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Mechanical Engineering Department

Graduation Project

Portable Water Mist Fire Extinguishing Using Pressurized Air

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Abstract

The progress on the research and application of Portable Fire Fighting System in fire suppression has been substantial over the last decade. To bring this work into focus, a review has been undertaken to identify future developments and potential efficacy improvements for portable fire suppression system. This report, provides a review of the fundamental research in water fire suppression systems. This includes a review of extinguishing mechanisms and the factors that influence the performance, such as spray characteristics, enclosure effects, dynamic mixing, the use of additives and methods of generating water mist.

The overall aim of the project is to finalize a design and building a portable water mist based fire fighting system which will ensure rapid extinguishing of fire with easy operation.

The system should be suitable for various types of fire, the total weight of the system about (20-30) kg to be easily carried and the lunching distance of water between (10-20) meter to reach the fire and increase safety to the fire man .

Table Of Contents

Chapter One

Chapter Two

Chapter Three

Chapter Four

Chapter Five

Chapter One

General Introduction

1.1 Project Background.

1.2 Project Goals and Objectives.

1.3 Project Choice Justification.

1.4 Project Implementation Plan.

1.5 Preliminary Budget.

1.1 Project Background

Fire is arguably one of the most dangerous and most useful elements. Fire represents the power of civization, through cooking, and the production of light and power to industry. It represents the power of destruction in that it is a threat to human farm, forest, and city alike.

According to the Palestine based on data received from the Police Department and reports of the Ministry of Health in 2003 records 167 injuries resulting from fires, distributed to 63 fires in Gaza and 104 fires in West Bank.

In a report to the Department of Public Relations and Humanity in the Civil Defense for accident statistics and interventions and a summary of the achievements that have dealt with the crews of rescue and fire within the statistical annual, with an explicit note in a high incidence of rescue (15%) and a rise in fires and incidents of fire (48%), which resulted Reported a rise in the number of casualties by (61%) from last year, and was more cause of the fire common is neglect (30%), mayors by (20%) and the futility of children (12%) and to seek power (4%) of the total accidents and accounted for road accidents The highest in the rescue and incidents recorded (42%) and evacuate the population and water drainage rate (33%) of the total accidents rescue crews spotted in attacks by settlers and the army of occupation on the Palestinian Territories and set fire to (116) times.

As written above there is lake in materials and so in machine that can meet the needed of fire fighting, to face these problems the civil defense department in Bethlehem proposed this project that must be small, light to be carried by the fire man, this portable fire fighting device will be easy to carry to able the fire fighting man reach the high buildings and far places that can't be reached by the fire fighting vehicle .

1.2 Project Goals and Objectives.

The overall aim of the project is to finalize a design and building a portable water mist based fire fighting system which will ensure rapid extinguishing of fire with easy operation. Specifically the project intends to:

1. Finalize the design of water mist based fire fighting system using compressed gas as propellant.
2. Design the complete system which will be backpack and handheld as well.
3. Build this device locally.
4. Make it easily to have by the famous public place.
5. Can face most of the fire classes

1.3 Project Components and Concept.

The system consists of two cylinder one of them contains water with capacity of 10 liter that is suitable to this portable system , another cylinder contains pressurized gas at specific pressure that will be determined later by calculation , the selection of other component that needed such as valves , pipes and nozzle based on the pressure developed in calculation.

The system should be suitable for various types of fire that will be discussed in Chapter Two, the total weight of the system about (20-30) kg to be easily carried and the lunching distance of water between (10-20) meter to reach the fire and increase safety to the fire man .

The concept of the system is that the pressurized gas from the gas cylinder through pipes and valves will force the water from water cylinder to exit though the nozzle toward the fire .

Figure (1.1) show the main component and concept of the system.

Figure 1.1 : Main Components and Concept of the System.

1.3 Project Choice Justification

Civil defense department in Bethlehem requires a design of a fire fighting system which can be easily carried to extinguish fires in the unreachable places and high building by fire fighting vehicle. The project will create sufficient experience for the students, which assist them in having an employment opportunity after graduation. Such a project provides the opportunity to apply what have been studied in five years in the engineering college.

1.4 Project Implementation Plan

The project will be performed at two stage the first one at the first semester and the other one in the second semester , the two stage will be discussed as follow :

- The first one is for:
    1. Design the system .
    2. Choose the materials.
    3. Select the valves and nozzle.
- The second one will be for:
    1. Check the design.
    2. Build the system.
    3. Check the safety.

1.4.1 Main Tasks and Activities

The main tasks for the first semester include:

1. Selecting the project name and problem
2. Finding the concepts and goals.
3. Scientific background on fire fighting systems.

4. Literature review and gaining.
5. Design calculations including mechanical design of cylinders, fluid mechanical.
6. Choose the valves and ancillary system.
7. Ensure safety of the system and its efficiency.
8. Preparing the report for the first stage.

1.4.2 Time Table

The time table for the first semester is illustrated in Table 1.1.

Table 1.1: The time table for 1st semester.

Objective	Week number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selecting project title	▨	▨														
Planning and Setting Project Concepts and Goals			▨	▨												
Establishing Scientific Background					▨	▨										
Literature Review				▨	▨	▨	▨	▨	▨	▨	▨					
Make a Preliminary Design for Project										▨	▨	▨				
Choose the Material and Find it													▨	▨	▨	
Find the Ancillary System, and Valve													▨	▨	▨	
Check the Safety														▨	▨	▨
Write the Final Report							▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

The main tasks for the second semester include;

1. Building and installing the project and its control.
2. Test the project and its operateablity
3. Preparing documentation, summarizing the results and recommendation, and making presentation about the project.

Table 1.2 Time table for the 2nd semester

	Week number															
Objective	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Collect the Material	▨															
Build the Final Design		▨	▨	▨												
Check the Safety					▨	▨	▨	▨	▨	▨	▨	▨				
Try the Device												▨	▨	▨	▨	
Recheck the Survivability															▨	▨
Write the Result							▨	▨	▨	▨	▨	▨	▨	▨	▨	
Write the Recommendation							▨	▨	▨	▨	▨	▨	▨	▨		
Final Report															▨	▨

1.6 Preliminary Budget

Preliminary estimates are made for the project components as listed in table 1.3. The total estimate budget is 650 JD

Table 1.3: Preliminary budget

Item	Estimated cost (JD)	Note
Materials	100	
Transportation	50	Will cover by Project Team
Valves	500	
Cylinders	-	Will given from CDD by free
Others	20	
Total	670 JD	

Chapter Two

General of Fire and the Principle of Fighting

2.1 Basics of a Fire.

2.2 Fundamentals of a Fire.

2.3 The Fire Triangle.

2.3.1 Fuel

2.3.2 Oxygen

2.3.3 Heat

2.4 Hazardous/Combustible Materials.

2.4.1 Flames

2.4.2 Heat

2.4.3 Gases

2.4.4 Smoke

2.5 Classification of Fires.

2.6 Extinguishing agents.

2.7 Extinguishing Capabilities of Water.

2.1 Basics of a Fire

Fire is a phenomenon with which everyone is familiar. We use it daily to heat our homes and cook our meals. When harnessed, the power and energy from fire serves us well; however, when it is uncontrolled, a fire can quickly consume and destroy whatever lies in its path. While we are all familiar with fire, few of us are aware of its nature and complex processes. This Section examines the phenomena and various mechanisms at work within a fire and is intended to provide a better understanding of the requirements in fire-fighting scenarios.

2.2 Fundamentals of a Fire

The combustion process, or burning , is in fact the rapid oxidation of millions of fuel molecules in the vapor form. Once there is sufficient oxygen and the fuel vapor molecules properly mix, an ignition source is typically needed for oxidation to be initiated. However, once oxidation is initiated, it is an exothermic process. If sufficient energy is released during the reaction to maintain the elevated temperature of surrounding oxygen and fuel molecules, and there are sufficient oxygen and vaporized fuel molecules available, then the oxidation process will continue. The heat released by the oxidation of the fuel molecules is radiant heat, which is pure energy, the same sort of energy radiated by the sun and felt as heat. It radiates, or travels, in all directions. Thus, part of it moves back to the seat of the fire, to the "burning" solid or liquid (the fuel). The heat that radiates back to the fuel is called radiation feedback. This part of the heat serves to release more vapors and also serves to raise the vapor (fuel and oxygen molecule mixture) to the ignition temperature. At the same time, air is drawn into the area where the flames and vapor meet The result is that the newly-formed vapor begins to burn and the flames increase, which starts a chain reaction. The burning vapor produces heat, which releases and ignites more vapor. The additional vapor burns, producing more heat, which releases and ignites still more vapor. As long as there is fuel and oxygen available, the fire will continue to grow. For a fuel source with a limited amount of surface area available, the amount of vapor released from the fuel reaches a maximum rate and begins to level off, producing a steady rate of burning. This usually continues until most of the fuel has been consumed When there is less fuel vapor available to oxidize, less heat is produced and the process begins to die out. A solid fuel may leave an ash residue and continue to smolder for some time, while a liquid fuel usually burns up completely.

2.3 The Fire Triangle

There are three components required for combustion to occur:

1. Fuel – to vaporize and burn .
2. Oxygen – to combine with fuel vapor.
3. Heat – to raise the temperature of the fuel vapor to its ignition temperature .

The following is the typical "fire triangle", which illustrates the relationship between these three components:

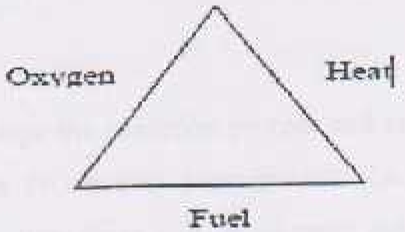


figure 2.1: fire triangle

There are two important factors to remember in preventing and extinguishing a fire:

i) If any of the three components are missing, then a fire cannot start.
ii) If any of the three components are removed, then the fire will go out.

It is important to have a clear understanding of these three components and their inter-reactions in a fire. The following Paragraphs examine each of these items in further detail.

2.3.1 Fuel

Fuel is necessary to feed a fire, and without fuel, the combustion process will terminate. The fuel molecules involved in a fire must be in the vapor (gas) state. However, the initial fuel source may be in a solid, liquid or gaseous state. Many examples of each type of these fuels can be found onboard a vessel.

2.3.2 Oxygen

Because the combustion process involves the oxidation of the fuel molecules, the availability of oxygen is vital for the process to exist. Accordingly, the second side of the fire triangle refers to the oxygen content in the surrounding air. Air normally contains about 21% oxygen, 78% nitrogen and 1% other gases, principally argon, and therefore, sufficient oxygen is typically available unless some type of controlled atmosphere (i.e., inerted, etc.) is involved.

2.3.3 Heat

For fuel molecules to undergo the oxidation process and result in a self-supporting fire, the molecules must be at elevated temperatures (i.e., ignition temperature). Without this elevated temperature, there will be no rapid oxidation or combustion of the fuel molecules. Further, the generation of additional fuel vapors is largely dependent upon feedback radiant heating of the fuel, except for gaseous fuels. Therefore, heat is the third side of the fire triangle. The production of energy from the initial reaction tends to raise the temperature of other molecules to the necessary elevated temperatures and tends to create the self-supporting nature of fire.

2.4 Hazardous/Combustible Materials

There are a number of hazards produced by a fire, including flames, heat, gases and smoke. Each of these combustion products can cause serious injuries or death and should be considered in the overall scope of fire-fighting arrangements onboard a vessel.

2.4.1 Flames

The flaming region of a fire is that portion of the combustion zone where the fuel and oxygen molecules are of an appropriate mixture and temperature to support the oxidation process. The direct contact with flames can result in totally or partially disabling skin burns and serious damage to the respiratory tract. To prevent skin burns during a fire attack, crewmen must maintain a safe distance from the fire unless they are properly protected and equipped for the attack. This is the reason that protective clothing, such as fireman's outfits, is required by the Rules. Respiratory tract damage can be prevented by wearing breathing apparatus.

