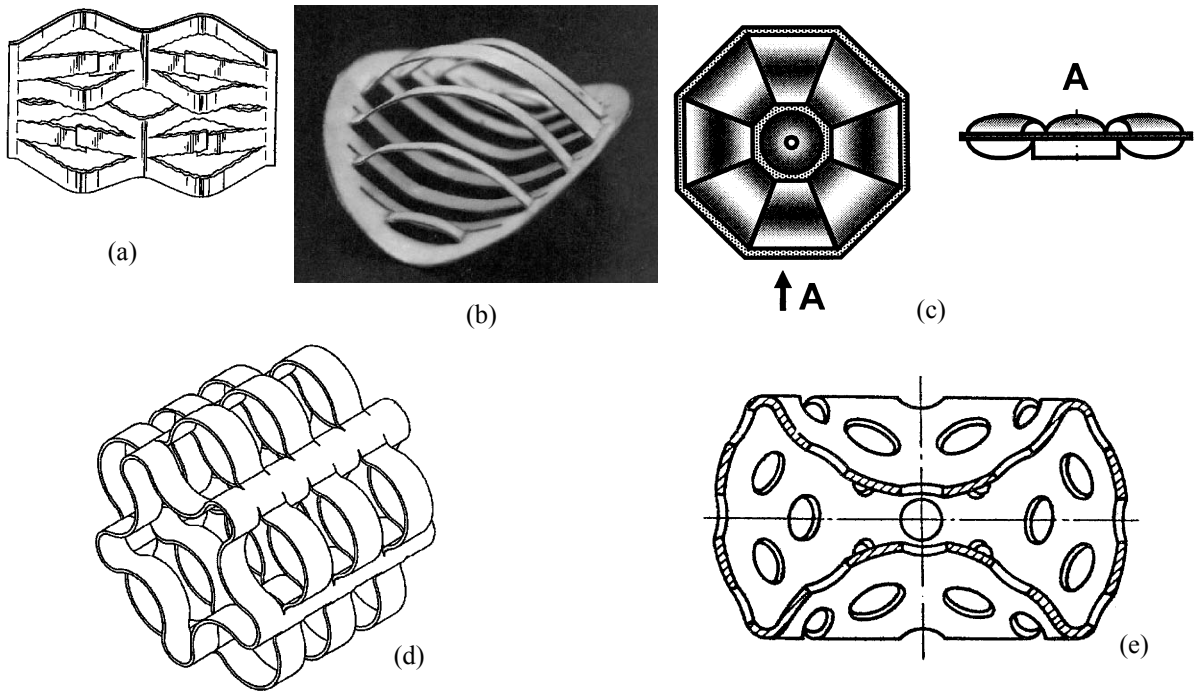
ring, which was improved many times, is being successfully used within many decades. So, tubular nozzle with longitudinal and screw bridges and edges (both internal and external), windows in the wall of the nozzles, bent inwards and outwards blades, longitudinal and transverse ledges, grooves and flutes of different forms and dimensions etc. (Fig. 4) is proposed. But the presence of flutes does not increase the specific surface and intensifies mixing of treated phases in apparatus (Patent of Ukraine no. 4980 U) that much but leads to complication of the construction of elements of nozzle and increase in its hydraulic resistance. Nozzles showed on Figs. 4b, 4c are being completely produced from the sheet material that significantly decreases its costs.

On Fig. 5 there are examples of technological nozzles of thin-walled workpieces: sheet (Figs. 5a–5c), tubular (Fig. 5d) and spherical (Fig. 5e).

Similar improvements also refer to elements in form of shells, polyhedrons (Patents of Ukrain nos. 1321 U, 1675 U, 1724 U, 2229 U, 3069 U, 12700 U).

The construction of nozzle made in a form of reticular tetrahedron is interesting (Fig. 6). It is not difficult to produce it from metal or polymer reticular sleeve by welding at angle 90° of opposite ends of opened workpiece, shell.

Also elements in a form of surfaces of the second order are spread: ellipsoid, single-cavity hyperboloid and hyperbolic paraboloid (Fig. 7).



(a) (b) (c) (d) (e)

Fig. 5. Construction of nozzles produced from thin sheet, tubular and spherical workpieces: (a) US Patent no. 5543088; (b) RF Patent no. 2398627; (c) UA Patent no. 25416; (d) RF Patent no. 2290992; (e) SU Patent no. 1064962.

