IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

Analysis and Simulation on Thermal Behavior of Cryogenic Tank for Different Types of Internal Support Materials

Jay N. Dave[1], Dr. D.B. Jani[2], Dr. K. K. Bhabhor[3]
Student, Department of Mechanical Engineering (CAD\CAM)[1]
Professor, Department of Mechanical Engineering[2]
Assistant Professor, Department of Mechanical Engineering[3]
Government Engineering College, Dahod, India
jaydave403.jd@gmail.com,dbjani@rediffmail.com,kiranmech12@gmail.com

Abstract: *The cryogenic vessel is mainly a double-walled vessel which mainly consists inner vessel, outer vessel, and inner support. The Inner support is the main part designing of the cryogenic vessel for thermal and structural criteria. Inner support material for cryogenic vessels can be made of various materials depending on Net evaporation rate (NER) criteria and structural criteria (i.e. road transport, marine transport, space condition). Material for the Inner support structure has low thermal conductivity and high strength, low weight. To meet the design goal for very low thermal conductivity, high strength, and low weight the next-generation materials like carbon fibber and polymeric-based composites are being developed for cryogenic fuel tank applications. By using different materials like SS304, G-10, Inconel, Invar-36, High strength Carbon fibber, and polymer-based composites same support structure will be analysed in FEA software for Thermal and structural conditions and will compare for different load conditions to check structural integrity. Also will compare the impact of different materials on NER and holding day for cryogenic fluid*

Keywords: Cryogenic Vessel

I. INTRODUCTION

The materials used in the tank that hold the gas at liquefaction temperatures must have a high level of ductility and fracture resistance while maintaining a high level of safety. In order to minimize the container's wall thickness, the material must also be strong enough to allow welding without risk of brittle fracture (Esab, 2001). In addition to strength, inner tank support should have very low conductivity at cryogenic temperature to minimize heat load. Understanding the plant operations, transport conditions and the environmental conditions to which the tank will be exposed is the first stage in selecting construction materials. So inner support material is crucial part in designing of cryogenic tank.

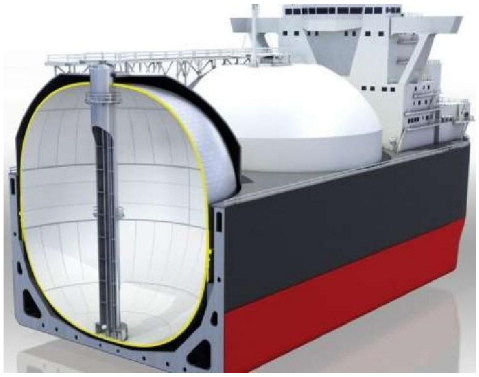


Figure 1. A marine LNG tank and its cut view

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

Peddada Thirumala Rao and all researched and study is done with both maximum and minimum stress strain settings, as well as static loading conditions. Glass epoxy for the homogenous vessel, structural steel, aluminium, copper, and titanium are among the materials being examined for various situations. The outside construction is made of steel, glass epoxy, copper, stainless steel, aluminium, and carbon fibre, while the inside structure is made of steel, carbon fibre, and aluminium fibre. When strain and stress are taken into account, carbon fibre epoxy for the inner structure and sglass epoxy for the exterior structure perform comparably better than the other materials. Therefore, the material that works best for creating cryogenic vessels is "glass epoxy" for homogenous vessels and "glass epoxy for outer structure with carbon fibre for the inner structure" for multilayered vessels.

Federico Ustolin and all used to simulate and assess how the tank ladder behaved during a fire test. A reasonable agreement was established when the generated model was validated using experimental data, taking into account the uncertainties on experimental measurements and specification. To find the vessel TTF 539, further confirm the suggested model, and examine the behaviour of these kinds of vessels and their load in such an accident scenario, more trials are required. Lastly, the risk assessment and emergency response planning of cryogenic liquefied gas vessels can benefit from and be supported by this numerical technique.