2.4.2 Heat

As a result of a fire, the temperature in an enclosed space can reach temperatures in excess of 93°C (200°F) very rapidly, and the temperature can build up to over 427°C (800°F) quickly. Temperatures above 50°C (122°F) are hazardous to humans, even if they are wearing protective clothing and breathing apparatus. The dangerous effects of heat range from minor injury to death. Direct exposure to heated air may cause dehydration, heat exhaustion, burns and blockage of the respiratory tract by fluids. Heat also causes an increased heart rate. A firefighter exposed to excessive heat over an extended period of time could develop hyperthermia, a dangerously high fever that can damage the nerve center.

2.4.3 Gases

The particular gases produced by a fire depend mainly on the fuel. The most common hazardous gases are carbon dioxide (CO2), the product of complete combustion, and carbon monoxide (CO), the product of incomplete combustion. Carbon monoxide is the more dangerous of the two. When air mixed with carbon monoxide is inhaled, the blood absorbs the CO before it will absorb oxygen. The result is an oxygen deficiency in the brain and body. Exposure to a 1.3% concentration of CO will cause unconsciousness in two or three breaths and death in a few minutes. Carbon dioxide works on the respiratory system. Above normal CO2 concentrations in the air reduce the amount of oxygen that is absorbed in the lungs. The body responds with rapid and deep breathing, which is a signal that the respiratory system is not receiving sufficient oxygen. When the oxygen content of air drops from its normal level of 21% to about 15%, human muscular control is reduced. At 10% to 14% oxygen in air, judgment is impaired and fatigue sets in. Unconsciousness usually results from oxygen concentrations below 10%. During periods of exertion, such as fire-fighting operations, the body requires more oxygen, and these symptoms may then appear at higher oxygen percentages. Depending upon the fuel source, there may be several other gases generated by a fire that are of equal concern to firefighters. Therefore, anyone entering a fire must wear an appropriate breathing apparatus.

2.4.4 Smoke

Smoke is a visible product of fire that adds to the problem of breathing. It is made up of carbon and other unburned substances in the form of suspended particles. It also carries the vapors of water, acids and other chemicals, which can be poisonous or irritating when inhaled.

2.5 Classification of Fires:

In fire fighting, fires are organized into several fire classes that describe what kind of fuel or heat source it has, and by extension which methods will be necessary to contain it or put it out. This paragraph deals with both the United States system and the European-Australasian system of classifying fires.

• The United States Fire Classification

– **Class-A fires**: are the most common type of fire, that occurs when a material, such as wood, becomes sufficiently hot, and has oxygen available to it, causing combustion. When the material bursts into flame, it will continue burning as long as heat, fuel, and oxygen continue to be available to it. Class-A fires are used all around buildings and everywhere in the world in controlled circumstances, such as a campfire, lighter, match, or candle. When a class-A fire burns in an environment where fuel and oxygen are in accessible positions, the fire can quickly grow out of control: this is the case where fire fighting and fire control techniques are required.

– **Class-B fires**: are combustible fuels, hydrocarbons or solvents on fire.Class-B fires follow the same basic as class-A fires, except that the fuel in question is a hydrocarbon or solvent.

– **Class-C fires**: are electrical fires, where the heat is caused by, for example, short-circuiting machinery or overloaded electrical outlets.

– **Class-D fires:** are metal fires. Certain metals, such as sodium, titanium, magnesium, potassium, uranium, lithium, plutonium, calcium and others are flammable.

– **Class-K fires**: are fires that involve cooking oils.

· **European and Australasian classifications**

In Europe and Australasia, a different classification system is used. The system is more or less the same as the U.S. system, with letter designations shifted around while the basic concepts and definitions are quite similar (for instance, Class C fires in the U.S system are known as Class E in Europe).

– **Class A**: fires that involve flammable solids such as wood, cloth, rubber, paper, and some types of plastics.

– **Class B**: fires that involve flammable liquids or liquefiable solids such as petrol/gasoline, oil, paint, some waxes and plastics, but not cooking fats or oils.

– **Class C**: fires that involve flammable gases, such as natural gas, hydrogen, propane, butane.

– **Class D**: fires that involve combustible metals, such as sodium, magnesium, and potassium.

– **Class E**: fires that involve any of the materials found in Class A and B fires, but with the introduction of an electrical appliances, wiring, or other electrically energized objects in the vicinity of the fire, with a resultant electrical shock risk if a conductive agent is used to control the fire.

– **Class F**: fires involving cooking fats and oils.

A generic fire occurring in a high rise building is usually a Class-A fire, and it could be partially a Class-B and/or a Class-C (i.e. European Class-E) fire.

2.6 Extinguishing agents

Each class of fire is best fought by a specific extinguishing agent. Class-A fires are fairly simple to fight and contain. This is done accordingly to a quite simple principle: by removing the heat or oxygen (or in some cases fuel), the fire should die out. The most common way to do this is by taking away the heat by spraying the fire with water. Other means of control or containment would be to 'smother' the fire with carbon dioxide or nitrogen from a fire extinguisher, cutting off its oxygen and causing the fire to die due to its 'suffocation'. Class-A fires are the most commonly encountered fires, and this is the reason why most fire departments have equipment to handle them specifically.

With Class-B fires, the strategy to be used when fighting them must change considerably, even if they follow the same basic as Class-A fires. As a matter of fact, the fuel in question is a hydrocarbon or solvent: if the fuel is a lighter than water liquid such as oil or gasoline, water that would ordinarily be used for fighting a Class-A fire would end up spreading the fire, as the on-fire hydrocarbon would float on top of the water and continue burning. Specialized methods are required to contain and put out this kind of fire, even if they are not usually available to regular fire departments. One method would be dropping or spraying a chemical retardant, such as slurry, onto the fire. This is usually done by plane, and the pumps required to handle a chemical retardant would not often be available to ground fire crews: this makes its use against class-B fires limited. On small class-B fires a carbon dioxide fire extinguisher may be used, though some fire extinguishers

are not designed to fight against all classes of fire. However, the most common method for fighting class-B fires would be to use a type of protein based foam to cut off the oxygen of the fire and cool the hydrocarbon/solvent: since it does not require any specialized equipment, this can be fired from any pump , even ones that were designed to hold only water. Unfortunately, most fire departments do not have direct access to foam and require it to be transported to them: this can delay fire fighters severely and make fighting class-B fires a logistical problem.

By definition, Class-K (i.e. European Class-F) is a subclass of Class-B, but the special characteristics of these types of fires are considered important enough to recognize it as an independent fire class. The high temperature of the oils when on fire far exceeds that of other flammable liquids making normal extinguishing agents ineffective.

U.S. Class-C fires (i.e. European Class-E fires) can be a severe hazard to fire fighters using water: when the solid stream of water hits the electrical fire, the electricity is conducted through it and into the hose, then into the body of the fire fighter: electrical shocks have caused many fire fighter deaths. There are two main ways of fighting a class-C fire: cutting off its oxygen, or simply turning off the electricity to the fire from a breaker. This last method is the primary approach, but if turning off the power could not be very simple, a class-C fire can be put out with a fire extinguisher rated for class-C fires, or with protein foam.

Between Class-D fires, magnesium and titanium fires are common. When one of these combustible metals ignites, it can easily and rapidly spread to surrounding class-A materials. Generally, masses of combustible metals do not represent usual fire risks because they have the ability to conduct heat away from hot spots so efficiently that the heat of combustion cannot be maintained. This means that it will require a lot of heat to ignite a mass of combustible metal. Commonly, metal fire risks exist when sawdust, machine shavings and other metal 'fines' are present, because they can be ignited by the same types of ignition sources that would start other common fires. Water and other common fire fighting agents can excite metal fires and make them worse. For this reason, the NFPA recommends that Class-D fires be fought with 'dry powder' extinguishing agents, which work by smothering and heat absorption. The most common of these agents are sodium chloride granules, graphite powder, and in recent years powdered copper has also come into use. Some extinguishers use dry chemical extinguishing agents, and this is easily confusable with dry powder, but they are quite different: using one of these extinguishers in error in place of dry powder can actually increase the size of a class D fire much like water. Class-D fires represent a unique hazard because people are often not aware of the characteristics of these fires and are not properly prepared to fight them. Therefore, even a small Class-D fire can spread Class-A fires to the surrounding combustible materials. Most fire stations do not have class-D extinguishing agents available to them, making fighting these fires a logistical problem, though in most places where these materials are found there is a hopper filled with the proper extinguishing agent.

Table 2.1: Fire classes in the international system

Fuel Source	Class of Fire	Extinguishing Agent
Ordinary combustibles (e.g. trash, wood, paper, cloth)	A	Water, chemical foam, dry chemical*
Flammable liquids (e.g. oils, grease, tar, gasoline, paints, thinners)	B	Carbon dioxide (CO_2), halon**, dry chemical, aqueous film forming foam (AFFF)
Electricity (e.g. live electrical equipment)	C	CO_2, halon**, dry chemical
Combustible metals (e.g. magnesium, titanium)	D	Dry powder (suitable for the specific combustible metal involved)

Table 2.1 is a first resume of fire classes related to their fuel sources and extinguishing agents. Between these agents, halon is mentioned referring to itself or to chemical agents which substituted it during the recent years. In fact halon extinguishers are no longer made (even if some may still be in use). Since a HRB fire should be a Class-A fire (and partially it could be a Class-B and Class-C/E fire), it is important to opt for one or more specific extinguishing agents in order to select the appropriate type of fire extinguishers. The following is a list of commonly used fire extinguishing systems and their corresponding A-B-C classes of fire (indicated in parentheses):

- Multi-Purpose Dry Chemical (A, B, C): a dry chemical agent called mono ammonium phosphate. The chemical is non-conductive and can be mildly corrosive if moisture is present. In order to avoid corrosion, it is necessary to scrub and thoroughly cleanup the contacted area once the fire is out. A dry chemical fire extinguisher is usually used in schools, general offices, hospitals, homes, etc.

- Halotron (A, B, C): a vaporizing liquid that is ozone friendly and leaves no residue. Because it requires no cleanup, fire extinguishers with Halotron are ideal for computer rooms, telecommunication areas, theaters, etc.

- Foam (A, B): foam oats on flammable liquids to tame the fire and helps prevent reflashes. To cleanup the affected area, it must be washed away and left to evaporate. Fire extinguishers with foam are usually used in garages, homes, vehicles, workshops, etc.

- Regular Dry Chemical (B, C): a dry chemical agent called sodium bicarbonate. It is non-toxic, non-conductive and non-corrosive. It is easy to cleanup, requiring only vacuuming, sweeping or flushing with water. Extinguishers with sodium bicarbonate are usually used in residential kitchens, laboratories, garages, etc.

- Carbon Dioxide (B, C): Carbon dioxide removes oxygen to stop a fire but has limited range. It is environmentally friendly and leaves no residue, so cleanup is unnecessary. Extinguishers with carbon dioxide are usually used in contamination-sensitive places such as computer rooms, labs, food storage areas, processing plants, etc.

- Purple K Dry Chemical (B, C): a dry chemical called potassium bicarbonate. It is non-conductive and non-corrosive. Clean up requires vacuuming , sweeping or flushing with water. Extinguishers with potassium bicarbonate are usually used in military facilities, oil companies, vehicles, etc.

- Water (A): the most common agent is water; however, usually it can not be used for class B or C fires because it is conductive. Water based fire extinguishers are usually used in stockrooms, schools, offices, etc.

Of all the agents cited above, water is one of the best to fight against Class-A fires. The major useful property of water as an extinguishing agent is its capacity to cool burning fuels to a temperature below which they cease to burn. In general this capacity substantially exceeds that of other extinguishing agents, including carbon dioxide and nitrogen, as indicated in table 2.2. The exception is the inability of water to cool fuels that can burn near or below normal ambient temperatures, particularly low flash point liquids like gasoline.

