Temporary gas pipeline sealing during fire works

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Abstract. The analysis of scientific literature, technical solutions and inventions in the field of polymer composite materials for temporary gas pipeline compaction is carried out. It was revealed that for sealing the pipeline, polymer compositions based on rigid polyurethane foams, or compositions that swell in the cavity of the gas pipeline with the formation of a gel-like plug, can be used. A mandatory requirement is the ability to remove the sealing plug from the insulated cavity of the gas pipeline after the completion of repair work.

The analysis also showed that there are few studies in the field of creating polymer composite materials for temporary sealing of gas pipelines. The development of compositions that meet all the requirements is of practical interest for the gas industry.

Key words: temporary sealing, gas pipeline, polymer compositions, temporary sealing devices, fire work, gas pipeline repair.

1 Introduction
In connection with the advent of new designs, machines, apparatuses and products operated under various adverse conditions, the problem of sealing and sealing is becoming more important [1-3]. Sealants are widely used in construction, aviation, shipbuilding, machine, instrument and automotive industry, electrical engineering. Sealants of cured and non-cured type are widely used as anti-corrosion coatings of various surfaces [4-8].

Sealing materials of various types are in demand during the repair and restoration work on the gas pipeline [9-12]. Overhaul of the linear part of the pipeline is carried out, as a rule, using fire work. In this case, there is a need for temporary localization of the pipeline section to prevent the ingress of gases or liquids into the work area. The place of repair work is isolated by installing temporary sealing devices (TSD) on both sides (figure 1).

![Temporary sealing device](image)

Figure 1. Temporary sealing device.
As TSD, various designs of rubber and rubber-tissue sealing pneumatic devices are used. Devices are introduced into the pipeline through technological holes, the sizes of which depend on the diameter of the pipeline and are strictly regulated. Technological openings should have the shape of an oval (ellipse) and be located in the upper quarter of the gas pipeline with an offset of ± 20 ° from the upper generatrix of the pipe. The dimensions of the hole should not exceed 250×350 mm and should not be less than 100×150 mm, while the width of the hole should not exceed half the diameter of the pipe. The difference between the width and the length of the hole must be at least 50 mm. After being introduced into the pipe, the water supply units are filled with air or inert gas, assuming a cylindrical shape and blocking the pipeline cavity (figure 2). At the end of the fire work, they are removed through the technological holes. Under these conditions, TSD should be lightweight, small in size and at the same time durable and provide the necessary tightness.

![Figure 2. Installation of a fire-fighting unit during fire work.](image)

In the Russian Federation there are several plants that produce unified TSD for gas pipelines, for example, CJSC Yaroslavl-Rezincatechnika, OJSC UZEMIK, OJSC NIIRP. As a material for such devices, rubberized fabric, PVC-coated or PU-coated fabric or just rubber is used. The diameter of the product varies from 200 to 1400 mm, the length is from 600 to 1500 mm, and the mass is from 2 to 20 kg. Devices can withstand excess gas pressure up to 6.4 MPa.

Installation of such a device is not possible for pipes of small diameter, because for this, it is necessary to cut out sufficiently large technological holes, which is prohibited by the standard for repair-and-renewal operations. It is also problematic to use a TSD in pipes with a seam, since irregularities do not allow a tight fit of the TSD to the walls of the pipeline. In addition, the TSD is quite difficult to remove from the pipe after completion of the replacement of the pipeline section, and they are quite difficult to manufacture.

For temporary sealing of small diameter gas pipelines (200 mm or less), clay plugs (RU66475U1) are mainly used today. Sealing a pipeline using clay cork is time-consuming and unreliable and does not provide a tight seal at relatively high overpressures (1 atm or more). After removal of clay plugs, abrasive particles remain inside the pipe, which cause intense wear of the gas pipeline, as well as equipment breakdown if gas distribution stations get into the mechanisms.

