

REDESIGNING OF FUEL FILLING ARRANGEMENT FOR GENSET USING CAD

A Thesis Submitted in Fulfilment of the Requirement for the Award of the Degree of

MASTERS OF ENGINEERING

In CAD CAM Engineering

Submitted By

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DECLARATION

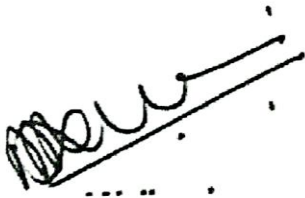
I, Anubhav Bhatnagar declare that the work presented in this thesis entitled “**Redesigning of Fuel Filling arrangement for Genset using CAD**” in fulfilment of the requirement for awarding degree of Masters of Engineering in CAD-CAM Engineering submitted to **Mechanical Engineering Department , Thapar Institute of Engineering & Technology (Deemed to be University), Patiala** is an authentic record of work carried out under supervision of **Mr Ajayinder Singh Jawanda**, Associate Professor, Mechanical Engineering Department, Thapar Institute of Engineering & Technology and **Mr Anand Kulkarni** , Senior General Manager Product Planning, Cummins India. The matter presented in this thesis has not been submitted either in part or full to any other university or institute for the award of any other degree.



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It is certified that the above statement made by the student is correct to the best of our knowledge and belief.




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Dedication

I would like to dedicate this thesis to my parents,

For their love and support.

Acknowledgement

I would like to express my deep sense of gratitude and sincere thanks to my thesis guide **Ajayinder Singh Jawanda**, Associate Professor, Mechanical Engineering Department, Thapar Institute of Engineering and Technology, Patiala for encouraging me to take an industry project as thesis work and have exposure to how industry works. With his invaluable guidelines and support I was able to complete my work with best of my ability and efforts within stipulated time. I would like to thank **Cummins India** and my supervisors there for giving me a good project as substantial part of my thesis work and their expertise to have an experience of a lifetime in industry. My guide and my supervisors kept my spirits and enthusiasm high all this time and helped me to not only work responsibly but enjoy my thesis work too.

I would like to thank my parents who gave me blessings, constant support and opportunity to study at Thapar Institute. Finally I want to thank my friends and classmates for their encouragement help towards thesis work and making this journey memorable.

Anubhav Bhatnagar

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Abstract

The genset in today's power shortage scenario is an important product for its users. The companies today are doing their best to offer competitive product with unique features that makes it stand out and differentiator from others. Improving genset by design changes is a good practice to keep the product up to date with necessary design changes. These changes should reflect voice of customer in their redesign. The concerned product in this thesis work is Cummins 125 kVA genset. The feature to be redesigned was chosen from VOC obtained by using human centred design methodology and tools. The fuel filling arrangement in this genset is inside canopy enclosure as the fuel tank is in the base rail of genset. This arrangement was redesigned for external filling which is more convenient for the user as internal arrangement has limited accessibility and limited working space. Moreover the fuel level indicator was also placed on top of tank which is now redesigned and placed on canopy body itself at good height and visibility for the user. The fuel theft being a major concern in genset is also addressed in this thesis work. Retrofit devices which act as anti-theft measures with perforated periphery have been modelled which allow better flow rate and prevent any approach for siphoning fuel. This arrangement was made further protected with locked arrangement for safe use. All this redesigning is modelled on PTC Creo CAD software and verified with all engineering aspects to have a safe and ergonomically sound design for the user keeping in mind the cost and manufacturing limitations of the company.

Keywords – genset design improvement, CAD modelling, fuel filling, HCD, anthropometry, canopy, anti-theft, level indicator.

Table of Contents

Acknowledgement	ii
Abstract	iii
List of Figures	vii
List of Tables	x
Chapter 1 - Introduction	1
1.1 General	1
1.2 Genset Design improvement and Fuel Filling Arrangement	2
1.3 Human centred approach and role of ergonomics	3
1.4 Summary of thesis.....	4
Chapter 2 – Problem Definition	5
2.1 General	5
2.2 HCD Tools	5
2.3 Problem Specification	12
2.4 Objectives of thesis work.....	12
Chapter 3 - Literature Review	13
3.1 General	13
3.2 Basics of genset working and fuel system	13
3.3 Role of CAD modelling in product design	15
3.4 Design for ergonomics and human factor engineering	15
3.5 Design for Aesthetics	18
3.5 Use of anthropometry in product design.....	19
3.6 Human centred design.....	25
Chapter 4 - Study of Existing Design	27
4.1 General	27
4.2 Canopy and Base design	27
4.3 Fuel tank with fuel filling arrangement	28

4.4 Type of fuel level sensor used	31
4.5 The problems faced in current design of fuel filling method.....	32
4.6 Conclusions from study of existing design	33
Chapter 5 - Study of Alternate designs	34
5.1 Identifying position on the canopy for external filling	34
5.2 Use of Anthropometric data to find suitable filling and level indicator height	37
5.3 Pocket.....	38
5.4 Changes in fuel tank and design of fuel inlet pipe.....	39
5.5 Choosing right type of level indicator and its position	41
5.6 Anti-fuel theft measures.....	44
5.7 Fuel inlet pipe cap	47
5.8 Fuel pocket flap or cover with locking arrangement	47
5.9 Flow area analysis.....	50
Chapter 6 - Results and Discussions.....	51
6.1 General.....	51
6.2 Space in and out of genset	51
6.3 Height of human filling point and level indication	51
6.4 Minimum cost and standard parts and process to manufacture	51
6.5 Safety and theft protection	52
6.6 Pipe flow area, venting and fuel tank sloshing	52
6.7 Environment of working	53
6.8 Assembly and aesthetics	53
6.9 Comparisons of different models.....	53
Chapter 7 - Conclusion and Scope for further work	57
7.1 Conclusion	57
7.2 Scope for further work.....	57
References.....	59

Web References	61
Appendix A - Fuel Level Indicator Details from supplier.....	62

List of Figures

S. No.	Figures
Figure 1.1	Cummins 125 kVA Genset
Figure 1.2	Existing fuel filling point inside enclosure in the base rail
Figure 2.1	HCD tools by Luma Institute
Figure 2.2	Stakeholder mapping
Figure 2.3	VOC of positive things in genset
Figure 2.4	VOC of negative things in genset
Figure 2.5	VOC of potential improvement in genset
Figure 3.1	Generator key components
Figure 3.2	Simplified illustration of the product development and design process
Figure 3.3	Anthropometric measures: standing and sitting
Figure 3.4	Anthropometric measures: hand, foot and head
Figure 3.5	The standing forward reaches area of a small male's right hand
Figure 3.6	The normal line of sight and the range of easy eye rotation
Figure 3.7	Normal and maximum working areas
Figure 4.1	Canopy model of the 125 kVA genset
Figure 4.2	Model of base rail of the genset
Figure 4.3	Model of assembly of canopy and base skid
Figure 4.4	3D view of fuel tank positioned inside canopy and base
Figure 4.5	Position of fuel tank inside canopy model from front view
Figure 4.6	Fuel tank dimensions with model
Figure 4.7	Fuel tank cover plate on top of tank
Figure 4.8	Original image of the design on Genset fuel tank

- Figure 4.9a Float type level sensor
- Figure 4.9b Fuel level dial indicator
- Figure 4.10 Working of float type level sensor and indicator
- Figure 5.1 Model showing space left after size of engine, radiator and alternator on frame
- Figure 5.2 Space for fuel pipe in between door of canopy
- Figure 5.3 Space for fuel inlet pipe to the left side of door
- Figure 5.4 Space for pipe below canopy door
- Figure 5.5 Space for fuel pipe in front of alternator
- Figure 5.6 Two of the sorted places where pipe can come out for filling fuel
- Figure 5.7 The normal line of sight and the range of easy eye rotation
- Figure 5.8 Front and side view of pocket with some dimensions
- Figure 5.9 Model of redesigned fuel pipe in reference to previous design can be seen
- Figure 5.10 Side and top view of the CAD model design
- Figure 5.11 Front view of CAD model of pipe going to the left side of tank
- Figure 5.12 Top and side view of the alternate design of fuel pipe
- Figure 5.13 Magnetic float type level sensor
- Figure 5.14 Dial indicator with sender and reciever
- Figure 5.15 Magnetic fuel level sensor with dial unit in original
- Figure 5.16 Model of ATM 1 showing plate for blockage with holes at bottom
- Figure 5.17 ATM 2 model on Creo
- Figure 5.18 ATM 3 model on Creo
- Figure 5.19 Fuel cap with lock or without lock
- Figure 5.20 Butt type hinge with spring
- Figure 5.21 The flap door assembly with hinge and spring

Figure 5.22 Torsion spring with the some important spring values

Figure 5.23 Spring dimensions formulated from online tool

Figure A1 Magnetic fuel level sensor details from Active Controls, Delhi

Figure A2 Magnetic fuel level sensor details from Active Controls, Delhi

List of Tables

Table 2.1 - Importance and difficulty matrix for selected VOCs

Table 3.1 - Anthropometric data for males and females while standing and seated

Table 3.2 - Anthropometric data for males and females for foot, hand and head

Table 6.1 – Comparison of fuel filling positions to find the best one

Table 6.2 – Comparison of different fuel theft arrangements

Table 6.3 – Comparison for different flap door arrangements

Chapter 1 - Introduction

1.1 General

Frequent power outages are the biggest problem faced by India being fastest developing country. Also India relies heavily on electricity for its manufacturing, transport and logistics, infrastructure, commercial, and other service sectors. Shortage in power calls for standby electricity supply which is most popularly filled by genset. Genset market in India is characterized by the presence of well-diversified international and regional vendors and constant innovation, new products and solutions is keeping the competition among towards having challenging portfolio. Key vendors in this market are – Cummins, KOEL, Mahindra, Volvo Eicher, Ashok Leyland, Perkins, Greaves Cotton and Cooper which serve industrial sector, commercial sector, infrastructure sector, residential sector, etc. Cummins India is one of the top manufactures of diesel and gas generators in India with a wide portfolio of generators on offer to suit all kind of power needs. Generators in key nodes are every company's priority to maintain a strong position to continue its dominance. So to have that key hold in market it needs to continuously redesign and makeover its Gensets to attract customers with better proposition. Having user friendly features in genset can attract users and can play a key role in buying decision. To have such a market differentiator in its portfolio will boost customer appreciation and companies sales and image. That user friendly approach can come only by changing its business strategy and making some strategic innovations in Gensets. The concept of Human Centred Design (HCD) has for long brought companies focus from its product based strategy towards user based strategy. It gives us a methodology to follow research steps and allow us to take views of users that what they want in their product which will help them to use their product seamlessly and then design their product or make changes accordingly with continuous feedback from customers at every stage. Hence this gives us reason to improve genset design.

Redesigning is a technique that brings desirability in any product. Making minor changes or completely overhauling gives any product fresh view and appeal to customers. Products in the market are needed to be redesigned at some point to meet new customer requirements. This redesign can be done from out-dated or current product. The need for redesigning is an important part of company's production and development process. This thesis focuses on improving Genset design by redesigning its fuel filling arrangement as a part of Voice of customer (VOC) researched and prioritised by company making the Genset and virtually

model it on CAD software taking into consideration all the engineering aspects required to have a sustainable design preferred by the user.

1.2 Genset Design improvement and Fuel Filling Arrangement

The product in consideration is Cummins India 125 kVA Genset model no. C125D5P. A low kVA model has its application mainly in service sector, commercial and residential realty.

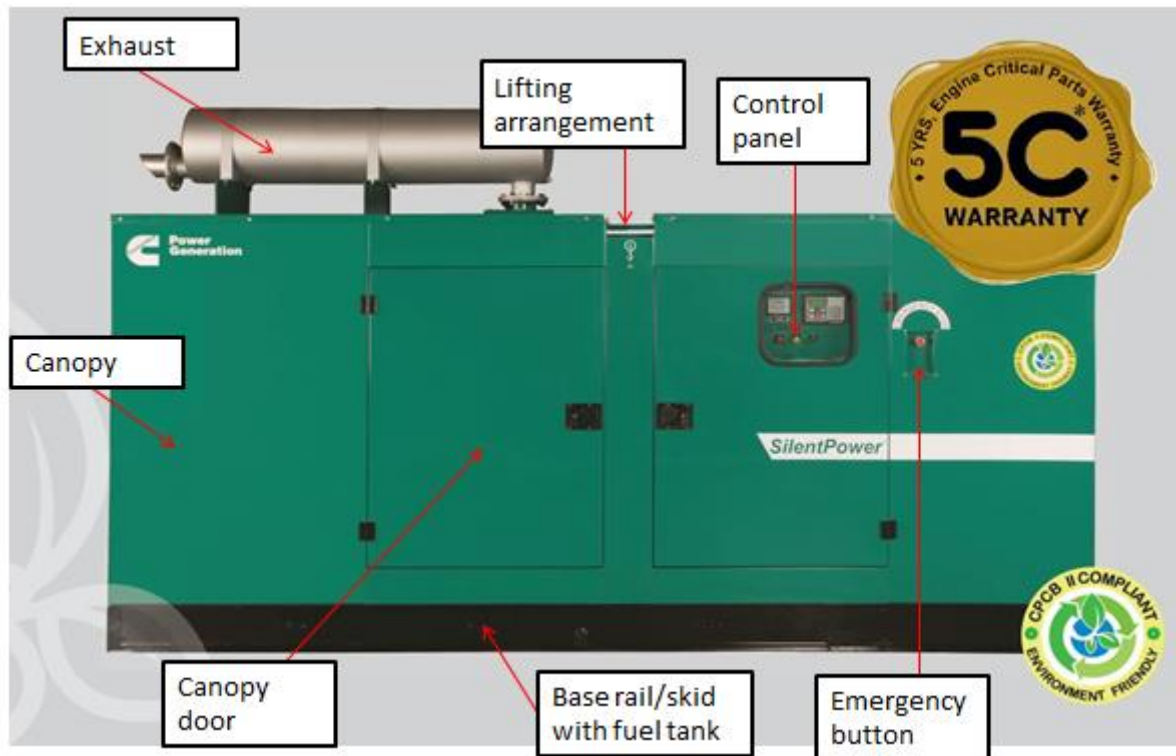


Figure 1.1 - Cummins 125 kVA Genset

Genset design improvement features identified by using HCD tools to arrive at a pool of VOC that are prioritised by the company with respect to cost and many other factors. One such feature which was chosen central to this thesis work is fuel filling arrangement which has to be redesigned and improved for better and easier use by the customer.

Fuel filling arrangement of a Genset is an important part of smoothly filling the fuel which is diesel in this case. The placement of the fuel tank and point of fuel filling should be easily accessible to the user for an easy operation. We will study the existing design of the filling arrangement, study its short comings and redesign it according to user preference.



Figure 1.2 - Existing fuel filling point inside enclosure in the base rail

1.3 Human centred approach and role of ergonomics

Human centred design (HCD) is about building a deep empathy with the people you're designing for; generating loads of ideas; building a bunch of prototypes; sharing what you've made with the stakeholders; and finally putting your innovative new solution out in the world. The concept of HCD has for long brought companies focus from its product based strategy towards user based strategy. It gives us a methodology to follow research steps and certain tools and allow us to take views of users that what they want in their product which will help them to use their product seamlessly and then design their product or make changes accordingly with continuous feedback from customers at every stage.

Inclusion of ergonomic characteristics into work environment as well as product design and taking into consideration both physical and psychological needs of users helps to enhance their efficiency, productivity and satisfaction. It is necessary to find the best design model with elements having characteristics which satisfy the users and also reduces fatigue, injury and MSDs disorders during its use in lifetime. Product characteristics in conjunction with user comfort are a vital factor during product design. Continuous interaction between product design stages and user voice leads to the desired product. Ergonomic design of product not only have influential factors but also considers cognitive and behavioural information during

design stages with ultimate aim of improving the level of comfort for the users and also maintain the aesthetic value of the product.

1.4 Summary of thesis

In Chapter 2 the detailed problem definition has been done. Certain HCD tools were used to arrive at the final voice of customer that clearly states the features that are need to be changed and can be prioritised by the company to work on. One such feature was making fuel filling arrangement external was chosen for redesigning in this thesis work.

Chapter 3 deals with the literature review required understanding the background of the work and do detailed researches about the key areas to address while this redesign.

In Chapter 4 the current design of the fuel arrangement is studied in detail and outlines the problems to work on and constraints we have to work with.

Chapter 5 deals with models of alternate designs of the current design and take into account all constraints and satisfy it that are necessary to have an ergonomically and aesthetically sound and safe design.

Chapter 6 discusses the results of CAD model in comparison with various parameters that affect them and outcomes of the change in design which are recommended to the company.

Chapter 7 presents conclusion of thesis work and scope for further work.

Chapter 2 – Problem Definition

2.1 General

The idea behind Genset Design improvement for the company is to find certain features of or on genset that make or break the deal for the buyers or users. The focus of company is to find non-performance features that are user friendly to the end users. The features that can be changed on the genset should improve its design and operation. The features that end users work with day in day out and make their daily work easier and comfortable. Such voice of customer has to be collected by interacting with all those end users that come in contact with the genset. A good approach for this is to follow certain tools that make the concept of HCD success. These tools enable the company to go to the deepest levels of the minds of end users and bring out their real voice that matter to them the most.

2.2 HCD Tools

Luma Institute which has created a framework to help choose the best tool for each step of innovation based on the people you are designing for and also considering the complexity of the system [W.1]. The tools enlisted by Luma will be used extensively in this work.



Figure 2.1 – HCD tools by Luma Institute

- Stakeholder Mapping** - It is an important HCD tool. A way of diagramming the network of people who have a stake in a given system. As a visualization of people's relationships, interactions, and needs, a Stakeholder Map helps you understand the extent and impact of your design decisions.

