Ensuring safe operation of the piping connection of apparatus column type

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Abstract. To ensure the safe operation of the piping connection of the column type apparatus, it is necessary to determine the potential destruction zones of the pipeline, which can lead to its depressurization and the realization of an accident with the "domino effect". The article presents an algorithm for assessing potential zones of destruction of piping connection of column-type devices, which can be used to make decisions aimed at improving the safety of hazardous production facilities in the oil and gas industry, both at the design stage and during operation, as well as during diagnostic works.

Oil and gas industry facilities are classified as hazardous production facilities, which are characterized by high risk indicators for emergency situations. During the exploitation of these facilities, the process medium can be released into the atmosphere, which can lead to environmental damage, and in case of spark, an explosion or (and) fire is possible, which can lead to significant economic losses and even fatalities.

Analysis of the results of technical investigations of accidents according to Rostekhnadzor over the past 5 years shows that the main causes of emergencies were:

- internal dangers associated with depressurization and destruction of technical devices, violation of the process technology, as well as the lack of design solutions for the organization of safe pipeline disconnection (45 accidents);
- personnel errors related to the violation of the requirements of the organization and production of hazardous types of work, the organization of work on equipment service (38 accidents) [1].

Approximately 80% of the equipment of the facilities of the oil and gas industry in Russia are large-sized, located very compactly and mainly on open production areas. Destruction or loss of stability of the equipment can contribute to the further development of the accident with the effect of "domino".

For an accident with the domino effect, whole destruction of the equipment is not necessary; depressurization of one of its elements is enough, which corresponds to a weak degree of damage. In this case, the full instant involvement of a hazardous substance from the equipment in the accident is unlikely to happen, but there will be a risk of further development of the accident. The outcome of this case will depend on many factors: the hazard class of the substance, the readiness of personnel to localize and eliminate the accident [2].
High potential hazard of oil and gas industry facilities remains an urgent task to ensure the safety of functioning of existing and at the design stage facilities.

Technological installations of hazardous production facilities in the oil and gas industry operate at high temperatures, in some cases exceeding 500 °C, pressures that are several times higher than atmospheric pressure and contain a large amount of hydrocarbon feed. Also at refinery are commodity parks and reagent warehouses in which keeps stocks of raw materials and products necessary to ensure the continuity of production.

The main equipment of technological installations are column-type devices, these include: distillation columns, absorbers, strippers, adsorbers, reactors, tanks, separators.

The life cycle of column-type devices passes through several stages, this is design, manufacture, installation and exploitation.

At the design stage, the column apparatus first acts as a virtual object, and then takes on material forms [3]. At the manufacturing stage, during the technological process, a state of damage may occur in which defects accumulate. Further, at the stage of installation and exploitation, damage can increase as a result of exposure to various types of internal and external loads, which can be reason of structural damage [4]. Under the influence of these loads, the device is in a complex stress-strain state, which can cause structural damage and lead to the development of an accident.

Technological equipment is interconnected by piping, which is distinguished by a considerable length, the presence of shut-off and shut-off and control valves, flange connections and are dangerous from the point of view of system reliability.

At the stage of installation and exploitation of technological pipelines, the appearance of stresses that occur in the material, which exceed the calculated values, is possible [5]. Short-term loads may not have a significant effect on the pipeline. But if the duration of the load increases, then the consequences may be irreversible. If the loads exceed the permissible values, this may entail an increase in the number of potentially dangerous sections in the pipeline in which metal destruction is possible [6,7].

To identify potential dangerous sections of the pipeline, an algorithm has been developed for solving problems in the field of evaluating potential zones of pipeline destruction included in the piping of column apparatuses under external and internal unsteady influences, which is presented in figure 1.

To study the object, it is necessary to use a software package that implements the method of finite elements (for example, ABAQUS, ANSYS, MARC, SolidWorks) [8,9].

At the first stage, it is necessary to create a design scheme - a design phase in which a solid model is built, which takes into account the main structural parameters of the column type apparatus with piping.

Next, the material properties used in the model are set. If there are shells in the model, then its thickness is set, in the case of beams - the cross section.

The next step is to set the boundary conditions and apply loads corresponding to the actual exploiting conditions. Boundary conditions are specified in the form of displacements, restrictions of degrees of freedom, conditions of symmetry, temperatures, etc. Also loads in the form of pressure, force, or moment of forces acting on bodies are set.

Next, a finite element mesh is created in the model. This stage includes the construction of a finite element mesh - in particular, the determination of the size and type of finite elements; the method for constructing a finite element mesh on the part zones is selected.

The final step is to calculate and get a picture of the stress distribution in the model, the results of which are analyzed and the hazard categories of pipeline sections are determined. Based on the results for the current apparatus, recommendations are given for diagnosis, the selection of non-destructive testing methods, depending on the category of apparatus. For devices at the design stage, recommendations for piping configuration.
The study of the object of the column type apparatus with piping

Creating a scheme of an object (design stage)

Solid state model building

Setting mechanical, thermal and other material properties

Setting boundary conditions and applying loads corresponding to actual exploitation conditions

Meshing finite elements in a model

Obtaining a picture of the distribution of equivalent stresses in the model

Analysis of the result and determination of the danger category of pipelines

Yes

No

Recommendations for the current apparatus for diagnosis, selection of the method of non-destructive testing, depending on the danger category of pipelines

Figure 1. An algorithm for solving problems in the field of assessing potential zones of pipeline destruction.

This algorithm will help to make management decisions aimed at improving the safety of industrial plants, both at the design stage and during its exploitation.

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