Design and Manufacturing of a thermoplastic Kevlar-based ballistic protection plate for a military patrol vehicle considering level 3 protection standards

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SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
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SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
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SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

In this research, a brief survey of the techniques used for the optimization of ballistic protection are discussed. Moreover, this paper focuses on the modeling techniques of the blast/explosions from an IED or a suicide bombing. The study focuses only one single aim i.e design of a highly efficient ballistic protection. Ballistic Protection is a major concern when there exist high level threats of terrorism targeting security personnel and military patrol vehicles. Land Mines do pose a significant threat to military operations. Two types of impacts that are the major cause of lethality of Improvised Explosive Devices and other Suicide Bombings are the shockwaves and the shrapnel. Similarly, law enforcing agencies often do tackle situations where law-breakers often use arms against them. In all these situations there is a high urge to briefly elaborate and discuss the effect of explosions and blast and how to develop a protection that can mitigate the effect of the bomb partially or completely. In this regard, the contribution of composite structures for the design and manufacturing of ballistic protection is surveyed. Laminating high-strength core materials with tough materials is one approach for designing a highly efficient ballistic protection. Woven fabrics such as Kevlar is another material that is very famous for its projectile protection capabilities. Other materials such as armor and Toolox were also investigated in the research. The behavior of polymeric materials and hybrid thermoplastics was also surveyed. The effect of coating on uni-directional fabric systems for ballistic protection was also discussed. Similarly, for the modeling techniques essential for simulating a blast/explosion, software such as LS-Dyna and Ansys are quite handy. Evaluation of materials with different behaviors used in the development of protection helmets and safety vests was also discussed. The technique and approach for solving the problems associated with explosion/ blast modeling in LS-Dyna was briefly elaborated in one of the publications surveyed. Later three samples of sandwich panels made from Kevlar and HDPE were produced and experimentally tested against 9 mm rounds to record the results. A further progress to the research was made by concluding the necessary phenomena involved throughout the phase

Keywords: *Armor, HDPE, Improvised Explosive Device (IED), Kevlar, LS-Dyna, Toolox.*

DECLARATION

We declare that all material in this thesis is our work, and that which is not our own work has been mentioned as such, and that no material from this work has previously been submitted or approved for the award of a degree by this or any other university.

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Symbols and Abbreviations

English upper case

a	Material parameter in yield function for the composite laminate room temperature yield stress of AISI 4340 steel
A2	Constant in polynomial equation of state
A3	Constant in polynomial equation of state
B	Strain hardening constant of AISI 4340 steel
B0	Constant in polynomial equation of state
B1 c	Constant in polynomial equation of state elastic constant of a lamina in the Composite laminate effective elastic constant of the composite laminate bulk sound speed stiffness matrix of the composite laminate
C1	Strain rate constant for the AISI 4340 steel
e	Internal energy
E	Young's modulus
G	Shear modulus
K	Bulk modulus
P	Pressure
R	parameter quantifying resistance of the material to plastic deformation rate parameter time

Greek

ε_p	effective plastic strain
e^*_p	rate of the normalized effective plastic strain
T_H	homologous temperature
D	bending or flexural stiffness of the plate
p	Pressure, acting in the same direction as z and w
∇^4	bi-harmonic differential operator

Abbreviations

AISI	American Iron and steel institute
ACH	Advanced Combat Helmet
ASTM	American society of testing and material
BP	Ballistic Protection

CNF	Carbon nano fibers
E	Modulus of elasticity
ECH	Enhanced Combat Helmet
FDM	Fused Deposition Modeling
FEA	Finite Element Analysis
IC	Initial conditions
IED	Improvised explosive device
NRL	Natural Rubber Latex
PASGT	Personnel Armor System Ground Troops
PBO	p-Phenylene -2,6-Bezobisoxazole
PTFE	Hybrid polytetrafluorethylene fabric
TLCP	Thermoplastic Liquid Crystal Polymer
TPO	Thermoplastic Polyolefin
TS	Tensile Strength
UDF	Uni-Directional Fabric
UHMPE	Ultra High Modulus Polyethylene

Chapter 1: Introduction

History was made when humans started to make clothes of various types to protect themselves from injuries or weather using several materials. Clothes and shield were the first things which they made, using animal skin. As time progressed first wood and then metals were used to make protections. Metals proved to be very efficient in terms of blocking traditional weapons like swords but with the introduction of bullets the thickness of the armor had also been increased and thus the mobility was greatly affected and presented the need for some high strength light weight armor.

The first known soft body armor was made by using silk in Japan in 1800s. After the assassination of president William McKinley, the United States military also became interested in the use of soft body armor. The silk armor was quite expensive and effective for only low velocity bullets 400 ft/s and could not provide sufficient protection against the modern handguns which had velocities up to 600 ft/s so the US military decided against the use of silk. Records dating back to 1919 can be found for patents of such protective materials. In the second world war flak jackets were created by using ballistic nylon, they provided protection against ammunition fragments and proved ineffective against many common weapons being used at that time.

In late 1960s new fibers were discovered and research was started to find light weight body armor. DuPont's Kevlar ballistic fabric was one of the most significant discoveries in body armor research, the intended purpose of the fiber was to replace the steel belting in vehicle tires. The bullet proof vest had also become a part of metropolitan police department. The anti-ballistic proof jackets were used in world war-II which is also known as Flak jacket. The designed jacket did not prove effective for the pistols and the rifle threats. The heavy weight of the jacket was a main reason behind the low demand of the jacket in the armor market.

Meanwhile, the creation of Kevlar armor protection by National institute of Justice was based on four phases that spanned several years. The very initial phase determined if Kevlar fabric could stop a bullet. The next phase covered estimation of the numeral of sheets of material sufficient enough to stop the bullet from penetration at various speeds with different calibers, as well as constructing a prototype vest to defend officers from the most common threats: 38 Special and 22 Long Rifle rounds. The researchers in

Edgewood arsenal which was of army had made a body armor which was made of seven sheets of Kevlar fibers. They made them keeping in view the demand of the battlefield in 1973. It was observed for the wet Kevlar fibers, that they became less resistive to the ballistic impacts. One more disadvantage of Kevlar fiber is, while facing the ultraviolet waves which primarily from sunlight, the resistance was cancelled out. With dry cleaning and bleach used on the body armor made of Kevlar fiber for cleaning, the body armor had its performance negatively affected. Considering these issues, the vest was designed to perform equally good in sunlight or after dry cleaning etc.

The movement's third phase included thorough medical examination and inspection to assess the amount of body armor performance required to preserve police officers' lives. So, if a bullet was halted by the protective/flexible fabric, the stress developed by the collision from the piercing bullet would leave a serious mark at the very least and, and may prove fatal by destroying key organs in the very worst case. Considering the situation, research and development teams devised studies for the measurement of the consequences of a hazardous blunt trauma, or injuries caused by forces developed by a bullet striking armor. The advancement of blood gas tests, which reflect the amount of lungs injury, was a consequence of the research on blunt trauma.

For the very final case, armor's method used to measure the effectiveness were monitored. The vest was found to be comfortable, prevented any undue generation of stress or pressure on the shoulders, and allowed typical body movement required for police duties in a preliminary test in three cities with ease. In 1975, 15 urban police agencies participated in a large-scale testing and examination of the new Kevlar body armor vests. Each department handled a population of over 250,000 people. The results revealed higher rates of officer assault than the national average. A total of 5,000 clothes were tested, with 800 of them coming from commercial sources. Adaptability in variations of temperature, comfort level during a complete working day, and durability over long years of use were all the necessary considerations for the design. Designers worked out to make a body armor which could bear the 38-caliber bullet which had the velocity of 800 ft/s. The design proved very effective as it demonstrated extremely low penetrations from bullets. The novel protective material proved as an effective solution in delivering a bullet protective jacket that was lighter in weight and comfortable for long shift/time duties, according to a report finalized in 1976. Even before the NIJ demonstration program, private business saw the margin and potential of business associated with the new upgradation of body armor, and body protective shield became available throughout the market in large quantities. The very first armor design which was considered practical and of use was developed by USA.

Even today there is no such vest which can stop the bullets or projectile. In reality, a balance must be struck between movement and protection. Wearing really "bullet-proof" vests would be an impediment in modern warfare, where troops are expected to be highly active. The vests supplied to US service members today are designed to stop 9mm shots, 7.62mm rounds at range, and most shrapnel in the vast majority of circumstances. When seen from a historical perspective, recent advancements in body amour are interesting. For many years, the main goal of body armor development was to provide increased levels of protection. This process appears to have reached a nadir, as modern body armor offers less protection than that of the 1970s, owing to the belief that increased mobility comes after a compromise on the level of offered protection.

1.1. Problem Statement

Design and Manufacturing of a thermoplastic Kevlar-based ballistic protection plate for a military patrol vehicle considering level 3 protection standards.

1.2. Motivation

Pakistan faces a huge threat of terrorism specially in Baluchistan. IED’s are the most effective and viable choice for terror attacks. World has developed new technologies/ materials associated with defence. But these materials are expensive to process and implement. Kevlar and thermoplastics are a newer field to research. It is the of the tie to develop such a material which can protect the military patrolling cars and to save the lives of soldiers.

1.3. Objectives

Our objectives for carrying out this research are:

i. To use economical materials using the idea of composite material matrix for ballistic protection

ii. To identify and implement techniques which can be implemented to resist the bullet against the protective plate.

iii. To produce a low cost but an effective ballistic protection plate.

iv. To use heating press which should be more effective

1.4. Scope of the thesis

The scope of the project includes, but is not limited to, the design and manufacture of a light-weight and a highly effective ballistic protection plate capable of protecting life and other essentials from high-velocity projectiles and fragments. The project involves methods of investigation, collection of data, analysis of data and finalization with justification of the results via prototyping and testing. A heated press is initially to be designed and the process is an integrated part of the whole procedure. With the heated press being designed by the members themselves, a higher control for the quality of the Ballistic plate is possible. After having the heater designed and the protective plate manufactured, the specimen would be tested in a firing range for the validation of results. Finally, a discussions phase would be considered that would include conclusions and recommendations for the methodological approach and the phase would mark a closure to the project.

Chapter 2: Literature Survey

2.1 Papers

Methods of development for improvement in ballistic protection of vehicles:

In this paper [1] three different composite armors were designed and analyzed via LS dyna software package and their individual performances were evaluated against a sub-caliber round. The authors further compared the performance of their composite designs with a homogenous armor they designed and simulated just to explicate the efficiency of each armor. It was concluded from the comparison of a homogenous ballistic protection plate from SSAB (Swedish Steel Group Company), a Silicon Carbide plate inserted between two armor 500T plates, a several layer woven Kevlar fibers sandwiched between two Armor 500T plates and the same Kevlar layer combined with two Toolbox 44 material, the Toolbox and Kevlar combination was clearly the most effective as it absorbed the most impact energy. They further concluded the advantage of composite plates that is their efficiency when combined in Ballistic Protection. They suggested the use of tiles and other panels of these composite plates that are replaceable and easy to re-install.

M. Štiavnický and N. Adamec, "Improved ballistic protection of vehicles using composites," International Conference on Military Technologies (ICMT) 2015, 2015, pp. 1-6, doi: 10.1109/MILTECHS.2015.7153750.

Evaluation of explosion resistance of ballistic polymeric materials:

Skalicky, Komenda, Vitek, Jedlicka and Vlhova published [2] the results of an experimental comparative study of different materials subjected to a highly explosive blast for ballistic testing. They used fabric from two different manufacturers, three laminated and three woven and therefore conducted six sample tests. Their experiment was primarily based on the exposure of the specimen to the effects of blast from a reference charge. The testing conditions were maintained the same for each of the six fabrics. Test samples with similar constraints were extracted from the set of fabrics chosen. Their experiment proved different explosion resistances and proved the claim of the manufacturers about their impact absorption values. They further elaborated the response of soft ballistic materials to high explosive blasts.

P. Skalický, J. Komenda, R. Vítek, L. Jedlička and J. Vlhová, “Evaluation of explosion resistance of ballistic polymeric materials,” *2021 International Conference on Military Technologies (ICMT)*, 2021, pp. 1-4, doi: 10.1109/ICMT52455.2021.9502804.

Evaluation of various Textiles for high performance as ballistic protection

Dr. Bipin [4] proposed a detailed analysis on high performance textiles essentially significant in ballistic protection. They explored the use of several textiles such as Nylon, Carbon fibers, Ceramic fibers, Aramids and Glass Fibers, Ultra High Modulus Polyethylene (UHMPE), Thermoplastic Liquid Crystal Polymer (TLCP), p-Phenylene -2,6-Bezobisoxazole (PBO). The further proposed an approach for the construction of ballistic protection such as woven textiles, non-woven, Composites and laminates, moreover he proposed the recent development in the field of ballistic safety particularly in bullet proof pocket square and Soldier exoskeleton. At last, he ended his research claiming that the advancements in the field of ballistic protection is another field of study to excel, because these laminates and composites have reduced the weight issues and minimized transportation costs while they still maintain and improve the ballistic protection.

C. Chaichuenchob and S. Sinchai, “The damaged analysis from ballistic threats on transparent armor,” *2015 Asian Conference on Defence Technology (ACDT)*, 2015, pp. 7-11, doi: 10.1109/ACDT.2015.7111575.

Damage modeling of ballistic impact in woven fabrics:

In this case study, S.D. Rajan and B. Mobasher [18] had made the structural system structural by dry woven and it was subjected to ballistic impact. The finite element analysis was main key which was used in modelling. They used fabric woven as it was having high strength to weight ratio in addition to it had the capability to fight from high-velocity piece impact. A continuum model was made at macroscale level instead of tale geometry at mesoscale level for analysis of ballistic influence. The fibric which was used was of small thickness and a thin shell finite element was used. Friction and tension test were used for this experiment. Friction test was basically used to determine the static and dynamic coefficient. In order to calculate the distortion, damage and catastrophe reply of polymer matrix. It used the influence condition and it required the accurate material model. The model which was made of dry woven fabrics which was the part of system and it went for ballistic impact. When this model was used correctly and efficiently then the system became the productive tool. The changes could come in this model as well to make it more efficient and worthful. More changes were coming such as the system was becoming economical and at low cost.

Rajan, S.D. & Mobasher, Barzin. (2016). Damage modeling of ballistic impact in woven fabrics. 10.1016/B978-1-78242-461-1.00017-0.

Ballistic impact performance of hybrid thermoplastic composite armors

In this Aswani Kumar Bandaru, Vikrant V Chavan, Suhail Ahmad R Alagirusamy, and Naresh Bhatnagar [20] used thermoplastic composite made by Kevlar of propylene composite armors. The performance of ballistic impact was observed by using this material. Kevlar fabrics of many architectures which are named as, 2D plain woven, 3D orthogonal and 3D angle interlock fabrics, were generated which made the panel of composite armor. The main technology which was used was compression molding. They used the coupling agent called maleic anhydride in order to make the interfacial property between Kevlar and propylene more efficient. There was reduced density in Kevlar thermoplastic-based composites. The Ansys was used to depict value of ballistic limit velocity and simulate failure codes. They found a nice connection between hydrocode replication and experimental results by comparing them. The enhanced fiber strengthened composites usage is growing day by day in order to make the light weight armor. The fiber played a key part in the defense in contradiction of the ballistic impact. It also gave a ballistic penetration fighting for varied orientations. Through using Kevlar and propylene matrix, the composite armor was made of three types. The hydrocode was used to get in touch with ballistic resistance of 3D armor panel. It was seen that the ballistic limit velocity was amplified by altering fibric.

Aswani Kumar Bandaru, Vikrant V. Chavan, Suhail Ahmad, R. Alagirusamy, Naresh Bhatnagar, Ballistic impact response of Kevlar® reinforced thermoplastic composite armors, International Journal of Impact Engineering, Volume 89, 2016, Pages 1-13, ISSN 0734-743X,

Fragment ballistic performance of homogenous and hybrid thermoplastic composites:

S.B. Sapozhnikov, O.A. Kudryavtsev and M.V. Zhikharev [26] had done many extensive ballistics tests on various protective composite structures. The speed had been reached up to 900 m/s. they used 6.35mm steel ball. The V50 threshold as well as the post V50 limit were used to evaluate the ballistic performance. It was seen that the effect of temperature was negligible. In high velocity impact condition, the absorbed energy and indicators of V_50 of UHMWPE fibers were good than by using other fibers. However, as the projectile's velocity reached the ballistic limit, their energy absorption capability dropped significantly. Mostly high strength composites materials were used in making the protective structures. It was commonly used in personal and military vehicles while it was used against bullets and fragments of exploding munitions. There were numerous thermoplastics materials which had low stiffness and high deformations. If the deformations were maximum then the weak fiber matric would make the fiber to undergrow through it. One of the critical factors was the ballistic limit, which determines the incident impact velocity at which there was 50% chance of damage. The ballistic effectiveness of aramid fabric and UHMWPE composites was examined in this study. Fiber fracture, delamination, fabric/matrix debonding, and fiber squeeze out were the most common failure modes in composites. The potential hybrid was made if it used high density of aramid textiles.

S.B. Sapozhnikov, O.A. Kudryavtsev, M.V. Zhikharev, Fragment ballistic performance of homogenous and hybrid thermoplastic composites, International Journal of Impact Engineering, Volume 81, 2015, Pages 8-16, ISSN 0734-743X,

Measurement of ballistic impact properties of woven kenaf-aramid hybrid composites:

In this case study, R. Yahaya, S.M. Sapuan, M. Jawaid, Z. Leman and E.S. Zainudin [27] made the two arrangements of woven kenaf Kevlar composite materials by varying the volume fraction of the composite material. The different impact and residual velocities were performed by using fragments simulating projectiles since the ballistic measurement test of hybrid composites was done. The failure modes were investigated by invigilating the damaged sample of hybrid composites. The 14 layers of Kevlar and 2 layers of kenaf had good properties and it had higher ballistic performance as compared to the other fiber composites. The hybrid composite had good thickness a areal density due to which the ballistic properties are increased. The armor system had the ability to bear the impact if projectiles. It was made of high strength materials, partial substitution of aramid fiber, we could get the maximum value for V_50 and energy absorption of aramid laminates. The ballistic properties of composite material were decreased if the content kenaf was increased.

Ballistic impact of a KEVLAR helmet: Experiment and simulation:

C.Y. Thama, V.B.C. Tanb and H.P. Lee [28] experimented and simulated the ballistic impact of Kevlar helmet. The experiment that was done was a light gas gun fired the spherical projectile which was hit the Kevlar helmet at the speed of 205 m/s and at the mean time when projectile was hit the helmet, it was detected through high-speed photography. The investigational and replicated results were compared. The simulation was compatible with the response that the helmet had bear. Basically, the used of helmet had been started to exit thousands of years ago. By the end of 13th century, helmets were used in battlefield then it indicates a significant shift in emphasis on head protection. The use of helmets was eradicated from the battlefield when gunpowder and firearms started to come in use. The main reason for the eradication of the helmet was that they were unable to protect from musket rounds. The heavy weight helmets were used to protect from fire in World War 1. M-1 helmet served for 30 years. Whether the fragment simulating projectile was defeated by Kevlar helmet was based upon simulations. The hydrocode simulation was done for checking the ballistic resistance of helmet. By getting the experimental and simulation results, it was seen that projectile could not penetrate through helmet. The helmet now made are having lighter fiber material and provide good resistance against bullets and fragments in this century and they are passed through many tests. By using hydrocode simulation, we could use lighter, cheaper and good fiber material.

An experimental investigation on the impact behavior of hybrid composite plates:

In this, Metin Sayer, Numan Bektas and Onur Sayman [29] had performed the behavior of hybrid composite plates that how they act. The two hybrid composite pates were used. The plates were tested by increasing the impact energy. They kept on increasing the impact energy until it caused the hole into the specimens. As to get the relationship between absorbed energy and impact energy, we used the energy profile method. When load deflection curve was added then we got about three things which were penetrations, rebounding and holes. We got the knowledge about the hole thresholds and penetration of hybrid composite plate. The glass fiber's surface had 30% lesser perforation threshold than by using carbon fiber. The hybrid composite had good fatigue life and corrosion resistance. When impact load was applied on the composites material s it had more importance in engineering field. The rebounding section was shrunk when impact energy rose whereas the closed bound area and deflection was enhanced. It was found between open type curves and closed type curve. The damage part and impact response had been investigated while using hybrid composites plates. The energy absorption capability of glass carbon fiber had more than the carbon glass fiber. The carbon glass hybrid composite didn't always penetrate or hole thresholds.

Composite materials with the polymeric matrix applied to ballistic shields:

In this paper, M. Rojek, M. Szymiczek, J. Stabik , A. Mężyk , K. Jamroziak E. Krzystała and J. Kurowski [30] made an alternative armor plate by using the composites paper. It was capable to resist against caliber bullets of 7.62 and 5.56. in this epoxy matrix composite was used which was strengthened with the glass fiber and the glass fiber was in the state of steel mesh, fabric or mat. The three sheets were attached with the ceramic panel. This composite fiber was used for the light weight armed vehicles in the ballistic protection. Through investigation of crew life threat, the standardization of protection of military vehicles is checked. The use of modular armors and supplementary covers, which were specified and mounted on the vehicle according to the type of threat, gives the necessary level of crew protection. As the plate was used which absorb kinetic energy of the striking projectiles and the normally plates used were passive armor plates. In order to protect from missile of cumulative acting, the active armor plates were used. The armor plate was used to safe the crew in the vehicle and whole structure. It was expected to construct such thing that uses hybrid drives, active protection, light armored plates, modular construction of vehicles and integration of systems. The steel mesh was connected with glass matts in order to strength it and by doing this, it would reduce the destruction of the composite material. The defragmentation was also reduced decreased by strengthening the ceramic panel with inter layer of steel mesh.

An Experimental and Numerical Study of Fracture Toughness of Kevlar- Glass Epoxy Hybrid Composite

J. Maheswaranand [31] his teammates observed the behavior of Kevlar and Glass Epoxy Hybrid Composite, they observed it in fracture using finite element analysis and experimental method. According to the ASTM standards tension test was used with fixtures. The Fracture Toughness for both across the direction of the fiber and along the direction of the fiber of the test material was obtained experimentally. It was observed from the results that the cracked sample was tougher along the direction of the fiber as relative to across the direction of the fiber. The elastic modulus for both cases had a difference of 417 MPa, more for along the fiber case, same behavior was observed for critical stress intensity factor. The fracture of the specimen was observed by electron microscopy to get better understanding of the failure. The fracture was found to be brittle cleavage failure, some debonding between fiber and matrix was also seen. The stress intensity factor was also obtained by using ANSYS post processor for different loadings, these from differed from the experimentally obtained values, the main reason for this discrepancy was found to be because of variable loading fixtures in experimentation.

Development of Zylon-Kevlar-Zylon Hybrid Fiber Reinforcement Technology:
Shuang Wang and his teammates [32] proposed reinforcement technology for the design of the 100 T pulsed magnet at the Wuhan National High Magnetic Field Center. The technology for reinforcement was created by combining a composite of Zylon-epoxy and a composite of Kevlar - epoxy. Previously the reinforcement layers of the 100 T pulsed magnet consisted of Zylon-epoxy composite, which has been substituted with a composite fiber of zylon-kevlar Zylon. In Zylon epoxy the von mises stress was about 3.5 GPa. Kevlar fiber has a rugher surface than Zylon fiber so it showed better wet impregnation properties with epoxy as compared to Zylon. By running simulations on the Zylon Kevlar Zylon composite fiber the maximum von mises stress was found to be 3.68 GPa. With small pulsed magnet the explosion test was used and the ultimate tensile strength was measured to be 4.97 GPa, which satisfies the stress requirements for the 100 T pulsed magnet. The hybrid fibers hoop strength degrades very little. While the Zylon-epoxy composite can resist most of the Lorentz forces, the shearing movements were effectively prevented by the Kevlar-epoxy composite mainly because of the good impregnation between Kevlar fiber and the epoxy layer.

Tribological properties of Hybrid Kevlar/PTFE Fabric Reinforced Phenolic Composite

Fan Bingli and his team [38] investigated the effect of addition of nano alumina on hybrid polytetrafluorethylene fabric (Kevlar/PTFE). The Kevlar/PTFE hybrid fabric was made by weaving fibers of Kevlar and PTFE. The phenolic used in this had shear strength of more than 15 MPa at normal temperature and at 200 degrees the sheer strength was more than 6 MPa. The nano-alumina use in this had an average diameter of about 30 nm. The diluent solution of alcohol: Ethyl acetate (1:1) had evenly dispersed particles of nanoalumina, this solution was then poured into the phenolic resin and magnetic stirring was used to evenly disperse this. For a time period of 3 Hours this was kept immersed in the resin which contained the nano-alumina. When the fabric was successfully impregnated with the resin then it was dried out by keeping it at the steady temperature of 120 degrees for 1 hour. To check how the tribological properties of the fiber were affected by the nano-alumina, for wear testing, block on ring friction and wear tester was utilized, the morphologies of worn surfaces of the counter face and the fabric composite were observed by using SEM. These tests showed that nano alumina increased the friction coefficient (also dependent on the working conditions) but at the same time the tensile resistance was improved along with wear resistance (improving the between the fibers and the matrix resin bonding strength was improved). Micro cutting and plastic deformation were found to be the main mechanism for wear to occur, by the use of SEM.

2.2 Experiments

During the survey many experiments were observed

Ballistic analysis of 14.5 AP bullet on armor material

In the very first significant methodology, a 14.5 mm AP bullet was tested to analyze the impact on armor. Furthermore, ballistic resistance numerical simulation was performed. In order to properly define and monitor the strength of metallic material Johnson-Cook strength model was used. The conditions under which the material was tested involved large and high strains, strain rates and temperatures.

$$Y = [A + B\varepsilon np]\,[I + C\,log\,e * p]\,[I - TmH\}] \quad \textbf{(2.1)}$$

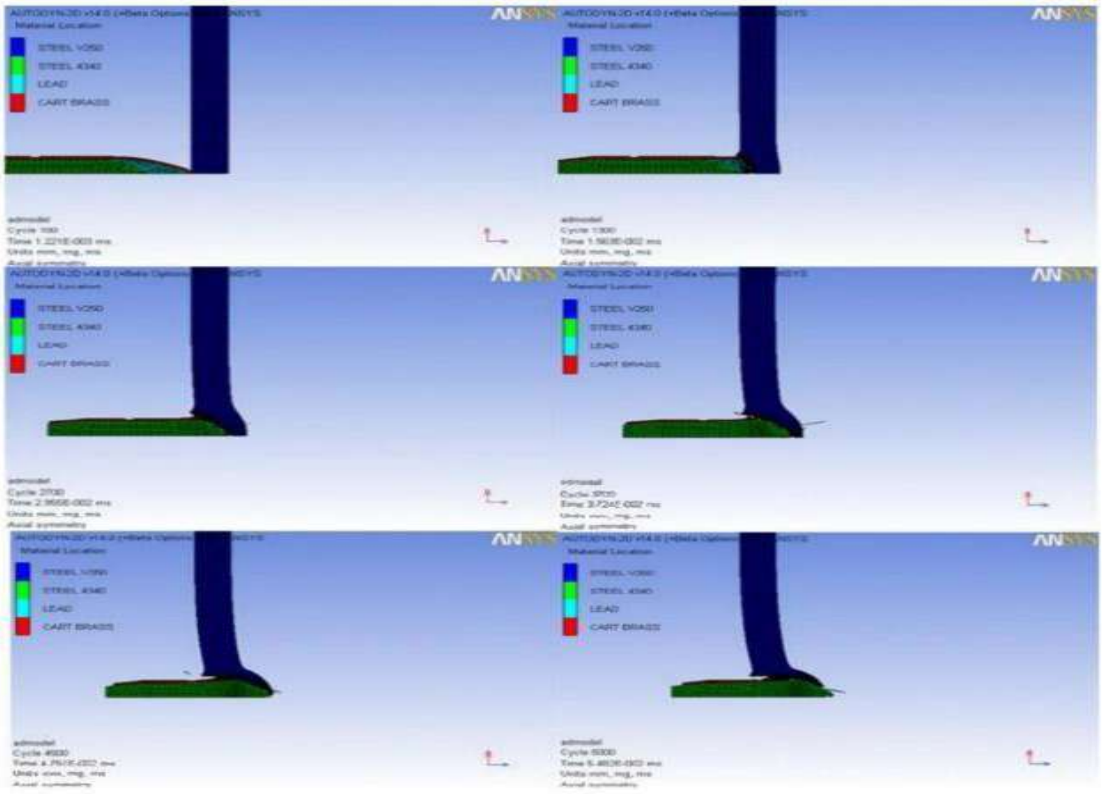

Figure 2.1: V250 steel (Simulation result, thickness 11.0 mm, steel core) [5].

Here the term $\varepsilon_p$can be defined as the effective plastic strain with $e*_p$ as the rate of the normalized effective plastic strain and the term T_H is the homologous temperature.

On ANSYS commercial software, the research progressed with explicit dynamic code on AUTODYN. The study found that a 14.5 mm AP bullet could not be stopped by a single layer of 10mm V250 steel, The simulation was done using explicit dynamic method with non-liner finite element. The simulation consisted of two parts a bullet and the target, the bullet was made of three components, a steel core made with AISI 4340 hardened steel, Lead and brass were used for jacket and cartridge. A circular shape of steel V250 was used for the target. The bullet made impact on the center of the target. Because of restricted computational resources the analysis was done with plain strain condition in 2-D manner, the components were set up into frictionless pullies.

The study was carried out in two cases in case 1 the armor was made of V250 only and in case 2 a layer of alumina was also added.

The following results were obtained from simulations of case 1.

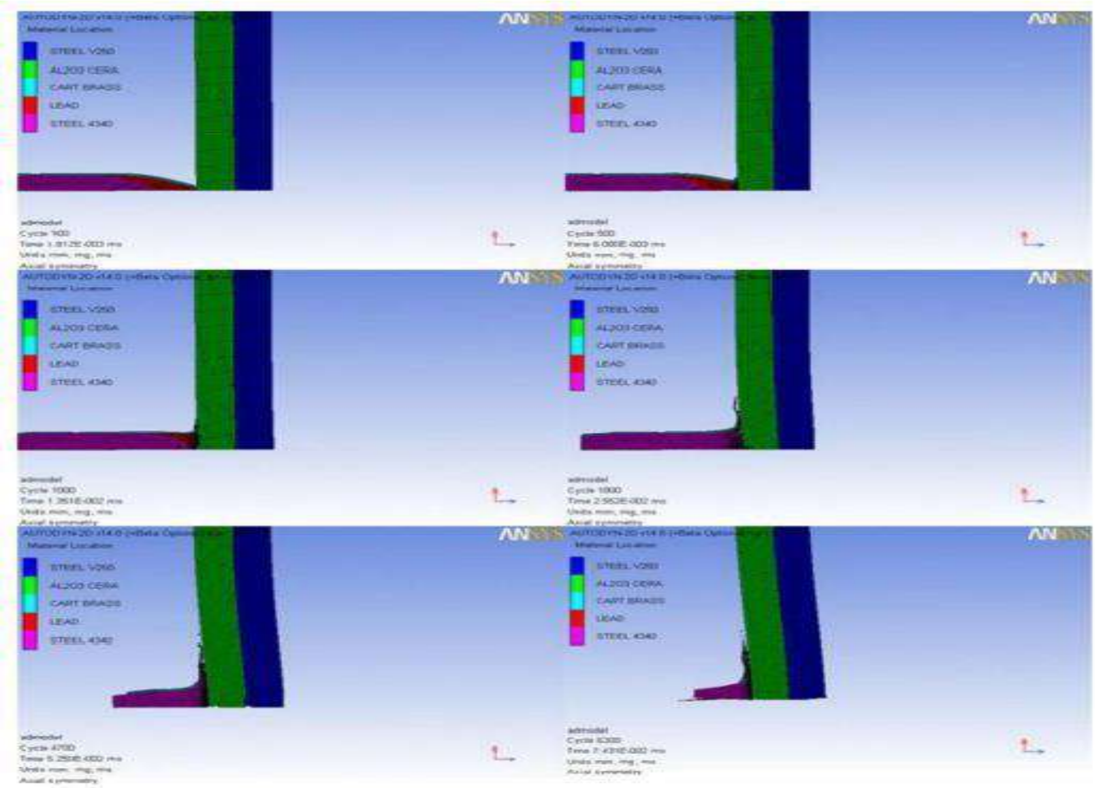

Figure 2.2: V250 steel (Simulation result, thickness Figure 10.0 mm additional alumina) [5].

The maximum plastic deformation was observed at 0.55 millisecond but at that time the bullet had perforated the target and still had a velocity of 650 ms^{-1}, adding a second layer of alumina ceramic increased the resistance of V250 steel to ballistic impact. The bullet hit the target with an impact velocity of 911 ms^{-1}. The simulations done for case 2 got the following results.

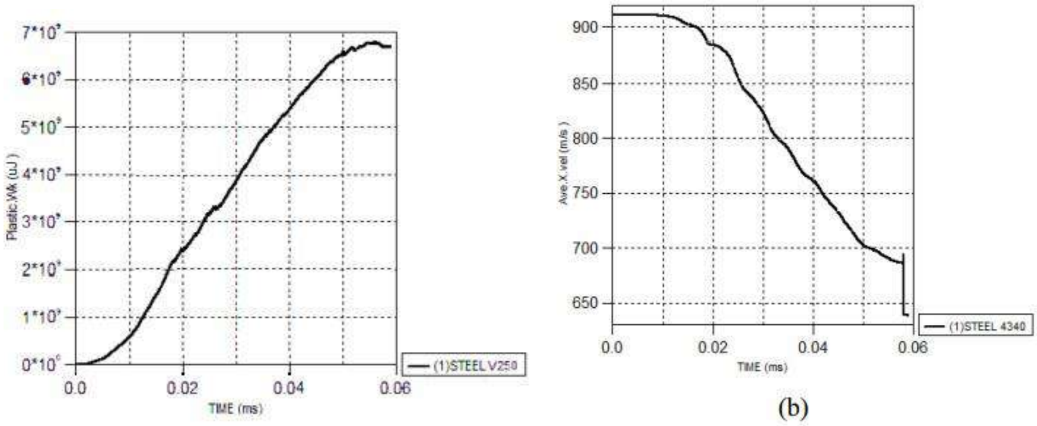

Figure 2.3: : Results of simulation of 10 mm V250 steel (a) Plastic work of the sheet vs. time (b) Velocity of the projectile vs. time [5].

$2.2x10^8$ and $5.5x10^8$mj were plastic work ofV250 steel and alumina respectively, At 0.055 ms. In case of double layer, the plastic work of V 250 steel was significantly less than that for the single layer.

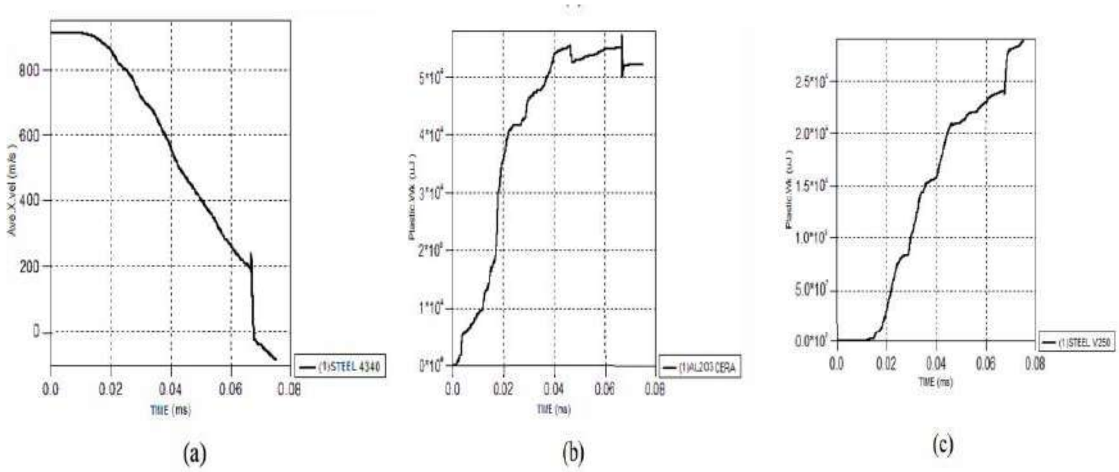

Figure 2.4: The result of the simulation of l0 mm alumina added with V250 steel (a) Velocity of steel core vs. time (b)Plastic workof alumina vs. timeand (c) Plastic work of V250 steel vs. time [5].

The ceramic layer increased the ballistic response as the V 250 could not stop the bullet but adding alumina proved helpful. The mathematical model of the material used for simulation assumed that the strain rate of a material is independent of the temperature sensitivity, which is contrary to what happens in real life. Due to lack of computational resources only 2D analysis was done.

Modeling and Simulation of a Shock Absorbing Shell for Ballistic Vests and Helmets to Achieve Optimal Protection

By using modeling and simulation-based study of shock-absorbing shells, Suciu, Fukui, and Kimura's research was published with the intention of enhancing the design of helmets and vests for ballistic protection [5]. When a colloidal pad was positioned on the exterior of the shell, up against the bullet, it was discovered that the back-face signature was reduced by 10%. However, when the colloidal pad was positioned on the inside of the shell, up against the striking bullet, the back-face signal was diminished by 25%. The three created a model of the shock-absorbing shell that looked like a thin membrane with a clamped edge. For bullets with buttons and truncated cone noses, the loadings subjected the armor to uniform pressure distribution over the shell, uniform pressure distribution over a portion of the shell; and central focused force for bullets with conical plus tangential ogive noses.

The following equation can be used to calculate a membrane's transverse out-of-plane displacement,

$$\mathrm{w}:\nabla^2 D\nabla^2 w = p \quad \textbf{(2.2)}$$

Or for constant flexural rigidity throughout the plate

$$\nabla^4 w = \frac{p}{D} \quad \textbf{(2.3)}$$

Where the bending or flexural stiffness of the plate is D, defined as: where Pressure, acting in the same direction as z and w, is represented by p,∇^4 is known as the bi-harmonic differential operator, and ∇^2 is Laplace's differential operator.

$$D = Et^3/12(1 - v^2) \quad \textbf{(2.4)}$$

Here, E stands for the Young's modulus of elasticity, v for the Poisson's ratio of the material used to make the plate, and t for the plate's thickness.

$\nabla^2$is the Laplace’s differential operator and can be written as:

$$\nabla^2 = \frac{\partial^2}{\partial \mathrm{r}^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial \mathrm{z}^2} \quad \textbf{(2.5)}$$

For a pressure that was evenly distributed across the surface of a shell with a clamped edge, the equation shown below was found. With the origin at (r = 0) and the clamped edge at (r = R) and the following boundary conditions:

$$w_{p,1}(r=R) = \frac{dw_{p,1}}{dr}(r=R) = \frac{dw_{p,1}}{dr}(r=0) \qquad \textbf{(2.6)}$$

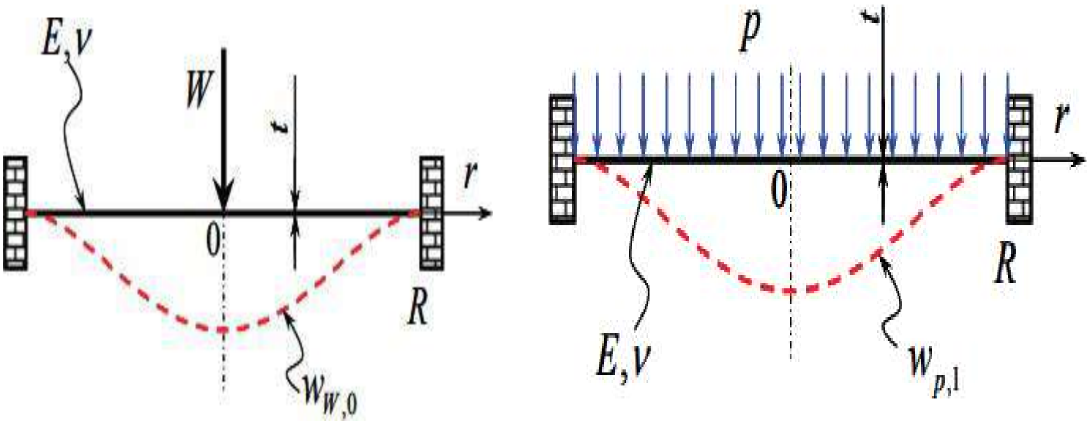

Figure 2.5: Graphical representation of the entire results [33].

