

ELABORATION OF A FIRE PREVENTION AND FIRE FIGHTING PROJECT IN THE MANAUS-AMAZONAS CITY

Matheus Pereira da Silva¹, David Barbosa de Alencar², Davi Samuel Dias Maia³ and Igor Felipe Oliveira Bezerra⁴

¹ Braulo Cardoso de Mattos Higher Education Institute – FASERRA. Manaus-Amazonas, Brazil.

^{2,3} Galileo Institute of Technology and Education of the Amazon – ITEGAM. Manaus-Amazonas, Brazil.

⁴ Nilton Lins University. Manaus-Amazonas, Brazil.

Email: matheuslv2012@gmail.com, david002870@hotmail.com, davidm39@gmail.com, igor.bezerra@uniltonlins.edu.br

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ABSTRACT

There is a known shortage in the technical literature regarding fire prevention and fire fighting, which is often not even a constant subject in the curriculum of engineering courses. In Manaus, fire projects are regulated by the Fire Brigade Technical Standards, so there is often a technical deficiency in the preparation of these projects. In this context this work is inserted, aiming to provide a logical and normative roadmap for the correct design of fire prevention and fire prevention facilities. The object of study adopted is a Shed of 2,112.00 square meters, located in the West Zone of Manaus. The design determined a mixed fire fighting system between extinguishers and fire hydrants, requiring the adoption of elevated reservoir systems and fire pumps.

Keywords: Prevention, Fire, Water Pumps.



I. INTRODUCTION

There is a close relationship between the discovery of fire, its use as a tool and the beginning of technological advances in the early Paleolithic period. Once under control, man used fire in exquisite innovations and gained the primacy and control under his surroundings to begin to develop the first great civilizations.

However, historically the use of fire has had consequences, such as the 64 AD fire in Rome, which devastated the metropolis and the 1666 AD fire in London. This history of major fires has led to a natural evolution in fire fighting systems.

In Brazil, it was no different, with outdated legislation behind the rest of the world, it was only after the Joelma Building fire [1] in 1975 that modern prevention techniques were developed, with prior control of projects, and supervision of normative criteria by the Fire Department, the Table below shows the history of large fires in Brazil.

Table 1: Fires in Brazil.

Fires and Tragedies in Brazil		
Gran Circo Norte Americano (1961)	RJ	500 dead and 800 injured ²
Edifício Andraus (1972)	SP	16 dead and 332 injured
Edifício Joelma (1974)	SP	179 dead and 320 injured
Edifício Grande Avenida (1981)	SP	17 dead and 53 injured
Pojuca (1983)	BA	100 dead and 200 injured
Vila Socó (1984)	SP	500 dead ²
Osasco Plaza (1996)	SP	45 dead and 482 injured
Boate Kiss (2013)	RS	242 dead and 680 injured

Source: [2].

1. Some images in this manual were obtained from the internet.
2. Approximate or estimated values.

In fact, Brazil has an unfortunate history of fires, resulting from the negligence of engineering professionals with the necessary regulations for the approval of the Fire Department, a fact that often occurs due to ignorance of people.

In this context, this course completion work is a means of disseminating, by practical example, the application of technical standards and analysis and design tools for firefighting installations.

II. LITERATURE REVISION

II.1 FIRE THEORY

Humankind incorporated fire into its routine thousands of years ago, and over time it has been establishing better ways to control and deal with it in ways that compromise its integrity less and less. However, one of the remaining challenges is full control of fire. Equipment has been developed and strategies designed to prevent the unbridled spread of the flames, but eventually they get out of control, and this episode we call Fire (Conflagration) [3].

Fire is a chemical reaction that occurs with the rapid oxidation of combustible material with air by a heat source that generates flame, releases heat, emits smoke, gases and other debris [4]. Fire can also be called combustion, which is the exothermic reaction that consists of combining combustible material with oxidizer (oxygen from the air), which initiates a chemical reaction when in contact with air [5].

A [6] conceptualizes fire as a combustion process characterized by the emission of light and heat. According to [7], fire can also be called combustion, which is an exothermic reaction, and for the phenomenon of fire to occur, there must be the simultaneous occurrence of four essential elements, which are:

- fuel; Oxidant (oxygen); Heat; Chain reaction.

Fuels are the materials susceptible to burning, that is, what will be consumed by the flames, can be solid, liquid or gaseous.