Table 2.2 : Maximum cooling capacity [J/g] of water and other agents for extinction processes

Agent	T^0	ΔH^*				ΔH^{**}	
	°C	0 °C	100 °C	250 °C	16 - 285	855	
H_2O	15	0	2612	2930	5617	2704	
CO_2 (solid)	−78	657	734	872	2156	1585	
N_2 (liquid)	−196	105	309	652	885	1685	

The most probable mechanisms acting when water droplets are supplied in the combustion zone, is a combination of oxygen depletion by production of steam, and cooling by the evaporation of water. The water may influence the heat transfer from the fire to the compartment and the surrounding in several ways: it may reduce the temperature of the gases inside the room and in the effluent gases, leading to less heat transfer to the walls, the ceiling, the floor and to objects close to the outlet opening. Surfaces are directly cooled by impinging water droplets. Moreover, the content of water droplets and vapor increases the absorptivity of the gases inside the fire room, reducing consequently the radiation from the flames to surfaces. The amount of heat removed by the water is dominated by the amount of water which is evaporated. The proportion of heat necessary to bring the water from the normal tap water temperature to the boiling point and the heat of evaporation is (1/6). This means that evaporating the water inside the room is the most effective way of taking heat out of a fire compartment.

2.7 Extinguishing Capabilities of Water

Water primarily extinguishes a fire by the removal of heat. It absorbs heat more effectively than any other commonly used extinguishing agent due to its good thermal conductivity and its high latent heat of vaporization. It is most effective when it absorbs enough heat to raise its temperature to 100°C (212°F). At that temperature, water absorbs additional heat as it goes through the transition from a liquid to a vapor (i.e., steam). In the process of heating the water from normal temperatures, up through its conversion into steam, water absorbs approximately 2.6 kilo-joules of heat per gram (1117 BTU/lb) of water, which is a much higher heat absorption value than any other agent. This absorption of heat reduces the temperature of the burning vapors and also reduces the amount of vapor being generated by the cooling of the fuel surface. With adequate cooling, there is insufficient heat to maintain the self-supporting combustion process and the fire goes out. Water also has an important secondary effect. When it turns to steam, it expands about 1600 times in volume at atmospheric pressure. As a result, one cubic meter (cubic foot) of water can generate up to 1600 cubic meters (cubic feet) of steam vapor. This great cloud of steam surrounds the fire, displacing the air that supplies oxygen for the combustion process. Thus, water provides a smothering action as well as cooling.

Chapter Three

3.1 Portable Fire Extinguishers

3.1.1 Dry Chemical Extinguisher

3.1.2 Carbon Dioxide Fire Extinguisher

3.1.3 Aqueous Film-Forming Foam Fire Extinguisher

3.1.4 Portable Water Mist

3.2 Water Mist

3.2.1 Water Mist System Description

3.2.2 Extinguishing Mechanisms

3.2.3 Water Mist Droplets

3.2.4 Water Mist Pressure and Droplet Size

3.2.5 Methods of Generating Water Mist

3.1 Portable Fire Extinguisher

Portable fire extinguishers are used aboard all Navy ships, and the three types most often used are as follows.

- Dry chemical
- Carbon dioxide (CO2)
- Aqueous film-forming foam (AFFF)

3.1.1 Dry Chemical Extinguisher

Portable dry chemical extinguishers (fig. 3-1) are used primarily on class BRAVO fires. Purple-K-Powder (PKP) is the chemical most often used in these extinguishers. The dry chemical dispensed from the extinguisher interrupts the chemical reaction producing a fire and this action stops combustion. Dry chemical is also safe and effective for use on class CHARLIE fires; however, carbon dioxide is preferred because PKP fouls electrical and electronic components. Also, PKP should not be used on inter fires of gas turbines or jet engines unless absolutely necessary because it also fouls engines. PKP is not effective on class ALPHA fires and can only be used to knock down flames and keep the fire under control until an appropriate extinguisher can be used.

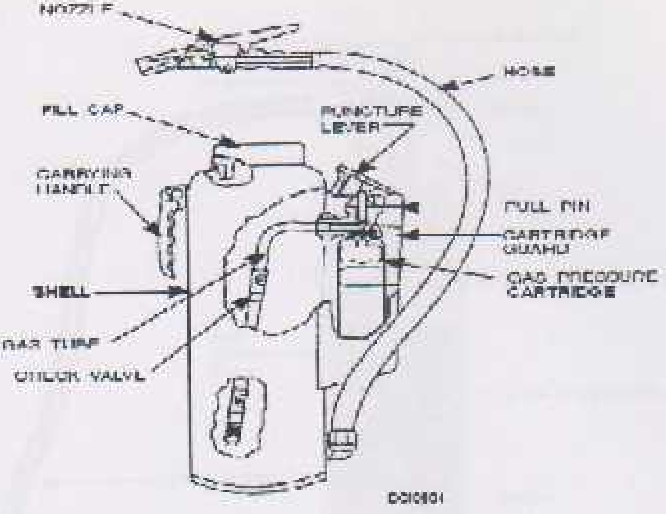


Figure 3.1: Portable Dry Chemical Fire Extinguisher.

3.1.2 Carbon Dioxide Fire Extinguisher

The standard Navy CO2 fire extinguisher (fig. 3-2) has a rated capacity (by weight) of 15 pounds of CO2. Removing the locking pin and squeezing the release

valve built into cylinder valve operates it. CO2 extinguishers are primarily used on small electrical fires (class CHARLIE) and have limited effectiveness on class BRAVO fire

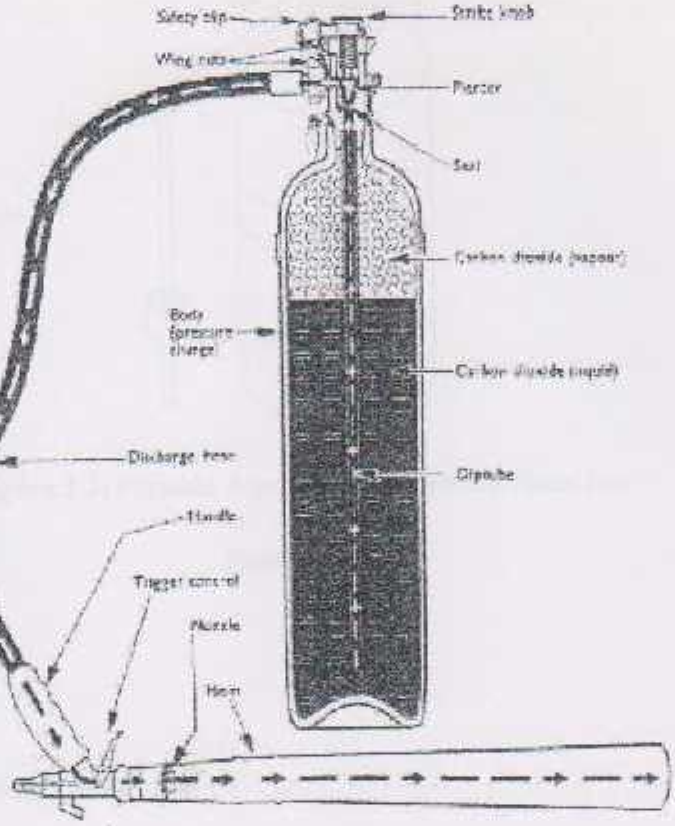


Figure 3.2: Carbon Dioxide Fire Extinguisher

3.1.3 Aqueous Film-Forming Foam Fire Extinguisher

Portable aqueous film-forming foam (AFFF) fire extinguishers are used to provide a vapor seal over a small fuel spill, extinguish small class BRAVO fires

(such as deep fat fryers), and for standing fire watch during hot work. The portable AFFF fire extinguisher (fig. 3-3) is a stainless steel cylinder containing 2 1/2 gallons of premixed AFFF concentrate and water. It is pressurized with air to 100 psi at 70° and weighs approximately 28 pounds when fully charged. The mixture will expand about 6.5 to 1 and will produce about 16 gallons of foam. The AFFF extinguisher has a 55-65 second continuous discharge time and an initial range of 15 feet, which decreases during discharge.

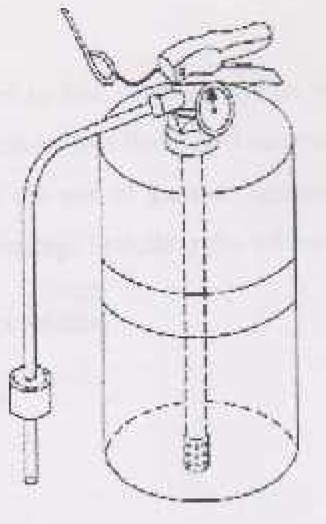


Figure 3.3: Portable Aqueous Film-Forming Foam Fire Extinguisher.

3.1.4 Portable Water Mist

In these chapter to study of water mist fire extinguishing using pressure are and to study characteristic of water mist. In figure(3.4) describe initial idea for the project.

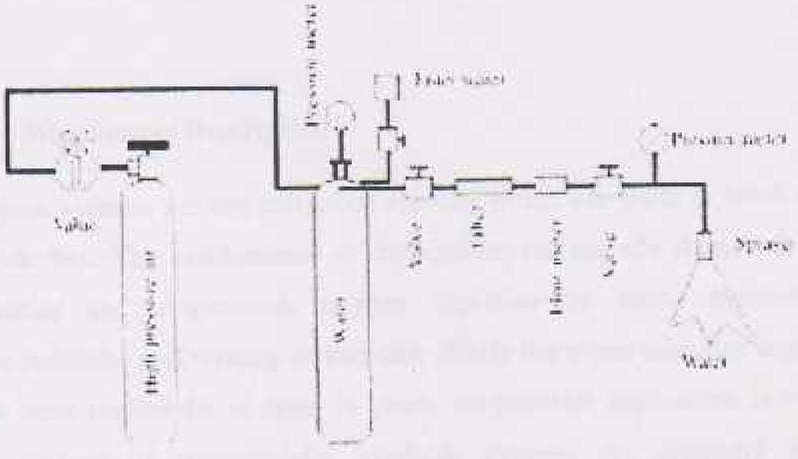


Figure 3.4: High Pressure Water Mist

3.2 Water Mist

The term " water mist" refers to fine water sprays in which 99% of the volume of the spray is in drops with diameters less than 1000 microns.[1] The use of water mist in fire suppression, compared to the use of gaseous agents and conventional sprinkler systems, has demonstrated advantage including the following:

1- No toxic and asphyxiation problems.

2- No environmental problems.

3- low system coast.

4 -Limited or no water damage.

5- High efficiency in suppression certain fires

. Water mist technology reached a new and critical stage. A water mist system is a distribution system connected solely to a water supply or alternatively to a water supply and an atomizing media (air or nitrogen), that is equipped with one or more nozzle capable of delivering water mist intended to control, suppress, or extinguish fires. Water mist system have to potential to serve as replacement systems for occupancies formerly projected by halon systems. Water mist systems are similar in cost to clean-agent systems.

3.2.1 Water Mist System Description

Water mist systems are fire protection systems which use water in small droplets to extinguish fire. The mechanisms of extinguishment include flame cooling by droplet heating and evaporation, oxygen depletion by steam expansion and combustion products, and wetting of surfaces. While the water mist fire suppression system has been studied for at least 50 years, its practical application is relatively new. The designs of commercially available systems are distinctly different. Generally they can be categorized as follows:[2]

1. Type of atomization method: single fluid, twin fluid.

2. Delivery type: wet pipe, dry pipe, pre-action and deluge system.

3. Pressure supply method: gas propellant, pumps.

4. Operation pressure level: low pressure (≤12.5 bar), medium pressure (>12.5 bar and <34.5

bar), high pressure (≥34.5 bar).

