RG SYSTEMS - WATER MIST SYSTEM

FM 5560

Annex D: **Protection of machinery spaces with volumes not exceeding 9175 ft^3 (260 m^3).**

Annex E: **Protection of special hazards machinery spaces with volumes not exceeding 9175 ft^3 (260 m^3).**

Annex F: **Protection of combustion turbines with volumes not exceeding 9175 ft^3 (260 m^3).**

RG W-FOG UAC - CYLINDERS SYSTEMS

DESIGN MANUAL

-CONSTANT & CONTROLLED FLOW TECHNOLOGY

DESIGN MANUAL INDEX

1 Introduction

The design criteria explained in this design manual are based on the requirements of the FM5560 *"Approval Standard for Water Mist Systems"*, FM Global Property Loss Prevention Data Sheet Number 4-2 *"Water Mist Systems"* and the NFPA 750 *"Standard on Water Mist Fire Protection Systems"*.

Users of this manual should be familiar with the requirements of these standards and any other relevant national legislation.

Note: Reference must be made to the RG W-FOG UAC - CYLINDERS SYSTEMS COMPONENTS MANUAL (FM_RG W_FOG Components Manual) for information on those components which are part of the FM Approval of this water mist system. Only those components included in the reference components manual are permitted for use in FM Approved systems.

Note: Reference must be made to the RG W-FOG UAC - CYLINDERS SYSTEMS INSTALLATION MANUAL (FM_RG W_FOG Installation Manual) for information on installing RG systems water mist systems.

Note: Reference must be made to the RG W-FOG UAC - CYLINDERS SYSTEMS MAINTENANCE MANUAL (FM_RG W_FOG Maintenance Manual) for information on the maintenance of RG systems water mist systems.

NOTE: **The fixed extinguishing systems manufactured by RG-SYSTEMS, containing WATER MIST extinguishing agent, are custom designed for a specific application. RG-SYSTEMS do not guarantee nor will be responsible for improper design, use or application of the product.**

Any non-approved use or application and/or any non-approved modification of the product or its operation may result in serious accidents and/or personal injury. RG-SYSTEMS are not responsible for any non-approved use or application.

2 General Information

The designer of the system must be familiar with the Water Mist System developed by RG-Systems and, also, with the latest version of the standard NFPA 750 “Standard on Water Mist Fire Protection Systems” and with all relevant national standards which could apply on each installation.

The Water Mist Systems of RG-Systems are designed taking in count the efficiency requirements of the objectives in the fire extinguishing systems. The objective of the Water Mist Nozzles is to scatter the water with small droplets, in the way that the distributions of these droplets are uniformly as possible.

The design and installation parameters of the system are based on the real fire testing done in Sintef - Norway, and described in the FM5560 (March 2009) “Approval Standard for Water Mist Systems”:

-Appendix D “Fire Test for Water Mist Systems for the Protection of Machinery Spaces with Volumes not Exceeding 9175ft3 (260 m3)”,

-Appendix E “Fire Test for Water Mist Systems for the Protection of Special Hazard Machinery Spaces with Volumes not Exceeding 9175ft3 (260 m3)” and

-Appendix F “Fire Test for Water Mist Systems for the Protection of Combustion Turbines with Volumes not Exceeding 9175ft3 (260 m3)”.

The objective of the Water Mist System is the protection of areas catalogued as risks described above (FM5560 - appendix D, E and F). For the protection of other types of spaces, please, contact RG-Systems.

The applications which are FM Approved for which the system can be designed include the following:

-Machinery Spaces with volumes not exceeding 4590 ft^3 (130 m^3), such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators and other similar machinery using fuel and/or lubrication fluids with volatilise less than or equal to heptane.

-Special Hazard Machinery Spaces with volumes not exceeding 4590 ft^3 (130 m^3), such as rooms with machinery such as internal combustion engines or other equipment using fuel and/or lubrication fluids with volatilise less than or equal to heptane and incidental use or storage of limited quantities of flammable liquids of not more than two (208 L) drums.

-Combustion Turbines with volumes not exceeding 4590 ft^3 (130 m^3).

-Machinery Spaces with volumes not exceeding 9175ft3 (260 m3), such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators and other similar machinery using fuel and/or lubrication fluids with volatilies less than or equal to heptane.

-Special Hazard Machinery Spaces with volumes not exceeding 9175ft3 (260 m3), such as rooms with machinery such as internal combustion engines or other equipment using fuel and/or lubrication fluids with volatilies less than or equal to heptane and incidental use or storage of limited quantities of flammable liquids of not more than two (208 L) drums.

-Combustion Turbines with volumes not exceeding 9175ft3 (260 m3).

The user of this manual should assure that the system designed will be used in the applications described in this manual, if there is any doubt the designer should contact RG-Systems.

3 Functioning Description

In these systems the piping network(s) have open nozzles where the pipe between them and the cylinder bank is empty. In this case, in the event of a fire the detectors will send an electrical signal to the fire control panel which triggers the following event protocol and which furthermore always includes at least setting off alarms:

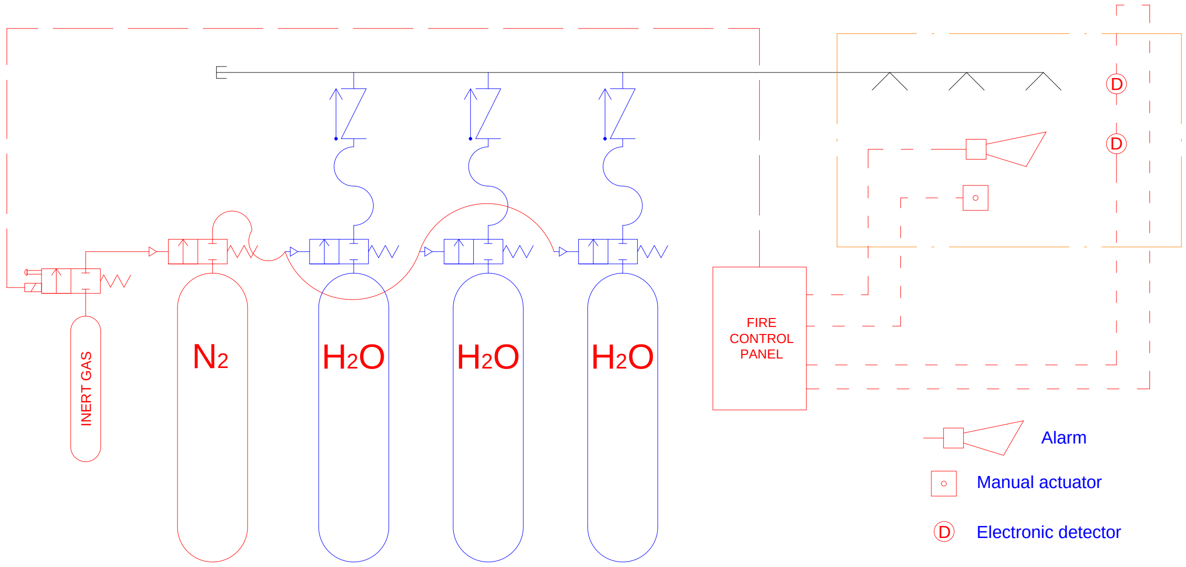

Figure 1.- P&iD: Flow Diagram of a Water Mist System.

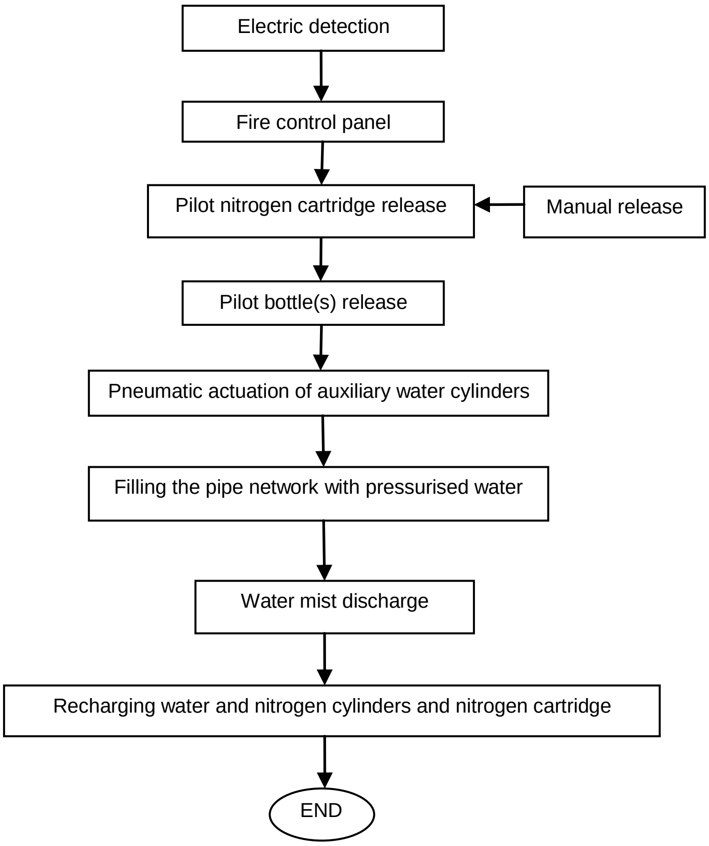

Figure 2.- Operation Sequence.

The operation of the system is as follows:

System in standby

1.- When the system is stationary, the cylinders containing nitrogen are pressurised with this gas at 2900 or 4350 psi (200 or 300 bar), while the cylinders containing water store the agent awaiting activation of the first ones and the subsequent pressurisation of water and its flow throughout the piping network.

System in operation

2.- *An electrical signal is sent to the trigger device or the system is turned on manually*: The 227SOLR or 227SOLCR electric discharge head, in the valve RGS-MAM-03 of the nitrogen cartridge attached to the container valve RGS-MAM-RD9/11 of the bank's pilot bottle, receives a 24 volt signal from the fire control panel that will lead to the opening of the RGS-MAM-RD9/11 valve wherever it is mounted. The triggering of the 227DM manual head will trigger the same sequence.

3.- *Activation through the nitrogen cartridge*: nitrogen will be released from the RGS-MAM-03 valve delivery port.

