SUPPORT OF THE CAPITAL EQUIPMENT OF OIL REFINING, PETROCHEMICAL AND CHEMICAL COMPLEX ENTERPRISES IN CONDITIONS OF THE INCREASED INTER-REPAIR INTERVAL WITH THE HELP OF NON DESTROYING CONTROL MEANS.

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The problems of technological installations transfer to the increased inter-repair interval.

Today the aspiration of the majority of oil refining, petrochemical and chemical complex companies' management to increase the intervals between major repairs (inter-repairs intervals) is a quite developed tendency, based on economic interests. This tendency runs counter to the planned-preventive repairs System, which is currently in force in Russia, but has every reason to be realized.

The organization of service and repair of the basic equipment of technological installations of an oil refining, petrochemical and chemical complex enterprises in Russia, regulates, within the limits of the planned-preventive repairs System, the fixed periodicity and the basic repair work volumes, submitted, as a rule, in defective lists. It also takes into account requirements on work within the limits of complex technical condition inspections (technical examinations, revision, industrial safety examination with prolongation of a residual resource, etc.) of the technological equipment. The fixed periodicity of repairs' carrying out doesn't contradict the requirements on terms of technical examinations and equipment revision carrying out, thus, providing the control over its technical condition. The common technology and the organization of technical service and operating repair performance are used on the basis of available normative documents (**fig. 1**).

The planned-preventive repairs System, which is currently in force, is directed toward an average level of the equipment's technical condition and doesn't take into account an actual technical condition of each unit of equipment. The repair rules provide the obligatory, certain examination volume and repair work fulfillment without any dependence on an operating time and an actual technical condition of the equipment. Some, unplanned part of equipment repair work, connected with the elimination of the defects, revealed during the process of complex inspection, is carried out beyond the limits of defective lists.

It is necessary to note, that by way of "perfection", the planned-preventive repairs System is regularly being corrected (becomes tougher) both at a level of branch, and at a level of enterprises. First of all, it concerns the kinds of repair and terms of its carrying out list.

The inter-repairs intervals within the planned-preventive repairs system, which have initially been accepted equal to one year, are today in an interval from one till three years for different technological installations. These intervals are established proceeding from earlier developed general instructions of the branch ministries leading materials, or on the basis of normative documents developed today by branch institutes or the specialized organizations, which are the production, directly adhered to the specific manufacture and technological installation. In the latter case, the main time intervals setting principles are:

- observance of actual technological parameters on raw material, pressure and temperature conformity to the requirements of technological schedules;
- an opportunity to determine an operation of the equipment admissibility in the stated inter-repairs time interval, on the basis of the data on the complex inspections, objectively displaying a metal condition and opportunities of each equipment unit;
- observance of technical examinations and the equipment revision terms, directed by rules, and their conformity to new inter-repair intervals;
- opportunities of the technical and technological services of the enterprise to guarantee safe equipment operation.

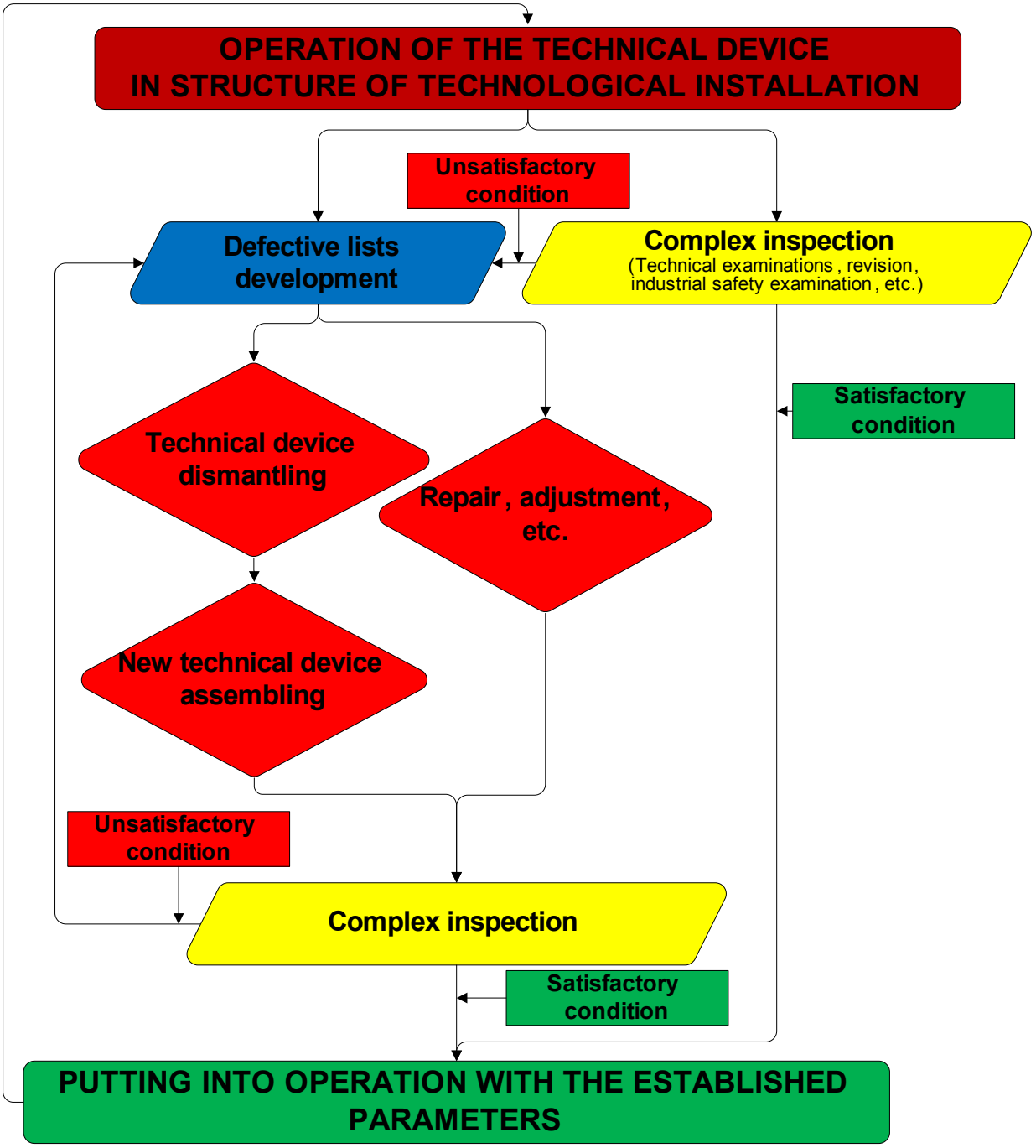


Fig.1. the block diagram of the planned-preventive repairs System.

However the rigid rules on the terms, accepted and established within the planned-preventive repairs system, which are formally not allowed to be changed, but are usually broken, does not take into account those changes that has taken place in the industry.