5. Water source: self-contained water tank/cylinders, private water source, public water source.

6. Mist discharge type: continuous discharge, cyclical discharge.

Although differences exist in the various products, there are eight typical configurations which are commonly used and listed in the National Fire Protection Association Standard 750 [3]. The characteristics of these eight systems are simplified as follows:

System A: high pressure and gas driven system with stored water.

System B: high pressure and gas driven with multiple accumulator units.

System C: low pressure twin fluid water mist system.

System D: single fluid mist system.

System E: pump driven water mist system.

System F: positive displacement pump assembly with unloader valves on each pump and pressure relief valve on discharge manifold.

System G: gas pump unit for machinery spaces and gas turbine enclosure.

System H: gas pump for light hazard applications.

3.2.2 Extinguishing Mechanisms

Water has favorable physical properties for fire suppression. Its high heat capacity (42J/g.K) and high latent heat of vaporization (2442J/g) can absorb a significant quantity of heat from flames and fuels. Water also expands 1700 times when it evaporates to steam. Which results the dilution of the surrounding oxygen and fuel vapors. With the formation of fine droplets, the effectiveness of water in fire suppression is further increased due to the significant increase in the surface area of water that is available for heat absorption and evaporation. Such an increase in the surface area of water in shown in Table 1 for a given volume of water ($0.001m^3$). [4]

Table 1. The Variation of Surface Aria of Water with Droplet Size(Volume of Water $0.001\ m^3$).

Droplet Size (mm)	6	1	0.1
Total Number of Droplet	$8.8*10^3$	$1.9*10^6$	$1.9*10^9$
Total Surface Area (m^2)	1	6	60

Water mist in fire suppression, however, dose not behave like a " true" gaseous agent. When water is injected into a compartment, not all the spray that are formed are directly involved in fire suppression. They are partitioned into a number of fractions as follows [5]

1-Droplets that are blown away before reaching the fire.

2-Droplets that penetrate the fire plume, or otherwise reach the burning surfaces under the fire plume, to inhabit pyrolysis by cooling, and the resultant steam that dilutes the available oxygen.

3-Droplets that impact on the walls, floor and ceiling of the compartment and cool them, if they are hot, or otherwise run-off to waster.

4-Droplets that vaporize to steam while traversing the compartment and contribute to the cooling of the fire plume, hot gases, compartment and other surfaces.

5-droplets that pre-wet adjacent combustibles to prevent fire spread.

They classified the extinguishing mechanisms of water mist in fire suppression as primary and secondary mechanisms[6], which can be summarized as figure (3.5)

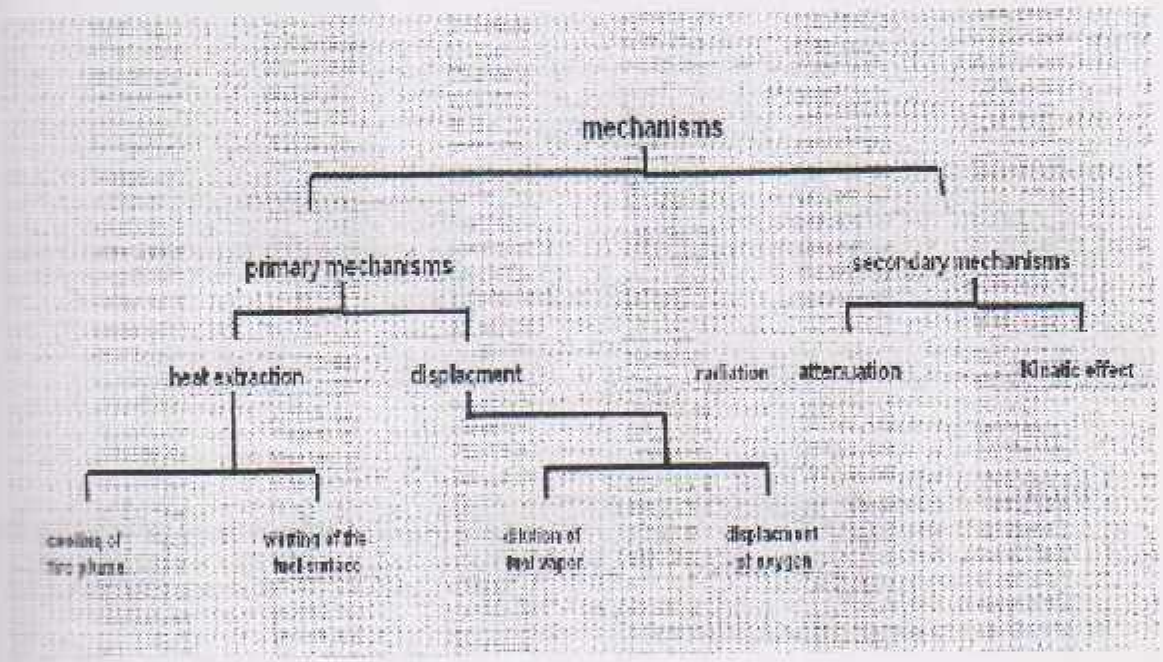


Figure 3.5: They Classified The Extinguishing Mechanisms of Water Mist in Fire Suppression

3.2.3 Water Mist Droplets

Water mist as a water spray with water droplets of "less than 1000 microns at the minimum operation pressure of discharge nozzle." Size of water droplets is a function of the discharge pressure through an orifice of fixed diameter, and is a key contributing factor in ability of water spray to evaporate and cool a flame for certain configurations of combustibles. The total absorption of heat per unit time increase greatly as drop size decreases, given a fixed water volume, because the available surface area for heat transfer increases, as illustrated in figure 3.6.

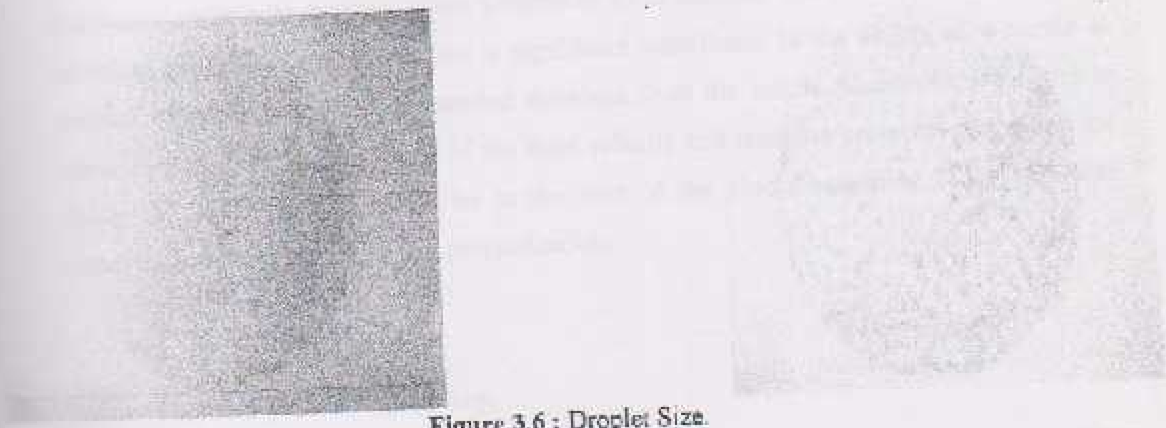


Figure 3.6 : Droplet Size.

water divided into very small droplets :

1- Larger water surface area exposed to heat
2- More drops will evaporate and turn to steam
3- More droplets.
4- Steam absorbs more heat per unit time

one gallon of water divided into very large droplet:

1- Fewer droplets.
2- Smaller water surface area expose to heat
3- More drops will remain un evaporated and coat the surface of the combustibles.
4- A combustible coated with water is cooled by the water from the flame, reducing the flame temperature.

Small droplets absorb heat quickly and evaporate readily, creating steam, whereas larger droplets are less prone to do so. Large droplets are much more likely to provide coating of exposed combustibles, which is an important performance objective of class A fires. Large drops are more prone to agitate the surface of a flammable liquid fire, which explains why smaller droplets are more conductive to extinguishment of class B fires.

3.2.4 Water Mist Pressure and Droplet Size

Pressure, either by fire pump or by pressurized air or gas, it a strong contributor to the size of water mist droplets, given a nozzle of fixed diameter and orifice characteristics. In addition, the pressure at the nozzle is significant contributor to the ability of a nozzle to project water mist droplets at extended distances from the nozzle. Generally, the lower to pressure at the nozzle. The lower of the fluid velocity and resultant projected range, and the closer the nozzle is required to be to the axes of the plume centerline. They are three classification fications for system pressurization.

1.Low-Pressure Water Mist System

The system piping are 175 psi (12.1 bar) or less, the same pressure range used for most standard sprinkler systems.

2.Intermedate-Pressure Water Mist System

In which the pressure encountered by the system piping are between 175psi (12.1 bar) and 500 psi (34.5 bar).

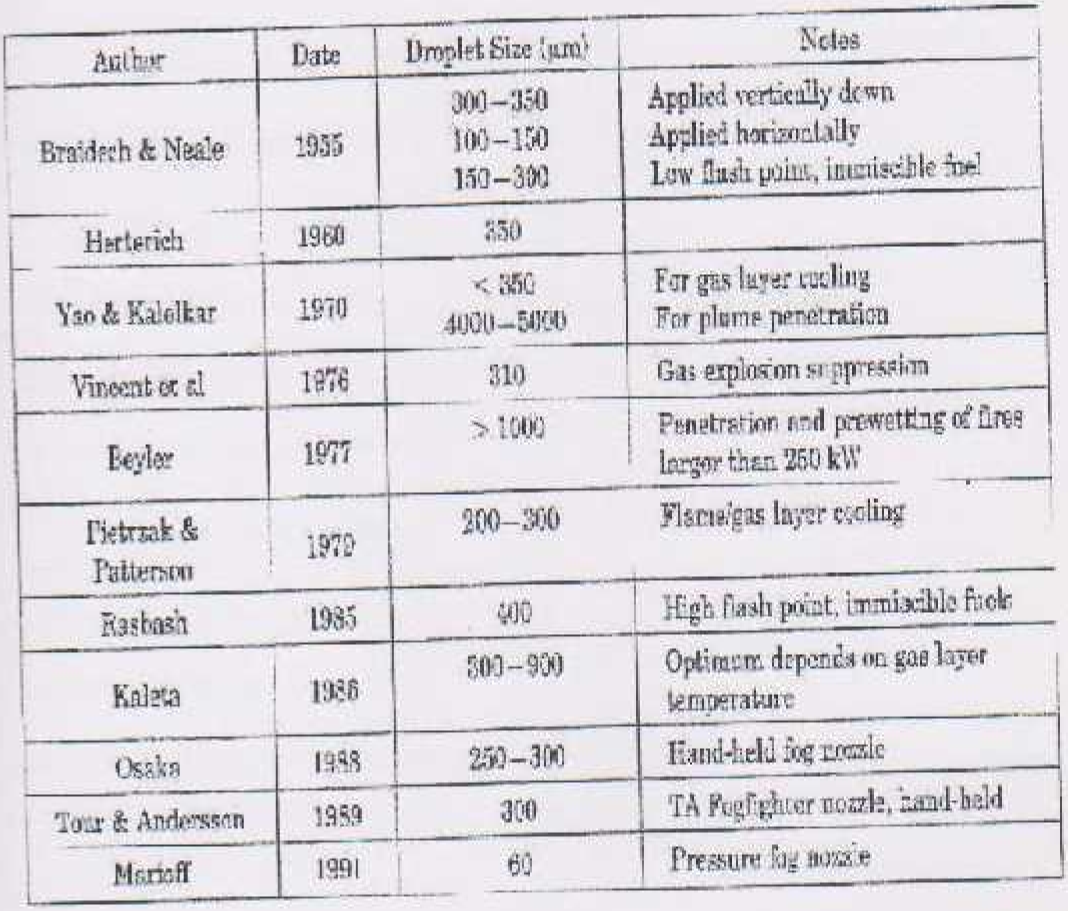
3.High-Pressure Water Mist System

In which the pressure encountered by the system piping are 500 psi (34.5 bar) or greater.