The shell displacement $w_{p,1}$

$$w_{p,1}(\bar{r}) = \frac{3(1-\nu^2)}{16\pi}\frac{WR^2}{Et^3}(1-\bar{r}^2)^2 \qquad \textbf{(2.7)}$$

Where the W is the force and $\bar{r}$ is the dimensionless radius, both can be expressed as.

$$\bar{r} = \frac{r}{R}, \quad W = \pi R^2 p \qquad \textbf{(2.8)}$$

At the center of the shell the backface signatures depth is

$$w_{p,1max} = w_{p,1}(\bar{r} = 0) = \frac{3(1-\nu^2)}{16\pi}\frac{WR^2}{Et^3} \qquad \textbf{(2.9)}$$

The volume of the blackface can be calculated from the equation

$$V_{p,1} = 2\pi R^2 \int_0^1 \bar{r}\, w_{p,1}\, \bar{r}.\, d\bar{r} = \frac{(1-\nu^2)}{16}\frac{WR^4}{Et^3} \qquad \textbf{(2.10)}$$

The shell’s stiffness

$$k_{p,1} = \frac{W}{w_{p,1max}} = \frac{16\pi}{3(1-v^2)}\frac{Et^3}{R^2} \quad \textbf{(2.11)}$$

For the modeling of a circular ballistic shell with a clamped edge that has been evenly loaded throughout.

$$Q_r = -\frac{W}{2\pi r} \quad \textbf{(2.12)}$$

The shell displacement;

$$W_{W,0}(\underline{r}) = \frac{3(1-v^2)}{16\pi}\frac{WR^2}{Et^3}(1-\underline{r}^2+2\underline{r}^2\, ln\underline{r}) \quad \textbf{(2.13)}$$

The volume of the backface signature;

$$V_{W,0} = 2\pi R^2 \int_0^1 \underline{r} w_{W,o}\, \underline{r}.\, d\underline{r} = \frac{3(1-v^2)}{16}\frac{WR^4}{Et^3} = 3V_{p,1} \quad \textbf{(2.14)}$$

The shell stiffness;

$$k_{W,0} = \frac{W}{w_{w,o\,max}} = \frac{4\pi}{3(1-v^2)}\frac{Et^3}{R^2} = \frac{k_{p,1}}{4} \quad \textbf{(2.15)}$$

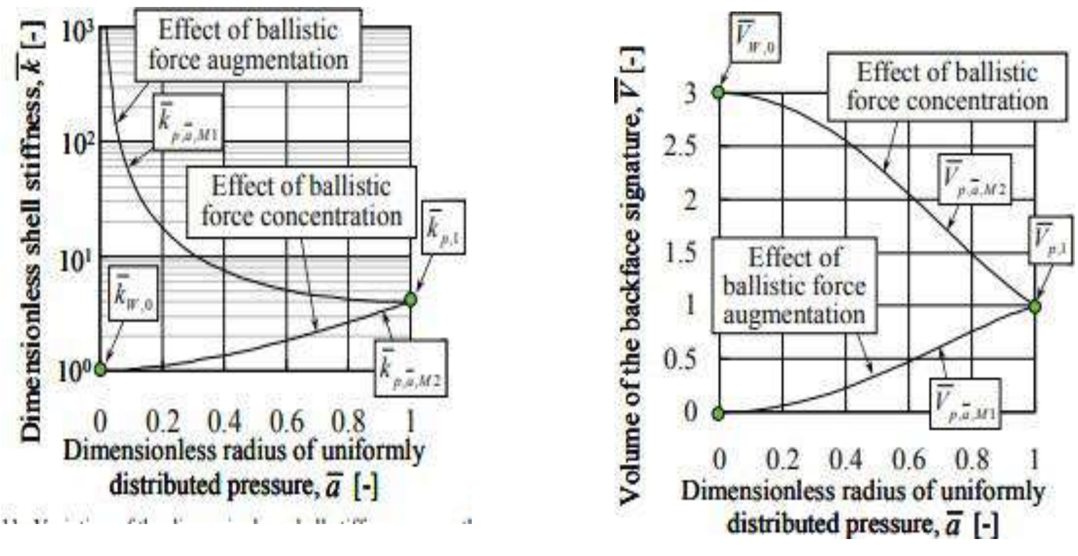

Figure 2.6: Centric concentrated force [33]

For the modeling of a circular shell with clamped edge, loaded by eccentric focused

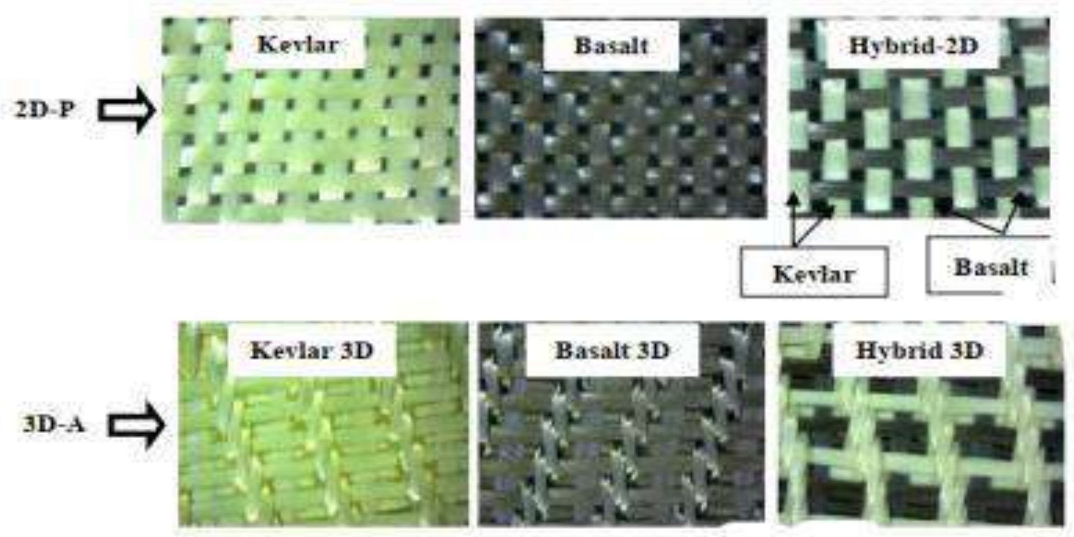

Figure 2.7: Surface micrographs of 2D-P and 3D-A fabrics [33].

force, the dimensionless depth of the back-face signature is given by:

$$\overline{w}_{w,\overline{b},max} = \overline{\overline{w}}_{w,\overline{b}}(\overline{b} = \overline{\overline{r}}, \Theta = 0) = 4(1 - \overline{b}^2)^2 \quad \textbf{(2.16)}$$

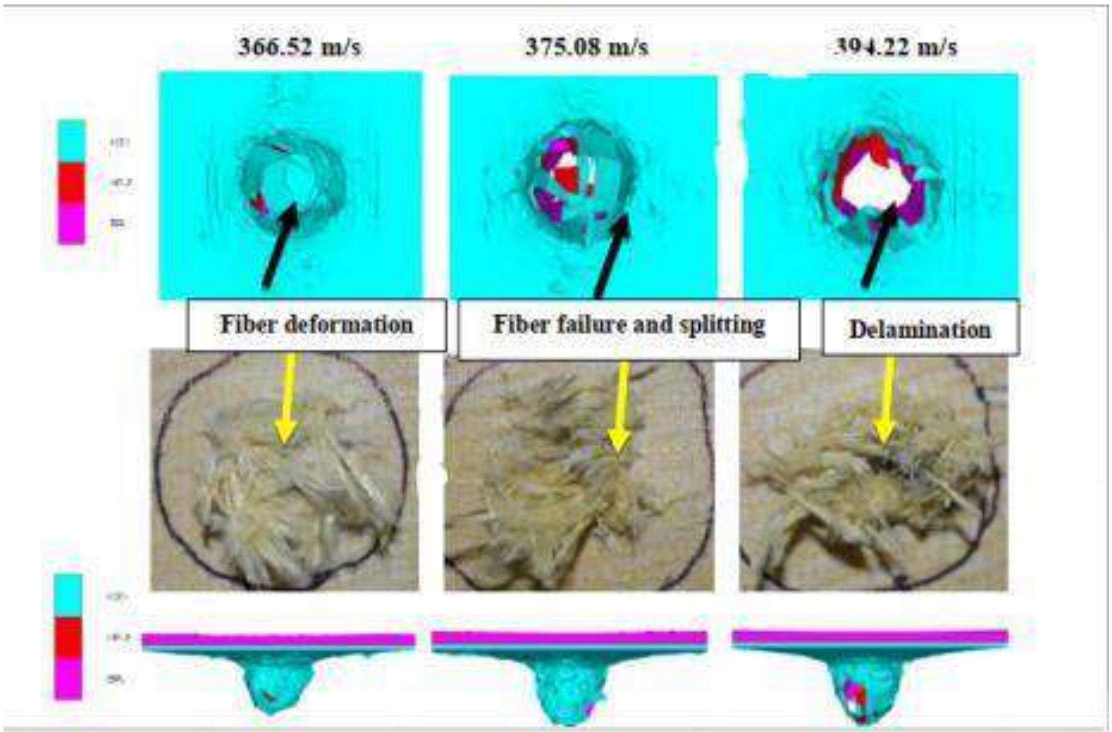

Figure 2.8: Uniformly distributed pressure over entire surface [33].

They investigated the impact of the force eccentricity in more detail and came to the conclusion that ballistic vests and helmets could not provide the highest level of protection. This was so that they could make the biggest back face autographs the majority of the time. They discovered that when the bullet impacted the unit cell at a specific eccentricity and caused the impact force to spread over a larger area, it was able to boost the protection of the helmets and vests. They conducted an experiment to see the armor strengthening and added silica colloidal pads to either the exterior or inner face of the shell unit.

Ballistic impact performance of hybrid thermoplastic composite armors reinforced with 2D/3D Kevlar and basalt fabrics:

The composite thermoplastic material is used in which it includes the Kevlar with basalt fabrics of 2D plain woven as well as 3D interlock angle was also viewed through simulations and experiment to check the ballistic protection performance. Random stacking sequence (H-1) was used as well as symmetric stacking sequence(H-2) as hybrid armors types. The 9mm full jacket impact was targeted on H-1 as well as H-2 armor. H-2 resisted perfectly but H-1 armor was perforated for velocity between 365 to 395 ms^{-1}. The material and method they used to test the armor was similar to our working process for the Kevlar based ballistic protection for military armor vehicle. The aim of the working of this paper is to develop polypropylene-based Kevlar/basalt composite armors to check the performance of ballistic protection. The hybrid 3D fabric is implemented for the composite armors.

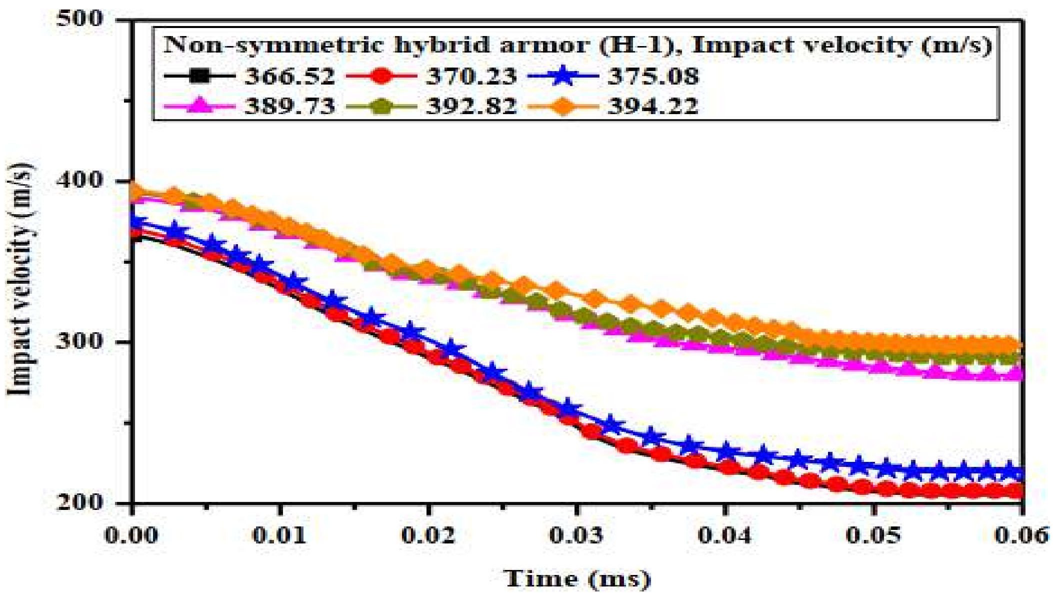

Figure 2.9: Non-symmetric hybrid armour

The Defense Metallurgical Research Laboratory is used to the ballistic protection. The software which was used for the ballistic protection performance of hybrid composite material is ANSYS-AUTODYN -3D. The equivalent pressure is given as:

$$P = -\frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \quad \textbf{(2.17)}$$

Whereas the effective bulk modulus is given as:

$$K = \frac{(C_{11}+C_{22}+C_{33}+2(C_{12}+C_{23}+C_{31}))}{9} \quad \textbf{(2.18)}$$

It was seen that there is linear relation in pressure and volumetric strain.

The following equation enables the connection of an orthotropic material toughness with a nonlinear equation of state.

$$C_0 = \sqrt{\frac{k}{\rho}} \quad \textbf{(2.19)}$$

where k denotes the effective bulk modulus, C_0 is the bulk acoustic speed of sound, and ρ is the material density.The following graph depicts that the ballistic limit velocity is less than these velocities. In order to predict he ballistic impact velocity further simulations were made at lower velocity

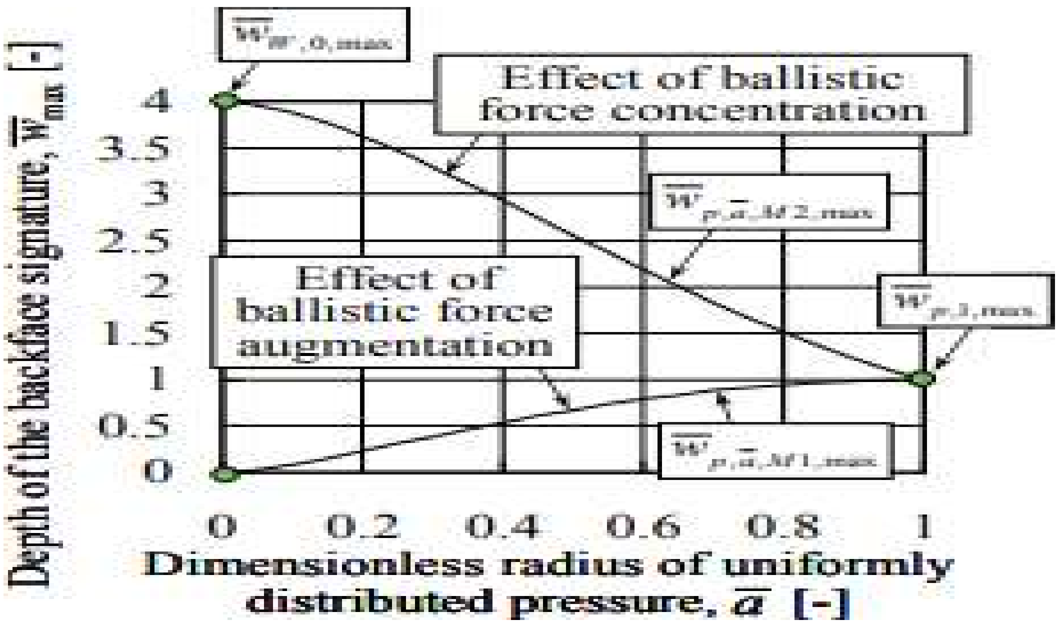

Figure 2.10: Effect of ballistic force concentration

Chapter 3: Mathematical Formulation

For the analysis of the bullet moving with a particular velocity we used the famous second law of newton.

$$F = m\frac{d\bar{v}}{dt} \qquad \textbf{(3.1)}$$

Which means that rate of change of momentum of any body is equal to the force with which it moves.

This equation was modified and later used for the stress analysis on the frame of the heater design. The modified form of this equation is

$$\sigma = \frac{F}{A} \qquad \textbf{(3.2)}$$

Where F is the force distributed on an Area A to produce stress σ

The stress is also represented by the following equation

$$\sigma = E\varepsilon \qquad \textbf{(3.3)}$$

Where E is the modulus of elasticity and ε is the strain induced

For the strain energy of the bullet, we used the following strain energy equation

$$U = \frac{F\delta}{2} \qquad \textbf{(3.4)}$$

Moreover,

$$U = \frac{V\sigma\varepsilon}{2} \qquad \textbf{(3.5)}$$

Here F is the force applied, σ is the stress, V is the volume of the body, ε is the strain produced.

For the thermal analysis of the body two of the major equations were Fourier’s law and Newton's Law of Cooling.

For Fourier’s law, the equation is

$$q = -k\nabla T \qquad \textbf{(3.6)}$$

Where q is the local heat flux density, k is materials conductivity and ∇T is temperature gradient.

For Newton's law of cooling, the equation is

$$Q = hA(T_t - T_{env}) \tag{3.7}$$

Where h is heat transfer co-efficient, A is heat transfer surface area, and T_t is the time dependant temperature and T_{env} is the environmental temperature.

For the current and power analysis of the machine the following equations were used.

$$V = IR \tag{3.8}$$

Where V is the voltage applied, and I is the current flowing through and R is the resistance.

For series combination the current remains the same, therefore we have our equation modified as

$$I_{SERIES} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \frac{V_4}{R_1} + \ \dots \dots + \frac{V_n}{R_n} \tag{3.9}$$

Where V_1 , V_2 , V_3…...V_n are the voltages across resistances R_1 , R_2 , R_3 .... R_n

For parallel combination we have our modified equation as

$$V_{PARALLEL} = I_1R_1 + I_2R_2 + I_3R_3 + \cdots \dots . + I_nR_n \tag{3.10}$$

Where I_1 , I_2 , I_3..........I_n are the currents flowing through resistances R_1 , R_2 , R_3…...R_n.

For the power rating analysis, we used the following equation.

$$P = \frac{V^2}{R_{eqv}} = I^2R_{eqv} \tag{3.11}$$

Where V is the voltage, I is the current flowing through and R is the equivalent resistance

Chapter 4: Methodology

4.1. Design of the Heated Press:

The heater design began from the determination of the constraints required for the conformance and effective performance of the heater. The following constraints were initially discussed and after a lot of iterations the design which was finalized with mutual consent is shown in figure below.

- **Load Application:**
  The heat press should have a capacity to apply a load equal or greater than 100 Kgs
- **Heat Supply:**
  The heat press should be able to heat the specimen up to the melting point of the matrix material. (i.e 130 ^{o}C for this case).
- **Data Acquisition:**
  The heat press should be able to record the conditions at which the plates were produced.
- **Safety Equipment:**
  The heat press should be fitted with safety equipment to cope with any sort of emergency circumstances or hazardous event.
- **Manual Indicators:**
  The heat press should be fitted with manual indicators to show the agreement between the readings displayed by the computer and the manual readings.

4.2. CAD Model:

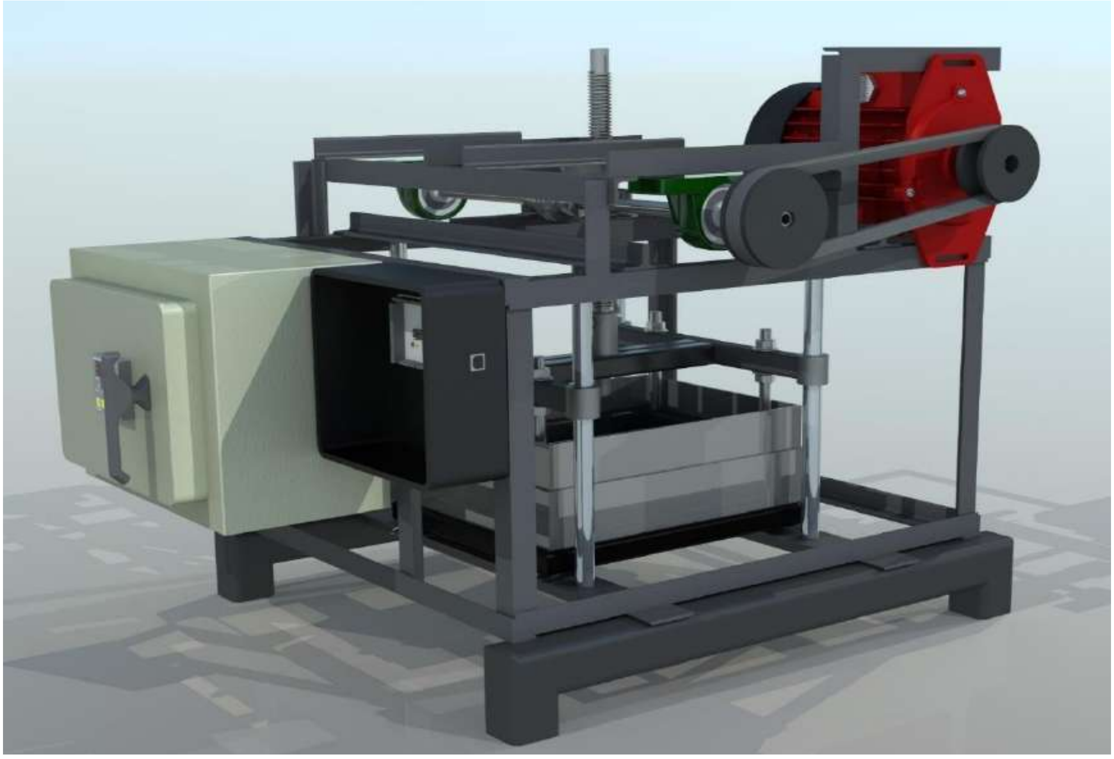

Figure 4.2: Finalized Cad Model of the machhine view

Figure 4.1: Finalized CAD model of the machine (View 1)

4.3. Dynamic Analysis:

We performed the structural, thermal as well as dynamic analysis on the heater design. We also performed the analytical solution to verify over results. the dynamic analysis our heater deigns is given as:

$\boldsymbol{T} = \frac{Fd_m}{2} \times (\frac{l+\pi f d_m}{\pi d_m - fl}) + \frac{Ff_c d_c}{2}$

$\boldsymbol{F} = 50\,N$

$\boldsymbol{d_m} = 19\ mm$

$\boldsymbol{f} = 1.35$

$\boldsymbol{l} = (1)(3\,mm)$

$\boldsymbol{f_c} = 0$

$\boldsymbol{d_c} = 29\,mm$

$\boldsymbol{T}$= 0.71353691 Nm

Where,

Torque T = torque use to raise the load

$\boldsymbol{F}$ = Principle Load

$\boldsymbol{d_m}$ = Major diameter of the thread

$\boldsymbol{f}$ = friction factor

$\boldsymbol{f_c}$ = collar friction

$\boldsymbol{d_c}$ = collar diameter

$\boldsymbol{\Lambda} = Lead\ angle$

Figure 4.3: Dynamic Analysis of the drive mechanism

$\boldsymbol{W_t}$ = 0.71353691/0.019 = 37.5545 N

$\boldsymbol{\Lambda} = tan -1(L/\pi dw)$

L = (0.006)(1) = 0.006 mm

$\boldsymbol{\Lambda} = 2.95486\,°$

W = 26.86

P = 0.5 Watt.

T = 6 Nm @ 5 RPM

$\boldsymbol{\Lambda} = Lead\ angle$

4.4. Static Analysis:

4.4.1 Structural Analysis:

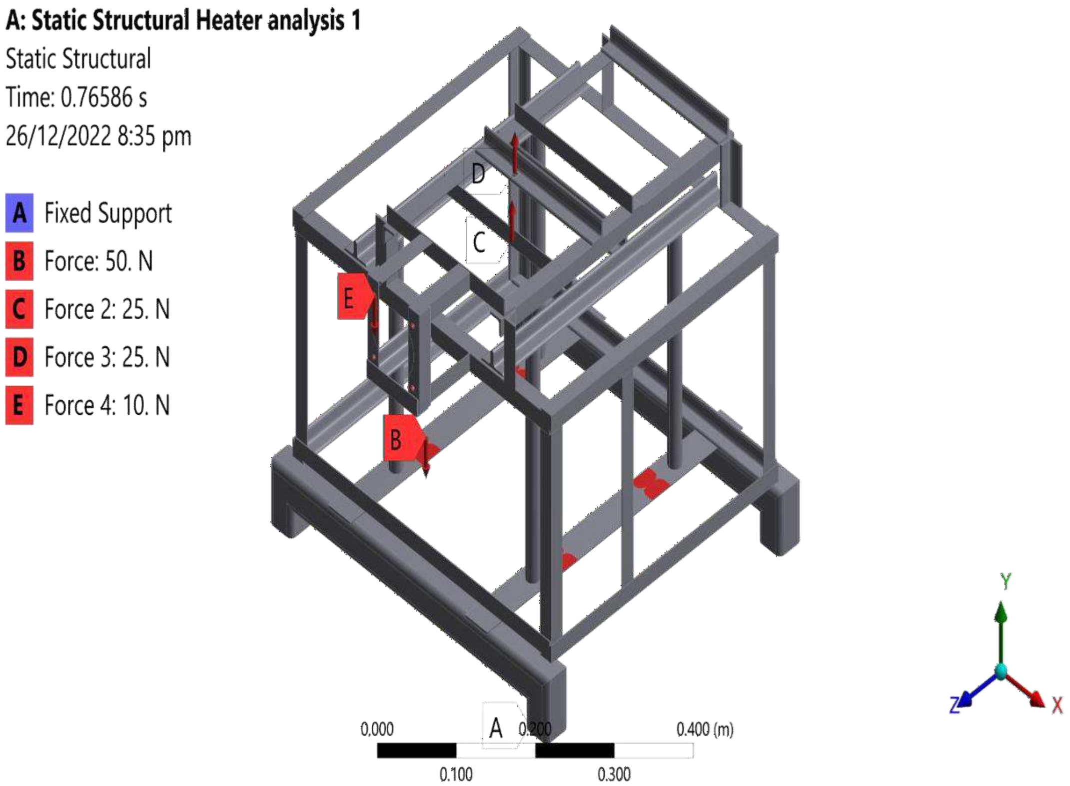

Figure 4.4: Structural analysis / Boundary conditions

For the structural analysis, stress evaluation, each auxiliary equipment from the weldment frame was removed and the force/load was applied after creating a face-split on the part where the auxiliary part was joined with “coincident mate’ in Solidworks.

The base of the frame was grounded with fixed support.

The contacts were ensured to be same as they were to be manufactured. (i.e weld, free, adhesive).

The software used was Ansys 19.2 with static structural module.

4.4.2 Stress Analysis:

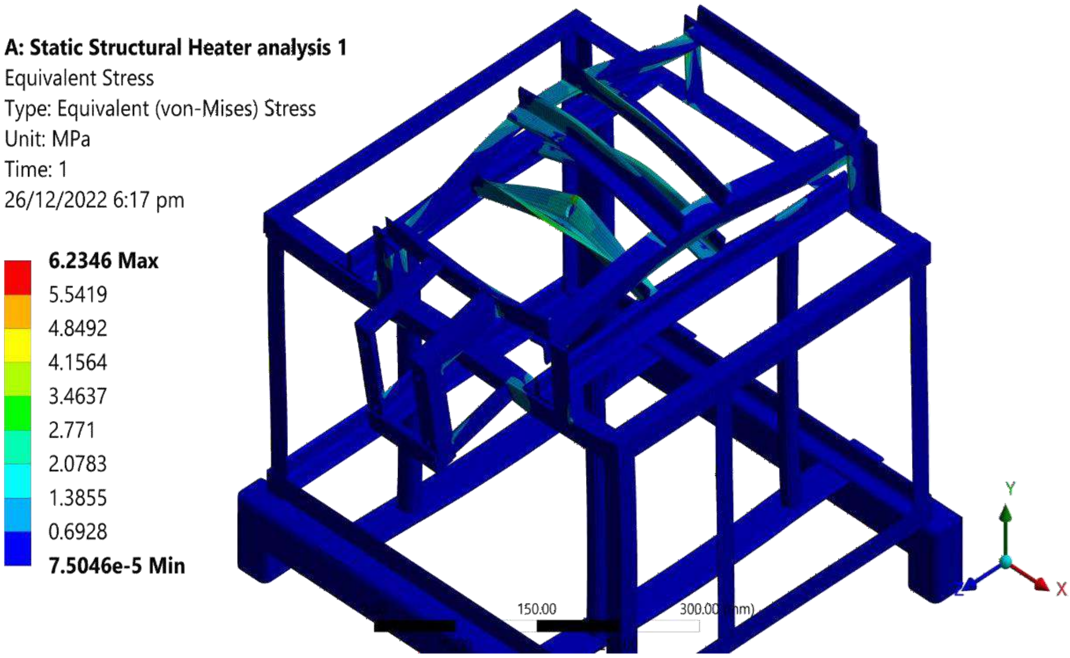

Figure 4.5: Equivalent stress analyses of the machine frame

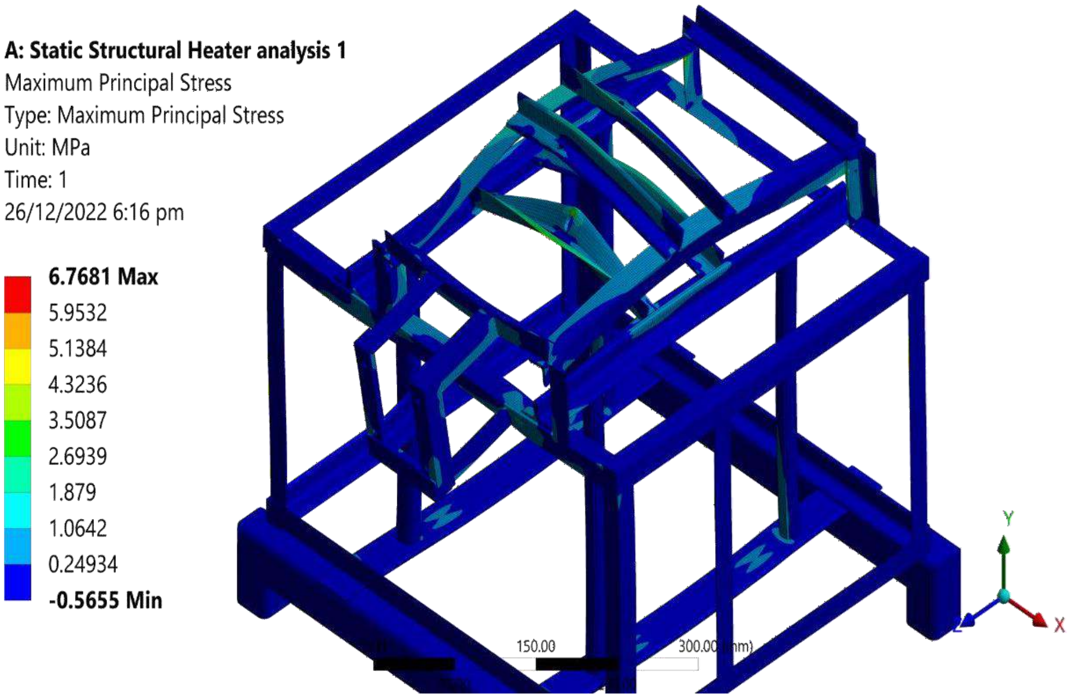

Figure 4.6: Maximum principal stress analyses of the machine frame

4.4.3 Total Deformation:

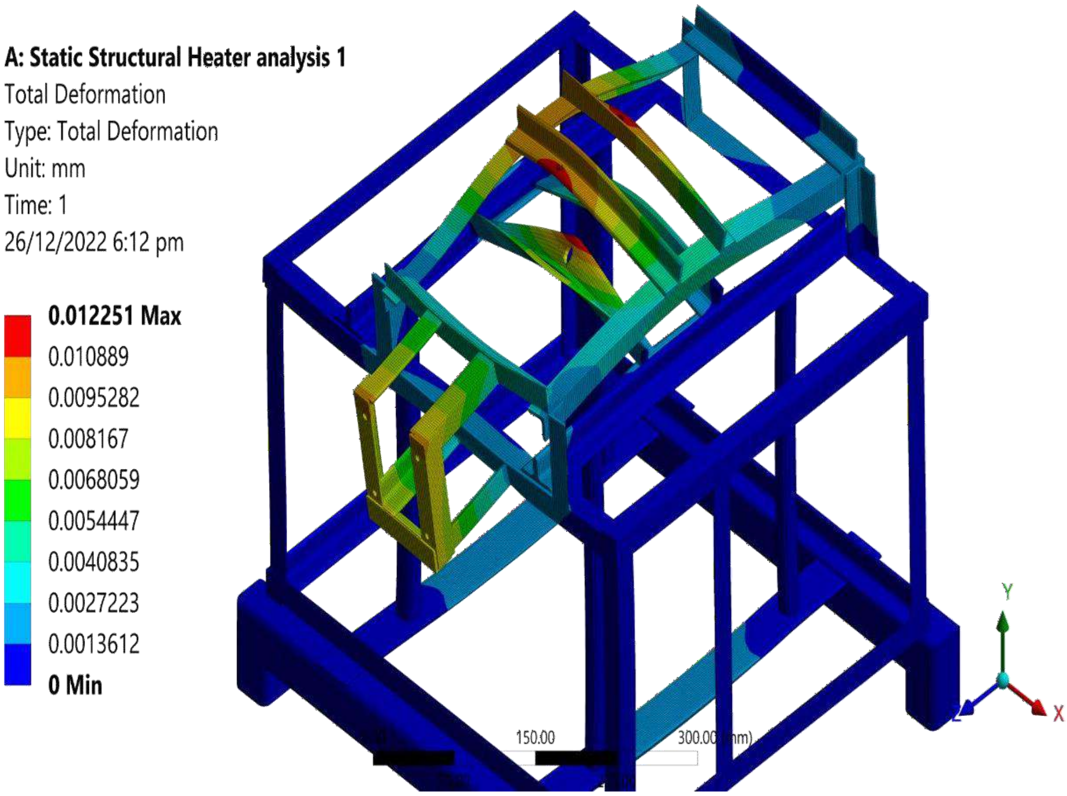

Figure 4.7: Total deformation analyses of the machine frame

4.4.4 Thermal Analysis:

Cure time is the time that determines how long things take to fully cure. A series of chemical reactions occurs during cure time. These chemical reactions allow things to set, harden and develop traits. The application of heat to the HDPE needs to be carefully managed to the following reasons. Just near the melting temperature, there is a drop in the heat flow.

This drop is due to the phase change of the HDPE from solid to liquid.

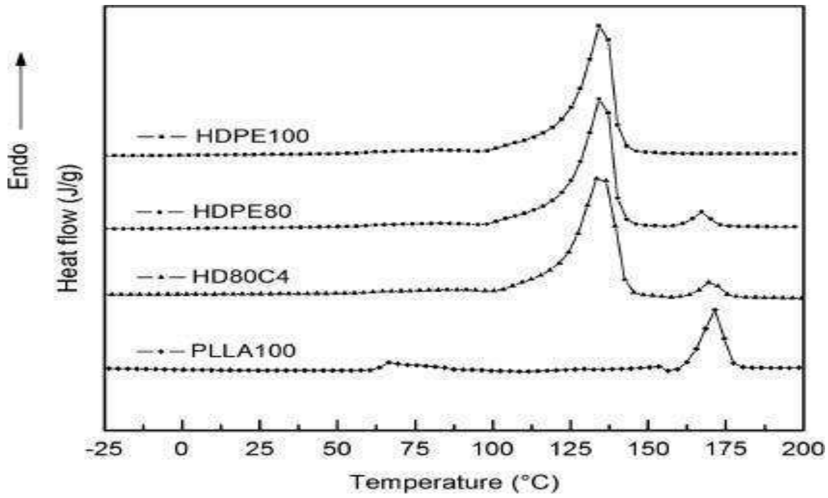

Figure 4.8: Thermal Energy absorption of HDPE and other polymers before melting

The abrupt change in heat can affect the crystalline structure of the adjacent sheets. Considering this effect, the temperature will be kept just below the melting point for a prolonged period of time. The time of curing can only be determined after the detailed pre-analysis of the plate design. However, a general concept of the application of heat with respect to time is shown on the graph alongside.

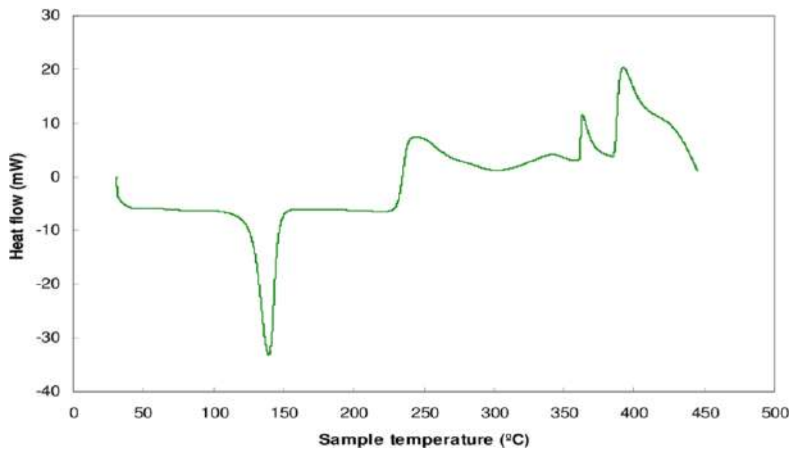

Figure 4.9: Heat flow for HDPE with respect to the melting temperatures

The time of curing can only be determined after the detailed pre-analysis of the plate design.

However, a general concept of the application of heat with respect to time is shown on the graph alongside.

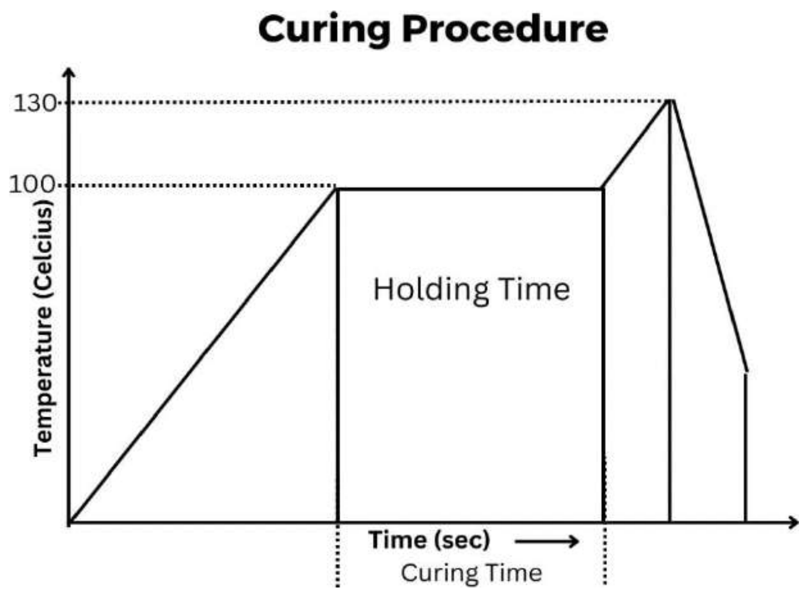

Figure 4.10: Curing procedure (idealized) for transition of HDPE used.

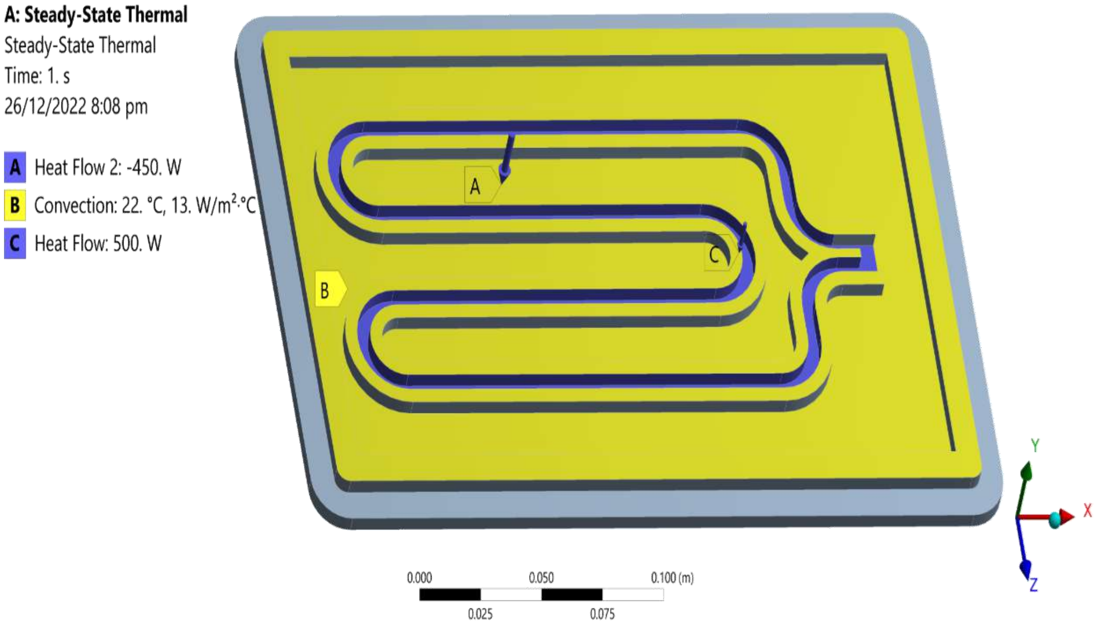

Figure 4.11: Steady state thermal analyses of the heating plate.