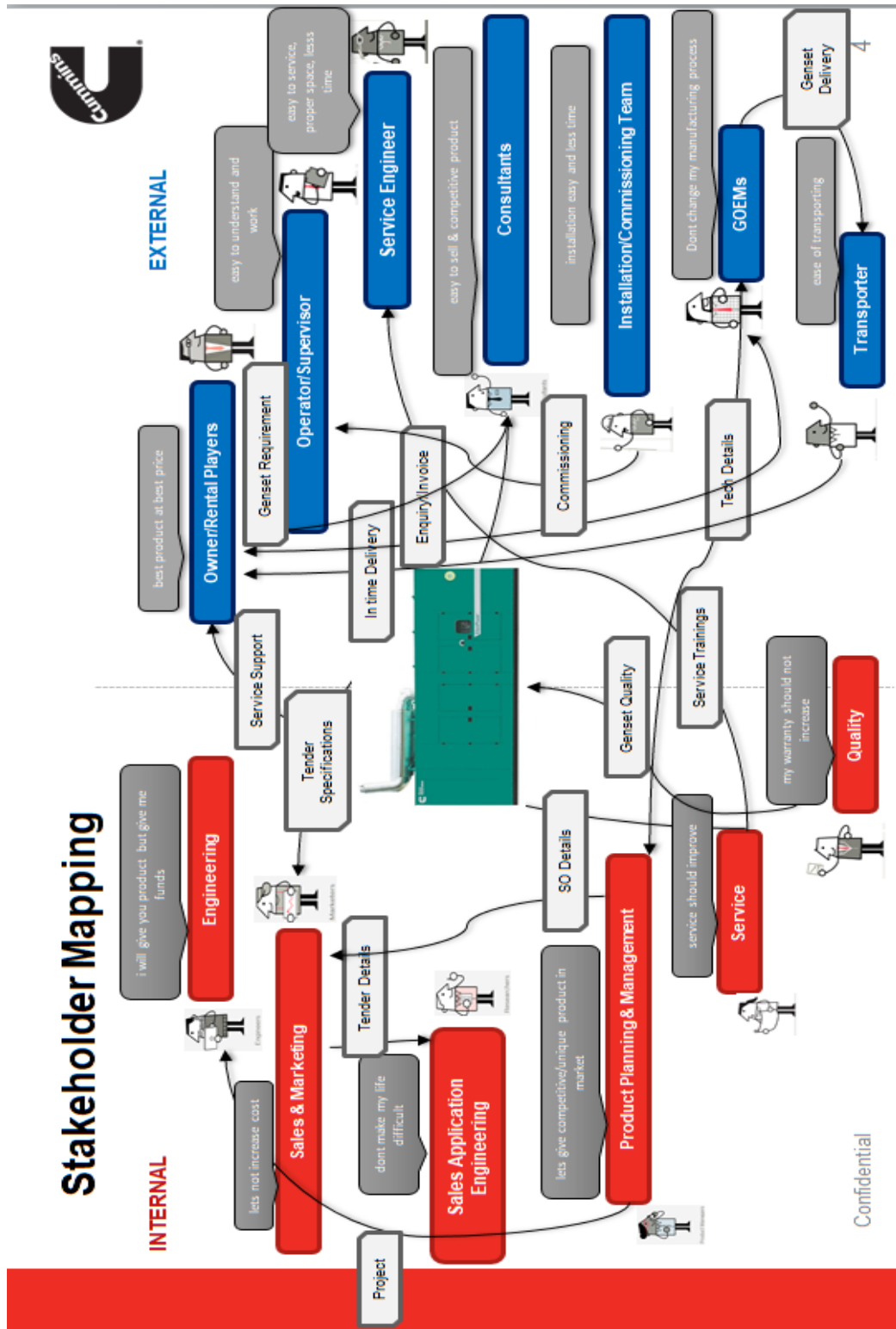


Figure 2.2 – Stakeholder mapping

- **Interviewing** - A technique for gathering information through direct dialogue. A good interview helps you take advantage of this natural inclination in order to gather valuable information. Through these interviews you gain a better sense of people and their views of the world by subtly eliciting their true feelings, desires, struggles, and opinions through a few carefully crafted questions.

Questionnaire Preparation to understand the Genset usage, do stakeholder mapping.

Assembler - only setting up/commissioning

- please guide us through the assembling process
- How is your experience working with Cummins products
- What kind of problems/bottlenecks you faced while assembling as well as respect to individual components
- did any tools or technique apart from your usual was needed to work on product
- How much time it took to assemble the genset
- How you think this time can be reduced and by how much
- Which features are good and bad over competition
- What kind of user friendly features would make your work easier

Operator

- What is your daily routine with our product
- How has been your experience with our genset in terms of operation
- If you have worked with other Gensets what good and bad you can point out
- Best & worst features in terms of operation on this genset

What other features in terms of operation would ease your job your views on following -

- ❖ Fuel filling arrangement
- ❖ Canopy design
- ❖ Placement of controls and switches
- ❖ Genset door opening
- ❖ Aesthetics of Genset from outside
- ❖ Placement of emergency stop button
- ❖ Placement of control panel
- ❖ Routine maintenance

Service engineer

- how has been your experience with servicing our gensets
- Which features/components of this genset affects you most during servicing
- which additional features would ease your work
- rate our genset on ease of serviceability
- Do you have proper space inside out and light to carry out your work at all times
- How much time it takes to service, how this time can be reduced in your opinion considering design changes
- Service features in competition genset which made your work easier

Current owners

- Since when you are using our product
- how has been your experience with our product
- what kind of problems you faced while installing and using the genset
- which current features you find most useful
- which other features would you love to have
- please give your suggestions on following ideas -
 - ❖ Fuel filling arrangement - inside or outside
 - ❖ Canopy design
 - ❖ Extra fuel tank
 - ❖ more colour options
- Complaints you get from supervisors, operators, service engineers other than performance related

Rental owner

- purpose of renting the genset
- did you get proper consultation for renting the right generator
- what do you think about our portable and trailer mounted generators
- are they easy to use, transport and user friendly in operation
- what kind of barriers you faced while using them
- what kind of features would make them more easy to use
- how you compare them with other brands
- are the cable lengths proper and enough
- what kind of maintenance plan do you follow

- **Rose, Thorn, Bud** - A technique for identifying things as positive, negative, or having potential

Adapted for use as a design method, this structure provides an opportunity to analyse a set of data or help scope a problem by revealing focus areas, allowing you to plan next steps.

Rose = Pink (indicates things that are positive).

- Paint Quality is good currently as compared to the competition.
- Service Support is good
- Green color is better than white (gets faded)
- PC 3.3 controller better and user friendly

Figure 2.3 – VOC of positive things in genset

Thorn = Blue (indicates things that are negative)

Forklift Arrangement	No Color Options Available	Door Gasket Issues			
Inconsistent installation	Water Ingress Issues	No Fuel level Sensor Available	Telematics (KOEL) has tie-up with Vodafone	Radiator Bracket is failing in transportation	Competition gives 5 year AMC option
Door lock not working after a certain time	CAT yellow color even better than Cummins Green	KOEL 250 kVA control Panel better	Extra Bracket on radiator top side on some models	PV sheets are falling down in transportation	Radiator water Drain is difficult to access
Oil Drain Issue - Double Time & Resources Required	Day tank fuel level pipe visibility hampered	Quality of Stickers need to be improved	QSK 19 difficult to service fuel filter	Sync ready controller in MHP	Leakage issue high
Customer not able to do 1 st level maintenance on Genset	Battery theft issue as door lock is easily accessible	For any trouble shooting manual has to be referred	GOEMs ask for core replacement instead part replacement during transportation	500 kVA Shipping Skid design complicated & difficult to disassemble	System is Complicated
Control panel in low kVA not accessible	Poor accessibility during AMC/Failure	Issues in door closing gaps remain			

Figure 2.4 – VOC of negative things in genset

Bud = Green (indicates things that have potential)

Fuel Tank & Fuel Filling - currently internal - can explore to move it externally	Genset Canopy Design - well received by end customer but need more options	After Sales Support can be improved instead of genset replacement	KTA38 radiator transportation mounting brackets and nuts not tight properly	990 Liter tank if placed inside canopy its capacity is reduced	Canopy design is different for different OEMs for same model
Lights quality inside canopy can be improved	Provision for soot collection to be given	Fuel Level Display at Controller	Packaging quality should be improved	Coolant draining plug not accessible	Fuel tank inside on HHP models in competition
CAT service people bring parts with them	Parts support better in competition	Door hinges quality can be improved	Hoses not having min. clearance to fit clamps properly	Water pipe difficult to assemble and torquing clamp	Emergency Stop - can be covered with a breakable glass
Electrical Connections more organized	Brackets / AVMs send through kit	Loose Connections (Clamps)	Door Design - folding & Sliding	Compact Canopy Design	Transportation Issues
Emergency Stop - can be covered with a breakable glass	Stickers on genset for basic understanding	Better Cable/Harness Routing	Battery Status Indicator	Fuel tank cap accessibility	Brackets / AVMs send through kit

Figure 2.5 – VOC of potential improvement in genset

- **Importance/Difficulty Matrix** - A quad chart for plotting items by relative importance and difficulty

Making thoughtful decisions is a challenging, yet essential, part of making progress. It's especially difficult to do when you're dealing with various options and differing criteria. A simple 2x2 matrix can be a powerful instrument for establishing priorities. Specifically, placing Importance (low to high) on the x-axis and Difficulty (low to high) on the y-axis equips you to work out tensions between these opposing forces. When you plot items according to priorities, you and your team will likely arrive at a workable resolution

The items that land in the lower left quadrant are characterized as targeted because they are the easiest to realize. The upper left quadrant contains luxurious items—costly endeavours with little return. The items in the upper right quadrant are considered to be strategic because they require large investments to get big results. And last but not least, the items in the lower right quadrant are high-value because they yield great impact at a low price.

Table 2.1 – Importance and difficulty matrix for selected VOCs

Difficulty of Implementing VOC	10										
	9										
	8					14				15	
	7				19			11,20			
	6		1	4					6,17		
	5				18		10			7	
	4					13	16		5	8	
	3			2		12			3	9	
	2									21	
	1										
	0	1	2	3	4	5	6	7	8	9	10
		Importance of that VOC									

1. Forklift Arrangement
2. No colour options
3. Door lock and door gasket and hinges issues
4. Water Ingress Issues
5. Fuel level sensor/remote monitoring
6. Lube oil and coolant filling and changing issues
7. After Sales Support can be improved instead of Genset replacement
8. Parts support better in Competition
9. Quality of stickers to be improved
10. Competition gives 5 year AMC option

11. Proper Provision for soot collection
12. Loose connections at clamps
13. Better cable routings
14. Sliding fuel tank
15. Use of Telematics
16. Packaging Quality to be improved
17. Battery status indicator
18. Standard canopy design for same model by different GOEMs
19. Accessibility to control panel in low kVA
20. Sync ready controller in MHP
21. External Fuel filling Arrangement

2.3 Problem Specification

From using above tool and making note of the voice of customer obtained the feature chosen by company to improve on Genset is to have an external fuel filling arrangement. The problems faced while filling internally are low accessibility, improper working position, spillage of fuel while filling, more maintenance and increased time to fill.

2.4 Objectives of thesis work

The objectives derived from understanding the problem act as our specifications for this redesign. The following are main things to achieve in this redesign –

1. External inlet of fuel
2. External gauge for fuel level indication
3. Locked panel for fuel theft proof
4. Tamper proof design and safe operation

Chapter 3 - Literature Review

3.1 General

Literature review is necessary to have in depth understanding of all the important aspects we will cover in our thesis. In this chapter we will do a detailed study of all engineering aspects required to model this redesigned feature like role of CAD modelling in product design, role of ergonomics and anthropometry in design modification, how human centred design leads to focused product optimisation and also basic understanding of how genset fuel filling system works and components used to support it.

3.2 Basics of genset working and fuel system

Genset or diesel generator has in basic a diesel engine as source of mechanical energy (rotation of shaft) connected with an alternator generating electric power through induction.

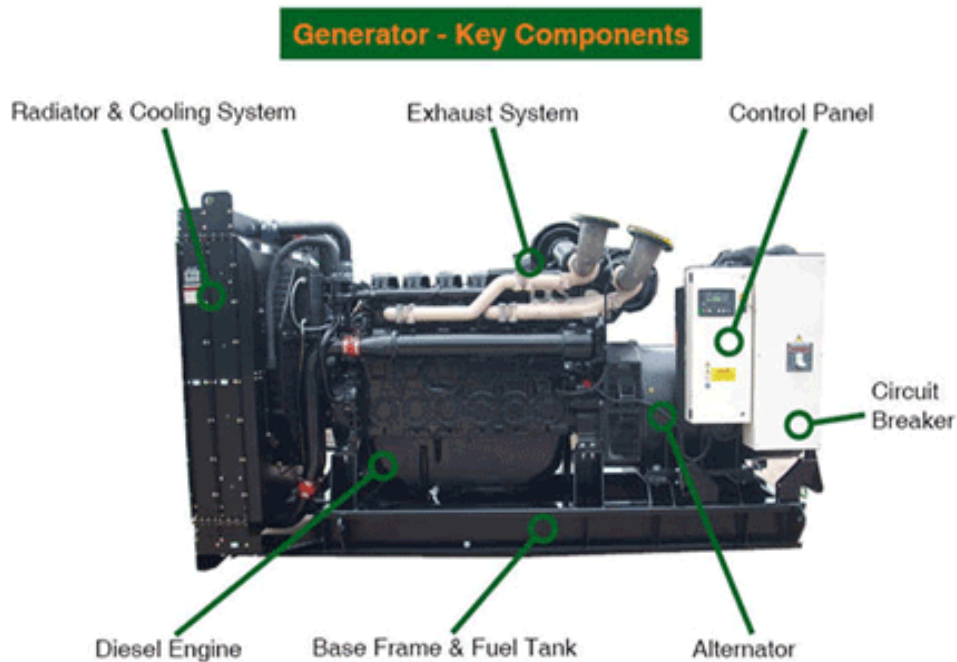


Figure 3.1 – Generator key components

The fuel system supply diesel fuel to the engine. The tank either a separate day tank for large units or fitted within base rail or frame for limited needs should have enough capacity to run genset for 8-10 hours or more. Other parts of fuel system includes pipe work to get fuel to the tank and then to the engine, a fuel pump to pump oil to the engine and back, a fuel filter, a ventilation pipe preventing overpressure or vacuum inside. [W.2]

Liquid level sensors are used for leak detection or level measurement. The need of using expensive pieces for any processes can now be achieved using innovative, intelligent and

creative technologies that are cost effective, highly accurate, reliable, robust and simple to install and use [W.3]. Fluids that are extremely challenging to detect such as soap containing bubbles/foam, sticky substances such as glue, milk and ink are now possible to detect with new variety of level sensing technologies.

- **Vibrating or Tuning Fork** - the vibrating sensor technology is perfect for solid and liquid level control which may include sticky materials and foam, as well as powder or fine grained solids. Applications that can use tuning forks are limited to overflow. However can be used with continuous level detection systems, acting as alarm points for leaks and over-fill.
- **Capacitance** - they measure the change in capacitance between two plates produced by changes in level. Two versions available - for fluids with high dielectric constants and with low dielectric constants. They are also available in contact and non-contact type which can be attached outside the tank. Not every capacitance sensor works with every type of material or tank and can be calibrated accordingly.
- **Ultrasonic** - measures level by calculating the duration and frequency of high frequency sound waves that are reflected off the surface of the liquid and back to the sensor. The time taken is relative to the distance between the sensor and the fluid.
- **Microwave/Radar** - radar works in a similar way to ultrasonic, but the pulses travel at the speed of light. The repeatability and reliability can be affected by the dielectric constant of the fluid. The downside can be that the initial cost of the sensor is relatively high. However, radar can provide very precise level information.
- **Optical Level Switch** - The switch operates very simply. Inside the sensor housing is an LED and a phototransistor. When the sensor tip is in air, the infrared light inside the sensor tip is reflected back to the detector. When in liquid, the infrared light is refracted out of the sensor tip, causing less energy to reach the detector. Optical liquid level switches are suitable for high, low or intermediate level detection in practically any tank. Being a solid-state device, these compact switches are ideal for a vast range of point level sensing applications, especially where reliability is essential.
- **Conductive sensors** - are used for point-level sensing conductive liquids such as water and highly corrosive liquids. They have two metallic probes of different lengths (one long, one short) inserted into a tank. The long probe transmits a low voltage; the second shorter probe is cut so the tip is at the switching point. When the probes are in liquid, the current flows across both probes to activate the switch. One of the benefits of such devices is that they are safe due to their low voltages and currents.

- **Float Switch** - A float switch includes a magnet within a float and a magnetic reed switch contained within a secure housing. The float moves with the change in liquid level and will cause the reed switch to either open or close depending on if it's in air or in liquid. This technology offers long-term reliability at an attractive price point.

3.3 Role of CAD modelling in product design

Design innovations need to satisfy customer expectation more than guaranteed success. Today customer demands are changing more rapidly than ever. Customers are now at central role in product development with their “voice of customer” a key element in product development and design stage [W.4]. Companies are launching innovative products through a combination of people, process and technology to translate knowledge of customer requirement into varied products. Companies that want to stay in business absolutely must know their customers deeply, develop ideas through sound engineering fundamentals and rely on computer based tools such as CAD, CAE to evaluate and refine designs as quickly and accurately as possible.

Nowadays virtual modelling or CAD modelling is used as the standard tool used for design of mechanical components and assemblies. Projects can now go from concept to prototype in record time. They have enabled designers and manufacturers to make significant cost savings. The virtual model is a digital representation of the physical product and serves as a basis for simulating the other processes and behaviour of the part [1]. The virtual model is also used to prototype the object. Virtual reality is an important and useful tool in science and engineering. The design of any product and its manufacturing process can be viewed, evaluated and then improved with use of virtual environment technique before prototyping it, this eventually leads to enormous cost saving.

3.4 Design for ergonomics and human factor engineering

Ergonomics is study of work. Ergonomics is science that gives us concept of designing the job to fit the worker rather than making the worker's body adapt to the job need. Thus adapting tasks, work station and tools and equipment to fit the worker ability and comfort can reduce physical stress on worker's body and eliminate work- related musculoskeletal disorders (MSDs) [2]. This study further highlights that employers in manufacturing, construction, maritime, and agricultural industries need to understand importance ergonomics for their employees. Which ergonomics is important, what are MSDs, what causes work related MSDs, type of work causing ergonomic hazards, how to know if you have MSD. Cost to prevent MSDs, develop workspace using ergonomics and control risk factors were studied

in detail. Role of ergonomics in sustainable design was studied in this paper [3] which highlights to follow a systematic approach which involves physical environment; physical demands, cognitive demands and psychosocial environment are all related to each other and work with the perception of interpretation of any task. Thus ergonomics helps to create a balance between work performance and well-being of human being.

