DEVICES TO BEAT OUT THE FLAMES OF ROCKET PROPULSIVE JETS AT SPACESHIP STARTING

[1]Zakhmatov V.D., [2,3]Silnikov M.V., [2,3]Chernyshov M.V.

[1]P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, e-mail: zet.pulse@gmail.com;
[2]Peter the Great Saint-Petersburg Polytechnic University, Saint-Petersburg;
[3]Special Materials, Corp., Saint Petersburg

New generation of automatic fire-extinguishing systems to beat out the flames at the spaceship launch area is proposed. The modernization consists in supplementary equipping of the existing fire-extinguishing automatic systems used at the launch ground by the multi-barrel modules (MMs) with volley dispersion of the extinguishing media. The parallel executive system consisting of several MMs situated around the launch area at the distances form 50 to 200 m can be also created. This modernization of fire-extinguishing systems can protect the launch complex structures from the high-power rocket engine flame jets quickly, effectively and fully. It can also provide the effective light radiation and heat protection and prolong the life duration of the expensive start facilities. The correctness of the proposed project is confirmed by the results of the last successful tests of the modern MBMs ensemble situated around the goal in semi-circular order which concentrated their volleys on the alone local but powerful flame.

Keywords: Spaceship, Starting, Propulsive Jets, Rocket, automatic fire-extinguishing systems

Actuality of the Topic

The analysis of the rocket launch area fire protection practice during the last several dozens years have shown the low effectiveness of the high-power water supply systems (with water supply rate from 330 up to 500 liters per second) designed to beat out the flames of the launch rocket engines. It was quite convincing at the series of rocket launches in USA (Cape Canaveral) when the executive systems provided the real waterfalls but could not protect the launch facilities satisfactorily and in time [1, 2]. Up-to-date water monitors (water supply cannons) can not provide enough water in very small time duration due to their high complexity, the large time lag from the initial signal to water emission, and also due to their low reliability at the extreme work regimes. The monitors require dozens seconds from the initial signal to the maximum water supply regime beginning [3, 4]. It means that the water emission to the rocket launch complex should begin in the minute before rocket start, and it can not be admitted. In rocket launch reality, water emission should begin only just after the rocket separation from the ground. As an alternative, it can be accepted that the monitors sprinkle the water to some other side before the rocket separation, and turn to the launch facilities only after it. But the strong water cannon turns around not more quickly than the tank turret (really, in 20–30 seconds). The launch facilities undergo the powerful flame heating during this time, and their posterior cooling is not effective, even from their integrity point of view. The most intensive and destructive flame heat action corresponds to time lag from 10 to 30 seconds after the rocket separation.

The above-mentioned lacks of the executive hydraulic systems, such as sprinklers, drenchers, and hydro-monitors, were known in 1980s yet [5–7]. It was a reason why the Soviet ministries respondent for fuel and energy as well as the Ministry of Defense financed in 1982–1991 (till the USSR collapse) the research works aimed to design principally new fire-extinguishing executive subsystems. These subsystems were both stationary impulse facilities directed to the fire source and mobile systems based on trailers and gun carriages. The impulse MM systems provided the volley dispersions of the various fire-extinguishing media (different liquids, gels, powders, dust, or sand). Combined fire extinguishing easily controlled on type, scale and power of action, minimum extinguishing media expense less harmful to buildings and equipment, high distance and precision of action on any areas, system compactness and absence of pumps, pipelines and tanks for extinguishing media, and safety for personnel were their important advantages.

The armored track-type fire service machines “Impulse-3M” with 50-barrelled turret MMs based on T-62 Soviet tank chassis worked successfully in Ukrainian (6 machines) and Russian (up to 10 machines) fire units till nowadays. They are used primarily at nuclear power plants, in chemical, oil and gas industry. Their application to ammunition storages and rocket launch areas is also recommended.

But, in spite of numerous designers’ letters and papers in special journals, the development of impulse fire-extinguishing systems were never supported neither in Russia nor in Ukraine. New wave of interest to this research arose in last several years due to industrial accident, terrorist attacks, and forest fire scale and quantity growth. Some number of the industrial projects is being realized now in China, the Czech Republic, Estonia and Finland under Prof. V.D. Zakhmatov's scientific supervision. Financial support and work intensity are especially high in China, and it allowed us in the last two years to reach new results discussed in the final part of this paper.

