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Approaches to Extinguish Gas Blowout Fires: World Experience and Potential for Development²

Способы и средства тушения пожаров газовых фонтанов: мировой опыт и перспективы развития

Sposoby i środki gaszenia pożarów przy wyciekach gazu: doświadczenie światowe i perspektywy rozwoju

ABSTRACT

Aim: Fires caused by a gas blowout are complex man made emergencies. Attempts to extinguish such fires attracts considerable effort and resources. Such incidents culminate in significant financial losses, damage to the environment and, sometimes, human sacrifice. Firefighters from different countries extinguish gas blowout fires in different ways. The purpose of this article is to analyse global experiences with such incidents, identify challenges and the potential for further development of firefighting techniques.

Methods: The main approach involves analysis and synthesis. During the analysis stage, the following sources were accessed for information: periodicals and technical publications from different countries, workshop, symposium and scientific conference materials, public information from the internet and patent databases from various countries. Additionally, the authors applied personal knowledge and experience, and other practitioners knowledge of extinguishing gas blowout fires.

Results: Extinguishing methods were categorised into five groups: dousing with the aid of a continuous stream delivery of an extinguishing agent, firing a volley of impulses with the aid of appliances: SPT-200, Impulse-Storm, Fire Commander, use of explosives to disrupt and extinguish a “burning torch”, use of preventers and drilling of directional wells without the use of extinguishing agents, and a combination of afore mentioned approaches. For each approach an in depth analysis was performed on firefighting equipment used, identifying relevant features and process for extinguishing flames and determining relative advantages and disadvantages.

Conclusion: From this research the authors identified a development path for optimization of resources in the process of quenching fires, by increasing the effective suppression range and reduction in the quantity of extinguishing agents used, thus enhancing the protection of personnel from exposure to fire hazards and minimization of damage to the environment. It was determined that the most effective extinguishing method for the oil and gas industry fire, caused by a blowout, was found in the application of fire extinguishing agents by pulsing techniques.

Keywords: gas blowout, firefighting, impulse supply, fire nozzle, extinguishing method

Type of article: review article

АННОТАЦИЯ

Цель: Пожары газовых фонтанов являются сложной чрезвычайной ситуацией техногенного характера, при тушении которых возникает необходимость привлечения большого количества сил и средств. Такие чрезвычайные ситуации влекут за собой значительные материальные и экологические потери, а иногда и человеческие жертвы. При этом для тушения пожаров газовых фонтанов в разных странах используются различные способы и средства. Целью данной статьи является анализ мирового опыта применения различных способов и средств для тушения пожаров газовых фонтанов, определение их недостатков и перспектив развития.

Методы: Основным методом исследования является метод анализа и синтеза. Во время анализа использованы следующие источники информации: печатные издания и периодические издания разных стран, материалы семинаров и научно-практических конференций, открытая информация в сети интернет, доступные патентные базы разных стран. Кроме этого, авторы использовали собственный опыт и опыт практических работников по тушению газовых фонтанов.

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Rezultaty: Все известные средства тушения пожаров газовых фонтанов авторами разделены на пять основных групп: тушение с помощью доставки в факел струйного непрерывного потока огнетушащего вещества (применение лафетных стволов, автомобилей газодыяного тушения и т.п.), тушение импульсными установками пожаротушения (ППП200-, Импульс-Шторм, Fire Commander и т.п.), применение взрывчатых веществ для срыва и тушения горящего факела, без доставки огнетушащего вещества в зону горения (применение превенторов и бурение наклонных скважин) и совместное использование нескольких подходов. По каждой из групп проведен глубокий анализ всех средств пожаротушения, раскрыты особенности каждого из них, механизмы прекращения горения, которые реализует каждый из этих способов при взаимодействии с факелом. Определены их недостатки и преимущества.

Выводы. На основании проведенного анализа авторами определены основные пути развития средств тушения газовых фонтанов: увеличение дальности эффективного тушения, уменьшение расхода огнетушащего вещества, повышение защищенности личного состава от воздействия опасных факторов пожара, уменьшение экологического ущерба окружающей среде. Определено, что наиболее перспективным средством пожаротушения для газовой отрасли является применение импульсной подачи огнетушащих веществ к факелу фонтана.

