DEVELOPMENT OF FILTERS CLASSIFICATION METHOD FOR OPTIMIZING FILTERS SELECTION

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Filtration techniques and technology development make it advisable to extend classification principles for filtering equipment. in grades gives the possibility of designing new filter versions by synthesis of different sub-groups features and developing new filtration methods.

Besides, the idea of extending the scheme to methods of filtration processes calculation, is discussed. The classification scheme application for optimizing filters selection is shown by numerous examples. The scheme can be adopted to an expert system of solid-liquid filters selection.

There are a number of established approaches to the classification of filtering equipment. Most often filtration equipment is classified according to the methods of creating the driving force of filtration process. The major shortage of this classification is different types of filtering equipment bilonging to the same group although they have the different function principles.

For example, the group of equipment where the filtration driving force is vacuum getting in vacuum drum and belt filters (continuous filtration) with continuous movement of filter medium, leaf and cartridge filters (batch filtration) with fixed filter elements, etc.

The group of filters working under hydrostatic pressure include deep bed filters (fixed or movable grained bed) and belt filters for coolant which acts continuously or semicontinuously. The group of filters with pressure driving force looks more eclectic.

This classification system needs a large amount of actual information. As a rule the system does not allow to conduct either a detailed analysis of possible filters constructions or synthesis of new constructions. Moreover the calculation methods of filters from the same group can differ cardinally. It makes difficult to use the classification system and ist computer application.

Filtration techniques and technology development makes it advisable to extend classification principles for filtering equipment. The aim of the below described principles of classification is to find out some trends in filters design and filtering equipment usage. This will help improve methods of calculation and design of filtering equipment. The basis for filtering equipment classification here is space and time position of filtering elements (FEs) or filtering medium during the filtration process as well as during FEs regeneration.

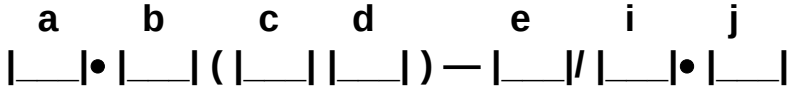
Note, that for numerous filtration processes the regeneration cannot be considered as an independent process, for instance, when the regeneration of filter medium occurs at the same time as filtration takes place. Here we consider as regeneration not only methods of filter medium output increasing but also methods of cake removal from filtering medium surface or prevent the surface against cake formation, since in numerous processes we try to change environmental conditions around FEs during filtration.

According to the proposed classification scheme all filtering equipment may be divided into 2 main groups: 1) filters with fixed FEs during filtration and 2) filters with FEs which change their spatial position during filtration (filters with movable FEs).

The abbreviated names of filters sub-groups are expressed by conditional indices shown in Fig.1. Point of departure for classification is shown in Fig.2.

As a rule, in most cases the FE (filter medium) regeneration is taking place during filtration or after it for either continuous or batch filters.

In both cases FE regeneration may be accomplished by means of hydromechanical, mechanical and physical ways. Hydromechanical regeneration is carried out by changing the direction or velocity of the fluid and pressure in various parts of the filter. Jet flow, turbulence and hydroshock are used. Mechanical regeneration is the removal of contaminants from the FE surface with the help of mechanical action such as shock, vibration, oscillating movements, shaking, cut-off, shear, etc. Physical regeneration methods suppose usage of various physical fields and their combinations to affect polluted FEs. These are sonic, infra and ultrasonic, electric, magnetic fields, centrifugal forces, etc.



(a) - 1 - continuous filter; 2 - batch filter.
(b) - 1 - fixed filter medium (FEs); 2 - movable medium (FEs).
(c) - PM - periodical movement; CM - continuous movement; RM - FEs reciprocating motion.
(d) - C - FEs movement by closed trajectory; O - FEs movement by open trajectory.
(e) - 1 - continuous filter medium; 2 - interrupted (discrete) filter medium.
(i) - CN - Continuous regeneration of FEs; P - periodical regeneration of FEs.
(j) - FR - all FEs (medium) regeneration; PR - regeneration of the part of FEs (medium);

Fig.1. Conditional indices of filters sub-groups used.

During regeneration FEs may be both in fixed position and in motion. Here we shall consider cases when filter medium or FE regeneration takes place during filtration. However the described below classification method permits to extend it to the field of regeneration operations which take place when filtration is completed.