Comburent is the chemical agent that activates and conserves combustion, combining with fuel gases or vapors to form a flammable mixture. In other words, oxidizer is considered the oxygen present in atmospheric air. To maintain the occurrence of fire, the percentage of oxygen present in the environment cannot be less than 14% by volume. [2], Oxygen is the most common of oxidants, since its constant presence in the atmosphere (21% in air) allows the burning to develop quickly and completely. However, in environments where oxygen supply is reduced or consumed during combustion a combustion depletion is observed, with less enthusiastic flames and a predominant presence of embers when the concentration is between 15% and 9% and finally with combustion termination occurring in environments where oxygen supply in the air is less than 9%.

Heat is the energy that initiates, maintains and encourages the spread of fire. It is the causative agent of the chemical reaction of the flammable mixture from the combustion of fuel and oxidizer.

Chain Reaction is a heat transfer from one molecule of the combustion material to the still intact neighboring molecule, which will heat and ignite, successively, until all material is in combustion.

Combustion then is nothing more than the reaction involving these four elements, didactically represented by the fire tetrahedron:

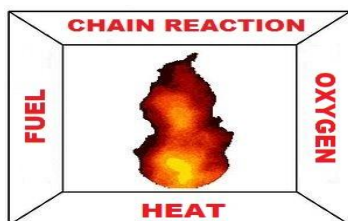


Figure 1: Fire Tetrahedron.
Source: [2].

II.2 FIRE THEORY (CONFLAGRATION)

For [8] fires are classified according to combustible material, and can be described in six different classes, which are: A, B, C, D, K and I.

This classification was prepared by NFPA - National Fire Protection Association / USA, and adopted by the following institutions: IFSTA - International Fire Service Training Association/ USA; ABNT - Associação Brasileira de Normas Técnicas e Corpo de Bombeiros (Brazilian Association of Technical Standards and Fire Departments) / BR.

- Class "A": fire in solid fuels such as wood, paper, fabric, rubber, etc. These materials burn at surface and depth and, because of their volume, leave residues after combustion such as ashes and embers. The best method of extinction is cooling, mainly by the action of water, which is the most effective extinguishing agent, and by muffling, as a secondary action.

- Class "B": fire in flammable liquids and gases or solid fuels such as gasoline, oil, kerosene, liquefied petroleum gas (LPG), etc. It is characterized by leaving no residue and burning only on the exposed surface. The best extinguishing method is by muffling, by breaking the chemical chain reaction, and the best extinguishing agent for this case is the mechanical foam, and may also use dry chemical powder and gases.

- Class "C": fire in energized materials and equipment, such as motors, transformers, generators, electrical panels, etc. For extinguishing fires of this class clean agents should be used and carbon dioxide (CO₂) the best agents for this class of fire.

- Class "D": fire in combustible metals such as magnesium, selenium, antimony, lithium, potassium, fragmented aluminum, zinc, titanium, sodium and zirconium and etc. It is characterized by burning at high temperatures and reacting with common fire extinguishers agents, especially if it contains water. To extinguish this type of fire, special dry chemical powder extinguishing technique, equipment and agents are required.

- Class "K": fire involving vegetable oil and animal fat, either in solid or liquid state, with commercial or industrial kitchens as an example of environments. This class is still little known in Brazil, and for the extinguishing of this type of fire, extinguishing agents are required to provide excellent coverage in the form of a muffled sheet.

- Class "I": fire involving radioactive and chemical materials in large proportions, requiring highly trained equipment and teams. There is not enough technical literature to safeguard this fire class.

The fire presents a phase of evolution, as stated by [9], the phases of the fire can be simplified between Ascending and Descending.

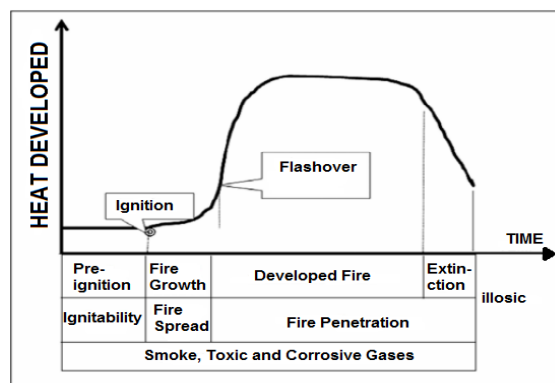


Figure 2: Fire Evolution.
Source: [9].