The Modern State in Extinguishing Media Supply Systems

The experience of the series of the industrial accidents in peace time has shown that the effectiveness of some up-to-date fire systems (even the best American and European models) is not satisfactory. The gun-carriage fire barrels with 70–330 liters per second (lps) water (or low-expansion foam) supply rate and hydromonitors with water supply rate up to 400 lps seems to be most effective and vigorous nowadays. They are expensive, sophisticated, difficult in everyday service, and require the long time for their installation and work beginning.

The tragic death of more than 20 firemen and 4 fire cars covered by burning oil splash at oil storage fire in Vasilkov (Kiev region, Ukraine, 2015) demonstrated the necessity of fire extinguishing of all dangerous objects from the maximum distances. Up to our experience, the eruptions of dozens tons of burning oil and oil products to the distance up to 300–500 meters from the reservoir with the formation of large burning "lakes" are known. The requirements to the fire-extinguishing systems in large-scale oil fires (quick, safe and precise beating the flame out at the given limited area with its following cooling) are some analogous to the requirements in the case of rocket launch.

The impulse fire-extinguishing systems combine the uniform blow by the continuous dense wave front beating the flame out and fire-directed water dispersion. Its effectiveness depends on such factors as:

– operability of its action on the fire flashpoint;

– sufficient concentration of the fire area irrigation by water or low-expansion foam which also can be delivered on relatively large distances (low-expansion foam range distance is approximately 10% less than water jet one [1]).

To improve these factors, most modern and powerful gun-carriage barrels are used to extinguish the fire on dangerous industrial objects [2, 3]. The theory of high-velocity jet flows confirms [] that such facilities provide us the maximum range of jet flow flight which allows the firemen to be situated at relatively safe distance from the flame vortex front [1, 4]. But even the most modern specimens of gun-carriage barrels with water supply rate equal to 70, 100 and 150 lps provide the maximum range distance up to 110 meters. It is evidently insufficient for personnel safety at flame extinguishing.

Another unsolved problem is the control of high dynamic pressure jet irrigation square. When we enlarge supply rate and range distance, we inevitably widen the irrigation square, even in windless weather. Multiple expensive attempts of barrel modernization and surface strength factor enlargement due to fluid viscosity growth have no positive results up now. Even at the windless weather, at liquid supply rate equal to 100–150 lps, the dispersion of liquid droplets is more than 100–200 meters, instead of the optimal distance equal approximately to 40–60 meters. Wind changes the irrigation area configuration crucially and shifts the liquid droplets up to 1 kilometer. As a result, only minor part of the dispersed water or low-expansion foam really hits the reservoir of fuel or the rocket launch burning facilities.

As a result of low fire-extinguishing system effectiveness, the firemen can work up to several hours in dangerous and harmful (due to solid of liquid rocket propellants, for example) under the menace of sudden fire front attack. So the manufacturers of the fire equipment waste a lot of their means to enlarge the range distance and to diminish the area of the distance irrigation. To solve these problems means to provide the safe extinguishing of the burning reservoirs at the small time till the beginning of dangerous pollutions or contemporarily with the rocket separation, to provide the thermal protection of the launch facilities and to save it for the future starts with minimal repairs.

We also should remark that even the most powerful systems of launch facilities cooling are not able to extinguish the large-scale fires and to deactivate the pollution of the toxic rocket propellant. This is crucially important, because it is typical situation at the rocket collapse at its start, and also when the parts of rocket and its fuel reservoirs drop, explode and burn in dozens seconds after the start at the space launching site territory.

The fire safety cars are applied to this goal traditionally. Their work is based of the release of hundreds tons of water and the sedimentation of the poisonous clouds by dispersed jets. The electronics of such systems is well-developed and unified in different countries. But the mechanics of their executive devices consisting of the pipelines, high-pressure tanks, large and heavy reservoirs and powerful pumps is very complicated and slow.

To avoid these important problems in long-distance fire-extinguishing mechanics, we propose to equip the automatic quenching systems by cheap, easily and quickly installed executive system consisting of MBMs with volley dispersion of fire-extinguishing, heat-protecting, pollution-localizing media.