To reduce emergency downtime, you need a way to quickly and tightly shut off the pipeline. The method should also provide the ability to quickly and easily remove the sealing device from the pipeline after completion of the repair. For these purposes, the most convenient is the use of polymer composite materials.

The practice of conducting fire work forms the following requirements for such sealants and for the gas pipeline sealing technology:
- the sealant should be ready for operation one hour after sealing the gas pipeline;
- the sealant must have the necessary level of the following characteristics: adhesive and cohesive strength, which ensures its operation in accordance with the requirements of regulatory documents, in particular, ensure tightness at a gas pressure of 0.1 MPa;
- the sealant should be able to be used in the temperature range from -40 to +40 °C;
- the sealant must not ignite and burn when a spark or scale gets on the surface;
- the sealing composition must have the ability to decompose upon exposure for 40 minutes.
It should be noted that the criteria presented are quite strict and to date there are no sealants that satisfy all of the above requirements. We also note the practically lack of scientific research and a small number of technical solutions devoted to the development of compositions for temporary sealing of gas pipelines.

2 Materials and methods

As the analysis of patent literature has shown (despite the fact that the retrospective of the search was 35 years), the number of patent documents found is extremely small. The inventive activity curve based on the cumulative time series is shown in the figure 3.

Based on existing technical solutions, the following areas of promising research on the use of polymer compositions for temporary sealing of gas pipelines can be distinguished.

3 Results and discussion

First of all, this is the use of ready-made cylindrical sealing plugs that are introduced into the cavity of the gas pipeline through the end of the pipe. Such plugs can be made of polyurethane foam, expanded polystyrene, and foamed polymethyl methacrylate. The necessary tightness is ensured by gluing the sealing plug to the inner wall of the pipe using a polyurethane foam composition (figure 4).

![Figure 4. Method of repair work using a sealing plug for temporary blocking of the pipeline: 1 – sealing plug (polystyrene foam or foamed polymethyl methacrylate); 2 – adhesive composition (mounting foam).](image-url)
Removing the sealing plug in this case is possible in two ways:

- by mechanically destroying it or pushing it into special devices - camera traps, which complicates the repair process and causes the risk of damage to the pump blades with pieces of sealant (RU1643852);
- by spraying through a nozzle under a pressure of 2-3 atmospheres of the solvent (RU2341721). If the swab is made of expanded polystyrene, then toluene, xylene, ethylbenzene, isopropylbenzene are used, if the swab is made of foamed polymethyl methacrylate, then chloroform, dichloroethane, trichloroethane.

Significant disadvantages of such a solution are, firstly, the possibility of its use only for gas pipelines with a diameter of 200 mm or less, since only at such diameters the gas pipeline is repaired by cutting a “coil”. Secondly, to dissolve the sealant, a large amount of solvent is needed, which, in addition, needs more heating for more efficient use.

There are technical solutions where, in order to increase the reliability of sealing, the defective area is localized with inflatable locking elements and the defective area is degassed with foam of the following composition: water (95.8%), foaming agent (4%), polyacrylamide (0.05%), polyvinyl alcohol (0.15%). However, this solution significantly complicates the sealing technology and is advisable for pipes with a diameter of 300 mm or more (RU1167400).

From the point of view of installing a sealing device, an attractive solution is foaming foaming polymer compositions directly in the cavity of the pipe.

In [14, 15], a method is proposed for emergency sealing of a gas pipeline by foaming polyurethane foam sealant in a pipe cavity (figure 5). The sealing composition in accordance with this technical solution should have the ability to controlled thermal decomposition under specified conditions, which can be achieved by varying the content of the components of the sealing composition or using certain additives. This requirement is mandatory because after completion of repair work the removal of the sealing plug is carried out by pyrolysis. To date, in the scientific and technical literature there are a lot of studies devoted to the study of the thermal resistance of rigid polyurethane foams depending on the composition [15-20].