4.- *Actuation of the container valve RGS-MAM-RD9/11*: the nitrogen from the nitrogen cartridge produces the opening of the container valve RGS-MAM-RD9/11. This valve is a constant pressure and constant flow valve and the outlet pressure for this valve is the same as in the nitrogen cartridge. It allows get a controlled and constant outlet pressure.

5.- *Pressurisation of the agent*: nitrogen flowing through the network connecting the nitrogen and water cylinders pressurises water and thrusts it through the siphon tube and the RGS MAM-10 valves throughout the piping network.

6.- *Charging the pipe network*: the piping network is filled with pressurised water.

7.- Discharge of Water Mist: once the piping network is filled with pressurised water starts the water mist discharge. Thanks to the special design of this valve produces a constant pressure at the water mist nozzles. It is essential to send all cylinders and cartridge that make up the bank back to RG-SYSTEMS for recharging.

4 System Purpose

Water mist systems may have different purposes:

a) Fire control: Consists of limiting the growth and spread of a fire by cooling objects, adjacent gases and / or pre-dampening of adjacent combustible objects. Discharge time is long enough to allow manual fire-fighting to be carried out. This aim is similar to that of the traditional automatic sprinklers.

b) Fire suppression: Sharp reduction in the rate of heat emitted and prevention of resurgence of fire during the duration of the discharge.

c) Fire extinguishing: After system discharge, it is capable of preventing the reactivation of the fire, until the total disappearance of burning materials. The systems are capable of extinguishing fires in the relevant application. Meeting this goal requires quick response from the fire detection and extinguishing system and greater extinguishing intensity.

d) Fire barrier: complementing and reinforcing fire protection structures, preventing the spread of the fire to other areas and knocking down smoke and other combustion gases.

e) Heat retention: Absorption of heat produced in the vicinity of the protected object, besides washing out smoke and gases generated and ultimately safeguarding the safety of structures and facilities.

According to the approval standard FM 5560 (appendix D, E and F), the design criteria used is the protection of the volume with the extinguishing of the fire.

5 Water Mist System Parameters

The type of risk to protect and the design and installation parameters of the system are based on the real fire testing done in Sintef, and described in the FM5560 (March 2009) “Approval Standard for Water Mist Systems”:

-Appendix D “Fire Test for Water Mist Systems for the Protection of Machinery Spaces with Volumes not Exceeding 9175 ft3 (260 m3)”,

-Appendix E “Fire Test for Water Mist Systems for the Protection of Special Hazard Machinery Spaces with Volumes not Exceeding 9175ft3 (260 m3)” and

-Appendix F “Fire Test for Water Mist Systems for the Protection of Combustion Turbines with Volumes not Exceeding 9175ft3 (260 m3)”.

The pressurising system has a maximum filling pressure of 4350 psi (300 bar). The nominal operating pressure hinges on the pressure drop throughout the piping calculated from the outlet of the cylinder bank to the farthest nozzle. The working pressure for the most distant nozzle should be at least 580 psi (40 bar) for volumes between 4590 ft^3 ($130m^3$) and 9175 ft^3 (260 m^3). or 1015 psi (70 bar) for volumes up to 4590 ft^3 ($130m^3$).

Practical steps should be taken to ensure continuity and reliability of water supply, which should not be affected by any frost, drought or flood conditions or any other conditions that could reduce the flow rate, the effective capacity or cut off supply, including manipulation.

The RG SYSTEMS water mist equipment is designed to operate at a temperature range of minimum 40 ºF (4.4° C) to avoid freezing and maximum 122ºF (+50° C) for the water cylinders and between 40ºF and 122ºF (4.4° C and +50° C) for the nitrogen cylinders. If this is not possible, appropriate measures should be taken to ensure that the frost or excessively high temperatures have no adverse effects. The stored water, the feed pipe and the control valve should all be kept at a minimum temperature of 40 ºF (+4.4° C).

Water supply equipment should not be housed in buildings or areas of premises where dangerous processes are carried out or there is any risk of explosion. If water supplies and shut-off and test valves are installed, they can be accessed safely, even in case of fire. All components water supply must be installed so that they are protected against manipulation, freezing and out of danger areas.

Water supplies should automatically provide at least the pressure / flow required by system for its operation for at least 10 minutes. The maximum protected volume is 9175 ft^3 (260 m^3) and the maximum height is 16.4 ft (5m). The nozzles are located in a grid type with 12 ft (3.65m) as maximum spacing between them and 6 ft (1.825m) as maximum distance between the nozzle and the wall.

To summarize the parameters of the system:

Discharge Time: 10 minutes.
Storage Temperature: between +40ºF and 122ºF (+4.4º C and +50º C).
Working Pressure of the Nozzles:
Protected risk < 4590.9 ft^3 = 1015 psi ($130m^3$ = 70 bar).
4590.91 ft^3 ($130m^3$) < Protected risk < 9182 ft^3 = 580 psi ($260m^3$ = 40 bar).
Filling Pressure of the Cylinders: 2900 or 4350 psi (200 or 300 bar).
Maximum Protected Volume: 9182 ft^3 ($260m^3$)
Maximum Height of the Protected Volume: 16.4 ft (5m).
Maximum Spacing between Nozzles: 12 ft (3.65m).
Maximum Spacing between Nozzle and wall: 6 ft (1.825m).
Nozzle EMM-416549 k-factor: 0,75 $l/min/bar^{1/2}$

6 Installation Requirements

6.1 Electrical Equipment

Control and activation systems should be able to function automatically. Activation, alarm and control systems must be installed, maintained and started up in accordance with applicable national standards.

The electrical installation of automatic extinguishing systems must meet the latest high/low voltage standards. Special attention should be paid to ensuring secure electrical earthing of the pipe network.

All detection, releasing, and control equipment is required to be FM Approved.

All equipment meets the relevant national legislation.

NFPA 70, National Electrical Code
NFPA 72, National Fire Alarm and Signaling Code

Special attention must be given to equipment in areas classified as hazardous, and the degree of protection should be adequate.

Note: *See EN 60079 and IEC 61241 standards.*

6.1.1 Control and Signalling Devices

They must meet the following minimum requirements:

a) Power to include batteries

b) Monitoring of active circuit elements

c) System start-up is indicated on the control panel.

This latter device may be a pressure switch or flow detector.

There is a switch for electrically isolating the circuits of the discharge device from the system to allow proper maintenance of the system. The status of this switch must be clearly marked on the control panel.

6.1.2 Power Supply for Monitoring

The emergency power source must be able to keep the system running for at least 24 hours since the first time power is interrupted. The power supply must be exclusively for the control system.

The isolation switch of the power supply for the control system must be clearly marked as follows:

DO NOT SWITCH OFF AUTOMATIC FIRE FIGHTING SYSTEMS

The connection must be on the inlet side of the main electrical distribution box.

6.1.3 Power supply for detection and control system

The isolation switch of the power supply for the detection and control system must be clearly marked as follows:

DO NOT SWITCH OFF AUTOMATIC FIRE FIGHTING SYSTEMS

6.1.4 Alarm Generation

The alarms must comply with the requirements of authority having jurisdiction. Audible alarms (sirens) and visible warning signs are installed in the fire control panel:

a) Fire alarm signal triggered by the first alarm from one of the detectors installed. The signal could be emitted by a visual indication and/or an alert tone. The alarm of each installation should be connected to a place where there is always staff present.
Note: if it is a noisy environment, it is advisable to install a visual device to attract attention through, for example, a flashing light instead of the warning buzzer.

b) Evacuation alarms whenever it is necessary to leave the protected area prior to or as a result of system discharge. Visual devices should have texts such as: "do not enter", "abandon area", "automatic extinguishing" and the evacuation alarm buzzers will go off and will continue until the hazard area is declared safe by qualified personnel. The alarm tones and signals must comply with local requirements.

c) The operational status of the system, all conditions that may affect the automatic operation or effectiveness of the installed system, must produce a visual indication on the device monitoring and signalling system. These conditions should include but are not limited to the following:

Activation of the maintenance cancelling function
Release circuit fault
Fire protection capacity fail, i.e., low expellant gas pressure
"Manual" status if the installed device allows automatic or manual operation
Power fail

The fail indicators should be connected to a place that is under constant monitoring by staff.

6.2 Piping Supports

The piping supports should be designed and installed according to the specifications in this design manual and in the RG Systems installation manual and should also comply with the minimum safety standards described in standard NFPA 750 (see installation manual).

6.3 Automatic Stop and Closure

The power of equipment in the affected area should be cut as soon as the system is activated or a fire is detected. The exception is the minimum power supply for the operation of emergency systems.

In addition, all the ventilation openings or forced ventilation arrangements shall be able to automatic closure or shut-down prior to system discharge.

7 Water Mist System Design

7.1 Risk analysis and inspection in the protected area

The first and most important step in designing an extinguishing system is to carefully analyse the risk to be protected.

At least the following parameters must be known:

1) CLASS OR TYPE OF RISK.

2) TYPE OF FIRE PRODUCED

3) ENVIRONMENTAL CONDITIONS (TEMPERATURE, HUMIDITY, CORROSION, ETC.)

4) SYSTEM OF OPERATION UNDER NORMAL CONDITIONS AND AFTER THE DISCHARGE OF THE EXTINGUISH AGENT

5) PROTECTED AREA ACCESS (EVACUATION ROUTES, EVACUATION TIME, ETC.)

6) TYPE OF CONSTRUCTION OF THE PROTECTED AREA (DOORS, FIRE RESISTANT WALLS, ETC.)

7) SURFACE AREA OF THE ENCLOSURE TO BE PROTECTED

8) MAXIMUM HEIGHT OF THE ENCLOSED AREA TO BE PROTECTED

9) FALSE FLOORS AND CEILINGS IN THE ENCLOSED AREA

10) LOCATION OF THE EXTINGUISHING SYSTEM (CYLINDER BANK)

11) ANY OTHER SPECIAL CONSIDERATION TO BE TAKEN INTO ACCOUNT WHICH MAY AFFECT THE RISK

7.2 Calculation of Water Quantity

The procedure for calculating the amount of agent to use is described below.