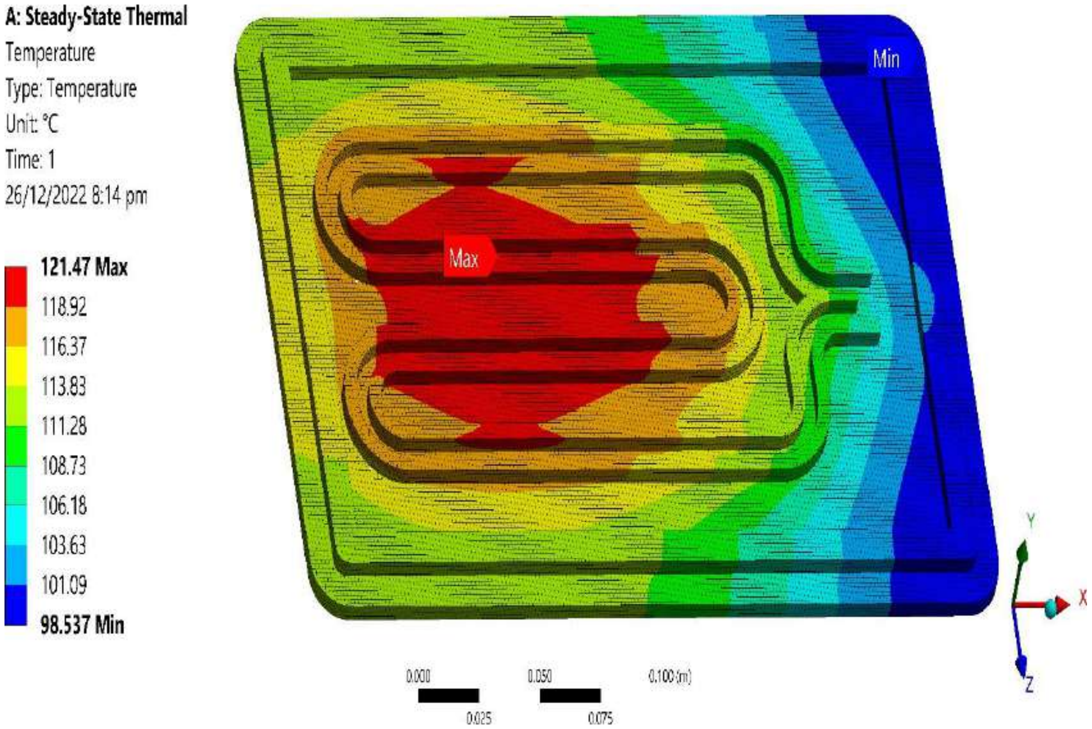

Figure 4.12: Temperature profile analyses of the heating plate.

4.5. Manufacturing Part:

4.5.1 Mechanical Design:

The following parts were either to be procured or manufactured. The details of each individual part are given below:

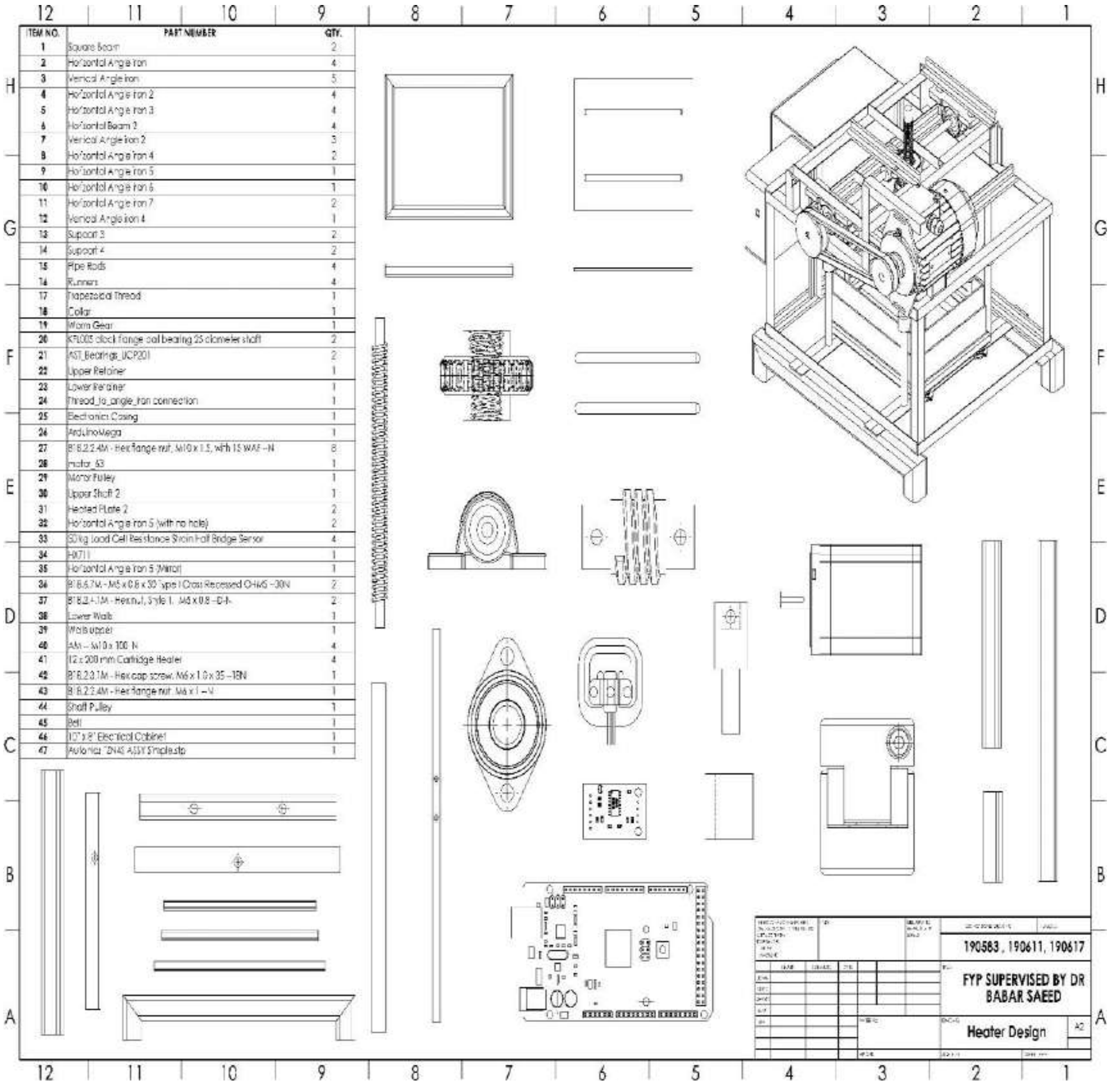

Figure 4.13: Assembly drawings used for the manufacture of the machine (Equipment drawings)

1. **Square Beam 2:**

   Quantity: 2

   Part no: 1

   Material: Mild Steel (MS)

   Length: 5 Ft

Description: 1.5 X 1.5 X $1\frac{1}{2}$ square beam.

2. **Horizontal Angle iron:**

   Quantity: 4

   Part no: 2

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

3. **Vertical Angle iron:**

   Quantity: 5

   Part no: 3

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

4. **Horizontal Angle iron 2:**

   Quantity: 4

   Part no: 4

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

5. **Horizontal Angle iron 3:**

   Quantity: 4

   Part no: 5

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

6. **Horizontal Beam 2:**

   Quantity: 4

   Part no: 6

Material: Mild Steel (MS)

Weight: (8 kg total weight for all the angle irons)

Description: 0.75 X 0.75 X 1/8 angle iron.

7. **Vertical Angle iron 2:**

   Quantity: 3

   Part no: 7

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

8. **Horizontal Angle iron 4:**

   Quantity: 2

   Part no: 8

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

9. **Horizontal Angle iron 5:**

   Quantity: 1

   Part no: 9

   Material: Mild Steel (MS)

   Weight: (8 kg total weight for all the angle irons)

   Description: 0.75 X 0.75 X 1/8 angle iron.

10. **Horizontal Angle iron 7:**

    Quantity: 1

    Part no: 10

    Material: Mild Steel (MS)

    Weight: (8 kg total weight for all the angle irons)

    Description: 0.75 X 0.75 X 1/8 angle iron.

11. **Horizontal Angle iron 7:**

    Quantity: 2

Part no: 11

Material: Mild Steel (MS)

Weight: (8 kg total weight for all the angle irons)

Description: 0.75 X 0.75 X 1/8 angle iron.

12. Vertical Angle iron 4:

Quantity: 2

Part no: 12

Material: Mild Steel (MS)

Weight: (8 kg total weight for all the angle irons)

Description: 0.75 X 0.75 X 1/8 angle iron.

13. Support 3:

Quantity: 2

Part no: 13

Material: Mild Steel (MS)

Weight: (Half-length used/ 10 Ft length)

Description: 0.75 X 0.75 X 1/8 square beam.

14. Support 4:

Quantity: 2

Part no: 14

Material: Mild Steel (MS)

Weight: (Half-length used/ 10 Ft length)

Description: 0.75 X 0.75 X 1/8 square beam

15. Pipe Rods:

Quantity: 4

Part no: 15

Material: 1045 Carbon Steel (CS)

Weight: (2.6 Kg with pipe rods included)

Description: 14 X 270 rod (Units: mm)

16. Runners:

Quantity: 4

Part no: 16

Material: 1045 Carbon Steel (CS)

Weight: (2.6 Kg with runners included)

Description: 30 X 37.5 rod (Units: mm)

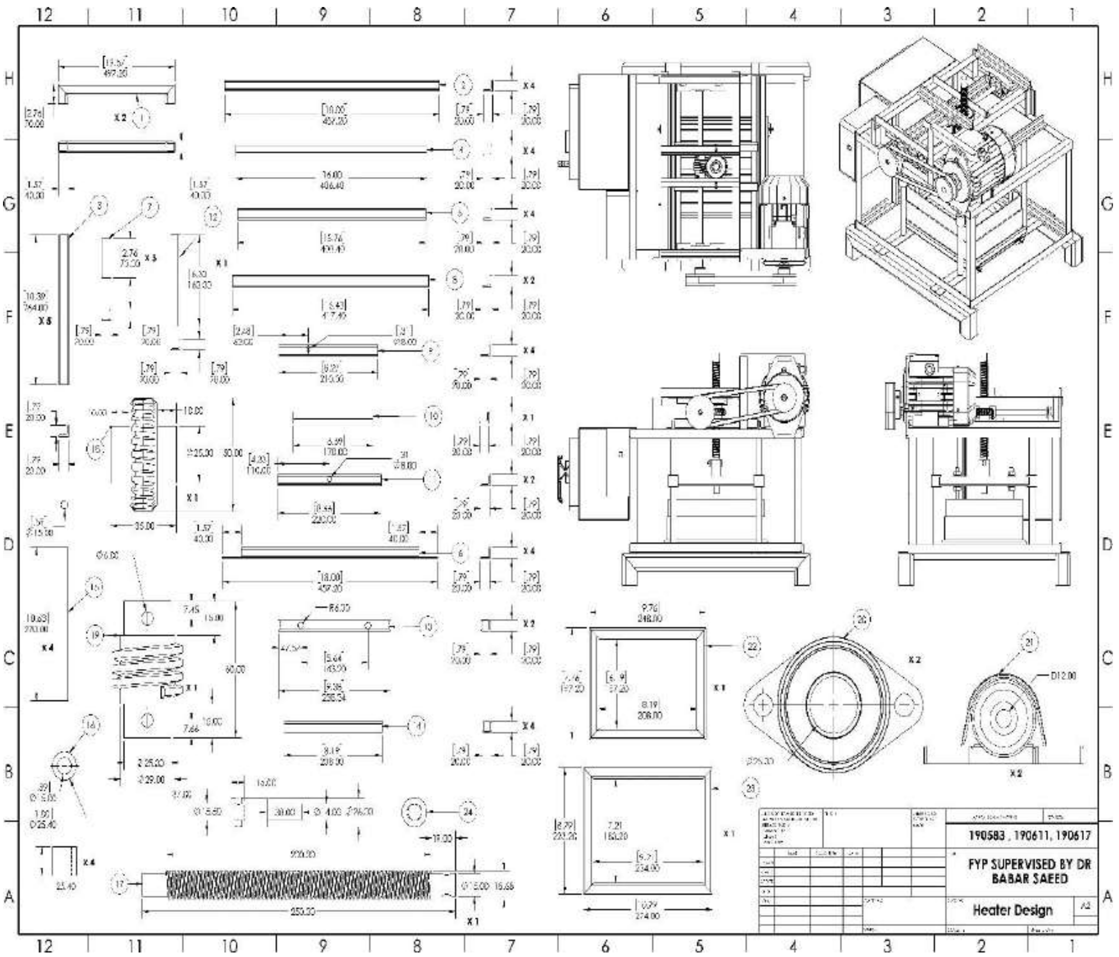

Figure 4.14: Assembly drawings used for the manufacture of the machine (Weldments and mechanical drives)

17. Trapezoidal Thread:

Quantity: 1

Part no: 17

Material: 1045 Carbon Steel (CS)

Weight: (Outsourced Manufacturing)

Description: ¾ Inch TPI thread (external) on a 20 X 250 mm rod / Thread length 200 mm

18. Collar:

Quantity: 1

Part no: 18

Material: Cast Iron

Weight: (Outsourced Manufacturing)

Description:

- ¾ Inch TPI thread (internal) on a 25 X 35 mm rod (bore size 20 mm) / Thread length 35 mm
- 26 teeth worm gear with gear width 15 mm

19. Worm Gear:

Quantity: 1

Part no: 19

Material: 1045 Carbon Steel (CS)

Weight: (Outsourced Manufacturing)

Description: 37 mm rod processed for 26 teeth gear on collar.

20. KFL005 block flange ball bearing 25:

Quantity: 2

Part no: 20

Material: Cast iron for bearing housing / NTN bearings

Procured from: Brandreth Road / Lahore

Description: Shaft diameter: 25 mm

21. AST_Bearings_UCP201:

Quantity: 2

Part no: 20

Material: Cast iron for bearing housing / NTN bearings

Procured from: Brandreth Road / Lahore

Description: Shaft diameter: 12 mm

22. Upper Retainer:

Quantity: 1

Part no: 22

Material: Mild Steel (MS)

Weight: (Half-length used/ 10 Ft length)

Description: 0.75 X 0.75 X 1/8 square beam

23. Lower Retainer

Quantity: 1

Part no: 23

Material: Mild Steel (MS)

Weight: (Half-length used/ 10 Ft length)

Description: 0.75 X 0.75 X 1/8 square beam

24. Thread_to_angle_Iron connection:

Quantity: 1

Part no: 24

Material: 1045 Carbon Steel (CS)

Weight: (0.75 Kg with pipe rods included)

Description: 30 mm rods (3-inch length)

25. Electronics Casing:

Quantity: 1

Part no: 25

Material: Poly Vinyl Chloride (PVC)

Weight: Nil

Description: 8-inch X 10-inch electrical board for switches /closed type.

26. Arduino Mega (ATmega 2560):

Quantity: 1

Part no: 26

Material: Multiple / PCB

Weight: Nil

Description: Arduino Mega with USB cable, 5-volt dc charger, jumper wires and other accessories.

27. B18.2.2.4M - Hex flange nut, M10 x 1.5:

Quantity: 12

Part no: 27

Material: Stainless Steel

Weight: Nil

Description: M10 x 1.5, with 15 WAF –N /Stainless Steel / 12 Pieces

28. Motor:

Quantity: 1

Part no: 28

Material: Multiple / Assembly

Weight: Nil

Description: Motor assembly with complete wiring switches and power cords.

29. Motor Pulley:

Quantity: 1

Part no: 29

Material: Cast Iron

Weight: Nil.

Description: 2.5 Inch pulley

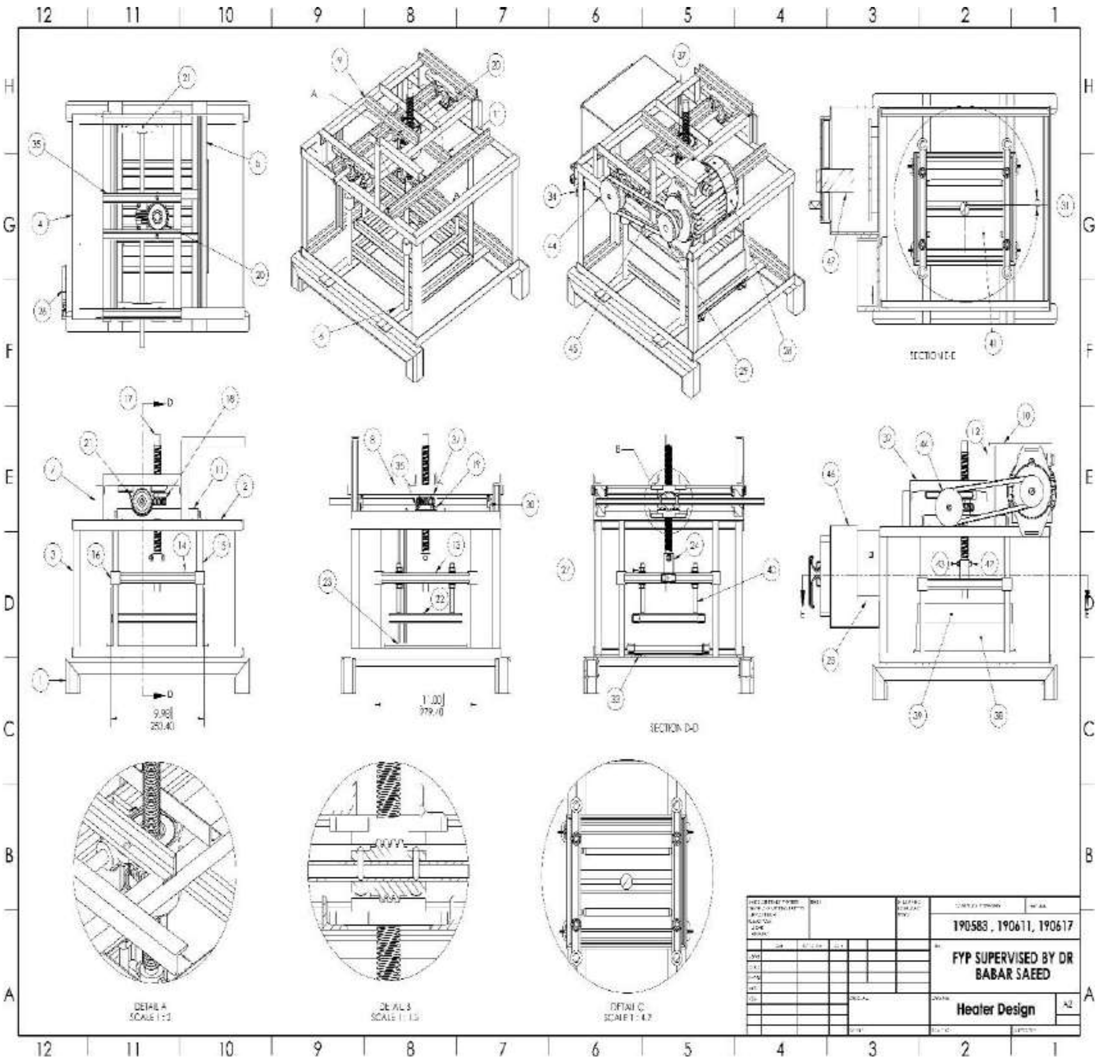

Figure 4.15: Assembly drawings used for the manufacture of the machine (Section views and detail views)

30. Upper Shaft 2:

Quantity: 1

Part no: 30

Material: 1045 Carbon Steel (CS)

Weight: 0.4 kg

Description: 16 X 500 rod (Units: mm)

31. Heated Plate 2:

Quantity: 2

Part no: 31

Material: Stainless Steel 316 (SS)

Weight: 4.3 Kg

Description: Post-processing = Buffing

32. Horizontal Angle iron 5 (with no hole):

Quantity: 2

Part no: 32

Material: Mild Steel (MS)

Weight: (8 kg total weight for all the angle irons)

Description: 0.75 X 0.75 X 1/8 angle iron.

33. 50 kg Load Cell Resistance Strain Half Bridge Sensor:

Quantity: 5

Part no: 33

Material: Multiple / Assembly

Weight: Nil

Description: 5 Pieces

34. HX711:

Quantity: 5

Part no: 34

Material: Multiple / Assembly

Weight: Nil

Description: 5 Pieces

35. Horizontal Angle iron 5 (Mirror):

Quantity: 1

Part no: 35

Material: Mild Steel (MS)

Weight: (8 kg total weight for all the angle irons)

Description: 0.75 X 0.75 X 1/8 angle iron.

36. B18.6.7M - M5 x 0.8 x 30 Type I Cross Recessed OHMS --30N:

Quantity: 4

Part no: 36

Material: Stainless Steel

Weight: Nil

Description: M5 x 0.8 x 30 Type I Cross Recessed OHMS --30N

37. B18.2.4.1M - Hex nut, Style 1, M5 x 0.8 --D-N

Quantity: 2

Part no: 37

Material: Stainless Steel

Weight: Nil

Description: Hex nut, Style 1, M5 x 0.8 --D-N

38. Lower Walls:

Description: Piece not manufactured

39. Walls upper:

Description: Piece not manufactured

40. AM -- M10 x 100 N:

Quantity: 4

Part no: 40

Material: Stainless Steel

Weight: Nil

Description: M10 x 100 N

41. 12 x 200 mm Cartridge Heater:

Quantity: 4

Part no: 41

Material: Stainless Steel 304 (SS)

Weight: Nil

Description: 12 X 200 rods (Units: mm)

42. B18.2.3.1M - Hex cap screw, M6 x 1.0 x 35 --18N:

Quantity: 4

Part no: 42

Material Stainless Steel

Weight: Nil

Description: Hex cap screw, M6 x 1.0 x 35 --18N

43. B18.2.2.4M - Hex flange nut, M6 x 1 –N:

Quantity: 4

Part no: 43

Material: Stainless Steel

Weight: Nil

Description: Hex flange nut, M6 x 1 --N

44. Autonics TZN4S ASSY:

Quantity: 1

Part no: 44

Material: Multiple

Weight: Nil

Description: REX 606 temperature controller

45. Magnetic Contactor CHNT 18 Ampere:

Quantity: 1

Part no: 45

Material: Multiple

Weight: Nil

Description: Magnetic Contactor CHNT 18 Ampere/ (1 NC / 1 NO contacts) / 3 Pole.

46. K-Type Thermocouple:

Quantity: 4

Part no: 46

Material: Stainless Steel 304 (SS)

Weight: Nil

Description: K-type thermocouple with M6 thread & M8 thread

47. Driver Module for K-Type Thermocouple:

Quantity: 3

Part no: 47

Material: Multiple / PCB

Weight: Nil

Description: MAX6675 module for Arduino Mega 2560.

48. 10'' x 8'' Electrical Cabinet:

Quantity: 1

Part no: 48

Material: Sheet Metal (MS)

Weight: Nil

Description: 10" x 8" inch cabinet

49. Shaft Pulley:

Quantity: 1

Part no: 49

Material: Cast Iron

Weight: Nil

Description: 3-inch pulley with no hole.

50. Belt:

Quantity: 1

Part no: 50

Material: Nylon Rubber

Weight: Nil

Description: 21 number V-belt used.

51. M12 Bolts + M12 Nuts:

Quantity: 12

Part no: 51

Material: Aluminium Alloy / Stainless Steel

Weight: Nil

Description: M12 Bolts + M12 Nuts.

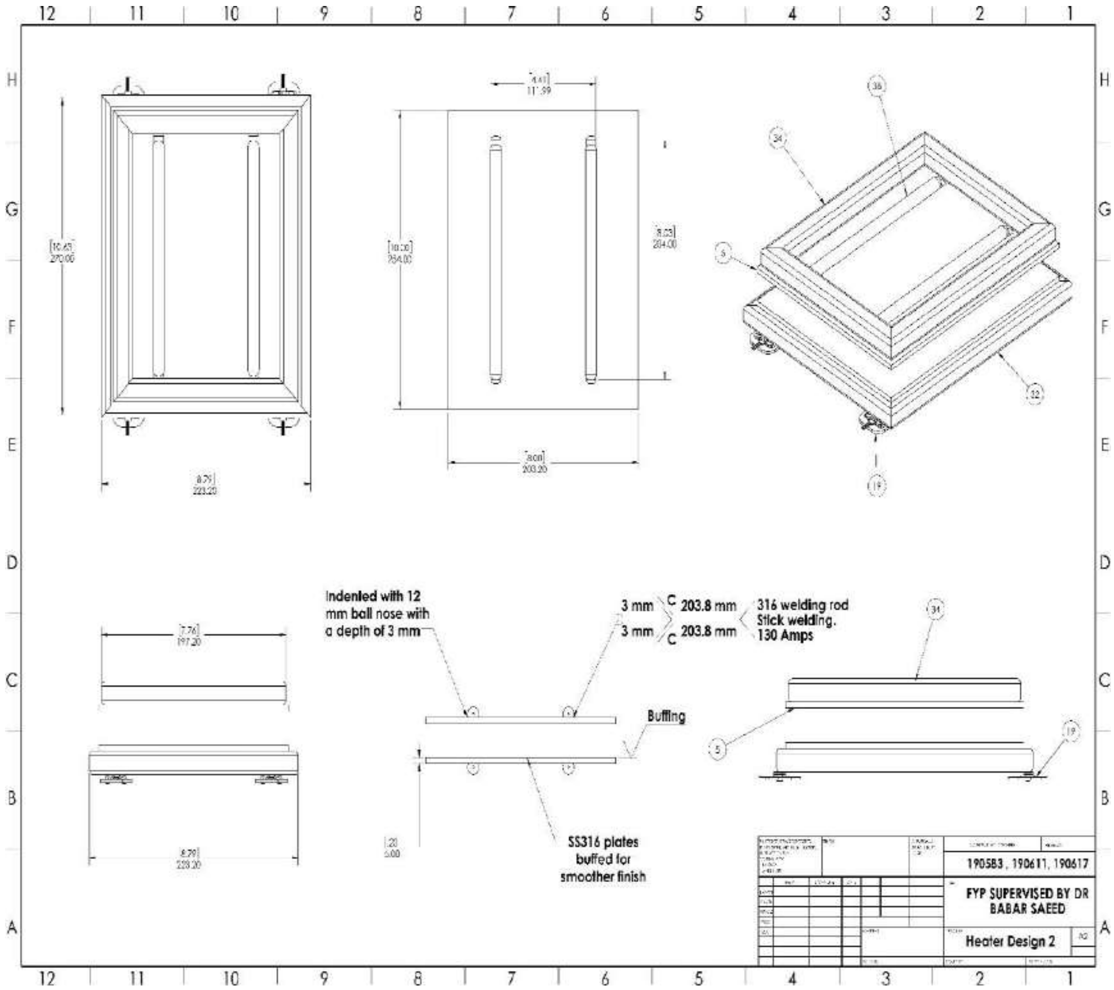

Figure 4.16: Assembly drawings used for the manufacture of the machine (Heating plate design)

52. Stainless Steel SS316L stick welding rods:

Quantity: 6

Part no: 52

Material: SS316L (2.5 mm or 12 no)

Weight: Nil

Description: Stainless Steel SS316L

53. Paint Job:

Quantity: 3 Piece

Part no: 53

Material: Red Oxide + Synthetic Enamel

Weight: Nil

Description: Red Oxide + Synthetic Enamel

54. 7/0.029" wire + 3/0.029" wire:

Quantity: 2 Piece

Part no: 54

Material: Copper

Weight: Nil

Description:

- 7/0.029" wire = 12 meter
- 3/0.029" wire = 11 meter

55. Electrical Switch Panel 8" x 10":

Quantity: 1

Part no: 55

Material: Poly Vinyl Chloride (PVC)

Weight: Nil

Description: 8-inch X 10-inch electrical board for switches /closed type.

56. Electrical switches + Electrical sockets:

Quantity: 1

Part no: 56

Material: Multiple / Assembly

Weight: Nil

Description: 10 Pieces

57. Ducting pipe:

Quantity: 1

Part no: 57

Material: Multiple / Assembly

Weight: Nil

Description: 15 Ft length

58. Insulation Tape:

Quantity: 3

Part no: 58

Material: Vinyl / PVC

Weight: Nil

Description: 3 Pieces / 2 Black , 1 Red

59. Electrical Ties:

Quantity: 84

Part no: 59

Material: Polyamides / Nylon (6/6)

Weight: Nil

Description: 84 Pieces

60. 11 No bolts / nuts:

Quantity: 8

Part no: 60

Material: Aluminium Alloy

Weight: Nil

Description: 8 Pieces

61. Jumper wires:

Quantity: 155

Part no: 61

Material: Copper

Weight: Nil

Description: (Male to Male = 50 / Male to Female = 105)

62. SPST relay module:

Quantity: 3

Part no: 62

Material: Multiple /Assembly

Weight: Nil

Description: 5 Volt Single Channel Relay for Arduino, 3 Pieces / Modules

63. 240 Volt Led lights:

Quantity: 6

Part no: 63

Material: Multiple /Assembly

Weight: Nil

Description: LED indicators for 240 Volts AC

64. 3"x6" board with 4 sockets:

Quantity: 1

Part no: 64

Material: Poly Vinyl Chloride (PVC)

Weight: Nil

Description: 3"x6" board with 4 sockets

65. 2 Pin shoe:

Quantity: 8

Part no: 65

Material: Poly Vinyl Chloride (PVC)

Weight: Nil

Description: 8 Pieces

66. Conducting clip:

Quantity: 12

Part no: 66

Material: Copper

Weight: Nil

Description: 12 Pieces

67. M3 Screws:

Quantity: 9

Part no: 67

Material: Stainless Steel (SS)

Weight: Nil

Description: 9 Pieces, self-drilling.

68. LM 2596 module:

Quantity: 1

Part no: 68

Material: Multiple / Assembly

Weight: Nil

Description: Module for providing constant 5 volts to auxiliary modules connected with Arduino.

69. Bread board (mini):

Quantity: 1

Part no: 69

Material: Multiple / Assembly

Weight: Nil

Description: Type: Mini

70. Bulb Holder:

Quantity: 1

Part no: 70

Material: Multiple / Assembly

Weight: Nil

Description: Nil

71. Tubular Fuse with holder:

Quantity: 11

Part no: 71

Material: Multiple / Assembly

Weight: Nil

Description: 2 Ampere: 3 Pieces, 10 Ampere: 3 Pieces, 15 Ampere: 3 Pieces, 2 Fuse Holder

72. Audio Sockets:

Quantity: 18

Part no: 72

Material: Multiple / Assembly

Weight: Nil

Description: 18 Pieces

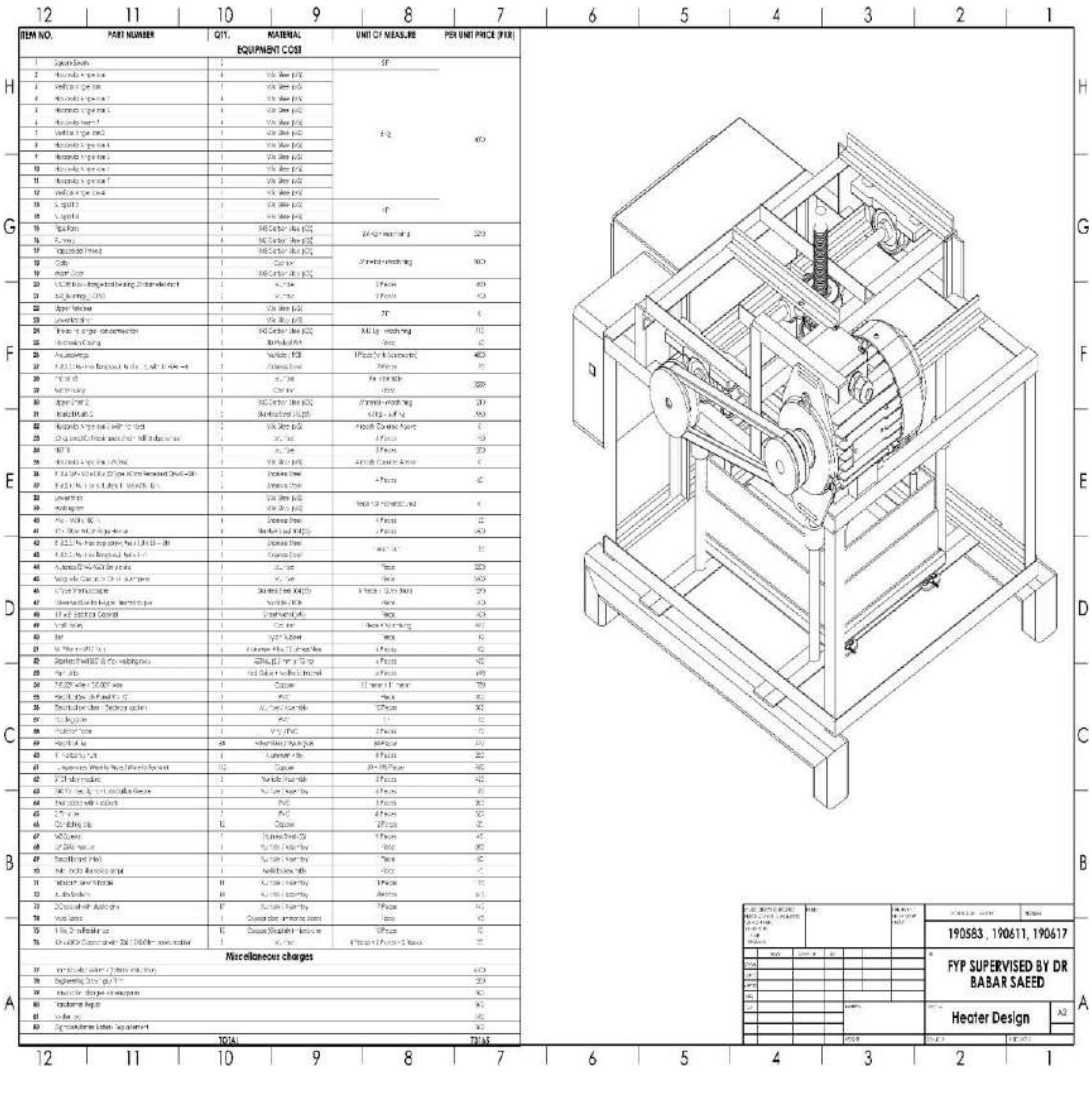

Figure 4.17: Assembly drawings used for the manufacture of the machine (Bill of Quantities)

73. DC socket with studio pins:

Quantity: 17

Part no: 73

Material: Multiple / Assembly

Weight: Nil

Description: 17 Pieces

74. Vero Board:

Quantity: 1

Part no: 74

Material: Copper clad laminated board

Weight: Nil

Description: Copper clad laminated board

75. 1 Kilo Ohm Resistance:

Quantity: 10

Part no: 75

Material: Carbon (Graphite) mixed clay

Weight: Nil

Description: Nil

76. 104k 630W Capacitor with 220 / 270 Ohm power resistor:

Quantity: 8

Part no: 76

Material: Multiple

Weight: Nil

Description: 4 Pieces + 2 Pieces + 2 Pieces

Table 4.1: Bill of Quantities and the calculated cost for the manufactured machine.

ITEM NO.	PART NUMBER	QTY.	MATERIAL	UNIT OF MEASURE	PER UNIT PRICE (PKR)
EQUIPMENT COST					
1	Square Beam	2	Mild Steel (MS)	5 Ft	4000
2	Horizontal Angle iron	4	Mild Steel (MS)	8 Kg	
3	Vertical Angle iron	5	Mild Steel (MS)		
4	Horizontal Angle iron 2	4	Mild Steel (MS)		
5	Horizontal Angle iron 3	4	Mild Steel (MS)		
6	Horizontal Beam 2	4	Mild Steel (MS)		
7	Vertical Angle iron 2	3	Mild Steel (MS)		
8	Horizontal Angle iron 4	2	Mild Steel (MS)		
9	Horizontal Angle iron 5	1	Mild Steel (MS)		
10	Horizontal Angle iron 7	1	Mild Steel (MS)		
11	Horizontal Angle iron 7	2	Mild Steel (MS)		
12	Vertical Angle iron 4	2	Mild Steel (MS)		
13	Support 3	2	Mild Steel (MS)	4 Ft	
14	Support 4	2	Mild Steel (MS)		
15	Pipe Rods	4	1045 Carbon Steel (CS)	2.6 Kg + Machining	2260
16	Runners	4	1045 Carbon Steel (CS)		
17	Trapezoidal Thread	1	1045 Carbon Steel (CS)	Material + Machining	8000
18	Collar	1	Cast Iron		
19	Worm Gear	1	1045 Carbon Steel (CS)		
20	KFL005 block flange ball bearing 25 diameter shaft	2	Multiple	2 Pieces	1650
21	AST_Bearings_UCP201	2	Multiple	2 Pieces	1400
22	Upper Retainer	1	Mild Steel (MS)	7 Ft	0
23	Lower Retainer	1	Mild Steel (MS)		
24	Thread_to_angle_Iron connection	1	1045 Carbon Steel (CS)	0.45 Kg + Machining	710
25	Electronics Casing	1	3D Printed PLA	1 Piece	150
26	ArduinoMega	1	Multiple / PCB	1 Piece (with Accessories)	4800
27	B18.2.2.4M - Hex flange nut, M10 x 1.5, with 15 WAF --N	8	Stainless Steel	12 Pieces	120
28	motor_63	1	Multiple	Full Assembly	3280
29	Motor Pulley	1	Cast Iron	1 Piece	

30	Upper Shaft 2	1	1045 Carbon Steel (CS)	Material + Machining	1210
31	Heated PLate 2	2	Stainless Steel 316 (SS)	4.3 Kg + Buffing	7950
32	Horizontal Angle iron 5 (with no hole)	2	Mild Steel (MS)	Already Covered Above	0
33	50 kg Load Cell Resistance Strain Half Bridge Sensor	5	Multiple	5 Pieces	1450
34	HX711	5	Multiple	5 Pieces	1200
35	Horizontal Angle iron 5 (Mirror)	1	Mild Steel (MS)	Already Covered Above	0
36	B18.6.7M - M5 x 0.8 x 30 Type I Cross Recessed OHMS --30N	2	Stainless Steel	4 Pieces	60
37	B18.2.4.1M - Hex nut, Style 1, M5 x 0.8 --D-N	2	Stainless Steel		
38	Lower Walls	1	Mild Steel (MS)	Piece not manufactured	0
39	Walls upper	1	Mild Steel (MS)		
40	AM -- M10 x 100 N	4	Stainless Steel	4 Pieces	120
41	12 x 200 mm Cartridge Heater	4	Stainless Steel 304 (SS)	4 Pieces	5600
42	B18.2.3.1M - Hex cap screw, M6 x 1.0 x 35 --18N	1	Stainless Steel	4 Allen Nut	150
43	B18.2.2.4M - Hex flange nut, M6 x 1 --N	1	Stainless Steel		
44	Autonics TZN4S ASSY Simple.stp	1	Multiple	1 Piece	3200
45	Magnetic Contactor CHNT 18 Ampere	1	Multiple	1 Piece	2600
46	K-Type Thermocouple	3	Stainless Steel 304 (SS)	1 Piece + 12 M6 (Nuts)	1270
47	Driver Module for K-Type Thermocouple	3	Multiple / PCB	1 Piece	1400
48	10" x 8" Electrical Cabinet	1	Sheet Metal (MS)	1 Piece	1400
49	Shaft Pulley	1	Cast Iron	1 Piece + Machining	620
50	Belt	1	Nylon Rubber	1 Piece	150
51	M12 Bolts + M12 Nuts	6	Aluminum Alloy / Stainless Steel	6 Pieces	100
52	Stainless Steel SS316L stick welding rods	6	SS316L (2.5 mm or 12 no)	6 Pieces	480
53	Paint Job	1	Red Oxide + Synthetic Enamel	3 Pieces	1890
54	7/0.029" wire + 3/0.029" wire	1	Copper	12 meter + 11 meter	1780
55	Electrical Switch Panel 8" x 10"	1	PVC	1 Piece	200
56	Electrical switches + Electrical sockets	1	Multiple / Assembly	10 Pieces	300
57	Ducting pipe	1	PVC	15 Ft	150
58	Insulation Tape	3	Vinyl / PVC	3 Pieces	170

59	Electrical Ties	84	Polyamides / Nylon (6/6)	84 Pieces	420
60	11 No bolts / nuts	8	Aluminum Alloy	8 Pieces	220
61	Jumper wires (Male to Male / Male to Female)	155	Copper	50 + 105 Pieces	630
62	SPST relay module	3	Multiple /Assembly	3 Pieces	420
63	240 Volt Led lights + Lubrication Grease	6	Multiple / Assembly	6 Pieces	180
64	3"x6" board with 4 sockets	1	PVC	5 Pieces	200
65	2 Pin shoe	8	PVC	8 Pieces	320
66	Conducting clip	12	Copper	12 Pieces	30
67	M3 Screws	9	Stainless Steel (SS)	9 Pieces	45
68	LM 2596 module	1	Multiple / Assembly	1 Piece	200
69	Bread board (mini)	1	Multiple / Assembly	1 Piece	60
70	Bulb Holder (for series lamp)	1	Multiple/Assembly	1 Piece	40
71	Tubular Fuse with holder	11	Multiple / Assembly	11 Pieces	190
72	Audio Sockets	18	Multiple / Assembly	18 Pieces	540
73	DC socket with studio pins	17	Multiple / Assembly	17 Pieces	440
74	Vero Board	1	Copper clad laminated board	1 Piece	100
75	1 Kilo Ohm Resistance	10	Carbon (Graphite) mixed clay	10 Pieces	10
76	104k 630W Capacitor with 220 / 270 Ohm power resistor	8	Multiple	4 Pieces + 2 Pieces + 2 Pieces	70
Miscellaneous charges					
77	Train Tickets / Return / (Lahore Visit / Tour)				6400
78	Engineering Drawings / Print				1200
79	Transaction charges via easypaisa				300
80	Transformer Repair				500
81	Solder Job				530
82	Digital Multimeter Battery Replacement				300
TOTAL					**73165**

4.5.2 Material Properties:

The material which we used while fabricating the heating press are.