III. MATERIALS AND METHODS

For the elaboration of this article, an evaluation was first made about the place to be dimensioned and its surroundings. After this, we sought in the technical-normative references the practical criteria to define the fire fighting techniques to be adopted.

III.1 DESCRIPTION OF THE COMPANY EVALUATED



Figure 3: Company Location.
Source: Authors, (2019).

Address: José Tadros Street, Neighborhood: Santo Antônio - Manaus, AM.

Construction Type: Industrial Shed.

Total Area: 2,747.00 m²

Constructed Area: 2.112,00 m²

The venture was intended to act as a commercial deposit, of inputs brought upon importation, with medium flammability potential.

It has a medium construction standard, with galvanized roofing, structured under metal profiles, concrete block masonry walls and reinforced concrete floor.



Figure 4: Company Interior.
Source: Authors, (2019).

IV. RESULTS

IV.1 BUILDING FRAMEWORK

According to the characteristics of the project, the framework will be defined, which will define specific dimensioning issues.

Building Height 7,0 m - Classification II (According to Table below):

Table 2: Height Classification.

Type	Height
I	Ground Floor
II	H ≤ 6,00 m
III	6,00 m < H ≤ 12,00 m
IV	12,00 m < H ≤ 23,00 m
V	23,00 m < H ≤ 30,00 m
VI	Above de 30,00 m

Source: [10].

Occupation: Flammable Potential Material Storage Area between 300 MJ / M² to 600 MJ / M².

Risk: Risk defined as Medium Risk, according to Table 3.

Table 3: Risk Rating.

Risk	Fire charge MJ/m ²
Low	Up to 300MJ/m ²
Medium	Between 300 and 1.200MJ/m ²
High	Over 1.200MJ/m ²

Source: [10].

Protected Area: 2,112.00 m².

According to NT 01/2014, the project falls into category J - 3.

IV.2 EXTINGUISHER SIZING

In line with current NT, the number of extinguishers has been sized so that they are located no more than 5 meters away from access doors and stairs.

Since the building is considered as Medium Risk, the extinguishers obey the spacing within a radius of 20 meters, as shown in the tables below.

Table 4: Fire Hazard Classification.

Domain Area	Fire Hazard	Maximum distance to be traveled
500 m ²	Small (Class A)	20 m
250 m ²	Medium (Class B)	10 m
150 m ²	Large (Class C)	10 m

Source: [11].

Table 5: Structure Risk classification.

Structure fire hazard	Distance to be traveled
Small (Class A)	25m
Medium (Class B)	20m
Large (Class C)	15m

Source: [11].

Were dimensioned for the project 18 standard ABC Fire extinguishers of 6.0 KG.

In the case of extinguishers, regarding the execution, the technical norm will be obeyed: The extinguishers must be sealed, with due pressure and have a seal of conformity granted by a body accredited by the Brazilian Certification System (Inmetro). For inspection by the Fire Department, the expiry date of the charge and the operation guarantee of the extinguishers shall be as set by the manufacturer, if new, or by the Inmetro-certified maintenance company if it is recharged.

The extinguisher will be demarcated under the pavement with the following pattern:

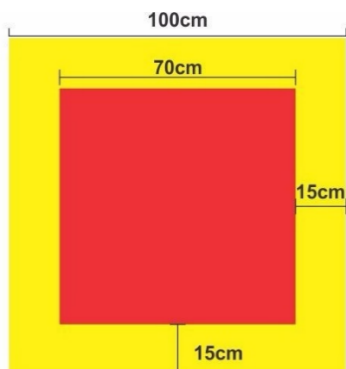


Figure 5: Fire Extinguisher Demarcation. Source: [11].

IV.3 HYDRANT SIZING

The sizing took place in accordance with the technical norms, so that criteria were obeyed:

In any building, sizing shall consist in determining the necessary and sufficient piping, diameters, fittings and supports to ensure the operation of the systems provided for in this Standard.

Fire hydrants or mangotinhos should be distributed in such a way that any point in the area to be protected is reached by one (type 1 system) or two (type 2 and 3 systems) nozzles, considering the length of the hose (s) and its actual path and disregarding the range of the water jet.

For sizing, it should be considered the simultaneous use of the two water jets most unfavorable hydraulically, for any type of system specified, considering at least the flows obtained according to table 1 and conditions.