History of Impulse Fire-Extinguishing System Applications

Multi-barrel modules (MMs) were designed from the beginning of 1980s, at first as the authors' initiative, and as a part of the Soviet state military and industrial programs after it. Those were MMs which dispersed water by its shot or volley mounted at two-axis gun carriages or at sledge runners. They were produces in a large number and tested successfully at filed as well as at real fires in industry. The first 4-barrelled module (MM-4) was designed and tested under V.D. Zakhmatov's scientific guidance in the Moscow High Engineering and Technical School of the Soviet Interior Ministry in 1982. Since 1983, the 9-barrelled modules (MM-9) based on nine wagons began to be manufactured in Sverdlovsk (now – Yekaterinburg, Russia) at the Urals Staff of Mine-Rescue Works enterprise. They were widely used at the mines of the Soviet Non-Ferrous Metallurgy Ministry afterwards.

New MM (MM-8) was demonstrated at the Soviet Civil Defense test field in Koncha-Zaspa (near Kiev) in September, 1984 at the All-Soviet Maneuvers of the Civil Defense. The burning stack of wood was successfully extinguished from the distance of 50 meters during 2 seconds. This MM-8 module was designed under V.D. Zakhmatov's supervision in the repair shop of Kiev civil defense regiment. The full volley of its 8 barrels dispersed 120 kg of fire-extinguishing powder and created the gas-particle vortex with effective range up to 60 meters. As the vortex spreading, it widened its front from 1 to 8 m in width and from 0,5 to 3 m in height. The effective area of fire extinguished reached 350 square meters and was shaped as oblong drop longitudinal cross-section.

At that time and until nowadays, the pneumatic one-barrel impulse dispersion system elaborated by Prof. I.M. Abduragimov and Dr. V.A. Makarov (Moscow High Engineering and Technical School of the Soviet Interior Ministry []) was the only rival of the mentioned MMs at Soviet and post-Soviet territories. It pulverizes up to 200 kg of the fire-extinguishing powder to the distance not more than 15–20 meters. So it can extinguish a fire of the low-pressure gas fountains from the distance up to 10 meters. One-barreled systems are also inconvenient, because their recoil is larger than the recoil of the multi-barrel systems of the same media supply rate and jet velocity (up to 20–35% in the above-mentioned case, for example).

Up to 40 MMs (MM-9, MM-16) were manufactured at the pilot plants of the Soviet Academy of Sciences in May-July, 1986. They were actively applied in the zone of the Chernobyl catastrophe (near Kiev, 1986) to defend the transformer stations and to extinguish some parts of the 3rd and the 4th units of the Chernobyl nuclear power plant which suffered much of blast and radiation. MM-8, MM-9 and MM-25 were successfully applied to quench the fire of 14 gas and oil wells at Neftyanye Kamni ("Oil Stones" at Caspian Sea, now in Azerbaidzhan). These MMs were mounted at the wide deck of torpedo boat and, after it, at the high deck of Finnish floating crane. They were arrayed and directed in such manner for the vortices formed by the neighbor MMs were to meet at the 80-100 m distance. It allowed us to reach the maximum effectiveness to beat out the turbulent integral fountain torch from the relatively safe distance. A volley of 40 barrels created a mighty tornado with the front width up to 20 meters, front height up to 5 meters. After the flame beating out, oil workers were landed to the oil platform deck to block the well without risk of the secondary inflammation. MMs acted simultaneously with the fire safety ships of the Caspian and Volga flotilla, but they sufficiently excelled the fire ship in the range and scale of the fire-extinguishing tornado. At the same industrial accident, our MMs were effectively used to localize the oil pollution producing the large-scale dispersion of the oil sorbates (granulated turf) onto the oil film.

High-power and long-distance 9-barrelled MM based on two-axis gun carriage diffuses up to 180 kg of fire-extinguishing media on the range up to 90 meters by the area square up to 500 square meters at its only volley from all its barrels. More powerful systems were designed some later, for example, 25-barrelled MM which disperses 120–135 kg of useful media on the distance up to 60–70 meters by each its volley from 8–9 active barrels. Its fire-extinguishing area reaches 350–400 square meters by alone volley, 1200 square meters at volleys with long intervals between them, and up to 2500 square meters when the intervals between volleys are equal to 3–5 seconds. 30-barrelled recoilless MM with 152 mm barrel caliber (the barrels are optionally removable) which disperses 75–90 kg of the extinguishing media by each volley from 5–6 barrels on 40–45 m distance and quenches 150–200 square meters area by each volley was also designed and tested.

