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*Article*

# Main problems in the operation of metal gas discharge pipes

Zmagul Nuguzhinov, Daniyar Tokanov*, Ashat Rakhimov, Almas Nurzhigit

Department of Civil Engineering, Karaganda State Technical University, Karaganda, Kazakhstan
*Correspondence: tokanov-daniyar@mail.ru

**Abstract.** This paper considers the main problems of operation of metal gas discharge pipes on the example of research and survey work on the examination of building structures of the exhaust tower with three gas discharge trunks 180 m high, flue gas purification unit of the sintering shop of LLP "NDFZ" in Zhambyl region. Analysis of the actual technical condition, considered in this article exhaust tower with three gas discharge shafts, according to the results of the survey, its volume-planning and structural solutions, showed its generally unrepairable, due to the mass of characteristic critical and unacceptable damage to the load-bearing elements of the frame, physical fatigue of materials, significant corrosion wear of metal structures, which will require a significant amount of proposed repair and maintenance work to eliminate them. The conducted complex of researches has shown that the service life of chimneys built before the 1960s and after has practically expired. Repair or reconstruction of chimneys using previously mastered technologies and materials does not solve the issues of reliability improvement. Rational solutions to these problems are periodic technical expertise by highly specialized organizations and implementation on its basis of methods of overhaul of both gas-exhausting trunks and building structures and interface units, wide implementation of which will solve the problem of extending the life of chimneys.
**Keywords:** structure, exhaust tower with gas exhaust shafts, technical inspection, defects, corrosion, experiments, research.

## 1. Introduction

The industry of Kazakhstan has received the development in 50-60th years of XX century, thus in the Republic, owing to the pronounced raw material character of its economy, the branches of extractive industry have received the predominant development. And though existence and development of the basic branches of industry were supported not by intensification of production, but mainly at the expense of increase of capital investments, input of new capacities, nevertheless, in basic, especially in raw material branches of the Republic there was no stagnation. In 1961-1965 alone, more capital investments were utilized in the national economy of the Republic than in all previous years of Soviet power, thanks to which the industrial potential of the Republic doubled. 729 large industrial enterprises and 535 workshops were put into operation. In the second half of the 1960s, another 445 large enterprises and workshops were put into operation, hundreds of plants and factories were reconstructed and technically re-equipped [1-2].

Many of these enterprises became city-forming enterprises and, accordingly, the cities had to be provided with electricity and heat/water supply through the construction of CHPPs [3].

Today, many of the industrial enterprises, including CHPPs, continue to operate. However, most of them have a large physical and moral deterioration of both bearing and enclosing building structures of buildings and structures, and engineering networks. Various topical problems of the technical condition of industrial buildings and structures in Kazakhstan are identified below [4-5].

Lack of regular maintenance: Many enterprises suffer from a lack of systematic maintenance of their buildings and facilities, which can lead to an accumulation of faults that can become serious problems over time [6].

Infrastructure deterioration: Many industrial buildings and facilities were built decades ago and are nearing the end of their useful life or have long since expired. This includes not only physical deterioration of materials, but also outdated HVAC systems, electrical networks, etc [7].

Environmental and health and safety issues: Unmaintained or improperly maintained facilities can become hazardous to workers and the environment. This can include the risk of collapse of old structures, leakage of hazardous substances, fires due to electrical faults due to accidents, and interruption of the city's life support [8].

Lack of adaptation to new technologies and standards: many industrial facilities are lagging behind in terms of technological innovation and safety standards. For example, lack of automated control systems or low energy efficiency can reduce the competitiveness of enterprises [9].

Environmental issues: outdated equipment and technologies are environmentally unsafe and lead to air, water and soil pollution. These problems require serious attention from both the owners and managers of enterprises, as well as from government and regulatory authorities, to ensure the sustainable development of Kazakhstan's industry [10].

Chimneys in industrial complexes play an important role in the removal of exhaust gases, vapors and other emissions from production facilities and operated under the continuous action of high-temperature aggressive gas flows and external natural factors that reduce the durability of the structure in connection with what requires periodic inspection to determine the actual technical condition of chimneys, which has certain specifics [11].