These changes are directly connected to the technological processes' management improvement, modernization and the replacement of the out-of-date equipment. But first of all they are connected to the opportunities, which give modern achievements in the field of non destroying control, which, with a high degree of reliability, both in conditions of planned inspections realization, and in conditions of continuous technological process conducting, allow to determine a condition of the equipment, providing thus its required reliability and safety.

Everything mentioned allows considering an established situation as an opportunity to pass to the realization of the technological installations equipment repair according to its actual condition (**fig. 2**). It is obvious, that it will allow optimizing essentially the intervals between major repairs, regulated and repair work volumes and, accordingly, the expenses for equipment service.

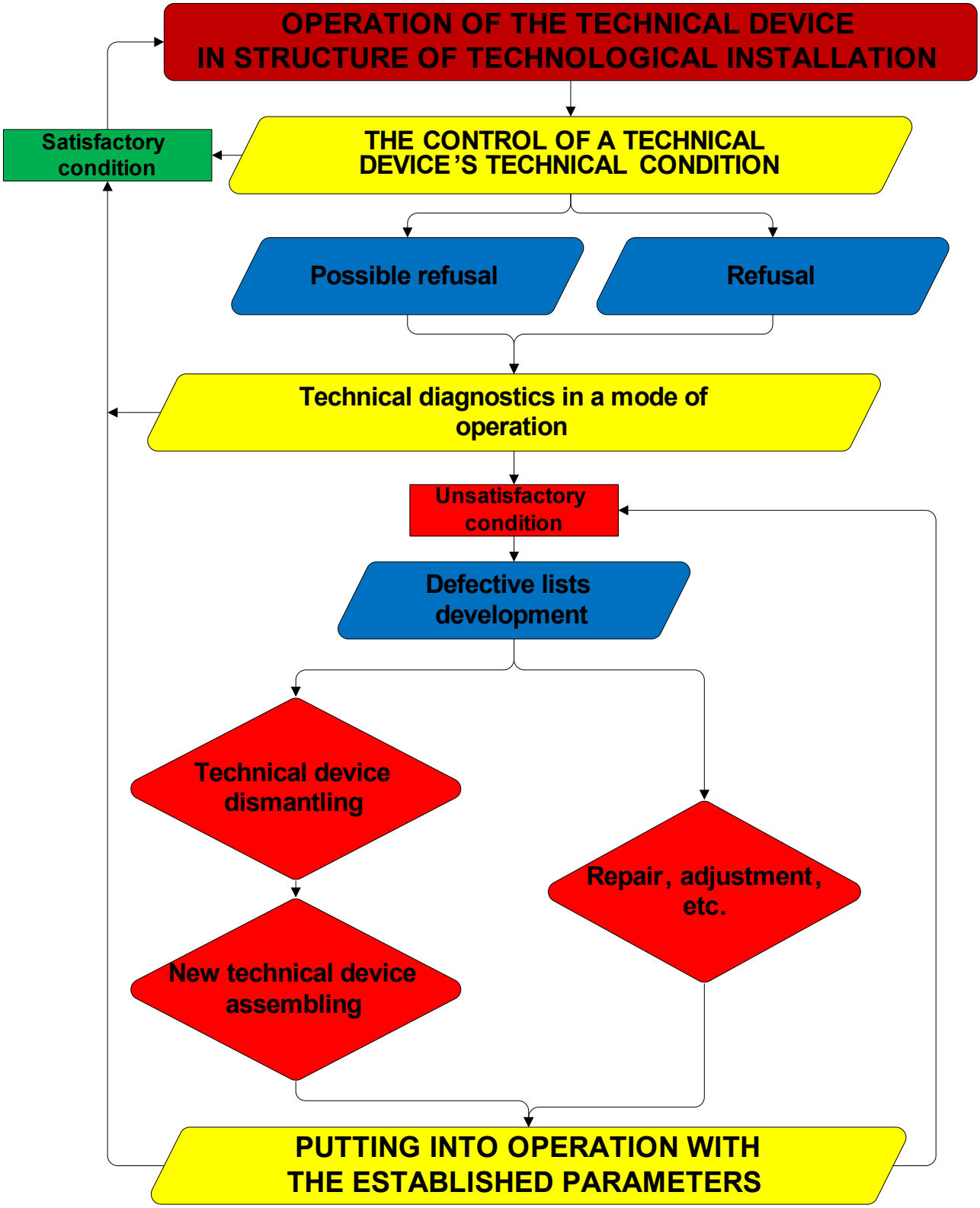


Fig.2. the block diagram of the system by "actual condition".

Comparison of approaches on industrial safety of technological installations guaranteeing in conditions of the increased inter-repairs interval.

The control of the technological equipment technical condition (monitoring) in a real time mode on the basis of the powerful information technologies use, including methodological and instrument equipment of the continuous control process, is becoming the basic element, providing in this case its industrial safety.

There are several approaches on the industrial safety maintenance in condition of the increased inter-repairs interval.

1. Information systems based on API 581. Difficulty in introduction of the given approach lies in the fact that in most cases it is based on requirements of **API 581** « Risk-Based Inspection » standard. It contradicts the domestic specifications and technical documentation in terms of technical examinations, and also practically excludes the noncritical equipment (criticality is basically determined after the analysis of damage size if a technical device wrecks) from the monitoring system. The control over such approach is based on the data on corrosion speed (ultrasonic thickness measurement), and also on internal surveys and hydrotests during major repairs.

2. Information systems of the managerial processes by technical service and repair automation. The given systems are distributed in the territory of Russian Federation, but they are basically directed to the basic funds registration and repairs planning. Realization of the work plan «on an actual condition» within the framework of such system demands additional development.

3. The automated monitoring systems. For separate groups of the equipment, for example pump-compressor, information safety is now provided. In connection with the fact that this equipment is the most problematic, it is either already equipped or is being equipped with the vibrodiagnostics systems (monitoring), that allows estimating the equipment's condition in a real time mode and, if there's reserve equipment, conducting repair planning on an actual condition and carrying out repairs, without stopping all the installation. For the static equipment (vessels, pipelines, etc.) such systems are basically based on the usage of acoustico-emissive complexes and on monitoring of corrosion speed on various parameters (pH, contention of various components in the medium, patterns-witnesses, etc.). Difficulty of this method's distribution on all technical devices lies in the capital intensity of necessary amount of control means, and also in a great amount of the information which is to be received from a control object and it will lead to difficulties in an operative estimation of a situation.

4. The periodic control with the help of nondestroying control means. It is necessary to attribute to positive factors of such approach the availability at the majority of the enterprises of technical supervision services and their equipment by means of nondestroying control, allowing to realize such approach with minimal expenses. It is necessary to attribute the difficulties while carrying out the control of remote sites of technical devices to the negative moments.

5. Mixed systems. The given systems allow using the advantages of the periodic control with the use of enterprise services' opportunities and an opportunity of introduction on remote and crucial sites of the automated monitoring systems. There is an opportunity to provide industrial safety at the increased inter-repairs interval and to react operatively at the occurrence of supernumerary situations, with the help of automation of such approach within the framework of various information systems.

