Modification of an Existing Car Shower Tester to Develop 52 Seated Bus Shower Tester at Pragoti Industries Limited.

This thesis is submitted to the Department of Mechanical Engineering of Chittagong University of Engineering & Technology as a partial fulfillment of requirement for the degree of

MASTER OF ENGINEERING IN MECHANICAL ENGINEERING

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I hereby declare that this project work or any part of it has not been submitted elsewhere for the award of any degree or diploma. To the best of my knowledge and belief, the project contains no material previously published or written by another person except where due reference is cited. Furthermore, the thesis complies with PLAGIARISM and ACADEMIC INTEGRITY regulation of CUET.

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Abstract

Shower tester booths are used in the automotive industry for leakage tests and to verify the water tightness of fully manufactured and assembled vehicles. By simulating real-world rain conditions, water is sprayed at the vehicle as part of a quality control procedure. Pragoti Industries Ltd. currently has a shower tester booth for testing Cars/SUVs, which will be modified to make it compatible for Bus testing. In the existing Car/SUV shower tester, the shower testing is done by placing the vehicle above 5 bar water pressure, whereas the standard pressure should be maintained between 2-2.5bar in order to avoid the disadvantages of excessive pressure on vehicles. During the modifications for Bus testing, a theoretical issue arose where negative pressure (calculated to be between 2-2.5 bar) could develop. To resolve this, centrifugal pumps will be used to ensure proper water distribution as well as Standard Pressure. The existing Car/SUV shower tester is equipped with flat fan nozzles and primarily use gate valves. In the modified version for Bus testing brass gate valves, glove valves, ball valves, pressure gauges and full cone nozzles will be introduced to improve performance. The transmission pipes in the shower tester booth, with diameters of 1.5, 3, and 5 inches, are crucial as they form the backbone of the water distribution system. Additionally, several pressure gauges will be installed to measure the water pressure within the system, providing real-time data on the force exerted by the water as it flows through pipes, valves, and other equipment. To accommodate the Bus testing, a modified structural design have to be fabricated, using some existing older resources and adding new equipment where necessary. New control and maintenance components need to be installed, and electrical connections have to be checked to ensure proper functionality. Various calculations were performed for both the existing SUV shower tester and the modified Bus shower tester, including flow rate, head loss, power consumption, water pressure, and water consumption. The operating cost for the modified shower tester was calculated to be between 18-22.5 taka (or 0.18-0.22 dollars) for 4-5 minutes of testing. Simulations were conducted using ANSYS for both the older and modified shower testers. These simulations provided valuable insights into the performance variations such as nozzle pressure and pipe flow pressure between the Bus and SUV configurations. For SUV shower tester the simulation showed nozzle pressure around 2 bars. Besides the simulation for Bus shower tester showed the pressure in nozzles around 2.2 bars. These results helped to optimize the shower tester for testing both vehicle types, ensuring structural integrity and operational efficiency under various operating conditions.

বিমূর্ত

শাওয়ার টেস্টার বুথগুলি অটোমোটিভ শিল্পে লিকেজ পরীক্ষা এবং সম্পূর্ণরূপে প্রস্তুত এবং একত্রিত যানবাহনের জলরোধীতা যাচাই করার জন্য ব্যবহৃত হয়। বাস্তব-বিশ্বের বৃষ্টির অবস্থার অনুকরণ করে, গুণমান নিয়ন্ত্রণ প্রক্রিয়ার অংশ হিসাবে গাড়ির উপর পানি স্প্রে করা হয়। প্রগতি ইন্ডাস্ট্রিজ লিমিটেড বর্তমানে কার / এস ইউ ভি পরীক্ষার জন্য একটি শাওয়ার টেস্টার বুথ ব্যবহার করছে, যা বাস পরীক্ষার সাথে সামঞ্জস্যপূর্ণ করার জন্য সংশোধন করা হবে। বিদ্যমান কার / এস ইউ ভি শাওয়ার টেস্টারে, গাড়ির উপর ৫ বার পানির চাপ দিয়ে পরীক্ষা করা হয়, যেখানে স্ট্যান্ডার্ড চাপ ২-২.৫ বারের মধ্যে থাকা উচিত, যাতে অত্যধিক চাপের কারণে যানবাহনে কোন ক্ষতি না হয়। বাস পরীক্ষার জন্য সংশোধনের সময়, একটি তাত্ত্বিক সমস্যা দেখা দেয় যেখানে নেতিবাচক চাপ (২-২.৫ বার এর মধ্যে গণনা করা হয়েছে) তৈরি হতে পারে। এই সমস্যার সমাধান করার জন্য, সেন্ট্রিফিউগাল পাম্প ব্যবহার করা হবে যাতে পানি সঠিকভাবে বিতরণ হয় এবং স্ট্যান্ডার্ড চাপ বজায় থাকে। বিদ্যমান কার / এস ইউ ভি শাওয়ার টেস্টারটিতে ফ্ল্যাট ফ্যান নোজল রয়েছে এবং প্রধানত গেট ভালভ ব্যবহার করা হয়। বাস পরীক্ষার জন্য সংশোধিত সংস্করণে পিতলের গেট ভালভ, গ্লোভ ভালভ, বল ভালভ, চাপ গেজ এবং পূর্ণ শঙ্কু নোজল যুক্ত করা হবে যাতে কর্মক্ষমতা উন্নত হয়। শাওয়ার টেস্টার বুথের ১.৫, ৩, এবং ৫ ইঞ্চি ব্যাসের ট্রান্সমিশন পাইপগুলি গুরুত্বপূর্ণ, কারণ এগুলি জল বিতরণ ব্যবস্থার মেরুদণ্ড গঠন করে। এছাড়াও, সিস্টেমে পানির চাপ পরিমাপের জন্য বেশ কয়েকটি চাপ গেজ ইনস্টল করা হবে, যা পাইপ, ভালভ এবং অন্যান্য সরঞ্জামের মধ্য দিয়ে প্রবাহিত হওয়ার সময় পানির দ্বারা প্রয়োগ করা বলের উপর তাৎক্ষণিক ডেটা সরবরাহ করবে। বাস পরীক্ষার জন্য একটি সংশোধিত কাঠামোগত নকশা তৈরি করতে হবে, যেখানে কিছু পুরানো সম্পদ ব্যবহার করা হবে এবং প্রয়োজনে নতুন সরঞ্জাম যোগ করা হবে। নতুন নিয়ন্ত্রণ এবং রক্ষণাবেক্ষণ উপাদান ইনস্টল করতে হবে এবং যথাযথ কার্যকারিতা নিশ্চিত করার জন্য বৈদ্যুতিক সংযোগগুলি পরীক্ষা করতে হবে। বিদ্যমান এস ইউ ভি শাওয়ার টেস্টার এবং সংশোধিত বাস শাওয়ার টেস্টারের জন্য বিভিন্ন গণনা করা হয়েছে, যেমন প্রবাহের হার, হেড লস, বিদ্যুৎ খরচ, পানি চাপ, এবং পানি খরচ। সংশোধিত শাওয়ার টেস্টারের অপারেটিং খরচ ১৮-২২.৫ টাকা (অথবা ০.১৮-০.২২ ডলার) হিসাবে গণনা করা হয়েছে ৪-৫ মিনিট পরীক্ষার জন্য। এস ইউ ভি এবং বাস শাওয়ার টেস্টার উভয়ের জন্য ANSYS ব্যবহার করে সিমুলেশন করা হয়েছে। এই সিমুলেশনগুলি বাস এবং এস ইউ ভি কনফিগারেশনের মধ্যে নোজল চাপ এবং পাইপ প্রবাহের চাপের মতো কর্মক্ষমতা পরিবর্তন সম্পর্কে মূল্যবান অন্তর্দৃষ্টি প্রদান করেছে। এস ইউ ভি শাওয়ার টেস্টারের জন্য সিমুলেশনে নোজল চাপ প্রায় ২ বার দেখা গেছে। অন্যদিকে, বাস শাওয়ার টেস্টারের জন্য সিমুলেশন চাপ প্রায় ২.২ বার দেখিয়েছে। এই ফলাফলগুলি দুটি ধরণের গাড়ির পরীক্ষা করার জন্য শাওয়ার টেস্টারকে অপ্টিমাইজ করতে সাহায্য করেছে, বিভিন্ন অপারেটিং অবস্থার অধীনে কাঠামোগত অখণ্ডতা এবং কার্যকর অপারেশন নিশ্চিত করে।

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List of Abbreviations and Acronyms

1. QC	Quality Control
2. SUV	Sports Utility Vehicle
3. DC	Double Cabin
4. HD PVC	High Density Polyvinyl Chloride
5. PVC	Polyvinyl Chloride
6. GPM	Gallons Per Minute
7. HVAC	Heating, Ventilation, and Air Conditioning
8. PIL	Pragoti Industries Limited
9. GI	Galvanized Iron
10. HDPE	High-Density Polyethylene
11. FEM	Finite Element Method
12. CFD	Computational Fluid Dynamics
13. PDPA	Phase Doppler Particle Analyser
14. MS	Mild Steel
15. RCC	Reinforced Cement Concrete
16. SST	Shear Stress Transport
17. CFD	Computational Fluid Dynamics

CHAPTER 1

INTRODUCTION

1.1 Introduction:

Nowadays, with globalization taking precedence over all other factors, auto and bus manufacturers are unwilling to sacrifice quality in their manufacturing processes. Every device that is produced must meet strict safety requirements. The government is considering requiring all truck, bus and automobile manufacturers to install a Shower Tester Booth in their manufacturing line in order to check for water seepage or to ensure that water does not enter the vehicles [1].

In light of such a competitive, almost hostile, environment, water intrusion into a vehicle can do irreparable damage to a manufacturer's reputation. The main aim of this paper is, to collect data of shower leakages, Rectification of leakage problems, Finding the permanent solution. It is very important to prevent water leakage because various problems due to shower leakages:

- Water affects the electronic parts and may cause permanent damage.
- Leakages inside the vehicle are due to improper joints which symbolizes the quality of vehicle.
- Water leakage inside the vehicle causes discomfort to the consumer

Vehicle water tightness is checked via shower testing, a quality control procedure. Shower testing operation is an important part of the Quality Control (QC) line of Pragoti Industries Limited. After doing the shower testing, other successive QC line operations have to be done. However, the existing model is limited to only Sports Utility Vehicle (SUV) and Double Cabin (DC) pickup testing. The new shower tester booth model that Pragoti Industries Limited is proposing will make it easier to operate large vehicles like buses, mini buses and Sedan cars while also accommodating SUVs and DC pickup. Shower Tester Booth can be used to test a wide range of vehicles, including: Cars, Buses, Trucks, Trains, SUVs, Vans, Off-road vehicles, Military vehicles, Construction vehicles and it is a crucial stage in the production process[1] [2].

1.2 Shower Tester Booth:

Shower Tester Booths are used for the leakage test of a fully assembled vehicle. Essentially, they comprise a spray system, filling water system, water cycle system, sewage system and electric control system. Also known as a rain simulating chamber, a Shower Tester Booth helps ascertain the water tightness of vehicles before they are brought to the market for sale.

Shower tester systems simulate real-world rain conditions by spraying water at the vehicle from all angles. This allows manufacturers to identify and repair any leaks before the vehicle is delivered to the customer [3].

1.2.1 Components:

A shower tester booth is a crucial part of the automotive manufacturing process, ensuring that vehicles are watertight and free from leaks. Let's dive into the essential components and how they work:

- **High-Pressure Nozzles:** These deliver water at high pressures to test whether it enters the vehicle or component. The goal is to identify any leaks.
- **Air Shower Booth:** After the water test, this booth uses blowers and air nozzles to quickly dry the external surface for immediate inspection.
- **Special Nozzles:** Full cone type nozzles ensure water covers the entire component area.
- **Air Washing Risers:** These provide pre-cleaning and air blow-off to remove excess water.
- **Filters:** Placed before the pump, they eliminate dust particles, protecting the pump and nozzles.
- **Corrosion-Proof Structure:** Ensures longer life and reduces replacement costs.
- **Recycling System:** Filters and recycles water from the booth.
- **Valves:** Control water flow and pressure within the shower tester booth.
- **Centrifugal pump:** Circulate water through the system, ensuring consistent pressure and flow and eliminate the negative pressure.
- **Pressure gauge:** Monitors and displays the water pressure to maintain optimal testing conditions.
- **Transmission pipes:** Transport water throughout the booth, connecting pumps, valves, and testing areas.
- **Automation**: Customizable programs automate the process, from vehicle entry to exit [4].

1.2.2 Functions:

The water spraying system simulates various levels of rain intensity to evaluate a vehicle's rain resistance under different harsh weather conditions. Stainless steel nozzles positioned at the top, sides, and bottom spray water onto the vehicle at controlled pressures. The pumps operate independently with separate valves to maintain adequate water pressure for proper functioning. Additionally, the system includes a sewage treatment unit, which filters the circulating water to remove mud, sand, and other impurities, ensuring it meets the standards for recirculated water [5].

Since there are rarely any impurities in leak test applications, the pumping and filtration cycle can go on for a long time. However, the water can be pumped out or subjected to further filtration before being released into the sewer when it is too contaminated to be used again. These are explained as follows:

i. **Containment Pad with Canopy/Walls**:
    - The containment pad, typically made of fiberglass-covered steel or High Density Polyvinyl Chloride (HD PVC), provides a secure area for testing.
    - Entrance and exit ramps allow vehicles to access the pad.