Complexity of ergonomics in product design can be understood by creating possibilities of interaction between product and user. Using ergonomic data to define the requirements of product design at conceptual stage of product development highlighted in [4]. Understanding human behaviour through ergonomic perspective opens new dimensions in industrial design.

Affective satisfaction of user with product functional performance and comfort of user can enhance design process of product or component. Objective performance originates from effectiveness use of comfort level which can be quantified through biomechanical and physiological perspective of human body while interacting with product [5]. An integrated approach can be defined that deals with subjective and objective design criteria of product with ergonomics values. Customer driven approaches like QFD and factor analysis establish relation between design elements and user needs. Intelligence techniques like ANFIS build relation between customer satisfaction and design parameters. Human office chair design was used an example in this study.

Today virtual reality has been using techniques that employ ergonomic applications. The results obtained in virtual environment represent the real ones. A group of digital human models (DHMs) having various sizes of body segments like stature and weights can be used to represent target population under consideration in workplace [6]. Digitalization with ergonomics is latest trend. These trends use software tools which use DHMs. Each tool has its strength and weakness in their implication and outputs. A production workplace can be defined for ergonomic analysis and using software packages on DHMs their ergonomic analysis like carrying conditions, lifting and lowering conditions with biomechanical conditions were studied and differentiated. These software packages were Technomatix Jack and Delmia [7]. Using digital human models and VR simulations ergonomic problems in industrial work activities can be evaluated at early design stages which help to reduce costs, design time, increase quality and customer satisfaction. Certain indices were measured in real and virtual environment for some specific tasks like drilling. Three objective indices (maximum force capacity reduction, elbow angle, and task completion time) and two subjective (RPE-Rated Perceived Exertion and BPD-Body Part Discomfort) were used to

evaluate the similarities between Virtual and Real Environment for the selected specific “drilling” task [8]. Four out of five indices except elbow angle were significantly higher in Virtual environment than real one. This indicates that subjects grew discomfort and got more fatigued quickly in virtual space.

Crane cabins are the best examples today of employing ergonomics in design. Minimising crane operator’s visual problem and biomechanical discomfort through anthropometric data to improve safety of operators and prevent crane related fatalities and injuries [9]. Critical characteristics like seat and armrest positions were identified by Pareto analysis were addressed. Data on operators was collected followed with a proposed methodology for assessment of ergonomic characteristics required for crane cabins based on manikins and kinematic modelling was done to minimise risk of musculoskeletal disorders. The recommendations had number of applications in design like increased enthusiasm of crane operators, reduction in risk of injury, reduction in work-related pain, increase in the comfort level and efficiency of crane operators, and an increase in overall system safety and productivity.

Foremost goal of computer-aided ergonomics is to develop software packages and tools that allow ergonomic information at earliest stage of design. A PC-based software program allows a designer to identify a worker's space environment design and risks of biomechanical injury [10]. This study establishes a software tool like Three-Dimensional Static Strength Prediction Program (3DSSPP), with CAD software AutoCAD, for biomechanical analysis and the results compared with an independent assessment of observing workers performing the same task.

Ergonomics is described consequently, as an innovation and safety factor in design. This study gives example of concurrent engineering using ergonomic analysis with design process. The role of ergonomist as an advisory person within design process to ensure that the role of human factor while designing is fully integrated in design was done. The design of the driving cabin of the new high-speed trains like TGV-NG, through the ergonomic study of technical sub-systems of this product was done [11]. Thus, throughout the design process, the ergonomist advised the designer on the required characteristics of the target user – train operators and, on the basis of a “desirable future activities” approach help him or her to assess the consequences of the design choices made.

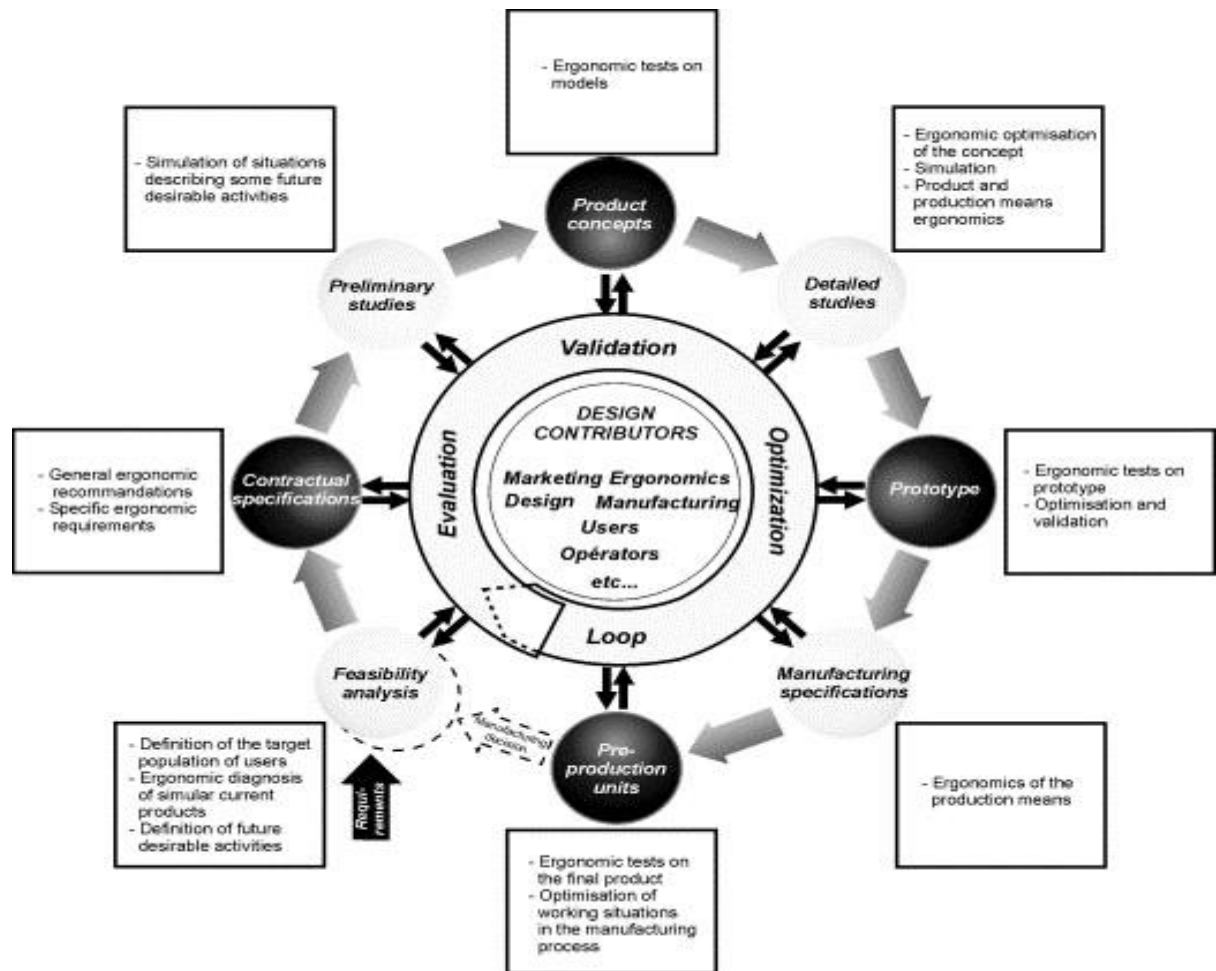


Figure 3.2 - Simplified illustration of the product development and design process (source- <https://ars.els-cdn.com/content/image/1-s2.0-S0925753502000383-gr1.jpg>)

This contrasts with corrective ergonomics involving modifications to existing products, to overcome problems relating to safety, health, comfort, and the efficiency of the man-product system.

3.5 Design for Aesthetics

Engineering involvement with aesthetics is necessary for the creation of innovative and successful products in today's fast changing world [12]. Aesthetics are at centre of every creative process. To be creative engineers and designers have to be sensitive to implications of aesthetics in their design and work with their aesthetics capabilities.

Aesthetics can be broken into its essential elements like form, colour, texture and proportion. These are the psychological evaluation of human beings [13]. This reflects the primary criterion for the initial stage of design.

Aesthetics are a challenge to maintain during engineering design. Aesthetics are a source of progress and innovation. Link between aesthetics and engineering design should be established. The link is inspired by people and their lifestyle [14]. Appreciation of product has to be developed. Complexities of design should be challenged to improve aesthetics. The aim is to take product from sketch stage and initial ideas to prototyping stage whilst maintaining aesthetics designed in the product [15].

3.5 Use of anthropometry in product design

Anthropometry is the science that measures the range of body sizes in a population. When designing products it is important to remember that people come in many sizes and shapes. Anthropometric data varies considerably between regional populations. This study [16] highlights necessity of having Indian anthropometric data for applications in academics, industry and government agencies. NID laid foundation of this study of developing such database for NSSI.

Anthropometry is a potential tool in estimating body composition indicators and understanding human physical variations that occur with body growth in long range utility. This study [17] was done on rural male population of Orissa, India. 26 Anthropometric parameters were measured like length, circumference, skinfold thickness, etc. Study concentrated on clustering of body dimension data as body composition indicators.

Many anthropometric studies are done but only some contain data of either males or females. This study [18] uses a different F/M ration for each body part instead of single sex data. Stature, sitting shoulder height, shoulder breadth, and hip breadth are used in the study.

One of the most used Indian anthropometric data done by NID is presented well in this book [19]. Values from this particular study only will be used for any anthropometric data for this thesis work. Measurement of human external body dimensions in static and dynamic conditions which include measurements of body parts, their strength and speed and range of motion. Dynamic anthropometry is required more than static body measurements in field of design. Another study like [20] measuring anthropometric data for ergonomic design of student furniture in India strengthens its role in designing field. This was done for engineering students India. Dimensions recommended included: back rest width and height, bench surface height and depth and width backrest angle, desk depth, width and height and desk angle. This data was implemented to have comfort, safety, wellbeing, suitability and reduce MSDs and improve performance to students in academics. Eliminating poor posture in long durations of class was main aim.

Anthropometric dimensions for each population are ranked by size and described as percentiles. It is common practice to design for the 5th percentile (5th%) female to the 95th percentile (95th%) male [21]. This particular data is of US military but only used here to show the terms and measures used in anthropometric data. To avoid potential ambiguity in interpretation the following terms are defined and used in Anthropometry.

Height: A straight-line, point-to-point vertical measurement.

Breadth: A straight-line, point-to-point horizontal measurement running across the body or segment.

Depth: A straight-line, point-to-point horizontal measurement running fore-aft the body

Distance: A straight-line, point-to-point measurement between body landmarks.

Circumference: A closed measurement following a body contour, usually not circular.

Curvature: A point-to-point measurement following a body contour, usually neither circular nor closed Due to the lack of reliable Anthropometric information on civilian populations in the United States and worldwide, the current practice in ergonomic design is to use military data as estimates of the body dimensions of the civilian population.

To convert static data to dynamic use following -

1. Heights (stature, eye, shoulder and hip) should be reduced by 3 per cent.
2. Elbow height requires no change or an increase of up to 5 per cent if elbow needs to be elevated for the work.
3. Forward and lateral reach distances should be decreased by 30 per cent if easy reach is desirable, and they can be increased by 20 per cent if shoulder and trunk motions are allowed.

Depending on how they are collected, anthropometric data can be classified into two types: Structural data and functional data.

Structural anthropometric data are measurements of body taken in standing and sitting positions Functional Anthropometric data are measurements of body in various working postures i.e. when body move with reference to a point in space.

Table 3.1 - Anthropometric data for males and females while standing and seated [21]
(all dimensions in inches)

<i>Measurement</i>	<i>Males</i>		<i>Females</i>		<i>Population Percentiles, 50/50 Males/Females</i>		
	<i>50th percentile</i>	<i>± 1S.D</i>	<i>50th percentile</i>	<i>± 1S.D.</i>	<i>5th</i>	<i>50th</i>	<i>95th</i>
Standing							
1. Forward Functional Reach							
a. includes body depth	32.5	1.9	29.2	1.5	27.2	30.7	35.0
at shoulder	(31.2)	(2.2)	(28.1)	(1.7)	(25.7)	(29.5)	(34.1)
b. acromial process to function pinch	26.9	1.7	24.6	1.3	22.6	25.6	29.3
c. abdominal extension to functional pinch	(24.4)	(3.5)	(23.8)	(2.6)	(19.1)	(24.1)	(29.3)
2. Abdominal Extension Depth	9.2	0.8	8.2	0.8	7.1	8.7	10.2
3. Waist Height	41.9	2.1	40.0	2.9	37.4	40.9	44.7
	(41.3)	(2.1)	(38.8)	(2.2)	(35.8)	(39.9)	(44.5)
4. Tibial Height	17.9	1.1	16.5	0.9	15.3	17.2	19.4
5. Knuckle Height	29.7	1.6	28.0	1.6	25.9	28.8	31.9
6. Elbow Height	43.5	1.8	40.4	1.4	38.0	42.0	45.8
	(45.1)	(2.5)	(42.2)	(2.7)	(38.5)	(43.6)	(48.6)
7. Shoulder Height	56.6	2.4	51.9	2.7	48.4	54.4	59.7
	(57.6)	(3.1)	(56.3)	(2.6)	(49.8)	(55.3)	(61.6)
8. Eye Height	64.7	2.4	59.6	2.2	56.8	62.1	67.8
9. Stature	68.7	2.6	63.8	2.4	60.8	66.2	72.0
	(69.9)	(2.6)	(64.8)	(2.8)	(61.1)	(67.1)	(74.3)
10. Functional Overhead Reach	82.5	3.3	78.4	3.4	74.0	80.5	86.9
Seated							
11. Thigh Clearance Height	5.8	0.6	4.9	0.5	4.3	5.3	6.5
12. Elbow Rest Height	9.5	1.3	9.1	1.2	7.3	9.3	11.4
13. Midshoulder Height	24.5	1.2	22.8	1.0	21.4	23.6	26.1
14. Eye Height	31.0	1.4	29.0	1.2	27.4	29.9	32.8
15. Sitting Height, Normal	34.1	1.5	32.2	1.6	32.0	34.6	37.4
16. Functional Overhead Reach	50.6	3.3	47.2	2.6	43.6	48.7	54.8
17. Knee Height	21.3	1.1	20.1	1.9	18.7	20.7	22.7
18. Popliteal Height	17.2	1.0	16.2	0.7	15.1	16.6	18.4
19. Leg Length	41.4	1.9	39.6	1.7	37.3	40.5	43.9
20. Upper-Leg Length	23.4	1.1	22.6	1.0	21.1	23.0	24.9
21. Buttocks-to-Popliteal Length	19.2	1.0	18.9	1.2	17.2	19.1	20.9
22. Elbow-to-Fit Length	14.2	0.9	12.7	1.1	12.6	14.5	16.2
	(14.6)	(1.2)	(13.0)	(1.2)	(11.4)	(13.8)	(16.2)
23. Upper-Arm Length	14.5	0.7	13.4	0.4	12.9	13.8	15.5
	(14.6)	(1.0)	(13.3)	(0.8)	(12.1)	(13.8)	(16.0)
24. Shoulder Breadth	17.9	0.8	15.4	0.8	14.3	16.7	18.8

Table 3.2 - Anthropometric data for males and females for foot, hand and head [21]

(all dimensions in inches)

<i>Measurement</i>	<i>Males</i>		<i>Females</i>		<i>Population Percentiles, 50/50 Males/Females</i>		
	<i>50th percentile</i>	<i>± 1S.D</i>	<i>50th percentile</i>	<i>± 1S.D.</i>	<i>5th</i>	<i>50th</i>	<i>95th</i>
Foot							
25. Hp Breadth	14.0	0.9	15.0	1.0	12.8	14.5	16.3
26. Foot Length	10.5	0.5	9.5	0.4	8.9	10.0	11.2
27. Foot Breadth	3.9	0.2	3.5	0.2	3.2	3.7	4.2
Hand							
28. Hand Thickness Metacarpal III	1.3	0.1	1.1	0.1	1.0	1.2	1.4
29. Hand Length	7.5	0.4	7.2	0.4	6.7	7.4	8.0
30. Digit Two Length	3.0	0.3	2.7	0.3	2.3	2.8	3.3
31. Hand Breadth	3.4	0.2	3.0	0.2	2.8	3.2	3.6
32. Digit One Length	5.0	0.4	4.4	0.4	3.8	4.7	5.6
33. Breadth of Digit One Interphalangeal Joint	0.9	0.05	0.8	0.05	0.7	0.8	1.0
34. Breadth of Digit Three Interphalangeal Joint	0.7	0.05	0.6	0.04	0.6	0.7	0.8
35. Grip Breadth, Inside Diameter	1.9	0.2	1.7	0.1	1.5	1.8	2.2
36. Hand Spread, Digit One to to Two, 1st Phalangeal Joint	4.9	0.9	3.9	0.7	3.0	4.3	6.1
37. Hand Spread, Digit One to Two, 2nd Phalangeal Joint	4.1	0.7	3.2	0.7	2.3	3.6	5.0
Head							
38. Head Breadth	6.0	0.2	5.7	0.2	5.4	5.9	6.3
39. Interpupillary Breadth	2.4	0.2	2.3	0.2	2.1	2.4	2.6
40. Biocular Breadth	3.6	0.2	3.6	0.2	3.3	3.6	3.9
Other Measurements							
41. Flexion-Extension, Range of Motion of Wrist, Degrees	134	19	141	15	108	138	166
42. Ulnar-Radial Range of Motion of Wrist, Degrees	60	13	67	14	41	63	87
43. Weight, in Pounds	183.4	33.2	146.3	30.7	105.3	164.1	226.8

