بسم الله الرحمن الرحيم

Palestine Polytechnic University
College Of Engineering And Technology
Mechanical Engineering Department

Project name:

Cables Insulator Smelting Furnace(CISF)

Prepared by:

Montaser Tomiazeh

Supervisor: Eng.Majdi Zalloum

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Thanks for my wonderful parents, who have raised me to be the person I am today. You have been with me every step of the way, through good times and bad.

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Table of contents

List of tables

List of Figures

Chapter One

Introduction

1.1 Overview.

1.2 Project idea.

1.3 Recognition of the Need.

1.4 Project Objectives.

1.5 Risk Management.

1.6 Time Plan.

1.1 Overview.

We live in this planet; we breathe, drink and eat from its components. So that, we have to save these components, by all means we have. One of these means is to prevent the pollution in the air, water and soil. Almost the sources of pollution are come from the oil and its derivatives. It is starting from the elicitation of petrol, treating, using and then how do we get rid of it. So we have to deal with it properly.

The problem in this project is the cable insulator's burning, which happens while trying to recycle the copper wires, the results is disastrous, which will pollute the air, water and the soil where we burn, in addition to the negative effects of the human health.

1.2 Project Idea.

The idea comes from the problem mentioned in the previous section, which will be a cable insulator's smelting furnace, to smelt the insulators of copper wires cleanly. The electrical wires will be inserted in a thermal isolated chamber then we will increase the temperature inside, until we reach the smelting point of the insulators' materials, which is much less than the smelting point of the copper. Then these materials will turn to liquid, so that it's easy to trap it out of the chamber. Then these materials can be recycled, heat treated,…etc.

1.3 Recognition of the Need.

This project aims to avoid the pollution happens in the environment and the bad effects of burning the insulators' cables on the human health. This habit is spread in Palestine, especially in the regions where the electrical and mechanical scraps is brought to be sorted as metals and dispose other materials like the plastic materials. One of these regions is Idna village, sorting these materials is an important economic source in this village, and as a result electrical wire will be burnt. So the necessity requires a solution to continue these works, but with other clean process, which is the need.

Achieving this the aim of project, and building the machine will guarantee the continuity of sorting processes to get the output, save the environment from the pollutants of these processes, save time wasted in burning electrical wires, and save money because of loosing of the copper materials in burning processes, and finally and the most important, protect the peoples in this village from the negative effects of these processes.

1.4 Project Objectives.

The objectives of this project are listed below:

1-Present the effects of burning scraps outdoors.

2-Identify the insulators, and know its types and define its properties, like its melting points (Literature view).

3- Concepts of the operating principle of the Cable Insulators Smelting Furnace (CISF) system, and selection parts and materials needed for the project.

4- Identifying the mathematical model for the operation to get the best design.

5- Design the allover system (Mechanical→ Electrical→ Process).

1.5 Risk Management

The risks expected while building and using the final products:

1- Heat needed to melt the cable insulators in the furnace (100 - 250) °C .

2- High pressure caused by heating the plastic materials (insulators).

3- The smell of molten plastic dangerous to human health.

4- The gasses result from this operation.

1.6 Time Plan

The time plan explains the levels of designing and building the system components and parts. The section includes the table that shows the activities and task scheduling for the project.

Table (1-1): Timetable for the project time (week)

Process	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Designing smelting furnace																
Do some experiments																
Mechanical and electrical modeling																
Documentation																

Chapter two

Burning scrap materials outdoors and its risks

2.1 Introduction.

2.2 What's the problem?

2.3 Facts and numbers.

2.4 Inputs and outputs of burning scrap operations

2.5 Effects of burning scrap outdoors.

2.6 Results and recommendations.

2.1 Introduction.

Scrap burning outdoors is widespread in Idna, Deir-Samit, Beit-Awwa and some other villages in south Hebron regions, where huge quantities of scrap entered these villages from the occupied lands since 1948 to separate the metals from the scrap like steel, copper and aluminum, this metal sold again for the investors in the occupied lands.

Figure 2.1: Scrap materials.

There are many contractors and workers work in this field, where the scrap is coming in, the workers start separate the scrap to many metallic material types using some tools like the cutting tools, to get the metals separated, but some metals like copper cables cannot be separated from its insulators, so that they go to burn it outdoors.

People who invest in the separation field are trying to get money from these operations, regardless of their environmental negative effects, on the other hand, there are many people get their incomes from this field, where this business is a source of revenues and labors, and for these reasons cable insulator smelting furnace (CISF) and other machines like this are needed.

2.2 What is the problem?

The problem here is the bad effects of burning the scrap outdoors, where population around suffered, in the absence of the rule of law in the regions where they burn, and as a result there are many risks and disadvantages break away and appear in the round regions from the bad habits ;

Figure 2.2: smoky clouds result from burning scrap

Clouds of smoke volatilized from these places, this will cause highly dangerous effects on the environment elements like plants, animals, soil, water, air, and finally humans.

2.3 Facts and numbers.

Some studies and press reports talked about this problem, they come out of many results. A study done by the researchers Ali Abu znied and Nafez Al-Shaerawi, they do a survey about scrap the incinerators in some villages, like Idna, Deir-Samit, Beit-Awwa and some other villages in south Hebron regions [18]. More than 54 incinerators are allocated in south Hebron, 29 of these incinerators are in Idna village, they are distributed near the apartheid wall, where the agricultural lands; There are an incinerators exist between the compounds and it is the most dangerous, because of its direct effects on the human life and the environment.

Figure 2.3: scrap incinerator.

About 88% of the incinerators are in open places and they exposed to the winds, which will take the black clouds where the people live where many problems will appear and directly will affect the human health, these problems will be mentioned in some details in the next sections.

2.4 Inputs and outputs of burning scrap operations

Many materials in huge quantities have been burnt in the regions where scrap entered to be separated, and the survey of the researchers Ali Abu znied and Nafez Al-Shaerawi-in their study "survey about scrap the incinerators in some villages, like Idna, Deir-Samit, Beit-Awwa and some other villages in south Hebron regions"- they listed the materials burned in a table with the percentage of each material as listed in the table 2.1 below:

No.	Materials burnt	Percentage (%)
1.	Electrical devices: TVs, PCs…etc	34
2.	Caoutchouc, rubber, plastic	25
3.	Motors and transformers cores	12
4.	Wires and cables	21
5.	Others	8
	The sum	100%

Table 2.1: materials burnt in the incinerators.

As noticed in the table above about 58% or more of these materials can be separated using cable insulators smelting furnace (CISF), where the caoutchouc, rubber, plastic, motors and transformers cores, and finally wires and cables, all of these materials can be separated using cable insulators smelting furnace (CISF), if the facilities were available. And if they were, the project will include the other materials.

All of these materials have been burnt to separate other materials like copper 17%, aluminum 23% and iron 57%; these materials are the output of burning scrap.

2.5 Effects of burning scrap outdoors.

The presence of a negative phenomenon like burning scrap outdoors has very dangerous effects, where it affects the people life, spreads the chronic diseases, destroys the vegetation, pollutes the soil, air and the water, and finally will affect the animal's health negatively.

The survey of the researchers Ali Abu znied and Nafez Al-Shaerawi-in their study "survey about scrap the incinerators in some villages, like Idna, Deir-Samit, Beit-Awwa and some other villages in south Hebron regions"- they listed the some diseases in a table with the percentage of each disease conditions before and after the presence of this phenomenon as listed in the table 2.2 below:

No.	Disease	After	Percentage (%)	Month before
1.	Dermatitis	26	17.5	4
2.	Dyspnea	42	28.5	3
3.	Asthma	27	18	4
4.	Heart attack	19	13	2
5.	Cancer	13	9	2
6.	Congenital malformation	17	11	1
7.	Others	4	3	1
	The sum	148	100%	17

Table 2.2: disease conditions spread.

The information in the table 2.2 confirms the bad effects of burning scrap with the wrong ways. It was found that the disease cases increased more than 8 times than before a month of starting this phenomenon.

Moreover, the vegetation has been affected by this phenomenon, where a general emaciation happened to the plantings around the incinerators and the crops is decreased, also some kinds of plant gone from the places around the incinerators. These effects happens because of the smoke spread in the around.

Figure 2.4: Scrap incinerators between trees.

Also the animals affected by burning scrap outdoors in the around, where some diseases appear and affect the animals in the regions where the incinerators surround, and the animal productions decreased.

Finally, burning scrap outdoors affects the air, soil and water, where the accumulated residual materials after burning scrap pollute the soil, and it will be hard to plant the areas where the incinerators. But there are a bad effects on the air and the water in the long term.

Figure 2.5: the effects of scrap burning on the soil.