7.2.1 Volume Protection Systems

In this type of system, the entire enclosure of the risk is protected. The placement of the nozzles is defined by the design parameters stipulated in the tests conducted. The number of nozzles to be installed for each risk can be determined by the size of the enclosed area, the spacing between nozzles and their maximum distance from the wall. Once their placement is determined, with the k-factor of the nozzle and the minimum working pressure, the amount of water needed can also be determined. In addition, once the discharge time is known (10 minutes), the total amount of water that must be stored can also be determined.

7.2.2 Nozzle Selection

Its function is to discharge the extinguishing agent within the conservation area by ensuring a proper distribution of flow. This nozzle consists of a body, which facilitates installation and maintenance, and consists of micro-nozzles located in the body around its head.

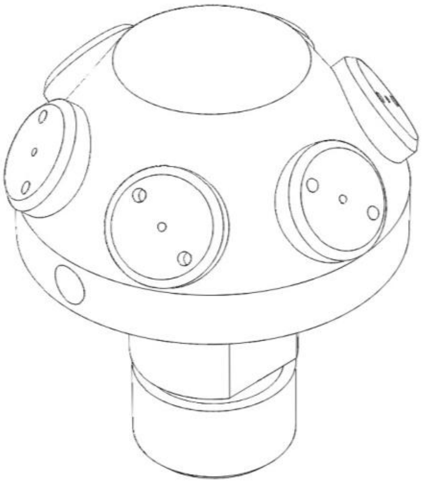

Figure 3.- Water mist nozzle.

WATER MIST NOZZLES						
NOZZLE CODE	STANDARD & HAZARD	MAX. SPACING Between Nozzles	MAX. DISTANCE From Nozzle to Wall	MAX. HEIGHT	WORKING PRESSURE	K-FACTOR
EMM-416549	FM-5560 Annex D, E, F *$4590ft^3 < x < 29175ft^3$* ($130m^3 < x < 260m^3$)	11.98 ft (3,65 m)	5.99 ft (1,825 m)	16.4 ft (5 m)	580 psi (40 bar)	0,75 l/min/bar $^{1/2}$
EMM-416549	FM-5560 Annex D, E, F <4590 ft^3 (130 m^3)	11.98 ft (3,65 m)	5.99 ft (1,825 m)	16.4 ft (5 m)	1015 psi (70 bar)	0,75 l/min/bar $^{1/2}$

Table 1.- Technical characteristics for Water Mist Nozzle.

7.2.3 Nozzle Location

For the proper design of RG SYSTEMS water mist systems, it is essential to respect the maximum and minimum distances and heights for the placement of nozzles. The tables given in this manual are approximate. The final, correct design will be done at RG SYSTEMS.
Nozzles must be placed following the instructions in this manual, taking into account the following parameters:

- ✓ Risk type
- ✓ Nozzle position, maximum and minimum space between nozzles.
- ✓ Distance from walls and other obstructions, installation of nozzles to compensate for obstructions, installation around openings, etc.
- ✓ Distance from the risk
- ✓ Distance below ceilings and design height for ceiling.

The location of nozzles in the protected enclosure determines the number of nozzles that must be installed and they must discharge simultaneously in case of fire. In turn, this value indicates water supply and storage.
The nozzles cannot be located in positions that result in direct nozzle spray to a turbine shell.

7.2.3.1 Obstructions to Nozzle Discharge

It must be taken into account when there are racks, shelves, partitions and tall items of equipment in the protected compartments which may represent an obstacle to the agent discharge through the nozzles when extinguishing discharge occurs. Hence, the “route” of the discharge from the nozzles must be taken into account when the number of nozzles required is determined.

All the permanent solid obstructions which could interfere with the “line of sight” of the discharge route must be considered as separate areas. All the nozzles must be located in such a way that the discharge route reaches all the extremes of the protected space.

It is possible find more information about obstructions in NFPA 750 Section A.8.2.5.

7.2.4 Selection of the Cylinder Bank

The selection of the cylinder bank is determined by the flow rate needs, which varies depending on the number of nozzles that must discharge simultaneously in the event of a fire. Below are the most common configurations of cylinder banks (see page 14).

The W-FOG UAC cylinder banks consist of cylinders containing nitrogen and water. The nitrogen cylinder is installed depending on the water cylinders that it has to pressurize.

CYLINDER BANKS CONFIGURATIONS _Gal																		
Number Of Nozzles	Protected Volume < 4590 ft^3 (130m^3)									4590 ft^3 (130m^3)< Protected Volume < 9175 ft3 (260m^3)								
	H2O			IG-100 @ 2900 psi (200 bar)			IG-100 @ 4350 psi (300 bar)			H2O			IG-100 @ 2900 psi (200 bar)			IG-100 @ 4350 psi (300 bar)		
	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)	15.21 (67 l)	18.16 (80 l)	31.78 (140 l)
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	1	2	1	1	1	1	1	2	2	1	1	1	1	1	1	1
3	3	3	2	2	2	1	1	1	1	3	2	2	1	1	1	1	1	1
4	4	4	2	3	2	1	2	1	1	3	3	2	1	1	1	1	1	1
5	5	4	3	3	3	2	2	2	1	4	3	2	1	1	1	1	1	1
6	6	5	3	4	3	2	2	2	1	5	4	3	2	1	1	1	1	1
7	7	6	4	4	4	2	3	2	1	5	5	3	2	2	1	1	1	1
8	8	7	4	5	4	2	3	2	2	6	5	3	2	2	1	1	1	1
9	9	8	5	5	4	3	3	3	2	7	6	4	2	2	1	1	1	1
10	10	8	5	6	5	3	3	3	2	8	6	4	2	2	1	2	1	1

Table 2.- Cylinder Banks Configurations.

7.2.5 Sizing the Cylinder Bank

The sizing of the supply system is determined as the product of the total flow of water to be discharged and the minimum time of discharge, which is at least 10 minutes. The outcome of both values gives the minimum amount of agent that must be discharged in the protected risk. The number of water cylinders in the bank is determined on the basis of the volume of water that each of the cylinders can store:

$$N_{cylinders H_2O} = \frac{V_{TOTAL H_2O}}{V_{CYLINDER\ H_2O}}$$

For determine the number of nitrogen cylinders, please check the table 2.

When the discharge duration of 10 minutes is not long enough, It is necessary an extended discharge and it is necessary to know how calculate the size of the system, this is determined as above, you need use the table 2 but pass over the column of the nozzle, only need search the number of water cylinders it´s necessary and how many cylinders of gas it´s necessary.

7.2.6 Cylinder Selection

The containers where water is stored within the same bank must be of the same size with the same filling range. Nitrogen gas is stored as a gas in cylinders with different nominal volumes and pressurised at 2900 or 4350 psi (200 or 300 bar). The nitrogen containers which make up the cylinder bank must all be the same size and have the same fill density.

8 Pipe Network Design

8.1 General

Piping must be designed and installed according to RG SYSTEMS specifications, with the same level of safety described in standard NFPA 750 & ISO 14972. The pipe network should be capable of handling at least four times the design pressure.

The piping should be exposed to damage caused, for example, by fire, freezing, moving vehicles, etc. (NFPA 750 & ISO 14972).

The pipe material should be stainless steel, taking into account particularly corrosive environments. The risk of thermal expansion should also be borne in mind in very long straight pipe runs.

As far as the pipe supports, they should be spaced according to RG SYSTEMS and with the same level of safety as described in NFPA 750 & ISO 14972.

The pipe network for these systems is based on the flow that will pass through them. Below are some guidelines for designing the pipe network. ***Installation should not be done until it has been approved by RG SYSTEMS.***

8.2 Piping

The pipe network materials must be stainless steel AISI 316L according to ISO-1127.

Other materials from those mentioned previously could be employed if they are shown to be adequate by the relevant tests. The pipe network and fittings shall be suitable for the pressure of the system, and must be tested by a hydrostatic test at 150% of design pressure.

Where appropriate, the joints must comply with standard ISO / DIS 6182-12. The components for pressures greater than those mentioned in this standard should have the same level of safety. If the there are no European Standards which apply, the manufacturer must prove that the components meet the following basic requirements:

-minimum burst strength.

-vibration;

-water hammer;

-corrosion;

-heat resistance.

8.3 Attaching the piping

The manufacturer must prove that the following basic requirements are met:

-load;

-vibration;

-heat resistance.

The supports for the pipe network which must comply with the ISO 6192-11 standard will be subject to compliance with this requirement.

The supports must be adequate for the environmental conditions to which they will be exposed and expected temperature range, including the thermal stress that the pipe network will suffer due to temperature variation, besides being able to withstand the static and dynamic forces expected.

The pipe supports should be spaced according to RG SYSTEMS and with the same level of safety as described in NFPA 750.

NOMINAL PIPE DIAMETER (mm)	MAXIMUM DISTANCE BETWEEN SUPPORTS ft (m)
8	4.9 (1.5)
12	4.9 (1.5)
16	4.9 (1.5)
30	6.5 (2)
38	6.5 (2)
1 1/2"	6.5 (2)
2”	8.2 (2.5)

Table 3.- Maximum distance between supports.

8.4 System Piping

To determine the appropriate size in each pipe section, this is selected based on the design flow rate for each pipe section. The size selection depends on the design flow quantity carried by each of the different branch pipes.

The following table shows the **approximate** maximum flow that can flow through the pipeline in depending on its size.

Note: The above Table must only be used as an APPROXIMATE DESIGN GUIDE. The final calculations must be made by RG SYSTEMS.

System installation MUST NOT start until the final pipework design has been verified using the RG SYSTEMS flow calculation program.

8.5 Hydraulic and Pneumatic Calculations

8.5.1 Pressure Drop

Only calculation methods validated by RG Systems and based on the Darcy-Weisbach formula shall be used.

8.5.2 Water Hammer

The effects of a possible water hammer should be taken into account in the design of the installation and its support.

9 Water Supply

9.1 General

The water supply must be based on drinking water.

The water should be free of fibres or other particulate matter responsible for causing accumulation in the pipe system. Neither salt nor brackish water should be allowed to accumulate in the pipes.

Some parameters on the quality of water to be used are as follows:

Water supply should be able to automatically provide at least the required system pressure and flow conditions.

9.2 Safety Guidelines

Water mist is harmless to people. In cases where the oxygen concentration is within critical limits early warning signals and a delayed activation system must be set up in order to evacuate the area.

However, if a fire occurs, there is a risk inherent in the aftermath of a fire. ALL existing fire regulations require the evacuation of the room in case of fire.