The system must be dimensioned so that the dynamic pressures on the inputs of the squirts do not exceed twice that obtained in the most unfavorable squirt hydraulically. You can use any pressure reduction devices, provided that you have proven your technical adjustments.

It is recommended that the system be dimensioned so that the maximum working pressure, at any point in the system, does not exceed 1 000 kPa. Situations that require pressures exceeding the stipulated will be accepted, provided that the technical adequacy of the components employed and fulfilled the requirement specified in.

The hydraulic calculation of the pipes must be performed by methods suitable for this purpose, and the results achieved must satisfy one of the following equations:

$$h_f = f \cdot \frac{L \cdot v^2}{D \cdot 2 \cdot g}$$

Figure 6: A) Colebrook ("universal formula"). Source: [12].

Where: h_f is the load loss, in meters of water column; f is the friction factor; L is the virtual length of the pipe (pipes + fittings), in meters; D is the inner diameter, in meters; v is the velocity of the fluid, in meters per second; g is the acceleration of gravity, in meters per second, per second;

$$J = 605 \times Q^{1,85} \times C^{-1,85} \times D^{-4,87} \times 10^4$$

Figure 7: B) Hazen Williams. Source: [12].

Where: J is the loss of friction load, in kilopascals per metre; Q is the flow rate, in liters per minute; C is the factor of Hazen Williams (see table 3); D is the inner diameter of the tube, in millimeters.

The water velocity in the suction tube of the fire pumps should not be more than 5 m/s, which should be calculated by the equation: $A Q V =$; For the area should be considered the internal diameter of the pipe where: V is the water velocity, in meters per second; Q is the water flow, in cubic meters per second; A is the inner area of the pipe, in square meters.

The maximum water speed in the pipe shall not exceed 5 m/s, which shall be calculated according to the equation indicated; The calculation of the load loss factor occurs according to the option of the material and the query to the table:

Table 6: Roughness factor.

Tube type	Factor "C "
Cast iron or ductile without internal coating	100
Black steel (dry tube system)	100
Black steel (wet tube system)	120
Galvanized	120
Plastic	150
Cast iron or ductile without internal cement coating	140
Copper	150

Source: [13].

IV.4 HYDRANT POSITIONING

The water outlets must be positioned:

- (a) in the vicinity of external doors and/or accesses to the area to be protected, not more than 5 m;
- (b) in central positions in protected areas;
- (c) outside of the stairs or smoke antechambers;
- (d) from 1.0 m to 1.5 m from the floor.

In external hydrants, when they are removed at least 15 m or 1.5 times the height of the external wall of the building to be protected, can be used up to 60 m of hose (preferably in bids of 15 m), provided that properly dimensioned hydraulically. It is recommended to use 65 mm diameter hoses to reduce the system load loss and the last bid of 40 mm to facilitate handling.

The use of the system should not compromise the escape of the occupants of the building; Therefore, it must be designed in such a way that it gives protection throughout the building, without the need to enter the stairs, antechambers or other places determined exclusively to serve as an escape route for the occupants.

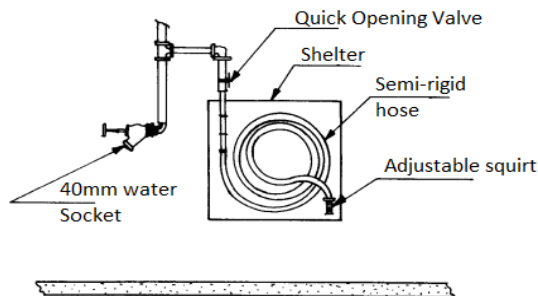


Figure 8: System model. Source: [13].

All hydrant or mangotinhos points must be signalling according to NBR 13435, in order to allow their quick location.

IV.5 RESERVOIR SIZING

According to [4] the reservoirs can be classified as upper or lower and the volume is defined by the flow of the type of hydrant indicated by the 13714/2011 standard and the operating time which is 1 hours for types 1 and 2:30 hour for type 3. For type 2 hydrants with a flow rate of 300l/min The Minimum Fire Technical Reserve (RTI) should be 36000l. It is important to emphasize that the standard determines the simultaneous use of at least two hydrants and that the minimum flow rate should meet the hydrants or mangotinhos less Favorable, those with lower pressure.

According to [12] of the São Paulo Fire Department, one can admit to the undertaking a fire technical reserve of 12,000 liters.

Table 7 – Reservoir Sizing.