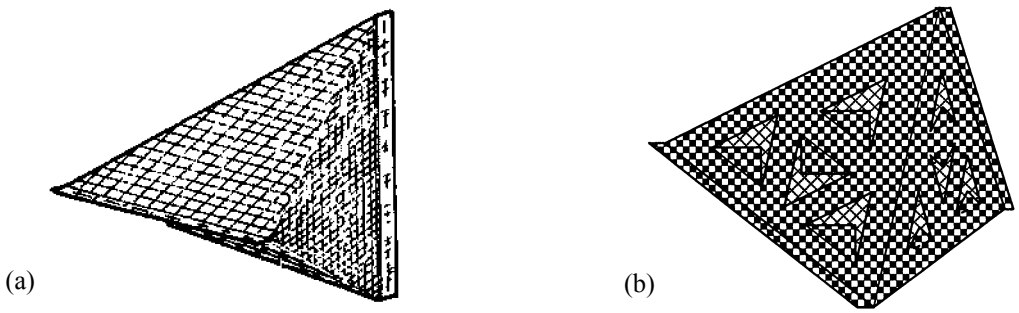


Fig. 6. Construction of nozzle in a form of reticular tetrahedron: (a) US Patent no. 6251227; (b) UA Patent no. 25414.

Besides, nozzle in a form of anchor ring and its elements is being used: both in a form of continuous body (saddle "Intaloks") and perforated elements (Patents of Ukraine nos. 2555 U and 2556 U).

The working material of the element independently from the form of this element can be solid and porous. In second case its specific surface and wettability increase a bit but tendency to pollution increases.

By construction elements represent both separate details and assembly units consisting of several details: of the similar and different types, mobile and motionless relative to each other. The production of elements from several details increases the specific surface of the nozzle, and in case of relative motion of details provides additional dispersion and mixing of phases (for example, a.c. USSR no. 1678437, a.c. USSR no. 1703171, Patent no. Ukraine no. 6504 U).

Constructions of nozzles made of wire or filament material are quite simple but disposed to compression and mutual interlacing that make difficult its separation from each other (Fig. 8).

By type of material elements can be metallic, nonmetallic and combined. Combined ones can be made in a form of assembly units or separate details with coating from another material, for example, standard carbon steel with anticorrosion coating (a.c. USSR no. 1761250).

Nozzles from ceramic materials are being continued to be improved. At that elements are being proposed both

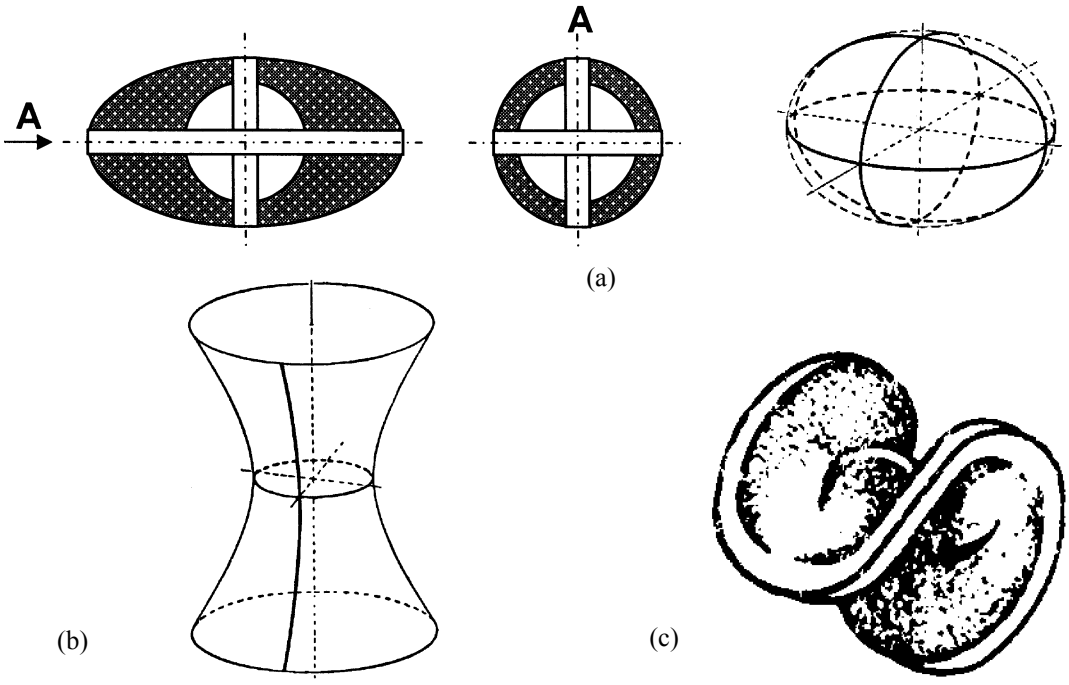


Fig. 7. Construction of nozzle in form of surfaces of second order: (a) ellipsoid (UA Patent no. 42587); (b) one-sheet hyperboloid (UA Patent no. 2396, UA Patent no. 6504); (c) hyperbolic paraboloid (Burley saddle [9]).