Water mist is harmless to humans. Since the system keeps a supply of nitrogen, any risks will be related to this (risk from displacing oxygen). In cases where the oxygen concentration is within critical limits early warning signals and a delayed activation system must be set up in order to evacuate the area. Listed below are the maximum concentrations that can be achieved in the compound when water mist systems are used with water and nitrogen cylinders. The maximum concentration of nitrogen discharged shall not exceed 52%.

PROPERTIES	VALUE
NOAEL	*43 %*
LOAEL	*52 %*
➢ ***NOTE:*** *Based on effects on humans in hypoxic atmospheres. These values are the functional equivalents of NOAEL LOAEL values and correspond to 12 percent oxygen for the NoEffect Level and 10 percent oxygen for the LowEffect leve*	

Table 4.- NOAEL and LOAEL percentages.

However, if a fire occurs, there is a risk inherent in the aftermath of a fire. ALL existing fire regulations require the evacuation of the room in case of fire.

9.2.1 Identification

Water mist systems using additives must be clearly identified by labels on the containers, if necessary, and by including the Material Safety Data Sheet of the additive in the design and installation manual. The additive effects should be detailed in the system manual.

9.2.2 Safety Requirements

Systems that use additives not be used in occupied areas unless they have been tested for safe exposure to the maximum concentration which can be reached during system discharge. This testing must include at least skin irritation, eye irritation and toxicity in humans.

9.2.3 Registration in the Manufacturer Manual

All systems using additives, whatever the reason, must be tested and registered in the manufacturer's design and installation manual. The record must include at least:

-Specific concentration.
-Method of mixing additive with water.

RG SYSTEMS shall evaluate the use of the additive and must prove that it does not adversely affect the system's fire fighting capabilities.

Systems that use additives to improve suppression capabilities should be tested with the specific additive in the specific concentration. Whenever a method for mixing additives with water is used, the mixing mechanism must also be tested.

Systems that use additives to improve fire suppression capability should have a supply of additive sufficient to cover at least the same length of time as the manufacturer has used in the test, which provides the design criteria in each case.

10 Practical Example 1

We will study the case of the protection with a Water Mist System of a machinery room with sizes of 23 ft long, 23 ft wide and 16.5 ft height (7m long, 7m wide and 5m height). The total volume is 8652 ft^3 (245m^3).

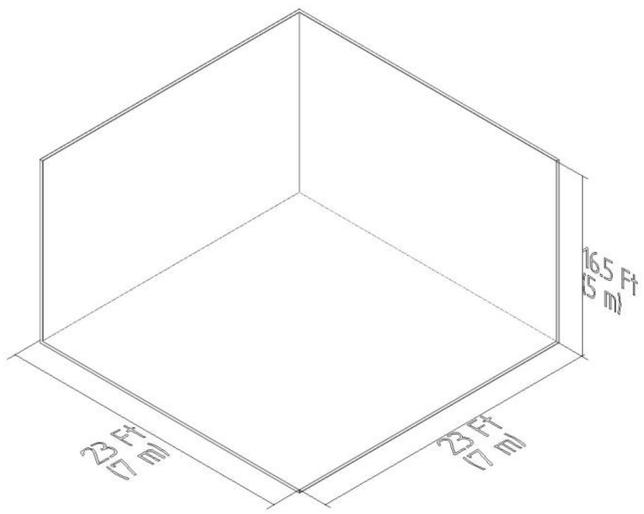

Figure 4.- Example of Design for the protection of a machinery space of 23x23x16.5ft (7x7x5m).

First of all, we should **check** if the risk complies with all **requirements**:

Risk to protect:	System Parameters:	Result:
Protected Volume = 7·7·5m=245m^3	Maximum Risk Volume: 260m^3	OK
23·23·16.5ft=8652 ft^3	9175 ft^3	
Height of Risk = 16.5 ft (5m)	Maximum Height of the Risk: 16.5 ft (5m)	OK
Risk = Machinery Space	According to FM 5560, Appendix D	OK

Then, we can confirm that the risk could be protected with a Water Mist System approved by FM under the standard FM5560 Appendix D. The next step is to **determine the number of nozzles** to be used in this room:

Risk to protect:	Restrictions:
Long = 23 ft (7m)	Maximum Spacing between Nozzles: 11.98 ft (3.65m).
Wide = 23 ft (7m)	Maximum Spacing between Nozzle and wall: 5.99ft (1.825m).

The nozzle grid are calculated with the following formulae and rounded up:

$$N_{NOZZLES} = \frac{Wide_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{7m}{3.65m} = 1.917 \approx 2 \;\; nozzles$$

$$N_{NOZZLES} = \frac{Long_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{7m}{3.65m} = 1.917 \approx 2 \;\; nozzles$$

The nozzle grid is compounded by 2 nozzles wide and 2 nozzles long, 4 nozzles in total. Once we have determined the nozzle grid for the risk, the installation is designed making equidistant the nozzle locations between them and between the nozzles and the wall.

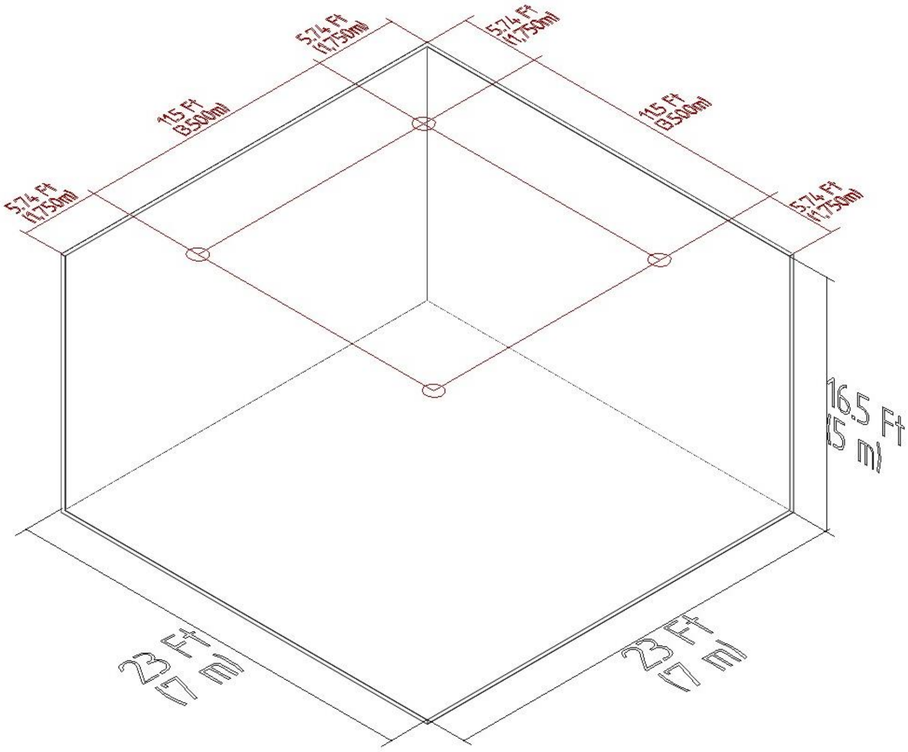

Figure 5.- Designing the Nozzle grid in example 1.

Following with the installation, we can **calculate the amount of water** required for the risk, taken into account the nozzle used, the discharge time and the pressure of the nozzle:

<u>Risk to protect:</u>
Number of nozzles = 4
Protected Volume = 7·7·5m=245m^3
23·23·16.5ft=8652 ft^3

<u>System Parameters:</u>
Discharge time: 10 minutes.
Protected volume between: 4590 ft^3 and 9175 ft^3 (130m^3 and 260m^3)
Min. Nozzle working pressure: 580 psi (40 bar)
K-factor of EMM-416549 nozzle: 0,75 l/min/bar 1/2

$$Q_{NOZZLE} = k \cdot \sqrt{p} = 0.75 \cdot \sqrt{40} = 1.25 gal/\min(4.743\ l/\min)$$

$$Q_{TOTAL} = Q_{NOZZLE} \cdot N_{NOZZLES} \cdot T_{MINUTES} = 4.743 \cdot 4 \cdot 10 = 43 gal(189.72)\ litres$$

This step is for confirmation only, if you go directly to the table 2 with the number of nozzles and the volume of the protected risk, then you will have the required amount of water and nitrogen cylinders.

Go to the "Table 2.- Cylinder Banks Configurations" and in the appropriate column and line, **select the cylinder bank** which better adjust to our purposes:

<u>Risk to protect:</u>
Amount of water = 43.13 gal (190 litres)

<u>Restrictions:</u>
Protected volume between: 4591 ft^3 and 9175 ft^3 (130m^3 and 260m^3)

<table>
<tr><th rowspan="3">Number Of Nozzles</th><th colspan="9">4590 ft3 (130m3)< Protected Volume < 9175 ft3 (260m3)</th></tr>
<tr><th colspan="3">H2O</th><th colspan="3">IG-100 @ 2900 psi (200 bar)</th><th colspan="3">IG-100 @ 4350 psi (300 bar)</th></tr>
<tr><th>15.21 gal (67 l)</th><th>18.16 gal (80 l)</th><th>31.78 gal (140 l)</th><th>15.21 gal (67 l)</th><th>18.16 gal (80 l)</th><th>31.78 gal (140 l)</th><th>15.21 gal (67 l)</th><th>18.16 gal (80 l)</th><th>31.78 gal (140 l)</th></tr>
<tr><td>4</td><td>3</td><td>3</td><td>2</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

Table 5.- Extract of the Table 2 according to the result of the example 1.

Check that the required amount of water calculated and the number of water cylinders given in the table 2 match:

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{190}{67} = 2.835 \approx 3\ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{190}{80} = 2.375 \approx 3\ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{190}{140} = 1.357 \approx 2\ \ cylinders\ of\ \ water$$

According to the table 2, we can choose different cylinder banks configurations:

3 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 2900 psi (200 bar).
3 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 2900 psi (200 bar).
2 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 2900 psi (200 bar).
3 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 4351 psi (300 bar).
3 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 4351 psi (300 bar).
2 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 4351 psi (300 bar).

11 Practical Example 2

We will study the case of the protection with a Water Mist System of a machinery room with sizes of 33 ft long, 16.5 ft wide and 13 ft height (10m long, 5m wide and 4m height). The total volume is 7063 ft^3 (200m^3).