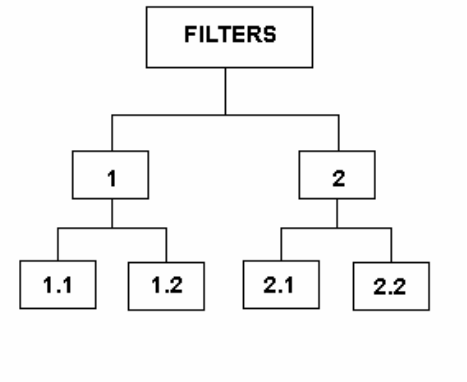


Fig.2. Point of departure for classification. 1 - Continuous filters; 2 - Batch filters; 1.1 - Fixed FEs; 1.2 - Movable FEs; 2.1 - Fixed FEs; 2.2 - Movable FEs.

CONTINUOUS FILTERS WITH FIXED FEs (FILTERING MEDIUM)

These filters can have continuous filter medium (1.1-1) or interrupted (discrete) filter medium in the view of filter elements or single sections (1.1-2), Fig.3.

The group of filters with continuous regeneration of total surface of filtration or of some part of it, as well as filters with periodic regeneration of all filtering surface or its part during filtration are shown in Fig.3.

Let's enumerate the most widespread filters constructions belonging to sub-groups of lower levels of classification.

1.1-1/CN.FR. These are filters with continuous filter medium and continuous regeneration of total filter medium during filtration. They may be the following:

- filters with tangential movement of filtrated liquid relative to the surface of FEs (cross-flow filters);
- dynamic filters of ARTISAN type where discs with paddles are placed between fixed annular filtering elements located on the axial driving shaft. Rotating discs create slurry flow along filtering surface;
- cyclone filters;
- screw filter-presses;
- filters with Talor vortex;
- tank filter-thickeners and Nutch filters with continuous stirring and other less spread varieties of filters.

To intensify FEs regeneration physical regeneration methods can be used here. Filters of the group are of great interest due to their comparatively simple design and a broadening field of application in micro- and ultrafiltration, where analogous designs are used.

1.1-1/CN.PR. Filters with continuous filter medium and continuous regeneration of a part of medium during filtration. The characteristic of the filters is that they impose regeneration of some part of filtering surface on filtration process, i.e. the total filtering surface or all filtering elements are under filtration conditions, regeneration zone contunuously moving over their surface. Only part of the filtering surface is regenerated at any given moment. Filters of the type are the following:

- filters provided with movable devices positioned above filtering surface for suction, blowing or outwash of pollutions, or filters with movable devices placed at the inner side of filtering surface and operating in accordance with the principle of blowing or outwash;

- filters with scrapers, brushes for removing pollutions, and other devices used for the same purpose, continuously moving over filtering surface.