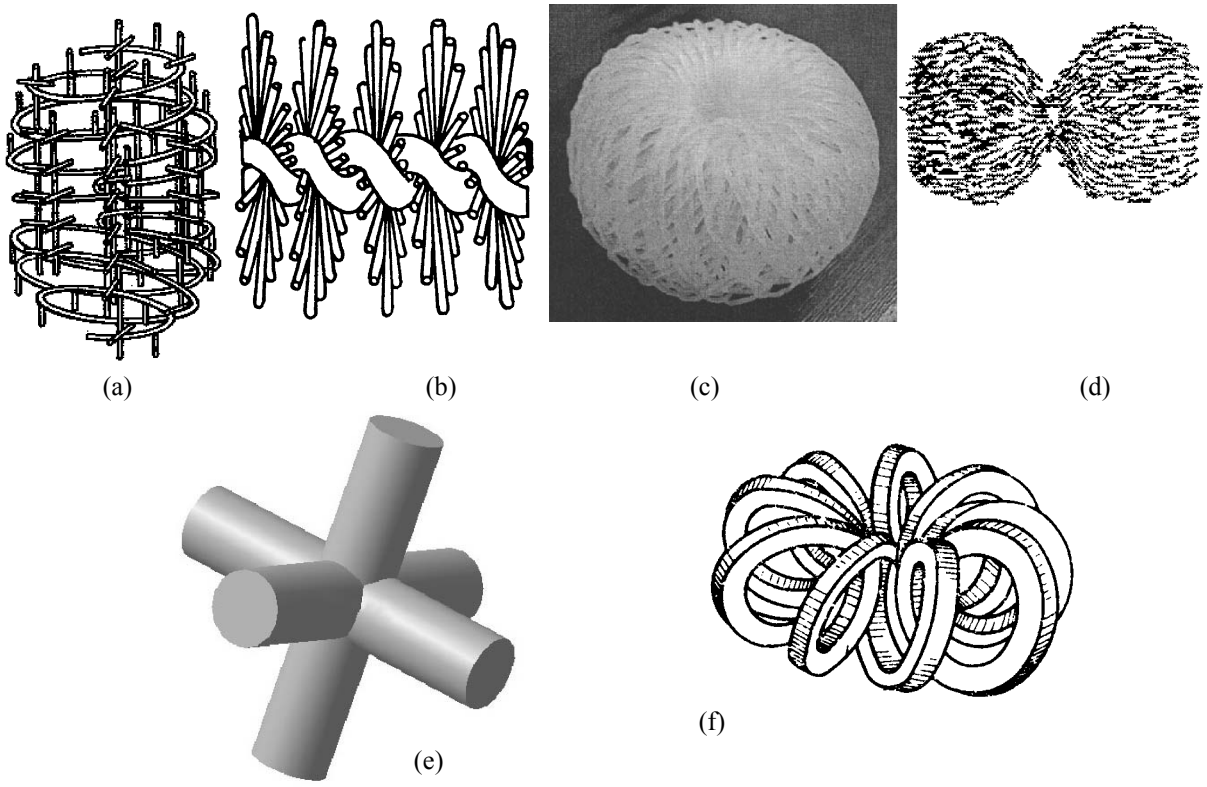


Fig. 8. Construction of nozzle from wire (filament) material: (a) Patent no. 5714097 US; (b) SU Inventor's Certificate no. 1669533; (c) RF Patent no. 2289472; (d) US Patent no. 5587239; (e) UA Patent no. 23562; (f) Teller socket [9].

with curved and rectilinear surfaces (Fig. 9).

Polymer materials which have technological features which enable to produce nozzles of absolutely different form provide elaborators with wide opportunities (Fig. 10).

By density of the material elements can be divided depending on ratio of densities of materials of nozzle and treated phases, in particular, solid phase.

If the density of the material of nozzle is less than densities of treated phases then elements of the nozzle at their free distribution in the contacting part of the apparatus during the operating time start to move that contributes to effective mixing of phases [2].

The last example shows also another two possible groups of nozzles: different *by parts density* in the contacting part of apparatus (both with contact of elements with each other and without mentioned contact) as well as by degree of motion freedom of elements in relation to each other.