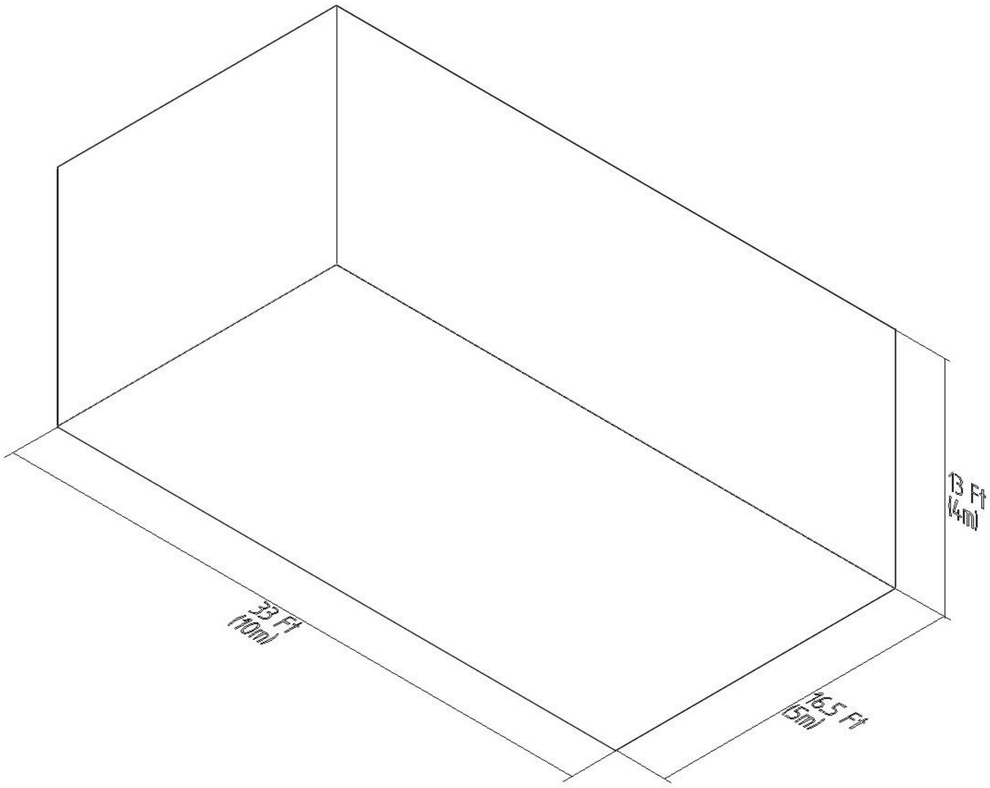

Figure 6.- Example of Design for the protection of a machinery space of 33x16.5x13ft (10x5x4m).

First of all, we should **check** if the risk complies with all **requirements**:

Risk to protect:	System Parameters:	Result:
Protected Volume = 10·5·4m=200m^3	Maximum Risk Volume: 260m^3	OK
33x16.5x13ft = 7063 ft^3	9175 ft^3	
Height of Risk = 13 Ft (4m)	Maximum Height of the Risk: 16.5 ft (5m)	OK
Risk = Machinery Space	According to FM 5560, Appendix D	OK

Then, we can confirm that the risk could be protected with a Water Mist System approved by FM under the standard FM5560 Appendix D. The next step is to **determine the number of nozzles** to be used in this room:

Risk to protect:	Restrictions:
Long = 33 ft (10m)	Maximum Spacing between Nozzles: 12 ft (3.65m).
Wide = 16.5 ft (5m)	Maximum Spacing between Nozzle and wall: 6 ft (1.825m).

The nozzle grid are calculated with the following formulae and rounded up:

$$N_{NOZZLES} = \frac{Wide_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{5m}{3.65m} = 1.369 \approx 2 \;\; nozzles$$

$$N_{NOZZLES} = \frac{Long_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{10m}{3.65m} = 2.739 \approx 3 \;\; nozzles$$

The nozzle grid is compounded by 2 nozzles wide and 3 nozzles long, 6 nozzles in total. Once we have determined the nozzle grid for the risk, the installation is designed making equidistant the nozzle locations between them and between the nozzles and the wall.

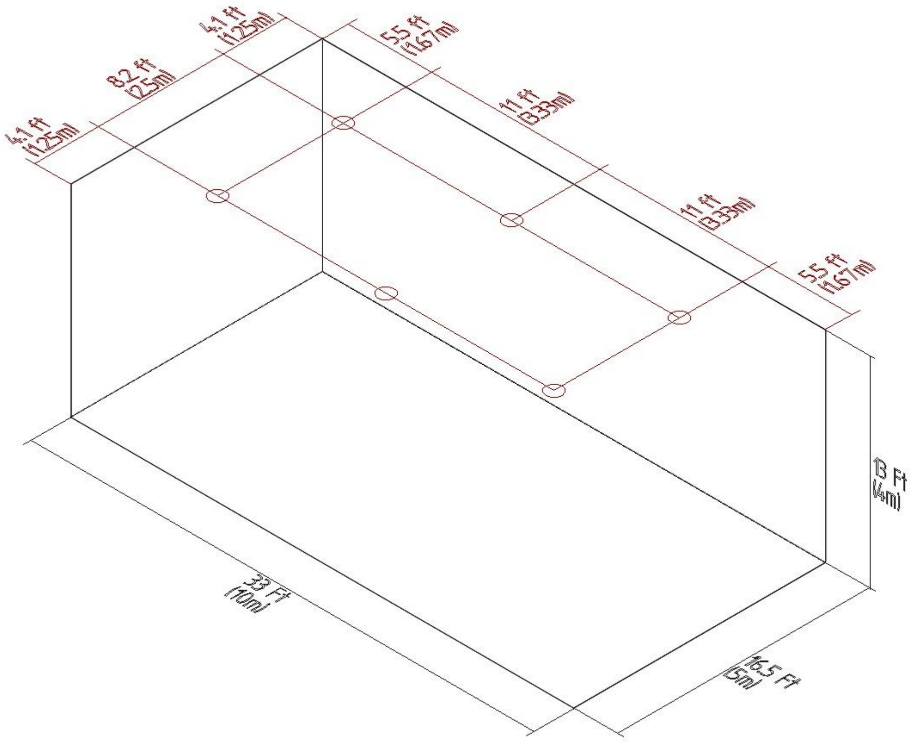

Figure 7.- Designing the Nozzle grid in example 2.

Following with the installation, we can **calculate the amount of water** required for the risk, taken into account the nozzle used, the discharge time and the pressure of the nozzle:

<u>Risk to protect:</u>
Number of nozzles = 6
Protected Volume = 10·5·4m=200m^3
33x16.5x13ft = 7063 ft^3

<u>System Parameters:</u>
Discharge time: 10 minutes.
Protected volume between: 130m^3 and 260m^3
4350 ft^3 and 9175 ft^3
Min. Nozzle working pressure: 580 psi (40 bar)
K-factor of EMM-416549 nozzle: 0.75 l/min/bar^{0,5}

$$Q_{NOZZLE} = k \cdot \sqrt{p} = 0.75 \cdot \sqrt{40} = 1.25 gal/\min (4.743 \;\; l/\min)$$

$$Q_{TOTAL} = Q_{NOZZLE} \cdot N_{NOZZLES} \cdot T_{MINUTES} = 4.743 \cdot 6 \cdot 10 = 64.61 gal (284.58 \;\; litres)$$

This step is for confirmation only, if you go directly to the table 2 with the number of nozzles and the volume of the protected risk, then you will have the required amount of water and nitrogen cylinders.

Go to the "Table 2.- Cylinder Banks Configurations" and in the appropriate column and line, **select the cylinder bank** which better adjust to our purposes:

Risk to protect:
Amount of water = 65 gal (285 litres)

Restrictions:
Protected volume between: 4590ft^3 and 9175 ft^3 (130m^3 and 260m^3)

Number Of Nozzles	**4590 ft3 (130m3)< Protected Volume < 9175 ft3 (260m3)**								
	H2O			**IG-100 @ 2900 psi (200 bar)**			**IG-100 @ 4350 psi (300 bar)**		
	15.21 gal (67 l)	**18.16 gal (80 l)**	**31.78 gal (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 gal (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 gal (140 l)**
6	5	4	3	2	1	1	1	1	1

Table 6.- Extract of the Table 2 according to the result of the example 2.

Check that the required amount of water calculated and the number of water cylinders given in the table 2 match:

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{284.58}{67} = 4.247 \approx 5 \ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{284.58}{80} = 3.557 \approx 4 \ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{284.58}{140} = 2.032 \approx 3 \ \ cylinders\ of\ \ water$$

According to the table 2, we can choose different cylinder banks configurations:

5 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 2900 psi (200 bar).
4 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 2900 psi (200 bar).
3 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 2900 psi (200 bar).
5 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 4351 psi (300 bar).
4 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 4351 psi (300 bar).
3 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 4351 psi (300 bar).

12 Practical Example 3

We will study the case of the protection with a Water Mist System of a machinery room with sizes of 35 ft long, 11.5 ft wide and 16.5 ft height (10.5m long, 3.5m wide and 5m height). The total volume is 6497 ft^3 (184m^3).