Ключевые слова: газовый фонтан, пожаротушение, импульсная подача, пожарный ствол, способ тушения

Вид статьи: обзорная статья

ABSTRAKT

Cel: Pożary przy wyciekach gazu są trudnymi sytuacjami nadzwyczajnymi, których gaszenie związane jest z koniecznością zadysponowania dużej liczby sił i środków. Tego rodzaju sytuacje nadzwyczajne skutkują znacznymi szkodami materialnymi i ekologicznymi, a czasem i ofiarami w ludziach. W różnych krajach do gaszenia pożarów wycieków gazu wykorzystywane są inne sposoby i sprzęt. Celem artykułu jest przeanalizowanie światowego doświadczenia w stosowaniu różnych metod i sprzętu do gaszenia pożarów przy wyciekach gazu, określenie ich wad i perspektyw rozwoju.

Metody: Głównymi metodami badań były analiza i synteza. Podczas analizy wykorzystywano następujące źródła informacji: wydania drukowane i periodyki z różnych krajów, materiały z seminariów i konferencji naukowo-praktycznych, ogólnodostępne informacje z sieci Internet oraz dostępne bazy patentowe różnych krajów. Ponadto autorzy korzystali z własnego doświadczenia oraz doświadczenia praktyków, którzy uczestniczą w gaszeniu pożarów przy wyciekach gazów.

Wyniki: Wszystkie znane metody gaszenia pożarów przy wyciekach gazów zostały podzielone przez autorów na pięć podstawowych grup: gaszenie poprzez kierowanie na płomień nieprzerwanego strumienia substancji gaśniczej (zastosowanie działek stacjonarnych, pojazdów pożarniczych wyposażonych w sprzęt gaśniczy wodno-gazowy itd.), gaszenie impulsowymi urządzeniami gaśniczymi (PPP-200, Impuls-Sztorm, Fire Commander itd.), zastosowanie substancji wybuchowych do przerwania i gaszenia płonącego strumienia gazu, metody nieuwzględniające kierowania środka gaśniczego na strefę spalania (użycie głowicy przeciwybuchowej (prewentera) i wiercenie pod kątem) oraz jednocześnie użycie kilku metod. Dla każdej z grup przeprowadzono szczegółową analizę wykorzystywanych metod gaśniczych, opisano ich charakterystyki, mechanizmy powstrzymywania palenia podczas ich zastosowywania w warunkach oddziaływania strumienia gazu. Określono ich główne wady i zalety.

Wnioski: Na podstawie przerodzonej analizy autorzy określili kierunki rozwoju metod gaszenia pożarów przy wyciekach gazu: zwiększenie skutecznego zasięgu gaśniczego, zmniejszenie zużycia środka gaśniczego, zwiększenie ochrony ludzi przed oddziaływaniem niebezpiecznych czynników pożarowych, zmniejszenie szkód ekologicznych w środowisku naturalnym. Określono, że najbardziej perspektywiczną metodą gaszenia pożarów w przemyśle gazowym jest zastosowanie impulsowego dozowania środków gaśniczych na strumień wyciekającego gazu.

Słowa kluczowe: wyciek gazu, gaszenie pożaru, dozowanie impulsowe, działko pożarowe, sposób gaszenia

Typ artykułu: artykuł przeglądowy

1. Introduction

Open blowouts, which manifest an uncontrollable release of stored fluids, cause considerable economic and ecological damage to the environment, sometimes taking the character of natural disasters. At different distances from the flowing wells one may find gas springs. These receive accumulations of gas in low areas, which pose a threat from explosion and fire.

Open blowouts can be categorized according to their power level [1]:

- small-scale with gas output of less than 0,5 M m³ per day and oil output of less than 100 t per day;
- medium-scale with gas output of 0,5-1,0 M m³ per day and oil output 100-300 t per day;
- powerful with gas output of 1,0-10,0 M m³ per day and oil output 300-1000 t per day;
- high-power with gas output more than 10 M m³ per day and oil output more than 1000 t per day.

Practice shows that the frequency of accidents for “gas shows” and blowouts is on average 0.12 cases per 100 wells [2].

Gas blowout fires are complex man-made emergencies and elimination of such fires is associated with significant financial costs, and need to deploy large number of firefighting equipment and staff.