New construction of the stationary MM to be mounted on the two-axis gun carriage which includes the hermetic containers for liquids and gels was designed in 2013–2014. Hermetic containers for the working media are firm enough for their transportation, reload and charge, but, at the same time, they can be easily destroyed by the propelling wave of gunpowder gases into small and light pieces which are not dangerous and fly out not more than to 10 meters. The dispersing charges are manufactured in most convenient and safe for personnel modification. The metal cartridges with electric capsule bushing were manufactured in China industrially. The last stage of the field tests was conducted in 2014–2015 and revealed the high possibilities of the modified MM-9, MM-20 and MM-30 modules. They extinguished the strong standard fire source in 1 second from 100 m distance. The vortex of the working media spreads more than to 200 meters, and the subjected area square was up to 1000–1200 square meters at the every volley of 200 kg of the useful media from 10 barrels.

The most completed multi-barreled system, MM-50 based on T-62 Soviet tank chassis, is known at fire safety car "Impulse-3M". It is used in Ukraine (7 systems) and in Russia (12 systems) from 1992 till nowadays. "Impulse-3M" can be used at the temperature range from –50 to +50 °C. This fact makes it applicable in different weather conditions, from cold Russian North, Siberia and Far East cosmodromes ("Plesetsk", "Baykonur", "Vostochny") to the tropical launch areas (Florida, French Guiana). One volley produced from 10 barrels disperses 250 kg of the fire-extinguishing powder up to 110 meters. A series of 5 volleys covers the area up to 3000 square meters without barrel recharge. We do not know the analogous systems applicable for fire extinguishing in toxic, blast-dangerous or radioactive surroundings where the quickness and accuracy of volley, as well as the armor protection for personnel are very important. A wide range of the ecologically pure natural materials (soil, sand, dirt, dust) can be used as the working media. Due to above-mentioned advantages, this machine can be effectively applied to launch complex cooling, as well as for the suppression of any accidents at the launch area, including rocket destruction at the beginning of the trajectory or immediately at start. "Impulse-3M" is armored; it has also light and heat radiation protection systems, and can be used as bulldozer to operate inside construction debris.

"Impulse-3M" MMs are used now at the chemical industry enterprises ("Azot" factory in Cherkassy, Ukraine), in radioactive areas (Chernobyl, Ukraine) and nuclear power plants (Balakovo, Russia), as well as in oil and gas industry (specialized unit for the suppression of gas and oil fountains, Poltava, Ukraine; fuel enterprises "Gnezdinsky" (Chernigov region, Ukraine), in Syzran (Samara region, Russia), and in Bashkortostan, Russia), and also in mining industry (Norilsk, Russia). It seems possible to apply the "Impulse-3M" MMs to rocket launch sites, but it should be more effective to modify its construction using special containers and dispersing charges of original design that are manufactured in China now. The universal containers are at the first time fit for almost every working media, such as liquids, gels, powders, and other natural materials which can be found at the place of accident and can be applicable for fire extinguishing, localization and deactivation of harmful pollutions. For example, microbiological remedies and alive microorganisms can be used for biological destruction of oil and rocket propellant pollutions, their ecological screening and soil re-cultivation.

Special Multi-Barreled Modules to be Mounted Around the Rocket Launch Site

Special MM ("MM-laf") can be designed as stationary one or based on gun carriage or on trailer. Its prototypes based on two-axis gun carriages were consisted of 7–10 or 25 barrels and applied to fire extinguishing in Chernobyl area, coal and ore mines, burning airplane at the runway, etc. The recoil of this MM does not exceed 1–3 meters at the volley from 9 barrels.

"MM-laf" system does not require the special maintenance works except of the initiation electric chain checking by small-amperage electric impulse. As a measure of supplementary safety control, 1 or 2 barrels can be changed every year.

Fig. 1. Field tests of the joint concentrated action of various improved MMs (MM-9, MM-20, MM-30) in China (December, 2014)

If the system is properly charged, and containers with useful media and the pulverizing cartridges are assembled qualitatively, "MM-laf" is reliable even when this system stands 5 years without practice. Containers with fire-extinguishing media can, after all improvements, reach reliable workability after 15 years storage. "MM-laf" also can be situated around the dangerous area very quickly, and this is an important advantage of those systems in emergencies.