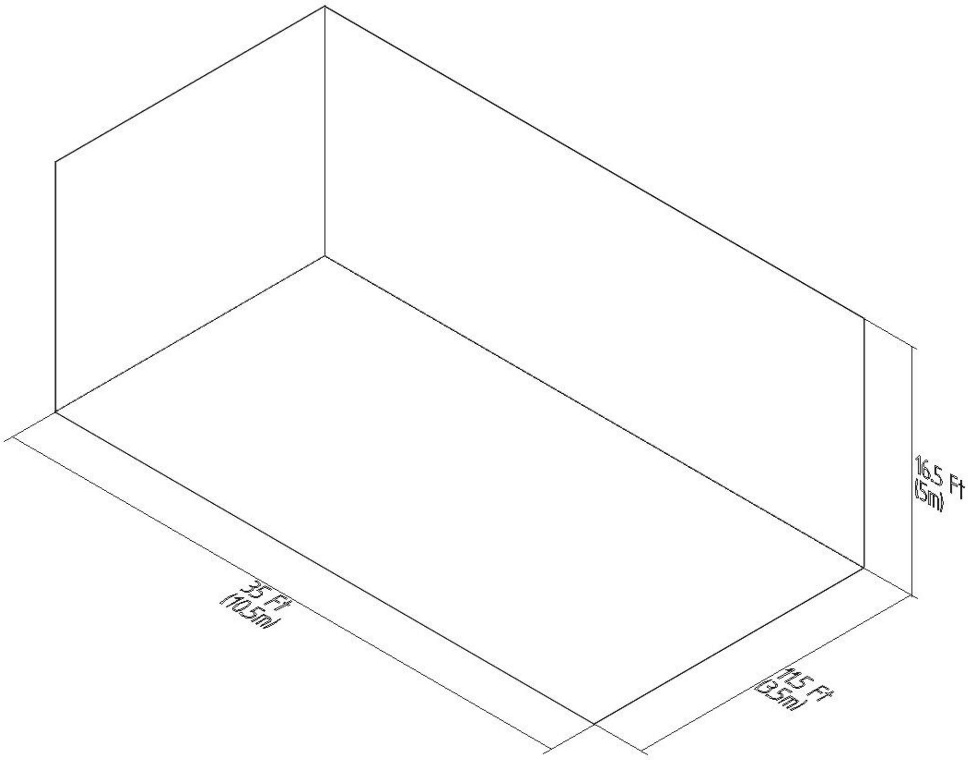

Figure 8.- Example of Design for the protection of a machinery space of 35x11.5x16.5ft (10.5x3.5x5m).

First of all, we should **check** if the risk complies with all **requirements**:

Risk to protect:	System Parameters:	Result:
Protected Volume = 10.5·3.5·5m=184m^3 35x11.5x16.5ft= 6497 ft^3	Maximum Risk Volume: 9175 ft^3 (260m^3)	OK
Height of Risk = 16.5 ft (5m)	Maximum Height of the Risk: 16.5 ft (5m)	OK
Risk = Machinery Space	According to FM 5560, Appendix D	OK

Then, we can confirm that the risk could be protected with a Water Mist System approved by FM under the standard FM5560 Appendix D. The next step is to **determine the number of nozzles** to be used in this room:

Risk to protect:	Restrictions:
Long = 35 ft (10.5m)	Maximum Spacing between Nozzles: 11.98 ft (3.65m).
Wide = 11.5 ft (3.5m)	Maximum Spacing between Nozzle and wall: 5.99 ft (1.825m).

The nozzle grid are calculated with the following formulae and rounded up:

$$N_{NOZZLES} = \frac{Wide_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{3.5m}{3.65m} = 0.958 \approx 1 \ \ nozzles$$

$$N_{NOZZLES} = \frac{Long_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{10.5m}{3.65m} = 2.876 \approx 3 \;\; nozzles$$

The nozzle grid is compounded by 1 nozzle wide and 3 nozzles long, 3 nozzles in total. Once we have determined the nozzle grid for the risk, the installation is designed making equidistant the nozzle locations between them and between the nozzles and the wall.

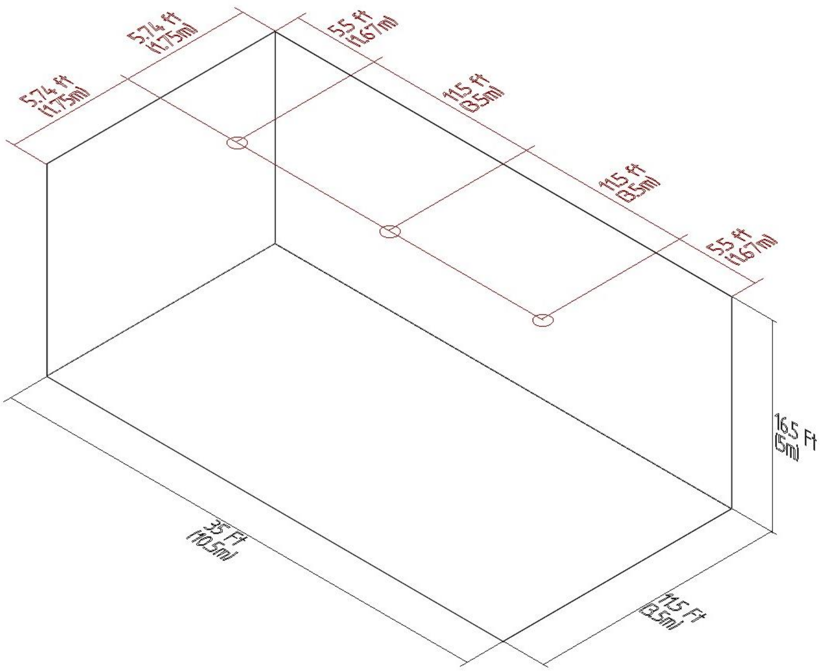

Figure 9.- Designing the Nozzle grid in example 3.

Following with the installation, we can **calculate the amount of water** required for the risk, taken into account the nozzle used, the discharge time and the pressure of the nozzle:

Risk to protect:	System Parameters:
Number of nozzles = 3	Discharge time: 10 minutes.
Protected Volume = 10.5·3.5·5m=184m^3 35x11.5x16.5ft= 6497 ft^3	Protected volume between: 4590ft^3 and 9175ft^3 (130m^3 and 260m^3)
	Min. Nozzle working pressure: 580 psi (40 bar)
	K-factor of EMM-416549 nozzle: 0.75 l/min/bar^{0,5}

$$Q_{NOZZLE} = k \cdot \sqrt{p} = 0.75 \cdot \sqrt{40} = 1.04 gal \min(4.743 \;\; l/\min)$$

$$Q_{TOTAL} = Q_{NOZZLE} \cdot N_{NOZZLES} \cdot T_{MINUTES} = 4.743 \cdot 3 \cdot 10 = 32.3 gal (142.29 \;\; litres)$$

This step is for confirmation only, if you go directly to the table 2 with the number of nozzles and the volume of the protected risk, then you will have the required amount of water and nitrogen cylinders.

Go to the “Table 2.- Cylinder Banks Configurations” and in the appropriate column and line, **select the cylinder bank** which better adjust to our purposes:

Risk to protect:
Amount of water = 32.5 gal (143 litres)

Restrictions:
Protected volume between: 4590 ft^3 and 9175 ft^3 (130m^3 and 260m^3)

Number Of Nozzles	4590 ft3 (130m3)< Protected Volume < 9175 ft3 (260m3)								
	H2O			IG-100 @ 2900 psi (200 bar)			IG-100 @ 4350 psi (300 bar)		
	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)
3	3	2	2	1	1	1	1	1	1

Table 7.- Extract of the Table 2 according to the result of the example 3.

Check that the required amount of water calculated and the number of water cylinders given in the table 2 match:

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{143}{67} = 2.134 \approx 3\ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{143}{80} = 1.787 \approx 2\ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{143}{140} = 1.021 \approx 2\ \ cylinders\ of\ \ water$$

According to the table 2, we can choose different cylinder banks configurations:

3 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 2900 psi (200 bar).
2 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 2900 psi (200 bar).
2 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 2900 psi (200 bar).
3 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 4351 psi (300 bar).
2 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 4351 psi (300 bar).
2 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 4351 psi (300 bar).

13 Practical Example 4

We will study the case of the protection with a Water Mist System of a machinery room with sizes of 11.5 ft long, 11.5ft wide and 16.5ft height (3.5m long, 3.5m wide and 5m height). The total volume is 2163 ft^3 (61.25m^3).

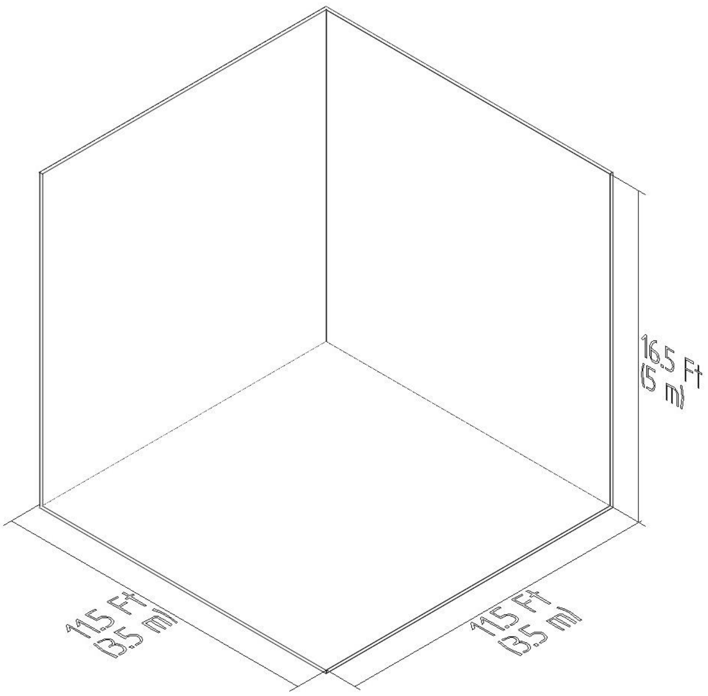

Figure 10.- Example of Design for the protection of a machinery space of 11.5x11.5x16.5ft (3.5x3.5x5m).

First of all, we should **check** if the risk complies with all **requirements**:

Risk to protect:	System Parameters:	Result:
Protected Volume = 3.5·3.5·5m=61.25m^3 11.5·11.5·16.5ft=2163 ft^3	Maximum Risk Volume: 9175 ft^3 (260m^3)	OK
Height of Risk = 16.5 ft (5m)	Maximum Height of the Risk: 16.5 ft (5m)	OK
Risk = Machinery Space	According to FM 5560, Appendix D	OK

Then, we can confirm that the risk could be protected with a Water Mist System approved by FM under the standard FM5560 Appendix D. The next step is to **determine the number of nozzles** to be used in this room:

Risk to protect:	Restrictions:
Long = 11.5 ft (3.5m)	Maximum Spacing between Nozzles: 11.98 ft (3.65m).
Wide = 11.5 ft (3.5m)	Maximum Spacing between Nozzle and wall: 5.99 ft (1.825m).