2.6 Results and recommendations.

- **Results.**

  1. About 24% of the incinerators spread between compounds.
  2. People who live around the incinerators exposed to many diseases like Dermatitis and Dyspnea.
  3. Vegetation and animals exposed to many negative effects which will affect their production.
  4. Burning scrap outdoors pollutes the soil dangerously, and it will make using these areas again hard.
  5. Burning scrap outdoors will affect negatively the air and the water indirectly.

- **Recommendations.**

  1. Setting a hard rules and sanctions to reduce and prevent the wrong practices that hurt the environment and human.
  2. Striving to save people and environment from the dangerous phenomenon.
  3. Raise the awareness between people.
  4. Support and develop the clean ways of separating scrap materials like cable insulators smelting furnace.

Chapter Three

Insulators' materials

3.1 Introduction about cable insulators.

3.2 Cables insulators materials and its properties.

3.3 Common used materials.

3.4 Conclusion.

3.1 Introduction about cable insulators.

3.1. 1. General formula.

Electrical cable insulators are a plastics or polymers, a very large molecules made up of smaller units called monomers which are joined together in a chain by a process called polymerization. The polymers generally contain carbon and hydrogen with, sometimes, other elements such as oxygen, nitrogen, chlorine or fluorine. There exist natural plastics such as shellac, tortoise shell, horns and many resinous tree saps but the term "plastic" is commonly used to refer to synthetically (synthetic or semi-synthetic) created materials that is constantly use in our daily lives: in our clothing, housing, automobiles, packaging, electronics, signs, recreation items, and medical implants and cables insulators .. etc.

3.1.2. How it's made?

Different insulation materials may be used depending on the characteristics of the cable required. The quality of an insulation material depends on two basic characteristics: its insulation capacity and its heat resistance. In this process, the insulating material is added by a process of extrusion at high temperature. The insulation ensures there are no current leakages. Several insulating materials may be used: PVC, EPR, XLPE, etc [1].

3.2 Cables insulators materials and its properties.

3.2.1. Cable insulators materials.

Insulation is a non-conductive material, or a material resistant to the flow of electric current. Insulation resists electrical leakage, prevents the wire's current from coming into contact with other conductors, and preserves the material integrity of the wire by protecting against environmental threats such as water and heat. Both the safety and effectiveness of the wire depend on its insulation.

Following is a list of insulation materials with information on the typical uses, advantages, and disadvantages for each option.

Polyvinyl Chloride (PVC)

PVC is a relatively inexpensive and easy-to-use material, with the potential to be used in diverse applications. The maximum temperature range is -55°C to 105°C and is flame, moisture, and abrasion resistant.

It also holds up against gasoline, ozone, acids, and solvents. It can also be used for medical and food related purposes as it is odorless, tasteless, and non-toxic. PVC can be used in both heavy and thin wall applications. PVC should not be used when flexibility and an extended flex life are required at low temperatures. When used in retractile cord applications, it also shows below average flexibility. PVC displays high attenuation and capacitance loss, meaning that power is lost when used in an electrical system.

Semi-Rigid PVC (SR-PVC)

This is mainly used as a primary insulation and is very abrasion resistant. (For 30-16 gauge, a 10 mil. wall meets UL style 1061, 80°C, 300 volts.) Semi-Rigid PVC is also heat, water, acid, and alkali resistant, as well as flame retardant.

Plenum Polyvinyl Chloride (Plenum PVC)

Plenum PVC is suitable for use in building spaces behind dropped ceilings or raised floors which are left open to allow for air circulation. Standard PVC is considered a non-plenum insulation option because it does not exhibit the qualities necessary for safe usage in plenum areas. To be plenum-rated the insulation must meet more stringent fire safety regulations [10].

Polyethylene (PE)

This compound is used most in coaxial and low capacitance cables because of its exemplary electric qualities. Many times it is used in these applications because it is affordable and can be foamed to reduce the dielectric constant to 1.50, making it an attractive option for cables requiring high-speed transmission. Polyethylene can also be cross-linked to produce high resistance to cracking, cut-through, soldering, and solvents. Polyethylene can be used in temperatures ranging from -65°C to 80°C. All densities of Polyethylene are stiff, hard, and inflexible. The material is also flammable. Additives can be used to make it flame retardant, but this will sacrifice the dielectric constant and increase power loss [2].

Polypropylene(PP)

This material is very similar to Polyethylene, but has a wider temperature range of -30°C to 80°C. It is used primarily for thin wall primary insulations. Polypropylene can be foamed to improve its electrical properties.

Polyurethane (PUR)

Polyurethane is known for its extreme toughness, flexibility, and flex life, even in low temperatures. It also has excellent ratings for chemical, water, and abrasion resistance. This material works well in retractile cord applications and can be a good option for salt-spray and low-temperature military purposes. Polyurethane is a flammable material. The flame retardant version sacrifices strength and surface finish. Polyurethane's main disadvantage though, is its poor electrical properties, making it suitable for jackets only.

Chlorinated Polyethylene (CPE)

CPE displays very good heat, oil, and weather resistance. Many times CPE serves as a lower cost, more environmentally friendly alternative to CSPE. Its reliable performance when exposed to fire also makes it a favorable alternative to PVC insulation. Chlorinated Polyethylene is commonly found in power and control cables and industrial power plant applications.

3.2.2 Properties of cable insulators.

The insulation materials have many properties to study in this project, and to achieve that, about these materials properties a study was made in this field, the results of this study will be shown in this section, the following tables show a useful properties like density, operating point temperatures, melting points, and some needed constants for some of these materials (as needed) [3],[4],[5],[6].

3.1 Insulation Materials (PVC)

	Y	Yw	Yw	Yk
	PVC Polyvinylchloride Compounds	PVC Heat-resistant 90°C	PVC Heat-resistant 105°C	PVC Cold Resistant
Density g/cm^3	1.35 - 1.5	1.3-1.5	1.3-1.5	1.2-1.
Breakdown Voltage KV/mm (20oC)	25	25	25	25
Specific Volume Resistivity Ω cm (20oC)	1013-1015	1012-1015	1012-1015	1012-1015
Dielectric Constant 50 Hz (20oC)	3.6-6	4-6.5	4.5-6.5	4.5-6.5
Dielectric Loss Factor (tan δ)	4 x 10-2 to 1 x 10-1	4 x 10-2 to 1 x 10-1	4 x 10-2 to 1 x 10-1	4 x 10-2 to 1 x 10-1
Working Temperature	Permanent °C	-30 +70 -20 +90	-20 +105	-40 +70
	Short Time °C	+100 +120	+120	+100

Melt Temperature °C	>140	>140	>140	>140

3.2 Insulation Materials (PE)

		2Y	2Y	2X	O2Y
		LDPE	HDPE	VPE	
		Low density Polyethylene	High density Polyethylene	Cross Linked Polyethylene	Foamed Polyethylene
Density g/cm³		0.92-0.94	0.94-0.98	0.92	≈0.65
Breakdown Voltage KV/mm (20°C)		70	85	50	30
Specific Volume Resistivity Ω cm (20°C)		$10^{[illegible]}$	$10^{[illegible]}$	$10^{1[illegible]}$-$10^{[illegible]}$	$10^{[illegible]}$
Dielectric Constant 50 Hz (20°C)		2.3	2.3	4-6	≈1.55
Dielectric Loss Factor (tan δ)		2 x 10^{-4}	3 x 10^{-4}	2x 10^{-3}	5 x 10^{-4}
Working Temperature	Permanent °C	-50 +70	-50 +00	-35 +90	-40 +70
	Short Time °C	+100	+120	+100	+100
Melt Temperature °C		105-110	130	-	105

3.3 Insulation Materials (other materials)

		3Y	4Y	9Y	11Y	TPE-E (12Y)	TPE-O
		PS	PA	PP	PUR		
		Polystrole	Polyamide	Poly-propylene	Poly-urethane	PolYester Elastomer	Polyolefine Elastomer
Density g/cm^3		1.05	1.02-1.1	0.91	1.15-1.2	1.2-1.4	0.89-1.0
Breakdown Voltage KV/mm (20°C)		30	30	75	20	40	30
Specific Volume Resistivity Ω cm (20°C)		10^{16}	10^{15}	10^{16}	10^{11}-10^{13}	$>10^{10}$	$>10^{11}$
Dielectric Constant 50 Hz (20°C)		2.5	4	2.3-2.4	4-7	3.7-5.1	2.7-3.6
Dielectric Loss Factor (tan δ)		1×10^{-4}	2×10^{-2} to 1×10^{-3}	4×10^{-4}	2.3×10^{-2}	1.8×10^{-2}	1.8×10^{-3}
Working Temperature	Permanent °C	-50 +80	-60 +05	-10 +100	-55 +80	-50 +100	-50 +100
	Short Time °C	+100	+125	+140	+100	+140	+130
Melt Temperature ~°C		>120	210	160	150	190	150

3.3 Common used materials.

The most used materials to insulate electrical wires firstly is **Polyvinyl Chloride (PVC)** and it's family like Semi-Rigid PVC (SR-PVC), Plenum Polyvinyl Chloride (Plenum PVC). And at the second level is **Polyethylene (PE)** with his own family. The other materials is not used widely, like the last so I neglect it in my project.