System pressure becomes extremely important in specifying material characteristics for water mist system, such as piping, fittings, nozzle, and valves. System components are required to be capable for meeting or exceeding the highest pressures expected to encountered on a water mist system.

Table 2. [7] It can be seen that the optimum size of droplets for fire suppression is strongly dependent on many factors, such as the properties of the combustibles, the degree of obstruction in the compartment, and the size of the fire. The droplet size distribution that is most effective in extinguishing on fire scenario will not necessarily be the best for other scenarios. The is not-size distribution to fit all fire scenarios. Actually, the performance of water mist with a well-mixed distribution of fine and coarse droplet is better than that with a uniform droplet size .1 41 Further-more, any changes in fire size, spray velocity and enclosure effects will change the optimum droplet size for fire suppression.

Table 2. Comparison of Optimum Droplet size for Fire Extinguishment



Author	Date	Droplet Size (μm)	Notes
Braidech & Neale	1955	300–350 100–150 150–300	Applied vertically down Applied horizontally Low flash point, immiscible fuel
Herterich	1960	350	
Yao & Kalelkar	1970	< 350 4000–5000	For gas layer cooling For plume penetration
Vincent et al	1976	310	Gas explosion suppression
Beyler	1977	> 1000	Penetration and prewetting of fires larger than 250 kW
Pietrzak & Patterson	1979	200–300	Flame/gas layer cooling
Rasbash	1985	400	High flash point, immiscible fuels
Kaleta	1986	500–900	Optimum depends on gas layer temperature
Osaka	1988	250–300	Hand-held fog nozzle
Tour & Andersson	1989	300	TA Fogfighter nozzle, hand-held
Marioff	1991	60	Pressure fog nozzle

3.2.5 Methods of Generating Water Mist

In general, water mist generating systems can be divided into three basic categories based on the atomizing mechanisms used to product the fine droplets: impingement nozzle, pressure jet nozzle, and twin fluid nozzle .1 Any other type of nozzle is a combination of these three basic types.

These three types of nozzle work under different operating pressures and can produce different spray characteristics. NFPA 750 49 defines three pressure regions for water mist generating technologies: low, intermediate and high pressure systems . Low pressure systems operate at pressure of 12.0 bar (175 psi) or less, intermediate pressure systems operate at pressures greater than 12.0 bar (175 psi) and less than 34.0 bar (500 psi), and high pressure systems operate at pressure greater that 34.0 bar (500 psi).

Chapter Four

4.1 Introduction

The previous chapters discuss the basic of fire, fire triangle, classification of fire, extinguishing fire using water, and also it discusses different types of portable fire extinguishers, such as: dry chemical, carbon dioxide, and eater mist extinguisher.

This chapter will discuss the two design ideas that have been implemented, also it will discuss the design concept of each device, and it's advantages and disadvantages, and other parameters.

4.2 Design Concept

As shown the figure 4.1 below, there were two cylinders, one of them for CO2, and the other for water, with different capacities and pressures. Also there were a cylinder that contains two rooms, one for CO2, and the other for water.

Hence; shooting criteria depends on the design idea used.

4.2.1 First Design Concept

The first design is a portable fire fighting distinguisher based on Bernoulli principle. The concept of the design is composed of the following:

1. The first cylinder contains CO2, at a pressure of 40 bar, and a capacity of 3 Liters.
2. The second cylinder contains water at an atmospheric pressure, and a capacity of 10 Liters.
3. The pressure regulator is used to regulate the output pressure from the CO2 cylinder, and it's operation ranges between 0-10 bar.
4. The nozzle formulates the venturi, and controls the angle of stream, usually made of Acrylic shown in figure 4.2.

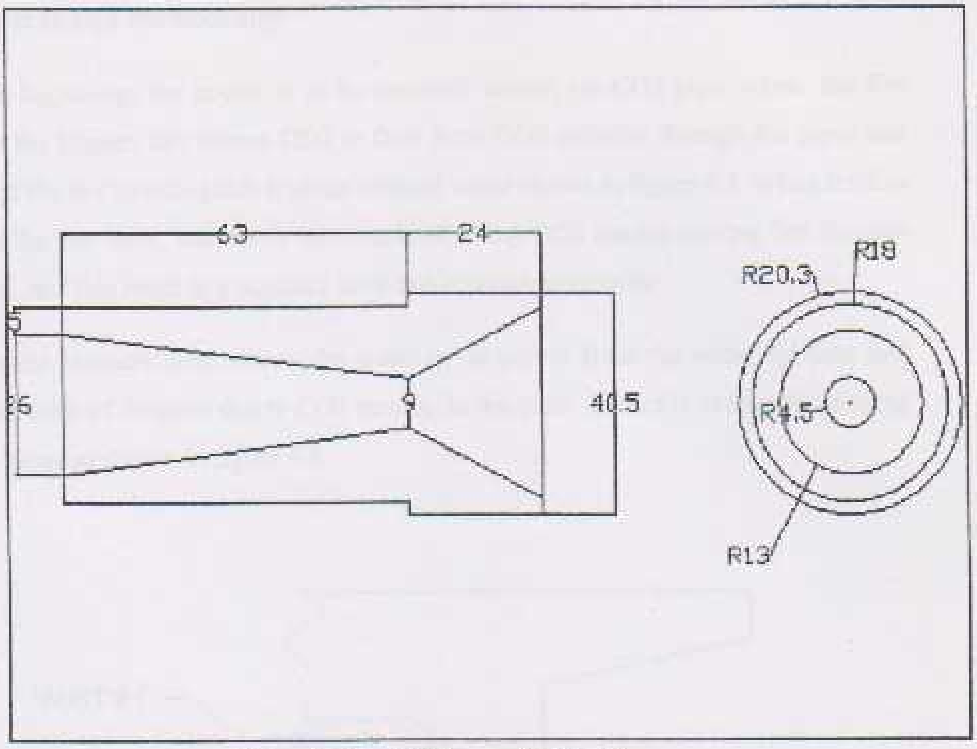


Figure4.2 Nozzle Front and Side View

5. The design includes also three pipes, one for CO2, and the second is for water, and the third which is the main one combines the previous two mentioned pipes.
6. The Gun, which is the main operator of the device, once a fire man presses the trigger of the gun, this allows CO2 to flow.

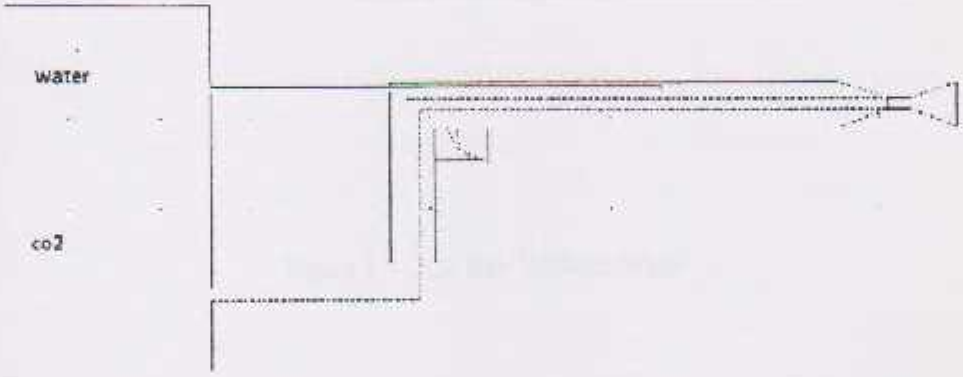


Figure 4.3 Design Concept

4.2.1.1 First Design Methodology

At the beginning, the nozzle is to be normally closed via CO2 pipe, when the fire man press the trigger, this allows CO2 to flow from CO2 cylinder through the pipes and exit toward the fire to extinguish it alone without water shown in figure 4.4. When the fire man pulls the gun back, this opens the nozzle allowing CO2 stream moving fast through the venturi, and this leads to a pressure drop and increasing velocity.

The exist pressure drop allows the water to be pulled from the water cylinder and exits in the form of droplets due to CO2 stream. In the case, the fire is extinguished using CO2 and water as shown in figure 4.5.

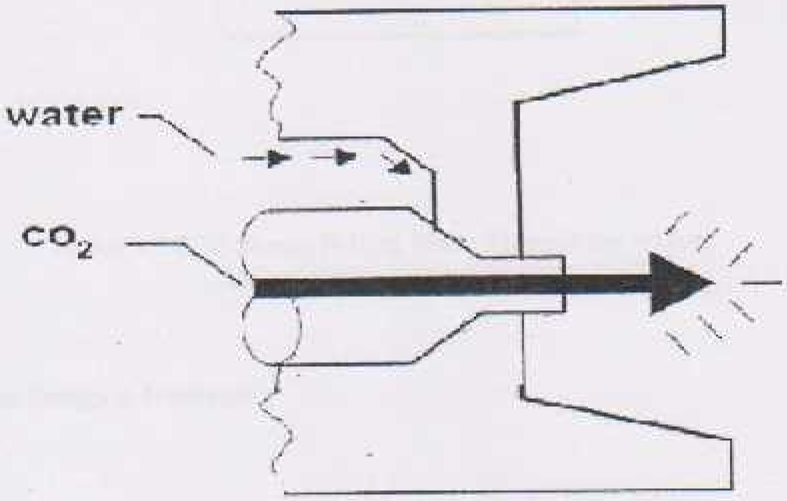


Figure 4.4 CO2 Exit Without Water

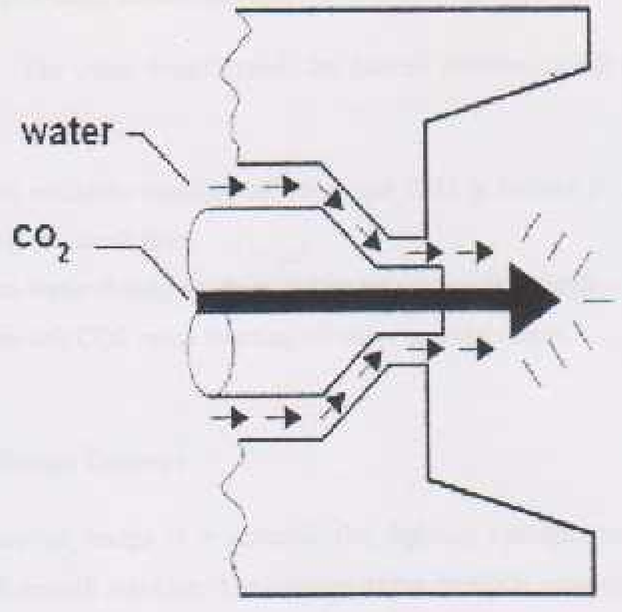


Figure 4.5 CO2 Stream Pulling Water Through the venturi.

4.2.1.2 First Design Advantages

1. Uses two extinguishing techniques, either using CO2 alone, or CO2 with water together.
2. The usage of CO2 as an inert gas, which is usually used to extinguish fire, with a density higher than Oxygen and air, so that CO2 insulates oxygen away from fire, and this helps in fire fighting process.
3. The device has a light weight which enables the fire man to carry it, with a total weight of 20 kg.
4. CO2 cylinder maintain a constant pressure during the time of operation.

4.2.1.3 First Design Disadvantages

The water doesn't reach the desired distance so this may be cause danger to fireman.

1. The available capacity of water and CO2 is limited so the device will be used only for small fires.
2. The water should be clean to prevent closing the nozzle.
3. The exit CO2 cause freezing of water at nozzle head.