Not calling into question possibility and depth of forecasts of a condition of the equipment received by means of the analysis of risks, we focus attention on the mixed systems of support.

Any of support systems provides:

1. The creation of the information-analytical operative database including data on a condition of the control object , the technological parameters, refusals that took place, repairs, corrosive attack of the media to the performing ability of the constructive elements, allowing to get an idea about a rank of object, possible consequences, connected to refusals, etc.;
2. Definition of zones, amount and periodicity of control;
3. A choice of control means to be used;
4. Determination of structure and qualification of the experts, carrying out control and making decision by results of control.

Estimation of a basic equipment technical condition, previous to the equipment by systems of support, on the basis of means of non destroying control.

The basis for realization of any approach on industrial safety guaranteeing at the increased inter-repairs interval is the estimation of a technical condition of technical device with the use of the data on **a history and parameters of operation and technical characteristics (fig. 3, 4, 5)**. These are the data accordingly about a technical condition of object at some past and present moments of

time. At the given stage there is an establishment of a priority with a subsequent technical device ranging.

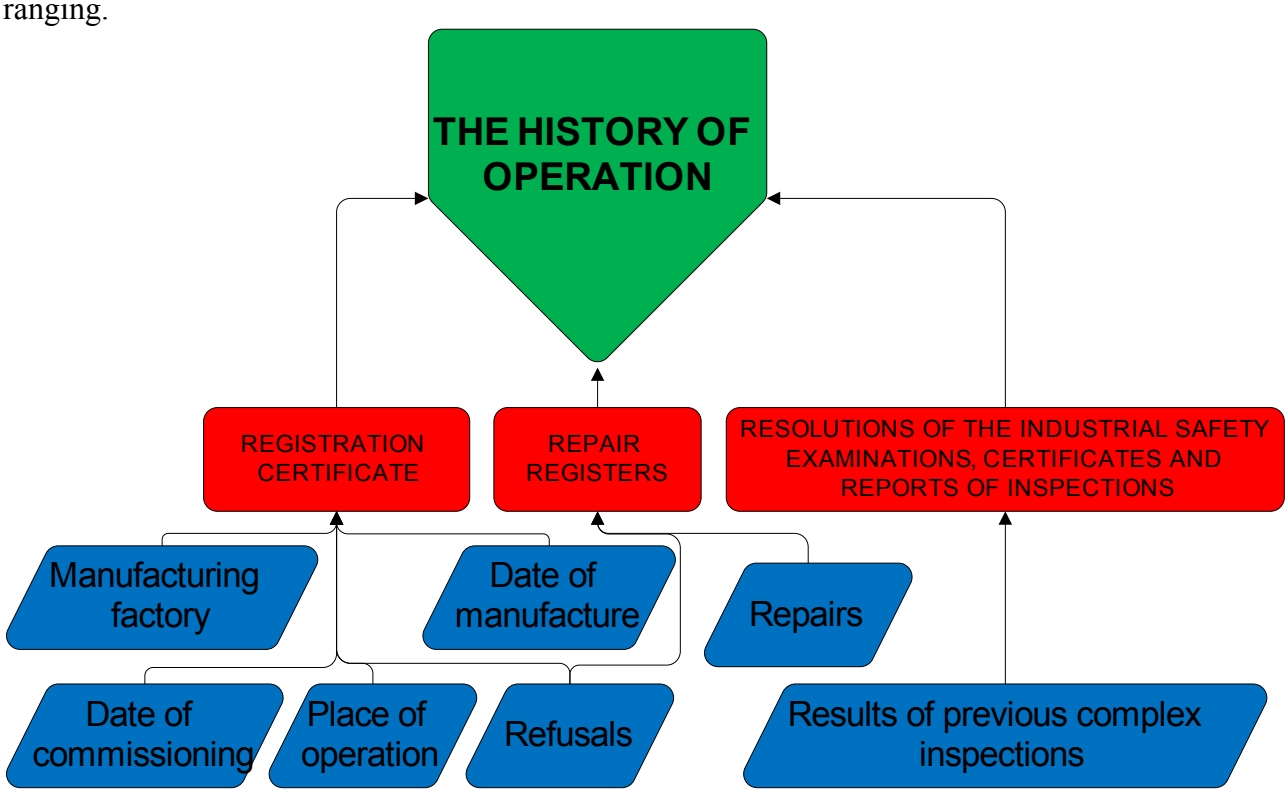


Fig.3 block diagram of the history of operation analysis.

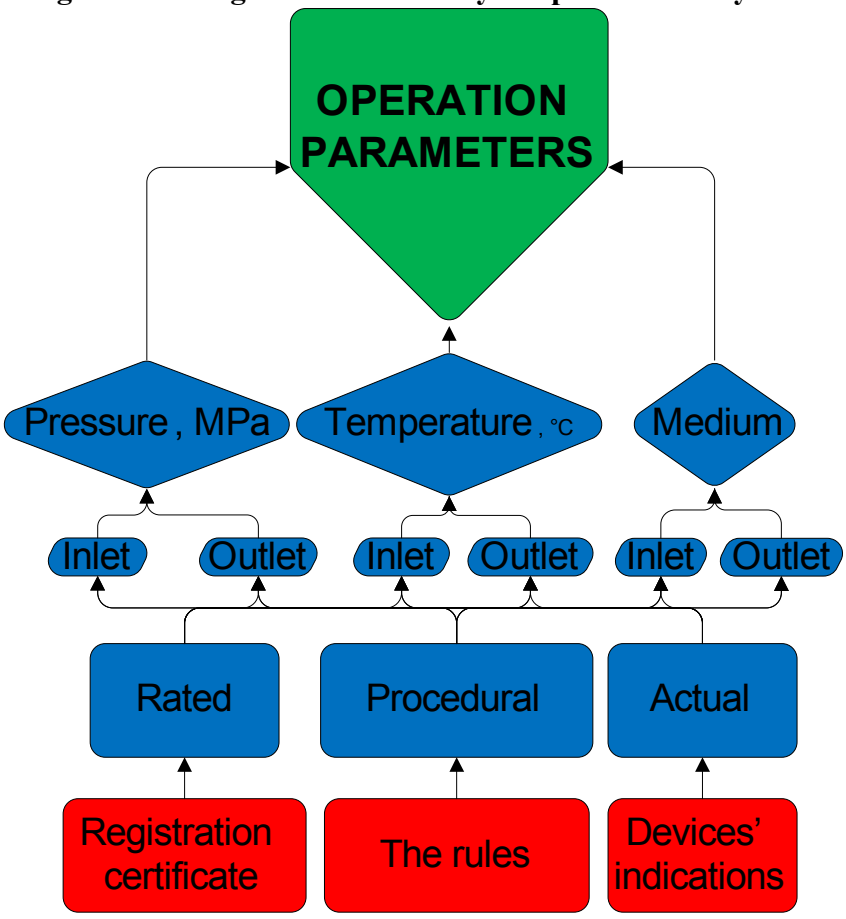


Fig.4 block diagram of the operation parameters analysis.