AREAS OF BUILDINGS AND AREAS OF RISK	CLASSIFICATION OF BUILDINGS AND AREAS OF RISK				
	A-2, A-3; C-1; D-1 e D-3 (up to 300 MJ/m²); D-2 e D-4; E-1, E-2, E-3, E-4, E-5, E-6; F-1 (up to 300 MJ/m²); F-2, F-3, F-4, F-8; G-1, G-2, G-3, G-4; H1, H-2, H-3, H-5, H-6; I-1; J-1, J-2; M-3.	B-1, B-2; C-2 (above 300 até 1000 MJ/m²); C-3; D-1 (above 300 MJ/m²); D-3 (above 300 MJ/m²); F-1 (above 300 MJ/m²); F-5, F-6, F-7, F-9, F-10; H-4; I-2 (above 300 up to 800 MJ/m²); J-3 (above 300 up to 800 MJ/m²).	C-2 (above 1000 MJ/m²); I-2 (above 800 MJ/m²); J-3 (above 800 MJ/m²); L-1; M-1 e M-10.	G-5, G-6; I-3; J-4; L-2 e L-3.	
Above 2 500 m²	Type 1 RTI 5 m³	Type 2 RTI 8 m³	Type 3 RTI 12 m³	Type 4 RTI 28 m³	Type 4 RTI 32 m³
Above 2500 m² up to 5000 m²	Type 1 RTI 8 m³	Type 2 RTI 12 m³	Type 3 RTI 18 m³	Type 4 RTI 32 m³	Type 4 RTI 48 m³
Above 5000 m² up to 10000 m²	Type 1 RTI 12 m³	Type 2 RTI 18 m³	Type 3 RTI 25 m³	Type 4 RTI 48m³	Type 5 RTI 64 m³
Above 10000 m² up to 20000 m²	Type 1 RTI 18 m³	Type 2 RTI 25 m³	Type 3 RTI 35 m³	Type 4 RTI 64 m³	Type 5 RTI 96 m³
Above 20000 m² up to 50000 m²	Type 1 RTI 25 m³	Type 2 RTI 35 m³	Type 3 RTI 48 m³	Type 4 RTI 96 m³	Type 5 RTI 120 m³
Above 50000 m²	Type 1 RTI 35 m³	Type 2 RTI 48 m³	Type 3 RTI 70 m³	Type 4 RTI 120 m³	Type 5 RTI 180 m³

Source: [12].

IV.6 SIZING PIPES

The sizing of pipelines was made by tracing and calculating the lengths and differences of quota, and applications of the distributed load loss, inserting the values in the table below:

Table 8: Conductos dimensioning.

Stretch	Flow lpm	P Valve Mca	Load loss (pipig)						Elevation m	v (m/s)	P amount mca
			D (mm)	L _{real}	L _{virtual}	L _{total}	J _{upik}	J _{total}			
BI – HA	200,0	40,01	65	34,20	11,50	45,70	0,032	1,48	0,60	1,005	42,09
BI – HB	200,0	42,09	65	120,87	7,20	128,07	0,032	4,14	0,60	1,005	46,83
BI-RI	400,0	46,83	65	4,95	5,20	10,15	0,117	1,18	0,00	2,009	48,01

Source: Authors, (2019).

Table 9: Fire Pump Sizing.

Fire Pump and RTI	
H _{man} = 48 mca	Fire Technical Reserve
Flow = 400 l/min (24,0 m³/h) (X) High	Volume: 12 m³
Pot = 9,5 cv	() Underground
	() Ground level

Source: Authors, (2019).

V. FINAL CONSIDERATIONS

As demonstrated, there is a logical sequence for sizing, where normative criteria often merge into different technical norms, treating each fire-fighting device differently, which may cause some difficulty the designer at the time of dimensioning.

Within the scope and initial premise, a step-by-step was elaborated, collecting didactic and expository tables along different technical norms, between NBRs, NT's and memorials, in order to expose a clear relationship between that required by law and what options Available to the designer.

For the analyzed undertaking, a system with the use of a hydrant was defined, with a technical reserve of 12,000 liters and a fire pump of 9.5 CV, with the hand of spreadsheets to assist with the various calculations preposed by NBR 13,475, in order to facilitate the Sizing process.

Finally, the work concludes a normative roadmap that can help other designers in the analysis and sizing of prevention and fire-fighting projects, in order to disseminate the technical knowledge and collaborate with the current literature in this area.

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