FABRICATION SYSTEM HAZARD DETECTION
IN OIL AND GAS PROCESSING PLANTS

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This article is aiming at target setting and solution for working out of Decision Support System, with regard to risk detection in oil and gas processing plants.

In order to determine system's "weak point" able to destruct or to provoke plants failures and system decapsulation, danger criteria as well as methods of detection were considered here, according to which all the objects, such as plants and pipelines, could be ranked.

1. INTRODUCTION

Acceleration in the rates and expansion of oil and gas operations observed nowadays [1, 10], is accompanied by continual intensification of high temperature and high pressure engineering processes and gas, explosives and fire danger substances collection as well (Table 1). As a result potential threat to human's life and health, environment and material resources increases.

Table 1

Technological factors of oil and gas processing units

Plant installation	Dangerous substances	Pressure , MPa	Temperature , °C
Catalytic installation	flammable gases (gas , liquefied gas), burning liquid (vapor, liquid), toxic liquid	atm ¸ 5,0	- 44 ¸ 525
Oil installation		0,01 ¸ 2,4	- 43 ¸ 320
Fuel installation		vacuum ¸ 3,5	30 ¸ 430
Commodity production		atm ¸ 1,6	- 40 ¸ 100

In order to forecast and to model conditions it is necessary to identify fabrication systems' danger, i.e. to detect probable emergency situation and to speculate system's 'weak points' location.

At present danger identification is carried out by means of bringing hazardous substances' number in processing plants to conformity with SR 09-540-03 [5]. This approach ignores statistics and processing plant reliability level and its operation period.

So, it is necessary to find new approaches to danger identification that are capable to clearly recognize and describe dangers of oil and gas processing plants since the stage of identification is the most important one. Dangers that have not been revealed on that very stage are out of analysis at a later time.

In order to identify dangers of oil and gas processing plants, the authors found out method based on heterogeneous data collage.

For this purpose it is necessary to develop decision–making support system (DMSS) aiming at processing plant's weak point detection by means of pictorial model (Fig. 1). Elaboration of DMSS is to ensure support for engineers engaged in intellectual and creative activity in changeable oil and gas processing plants' service conditions and to contribute to efficient analysis in accordance with suggested criteria.

This work contains instructions on pictorial model construction. [11].

For the purpose of emergency situation forecasting and modeling it is necessary to identify dangers of oil and gas processing plants, i.e. to detect probable emergency situations and to speculate system's 'weak points' location.

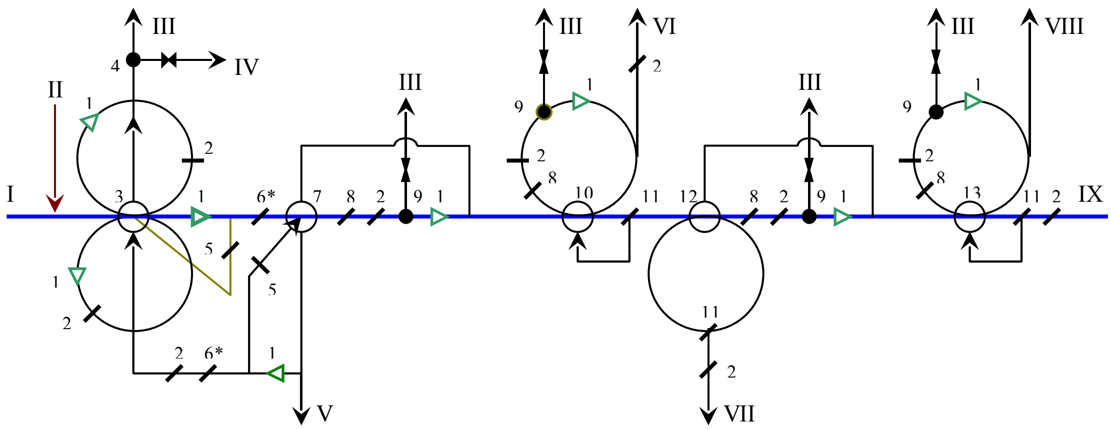

Figure 1. AGFP pictorial model

1 - pumps; 2 - condenser; 3 – fractionating absorber;
4 – entrainment separator; 5 – pipe furnace; 6 – heat exchanger;
7, 10, 12, 13 - fractionators; 3 – air-cooling device; 9 - receiver; 11 – preheater boiler;
I – fat gas; II – gasoline unstable; III – dry gas; IV - condensate;
V – gasoline stable; VI – C3 fraction; VII –C5 fraction;
VIII – isobutane fraction; IX – н.butane

Pictorial model helps to work out process image under recognition made up from standard "objects" preserved at any component granularity.

2. DANGER CRITERIA

Oil and gas processing plants' danger criteria are to be divided into two types: constant and temporary.

Constant criteria should be defined as information on operation factors of the plant and hazardous substances allocation.