3.4 Conclusion.

Finally, by identifying the materials we used commonly (PVC, PE), the smelting points is (105-130)° for polyethylene, and almost over 140° for the PVC, so that our operating point will start from 140° to reach 210°, and may be more. The experiments will tell the actual temperatures needed.

Chapter Four

Project systems design

4.1 Introduction.

4.2 Conceptual design.

4.3 Selected design and system parts.

4.4 Conclusion.

4.1 Introduction.

To get the best design for the system as possible, it is desired to know: what are the goals to be achieved through the design, so that the design must perform the need of the system. As mentioned above, the system will fought one of the bad habits, which is burning the insulated electrical cables outdoors, to save the environment and human from the resulting pollutants from these processes.

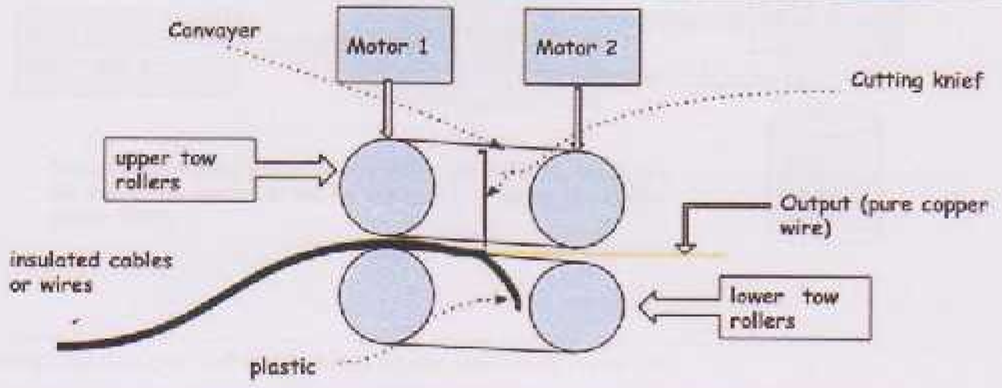
The cables are burnt in many places, and by many investors in the scrap separation, so the system must built in a small size, low cost thus the price, and makes the separation of insulators process in less possible time. That to convince the workers in this field to leave these disastrous processes, by giving a suitable solution, that satisfying their goals corresponds with the project goals.

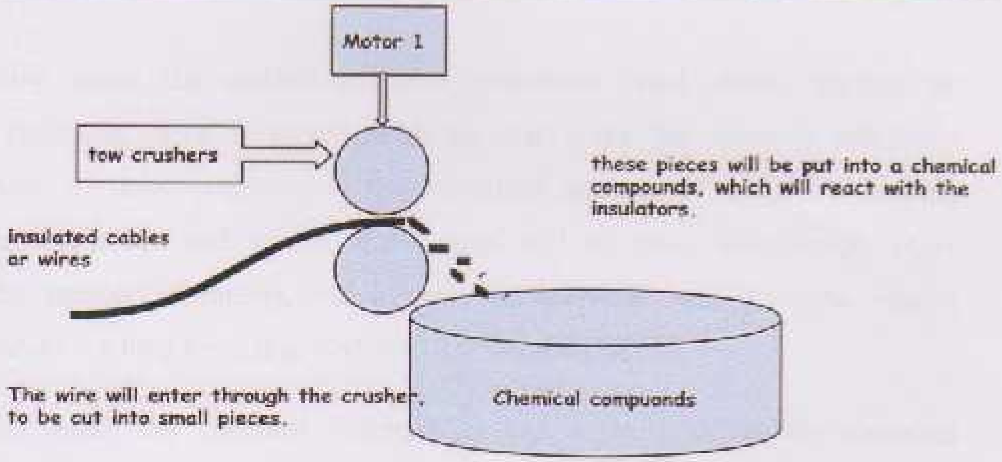
Finally, the design has to be suitable with the operating conditions, in other words, which mechanisms must used in the system, the processes done on the input of the system, and as a result the output desired. On the other hand, the surrounding circumstances should be taken into account, like the work environment, and the changes of this environment.

4.2 Conceptual design.

In this project, there are many techniques may be used to build the system of cables insulation smelting, going through mechanical, chemical, and thermal behaviors. The process depends on one or more of these behaviors, as a combination.

The options existent is listed in the table 3.1:

<table>
<tr><th>Approach</th><th>Design and sketch</th></tr>
<tr><td>Mechanical approach</td><td>


The wires will be inserted in the rollers then ths knief will start cutting the insulators
</td></tr>
<tr><td>Chemical approach</td><td>


This operation will take long time to finish.
</td></tr>
</table>

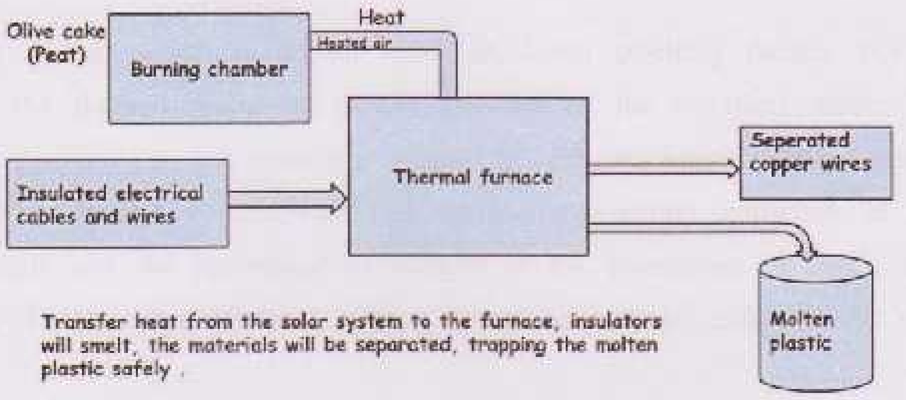
Thermal approach	

Table 4.1: The conceptual designs and the process of the system approaches.

By searching about the mechanisms and operations listed above, starting by the mechanical approach, there is some problems, that make the system's efficiency in low levels. One of these problems is the enormous number of cable's diameters, so that, including diameters and control the system will be more complicated, other problems like the smallest diameters, which can't be operated; And the time needed to achieve the process is a long time, that's what will affect the quantity.

On the other hand, the chemical approach is too difficult to get the chemical compounds, which are too many to make the interactions with the cable's insulators. Moreover, it needs to a specialized people in the chemical department, so it is hard to do by mechatronics students.

Finally, the thermal approach, this approach is the more efficient one, so that it will be the selected design, the next sections will clarify this design concept.

4.3 The selected design and system parts.

In this section, the design, the parts, and the mechanisms or operations of the system will be discussed. These components will be integrated to get the best system may built in this field.

4.3.1 What's the design selected?

The system design, which is named cable insulators smelting furnace (CISF), will depend on the thermal properties of the insulator of the electrical wires; The most important property is the smelting points of the insulators. Other needed properties like the thermal conductivity and convection thermal constants of the insulator's materials and the percentage of oxygen in the boundaries of the system (oxygen index). These properties and others are mentioned in chapter two with some details.

The idea is to use a thermal insulated furnace to smelt the insulator of cables; As mentioned in chapter tow, the smelting temperatures rang are desired to be reached is between (105-210) C°, so that, to operate the system an energy is needed. As known the system will built to save the environment from pollution, so the system has to be operated by a clean energy. The most compatible energy is the heat produced by the composition of the peat (olive cake), because it is cheap material and available in our country.

The heat generated from the composition of the peat material will be used to smelt the cable insulators, so that, the heat has to flow inside the smelting chamber to get the desired output, which is separating the plastic materials from the copper cables.

An insulated burning chamber is needed to burn the peat, to reach the heat flow desired to smelt the plastic material, and to control the temperature inside the smelting chamber, the composition rate must be controlled, so an air pump is installed on the burning chamber to increase or decrease the quantity of oxygen enters the burning chamber as needed.

Figure 4.1 shown below shows the whole system parts built and assembled, where the chamber above the table -in the left side- is smelting chamber, and the other one –on the right side is the burning chamber.