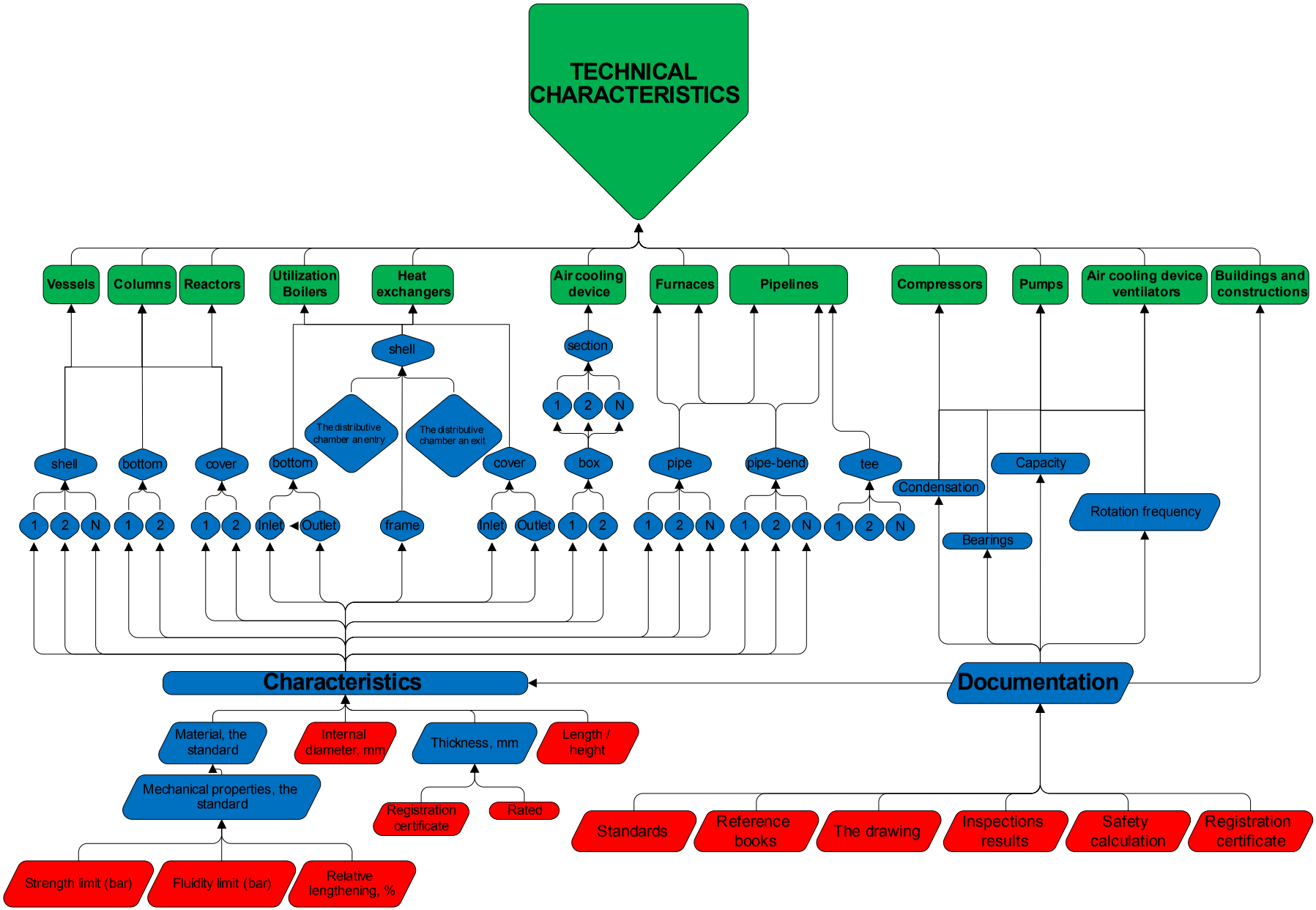


Fig.5. block diagram of the technical characteristics analysis .

An important factor at an estimation of an actual technical condition is the analysis of the previous works connected with technical diagnostic of technical devices. In a case if the received information is not enough for actual technical condition estimation it is necessary to make a complex inspection according to specially developed program.

It is obvious, that in all cases such procedure should precede a binding of support system to the object of control and be its starting point.

Creation of support systems.

The main load at the creation of support system falls to the second stage, where the questions about a definition of control zones, its periodicity, a choice of means and amount of control, etc. are solved. **The concept of creation of support system lies in the fact** that not the whole of control object but only its sick points can be supervised, namely the zones most subjected to degradation processes of any nature. These zones can be established by the rated determined way with the use of results of an actual technical condition of technical device estimation, previous to the creation of the system.

Let's stop on the approaches of the analytical definition of degradation zones in vessels and devices. Its results allow establishing the priority of the objects.

As a rule, the zones where processes of metal degradation including corrosion proceed most intensively are the zones with the increased level of voltage, caused basically by local loads and their gradients, residual voltage after welding, changes of the geometrical form, etc.

If there existed:

- ways of calculation, which would allow to take into account all factors of influence on the technical device,
- exact designing,
- and ideal manufacturing,

then the monitoring procedure of a technical condition of such technical device could be reduced only to the technological process control.

However the impossibility of taking into account all influencing factors, and first of all those that determine a voltage level, naturally results in distortions of an ideal picture of design reliability.

Therefore, in a case if all constructive elements, where peak voltage is realized, will be established, the control of all technical devices could be reduced to the control of these elements.

For vessels and devices working under pressure, it is possible to present the order of such zones' establishment in the following sequence:

1. Durability φ_1 of the plain not weakened casing wall designed according to effective standards by safety calculation is accepted as basic and equal to 1.
2. To all factors, limiting or lowering its safety, i.e. changing an amount of safety of a basic constructive element in a real construction, the factor distinct from unit is appointed.
3. The maximum product of the received factors characterizes the most dangerous zone.

Some factors and their quantitative estimation are given in **table 1**. The quantitative estimation of media's corrosive attack on metal is given in **table 2**. Tables are focused on a clearing of hydrogen sulphide.

Let's consider everything mentioned before at the example of quite specific device - a regenerator (**fig. 6**) of the monoethanolamine clearing section with an operating time about 350000 hours.

Type of the technical device - columned device of shed bearing, purpose of the device - regeneration of a monoethanolamine solution (in the subsequent methyldiethanolamine solution) from the compounds of hydrogen sulphide.

A Regenerator is heat-insulated; heat insulation is protected at the external surface by insulation with aluminum coating.

The basic technological parameters are: pressure - 0,23 MPa; temperature – 135 ^{o}C. Medium: monoethanolamine, hydrogen sulphide, water steam.

Medium characteristics - toxic (class of danger - 2), corrosion.

Proceeding from an estimation of the corrosion deterioration caused by the general corrosion, an operating time of the given technical device will be more than 20 years.

Table 1.