This article will consider one of the examples of technical inspection of bearing and enclosing structures of a chimney with violation of modes during their operation, almost complete absence of technical supervision, underestimation of the importance of technical diagnostic measures.

The purpose of this article is to consider an example of technical inspection of bearing and enclosing structures of a chimney with violations of modes during their operation. The main emphasis is made on the analysis of almost complete absence of technical supervision and underestimation of the importance of technical diagnostic measures. By considering this example, the article aims to identify current problems of the technical condition of industrial facilities in Kazakhstan and discuss the need for systematic maintenance and control to ensure the safety and sustainable development of the country's industry.

## 2. Methods

In 2023, specialists of the Research, Expertise and Design and Survey Kazakhstan Multidisciplinary Institute of Reconstruction and Development (KazMIRD) at the "Karaganda Technical University named after A. Saginov" carried out comprehensive research and survey works on the examination of building structures of the structure "Exhaust tower with three gas discharge trunks H=180m" of the flue gas purification unit of the sintering shop of "NDFZ" LLP in Zhambyl region.

Complex research and development work on examination of the object defined by the Customer's technical task in accordance with [12–16].

The year of construction and commissioning of the Object - 1978. According to [13] the service life of such structures should not exceed 30 years, moreover, the object at the time of the survey is operated for more than 45 years in the absence of capital repairs required by the norms.

The preliminary survey determined the volume-planning and structural solution of the object.

The foundation for the main load-bearing tower is a monolithic reinforced concrete strip foundation (ring-shaped in plan) made of M200 grade concrete. The foundation for each of the tower pyramidal base struts is a monolithic reinforced concrete freestanding foundation made of M200 grade concrete.

The structural scheme of the Facility is of the tower type, which consists of a load-bearing tower and three gas discharge trunks designed from steel structures; in terms of the design scheme, the Facility is designed as a cantilevered rod rigidly fixed in the base. In this case, the supporting tower is a hexagonal prism (hereinafter referred to as the main supporting tower) with a height of 169.2m (relative elevation +169.200), which is pinched in the base and at the levels of elevations +19.200 and +49.200 is reinforced by a system of underpinnings (hereinafter referred to as the pyramidal base of the tower). The geometric invariability of the tower cross-section is ensured by horizontal ties located between the tower belts in the form of a triangle. The 180-meter-high gas discharge trunks are located outside the tower on remote cantilevered platforms. The absolute mark of 550.90 is taken as the relative mark ±0.000.

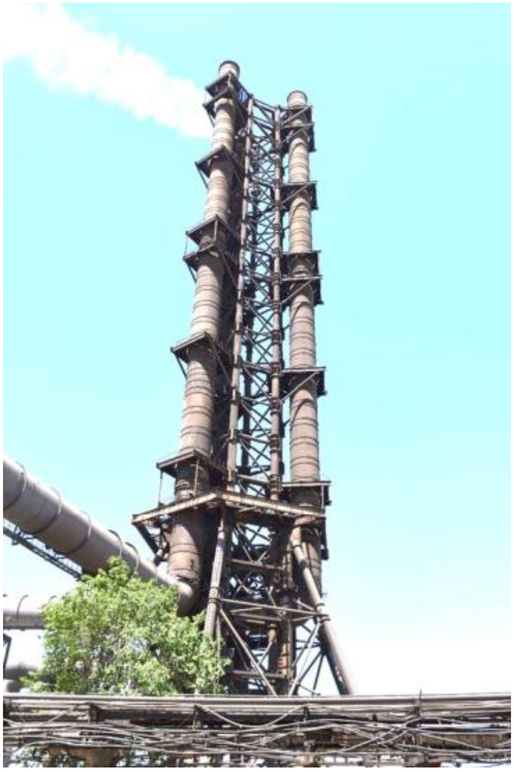

Figure 1 – General view of the Object

In order to reinforce the main load-bearing tower during its erection, the pyramidal base of the tower is designed as a spatial structure, which includes additional struts and guide beams, supported by a system of vertical and horizontal connections. The designed system of connections ensures spatial invariability of the pyramidal base of the tower at all stages of installation.