The purpose of this article is to analyze approaches for extinguishing gas blowout fires across the world, to determi-

ne strengths and weaknesses of each approach, and identify areas for improvement.

2. Methods

This article deals with the theoretical level of scientific knowledge by applying analysis and synthesis, which allows for maximum research coverage of the topic.

In writing the article, the following sources of information were accessed: publications and periodicals from different countries, workshop, symposium and scientific conference materials, public information from the internet and patent databases from various countries, for example: www.fips.ru, www.uipv.org, www.epo.org, www.wipo.int etc. Additionally, the authors applied personal experience, and other practitioners knowledge of extinguishing gas blowout fires.

3. Analysis of existing extinguishing methods

Over time, many different approaches and techniques were developed to extinguish gas blowout fires. The range of approaches is, on the one hand, attributable to variability and exceptional technical complexity associated with individual incidents and, on the other hand, the limited effectiveness of fire fighting methods used to date.

Given the current development stage of solutions and means of suppressing escaping gas, different approaches can be

grouped as follows:

1. Firefighting with a continuous delivery of an extinguishing agent by means of a jet flow.
2. Impulse fire dousing with the use of different extinguishing agents.
3. Use of explosives to depress and extinguish burning flames.
4. Mechanical methods, without the delivery of an extinguishing agent into the combustion zone.
5. Combination of aforementioned approaches.

These groupings should not be regarded as a classification of fire suppression methods since each group includes a number of processes and the span is too broad.

3.1. Extinguishing with the continuous delivery of an extinguishing agent by means of a jet flow

This is perhaps the most common approach of extinguishing gas blowout fires.

The easiest way of implementing this approach is to bombard a fire with a continuous stream of water from fire nozzles [3-11]. In the majority of cases [3-7], this method supplies a jet of water from a nozzle at speeds of up to 50 m/s. Such jets are directed to the base of the blowout at the wellhead. Then, simultaneous application of water jets along the combustible pillar supporting the flame completes the separation of fire from the combustible source (see fig. 1). Monitors are used for extinguishing small gas, gas condensate and oil blowout fires. Such monitors should be located at a distance of 15 metres from the fire [6-7]. Hence, under conditions of strong thermal radiation, associated with large eruptions, the use of such equipment is not possible. In addition, this method requires good skilled fireman and synchronization of their actions.

Established methods [8-9], in which stationary nozzles are mounted at the wellheads and inclined in a coaxial direction to the flow of oil and gas is presented in fig. 1. In such situations, water is supplied directly to the combustible mixture area and this increases extinguishing efficiency. The disadvantage of this method is the need to install nozzles at each well and lay suitably protected hoses for the water supply in the most economic way. Other approaches combine water jets with dry powder [12], which affords an opportunity to mix flame retardant additives.

In some countries a range of wheeled and tracked vehicles are used with an armoured chassis, incorporating fixed monitors of different capacities: GPM-54 GPM-54m, GPM-64 (USSR, Ukraine), SPOT-55 (Czech Republic, Slovakia), fire appliance based Nona-SVK (Russia), Chinese fire tank [7, 10, 13-15]. These are illustrated in fig. 2. Their main advantage lies in the protection of personnel afforded by armour. This facilitates firefighting operations in forests and dealing with fire incidents at ammunition depots. The disadvantage of such vehicles lies with their limited carrying capacity of extinguishing agents. Therefore, in practice they cannot be used for major incidents involving crude oil and gas blowout fires.

A common and effective way of extinguishing a gas blowout fire is to use a special technique that allows continuous delivery of a gas and water mixture, at high speed, into the combustion area. Depending on version, these vehicles can perform the function of an appliance; AGVT 100 and AGVT-150 (USSR, CIS), a tank "The Big Wind" (Hungary) and JFR-250 (Ukraine) or track propelled by steam; PSUGVT-200 (Ukraine) (see fig. 3) [6-7], [10], [17-21]. A gas/water jet is produced by this equipment, made up from a mixture of turbo-jet engine exhaust gas and water. The gas-jet vehicle discharges a mixture of about 60% water and 40% gas from its total mass at the nozzle outlet, where the concentration of oxygen is not more than 14%. As the distance from the nozzle increases so does the oxygen content. At a distance of 12-15 metres it is 17-18%. Water is partially vaporised on contact with a stream of incandescent gas and enters the combustion zone in the form of tiny drops. During experiments it was found that the jet mixture of gas and water has a high cooling effect. For example when applying water at 60 litres per second (AGVT-100) for 5 minutes, the wellhead temperature decreases from 950°C to 100-150°C.