Very convincing ground tests on multiple protection of the fire-dangerous area by different MMs were conducted in China in December, 2014. Three improved MMs participated in testing: MM-20 made the first volley from 100 m distance, MM-30 made the second one from 120 m, and MM-9 made the third volley from 85 meters. Model of the standard fire hotbed was extinguished by the very first volley; two other volleys demonstrated the reliable workability of the system and its multiple usages only. It was demonstrated also that the fire suppression with several MMs can be combined due to programmed dispersion of different working media from the various distances with different time intervals.

For any facility to be protected, the principles of flame spreading can be studied depending on a number of factors (technologies and regimes of its applications, possibilities to switch off the power cables and fuel pipelines, the special features of the separate apparatus and venting, etc.). When the fire appearance and spreading is studied, it helps to determine the optimal fire-fighting tactics. Speaking about MMs, it is an order of volleys produced by groups of MMs and separate MMs and time intervals between them. The effectiveness of MM assembly depends on easiness of their work program change and correction, if the conditions at the protected area are changed during the fire development. MMs can change their positions, order of volleys and number of barrels participating in each volley, and this makes the assembly work not only powerful, but also very flexible.

Fire sensors and other transducers can be applied at the same system with the MM complex. It can help the system to cope with the arsons and quickly-developing fires. So not only possibilities to apply different liquids, gels, powders and other media is this system advantage, but also the possibility of the flexible control on the basic impulse dispersion parameters, such as distance, scale and the shape of the moistened area. This type of control is achieved by the variation of the number of barrels, their mutual position in the same volley and in the different volleys, the control of time micro-intervals between volleys.

Special Features of MM physics

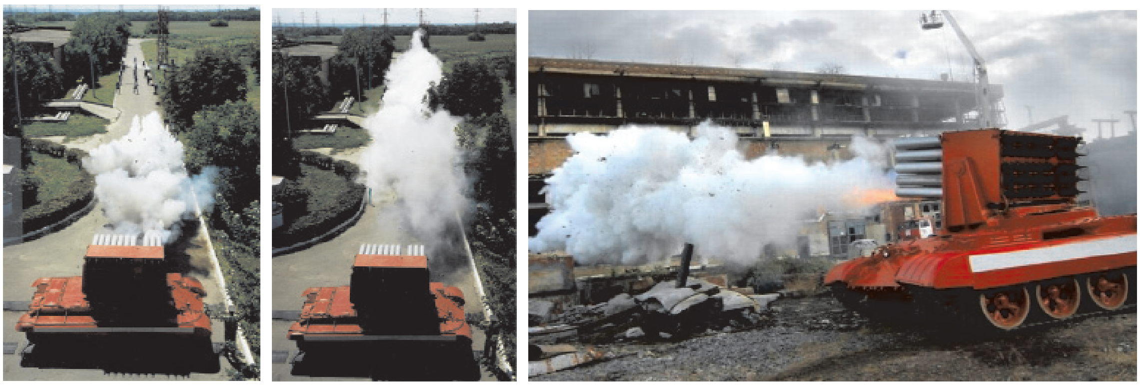
To provide the variety of working media, the dispersing system of MM is supplied with the universal containers filled by various liquids and mixtures. **The ability of MM to complex (or combined) action** can be characterized as its possibility to pulverize the working media of different state, density, dispersibility, viscosity, as well as its rate of fire. **MM action scale** is characterized by size (width and height) of disperse tornado front, and also by area square or volume which is subjected to the tornado of the required concentration and velocity. This scale characterizes the ability of impulse tornado to extinguish the hotbed of fire spread on any area, to protect some objects from the heat flux, to localize the cloud of the active aerosols, and even to neutralize a group of criminals at the given area.

The simultaneous volley from the multi-barreled system realizes its important advantage inherent only in gas – disperse media vortices. Tests confirm that they strengthen one another mutually at their confluence and interaction. Their interaction allows to enlarge the scales of the aggregate vortex action up to 1,5–2,5 times comparing with the arithmetic sum of separate vortices action areas. It is possible to heighten sufficiently the distance of effective total tornado action (up to 4–5 times comparing with the shot from the alone barrel): up to 53 m when the sorbates are working media, up to 120 m at volley dispersion from 10 barrels (20 kg of powder in each of them), up to 60 m at volley water dispersion from 8 barrels (10 liters of water in each). The uniformly moistened area square enlarges correspondingly: up to 450 square meters at sorbate volley from 5 barrels. It is 2–3 times more than the sum of the results of separate actions of the same 5 barrels.