The outrigger cantilever platforms are designed for fastening the gas discharge trunks to them and transferring the loads from the wind and own weight of the trunk sections between the expansion joints to the supporting tower.

For climbing the tower, its maintenance and structural inspection, walking ladders and transition platforms were designed.

Continued monitoring and inspections will be crucial to ensure the structural integrity and safety of the tower over time.

## 3. Results

The technical condition of the object at the time of the survey is generally assessed by the category of significant damage, due to the presence of critical and inadmissible identified damage caused by long-term operation in conditions of medium and highly aggressive gas-air environment, as well as the impact of electrochemical corrosion. At the same time, it is necessary to take into account the impact of significant wind loads in this climatic region, as well as the location of the object under consideration in an earthquake-prone zone, which creates significant dynamic processes during operation in the form of chaotic vibrations of structures and their components, causing fatigue of materials. In addition, the above factors have radically changed the design scheme of the structure, which significantly reduces the load-bearing capacity of the frame of the extraction tower, due to the violation of the strength conditions of load-bearing steel structures, and also creates conditions for the possible loss of overall stability, in the form of its overturning.

The detailed instrumental inspection revealed significant defects and damages that reduce the load-bearing capacity and affect the serviceability, namely:

1) inspection of the foundations in the opened pits showed that the structures were made with deviation from the geometric parameters regulated by the album of the project drawings, in particular, the foundation for the load-bearing tower is made as a continuous slab, while the project provides for a strip foundation (in the plan in the form of a ring), also, the bottom (sole) of the foundation is actually located at the level of relative elevation -3.300, but the project specifies elevation -3.500. The geometric parameters of the foundation for the tower's base struts also do not correspond to those given in the project. According to the project, the specified free-standing foundations should have been made of pyramidal shape with one vertical face without ledges with a gentle (at an acute angle) extension to the bottom, but in fact the foundation structure is made in the form of a triangle with two sloping (when viewed in profile as in the drawing) and two vertical side faces with a developed bottom part (see Figure 2).

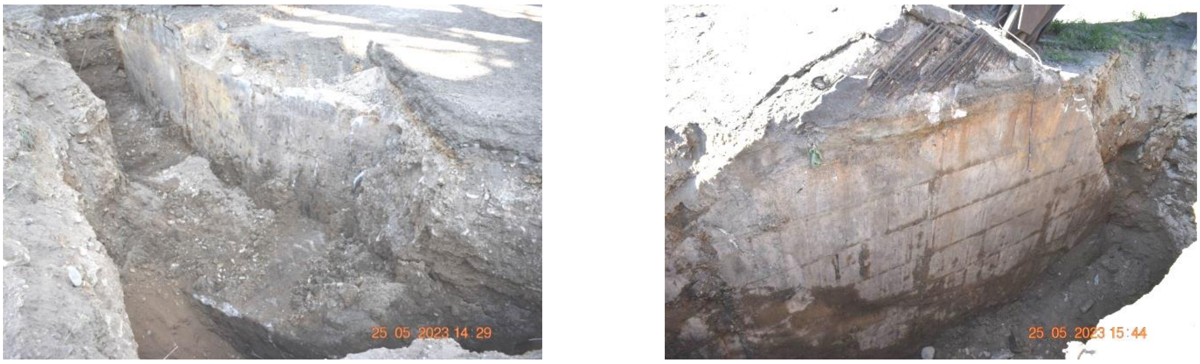

Figure 2 – General view of the opened test pits

2) characteristic critical damage to the supporting foundation base of the load-bearing tower belt: the foundation bolts are broken, a rattling sound is heard when tapping - the damage was found in 3 bolts out of 12, which is 25% of the total number of bolts (see Figure 3);