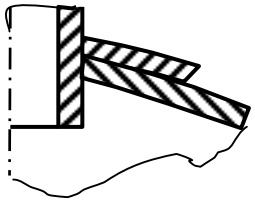
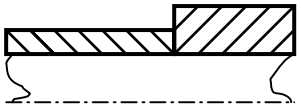
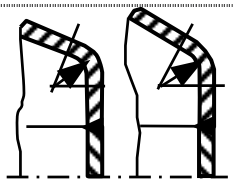
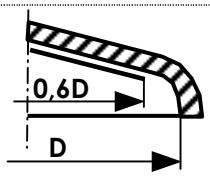
№	The name of the weakening factor	Geometrical interpretation	Coefficient
1	Welded joints of the connecting pipe, φ_{cp1}	-	**1,3**
2	Casings strengthened with winches and connecting pipes, φ_{cp2}		**1,5**
3	Vibration of the supply, drawing off pipeline, φ_{cpvib}	-	**1,2**
4	The welding of connecting pipe from bimetal, φ_{cpbm}	-	**1,25**
5	Welded joints, residual voltage, φ_{res}	-	**1,4÷1,7**
6	Longitudinal joints with an undercut	-	**1,25**
7	Different sided casings, φ_{difs}		**1,3÷1,5**
8	The zone of spherical and half elliptical bottoms flanging, transitions with flangings on conic casings, φ_{bot1}		**1,4**
9	The convex and flat bottoms of an average diapason (0,6D), φ_{bot2}		**1,1**

Table 2.

Medium	Parameters of medium	Material	Corrosion type	Coefficient
Methyldiethanolamine (0,5-0,8) + H_2S (more than 10 g/l)	**Water solution. Temperature more than 120 °C**	Carbonaceous steels	Corrosion cracking	**3**
		Chromo molybdenum, chromic steels (X5M, X8)		
		Stainless steels, ferritic steels type 0X13	Stable to corrosion cracking	**1**
			Corrosion cracking (at the increased level of residual voltage)	**2**

However, other kinds of corrosion degradation of a regenerator's constructive elements, which are not mentioned in the device documentation, are also possible. It is necessary to attribute corrosion cracking and sore affection to them (**fig. 7**), as the most dangerous kinds of corrosion in the sections of monoethanolamine (methyldiethanolamine) clearing, resulting in the occurrence of through defects.

This fact is proved by repair documentation, from which follows that full replacement of two bottom shells and the connecting pipe have been earlier substituted. The conclusion is obvious - a partial deterioration of the device by this time has achieved a critical value.

The device has been admitted to operation after repair and reconstruction. If we raise a question about a possibility of its operation at the increased inter-repairs interval, it is possible to answer it unequivocally - yes, it is possible, but only after the performance of a certain complex of actions connected to control in an amplified mode during the inter-repairs period.

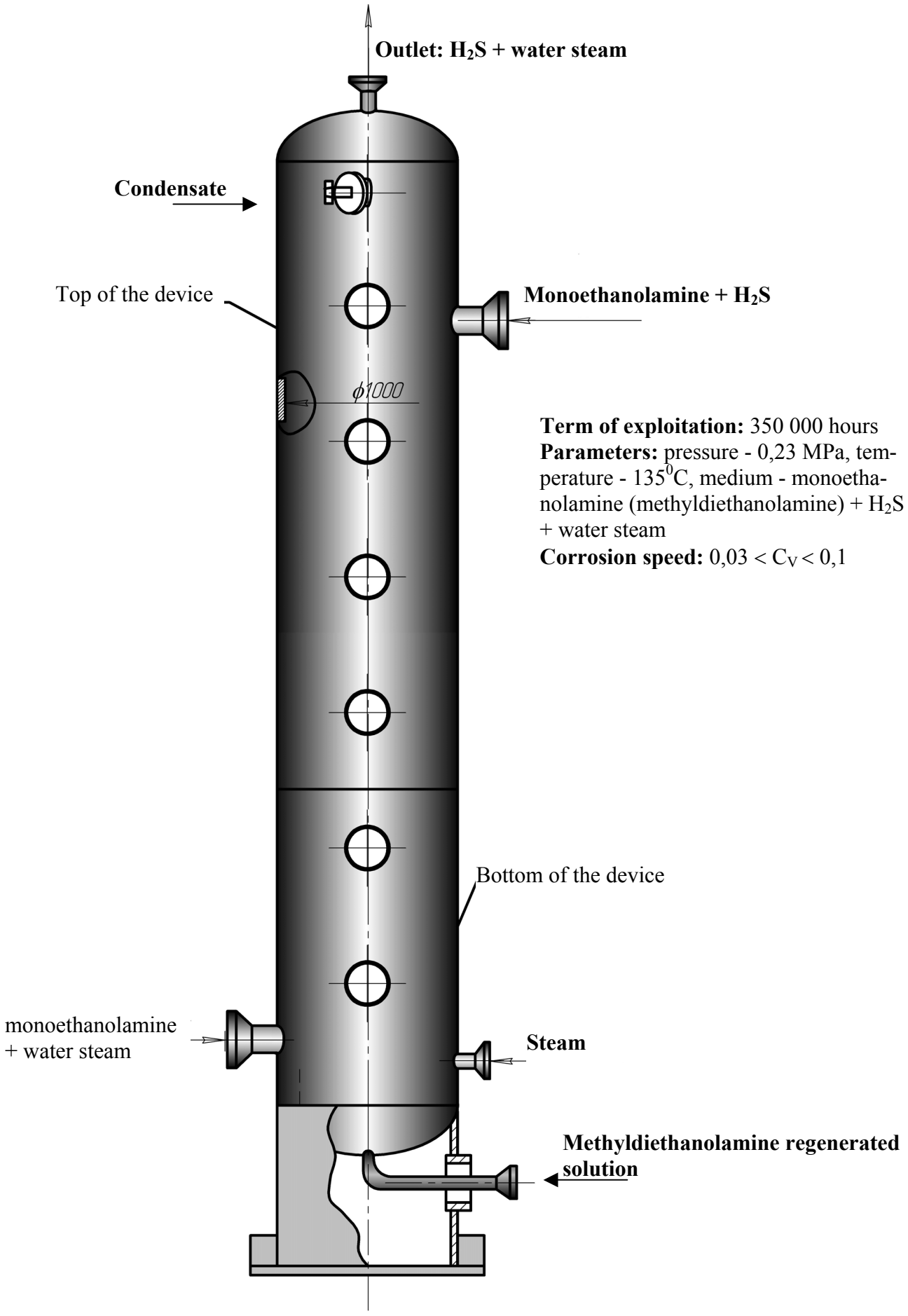


Fig. 6. The scheme of a regenerator.

Fig. 7. Corrosion defeat of monoethanolamine clearing regenerator.