- A drive-over, galvanized grating is installed with supports.
- The canopy can be made of water-proof canvas, Polyvinyl Chloride (PVC) curtains, or fiberglass walls, providing protection during testing.

ii. **Leak Test System** (Installed within the Containment Pad):
   - **Spray Arches**: These use PVC piping and aluminum frames to deliver water at high pressures, simulating rain. They test whether water enters the vehicle or specific components.
   - **Entrance/Exit Spray Posts**: Similar to spray arches, these ensure thorough coverage.
   - **Undercarriage Spray Floor Spray Bar**: Targets the vehicle's underside.
   - **Stainless Steel Fixed Nozzles**: Installed in PVC piping, they precisely direct water flow.

iii. **Pumping & Treatment System** (Adjacent to the Containment Pad):
   - **Flow Rate**: Typically, around 60 GPM (Gallons per minute) at 40 psi, but this can be adjusted based on client specifications.
   - **Construction**: Non-ferrous materials like stainless steel and PVC ensure durability.
   - **Fully Automatic**: Pre-wired and pre-plumbed for seamless operation.
   - **Custom Control Panel**: UL-listed, with relays, valves, and level switches.
   - **Remote Start/Stop**: Allows convenient control.
   - **Water Storage Tanks**: Receive water from the basin and have level sensors.
   - **Fresh-Water Make-Up System**: Keeps tanks filled.
   - **Multiple Pumps**: Circulate water from the pad to the arches and filtration system.
   - **Initial Filter System**: Catches particulate matter [6].

Figure 1.1: Shower Tester Booth (SUV & Bus)[7][8][9]

1.3 Necessity of Standard Pressure:

Standardizing water pressure in a shower tester booth is crucial for ensuring consistent, reliable, and comparable results across different tests. This consistency is particularly important for assessing the performance of showerheads, valves, and related fixtures under controlled conditions. The necessity of standardization of pressure, along with average pressure values and references are:

i. **Leak Testing Precision**:
   - Standardized pressure ensures consistent results across different tests.
   - High-pressure nozzles simulate rain, allowing precise detection of leaks.
   - Water-saving showerheads, which earn the Water Sense label, must use no more than 2.0 gallons per minute (gpm) while maintaining satisfactory shower performance.
   - The force test apparatus aligns the center of the force target and the showerhead faceplate at 18 inches apart.

ii. **Water Recycling Efficiency**:
   - Standard pressure optimizes water usage. It ensures efficient recycling and filtration.
   - Consistent pressure allows effective water management.

iii. **Cost and Environmental Benefits**:
   - **Water Conservation**: Maintains optimal flow rates, minimizing water waste during testing.
   - **Energy Efficiency**: Reduces energy usage by avoiding excessive water heating.
   - **Lower Emissions**: Decreases the carbon footprint associated with water heating and pumping.
   - **Operational Savings**: Lowers utility costs by conserving water and energy.
   - **Prolonged Equipment Life**: Reduces wear, leading to fewer replacements and repairs.
   - **Sustainable Compliance**: Meets environmental regulations, avoiding fines and enhancing brand reputation.

iv. **Quality Control**:
   - Consistent testing conditions help in quality control, allowing manufacturers to detect defects or inconsistencies in their products [4] [5] .

1.3.1 Average Standard Water Pressure in Shower Systems:

- **Standard Pressure Testing**: The standard pressure used in a shower tester booth, commonly employed to test vehicles for water ingress, typically ranges from 2 to 3 bar [10]. This pressure range is necessary to simulate various weather conditions and ensure that vehicles are properly sealed against water leaks. However, the exact pressure can vary depending on the specific requirements of the vehicle [11]. In my new tester the measurable standard pressure will be 2 bar-2.5 bar. The current pressure in the older shower tester of Pragoti Industries Limited is above 500 KPa (5 bar). Standard pressure maintains accuracy, conserves resources, and speeds up the testing process in shower tester booths.

1.4 Disadvantage of Excessive Pressure:

Excessive water pressure in a shower tester booth can lead to several disadvantages that can affect the accuracy of the test results, the safety of the equipment, and the integrity of the product being tested. The key disadvantages due to excessive pressure, along with relevant references:

i. Misleading Test Results:

- **Performance Overestimation**: High water pressure may result in a false assessment of a showerhead's performance. A product might appear to perform well under excessive pressure but may not deliver similar results under normal operating conditions.
- **Unrealistic Flow Rates**: Excessive pressure can produce unnaturally high flow rates, leading to inaccurate flow rate measurements that do not reflect real-world usage.

ii. Damage to Products:

- **External Damage:**
  - **Paint and Coating Erosion**: High pressure can strip off paint and protective coatings, leading to corrosion and rust over time.
  - **Seal and Gasket Failure**: Excessive pressure can compromise external seals and gaskets, causing leaks and potential water ingress.
  - **Glass and Mirror Damage**: Windows, windshields, and mirrors may crack, chip, or shatter due to intense pressure.
  - **Component Wear**: External parts like wipers, antennas, and sensors can be damaged or dislodged.
- **Internal Damage:**
  - **Water Infiltration**: High pressure can force water into the vehicle’s interior, damaging upholstery, electronics, and internal panels.
  - **Electronic Malfunctions**: Water ingress into sensitive areas can short-circuit electronics, affecting systems like navigation, lighting, and infotainment.
  - **Corrosion**: Water entering through compromised seals can lead to rust and corrosion of internal components, especially in the chassis and undercarriage.
  - **HVAC System Damage**: The heating, ventilation, and air conditioning (HVAC) system may be damaged if water enters through vents or seals [12].

iii. Safety Concerns:

- **Equipment Failure**: Testing equipment in the booth may not be designed to handle excessive pressure, which can lead to malfunctions or even catastrophic failures, posing safety risks to personnel and equipment.
- **Inconsistent Standards Compliance**: If products are tested at pressures higher than industry standards, they may not comply with regulatory requirements, leading to potential legal and safety issues when the product is released to the market.

iv. Increased Wear and Tear:

- **Accelerated Aging**: High pressure can cause accelerated wear and tear on shower fixtures, leading to an inaccurate assessment of product longevity. Products may appear less durable than they actually are under normal conditions.

v. False Positives:

- Extremely high pressure might force water into areas that wouldn't be affected under normal conditions.
- This can lead to false positives, where leaks are detected even if they wouldn't occur during regular use [5].

Disadvantage of Excessive Pressure to vehicles:

i. Component Dislodgement:

- **Effect:** External components such as antennas, wipers, and sensors can be dislodged or damaged.
- **Consequence:** These parts may malfunction or fall off entirely, affecting vehicle functionality and safety.

ii. Water Infiltration into Electronics:

- **Effect:** Excessive pressure can force water into electronic components and sensors.
- **Consequence:** This can lead to short circuits, malfunctioning systems (like navigation and airbags), and potential electrical fires, which are dangerous and costly to repair.

iii. Mechanical System Strain:

- **Effect:** Pressure can affect mechanical systems like brakes, steering, and suspension if water enters these areas.
- **Consequence:** This can lead to decreased vehicle performance, safety hazards, and increased wear and tear on essential components.

iv. Engine Compartment Issues:

- **Effect:** Water entering the engine compartment due to damaged seals can affect the engine and other critical systems.
- **Consequence:** This can cause engine misfires, stalling, or even complete engine failure, leading to expensive repairs or vehicle breakdown [4] [12].

Excessive pressure in a shower tester booth undermines the reliability and safety of the testing process, potentially leading to incorrect assessments of product performance and durability. Standardized testing conditions are therefore critical to producing meaningful and safe results.

1.5 Modification:

In Pragoti Industries Limited (PIL) existing shower tester booth can only allow for Sedan cars, SUV and DC pickup testing but doesn't suitable for Buses and other vehicles. No use of a pressure gauge was observed in the existing model. The new shower tester booth model that Pragoti Industries Limited is proposing will make it easier to operate large vehicles like buses, mini-buses while also accommodating SUVs, Sedan Cars and DC Pickups. To achieve optimum and cost-effective performance, the arrangement incorporates pipe configuration based on the size of the various vehicles. After performing all the mathematical calculation regarding water pressure, if I find any negative pressure then I will solve the issue by installing centrifugal pump in the modified shower tester. In the older shower tester system flat fan nozzles are using, whereas full cone nozzle will be used for the modification of the shower tester. The proposed model of the new design for the shower testing operation would certainly comply with requirements such as allowing operation for vehicles such as Buses and Car/SUVs both in one configuration at standard water pressure, optimizing performance by minimizing the earlier drawbacks being cost-effective.

1.6 Full Cone Nozzle replacing Flat Fan Nozzle for the Modification:

Due to the benefits of full cone nozzles, the old system's flat fan nozzles will be swapped out for full cone nozzles in the event that the shower tester booth is modified to be bus compatible. Below is a comparison of those with a flat fan nozzle:

i. Spray Pattern:

- **Flat Fan Nozzle**: Produces a narrow, fan-shaped spray pattern. The spray is typically thin and elongated, forming a line or a sheet. This makes it ideal for applications requiring even coverage along a narrow path, such as cleaning, coating, or cooling.
- **Full Cone Nozzle**: Produces a circular or conical spray pattern, covering a broad area with a uniform distribution of droplets. This makes it suitable for applications like dust suppression, cooling, or chemical application, where a wider coverage is needed.

ii. Flow Distribution:

- **Flat Fan Nozzle**: The flow distribution is concentrated along the edges of the spray, with a higher impact force along the fan edges. The spray angle can vary, usually ranging from 15° to 120°, depending on the nozzle design. In this case 40° angle was found.
- **Full Cone Nozzle**: The flow is evenly distributed across the entire spray pattern, providing a uniform impact over the covered area. The spray angle can range from 30° to 120°, depending on the application. In this case 60° angle was found.

iii. Applications:

- **Flat Fan Nozzle**: Commonly used in applications that require precise, linear coverage, such as car wash systems, conveyor belt lubrication, and pesticide application.
- **Full Cone Nozzle**: Often used in scenarios requiring full coverage over a larger area like SUVs as well as buses, trucks, also cooling towers, fire suppression systems, and surface treatment processes.

iv. Spray Droplet Size:

- **Flat Fan Nozzle**: Typically produces finer droplets, making it suitable for applications needing fine atomization, like spray painting or light cleaning.
- **Full Cone Nozzle**: Produces larger droplets, which are better for applications requiring heavy coverage or where finer misting is not necessary.

v. Pressure Sensitivity:

- **Flat Fan Nozzle**: More sensitive to changes in pressure; a slight variation can significantly alter the spray pattern and impact.
- **Full Cone Nozzle**: Generally, less sensitive to pressure changes, maintaining a consistent spray pattern even with some pressure variation [13] [14] [15]

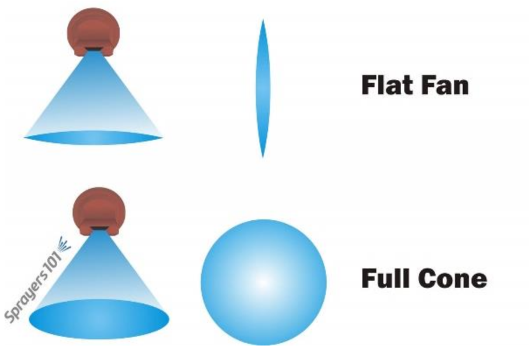


Figure 1.1: Flat fan nozzle & Full cone nozzle [16]

Because of all these differences Full cone nozzles have been chosen over Flat fan nozzles for this modification, where a large area can be covered by these nozzles for bus compatible.

1.7 Nozzle Pitch in Shower Tester Booths for Car/SUVs and Buses:

Nozzle pitch refers to the distance between adjacent nozzles in a shower tester booth. This distance is crucial for ensuring uniform water coverage on the vehicle's surface during testing.

The design of the nozzle pitch varies depending on the type of vehicle being tested, such as SUVs or buses.

i. Nozzle Pitch for Car/SUVs:

- **Pitch Range**: The nozzle pitch for Car/SUVs in the new shower tester booth is **12 inch**.
- **Rationale**: SUVs, being smaller than buses, require a denser nozzle arrangement to achieve even water coverage across all surfaces. The tighter pitch ensures that the water spray reaches all parts of the vehicle, including the lower sections.
- **Application**: This pitch is designed to test water resistance, seal integrity, and overall durability against water ingress for SUVs, which are often used in varied environmental conditions.

ii. Nozzle Pitch for Buses:

- **Pitch Range**: The nozzle pitch for Buses in the new shower tester design is **14 inch**.
- **Rationale**: Buses have a much larger surface area and height compared to SUVs. A wider pitch is often sufficient because buses require fewer but more powerful nozzles to cover the entire vehicle surface effectively. The goal is to ensure that water is evenly distributed across the height and length of the bus.
- **Application**: This arrangement is critical for testing larger vehicles like buses, where ensuring that the entire surface is exposed to water, especially at higher points, is important [17].

In a shower tester booth, the nozzle pitch is carefully calibrated based on the type of vehicle being tested. SUVs typically require a denser pitch to ensure comprehensive coverage, while buses, due to their size, are tested with a wider pitch but with more powerful nozzles. This setup ensures that both vehicle types are subjected to rigorous water resistance testing under controlled conditions.