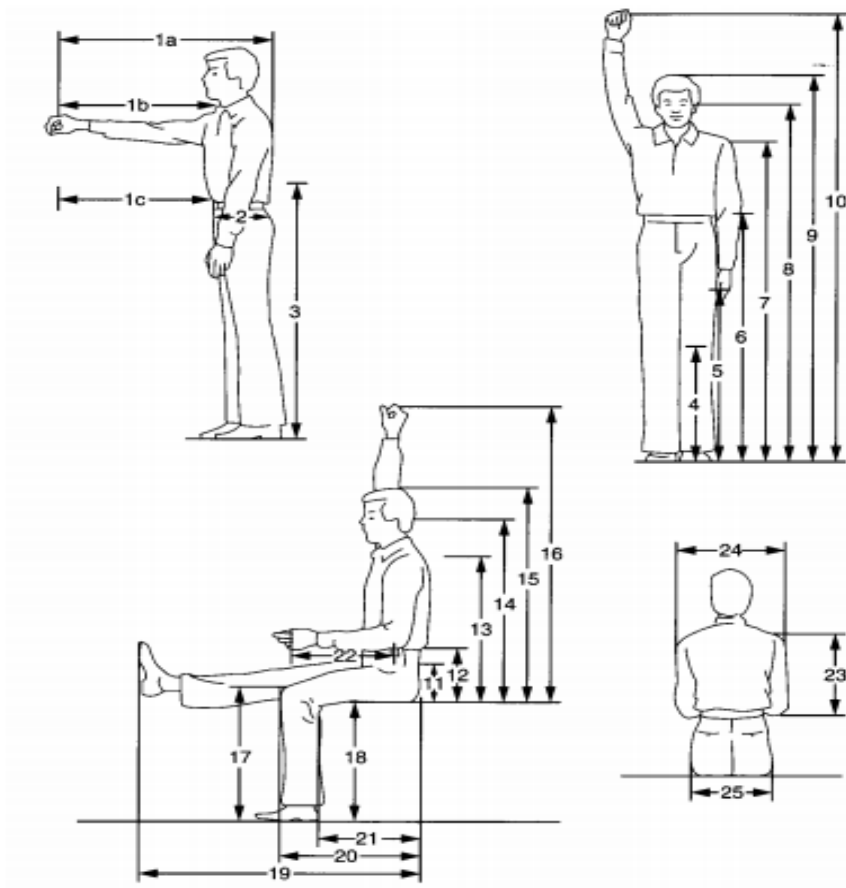


Figure 3.3 - Anthropometric measures: standing and sitting [21]

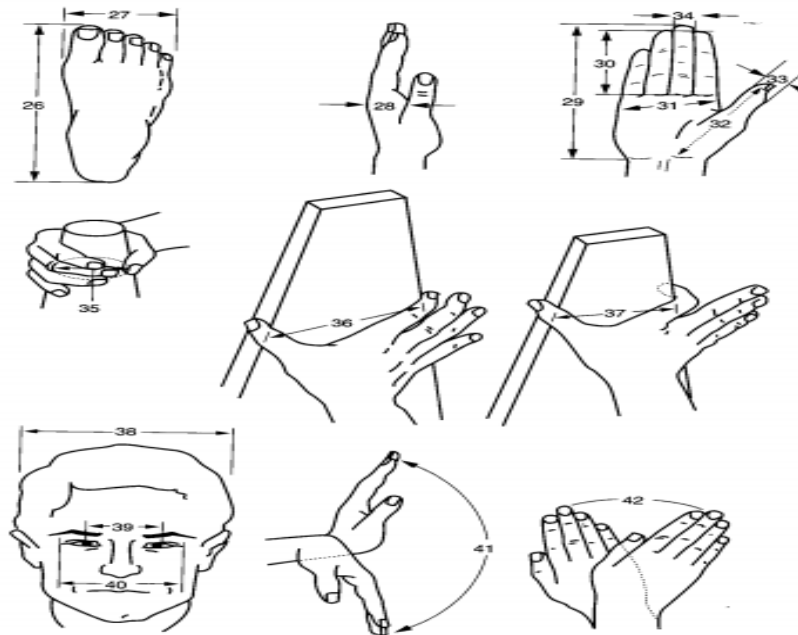


Figure 3.4 - Anthropometric measures: hand, foot and head [21]

A well-designed workplace should not only consider the regular functions of the workplace and the workers who work there every day, but also the maintenance needs and the special requirements of maintenance personnel because regular workers and maintenance people often have different needs, an adjustable workplace becomes particularly desirable.

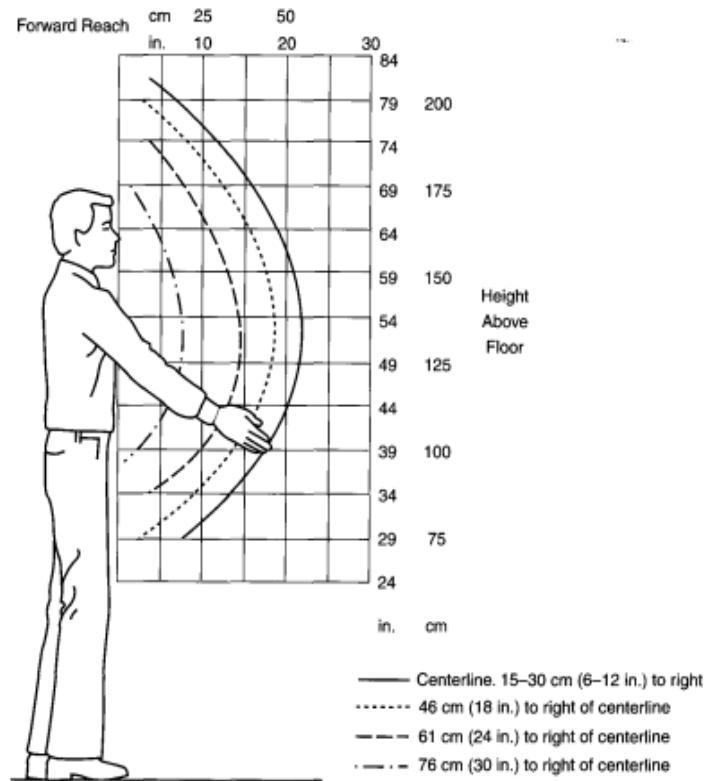


Figure 3.5 - The standing forward reach area of a small male's right hand [21]

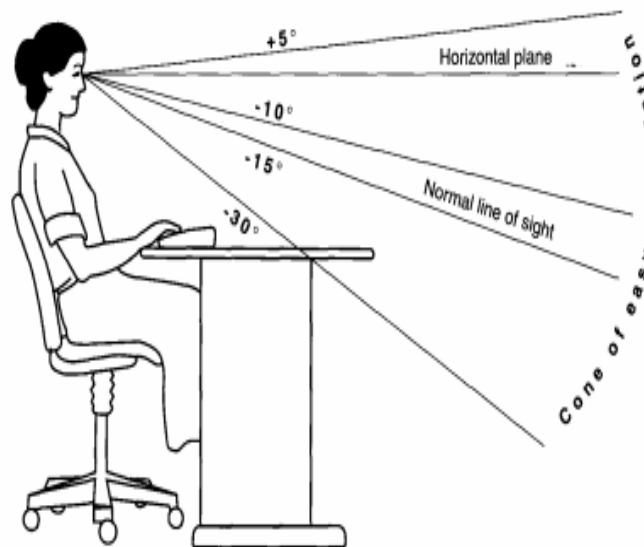


Figure 3.6 - The normal line of sight and the range of easy eye rotation [21]

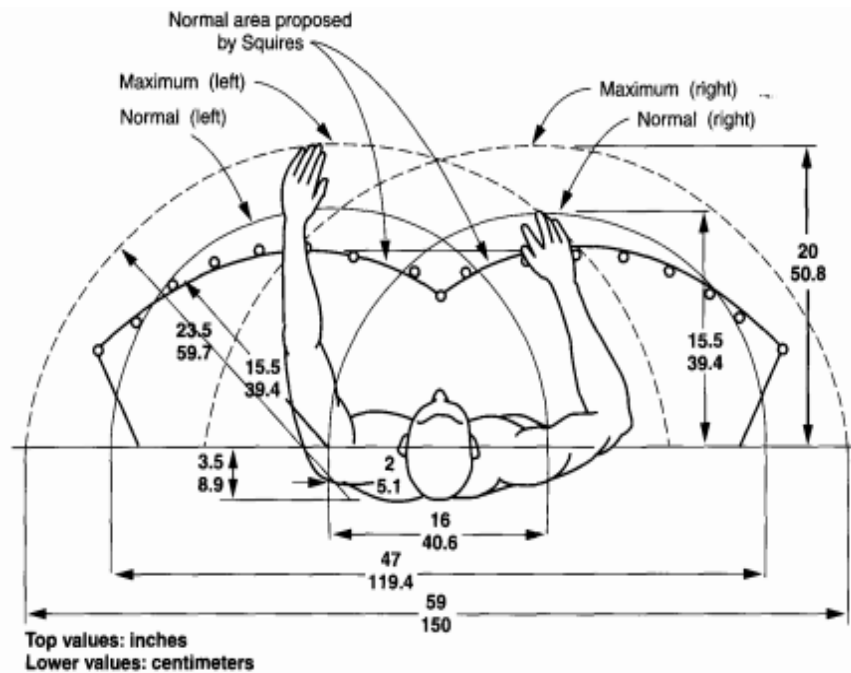


Figure 3.7 - Normal and maximum working areas (in inches and centimetres) [21]

3.6 Human centred design

Brief history of HCD helps you understand what questions to ask when designing a technology or a system or when you are evaluating a design that already exist and how focus on physiological, cognitive, and social aspects of the human user, aspects that will affect how someone will use what you design [22]. When designing we need to consider variation and similarity in the contexts, people, and tasks that characterize different design situations and settings. A one-size-fits-all approach seldom works to achieve the most productive, safe, and enjoyable design solution. There is evidence of HCD being an economic benefit tool in business settings as an approach for designing products, systems and services which are perceptually, physically, emotionally and cognitively intuitive [23].

Six characteristics are –

- The adoption of multidisciplinary skills and perspectives
- Explicit understanding of users, tasks and environments
- User-centred evaluation driven/refined design
- Consideration of the whole user experience
- Involvement of users throughout design and development

The study in [23] proves strategic innovation as an approach for designing products, systems and services and taking it to deepest levels of human interaction. HCD offers vast experience and expertise in various ways of engaging with and understanding of human beings, while design innovation offers practical methods and tools for strategic innovation [24]. HCD is moving towards deeper levels of insight about human being's needs and aspirations. At the same time strategic design innovation is becoming more human-centric.

Luma Institute [W.1] helps organizations transform into places where people and innovation flourish through our unique System of Innovation through Human-Centred Design. It has a workplace website with its complete list of research methods and various other tools to help you choose right methods for your project.

Also other HCD methodology websites provide useful matter and innovative design kits [25] to even more refine your methodology of working and use these tools to open up new ideas and innovation possibilities.

Chapter 4 - Study of Existing Design

4.1 General

To understand the current design of the fuel filling arrangement the components related to it like canopy, base rail, fuel tank etc. will be studied. These components will be modelled and their respective positions will be understood. The constraints that will limit our redesigned model will also be listed.

4.2 Canopy and Base design

Canopy is an acoustic enclosure that sits over the base rail of genset and covers all its components. Canopy has doors to access these parts. Canopy is used to silent the noise genset produces. The canopy enclosure is fabricated from CRCA sheets 16G (1.29 mm) thick and is padded with 35 mm thick PU-foam. The canopy model is modelled in PTC Creo CAD software in Cummins India for 125 kVA Genset model.

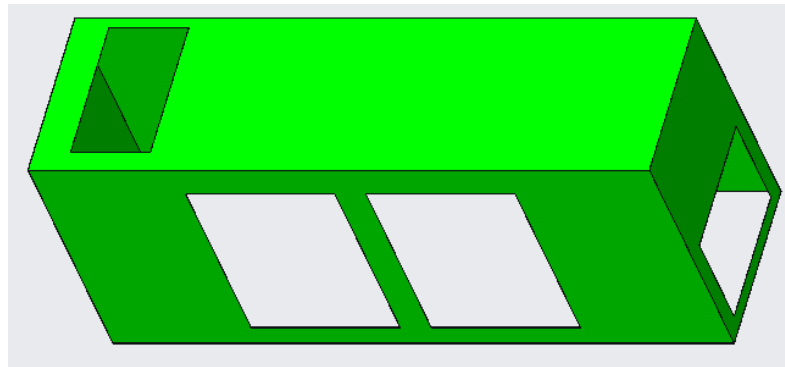


Figure 4.1 – Canopy model of the 125 kVA genset

Canopy dimensions are 4000 mm in length, 1650 mm in height and 1050 mm in width. On Base rail of Genset all other components of Genset are attached. It is fabricated with HR sheet 4 mm thick. The base rail of the Genset also holds the fuel tank which is bolted and welded to it.

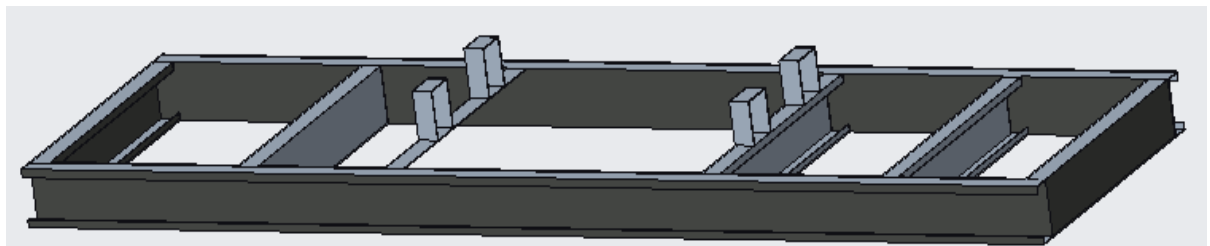


Figure 4.2 – Model of base rail of the genset

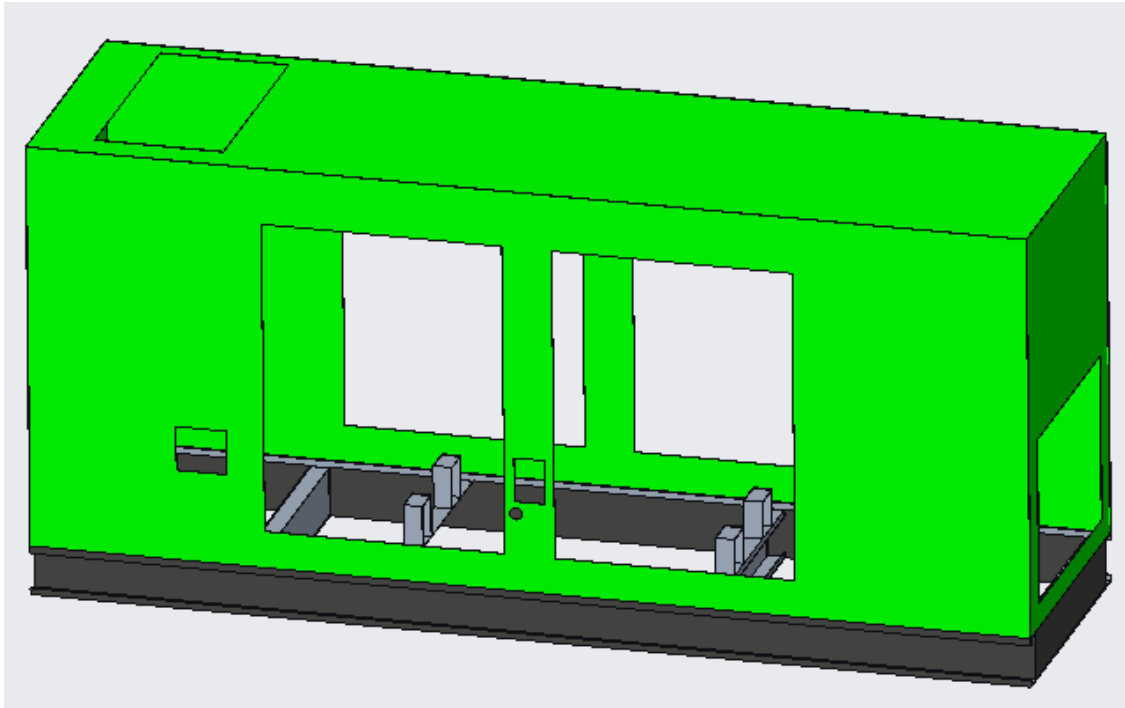


Figure 4.3 – Model of assembly of canopy and base rail

4.3 Fuel tank with fuel filling arrangement

Fuel tank is located inside base rail of the genset. Fuel tank is fabricated using HR sheet 3mm thick. Fuel tank has a capacity of 330 litres of fuel. The dimensions and position of fuel tank are shown in **Figure 4.5** and **Figure 4.6**.