4.2.2 Second Design Concept

The second design is a portable fire fighting extinguisher based on continueity equation and Bernoulli equation. The concept of the design is composed of the following:

1. The first cylinder contains CO2, at a pressure of 40 bars, and a capacity of 3 Liters.
2. The second cylinder contains water at a pressure of 3 bar and a capacity of 10 Liters.
3. The design includes also two pipes, one for CO2, and the second is for water.
4. The main component of the device is a big cylinder which contains two rooms shown in figure 4.6, one for CO2, and the other for water, and the gate between the two rooms should be closed.

Figure 4.6 Device Contain Two Rooms

5. The gate between the two rooms contains four holes. naturally are normally closed. Hence; the upper half the holes is normally closed due to the cylinder itself, and the lower half of the holes is normally closed due to the rod stopper shown in figure 4.7(red color is normally closed due to the cylinder itself and black color is closed via gate, the gray color is open when fire man press the gun.

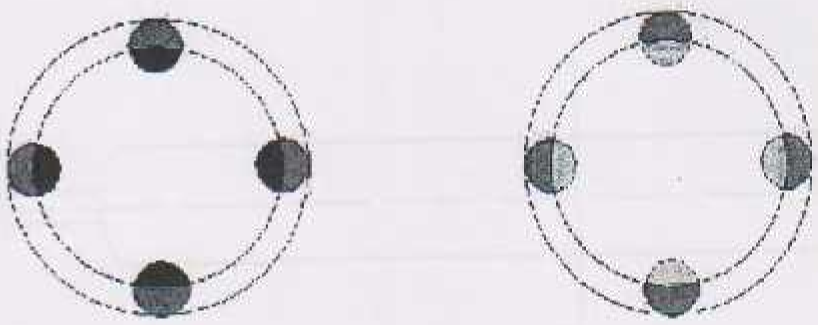


Figure 4.7 Gate Side View When is Open and Closed

6. There is a nozzle at the top of water room, in order to separate water when shooting shown in figure 4.8

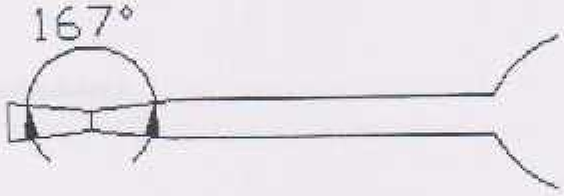


figure 4.8 Side View the Nozzle

7. At the center of the cylinder, there is a rod extended align with the cylinder itself, in order to control the shooting process shown in figure 4.9 .

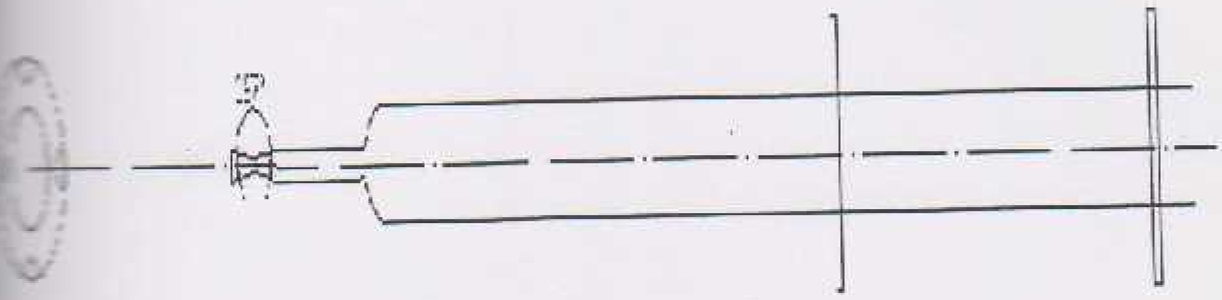


Figure 4.9 Side View of Rod

8. the pressure regulator is used to regulate the output pressure from the CO2 cylinder, and it's operation ranges between 0-10 bar.
9. Pressure Gauge in the CO2 room to monitor the internal pressure of CO2.
10. One way valve which is fixed to the inlet of the water room, in order control the process of allowing water to get in not out.

4.2.2.1 Second Design Methodology

CO2 from main cylinder at high pressure, and via pressure regulator, regulates the pressure, and so, CO2 gets into the gun at a pressure equals 10 bar.

At the natural case, the nozzle and the gate is closed by means of the rod. In addition to that, the CO2 inlet is opened, so that water fulfills the first room, whereas CO2 fulfills the second room.

When activating the device, the rod will go back and the gate between rooms will open, which leads to a mixing operation between CO2 and water, maintaining high pressure inside water room, then the nozzle will open allowing the mixture to get out with high speed and pressure.

After deactivating the device, the rod recovers back to it's original location, allowing to the possibility of start the process again.

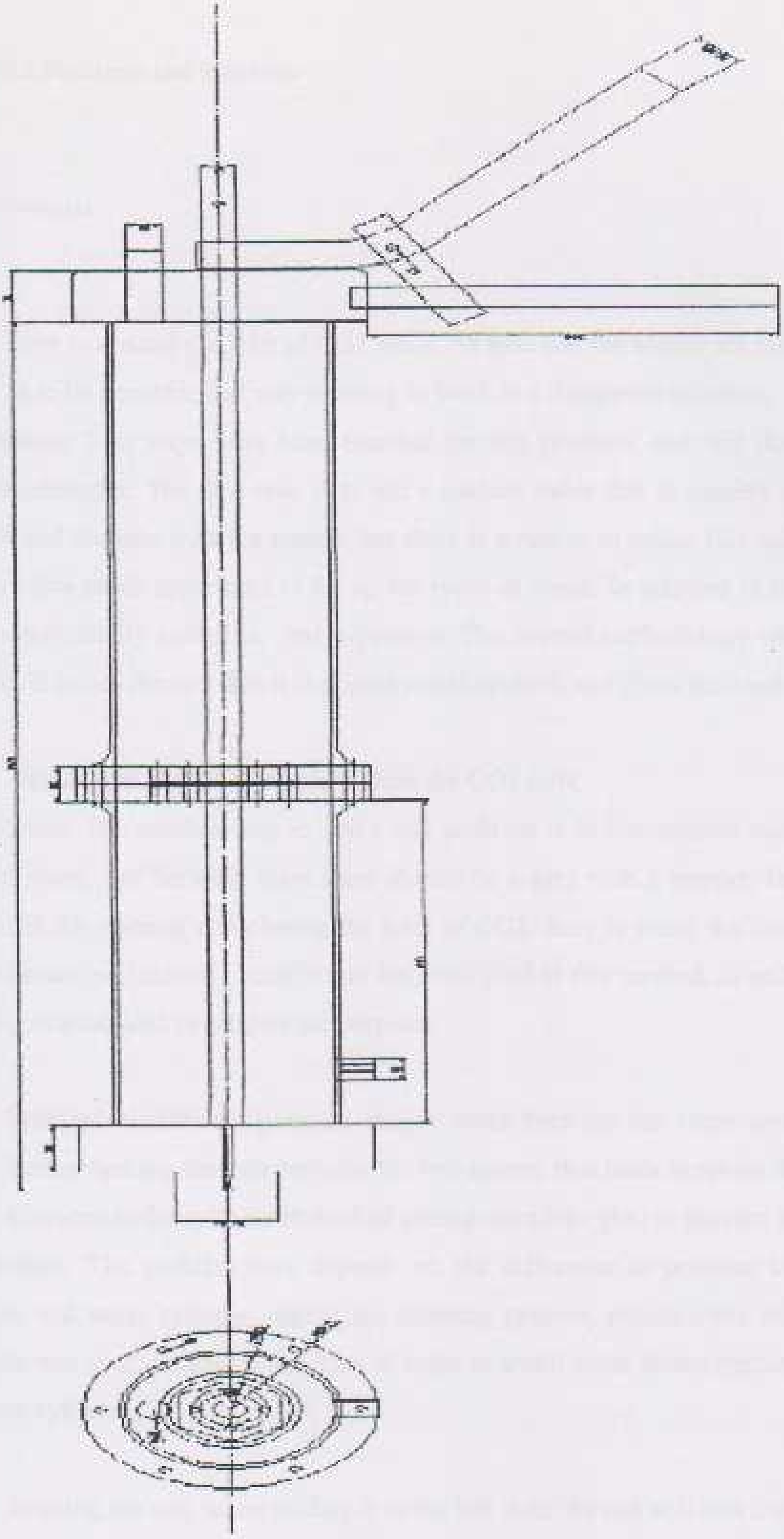


Figure4.10 Design Two

4.2.2.2 Problems and Solutions

- Problems:

1. How to control the inlet of CO2 while the gate and the nozzle are being closed, so as to be a mechanical way insuring to work in a dangerous situation.

Solution: Two ways have been founded for this problem, and will discuss the two methodologies. The first one, is to use a manual valve that is capable to control the inlet and the gate with the nozzle, but there is a reason to refuse this solution, that is; this valve needs more time to fill up the room of water. In addition to that, this valve is commercially available, but expensive. The second methodology which has been used, is to use the rod, that it is a mechanical method, and gives the needed control.

2. Problem in how to completely close the CO2 inlet.

Solution: The another way to solve this problem is to use another room before the CO2 room, and between them there should be a gate with a stopper, this gives easy control for opening and closing the inlet of CO2. But; to avoid the heavy weight of the device, an internal - small room has been used at this method, in order to simplify the operation, and to achieve the purpose.

3. Problem in different pressure ranges water between the room and the cylinder during opining the gate between the two rooms, that leads to return the water from it's room to the cylinder instead of getting out of the gun, to prevent loss of water.

Solution: The problem here depends on the difference in pressure between water room and water cylinder, during the shooting process, and to solve this, a one way valve was used, located at the inlet of water to avoid water from returning back to the water cylinder.

4. In using the rod, when pulling it to the left side, the rod will loss it's balance, and there is a chance to not return back to it's place, and this leads to not fully closed the nozzle and the gate.

Solution: A hole has been used on the gate between the two rooms, and so the rod can go through that hole, in order to maintain a rod balance.

5. The gate and the nozzle opens together, when pulling the rod.

Solution: The head of the rod was made in a conic shape, so as to delay the nozzle opening process, in relevance with gate opening.

6. The weight of the device was the main problem during the implementation, that's because the gun is made of a stainless steel material, which can handle with high pressures and resists corrosion, but; stainless at the same time is considered a heavy material.

Solution: Weight should be taken as the highest priority consideration for this project, and when using stainless steel as a material for making the stopper, stainless is a heavy material, so; an Acrylic material should be used instead, but; the problem was still occurred due to the weight of CO2 and water, and this has been handled in the build of the first design methodology.

7. Pressure: the CO2 cylinder is maintained under 40 bar, where as the device should operate maintain a pressure of about 10 bar.

Solution: This problem has been resolved due to the occurrence of the main valve, which reduces the pressure that gets out of the CO2 cylinder.

8. Gun maintenance: the problem is how to clean, repair, and change it's parts when needed.

Solution: In order to facilitate the process of separating the two rooms, screws for fastening them were used, so that separation will be easy through screw driving. And to resolve of the problem of the rod, it can be removed easily through threading it.

4.2.2.3 Second Design Advantages

1. Uses two extinguishing techniques, either using CO2 alone, or CO2 with water together.
2. The usage of CO2 as an inert gas, which is usually used to extinguish fire, with a density higher than Oxygen and air, so that CO2 insulates oxygen away from fire and this, helps in fire fighting process.
3. Simplicity in removing and install parts.

4.2.1.4 Second Design Disadvantages

1. The device has a heavy weight which enables the fire man to carry it, with a total weight of 26 kg.
2. The water should be clean to prevent closing the nozzle

4.3 Fluid Properties Affecting the Spray

A variety of factors affect droplet size and how easily a stream of liquid atomizes after emerging from an orifice. Among these factors are fluid properties of surface tension, viscosity, and density.