As shown in the figure 4.1 and figure 4.2 the starting point of the system operations will be the peat (olive cake) burning, to generate heat energy, then the air inside the burning chamber will be heated to reach a specific temperature, after the air heating operation ends, the heated air will start flow through the thermal insulated tube -at the top of burning chamber- to reach the smelting chamber, where the valve will control this operation.

The last level of the system operations is transferring the heat from the air to the insulated electrical wires inside the smelting chamber. When the insulation materials smelted, the molten plastic will be trapped through a hole in the bottom of the smelting chamber, to be safe in the molten plastic tank.

Finally, the air will return to the burning chamber with high temperature, but less than the smelting temperature of the insulation materials, thus it will be heated again with less quantity of energy needed at the first time, to separate the insulated copper wire once again.

Figure 4.1: The whole system of cable insulators smelting furnace.

Figure 4.2: The whole system of cable insulators smelting furnace (another view).

4.3.2 The system parts and components.

The system will consist of mechanical and structural parts, electrical parts and the control components and, finally, pneumatic parts and components, the figure 4.3 show the parts number associated in the table 4.2:

Components	Part no.	Part name
Mechanical and structural parts	1.	Insulated chamber
	2.	Metal grid
	3.	Table (stand)
	4.	Burning chamber(peat burner)

Pneumatics components	5.	Hydraulic tubes
	6.	Valves
	7.	Air pump
	8.	Gas (air)
	9.	Filters
	10.	Molten plastic tank
Electrical parts and Control components	11.	Printed circuits
	12.	Resistors and capacitors
	13.	Switches
	14.	Electrical wires
	15.	Temperature sensor
	16.	At mega 328p arduino Controller

Table 4.2: The system parts and components.

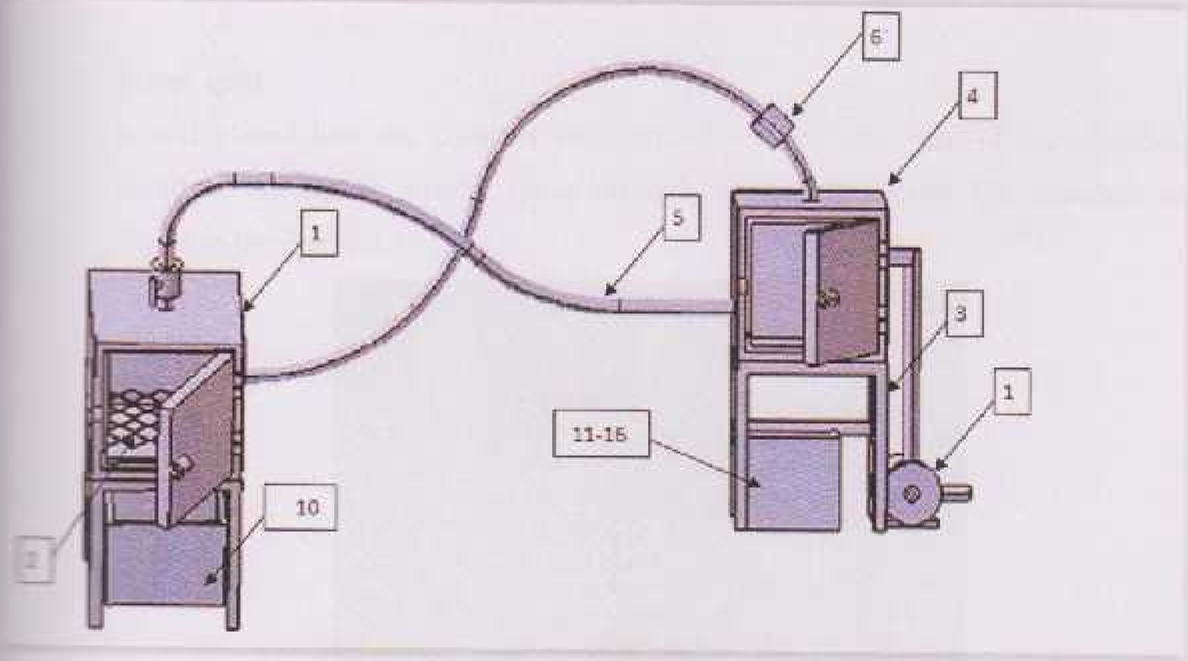


Figure 4.3: The numbered system parts.

Now it is the time to explain why these parts and components are selected to build the system:

1. **Insulated smelting chamber.**

   The scratches of electrical wire insulators have to be smelted in a thermal isolated chamber to keep the thermal energy inside, without heat dissipation, as shown in the Figure 4.4.

Figure 4.4: smelting chamber.

2. **Metal grid.**

   It will placed into the chamber few centimeters over the base of the chamber, to allow the molten plastic going through, to trap it outside the chamber, as shown in the Figure 4.5.

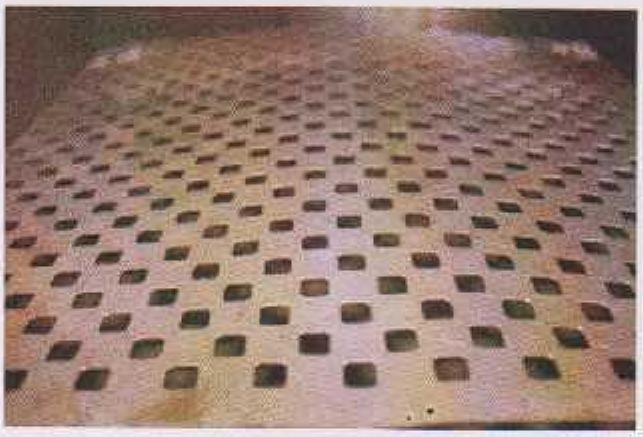


Figure 4.5:Metal grid.

3. **Metallic table.**

To loud the chamber and other components on this table, for safety; as shown in the Figure 4.6.

Figure 4.6: Metal table.

4. **Burning chamber.**

This chamber will be used to burn the peat material, to generate heat needed for the smelting operations, as shown in the Figure 4.7.

Figure 4.7: Burning chamber.

5. **Hydraulic tubes.**

To allow the heated gas flowing inside/outside the chamber, as shown in the Figure 4.8.

Figure 4.8: Hydraulic tubes.

6. **Valves.**

To control the processes of gas flow, as shown in the Figure 4.9.

Figure 4.9: Electrical valve.

7. **Electrical air pump.**

To control the oxygen amount entered the burning chamber to increase or decrease the composition rate, as shown in the Figure 4.10.

Figure 4.10: Electrical air pump.

8. **Gas.**

It is the fluid used to transfer the heat energy inside the chamber.

9. **Filters.**

Used for fluid filtration; as shown in the Figure 4.11.

Figure 4.11: Gas filter.

10. **Molten plastic tank.**

This tank will be used to contain the molten plastic trapped from the smelting chamber, after the insulation materials smelt, which is shown in figure 4.12.

Figure 4.12: Molten plastic tank.

11. **Printed circuits.**

To build the circuits of operating and switching the system, as shown in the Figure 4.13.

Figure 4.13: Printed circuit

12. **Resistors and capacitors.**

Used in the circuits to operate system correctly, as shown in the Figure 4.14.

Figure 4.14: Resistors and capacitors.

13. **Switches.**

On/off the system and its operations, as shown in the Figure 4.15.

Figure 4.15: Switches.

14. **Electrical wires.**

Connecting the system components.

Figure 4.16: Electrical wires.

15. **Temperature sensors.**

To measure the temperature inside the chamber, as shown in the Figure 3.17.

Figure 4.17: Temperature sensor.

16. **At mega 328p arduino controller.**

To control the system operations, the control system and the controller will discussed in details next chapters. Shown in the figure 4.18.

Figure 4.18: at mega 328p microcontroller.

4.4 Conclusion.

This project will depend on the synergistic integration between the mechanical parts, and electrical parts through a control system.

At the end of this chapter, it's really important to know what the stages of building of this system are; finally, it is the time to talk briefly about the building stages step by step:

1. Building the structural and mechanical parts, where the calculations will depend on the structure geometry.
2. Build the electrical part and circuits depending on the mechanical and structural system, based on the preceding calculations.
3. Generate the codes to control the system, to make sure that the system working properly, that's happened through using the controller. This operation need to build an excellent mechanical and electrical subsystems.

Chapter Five

Mathematical modeling and calculations

5.1 Introduction.

5.2 Thermal mathematical modeling and calculations.

5.3 Conclusion.

5.1 Introduction.

Firstly, it's necessary to talk about the source of energy powered this system, which is -as known- the heat generated from peat burning so that, the heat generated from burning one kilogram must be known to start the system calculations.