Just for comparison, the volley action of military missiles and shells usually enlarges its subjected area square not more than in 1,5 times comparing with the arithmetic sum of the areas stricken by separate shots. Missile or shell flight distance does not enlarge at volley.

Fig. 2. "Impulse-3M" system with 50-barreled turret MM installed onto the armored chassis of T-62 tank. Each barrel contains up to 20–25 kg of the working mixture. The MM working distance is up to 120 m, the area covered by the only volley is up to 3500 square meters. This "Impulse-3M" can extinguish the gas well with reservoir pressure 140 atm and gas expence 1,2 million cubic meters per 24 hours at one second by the volley from its 10 barrels

Fig. 3. "Impulse-3M" extinguishes 2×200 square meters area where diesel oil burns by the only volley from its 10 barrels



a b c

Fig. 4. a – personnel protection from fire, heat radiation: maneuvers with evacuation of volunteers from zone surrounded by flame ring; b – impulse non-lethal influence on presumably terrorist group at guarded area; c – fire hotbed extinguishing in industrial area by artificial vortex through open gates, doors and windows

So we can surmise that the effectiveness of impulse MMs at its volley application can reach the effectiveness of the modern artillery but serves to the solution of the other problems actual in space industry and in our everyday life.

MMs create the gas-dust vortices with wide front surfaces or the gas-droplets tornados. At their interaction with the flame and burning surface, they realize several mechanisms of fire extinguishing. Space scales, uniformity, high power and combined action are the basic advantages of the impulse fire distinguishing which can reach the quick fire suppression at very small working media expenses (less than 1 liter per square meter). These expenses can not be reached by traditional methods: their typical numbers are 100–1000 liters per square meter when the specialized cars are used, 1–10 liters when the portative fire extinguishers are applied, and 5–50 liters per square meters if the automatic fire-extinguished systems (based on sprinklers, for example) are applied.

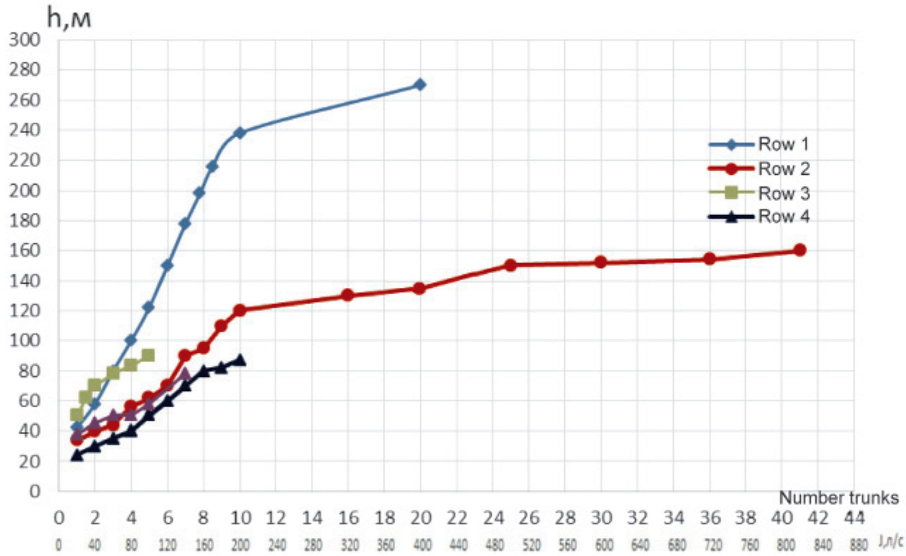


Fig. 5. Dependences of fire-extinguishing powders dispersion distance on the number of barrels at one volley:
curve 1 – volleys from the Chinese modified modules (up to 200 kg of the useful powder in one volley); curve 2 – volleys from 50-barreled “Impulse-3M” MMs;
3 – Chinese modified MMs, water dispersion; 4 – Ukrainian MMs working on water;
5 – German two-barreled modules “IFEX-20” (1–4 modules in each volley)

If the gas-powder vortex included special inhibitors, it impedes the burning of fuel because of its influence on fuel radicals. If the tornado consists of gas and water, smoke removal by shock, flame suppression, cooling and destruction of the burning surface are the basic processes. Since a number of volleys and barrels can be large, and their vortices can be concentrated at the same area, the energy applied to fire suppression, or to toxic pollution deactivation seems almost unlimited.