![Figure 5 The method of repair work by foaming in the cavity of the pipe polyurethane foam composition.](image)

In addition to polyurethane foam compositions, there are others capable of forming a sealing plug. Such compositions can be established in the process of the pumped medium. As the polymer base, compositions based on polymethyl methacrylate, foamed isoprene rubber, polyacrylamide, and polyurethane foam compositions are used. A sealing method using polyurethane foam compositions is described above.
Polymethyl methacrylate-based formulations are mainly used for sealing oil pipelines. Polymethylmethacrylate and its analogues, swelling in a solvent, form a gel-like swab. Their size should be more than 3-4 pipelines. A gel-like swab with a diameter of 10 cm and a length of 150 cm can withstand pressure of only 0.07 MPa (RU2076262).

Sealing with foamed isoprene rubber implies the need for a portable extruder. In addition, such a sealing can only be carried out at high temperatures (190-200 °C), and, accordingly, the time required to ensure the tightness is required (a pipe with a diameter of 150 mm is filled in 80 minutes, the resulting elastic swab 75 cm long) (RU1702067).

There are also attempts to modify clay plugs by adding polyacrylamide and a crosslinker (RU3227523). In order to convert the polyacrylamide solution to a gelatinous state, time is required, which leads to the formation of a polymer material.

One of the significant drawbacks of the above methods is the large size of the sealing plugs, due to the fact that the sealing composition is fed into the pipeline, as a rule, a sufficiently long time is required to increase its viscosity. The length of the plugs with the specified sealing method is up to 10 pipeline pipelines.

To prevent spreading, dispersed adsorbent with ferromagnetic properties or carbonyl iron powder are added to the sealing composition, which is in the process of injection in the zone of formation of the sealing swab on the composition exposed to the magnetic field. Thus, it is possible to adjust the length of the sealing swab. Additional equipment is required to create a magnetic field.

An interesting and promising direction for the gas pipeline is the use of thermoplastic polymer compositions filled with a blowing agent. They have rather high temperature characteristics (from -40 to + 40°C).

Unfortunately, it was not possible to remove the sealant compositions from the pipeline for final repair. The only exceptions are solutions that suggest the removal of a polyurethane plug by pyrolysis and the destruction of water-soluble formulations by propagation by a water jet [21].

The adoption of the latter decision is not applicable for gas pipelines when they avoid gas pipeline corrosion. It should also be noted that most methods and compositions are only suitable for sealing oil pipelines.

In addition to polymer composite materials, there is a technology for sealing pipelines using ice plugs [22].

| Table 1. The test results of ice plugs withstand pressure [22]. |
|---------------------------------------------------------------|
| Indicators | The inner diameter of the pipe, mm | 289 | 340 | 173 |
| Curing time, min | 196 | 162 | 117 | 47 | 71 | 87 | 86 |
| Liquid nitrogen consumption, dm³ | 5000 | 2001 | 2000 | 307 | 526 | 580 | 506 |
| Withstanding pressure, bar | 45 | 16 | 16 | 139 | 80 | 250 | 250 |
| Pressure plug test time, hours | 20 | 46 | 22 | - | - | 13 | 13 |

As can be seen from table 1, ice plugs withstand significant fluid pressure. But this technology is applicable for pipelines transporting liquid media. When used for sealing gas pipelines, the technology is much more complicated. Also, the presence of water in the pipe will lead to corrosion, and deposits in the pipes will not allow you to create an airtight plug.

Thus, as a result of the analysis, it can be concluded that polymer compositions can be used to seal the pipeline, capable of forming foam or gel in the inner cavity of the pipe. For these purposes can be used:
- gas-filled (foamed) sealing material - polyurethane foams or polyurea foam;
- systems that swell in the cavity of the gas pipeline with the formation of a gel-like plug, preferably without structuring or partially structuring, and then dissolving with the introduction of the solvent.
The analysis also showed that research in the field of creating polymer composite materials for temporary sealing of gas pipelines is scarce. The development of compositions that meet all the requirements is of practical interest to the gas industry.

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