Modeling and calculating the system parts' requirements depend on specified dimensions of two parts, which is the smelting chamber and the heat capacitance of air gas. The smelting chamber will be a cubic one, and dimensions are (50*50*50) cm. So that, the calculations will depend on these dimensions and the gas constant.

In this chapter, there is some numbers must be identified related to the subsystems or combined subsystems, some matters will be discussed, which are mentioned bellow:

1. Heat transferred by radiation.
2. Heat transferred by convection.
3. Thermal mathematical modeling and calculations.
4. Conclusion.

5.2 Thermal mathematical modeling.

Before start modeling the thermal system in this project, it's very important to know what the way that heat transferred in this system is.

When the peat burnt the heat will start generating from this operation, while the air gas will enter into the burning chamber, thus the heat will transferred to the gas, then the gas will transport the heat into the smelting chamber.

5.2.1 Heat transferred by radiation.

As mentioned above, the heat transferred by radiation from the burnt peat to the air gas inside the chamber. The calculations of radiation heat transfer depend on the peat composition radiations.

The mathematical equation used to evaluate the heat transferred from the burnt peat light to the gas container is:

$$\dot{Q} = e\,\sigma A\,(T_2^4 - T_1^4) \qquad (1)$$

Where :

$\dot{Q}$: the heat flow or power.

e: surface emissivity.

σ: Stephan Boltzmann constant.

A: the surface area of the gas container.

T_1: Container surface before heating temperature.

T_2: the temperature of burnt peat light through burning.

5.2.2 Heat transferred by convection.

When the heat transferred by radiations to reach the gas container, the heat will be transferred by convection to the smelting chamber, using the gas as a transporting fluid. The point is transferring the heat into the chamber to smelt the cable insulator, and to achieve this goal, convection heat transfer equation has to be defined; Where the mathematical equation is:

$$\dot{Q} = h\,A\,(T_W - T_\infty) \qquad (2)$$

Where :

$\dot{Q}$: the heat flow or power.

h: the convective heat transfer coefficient.

A: the surface area of the gas container.

T_w: Container surface after heating temperature.

T_∞: Gas before heating temperature.

5.2.3 Specifications of the prototype and the materials selection.

There are some specifications and givens must be identified and controlled in this system to reach the maximum efficiency for this system, which are listed below:

1. The thermal efficiency of the both chambers (burning chamber and smelting chamber). The thermal efficiency in the chambers is about 90% referring to the selected chambers with Rockwool insulating materials with 10 cm thickness.
2. The heat loses in the gas tubes through transferring the heat from the burning chamber to the smelting chamber. The will be insulated like the chambers, with an efficiency of 90% .
3. The thermal quantity generated by the peat (olive cake) burning which is 16.75 (Mj/kg).
4. The thermal constants of the materials used or processed in the system, like surface emissivity(e) for air, Stephan Boltzmann constant (Ơ) in radiation heat transfer, and the convective heat transfer coefficient (h) in convection heat transfer[7],[9].

These numbers are defined in the following table referring to the heat transfer thermal properties tables:

Constant/Coefficient	Symbol	Value
Wood(Peat) surface emissivity	Ε	0.9
Stephen Boltzmann constant	Ơ	5.670373×10^{-8} kg s^{-3} K^{4}
Convective coefficient	H	420-880 (W /m^2 K)

Table 5.1: The constant and coefficient values.

5.2.4 How to model and calculate the radiation and convection heat transfer specifications ?

The convective heat transfer coefficient (h) in the plastic materials is in the range between 0.19-0.5 (W /m2 K), but the calculations will based on the minimum value of convective heat transfer coefficient (h), thus the overall heat transfer will be minimized so the system building calculations will be in the safe side.1

The calculation will start from the smelting furnace to define the quantity of heat to be transferred to the insulation materials by convection to smelt it; it is important to know what is the specific heat energy for the insulation materials, which is in the range (18-46) Mj/kg but the maximum value will be considered; now return to the convection heat transfer equation (1):

$$\dot{Q} = \mathbf{h\ A\ (T_{air} - T_{insulator})} \qquad \textbf{(3)}$$

But the heat needed to smelt 1 kg of plastic material is 46 Mj.s/kg, and the initial temperature of the insulator is about 278 k so that:

$$\mathbf{T_{air} = (46000/880*0.25)+278}$$

$$\mathbf{T_{air} = 487\ ^{\circ}k}$$

$$T_{air} = \mathbf{487 - 273 = 214}\ ^{\circ}C$$

Now finding the total efficiency of the system:

$$\square_{overall} = \square_s * \square_t * \square_b \qquad \textbf{(4)}$$

$$\square_{overall} = \mathbf{90\% * 90\% * 90\%}$$

$$\mathbf{=72.9\%}$$

Where:

$\eta_{overall}$: The overall efficiency of the system.

η_s: The efficiency of the smelting insulated chamber.

η_t: The efficiency of the insulated tubes.

η_b: The efficiency of the insulated burning chamber.

Now the heat generated by burning the peat (olive cake) to smelt 1 kg of insulators' material can be calculated as shown below:

$$\dot{Q}_g = \dot{Q}_c/\eta_{overall} \qquad (5)$$

$$\dot{Q}_g = 46*10^6/0.729$$

$$\dot{Q}_g = 63.1 \text{ Mj/s.kg}$$

Where:

$\dot{Q}_g$: The heat energy generated by burning the peat (olive cake).

$\dot{Q}_c$: The heat energy consumed through smelting 1 kg of insulators' material

$\eta_{overall}$: The overall efficiency of the system.

Now the quantity of peat (olive cake) needed to smelt 1 kg of insulators' material can be defined using the following equation:

$$\text{Quantity of peat} = \dot{Q}_g/(\dot{Q}_p/\text{kg}) \qquad (6)$$

$$\text{Quantity of peat} = 63.1/16.75 = 3.76 \text{ kg}$$

Where:

$\dot{Q}_g$: The heat energy generated by burning the peat (olive cake).

($\dot{Q}_p$/kg): The heat energy generated by burning 1 kg of the peat (olive cake).

Finally, the value of temperature desired to reach through burning the peat (olive cake) can be evaluated as shown:

$$\dot{Q}_g = e\, \sigma A\, (T_b^4 - T_{air}^4) \qquad (7)$$

$$\text{But, } T_b^4 = (Q/ e\, \sigma A) + T_{air}^4$$

$$T_b = \sqrt[4]{(Q/ e\, \sigma A) + T_{air}^4}$$

$$T_b = \sqrt[4]{(63.1 * 10^6/0.9 * 5.670373 \times 10^{-3} * 0.25) + 298^4}$$

$$= 489\ °k$$

$$T_b = 490 - 273 = 217\ °C$$

Where:

$\dot{Q}_g$: The heat energy generated by burning the peat (olive cake).

e: surface emissivity.

σ: Stephan Boltzmann constant.

A: the surface area of the chamber (gas container).

T_{air}: Container surface after heating temperature.

T_b: the temperature of the burnt peat light through burning.

5.3 Conclusion.

Firstly, there is energy loses in the system, occurs through heat generation in the burning chamber, heat transfer in the tubes, and through heat transfer in the smelting chamber, the point here is the real thermal insulated systems lose energy, so it is not conservative system.

Finally, if the power source of the system cannot reach the desired heat energy, then, there is an alternative power system, which is the electrical power source using the heaters to reach the temperature desired, and the calculation will done in short time.

Chapter Six

Control system and Microcontroller code

6.1 Introduction.

6.2 Heat control system.

6.3 The at mega 328p controller.

6.4 Microcontroller code.

6.1 Introduction.

Any mechatronics project with its mechanical and electrical parts needs to be controlled through control system that achieved the synergy and integration between the whole subsystems. To reach the point of integration and synergy in the project, the control system must meet the requirements of each subsystem and then has the ability to match these requirements and lead the subsystems to do their duties without overlapping between these subsystems.

6.2 Heat control system.

In this project the most important property must be controlled is the temperature in the smelting chamber and the olive cake burning chamber, this operation is important to prevent the happening of the inflammation inside the smelting chamber to avoid the direct and indirect negative effects of these phenomenon.

When starting the process of the project, the air in the burning chamber will be heated, because of the heat generated through burning the olive cake, and when the temperature of the air reach the desired rang a directional valve will open to allow the air flowing into the smelting chamber to smelt the plastic insulators and if the heat flow temperature increased the directional valve will close to keep the temperature fixed inside the smelting chamber, and it depends on the ranges of smelting temperature according to material properties as mentioned in chapter three-.