1.8 Why Standard Pressure in Case of SUVs and Negative Pressure in Case of Buses:

The difference in pressure observed between testing SUVs and buses in a shower tester booth, particularly the occurrence of negative pressure in the case of buses, can be attributed to several factors related to vehicle size, the configuration of the shower booth, and the dynamics of fluid flow. These aspects are discussed here:

i. Vehicle Size and Volume:

- **SUVs:** Being smaller in size, SUVs occupy less space within the shower tester booth. This means that the displacement of air and water around the vehicle is less significant, leading to a more stable pressure environment.
- **Buses:** Buses are significantly larger, which means they displace a greater volume of air when entering the booth. This displacement can cause an imbalance in

pressure, leading to negative pressure conditions as the air is forced out of the booth more rapidly than it can be replenished.

ii. **Booth Configuration:**

- The design of the shower booth, including the size, shape, and placement of nozzles, can lead to different pressure dynamics when testing different vehicles. Larger vehicles like buses may block or alter the airflow patterns more significantly, resulting in negative pressure.
- In contrast, SUVs may fit better within the intended airflow design of the booth, allowing for a more uniform distribution of pressure.

iii. **Airflow and Ventilation:**

- Ventilation systems in the booth are designed to manage the pressure and air quality. When a large vehicle like a bus is present, the ventilation system may struggle to maintain positive or neutral pressure, especially if it's not designed to handle such a large volume of displaced air [18] [19].

In case of Bus shower tester booths, sometimes negative pressure is intentionally created. Negative pressure helps identify leaks more effectively. When the booth is under negative pressure, any water entering through leaks is drawn inward, making it easier to spot the problem areas. But in this modification of shower booth, the negative pressure issue is resolved by adding a centrifugal pump. Some details about centrifugal pump are given below:

i. **A Centrifugal Pump:**

- A centrifugal pump is a hydraulic machine that converts mechanical energy into hydraulic energy.
- It achieves this by using centrifugal force acting on the fluid.
- The pump flows in a radially outward direction, similar to a reverse reaction turbine.
- Centrifugal pumps are commonly used to raise water or other liquids from a lower level to a higher level.

ii. **Parts of a Centrifugal Pump**:

- **Shaft and Shaft Sleeve**:
  - The central rotating part of the pump is the shaft, which connects to the impeller.
  - A shaft sleeve prevents shaft leakage and corrosion.
- **Impeller**:
  - The impeller consists of a series of backward-curved vanes.
  - It rotates with an electric motor and is enclosed in a watertight casing.
  - There are three types of impellers:
    - **Open Impeller**: Vanes attached directly to the shaft, easy to clean and repair.
    - **Closed Impeller**: Sandwiched between front and back cover plates.
    - **Semi-open Impeller**: Has a back-wall cover plate, providing mechanical power to the vanes.

iii. **Working Principle**:

- The rotating impeller generates velocity in the fluid.
- The casing then converts this velocity into flow, pushing the fluid through the pump and into the discharge pipe [20] [21].

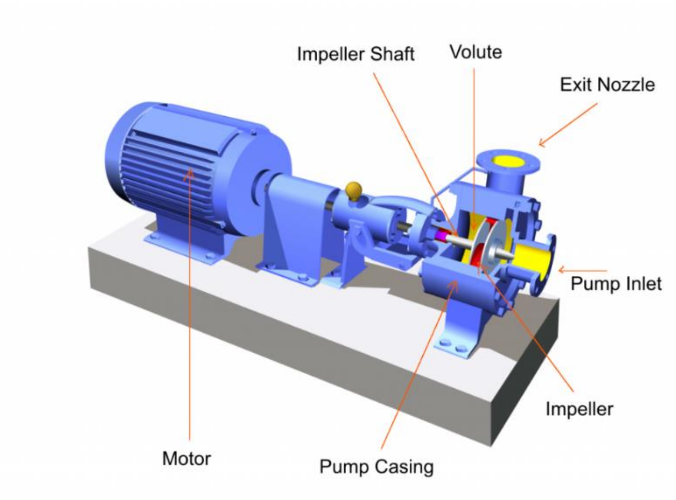


Figure 1.3: A centrifugal pump[22]

1.9 Role of a Centrifugal Pump in Resolving Negative Pressure:

A centrifugal pump could be used to address the negative pressure issue in the shower tester booth by manipulating the flow of water and air within the system. Here's how:

i. Enhanced Water Circulation:

- **Increased Flow Rate:** A centrifugal pump can increase the flow rate of water within the booth, ensuring that water is delivered evenly across the vehicle's surface. This can help to counteract the effects of negative pressure by stabilizing the flow of water and maintaining consistent pressure.
- **Pressure Boosting:** Centrifugal pumps can boost the water pressure, ensuring that even large vehicles like buses receive the same water pressure as smaller vehicles like SUVs. This helps in maintaining a standard pressure across different vehicle sizes.

ii. Air Management:

- **Airflow Regulation:** In some setups, centrifugal pumps can be used to regulate the airflow within the booth by creating positive pressure zones that counteract the negative pressure. This ensures that the air inside the booth remains balanced, preventing the negative pressure that might otherwise develop when a large vehicle is tested.
- **Integration with Ventilation Systems:** The centrifugal pump can be integrated with the booth’s ventilation system to manage air pressure more effectively, ensuring that the negative pressure is neutralized.

iii. Water and Air Separation:

- By maintaining a consistent flow and pressure of water, a centrifugal pump can help separate water from air more efficiently within the booth. This reduces the likelihood of air pockets forming, which can contribute to negative pressure conditions [19] [23].

Implementation Considerations:

- **System Design:** The design and capacity of the centrifugal pump must be carefully matched to the requirements of the shower tester booth. It should be capable of handling the specific flow rates and pressure levels needed for larger vehicles like buses.
- **Booth Modifications:** In some cases, additional modifications to the booth's design or ventilation system may be necessary to fully resolve the negative pressure issue, even with the addition of a centrifugal pump [24] [25].

1.10 Valves:

In current shower tester booth, mostly two types of valves, such as glove valves and brass gate valves are used to control the flow of water during testing. Here's how they function:

i. Glove Valve:

- **Use**: Glove valves are commonly used for regulating flow and pressure in the shower tester booth. They provide precise control over the flow rate, making them ideal for applications where the flow needs to be adjusted during testing.
- **Functionality**: The valve's design allows for fine-tuned adjustments, enabling the tester to gradually increase or decrease the water flow to simulate different shower conditions. This is especially important in testing scenarios where varying flow rates are required to assess the performance of showerheads, nozzles, or other components.
- **Material**: Glove valves can be made from various materials, but in a shower tester booth, corrosion-resistant materials like stainless steel or brass are often preferred due to the constant exposure to water [26].

ii. Brass Gate Valve:

- **Use**: Brass gate valves are typically used for isolation purposes in a shower tester booth. They are ideal for fully opening or closing the water flow.
- **Functionality**: The gate valve operates by lifting a gate out of the path of the water flow, allowing for a full flow of water or stopping it entirely. This makes brass gate valves suitable for scenarios where the water supply needs to be completely turned on or off during different phases of the testing process.
- **Material**: Brass is chosen for its durability, resistance to corrosion, and ability to withstand high temperatures, making it a reliable choice in environments like a shower tester booth where water and moisture are constantly present [27].

Application of Glove Valves and Brass Gate Valves:

In a shower tester booth, these valves are critical components that ensure precise control and safety during testing:

- **Glove valves** are used where precise flow control is required, such as adjusting the water pressure to simulate different shower conditions.
- **Brass gate valves** are used in situations where the water supply needs to be completely shut off or fully opened, ensuring that the test environment can be safely managed.

These valves, when used in conjunction with each other, provide the necessary control and flexibility to conduct comprehensive shower performance tests, ensuring that all aspects of the shower system meet required standards.

Now in this modification of shower tester booth compatible for buses, ball valve will be used particularly in the area of centrifugal pump being used. Ball valves play a crucial role in managing water flow. Here's how they function in that setting:

iii. Ball Valve:

- **Use**: Ball valves are commonly used in the centrifugal pump area of a shower tester booth for on/off control of water flow. They provide a quick and reliable method to start or stop the flow of water, which is essential during different testing phases.

- **Functionality**: The ball valve operates by rotating a spherical ball with a hole (bore) through it inside the valve body. When the hole is aligned with the water flow, the valve is open, allowing water to pass through. When the ball is rotated 90 degrees, the hole is perpendicular to the flow, and the valve is closed, stopping the flow completely.

- **Advantages**:
    - **Quick Operation**: Ball valves are known for their fast and easy operation, usually requiring just a quarter turn to go from fully open to fully closed. This makes them ideal in a testing environment where the water flow may need to be stopped or started quickly.
    - **Durability**: Ball valves are highly durable and can handle high pressure, making them suitable for use in the centrifugal pump area where water is often pressurized.
    - **Leak Prevention**: When properly closed, ball valves provide a tight seal, preventing leaks, which is crucial in maintaining accurate testing conditions [28].

Application of Ball Valves in the Centrifugal Pump Area:

- **Flow Control**: In the shower tester booth, the centrifugal pump is responsible for maintaining consistent water pressure and flow. Ball valves are installed on the inlet and outlet sides of the pump to control water flow to and from the testing area.
- **Maintenance and Safety**: During maintenance or in the event of an emergency, the ball valves can quickly isolate the pump from the rest of the system, preventing water from flowing through the pump or the test booth.
- **Isolating Components**: Facilitating maintenance by isolating the pump or other components without needing to drain the entire system.
- **Ensuring Safety**: Providing a reliable means to shut off water in emergency situations, protecting both equipment and personnel [28] [29].

Ball valves are selected for their reliability, ease of operation, and ability to handle high pressure, making them well-suited for the demanding environment of a shower tester booth, particularly around the centrifugal pump area.

1.11 Transmission Pipes and Transmission Systems:

Transmission pipes in a shower tester booth are crucial for several reasons, as they form the backbone of the water distribution system that is essential for the booth's operation. Here's why they are necessary:

Role of Transmission Pipes:

- **Water Supply**: Transmission pipes deliver water to the high-pressure nozzles used for testing.
- **Coverage**: They ensure that water covers the entire area being tested, including the vehicle or component.
- **Corrosion-Proof Design**: Special pipes and structures are corrosion-proof, leading to longer life and reduced replacement costs.
- **Filtering**: Filters prevent dust particles from damaging the pump and nozzles, ensuring longevity.
- **Recycling**: Water from the booth is filtered and recycled, reducing running costs [4] [30].

The flow of water from the main supply to various testing points. These pipes are typically categorized as main transmission, sub-main transmission, and branch transmission pipes, each serving a specific purpose in the water distribution process. In this new modification compatible for buses, we will use 5 inch, 3 inch and 1.5 inch GI (Galvanized Iron) pipes for main transmission, sub-main transmission, and branch transmission respectively. Those transmission systems are described below:

i. Main Transmission Pipes (5″ Diameter):

- **Use**: Main transmission pipes are the primary conduits that carry water from the main supply source (such as a water tank, reservoir, or central pumping station) to the shower tester booth.
- **Functionality**:
  - **High Capacity**: These pipes are usually large in diameter to accommodate a high volume of water. They ensure that there is enough water pressure and flow to meet the demands of the entire shower testing facility.
  - **Material**: Main transmission pipes are often made from materials like steel, ductile iron, galvanized iron (GI) or high-density polyethylene (HDPE) due to their durability, ability to withstand high pressure, and resistance to corrosion. In this modification we have used GI pipes of 5 inch diameter [31].
- **Role in the Shower Tester Booth**: These pipes ensure that a consistent and sufficient supply of water is delivered to the testing booth, which is essential for conducting accurate and repeatable tests on shower systems.

ii. Sub-Main Transmission Pipes (3″ Diameter):

- **Use**: Sub-main transmission pipes distribute water from the main transmission pipes to various sections within the shower tester booth.
- **Functionality**:
  - **Intermediate Distribution**: These pipes are slightly smaller in diameter compared to the main transmission pipes and serve as intermediaries that direct water from the main pipes to different testing areas or stations.
  - **Flow Management**: They help in managing and distributing the water flow efficiently across different parts of the testing booth, ensuring that each section receives the appropriate amount of water pressure and volume.
  - **Material**: Like main transmission pipes, sub-main pipes are typically made from durable materials like steel, galvanized iron (GI), copper, or PVC, depending on the specific requirements of the testing booth. For this sub-main transmission pipes we have also used GI pipes of 3 inch diameter [31].
- **Role in the Shower Tester Booth**: These pipes are crucial for dividing the water supply from the main line to various testing zones, enabling simultaneous testing at multiple points within the booth.

iii. Branch Transmission Pipes (1.5″ Diameter):

- **Use**: Branch transmission pipes are the final distribution lines that carry water from the sub-main transmission pipes directly to individual test stations or shower units within the booth.
- **Functionality**:

    - **Localized Distribution**: These pipes are smaller in diameter and are designed to deliver water to specific testing points, such as individual showerheads or nozzles.
    - **Precision Control**: They are often connected to valves that allow for precise control of water flow and pressure at each test station, enabling detailed performance testing of shower components.
    - **Material**: Branch transmission pipes are usually made from materials like galvanized iron (GI), copper, PEX, or stainless steel, which offer flexibility, corrosion resistance, and ease of installation. GI pipes of 1.5 inch diameter are used for branch transmission in this modification [31].
  - **Role in the Shower Tester Booth**: These pipes ensure that water reaches the exact testing locations, allowing for controlled and consistent water flow during performance evaluations of shower systems [32] [33].

In a shower tester booth, these three types of transmission pipes work together to ensure that water is effectively distributed throughout the testing facility. This organized distribution system is essential for maintaining consistent testing conditions, ensuring that every part of the shower system can be evaluated under controlled and repeatable conditions.