J.E. Fesmire and all researched along with implications for densified cryofuel applications, the approach, problem solving, and system design for an integrated heat exchanger system for an existing liquid hydrogen storage tank are provided. Through testing with this new facility, the goals of long-term storage, densified cryofuels, and effective operational methods will be advanced. The findings will have implications for both space launch facilities and the transportation sector.

The idea is founded on the idea that by combining an Integrated Refrigeration and Storage (IRAS) tank with a cryogenic refrigeration system, LH2 losses can be completely eliminated and operational procedures can be enhanced.

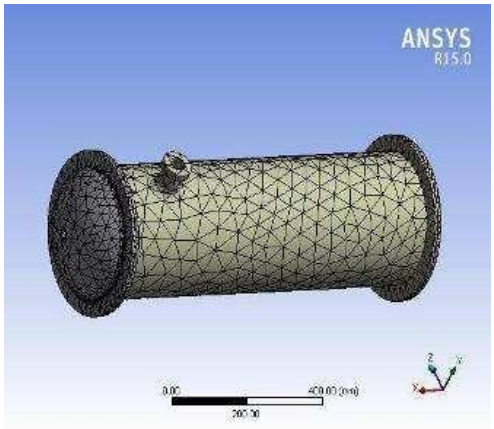
Gregory J. Hanna and all and all have Comprehensive temperature measurements in the vapour phase and two-dimensional model projections will be needed to fully characterise the system's mixing and thermal behaviour. An envelope of temperatures, vent rates, heat fluxes, and transient responses was obtained by simulating the behaviour of the GRCT under extensively varied testing settings. The envelope will significantly improve the creation of test scenarios for testing with both liquid nitrogen and liquid hydrogen.

William L. Koand all have a comparison to the thermocryogenic loading, the stress fields caused by liquid pressure, internal pressure, and inertia loadings are secondary in nature.

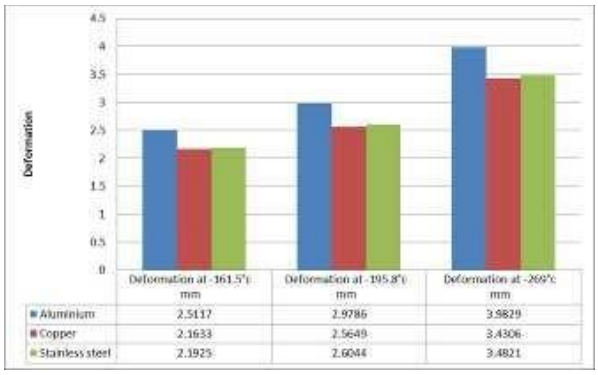
On the cryogenic tank wall, high-stress areas were marked out for experimental strain gauge installations.

Two cryogenic tank finite element models were created for thermocryogenic buckling analysis and stress analysis under various loading situations.

Craig A and all analysesd and discovered various factors that influenced the thermal behaviour of the Generic Research Cryogenic Tank. The features of ullage mixing, the location of applied high temperatures, and the apparent thermal conductivity of helium-insulation all influenced the behaviour of the Generic Research Cryogenic Tank. The focus of the thermal conductivity tests at the National Institute of Science and Technology, as well as most of the upcoming testing with the Generic Research Cryogenic Tank, will be on improving later thermal models.



IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023



	Deformation at -161.5°c mm	Deformation at -195.8°c mm	Deformation at -269°c mm
Aluminium	2.5117	2.9786	3.9829
Copper	2.1633	2.5649	3.4306
Stainless steel	2.1925	2.6044	3.4821