To achieve these specifications at-mega 328P arduino controller is needed to control the system and keep the temperature at the same rang desired. Also two temperature sensors must be installed in the two chambers, these sensors will be controlled by at mega328P, the next sections will explain what is the at-mega 328P controller, how the sensors connected, and the code installed on the controller.

6.3 The at mega 328p controller.

6.3.1 Features

Figure6.1: at-mega 328p controller

- High Performance, Low Power Atmel®AVR® 8-Bit Microcontroller Family.
- Advanced RISC Architecture – 131 Powerful Instructions – Most Single Clock Cycle Execution – 32 x 8 General Purpose Working Registers – Fully Static Operation – Up to 20 MIPS Throughput at 20MHz – On-chip 2-cycle Multiplier.
- High Endurance Non-volatile Memory Segments – 4/8/16/32KBytes of In-System Self-Programmable Flash program memory – 256/512/512/1KBytes EEPROM – 512/1K/1K/2KBytes Internal SRAM – Write/Erase Cycles: 10,000 Flash/100,000 EEPROM – Data retention: 20 years at 85°C/100 years at 25°C(1) – Optional Boot Code Section with Independent Lock Bits In-System Programming by On-chip Boot Program True Read-While-Write Operation – Programming Lock for Software Security.
- Atmel® QTouch® library support – Capacitive touch buttons, sliders and wheels – QTouch and QMatrix® acquisition – Up to 64 sense channels.
- Peripheral Features – Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode – One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode – Real Time Counter with Separate Oscillator – Six PWM Channels – 8-channel 10-bit ADC in TQFP and QFN/MLF package Temperature Measurement – 6-channel 10-bit ADC in PDIP Package Temperature Measurement – Programmable Serial USART – Master/Slave SPI Serial Interface – Byte-oriented 2-wire Serial Interface (Philips I2 C compatible) – Programmable Watchdog Timer with Separate

On-chip Oscillator – On-chip Analog Comparator – Interrupt and Wake-up on Pin Change.

- Special Microcontroller Features – Power-on Reset and Programmable Brown-out Detection – Internal Calibrated Oscillator – External and Internal Interrupt Sources – Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby.
- I/O and Packages – 23 Programmable I/O Lines – 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF.
- Operating Voltage: – 1.8 - 5.5V.
- Temperature Range: – -40°C to 85°C.
- Speed Grade: – 0 - 4MHz@1.8 - 5.5V, 0 - 10MHz@2.7 - 5.5V, 0 - 20MHz @ 4.5 - 5.5V.
- Power Consumption at 1MHz, 1.8V, 25°C – Active Mode: 0.2mA – Power-down Mode: 0.1µA – Power-save Mode: 0.75µA (Including 32 kHz RTC).

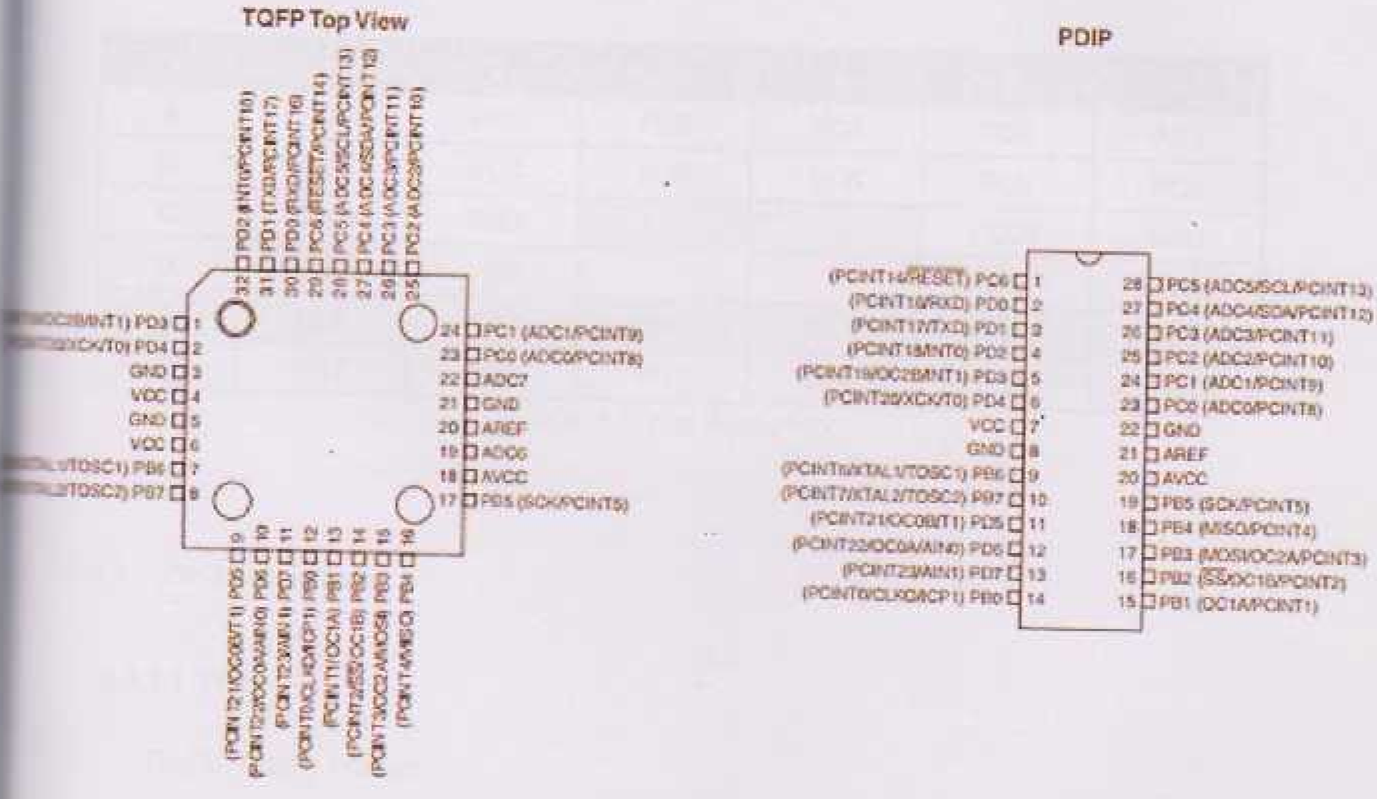


Figure 6.2: pins description for at mega328p arduino

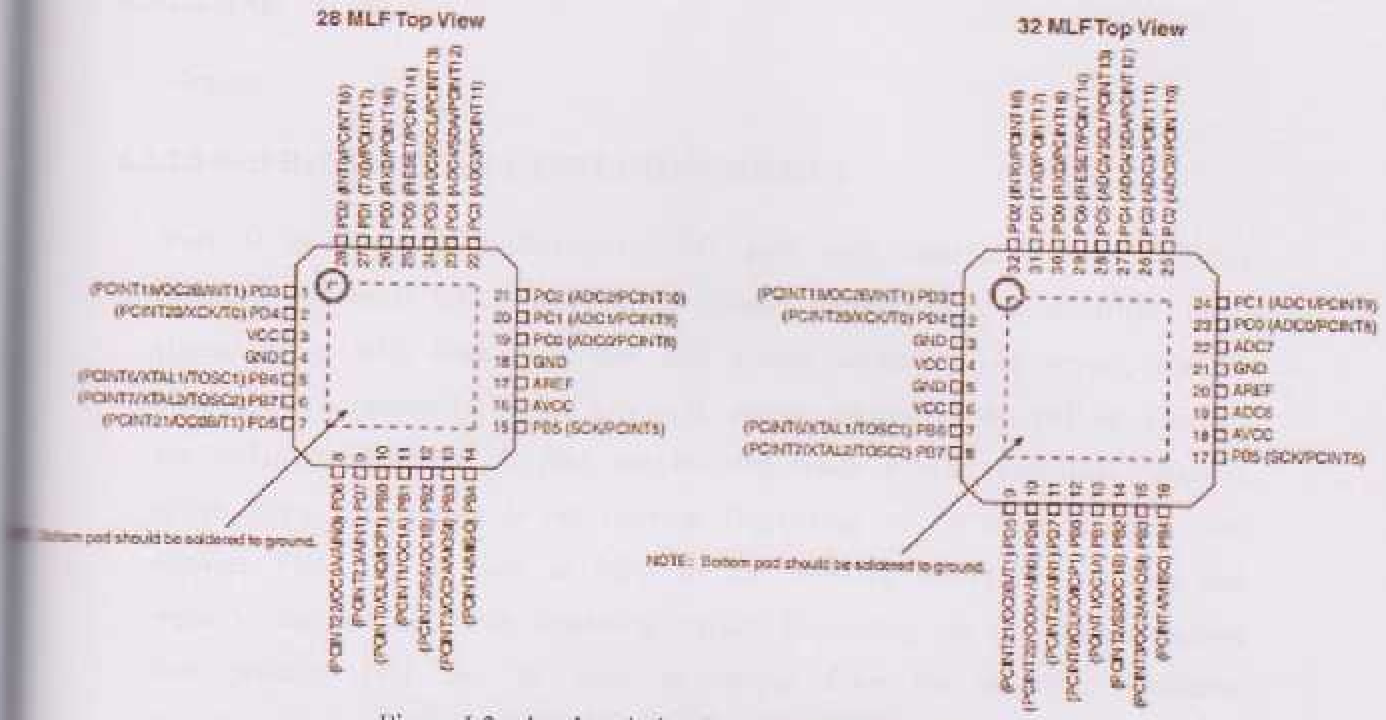


Figure 6.3: pins description for at mega328p arduino

	1	2	3	4	5	6
A	PD2	PD1	PC6	PC4	PC2	PC1
B	PD3	PD4	PD0	PC5	PC3	PC0
C	GND	GND			ADC7	GND
D	VDD	VDD			AREF	ADC6
E	PB6	PD6	PB0	PB2	AVDD	PB5
F	PB7	PD5	PD7	PB1	PB3	PB4