3) significant damage characteristic for all foundation bolts of the support base (see Figure 4): continuous irregular corrosion of bolts with damage of up to 14% of the area of the design cross-section, the residual diameter of bolts in localized areas of the non-threaded part is 69mm (M80 bolts are regulated by the project);

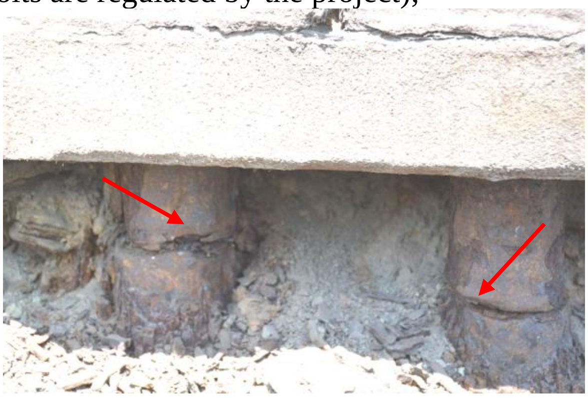
Figure 3 – Breakage of foundation bolts

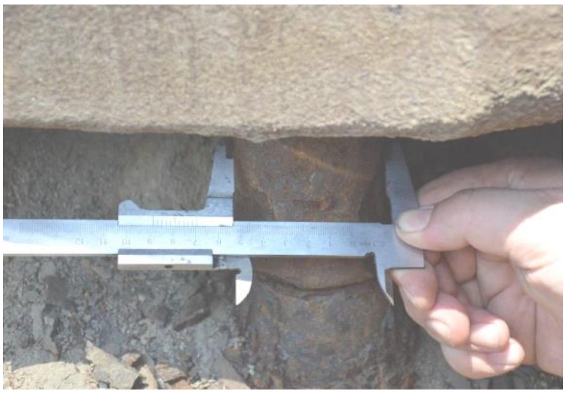
Figure 4 – Continuous irregular corrosion of foundation bolts

4) critical damage to all the chords of the load-bearing tower, due to the presence of characteristic closing nodes at the levels of +19,200 and +49,200, the presence of which changes the design scheme of the main load-bearing tower, thus significantly reducing its load-bearing capacity and creating conditions of unsuitability of the load-bearing tower as a whole under the action of design (project) loads (see Figure 5);

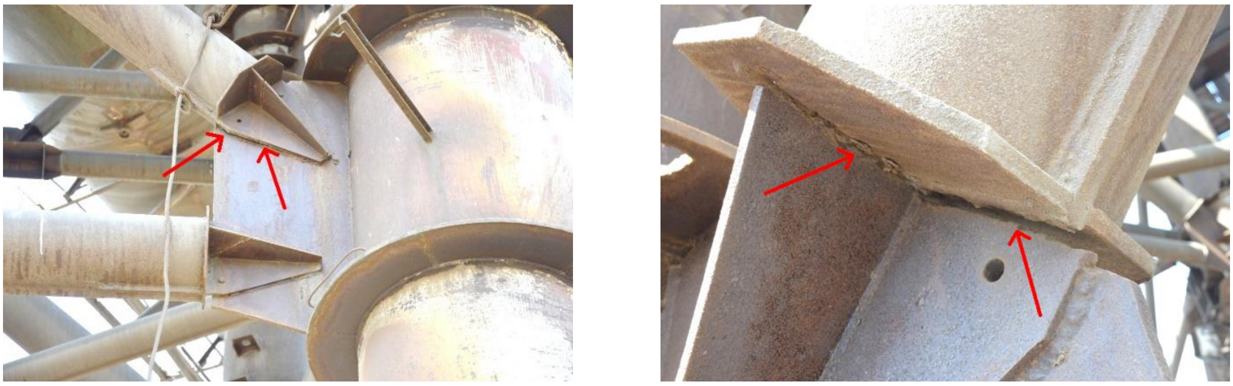

Figure 5 – Characteristic critical defect: weld rupture in the connection between the strut attachment plate and the fascia