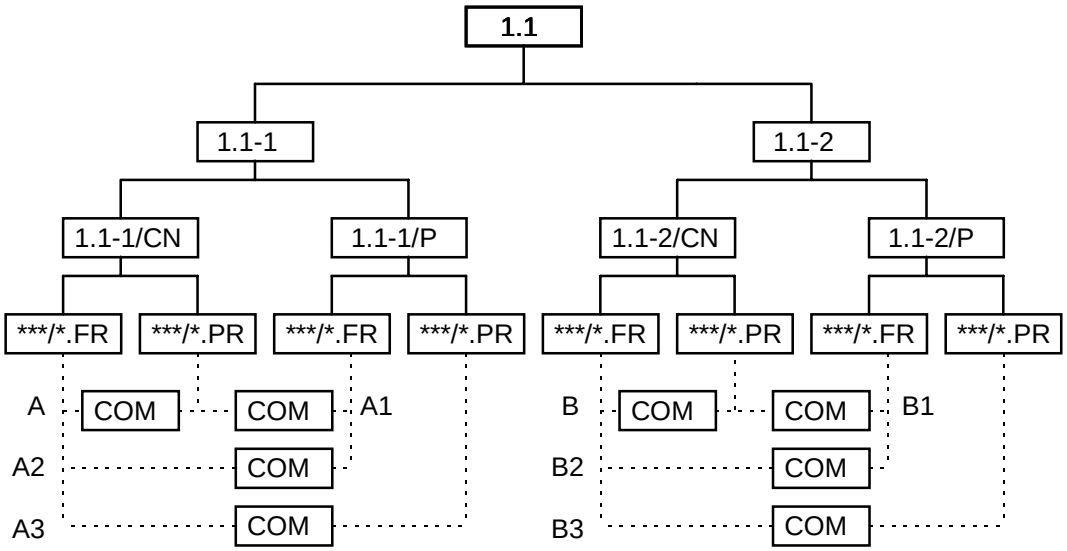


Fig.3. The classification scheme of continuous filters within fixed FE (1.1).
Here (1.1-1) and (1.1-2) are filters with continuous filter medium and discrete FEs, accordingly.
***/CN and ***/P - filters with continuous and periodical Fes regeneration during filtration, accordingly;
***/*.FR and ***/*.PR - filters with regeneration of total filtration surface (of all FEs) and regeneration of some part of total filtration surface (part of FEs of their total number), accordingly.
COM - combined (joint) regeneration action on FEs (filter medium) of FR and PR during filtration.

Filters of this type have recently begun to be used wider because they happen to realize continuous filtration closed to 1.1-1/CN.FR models. At present, however, their application
range is limited by movable mechanic devices operating under conditions of abrasion wear, which makes the filter design more complicated and demands thorough control of the devices during their operation. Besides, it is problematic to apply them for filtration of slurries giving cake with great adhesion to filtering medium.

1.1-1/P.FR. Filters with continuous filter medium and periodical regeneration of filtering surface during filtration.

During filtration periodic regeneration of the total filtering surface or some part of it is accomplished here, as a rule, after equal and quite short periods of time. This assures high filtration rate when regeneration time is much less than filtration period.

Filters of this type include a small group of filters, in which regeneration of filtering surface (cake removal) is done by periodical imposition of vibration. As a result the accumulated cake slips from the filtering element without stopping filtration. Regeneration is also possible by means of quick changes of form and configuration of filtering surface, which results in cake cracking and its discharge from filter element due to inertial forces. At this moment filtration is continued.

Filters in which filtering surface regeneration is done by impulse influence on its filtrate back flow (for example, filtration through filter element in direction opposite to gravity force) can be considered in this group.

These filters are practically of semi-continuous functioning but the duration and frequency of additional periodic effect during regeneration of the total filtration surface being much
less than filtration time, they may be conventionally referred to the group of continuous filters.

All above-mentioned regeneration methods may be used to intensify the process of regeneration. It is possible to impose periodic influence as an additional constituent on the total filtering surface according to the scheme: 1.1-1/(CN + P).FR = A2. For example, during cross-flow filtration the periodical impulse of filtrate back flow affects filter medium, Fig.3, A2.

Scheme 1.1-1/CN.(FR + PR) = A, Fig.3, A, can be realized in cross-flow filters when a movable device is used for continuous regeneration of a part of filter medium. Also, the scheme A1 = 1.1-1/CN.PR + P.FR is possible where the same impulse force is used for periodical regeneration of total filtering surface when another device performs simultaneously continuous regeneration of the part of filtering surface.

1.1-1/P.PR. These filters are more often represented by the variety of 1.1-1/CN.PR sub-group filters with a regeneration device being set in motion periodically. For example the device is used when maximal differential pressure of filter medium is to be reached. But usage of this filters type is limited.

The next combination of possible filtration methods is: 1.1-1/CN.FR + P.PR = A3. This takes place in tubular crossflow filters with filtration from inside to outside. For removing contamination from inside FE surface the tube cleaning bodies (spherical or other shape bodies) are passed periodically through tubular filtering element with slurry stream.

The group of filters 1.1-2/CN.FR is most often represented by filter-thickeners where the filter elements are continuously washed by filtering slurry flow which brings to minimum solids
deposition on filtering surface.

The negative characteristic of filters 1.1-2/CN.PR is the regeneration, by turns, of a part of FEs or single FEs when other FEs work in filtration conditions. Then the filtration

conditions for the whole of the filter are not stopped. Usually these are filters having a funnel for suction of cake. The funnel is periodically brought to filter elements, some part of purified liquid being lost together with the cake because of the reverse flow of filtrate during suction.

1.1-2/P.FR - filters with filter elements which are periodically simultaneously regenerated by back flow impulses of filtrate.