(1) Mild Steel:

Chemical Properties of Mild Steel

Mild steel has lower carbon content than medium and high carbon steels. The carbon content is up to 0.25% in mild steel but some schools of thought consider carbon steel as mild steel up to a carbon content of 0.45%.

The low carbon content makes this steel a highly Machinable metal. It can be cut, machined and formed into intricate shapes without adding proportional stresses to the work piece. It also facilitates better weldability.

A host of alloying elements can improve the chemical properties. These elements will affect the physical/chemical properties favorably and make the final product suitable for the application. The elements that may be added include chromium (Cr), cobalt (Co), phosphorus (P), sulphur (S), and manganese (Mn), among others.

For instance, chromium imparts the property of corrosion resistance and increases mild steel's hardness. In its pure form, mild steel will rust easily due to oxidation. Unlike iron oxide, chromium metal on exposure to the atmosphere forms a dense layer of chromium oxide that does not fall off, and ultimately protects the metal underneath from further corrosion attacks.

Copper in limited quantities also works like chromium oxide. Mild steel pipes may be galvanized for better protection from the atmosphere.
Other elements may be added to improve wear resistance, ultimate tensile strength, and heat resistance.

Physical Properties of Mild Steel

Its impressive properties are responsible for growing use in a variety of industries. Some mild steel's physical properties are as follows:

- High tensile strength
- High impact strength
- Good ductility and weldability

- A magnetic metal due to its ferrite content
- Good malleability with cold-forming possibilities
- Not suitable for heat treatment to improve properties

Common Grades

The following are some of the common steel grades. A common denominator for all of them and other similar metals is their universal nature. Their properties make them a popular choice for a wide range of applications.

(i) EN 1.0301

Equivalent grades: AISI 1008; C10; DC01

EN 1.0301 carbon steel contains 0.1% carbon, 0.4% manganese and 0.4 percent silicon. It also contains small amounts of copper (Cu), nickel (Ni), chromium (Cr), aluminum (Al), and molybdenum (Mo). This grade has excellent weldability and is commonly used for extruded, forged, cold headed, and cold-pressed parts and forms. It is primarily used in automotive equipment, furniture, and appliances.

(ii) EN 1.1121

Equivalent grades: AISI 1010

EN 1.1121 carbon steel contains carbon in the range of 0.08% to 0.13%. Manganese is present in the range of 0.3% to 0.6%. It is used in the manufacturing of cold headed fasteners and bolts.

This grade also had good formability and ductility and can be formed using traditional methods. It also supports joining by all welding techniques. Its strength may be improved by heat treatment, quenching, and tempering but the cost of carrying out these processes is high. It is a general-purpose steel largely present in various structures and the automotive industry.

(iii) EN 1.0402

Equivalent grades: AISI 1020; C22

This grade of steel has excellent weld ability. EN 1.0402 is especially suitable for carburized parts. It also has a good balance between ductility, strength and toughness. It has a carbon content from 0.18% to 0.23% with a manganese content range of 0.3% to 0.6%. Compared to EN 1.1121, it is not used as much but it does have great machinability in its as-forged condition.

This grade finds use in machinery in the form of hydraulic parts and camshafts.

(2) Cast Iron:

Table 4.2: Table showing proportions of alloying materials for cast iron

Tellurium ,Te	0.0200%	0.0200%	Average value :0.0200% Grade Count :6
Tin ,Sn	0.0100-0.300%	0.0100-0.300%	Average value :0.0538% Grade Count :12
Titanium ,Ti	0.0400%	0.0400%	Average value :0.0400% Grade Count :6
Vanadium ,V	0.100-2.00%	0.100-2.00%	Average value :0.478% Grade Count :9

	BRINELL HARDNESS	TENSILE STRENGTH	MODULUS OF ELASTICITY	% ELONGATION (IN 50 MM)
Gray iron class 25	187	29.9 ksi	16.1 Msi	–
Gray iron class 40	235	41.9 ksi	18.2 Msi	–
Ductile iron grade 60-40-18	130 – 170	60 ksi	24.5 Msi	–
Ductile iron grade 129-90-02	240 – 300	120 ksi	25.5 Msi	–
CGI grade 250	179 max	36.2 ksi min		3
CGI grade 450	207 – 269	65.2 ksi min		1

Figure 4.18: Physical properties of cast iron

(3) Stainless steel:

Stainless steel has many desirable properties that contribute greatly to its widespread application in the making of parts and components across many industrial sectors. Above all, because of its chromium content, it is extremely resistant to corrosion. The 10.5% minimum content makes steel approximately 200 times more resistant to corrosion than steels without chromium. Other favorable properties for consumers are its high strength and durability, its high and low temperature resistance, increased formability and easy fabrication, low maintenance, long-lasting, attractive appearance and it is environmentally friendly and recyclable. Once stainless steel is put into service, it does not need to be treated, coated or painted.

- Corrosion resistant
- High tensile strength
- Very durable
- Temperature resistant
- Easy formability and fabrication
- Low-maintenance (long lasting)
- Attractive appearance
- Environmentally friendly (recyclable)

4.5.3 Electrical and Electronics Design:

The electrical design began from the following connections:

- 4 Cartridge Heaters (Part No: 41) excited by 230 Volts main controlled by CHNT Magnetic contactor (Part no: 45).
- Each Cartridge Heater (Part No: 41) controlled by an additional switch (Part No: 56)
- CHNT Magnetic Contactor (Part no: 45) coil excited by 230 Volts main controlled by 5 Volt Single Channel SPST relay (Part no: 62) and Temperature Controller (Part no: 44) connected in series.
- CHNT Magnetic Contactor (Part no: 45) coil connected in parallel with a snubber circuit (Part no: 76).
- Motor (Part no: 28) powered by 230 volts mains controlled by 5 Volt Single Channel SPST relay (Part no: 62) and a two-way switch (Part no: 28) connected in parallel to each other, and another two-way switch (Part no 28) connected in series (Series – Parallel Combination).
- Temperature Controller (Part no: 44) excited by 230 volts mains.

- The Heater Assembly protected by a 10 Ampere fuse (Part no 71) and a 20 Ampere toggle switch.

The electronics design began from the following connections:

- Three 5 Volt Single Channel SPST (Part no: 62) Relay powered by VCC through LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- Data Pins of 5 Volt Single Channel SPST (Part no: 62) Relay connected with Pins: 48, 49, 50 of Arduino Mega (Part no:26)
- Ground Pins of 5 Volt Single Channel SPST (Part no: 62) Relay connected with Ground pin of LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- Three MAX6675 Modules (Part no: 47) powered by VCC through LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- DO, CS, and SCK Pins of MAX6675 Modules (Part no: 47) connected with Pins: 34, 35, 36, 38, 39, 40, 42, 43 and 44 of Arduino Mega (Part no:26)
- Ground Pins of MAX6675 Modules (Part no: 47) connected with Ground pin of LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- K-Type Thermocouple (Part no: 46) connected with MAX6675 Modules (Part no: 47).

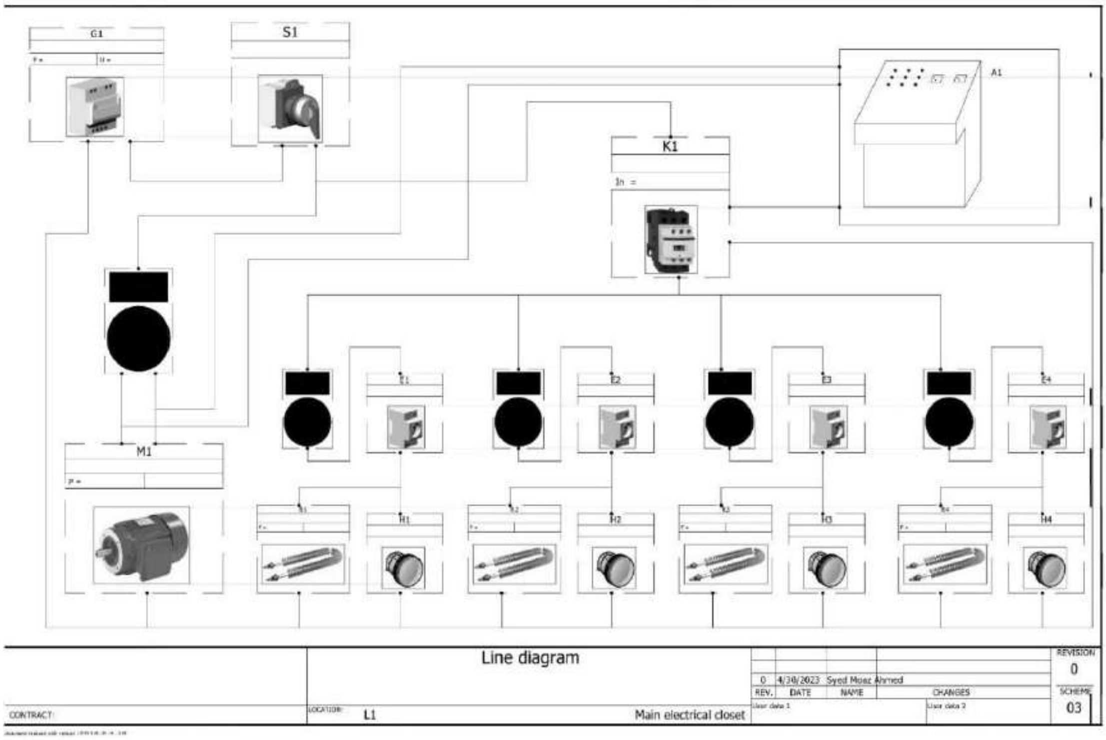

Figure 4.19: Electrical supply design for the heated press.

- Four HX711 modules (Part no: 34) powered by VCC through LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- DT and SCK Pins of HX711 modules (Part no: 34) connected with Pins: 24, 25, 26, 27, 28, 29, 30 and 31 of Arduino Mega (Part no:26)
- Ground Pins of HX711 modules (Part no: 34) connected with Ground pin of LM 2596 Module (Part no: 68) via Veroboard (Part no: 74).
- A+, A-, E+ and E- pins of HX711 modules (Part no: 34) connected in accordance with red, black and white wires of Half-bridge sensor (Part no: 33)
-

4.5.4 Coding for Arduino:

4.5.5 Arduino Code:

The code for Arduino is divided into three main parts. The first part deals with the 5 Volt Single Channel SPST (Part no: 62) Relays which are responsible for turning the Cartridge Heaters (Part No: 41) on and off, for turning the Motor (Part no: 28) on and off and for controlling the direction of motor. The second part targets the extraction of temperature readings from MAX6675 Modules (Part no: 47). The third part focuses on the extraction of load values from HX711 modules (Part no: 34). The code initially began from calling out the necessary libraries. Some of the libraries are HX711.h, SPI.h, Arduino.h and max 6675.h.

Next the necessary pin identification is done for the HX711 library provided by Bodge – An engineer at Arduino Forums.

```
/*
 Setup your scale and start the sketch WITHOUT a weight on the scale
 Once readings are displayed place the weight on the scale
 Press +/- or a/z to adjust the calibration_factor until the output
readings match the known weight
 Arduino pin 25 -> HX711 CLK
 Arduino pin 24 -> HX711 DOUT
 Arduino pin 5V -> HX711 VCC
 Arduino pin GND -> HX711 GND
*/
```

```
HX711 scale1(24 , 25);
HX711 scale2(26 , 27);
HX711 scale3(28 , 29);
HX711 scale4(30 , 31);
```

Now the delay times used at various instances in the code are declared. The delay are represented in milli secs in Arduino.

```
int D1 = 300;
int D2 = 500;
int D3 = 3000;
int D4 = 6000;
```

Next the total load at which the machine should press the HDPE into the Kevlar Layers is defined. Moreover, the temperature at which the process should be carried out is defined as target_temperature.

```
float load = 80000;
float target_temperature = 145;
```

Next the two statuses required for turning any of the 5 Volt Single Channel SPST (Part no: 62) Relay are declared.

```
char status_high = HIGH;
char status_low = LOW;
```

Next, a variable n is declared to rewrite the value of a particular variable back to zero.

```
int n = 0;
```

```
float C1;
float C2;
float C3;
float average_temperature;

float calibration_factor1 = (-46.98); // this calibration factor is
adjusted according to my load cell
float calibration_factor2 = (44.92);
float calibration_factor3 = (59.93);
float calibration_factor4 = (-37.62);

float units1;
float units2;
float units3;
float units4;
float ounces1;
float ounces2;
float ounces3;
float ounces4;
float load_measured;
```

Now all the necessary variables, required at the later stage of the code are declared in the global scope. The calibration factor is according to the sensor sensitivity and the point of placement of the sensor.

Now the Arduino pins connected with the 5 Volt Single Channel SPST (Part no: 62) Relay and MAX6675 Modules (Part no: 47) are defined.

```
int Coil_Pin = 50;
int Motor_Status_Pin = 49;
int Motor_Rotation_Direction_Pin = 48;


int  thermoDO1  =  34;
int  thermoCS1  =  35;
int thermoCLK1 = 36;

int  thermoDO2  =  38;
int  thermoCS2  =  39;
int thermoCLK2 = 40;

int  thermoDO3  =  42;
int  thermoCS3  =  43;
int thermoCLK3 = 44;
```

Now the variables containing the pin numbers for MAX6675 Modules (Part no: 47) are defined for the MAX6675 libraries.

```
MAX6675 thermocouple1(thermoCLK1, thermoCS1, thermoDO1);
MAX6675 thermocouple2(thermoCLK2, thermoCS2, thermoDO2);
MAX6675 thermocouple3(thermoCLK3, thermoCS3, thermoDO3);
```

```
void setup() {
  Serial.begin(9600);
  Serial.println("HX711 calibration sketch");
  Serial.println("Remove all weight from scale");
  Serial.println("After readings begin, place known weight on 
scale");
  Serial.println("Press + or a to increase calibration factor");
  Serial.println("Press - or z to decrease calibration factor");

  // Set RelayPin as an output pin
  pinMode(Coil_Pin, OUTPUT);
  digitalWrite(Coil_Pin, status_high);
  pinMode(Motor_Status_Pin, OUTPUT);
  //pinMode(Motor_Rotation_Direction_Pin,  OUTPUT);
```

Now the initial settings necessary for running the code are defined. It should be noted that anything written in the void setup () will execute only once throughout the running of the code. The commands such as pinMode and digitalwrite are used for changing the status of the relay coil defined on the first parameter inside the curly brackets.

The part of the code below is used to reset the values of the load sensor and calibrates them back to zero.

```
 scale1.set_scale();
  scale1.tare();  //Reset the scale to 0

  scale2.set_scale();
  scale2.tare();  //Reset the scale to 0

  scale3.set_scale();
  scale3.tare();  //Reset the scale to 0

  scale4.set_scale();
  scale4.tare();  //Reset the scale to 0
```

Next the variables for the four readings from HX711 modules (Part no: 34) are declared to get a baseline average reading. Later the values of the zero factor for each HX711 modules (Part no: 34) are printed below:

```
  long zero_factor1 = scale1.read_average(); //Get a baseline reading
  long zero_factor2 = scale2.read_average(); //Get a baseline reading
  long zero_factor3 = scale3.read_average(); //Get a baseline reading
  long zero_factor4 = scale4.read_average(); //Get a baseline
reading
  Serial.print("Zero factor1: "); //This can be used to remove the
need to tare the scale. Useful in permanent scale projects.
  Serial.println(zero_factor1);
  Serial.print("Zero factor2: "); //This can be used to remove the
need to tare the scale. Useful in permanent scale projects.
  Serial.println(zero_factor2);
  Serial.print("Zero factor3: "); //This can be used to remove the
need to tare the scale. Useful in permanent scale projects.
  Serial.println(zero_factor3);
  Serial.print("Zero factor4: "); //This can be used to remove the
need to tare the scale. Useful in permanent scale projects.
  Serial.println(zero_factor4);
}
```

This section of the code, written inside the void loop () is executed in a loop up to infinite number of times until and unless a break command is executed. The commands that are greyed were used to diagnose any problem with the code execution and troubleshoot it. These commented lines are not the part of the active code.

```
void loop() {

  /*// Let's turn on the relay...
  digitalWrite(Coil_Pin, status_high);
  delay(D1);

  // Let's turn off the relay...
  digitalWrite(Coil_Pin, status_low);
  delay(D1);


  // Let's turn on the relay...
  digitalWrite(Motor_Status_Pin, status_high);
  delay(D1);

  // Let's turn off the relay...
  digitalWrite(Motor_Status_Pin, status_low);
  delay(D1);


  // Let's turn on the relay...
  digitalWrite(Motor_Rotation_Direction_Pin, status_high);
  delay(D1);

  // Let's turn off the relay...
  digitalWrite(Motor_Rotation_Direction_Pin, status_low);
  delay(D1);*/


  // basic readout test, just print the current temp

  /*Serial.print("C1 = ");
  Serial.println(thermocouple1.readCelsius());*/
  /*Serial.print("F1 = ");
  Serial.println(thermocouple1.readFahrenheit());*/

  /*Serial.print("C2 = ");
  Serial.println(thermocouple2.readCelsius());*/
  /*Serial.print("F2 = ");
  Serial.println(thermocouple2.readFahrenheit());*/
```

```
 // For the MAX6675 to update, you must delay AT LEAST 250ms between
reads!
  delay(1000);

  Serial.print(millis()/1000);
  Serial.print(" ,");

  delay(D2);

  C1 =  thermocouple1.readCelsius();
  Serial.print(C1);
  Serial.print(" ,");

  delay(D2);

  C2 =  thermocouple2.readCelsius();
  Serial.print(C2);
  Serial.print(" ,");

  delay(D2);

  C3 =  thermocouple3.readCelsius();
  Serial.print(C3);
  Serial.print(" ,");

  average_temperature = (C1 + C2 + C3)/3;

  Serial.print(average_temperature);
  Serial.print(" ,");

  delay(D2);
ounces1 = units1 * 0.035274;

  scale2.set_scale(calibration_factor2); //Adjust to this calibration
factor

  //Serial.print("Reading: ");
  units2 = scale2.get_units(), 10;
  /*if (units2 < 0)
  {
    units2 = 0.00;
  }*/
  ounces2 = units2 * 0.035274;

  scale3.set_scale(calibration_factor3); //Adjust to this calibration
factor

  //Serial.print("Reading: ");
```

each sensor and the average temperature reading from K-Type Thermocouple (Part no: 46) and MAX6675 Modules (Part no: 47)., the following commands are executed.

To get the load readings from each HX711 modules (Part no: 34) and Half-bridge sensor (Part no: 33) and display the total load with individual sensor readngs, the following commands are executed.

```
  units3 = scale3.get_units(), 10;
  /*if (units3 < 0)
  {
    units3 = 0.00;
  }*/
  ounces3 = units3 * 0.035274;

  scale4.set_scale(calibration_factor4); //Adjust to this calibration
factor

  //Serial.print("Reading: ");
  units4 = scale4.get_units(), 10;
  /*if (units4 < 0)
  {
    units4 = 0.00;
  }*/
  ounces4 = units4 * 0.035274;


  Serial.print(units1);
  /*Serial.print(" kg");
  Serial.print(" calibration_factor1: ");
  Serial.print(calibration_factor1);
  Serial.println();*/
  delay(D2);

  if(Serial.available())
  {
    char temp = Serial.read();
    if(temp == '+' || temp == 'a')
      calibration_factor1 += 1;
    else if(temp == '-' || temp == 'z')
      calibration_factor1 -= 1;
  }
  Serial.print(" ,");
```

```
  Serial.print(units2);
  /*Serial.print(" kg");
  Serial.print(" calibration_factor2: ");
  Serial.print(calibration_factor2);
  Serial.println();*/
  delay(D2);

  if(Serial.available())
  {
    char temp = Serial.read();
    if(temp == '+' || temp == 'a')
      calibration_factor2 += 1;
    else if(temp == '-' || temp == 'z')
      calibration_factor2 -= 1;
  }
  Serial.print(" ,");

  Serial.print(units3);
  /*Serial.print(" kg");
  Serial.print(" calibration_factor3: ");
  Serial.print(calibration_factor3);
  Serial.println();*/
  delay(D2);

  if(Serial.available())
  {
    char temp = Serial.read();
    if(temp == '+' || temp == 'a')
      calibration_factor3 += 1;
    else if(temp == '-' || temp == 'z')
      calibration_factor3 -= 1;
  }

  Serial.print(" ,");
  Serial.print(units4);
  /*Serial.print(" kg");
  Serial.print(" calibration_factor4: ");
  Serial.print(calibration_factor4);
  Serial.println();*/
  delay(D2);
if(Serial.available())
  {
    char temp = Serial.read();
    if(temp == '+' || temp == 'a')
      calibration_factor4 += 1;
    else if(temp == '-' || temp == 'z')
      calibration_factor4 -= 1;
  }
```

```
  Serial.print(" ,");

  load_measured = units1 + units2 + units3 + units4;
  Serial.print(load_measured);
  Serial.println();
  delay(D2);
```

In this section of the code, Arduino checks the load and continues to take the readings until it reaches the load set. In the meanwhile, the motor continues to increase the load. Once the load is reached (i.e total_load >= 80,000 grams), the Arduino calls the motor function that simply turns the motor off and record the necessary readings.

```
 if ((abs(load_measured) < load) && (n<1))
  {
    motor();
    n = n + 1;
  }
```

Next the average temperature reading is checked, the Arduino turns the CHNT Magnetic contactor (Part no: 45) off, if the average temperature gets higher or equal to target temperature (i.e 145 ºC).

```
  if (abs(average_temperature) < target_temperature)
  {
    coil();
  }

}
```

The motor function declared inside the Arduino code, checks if the load is higher than the load declared and turns the Motor (Part no: 28) off.

```
void motor()
{
  if (abs(load_measured) < load)
  {
  // Let's turn on the relay...
  digitalWrite(Motor_Status_Pin, status_low);
```

```
  while (true)
  {
    units1 = scale1.get_units(), 10;
    units2 = scale2.get_units(), 10;
    units3 = scale3.get_units(), 10;
    units4 = scale4.get_units(), 10;
    load_measured = units1 + units2 + units3 + units4;
    Serial.print(abs(load_measured));
    Serial.println();
    if (abs(load_measured) > load)
    {
      digitalWrite(Motor_Status_Pin, status_high);
      break;
    }

  }
  }
  return;
}
```

The motor function declared inside the Arduino code, checks if the load is higher than the load declared and turns the CHNT Magnetic contactor (Part no: 45) off. The code

```
void coil()
{
  while (true)
    {
      if (average_temperature < target_temperature)
      {
        Serial.print(millis()/1000);
        Serial.print(" ,");

        C1 =  thermocouple1.readCelsius();
        Serial.print(C1);
        Serial.print(" ,");

        C2 =  thermocouple2.readCelsius();
        Serial.print(C2);
        Serial.print(" ,");

        C3 =  thermocouple3.readCelsius();
        Serial.print(C3);
        Serial.print(" ,");

        average_temperature = (C1 + C2 + C3)/3;
```

further displays the entire set of readings when and the CHNT Magnetic contactor (Part no: 45) is on as well as off.

```
        Serial.print(average_temperature);
        Serial.print(" ,");

        units1 = scale1.get_units(), 10;
        Serial.print(units1);
        Serial.print(" ,");

        units2 = scale2.get_units(), 10;
        Serial.print(units2);
        Serial.print(" ,");

        units3 = scale3.get_units(), 10;
        Serial.print(units3);
        Serial.print(" ,");

        units4 = scale4.get_units(), 10;
        Serial.print(units4);
        Serial.print(" ,");

        load_measured = units1 + units2 + units3 + units4;
        Serial.print(abs(load_measured));
        Serial.println();

        digitalWrite(Coil_Pin, status_high);
        delay(D4);
        digitalWrite(Coil_Pin, status_low);
        delay(D3);

      }
      else
      {
        break;
      }
    }
  return;
}
```

4.6. Testing the Machine:

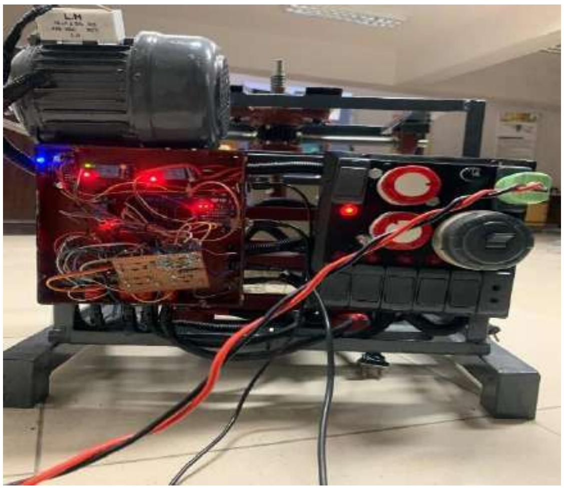

Figure 4.20: Heat press manual control panel view

Figure 4.21: Heat press manual temperature controller

Figure 4.23: Heat press operating and data recording via Arduino serial monitor

Figure 4.22: Heat press heating plates

4.7. Design of the plate:

A total of 3 samples were produced:

4.7.1 Sample 1:

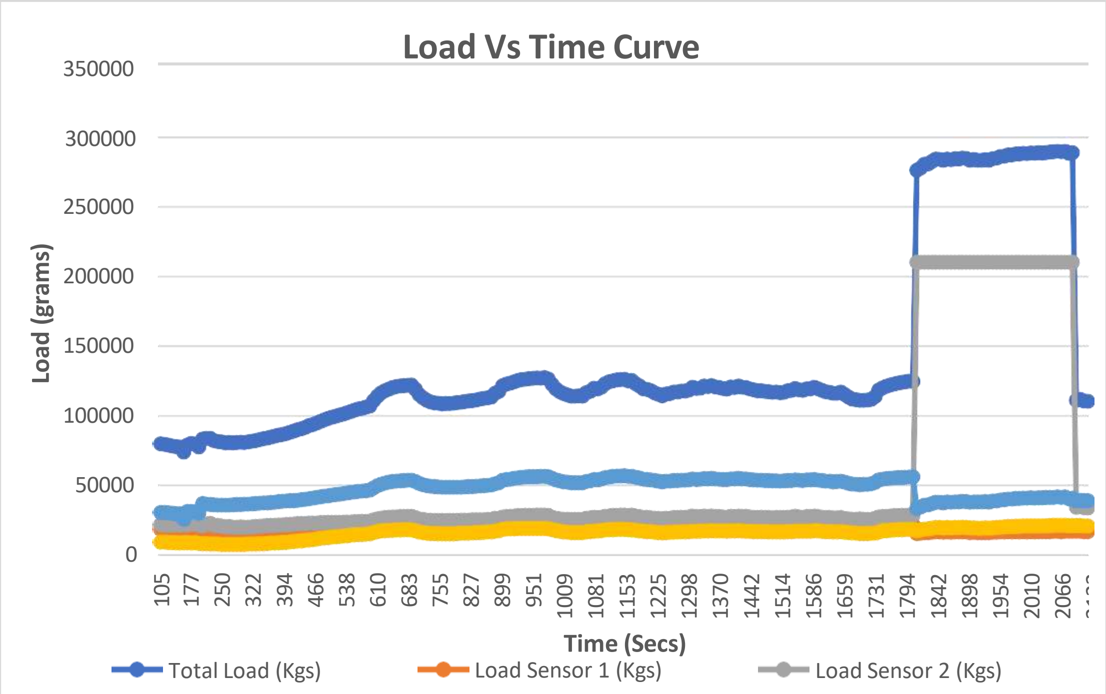

Figure 4.24: Load versus time plot for the first sample of plates produced

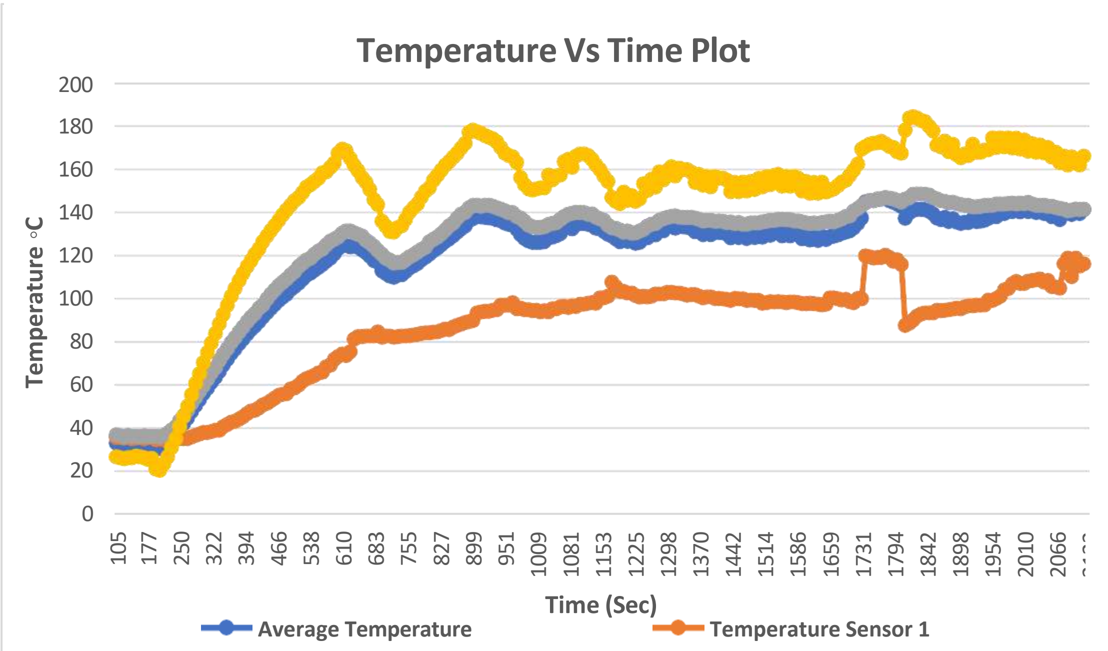

Figure 4.25: Temperature versus time plot for the first sample of plates produced

Figure 4.26: First sample of plates produced

4.7.2 Sample 2:

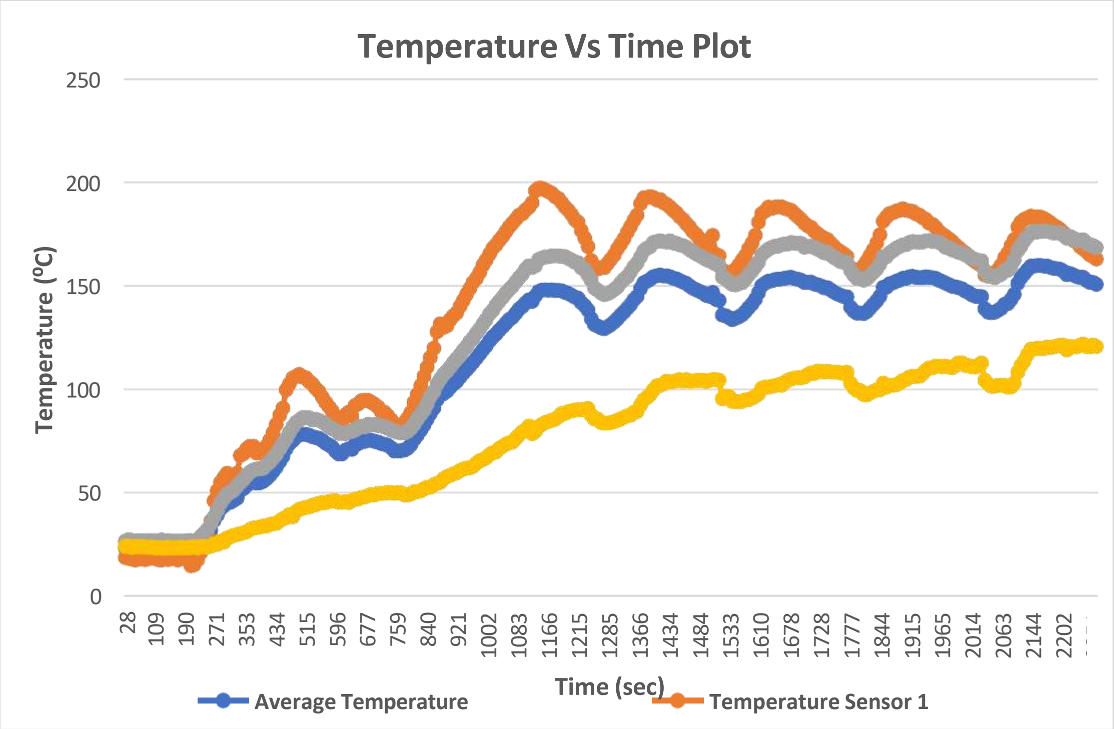

Figure 4.27: Temperature versus time plot for the second sample of plates produced

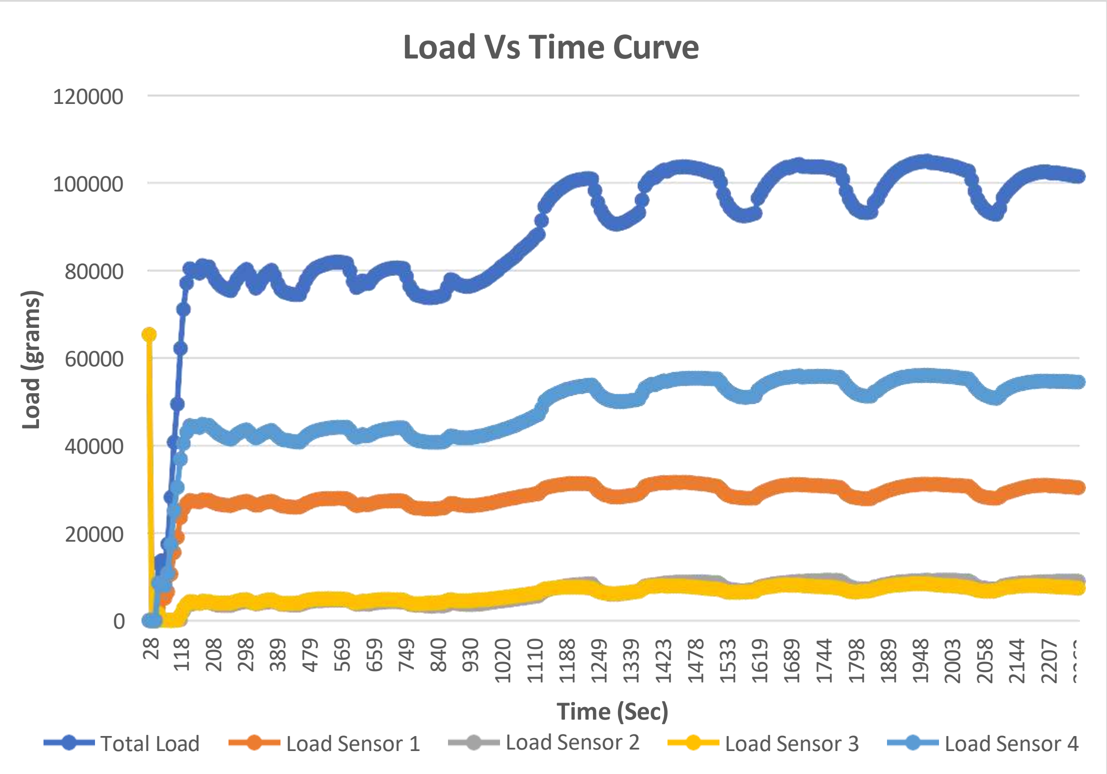

Figure 4.28: Load versus time plot for the first sample of plates produced

Figure 4.29: Second sample of plates produced

4.7.3 Sample 3:

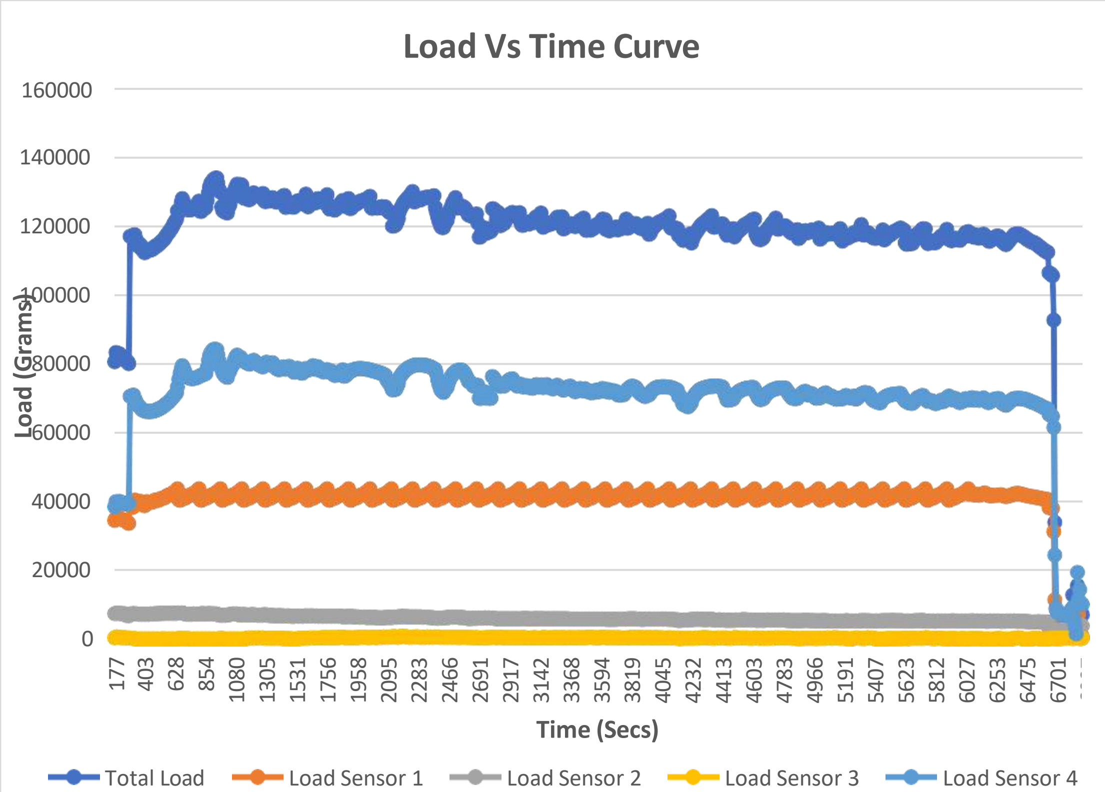

Figure 4.30: Load versus time plot for the third sample of plates produced

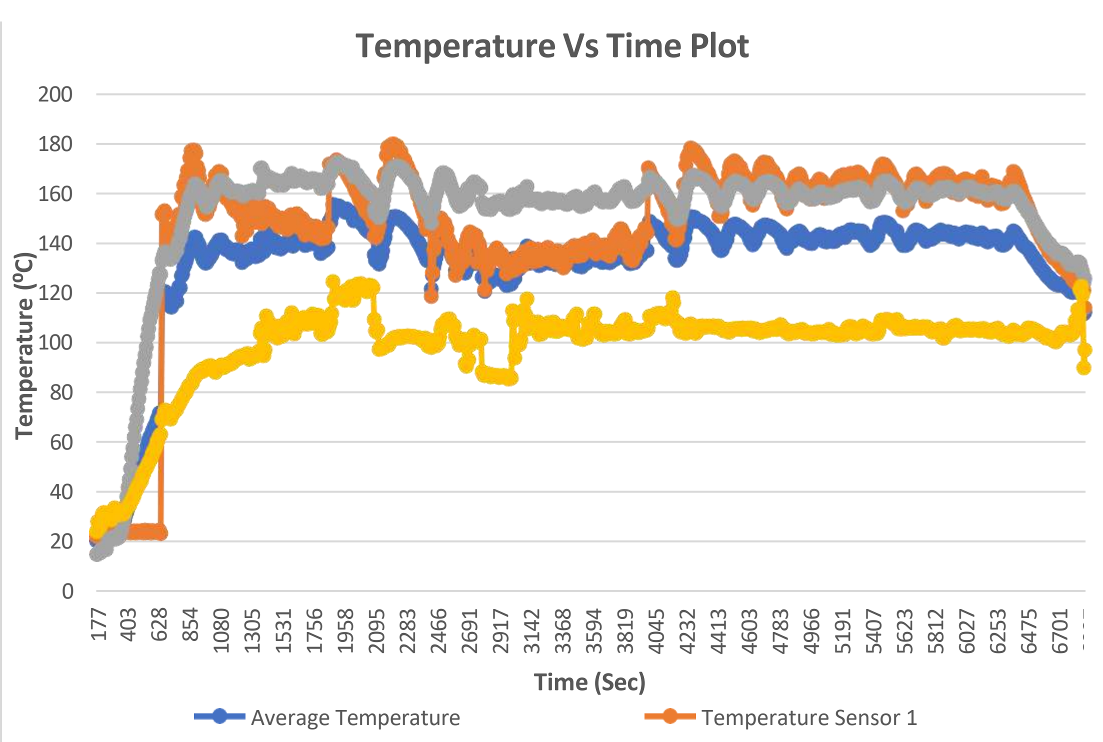

Figure 4.31: Temperature versus time plot for the third sample of plates produced

Figure 4.32: Third sample of plates produced

The project initiated with the collection of data for the components of the plate and heated press assembly. After the collection of sufficient data for the plate components and heater assembly, the plate and heated press were analyzed and modelled both theoretically and computationally. For the production of the ballistic plates, we used Kevlar (Specifications: 940 DeciTex / 846 Denier). Kevlar is an aramid fiber strongly known for its anti- bullet characteristics. We introduced the sheets of HDPE for the reinforcement of the sandwiched panel plate. The process was continued in a Heated Press.