The main disadvantages of using gas/water jet vehicles for extinguishing fires is their limited range of effectiveness - not more than 15 metres, and the high costs of extinguishing agent used.

Another illustration of a continuous jet delivery of an extinguishing agent to the combustion zone involves the use of powder. The powder extinguishing vehicle is capable of feeding fire-extinguishing powder at a rate of 50 kg per second from a distance of 50 metres [7], [22-23]. However, this method is not widely used because of high costs and risks of large contamination of the environment (see fig. 4).

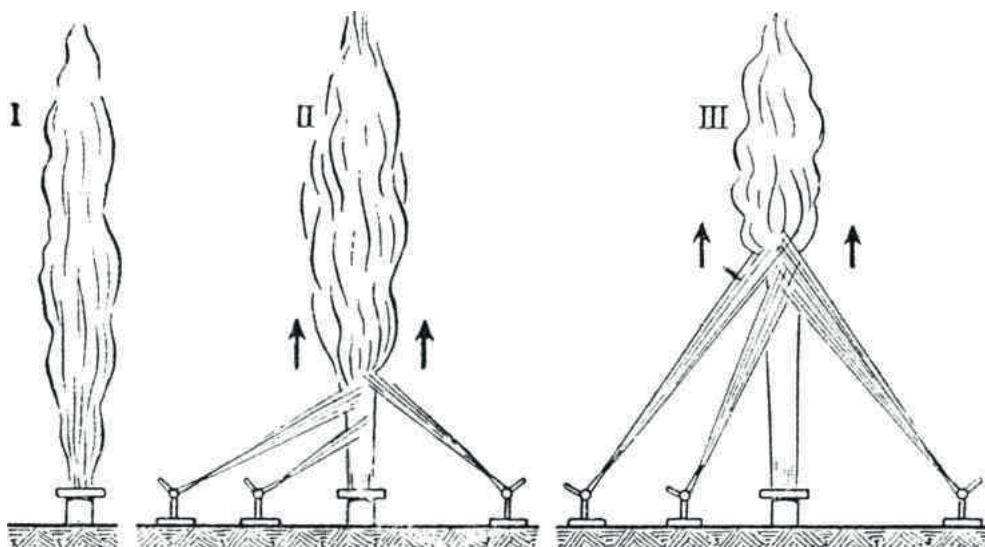


Fig. 1. Extinguishing a gas blowout fire using water jets: I – blowout flame; II – directed jets of water to the base of flame above combustion area; III – synchronous lifting of the water jets up the combustible pillar eventually separates the flame from the combustion area [6]



Fig. 2. Some examples of appliances with fixed monitors [13]



Fig. 3. Gas/water jet extinguishing vehicles [17], [18], [21]



Fig. 4. Extinguishing of gas blowout fire by using a powder jet
Source: Own elaboration.

There are known developments of an approach [24-25] based on a bombardment of the combustion zone with inert gases, within certain parameters relating to gas volume and speed of delivery. However, in practice, this approach is very seldom used.

3.2. Extinguishing of fires by using impulse extinguishing systems

Impulse delivery of an extinguishing agent into a combustion area provides the most promising line of development for a range of firefighting conditions, in particular, oil and gas blowout fires. The advantages of an impulse extinguishing approach are: improved extinguishing efficiency caused by an increase of flow dispersion, increase in the range for the extinguishing agent and increased mobility of extinguishing systems.

An effective way of extinguishing a gas blowout fire entails the use of an impulse discharge system, which can deliver ex-

tinguishing powder at different charge settings [7], [26-30]. The fire is extinguished as a result of an inhibitory effect on the flame caused by the extinguishing powder, released under the influence of compressed air energy or gunpowder charge. The ejection unit aims a volley of powder concentration at the combustion area in short blasts of 1-2 pulses.