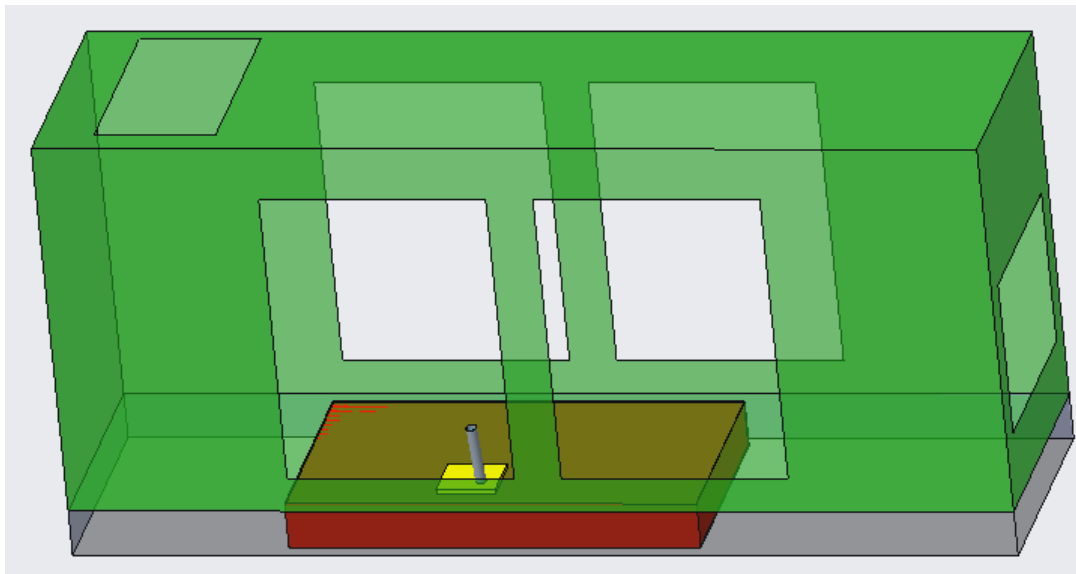


Figure 4.4 – 3D view of fuel tank positioned inside canopy and base

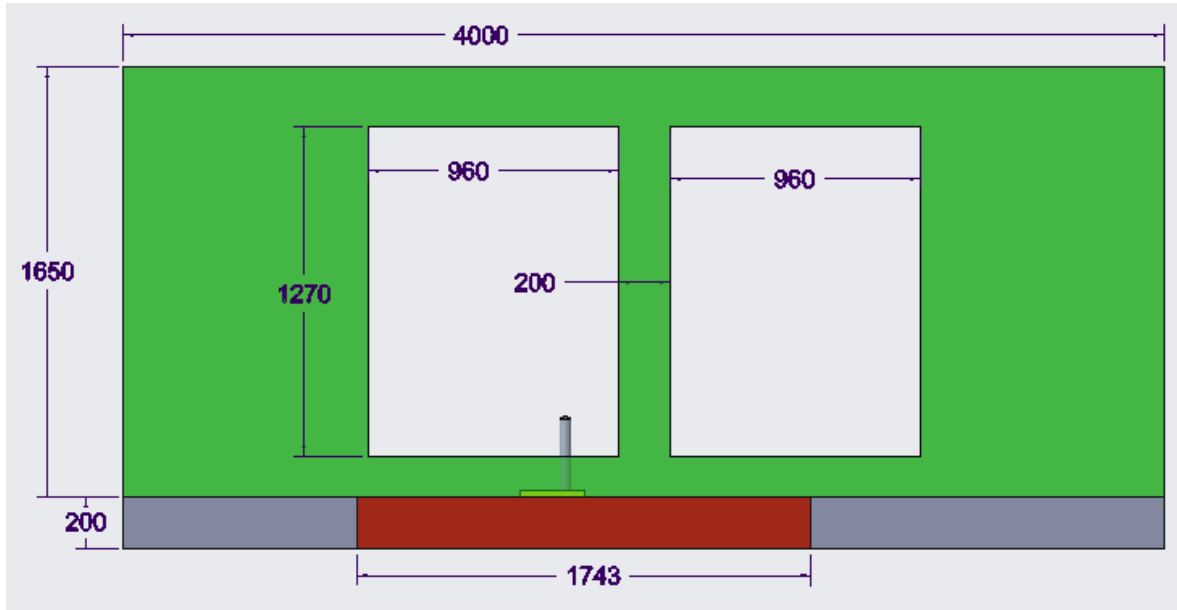


Figure 4.5 – Position fuel tank inside canopy model from front view (all dimensions are in mm)

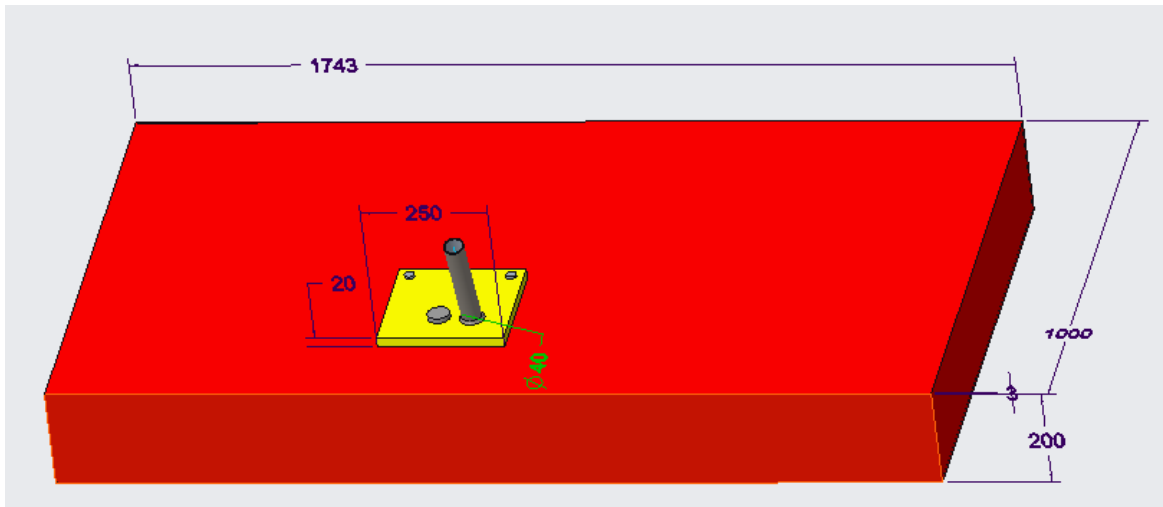


Figure 4.6 – Fuel tank dimensions with model (all dimensions are in mm)

On top of fuel tank is the fuel filling pipe protruding with cap on its mouth. To the side of fuel pipe we can see fuel level indicator also placed on top of tank only. The level indicator is a float type mechanical operated. Also we have fuel inlet and outlet pipes going to the engine for fuel needs. This part is bolted to the tank which is also used for cleaning of tank.

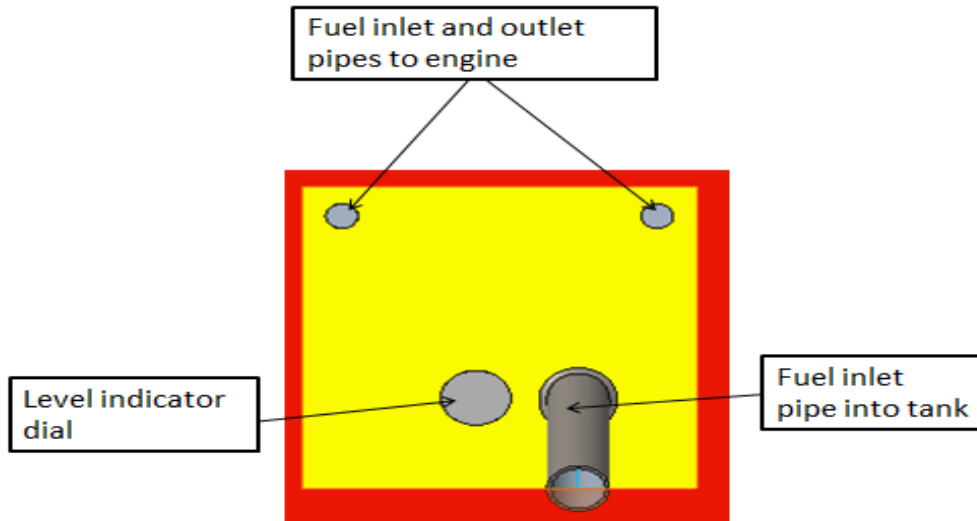


Figure 4.7 – Fuel tank cover plate on top of tank



Figure 4.8 – Original image of the design on Genset fuel tank

4.4 Type of fuel level sensor used

Fuel level used in this genset is mechanical float type sensor attached to a dial indicator that shows fuel level pointer between zero to full and minimum to maximum this level can be set by calibrating the device.



Figure 4.9a – Float type level sensor



Figure 4.9b – Fuel level dial indicator

The functioning of above float level indicator can be understood as follows. There are two main parts to a fuel gauge -

1. Sender - This measures the level of fuel in the tank shown in **Figure 4.10**
2. Gauge - This displays the fuel level as shown in **Figure 4.10**

The sending unit consists of a float, usually made of foam, connected to a thin, metal rod. The end of the rod is mounted to a variable resistor. The more resistance there is, the less current will flow. In a fuel tank, the variable resistor consists of a strip of resistive material connected on one side to the ground. A wiper connected to the gauge slides along this strip of material, conducting the current from the gauge to the resistor. If the wiper is close to the grounded side of the strip, there is less resistive material in the path of the current, so the resistance is small. If the wiper is at the other end of the strip, there is more resistive material in the current's path, so the resistance is large.

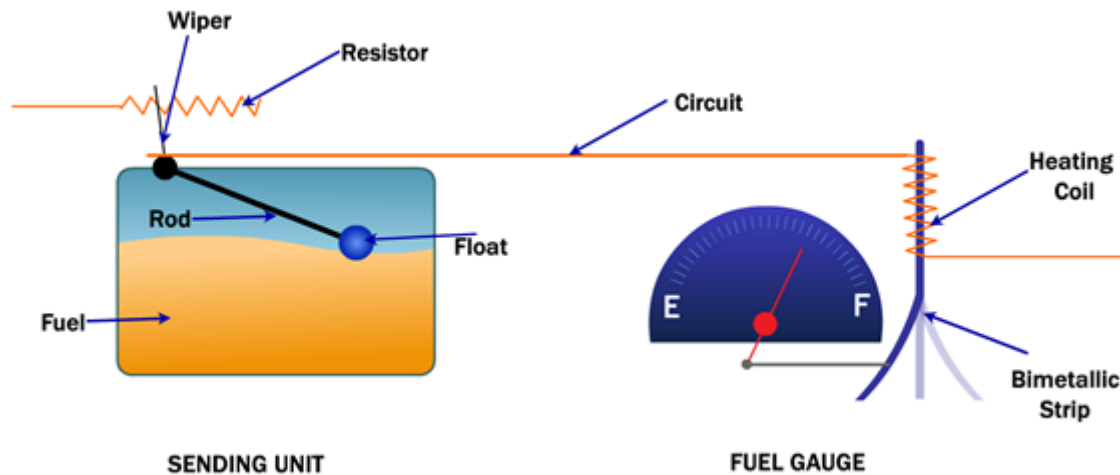


Figure 4.10 – Working of float type level sensor and indicator

The gauge is a simple device. The current from the sender passes through a resistor that reaches a bimetallic strip. The bimetallic strip is connected to the needle of the gauge through a linkage. As resistance increases low current passes through the heating coil, so the bimetallic strip cools. As the strip cools it expands pulling the gauge from full to empty.

4.5 The problems faced in current design of fuel filling method

Since the arrangement is inside canopy although it's safe from theft but not convenient to use. The user who fills the fuel has to open door and get inside so limited space is available to the user and takes more than just proper filling of fuel. While talking to the end users spillage of fuel over the tank was main problem reported and increases maintenance work also.

Such filling operation can only be performed while the genset is not running or is off that limits the chance of filling fuel and also checking level at times. The time taken to fill and perform this operation also leaves for scope to look for other approach that reduces time and effort. Also the filling point level or height is very low which invites uncomfortable and extra human effort.

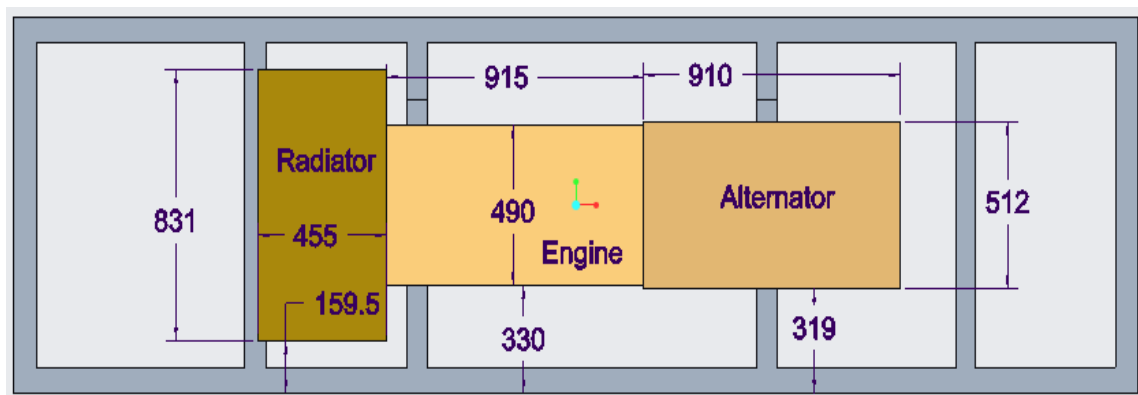
4.6 Conclusions from study of existing design

- The internal fuel filling arrangement is inconvenient for the end users who have to fill fuel at regular intervals.
- This calls for an external fuel filling method which will remove the short comings of existing design.
- The inlet of fuel filling pipe and the level indicator have to be brought externally.
- The fuel filling point height as well as fuel level indicator height should be decided ergonomically.
- The redesign should have minimum changes so that other components supporting it are not changed.
- The cost of redesign should be within company's scope.
- New design should not completely change existing components.
- The redesign should use standard parts.
- If the fuel filling has to be done externally, so fuel theft could be a problem
- Gensets have to be made safe and theft proof.
- Changes in new design that prevent fuel from being stolen or siphoned have to be explored.
- The new fuel pipe should have minimum bends to have proper fuel flow.
- The aesthetics of genset has to be kept in mind so that it appeals to the customer the redesigned feature.
- The venting of tank as well as flow analysis for tank sloshing of fuel can be simulated with new design.
- Last but not least the working environment and maintenance work has to be minimised and made easy for the user that ultimate aim of any improved design.

Chapter 5 - Study of Alternate designs

5.1 Identifying position on the canopy for external filling

The first step towards making arrangement from outside is identifying the space on canopy where a hole in the sheet will be cut and filling point or fuel intake pipe mouth will come out. For this purpose the space inside and outside is explored and seen there are no interference with any components when pipe goes through it. For this purpose looking into the sizes of main components of a genset with their maximum sizes was also checked and that gave us our boundary condition or space available to work with and design.



**Figure 5.1 - Model showing space left after size of engine, radiator and alternator on frame
(all dimensions in mm)**

Based on above figure there are many places on genset to explore for new arrangement of filling point. Every space has its shortcomings to that will be investigated in following models.

Position 1 - The space on the centre member between the two doors is best space because it does not change much of the periphery of the current design and also pipe length is shortest and can be conveniently positioned at good height. Still there is challenge to how the pipe should go into tank.

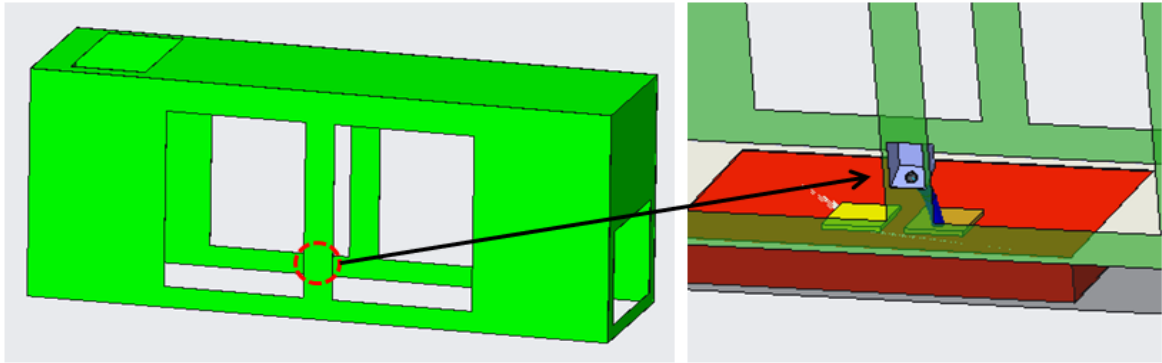


Figure 5.2 – Space for fuel pipe in between door of canopy

Position 2 - This part of canopy to the left side of the door has inside radiator compartment but does not interfere with any of its part. The fuel pipe if designed doesn't reach straight to the tank but has more than 1 bend which will affect fuel flow also there is concern about the temperature inside radiator compartment that could affect the pipe.

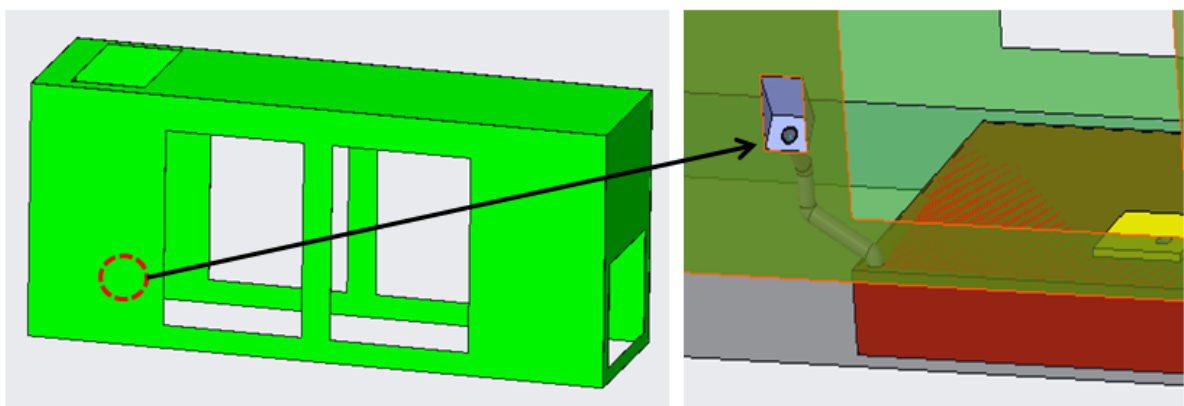


Figure 5.3 – Space for fuel inlet pipe to the left side of door

Position 3 - This particular space to the right side of canopy door comes in front of alternator although any pipe going through it wont interfere with any of its part but the fuel tank is away from it and pipe also not goes straight into tank and has even greater length than 2nd case.

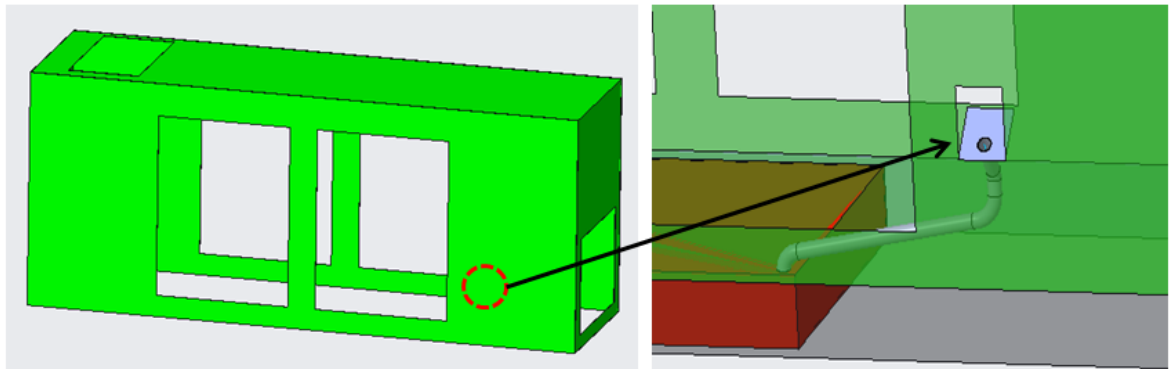


Figure 5.5 – space for fuel pipe in front of alternator

Position 4 - This space below the door is not most preferable as it gives very low filling height the user will have to bend or bow down a lot to fill fuel and this is not ergonomically advisable.