1.12 Pressure Gauge, Uses and Importance:

In this modification pressure gauges are used. A pressure gauge measures the pressure of water within a system, providing real-time data on the force exerted by the water as it flows through pipes, valves, or other equipment. It is used to monitor and regulate the pressure to ensure it stays within safe and optimal levels, preventing potential damage to the system, ensuring consistent performance, and aiding in troubleshooting issues related to water flow. In applications like shower tester booths, it helps maintain the correct testing conditions and supports quality control processes by verifying that the water pressure meets specified standards [34] [35].

Uses and Importance of Pressure Gauges in a Shower Tester Booth:

i. Monitoring Water Pressure:

- **Primary Use**: In a shower tester booth, pressure gauges are crucial for monitoring the water pressure that is delivered through the showerhead. Consistent and accurate water pressure is essential for testing the performance and durability of showerheads.
- **Importance**: By ensuring that the standard water pressure is within the desired range 2-2.5 bar, the pressure gauge helps in assessing the functionality of the showerhead under realistic conditions. It prevents damage that could occur from pressure that's too high, and it helps identify if the pressure is too low, which could indicate a problem with the water supply system or the showerhead itself.

ii. Quality Control:

- **Primary Use**: Pressure gauges play a vital role in quality control processes during the manufacturing of showerheads and related products. They ensure that each product can withstand standard operating pressures without leaking, failing, or underperforming.
- **Importance**: Maintaining consistent pressure across tests allows manufacturers to compare the performance of different units under identical conditions, which is critical for ensuring product reliability and customer satisfaction.

iii. Safety:

- **Primary Use**: Pressure gauges are used to ensure that the pressure within the shower tester booth does not exceed safe limits, which could potentially lead to equipment failure or even accidents.
- **Importance**: By monitoring the pressure, operators can take immediate action if the pressure exceeds safe levels, thereby protecting both the equipment and the operators from potential harm.

iv. Troubleshooting and Maintenance:

- **Primary Use**: Pressure gauges help in diagnosing issues within the shower tester booth. For example, if the water pressure is too low, the gauge can help identify whether the issue lies with the water supply, the pressure regulator, or other components of the system.
- **Importance**: Quick identification of problems through accurate pressure readings reduces downtime and ensures that the shower tester booth remains operational and effective in testing products.

v. Calibration:

- **Primary Use**: Pressure gauges are essential for the calibration of other instruments within the shower tester booth. Ensuring that all devices are correctly calibrated ensures that the testing results are accurate and reliable.
- **Importance**: Proper calibration is vital for compliance with industry standards and regulations, ensuring that the products meet the required specifications [36] [37].

1.13 Objectives with Specific Aims:

i. To identify the limitations of existing car shower tester booth.

ii. To develop an affordable design for bus shower tester.

iii. To analyze the design using ANSYS software

iv. To modify the existing car shower tester to bus shower tester according to developed design.

v. Performance evaluation of the modified shower tester

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

Gatot Ranggatama et al. [38] explained Shower testing is one of the procedures used by the automobile industry to create a respectable car for the market. As the name suggests, the shower test determines how resistant an automobile is to water exposure because, once delivered to a customer, the car will be utilized in all weather conditions, including severe downpours and rain.

Gautam A. Ghabade et al. [39] described that One of the most warranty problems and consumer complaints the automobile industry is now dealing with is water penetration into passenger cars. In order to prevent cars from leaking and from reaching customers, manufacturers have put in place a number of facilities and procedures related to design, engineering, development, testing, production, and auditing. They discovered that an incorrectly lengthened weather strip and the body flange bend are the causes of water infiltration. Therefore, process control—which is extremely difficult since it incorporates human variation—is required to prevent water incursion. For this reason, special gauges were created for 100% inspection and in cars that weren't up to par.

Thomas Parker et al. [40] in their study, clarified that addressing leaks at their source is essential for prolonged product lifetime quality and lifespan, in addition to the original vehicle quality. An easy way to define a leak is this. A hole, fracture, or porosity can be found in a polymeric hose, blow-molded container, tubing, forging, or casting. Even if there are leaks found at every stage of production, there should be one last inspection, similar to this shower tester booth test.

Seiji Manabe et al. [41] described about Shinichi Sasaki (In 1997), a senior manager in the production division at Toyota's Tsutsumi Plant, attempted to find a solution to the issue of rain leaks in Toyota cars. Customer satisfaction has suffered greatly as a result of rain leaks in cars, a serious issue that necessitates several hours of repairs at dealers. Shower tests, which involved sprinkling cars with copious volumes of water from several nozzles, were implemented as a quality control measure at the factory in response to this issue. They did discover some limitations with the shower test, though.

Mariano Ramirez et al. [42] in his study described that BMW uses Water for the shower tests in the passenger, luggage and engine compartments, as well as for washing new cars, gets reconditioned and recycled, leading to 80% water savings.

Sumukh Kengar et al. [18] described about an automobile manufacturing business assembles vehicles at its Pune plant. wherein a water test is conducted to find any leaks within the vehicle.

This is where seepage testing is carried out. For ten minutes, the car is submerged in a 2.8 bar shower jet. The primary areas that need to be examined are the car interiors when they are submerged in water at low to medium pressure, simulating a situation similar to that of heavy rain. The amount of water was extremely large despite the low water pressure, creating a situation that was very similar to that of heavy rain. Depending on the size and shape of the vehicle, different angles were used to direct the nozzles. Depending on the number of cars that needed to be inspected per hour, there were two different kinds of Shower Inspection chambers. **(I)** Conveyorized Shower Inspection : A conveyorized shower inspection booth or system is one in which the cars travel through the shower testing area while mounted on a conveyor. This is best suited for compact cars, SUVs, and MUVs. **(II)** Fixed Shower Inspection Chamber: Larger cars are used with this type of shower inspection booth/system in locations where there are very few vehicles that need to be inspected.

HE Xiao-ming et al. [43] conducted a study about the standards for the car rain protection airproof performance test were proposed by China's national standard commercial vehicles' comprehensive performance requirements and test methodologies (GB18565-2001). The test procedure is to spray the front, rear, side and bottom sections of cars that have been parked in the rain with an artificial mist that has the same intensity as the rainfall for 15 minutes. The observer-registrar then stays in the car to check for leaks of water and completes the original records table after the test has been going on for five minutes. Based on a set of standards, the car's performance in terms of rain protection and airtightness is evaluated, and it is then determined.

2.2 Valves:

Dhanwe Sunil Shivaji et al. [44] conducted an experiment and described, when little restriction and a straight-line fluid flow are required, gate valves are employed. Gate valves get their name from the component that controls the flow of fluid through the valve; this component is fittingly titled the gate and behaves something like an opening or closing of a gate. They carried out a stress investigation on the crucial Gate Valve component. The body, gate stem, and slab gate are the three essential parts of the gate valve. Gas pressure causes cyclic loads on the various components when the gate valve is linked in line. The material of the gate valve experiences significant stresses from bending, shearing, and tension-compression as a result of these forces and associated moments. They simulated a ANSYS model and found the stress values obtained by classical theory of mechanics and stress values obtained by Finite element method (FEM) are approximately same.

Hui Wu et al. [45] researched and explained, Researchers have focused a lot of attention on gate valves since they are frequently employed in the plumbing system. To examine their impacts on the flow and loss coefficients of the gate valve, different Reynolds numbers ranging from 200 to 500,000, valve opening degrees ranging from 20% to 100%, and groove depths ranging from 2.3 mm to 9 mm were used. The flow coefficient increased while the loss coefficient decreased as the Reynolds number climbed, according to the data. The fluctuation of the flow and loss coefficients was quite considerable when the Reynolds number was less than 5000. When the Reynolds number exceeded 5000, the flow coefficient's volatility reduced and the loss coefficient essentially stayed constant.

Quang Khai Nguyen et al. [46] investigated that, globe valves are frequently used in offshore structures and ships to control the flow of fluids through piping systems. Because of the complicated geometry of the valve and the resulting high pressure drop, the valves may be endangered during operation by a variety of phenomena, including cavitation and flashing. They discussed numerous computational fluid dynamics (CFD) analyses of forces and pressure distribution. CFD was used to design cages that would lessen the amount of cavitation-related damage to the valve plug.

According to Sreekala S. K. et al.'s [47] study, globe valves can be used to control flows because of their good throttling capability. They conducted a thorough analysis of the flow through Globe valves with a variety of shaped cage apertures, as well as how this affected the flow characteristics and optimisation. A code based on finite volumes, called FLUENT, was used to conduct the computational study. Experiments were used to validate the results of grid sensitivity tests.

Ming-Jyh Chern et al.[48] in their experiment explained, Ball valve is control valve to control the flow rate. For a manufacturer of ball valves, it is very important to know the characteristics of flows inside a ball valve. Their investigation of flow inside a ball valve, surface pressure distribution, balance between the pressure distribution and Reynolds shear stress along the separation streamline, flow structure and flow visualization were the main information to design a ball valve.

Baoling Cui et al. [49] researched that and described, ball valves are frequently used as pipe flow control components in the process industry to regulate the direction and rate of flow or stop the flow of pipeline systems. The operation reliability is directly impacted by the dynamic features of the valve's opening and closing. They reported the results of experiments and numerical simulations used to examine how the opening and closing procedure affected the ball valve's internal flow characteristics and external transient performance at various opening and closing times.

2.3 Nozzles:

A.C. Arnold et al. [50] demonstrated in their investigation that, notwithstanding a few small variations, the droplet-size spectra of the three flat fan nozzles were identical overall. Two primary sources of error were (1) growing droplet dispersion with distance from the nozzle and (2) sampling errors caused by the laser beam's width while taking readings in the liquid sheet's edges.

Nasir S. Hassen et al. [51] researched and reported that a spray patternator was created to help choose an appropriate nozzle for a consistent spray liquid distribution. Utilizing two different types of spray nozzles (a standard flat fan nozzle TP for broadcasting and an even flat fan nozzle TPE for banding application), experiments were carried out on a spray patternator. Utilizing banding flat fan nozzles produced the optimal spray distribution, while broadcasting flat fan nozzles produced an uneven spray distribution with a high peak located directly below the nozzle center and tapering off towards the spray pattern's edges.

Faizan Ahmad et al. [14] examined the nozzles which were full cone nozzles, which discharge liquid in a shape resembling a cone with an even distribution "within" the cone. Interestingly, the "full cone nozzle" is the most widely used nozzle and is present in nearly every industry sector. Nozzle spray angles can vary, but they typically fall between 0° and 170°.

As part of a research project, D. Nuyttens et al. [52] experimented with a test rig for spray nozzle characterization. A measuring protocol was established and a phase doppler particle analyser (PDPA) was developed. Massive amounts of repeatable and valuable data could be produced by this PDPA. The findings made it evident that both the size and type of nozzle had a significant impact on both droplet size and velocity spectra. The finest droplet size spectrum was produced by cone nozzles at the same nozzle size and spray pressure, followed by air injection, low-drift, and standard flat fan nozzles.

In their study, D Padhee et al. [53] assessed how spraying performance was impacted by nozzle type, nozzle height, and operating pressure. The findings showed that the spray uniformity distribution is influenced by the nozzle operating pressure and nozzle height. The interactions between nozzle pressure and height did not appear to have much of an impact on the spray pattern. The uniformity and coverage of the spray dose tend to increase with increasing nozzle height. Additionally, spray solution uniformity tends to improve with increased nozzle pressure. The information gathered from this investigation may be utilized to choose the appropriate sprayer nozzle.

2.4 Centrifugal Pump:

Gatot Ranggatama et al. [54] explained pump as a device that transfers fluid through a piping system by converting mechanical energy into fluid energy and pressure. It is utilized as a shower testing booth.

Brad Parkhurst et al. [20] described Centrifugal pumps use centrifugal force to increase the liquid's velocity in order to move it. Low viscosity fluids, such as water, are the ideal candidates for centrifugal pumps. They work well for quickly moving large amounts of low viscosity fluid. Compared to positive displacement pumps, they have a higher tolerance for solids, and some are designed specifically to handle large solids up to 3" in diameter. Centrifugal pumps come in a wide variety to suit any kind of need. Its widespread use in mechanical applications stems from this.

Faizan Ahmad et al. [14] investigated and explained, They could increase the pumps' dependability by utilizing a pump that is more appropriate for the existing infrastructure. A few different kinds of pumps could meet their system's project requirements. Their group was given the option to select from centrifugal, magnetic drive, and jet pumps.

According to Alfa Laval Kolding et al.'s [19] (centrifugal pumps problem) study, proper installation of any pump unit is crucial for ensuring optimal pump performance. The pipework, pump protection, and operation should all be taken into account when designing a pumping system.

2.5 Pump Installation:

According to Nischal Pokharel et al. [55] the researchers recommended that the pump be installed correctly, adhering to the manufacturer's specifications. The main causes of cavitation are pump locations, the length and size of connection accessories, and the transition of the suction pipe. There are various areas where cavitation can be reduced. In terms of the plumbing systems, the pump ought to be positioned in close proximity to the reservoir. The best place for the pump should maximize static head. It's commonly said that placing the pump below the water level in the tank it pumps from keeps the flooded suction going because of gravity, which, in most situations, keeps cavitation at bay. The suction lift ought to be positioned as low as feasible. High suction lift increased turbulence, demanded a lot of energy, and reduced NPSH-r. Using a large diameter suction pipe, which increases suction pressure and lessens the chance of pressure drop in the impeller, is the next technique to lessen the chance of cavitation. Contrarily, suction-side pipework is usually one or two sizes bigger than the pump inlet, but it is never smaller.