5) the presence of characteristic critical damage in the form of ruptures and cracks in the welded joints of girder strut attachment assemblies, as well as due to the presence of irregular corrosion of girder walls and flanges in the support and span sections with up to 30% of the cross-section of the elements, In addition, there are deformations of overlays (bulging), due to the development of crevice corrosion in the gaps, the size of corrosion products in some places reaches a thickness of 8 mm, indicating a significant reduction in load-bearing capacity and threatening, if no action is taken, the collapse of structures (Figure 6);

- the presence of gaps and cracks in welded joints in the nodes of fixing elements on beams and links, indicating the loss of their load-bearing capacity and threatening their collapse (Figure 7);

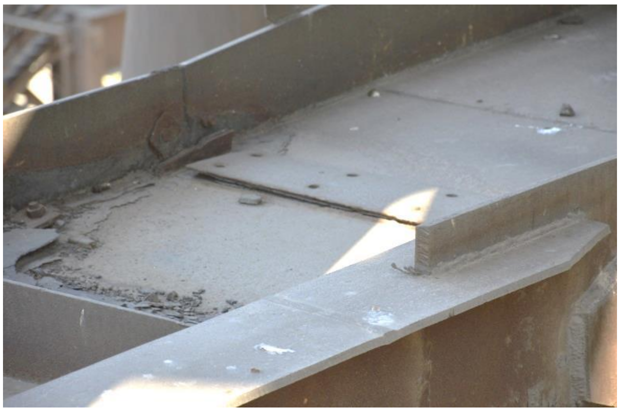

Figure 6 – Fracture of the weld along the entire length of the joint

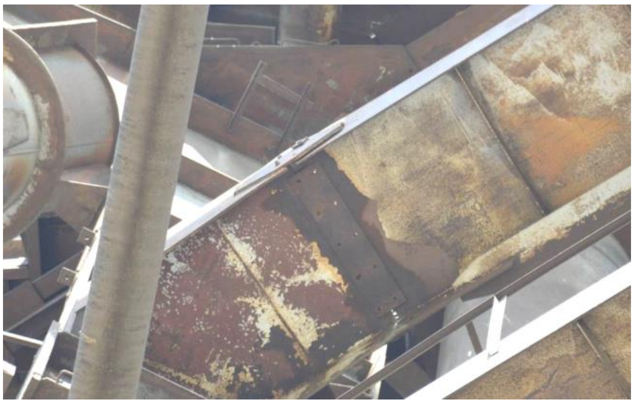

Figure 7 – Fracture of the weld at the fusion boundary along the entire length of the joint

6) a set of critical defects and damages of the gas exhaust trunks No.1, No.2 and No.3, namely (Figures 8, 9):

- deviations from the original design in terms of reduction of the thickness of the shell sheets and trunk support rings in comparison with the original design;
- deviations from the design in the form of non-compliance of the support units of trunk support beams;
- ruptures of shaft shells in the places where the support ring ribs meet;

- critical damage typical for the majority of similar connections of support beams: breaks and cracks in welded joints in the areas of support of elements; in addition, significant damage typical for the majority of similar assembly overlap welded joints of beam support assemblies: development of crevice corrosion, thickness of corrosion products is 5...10 mm;
- critical damage typical for all elements of sliding supports: ruptures of welded joints of guide angles with the beam, ruptures of welded joints of support plates of sliding element (channels) with ring ribs; in addition, development of crevice corrosion between contact surfaces of elements, thickness of corrosion products reaches 30 mm;
- cracks along the entire length of the butt-welded joints of the butt-welded assembly of the support ring ribs, as well as the ring support ribs are welded to the barrel shell with a one-sided weld; butt welded joints of the ring ribs are made with incomplete welds, there are also metal inclusions in the joints;
- gas-diverting trunks #1 and #3 have deviation from the vertical plane (roll), the values of which exceed the values allowed by the burrows, trunk #1 - deviation of 540 mm, trunk #3 - deviation of 550 mm [the permissible value of the line of intersection planes from the vertical at a height of h≈140m is 420mm according to [17];
- the results of the performed works on thickness measurement of gas-venting trunks have shown that at the whole height of trunks there is a significant wear of the trunk shell, with damage of up to 20% of the thickness of the sheets; at the same time, in some areas, at the level of the heads, the wear reaches 65%;
- in localized areas, replacement of the gas venting shaft sheathing sheets with carbon structural steel sheets is observed.