It is necessary to attribute to these actions:

1. Carrying out during a stop for the major repair, previous to a lead-in of the device to the increased inter-repairs interval, non destroying control in volume: the visual control of an internal surface of the regenerator's frame, the acoustico-emissive control, the selective control by a method of the zones' metal magnetic memory, which are determined as the zones of accompanying diagnostic control. At the lack of information on heat treatment of repair joints, it's expedient to carry out the researches on a definition of residual voltage's size with the help of magnetic anisotropic flaw detectors. It is necessary to carry out metallographic researches of metal, and also - ultrasonic thickness measuring, gauging of solidity, since the device has been operated for long period of time.

Necessity of such complex control is dictated, in our opinion, by a long (more than 30 years) operation of the device.

It's possible to get an ambiguous result, after carrying out the complex control. The first - positive. In this case operation is possible. The second - negative. In this case either repair intervention, or its dismantle is required. After repair control and also accompanying diagnostic control of the revealed potentially dangerous zones should be carried out in more rigid mode.

2. Definition of control zones.

While choosing control zones, all factors influencing reliability of the device, including medium's corrosive attack, are taken into account. Zones of frame weakening, and also the **Coefficients** describing this weakening, are given in **table 3**.

According to the data given in the table, the most problematic in the given device and the given situation are the welding zones of connecting pipes of an input and an output of a product, steam submission, taking out methyldiethanolamine solution, and also the circular joint connecting the top and the bottom of the device and an assembly joint. These zones are given in **figure 8**.

Table 3.

№	The name of a zone	Total coefficient	The note
1	The welding of H_2S outlet connecting pipe; water steam	**3,51**	-
2	Unit of connection of an elliptic cover with the frame	**2,541**	Regenerative repair zone
3	The welding of submission of the sated solution (H_2S; monoethanolamine solution) connecting pipe	**3,9**	-
4	The welding of five top hatches - trapdoors	**2,925**	-
5	Circular joint of frame shell of bimetal and the steel model St3kp connection	**2,07**	Corrosion cracking is possible
6	Circular assembly joint of connection different-sided shells frame of bimetal	**4,843**	Without heat treatment. Corrosion cracking is possible.
7	The welding of two bottom hatches - trapdoors	**2,437**	-
8	The welding of product submission connecting pipe	**9,75**	Without heat treatment. Corrosion cracking is possible.
9	The welding of steam submission connecting pipe	**4,87**	-
10	The welding of monoethanolamine solution outlet connecting pipe	**4,87**	-
11	Unit of connection of the elliptic bottom with the frame	**2,541**	-

3. A choice of means of control.

Proceeding from the data given in the table, and also the data on speed of corrosion deterioration which is less than 0,1 mm/year, it is possible to recommend a method of magnetic memory of metal for carrying out a qualified estimation of condition of welded joints, where the corrosion cracking display is possible, and selective thickness measurement for the control of the frame's wall thickness, for example, in a zone of the saturated solution input - a zone IV in **figure 8**.

One of conditions of accompanying diagnostics should be an easy approach to a surface of control. Therefore some words are necessary to be told about windows in heat insulation. As our experience shows, this infringement of isolation solidity is restored with the help of « demountable thermal chokes ».

4. Definition of periodicity of the control.

Periodicity should be two-leveled. The first is carried out during major repairs - at a stop and when the device is put out of operation. The second - during operation. If with periodicity of carrying out of major repairs everything is extremely clear, and they are determined in an established order by either normative or adjusting documents, but everything is a bit more difficult with the periodicity of carrying out of accompanying diagnostics. The terms should be established proceeding from the available data on time parameters of corrosion processes' development, or from the experimental data, or from the operating experience based on the refusals' analysis.

In this case carrying out of thickness gaugings once a year, the control of a welding joints condition with the help of a method of magnetic memory of metal - once in six months are recommended.

Terms updating of accompanying diagnostics' carrying out, on the basis of the coming data on changes of the rules, parameters on pressure, temperature and medium, is obvious.

5. Obligatory presence of experts in non destroying control and industrial safety System experts.

The means of non destroying control, incorporated in the accompanying diagnostics program, determine the quantity of experts of the given orientation. We suppose that in the process should be involved: the engineer - mechanic, the engineer - technologist, experts in durability, corrosion, metallurgical science, and also the expert in non destroying control.

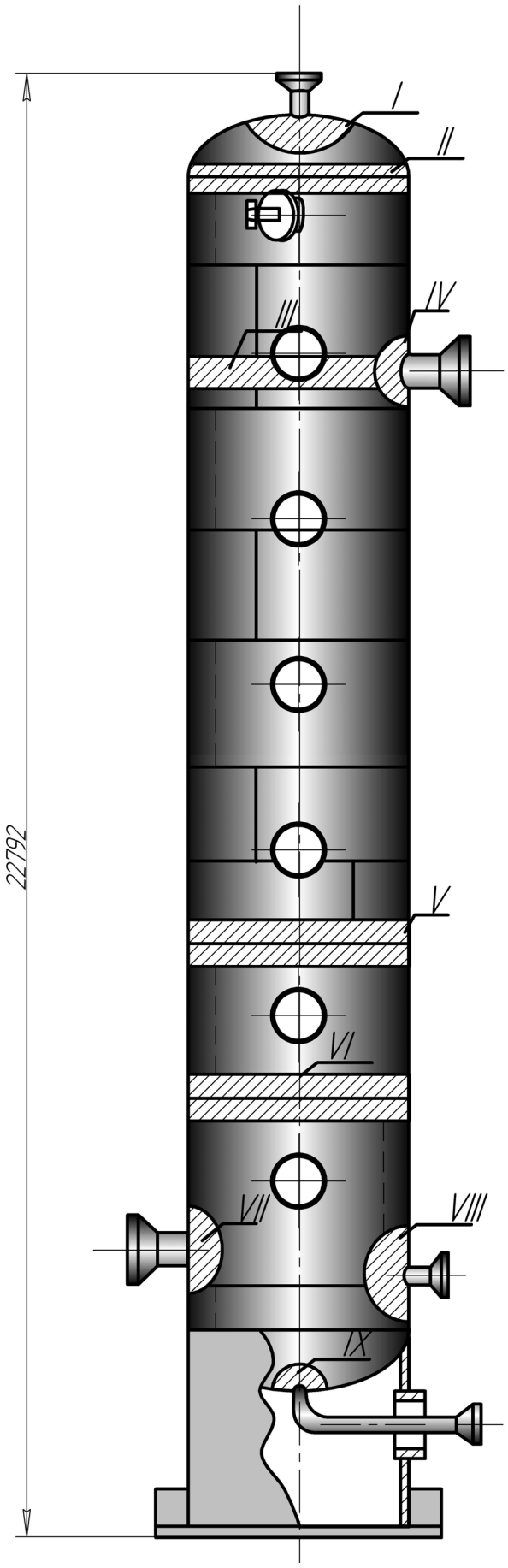


Fig. 8. The scheme of diagnostic sites of a regenerator (control zones I – IX).

Whereas the fact, that sometimes the presence of experts on durability, corrosion and metallurgical science is problematic, the suggested zones of defeat coefficient estimation system, which can be corrected for the set technological process, the set medium and constructive registration of the considered technical device, allows to solve this question .