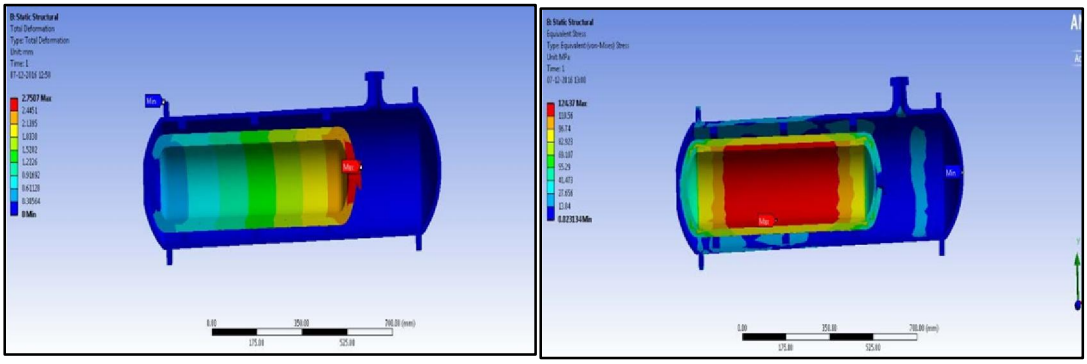
Theodore F. Johnson and all, These research' techniques and analytical tools provided an effective way to analyse, size, and assess candidate-integrated designs for future RLVs. The thermal sizing research developed a method for calculating the thickness of insulation layers using FEM.

By combining reliability optimisation approaches with deterministic optimisation techniques, the structural sizing study established an optimisation strategy that provided more resilient alternate structural designs than deterministic optimisation methods.

Matthew J. Daigle and all had a correlation relations are used to account for temperature and velocity boundary layers at tank walls. The lumped-parameter method is used to consider heat exchange affecting the tank wall. The model considers the major multi-phase mass and energy exchange processes involved, such as hydrogen condensation-evaporation, as well as fluxes of hydrogen liquid and vapour in the presence of pressurising helium gas, by employing basic conservation laws. For pressure management, the model includes a liquid hydrogen feed line and a tank ullage vent valve. The consequences of temperature stratification are studied, including the existence of vent valve oscillations. In Matlab, a simulation of temperature stratification effects in a generic cryogenic tank was built, and results for various tank settings are provided.

k. J. Jaya Kumarand all followed an evaluation of the various thermal insulation options, it was determined that a vacuum-jacketed design with an aluminium tank provided the most efficient thermal insulation design choice. Due to a higher rate of heat penetration and more propellant boil off, a tank design with high or low density aerogels results in a substantially heavier tank system. As a result, aerogels are not a viable insulation choice for cryogenic fuel storage.

As a result of the investigation, a vacuum-jacketed design outperforms high or low density aerogel designs in terms of thermal insulation. As a result, we can conclude that aerogels are not a suitable design solution.



Matteo sambicci and all researched with a finite element method (FEM) model was built to compare the thermal insulation performance of a commercial FRAB for use in cryogenic storage/transport LNG tanks to that of classic perlite-based systems. Within the computational model's dependability restrictions, investigation revealed that FRAB insulation technology produced promising results and could be theoretically scalable for transporting cryogenic liquid. In addition to outperforming the perlite-based system in terms of thermal insulating efficiency and boil-off rate, FRAB technology allows for higher levels of insulation without a vacuum and with a lower thickness of the outer shell, which is advantageous for storing more material and lightening the weight of the LNG transportation semitrailer.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