Ukraine has developed and actively uses a transportable pneumatic powder gun SPT-200, which can discharge 200 kg of extinguishing powder per blast (see fig. 5) [7], [26]. In practice the Firefighter SPT-200 performed well with extinguishing gas blowout fires of different capacities. However, unresolved problems exist with short-range effectiveness, up to 20 metres, and the negative impact of fire extinguishing powder of all types on the skin, respiratory and central nervous system, as well as contamination of the environment. Additionally, one blast will discharge a large volume of fire extinguishing powder with a commensurate impact on costs.

Known developments [27-28] activate permanently installed equipment automatically in the event of a fire by thermal imaging or infrared emitters. The disadvantage of these systems is associated with the need for a permanent installation and organization of work for each well, which leads to large material costs.

Ukraine has constructed a powerful impulse sprinkler installation Impulse-1, pulse 2, pulse-3M, as well as pulse-storm (see fig. 6) [13], [29-30] and these are mounted on a tank vehicle chassis. The vehicles have 50 barrels (Impulse 1 has 40), each of which is charged with up to 30 kg of powder. Impulse-Storm is able to deliver 1.5 tons of fire extinguishing powder



Fig. 5. Pneumatic powder gun SPT-200 before discharge
Source: Own elaboration.



Fig. 6. Setting the extinguishing pulse "Impulse-Storm"
Source: <http://shushpanzer-ru.livejournal.com/1433550.html?thread=28162254>



Fig. 7. Fire Commander [13]

to the base of a fire in 4 seconds. This provides an immediate, simultaneous and powerful dousing force in terms of volume across the entire affected area. The main difference for this installation is the powerful dousing impact in conjunction with the effect produced by a special powder formulation. The effective discharge range is up to 50 m.

The main disadvantage of Impulse equipment is the harmful negative impact that extinguishing powder has on the human body and the environment, design complexity, high cost, the need for a large number of rounds to hit the flame and the high volume of fire extinguishing powder used (300-1500 kg per round).

The safest extinguishing agent, in terms of impact on humans and the environment, is water. Its use for extinguishing gas blowout fires is facilitated by an impulse supply system. The impulse fire extinguishing system iFEX can be installed on the chassis of the SUV helicopter or Leopard 1 tank [13], [31-34]. The most impressive of these is the Fire Commander appliance (fig. 7). This vehicle is capable of discharging 25 litres of water at a distance of up to 65 metres in 6-7 pulse emissions within 1 minute. To ensure continuous water supply, the vehicle is equipped with a pump unit. Although, at present, the authors did not have the test results for this appliance, it is believed that its operational potential is strong. However, the reliability of the Fire Commander's complex systems is yet to be verified in an operational environment involving high temperatures and air pollution.

The use of high speed impulsed liquid jets, delivered to the blowout ignition area [7], [36] reveals a new and promising approach to dousing gas blowout fires.

Application of this method reduces the cost of firefighting and can significantly increase the range of effectiveness. However, to date, the development of this method is undergoing experimental investigation.

3.3. The use of explosives to disrupt and extinguish a burning torch

Extinguishing gas blowout fires by means of an explosive charge detonation was one of the earlier approaches in dealing with such fires and is sometimes used in the present day [6-7], [10], [36-39].

An explosive charge is applied to the wellhead or located along a steel cable spanning blocks suspended on special supports. The charge can also be mounted on a trolley with a jib and moved along rail tracks placed by the mouth of the well (see fig. 8). The main disadvantages of this approach are; the high risk and need for large amounts of explosive (100-1000 kg). Explosives generate strong shock waves. A safe operator distance for

a 100kg discharge of explosive is more than 150 metres, whereas a wellhead is destroyed at a distance of less than 40 metres.

Another known dousing technique involves a circular distribution of explosive charges at the wellhead. Containers with extinguishing powder are placed on top of explosives [38-39]. After detonation the dry chemical penetrates the ignition ring of the blowout area with a consequential inhibitory impact. This approach requires a smaller volume of explosives compared with the previously described technique. The reduction can be at the rate of 1 kg of explosive per 100 kg of extinguishing powder. However, to use this approach, one must perform a tremendous amount of difficult and dangerous preparatory work, which is not always possible in given circumstances.