2.6 Pressure Gauge:

Okolie Paul Chukwulozie et al. [56] described in their article that, Electromechanical pressure gauges are crucial for pressure calibration as well as measurement and control in a variety of industrial applications. Due to their high resolution and both short- and long-term stabilities, pressure balances are the preferred reference devices for pressure calibration; however, accurate and efficient operation requires expertise. Chukwulozie added, "High-accurate electromechanical pressure gauges are becoming more widely used as reference devices to facilitate pressure calibrations." In the process industries, pressure gauges are widely used instruments that are easily calibrate able. They measure the pressure of liquid or gaseous materials by calculating the force they exert at a steady state.

Do Guen Yoo et al. [57] studied and suggested that for efficient management and upkeep of water distribution systems, it is crucial to choose the ideal location for the pressure gauge. Their work used entropy theory to define the pressure change at other nodes as a result of demand change at a particular node, offering a measurable and objective criterion for selecting the best position for the pressure gauge. The water distribution system's main points should be measured for flow and pressure, but the system does not clearly define or set a standard for these points. In order to quantify a specific standard for determining the gauges' location, research was necessary before gauges were installed at the entrance of the small block based on advice from experts in the field. They suggested that the node that receives the most information from the entire system should be the priority location for the pressure gauge's placement, based on the entropy standard.

2.7 Overhead Tank:

Ritwik Bandyopadhyay et al. [58] researched that, It is possible to construct overhead water tanks as TLDs for vibration control, especially to solve serviceability concerns under wind and seismic loads. Different tank forms have been produced where the water's fundamental lateral sloshing frequency is almost consistent throughout a wide range of water levels. This avoids detuning between the structural frequency and the sloshing frequency that occurs in normal rectangular and circular tanks due to water level fluctuations. With a normal sloshing simulation based on the Laplace equation running in the background, they employed optimization and a novel, assumed simple functional form to generate the tank forms. Two types have been found: one for tanks that are axisymmetric and another for tanks that face the other way and are rectangular.

According to a study by D. K. Landge et al. [59] the circular shaft-type supporting structures of elevated water tanks that are currently designed are very susceptible to lateral forces from earthquakes. A reinforced elevated water tank with capacities of 1000 m3, 750 m3, and 500 m3 has been taken into consideration in their study. It is supported by a staging system that is fixed on a base shaft. Seismic responses, including displacements and base shear, were evaluated under four earthquake records, taking into account one mass model according to IS:1893-1984 and two mass water models according to IS:1893-2002.

Hassan Khurshid et al. [60] in their study, examined how solar radiation affected the summertime water temperature in the overhead storage water tanks. Their research concentrated on using shade and insulation to reduce the effects of solar radiation. A straightforward analytical model had been put forth, and the results closely matched the experimental data. Additionally, insulation has been shown to significantly lower the water temperature inside tanks. The thickness of the insulating material can be increased to a certain degree to improve results. They came to the conclusion that insulating the tank might be a low-cost financial fix for the current issue.

2.8 GI (Galvanized Iron) Products:

Walter Arthur et al. [61] explained in their study, rather than being a sheet of iron covered in a layer or skin of pure zinc, as one might expect, galvanized iron—by which they included all zinc-protected iron in this article—consists of a complex system of iron-zinc compounds that start with pure zinc on the outside and work their way inside to the iron base.

H.A. Abdul Bari et al. [31] investigated One of the main issues in the field of power saving was the issue of pumping power losses in pipes that carried liquids and flowed in turbulent mode. Water, a natural drag-reducing agent, was used as the transporting liquid in flow testing. Pumping water from a reservoir tank that had been combined with mucilage was the first step in the experimental process. The pipes that were utilized were made of galvanized iron. This flow system's testing length was 1.5 meters. The flow system was built using three galvanized iron pipes with different internal diameters (0.015, 0.025, and 0.038 m ID). A full closed-loop plumbing system was constructed.

Subbiah Karthick et al. [62] investigated that, Transmission towers, telecommunications equipment, road safety, and civil construction all made extensive use of galvanized goods. One 1 cm2 G.I. specimen was cut for their research, and the wire was soldered and epoxy-sealed for electrochemical analyses. Acetone was used to clean the G.I. specimens without causing any harm to the surface's galvanizing coating. Studies on earth excavation were conducted. The G.I. specimen corroded, forming pits and crimson rust. It was determined how well MS and G.I. performed in terms of corrosion. It is further stated from the study that certain precautions should be taken to assure the zinc layer's coating thickness and the longevity of GI goods if any construction was exposed to a harsh environment.

2.9 Transmission System and Transmission Pipes:

B. A. Konnur et al. [63] in their study explained that, the water transmission system is made up of pipelines, storage facilities, pumping stations, and associated infrastructure. The water transmission network, which often uses long-distance pipelines with large diameters, receives the majority of the capital investment in a water supply system. Water transmission network design methodologies include: (I) Gravity main design; (II) pumping main design; (III) single branch pumping transmission system; (IV) multi-branch pumping transmission system.

In their paper, Wentao Wang et al. [64] used a structural reliability framework to estimate the likelihood that pipe segments in a water transmission system will fail under predicted service loads. They used a technique called maximum transient pressures to estimate the likelihood that any given gearbox system segment would fail. Their investigation, which used data from the GLWA gearbox system, looked at the likelihood that PCCP pipe segments would fail close to a pump station that frequently experiences high-pressure transient events. In order to determine the probability of failure for every system branch, future work will generalize the approach and apply it to the gearbox system as a whole.

Richard D. Mielke et al. [65] researched and explained that standardizing the performance requirements for all gearbox main pipe results in uniform designs, equal performance, and the best long-term value for the owner. The phrase "Pressure Class Design" was employed, denoting the pipe's capacity to withstand internal pressure.

Mahmoud Annan et al. [66] investigated that in general, minor losses for long pipelines typically have a much smaller value than major losses. However, the value of the small losses could add up because long pipelines can have a large number of fittings installed. They also discovered that the precise value of the minor losses needs to be computed in order to carry out an accurate hydraulic analysis of the gearbox system. From one pipeline to another, the impact of the small losses on the gearbox system design can differ.

2.10 Welding of Pipes:

Eung Seok Kim et al. [67] in their study described that, the welded connection is recognized as a crucial component for ensuring qualified construction and/or maintenance of wrapped steel pipe. This study estimates the welded connection conditions in coated pipes larger than 700 mm in diameter found in Korea's water distribution systems in order to recommend a welded connection method that is both technically and financially feasible. Accordingly, in terms of pure construction cost (average 9%) or pure welded connection cost (average 13.5%), automatic welded connection method performs better than manual welded connection method.

2.11 Shower Head and Flow Rate:

According to research by Yang Zhou et al. [68] One common demand-side water management tactic that is being endorsed by legislators and water companies is the installation of water-efficient appliances. In addition to drastically lowering the total amount of water used for showering throughout the system, installing low flow showerheads in large, complex plumbing systems will also have an effect on the water supply system's design. Installing all low flow showerheads can lower the design flow rate by 15%, which equates to a 1.5% gain in energy efficiency, per the design simulation results.

J. Puig-Bargues et al. [69] Experimented to analyze head losses across filters. Five effluents with 115, 130, and 200 micrometer disc filters were used in their experiment. Three popular filter types—screen, disc, and sand—that are used in microirrigation systems were put to the test. the primary features of the filters that were employed in the studies, along with the effluents that were examined using 98, 115, 130 and 178 mm screen filters as well as a sand filter with an effective grain size of 0.65 mm for each filter. Two filled manometers were used at the filter's inlet and outlet, respectively, to measure the head loss. The filter that permitted a lower volume to pass before the sand filter experienced a 49 kPa head loss was indicated by the results. The frequency of backwashing for sand filters is typically lower than that of disc and screen filters.

CHAPTER 3

PROPOSED DESIGN OF THE NEW SHOWER TESTER

3.1 Introduction:

A type of testing tool used in the automotive business to assess a vehicle's water tightness is the shower tester booth. Its purpose is to evaluate how well vehicles can keep water out of the interior cabin or other important spaces like the engine bay, by simulating driving circumstances in heavy rain and wet weather. Automotive manufacturers and suppliers frequently utilize shower test booths to confirm that their products conform to the necessary water tightness standards and to prevent potential problems, such as water damage and related issues. For the customer's satisfaction these booths always play a crucial role to ensure that vehicles are dependable and secure, no matter the weather conditions are. Now I am giving the flow diagram of older shower tester shown in fig 3.1.

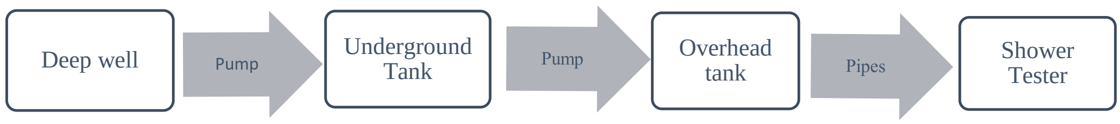


Figure 3.1: Flow diagram of the existing shower Tester

3.2 Existing Older Shower Tester:

In the existing older shower tester, Bus body can not be tested because of its size. Only Car/SUV and Double Cabin Pick up's shower testing is possible by the older shower tester. The size of the older shower tester is Length-20ft ,Width-11ft and Height-10ft .The frame was built by total 10 no of 3″ MS pipe. In the lateral side total 4 no of 1.5″ MS pipe were used. On the top side total 7 no of 1.5″ MS pipe were used for spraying water from the top portion. The structure is not so strong because when some gusty wind blow then it starts to vibrate frequently. The welding joints are also becoming weaker. Some crack already been formed in several joints. So it is becoming risky while doing some shower testing inside it. Among the pipes (Top & lateral side) Flat fan nozzles are fixed at a successive distance of 8″, among them some nozzles are not fixed at a regular interval. The total number of nozzles are 300. In the older shower tester the water pressure is not maintained properly because there is no pressure gauge in each branch pipe. By using individual gate valve in each branch pipe the water pressure has maintained shown in figure 3.5. During this period water pressure is found always higher (Before designing new shower tester once checked by installing pressure gauge in the older one as experimental basis and found water pressure above 5 bar) than the standard operating pressure. Due to the use of gate valve in each branch pipe as well as using less quantity of pipes, pressure drop is less so excessive water pressure is found in each branch pipe. Moreover, the number of branch pipes in lateral side are few and they were not placed at an appropriate height (one placed at 4ft height and another placed at 5.5ft height) shown fig 3.5 so shower testing work is not properly perform by maintaining standardization. Furthermore, the pipes are being rusted within few months instead of painting the pipes at regular intervals. The detail specifications of the older shower tester shown in Table-1 as well as some images of the existing older shower tester shown in fig (3.2-3.5)

Table 1: Details of existing shower tester (L-20′, W-11′ and H-10.1′)

Length & Quantity of MS Pipes			**Pipe Dia. (inch)**	**No of Nozzles (Flat fan nozzle)**	**Nozzle Successive distance**	**Quantity of Total gate Valves**
Lateral Side	L-20ft 2 No L-10ft 2 No	Total=4 No	1.5	90	8 inch	8
Top Side	L-20ft	7 No	1.5	210		
Frame	L-20ft 2 No L-10ft 6 No L-11ft 2 No	Total=10 No	3	Nil		
				Total-300		

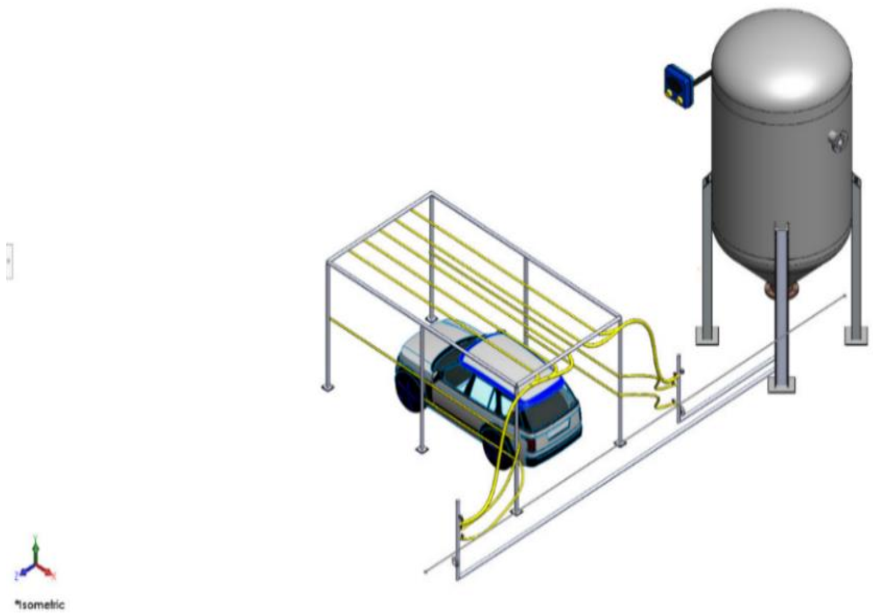


Figure 3.2: Isometric view of the existing shower tester

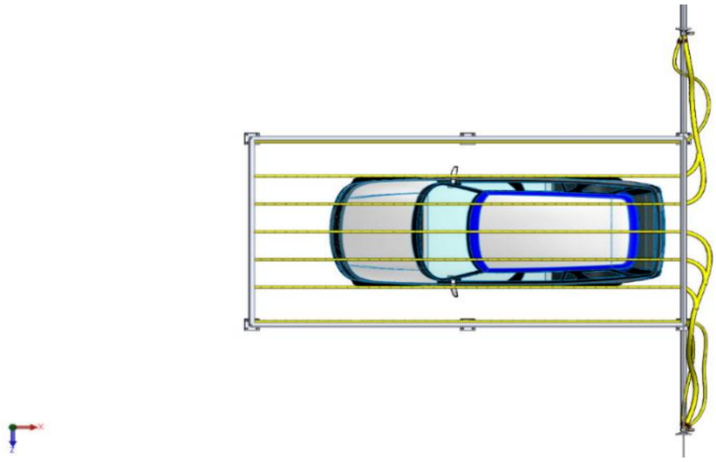


Figure 3.3: Top view of the existing shower testing booth

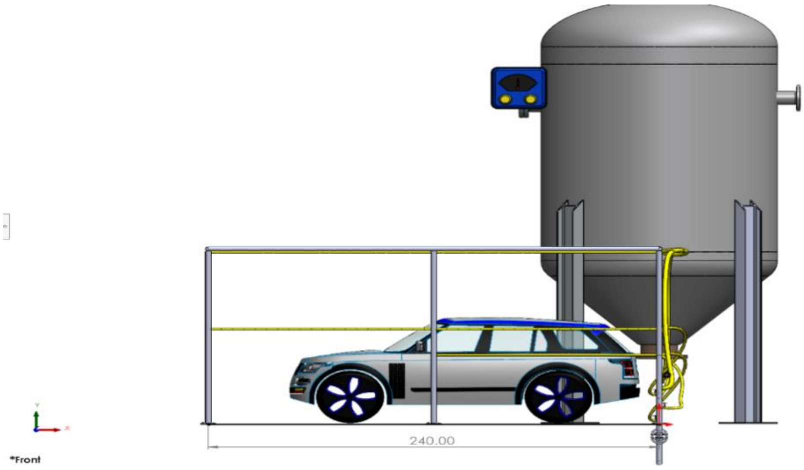


Figure 3.4: Lateral side view of the existing shower tester booth (L-240 inch or 20ft)