II. FINDINGS OF GAPS FROM LITERATURE REVIEW

1	Prototype cryogenic tanks offer 20% weight reduction for space vehicles. Liquid oxygen compatibility is crucial for mission safety. Mechanical properties ensure tanks withstand extreme conditions. Research focuses on improving tank strength and durability. Findings pave the way for lightweight and reliable space vehicles. [Ni Liu, Bin Ma, Feng Liu, Wenxuan Huang, Baosheng Xu, Lijie Qu, Yazheng Yang](2017)
2	The detail about minimum inner vessel thickness calculation Outer vessel minimum thickness calculation Material properties and allowable limits as per code [Pratik Patel, Ronak Shah](2014)
3	Carbon fiber composites offer lightweight, high-strength solutions. Potential to revolutionize cryogenic storage and transportation. Various manufacturing techniques explored. Addressed challenges and solutions for large-scale cryotank manufacturing. Analyzed mechanical properties under extreme cold. Highlighted thermal insulation benefits. Comprehensive overview for cryogenic storage system development. [Hongfei Zheng, Xuesen Zeng, Jianbao Zhang and Hongjie Sun](2018)
4	Material properties like Glass fiber, Epoxy poly propelene for support Insulated material for Glass bubbles are advantageous for high-vacuum [J.E. Fesmire, J.P. Sass Z. Nagy, S.J. Sojourner](2018)
5	Study explores CFRP behavior in low temperatures. Focus on mechanical and fatigue properties. Investigates influence of temperature on CFRP performance. Microstructural changes impact mechanical properties. Contributes to understanding CFRP behavior in cryogenic conditions. [Okayasu, Mitsuhiro; Tsuchiya, Yuki](2016)
6	Mildly surface-functionalized graphene oxide improves epoxy nanocomposite mechanical properties significantly. Optimized surface functionalization enhances the interface between graphene oxide and the epoxy matrix. Important insights into the role of surface chemistry in enhancing mechanical performance. [Jie Fan, Jiping Yang, Letian Wang, Hong Li, Junpeng Tian, Jinrui Ye, Yunfeng Zhao](2019)
7	Strategies and modifications enhance robustness and crack resistivity. Improved structural integrity and durability for space applications. [Michal Delkowski, Christopher T.G. Smith, Jos´e V. Anguita, S. Ravi,P. Silva](2020)
8	Emphasis on the importance of studying materials for extreme cold applications. Understanding the influence of temperature on mechanical and thermal properties. Insights into different composite types and their behavior in cryogenic conditions. Summary of key research trends and advancements in the field. [S´api, Zsombor, Butler, Richard](2021)
9	Graphene oxide oxidation degree significantly influences cryogenic mechanical properties. Higher oxidation degrees enhance mechanical performance in nanocomposites. Improved dispersion, stronger interfacial interactions, and cross-linking structures contribute to enhanced properties. Optimization of oxidation degree is key for tailoring nanocomposite properties in cryogenic applications. [Jie Fan, Jiping Yang, Hong Li, Junpeng Tian, Meng Wang, and Yunfeng Zhao](2022)
10	Design calculations and results for the analysis of different materials have been shown.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

	design calculations and results for the analysis of different materials have been shown. Different materials are analysed. Taking weight into consideration and stress into account, glass epoxy for the outer structure with carbon fiber epoxy for the inner structure is comparably better than the other materials. Different materials are analysed. Taking weight into consideration and stress into account, glass epoxy for the outer structure with carbon fiber epoxy for the inner structure is comparably better than the other materials. [P. T. Rao , Hepsiba S. eeli](2018)
11	Method to do FEA in Ansys. Structural behavior of support material and its attachments in FEA. [K. Sunil. , B. Nagar., J. Arulmani](2016)
12	The shortcomings in the research and application of cryogenic materials for liquid hydrogen storage and transportation containers are summarized to provide guidance for the future development of container materials. [YinanQiu, Huan Yang , Lige Tong](2021)
13	Temperature distribution of the tank and magnitude are obtained and used for estimation of transient heat transfer, induced thermal stress, structural stress, distortion in the material due to chill-down and pressurization. [S. Murugan, M.S. Starvin, K. MurugaDhas](2013)
14	A vacuum-jacketed design with an aluminum tank offered the most efficient thermal insulation design option. A tank design with high or low density aerogels results in a much heavier tank system, due to a higher rate of heat penetration and more propellant boil off. [K. J. Jaya Kumar](2015)
15	In this paper , risk analyses is performed which shows inner vessel material is most crucial part in design. [H. Nemati, R. Heidary](2012)
16	To understand how insulation thickness affects the development of the tank's pressure and temperature, a transient, two-phase thermodynamic model of a liquid hydrogen cryogenic propellant tank utilized in a typical launch mission is built. As time passes temperature and pressure of the cryogenic tank increase till their steady value. [Prabhash Singh , Divyansh Prakash](2023)
17	The CFD-MP model was used to simulate the evaporation of LN2 by which holding time calculation is carried out. [Felipe Huerta Pérez](2021)
18	The calculation of transient heat conduction and the temperature profile evolution in the support system during the whole flight trajectory. the long-term stability for different types of structural materials, An experimental setup was developed and serval material samples were tested [Felipe Huerta Pérez](2016)
19	During the development it is found that the heat transfer cannot be well predicted by means of existing correlations due to the extreme temperatures and pressures in the tank. It is realized that radial injection reinforces the natural convection pattern in the tank, likely increasing heat transfer. Axial injection destroys this convective pattern and thus has likely less heat transfer. [R.J.G. Hermsen](2017)
20	Fracture toughness does not change significantly at cryogenic temperatures, but the thermal stresses play a major role in fracture and initiation of delaminations from transverse cracks [Sukjoo Choi , Bhavani Sankar](2006)
21	Several of these films were introduced as a layer in the composite to form an interleaved, or hybrid, composite to found have high strength in compression and low strength in shear. [Brian Grimsley, Roberto Cano, Norman Johnston](2020)
22	Glass epoxy can be utilized which will decrease warm exchange from the conduction of Surge plates