Temporary criteria should be define as temporary danger, critical values of engineering process' operation factors in particular (one or several values able provoke fabrication system explosion or system decapsulation) and equipment operation values able to provoke breakage or destruction of equipment, that, in its turn, results in system decapsulation.

2.1. CONSTANT CRITERIA ANALYSIS

As to constant criteria, the following estimations are analyzed:

- "Service conditions" criterion.
- "Substance" criterion.
- "Hazardous substance allocation" criterion .

"Service conditions criterion" reflects equipment operational factors, such as operational temperature and pressure, that determines equipment reliability and ensure its durability and stability.

"Substance" criterion is based on physicochemical property of substance in "object" of fabrication system: substance condition, inflammability, type of emergency event, flash point, ignition and autoignition of substance in "object".

"Hazardous substance allocation" criterion allows calculating hazardous substance quantity in "object" (this value is basically determined by object's dimensions data).

2.2. TEMPORARY CRITERIA ANALYSIS

As to temporary criteria, the following estimations are analyzed:

- "objects' reliability" criterion;
- "residual resource" criterion (corrosive resistance);
- "ruptured zone" criterion;

- “equipment breakage” criterion.

2.2.1. OBJECT RELIABILITY ESTIMATION

Emergency conditions on hazardous industrial units can take place not merely under external and internal disruptive processes but in case of breakage of individual elements of fabrication system as well.

Object reliability estimation is based on information on composition of the objects and their failure rate (λ). These data contributes to approximate evaluating of reliability level of each object taken separately.

Any pictorial model of fabrication system of oil and gas processing plant can be represented as a number of linear concatenated objects (Fig. 2).

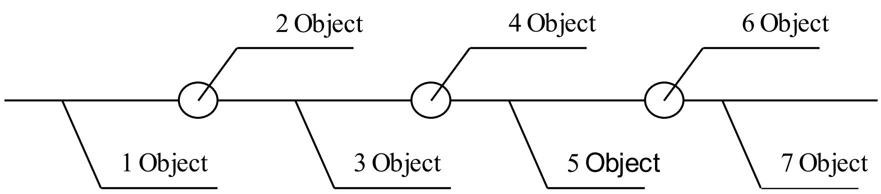

Figure 2. Pictorial model

If that’s the case, uninterrupted operation probability is represented as

$$\boldsymbol{P} = \prod_{j=1}^{n} \boldsymbol{P}_j(\tau), \tag{1}$$

if n – number of “objects”;

$\boldsymbol{P}_j(\tau)$ -fabrication system reliability.

In its turn, every single ‘object’ of fabrication system can be composed of several ‘elements’ arranging as a composite joint as follows (Fig. 3).

Figure 3 is combined due to concatenate and concurrent joint of its elements.

Taking into consideration the fact that uninterrupted operation probability during definite period of time are rated in accordance with exponential law and failure rates (λi) for each element are given, , we have the following formula:

$$P_c=f(\lambda_i, t). \tag{2}$$

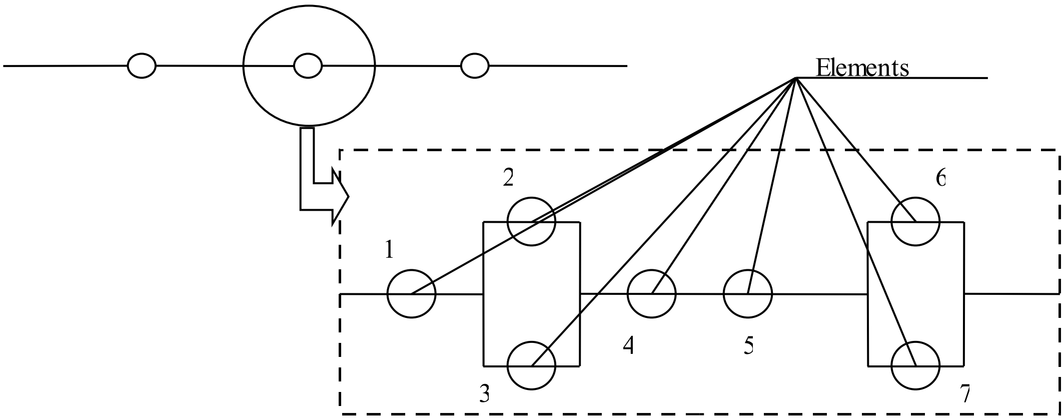

Figure 3. Composite joint of elements of the "object"

In particular case, for the model (Fig. 3) the formula will be as follows:

$$P_c = e^{-(\lambda_1+\lambda_4+\lambda_5)} \cdot \left[1 - (1 - e^{-\lambda_2 \cdot t})^2\right] \cdot \left[1 - (1 - e^{-\lambda_3 \cdot t})^2\right] \cdot \left[1 - (1 - e^{-\lambda_6 \cdot t})^2\right] \cdot \left[1 - (1 - e^{-\lambda_7 \cdot t})^2\right]. \quad (3)$$

On basis of estimation of reliability level of fabrication system's objects one can draw an important conclusion as regards 'weak point' of this fabrication system as well as its reliability. So-called 'weak point' is a speculative system decapsulation point that, consequently, can provoke explosives and fire danger substances emission.