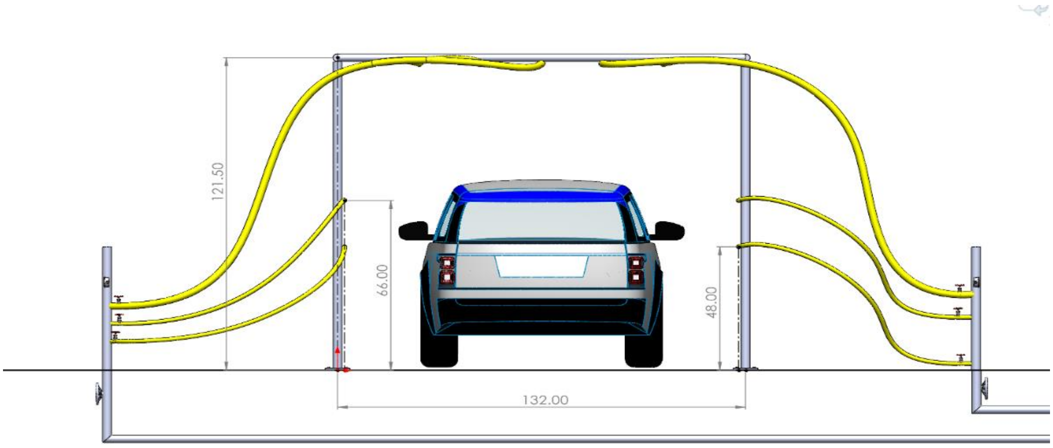


Figure 3.5: Front view of the existing shower tester (W-132″/11ft & H-121.5″/10.1ft)

3.3 Place of modification:

As previously mentioned, we had several issues with the older shower tester, including the inability to use a pressure gauge, high water pressure, fewer pipes and improper lateral side pipe distribution, the use of flat fan nozzles and irregular nozzle gaps, the booth's small size and weak structure, and more. These issues made us eager to modify the older shower tester. With the exception of the shower tester's plumbing and structure, we shall maintain all of the previous configurations. As illustrated in Figure 3.6, the red box indicates the alteration area.

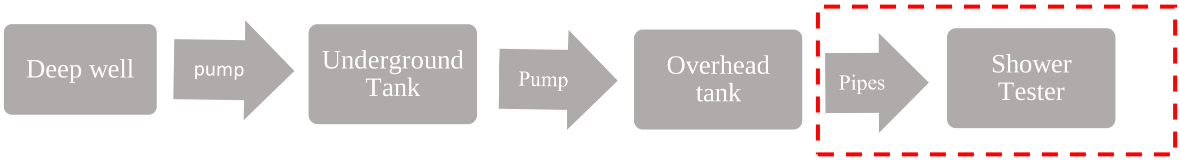


Figure 3.6 Flow diagram of New shower tester with modification zone (red box)

3.4 Proposed Design of the New Shower Tester:

In the new shower tester booth, we will enlarge its structure and position of all the branch pipes at an appropriate height so that all types of vehicle including Bus, SUV, Double cabin Pick up and Sedan cars can be shower tested as well as arranging the pipes at a standard height. Because of frequent rusting problem in the Mild Steel (MS) pipes, we will use GI pipes in the new shower tester so rusting problem might be eliminated. All of the water pressures in the branch pipes are within the desired range (2-2.5 bar) when I compute the water pressure for SUVs. However, I discovered that every branch pipe's water pressure was negative after calculating the water pressure for the bus. Then, in order to increase the water pressure into the branch pipe during bus shower testing, I have to change the design of the new shower tester by adding two centrifugal pumps to the 5-inch main transmission pipe. Figures 3.16 and 3.17 display the design prior to pump configuration. Fig. (3.7-3.10) displays the final updated shower tester design.

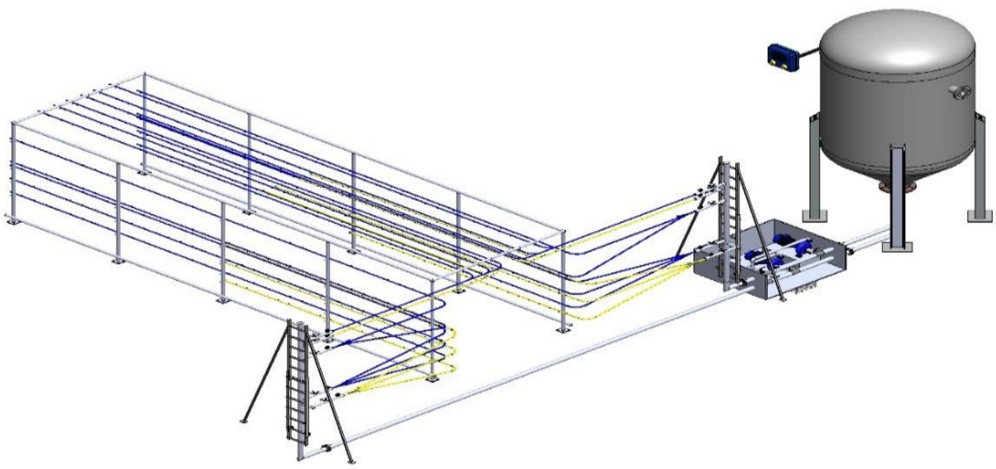


Figure 3.7: Isometric view of New shower tester booth

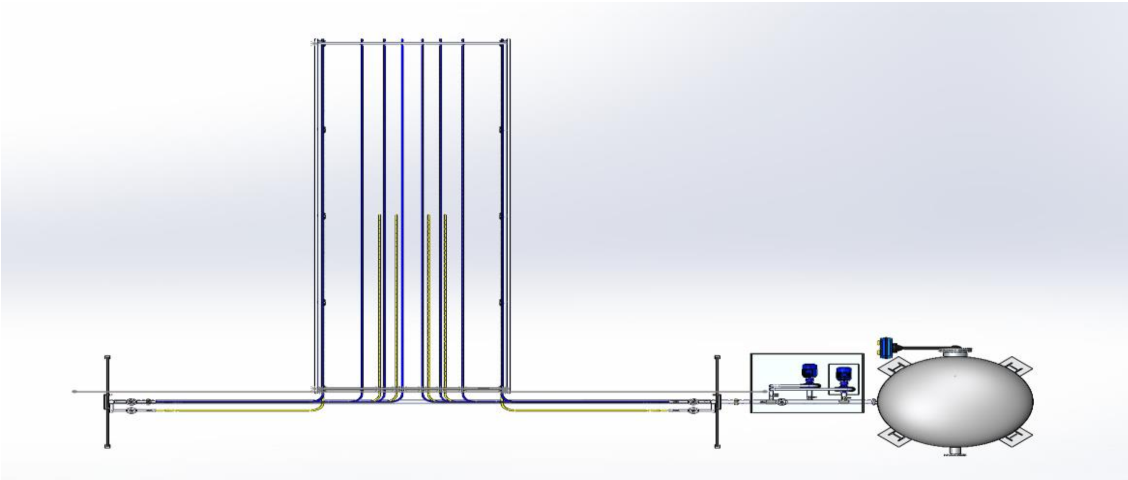


Figure 3.8: Top view of the New shower tester booth

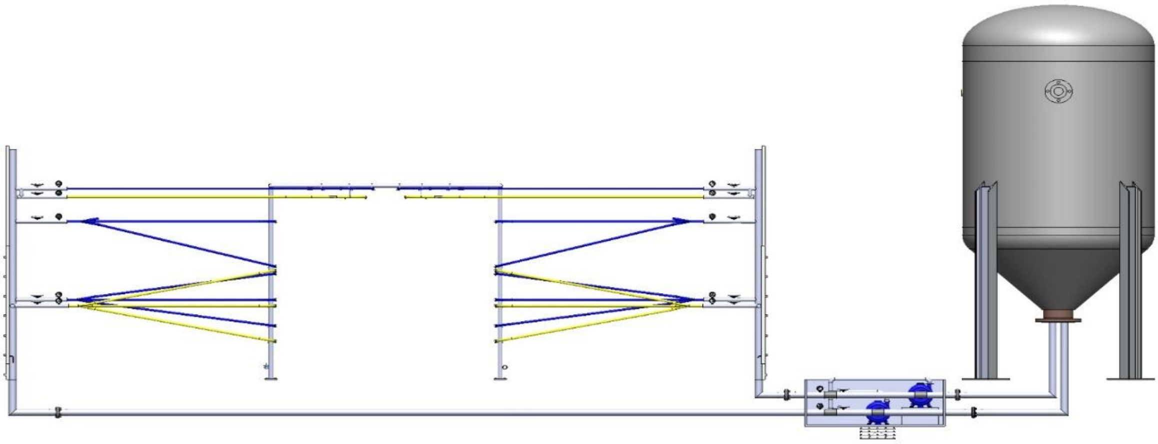


Figure 3.10: Front view of the New shower tester booth

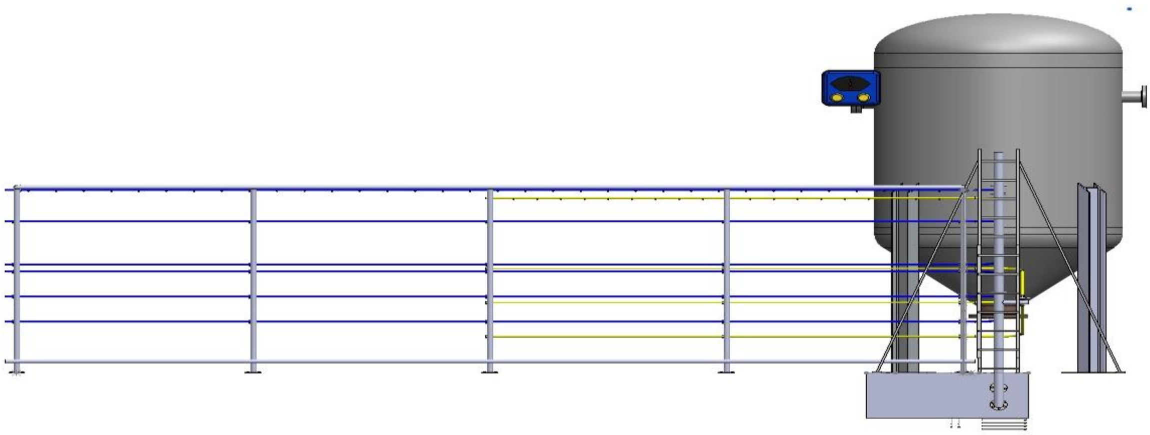


Figure 3.9: Lateral side view of the New shower tester booth

3.5 Description of New shower tester structure:

The new shower tester's size will be in Height: 12.5 feet, Width: 12.5 feet, Length: 40 feet. We will have to install two different plumbing configurations in the new shower tester in order to support bus and SUV and DC pickup. For the DC Pick Up and SUV we will use total 10 no of 20 feet length 1.5-inch GI branch pipe. Among them 6nos pipes will be located in lateral side {Vertical height of lateral side pipes from the Ground Shown in the fig 3.13 & Table-2} shown in fig 3.12 and rest of 4 no pipes will be located on the top side (Distance from the corner frame pipe shown in the fig 3.13 partially & Table-2). The top pipe sets will be distributed uniformly over a 52-inch (4.34-feet) width, completely enclose the SUVs' roofs as depicted in fig 3.11. As seen in fig. 3.13, the top four pipes are 11.9 feet above from ground level. The "L" shaped bracket that is welded into the structure frame pipe depicted in figure 3.14 will support all the branch pipes. **The branch pipes which will be dedicated for SUV & DC Pick up painted yellow** shown in fig 3.12 & 3.13. For the **Bus Body** We will use total 16 no of 40ft length 1.5″ GI branch pipe. Among them10 no of pipe will be located in lateral side (Vertical height of lateral side pipes from the Ground Shown in the fig 3.13 & Table-2) and rest of 6nos of pipes will be located on the top side {Distance from the corner frame pipe shown in the fig 3.13 partially & Table-2}. The top pipe sets will perfectly cover the bus roof seen in figure 3.11, with an even distribution over a width of 82 inches/6.84 feet. As seen in fig. 3.13, the top six pipes are 12.4 feet above from ground level. These pipes will be also hanged on “L” shaped bracket and **the branch pipes which** will be **dedicated for bus painted blue color** shown in fig 3.12 & 3.13. Before placing all the blue and yellow branch pipes on the frame bracket, all the full cone nozzles will have to be fixed in the branch pipes (for yellow and blue pipes, nozzles successive distance are 12inch & 14inch respectively) shown in fig 3.15. To maintain the branch pipes in their precise positions and increase their stability, we will employ clamps at each bracket site.