To the 1.1-2/P.PR group some modifications of 1.1-2/CN.FR filters can be related when a device for FE regeneration is set in motion after critical filtration parameters are reached.

Here there also can be combinations of different periodical and continuous regeneration operations during filtration:

1.1-2/(CN+P).FR =B2;
1.1-2/CN.FR + P.PR = B3;
1.1-2/CN.PR + P.FR = B1, etc.

The majority of filters types (1.1) are represented by filter-thickeners for slurry concentration.

CONTINUOUS FILTERS WITH MOVABLE FEs (1.2)

The scheme of the classification is shown in Fig.4. We may distinguish the following sub-groups (1.2) of filters: 1) filters with periodical movement of filter medium or Fes 1.2(PM); 2) filters with continuous movement of filter medium or FEs 1.2(CM) and 3) filters with reciprocating motion of filter medium of EEs 1.2(RM) for example, when the role of
filter element play the piston with reciprocating motion.

The filter medium or FEs can be moved by closed **(*.C) or open **(*.O) trajectory (See Fig.4 and Fig.1, level (d)).

The next sub-groups, Level (e): 1. Filters with continuous filter medium **(*.*)-1, i.e. filter medium represented by closed surface or layer on different parts of which different operations are made simultaneously (filtration, dewatering, washing, drying, discharging, etc.). 2. Filters with discrete filter medium or FEs when on single FE or discrete parts of filter medium only one fixed operation is realized simultaneously **(*.*)-2.

Both sub-groups of filters can be divided into following: Level (i) and then Level (j) by analogy with 1.1 group of filters. Note, the Levels (c) and (d) have filters with movable filter medium or FEs only.

Examples of different sub-groups of filters, Level (e), are given below. 1.2(CM.C)-1. These are drum and disk vacuum or pressure filters; belt filters; belt filter-presses; filters with movable grainy filter medium (layer) when after passing through filtration zone the grainy medium is put to regeneration and returned to filtration zone; plate vacuum filters; centrifugal filters when filtration takes place through rotating filter element.

1.2(CM.O)-1. These are filters with a roll filter belt which is unwound from the roll to the filtration zone; belt filters with precoating filter layer which works as filtration medium.

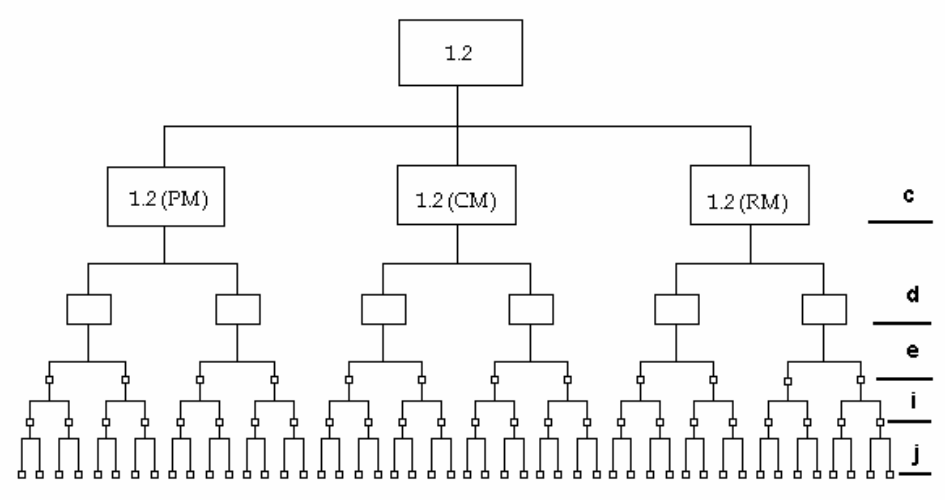


Fig.4. Scheme of classification of continuous filters with movable FEs (1.2):

1.2(PM), 1.2(CM) and 1.2(RM) - filters with periodical, continuous or reciprocating movement of FEs or filter medium, accordingly.

Level (d): **(*.C) and **(*.O) - filters with FEs movement by closed trajectory and open trajectory, accordingly.

Level (e): **(*.*)-1 - filters with continuous filter medium; **(*.*)-2 - filters with discrete filter medium or FEs.

Level (i): **(*.*)-*/CN - filters with continuous regeneration; **(*.*)-*/P - with periodical regeneration.