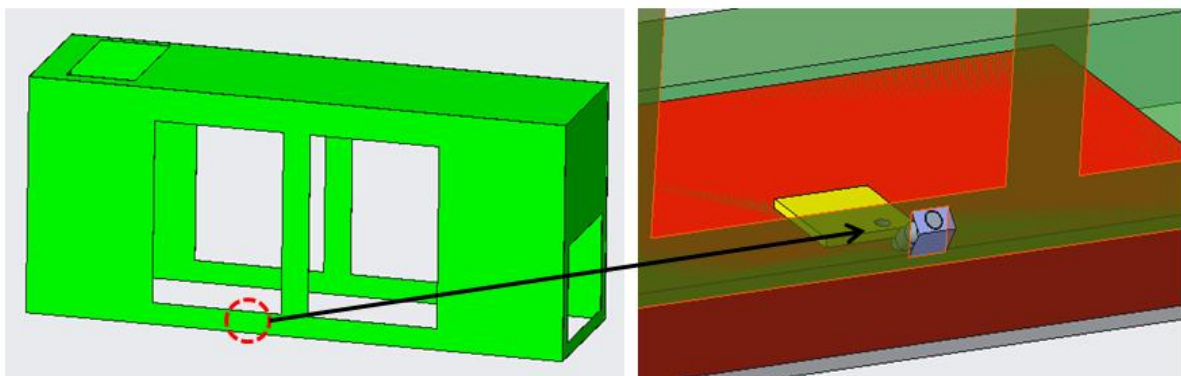


Figure 5.4 – Space for pipe below canopy door

From the detailed view of above designs only two spaces on canopy can be considered for designing external arrangement i.e., Position 1 and Position 2. Let's see these designs in detail how the pipe will go into tank.

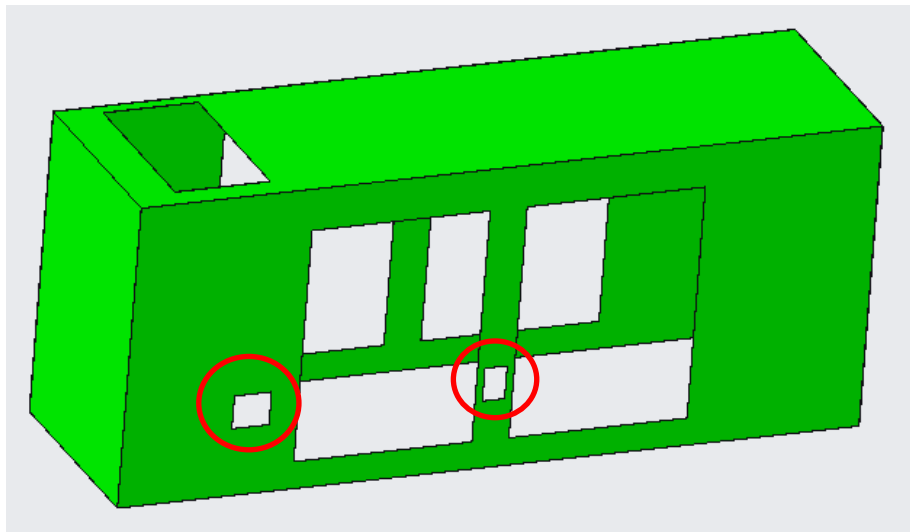


Figure 5.6 – Two of the sorted places where pipe can come out for filling fuel

Two best possible places were identified one in the centre of the space between the doors and one to the left side of the left canopy door. The dimensions of the cut-outs in the sheets have been given in the table below. The height from ground is in range of 500-600 mm approx. for ergonomic fuel filling operation. At this height any person filling the diesel fuel would take minimum effort.

5.2 Use of Anthropometric data to find suitable filling and level indicator height

Using anthropometric data the dimensions that are important to identify the right filling height can be chosen. These data will be taken in standing position for 95th percentile population. The data listed in the literature review belongs to US military [21] and is shown for reference to all the measurements in anthropometry and referenced that with the Indian study on anthropometry which will be used here [19]. The following dimensions used are for men and women both. All dimensions are in mm.

1. Normal standing – 1741 mm
2. Eye level – 1633 mm
3. Elbow height – 1115 mm
4. Forward arm reach – 939 mm

5. Mid position height – 1489 mm
6. Lower position height – 939 mm
7. Optimum line of sight angle range – 25° - 0° - 30°

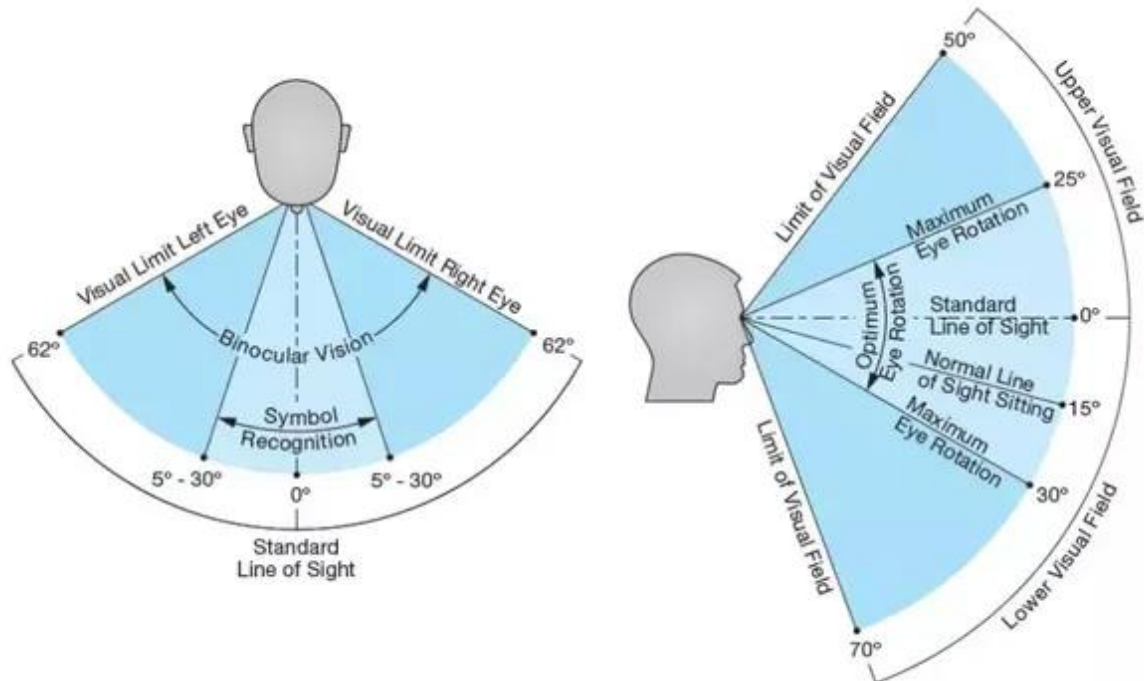


Figure 5.7 - The normal line of sight and the range of easy eye rotation (refer to Figure 2.7)

So the level indicator should be in range of 1633 to 1000 mm from ground level and filling height should be in range of 800-900 mm from ground level which sometimes also includes at least 200 mm flooring base.

5.3 Pocket

The sheet metal pocket that will cover the cut-out in the canopy sheet is designed to hold the mouth of pipe in correct place as well has enough space to fill by means of pump or place funnel over the mouth. This is bolted at its 4 corners to the canopy. This pocket is made from same CRCA canopy sheet of 11G.

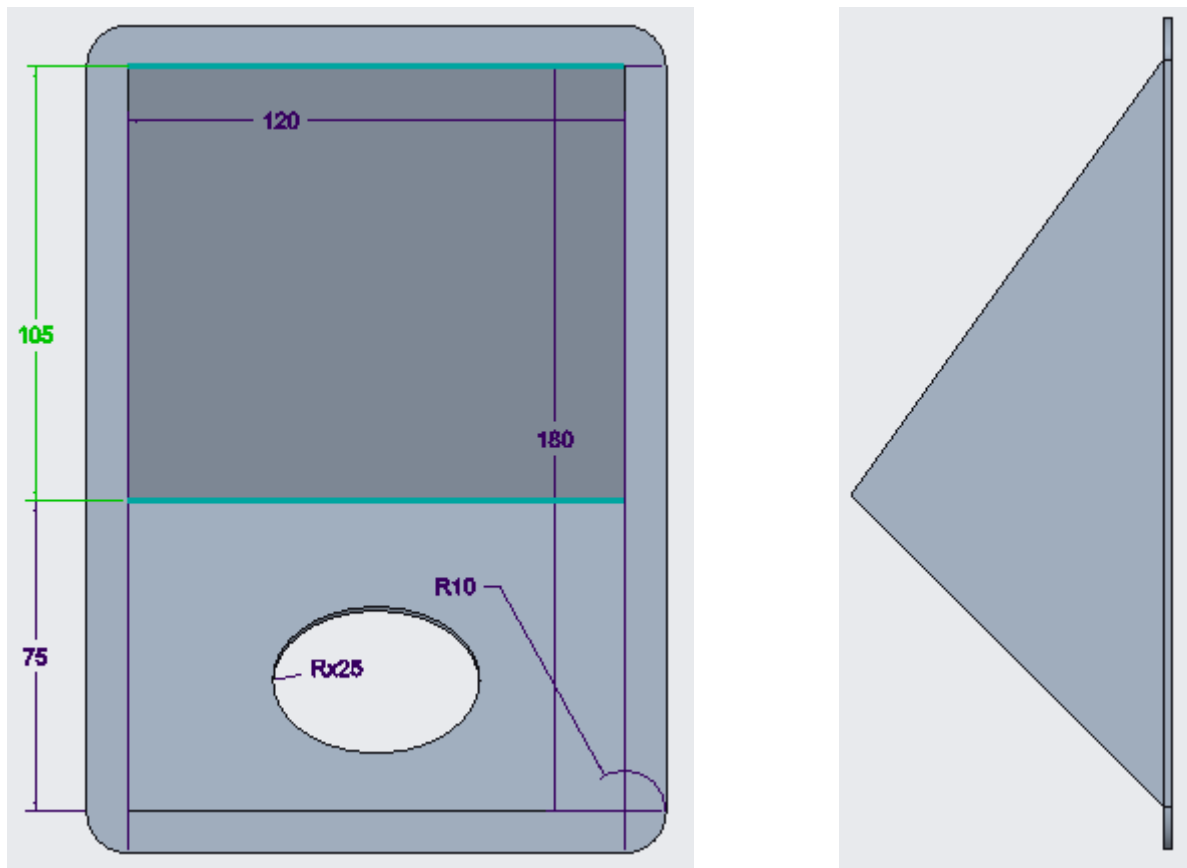


Figure 5.8 – Front and side view of pocket with dimensions (in mm)

5.4 Changes in fuel tank and design of fuel inlet pipe

Referring to **section 4.1** the first part or first space which was considered was between two canopy doors. This space also has central lifting arrangement on top of genset. This space is closest to the fuel tank and also to current fuel arrangement so this will have minimum cost in designing and manufacturing it.

The pipe length will also be less. The new pipe design as seen in **Figure 5.9** doesn't interfere with any of the other components of genset and also with working space of genset service engineers.

The pipe design is simple straight going into tank but now close to its edge rather than previous design. It has one bend but that doesn't hamper much flow of fuel into tank. How fuel flows inside this pipe will also be checked by simulating fuel flow in further sections.

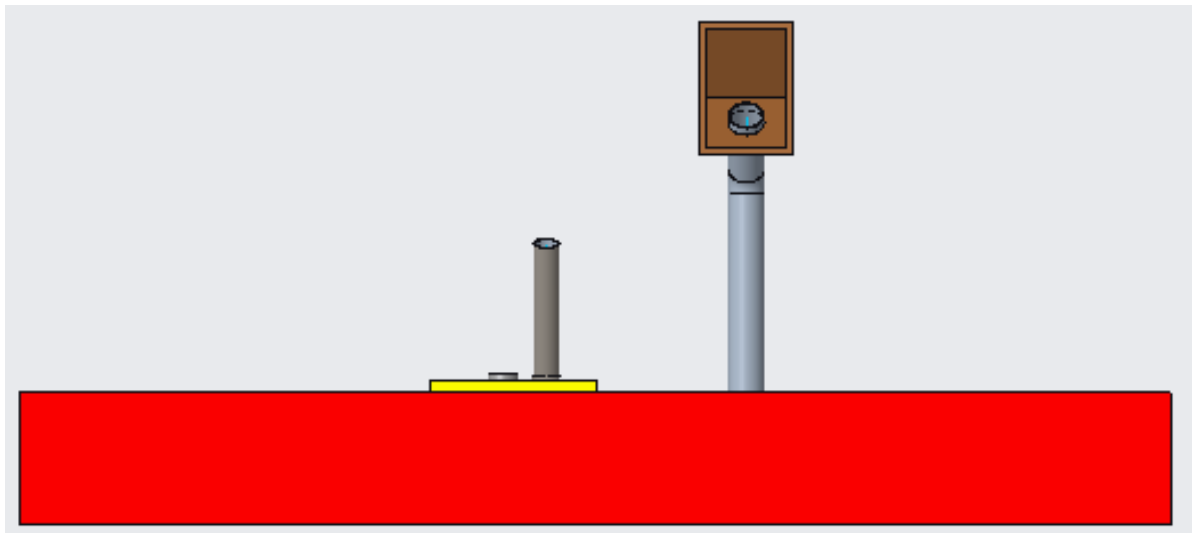


Figure 5.9 – Model 1 of redesigned fuel pipe in reference to previous design can be seen

The height of fuel filling point is 600 mm above tank or 800 mm above ground level. Most of the genset are placed on platform which also gives an extra height to the pipe mouth. In combined the fuel filling point is around 700-800 mm above the ground level which is ergonomically safe for most of the users. The pipe is bent at an angle ranging in between 40-50 degrees which gives the user a better visibility and mouth area.

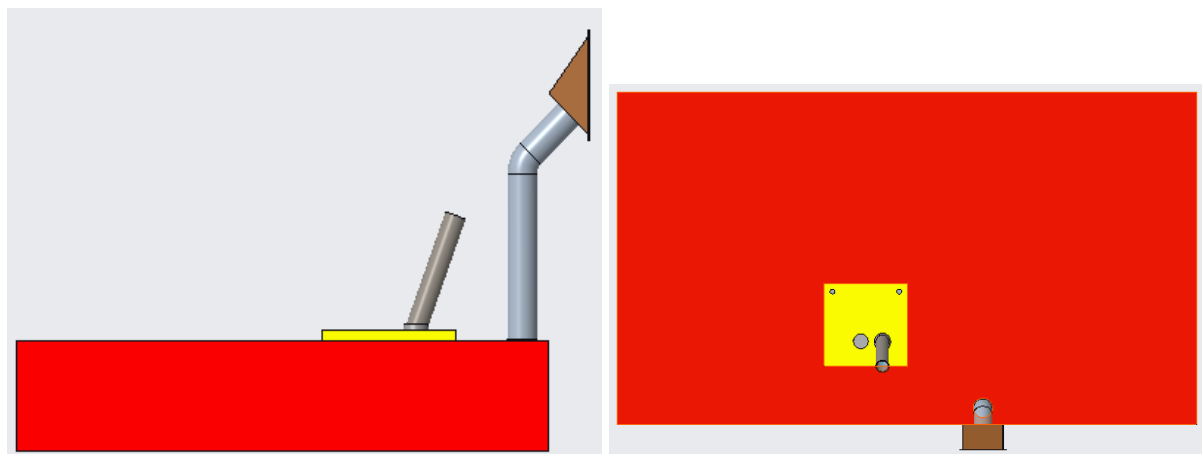


Figure 5.10 – Side and Top view of the model design

The second design is from the second space identified to the left of the canopy door. Here the pocket is of a bigger size and also has space for a fuel level indicator dial right next to the filling pipe.

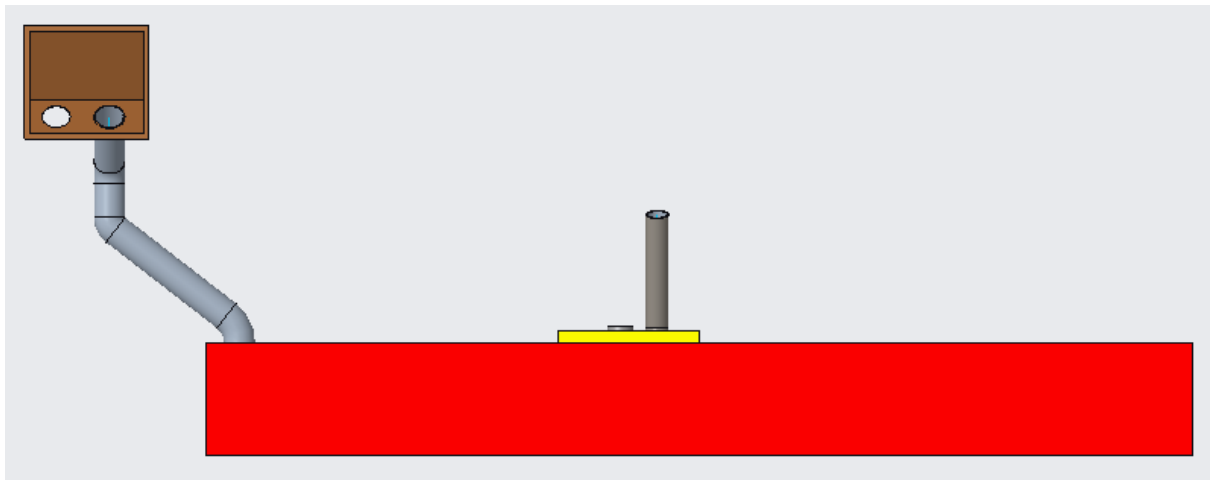


Figure 5.11 – Front view of Model 2 of pipe going to the left side of tank

This pipe also goes straight into the tank to its left most side and corner it is welded to the tank. The pipe here has more than one bend that could affect the fuel flow. The pipe does not interfere with any of the other genset components and also working space of service engineer. Since this pipe goes inside the compartment having radiator of genset which has temperatures more than other areas this design is preferred next to first one. Maybe if any insulation is done that it might work well and not affect fuel inside pipe. But this also increases cost so is made as suggestion to the company.