After finding the results in agreement, the members initiated the prototyping phase that involved the manufacture of the heated press with rugged testing for the temperature and desired pressures. Later the plate was manufactured via the heated press in a controlled and specified manner to maintain the track of the molecular structures of the plate that defines the physical properties of materials. Finally, the plates were tested and the results were declared. In the end, conclusions, recommendations and justifications for the methodological approach were discussed.

Chapter 5: Results and Discussion

5.1. Heating Press:

Figure 5.1: Heat press heating plates

Figure 5.2: Heat press operating and data recording via Arduino serial monitor

Figure 5.3: Heat press manual temperature controller

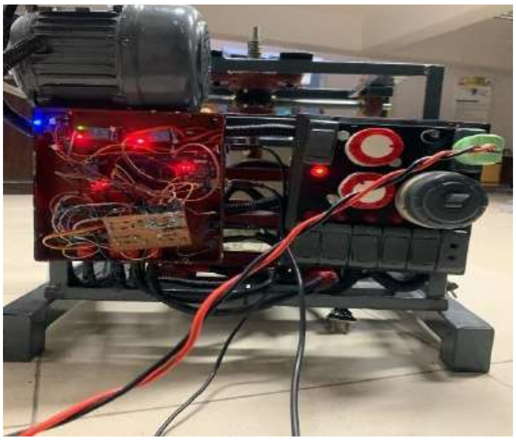

Figure 5.4: Heat press manual control panel view

5.2. Plate results:

Figure 5.5: Combined samples tested with a single fire. (Distance 15 ft / 9 mm round)

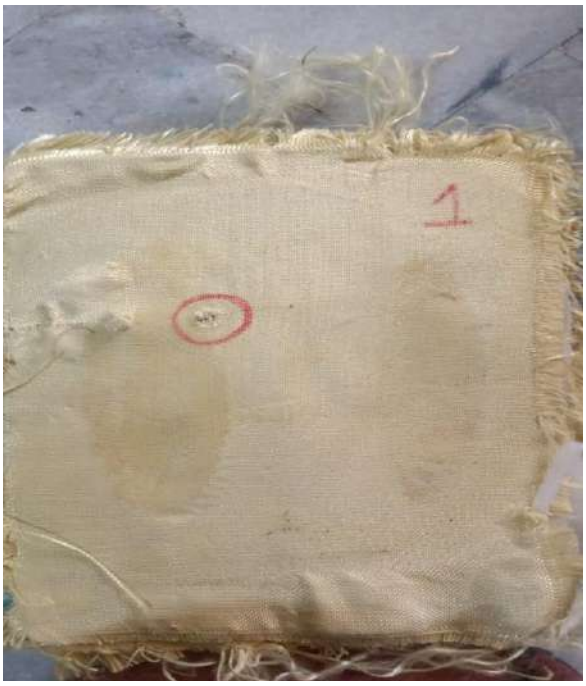

Figure 5.6: First sample tested with a single fire. (Distance 15 ft / 9 mm round)

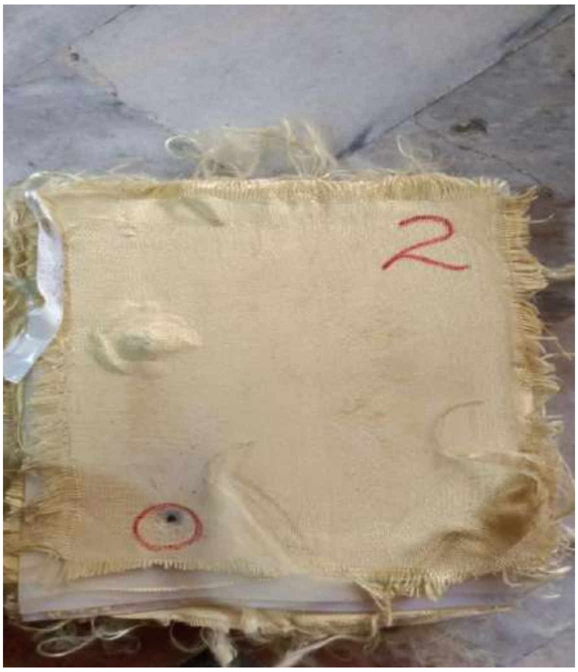

Figure 5.7: Second sample tested with a single fire. (Distance 15 ft / 9 mm round)

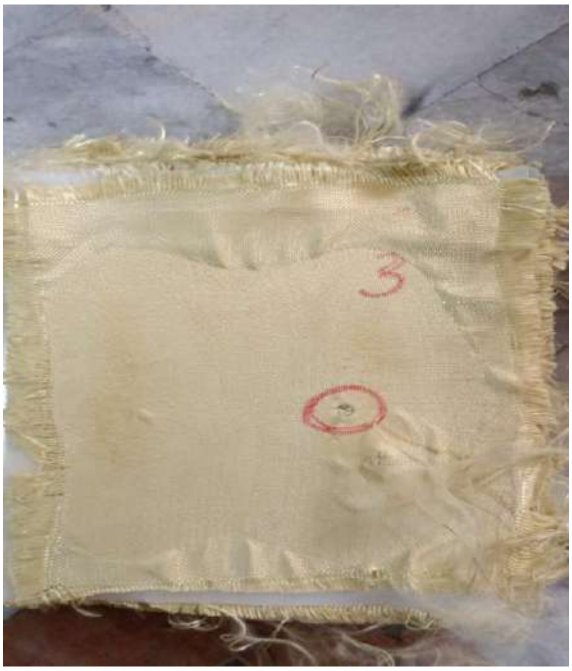

Figure 5.8: Third sample tested with a single fire. (Distance 15 ft / 9 mm round)

5.2.1. Stress localization:

Referring to figure 5.4, 5.5, 5.6 and 5.7, when a bullet or other high-velocity projectile strikes a bullet-proof material, the stress is often concentrated at the point of impact. This is referred to as stress localization. The material may become damaged or deformed as a result of this localized stress, which could result in the armor failing.

Body armor and vehicle armor are examples of bulletproof materials that are made to absorb and disperse the energy of a bullet or other projectile over a substantial surface area. Usually, many layers of durable yet flexible materials, such Kevlar, ceramic plates, or other composites, are used to achieve this.

It is crucial to properly develop and test armor materials to resist a range of probable impacts and stress concentrations to reduce the possibility of stress localization and assure successful bullet proofing. This may entail identifying possible weak points or areas of stress concentration using cutting-edge simulation tools or physical testing, and then altering the material or design to strengthen these places.

5.2.2. Localized Heating.

Referring to figure 5.4, 5.5, 5.6 and 5.7, when a bullet or other high-velocity projectile strikes a bulletproof material, heat is often concentrated in a particular spot or area of the material. This is known as localized heating. This might happen as a result of the high-speed projectile's compression and friction on the material, which causes localized heating.

The material may be harmed by the localized heating, which could impair its ballistic performance and compromise the protection it offers. Additional safety risks may result from the material melting or even burning as a result of this.

Bulletproof materials' composition and design can be optimized to reduce the possibility of localized heating. This can entail utilizing heat-dissipating materials with high thermal conductivity as well as adding cooling features like air vents or water channels into the material.

5.2.3. Poor Bonding.

Referring to figure 5.4, 5.5, 5.6 and 5.7, we believe that lack of adhesion between the layers of the panel causes poor bonding in sandwich panels made of HDPE and Kevlar, which might weaken or jeopardize the structure of the panel. Sandwich panels are composite materials made of a core material sandwiched between two exterior layers, or "skins." Kevlar often utilized as the outer shell and HDPE as the core material in sandwich panels made of Kevlar and HDPE.

The strength and stiffness of the panel may be reduced if the bonding between the Kevlar and HDPE layers is insufficient because the two layers may be unable to transfer load or stress adequately. As a result, the sandwich panel's protective qualities may be compromised in uses like body armor or ballistic shields.

Poor surface preparation, inappropriate adhesive selection or application, changes in material properties, and poor bonding in sandwich panels are only a few possible culprits. Carefully choosing and preparing the materials, as well as using the right adhesives and bonding techniques, are necessary to avoid improper bonding. To guarantee that the sandwich panels satisfy the necessary performance requirements and specifications, it is also crucial to conduct adequate testing.

If there has already been poor bonding, remedial action can be performed, such as re-bonding the layers using the proper adhesive techniques or redesigning the sandwich panel to enhance the connection between the layers.

5.2.4. Less number of layers.

Referring to figure 5.4, 5.5, 5.6 and 5.7, a sandwich panel's mechanical characteristics and performance can be significantly impacted by the number of layers in the panel. A sandwich panel typically consists of a core material sandwiched between two exterior skins, often known as face sheets. The number of layers in a sandwich panel refers to the total number of face sheets and core layers.

The sandwich panel may be less stiff and resistant to deformation under stress if it has fewer layers. This is because the majority of the panel's stiffness comes from the core material, and fewer layers mean there is less material to resist deformation.

A sandwich panel with fewer layers could also be weaker and less durable than a panel with more layers. This is due to the fact that the layers disperse the load and stress across a wider region, lowering the stress on individual layers and enhancing the panel's total strength.

Less layers in a sandwich panel, however, can potentially have some advantages. In applications where weight and production costs are critical factors, for instance, a panel with fewer layers may be lighter and more advantageous to make.

The ideal number of layers in a sandwich panel will ultimately be determined by the demands and limitations of the application, as well as by the materials and manufacturing processes employed to create the panel.

5.2.5. Low standard Kevlar.

Referring to figure 5.4, 5.5, 5.6 and 5.7, the linear density of fibers, usually in textiles, is expressed in deniers, a unit of measurement. A low denier value for anti-bullet Kevlar means that the fabric's individual Kevlar fibers are relatively thin or tiny.

Anti-bullet Kevlar may be more flexible and less weight due to the low denier count, but it may also be less durable and offer less ballistic protection. This is because a lower denier generally translates to thinner individual Kevlar fibers, which may have a lower tensile strength as well as a lesser capacity to absorb and distribute the energy from a projectile travelling at a fast speed.

Because they often offer greater levels of ballistic protection and better durability, anti-bullet Kevlar fabrics with higher denier counts are frequently favored for applications including body armor, ballistic helmets, and vehicle armor. A lower denier cloth might be preferred in some circumstances, though, because of things like weight, flexibility, or price.

The entire ballistic performance of anti-bullet Kevlar is dependent on a variety of elements more than just the denier count, including the weave pattern, thickness, and general fabric quality. To make sure the fabric satisfies the necessary performance standards and effectively protects against high-speed bullets, proper testing and evaluation are essential.

5.2.6. Use of HDPE instead of an energy absorbing material.

Referring to figure 5.4, 5.5, 5.6 and 5.7, it was realized that particularly in applications where it is subjected to impact or dynamic loading, high-density polyethylene (HDPE) is renowned for its good energy absorption properties. Due of its great toughness and ductility, HDPE has the ability to absorb strain energy.

Being viscoelastic, HDPE is a thermoplastic polymer that can bend under stress and release energy through internal friction and heat generation. HDPE can absorb a substantial amount of energy through plastic deformation under impact or dynamic loading without breaking or cracking.

Along with its viscoelastic properties, HDPE also has a low elastic modulus, which enables it to bend more easily under load than harder materials like metals. This makes it a good material for applications like automotive crash structures, safety barriers, and protective gear where impact or shock loads is anticipated.

By adjusting the material's qualities by the application of additives, reinforcement, or altering the production process, HDPE's strain energy absorbing properties can be further improved. For instance, adding rubber particles to HDPE can improve its toughness and ductility, while fiber reinforcement can improve its strength and stiffness without significantly affecting its capacity to absorb energy.

Overall, HDPE is a versatile and strong material for absorbing impact and shock loading in a number of applications thanks to its strain energy absorbing capabilities. In composite sandwich panels for ballistic protection, such as those used in body armor and vehicle armor, it is widely utilized as a core material.

Chapter 6: Conclusions and Recommendations

6.1. Conclusions:

To guarantee that a ballistic protection plate operates best and does not break when struck by a high-velocity projectile, localised stresses must be reduced. To lessen localised stresses in a ballistic plate, try the following methods:

- Curved Plate Design: By distributing the impact force over a greater surface area, a curved plate design can help to alleviate localised stresses. This reduces the amount of tension that builds up in any one spot of the plate.

- Design of the Tapered Edge: A tapered edge can help to lessen the amount of stress concentrated at the plate's edge, which is where the majority of failures take place. The stress concentration is lessened by narrowing the edge, which decreases the likelihood that the plate will break.

- Material Selection: The ballistic protective plate's choice of material can also help to lessen localized stresses. The energy of a projectile impact is better absorbed and dissipated by materials that are more ductile and can deform without splitting or shattering.

- Design with Multiple Layers: A design with multiple layers, each of which has unique features, can also aid in reducing localized pressures. It is possible to build the layers so that they absorb and disperse the impact energy in a way that minimizes the concentration of stress in any one layer.

- Stress Analysis: A thorough stress analysis of the plate design can reveal regions with a high concentration of stresses and aid in their modification. A typical technique for simulating and analysing stress in ballistic protection plates is finite element analysis (FEA).

These techniques can be used to lessen localized stresses and enhance the effectiveness of a ballistic protective plate. The plate design must be optimized for the particular use and adhere to the necessary safety regulations.

A bulletproof plate's performance and integrity must be maintained by reducing localized heating. The level of protection provided by the plate may be reduced by excessive localized heating, which can result in material degradation, weakness, or even failure. The following techniques can help to lessen localized heating in bulletproof plates:

- Material Selection: The bulletproof plate's choice of material can have a big impact on how much localized heating occurs. High thermal conductivity materials, such metals, composites, and ceramics, can swiftly dissipate heat and lessen localized heating.
- A bulletproof plate's performance and integrity must be maintained by reducing localized heating. The level of protection provided by the plate may be reduced by excessive localized heating, which can result in material degradation, weakness, or even failure. The following techniques can help to lessen localized heating in bulletproof plates:
- Material Selection: The bulletproof plate's choice of material can have a big impact on how much localized heating occurs. High thermal conductivity materials, such metals, composites, and ceramics, can swiftly dissipate heat and lessen localized heating.
-

6.2. Recommendations for Further Work

Kevlar® sandwich panels can provide outstanding ballistic and impact protection while still being lightweight. The following techniques can be used to improve the performance of sandwich panels constructed of Kevlar® fibres:

- Core Material: The sandwich panel's performance may be significantly impacted by the choice of core material. While keeping the weight low, materials like foam, honeycomb, or balsa wood can give rigidity and strength.

- One must improve the orientation of the fibres to mimic the isotropic behaviour of the Plate. The Performance may also be impacted by the orientation of the Kevlar® fibres in the panel. In contrast to multidirectional fibre orientation, which can offer strength in all directions, unidirectional fibre orientation can only offer strength in one direction.
- The strength and stiffness of the panel can be increased by increasing the fibre volume fraction. Higher load-carrying ability and impact resistance will come from a higher volume fraction of Kevlar® fibres.
- The resin used to bind the layers together can also influence the performance of the panel. Polyester resins may be more flexible, whereas epoxy resins provide excellent bonding strength.
- The panel design might influence performance as well. A panel that is thicker can withstand impacts better, while a panel with tapered edges will have less stress buildup and won't delaminate.

Chapter 7: Appendix

7.1 Sample 1:

Table 7.1: Data recorded for first sample of plates produced

Time (Sec)	Temperature Sensor 1 (ºC)	Temperature Sensor 2 (ºC)	Temperature Sensor 3 (ºC)	Total Temperature (ºC)	Load Sensor 1 (grams)	Load Sensor 2 (grams)	Load Sensor 3 (grams)	Load Sensor 4 (grams)	Total Load (grams)
105	35.75	37	26.75	33.17	-18303.08	-21800.25	-9263.21	-30639.52	80006.06
114	35.75	36.5	26.25	32.83	-18139.85	-21619.83	-9123.06	-30584.67	79467.42
123	35.5	36	25.75	32.42	-18072.62	-21576.24	-9039.47	-30355.45	79043.78
132	35.75	36.75	26.25	32.92	-17952.87	-21500.75	-8877.49	-30029.82	78360.92
141	35.25	36.25	26.25	32.58	-17880.38	-21650.55	-8672.66	-29695.29	77898.88
150	35.5	36.25	27	32.92	-17791.53	-21695.1	-8501.69	-29586.43	77574.75
159	36	36	26.75	32.92	-17783.71	-21762.82	-8610.45	-25733.63	73890.61
168	35.25	36.5	26.25	32.67	-17639.16	-21509.47	-8619.57	-31201.16	78969.36
177	35.75	36.25	25.5	32.5	-17802.76	-22510.76	-8555	-31245.34	80113.87
186	35.75	36.25	26	32.67	-17770.69	-22310.81	-8630.91	-31045.94	79758.35
195	34.75	36.25	21	30.67	-17491.01	-21876.37	-8252.39	-29983.43	77603.19
204	35	36	20.5	30.5	-17394.18	-20947.17	-8103.88	-37066.54	83511.78
213	34.75	36.75	23.5	31.67	-17190.36	-22184.47	-7909.83	-36556.19	83840.86
222	34.25	37.75	26.75	32.92	-17063.34	-22721.15	-7848.85	-36230.93	83864.27
231	35.5	39.25	31	35.25	-17028.76	-21323.51	-7781.48	-36020.03	82153.78
240	35	40.75	35	36.92	-16948.12	-21160.69	-7683.64	-35855.82	81648.27
250	35.25	43.5	40.75	39.83	-16939.37	-20893.29	-7665.06	-35848.81	81346.53
259	35.25	45.75	45.25	42.08	-16917.73	-20203.7	-7638.87	-35931.6	80691.89
268	35.25	48.5	50.25	44.67	-16918.16	-20451.69	-7635.36	-35945.27	80950.49
277	36	51.5	55.5	47.67	-16913.41	-19991.23	-7633.38	-36067.58	80605.6
286	36.75	54.25	60.75	50.58	-16931.9	-20016.15	-7652.65	-36230.11	80830.82
295	37.25	57	65.25	53.17	-16912.26	-20231.68	-7620.98	-36343.14	81108.07
304	38	59.75	70.5	56.08	-16925.41	-19959.17	-7630.2	-36460.82	80975.6
313	38	62.75	75	58.58	-16974.06	-20034.42	-7698.96	-36594.55	81301.99
322	38.5	65.75	79.5	61.25	-17009.41	-20316.87	-7732.96	-36764.98	81824.23
331	39	68	84	63.67	-17060.01	-20415.83	-7818.42	-36967.9	82262.16
340	39	71.5	88.5	66.33	-17162.48	-20671.52	-7947.47	-37181.92	82963.39
349	40.75	74.25	92.75	69.25	-17274.7	-20879.4	-8132.13	-37330.61	83616.85
358	41.75	77	97	71.92	-17364.11	-21033.75	-8276.06	-37477.69	84151.6
367	42.75	79.75	101.25	74.58	-17437.3	-21265.73	-8414.96	-37707.62	84825.62
376	43.25	82	104.75	76.67	-17518.29	-21392.07	-8535.25	-38006.31	85451.92
385	44.25	84.75	108.5	79.17	-17627.85	-21477.31	-8676.65	-38303.49	86085.31
394	45.25	87	111.75	81.33	-17674.84	-21536.31	-8827.23	-38603.69	86642.07
403	46.75	89.5	115	83.75	-17761.94	-21787.62	-9038.27	-38763.77	87351.6
412	48	91.5	117.75	85.75	-17930.37	-22074.28	-9324.25	-39015.75	88344.64
421	48.25	93.25	120.75	87.42	-18067.63	-22351.44	-9567.98	-39161.19	89148.25
430	49.5	95.75	123.25	89.5	-18203.68	-22587.75	-9804.15	-39392.5	89988.08
439	50.75	97.25	126.5	91.5	-18380.55	-22584.25	-10147.61	-39749.03	90861.44
448	51.5	100	129.25	93.58	-18593.26	-22585.34	-10505.14	-40067.08	91750.83

457	52.75	102.25	131.75	95.58	-18816.95	-22857.85	-10852.14	-40496.01	93022.96
466	54	104.25	134	97.42	-18922.28	-22857.48	-11093.43	-40786.85	93660.03
475	55.25	106.25	136.5	99.33	-19117.47	-22919.11	-11497.61	-41255.52	94789.71
484	55.75	107.75	139	100.83	-19297.19	-23138.59	-11817.12	-41740.56	95993.47
493	56	109.25	141.25	102.17	-19492.78	-23297.89	-12155.42	-42167.36	97113.45
502	58.25	111.25	143.5	104.33	-19635.79	-23487.62	-12486.63	-42557.33	98167.37
511	58.75	112.75	145.5	105.67	-19773.61	-23483.75	-12784.4	-42942.27	98984.03
520	60	115	147	107.33	-19905.17	-23451.24	-13050.47	-43373.33	99780.21
529	61.75	116.5	149.25	109.17	-20015.89	-23484.44	-13315.17	-43742.79	100558.3
538	63	118	151.75	110.92	-20143.74	-23580.96	-13459.77	-44149.23	101333.71
547	63.75	119	153	111.92	-20279.11	-23688.54	-13717.75	-44587.39	102272.81
556	64.5	120.75	154.5	113.25	-20378	-23692.54	-14124.15	-45001.14	103195.83
565	65.75	122.25	156	114.67	-20605.61	-23852.86	-14412.89	-45325.6	104196.96
574	66	123.25	158.5	115.92	-20711.01	-23954.7	-14629.15	-45610.13	104904.99
583	68.5	125	159	117.5	-20751.03	-24017.52	-14780.1	-45930.68	105479.35
592	69.25	126.75	161	119	-20867.5	-24203.98	-14976.42	-46282.39	106330.28
601	72	127.75	163	120.92	-20952.11	-24413.12	-15167.27	-46623.33	107155.83
610	73.25	128.75	167.5	123.17	-21473.43	-25318.34	-15962.16	-48191.06	110944.99
620	74.5	130.5	169.5	124.83	-21801.77	-25976.86	-16658.62	-49746.83	114184.08
629	73.75	131.5	168.75	124.67	-22035.49	-26420.03	-17141.66	-50849.97	116447.16
638	75.5	131.5	165.25	124.08	-22231.24	-26754.92	-17456.87	-51673.18	118116.21
647	81.25	130.75	162	124.67	-22371.91	-27011.93	-17666.68	-52295.49	119346.01
656	82.5	130	159.5	124	-22470.78	-27291.3	-17779.1	-52769.98	120311.16
665	82.5	129.25	156.25	122.67	-22554.66	-27417.62	-17939.27	-53106.81	121018.36
674	82.75	127.25	154.25	121.42	-22588.02	-27595.9	-18009.28	-53358.44	121551.65
683	82.75	126	150.75	119.83	-22615.02	-27633.72	-18030.67	-53553.37	121832.78
692	82.75	124.5	146	117.75	-22644.92	-27742.72	-18044.45	-53676.77	122108.86
701	84.75	122.5	143.75	117	-22619.78	-27814.54	-18005.02	-53728.06	122167.39
710	82.25	120.75	136	113	-22126.31	-26969.41	-17468.01	-52728.8	119292.53
719	82.75	119	133.75	111.83	-21450.39	-25897.91	-16629.42	-51386.2	115363.93
728	82.75	118	131.25	110.67	-21031.27	-25465.36	-16015.92	-50488.58	113001.14
737	82.25	116.75	131	110	-20656.94	-25090.06	-15641.07	-49860.25	111248.32
746	82.5	117	133	110.83	-20439.47	-24937.03	-15359.35	-49382.39	110118.24
755	82.75	117	134	111.25	-20315.02	-24759.09	-15292.16	-49065.05	109431.33
764	82.75	118.25	137	112.67	-20269.27	-24706.66	-15247.03	-48840.93	109063.89
773	83	119.5	140.25	114.25	-20225.09	-24690.46	-15039.74	-48726.1	108681.39
782	83.25	120.5	142.25	115.33	-20255.5	-24623.21	-15166.65	-48772.16	108817.52
791	83.5	121.75	144	116.42	-20307.78	-24686.53	-15223.29	-48749.1	108966.71
800	84	123	147.25	118.08	-20394.57	-24849.25	-15110.6	-48724.69	109079.11
809	84.25	124	150	119.42	-20472.72	-24850.67	-15487.47	-48807.33	109618.19
818	84.25	126.5	151.5	120.75	-20543.2	-24950.32	-15545.55	-48803.29	109842.38
827	84.5	127.75	155	122.42	-20645.91	-25116.75	-15609.48	-48962.41	110334.54
836	84.75	128.75	157.25	123.58	-20708.82	-25142.67	-15703.04	-49094.38	110648.91
845	85.25	130.25	159.75	125.08	-20779.6	-25145.8	-15871.18	-49232.91	111029.49
854	86	132	162	126.67	-20861.38	-25235.83	-16013.31	-49393.36	111503.89
863	85.75	134	163.75	127.83	-20914.43	-25329.47	-16121.41	-49656.44	112021.75
872	87	135.25	165.75	129.33	-21014.5	-25368.64	-16289.86	-49874.86	112547.86

881	87.75	137.5	167.5	130.92	-21091.48	-25485.29	-16433.09	-50084.15	113094
890	88.25	139.25	170	132.5	-21121.43	-25562.33	-16577.26	-50217.31	113478.33
899	89	140.25	172.25	133.83	-21532.68	-26299.03	-17081.09	-51302.33	116215.14
908	89.5	142.25	177.25	136.33	-21702.07	-26487.3	-17458.83	-51952.3	117600.5
918	90	143.25	178.25	137.17	-22360.17	-27405.52	-18414.88	-53647.79	-121828.36
924	93.5	143.5	177.5	138.17	-22514.03	-27572.02	-18673.78	-54132.83	-122892.66
929	94	143	176.75	137.92	-22612.21	-27839.07	-18720.17	-54526.1	-123697.55
935	94.25	143.5	175.75	137.83	-22721.15	-27994.38	-18907.81	-55032.96	-124656.3
940	94.25	143.5	175	137.58	-22797.57	-28160.11	-19029.21	-55440.69	-125427.58
946	94.75	143	174.25	137.33	-22873.92	-28355.59	-19096.59	-55810.03	-126136.13
951	95	142.25	172.75	136.67	-22893.35	-28455.14	-19076.84	-55995.32	-126420.66
957	97	141.75	170.25	136.33	-22961.73	-28524.48	-19142.49	-56191.85	-126820.54
962	97	141	167.5	135.17	-22972.95	-28583.65	-19140.1	-56313.99	-127010.69
968	97	140	166.5	134.5	-23030.58	-28659.74	-19115.95	-56389.42	-127195.71
972	98.25	140	166	134.75	-23039.43	-28628.73	-19099.76	-56408.96	127176.89
982	95.5	138.25	163.25	132.33	-23178.04	-28610.44	-19045.28	-56615.2	127448.96
991	95.75	137.5	156.25	129.83	-22963.08	-28486.53	-18784.39	-56380.23	126614.24
1000	95	136	153	128	-22293.35	-27109.34	-18157.71	-55089.05	122649.46
1009	95	134.25	151	126.75	-21701.75	-26310.34	-17434.89	-53999.9	119446.88
1018	94.5	133.5	150.5	126.17	-21260.95	-25920.25	-16908.5	-53232.37	117322.07
1027	94.75	133	151	126.25	-21008.63	-25656.56	-16581.09	-52684.15	115930.43
1036	94	133.25	151.5	126.25	-20809.17	-25621.62	-16341.93	-52302.62	115075.35
1045	94.5	133.5	151.5	126.5	-20678.97	-25511.23	-16148.1	-51978.1	114316.41
1054	94	134.5	157.5	128.67	-20616.64	-25508.57	-16110	-51882.54	114117.75
1063	95.5	135	155.25	128.58	-20686.33	-25562.03	-16133.27	-51945.81	114327.44
1072	95.5	135.5	157	129.33	-20591.51	-25526.44	-16151.05	-51901.33	114170.35
1081	96.25	137	157.5	130.25	-20959.32	-26477.56	-16500.29	-52905.64	116842.82
1090	96.5	138.25	163.75	132.83	-21150.13	-26573.86	-16719.6	-53185.01	117628.6
1099	96	139.25	164.75	133.33	-21467.88	-27203.8	-17085.02	-54204.55	119961.26
1108	96.75	139.75	161	132.5	-21481.02	-26677.14	-17303.93	-54048.16	119510.25
1117	96.5	140.25	166.25	134.33	-21644.85	-27002.11	-17520.66	-54582.32	120749.94
1126	97.5	140	167.25	134.92	-21931.99	-27754.97	-17888.04	-55489.52	123064.52
1135	97.5	140	167.25	134.92	-22153.66	-28099.2	-18125.01	-56120.75	124498.62
1144	98	139.25	166.5	134.58	-22239.94	-28410.19	-18148.96	-56455.52	125254.61
1153	98.25	139.5	164.75	134.17	-22365.2	-28584.05	-18311.38	-56654.26	125914.89
1162	98	138	162.25	132.75	-22374.27	-28653.18	-18327.18	-56749.67	126104.3
1171	100.5	137.25	160	132.58	-22388.4	-28735.44	-18326.49	-56881.35	126331.67
1180	100.5	136.5	157	131.33	-22213.51	-28498.48	-18034.66	-56474.96	125221.62
1189	101.25	134.25	154.5	130	-22169.15	-28776.64	-17871.78	-56615.92	125433.49
1198	107.75	133	147	129.25	-21756.68	-28067.15	-17618.65	-55775.66	123218.13
1207	105.75	132.75	145.25	127.92	-21438.69	-27648.78	-17290.12	-55280.19	121657.78
1216	103.5	132	144.25	126.58	-21103.92	-26945.9	-17051.97	-54472.24	119574.03
1225	103.5	131	149.5	128	-20987.2	-27020.55	-16789.32	-54254.92	119052
1234	102.75	131.5	145.75	126.67	-20841.5	-26654.65	-16661.1	-54043.41	118200.66
1243	102.75	130.5	148	127.08	-20522.63	-26353.63	-16269.96	-53465.03	116611.25
1252	101.5	130.75	145.25	125.83	-20335.65	-26141.13	-16098.67	-53086.87	115662.32
1261	100.75	131.5	146.5	126.25	-20070.74	-25941.4	-15934.37	-52571.54	114518.06
1270	101.25	132.25	153.5	129	-20228.57	-26424.8	-16085.69	-52968.69	115707.75

1279	101	133.75	150.25	128.33	-20341.29	-26479.13	-16287.89	-53024.49	116132.8
1288	101.25	134.75	155.5	130.5	-20448.03	-26805.59	-16386.76	-53450.22	117090.6
1298	102.25	135	151.75	129.67	-20428.16	-26863.39	-16444.29	-53466.09	117201.94
1307	102.25	136.5	159	132.58	-20529.47	-27067.67	-16580.53	-53787.07	117964.73
1316	102.25	137.25	155.25	131.58	-20561.38	-27063.89	-16620.14	-53707.4	117952.82
1325	103	137.75	159.5	133.42	-20650.46	-27271.4	-16682.15	-53916.91	118520.92
1334	103	138.25	161.25	134.17	-21020.8	-27981.61	-16997.01	-54665.92	120665.35
1343	102.75	138.5	157	132.75	-20923.39	-27481.66	-17020.32	-54308.49	119733.86
1352	102.75	138	160.75	133.83	-20951.66	-27496.5	-17068.42	-54394.53	119911.1
1361	102.25	137.75	160	133.33	-21246.76	-28128.6	-17264.04	-54960.69	121600.1
1370	101.75	137.75	160	133.17	-21192.86	-27777.61	-17306.23	-54789.37	121066.08
1379	102	137.75	158.75	132.83	-21302.57	-28046.57	-17364.43	-55080.95	121794.53
1388	102	137.5	154	131.17	-21184.77	-27645.67	-17303.85	-54657.4	120791.69
1397	101.25	137	157.75	132	-21085.69	-27452.96	-17273.71	-54500.49	120312.85
1406	100.5	136.25	152.75	129.83	-21012.71	-27312.35	-17144.69	-54236.18	119705.94
1415	101	136.5	156.75	131.42	-20916.72	-27178.16	-17094.52	-54172.63	119362.03
1424	101	136.5	152	129.83	-21168.07	-27688.69	-17269.86	-54649.92	120776.55
1433	100.25	136	156.75	131	-21073.97	-27559.05	-17238.4	-54570.97	120442.39
1442	100.25	136.25	156	130.83	-21281.65	-27939.29	-17350.37	-55049.6	121620.92
1451	100	136	156	130.67	-21106.1	-27677.21	-17149.29	-54671	120603.6
1460	99.75	135.5	155	130.08	-21057.23	-27674.16	-17012.98	-54594.42	120338.8
1469	99.25	135.75	149.75	128.25	-20898.85	-27378.75	-16919.51	-54215.33	119412.44
1478	100.25	135	154	129.75	-20796.88	-27183.9	-16829.94	-53995.51	118806.23
1487	100	135.5	149.75	128.42	-20683.21	-26975.17	-16756.07	-53749.06	118163.52
1496	100	134.75	154.25	129.67	-20632.99	-26988.3	-16680.48	-53717.58	118019.35
1505	99.25	134.75	150	128	-20559.84	-26820.68	-16693.58	-53529.32	117603.41
1514	99.5	135.25	154.5	129.75	-20544.89	-26851.42	-16570.55	-53461.39	117428.25
1523	99.25	135.25	150.75	128.42	-20518.81	-26706.74	-16551.41	-53199.48	116976.44
1532	99.25	135.25	155.75	130.08	-20492.9	-26834.15	-16566.93	-53260.35	117154.32
1541	98	135.75	152	128.58	-20461.47	-26800.1	-16497.71	-53028.92	116788.21
1550	98.25	136	156.75	130.33	-20466.38	-26830.24	-16527.05	-53214.16	117037.85
1559	98.75	136.5	153	129.42	-20663.85	-27107.65	-16794.03	-53531.17	118096.71
1568	98.5	136.5	157.25	130.75	-20719.6	-27226.64	-16789.49	-53559.66	118295.39
1577	98.75	137	157.75	131.17	-20985.62	-27674.28	-17047.32	-53971.87	119679.09
1586	98.5	137	152.25	129.25	-20863.54	-27314.36	-17044.91	-53660.52	118883.33
1595	98.25	136.75	156.75	130.58	-20729.12	-27165.46	-16995.75	-53536.38	118426.71
1604	98.5	136.75	152.25	129.17	-20919.21	-27504.94	-17091.66	-53917.43	119433.24
1614	98.5	136.25	156.75	130.5	-20913.81	-27509.07	-17058.64	-53958.37	119439.88
1623	98.25	136.25	156	130.17	-21143.43	-27904.57	-17346.48	-54321.67	120716.14
1632	97.75	135.75	150	127.83	-20940.68	-27533.33	-17101.51	-53866.66	119442.18
1641	97.75	135.25	154.5	129.17	-20743.58	-27181.21	-16872.14	-53531.82	118328.75
1650	98	135	149	127.33	-20601.25	-26919.73	-16727.49	-53095.19	117343.67
1659	97.75	135.25	154	129	-20491.13	-26779.2	-16742.16	-52958.17	116970.67
1668	97.5	135	149	127.17	-20377.22	-26589.56	-16627.15	-52660.75	116254.67
1677	97.25	135.5	154.25	129	-20348.01	-26654.15	-16499.69	-52821.76	116323.62
1686	97.5	135.75	149.5	127.58	-20568.1	-26819.83	-16652.16	-53086.42	117126.52
1695	100.5	136	150.25	128.92	-20283.42	-26289.71	-16409.36	-52351.61	115334.1

1704	100.5	135.75	151	129.08	-19982.27	-25935.56	-16093.38	-51565.28	113576.49
1713	100	136.5	152.5	129.67	-19742.82	-25784.25	-15770.64	-50943.11	112240.82
1722	99.5	137.25	154.25	130.33	-19592.08	-25822.04	-15518.06	-50710.65	111642.84
1731	99.75	138.25	155	131	-19555.69	-25912.33	-15273.95	-50508.76	111250.74
1740	98.75	138.5	157.25	131.5	-19510.32	-25639.86	-15415.69	-50685.68	111251.55
1749	98.25	140.75	159.75	132.92	-19545.34	-25541.95	-15446.45	-50847.17	111380.91
1758	100.25	142	162.5	134.92	-19546.83	-25593.41	-15530.43	-51188.26	111858.94
1767	100	143.25	169.5	137.58	-19937.42	-26506.41	-15508.93	-52103.44	114056.2
1777	120	144.5	170.75	145.08	-20747.87	-27289.09	-16598.98	-53960.89	-118596.83
1783	119.5	145.5	171.75	145.58	-21035.65	-27546.75	-17105.55	-54496.33	-120184.27
1788	119	145.5	172.25	145.58	-21246.92	-27781.24	-17488.12	-54798.44	-121314.72
1794	119.25	146.5	172.5	146.08	-21410.52	-27980.96	-17744.48	-55087.89	-122223.86
1799	119.25	146.5	173	146.25	-21557.25	-28187.92	-17900.31	-55358.91	-123004.4
1805	120.25	147	172	146.42	-21684.98	-28318.76	-18076.79	-55581.8	-123662.33
1810	119.25	146.75	170.75	145.58	-21798.11	-28465.56	-18238.37	-55691.23	-124193.27
1816	117.5	146.5	170.25	144.75	-21877.88	-28512.28	-18343.22	-55883.08	-124616.46
1821	118.25	145.75	168.25	144.08	-21949.61	-28630.27	-18386.32	-56023.67	-124989.87
1827	116	145	167.5	142.83	-21945.04	-28564.31	-18409.53	-55957.97	-124876.86
1835	87.75	146.25	178.25	137.42	-15265.71	-209750.53	-17394.39	-33622.41	276033.03
1842	88.75	147	184	139.92	-15570.05	-209750.53	-17834.05	-34456.16	277610.78
1849	90.25	148.5	184.5	141.08	-16055.74	-209750.53	-18659.07	-35817.16	280282.5
1856	92	148.75	184	141.58	-16010.97	-209750.53	-18851.59	-36012.73	280625.81
1863	93	148.75	182.75	141.5	-16402.61	-209750.53	-19267.89	-37016.66	282437.68
1870	93.5	148.5	182.25	141.42	-16665.29	-209750.53	-19764.1	-37934.64	284114.56
1877	93.5	148.25	180	140.58	-16506.46	-209750.53	-19662.63	-37807.38	283727
1884	93.5	147	178	139.5	-16347.68	-209750.53	-19492.13	-37540.61	283130.96
1891	94.75	146.5	171.25	137.5	-16496.18	-209750.53	-19685.59	-38123.05	284055.37
1898	94.5	145.5	170.5	136.83	-16375.9	-209750.53	-19594.97	-37818.57	283539.96
1905	94.75	145.25	173.25	137.75	-16529.9	-209750.53	-19774	-38242.72	284297.15
1912	95	144.5	168.25	135.92	-16465.64	-209750.53	-19774.41	-38163.25	284153.81
1919	95.25	144.75	171.75	137.25	-16543.36	-209750.53	-19868.76	-38516.69	284679.34
1926	95.75	144.25	166.75	135.58	-16484.27	-209750.53	-19849.14	-38426.03	284509.96
1933	95.5	143.75	165.5	134.92	-16144.71	-209750.53	-19520.84	-37811.04	283227.12
1940	96.25	143.25	167.25	135.58	-16241.26	-209750.53	-19523.6	-38192.94	283708.31
1947	96.75	143.25	166.5	135.5	-16073.24	-209750.53	-19358.93	-38053.54	283236.25
1954	96.75	142.75	171.75	137.08	-16043.95	-209750.53	-19377.96	-38059.31	283231.75
1961	97	142.75	168	135.92	-16095.52	-209750.53	-19461.83	-38256.51	283564.37
1968	97	143	168	136	-15964.44	-209750.53	-19322.69	-37989.62	283027.28
1975	97.25	143.25	169	136.5	-16247.13	-209750.53	-19606.87	-38775.88	284380.4
1982	99.5	143.5	169.25	137.42	-16224.83	-209750.53	-19783.58	-38908.15	284667.09
1989	99.25	143.5	174.75	139.17	-16512.07	-209750.53	-19948.87	-39594.55	285806
1996	100.25	144	170.25	138.17	-16486.8	-209750.53	-20185.17	-39756.83	286179.34
2003	101.25	144	174.75	140	-16645.29	-209750.53	-20471	-40265.01	287131.81
2010	104.25	144	170.5	139.58	-16554.09	-209750.53	-20494.27	-40236.35	287035.25
2017	104.75	144.25	174.75	141.25	-16672.39	-209750.53	-20688.06	-40622.51	287733.5
2024	107	144.5	170	140.5	-16598.44	-209750.53	-20746.46	-40601.14	287696.56
2031	108	144	174.5	142.17	-16677.77	-209750.53	-20821.99	-40928.1	288178.4
2038	107.25	144.5	169.5	140.42	-16626.88	-209750.53	-20790.77	-40818.62	287986.78