Table 2: Information on the height and distance of the New Shower Tester Pipes

<table>
<tr><td>Vehicle type</td><td colspan="5">Pipe Vertical height in feet, measured from the pipe’s center to the ground.
LATERAL SIDE</td><td colspan="6">The distance in feet between the center of the pipe and the corner frame pipe.
TOP SIDE</td></tr>
<tr><td rowspan="2">Bus</td><td>1st</td><td>2nd</td><td>3rd</td><td>4th</td><td>5th</td><td>1st</td><td>2nd</td><td>3rd</td><td>4th</td><td>5th</td><td>6th</td></tr>
<tr><td>3.5</td><td>5.2</td><td>6.9</td><td>7.38</td><td>10.3</td><td>2.83</td><td>4.35</td><td>5.57</td><td>6.93</td><td>8.15</td><td>9.67</td></tr>
<tr><td rowspan="2">SUV</td><td colspan="2">1st</td><td colspan="2">2nd</td><td>3rd</td><td>1st</td><td colspan="2">2nd</td><td>3rd</td><td colspan="2">4th</td></tr>
<tr><td colspan="2">2.5</td><td colspan="2">4.8</td><td>7.1</td><td>4.04</td><td colspan="2">5.17</td><td>7.33</td><td colspan="2">8.46</td></tr>
</table>

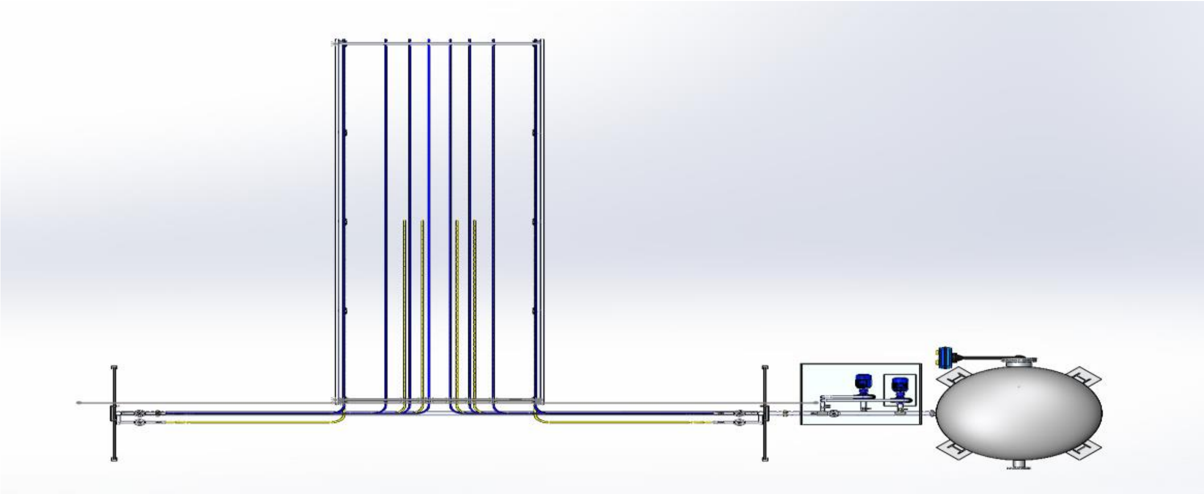


Figure 3.11: Top view of the New shower tester booth

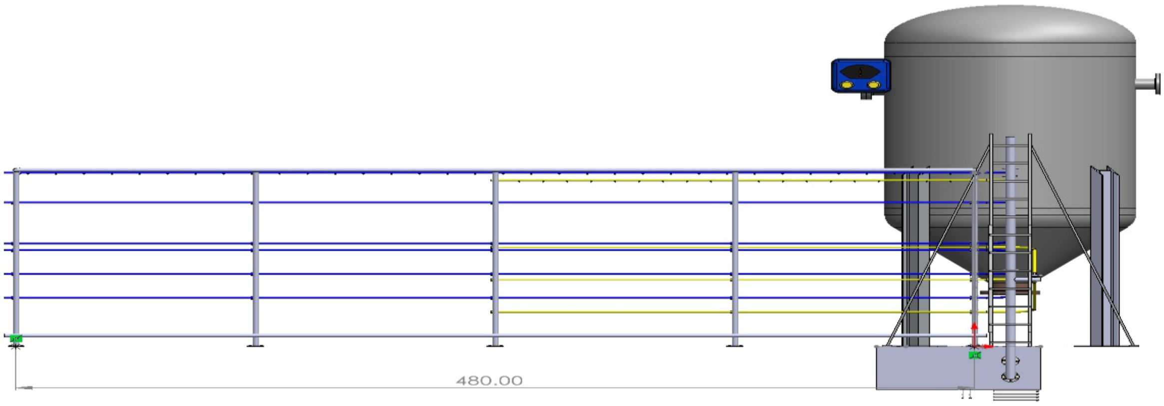


Figure 3.12: Lateral side view of the New shower tester booth

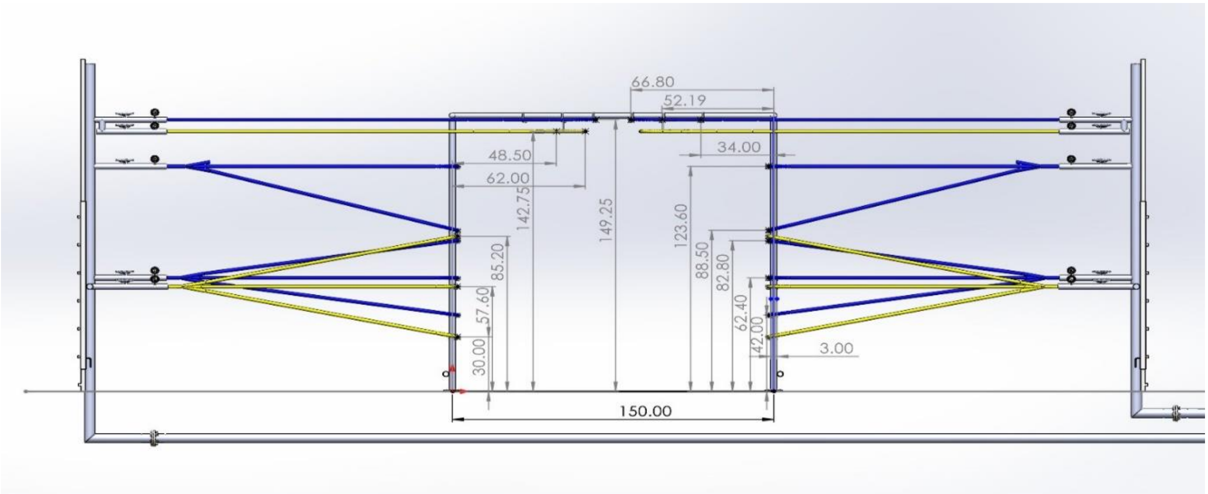


Figure 3.13: Front view of New shower tester with detail dimensions (inch)

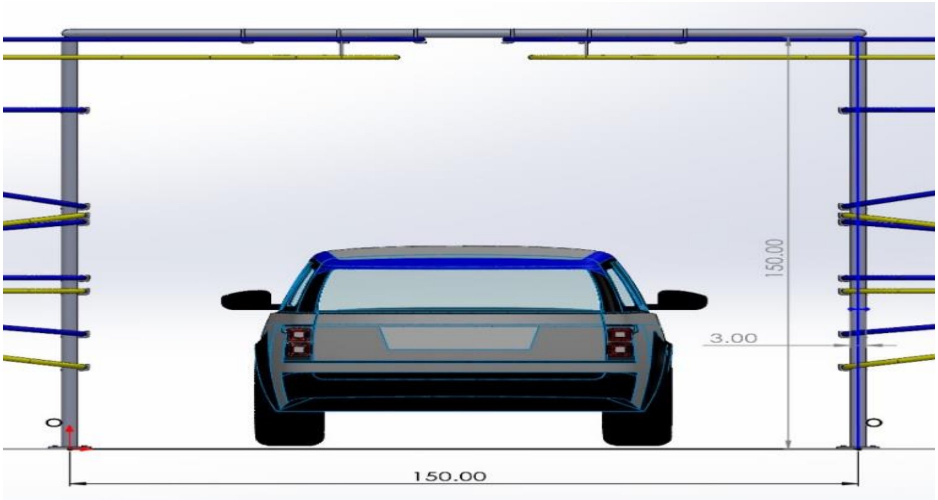


Figure 3.14: Front view (W-150″/12.5′, H-150″/12.5′ & Frame Pipe Dia 3″)

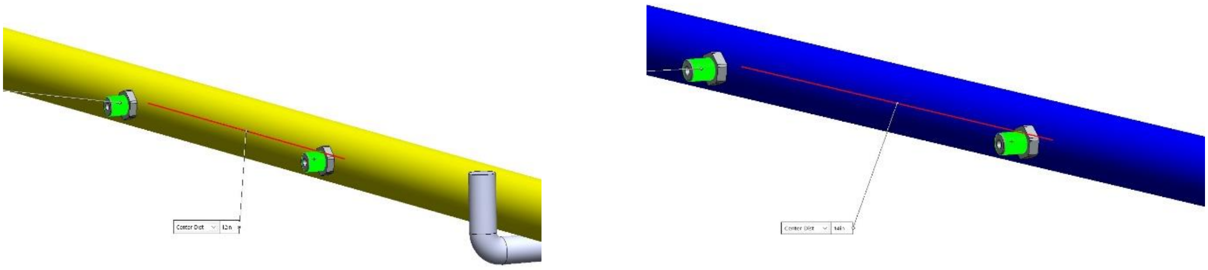


Figure 3.15: Full Cone Nozzle Successive distance for Car/SUV (Yellow) & Bus (Blue)

3.6 Front & Rear side Shower Option:

Though in the previous design we have some limitations for shower testing at front and rear position of the bus. Thats why the shower tester booth needs to be modified again. The updated and modified design of the shower tester is shown in the Figure 3.18 and 3.19 to facilitate shower option from the front side both right & left hand lateral side blue pipes will be extended at the front portion of the structure connecting by elbow. The length of the each front extension pipe is 66.50 inch and shown in Figure 3.16 In order to provide rear shower facility, we will install 3 consecutives nozzles slightly inclined position in the all branch pipes (including lateral & top side) entry position shown in Figure 3.17.