Table 6.1: pins description

6.3.2 Pin Descriptions

6.3.2.1 VCC

Digital supply voltage.

6.3.2.2 GND

Ground.

6.3.2.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tristated when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit. Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier. If the Internal Calibrated RC Oscillator is used as chip clock source, PB7...6 is used as TOSC2...1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set. The various special features of Port B are elaborated in "Alternate Functions of Port B" on page 82 and "System Clock and Clock Options" on page 27.

6.3.2.4 Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5...0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tristated when a reset condition becomes active, even if the clock is not running.

6.3.2.5 PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. The minimum pulse length is given in Table 29-11 on page 305. Shorter pulses are not guaranteed to generate a Reset. The various special features of Port C are elaborated in "Alternate Functions of Port C" on page 85.

6.3.2.6 Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tristated when a reset condition becomes active, even if the clock is not running. The various special features of Port D are elaborated in "Alternate Functions of Port D" on page 88.

6.3.2.7 AVcc

AVcc is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that PC6...4 use digital supply voltage, VCC.

6.3.2.8 AREF

AREF is the analog reference pin for the A/D Converter.

6.3.2.9 ADC7:6 (TQFP and QFN/MLF Package Only)

In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

6.4 Microcontroller code.

The most used programming language for the arduino controllers is C language, that is because it's easy to program and universal. The code built to program the controller at mega328p is listed below:

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(5, 4, 3, 2, 1, 0);
int T1=0;
int T2=0;
int Toven=0;  // temprature of room 1
int Toven2=0;
int V=13; // Valve open
int Tset1=200;  // Set temprature of room 1;
int Tset2on=180;  // set temprature of room 2 for opening the valve.
int Tset2off=160;  // set the temprature of room 2 for closeing the valve.
int change=10;
int uppb=12;
int downpb=11;
int var=0;
void setup() {
  lcd.begin(16, 2);
pinMode(13,OUTPUT);
pinMode(uppb,INPUT);
pinMode(downpb,INPUT);
pinMode(change,INPUT);
```

```
}

void loop() {

if (digitalRead(change) == HIGH)
 {
 var=var+1;
 if (var==4)
 {
 var=0;
 }
 delay(200);
 }
  if (var==0) //////////////////////////////////////////////////////////// initilizing
  {
  lcd.setCursor(0,0);

lcd.print("   press on SET    ");
lcd.setCursor(0,1);
lcd.print("   for settings    ");

   }else
  if  (var==1)  ///////////////////////////////////////////////////////////  //  changing  SET
Temprature in room 1
   {
```

```
if (digitalRead(uppb)==HIGH)  // changing SET Temprature in room 1 increasing
{
lcd.setCursor(0,0);
 lcd.print("  set the temp   ");
 lcd.setCursor(0,1);
 lcd.print("     ");
    lcd.print(Tset1);
       lcd.print("         ");

Tset1=Tset1+1;
if (Tset1>300);
{
Tset1=300;
}
delay(100);
}else

if (digitalRead(downpb)==HIGH)             // changing SET Temprature in room 1
dicreasing
{
 lcd.setCursor(0,0);
 lcd.print("  set the temp   ");
 lcd.setCursor(0,1);
 lcd.print("     ");
    lcd.print(Tset1);
```

```
        lcd.print("        ");
 Tset1=Tset1-1;
 if (Tset1<100)
 {
 Tset1=100;
 }
 delay(100);
 }
  }
 if   (var==2)     //////////////////////////////////////////////////////////////////////////////////////// changing   SET Temprature in room 2 for closing valve
  {

 if (digitalRead(uppb)==HIGH)   // changing SET Temprature in room 2 closing valve increasing temp
 {
 lcd.setCursor(0,0);
  lcd.print("  set T2 off   ");
  lcd.setCursor(0,1);
  lcd.print("     ");
     lcd.print(Tset2off);
        lcd.print("        ");

Tset2off=Tset2off+1;
 if (Tset2off>300);
 {
```

```
Tset2off=300;
}
delay(100);
}else

if (digitalRead(downpb)==HIGH)          // changing SET Temprature in room 2
closing valve dicreasing temp
{
 lcd.setCursor(0,0);
 lcd.print("  set T2 off  ");
 lcd.setCursor(0,1);
 lcd.print("    ");
   lcd.print(Tset2off);
      lcd.print("       ");
Tset2off=Tset2off-1;
if (Tset2off<100)
{
Tset2off=100;
}
delay(100);
}
 }else
if (var==3)   ////////////////////////////////////////////////////////////////////   changing SET
Temprature in room 2 for opening valve
 {
```

```
if (digitalRead(uppb)==HIGH)   // changing SET Temprature in room 2 opening valve increasing temp

 {

 lcd.setCursor(0,0);

  lcd.print("  set T2 on   ");

  lcd.setCursor(0,1);

  lcd.print("     ");

    lcd.print(Tset2on);

       lcd.print("        ");


Tset2on=Tset2on+1;

 if (Tset2on>300);

 {

Tset2on=300;

 }

 delay(100);

 }else


 if (digitalRead(downpb)==HIGH)            // changing SET Temprature in room 2 opening valve dicreasing temp

 {

  lcd.setCursor(0,0);

  lcd.print("  set T2 on   ");

  lcd.setCursor(0,1);

  lcd.print("     ");

    lcd.print(Tset2on);
```

```
        lcd.print("        ");
  Tset2on=Tset2on-1;
  if (Tset2on<100)
  {
  Tset2on=100;
  }
  delay(100);
  }
   }

 T1=analogRead(A0);    // Reading the temp in room1
  T2=analogRead(A1);  // reading the temp in room2

lcd.setCursor(0, 0);

 Toven=T1-17;  // Caliberating the temp reading of sensor 1.
 Toven2=T2-17;    // Caliberating the temp reading of sensor 2.
lcd.print("Temp of ov.=");
lcd.print(" ");
lcd.print(Toven);   // printing on lcd the real value of room1 temprature
lcd.print(" ");

if ( Toven >= Tset1)
{
  lcd.setCursor(0, 0);
```

```
  lcd.print("door is open");
   lcd.setCursor(0, 1);
digitalWrite(V,HIGH); // open the door between two rooms if temp in room 1 is up the set temp
}
if ( Toven2 >= Tset2on)

{
digitalWrite(V,HIGH); // open the door between two rooms if temp in room 2 is up the set temp
  lcd.setCursor(0, 0);
 lcd.print("door is open");
}

if ( Toven2 <= Tset2off && Toven <= Tset1)
{
digitalWrite(V,LOW); // close the door between two rooms if the temp in room 1 and 2 is below the set temp .
  lcd.setCursor(0, 0);
 lcd.print("door is open");
}