The nozzle grid are calculated with the following formulae and rounded up:

$$N_{NOZZLES} = \frac{Wide_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{3.5m}{3.65m} = 0.958 \approx 1 \ \ nozzles$$

$$N_{NOZZLES} = \frac{Long_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{3.5m}{3.65m} = 0.958 \approx 1 \ \ nozzles$$

The nozzle grid is compounded by 1 nozzle in total. Once we have determined the nozzle grid for the risk, the installation is designed making equidistant the nozzle locations between them and between the nozzles and the wall.

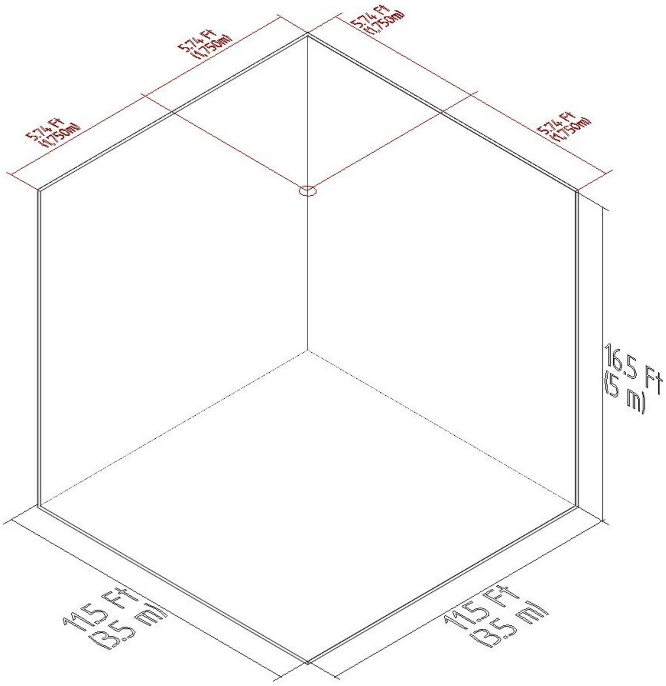

Figure 11.- Designing the Nozzle grid in example 4.

Following with the installation, we can **calculate the amount of water** required for the risk, taken into account the nozzle used, the discharge time and the pressure of the nozzle:

Risk to protect:
Number of nozzles = 1
Protected Volume = 3.5·3.5·5m=61.25m^3
11.5·11.5·16.5ft=2163 ft^3

System Parameters:
Discharge time: 10 minutes.
Protected volume: <4590 ft^3 (130m^3)
Min. Nozzle working pressure: 1015 psi (70 bar)
K-factor of EMM-416549 nozzle: 0.75 l/min·bar^{0,5}

$$Q_{NOZZLE} = k \cdot \sqrt{p} = 0.75 \cdot \sqrt{70} = 1.38 gal/\min(6.275\ l/\min)$$

$$Q_{TOTAL} = Q_{NOZZLE} \cdot N_{NOZZLES} \cdot T_{MINUTES} = 6.275 \cdot 1 \cdot 10 = 14.25 gal(62.75\ litres)$$

This step is for confirmation only, if you go directly to the table 2 with the number of nozzles and the volume of the protected risk, then you will have the required amount of water and nitrogen cylinders.

Go to the "Table 2.- Cylinder Banks Configurations" and in the appropriate column and line, **select the cylinder bank** which better adjust to our purposes:

Risk to protect:
Amount of water = 14.3 gal (63 litres)

Restrictions:
Protected volume: <4590 ft^3 (130m^3)

Number Of Nozzles	Protected Volume < 130m³								
	H2O			IG-100 @ 200 bar			IG-100 @ 300 bar		
	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)	15.21 gal (67 l)	18.16 gal (80 l)	31.78 gal (140 l)
1	1	1	1	1	1	1	1	1	1

Table 8.- Extract of the Table 2 according to the result of the example 4.

Check that the required amount of water calculated and the number of water cylinders given in the table 2 match:

$$N_{WATER\,CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{63}{67} = 0.94 \approx 1 \;\; cylinders\; of\; water$$

$$N_{WATER\,CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{63}{80} = 0.787 \approx 1 \;\; cylinders\; of\; water$$

$$N_{WATER\,CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{63}{140} = 0.45 \approx 1 \;\; cylinders\; of\; water$$

According to the table 2, we can choose different cylinder banks configurations:

1 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 2900 psi (200 bar).
1 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 2900 psi (200 bar).
1 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 2900 psi (200 bar).
1 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 4351 psi (300 bar).
1 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 4351 psi (300 bar).
1 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 4351 psi (300 bar).

The best solution is to use one cylinder of 15 gal (67 liters) of water. We can optimize the cylinder of nitrogen with the use of the RG Calculation sheet to calculate the amount of nitrogen needed for each system. In this case, the system is compounded by 1 cylinder of 15 gal (67 liters) of water and 1 cylinder of 5.9 gal (26 litres) filled with nitrogen at 4350 psi (300 bar).

14 Practical Example 5 (Extended discharge)

We will study the case of the protection with a Water Mist System of a combustion turbine room with sizes of 23 ft long, 23 ft wide and 16.5 ft height (7m long, 7m wide and 5m height). The total volume is 8652 ft^3 ($245m^3$).

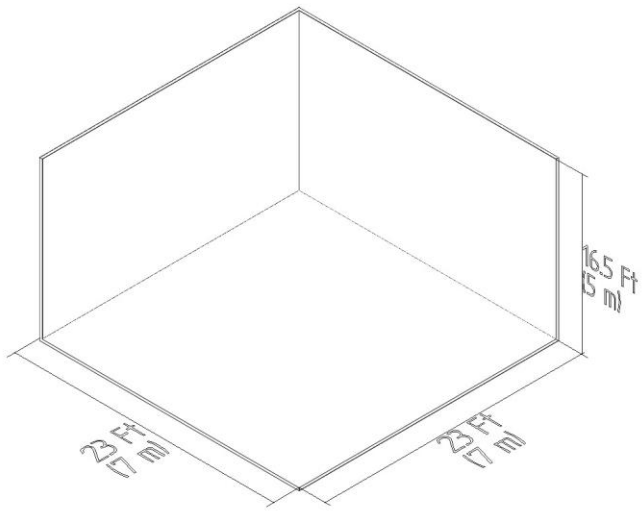

Figure 4.- Example of Design for the protection of a machinery space of 23x23x16.5ft (7x7x5m).

First of all, we should **check** if the risk complies with all **requirements**:

Risk to protect:	System Parameters:	Result:
Protected Volume = 7·7·5m=245m^3 23·23·16.5ft=8652 ft^3	Maximum Risk Volume: 260m^3 9175 ft^3	OK
Height of Risk = 16.5 ft (5m)	Maximum Height of the Risk: 16.5 ft (5m)	OK
Risk = combustion turbine enclosure	According to FM 5560, Appendix D	OK

Then, we can confirm that the risk could be protected with a Water Mist System approved by FM under the standard FM5560 Appendix D. The next step is to **determine the number of nozzles** to be used in this room:

Risk to protect:	Restrictions:
Long = 23 ft (7m)	Maximum Spacing between Nozzles: 11.98 ft (3.65m).
Wide = 23 ft (7m)	Maximum Spacing between Nozzle and wall: 5.99ft (1.825m).

The nozzle grid are calculated with the following formulae and rounded up:

$$N_{NOZZLES} = \frac{Wide_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{7m}{3.65m} = 1.917 \approx 2 \ \ nozzles$$

$$N_{NOZZLES} = \frac{Long_{RISK}}{MaxSpacing_{NOZZLE}} = \frac{7m}{3.65m} = 1.917 \approx 2 \ \ nozzles$$

The nozzle grid is compounded by 2 nozzles wide and 2 nozzles long, 4 nozzles in total. Once we have determined the nozzle grid for the risk, the installation is designed making equidistant the nozzle locations between them and between the nozzles and the wall.

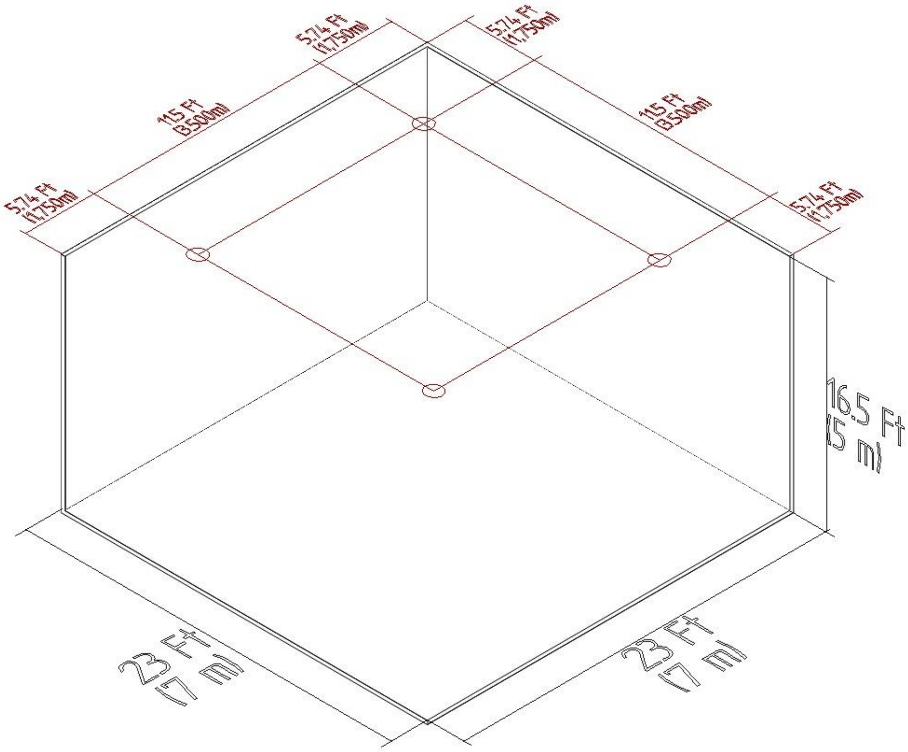

Figure 5.- Designing the Nozzle grid in example 1.