In case of movable elements beside intensification of dispersity and mixing of phases also possibility of the ef-

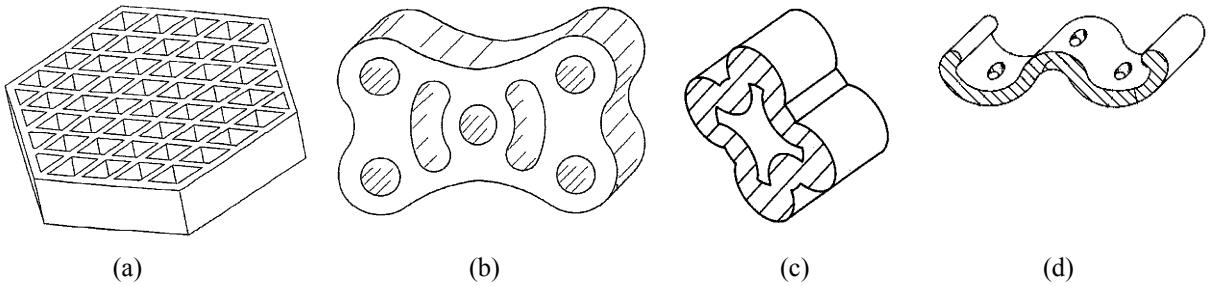
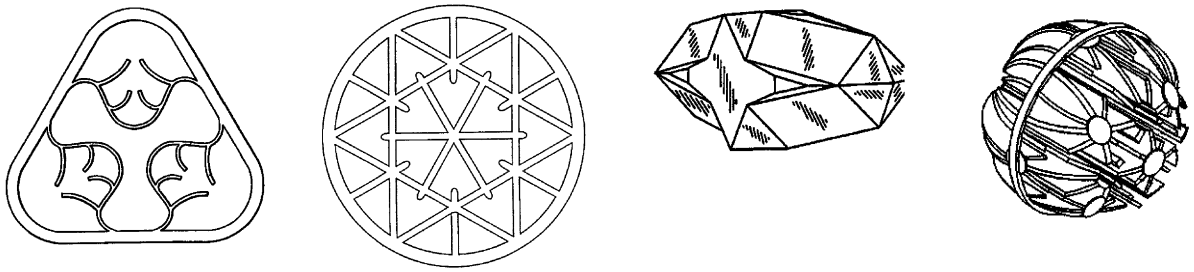


Fig. 9. Construction of nozzles from ceramic materials: (a) RF Patent no. 2288778; (b) RF Patent no. 2281156; (c) EP Appl. no. 0579234; (d) US Patent no. 5747143.



(a) (b) (c) (d)

Fig. 10. Construction of nozzles from polymer materials: (a) WO Appl. no. 9804343; (b) RF Patent no. 2207902; (c) WO Appl. no. 9640432; (d) US Patent no. 5690819.

fective treatment of polluted environment can be reached because mutual impact of elements of nozzle provides their self-purification from sediments.

Mass transfer apparatuses can be divided by character of motion of packed element on following apparatuses:

– with weighted nozzle [2];

– with weighted component of nozzle (as an example it can be nozzle which has a form of ensemble of reticular spheres and placed inside of them balls made from material which has both higher and lower densities in comparison with density of treated phases, according to a.c. USSR no. 1782642);

– with spounting nozzle [2];

– with circulating nozzle [2];

– with rotating nozzle (for example, in form of propellers rotating at the effect of upward current of the light phase and installed directly on vertical columns (a.c. USSR no. 1678437) or on guiding head (a.c. USSR no. 1741884);

– with combined (complicate) motion of nozzle [2].

Mass transfer apparatus (Patent of Ukraine no. 52742) has hollow body made from nonmagnetic material and filled with nozzle made from magnetic material with Curie point conforming to the temperature of realization of the mass transfer process. At that the inductance coil is placed in the area of nozzle from the external wall of the apparatus.

Ferromagnetic elements of the packing due to inductance start to heat up after switch on of the inductance coil to the source of electric current. After reaching by them temperature conforming to Curie point of the material of nozzle, elements loose magnetic features and stop to heat up. At further cooling they again get magnetic features and again start to heat up. This way the constant temperature of the nozzle and treated in apparatus mediums are being kept.

In this article there was an attempt to make classification of nozzles of mass transfer apparatuses from different points of view. At that, even starting from proposed classification but not specific options of nozzles production it is possible to make conclusion about their diversity which enable successful competition with other types of contacting devices of mass transfer apparatuses. Also modern achievements of materials science and technology, which can quickly respond on need of nozzles production subjected to treatment of absolutely different substances and their mixtures, contribute to this.

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