2045	107.25	144.25	173.75	141.75	-16667.55	-209750.53	-20891.56	-41037.96	288347.59
2052	108.25	144.75	168.5	140.5	-16630.93	-209750.53	-20917.92	-40994.57	288293.93
2059	108.5	144	172	141.5	-16684.15	-209750.53	-21002.21	-41156.14	288593
2066	108.75	143.5	168	140.08	-16657.65	-209750.53	-20977.66	-41093.58	288479.43
2073	109.25	143.5	171.5	141.42	-16695.36	-209750.53	-20984.13	-41286.03	288716.06
2080	107.75	143.5	167.75	139.67	-16797.97	-209750.53	-21151.45	-41414.19	289114.12
2087	108.5	143	170.25	140.58	-16875.26	-209750.53	-21249.73	-41453.91	289329.4
2094	105.75	143	165.75	138.17	-17003	-209750.53	-21432.26	-41706.66	289892.46
2101	105.5	142.5	168	138.67	-16865.43	-209750.53	-21299.17	-41444.8	289359.93
2108	105	142	163.25	136.75	-16983.14	-209750.53	-21456.09	-41699.06	289888.81
2115	116.25	141.75	166.25	141.42	-16929	-209750.53	-21168.53	-40322.61	288170.68
2122	119	141	162	140.67	-16884.36	-209750.53	-21233.08	-40868.82	288736.78
2129	110.25	141.25	166	139.17	-16893.37	-34294.18	-21052.42	-38897.62	111137.6
2136	119	141.75	164	141.58	-16919.38	-34567.39	-21123.76	-39183.92	111794.46
2143	115.25	141.5	162	139.58	-16807.47	-33898.46	-20976.41	-38977.64	110659.97
2150	116.25	141.75	166.25	141.42	-16791.35	-33692.34	-20920.9	-39133.21	110537.8

7.2 Sample 2:

Table 7.2: Data recorded for second sample of plates produced

Time (Sec)	Temperature Sensor 1 (ºC)	Temperature Sensor 2 (ºC)	Temperature Sensor 3 (ºC)	Total Temperature (ºC)	Load Sensor 1 (grams)	Load Sensor 2 (grams)	Load Sensor 3 (grams)	Load Sensor 4 (grams)	Total Load (grams)
28	18.75	26.75	24.25	23.25	-49.36	84.31	-65333.54	-18.79	65317.39
37	18.25	27.5	24.25	23.33	-77.91	125.58	-12.58	-20.12	14.97
46	18	27	23.75	22.92	-37.63	63.82	-3.35	-41.55	18.71
55	17.5	26.75	24	22.75	-2891.42	23.24	-1635.72	-8635.91	13139.82
64	18	27	24	23	-5358.47	119.1	-190.22	-8263.48	13693.07
73	18.25	27	24	23.08	-5131.31	88.8	-127.52	-8069.43	13239.45
82	17.75	26.75	23.75	22.75	-6618.56	116.38	-116.85	-10869.94	17488.97
91	18.25	27	23.75	23	-10684.99	58.35	-96.18	-17473.71	28196.54
100	18.25	27	23.75	23	-15606.19	112.53	-97.15	-25220.84	40811.65
109	18.25	27	23.5	22.92	-19065.82	170.1	-129.27	-30454.39	49479.37
118	17.75	26.75	23.5	22.67	-23594.74	-300	-1381.09	-36927.73	62203.56
127	17.5	27.25	23.5	22.75	-25606.77	-2201.34	-2791.31	-40505.45	71104.86
136	18	26.75	23.25	22.67	-26830.31	-3356.81	-3876.41	-43075.25	77138.78
145	17.75	27	23.75	22.83	-27470.92	-3864.18	-4461.29	-44589.74	80386.14
154	18.25	26.75	23.5	22.83	-27351.81	-3838.4	-4337.78	-44296.97	79824.96
163	18.5	26.75	23.5	22.92	-27278.33	-4053.43	-4109.04	-44352.05	79792.85
172	17.5	26.75	23.5	22.58	-27191.98	-3919.35	-4085.97	-44166.35	79363.64
181	18.25	26.75	23.75	22.92	-27633.38	-4204.9	-4484.5	-44845.91	81168.68
190	18.25	26.75	23.5	22.83	-27549.62	-4179.43	-4405.74	-44737.56	80872.35
199	17.5	27	23.5	22.67	-27538.85	-4194.32	-4408.03	-44683.25	80824.46
208	14.75	27	23.75	21.83	-27170.05	-3960.04	-4222.09	-44002.92	79355.11
217	15.25	26.5	24	21.92	-26879.35	-3694.43	-4111.01	-43299.63	77984.43
226	17.75	27.25	23.5	22.83	-26689.57	-3563.49	-4073.69	-42770.6	77097.35
235	21.25	29	24	24.75	-26538.36	-3465.78	-4036.26	-42318.18	76358.58
244	25.5	30.5	24	26.67	-26466.16	-3479.96	-4039.56	-41947.95	75933.64
253	29.75	32.25	23.75	28.58	-26387.59	-3505.81	-4043.97	-41633.71	75571.08
262	36.5	35.25	24.25	32	-26326.29	-3518.57	-4038.01	-41462.89	75345.76
271	46.25	38.5	25.25	36.67	-26566.26	-3769.46	-4273.82	-41947.9	76557.44
280	51	41.5	25	39.17	-26825.03	-4012.91	-4511.31	-42597.08	77946.34
289	55	45	26.75	42.25	-27033.14	-4127.58	-4699.63	-43034.82	78895.19
298	57.5	47.5	26.25	43.75	-27210.09	-4297.22	-4801.54	-43393.94	79702.78
307	59.5	49.5	28.25	45.75	-27346.47	-4424.24	-4849.26	-43646.57	80266.54
316	57.25	50.25	28.75	45.42	-27095.64	-4321.77	-4501.54	-43073.79	78992.74
325	58.25	51.25	29.5	46.33	-26659.56	-4081.06	-4175.22	-42260.07	77175.91
335	59.5	53.25	29.75	47.5	-26354.05	-3846.19	-4043.25	-41730.73	75974.22
344	68	55	30.25	51.08	-26477.67	-3933.62	-4208.74	-42059.65	76679.68
353	69	56.5	30.75	52.08	-26791.3	-4139.43	-4440.8	-42618.9	77990.42
362	71.25	58.5	31.25	53.67	-27018.75	-4248.66	-4633.61	-42967.89	78868.92
371	72.5	60	32.25	54.92	-27203.83	-4316.87	-4773.94	-43243.91	79538.57
380	72.5	61	33	55.5	-27325.01	-4400.76	-4832.34	-43454.39	80012.5

389	69.25	61.5	33.25	54.67	-27042.08	-4305.14	-4519.31	-42845.62	78712.15
398	69.5	61.75	33.5	54.92	-26595.59	-4045.59	-4198.01	-42087.11	76926.32
407	70.5	62	34	55.5	-26285.46	-3807.77	-4013.68	-41547.5	75654.42
416	72.75	63.75	34	56.83	-26122.31	-3718.1	-3961.61	-41299.68	75101.7
425	75.5	65	34.75	58.42	-26045.81	-3669.06	-3977.24	-41192.34	74884.45
434	79	66.75	35	60.25	-25999.24	-3646.26	-3983.21	-41040.19	74668.9
443	83	68.5	35.25	62.25	-25958.71	-3628.76	-4006.94	-40909.17	74503.58
452	87.5	71.5	36.5	65.17	-25963.99	-3629.07	-4041.78	-40862.17	74497.02
461	91	74	37.5	67.5	-25977.46	-3629.36	-4065.54	-40802.15	74474.52
470	99.75	76.25	38	71.33	-26394	-3838.78	-4431.15	-41469.06	76132.99
479	102.5	79.25	39.5	73.75	-26822.84	-4163.29	-4674.97	-42186.31	77847.42
488	105.5	82	38.5	75.33	-27138.12	-4361.89	-4808.21	-42708.8	79017.03
497	106.25	84	41	77.08	-27404.77	-4461.84	-4898.58	-43069.17	79834.36
506	107.25	85	42	78.08	-27615.69	-4549.91	-4943.7	-43341.17	80450.47
515	106	86.25	42.5	78.25	-27766.52	-4591.1	-4991.97	-43534.98	80884.57
524	105.75	86.25	43	78.33	-27839.47	-4604.16	-5010.98	-43704.41	81159.03
533	103.75	86.25	43.25	77.75	-27883.27	-4625.78	-5050.41	-43829.56	81389.02
542	102.5	85.25	44	77.25	-27915.28	-4665.43	-5063.82	-43973.42	81617.96
551	100.5	85.5	44.25	76.75	-27934.38	-4715.63	-5051.21	-44094.18	81795.39
560	99	85	45	76.33	-27934.61	-4735.22	-5028.95	-44168.82	81867.6
569	96.25	84.25	45.25	75.25	-27943.81	-4745.28	-5043.82	-44214.78	81947.69
578	93.75	83.25	45.25	74.08	-27965.43	-4694.77	-5041.78	-44190.08	81892.07
587	91.75	82	45.75	73.17	-27936.08	-4693.05	-4965.29	-44193.19	81787.63
596	89.75	81	46	72.25	-27867.63	-4691.18	-4881.06	-44211.72	81651.6
605	84	80.25	46.25	70.17	-27404.07	-4437.44	-4553.41	-43483.49	79878.42
614	82.25	78.75	45.5	68.83	-26734.65	-4032.28	-4205.64	-42489.71	77462.28
623	82.25	78.75	45.5	68.83	-26317.33	-3769.15	-4106.87	-41900	76093.35
632	87.5	78.5	45.75	70.58	-26360.45	-3771.62	-4263.16	-42068.37	76463.6
641	89	79.5	45.25	71.25	-26665.94	-3894.43	-4528.68	-42551.67	77640.74
650	87	79.75	46.25	71	-26540.04	-3829.76	-4407.89	-42205.96	76983.66
659	92.25	80.5	47	73.25	-26490.04	-3800.2	-4474.79	-42279.69	77044.72
668	93	81.5	47	73.83	-26771.12	-3936	-4662.71	-42705.42	78075.25
677	94.5	82.25	47.75	74.83	-26985.49	-4057.06	-4759.45	-43051.35	78853.35
686	94.75	82	48	74.92	-27139.12	-4162.38	-4807.64	-43313	79422.14
695	94.75	83.25	48.75	75.58	-27220.61	-4242.25	-4846.47	-43508.53	79817.86
704	93.75	82.75	49.25	75.25	-27292.27	-4301.45	-4861.96	-43678.04	80133.72
713	92.75	83	49	74.92	-27339.34	-4350.56	-4852.89	-43776.5	80319.3
722	91.5	82.5	49.75	74.58	-27384.38	-4363.36	-4840.2	-43883.81	80471.75
731	89.25	82.5	49.75	73.83	-27392.23	-4370.35	-4834.76	-43970.17	80567.52
740	89	81.75	49.75	73.5	-27396.64	-4363.42	-4818.04	-44034.5	80612.6
749	87.25	81.25	50.25	72.92	-27361.64	-4313.8	-4779.83	-44033.68	80488.96
759	85.25	80.25	50	71.83	-27344.04	-4319.15	-4761.05	-44031.76	80456.01
768	81.25	79.75	49.75	70.25	-26905.39	-4134.53	-4372.05	-43232.99	78644.96
777	81.25	79.25	50	70.17	-26270.69	-3772.64	-4106.91	-42303.78	76454.02
786	82.25	79	50	70.42	-25943.66	-3659.15	-3952.98	-41734.13	75289.92
795	84	79	49	70.67	-25738.38	-3557.28	-3887.15	-41253.22	74436.03
804	86	79.75	49	71.58	-25707.56	-3546.77	-3906.67	-41040.94	74201.94

813	88.75	81.25	49.5	73.17	-25655.85	-3532.46	-3950.18	-40984.21	74122.7
822	93.75	83.25	50.5	75.83	-25558.41	-3440.78	-4008.54	-40852.18	73859.92
831	97.5	85.5	50.5	77.83	-25534.63	-3403.12	-4041.25	-40789.55	73768.56
840	101.75	88	51	80.25	-25527.76	-3368.61	-4105.11	-40743.67	73745.15
849	106.25	90	52	82.75	-25576.2	-3445.01	-4068.16	-40744.39	73833.77
858	110.75	93	52.75	85.5	-25622.86	-3458.1	-4129.13	-40786.58	73996.67
867	115.5	96.5	52.75	88.25	-25705.58	-3435.86	-4190.07	-40808.27	74139.78
876	120	99	54	91	-25801.19	-3396.68	-4290.69	-40897.13	74385.69
885	127.75	102.5	54.5	94.92	-26281.14	-3630.34	-4676.12	-41573.44	76161.05
894	131.75	105	55	97.25	-26781.44	-4002.67	-4901.32	-42272.86	77958.3
903	130	107.25	56.75	98	-26773.74	-4050.51	-4742.05	-42173.07	77739.38
912	130.75	109	57.75	99.17	-26559.96	-3929.5	-4613.43	-41977.11	77080.01
921	133.75	110.75	58.5	101	-26419.6	-3816.94	-4608.39	-41830.76	76675.7
930	135.5	113	59.25	102.58	-26346	-3756.37	-4587.82	-41770.33	76460.52
939	137	114.75	59.75	103.83	-26272.01	-3716.3	-4575.35	-41753.64	76317.31
948	140.25	116.75	60.75	105.92	-26269.73	-3694.39	-4609.63	-41803	76376.75
957	143	119	61.5	107.83	-26316.22	-3725.33	-4639.73	-41859.97	76541.25
966	146	120.75	62	109.58	-26383.1	-3748.26	-4713.62	-41992.64	76837.62
975	148.75	123	62	111.25	-26461.79	-3800.16	-4801.02	-42149.63	77212.6
984	151.75	124.75	62.75	113.08	-26551.51	-3881.92	-4806.41	-42252.69	77492.53
993	153.75	127.25	64.25	115.08	-26643.34	-3974.58	-4849.87	-42416.32	77884.11
1002	156.5	129.25	65.5	117.08	-26778.23	-4079.74	-4906.96	-42612.84	78377.77
1011	160	131.5	66	119.17	-26918.33	-4187.02	-4983.36	-42794.05	78882.77
1020	162.5	133.75	67	121.08	-27077.31	-4306.21	-5081.33	-43027.27	79492.13
1029	165.5	136.5	68.5	123.5	-27237.89	-4405.52	-5148.72	-43210.21	80002.35
1038	168.25	138.25	69.5	125.33	-27453.19	-4521.59	-5308.53	-43484.4	80767.71
1047	169.75	140.75	69.75	126.75	-27606.37	-4585.71	-5337.76	-43675.81	81205.65
1056	172	142.5	71.5	128.67	-27778.86	-4662.96	-5432.07	-43944.6	81818.5
1065	174	144.5	72.5	130.33	-27917.65	-4751.38	-5521.29	-44203.99	82394.32
1074	176.25	146.5	73.5	132.08	-28043.57	-4840.25	-5611.25	-44424.93	82920
1083	178.5	148.25	74.25	133.67	-28156.64	-4921.19	-5704	-44738.33	83520.17
1092	180.25	149.75	74.5	134.83	-28379.97	-5066.56	-5844.37	-45069.91	84360.82
1101	182.25	152	76.25	136.83	-28470.35	-5163.49	-5916.44	-45395.85	84946.14
1110	184.25	154	78	138.75	-28582.78	-5271.15	-6000.62	-45689.48	85544.03
1119	184.75	155.75	79.5	140	-28692.93	-5358.35	-6098.46	-46038.3	86188.05
1128	186.75	158	80.5	141.75	-28807.75	-5475.2	-6203.59	-46385.89	86872.42
1137	188	159.75	82.25	143.33	-28982.97	-5634.95	-6352.81	-46759.51	87730.25
1147	190.25	159	78.5	142.58	-29031.27	-5704.12	-6418.2	-47046.84	88200.43
1156	196	159.75	79.75	145.17	-29763.99	-6244.1	-6904.84	-48465.1	91378.03
1166	197.25	162.75	82	147.33	-30346.53	-6825.45	-7274.92	-50114.83	-94561.74
1171	197.25	163.5	83	147.92	-30542.61	-7051.07	-7373.6	-50705.87	-95673.16
1177	196.25	164	84	148.08	-30701.98	-7255.77	-7458.4	-51198.94	-96615.09
1182	195.5	164	84.5	148	-30832.78	-7434.33	-7512.71	-51629.08	-97408.91
1188	194.75	164.5	85	148.08	-30964.65	-7600.09	-7557.75	-51980.25	-98102.74
1193	193.25	164.5	85.5	147.75	-31082.95	-7740.69	-7583.35	-52283.84	-98690.83
1199	192.25	164.5	86.75	147.83	-31147.72	-7876.85	-7618.57	-52561.22	-99204.36
1204	190.25	164.25	88.25	147.58	-31235.27	-7982.28	-7632.72	-52810.26	-99660.53
1210	188.25	164.25	88.25	146.92	-31307.81	-8075.51	-7649.64	-53015.1	-100048.07

1215	186.75	163.25	89.25	146.42	-31335.14	-8150.76	-7669.91	-53206.96	-100362.78
1221	184.5	162.5	89.5	145.5	-31342.61	-8227.52	-7669.36	-53353.11	-100592.61
1226	182	161.5	90	144.5	-31341.04	-8290.25	-7654.58	-53476.77	-100762.64
1231	180.75	161.25	90.25	144.08	-31353.92	-8316.9	-7638.51	-53525.44	100834.77
1240	176.75	158.75	90.25	141.92	-31309.3	-8391.21	-7596.21	-53690.8	100987.53
1249	173	157.75	90.5	140.42	-31283.59	-8429.43	-7535.47	-53784.5	101033
1258	169	155.25	90.75	138.33	-31168.75	-8449.89	-7457.63	-53830.25	100906.53
1267	162.25	152.75	87.5	134.17	-30511.09	-7675.45	-7030.22	-53036.68	98253.44
1276	159.5	149	85.75	131.42	-29700.21	-7040.16	-6701.84	-52111.57	95553.78
1285	158.25	148	85.75	130.67	-29200.68	-6596.71	-6504.49	-51412.04	93713.92
1294	158.75	146.5	84	129.75	-28811.07	-6382.61	-6351.96	-50861.94	92407.58
1303	158.75	145.75	83.75	129.42	-28611.11	-6191.54	-6268.73	-50484.98	91556.37
1312	160.75	146.25	83.75	130.25	-28358.43	-6069.28	-6225.06	-50254.23	90907
1321	162.75	147	84	131.25	-28250.41	-6076.54	-6211.13	-50125.94	90664.02
1330	165	148.25	84.5	132.58	-28248.51	-6052.4	-6255.16	-50039.9	90595.99
1339	168	149.5	85	134.17	-28258.88	-6152.94	-6283.23	-50052.92	90747.97
1348	170.25	151.5	85.75	135.83	-28326.76	-6203.29	-6328.3	-50078.98	90937.33
1357	172.75	153.25	86.5	137.5	-28468.71	-6302.49	-6385.87	-50102.05	91259.12
1366	176	154.5	87.25	139.25	-28574.22	-6410.51	-6451.79	-50204.68	91641.21
1375	178.75	156.75	87.5	141	-28672.01	-6560.35	-6533.47	-50325.62	92091.46
1384	181.75	159.25	89	143.33	-28818.9	-6674.87	-6628	-50464.65	92586.42
1393	184.25	161	89.25	144.83	-29040.23	-6826.18	-6717.69	-50617.23	93201.33
1402	189.75	164	92.5	148.75	-29723.69	-7350.96	-7174.05	-51783.78	96032.49
1412	192.5	167	95	151.5	-30669.73	-7913.56	-7646.32	-53118.79	-99348.41
1418	192.75	168.25	96	152.33	-30976.76	-8092.23	-7780.81	-53572.57	-100422.38
1423	193.25	169	97.5	153.25	-31157.09	-8163.02	-7902.44	-53994.37	-101216.92
1429	192.75	171	99.75	154.5	-31276.8	-8228.85	-7810.45	-53891.84	-101207.94
1434	191.5	171.5	101.75	154.92	-31434.33	-8370.79	-7907.22	-54224.16	-101936.52
1440	191.75	171.75	102	155.17	-31494.42	-8486.29	-7993.04	-54532.67	-102506.42
1445	190.25	171.5	102.5	154.75	-31548	-8575.71	-8039.56	-54797.95	-102961.23
1451	189.5	171.25	104	154.92	-31468.88	-8603.05	-7871.15	-54671.75	-102614.83
1456	188	171.75	103.5	154.42	-31564.97	-8729.3	-7909.43	-54922.44	-103126.13
1462	186.5	170.75	103.75	153.67	-31621.92	-8779.74	-7947.2	-55109.28	-103458.14
1467	185.25	170.5	104.25	153.33	-31646.55	-8793.19	-7949.71	-55216.35	-103605.8
1473	183.5	169.75	104.75	152.67	-31595.91	-8803.54	-7911.03	-55282.38	-103592.86
1478	182	169.5	104	151.83	-31664.73	-8812.42	-7884.73	-55333.87	-103695.75
1484	180	168.75	104.75	151.17	-31672.2	-8829.72	-7823.21	-55360.34	-103685.48
1489	178.5	167.5	104	150	-31587.63	-8829.72	-7778.76	-55387.19	-103583.3
1495	176.25	166.5	104	148.92	-31523.37	-8849.6	-7723.44	-55402.92	-103499.35
1500	174.75	165.5	104.25	148.17	-31449.53	-8866.81	-7658.18	-55405.69	-103380.22
1506	172.75	164.75	104.5	147.33	-31361.62	-8899.38	-7588.12	-55402.76	-103251.89
1511	171.75	163.75	104.5	146.67	-31292.02	-8882.75	-7518.96	-55383.09	-103076.82
1517	169.75	162.75	103.75	145.42	-31207.45	-8836.98	-7426.4	-55347.53	-102818.36
1522	168.5	162.25	104.25	145	-31100.26	-8804.3	-7361.47	-55303.99	-102570.02
1528	174.5	161.5	104.75	146.92	-30969.41	-8774.4	-7308.69	-55272.44	-102324.95
1533	165.25	160.5	104.75	143.5	-30834.7	-8772.8	-7268.66	-55243.75	-102119.91
1538	164.5	160	104.5	143	-30774.08	-8765.74	-7230.25	-55236.1	102006.16

1547	157.75	154.25	95.5	135.83	-30201.36	-8289.49	-7071.1	-54559.57	100121.53
1556	156.75	153.25	96.75	135.58	-29389.12	-7731.39	-6817.19	-53539.71	97477.42
1565	155.5	152	96.5	134.67	-28800.15	-7413.65	-6585.83	-52813.98	95613.61
1574	156.25	150.75	94.25	133.75	-28473.97	-7193.28	-6513.7	-52184.96	94365.91
1583	158	150.5	94.25	134.25	-28283.63	-7074.53	-6449.47	-51732.35	93539.99
1592	160.25	151.25	94	135.17	-28169.54	-6960.66	-6463.87	-51420.2	93014.28
1601	162.5	151.5	94.25	136.08	-28102.17	-6902.6	-6457.77	-51170.07	92632.62
1610	164.5	153.25	95	137.58	-28044.19	-6849.76	-6553.86	-51054.15	92501.96
1619	168	155.25	95	139.42	-27971.12	-6920.37	-6559.19	-51050.72	92501.39
1628	170.75	157.25	95.75	141.25	-27992.34	-6982.19	-6590.36	-51090.67	92655.56
1637	174.5	159.25	96.75	143.5	-27989.17	-7062.04	-6617.49	-51179.88	92848.58
1646	180.75	161.5	97.75	146.67	-28027.18	-7071.44	-6715.75	-51277.25	93091.62
1656	185	165	100.5	150.17	-28817.43	-7669.43	-7249.16	-52727.83	-96463.86
1662	186.25	166.5	101.25	151.33	-29222.63	-7847.71	-7417.79	-53271.64	-97759.77
1667	188	167.75	101	152.25	-29593.47	-8020.61	-7608.73	-53778.79	-99001.6
1673	187.5	168.5	101.5	152.5	-29911.47	-8177.36	-7735.49	-54208.58	-100032.91
1678	188	169.25	101.75	153	-30185.31	-8320.62	-7823.56	-54551.04	-100880.53
1684	188.25	169.25	102.25	153.25	-30408.26	-8446.44	-7880.81	-54841.89	-101577.41
1689	188.25	170	102	153.42	-30617.84	-8526.38	-7983.23	-55111.67	-102239.13
1695	187.5	170.25	103.5	153.75	-30786.19	-8611.09	-8079.04	-55314.99	-102791.32
1700	187	170.25	104.5	153.92	-30913.77	-8692.34	-8179.11	-55475.07	-103260.29
1706	186.5	171	105	154.17	-31012.94	-8762.56	-8224.73	-55614.94	-103615.17
1711	184.75	170.5	105.5	153.58	-30989.55	-8787.18	-8058.22	-55620.47	-103455.42
1717	183.5	170.5	105.75	153.25	-31093.06	-8862.71	-8088.97	-55750.56	-103795.3
1722	182	170.5	105.75	152.75	-31117.52	-8931.99	-8119.42	-55875.89	-104044.82
1728	180.25	168.75	106	151.67	-31126.35	-9026.85	-8127.68	-55983.12	-104264
1733	179	169	107.25	151.75	-31072.58	-8997.77	-8014.55	-55636.92	-103721.83
1739	178.25	169.25	108	151.83	-31026.42	-9052.52	-7970.68	-55705.71	-103755.33
1744	176.5	168.5	107.75	150.92	-30979.57	-9099.07	-7922.01	-55763.29	-103763.94
1750	175.25	167.75	108.75	150.58	-30932.01	-9099.35	-7880.16	-55759.3	-103670.83
1755	174	167	108.75	149.92	-30911.11	-9154.52	-7830.69	-55789.69	-103686.01
1761	173	166	108.25	149.08	-30870.86	-9189.45	-7801.72	-55815.76	-103677.8
1766	172.5	166.25	108.75	149.17	-30823.69	-9220.19	-7770.5	-55832.54	-103646.92
1772	170.75	165	108.5	148.08	-30780.21	-9254.54	-7711.18	-55831.1	-103577.03
1777	169.25	163.75	108.25	147.08	-30737.63	-9266.01	-7661.97	-55784.69	-103450.31
1783	167.5	162.75	108.25	146.17	-30677.93	-9278.76	-7647.29	-55739.61	-103343.6
1788	166.5	161.75	108	145.42	-30620.75	-9220.93	-7546.5	-55687.32	-103075.5
1794	165.5	161.5	107.75	144.92	-30521.03	-9234.66	-7477.16	-55642.35	-102875.21
1798	164.25	161.5	108.25	144.67	-30471.46	-9218.95	-7435.94	-55626.61	102752.96
1807	158.75	157.5	103	139.75	-29886.1	-8835.2	-7185.08	-54939.34	100845.72
1816	157.75	155.25	100.75	137.92	-29026.03	-8214.89	-6927.16	-53925.44	98093.53
1825	157.25	153.5	99.5	136.75	-28559.71	-7875.89	-6729.42	-53150.45	96315.47
1834	158	153.5	99.5	137	-28307.49	-7666.47	-6603.67	-52521.03	95098.67
1844	159.75	152.75	97.5	136.67	-28102.22	-7398.35	-6581.36	-51986.9	94068.83
1853	162	153.5	97.25	137.58	-28037.04	-7309.73	-6622.66	-51681.45	93650.88
1862	164.75	155	98.25	139.33	-27929.27	-7264.16	-6667.53	-51448.8	93309.76
1871	167.5	156.5	99	141	-27871.29	-7279.85	-6708.93	-51328.18	93188.25
1880	170.75	158.25	99.75	142.92	-27870.9	-7259.84	-6807.58	-51289.79	93228.11

1889	174.75	160.5	99.75	145	-27905.68	-7302.09	-6858.67	-51315.84	93382.29
1899	181.25	164	103	149.42	-28496.34	-7720.53	-7103.4	-52260.58	-95580.85
1904	183.25	164	101	149.42	-28650.7	-7807.15	-7268.56	-52550.69	-96277.11
1910	185	166	102	151	-28993.66	-8106.48	-7485.67	-53219.94	-97805.74
1915	185.5	167	102	151.5	-29332.18	-8235.33	-7673.65	-53727.38	-98968.55
1921	186.25	168.25	102.25	152.25	-29641.7	-8395.59	-7835.97	-54170.79	-100044.07
1926	186.5	169	103	152.83	-29893.85	-8556.75	-7954.63	-54557.36	-100962.59
1932	187.25	169.75	104.25	153.75	-30111.22	-8671.24	-8058.6	-54886.26	-101727.32
1937	186.5	170	104.75	153.75	-30307.98	-8775.91	-8131.2	-55173.23	-102388.33
1943	186.25	171	106	154.42	-30462.2	-8886.62	-8187.13	-55416.64	-102952.6
1948	186	171.5	106.25	154.58	-30598.28	-8973.66	-8240.95	-55596.25	-103409.14
1954	184.75	171.25	106.25	154.08	-30767.26	-8982.66	-8318.37	-55703.8	-103772.1
1959	184.25	171.25	106.25	153.92	-30882.4	-9058.75	-8387.13	-55809.12	-104137.4
1965	183	171.25	107.5	153.92	-30992.3	-9087.18	-8436.93	-55884.77	-104401.17
1970	182.25	171.75	109.25	154.42	-31074.54	-9111.55	-8438.23	-55952.92	-104577.25
1976	180.25	172	110.25	154.17	-31151.7	-9135.35	-8471.7	-55991.23	-104749.99
1981	179.75	171.5	110.5	153.92	-31192.32	-9195.28	-8468.05	-56007.07	-104862.72
1987	178.25	171.5	111.25	153.67	-31195.94	-9253.14	-8442.6	-56046.71	-104938.38
1992	176.25	171	111.25	152.83	-31222.12	-9231.63	-8477.79	-56056.83	-104988.38
1998	175	170.25	111	152.08	-31148.47	-9187.49	-8333.81	-55980.12	-104649.88
2003	174	168.75	111.25	151.33	-31182.82	-9206.48	-8248.11	-55957.79	-104595.2
2009	172.75	168.25	110.75	150.58	-31180.16	-9241.76	-8177.26	-55925.2	-104524.39
2014	171.5	167.25	110.5	149.75	-31151.09	-9264.85	-8126.43	-55881.98	-104424.35
2020	170	167	111.5	149.5	-31069.05	-9283.66	-8051.51	-55851.07	-104255.29
2025	168.5	166.25	112.75	149.17	-31018.41	-9286.49	-8001.37	-55813.72	-104119.99
2031	167	165.75	112.75	148.5	-30982.12	-9258.44	-7980.93	-55774.08	-103995.57
2036	166	165	111.5	147.5	-30938.91	-9263.54	-7936.11	-55704.39	-103842.94
2042	164.75	164.25	111.5	146.83	-30932.63	-9224.22	-7870.15	-55605.56	-103632.57
2047	163	163.5	111	145.83	-30895.96	-9175.07	-7819.47	-55506.19	-103396.69
2053	161.75	162.75	110.75	145.08	-30850.68	-9130.61	-7737.04	-55412.66	-103131
2058	160.75	162.25	111.75	144.92	-30780.63	-9122.35	-7651.19	-55315.55	-102869.73
2063	159.75	162.25	112.75	144.92	-30740.53	-9092.21	-7610.65	-55267.25	102710.64
2072	155.25	157.25	104.5	139	-30150.58	-8711.87	-7322.19	-54467.04	100651.67
2081	154.75	154.75	102.5	137.33	-29425.05	-8132.39	-7111.95	-53443.01	98112.41
2090	155.25	154.75	101.5	137.17	-28878.99	-7820.46	-6937.78	-52668.45	96305.68
2099	156.25	154	101.5	137.25	-28527.8	-7593.61	-6832	-52058.19	95011.6
2108	157.75	155	102	138.25	-28242.85	-7468.17	-6778.12	-51569.11	94058.25
2117	160	155.5	102	139.17	-28107.09	-7387.67	-6750.69	-51275.41	93520.86
2126	163.75	157.5	102	141.08	-28050.49	-7290.2	-6749.14	-51014.75	93104.6
2135	166	157.5	101	141.5	-27969.73	-7268.54	-6791.04	-50860.58	92889.9
2144	169.5	159.5	101.25	143.42	-27982.29	-7205.01	-6914.95	-50771.61	92873.86
2153	172.5	162.5	103	146	-28271.82	-7489.85	-7113.45	-51389.37	94264.49
2163	178.5	167	108.25	151.25	-28905	-7984.37	-7414.72	-52332.48	-96636.58
2169	181	169.25	111.5	153.92	-29207.45	-8145.39	-7580.86	-52798.41	-97732.11
2174	182.25	171.75	113.75	155.92	-29470.84	-8276.22	-7667.76	-53187.37	-98602.21
2180	182.75	173.75	116.75	157.75	-29679.78	-8382.55	-7733.12	-53489	-99284.45
2185	183.75	175.5	119.5	159.58	-29890.44	-8485.6	-7827.33	-53764.01	-99967.39

2191	182.75	176.25	119.5	159.5	-30120.52	-8565.45	-7923.04	-54004.78	-100613.8
2196	183.5	176	120	159.83	-30318.48	-8634.06	-7965.48	-54166.85	-101084.88
2202	183.25	176.5	119.75	159.83	-30472.97	-8694.19	-8017.5	-54316.4	-101501.07
2207	182.5	176.25	119.75	159.5	-30630.91	-8703.54	-8029.53	-54432.38	-101796.36
2213	181.5	176.5	120.5	159.5	-30739.98	-8734.24	-8024.11	-54519.17	-102017.5
2218	180.5	176	120.25	158.92	-30802.98	-8792.94	-8008.03	-54593.19	-102197.14
2224	179.25	175.5	120.5	158.42	-30869.16	-8828.81	-7997.91	-54669.73	-102365.61
2229	178.25	175.75	121	158.33	-30938.36	-8866.99	-7973.94	-54718.48	-102497.76
2235	177.25	175.5	121.25	158	-30977.76	-8907.9	-7950.54	-54742.56	-102578.77
2240	175.75	174.5	121.25	157.17	-30974.48	-8931.17	-7939.81	-54754.97	-102600.43
2246	174	173	119	155.33	-30834.63	-8937.51	-7798.16	-54693.35	-102263.67
2251	173.75	173.75	120.75	156.08	-30800.49	-8987.38	-7765.76	-54710.63	-102264.27
2257	172	173	120.5	155.17	-30769.8	-9035.04	-7736.61	-54706.54	-102247.99
2262	171.25	171.75	120.5	154.5	-30774.74	-9038.91	-7734.11	-54662.28	-102210.03
2268	169	172.25	121.25	154.17	-30677.63	-9045.75	-7679.96	-54664.12	-102067.46
2273	168	172.25	122	154.08	-30638.85	-9065.52	-7643.9	-54635.38	-101983.65
2279	166.5	170.75	120.75	152.67	-30590.57	-9058.48	-7600.95	-54601.54	-101851.55
2284	165	169.75	120.5	151.75	-30524.67	-9060.98	-7548.72	-54570.84	-101705.21
2290	164.25	169.5	121.5	151.75	-30467.05	-9054.34	-7504.32	-54551.38	-101577.1
2295	163	168.5	120.75	150.75	-30418.07	-9040.45	-7467.16	-54520.15	-101445.84
2268	169	172.25	121.25	154.17	-30677.63	-9045.75	-7679.96	-54664.12	-102067.46
2273	168	172.25	122	154.08	-30638.85	-9065.52	-7643.9	-54635.38	-101983.65
2279	166.5	170.75	120.75	152.67	-30590.57	-9058.48	-7600.95	-54601.54	-101851.55
2284	165	169.75	120.5	151.75	-30524.67	-9060.98	-7548.72	-54570.84	-101705.21
2290	164.25	169.5	121.5	151.75	-30467.05	-9054.34	-7504.32	-54551.38	-101577.1
2295	163	168.5	120.75	150.75	-30418.07	-9040.45	-7467.16	-54520.15	-101445.84

7.3 Sample 3:

Table 7.3: Data recorded for third sample of plates produced

Time (Sec)	Temperature Sensor 1 (ºC)	Temperature Sensor 2 (ºC)	Temperature Sensor 3 (ºC)	Total Temperature (ºC)	Load Sensor 1 (grams)	Load Sensor 2 (grams)	Load Sensor 3 (grams)	Load Sensor 4 (grams)	Total Load (grams)
177	22	14.75	24	20.25	-34438.4	-7363.74	-284.65	-38491.73	80578.52
186	22	15	28	21.67	-35212.98	-7489.25	-591.91	-40000.03	83294.17
196	21.75	15.75	26.25	21.25	-35140.36	-7473.29	-634.32	-39881.87	83129.84
205	21.75	15.5	25.75	21	-35079.46	-7470.01	-540.13	-39868.39	82957.99
214	22.75	16.75	27.75	22.42	-34982.23	-7439.49	-496.2	-40004.94	82922.86
223	22.25	17	31	23.42	-34865.6	-7435.44	-429.6	-39490.99	82221.63
232	22.5	16.5	31.5	23.5	-34759.66	-7411.33	-391.34	-39646.97	82209.3
241	22.25	17	31	23.42	-34636.21	-7402.58	-375.15	-39492.05	81905.99
250	22.5	16.75	31.25	23.5	-34542.3	-7351.05	-371.88	-39216.56	81481.79
259	23.5	19.5	31.25	24.75	-34338.97	-7110.35	-369.58	-39440.8	81259.7
268	24.75	21	30	25.25	-34164.41	-6801.07	-354.78	-39413.9	80734.16
277	24.25	20.75	29.5	24.83	-33857.21	-6965.94	-331.42	-39436.34	80590.91
286	24	21	28.75	24.58	-33615.16	-6757.88	-321.34	-39393.81	80088.19
295	24.25	21.5	32	25.92	-38840.85	-7325.91	-290.64	-70611.43	117068.83
304	24	21.5	32.5	26	-38781.23	-7330.65	-273.92	-70604.44	116990.24
313	24	21	33.5	26.17	-38312.88	-7374.02	-243.38	-70853.73	116784.01
322	24.5	21	32.5	26	-38920.69	-7347.37	-233.86	-70977.14	117479.06
331	23.75	21.75	31.25	25.58	-40430.35	-7350.73	26.85	-69792.85	117547.08
340	23.5	21.5	30.75	25.25	-39774.97	-7287.16	-25.18	-69050.32	116137.63
349	24.5	22	31.25	25.92	-39329.95	-7260.91	-25.28	-68373.82	114989.96
358	24.25	23.75	31.5	26.5	-39122.99	-7210.93	-39.88	-67836.47	114210.27
367	24.25	25	31.25	26.83	-40070.54	-7178.29	-46.99	-67538.02	114833.84
376	24.25	28	31	27.75	-39971.05	-7186.29	-83.13	-67137.99	114378.46
385	23.75	30.25	31.5	28.5	-39420.05	-7197.64	-31.3	-66626.32	113275.31
394	24	34.25	32.5	30.25	-39380.52	-7187.31	11.38	-66559.25	113115.7
403	24.25	38	33.25	31.83	-38793.19	-7170.99	-10.41	-66407.15	112381.74
412	24.25	41.75	34	33.33	-38980.29	-7188.29	-19.61	-66210.88	112399.07
421	24	45	34.5	34.5	-39935.53	-7183.88	-9.96	-66160.48	113289.85
430	23.5	49.25	35.75	36.17	-39861.39	-7237.53	31.09	-66155.56	113223.39
439	23.75	54	36.5	38.08	-39740.83	-7218.14	46.04	-66121.11	113034.04
448	23.75	57.5	37.25	39.5	-39753.49	-7272.57	62.66	-66206.01	113169.41
457	24.25	62	38.5	41.58	-39746.59	-7289.6	35.51	-66207.1	113207.78
466	23.5	66	40.25	43.25	-39901.83	-7294.41	28.95	-66229.35	113396.64
475	24	69	41	44.67	-40162.77	-7340.65	27.33	-66319.67	113795.76
484	24.25	73.5	42	46.58	-40416.6	-7353.47	51.48	-66442.03	114160.62
493	23.75	77.25	42.75	47.92	-40230.5	-7371.55	84.1	-66587.43	114105.38
502	24	81.25	43.75	49.67	-40558.73	-7399.78	58.62	-66692.08	114591.97