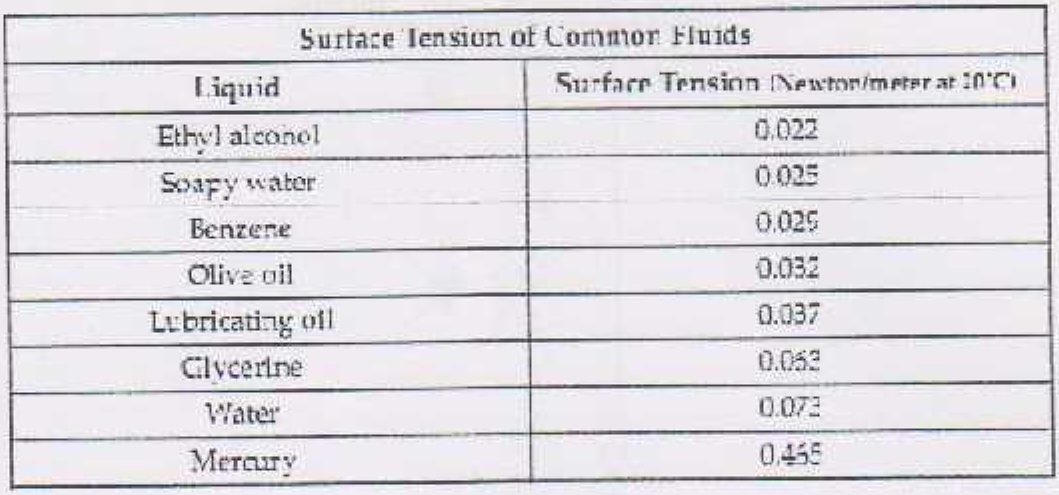
4.3.1 Surface Tension

Surface tension tends to stabilize a fluid, preventing its breakup into smaller droplets. Everything else being equal, fluids with higher surface tensions tend to have a larger average droplet size upon atomization .

In the project soap is mixed with water to decease the surface tension property of water and also this lead to fine and small droplets size which will increase the surface area exposed to fire and helps in quickly absorption of heat due to water droplets vaporization.

Table 4.1 shows the surface tension property of familiar liquids.

Table 4.1 Surface Tension Property of Familiar Liquids.



Surface Tension of Common Fluids	
Liquid	Surface Tension (Newton/meter at 20°C)
Ethyl alcohol	0.022
Soapy water	0.025
Benzene	0.029
Olive oil	0.032
Lubricating oil	0.037
Glycerine	0.063
Water	0.073
Mercury	0.465

4.3.2 Viscosity

A fluid's *viscosity* has a similar effect on droplet size as surface tension. Viscosity causes the fluid to resist agitation, tending to prevent its breakup and leading to a larger average droplet size. Figure 4.12 represents the relationship among viscosity, droplet size, and when atomization occurs .

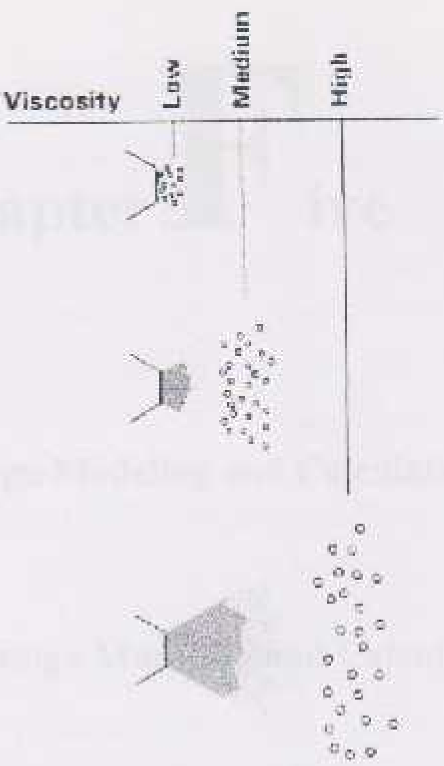


Figure 4.12 Effect of Viscosity on Droplets Size.

4.3.3 Density

Density causes a fluid to resist acceleration. Similar to the properties of both surface tension and viscosity, higher density tends to result in a larger average droplet size.

Chapter Five

5.1 First Design Modeling and Calculation

5.2 Second Design Modeling and Calculation

5.3 Comparative between Two Design

5.1 First Design Modeling and Calculation

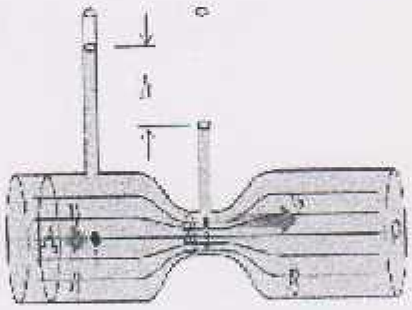
The Venturi effect is a jet effect; as with a funnel the velocity of the fluid increases as the cross sectional area decreases, with the static pressure correspondingly decreasing. According to the laws governing fluid dynamics, a fluid's velocity must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy. Thus any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is negated by a drop in pressure. An equation for the drop in pressure due to the Venturi effect may be derived from a combination of Bernoulli's principle and the continuity equation.

Referring to the diagram to the right, using Bernoulli's equation in the special case of incompressible flows (such as the flow of water or other liquid, or low speed flow of gas), the theoretical pressure drop at the constriction is given by:

$$p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$$

where ρ is the density of the fluid, v_1 is the (slower) fluid velocity where the pipe is wider, v_2 is the (faster) fluid velocity where the pipe is narrower (as seen in the figure). This assumes the flowing fluid (or other substance) is not significantly compressible - even though pressure varies, the density is assumed to remain approximately constant.

The pressure at "1" is higher than at "2", and the fluid speed at "1" is lower than at "2", because the cross-sectional area at "1" is greater than at "2".



Flow rate

A venturi can be used to measure the volumetric flow rate $\dot{Q}$.

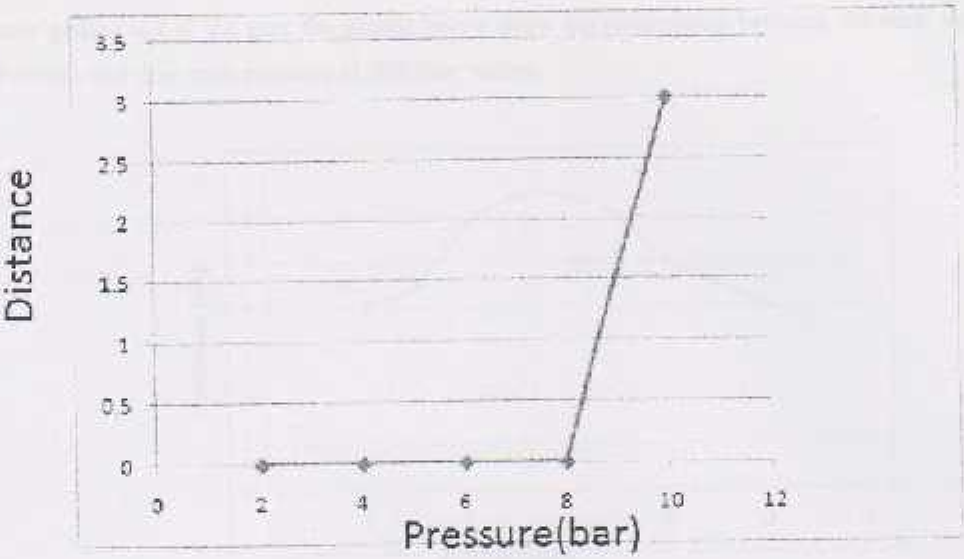
Since

$$\begin{cases} \dot{Q} = v_1 A_1 = v_2 A_2 \\ p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2); \end{cases}$$

then

$$Q = A_1 \sqrt{\frac{2\left(p_1 - p_2\right)}{\rho\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}} = A_2 \sqrt{\frac{2\left(p_1 - p_2\right)}{\rho\left(1 - \left(\frac{A_2}{A_1}\right)^2\right)}}.$$

A venturi can also be used to mix a liquid with a gas. If a pump forces the liquid through a tube connected to a system consisting of a venturi to increase the liquid speed (the diameter decreases), a short piece of tube with a small hole in it, and last a venturi that decreases speed (so the pipe gets wider again), the gas will be sucked in through the small hole because of changes in pressure. At the end of the system, a mixture of liquid and gas will appear

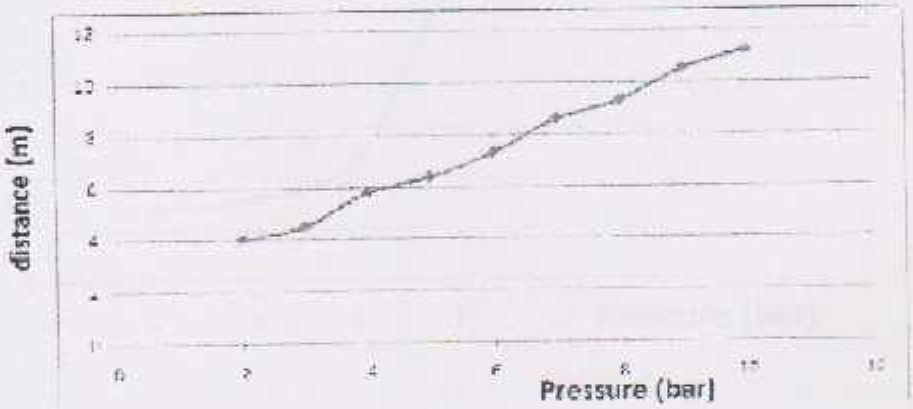


Graph 5.1 Relationship between Pressure and distance

5.2 Second Design Modeling and Calculation

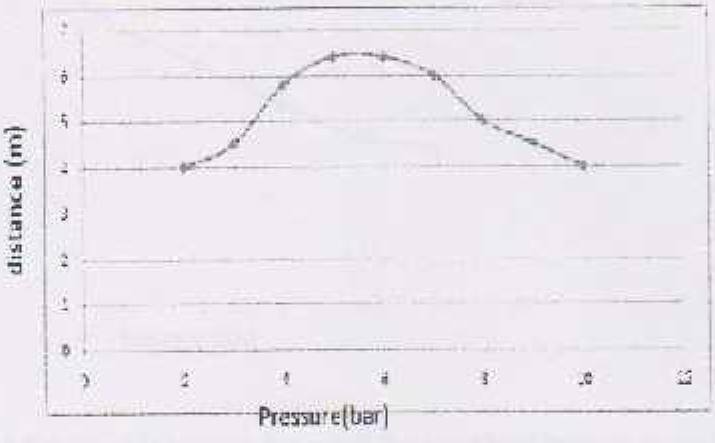
The second design based on projectile motion, Bernoulli and Continuity Equations to calculate the speeds that getting out from the device .

