ADVANCED FIRE PROTECTION FOR OIL AND PETROLEUM PRODUCT DEPOTS: THE REAL AND IMPENDING FUTURE

The fundamental inefficiency of existing methods of extinguishing fires in tanks with foam supplied to the surface or under the fuel layer has been shown through both experimentation and mathematical modeling. Normative foam supply rates are insufficient when it comes to combatting and overcoming the effects related to foam destruction or ablation that occur when extinguishing tanks with a volume of more than 5,000 m^3. We have evaluated advanced methods of extinguishing fires in reservoirs containing oil and petroleum products. It has been shown that the use of carbon dioxide and gas-powder mixtures for this purpose will lead to the formation of large gas contamination zones, which are dangerous to any people present and can disable the equipment involved in extinguishing. The best alternative to "classic" foam extinguishing is the use of self-foaming gas-aerosol foam (SFGAF) supplied at a high theoretical flow rate (up to 700 m/s or more), one that is sufficient to overcome the effects of foam destruction and ablation when extinguishing fires in reservoirs with a volume of more than 5,000 m^3. The conclusions of this work have also been confirmed experimentally.

RESERVOIR FIRE EXTINGUISHING TECHNIQUES: ADVANTAGES AND DISADVANTAGES

Two techniques are utilized to extinguish fires in reservoirs today: supplying air-mechanical foam from above to the center of the fire using foam generators, and supplying a film-forming foam concentrate through the fuel layer to the surface of the burning liquid. Experience shows that reservoirs with a capacity of more than 10,000 m^3 are, functionally speaking, not extinguished. Reservoirs with a capacity of 5,000 m^3 are only extinguished in one of every two cases, particularly those petroleum products that contain alcohols (modern fuel).

The main reasons for the ineffectiveness of the aforementioned fire extinguishing methods for fires in oil and petroleum product depots read as follows:

1. Automated systems installed on reservoirs cannot withstand the pressure from explosions of the

gas-air mixtures that form under the roof of the reservoir. A curve of explosion pressure versus petroleum product level is displayed below. We should bear in mind that over 90% of reservoir fires start with an explosion.

2. In the event of a growing fire, heat will bring both the reservoir walls and the petroleum product to high temperatures. Consequently, combustion can continue for a long time on the sides of the reservoir.

3. A fire in a reservoir significantly transforms the direction and speed of airflows, as shown in Figure 1. As a result, the foam supplied from standard fire extinguishing systems is drawn into fire's upward flow, preventing the majority of it from falling on the burning surface.

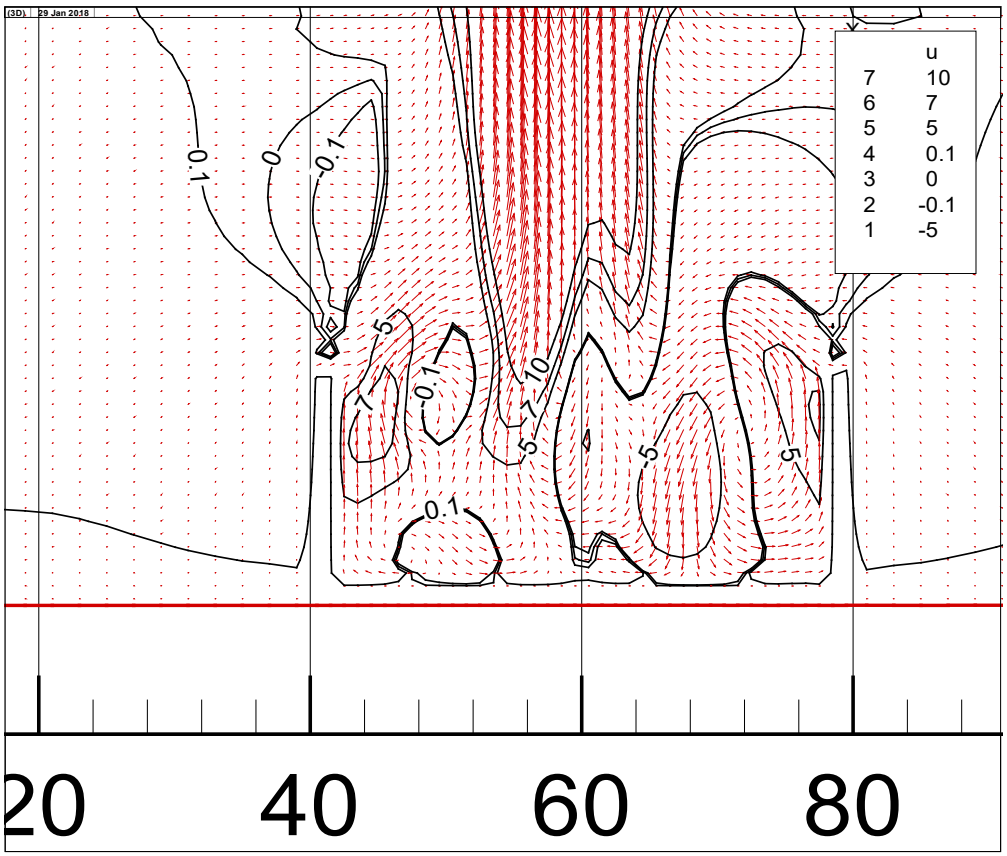

Figure 1. Velocity of gas flows (m/s) with a fire inRVS-20000 reservoir, 2-meter fill level, 60 seconds of combustion.