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

	which are bolster from external vessel to the inward vessel. The glass epoxy significantly withstands the temperature effects on strength. [ChintuJagadeesh, K. Srinivasa Rao](2019)
23	Thermal strcture Effect of sloshing during transportation on inner tank and its support and calculation for minimum thickness of support to withstand transport loads. [E. Lisowski, M. Domagała](2010)
24	Mathematical modeling is found to design support and inner vessel considering large thermal contraction and its ab normal material behaviour. [Gagan Agrawal , Jeswin Joseph, Deepak Agarwal](2017)
25	The procedure conforms to ASME SECTION 8, DIVISION-1 and DIVISION-2. The procedure for designing nitrogen cold convertor to the required specifications has been studied and modified to create a perfect storage cryogenic vessel. The design calculations and results have been shown in this paper. [HepsibaSeeli, Sri Harsha Dorapudi, PasalaVenkata Satish](2016)

REFERENCES

[1] B. M. F. L. W. H. B. X. L. Q. Y. Y. Ni Liu, "Progress in research on composite cryogenic pro- pellant tank for large aerospace vehicles," pp. 201-255, 2017.
[2] R. S. Pratik Patel, "Design and Optimization of Cryogenic Storage Vessel," IJEDR, vol. 3, pp. 208-216, 2014.
[3] X. Z. J. Z. a. H. S. Hongfei Zheng, "The Application of Carbon Fiber Composites in Cryotank," International Journal of science and Technology, vol. 21, pp. 280-324, 2018.
[4] J. S. Z. N. S. S. J.E. Fesmire, "Cost-efficient Storage Of Cryogens," Europian Journal for Engineering Research, pp. 655-666, 2018.
[5] M. a. f. p. o. l. c. f. r. p. a. l. temperature, "Mechanical and fatigue properties of long carbon fiber reinforced plastics at low temperature," journal-of-science-advanced-materials-and-devices, vol. 4, pp. 577-583, 2016.
[6] J. Y. L. W. H. L. J. T. J. Y. Y. Z. Jie Fan, "Enhanced mechanical properties of epoxy nanocom- posites with mildly surface-functionalized graphene oxide by tuned amine species," Applied Surface Science, vol. 6, pp. 1182-1210, 2019.
[7] C. T. S. J. V. A. S. R. Michal Delkowski, "Increasing the robustness and crack resistivity of high-performance carbon fiber composites for space applications," 2020.
Z. B. R. S´api, "Properties of cryogenic and low temperature com- posite materials," IJSER, 2021.
[9] J. Y. H. L. J. T. M. W. a. Y. Z. Jie Fan, "Cryogenic mechanical properties of graphene oxide/epoxy nanocomposites: Influence of graphene oxide with different oxidation degrees," Polymer Testing, vol. 96, 2022.
[10] H. S. e. P. T. Rao, "Design and Analysis of Cryogenic Storage Vessel Material Optimization," International Journal of Engineering and Techniques, vol. 4, pp. 263-277, 2018.
[11] B. N. J. A. K. Sunil., "Design And Structural Analysis Of Liquified Cryogenic Tank Under Seismic And Operating Loading," nternational Journal of Mechanical Engineering and Technology, vol. 7, no. 6, pp. 345-366, 2016.
[12] H. Y. ,. L. T. YinanQiu, "Research on Cryogenic Materials for Storage and Transportation of Liquid Hydrogen," Iternational jorunal of Material science, pp. 422-445, 2021.
[13] M. S. K. M. D. S. Murugan, "Thermo structural analysis of high pressure cryogenic tank," International Journal of Engineering Research & Technology, pp. 173-1738, 2013.
[14] K. J. J. Kumar, "Heat Transfer Analysis of Light Weight Cryogenic Tank for Space Vehicles," International Journal of science and Technology, pp. 314-319, 2015.
[15] R. H. H. Nemati, "Risk Analysis Of Cryogenic Ammonia Storage Tank In Iran By Fault Tree Method," 2012.
[16] D. P. Prabhash Singh, "Thermal Analysis Of The Cryogenic Propellant Tank In Launch Vehicles," EPRA International Journal of Research and Development (, pp. 140-148, 2023.
[17] F. H. Pérez, "Modelling the evaporation of cryogenic liquids in storage tanks," International Journal of Heat and Mass Transfer, 2021. International Journal of Scientific & Engineering Research, 2016.
[18] F. H. Pérez, "Concept Development of a Cryogenic Tank support for Reusable Launch Vehicle," EUROPEAN CONFERENCE FOR AERONAUTICS AND SPACE SCIENCES, vol. 8, 2016.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, December 2023