It is necessary to note, that while carrying out an accompanying diagnostics, the actions of experts in non destroying control should be regulated without fail by corresponding methodical instructions or standards of the enterprise.

6. Creation of the current condition of the device card.

The current condition card should contain the results **of genetics, diagnostics and prognostics,** i.e. all collected information, and also the scheme of zones of control, volume, a route and periodicity of control, criterion estimations of accompanying control results.

The card can be made either on the paper carrier, or in an electronic look. One of fragmentary variants of a card in a tabulated look for a corrosion contour is given in **table 4**.

Table 4.

№	The name of the factor			monoethanolamine clearing section (the name of the section, a corrosion contour) The names of devices, included in the section		
				Absorber	Regenerator	Separator
1	Factory №					
2	Registration №					
3	Technical index					
4	Year of commissioning					
5	Technical Parameters	Regulated	Pressure			
			Temperature, ^{0}C			
			Medium, Corrosion			
		Actual	Pressure			
			Temperature, ^{0}C			
			Medium, Corrosion			
6	Internal diameter, mm					
7	Height / length, mm					
8	Thickness, mm	Rated				
		According to registration certificate				
		Actual				
9	Actual increase, mm					
10	Corrosion type					
11	Vк, mm/y	Normative				
		Actual				
12	Corrosion deterioration resource					
13	Date of the last technical control					
14	The organization which was carrying out the control					
15	Non destroying control means and methods					
16	The results of control					
17	The data on refusals					
18	The data on repairs					
20	Zones of control					
21	Accompanying means and methods of NDC					
22	Control periodicity					
23	Control estimation					

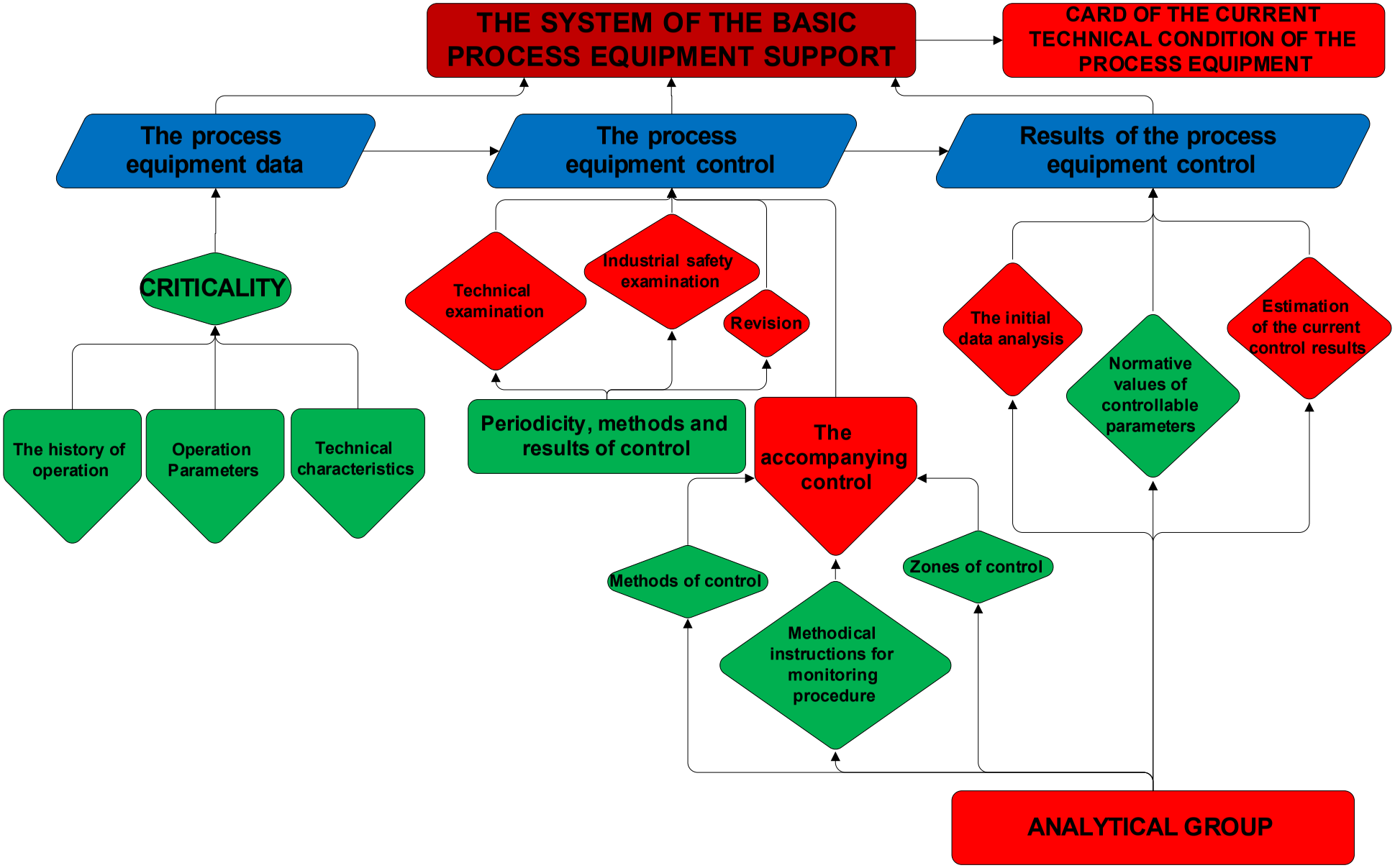


Fig. 9. The scheme of support system creation.

It is necessary to note, that the card of the current technical condition of the device is not a mechanical duplication of the registration certificate. It is the same instrument, as any component of accompanying diagnostics means.

Everything mentioned above is evidently illustrated by the scheme of support system creation (**fig. 9)**.