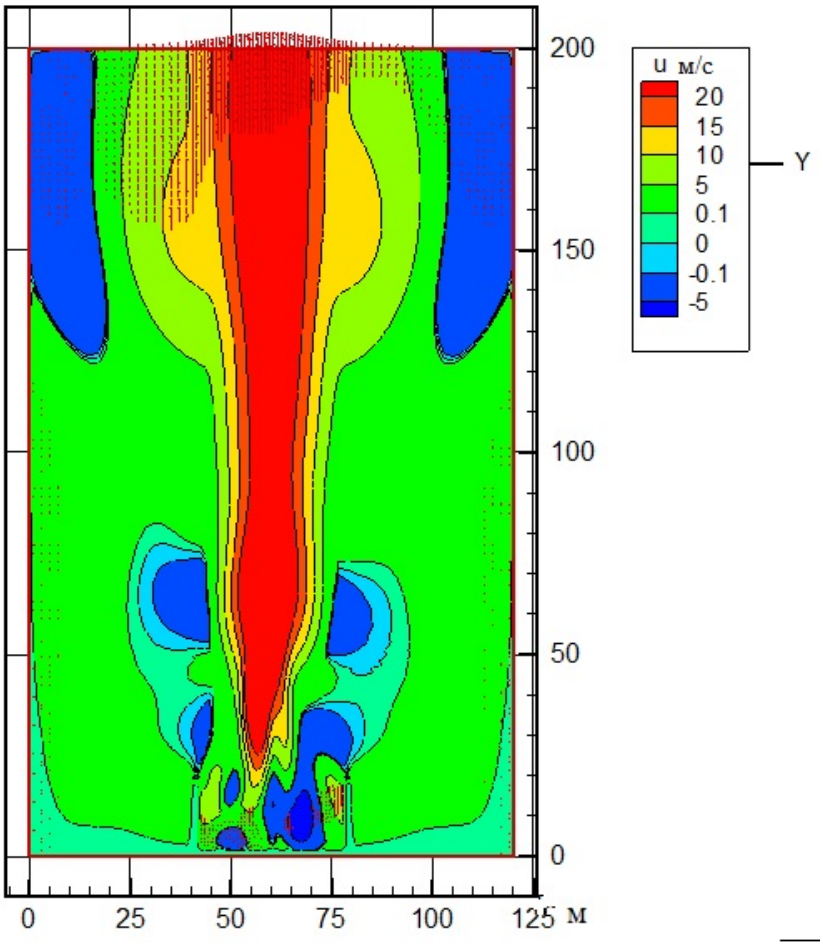

Figure 2. The vertical speed of gas flows with a fire in a VST-20000 reservoir, 2-meter fill level, 60 seconds of combustion.

4. The temperature of the combustion products in the convective column is high (see Figure 3). At such temperatures, the foam is largely destroyed.

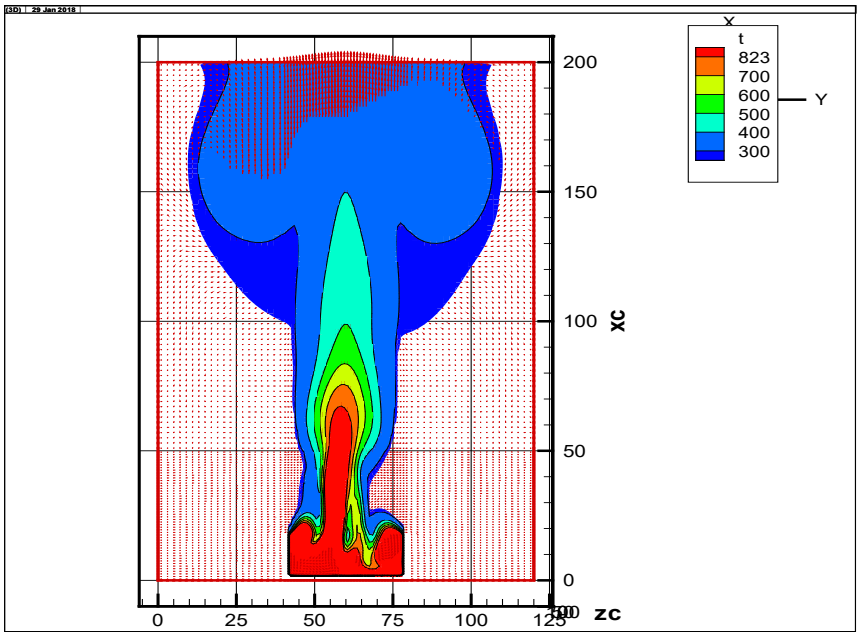

Figure 3. Temperature field in the convective column for the VST-20000 reservoir, 2-meter fill level, 60 seconds of combustion.