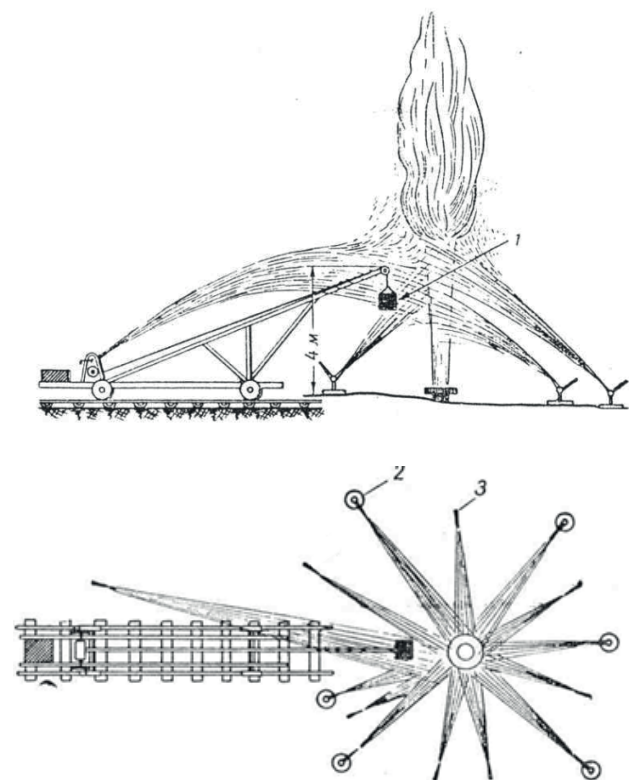


Fig. 8. Extinguishing a gas blowout fire with the aid of an explosive charge: 1 - explosive charge; 2 - master stream nozzle; 3 - manual nozzle [7]

3.4. Extinguishing without the delivery of an extinguishing agent into the combustion area

Metal caps, of various designs, or concrete slabs can be used to extinguish gas blowout fires, by bearing down on the “mouth” of the flame [7], [40-47]. This stops the supply of oxidants into the reaction zone and combustion ceases. However, these methods are rarely used due to their low efficiency and complexity.

In the far north, at below zero temperature levels and in presence of strong winds, this approach is sometimes used to eliminate open gas blowouts in the flame of a fire, that is, without its prior suppression [6-7], [48]. This approach may be necessary because after dousing a blowout flame, flammable substances may still exist near the well mouth for a period of time. As a rule, it is necessary to use different blowout preventers (BOP) such as: rope, hydraulic and articulated. After the installation of such devices and with the help of well seal valves, the emission of gas is curtailed (see fig. 9).

To quench a powerful blowout fire there may be a need to drill one or a series of relief wells in proximity of the main well [6-7], [10], [38]. After additional wells are connected to the main well the pressure and flow rate of gas in the main well will significantly decrease. The fire could then be starved of fuel with the use of BOP or extinguished by any other method described previously.

3.5. Combining techniques

The use of one of above mentioned techniques or methods, in isolation, is unlikely to effectively halt the burning process. Therefore, an approach most commonly used to extinguish and eliminate a gas blowout fire [6-7], [38] entails

the simultaneous utilisation of several methods such as: fire nozzles in conjunction with exhaust gas/water mix dousing, the SPT-200 in conjunction with the jet stream and so on.

4. Conclusions

The authors' analysis identified a variety of ways to extinguish gas blowout fires. The exposure of such a range is attributable to the complexity of such fires.

It is characteristic that to extinguish a small and medium-sized oil and gas blowout fire successfully it may be necessary to use most of the above described techniques. Bigger and more powerful gas blowouts require more complex approaches. Typically, complex fires may require the application of several extinguishing approaches simultaneously. However, work on the elimination of a powerful gas blowout fire can last a week or more.

Given the above analysis, it is possible to identify the main focus for future development of techniques to deal with gas blowout fires:

1. Increase in the effective extinguishing range.
2. Decrease in the flow of extinguishing agents.
3. Enhance the protection of personnel from exposure to fire hazards.
4. Reduce the damage to the environment.

Taking into account articulated areas for development, the most promising method for extinguishing oil and gas industry fires lies in the deployment of fire extinguishing agents by impulses. Simultaneously, maximum firefighting efficiency is achieved when an extinguishing agent is delivered to the combustible mixture area, namely to the ignition ring of the oil/ gas blowout.



Fig. 9. Installing the BOP
Source: Own elaboration.

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