Following with the installation, we can **calculate the amount of water** required for the risk, taken into account the nozzle used, the discharge time and the pressure of the nozzle:

Risk to protect:
Number of nozzles = 4
Protected Volume = 7·7·5m=245m^3
23·23·16.5ft=8652 ft^3

System Parameters:
Discharge time: 20 minutes.
Protected volume between: 4590 ft^3 and 9175 ft^3 (130m^3 and 260m^3)
Min. Nozzle working pressure: 580 psi (40 bar)
K-factor of EMM-416549 nozzle: 0,75 l/min/bar 1/2

$$Q_{NOZZLE} = k \cdot \sqrt{p} = 0.75 \cdot \sqrt{40} = 1.25 gal/\min(4.743\ l/\min)$$

$$Q_{TOTAL} = Q_{NOZZLE} \cdot N_{NOZZLES} \cdot T_{MINUTES} = 4.743 \cdot 4 \cdot 20 = 86.14 gal(379.44)\ litres$$

This step is for confirmation only, if you go directly to the table 2 with the number of nozzles and the volume of the protected risk, then you will have the required amount of water and nitrogen cylinders.

Go to the "Table 2.- Cylinder Banks Configurations" and in the appropriate column and line, **select the cylinder bank** which better adjust to our purposes:

Risk to protect:
Amount of water = 86 gal (380 litres)

Restrictions:
Protected volume between: 4591 ft^3 and 9175 ft^3 (130m^3 and 260m^3)

Number Of Nozzles	**4590 ft3 (130m3)< Protected Volume < 9175 ft3 (260m3)**								
	H2O			**IG-100 @ 2900 psi (200 bar)**			**IG-100 @ 4350 psi (300 bar)**		
	15.21 gal (67 l)	**18.16 gal (80 l)**	**31.78 gal (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 gal (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 gal (140 l)**
4	3	3	2	1	1	1	1	1	1

Table 5.- Extract of the Table 2 according to the result of the example 1.

As can see If you go to the line for 4 nozzle the amount of cylinder to water is not equivalent, because table 2 is calculated for 10 minutes, not for 20 minutes, but you can calculate the number of cylinders do you need.

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{380}{67} = 5.6 \approx 6 \ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{380}{80} = 4.75 \approx 5 \ \ cylinders\ of\ \ water$$

$$N_{WATER\ CYLINDERS} = \frac{Q_{TOTAL}}{Volume_{CYLINDER}} = \frac{380}{140} = 2.7 \approx 3 \ \ cylinders\ of\ \ water$$

And now you can search in the table 2 how many cylinders you need to discharge this numbers of water cylinders. Omitting the part of the number of nozzle.

4590 ft^3 (130m^3)< Protected Volume < 9175 ft3 (260m^3)								
H2O			**IG-100 @ 2900 psi (200 bar)**			**IG-100 @ 4350 psi (300 bar)**		
15.21 gal (67 l)	**18.16 gal (80 l)**	**31.78 (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 (140 l)**	**15.21 gal (67 l)**	**18.16 gal (80 l)**	**31.78 (140 l)**
6	5	3	2	2	1	1	1	1

According to the table 2, we can choose different cylinder banks configurations:

6 cylinder of 15 gal (67 litres) of water + 2 cylinder of 15 gal (67 litres) of nitrogen at 2900 psi (200 bar).
5 cylinder of 18 gal (80 litres) of water + 2 cylinder of 18 gal (80 litres) of nitrogen at 2900 psi (200 bar).
3 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 2900 psi (200 bar).
6 cylinder of 15 gal (67 litres) of water + 1 cylinder of 15 gal (67 litres) of nitrogen at 4351 psi (300 bar).
5 cylinder of 18 gal (80 litres) of water + 1 cylinder of 18 gal (80 litres) of nitrogen at 4351 psi (300 bar).
3 cylinder of 31.7 gal (140 litres) of water + 1 cylinder of 31.7 gal (140 litres) of nitrogen at 4351 psi (300 bar).

FM5560 - Annex D, E, F: Volumes not Exceeding 260m^3

1.- Compulsory Requirements:

Maximum Enclosure Volume:	260	m^3
Minimum Discharge time required by Authorities:	10	Minutes
Maximum Spacing between nozzles:	3,65	Meters
Maximum Spacing between nozzle and wall:	1,825	Meters
Maximum Enclosure Height:	5	Meters

2.- Nozzle Technical Information:

Nozzle type	Volume (m^3)	K- Factor		Working pressure		Flow	
EMM-416549	260	0,75	l/min*bar$^{1/2}$	40	bar	4,74	l/min
EMM-416549	130	0,75	l/min*bar$^{1/2}$	71	bar	6,32	l/min

3.- Information of the Hazard to be Protected:

Hazard Volume	61,25	m^3
Hazard Area	12,25	m^2
No.of nozzles	1	Units
Flow of Nozzle	6,32	l/min
Total Flow	6,32	l/min
Nozzle Pressure	71,00	bar

4.- Results:

Protection time:				10	Minutes
Total amount of water:	10	x	6,32	63,1961	Litres
Pressure of the N2 cylinder:				300	Bar

Number of	67	Litres	Water cylinders:	0,94323	Units
Number of	26	Litres	N2 Cylinders:	0,7536	Units

Figure 12.- RG Systems Agent Calculation sheet for the example 4.

15 RG Systems Agent Calculation Sheet

The following "RG Systems Agent Calculation sheet" shows the calculation sheet used for calculates the amount of agent needed for each system depending of different factors, like volume, number of nozzles and pressure required in the nozzles, volume of cylinders, etc. Also, it calculates the quantity of nitrogen needed to impulse the water to the nozzles depending on the pressure required in the nozzle and the pressure filled in the nitrogen cylinder.

This excel sheet needs to be filled some boxes, the yellow ones. The green boxes are given by the calculation sheet. The result is given in the point "4.- Results" with a table with the volume of the cylinders chosen and the number of each cylinder required. Will be taken the number immediately rounded up (for example, the figure 13 is a battery of 3 cylinders of 15 gal (67 liters) of water and 1 cylinder of 15 gal (67 liters) of nitrogen at 2900 psi (200 bar)).

FM5560 - Annex D, E, F: Volumes not Exceeding 260m^3

1.- Compulsory Requirements:

Maximum Enclosure Volume:	260	m^3
Minimum Discharge time required by Authorities:	10	Minutes
Maximum Spacing between nozzles:	3,65	Meters
Maximum Spacing between nozzle and wall:	1,825	Meters
Maximum Enclosure Height:	5	Meters

2.- Nozzle Technical Information:

Nozzle type	Volume (m^3)	K- Factor		Working pressure		Flow	
EMM-416549	260	0,75	l/min*bar$^{1/2}$	40	bar	4,74	l/min
EMM-416549	130	0,75	l/min*bar$^{1/2}$	71	bar	6,32	l/min

3.- Information of the Hazard to be Protected:

Hazard Volume	260	m^3
Hazard Area	52,00	m^2
No.of nozzles	4	Units
Flow of Nozzle	4,74	l/min
Total Flow	18,97	l/min
Nozzle Pressure	40,00	bar

4.- Results:

Protection time:				10	Minutes
Total amount of water:	10	x	18,97	189,737	Litres
Pressure of the N2 cylinder:				200	Bar

Number of	67	Litres	Water cylinders:	2,83189	Units
Number of	67	Litres	N2 Cylinders:	0,70797	Units

Figure 13.- RG Systems Agent Calculation sheet. Calculation of quantity of water and nitrogen cylinders.

16 RG Systems Pressure Drop Calculation Sheet

The following “RG Systems Pressure Drop Calculation Sheet” shows the calculation sheet used for calculate the pressure drop from the battery systems until de worst nozzle, which is usually the farthest nozzle. This pressure drop is taken in count for increase the activation pressure of the battery system consequently, because the minimum working pressure should be maintained in the worst nozzle during the whole discharge. This sheet is used in combination with the Agent calculation sheet.

CALCULATION OF THE PRESSURE DROP IN THE WATER MIST NOZZLE PIPE WEB

Node From	Node Until	D pipe (mm)	t thick (mm)	dint (mm)	A (mm2)	Q (lpm)	v (m/s)	ρ (Kg/m3)	ν (mm2/s)	Re	κ mm	k/dint	λ	L real (m)	AP pipe (bar)	h (m)	AP height (bar)	Elbows (num)	C elbow	Tees (num)	C tees	Valves (num)	C valves	CTotal	AP accesories (bar)
0	1	12	1,5	9	63,6174	21,5	5,632630905	998,2	1,004	50491,7113	0,002	0,000222222	0,015	8,7	2,296033179	1	0,09792342	3	0,15			1	2,2	2,65	0,419619857
1	2	12	1,5	9	63,6174	18,14	4,752368587	998,2	1,004	42600,91363	0,002	0,000222222	0,015	3,4	0,638756702		0			1	0,9			0,9	0,101449594
2	3	12	1,5	9	63,6174	14,78	3,872106269	998,2	1,004	34710,11595	0,002	0,000222222	0,015	3,4	0,424042877		0			1	0,9			0,9	0,067347986
3	4	12	1,5	9	63,6174	6,66	1,744805666	998,2	1,004	15640,68824	0,002	0,000222222	0,015	3,4	0,086101231		0			1	1,3			1,3	0,019752635
4	5	12	1,5	9	63,6174	3,3	0,864543348	998,2	1,004	7749,890572	0,002	0,000222222	0,015	7,2	0,044765389		0	1	0,15	1	1,3			1,45	0,005409151
5	6	12	1,5	9	63,6174	1,68	0,440131159	998,2	1,004	3945,398836	0,002	0,000222222	0,015	3,4	0,005478725	0,3	0,029377026	1	0,15	1	1,3			1,45	0,001401909

AP total	4,23745968	bar
Pipe	3,4951781	bar
Height	0,12730045	bar
Accesories	0,61498113	bar

Elbows

C 90º =0,15
Cang=0,15*ang/90º

Central tee 0

Tees

Ct	1,3	Ql/Qt=1
Ct	1	Ql/Qt=0,5
Ct	0,9	Ql/Qt=0,2

Valves

Ball	1
Check	1,2
Selector	2,2

AP pipe= $\lambda * L * \rho * v^2/(200*dhy)$

AP height= $h * \rho * g/100000$

AP accesories= $\Sigma c * \rho * v^2/200000$

Figure 14.- RG Systems Pressure Drop Calculation sheet.

17 Index of Figures and Tables