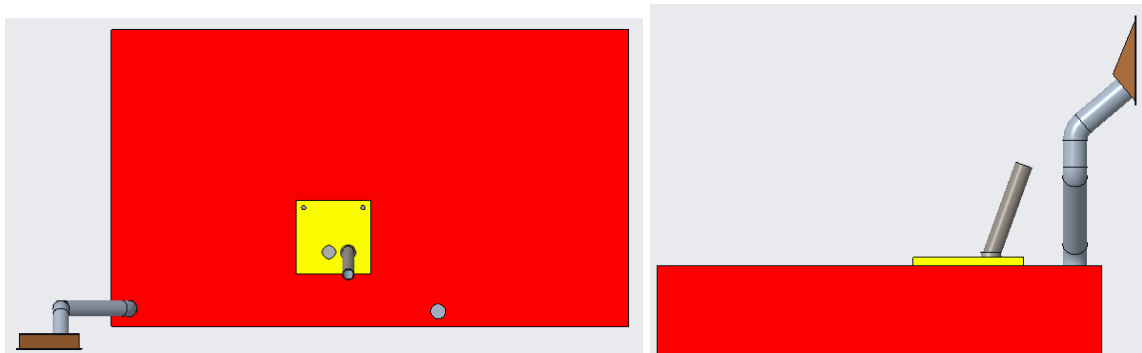


Figure 5.12 – Top and Side view of the alternate design of fuel pipe

5.5 Choosing right type of level indicator and its position

The level indicator previously used was manual float type which had less resolution also it was only reachable till top of tank i.e., its indicator dial was situated on top of the tank. For new design new level indicator magnetic type float indicator was chosen. Such type of indicator is used for low cost accurate measurement.

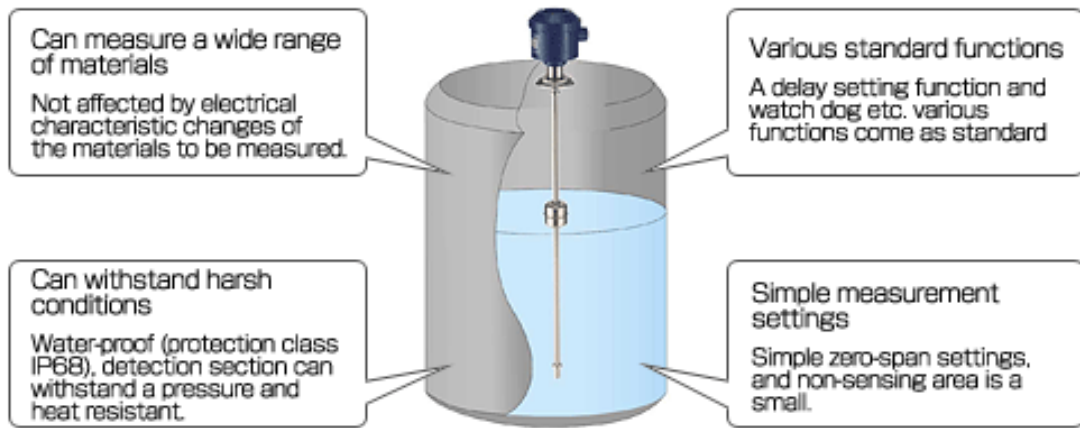


Figure 5.13 – Magnetic float type level sensor

The principle of buoyancy is used to move float up and down. A reed switch outputs detection signal after actuation by a magnet in the float. Float type liquid meter has advantage of not be affected by material on electrical aspect.

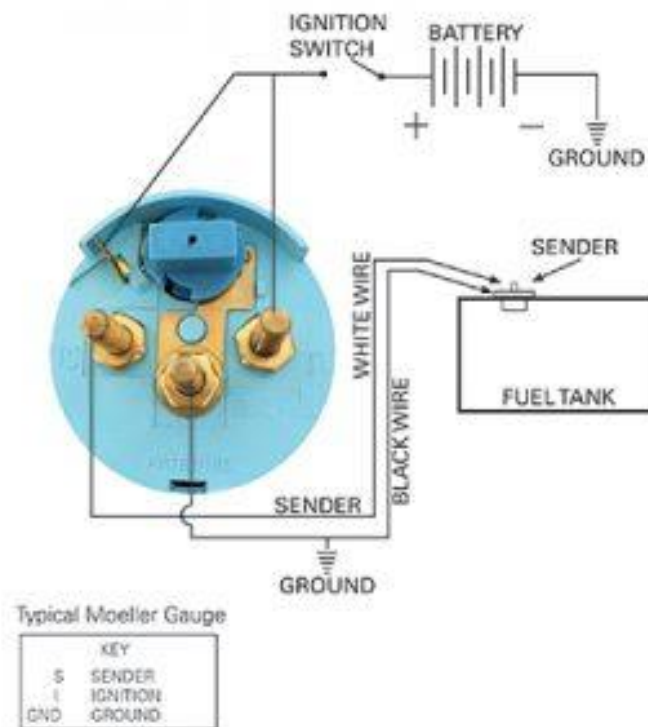


Figure 5.14 – Dial indicator with sender and reciever

The basic mechanical fuel gauge consists of very few parts, and its operation relies on the same simple principle as a voltmeter (voltage-measuring analogue meter). Essentially, the fuel gauge just needs to measure voltage across a variable resistor. But said resistor must somehow vary in direct proportion to the amount of fuel in the tank. To do this, within the fuel tank is a float at one end of a lever arm-and-slider running over a strip of resistor at the other end. Known as the Sending Unit, it is a vital part of every vehicular fuel tank and works flawlessly.

As the float moves vertically with the changing fuel level, the opposite end of the lever slides across the resistor, causing a change in voltage supply at the gauge. Finally, in direct response, the indicating needle moves to the appropriate position on the gauge. Fuel gauges have just two main markings – F for Full and E for Empty. Some have a “½” marking, too, to show half-tank.



Figure 5.15 – Magnetic level sensor with dial unit in original

Such fuel level indicators are readily available in market and can be easy contacted and asked for from suppliers based on the requirements.

They cost roughly in the range of Rs.2000-3000 tough not cheap but their advantages discussed further makes up for the cost spent.

Some important points to note about magnetic level sensor and gauge are –

- Output can be in purely resistance or voltage range, easy calibration
- Custom SAE standard holes and stainless steel material
- Low resolution in range of 5 mm and 10 mm
- Suitable for temperatures up to 55 degree Celsius
- Has an extra wire for alarm output, can be used for online monitoring
- Can measure accurately any liquid in static, flowing or turbulent conditions
- Professional and robust design can work under vibrating environment

5.6 Anti-fuel theft measures

Fuel theft is one of the biggest problems faced by the users of genset. Thieves try any means at times to steal fuel by siphoning majorly. Siphoning fuel by means of hose put in the fuel inlet pipe to the tank is the most common practice. The existing design though had fuel tank inside enclosure so there was protection from theft as doors are locked. But for new design now this fuel inlet point is outside and is more prone to theft. So to prevent this first thing is to provide a fuel door that will be locked from outside as by means of padlock. This will be addressed in detail in next section. Second line of fuel theft prevention is providing solutions like perforated plate in the passage of fuel pipe so that any hose cannot go inside and fuel cannot be siphoned. For this design in addition to a perforated plate a retrofit anti-theft measure (ATM) which has holes in its base and its periphery fit in the mouth of intake pipe is also designed that enable enough flow rate of fuel and offer better protection.

The model in figure below is a low cost idea to make blockage in form of series of perforated plates to limit any hose from entering the pipe and siphon or steal fuel. In this case we make a single plate with holes at bottom of the pipe. However they reduce the area and can cause less flow rate of fuel to tank. Let's take this model as ATM 1.

- Pipe diameter – 50 mm
- Pipe thickness – 2.5 mm
- Plate at bottom for blocking any hose to siphon fuel
- Plate thickness – 5 mm
- Number of holes at bottom – 24 holes
- Diameter of each hole – 5 mm



Figure 5.16 - Model of ATM 1 showing plate for blockage with holes at bottom

Now lets look at anti-fuel theft devices (AT2 and AT 3) that act as retrofit device which can be fit over mouth of pipe. This can be fit with help of screws. The device has holes over its periphery and bottom that allow increased flow area and fuel to pass through easily without any hindrance. Such devices can offer flow rates upto 150 litres per minute.

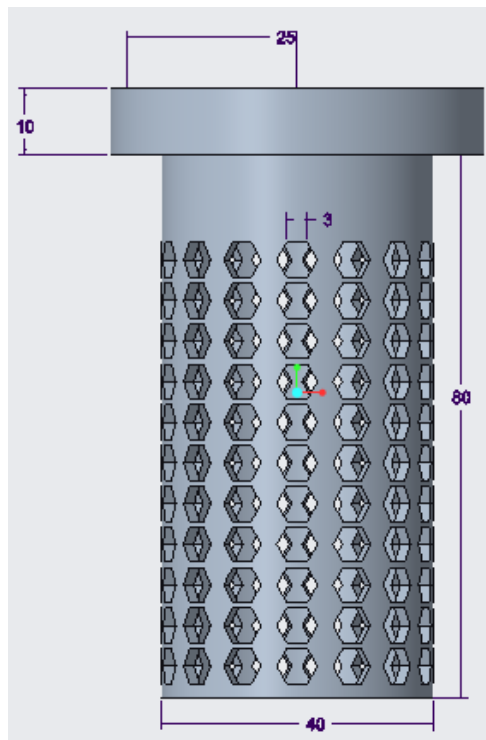


Figure 5.17 – ATM 2 model on Creo

- Pipe diameter – 50 mm
- Pipe thickness – 2.5 mm
- Holes at the bottom plate – 20 at 4ϕ + 10 at 5ϕ + 5 at 4ϕ
- Holes on periphery - 10x15 at 3 mm side hexagon

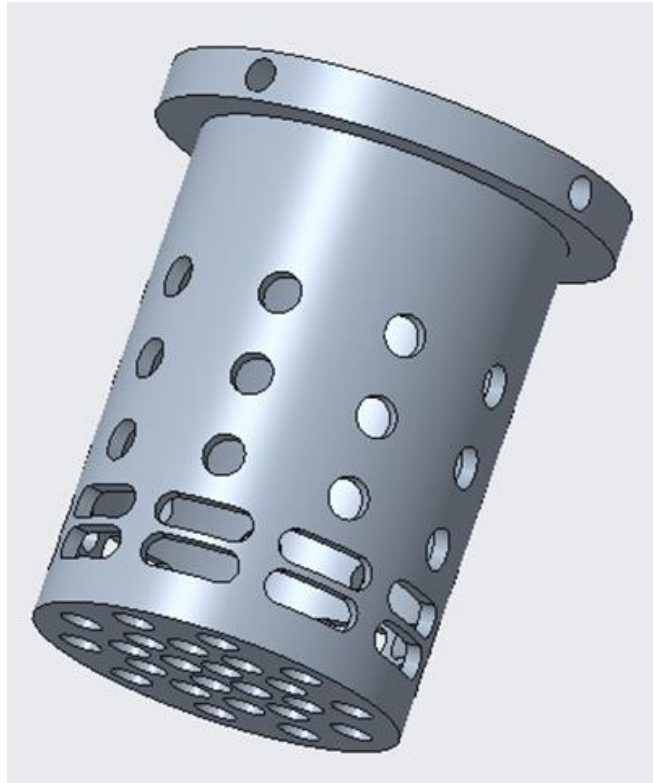


Figure 5.18 – ATM 3 model on Creo

- Pipe diameter – 50 mm
- Pipe thickness – 2.5 mm
- No. of holes on bottom – 24 at 5ϕ mm
- No. of holes on periphery – 27 at 5ϕ mm + 18 at $(10 \times 4 + 2\phi)$

These devices are made of strong material and thick walls that cannot be tempered easily. The trick with such devices is to allow more area for fuel to flow more than pipe diameter. The holes have diameter as low as 5 mm so no hose can be put through for theft. The fuel goes smoothly and there is no splash back also.

5.7 Fuel inlet pipe cap

A fuel cap keeps the pipe mouth closed and not exposed to the surrounding. Also keeps the fuel away from splashing if any moving genset. There are also caps with key lock in them but these are costly not required as we have provided for two layers of security i.e., anti-theft fuel device and locked fuel door. The fuel caps are easily available with suppliers and there is no need to design this for this arrangement.



Figure 5.19 – Fuel cap with lock or without lock

5.8 Fuel pocket flap or cover with locking arrangement

Fuel pocket should be covered with a flap that protects it from dust and water settling around the pipe mouth and cap. Also fuel flap/door can be locked from outside using padlock for further safety and theft protection. Such arrangement is cost effective and was also preferred by company. There are 3 ways for flap door designed to open these are flap door that open upside or down or to the side. A comparison will be done to find the best way to open it.

Let's see how it can open upside. This opening will be done by means of hinge. There are various types of hinges available in market to open a door. A butt hinge will serve our purpose in this case. There are many standard sizes available but considering size of our flap door a model is designed for it. Hinges are smooth way to open door which opens like that. Since this door will be opened many times we need smooth opening and longer life cycle of product.

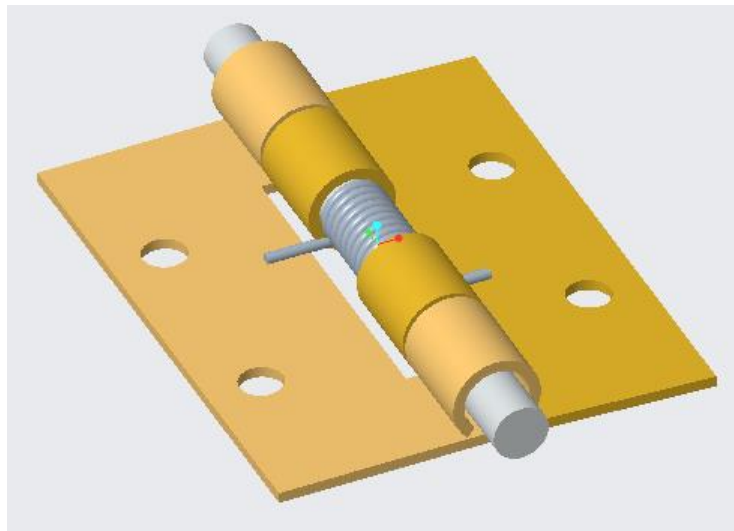


Figure 5.20 – Butt type hinge with spring

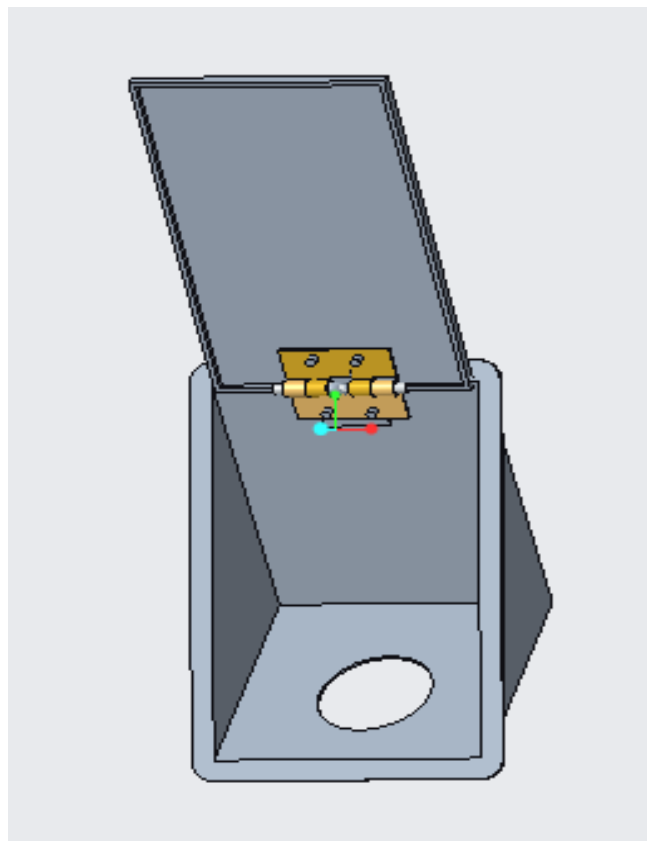


Figure 5.21 - The flap door assembly with hinge and spring

The spring used is torsion spring which is of open type i.e., it keeps the flap door open when lock is opened. The spring dimensions are calculated with help online spring generator which gives us standard spring for the shaft diameter or the deflection in the spring.