After the operation and testing of the device at different pressure, the distance that water reach is taken after one second which shown in graph 5.2

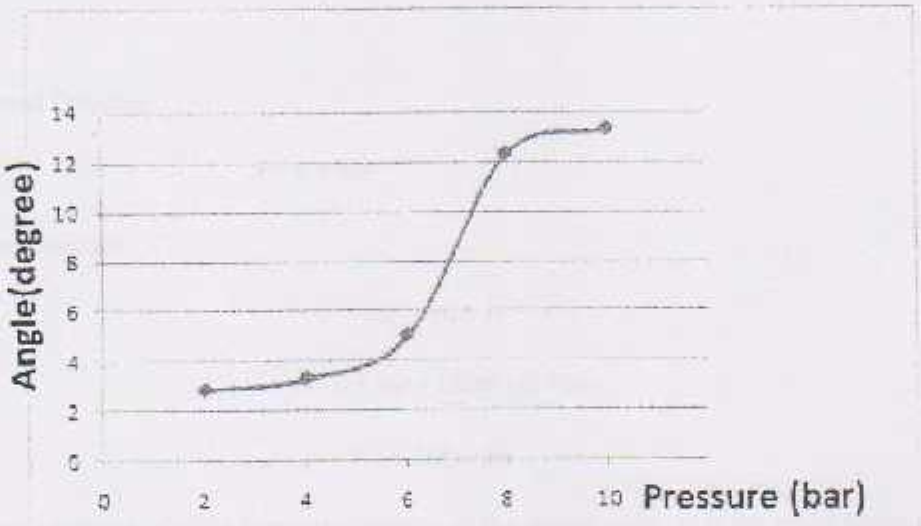


Graph 5.2 Relationship between Pressure and Distance

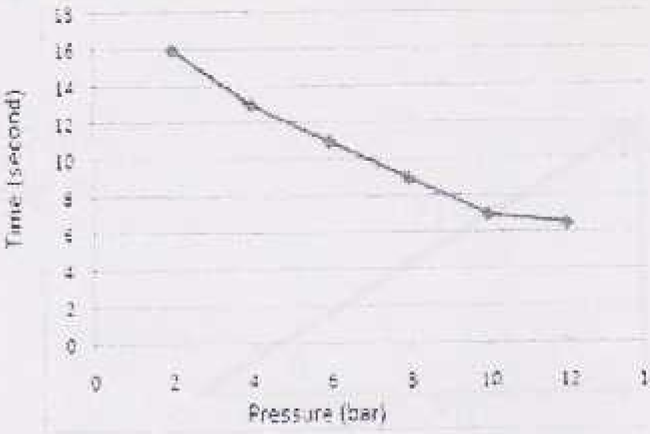
The average distance and time at different pressure taking for one liter of water getting out of the gun, the graphs below show the relationship between distance, angle of stream and time with pressure at different values.



Graph 5.3 Relationship between Average Distance and Inlet Pressure



Graph 5.4 Relationship between Angle Separated and Inlet Pressure



Graph 5.5 Relationship between Separated Time and Inlet Pressure at one Liter

By applying the equation of motion that relates all four quantities of motion (time, displacement, velocity and acceleration The distance which the water will reach whiling shooting will calculate on based on the Projectile motion equation as follow:

Horizontal Direction

$$x = x_i + v_{ix}t$$

Vertical Direction:

$$v_{fy} = v_{iy} + at$$

$$y = y_i + v_{iy}t + 1/2at_2\ v_{fy}2 = v_{iy}$$

$$2 + 2a(y - y_i)$$

In these equations, x is the horizontal position of the stream water, xi is the initial horizontal position of the water, vix is the initial velocity in the horizontal direction, t is the elapsed time, vfx is the final velocity in the vertical direction, vi is the initial velocity in the y-direction, a is the acceleration in the y-direction, yi is the initial height of the ball, and y is the vertical distance travelled (i.e. the height)

The initial velocities in the x and y direction are the vector components of the initial

Velocity. Figure 1 illustrates these relationships

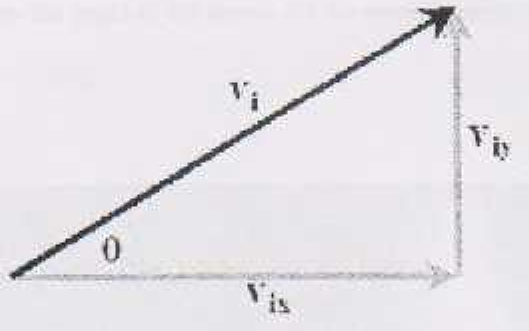


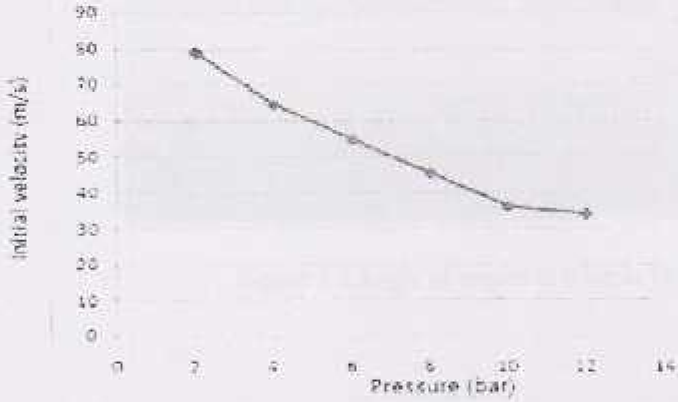
Figure 1: Vector components of the initial velocity

If the initial speed *vi* of the water stream and the launch angle, *μ*, are known, then the vector components can be found using methods of trignnometry:

vix = *vi* cos *μ*;

viy = *vi* sin *μ*;

Using these developed equations, the range, maximum height, and total time of flight will be calculated. These theoretical values will then be compared to experimental values, and calculate initial velocity shown graph 5.6.



Graph 5.6 Relationship between Initial Velocity and Inlet Pressure

The pictures below show the angle of the stream for the second design, while it getting out from the nozzle .

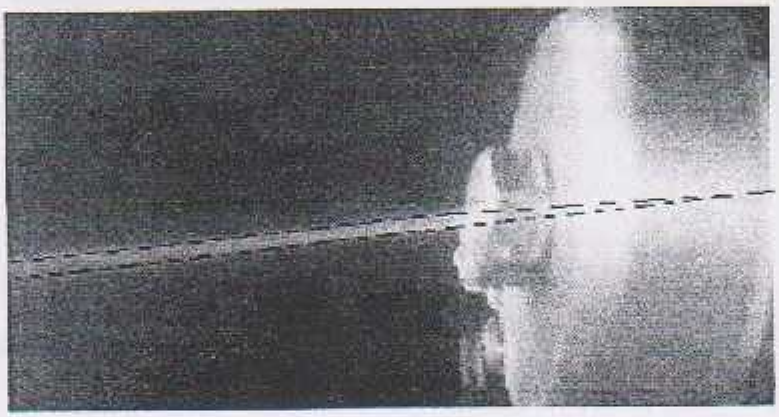


Figure 5.1 Angle of stream at 6 bar is 5 degree

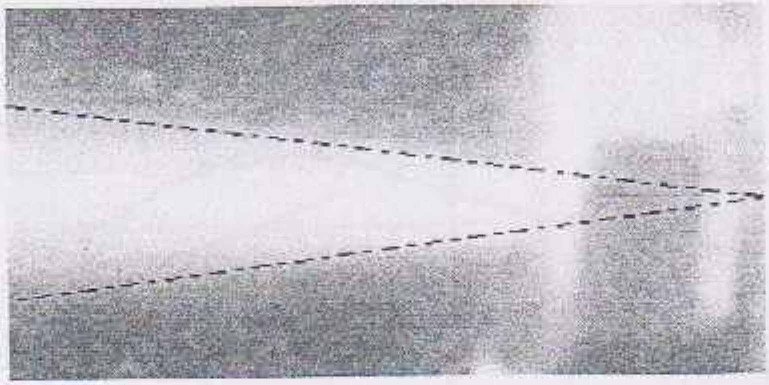


Figure 5.2 Angle of stream at 8 bar is 12.3 degree

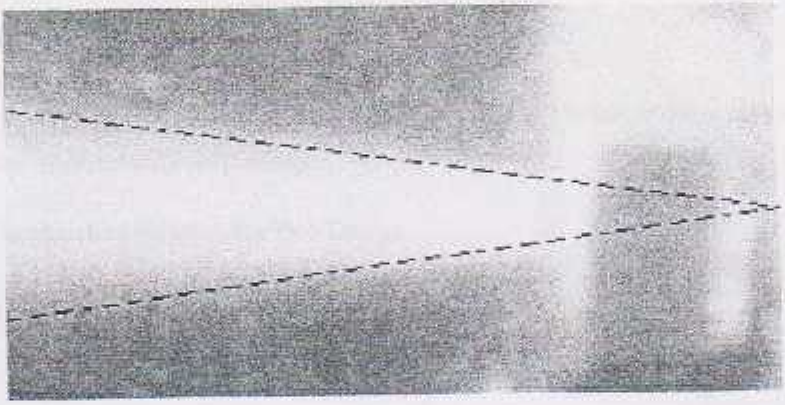
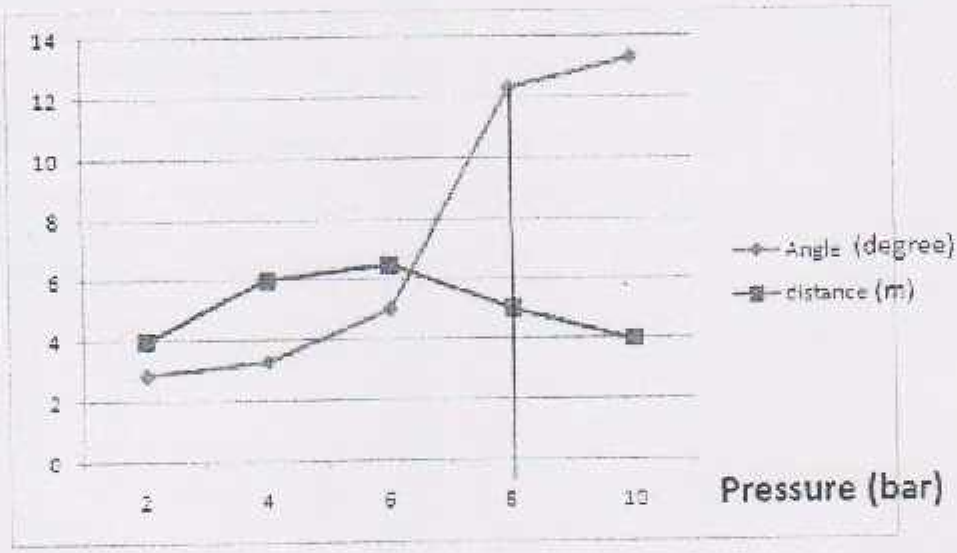


Fig Angle of stream at 10 bar is 13.3 degree

In figure below the relationship between pressure and angle



Graph 5.7 Relationship between Stream Angle and Distance with different Pressure.

5.3 Comparative between Two Design

The corporation is summarize in this table which show below and describe the properties and parameter for each design

Table 5.1 Comparative between the Two Design

Comparative	**Design I**	**Design II**
Weight	**Light**	**Heavy**
Shooting Max. Distance	**3m**	**11m**
Max. Separated Angle	**17 degree**	**13.5 degree**
Optimal Pressure Work	**(10 – 40) bar**	**(6-8)bar**
Time for 10 Liter	**(10-15) minute**	**90 second**

Reference:

[1] Mawhinney, J.R,."Fire Protection Water Mist Suppression System," NFPA Hand-Book-18th Edition, 1997

[2]- NFPA-750, 2003, National Fire Protection Association Standard on Water Mist Fire Protection Systems, Quincy, MA.

[3]- NFPA-750, 2003, National Fire Protection Association Standard on Water Mist Fire Protection Systems, Quincy, MA

[4]- Zhingang Liu and andrw K.kim, Fire Risk Management for Research Construction National Research Council Canada Ottawa, Ontario, Canada,KIA OR6.

[5]- Pietrzak,L.M. and Bell, J.A.,"Physically Based Fire Suppression Computer Simulation-Definition. Feasibility Assessment," Mission Research Corporation, MRC-R-732,April 1983

[6]- Mawhinney , J.R. ,Dlugogorski, B.Z, and Kim, A.K," a closer Look at the Fire Extinguishing Properties of Water Mist." Fire safety Science-Proceeding of Fourth International Symposium, 1994, pp. 47-60.

[7]- Andrews, S.P., "Literature Review: Fire Extinguishing by Water Sprays," Building Research Establishment, UK, Internal Report, 1992.

[8] http://www.pcd.ps/index.php?pagess=about