511	24.25	84.25	44.5	51	-40335.5	-7437.11	40.35	-66893.07	114625.33
520	24.25	88	46.25	52.83	-40635.91	-7441.74	55.55	-67062.66	115084.76
529	23.5	91.75	47.25	54.17	-40855.68	-7430.08	70.05	-67256.89	115472.6
538	24.5	95	48.75	56.08	-40890.04	-7446.46	82.91	-67446.97	115700.56
547	24	98.25	49.5	57.25	-40969.62	-7478.18	105.41	-67708.49	116050.88
556	23.75	102.5	50.5	58.92	-41089.91	-7491.87	86.95	-67945.28	116440.11
565	24.25	105.5	51.5	60.42	-41357.28	-7499.62	45.3	-68210.1	117021.7
574	24.25	109	52.5	61.92	-41601.94	-7510.4	-2.97	-68474.14	117589.45
583	23.5	111	53.5	62.67	-41811.19	-7478.12	5.14	-68754.17	118038.34
592	24.25	113.5	55.25	64.33	-41854.96	-7462.91	59.7	-69105.67	118363.84
601	24.25	115.75	56.25	65.42	-42035.35	-7498.37	53.6	-69443.5	118923.62
610	24	118	57	66.33	-42191.67	-7512.71	54.03	-69879.91	119530.26
619	23.75	120.25	58.25	67.42	-42431.93	-7516.9	67.3	-70285.17	120166.7
628	23.75	123	60.25	69	-42673.25	-7507.5	63.64	-70688.65	120805.76
637	24.25	125.5	61	70.25	-42942.44	-7527.58	76.36	-71097.19	121490.85
646	24.5	128	62.25	71.58	-43089.78	-7502.67	87.3	-71502.58	122007.73
656	23.25	127.5	63	71.25	-43704	-7574.22	16.72	-73294.03	124555.53
665	151.5	133	69	117.83	-40558.73	-7590.92	-202.77	-75532.96	123885.38
674	151.25	134.75	70	118.67	-40335.5	-7593.54	-97.23	-77290.94	125317.21
683	153	136.5	72	120.5	-40635.91	-7624.13	-111.11	-78585.54	126956.69
692	151.75	136.5	72.75	120.33	-40855.68	-7606.48	-100.18	-79516.67	128079.01
701	146	136	71	117.67	-40890.04	-7462.38	99.32	-78878.66	127131.76
710	143.5	135	71.25	116.58	-40969.62	-7316.94	130.7	-77844.08	125999.94
719	143.75	133.75	69.75	115.75	-41089.91	-7266.65	133.86	-76970.66	125193.36
728	140.5	133.5	69.25	114.42	-41357.28	-7225.58	128.32	-76409.17	124863.71
737	138.5	134	70.5	114.33	-41601.94	-7226.27	126.03	-76102.82	124805
746	142.25	134.25	71.25	115.92	-41811.19	-7235.02	87.92	-75859.5	124817.79
755	142.25	135.5	72	116.58	-41854.96	-7232.35	72.75	-75755.59	124770.15
764	145.75	136.5	72.75	118.33	-42035.35	-7247.35	71.8	-75708.06	124918.96
773	139.75	137	73	116.58	-42191.67	-7262.96	72.6	-75744.79	125126.82
782	148.5	139.5	74.5	120.83	-42431.93	-7278.12	69.6	-75787.25	125427.7
791	151.5	141.25	75	122.58	-42673.25	-7290.58	66.74	-75844.82	125741.91
800	148	142	76	122	-42942.44	-7305.74	65.69	-75980.39	126162.88
809	158.75	144.5	77	126.75	-43089.78	-7335.84	68.43	-76142.46	126499.65
818	158	146.5	77.75	127.42	-43704	-7339.89	63.56	-76346.97	127327.3
827	163.25	148.75	78.75	130.25	-40558.73	-7343.37	68.03	-76497.16	124331.23
836	163.5	151	79.75	131.42	-40335.5	-7349.2	56.13	-76682.51	124311.08
845	166.25	152.75	80	133	-40635.91	-7347.46	57.72	-76847.19	124772.84
854	169.25	154.5	81.5	135.08	-40855.68	-7363.82	53.21	-76961.67	125127.96
863	168.5	156.75	82.5	135.92	-40890.04	-7330.97	46.9	-77117.97	125292.08
872	174.25	158.75	83	138.67	-40969.62	-7310.37	29.57	-77268.85	125519.27
881	177	159.75	83.25	140	-41089.91	-7417.61	-35.74	-78968.88	127512.14
890	177.25	161	83.75	140.67	-41357.28	-7426.69	-12.21	-81003.22	129799.4
899	176.5	162.5	85.5	141.5	-41601.94	-7395.88	-24.11	-82355.32	131377.25
908	177.25	163.75	86	142.33	-41811.19	-7395.04	-54.46	-83239.35	132500.04
917	176	163.5	87	142.17	-41854.96	-7339.07	-9.71	-83773.71	132977.45
926	170.75	162.75	87.5	140.33	-42035.35	-7347.31	-16.82	-84129.59	133529.07
935	169.25	162.5	87.75	139.83	-42191.67	-7290.03	-4.17	-84264.39	133750.26

944	166.25	160.75	88.5	138.5	-42431.93	-7286.93	-7.54	-84289.1	134015.5
953	161.25	160.75	88.25	136.75	-42673.25	-7260.44	44.27	-84153.22	134042.64
962	155.25	159	89.25	134.5	-42942.44	-7085.69	77.47	-82607.58	132558.24
971	153.25	157.5	88.5	133.08	-43089.78	-6907.72	94.18	-80854.47	130757.79
980	151.75	156.5	89.5	132.58	-43704	-6882.68	101.9	-79486.16	129970.94
989	151.5	155.25	89.25	132	-40558.73	-6881.26	149.94	-78377.71	125667.76
998	152	154.5	90	132.17	-40335.5	-6887.13	145	-77549.1	124626.73
1007	155.5	155.75	90.5	133.92	-40635.91	-6887.44	62.76	-76910.35	124370.94
1016	154.5	156.25	90.5	133.75	-40855.68	-6888.02	59.89	-76513.93	124197.74
1025	156.5	157.25	90.75	134.83	-40890.04	-6936.44	81.11	-76239.88	123985.25
1034	157.75	158	89.75	135.17	-40969.62	-6978.34	87.08	-76065.26	123926.14
1043	163.5	158.5	89.75	137.25	-41089.91	-7081.68	63.91	-77424.75	125532.43
1053	162.75	160.25	88.5	137.17	-41357.28	-7150.2	83.81	-77877.89	126301.56
1062	167.25	161.5	88	138.92	-41601.94	-7217.19	52.08	-78830.63	127597.68
1071	166.5	163.25	89	139.58	-41811.19	-7256.61	61.3	-79427.73	128434.23
1080	167.25	164	89.5	140.25	-41854.96	-7342.21	38.36	-80047.96	129206.77
1089	168.75	164.75	89.75	141.08	-42035.35	-7315.07	16.79	-81157.1	130490.73
1098	166.75	165.25	90	140.67	-42191.67	-7294.12	-8.48	-81967.47	131461.74
1107	168	164.75	91	141.25	-42431.93	-7289.92	-17.79	-82547.1	132286.74
1116	161.5	165	90.5	139	-42673.25	-7119.48	44.5	-81782.43	131530.66
1125	161.75	164	90	138.58	-42942.44	-7049.35	8.54	-81409.28	131392.53
1134	162.25	163.75	91	139	-43089.78	-7098.31	-18.77	-81937.94	132144.8
1143	158	163.25	90.75	137.33	-43704	-7017.45	26.35	-81276.88	131971.98
1152	160.75	162.25	91.25	138.08	-40558.73	-7145.35	21.78	-81107.42	128789.72
1161	157.75	162.25	91.5	137.17	-40335.5	-7104.1	75.17	-80781.48	128145.91
1170	160	161	91.25	137.42	-40635.91	-7072.91	40.58	-80636.74	128304.98
1179	155.75	160.5	92	136.08	-40855.68	-7041.16	90.37	-80295.91	128102.38
1188	155.25	160.5	91.75	135.83	-40890.04	-7066.52	251.61	-80252.16	127957.11
1197	153.5	160.75	93	135.75	-40969.62	-7024.64	299.45	-80008.75	127703.56
1206	156.75	160.75	92.75	136.75	-41089.91	-7036.15	273.87	-79988.57	127840.76
1215	152.75	161	93.25	135.67	-41357.28	-7106.06	299.43	-80370.71	128534.62
1224	157.25	161	93.75	137.33	-41601.94	-7080.59	281.78	-80412.32	128813.07
1233	155.5	160.25	93.5	136.42	-41811.19	-7096.24	253.58	-81101.07	129754.92
1242	155.5	160.75	94.5	136.92	-41854.96	-7035.51	307.33	-80654.53	129237.67
1251	150.5	160.25	94.25	135	-42035.35	-6984.28	283.61	-80464.33	129200.35
1260	142.75	159.25	94.75	132.25	-42191.67	-6956.59	324.18	-80032.64	128856.72
1269	147.25	159	94.5	133.58	-42431.93	-6956.48	315.23	-79831.58	128904.76
1278	145.5	160.25	94.5	133.42	-42673.25	-6969.26	347.54	-79553.75	128848.72
1287	151.5	159.75	95	135.42	-42942.44	-6952.92	306.62	-79466.43	129055.17
1296	145	160.25	95.5	133.58	-43089.78	-6931.28	329.45	-79192.3	128883.91
1305	153.75	160.75	95.5	136.67	-43704	-6952.45	292.26	-79171.35	129535.54
1314	152.5	160.75	93.25	135.5	-40558.73	-7187.53	264.24	-79975.28	127457.3
1323	156.5	160.25	93.5	136.75	-40335.5	-6963.71	269.45	-80108.67	127138.43
1332	157.75	161	94	137.58	-40635.91	-6995.08	200.8	-80548.73	127978.92
1341	151.25	161.25	95	135.83	-40855.68	-6947.26	233.24	-80103.54	127673.24
1350	153.75	160.5	94.5	136.25	-40890.04	-6875.51	195.13	-79733.1	127303.52
1359	148.5	160.5	94.5	134.5	-40969.62	-6892.5	253.28	-79940.39	127549.23

1368	153	160.5	95.5	136.33	-41089.91	-6867.12	268.15	-79797.06	127485.94
1377	152.5	160.75	96	136.42	-41357.28	-6875.62	258.72	-80352.93	128327.11
1386	148.75	160	96.5	135.08	-41601.94	-6821.42	233.99	-79798.6	127987.97
1395	151.25	170	103.75	141.67	-41811.19	-6782.12	220.21	-79052.08	127425.18
1404	147.75	170.25	105.75	141.25	-41854.96	-6765.2	271.22	-78713.46	127062.4
1413	154.25	169.25	103.5	142.33	-42035.35	-6789.74	201.57	-78444.56	127068.08
1422	150.5	164.25	94.75	136.5	-42191.67	-6762.31	218.22	-78392.4	127128.16
1432	154.75	165.25	97	139	-42431.93	-6792.28	224.43	-78301.02	127300.8
1441	154.25	167	110.75	144	-42673.25	-6820.84	254.75	-78684.32	127923.66
1450	153.5	165.75	106.5	141.92	-42942.44	-6760.55	263.91	-78823.39	128262.47
1459	154	166.5	108.5	143	-43089.78	-6775.36	180.59	-79127.2	128811.75
1468	150.5	165.75	103.25	139.83	-43704	-6732.55	176.79	-78721.32	128981.08
1477	152	166	105.75	141.25	-40558.73	-6693.25	147.76	-78338.87	125443.09
1486	150.25	164.75	104.25	139.75	-40335.5	-6711.55	159.02	-78811.7	125699.73
1495	150	164.5	105.25	139.92	-40635.91	-6717.21	120.31	-78808.62	126041.43
1504	151	165.5	106.25	140.92	-40855.68	-6713	115.03	-79297.99	126751.64
1513	148	164	102.5	138.17	-40890.04	-6648.04	95.06	-78732.41	126175.43
1522	149.75	163.25	101.75	138.25	-40969.62	-6629.74	52.46	-78258.57	125805.47
1531	146.75	165	106.5	139.42	-41089.91	-6593.23	45.1	-77876.85	125514.89
1540	149.5	164.25	105.5	139.75	-41357.28	-6616.12	6.39	-77581.29	125548.3
1549	146.5	164	102.5	137.67	-41601.94	-6644.01	-6.74	-78107.87	126360.56
1558	150	163.75	102.75	138.83	-41811.19	-6643.59	-81.11	-78220.47	126756.36
1567	149.5	163.25	103	138.58	-41854.96	-6656.63	-129.75	-78739.24	127380.58
1576	147	165	106.25	139.42	-42035.35	-6645.5	-143.32	-78261.14	127085.31
1585	149.25	164.25	106.5	140	-42191.67	-6614.6	-179.31	-77764.71	126750.29
1594	145.5	165.75	108.5	139.92	-42431.93	-6611.69	-191.72	-77362.42	126597.76
1603	148.5	165.5	108	140.67	-42673.25	-6631.5	-219.34	-77242.3	126766.39
1612	147.75	165.75	107.25	140.25	-42942.44	-6670.35	-245.07	-77641.77	127499.63
1621	151.25	166.5	109.75	142.5	-43089.78	-6717.97	-239.7	-77977.78	128025.23
1630	151.25	168	112	143.75	-43704	-6738	-260	-78676.56	129378.56
1639	146.75	165.25	104.25	138.75	-40558.73	-6764.76	-267.2	-78430.07	126020.76
1648	151	164.75	103.5	139.75	-40335.5	-6754.76	-268.6	-78242.53	125601.39
1657	149.75	166	106	140.58	-40635.91	-6772.48	-281.93	-78571.75	126262.07
1666	151.75	165.25	106	141	-40855.68	-6767.52	-289.99	-78519.97	126433.16
1675	150	165.75	107.75	141.17	-40890.04	-6748.2	-300.88	-79037.14	126976.26
1684	148.75	166.25	108.5	141.17	-40969.62	-6766.3	-320.57	-79466.28	127522.77
1693	146	167	109	140.67	-41089.91	-6723.58	-319.59	-78876.53	127009.61
1702	150	166.25	109.25	141.83	-41357.28	-6688.18	-333.79	-78383.58	126762.83
1711	149.75	166.25	109	141.67	-41601.94	-6697.64	-339.16	-78801.42	127440.16
1720	147.5	166.25	110	141.25	-41811.19	-6689.92	-357.48	-79177.41	128036
1729	143.25	165.5	108.25	139	-41854.96	-6654.1	-334.01	-78563.96	127407.03
1738	147.75	164.25	107.5	139.83	-42035.35	-6680.08	-344.5	-78067.68	127127.61
1747	147	164.25	107.5	139.58	-42191.67	-6666.94	-368.28	-78484.4	127711.29
1756	145.75	165	108.75	139.83	-42431.93	-6656.23	-374.94	-77917.36	127380.46
1765	147	164.75	108.5	140.08	-42673.25	-6648.09	-382.11	-77637.09	127340.54
1774	146.75	164.75	107.75	139.75	-42942.44	-6659.57	-399.83	-78126.64	128128.48
1784	145.75	166	111.5	141.08	-43089.78	-6640.47	-405.32	-78139.99	128275.56
1793	146.5	165.25	111	140.92	-43704	-6664.67	-420.79	-78357.18	129146.64

1802	143	165.75	110.25	139.67	-40558.73	-6616.03	-430.49	-78026.4	125631.65
1811	146.75	165	110.25	140.67	-40335.5	-6624.82	-436.13	-77587.11	124983.56
1820	144.75	164.75	110.25	139.92	-40635.91	-6612.42	-441.23	-77996.87	125686.43
1829	143.25	165.5	111	139.92	-40855.68	-6605.81	-420.61	-77486.77	125368.87
1838	144.25	163.75	109.75	139.25	-40890.04	-6617.72	-431.09	-77091.32	125030.17
1847	141.75	162	103.75	135.83	-40969.62	-6610.29	-429	-76676.32	124685.23
1856	144.75	162.25	103.25	136.75	-41089.91	-6619.68	-440.48	-76646.36	124796.43
1865	146	162.25	104	137.42	-41357.28	-6651.47	-434.36	-77333.13	125776.24
1874	142	163.5	105.5	137	-41601.94	-6627.25	-425.91	-77035.2	125690.3
1883	145	163	104.25	137.42	-41811.19	-6608.79	-426.51	-76796.42	125642.91
1892	145.75	163.75	104.25	137.92	-41854.96	-6604.16	-473.07	-77413.75	126345.94
1901	146.25	163.75	104.75	138.25	-42035.35	-6579.5	-503.2	-77910.96	127029.01
1910	171.75	168	106.75	148.83	-42191.67	-6583.15	-483.51	-78275.21	127533.54
1920	169	167.75	108.25	148.33	-42431.93	-6501.76	-465.41	-76434.03	125833.13
1925	171.5	168.75	111.75	150.67	-42673.25	-6495.08	-435.34	-76403.86	126007.53
1931	171	171.25	124.5	155.58	-42942.44	-6537.22	-405.82	-76756.71	126642.19
1936	172.25	171.25	117.5	153.67	-43089.78	-6512	-360.92	-77086	127048.7
1942	172.5	171.75	117.75	154	-43704	-6535.93	-368.93	-77477.65	128086.51
1947	173.5	172.25	119.25	155	-40558.73	-6544.43	-385.83	-77731.32	125220.31
1953	173	172.5	119.25	154.92	-40335.5	-6530.57	-365.39	-77958.11	125189.57
1958	172.5	172.5	119.75	154.92	-40635.91	-6529.76	-368.33	-78174.49	125708.49
1964	172.25	171.75	119.25	154.42	-40855.68	-6536.62	-359.05	-78329.83	126081.18
1969	171.25	171.5	118.5	153.75	-40890.04	-6502.32	-393.64	-78423.24	126209.24
1975	170.75	171.75	119	153.83	-40969.62	-6486.09	-406.09	-78515.58	126377.38
1980	169.5	170.75	119	153.08	-41089.91	-6473.17	-450.01	-78576.59	126589.68
1986	169.75	170.5	117	152.42	-41357.28	-6444.08	-440.65	-78615.32	126857.33
1992	168.75	171.25	121	153.67	-41601.94	-6411.91	-476.69	-78625.68	127116.22
1997	167.25	170.75	120.5	152.83	-41811.19	-6405.05	-508.11	-78624.17	127348.52
2003	167.25	170.25	120.75	152.75	-41854.96	-6379.59	-499.35	-78626.27	127360.17
2008	165.75	169.5	120.75	152	-42035.35	-6361.22	-504.69	-78597.1	127498.36
2014	164.75	169.75	122.5	152.33	-42191.67	-6335.33	-493.18	-78541.82	127562
2019	164	170.5	117	150.5	-42431.93	-6323.51	-492.42	-78508.78	127756.64
2025	163	166.75	117.25	149	-42673.25	-6321.57	-479.06	-78445.86	127919.74
2030	161.75	167	119.25	149.33	-42942.44	-6299.18	-457.83	-78365.5	128064.95
2036	160.5	167	122.25	149.92	-43089.78	-6292.41	-454.5	-78304.1	128140.79
2041	160	167.5	123.5	150.33	-43704	-6316.3	-444.12	-78248.44	128712.86
2047	158.5	166.5	123	149.33	-40558.73	-6284.22	-494.76	-78164.28	125501.99
2052	157.5	166	123	148.83	-40335.5	-6261.73	-512.5	-78052.93	125162.66
2058	156.5	165.5	123.75	148.58	-40635.91	-6259.42	-493.23	-77947	125335.56
2063	155.75	164.5	122.5	147.58	-40855.68	-6251.16	-475.54	-77869.25	125451.63
2069	155	164.25	122.75	147.33	-40890.04	-6241.56	-458.7	-77786.5	125376.8
2074	154.5	163	122.25	146.58	-40969.62	-6227.94	-445.44	-77652.37	125295.37
2080	152.75	162.75	121.5	145.67	-41089.91	-6224.98	-476.04	-77543.01	125333.94
2085	153	162	120.5	145.17	-41357.28	-6203.67	-490.59	-77413.32	125464.86
2091	151.75	161	121	144.58	-41601.94	-6207.24	-502.95	-77273.13	125585.26
2095	152.25	161.25	123	145.5	-41811.19	-6201.51	-514.03	-77221.11	125747.84
2105	150.5	160.5	121.25	144.08	-41854.96	-6217.88	-563.71	-76925.47	125562.02

2110	150.25	159.5	122.75	144.17	-42035.35	-6215.07	-567.6	-76859.12	125677.14
2119	148.25	159.75	122	143.33	-42191.67	-6235.69	-549.86	-76688.78	125666
2128	142.75	153.75	109.25	135.25	-42431.93	-6245.01	-561.86	-75542.19	124780.99
2137	142.25	151.75	104.75	132.92	-42673.25	-6285.6	-550.28	-75144.5	124653.63
2146	143	151.5	104.25	132.92	-42942.44	-6286.31	-554.35	-74502.96	124286.06
2155	145	152	105	134	-43089.78	-6288.38	-582.76	-73879.03	123839.95
2164	147	150.25	97.25	131.5	-43704	-6306.99	-638.34	-73207.32	123856.65
2173	151	152	98	133.67	-40558.73	-6313.31	-708.99	-72452.16	120033.19
2182	154	152.75	97.5	134.75	-40335.5	-6330.14	-679.73	-72723.88	120069.25
2191	158	155	97.75	136.92	-40635.91	-6333.77	-751.38	-72489.45	120210.51
2200	166.25	157.75	98	140.67	-40855.68	-6373.62	-610.81	-72654.26	120494.37
2209	168	161	98.75	142.58	-40890.04	-6414.54	-492.17	-73436.6	121233.35
2218	175.25	163.5	98.75	145.83	-40969.62	-6476.56	-506.91	-74304.17	122257.26
2228	178.5	166	99.5	148	-41089.91	-6540.89	-696.65	-75918.42	124245.87
2234	178.75	167.75	99	148.5	-41357.28	-6532.72	-754.06	-76527.81	125171.87
2239	178.75	168.25	100	149	-41601.94	-6528.18	-753.21	-77049.45	125932.78
2245	179.5	169	100.75	149.75	-41811.19	-6508.73	-754.65	-77497.85	126572.42
2250	179.75	170.25	101.5	150.5	-41854.96	-6512.22	-748.99	-77910.42	127026.59
2256	179.75	170	101.5	150.42	-42035.35	-6493.63	-694.58	-78233.71	127457.27
2261	179.25	170.5	102	150.58	-42191.67	-6525.62	-649.79	-78484.91	127851.99
2267	178.75	171	102	150.58	-42431.93	-6507.77	-576.99	-78715.58	128232.27
2272	179	170.5	101.75	150.42	-42673.25	-6482.97	-531.82	-78912.55	128600.59
2278	177.5	170.75	102.25	150.17	-42942.44	-6466.59	-533.17	-79106.84	129049.04
2283	176.25	170.5	102.5	149.75	-43089.78	-6475.93	-539.7	-79300.4	129405.81
2289	176.75	170.5	101.75	149.67	-43704	-6444.06	-563.89	-79444.39	130156.34
2294	174.5	170	102.25	148.92	-40558.73	-6455.83	-574.25	-79555.03	127143.84
2300	174	169.5	102.25	148.58	-40335.5	-6474.6	-633.71	-79656.01	127099.82
2305	173.5	168.5	102.5	148.17	-40635.91	-6481.3	-658.57	-79660.45	127436.23
2311	171.75	168.25	102.5	147.5	-40855.68	-6463	-597.6	-79673.58	127589.86
2316	171.25	167.75	102.5	147.17	-40890.04	-6451.51	-578.36	-79678.1	127598.01
2322	170	167	102.75	146.58	-40969.62	-6434.55	-550.81	-79694.39	127649.37
2327	168.5	166.5	102.5	145.83	-41089.91	-6418.79	-535.59	-79678.66	127722.95
2333	167	165.75	102.5	145.08	-41357.28	-6414.56	-531.4	-79655.21	127958.45
2338	167.25	165.5	102.5	145.08	-41601.94	-6386.18	-525	-79623.24	128136.36
2344	165	164.75	102.5	144.08	-41811.19	-6391.16	-521.98	-79575.15	128299.48
2348	164.25	164.5	102.25	143.67	-41854.96	-6380.99	-519.79	-79556.09	128311.83
2357	163.25	162.75	102	142.67	-42035.35	-6353.18	-593.21	-79482.89	128464.63
2366	161	161.75	102	141.58	-42191.67	-6310.17	-581.18	-79364.76	128447.78
2375	159	160.5	102	140.5	-42431.93	-6280.16	-551.39	-79227.31	128490.79
2384	159	159.5	101.75	140.08	-42673.25	-6244.68	-555.48	-79082.96	128556.37
2393	156	158.75	101.5	138.75	-42942.44	-6203.36	-545.92	-78898.78	128590.5
2402	154.75	157.25	101.5	137.83	-43089.78	-6173.06	-544.9	-78726.93	128534.67
2411	153.25	156.75	100.75	136.92	-43704	-6147.2	-582.53	-78510.29	128944.02
2420	151.5	155.25	101	135.92	-40558.73	-6105.99	-588.67	-78347.14	125600.53
2429	148	154.25	101.75	134.67	-40335.5	-6055.72	-612.65	-77270.39	124274.26
2438	145.5	153.75	101	133.42	-40635.91	-6015.69	-622.18	-75540.67	122814.45
2447	147.5	152.25	98.75	132.83	-40855.68	-6052.03	-613.28	-74068.85	121589.84
2457	148.25	153	98.5	133.25	-40890.04	-6063.89	-547.22	-73014.23	120515.38

2466	152	154.5	101	135.83	-40969.62	-6079.01	-495.98	-72363.03	119907.64
2475	118.5	148	98	121.5	-41089.91	-6126.27	-461.76	-71935.57	119613.51
2484	128.25	153	99.75	127	-41357.28	-6147.11	-481.38	-71686.39	119672.16
2493	137.25	154.75	99.25	130.42	-41601.94	-6169.75	-474.62	-72373.88	120620.19
2502	139.25	157.5	99.75	132.17	-41811.19	-6198	-485.47	-72705.91	121200.57
2511	144.75	159.5	98.75	134.33	-41854.96	-6214.54	-471.35	-73160.56	121701.41
2520	149	161.25	99.25	136.5	-42035.35	-6276.63	-464.88	-74290.6	123067.46
2529	150.25	163	99.75	137.67	-42191.67	-6353.25	-482.43	-75253.73	124281.08
2538	149.5	164.75	102	138.75	-42431.93	-6364.31	-496.25	-76018.4	125310.89
2547	150	167	105.25	140.75	-42673.25	-6394.08	-491.82	-76640.6	126199.75
2556	148.5	168	107.25	141.25	-42942.44	-6354.7	-509.76	-77118.82	126925.72
2565	148.25	168.25	107.25	141.25	-43089.78	-6376.49	-503.34	-77474.09	127443.7
2574	148	167.75	108	141.25	-43704	-6397.62	-488.14	-77756.78	128346.54
2583	146.5	167.5	107.5	140.5	-40558.73	-6362.67	-464.63	-77970.58	125356.61
2592	145.5	167.5	109.25	140.75	-40335.5	-6342.39	-462.92	-78109.07	125249.88
2601	141.75	166.5	109	139.08	-40635.91	-6319.7	-411.8	-78155.93	125523.34
2610	140	165	109.5	138.17	-40855.68	-6288.6	-461.79	-78195.28	125801.35
2619	139.25	163.25	107.75	136.75	-40890.04	-6275.85	-483.33	-78180.89	125830.11
2628	135.75	162	107	134.92	-40969.62	-6253.36	-500.8	-78139.77	125863.55
2637	134	160.5	106.25	133.58	-41089.91	-6190.63	-495.58	-77553.49	125329.61
2646	134	159.5	106.75	133.42	-41357.28	-6141.54	-530.59	-77295.41	125324.82
2655	127	157.75	102.25	129	-41601.94	-6107.75	-485.28	-76523.08	124718.05
2664	131.25	156.5	102.25	130	-41811.19	-6040.63	-500.83	-75769.14	124121.79
2673	129.5	155.75	100.75	128.67	-41854.96	-6004.07	-448.52	-74970.39	123277.94
2682	130.75	154.75	99	128.17	-42035.35	-5944.92	-455.61	-74748.71	123184.59
2691	133.25	155.75	100	129.67	-42191.67	-5959.31	-475.92	-74430.31	123057.21
2700	134.5	155.25	99.5	129.75	-42431.93	-5950.98	-460.8	-74223.45	123067.16
2709	132.25	156.5	100.5	129.75	-42673.25	-6069.21	-424.58	-73632.17	122799.21
2718	138	159.75	101.25	133	-42942.44	-6006.21	-434.12	-73550.25	122933.02
2727	135.5	156.75	91.5	127.92	-43089.78	-6046.88	-392.86	-73476.56	123006.08
2736	140.75	157	90.5	129.42	-43704	-6026.4	-408.43	-73476.99	123615.82
2745	142.75	162	99.25	134.67	-40558.73	-6105.48	-378.66	-73857.74	120900.61
2754	141.75	158.5	93	131.08	-40335.5	-6110.31	-348.09	-70001.65	116795.55
2763	144.5	161.5	99	135	-40635.91	-6083.41	-323.58	-69899.66	116942.56
2772	140.5	161.75	99.75	134	-40855.68	-6099.22	-325.41	-70545.28	117825.59
2781	143.75	163.75	101.5	136.33	-40890.04	-6115.03	-328.57	-71095.62	118429.26
2790	142	164.5	103	136.5	-40969.62	-6108.26	-371.97	-71531.21	118981.06
2799	143.25	164.5	102	136.58	-41089.91	-6141.25	-366.06	-71890.12	119487.34
2809	143	163.5	100.75	135.75	-41357.28	-6132.86	-387.07	-70037.22	117914.43
2818	132.25	162.5	100.25	131.67	-41601.94	-6128.38	-398.2	-70206.12	118334.64
2827	140.25	163.25	101.25	134.92	-41811.19	-6161	-400.55	-70370.02	118742.76
2836	139	162.25	101	134.08	-41854.96	-6116.87	-424.96	-69949.85	118346.64
2845	136.75	162.25	101.25	133.42	-42035.35	-6112.33	-445.87	-69978.39	118571.94
2854	134.25	156.25	88.25	126.25	-42191.67	-6071.02	-473.89	-76342.99	125079.57
2863	135	155	87	125.67	-42431.93	-6046.77	-475.34	-76170.05	125124.09
2872	121.25	153.75	86.75	120.58	-42673.25	-6003.21	-476.22	-75572.31	124724.99
2881	133.25	154.25	87	124.83	-42942.44	-5923.29	-454.78	-74942.06	124262.57

2890	129	153.75	87.5	123.42	-43089.78	-5910.71	-445.69	-74380.78	123826.96
2899	132.25	153.75	87	124.33	-43704	-5910.46	-453.35	-73969.3	124037.11
2908	131.5	154	87.25	124.25	-40558.73	-5926.89	-463.39	-73646.04	120595.05
2917	134	153.5	86.25	124.58	-40335.5	-5921.33	-463.37	-73408.14	120128.34
2926	134	154.5	87	125.17	-40635.91	-5921.17	-459.62	-73896.92	120913.62
2935	135	155.75	86.75	125.83	-40855.68	-5931.03	-441.7	-73748.44	120976.85
2944	136.5	155.5	86.75	126.25	-40890.04	-5912.76	-436.56	-73535.39	120774.75
2953	136.75	155.5	86.5	126.25	-40969.62	-5924.38	-436.88	-74086.32	121417.2
2962	138	156.5	86.5	127	-41089.91	-5928.14	-455.28	-74536.96	122010.29
2971	134.75	156.75	86.75	126.08	-41357.28	-5936.4	-430.1	-74887.14	122610.92
2980	134.5	156.5	86	125.67	-41601.94	-5936.15	-435.91	-75180.89	123154.89
2989	135	157	86.5	126.17	-41811.19	-5946.48	-446.09	-75397.46	123601.22
2998	135.5	156.25	86.5	126.08	-41854.96	-5944.32	-447.14	-75555.11	123801.53
3007	132.75	155.5	86.5	124.92	-42035.35	-5937.09	-444.44	-75644.24	124061.12
3016	132.25	155.75	86.75	124.92	-42191.67	-5916.94	-449.36	-74909.84	123467.81
3025	132	155	86	124.33	-42431.93	-5858.15	-442.88	-74271.72	123004.68
3034	127.75	154.5	86.5	122.92	-42673.25	-5860.49	-444.65	-73948.01	122926.4
3043	130.75	153.75	85.75	123.42	-42942.44	-5876.83	-439.45	-73576.03	122834.75
3052	130.5	153.75	85.25	123.17	-43089.78	-5876.78	-441.85	-73897.8	123306.21
3061	132	153.5	86.25	123.92	-43704	-5891.56	-439.36	-73967.39	124002.31
3070	131	154	85.75	123.58	-40558.73	-5881.23	-398.58	-74120.32	120958.86
3079	129	159	112.75	133.58	-40335.5	-5899.33	-440.38	-73680.84	120356.05
3088	133	159.5	108.75	133.75	-40635.91	-5973.6	-443.4	-73226.08	120278.99
3097	129.25	154.25	93.75	125.75	-40855.68	-5967.23	-416.57	-73417.31	120656.79
3106	133.75	155.75	98.75	129.42	-40890.04	-5947.02	-401.1	-73373.26	120611.42
3115	131.5	156.75	99	129.08	-40969.62	-5965.69	-361.99	-73751.73	121049.03
3124	132	157.5	100	129.83	-41089.91	-5947.95	-349.37	-73400.49	120787.72
3133	133.25	156.75	99.25	129.75	-41357.28	-5929.59	-295.76	-73068.5	120651.13
3142	134.75	160.5	101	132.08	-41601.94	-5948.15	-341.4	-73475.87	121367.36
3151	130.75	160	111.75	134.17	-41811.19	-5940.25	-367.95	-73141.15	121260.54
3161	135	160	113	136	-41854.96	-5897.13	-399.9	-72867.65	121019.64
3170	136.75	159.75	111	135.83	-42035.35	-5892.19	-404.27	-73290.09	121621.9
3179	136.25	159.75	111.25	135.75	-42191.67	-5890.54	-396.15	-73744.21	122222.57
3188	136.25	162.75	117.5	138.83	-42431.93	-5991.03	-328.42	-74040.54	122791.92
3197	132.75	157.25	105.5	131.83	-42673.25	-5948.75	-320.87	-73607.16	122550.03
3206	135.75	157.25	106	133	-42942.44	-5909.8	-302.15	-73185.31	122339.7
3215	138	157.5	106.75	134.08	-43089.78	-5920.15	-311.56	-73527.94	122849.43
3224	135.75	157.75	108.5	134	-43704	-5950.6	-332.34	-73873.79	123860.73
3233	132.5	157.5	106.25	132.08	-40558.73	-5912.91	-402.04	-73433.26	120306.94
3242	135.5	157.25	106	132.92	-40335.5	-5873.35	-420.61	-73048.12	119677.58
3251	135.25	157.5	107	133.25	-40635.91	-5860.4	-391.86	-73386.92	120275.09
3260	134.5	157.75	107.5	133.25	-40855.68	-5899.98	-375.09	-73709.15	120839.9
3269	137.5	157.75	108.25	134.5	-40890.04	-5893.23	-366.43	-73966.35	121116.05
3278	133	156.5	103.25	130.92	-40969.62	-5900.38	-358.47	-73505.91	120734.38
3287	135.25	156	103.5	131.58	-41089.91	-5880.08	-370.82	-73058.64	120399.45
3296	135	155.75	103.5	131.42	-41357.28	-5903.47	-373.12	-73389.1	121022.97
3305	133.75	157	104.75	131.83	-41601.94	-5884.77	-364.56	-73022.23	120873.5
3314	135.25	156.5	105	132.25	-41811.19	-5906.52	-379.18	-72707.5	120804.39

3323	136	156.5	106	132.83	-41854.96	-5913.87	-411.36	-73062.36	121242.55
3332	135.25	157.5	106.25	133	-42035.35	-5918.97	-434.77	-73380.46	121769.55
3341	138.25	158	107.25	134.5	-42191.67	-5926.22	-444.39	-73670.95	122233.23
3350	136.25	157.75	108	134	-42431.93	-5926.49	-455.05	-73867.15	122680.62
3359	133.5	157.25	105	131.92	-42673.25	-5921.75	-453.5	-73341.42	122389.92
3368	136.25	156.25	104.75	132.42	-42942.44	-5882.01	-438.19	-72859.07	122121.71
3377	134.75	156	105.25	132	-43089.78	-5879.01	-434.76	-73133.68	122537.23
3386	133	157.75	108.25	133	-43704	-5868.41	-429.95	-72747.5	122749.86
3395	132.5	157	107.5	132.33	-40558.73	-5874.49	-426.88	-72369.86	119229.96
3404	132.5	156.75	104.5	131.25	-40335.5	-5926.47	-388.44	-72724.83	119375.24
3413	137	156.5	104.75	132.75	-40635.91	-5887.64	-349.42	-72863.72	119736.69
3422	135	156.5	104.75	132.08	-40855.68	-5878.83	-367.21	-73160.96	120262.68
3431	133	157.25	106	132.08	-40890.04	-5865.72	-392.52	-73394.13	120542.41
3440	136.25	157.25	106	133.17	-40969.62	-5851.49	-390.49	-73327.92	120539.52
3449	131.75	156.5	106.5	131.58	-41089.91	-5847.2	-383.61	-73502.75	120823.47
3458	130	156.25	106	130.75	-41357.28	-5840.47	-368.91	-72994.48	120561.14
3467	134.5	156	105.5	132	-41601.94	-5805.88	-361.12	-72509.89	120278.83
3476	131.75	155.75	106.25	131.25	-41811.19	-5829.59	-370.17	-72164.14	120175.09
3485	136.5	155.5	105.5	132.5	-41854.96	-5835.44	-369.5	-71838.17	119898.07
3494	136.25	156.5	105.75	132.83	-42035.35	-5840.69	-363.72	-72246.95	120486.71
3504	137.5	156	105.25	132.92	-42191.67	-5842.05	-369.85	-72377.28	120780.85
3513	136.5	156.5	105	132.67	-42431.93	-5844.66	-381.65	-72587.14	121245.38
3522	138.25	157	105.75	133.67	-42673.25	-5845.04	-370.83	-72877.62	121766.74
3531	134.75	158.25	109.5	134.17	-42942.44	-5832.44	-376.34	-72503.43	121654.65
3540	139	158.25	109.5	135.58	-43089.78	-5807.95	-390.14	-72143.73	121431.6
3549	137.75	158.75	110.25	135.58	-43704	-5817.45	-390.27	-72435.84	122347.56
3558	138.25	158.75	111.5	136.17	-40558.73	-5819.21	-386.67	-72755.93	119520.54
3567	134.75	156	101.75	130.83	-40335.5	-5820.75	-399.35	-72343.17	118898.77
3576	138.25	155.25	102	131.83	-40635.91	-5792.34	-444.4	-71971.88	118844.53
3585	139	154.75	102	131.92	-40855.68	-5792.12	-496.15	-72242.78	119386.73
3594	135	154.75	101.5	130.42	-40890.04	-5770.37	-517.52	-71887.46	119065.39
3603	137.75	155	101.25	131.33	-40969.62	-5792.08	-503.35	-71557	118822.05
3612	138.25	155.5	101.5	131.75	-41089.91	-5808.97	-497.45	-71939.14	119335.47
3621	140	155.5	102	132.5	-41357.28	-5812.4	-441.77	-71745.57	119357.02
3630	138.75	155.5	101.75	132	-41601.94	-5835.04	-374.62	-71687.11	119498.71
3639	139.5	157.25	104.75	133.83	-41811.19	-5838.98	-396.23	-72110.67	120157.07
3648	139	158.75	107.75	135.17	-41854.96	-5839.63	-370.55	-72466.59	120531.73
3657	137.5	158.75	106.5	134.25	-42035.35	-5827.98	-356.93	-72154.66	120374.92
3666	140.5	158.25	106.5	135.08	-42191.67	-5795.33	-384.32	-71857.6	120228.92
3675	141.25	159	108	136.08	-42431.93	-5794.46	-424.86	-72232.09	120883.34
3684	140	160.25	111.5	137.25	-42673.25	-5822.33	-467.45	-72596.63	121559.66
3693	140	160.5	111.5	137.33	-42942.44	-5815.41	-492.76	-72855.99	122106.6
3702	135.75	158	105.75	133.17	-43089.78	-5806.26	-487.07	-72379.03	121762.14
3711	138.5	158.25	105.25	134	-43704	-5767.72	-464.91	-71969.12	121905.75
3720	138.25	157.75	105	133.67	-40558.73	-5760.29	-449.71	-72304.31	119073.04
3729	139	157.75	104.5	133.75	-40335.5	-5750.11	-435.69	-72584.25	119105.55
3738	137.5	157.5	103.5	132.83	-40635.91	-5746.42	-414.92	-72103.17	118900.42