Figure 8 – Support ring of gas outlet shaft No.1 at the level of site level at level +49.200

Figure 9 – Rolls and loss of local stability of the walls of the support beams of gas outlet shafts characteristic for beams at the site level at level +49.200

Corrosive wear of metal structures of the Facility in some areas occurs on average with an intensity of more than 0.22mm/year (i.e., for 45 years of operation of the Facility the amount of corrosion damage of steel structures in some areas reaches 10mm). Based on this, the degree of aggressive impact of the operating environment on the structures is characterized as medium-aggressive, which excludes the possibility of operation of the building structures of the Object without special protective chemical-resistant paint and varnish coatings.

The analysis of the technical condition of the Object according to the results of the performed survey, its volume-planning and structural solutions, showed in general its emergency condition, unrepairable, due to the mass of characteristic critical and unacceptable damage to the load-bearing elements of the framework, physical fatigue of materials, which will require a significant amount of proposed repair and restoration work aimed at ensuring the normative load-bearing capacity and serviceability in the conditions of already

Due to the above-mentioned defects and damages, it was decided to dismantle the extraction tower with three gas discharge trunks (H=180m).

However, taking into account the critical importance of the object for ensuring the continuous nature of the Customer's production, the repair and restoration works on the object are theoretically possible, but technically extremely difficult, associated with high labor costs and associated with significant risks in the work.

Under the current conditions, in the presence of established defects and deviations of mass character in the gas-venting trunks, the development of working technical solutions to restore serviceability, including strengthening and replacement of individual structures, followed by their qualitative implementation was inexpedient. In this regard, KazMIRR Institute gave recommendations for the complete replacement of gas exhaust shafts No. 1, 2 and 3, including their supporting elements.

## 4. Conclusions

Analyzing the results of technical inspection, we can draw conclusions:

- chimneys in their bulk were built in Soviet times and practically exhausted their operational resource, therefore it is necessary to conduct periodic technical expertise by highly specialized organizations and on its basis perform major repairs, only in this way it is possible to extend the service life of chimneys;

- major overhaul or construction of new chimneys is expedient (high cost price) at present only for large industrial production facilities;

- relatively low cost of installation, as well as the speed of erection make the use of metal chimneys at small enterprises practically non-alternative;

- specialized design and construction organizations with experience in the design and construction of high-rise chimneys and (or) exhaust stacks should be engaged to develop the detailed design and to carry out the works.

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## Information about authors:


*Zmagul Nuguzhinov* – Doctor of Technical Sciences, Professor, Department of Civil Engineering, Karaganda State Technical University, Karaganda, Kazakhstan, kazmirr@mail.ru

*Daniyar Tokanov* – Candidate of Technical Sciences, Senior Lecturer, Department of Civil Engineering, Karaganda State Technical University, Karaganda, Kazakhstan, tokanov-daniyar@mail.ru

*Ashat Rakhimov* – PhD, Senior Lecturer, Department of Civil Engineering, Karaganda State Technical University, Karaganda, Kazakhstan, rakhimov.askhat@gmail.com

*Almas Nurzhigit* – Master's Student, Department of Civil Engineering, Karaganda State Technical University, Karaganda, Kazakhstan, almas290502@gmail.com


## Author Contributions:

*Zmagul Nuguzhinov* – concept, methodology, resources, funding acquisition,
*Daniyar Tokanov* – modeling, analysis, visualization, drafting.
*Ashat Rakhimov* – interpretation, editing.
*Almas Nurzhigit* – data collection, testing.


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