[19] R. Hermsen, Practical investigation on the tank collapse factor for small, high-pressure, cryogenic rocket propellant tanks, 2017.
[20] B. S. Sukjoo Choi, "Fracture toughness of transverse cracks in graphite/epoxy laminates at cryogenic conditions," Composites Engineering, 2006.
[21] R. C. N. J. Brian Grimsley, "Hybrid Composites For LH2 Fuel Tank Structure," 2020.
[22] K. S. R. ChintuJagadeesh, "Analysis of Thermal Criteria on Cryogenic Pressure Vessel," nternational Journal of Trend in Scientific Research and Development (, Vols. 205-208, 2019.
[23] M. D. E. Lisowski, "Simulation of liquid dynamics in a cryogenic mobile vessels," Foundry Commission of the Polish Academy of Sciences , 2010.
[24] J. J. D. A. Gagan Agrawal, "Mathematical Modelling of Thermal contraction in a Cryogenic Propellant Tank," Materials Science and Engineering, 2017.
[25] S. H. D. P. V. S. HepsibaSeeli, "Designing and Analysis of Cryogenic Storage Vessels,"

BIOGRAPHICAL NOTES

Jay N. Dave Born In the Nadiad in India. He Graduated from Ahmedabad Institute Of Technology, Ahmedabad in 2021 And Student Of ME CAD/CAM Of Government Engineering College, Dahod.

Dr D.B. Jani Received PhD in Thermal Science (Mechanical Engineering) From Indian Institute of Technology (IIT) Roorkee. Supervisor at Gujarat Technological University (GTU). Published More Than 100 Research Articles In International Conferences And Journals. Presently He Is Associate Professor At Gujarat Technological University, GTU, Ahmedabad (Education Department State Of Gujarat, India, Class-I, Gazetted Officer. His Area Of Research Is Desiccant Cooling, Ann, Trnsys, and Energy.

Dr. K Bhabhor Currently Working as Assistant Professor in the Department Of Mechanical Engineering at Government Engineering College Dahod under the Gujarat Technological University. Published More Than 20 Research Paper In Good Journals. His Area of Interest Are Thermal Engineering, Solar Energy and Energy Saving.