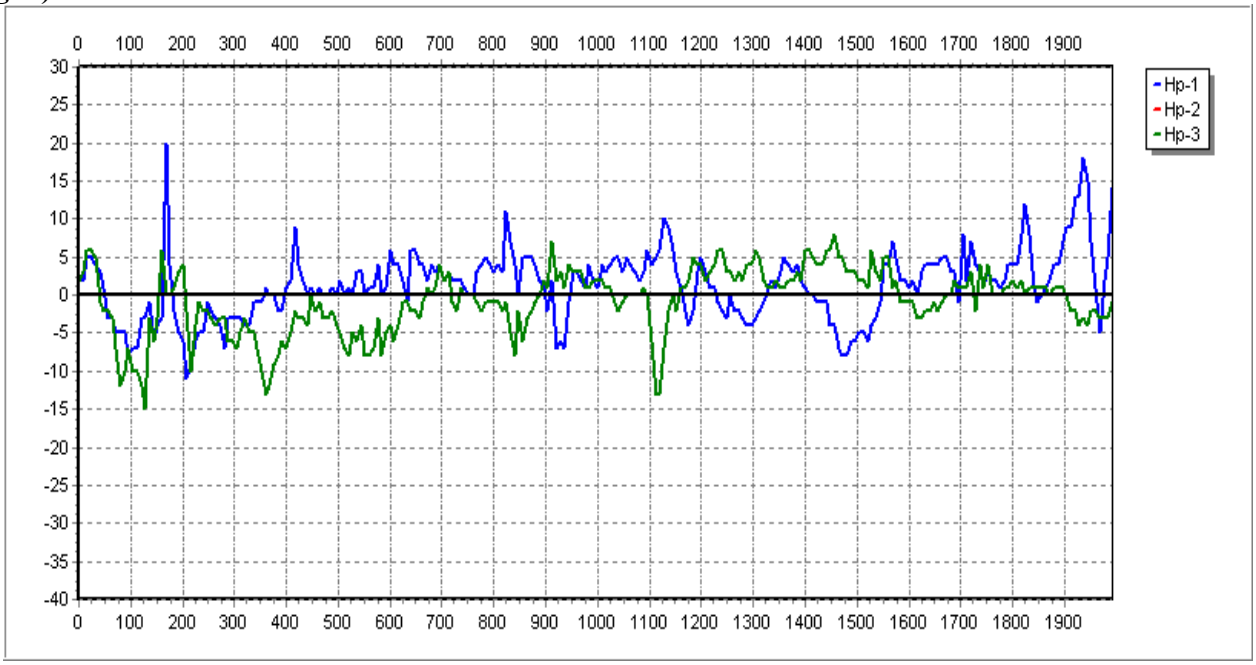


Fig. 10. A defectless part of a welded joint.

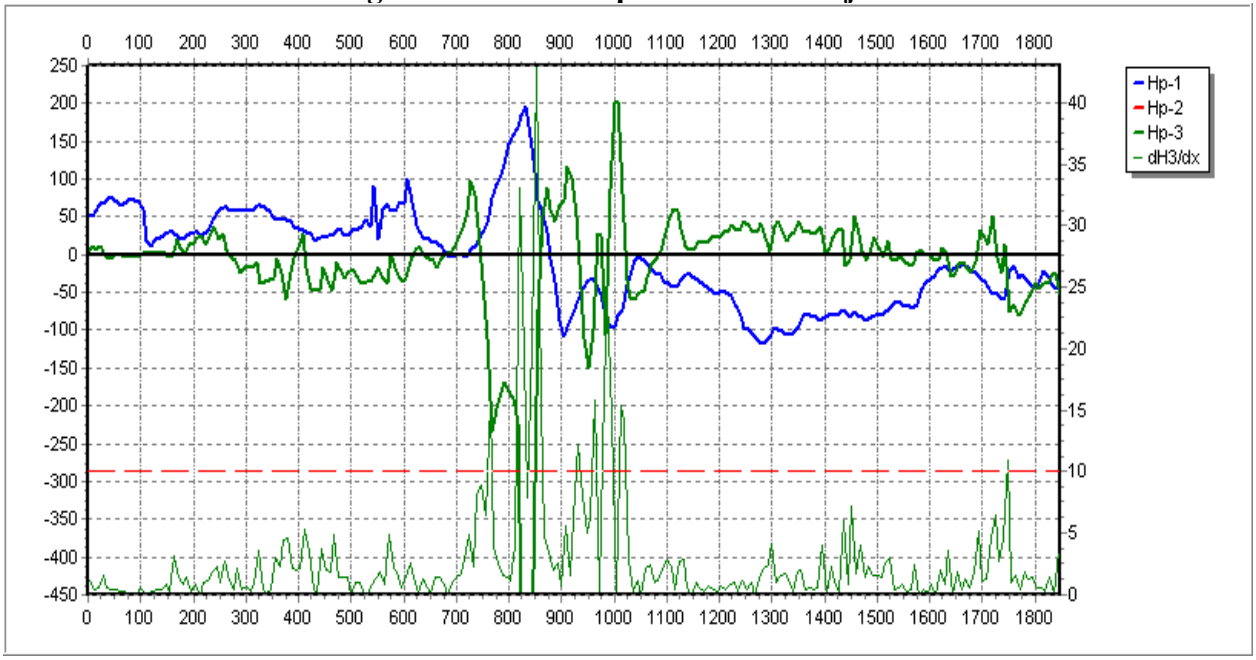


Fig. 11. A defective part of a welded joint.

<u>Modern means of not destroying control opportunities in diagnostics of the basic equipment in an operation mode.</u>

The supply of technological installations with support systems should provide multi-variant approach in their execution. These are the stationary automated systems of monitoring with a depict of the primary control results at the central management post and the automatic decision-making, working in constant or periodic modes and supervising, for example, on the basis of acoustico-emissive systems

«Physical Acoustics Corporation» (USA), "A-Line", "Resource - 2000" (Russia) the process of cracking formation, or the processes of corrosion degradation on the basis of systems «Rohrback Cosasco Systems» (USA).

There also exist integrated monitoring systems uniting together strictly profile systems, supervising temperature of constructional elements, deformation processes in metal with the systems which have been mentioned above.

As it was already mentioned above, the information safety is now provided for the pump-compressor equipment. This equipment is already either equipped or is being equipped with vibrocontrol systems at many enterprises.

The accompanying non destroying control is a two-leveled procedure, irrespective of a kind of chosen support system. The first level is the control during a stop for carrying out major repairs (up to coming to the increased inter-repairs interval) which can include internal survey, the acoustico-emissive control, thickness measurement, selective ultrasound control, selective metallography, the selective control with the help of a method of magnetic memory of metal and other methods depending on a kind of technical device.

The internal survey, selective ultrasound control, selective metallography, the control of constantly diagnosed welded joints zones with the help of a method of magnetic memory of metal should remain obligatory elements of control during the subsequent major repairs. Application of other kinds of non destroying control is determined by technical necessity.

At the second level, which is carried out without a stop, accompanying diagnostics (for support system on the basis of the periodic control) should include the visual control, selective thickness measurement, the thermal control and the control with the help of a method of magnetic memory of metal. Application of devices does not demand preparation of a surface of control, voltage higher than 12 Watt, that allows carrying out the control at the increased temperatures of walls of object of the control.

Our choice of the welded joints condition control by a method of magnetic memory of metal is based on an opportunity of carrying out a quality standard of a welded joint's condition.

We shall give as an illustration the data received at monitoring procedure of welded joints (**Fig. 10** - the welded joint without any defect. **Fig. 11** - with a defect).

Obvious condition of carrying out such kind of diagnostic monitoring should be the presence of criteria estimations system for each kind of control.

Conclusions:

Getting the information on an actual equipment condition in a mode of real time on the basis of wide introduction of the automated mixed support systems (on the basis of monitoring, control and diagnostics) is a basic way to solve a problem of industrial safety guaranteeing at the increased inter-repairs interval, as the wide field for maneuver is given to the owner of such systems at a choice of strategy for carrying out a repair of the equipment including on terms of carrying out the repairs which in this case are determined by the concrete technical condition of the equipment.