2.2.2. RESIDUAL RESOURCE ESTIMATION

Periodical survey of equipment, estimate of surface destruction level and statistical data manipulation make residual resource estimation possible.

Estimating "residual resource" it is important select the right maximum permissible damages. Residual resource specifies object's operational time till its breakage. As soon as it concerns chemical industry, it is necessary to take into account the fact that in 57 out of 100 cases the reason of untimely breakage of equipment is corrosion [7]. Residual resource, that determines object's reliability, will be estimated under corrosive action (corrosion rate).

Basic data for this estimate are the facts of the object's survey. Corrosion measuring procedures are selected depending on destruction level in accordance with GOST 9.908 [6].

In this case, “object” is considered to be a dynamic system. Residual resource forecasting approach being described here ensures minimum error [8] and helps to obtain minimum interval in which value is predicting.

On basis of estimation of residual resource of fabrication system’s object, a ‘weak point’ can be recognized, i.e. the less residual resource value, the more probable object’s breakage, and, consequently, its destruction probability.

2.2.3. RUPTURED ZONE ESTIMATION

Ruptured zone estimation embraces area determined by radius R and centered by ‘object’ itself as probable decapsulation point of fabrication system. Each zone boundary is specified by overpressure values within shock front ΔP and dimensionless factor K for structures destruction level estimation. This criterion estimation is based on conformity with SR 09-540-03 [5].

2.2.4. EQUIPMENT BREAKAGE ESTIMATION

Equipment breakage estimation is based on statistics on malfunction of equipment under analysis (as well as the whole plant where this plant installed).

Equipment malfunction rate, primarily applied for this criterion estimation, corresponds to the following distribution (Fig. 4). Statistics cited in this work [9] is based on analysis of oil and gas processing plants of Bashkortostan Republic.

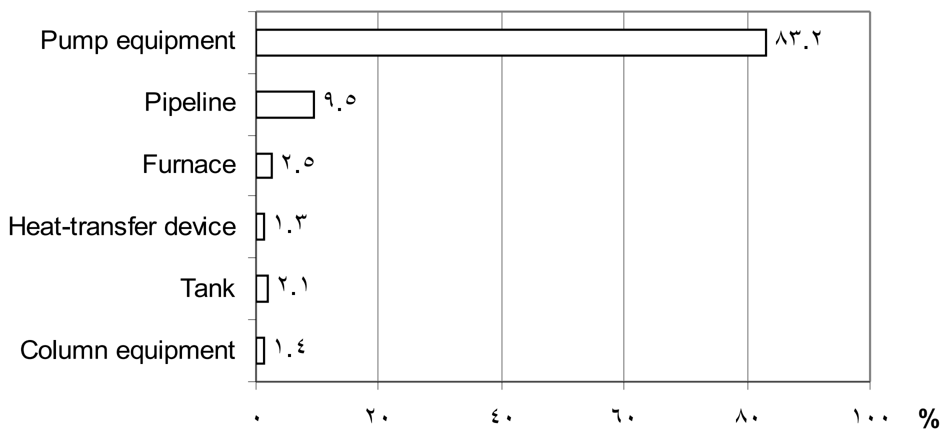

Figure 4 . Equipment malfunction rate capable to provoke emergency situation

According to statistics analysis, most often equipment breakage happens in pumping and compressor equipment (83,2 %).

CONCLUSION

Oil and gas processing plants danger detection, based on reliability evaluation, mathematical methods such as theory of probability and statistics, put forward by the author, allows to discover system 'weak point' in narrow term.

Taking to account the fact that with regard to danger all the criteria are of stochastic nature, findings on criteria should be generalized by means of similarity theory (data repeatability estimate)

As a result, we have ranked probable danger values for object of fabrication system.

Repeatability of object's 'weak point' values is estimated by means of average measures and accidental deviation range.

$$K^*_{cp} = \frac{1}{N} \cdot \sum_{i=1}^{N} K_c \,, \tag{4}$$

where N – number of criterion;

Kc – values of estimated danger criterion.

$$\sigma^*_{K_{cp}} = \sqrt{\frac{1}{N+1} \cdot \sum_{i=1}^{N} (K_c - K^*_{cp})} \tag{5}$$

Due to the fact that fabrication systems includes a great number of objects, manual estimation procedure is tedious and arduous enough, and for the purpose of facilitation of this procedure software was developed, based on pictorial models and providing support of engineers engaged in intellectual and creative activity and ensuring 'weak point' detection and analysis in narrow time. Taking into consideration the fact that criteria are of multiple-choice nature, software mentioned provide for developing probable script of emergency situation.

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