Level (j): **(*.*)-*/*.FR - all FEs (medium) regeneration; **(*.*)-*/*.PM - regeneration of a part of Fes (medium).

1.2(PM.C)-1 - filters with grainy filter media which are removed from filtration zone periodically and after regeneration come back to the filtration zone.

1.2(PM.O)-1 - filters with roll filter medium (belt) which is periodically moved to the filtration zone to take the place of exhaust belt part, for example, the filter with roll filter belt for coolant filtration.

1.2(CM.C)-2. These are tilting-pan vacuum filters; rotory cartridge filters (Application 55-45529, 1980) and (Patent 276004, 1982); rotary-disk filters.

1.2(CM.O)-2. These are conveyor type filters with disposable FEs, for example filters elements of cartridge or candle types installed on the conveyor system before filtration, are moved in the filtration zone and after filtration are removed from the conveyor.

In some cases the movement of filter medium can be periodical like in cases with: 1.2(PM.C)-2 - rotary cartridge filters etc.; 1.2(PM.O) - conveyor type filters.

In most cases filters of (1.2) type are intended for dewatering moderate or highly concentrated slurries.

The reciprocating motion of filter medium can be considered as utmost case of medium movement by closed trajectory.

The regeneration of filter medium or FEs in the most continuous filter types (1.2) is realized out of the filtration zone. But the version with additional regeneration of a filter medium or FEs in the filtration zone is not without sense if the filtration task is slurry thickening.

In the discussed group of filters note should be taken of rotary and conveyor filters the design development of which can give a new perspective to filtration system of moderate volume treatment of concentrated slurry.

Like in the filter group considered above (1.1), different features of filter constructions can be combined here, for instance in rotary-conveyor filter types. The design development of this type of filters is in the preliminary stage now.

BATCH FILTERS (2.1) AND (2.2)

Batch filters is the oldest type of filtering equipment having the greatest variety of constructions. Batch filters can be divided into filters with disposable FEs and filters with multiused FEs.

Into the group of filters with disposable FEs we include filters where FEs (filter medium) do not regenerate and are subjected to replacement after filtration cycle. This group of filters is well investigated since they are intended for work in hard conditions.

The sub-group 2.1 has the same scheme as sub-group 1.1, Fig.3.

2.1-1 - filters with fixed continuous disposable filter medium. The single plate, disk or belt filter media or filters with single FE are implied here as continuous medium. If the quantity of filter elements or media is more than one, these filters change to group 2.1-2 with discrete filter medium. As a rule filters with disposable filter medium are used for a liquid clarification of for finishing filtration. These filters are intended for liquid filtration with small solid phase concentration usually when clogging filtration takes place. Continuous regeneration for the filters used rarely.

2.1-1. In most cases this group of filters is the constructive development of the previous group but with repeated regeneration of FEs in the filter. Example: 2.1-1/CN - nutche or druk filters with stirrer; 2.1-1/P - automatic filter-press FPAKM.

2.1-2/CN or 2.1-2/P are the constructive development of version (2.1-1). Filtering equipment is: multielement candle, cartridge, tube, bag, disk filters; some types of filter-presses and lift filters. Position of filter elements during regeneration is not changed.

The regeneration of FEs in batch filters is conducted many times, so expenditures on regeneration become comparable with filtration expenditures. So, it is possible here to divide this type of filters into some sub-groups according to technical means characteristics which are used for regeneration processes:

1) manual regeneration;
2) mechanized regeneration;
3) automated regeneration;
4) robot or manipulator regeneration.

All technical means for filters regeneration and servicing can be used in the same types of filtering equipment. For example, small filter-presses served by manual means, moderate sized filterpresses supplied with mechanized regeneration means, large scale filter-presses supplied with automated and/or robot technical means for filter servicing.

The qualitative changes of filter servicing technical means take place when we pass from one group to another. The filter servicing by robot integrates all named above in points 1 - 3 technical means on the principally new level.

The robot system can be mostly used for filter servicing with many identical filter elements. New original filter constructions can be designed when robot system servicing is used.

Batch filters with continuous movable filter media 2.2(*.*)-1 may have disposable filter media with movement by open trajectory (The filter medium movement is carried out after filtration has been finished). The filters of 2.2 group include: automated filter-presses; horizontal belt filter-presses with hydraulic press; tank (disk) filters with endless filtering belt; filter-presses with paper filtering belt for coolant; "Nutrex" filter, etc.