3747	136.75	156.5	103.5	132.25	-40855.68	-5730.28	-395.68	-71720.64	118702.28
3756	138.5	156.75	103	132.75	-40890.04	-5734.46	-375.29	-72064.76	119064.55
3765	139.25	157	103.25	133.17	-40969.62	-5738.31	-371.9	-72360.03	119439.86
3774	135.75	157.5	104.5	132.58	-41089.91	-5740.29	-392.32	-72066.3	119288.82
3783	138.5	156.75	103.75	133	-41357.28	-5727.14	-396.65	-71691.36	119172.43
3792	138.75	156.75	103.5	133	-41601.94	-5738.27	-394.86	-72009.92	119744.99
3801	134.75	157	104.5	132.08	-41811.19	-5728.16	-404.86	-71743.65	119687.86
3810	139.5	156.5	103.75	133.25	-41854.96	-5810.71	-409.69	-70897.19	118972.55
3819	137	157.25	104	132.75	-42035.35	-5806.75	-389.44	-71028.79	119260.33
3828	140.25	157.75	103.5	133.83	-42191.67	-5826.47	-338.29	-70863.06	119219.49
3837	142	158.5	104	134.83	-42431.93	-5828.36	-347.29	-71182.07	119789.65
3846	138	159.5	103.5	133.67	-42673.25	-5840.45	-354.21	-71099.42	119967.33
3856	143.5	159.75	103.75	135.67	-42942.44	-5818.97	-357.8	-71060.85	120180.06
3865	142.5	160.5	104.5	135.83	-43089.78	-5832.97	-356.32	-71642.64	120921.71
3874	144.75	161.75	105	137.17	-43704	-5850.36	-353.33	-72169.07	122076.76
3883	145.75	162	106.5	138.08	-40558.73	-5863.31	-365.93	-72612.47	119400.44
3892	145.5	162.25	107.25	138.33	-40335.5	-5892.36	-376.94	-72959.15	119563.95
3901	144.25	162.25	108	138.17	-40635.91	-5904.54	-377.76	-73213.85	120132.06
3910	143.5	162.75	108.75	138.33	-40855.68	-5906.48	-391.32	-73415.71	120569.19
3919	142	161.75	109.25	137.67	-40890.04	-5929.65	-398.77	-73559.47	120777.93
3928	136.75	160	103.75	133.5	-40969.62	-5910.44	-405.14	-73461.3	120746.5
3937	139	159	103.75	133.92	-41089.91	-5888.78	-415.63	-73114.1	120508.42
3946	136.75	158.25	103.5	132.83	-41357.28	-5888.74	-424.71	-73184.72	120855.45
3955	133.5	158	103.5	131.67	-41601.94	-5853.07	-426.68	-72584.88	120466.57
3964	138.25	156.75	103.75	132.92	-41811.19	-5816.76	-429.02	-71996.89	120053.86
3973	133	157.75	105.5	132.08	-41854.96	-5807.37	-419.14	-71645.25	119726.72
3982	137.75	157	105	133.25	-42035.35	-5760.4	-398.88	-71253.81	119448.44
3991	134.75	157	105	132.25	-42191.67	-5756.75	-389.02	-71018.42	119355.86
4000	137.25	157.5	104.5	133.08	-42431.93	-5760.89	-413.83	-70825.84	119432.49
4009	137.75	158.5	104.75	133.67	-42673.25	-5763.85	-413.28	-70630.63	119481.01
4018	141.5	158.5	104	134.67	-42942.44	-5764.47	-417.9	-70514.33	119639.14
4027	142.75	159.25	104.5	135.5	-43089.78	-5766.96	-409.66	-71065.96	120332.36
4036	140	160.25	104.75	135	-43704	-5797.73	-399.05	-71040.83	120941.61
4045	143.25	160.5	104.5	136.08	-40558.73	-5767.32	-392.67	-70913.21	117631.93
4054	144.25	161	104.75	136.67	-40335.5	-5787.76	-377.81	-71438.82	117939.89
4063	146	161.5	104.75	137.42	-40635.91	-5801.29	-372.99	-71942.99	118753.18
4072	144	161.75	105	136.92	-40855.68	-5827.89	-366.69	-72357.96	119408.22
4081	144	161.75	105	136.92	-40890.04	-5827.56	-378.46	-72659.87	119755.93
4090	170.25	165.25	105.75	147.08	-40969.62	-5814	-379.24	-72903.96	120066.82
4100	169.25	166.5	110.5	148.75	-41089.91	-5811.24	-376.72	-73123.79	120401.66
4106	167.75	165.75	110.5	148	-41357.28	-5818.88	-387.34	-73204.55	120768.05
4111	166.75	165.5	110	147.42	-41601.94	-5823.62	-375.04	-73258.17	121058.77
4117	166	164.5	110.5	147	-41811.19	-5829.05	-367.81	-73302.98	121311.03
4122	165.25	164.75	109.75	146.58	-41854.96	-5833.15	-369.53	-73321.96	121379.6
4128	164.5	164.5	111.5	146.83	-42035.35	-5826.69	-360.47	-73359.23	121581.74
4133	163.25	164.25	111.25	146.25	-42191.67	-5801.25	-353.83	-73352.67	121699.42
4139	162.5	163.25	111.75	145.83	-42431.93	-5780.7	-350.48	-73340.57	121903.68
4144	161.75	163.25	111.75	145.58	-42673.25	-5773.17	-352.96	-73324.19	122123.57

4150	161	162.5	111.75	145.08	-42942.44	-5770.59	-356.88	-73308.62	122378.53
4155	159.25	161.75	111	144	-43089.78	-5762.04	-363.12	-73274.62	122489.56
4160	158.5	161	111	143.5	-43704	-5759.28	-368.16	-73255.08	123086.52
4169	157.25	160.5	109.75	142.5	-40558.73	-5751.74	-344.97	-73168.82	119824.26
4178	156	158.75	109.5	141.42	-40335.5	-5727.98	-321.56	-73062.82	119447.86
4187	155	159	110.75	141.58	-40635.91	-5707.86	-309.94	-72942.59	119596.3
4196	152.75	157.75	110.25	140.25	-40855.68	-5676.65	-297.78	-72812.23	119642.34
4205	152.5	157.25	112.25	140.67	-40890.04	-5650.4	-285.25	-72640.01	119465.7
4214	151.25	156.25	111.75	139.75	-40969.62	-5622.2	-257.28	-72488.52	119337.62
4223	148	155.75	112.75	138.83	-41089.91	-5587.36	-276.56	-72335.46	119289.29
4232	148.5	155.25	118	140.58	-41357.28	-5314.76	-169.21	-70569.81	117411.06
4241	146.75	153.75	116	138.83	-41601.94	-5397.86	-181.04	-70834.42	118015.26
4250	141.75	150.75	109	133.83	-41811.19	-5421.37	-179.41	-70093.31	117505.28
4259	141.25	150	108.25	133.17	-41854.96	-5450.98	-184.43	-68739.24	116229.61
4268	142.25	149.5	107.75	133.17	-42035.35	-5503.54	-187.44	-68141.76	115868.09
4277	145.75	150	107.75	134.5	-42191.67	-5528.12	-201.33	-68280.07	116201.19
4286	147.75	150	104.75	134.17	-42431.93	-5543.17	-200.28	-67881.05	116056.43
4295	151	151.5	104.25	135.58	-42673.25	-5527.92	-199.98	-67735.35	116136.5
4304	155.5	153.5	104.5	137.83	-42942.44	-5570.19	-217.17	-67453.78	116183.58
4313	163.5	155.5	104.75	141.25	-43089.78	-5584.51	-222.91	-67852.53	116749.73
4322	163.75	158.25	104.25	142.08	-43704	-5612.02	-219.02	-68303.51	117838.55
4331	171.25	160.5	103.75	145.17	-40558.73	-5624.35	-204.2	-68778.82	115166.1
4341	174.5	162.75	104.25	147.17	-40335.5	-5712.53	-195.06	-70098.92	116342.01
4347	175.5	163.75	104.25	147.83	-40635.91	-5744.37	-231.8	-70620.53	117232.61
4352	176.25	164.75	107.25	149.42	-40855.68	-5715.2	-284.2	-71083.6	117938.68
4358	178.25	166	107.5	150.58	-40890.04	-5728.41	-268.33	-71451.76	118338.54
4363	178	166.75	106.25	150.33	-40969.62	-5777.14	-231.45	-71904.53	118882.74
4369	176	167	105.75	149.58	-41089.91	-5712.53	-306.11	-72207.64	119316.19
4374	177.25	167.25	106.5	150.33	-41357.28	-5702.34	-363.11	-72482.75	119905.48
4380	176.75	166.5	103.75	149	-41601.94	-5720.81	-381.66	-72665.88	120370.29
4385	176.25	166	104.25	148.83	-41811.19	-5697.37	-349.86	-72828.02	120686.44
4391	175.5	165.75	105	148.75	-41854.96	-5679.03	-380.56	-72988.6	120903.15
4396	174.25	166.25	106	148.83	-42035.35	-5664.76	-426.3	-73086.26	121212.67
4402	174	165.75	106.5	148.75	-42191.67	-5666.36	-435.21	-73178.96	121472.2
4407	173	165.75	106.75	148.5	-42431.93	-5688.76	-398.7	-73291.5	121810.89
4413	172.5	165.75	106.5	148.25	-42673.25	-5672.08	-366.21	-73368.27	122079.81
4418	171.75	165.5	106	147.75	-42942.44	-5681.39	-342.27	-73406.52	122372.62
4424	170.25	164.5	106.5	147.08	-43089.78	-5674.4	-309.49	-73452.26	122525.93
4429	168.25	164.25	106.5	146.33	-43704	-5672.22	-249.77	-73470.24	123096.23
4435	168.25	163.25	106.25	145.92	-40558.73	-5658.7	-230.05	-73474.51	119921.99
4440	167.75	163	106.5	145.75	-40335.5	-5583.84	-239.51	-73520.66	119679.51
4446	166.25	162.75	106.5	145.17	-40635.91	-5573.95	-269.45	-73523.08	120002.39
4452	165	162	106.25	144.42	-40855.68	-5573.4	-286.43	-73508.06	120223.57
4456	164	161.5	106.5	144	-40890.04	-5574.11	-280.54	-73506.04	120250.73
4465	161.75	160.5	106.75	143	-40969.62	-5584.11	-278.52	-73483.74	120315.99
4474	159.25	159.5	106	141.58	-41089.91	-5541.16	-310.38	-73451.44	120392.89
4483	157.5	158.25	106.25	140.67	-41357.28	-5530.25	-323.03	-73372.15	120582.71

4492	155.75	157.25	106.5	139.83	-41601.94	-5508.37	-329.62	-73274.75	120714.68
4501	150.75	156.25	106.5	137.83	-41811.19	-5485.37	-290.01	-72449.55	120036.12
4510	151.75	155.25	105.75	137.58	-41854.96	-5424.09	-305.59	-71215.32	118799.96
4519	150.75	154.75	105.5	137	-42035.35	-5409.39	-316.19	-70192.67	117953.6
4528	152.25	154.75	105.25	137.42	-42191.67	-5440.56	-271.77	-69439.27	117343.27
4537	158.75	156	104.75	139.83	-42431.93	-5449.84	-251.31	-69436.92	117570
4546	156.75	156.5	105.25	139.5	-42673.25	-5454.34	-229.12	-69523.96	117880.67
4555	163.75	158	105.25	142.33	-42942.44	-5458.75	-258.23	-69615.1	118274.52
4564	161	159	104.75	141.58	-43089.78	-5460.22	-241.72	-69662.34	118454.06
4573	167.75	160.5	104.25	144.17	-43704	-5448.93	-363.91	-69781.96	119298.8
4582	170.5	162	104.25	145.58	-40558.73	-5468.45	-426.43	-70455.16	116908.77
4592	171.75	163	105.25	146.67	-40335.5	-5498.15	-422.71	-71208.8	117465.16
4598	172	163.5	105.25	146.92	-40635.91	-5536.02	-381.83	-71519.65	118073.41
4603	172.5	164	105.5	147.33	-40855.68	-5537.51	-354.26	-71771.19	118518.64
4609	173	164.5	105.25	147.58	-40890.04	-5567.88	-333.81	-72003.83	118795.56
4614	172.25	165	105.5	147.58	-40969.62	-5564.38	-319.22	-72220.02	119073.24
4620	172.25	164.25	105.5	147.33	-41089.91	-5592.68	-289.24	-72397.82	119369.65
4625	170.25	164	105.5	146.58	-41357.28	-5579.9	-294.19	-72561.52	119792.89
4631	170.25	164.25	105.5	146.67	-41601.94	-5582.99	-304.51	-72673.26	120162.7
4636	170.5	163.5	105.5	146.5	-41811.19	-5596.97	-314.43	-72773.03	120495.62
4642	168.5	163.75	105.25	145.83	-41854.96	-5585.51	-332.07	-72866.17	120638.71
4647	167.25	163.75	105.75	145.58	-42035.35	-5525.73	-325.45	-72951.71	120838.24
4653	167.25	163	105.5	145.25	-42191.67	-5523.02	-274.19	-73012.79	121001.67
4658	165.25	162.5	105.5	144.42	-42431.93	-5532.72	-267.36	-73062.98	121294.99
4663	164.75	162.25	105.5	144.17	-42673.25	-5534.06	-271.42	-73081.69	121560.42
4672	163.75	161.75	105.75	143.75	-42942.44	-5523.95	-269.88	-73134.75	121871.02
4681	161.5	160.25	105.5	142.42	-43089.78	-5527.56	-272.77	-73132.01	122022.12
4690	157.25	159.5	105.75	140.83	-43704	-5495.88	-309.78	-72570.26	122079.92
4699	160	158.5	105.75	141.42	-40558.73	-5448.8	-307.04	-71629	117943.57
4708	155.25	157.75	104.75	139.25	-40335.5	-5434.93	-281.18	-70967.15	117018.76
4717	160.25	157.5	104.75	140.83	-40635.91	-5415.14	-245.52	-70069.12	116365.69
4726	157.5	158.25	105.5	140.42	-40855.68	-5421.19	-226.66	-69920.79	116424.32
4735	164.25	158.75	104.5	142.5	-40890.04	-5423.51	-260.99	-69515.98	116090.52
4744	165.5	159.5	104.75	143.25	-40969.62	-5421.71	-221.84	-69783.02	116396.19
4753	167.5	160.25	104.25	144	-41089.91	-5435.4	-232.52	-69804.5	116562.33
4762	169.75	161.5	104	145.08	-41357.28	-5445.35	-222.18	-70081.08	117105.89
4772	171.25	163.25	104.75	146.42	-41601.94	-5463.96	-262.71	-70878.47	118207.08
4778	171	163.5	104.75	146.42	-41811.19	-5494.86	-248.79	-71223.35	118778.19
4783	172.5	164.25	104.5	147.08	-41854.96	-5523.24	-238.23	-71524.89	119141.32
4789	172.25	164.5	105	147.25	-42035.35	-5515.07	-237.89	-71807.6	119595.91
4794	171.75	164.5	105	147.08	-42191.67	-5529.39	-250.28	-72045.62	120016.96
4800	172.25	164.25	104.75	147.08	-42431.93	-5548.98	-279.29	-72253.22	120513.42
4805	170.75	164.75	105.25	146.92	-42673.25	-5561.13	-273.7	-72421.57	120929.65
4811	170.5	164.75	105.25	146.83	-42942.44	-5574.09	-274.6	-72566.3	121357.43
4816	169.75	164.5	105.75	146.67	-43089.78	-5575.18	-286.58	-72694.37	121645.91
4822	169.25	164.25	105.75	146.42	-43704	-5571.64	-313.87	-72785.81	122375.32
4827	168.75	163.75	105.25	145.92	-40558.73	-5565.07	-314.77	-72857.71	119296.28
4833	167	163.75	106	145.58	-40335.5	-5568.01	-303.67	-72906.49	119113.67

4838	166.75	163.25	105.75	145.25	-40635.91	-5557.35	-305.14	-72942.57	119440.97
4844	166.5	162.75	105.25	144.83	-40855.68	-5544.92	-293.88	-72968.56	119663.04
4848	165.25	162.5	105.5	144.42	-40890.04	-5557.66	-293.64	-72982.09	119723.43
4857	163.75	161.5	106	143.75	-40969.62	-5510.71	-305.71	-72944.45	119730.49
4866	161.75	161.5	107.25	143.5	-41089.91	-5488.96	-315.94	-72899.87	119794.68
4876	158.25	159.75	106.25	141.42	-41357.28	-5480.97	-319.44	-72966.14	120123.83
4885	159.75	158.75	106	141.5	-41601.94	-5435	-308.99	-72276.14	119622.07
4894	155.75	157.5	105	139.42	-41811.19	-5412.13	-320.74	-72079.99	119624.05
4903	158.25	156.5	105.25	140	-41854.96	-5355.92	-318.89	-71156.89	118686.66
4912	153.75	156	104	137.92	-42035.35	-5355.7	-297.3	-70722.01	118410.36
4921	159	156	104.25	139.75	-42191.67	-5341.16	-271.53	-70214.12	118018.48
4930	160.25	156.5	103.5	140.08	-42431.93	-5314.89	-273.74	-70094.77	118115.33
4939	161	157	104.5	140.83	-42673.25	-5324.18	-270.42	-69899.18	118167.03
4948	162	157.25	104	141.08	-42942.44	-5312.76	-250.86	-69923.9	118429.96
4957	159.25	158.5	104.5	140.75	-43089.78	-5340.78	-202.04	-69975.57	118608.17
4966	165	159	104.25	142.75	-43704	-5306.72	-178.44	-69890.2	119079.36
4975	166.75	160	104	143.58	-40558.73	-5309.33	-160.52	-70389.18	116417.76
4984	167	160.75	104.5	144.08	-40335.5	-5323.78	-149.17	-70843.54	116651.99
4993	167.25	161	104.75	144.33	-40635.91	-5343.45	-141.28	-71231.85	117352.49
5002	167.75	161.75	104.75	144.75	-40855.68	-5363.98	-165.86	-71532.17	117917.69
5011	167.5	161.5	105	144.67	-40890.04	-5384.51	-191.39	-71758.51	118224.45
5020	166.25	160.75	105	144	-40969.62	-5413.74	-211.06	-71935.81	118530.23
5029	164.25	160.75	105.25	143.42	-41089.91	-5405.16	-207.49	-72050.03	118752.59
5038	159.25	160	104.5	141.25	-41357.28	-5408.04	-231.97	-71463.29	118460.58
5047	162.75	159	103.75	141.83	-41601.94	-5369.23	-220.62	-70943.17	118134.96
5056	159.25	159.25	104	140.83	-41811.19	-5394.68	-192.17	-71280.97	118679.01
5065	162	158.75	103.75	141.5	-41854.96	-5359.71	-192.81	-71235.71	118643.19
5074	161.5	158.5	103.75	141.25	-42035.35	-5370.19	-192.61	-71396.04	118994.19
5083	157.75	158	104	139.92	-42191.67	-5370.01	-208.21	-70862.34	118632.23
5092	162.25	158.25	103.75	141.42	-42431.93	-5329.14	-208.54	-70471.75	118441.36
5101	157.75	158.25	103.5	139.83	-42673.25	-5309.35	-201.07	-70315.66	118499.33
5110	162	158	103.5	141.17	-42942.44	-5298.35	-174.57	-70036.82	118452.18
5119	163	157.75	103.75	141.5	-43089.78	-5307.59	-196.05	-70416.03	119009.45
5128	163.5	159	104	142.17	-43704	-5323.93	-211	-70233.71	119472.64
5137	164	159.5	104.25	142.58	-40558.73	-5290.41	-225.25	-70141.39	116215.78
5146	164.75	159.75	104.25	142.92	-40335.5	-5312.31	-219.72	-70526.53	116394.06
5155	165.75	160.25	104.25	143.42	-40635.91	-5333.84	-206.41	-70880.46	117056.62
5164	165.25	160.5	104.25	143.33	-40855.68	-5323.35	-208.13	-71190.86	117578.02
5173	165	160.25	104	143.08	-40890.04	-5343.34	-213	-71414.14	117860.52
5182	163.75	160	104.25	142.67	-40969.62	-5350.18	-253.15	-71593.78	118166.73
5191	158	159.75	104.25	140.67	-41089.91	-5341.32	-300.37	-71169.94	117901.54
5200	162.5	159	104	141.83	-41357.28	-5289.6	-344.1	-70669.7	117660.68
5209	158.25	158.5	104.5	140.42	-41601.94	-5281.23	-343.8	-70647.82	117874.79
5219	162.5	158.75	104.5	141.92	-41811.19	-5254.9	-324.91	-70426.16	117817.16
5228	162.5	159.5	105.25	142.42	-41854.96	-5252.83	-273.4	-70676.59	118057.78
5237	162.25	158.25	103.75	141.42	-42035.35	-5260.04	-293.38	-70202.5	117791.27
5246	162.25	158.5	103.25	141.33	-42191.67	-5228.05	-386.65	-70036.77	117843.14

5255	159	158.75	104	140.58	-42431.93	-5242.16	-331.22	-69932.86	117938.17
5264	163.25	158.75	104	142	-42673.25	-5246.15	-368.53	-69701.52	117989.45
5273	160	159	103.25	140.75	-42942.44	-5274.93	-277.02	-69829	118323.39
5282	164.5	159	103	142.17	-43089.78	-5272.71	-230.04	-69798.89	118391.42
5291	165.5	159.75	103.25	142.83	-43704	-5287.96	-235.84	-70137.4	119365.2
5300	161.75	160.5	103.25	141.83	-40558.73	-5279.1	-256.15	-70047.82	116141.8
5309	166.75	160.5	103.25	143.5	-40335.5	-5258.17	-266.29	-69818.24	115678.2
5318	167	160.75	103	143.58	-40635.91	-5271.97	-266.14	-70207.42	116381.44
5327	167	160.75	103.25	143.67	-40855.68	-5285.8	-193.39	-70570.13	116905
5336	167.5	161.25	103.25	144	-40890.04	-5310.6	-175.94	-70857.6	117234.18
5345	162.5	161	103.25	142.25	-40969.62	-5299.8	-112.2	-70518.93	116900.55
5354	166	161.25	104.25	143.83	-41089.91	-5267.99	-105.39	-70157.58	116620.87
5363	166.5	161.25	105.75	144.5	-41357.28	-5270.73	-68.93	-70455.42	117152.36
5372	164.75	161.75	106.25	144.25	-41601.94	-5290.38	-69.75	-70234.48	117196.55
5381	167.5	161.75	106.25	145.17	-41811.19	-5238.96	-180.58	-70022.44	117253.17
5391	168	161.75	106.25	145.33	-41854.96	-5269.79	-161.22	-70514.89	117800.86
5397	167.5	162	106.25	145.25	-42035.35	-5273.73	-232.1	-70633.63	118174.81
5402	167.5	161.25	104.75	144.5	-42191.67	-5245.77	-310.63	-69818.35	117566.42
5407	167	161.5	104.5	144.33	-42431.93	-5231.99	-342.28	-69783.76	117789.96
5416	168	161.5	103.5	144.33	-42673.25	-5249.8	-275.25	-70134.03	118332.33
5425	168.25	161.75	104.5	144.83	-42942.44	-5266.38	-233.19	-70542.35	118984.36
5434	168.5	162.25	104	144.92	-43089.78	-5300.36	-201.15	-70937.51	119528.8
5443	168	162.5	104	144.83	-43704	-5321.88	-216	-71244.29	120486.17
5452	167.25	162	104.75	144.67	-40558.73	-5327.07	-232.77	-71435.04	117553.61
5461	167	161.75	105.25	144.67	-40335.5	-5352.76	-173.07	-71595.94	117457.27
5470	165.25	161.75	106.75	144.58	-40635.91	-5339.6	-216.65	-71661.28	117853.44
5479	160.75	161	106	142.58	-40855.68	-5314.6	-219.09	-71615.21	118004.58
5488	162.75	160.25	106	143	-40890.04	-5304.43	-287.9	-71468.53	117950.9
5497	162.75	159	105.75	142.5	-40969.62	-5295.35	-369.26	-71505.64	118139.87
5506	158	158.5	105	140.5	-41089.91	-5306.63	-232.39	-70959.97	117588.9
5515	160.5	158	105	141.17	-41357.28	-5222.02	-279.49	-70336.96	117195.75
5524	157	156.5	103.75	139.08	-41601.94	-5223.35	-304.22	-69732.64	116862.15
5533	161.25	157	103.5	140.58	-41811.19	-5227.09	-248.66	-69416.32	116703.26
5542	158.25	157.25	104	139.83	-41854.96	-5233.39	-175.69	-69274.43	116538.47
5551	163	157	103.75	141.25	-42035.35	-5257.1	-132.62	-69122.86	116547.93
5560	163	158	103.5	141.5	-42191.67	-5271.91	-88.57	-68981.42	116533.57
5569	166.25	158.75	104	143	-42431.93	-5276.47	-76.72	-68840.89	116626.01
5578	163.75	159.75	103.75	142.42	-42673.25	-5294.21	-50.63	-68709.89	116727.98
5587	168.75	160.5	104.75	144.67	-42942.44	-5294.92	-38.44	-68675.44	116951.24
5596	170	162.5	107.25	146.58	-43089.78	-5308.53	-26.63	-69225.07	117650.01
5606	171.25	164	109	148.08	-43704	-5333.62	-54.43	-69860.75	118952.8
5612	171.75	164.5	108.5	148.25	-40558.73	-5334.62	-52.46	-70123.56	116069.37
5617	171.5	164.5	108.75	148.25	-40335.5	-5347.35	-95.26	-70342.3	116120.41
5623	171.5	164.5	109	148.33	-40635.91	-5357.48	-88.5	-70550.03	116631.92
5628	170	164.75	109.25	148	-40855.68	-5372.6	-112.28	-70708.91	117049.47
5634	170.25	164.75	109.25	148.08	-40890.04	-5376.11	-128.05	-70843.44	117237.64
5639	169.5	164.75	108.75	147.67	-40969.62	-5388.58	-139.4	-70954.1	117451.7
5645	168.5	164.25	109	147.25	-41089.91	-5385.13	-160.09	-71052.85	117687.98

5650	167.25	163.5	108.5	146.42	-41357.28	-5392.28	-173.67	-71132.6	118055.83
5656	166.75	163.25	108	146	-41601.94	-5375.16	-167.7	-71197.56	118342.36
5661	165.25	163	107.5	145.25	-41811.19	-5386.73	-162.69	-71235.33	118595.94
5667	165	162.5	107.5	145	-41854.96	-5391.03	-153.46	-71264.46	118663.91
5672	164	162	107.75	144.58	-42035.35	-5386.69	-147.02	-71287.57	118856.63
5677	163.25	162	109.25	144.83	-42191.67	-5376.78	-131.65	-71311.73	119011.83
5686	161.75	160.25	105.5	142.5	-42431.93	-5374.76	-137.28	-71367.68	119311.65
5695	160.25	158.75	106	141.67	-42673.25	-5361.55	-146.7	-71359.28	119540.78
5704	158	158	105.5	140.5	-42942.44	-5326.96	-169.76	-70708.22	119147.38
5713	157.75	157.5	105.5	140.25	-43089.78	-5267.79	-180.34	-70227.04	118764.95
5722	153	157.25	106.75	139	-43704	-5262.87	-186.68	-69712.45	118866
5731	157.5	156.5	106	140	-40558.73	-5207.88	-187.74	-69285.81	115240.16
5740	155.5	156.25	105.5	139.08	-40335.5	-5206.59	-162.42	-69080.04	114784.55
5749	159	156.75	105.75	140.5	-40635.91	-5219.55	-160.99	-68835.22	114851.67
5758	155.5	157	106	139.5	-40855.68	-5238.31	-179.99	-68716.25	114990.23
5767	160.5	157.75	105.75	141.33	-40890.04	-5250.65	-210.93	-68597.08	114948.7
5776	159.5	158	106	141.17	-40969.62	-5268.52	-220.52	-68531.75	114990.41
5785	163.5	159	106	142.83	-41089.91	-5279.9	-230.35	-68481.56	115081.72
5794	163	160	105.75	142.92	-41357.28	-5290.43	-244.42	-68953.25	115845.38
5803	166.75	160.75	105.75	144.42	-41601.94	-5300.89	-251.66	-69193.46	116347.95
5812	167.5	161.25	106.5	145.08	-41811.19	-5325	-257.78	-69655.67	117049.64
5822	167.75	162	105.75	145.17	-41854.96	-5373.26	-261.25	-70120.39	117609.86
5828	166.75	161.75	106	144.83	-42035.35	-5354.21	-259.37	-70294.71	117943.64
5832	166.5	162	106	144.83	-42191.67	-5369.08	-259.9	-70356.73	118177.38
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5850	165	161.5	105.75	144.08	-42673.25	-5392.79	-245.92	-70711.28	119023.24
5859	163.5	161.25	106.25	143.67	-42942.44	-5368.23	-239.18	-70814.31	119364.16
5868	159.5	160.75	106.25	142.17	-43089.78	-5354.25	-260.8	-70312.74	119017.57
5877	161.25	160.25	106	142.5	-43704	-5292.56	-415.18	-69837.46	119249.2
5886	156.75	159.25	106	140.67	-40558.73	-5285.84	-376.39	-69374.83	115595.79
5895	162.25	159.25	106.25	142.58	-40335.5	-5255.54	-317.47	-69032.7	114941.21
5904	159.75	159.25	105.5	141.5	-40635.91	-5264.43	-280.96	-69340.17	115521.47
5913	164.25	159	105.25	142.83	-40855.68	-5250.4	-211.95	-69132.17	115450.2
5922	164.25	159.75	104.75	142.92	-40890.04	-5242.12	-268.03	-69351.78	115751.97
5931	161.5	159.25	104.25	141.67	-40969.62	-5254.21	-226.3	-69051.92	115502.05
5940	164.5	159.75	105	143.08	-41089.91	-5218.39	-157.07	-68737.99	115203.36
5949	162.5	159.75	104.75	142.33	-41357.28	-5204.34	-118.39	-68561.46	115241.47
5959	166.25	160.25	104.75	143.75	-41601.94	-5180.52	-188.95	-68382.43	115353.84
5968	166.75	160.75	104.5	144	-41811.19	-5211.22	-268.46	-68856.89	116147.76
5977	166.75	161.5	105.25	144.5	-41854.96	-5214.89	-234.77	-68887.96	116192.58
5986	167.5	162	104.75	144.75	-42035.35	-5235.24	-203.17	-69085.94	116559.7
5995	167.75	162.25	105.5	145.17	-42191.67	-5226.69	-247.27	-69471.27	117136.9
6005	167.75	161	102.25	143.67	-42431.93	-5237.33	-180.11	-69051.42	116900.79
6009	167.75	161.5	101.75	143.67	-42673.25	-5239.76	-165.93	-69009.57	117088.51
6018	168	161.25	101.75	143.67	-42942.44	-5246.19	-112.51	-69410.24	117711.38
6027	167.75	162	103.5	144.42	-43089.78	-5260.86	-93.04	-69796.23	118239.91
6036	167.25	162.25	103.5	144.33	-43704	-5279.9	-67.28	-70126.4	119177.58

6045	167.25	162.5	104	144.58	-40558.73	-5282.12	-91.97	-70409.68	116342.5
6054	166.5	162.25	104.75	144.5	-40335.5	-5294.68	-119.41	-70640.46	116390.05
6063	162.25	161.5	104.75	142.83	-40635.91	-5295.7	-102.32	-69924.35	115958.28
6072	164.25	161.5	104.75	143.5	-40855.68	-5266.43	-104.91	-69551.73	115778.75
6081	160.25	161.25	106	142.5	-40890.04	-5334.75	-135.59	-69764.12	116124.5
6090	164.5	161.25	106.5	144.08	-40969.62	-5268.41	-139.56	-69895.38	116272.97
6099	164	161	106.5	143.83	-41089.91	-5269.37	-172.15	-70023.58	116555.01
6108	160.75	160.75	107	142.83	-41357.28	-5260.57	-147.36	-69714.33	116479.54
6117	163.25	160.25	106.25	143.25	-41601.94	-5237.2	-86.65	-69333.13	116258.92
6126	159.5	160.25	105	141.58	-41811.19	-5242.92	-60.8	-68909.57	116024.48
6136	163.25	160.25	104.75	142.75	-41854.96	-5233.33	-89.05	-68690.65	115867.99
6145	164.75	160.75	104.75	143.42	-42035.35	-5240.63	-128	-69092.27	116496.25
6154	164.75	161	105.25	143.67	-42191.67	-5257.28	-144.25	-69138.68	116731.88
6163	165.5	161.5	105.25	144.08	-42431.93	-5255.3	-113.18	-69206.14	117006.55
6172	165.75	161.25	105.25	144.08	-42673.25	-5265.74	-99.28	-69570.58	117608.85
6181	165.75	162.5	105	144.42	-42942.44	-5275.33	-88.32	-69903.83	118209.92
6190	161.75	162.25	105.25	143.08	-43089.78	-5297.57	-88.87	-69740.12	118216.34
6199	164.5	161.75	105.5	143.92	-43704	-5280.57	-79.48	-69431.16	118495.21
6208	164.5	162.25	105.25	144	-42068.96	-5267.41	-99.45	-69731.53	117167.35
6217	165	162.5	105	144.17	-42144.74	-5292.41	-105.42	-70009.04	117551.61
6226	164.5	161.75	105	143.75	-42222.05	-5303.27	-117.87	-70234.51	117877.7
6235	159.5	161.5	105.5	142.17	-42103.94	-5295.57	-116.44	-69868.77	117384.72
6244	164	161.25	105.25	143.5	-41945.91	-5253.32	-118.67	-69480.95	116798.85
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6262	163.25	160.75	105.25	143.08	-42093.89	-5265.56	-151.13	-69967.42	117478
6271	158.75	160.75	105.25	141.58	-42016.96	-5270.86	-131.39	-69650.38	117069.59
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6295	166.75	160.25	105.25	144.08	-41975.92	-5251.02	-106.57	-69779.22	117112.73
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6313	163.25	160.25	105.5	143	-42304.32	-5248.82	-58.72	-70145.78	117757.64
6322	158.5	159.75	104.75	141	-42486.44	-5239.38	-9.31	-69562.68	117297.81
6331	161	159.5	104.5	141.67	-42293.38	-5184.53	-8.63	-69128.55	116615.09
6340	157.25	159.5	104.5	140.42	-42021.35	-5201.11	8.56	-68930.42	116144.32
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6358	160	159.5	104.25	141.25	-41585.5	-5222.91	49.89	-68881.82	115640.34
6367	163.25	160	104.25	142.5	-41683.93	-5224.38	48.22	-69069.28	115929.37
6376	163	160.25	104.5	142.58	-41760.6	-5238.29	43.38	-69357.87	116313.38
6385	160.75	160.25	105.25	142.08	-41732.99	-5224.8	39.9	-69634.51	116552.4
6394	162.5	160.5	105	142.67	-41718.82	-5225.67	35.14	-69646.6	116555.95
6403	162.75	160.75	104.75	142.75	-41782.82	-5244.01	1.15	-69831.03	116856.71
6412	157.5	160.5	105.75	141.25	-41812.05	-5241.47	-180.38	-69942.19	117176.09
6421	161	159.5	104.25	141.58	-41825.8	-5224.91	-202.92	-69859.31	117112.94
6430	159.75	159	104.25	141	-41812.41	-5215.87	-172.63	-69899.9	117100.81
6439	155.75	158.25	104	139.33	-42011.75	-5205.01	-112.18	-69272.04	116600.98
6448	159.25	158	103.25	140.17	-41795.81	-5174.69	-69.56	-68804	115844.06
6457	156	158	103.5	139.17	-41759.96	-5174.91	-36.43	-68534.14	115505.44
6466	160.5	157.75	103.75	140.67	-41725.91	-5189.78	-24.63	-68243.86	115184.18

6475	158.25	157.75	103.25	139.75	-41456.41	-5194.1	-14.05	-68146.66	114811.22
6485	161.25	158.25	103	140.83	-41406.45	-5214.2	-3.79	-68003.89	114628.33
6494	163.25	158.5	102.5	141.42	-41575.1	-5227.34	-10.13	-68351.57	115164.14
6503	164.75	158.75	103	142.17	-41676.33	-5230.34	-18.81	-68591.74	115517.22
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6530	168.75	160.75	105	144.83	-41887.01	-5245.39	-12.97	-69637.7	116783.07
6539	168.25	160.75	104.5	144.5	-42077.71	-5217.3	-200.98	-69812.47	117308.46
6548	167.5	160	104	143.83	-42251.26	-5241.3	-255.7	-69939.29	117687.55
6557	166.25	159.5	103.25	143	-42311.32	-5197.26	-256.37	-69927.92	117692.87
6566	164.75	158.5	103.5	142.25	-42318.43	-5204.19	-246.29	-69922.6	117691.51
6575	163.5	157.75	103.5	141.58	-42351.08	-5183.75	-315.92	-69948.78	117799.53
6584	162.25	157.25	103.5	141	-42258.62	-5188.71	-296.71	-69968.64	117712.68
6593	160.25	156.25	103	139.83	-42200.08	-5173.04	-233.09	-69950.03	117556.24
6602	159	155.25	103.25	139.17	-42107.81	-5187.62	-91.97	-69922.12	117309.52
6611	158	154.5	103.75	138.75	-42030.52	-5175.76	-72.77	-69865.13	117144.18
6620	157	154.25	103.75	138.33	-41955.45	-5161.09	-10.11	-69771.53	116898.18
6629	155.5	153.75	105	138.08	-41837.21	-5148.53	-3.84	-69685.84	116675.42
6638	154.75	152.25	105.75	137.58	-41700.3	-5103.36	39.58	-69610.88	116374.96
6647	153.25	152.25	105.75	137.08	-41596.66	-5081.92	2.29	-69479.99	116156.28
6656	152	151.5	105	136.17	-41532.5	-5044.59	0.02	-69351.71	115928.78
6665	150.25	150	105.5	135.25	-41497.74	-5014.05	-11.85	-69169.03	115692.67
6674	149.5	149.5	105.5	134.83	-41463.54	-5010.11	-56.65	-69011.65	115541.95
6683	148.25	148.5	104.75	133.83	-41393.4	-4991.83	-113.5	-68917.36	115416.09
6692	147.25	148	105	133.42	-41316.54	-4997.82	-165.98	-68821.8	115302.14
6701	146.25	147	104.75	132.67	-41262.92	-5008.21	-195.98	-68693.54	115160.65
6710	144.75	146.25	104.5	131.83	-41200.02	-5009.57	-201.03	-68555.61	114966.23
6719	144.5	145.25	104	131.25	-41151.47	-5003.07	-195.86	-68330.97	114681.37
6728	143	144.75	103.5	130.42	-41063.96	-5021.17	-150.24	-68177.17	114412.54
6737	142	143.5	103.5	129.67	-40977.05	-5018.32	-133.16	-68011.86	114140.39
6746	141.25	143.25	103	129.17	-40904.94	-4991.01	-62.79	-67830.2	113788.94
6755	140.5	142	103	128.5	-40847.68	-4990.67	-39.18	-67647.03	113524.56
6764	139.5	142	103	128.17	-40806.34	-4993.32	-38.09	-67442.59	113280.34
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6782	138	140	102.5	126.83	-40615.48	-4997.04	-9.89	-67188.44	112810.85
6791	136.5	140	101.75	126.08	-40588.93	-4976.69	-62.21	-66944.48	112572.31
6800	136.5	139.5	102	126	-40575.76	-4984.26	-72.23	-66841	112473.25
6809	136	138	101.75	125.25	-38190.67	-2758.75	-112.9	-65400.67	106462.99
6818	134.75	138.25	101.5	124.83	-38178.29	-2798.33	-135.36	-65175.44	106287.42
6827	134	137.5	100.75	124.08	-38094.04	-2787.02	-180.11	-64941.15	106002.32
6837	133.75	137.25	100.5	123.83	-38005.9	-2760.77	-193.81	-64714.51	105674.99
6846	133.75	136.25	100.25	123.42	-31226.91	251.74	-197.18	-61529.4	92701.75
6855	133	135.75	100.75	123.17	-11421.65	2103.63	-177.92	-24438.92	33934.86
6864	132.5	136.25	102.5	123.75	-2079.35	2481.97	-166.63	-9016.88	8780.89
6873	131.75	135.25	102.25	123.08	-1856.73	2521.53	-155.82	-7949.84	7440.86
6882	131.25	135.75	102.25	123.08	-1955.96	2537.76	-144.82	-7625.84	7188.86
6891	130.25	136	104.25	123.5	-1998.45	2479.16	-165.61	-7397.85	7082.75

6900	130	135.25	104	123.08	-2014.43	2408.75	-143.33	-7225.84	6974.85
6909	129.75	135	104.25	123	-2043.08	2393.97	-183	-7119.7	6951.81
6918	129.25	134.5	104	122.58	-2046.17	2437.64	-207.61	-7256.09	7072.23
6927	128.75	133.75	103.75	122.08	-2030.25	2457.72	-189.27	-7213.16	6974.96
6936	128	132.75	104	121.58	-2066.24	2464.78	-186.82	-7139.13	6927.41
6945	127.75	132.5	103.75	121.33	-2064.41	2476.76	-195.28	-6951.22	6734.15
6954	127	131.25	103	120.42	-2053.21	2473.46	-199.77	-6956.73	6736.25
6963	126.25	131.25	103.5	120.33	-2043.55	2489.94	-215.25	-7015.82	6784.68
6972	125.25	131.25	103.75	120.08	-2124.97	2518.03	-236.04	-7022.17	6865.15
6981	125.5	131.25	105.25	120.67	-2482.95	2469.08	-193.34	-8381.69	8588.9
6990	124.25	131.75	108.75	121.58	-5914.2	2515.92	-219.86	-9165.71	12783.85
6999	124.5	131	106	120.5	-4330.61	2494.81	-145.14	-5744.47	7725.41
7008	124.25	132.5	113.25	123.33	-2700.55	2578.07	857.08	-3777.46	3042.86
7017	123.25	132.25	110.75	122.08	-4281.74	2583.5	931.07	1568.45	801.28
7026	123	132	121.25	125.42	-7530.4	2802.52	928.47	19392.8	15593.39
7035	122	130	122.5	124.83	-7282.27	2705.37	813.22	11449.18	7685.5
7044	121.75	128.5	119.25	123.17	-9770.6	2725.27	-165.61	14359.36	7148.42
7053	121	124	89.75	111.58	-1684.14	4045.88	-143.33	-10363.85	8145.44
7062	114	125.75	97	112.25	-638.8	3822.48	-183	-10048.3	7047.62

Chapter 8: References

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