5. With standard subsurface fire extinguishing in a reservoir, a sizable heated layer (the so-called inversion layer) is formed in the upper layer of the burning oil product. The foam rising through the fuel layer rests against this layer without penetrating through it to the burning area.

6. If the petroleum product contains alcohols, then the foam dissolves during subsurface extinguishing.

Existing standards for foam delivery rates are determined without taking the factors set out in paragraphs 1-6 into account, which largely explains the observed lack of extinguishing capacity. Thus, anyone who utilizes these outdated and ineffective methods of extinguishing reservoir fires can doom oil companies to multibillion-dollar losses and costs.

The following can be done to ensure successful extinguishing:

1. Ensure that the equipment is explosion resistant.
2. Provide for a large consumption of foam per unit of time when supplying a fire extinguishing agent.
3. Provide a high feed rate of the extinguishing agent.
4. Improve the effectiveness of the extinguishing agent.

The general criteria listed above for increasing the efficiency of reservoir extinguishing are met by a new technique for extinguishing reservoir fires, namely by supplying a fire extinguishing agent from above or below the layer of burning liquid. This technique involves supplying self-foaming gas-aerosol foam (SFGAF) as a means of combined extinguishing for reservoir fires.

This composition combines foam, gas, aerosol, and film-forming agent. SFGAF foam is produced without the use of traditional foam generators, foam monitors, pumps, or gas cylinders that saturate the foam with either air or whichever necessary gas would ensure resistance to explosions.

SFGAF is generated in the following way:

1. Water is poured into a container (steel or plastic), and foam concentrate is added to it.

2. The container must be able to withstand pressure of at least 7 bars.

3. Special gas-aerosol pressure generators are inserted into the container.

4. After activating the generators, aerosol combustion occurs along with the formation of carbon dioxide, nitrogen, and a small amount of fine-dispersion aerosol, mainly containing potassium carbonate and bicarbonate.

5. During generator operation, the foaming agent solution is mixed with water and the pressure in the tank rises to 7 bars.

6. Gases and aerosols are dissolved (sorbed) in the foaming agent solution.

7. When a pressure of 7 bars is reached, the membrane breaks open and the mixture flows through the pipe to extinguish the fire.

8. When exiting the pipe without a foam generator, gases in the solution are desorbed (similar to opening a bottle of champagne) due to the difference of pressure in the solution and atmospheric pressure, and low expansion foam is formed (with an expansion ratio of 10-18). Foam bubbles are not filled with air (which contains oxygen), but with CO2 and N2, and a small amount of fine-dispersion aerosol settles on the surface of the bubbles. Video demonstration - https://youtu.be/jcIXAbmkPxQ .

9. When the foam, which retains consistency for about 2 hours, finally breaks down, the film-forming foaming agent precipitates and covers the burn site with a film.

Thus, when extinguishing a fire, foam, gas, and gas-aerosol fire extinguishing methods are implemented, and the extinguishing agent has a high flow rate (up to 700 liters per second) and exit speed (up to 35 meters per second).

Video demonstration - https://youtu.be/fN8r2GPSWXs and https://youtu.be/eq2I1xG5OjM .

For comparison's sake, when "classical" foam fire extinguishing is applied to the surface of a tank with a volume of 20,000 m^3, the flow rate is 114 liters per second, and the exit speed of the extinguishing agent is less than 6 meters per second.

A fire can be extinguished with SFGAF in 30 - 90 seconds, video- https://youtu.be/kF77k8dmq68 .

In all of the field experiments we conducted on 5,000 m^3, 10,000 m^3, and 20,000 m^3 tanks, 100% of the fires were extinguished. There was not a single case of failed extinguishing.

CONCLUSIONS

1 Using mathematical modeling, the fundamental inefficiency of the existing methods of extinguishing fires in tanks with foam supplied to the surface or under the layer has been shown.

2. Standard foam supply rates are insufficient when it comes to combatting and overcoming effects related to foam destruction or ablation that occur when extinguishing tanks with a volume of more than 5,000 m^3.

3. The use of carbon dioxide and gas-powder mixtures for extinguishing fires in oil and petroleum reservoirs will lead to the formation of large gas contamination zones that are dangerous for the people present and disable the equipment involved in extinguishing.

4. The best alternative to the "classical" foam extinguishing is the use of SFGAF supplied at a high flow rate (up to 700 l/s or more), one that is sufficient to overcome any effects related to foam destruction or oblation when extinguishing fires in large reservoirs.