Discrete movable filter medium 2.2(*.*)-2 is used in disk filters with centrifugal cake discharging ("Funda" type); disk filters with brushes for removing ("Indrex Brush-Cleaned Pressure Filter" type); some types of filter-presses.

CONCLUSION

The limited volume of the paper does not give the possibility to do more complete analysis of the classification.

The classification characteristic feature received more deep gradation of filters constructions. The symmetric scheme of filters arranged in grades, Fig.5, give the possibility of designing new filters versions by synthesis of different sub-groups features. This scheme is convenient for using in expert system and for elaboration new constructions of filters.

Different types of filters which have similar sets of signs can be compare with each other with the help of the method, for instance, batch filter with fixed filter elements and batch filter with movable FEs, etc. So, we can ensure optimal filters construction selection.

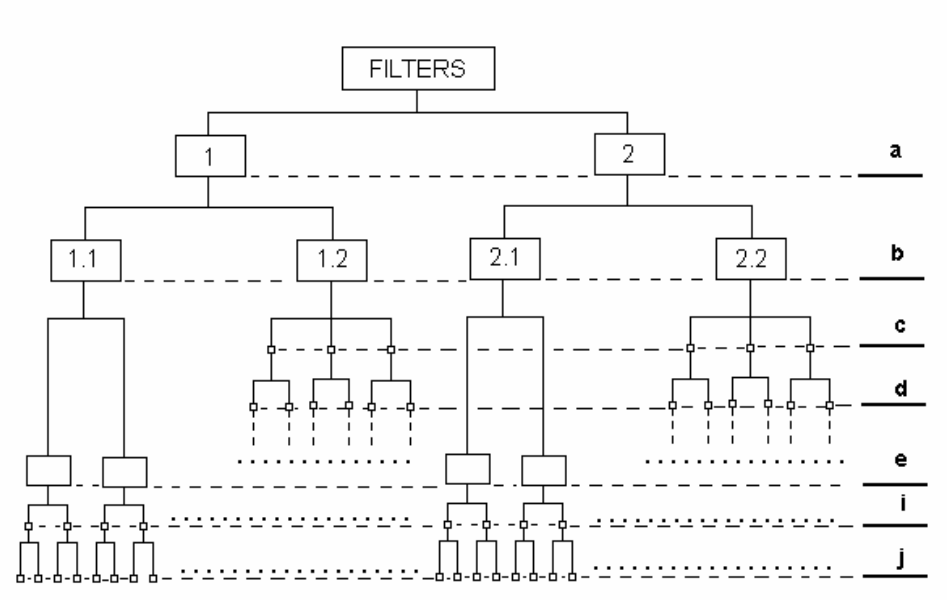


Fig.5. The general scheme of the classification. Levels (a), (b), (c), (d), (e), (i) and (j) see Fig.1. Levels (c) and (d) have filters with movable filter medium or FEs only (sub-groups 1.2 and 2.2). Levels:
(a) - 1 - continuous filter; 2 - batch filter.
(b) - 1 - fixed filter medium (FEs); 2 - movable medium (FEs).
(c) - PM - periodical movement; CM - continuous movement; RM - FEs reciprocating motion.
(d) - C - FEs movement by closed trajectory; O - FEs movement by open trajectory.
(e) - 1 - continuous filter medium; 2 - interrupted (discrete) filter medium.
(i) - CN - Continuous regeneration of FEs; P - periodical regeneration of FEs.
(j) - FR - all FEs (medium) regeneration; PR - regeneration of the part of FEs (medium);

The problem of the scheme application to similar classification of filtration processes calculation methods needs in futher investigation. Here are many cbstacles: influence on filtration hydrodynamic conditions, properties of suspension and filer medium, particle concentration in liquid, etc. Nevertheless we hope, that the classification development can to regulate the calculation methods on the "block" approach basis in the future:

Filtration (as technological processes)	**=**	**Filtration + (deep bed,cake, blocking, combined, etc.)**	**Environmental conditions near the filter medium surface**	**+**	**Regeneration of filter medium permeability**

In conclusion note, the scheme discussed here is the first approach of the classification method development on the basis of space and time position of filter elements.