MM Applications Together with Fire Automatics

For potential fire suppression, MMs can be situated, for example, in protected buildings of nuclear power plant, or in enveloped areas of rocket launch site. As was demonstrated in Dun-Hua field tests (winter 2014–2015), it is easy and cheap to create doubled or trebled covering of the protected area by working media streams.

To diminish the probability of false alarm, the following ways can be used:

– to enlarge the stability of heat and fire sensors due to their optimal structure, their duplication, and introduction of the systems which differs the interference from real ignition;

– to apply the sensors that use the logical circuits which can confirm the authenticity of the ignition message;

– to centralize the stream of information on area and surrounding parameters.

High MM performance can compensate the time loss wasted on the analysis of sensor system.

Summary

The executive subsystems based of MMs and proposed here is principally new, safe, and universal. It has some qualitative advantages over other subsystems serving for the same goal in fire and rescue service:

– the consumption of the fire-extinguishing media is 10–100 times smaller. That allows the system to work autonomously, using only the working media storages inside MM barrels;

– type, power and scale of the action can be easily regulated, changed and controlled;

– type, power and scale of the action enlarge proportionally to the number of the devices and number of barrels in each device without loss in reliability and effectiveness;

– cost price of system manufacturing and service is very small (a large number of obsolete artillery barrels and tanks can change its destination to peaceful one);

– fire extinguishing can be ecologically pure and can help the civil population evacuation;

– high pressure volumes used in these systems are small in size and time of existence (only parts of the second), the firmness of the construction is 10 times higher than the stresses it is subjected to;

– the system construction is very simple and rather safe in application; gas cylinders, compressors and pumps are not required;

– the useful media dispersion is reliable and stable in the wide range of temperatures (from –50 to +50°C), winds, humidity, dust rates and other climate conditions;

– the secondary blasts of gas, steam, dust and air mixtures are prevented as a rule;

– the rocket fuel pollution onto the launch site area can be localized;

– maximum distance from the flame enlarges up to 10 times; this fact enlarges the safety of firefighting activity and allows the firemen to work from the distances safe in practice;

– there are no restrictions on the state of the firefighting media; we can use dirty, fresh or salty water, sand, dirt, dust and other liquids, gels and foams with various density and viscosity. These media can be found on-site; that allows the long-duration work of MM complex, if it is necessary, without exterior supply.

As a result, the fire-extinguishing systems based on MMs seems to be the best choice for fire safety of rocket launch sites and also for prolongation of launch facilities workability at their severe heating situations.

References

1. Garpinichenko A.M., Evtiushkin N.M., Kimstach I.F. Firefighting Tactics. Part II. – M.: Literature on Construction Publishing House, 1971. – 285 p.

2. Russian State Standard GOST 51115. Fire Engineering. Combined Fire Barrels for Gun Carriages. Technical Requirements and Test Methods.

3. Web-site http://WWW.Cleper.ru/normative-documents/etc/primenenie-stacionarnyh-pozharnyhlofetnyh-stvolov-ostcilliruishego-tipa.

4. Terebnev V.V., Podgrushny A.V. Firefighting Tactics. Basics of the Fire Extinguishing. – M., 2009. – 504 p.

5. Melkumov T.M., Melik-Pashaev N.I., Chistyakov P.G., Shiukov A.G. Rocket Engines. – M.: Mashinostroenie, 1976. – 399 p.

6. Kuznetsov N.P., Kurguzkin M.G., Nikolaev V.A. Utilization of the Rockets with Liquid Fuel Engines (on Example of the 8K14 Rocket). – M., Izhevsk: Regular and Chaotic Dynamics, 2004. – 288 p.

7. The Federal Law of the Russian Federation No. 123-FZ, July 22, 2008, “The Engineering Regulations of Fire Safety Requirements”.