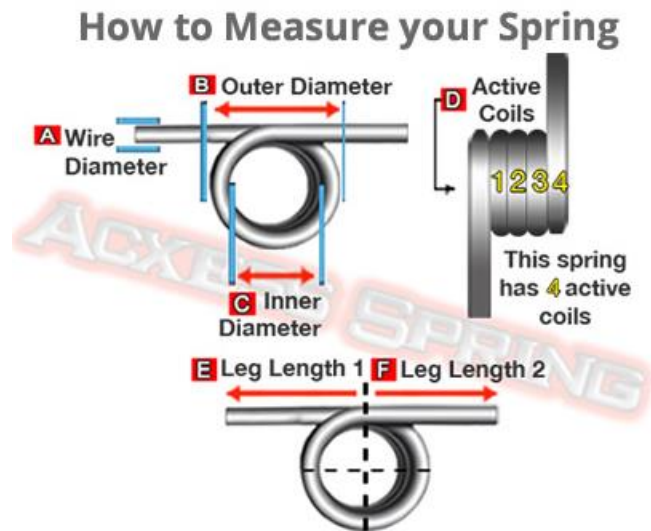
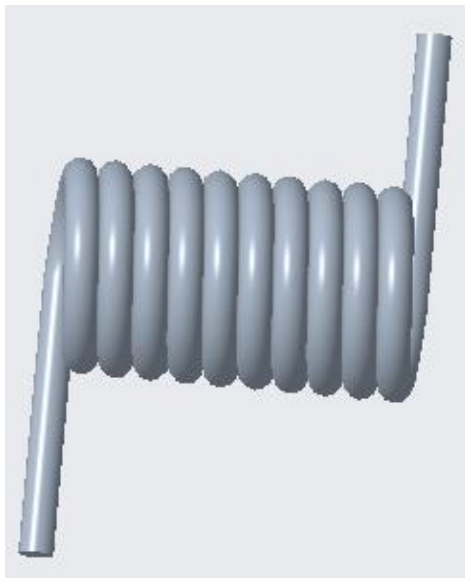


Figure 5.22 – Torsion spring with the some important spring values [W.5]

	Inner Diameter (mm)	4.902
	Outer Diameter (mm)	6.325
	Leg Length (mm)	25.400
	Body Length (mm)	6.350
	Total Coils	7.000
	Wire Diameter (mm)	0.711
	Wind Direction	RH - Right Hand
	Rate (Nmm/deg)	0.323
	Max. Torque (Nmm)	47.452
	Max. Deflection (Degrees of travel)	146.000
	Mandrel Size (mm)	4.064
	Material Type	SST - Stainless Steel 302

Figure 5.25 – Spring dimensions formulated from online tool [W.5]

5.9 Flow area analysis

Flow area has to be calculated to know how much area will be available after making holes or perforated plates. This area should not restrict flow and cause any fuel to flow back. Smooth flow of fuel to the tank is our aim.

For original design -

- Diameter of fuel pipe = 50 mm
- Area of inlet(mouth) – $3.14*(25*25) \text{ mm}^2 = 1963.5 \text{ mm}^2$
- Tank size – $(1743*1000*200) \text{ mm}^3 = 348 \text{ litres}$
- Tank capacity = 330 litres = 330000000 mm^3
- Let's take flow rate as 50 litres per minute to fill the tank
- Flow velocity – 0.42 m/sec
- Time taken to fill tank – 6.6 minutes

For ATM 1(refer **section 5.6** and **figure 5.16**)

- Holes – 24 holes at bottom of 5ϕ mm
- Flow area – 471.24 mm^2
- % of original design – 25% approx.

For ATM 2 (refer **figure 5.17**)

- Base holes – $10@4\phi + 10@5\phi + 5@4\phi$
- Base area – 384.84 mm^2
- Holes on periphery – 150 with each area – 23.33 mm^2
- Area on periphery – 3507 mm^2
- Total area for flow – 3892 mm^2
- % of original area – 200% approx.

For ATM 3 (refer **figure 5.18**)

- Holes at base or bottom – 24 holes of 5ϕ mm
- Area of base – 471.24 mm^2
- holes of periphery – 27 holes at 5ϕ + 18 holes
- Total area – 1947.6 mm^2
- % of original design – 100%

Chapter 6 - Results and Discussions

6.1 General

The redesigned model of 125 kVA genset had many issues to address with respect to human accessibility and space as well as easy operation. How well they have been addressed will be seen in this chapter. There were many constraints on new design which limit the scope of work and had been taken into consideration as well.

6.2 Space in and out of genset

The model was modelled well within the space available for redesigning. No new components interfere with other components. The position of components like fuel tank and cover plate used to clean tank which previously had the fuel inlet pipe coming out of tank remain unchanged physically and mechanically also. The working space inside genset is easily accessible with new design and there is ample space for service engineers and maintenance people too.

6.3 Height of human filling point and level indication

As studied in previous chapters and from literature review the height of filling point is of utmost importance in this arrangement. To reduce the human effort and make the operation easy for the user an ergonomically height of about 600 mm from base bottom was observed and suggested. This height ensures that the user doesn't have to go down much and also not reach high enough to fill the fuel. This ensures less effort and easy operation with high comfort level as filling fuel tank can take time so uneasy posture was not desirable.

The level indicator dial was also shifted to a convenient location from previous arrangement. Since the fuel arrangement is also from outside so the level indicator dial was also placed on the canopy body above the fuel inlet point at a convenient height so that while filling the user can see it in front of his eyes level of view range.

6.4 Minimum cost and standard parts and process to manufacture

Since optimising any product requires addition or subtraction of components cost is involved. The cost involved is change in parts or components that are new and are to be manufactured separately. But this is kept in check in this optimisation that the manufacturing process of company does not change much and any new components are cost effective.

The fuel pipe is only increased in length and is of the same material. The process of manufacturing the pipe is also not changed and is ERW pipes. The pipe has one bend in its total length. The bend is at angle of 45-50 degrees from vertical which gives maximum inlet mouth area to the user to fill. Some new parts like a pocket made of sheet metal i.e., CRCA sheet only is fitted by making hole in canopy. This pocket is protected by use of flap door locked from outside. The flap door is opened with used of torsion spring attached to butt hinge. The fuel level indicator is last new part used its position is change and is above fuel filling point and is a new magnetic sensor type level indicator. These few last things make up for some cost over standard parts but these changes are within companies cost to give user an added comfort and better product.

6.5 Safety and theft protection

Fuel theft in gensets being a major problem had to be addressed. The protection had to be for theft of fuel by means like siphon fuel using hoses. The first change in design to prevent theft was to have a anti-theft pipe or a device in pipe that prevent theft of fuel. The pipe passage design was modified with use of perforated plates or a retrofit device with holes along its periphery. The holes are made such that the flow of volume is not restricted and fuel has proper velocity to fill. The material used to make such devices is strong and cannot be easily tempered. These devices were fit over mouth of pipe and are irremovable once installed. Added protection to his arrangement is made by use of fuel cap and then locking by flap door makes it a two way safety and protection. The design is robust and has strong foundation.

6.6 Pipe flow area, venting and fuel tank sloshing

The fuel tank is of 330 litres capacity and can be filled within few minutes with proper amount of fuel flow rate of volume of fluid. A small vent on top of tank if necessary can be made to let air pass out and the temperature remain less than outside to avoid backflow.

Since the genset is stationary the fuel fills easily without any sloshing of liquid. There is minimum friction in pipes and flow is smooth. Also now position of inlet pipe is away from inlet and outlet delivery pipes to the engine so less foaming reaches to the pipes and fuel settles down. The flow area is maximised by use of anti-theft devices hence there is no spillage or backflow.

6.7 Environment of working

The fuel filling operation is now easier than previous due to this redesign. Now there is no need to get inside the genset through canopy door for filling the fuel. Just open the flap door from outside and remove the fuel cap and fuel can be filled easily by any means. External fuel filling also means that now fuel can be filled while genset is in running condition as the inside components and temperatures will not come in contact. Now it will also take less time to fill the fuel and it can be done with higher level of comfort and satisfaction.

6.8 Assembly and aesthetics

It is ensured that the design changes look as subtle as possible and does not change overall appeal of the genset rather give it a unique identification and advantage over other brands. The assembly of all new designed components is tight and compact with use of proper screws and seals where ever necessary.

6.9 Comparisons of different models

The above results can be summarised into a table to show main differences between different designs. The constraints that are discussed along with parameters that are affected by design changes are listed to see the advantages offered by different design models. This difference table gives us good idea of the best design that can be selected and suggested to the company.

For some parameters advantages offered by all designs are same so certain key or deciding parameters help in sorting the best design. These deciding elements can be seen in **Table 6.1**.

Table 6.1 - Comparison of fuel filling positions to find the best one

Parameters	Standard Model	Position 1	Position 2	Position 3	Position 4
Position	top of tank	centre btw doors	Left side of door	Right side of door	below door above skid
accessibility	low	Good	good	good	good
filling arrangement	Internal Filling	External filling			
interference with other components	no interference	No interference	may interfere	interfere with control panel	no
height of filling	More effort, Low filling point	easy to use, good filling height	good filling height	good filling height	very low filling height
Time factor (includes filling time, flow area)	takes more time, open door go inside and fill	takes less time	less	less	more
Safety factor	Since inside more safe	Exposed to theft , to be protected by fuel theft device and locked flap door			
Fuel Level Indication	inside next to filling point	at eye level	at eye level	at eye level	besides filling point
pipe length	short length	more than standard but less than 2 and 3	more length	more length	short length
no. of bends	no bend	single bend	multiple	multiple	single
working space	standard	no change	may affect	may affect	no change
effect of temp	normal	Normal	high temp	normal	normal

The deciding factors/parameters in following cases happen to be pipe length, minimum number of bends, height of filling and level indication and position as close to as standard. These parameters are best represented by design position 1 which is centrally located.

Hence for the position 1 or centrally located arrangement the position is closest to the standard design, accessibility is good from outside, the design doesn't interfere with any of the other genset components, height of filling fuel for the user is convenient as well as fuel level indicator is placed within optimal eye viewing range, the fuel filling time is also less, pipe length does not increase much, the bends in pipe are minimum and acceptable, the arrangement does not bear any high temperature and working space for user and service engineers remain unaffected.

For the following **Table 6.2** comparison of different fuel theft arrangements the approach used is to give for improvement in each feature by adding + and loss in each feature by adding – in the standard design S. For example since cost increases because we are bringing in new design changes but this cost should not be very much. Also factors like increased fuel velocity and flow area are good for new design so these are marked + over standard S.

Table 6.2 – Comparison of different fuel theft arrangements

		Concept models to prevent theft			
		Standard	ATM 1	ATM 2	ATM 3
Parameters for comparison	Cost	S	S-	S-	S-
	Accessibility	S	S+	S+	S+
	Manufacturing process	S	S-	S-	S-
	Fuel Flow rate Area	S	S-	S+	S
	Flow Velocity	S	S-	S+	S
	Fuel Filling time	S	S-	S++	S+
	Level indication	S	S	S	S
	Safety/Theft protection	S	S+	S++	S++

For selection of best fuel theft protection device or arrangement the following table gives us good idea of the factors affected by the design changes. These factors also help us decide the best solution. Any increased flow area and flow velocity and reduced time of filling over the standard design are strong factors for deciding that our redesign is better. More over added safety also contributes to our design.

Factor like having more flow area and thus more velocity and less filling time are key to fuel filling method. Anti-Theft Measure that has more positive value offers the best solution.

The next comparison in **Table 6.3** for different flap door arrangements is listed against parameters that will be affected by its use.

Table 6.3 – Comparison for different flap door arrangements

	Redesigned Flap door models		
Parameters	Flap door 1	Flap door 2	Flap door 3
opening method	Flap opens upwards	flap opens to side	flap open downwards
use of hinge	hinge used	hinge used	hinge used
use of spring	torsion spring	no spring	no spring needed
interference	no interference	interferes with canopy door	no interference
cost	more cost	less cost	less cost
locking method	Padlock		

- Although there is not much difference between all three arrangements and all three flap doors will get the job done.
- But use of spring in **flap door 1** adds extra cost that company can decide to use or not but still addition of spring eases the movement of flap door.
- The interference with canopy doors makes negative point for opening **flap door 2** but other than that it's fine.
- Since **flap door 3** opens downwards it will strike with the body of canopy so to prevent that a rubber stopper or support should be there.
-

Chapter 7 - Conclusion and Scope for further work

7.1 Conclusion

The genset optimisation using virtual modelling has been successfully done. The fuel filling arrangement is an important feature of every genset and now this process has been made easier and comfortable for the user.

The external fuel filling arrangement on the canopy door was given with help of making hole in the canopy body and extending inlet pipe to have filling point opening outside only and also at an ergonomically suggested human height level of filling

The fuel level indication was also shifted to convenient location above the filling point at a user height which can be at eye level and there is no problem to see at the indicator at all times.

There are concerns when fuel filling point is exposed to the outside world but that is now addressed with protection to theft by use of anti-fuel theft devices fit over the mouth of the pipe that don't allow any siphoning of fuel. Also this pipe opening is protected with a fuel flap door that when closed will be locked with help of padlock.

The arrangement has been made safe to use by all users of genset and can easily fill fuel at any time. The accessibility is now easy and time saving. The fuel can be filled while the genset is in running condition also.

7.2 Scope for further work

Since design improvement by redesigning involves cost so making more cost effective and convenient design is more scope of work here for this design. The arrangement can be made more protective from theft and also other fuel flow rate measures can be explored. Also due to limited data from company vibration analysis and flow analysis of fuel was not done which can provide more support to these design changes.

A pool of customer voice was obtained using HCD tools. These genuine voices of end users provide company with host of problems or issues to address in future. Some of the features which have potential for improvement or needed immediately are suggested that should be explored by company and other researchers to give more value to the genset and finally to its users.

- Due to limited space outside genset depending upon where it is kept doors opened takes lots of space and limit the work space available. So sliding of folding doors on genset is a good solution.
- Use of telematics is being considered highly in gensets to have online and remote monitoring of genset but as it comes with great cost so cost effective ideas solution are needed. And to control genset even though mobile devices.
- Having a forklift arrangement with pockets to pick and move gensets of small to medium sizes is another useful feature to have.
- Canopy design since genset time has been consistently rectangular box shaped though a classic design but with today's modern design language and role of aesthetics in any product innovative canopy design and shapes should be explored. An approach towards these areas can be seen in leaf gensets by Mahindra and concept of Vertical genset that takes least footprint.
- Making gensets more compact with innovative positioning of all components to reduce heat and emissions; proper harness, electric cables and hoses routing; having latest intelligent sensors for fuel level, coolant, oil drain and service reminders and more silent and other energy resource using gensets makes case for itself to do detailed research and improve the product.

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Appendix A - Fuel Level Indicator Details from supplier

The following is more detailed description of the fuel level indicator sensor used.

Active controls

SPECIFICATIONS & MOUNTING

Active Controls level sensors are used for monitoring of fuel, water and other liquids in tanks or static or mobile (vehicle) tanks.

The analog sensors are based on resistive continuous sensing with analog output based on Magnetic Float. A continuous chain of reed switches in parallel with a chain of resistances provides this output with the location of float in the tank.

The output can be in resistance range of 250 Ω to any specific requirement like 4-20 mA, purely resistance, or in Voltage options of 0.5-4.5, 0-5, 0-8 or 0-10 V DC.

Materials: The main body is made of SUS304 stainless steel
Length range: 100~3000 mm. It can be customized to your requirements.
Assembly: SAE standard 5 holes or custom
Accessories: 5 pieces of M5 screws, 2mm thick NBR gasket as applicable.
Protection rank: IP65


1. Rated Power: 125mW , Wire: PVC
2. Professional design can pass the vibration test.
3. Operating temperature:-40~+85C;
4. Resolution range: 10 mm

Installation, Operation and Working

The probe mounting is through a universal SAE standard flange with 5 holes. It can therefore be mounted directly in place of existing fuel sensor.

The sensors are a continuous chain of reed switches, with resistances in series. The movement of the float operates the nearest sensor which in turn gives output based on the value of resistance at that point.

The standard units are based on input voltage of 5 Volts DC or 12 V DC. (You need to specify this)



The standard output is 0-5 V DC (0 at bottom and 5 v at full level). Purely resistance or analog 4-20 mA can be provided. The instrument is supplied calibrated to these values.

Connections

The unit is a 3 wire instrument i.e. Red, Black and Yellow. (4 wire in case of Alarm output)

Red: Power supply 12 or 5 V (+)
Black: Ground or (-)
Yellow: Output

Connect Red and Black to the power source

Connect Yellow and Black to your monitoring hardware. White to Alarm

Special note

The output of the instrument is linear and varies uniformly every 10 mm rise or fall in level.

It will therefore provide accurate output only in terms of linear direction

It will give accurate output in case of cuboid tank. In case of cylindrical tanks (horizontal), to get accurate readings you will need to inform us the internal diameter of the tank.

Warranty: The probes carry a warranty of 18 months

Manufactured by	Contact
ACTIVE CONTROLS	☎ +91 11 24621802
1800 Gyani Bazar (FF)	☎ 09899379966
Kotla Mubarakpur	✉
New Delhi - 110003	activecontrols@liquidlevel.co.in
www.liquidlevel.co.in	activecontrols@yahoo.com

Figure A1 – Magnetic fuel level sensor from Active Controls, Delhi

ACTIVE CONTROLS

FUEL LEVEL SENSOR DATA SHEET

ACTIVE FUEL LEVEL SENSOR is an instrument for monitoring the level of Fuel Oil in a Tank. It is a sturdy and effective measuring sensor for all types of liquids including Diesel, Water, chemicals, Industrial Liquids etc. The liquid can be static, turbulent or flowing. The material of construction varies depending upon the liquid to be monitored.

Standard Specifications

- SS 304 Probe unit manufactured to the actual depth of tank. 16 mm outer diameter
- Top mounted through 5 hole SAE Flange, OR Screwed Cap or Threaded Plug.
- Based on Variable resistance with chain of reed switches.
- Actuating Float for sensors: High Density PU or PP
- Input and Output from Fuel sensors

Supply	Output available
12 V DC	0-5 V DC, 0-10 V DC
24 V DC	0-5, 0-10 V DC
5-32 V	0-5 V DC
24 V DC	4-20 mA
	Resistance 10-180 Ω or as required

Resolution

Resolutions possible are 10 mm & 5 mm. This implies that the changes in level are sensed for every 10 mm or 5 mm, depending on the instrument ordered.

Application Diesel, Petrochemicals, Industrial Water, All types of Oils and Chemicals, Cosmetic and Edible Oils.

MOC of the sensors can be varied to be compatible with the liquid to be monitored.



Physical Properties

- Suitable for temperatures up to 55 deg C
- Length of sensor/ Depth of tank to be provided by customer
- 5 hole SAE Mounting Flange
- Gasket : 3 mm th PVC
- 3 wire connection (30 cm wire provided for connections)
RED : Battery Positive
BLACK : Battery Negative
GREEN : Output 0-5 V DC (+)

For ordering please provide

1. Depth of tank / Length of sensor required
2. Supply Voltage 12/ 24/ 5-32 V DC
3. Output Required: Standard is 5 V DC
4. Resolution Required: 10 mm/ 5mm

Manufactured by

ACTIVE CONTROLS

1800 Gyani Bazar (FF), Kotla Mubarakpur
New Delhi - 110003

Phone: 011 24621802, 9899379966 (Rawl)

activecontrol@liquidlevel.co.in

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Figure A2 – Magnetic fuel level sensor from Active Controls, Delhi

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