}
```

Chapter seven

Gases released from separation materials using burning and smelting

7.1. Introduction.

7.2. Gases released from burning PVC and PE.

7.3. Gases released from smelting PVC and PE.

7.4. How to deal with gases released after smelting PVC and PE?

7.5. Conclusion.

7.1 Introduction.

Large Telecommunications Company authorized a study to determine which insulation materials to employ on wiring in its central offices. In addition to typical criteria related to electrical, mechanical, and environmental exposure characteristics, an analysis and comparison was made of the toxic gases given off by heating or burning of two materials, polyvinyl chloride (PVC) and polyethylene (PE)[15].

This analysis was based primarily upon reviews of information available in technical literature sources, which provided data on the nature of the emitted gases, various toxicity thresholds, and the results of animal experiments with PE and PVC [16].

7.2 Gases released from burning PVC and PE.

PE begins to decompose when exposed to a temperature of 330 to 480 degrees Celsius, and has a self-ignition temperature of 350 degrees Celsius. It gives off gases starting at about 200 degrees Celsius. The gases include ketones and aldehydes, whose combustion becomes self-sustaining at higher temperatures. If PE burns with poor ventilation, both carbon monoxide (CO) and carbon dioxide (CO2) are produced.

PVC is readily ignitable when a plasticizer such as a phthlalate is used; however, the flame retardant properties of PVC are retained with a plasticizer such as a phosphate ester. With the addition of a flame-retardant, PVC's low temperature performance is compromised, (i.e., brittleness is increased, and impact resistance is decreased). It decomposes in the range of 150 to 300 degrees Celsius; flash ignites at 390 degrees Celsius, and self-ignites at 460 degrees Celsius. Up to about 230 degrees C, hydrogen chloride is given off in a white mist and CO is given off mainly above 250 degrees Celsius. Between 400 and 600 degrees Celsius, ethylene, benzene, naphthalene, and other hydrocarbons are produced. When these products are burned with sufficient oxygen, hydrogen chloride, carbon monoxide, and carbon dioxide are produced [17].

Before this review and analysis began, it became apparent that it is extremely difficult to extract from the general literature information concerning toxic gases given off by PVC or PE formulations intended for specific electrical applications, (i.e., including degradation products of plasticizers, stabilizers, or other materials that are added to the basic polymer). For example, certain organo-metals which are used as stabilizers are powerful poisons. The results presented here do not include such possible effects.

As seen in this section there is many toxic gases released when PVC and PE burnt, so that burning scraps outdoors must stop in any way and cost.

7.3 Gases released from smelting scrap materials.

If PVC and PE heated in air to about 250 degrees Celsius, PE melts, sublimes, and to a degree decomposes without burning. The amount of CO given off during combustion, in the temperature range of 480 to 530 degrees Celsius, depends on the oxygen to PE monomer ratio. At a ratio of 1:1, a max CO concentration of 9400 ppm (parts per million) was reached after the burning of 10 grams of PE in a 60-cubic-foot closed compartment. But for a ratio of 3:1 oxygen to PE monomer, the maximum CO concentration reached was only about 1410 ppm. Both were achieved in the range of 480 to 530 degrees Celsius after about 20 min. It should be noted that the permissible exposure limit for CO at that time was 50v ppm, and the IDLH (Immediately Dangerous to Life or Health) level was 1500 ppm. In PVC tests, a maximum hydrogen chloride concentration of about 2100ppm was reached after burning of 10 grams of PVC for about 50 minutes, in the range of 500 to 570 degrees Celsius. The permissible exposure limit for hydrogen chloride was 5ppm, and the permissible IDLH level was 100ppm.

7.4 How to deal with gases released after smelting PVC and PE?

The Formation of Dioxins

First one must keep in mind that there are many production processes or activities that emit dioxins, not only the production of chlorine and the PVC lifecycle.

Despite this fact PVC has for a long time been accused of being the cause of the dioxin production, although PVC is not the only substance in Municipal Solid Waste (MSW) which contains chlorine-plants, food and paper are all among the waste streams which contribute to the chlorine present in MSW.

In fact, the production of dioxins depends more on the quality of incineration than on the type of materials burned.

To prevent the formation of these micro-pollutants it was thought advisable to:

- Reduce the content of chlorinated organic substances in the waste in order to reduce the content in hydrochloric acid in the flue gas of combustion
- Neutralise the hydrochloric acid resulting from their combustion as soon as it is formed in the combustion chamber, by addition of basic reagents (carbonate or calcium hydroxide)..

Given this knowledge of the mechanisms of dioxin formation, the scientific community now unanimously considers that PVC cannot be given the full responsibility for the presence of dioxins in the flue gas emitted from incinerators.

In conclusion, since the second half of the eighties the problem of reducing emissions of dioxins and organic micro-pollutants has been considered solved at the scientific and technology level. The combination of the following features ensures the reduction of dioxins down to values below the acceptable limits:

- Reaching temperatures of 1100°C
- Having a post combustor ensuring a contact time of 2 seconds
- Maintaining an oxygen concentration of 6% in the output gases
- Ensuring a fast cooling down to 250°C to avoid the 'de novo' synthesis of dioxins
- Having also a catalyst for destruction of dioxins or a system with adsorbent activated carbon.

The Emissions, Recovery and Recycling of Gas

In addition to hydrochloric acid, incinerator emissions also include sulphur and nitrogen compounds.

During the waste smelting or combustion process the rupture of the polymer chain, resulting in the release of chlorine in the form of HCl gas. Even in the absence of PVC, due to other sources such as household chlorine in the waste, combustion will always produce gaseous HCl that must be destroyed prior to the release into the atmosphere.

It must be emphasised that the removal of HCl gas is facilitated by its chemical characteristics, whereas it is more difficult to remove SOx, which should be blamed as the largest contributor to acid rain. Chlorine also has a positive contribution in flue gas, as it allows better capture of the heavy metals present in MSW waste, thereby reducing emissions into the environment.

Abatement of Gaseous Emissions

The acid gases, above all SOx and HCl, are mostly neutralised by adding alkaline substances, thus producing the corresponding salts. The amount of neutralisation residues depends on the type of technology used (dry, semi dry, wet, semi wet).

In the case of municipal solid waste incineration, assuming for example that PVC is responsible for approximately half the production of HCl while the wood, paper and other materials (other plastic materials) present are responsible for the rest, it was estimated that the traditional neutralisation process based on the use of hydrated lime requires that the residues are disposed of in a landfill for hazardous waste.

Today there are other processes that enable recycling a significant part of the neutralisation residues, among which the NEUTREC process uses sodium bicarbonate injected dry in the acid fumes, after they have passed an electrostatic filter to mostly eliminate them from the fly ash.

Sodium bicarbonate neutralises the acids and transforms them into sodium salts that are captured by a filtration section and collected, while the purified flue gas can be emitted to the atmosphere. Note that the sodium bicarbonate also contributes to absorb a large part of the heavy metals and dioxins, when injected together with activated charcoal.

The sodium salts generated by the neutralisation of acid gases, once collected in the final stage of filtration, may be recovered in a dedicated section, where they are dissolved in water with additives to promote the precipitation of metals, and subjected to a filtration. The insoluble phase is sent to disposal while the soluble phase (brine), after being further purified, is recycled for the industrial production of sodium carbonate.

A further development of the recovery process (Revasol®), also leads to the recycling of the insoluble phase which, with the SOLVAL®/Resolest® process, is sent for disposal. In this case however, it is recovered for use as a material for the construction or road foundations.

The Recovery of Chlorine as HCl

The incinerator in Hamburg previously mentioned can also be taken as a reference for the recovery of hydrochloric acid and its reuse as muriatic acid (aqueous solution of HCl) as a raw material for other industrial activities. The incinerator has in fact, besides the treatment sections for NOx and SOx, also a facility of purification of chlorinated gas.

The gaseous stream, still containing the chlorinated combustion products, is sent to a HCl 'rectification column' where a 30% aqueous solution of hydrochloric acid is produced, which can be sold to the chemical and construction industries, or used in energy production.

Conclusions

An MSW incinerator produces three types of waste - bottom ash, fly ash and waste neutralisation residues.

The bottom ashes are the heavier solid residue of combustion. Solid particles are also formed during combustion, and they contain metals entrained by the gases. In order to avoid atmospheric release, the solid particles must be absorbed or removed from the gas phase sent to the stack. So the first step is to 'capture' particles through mechanical or electrostatic filters. They constitute the so-called 'fly ash'. The recovery of this fraction, together with the recovery of the neutralisation residues is possible thanks to processes such as Resolest and Revasol, or Halosep.

The contribution of PVC to the production of both bottom ash and fly ash is very limited and is estimated around 0.5% of total ash produced.

Regarding the influence of the presence of heavy metals in PVC, one should also note that:

1. The contribution due to the heavy metals in PVC is not significant except for cadmium, which has been phased out

2. Stabiliser formulations containing heavy metals are used less and less, and are substituted by other chemical substances, which are not hazardous as shown by the Reach Regulations.

7.5 Conclusion.

Now after all of these information given about the gases released when burning plastic materials (cable insulators) and the gases released using cable insulators smelting furnace (CISF) and other machines or processes in this field; And how to deal with the gases through these processes, it must be a rules to prevent burning outdoors, and it must be facilities to develop the field of separation scrap materials with the proper ways, to save the environment and humans.

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