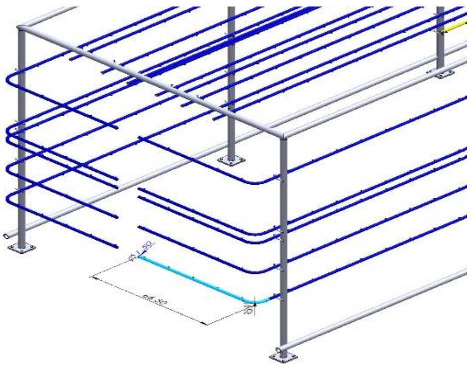


Figure 3.16: Extension pipes

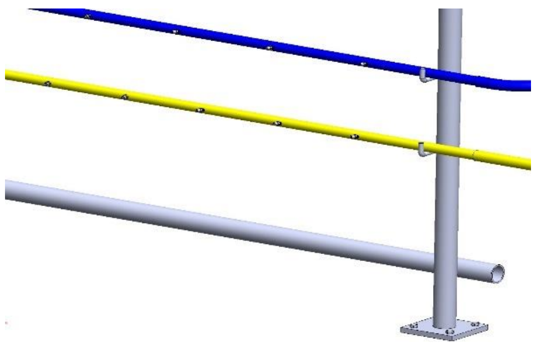


Figure 3.17: 30 Degree Inclined Nozzles

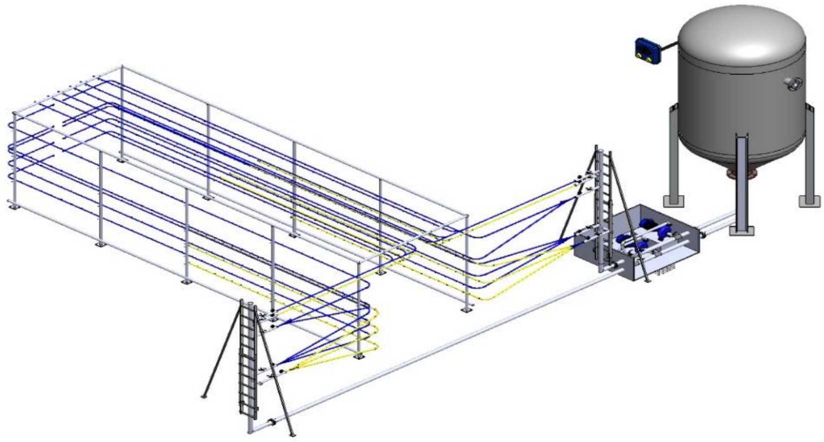


Figure 3.18: Isometric view of New shower tester booth

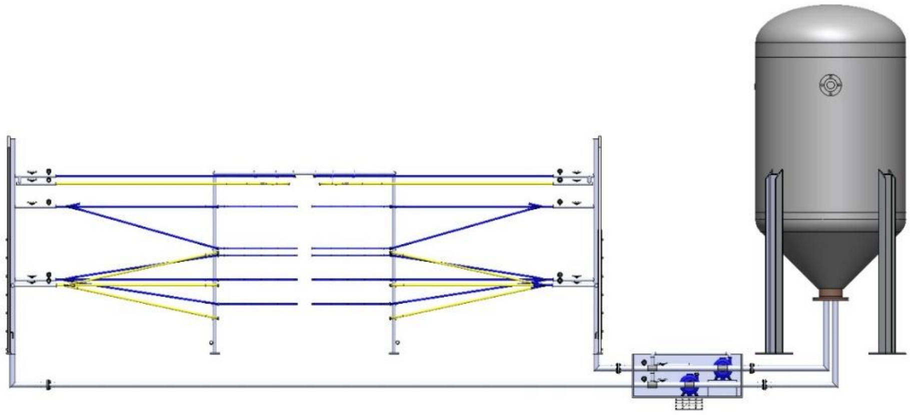


Figure 3.19: Front view of the New shower tester booth

3.7 New Shower Tester Installation Procedures in future:

3.7.1 Preparing the Existing Shower Tester for the Modification:

First we have to break the older shower tester booth, then need to clean the place. Though the floor is RCC so we should not do anything to prepare the floor. Then the Main transmission pipes (5inch) will have to be extended both left and right side shown in fig 3.20 & 3.21. There will be a total of four flanged joints in the two major transmission pipes. Two Gate valves will have to be used for controlling the water supply. Two pressure gauges have to be installed in the main transmission pipes for checking the water pressure. After that we have to fabricate the structure of new shower tester. The new shower tester booth will be fabricated by using 16 no of 3″ dia GI pipe. We will use 6″square plate as a flange in 10 no of GI pipe. Initially all the square plates have to be drilled for making 4 holes. Then the square plate have to be welded at the bottom side of each pipe. The floor must then be drilled at ten locations with a 10-foot lateral side spacing between each point, each of which will have four holes. Moreover Royal plugs will have to be inserted in the holes and then we will fix 10 no of pipes with flange in the pointed area and should be tighten with bolt (each flange 4 bolts).When all the vertical pipes

(10 no) will be installed then 2nos of 3″dia GI pipe of 40 feet length have to be placed laterally at the bottom side of the structure approximately 6″above from the ground and should fix them by welding joint. Additionally, we need to weld four 3-inch GI pipes (two measuring 40 feet in length and two measuring 12.5 feet) to the upper part of the vertical pipes.

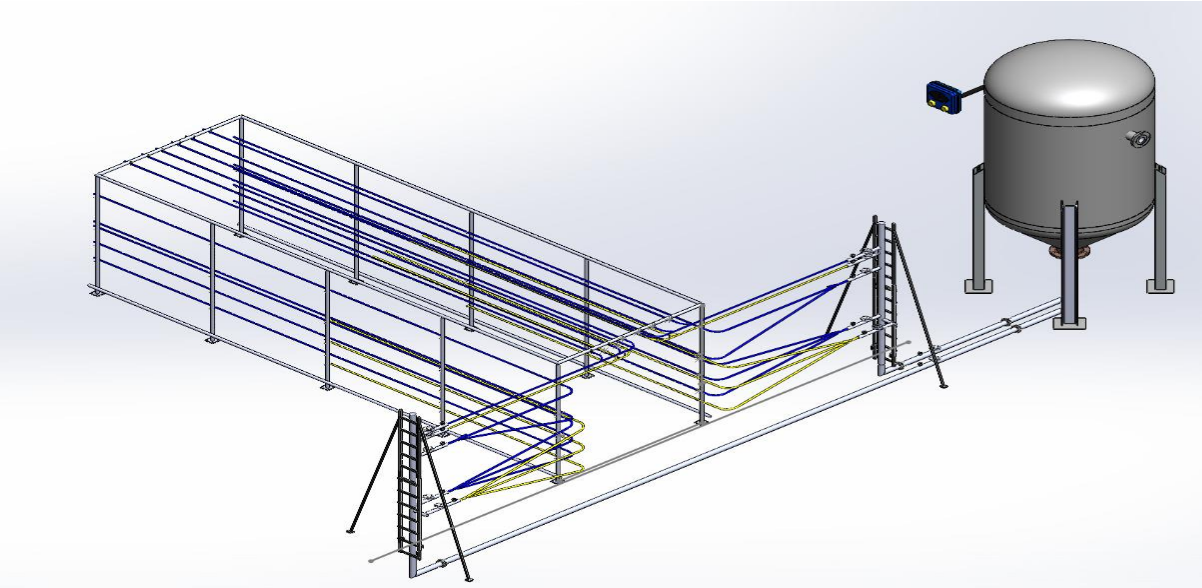


Figure 3.20: The new shower testing booth in an isometric view (without pumps)

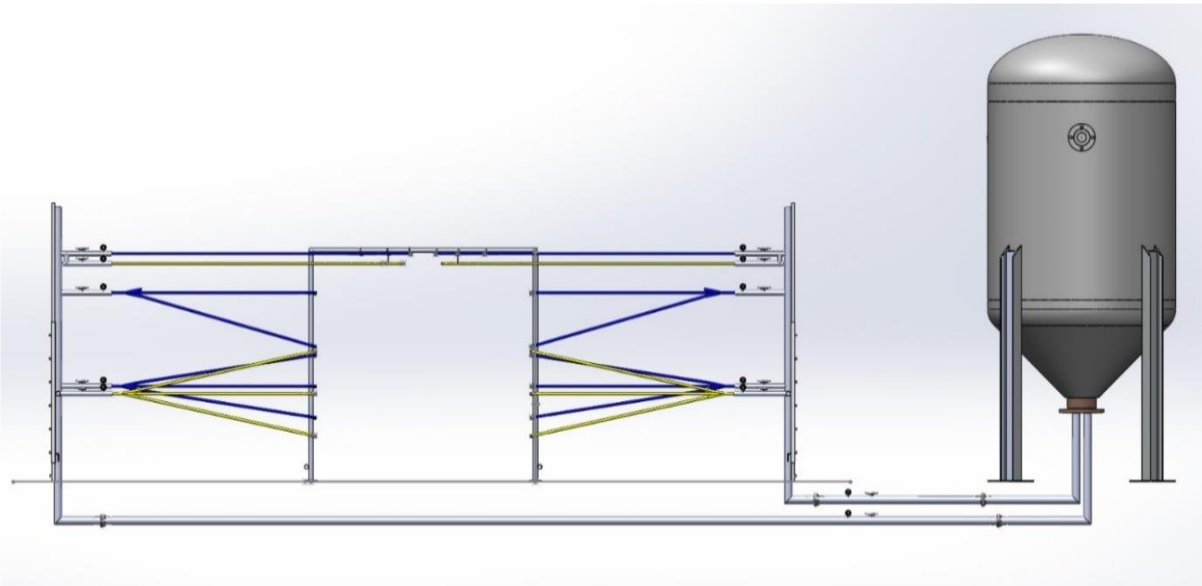


Figure 3.21: The new shower tester booth's front view (without pumps)

3.7.2 Transmission Pipes, Valves and Pressure Gauge Installation procedure:

Then I will have to start the work of connecting the main transmission line and the branch pipe. In order to do that I have to weld 3-inch diameter Sub-main transmission pipe with the 5-inch diameter main transmission pipe. This 3-inch diameter Sub-main transmission pipe will act as a link between 1.5-inch diameter branch pipe and the 5-inch diameter main transmission pipe shown in fig 3.22. Firstly for SUV and DC Pick Up, 4nos of 3-inch diameter sub-main transmission pipe have to be welded in the lateral side at a height from the ground level are 4.8feet and 11.9feet respectively. Then one pair of pressure gauge and globe valve have to be fixed in each sub-main transmission pipe shown in fig 3.22. Second, the bus body requires six (3inch)-diameter sub-main transmission pipes to be welded to the lateral side at a height of 5.2, 10.3 and 12.4 feet respectively, above ground level. Similarly one pair of pressure gauge and globe valve have to be fixed in each sub-main transmission pipe shown in fig 3.22. Later in the lateral side all the branch pipes (total 16nos, yellow & blue) will have to be connected through elbow with the sub-main transmission pipe shown in fig 3.23. On the other hand, all the branch pipes (total 10 no, yellow & blue) in the top side will be bended and welded to the top side branch pipe comes from the sub-main transmission pipe shown in fig 3.11 & 3.23.

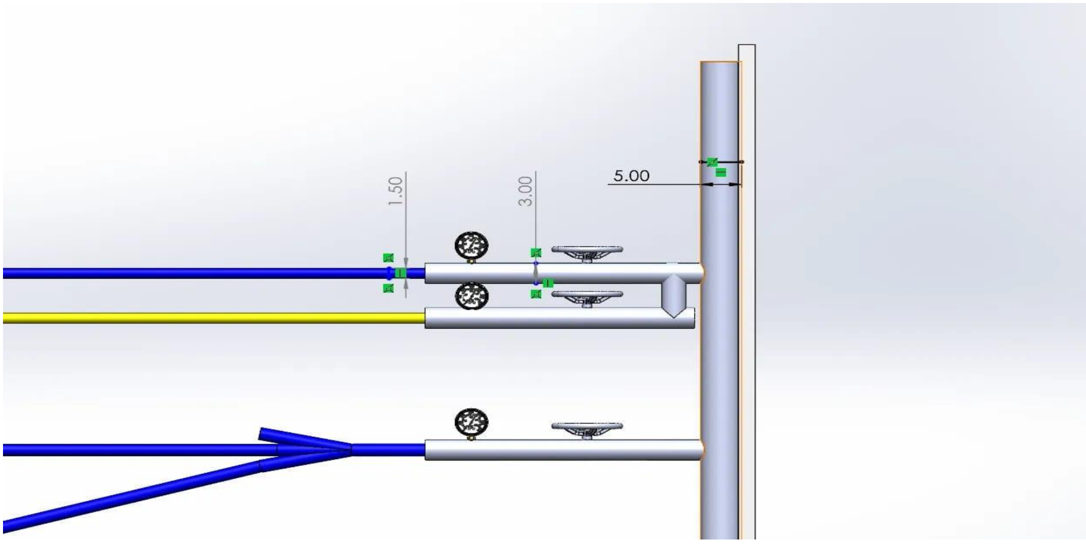


Figure 3.22: Front view of Branch pipe, Sub-main transmission & Main transmission pipe

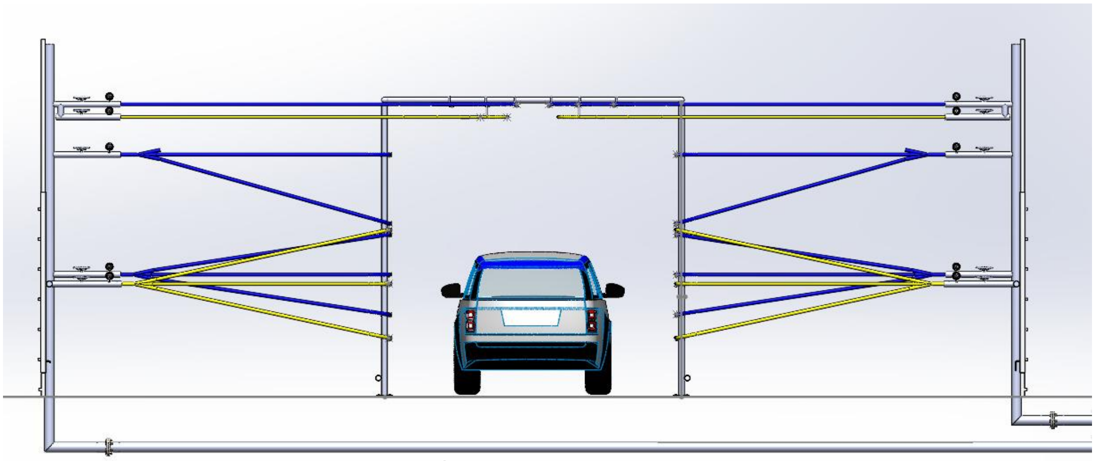


Figure 3.23: Front view of the New shower tester booth (with SUV)

3.7.3 Controlling and Maintaining Components Installation procedure:

The water pressure via the branch pipe will be managed by a total of ten globe valves on the lateral side. During shower testing, the operator will find it easy to operate the two globe valves on the lower side, but the next three globe valves on the higher side will be difficult to handle due to their height. We will fabricate the ladders using a 1.5-inch by 1.5-inch MS angle. We must first install two ladders on the lateral side that attach to the main transmission pipe. Square plates will be welded into place at the ladder's base. When the operators will climb on the ladder to operate the upper globe valves then there will be a possibility to vibrate. Which will be uncomfortable and unsafe. In order to avoid vibration and also to increase the ladder's strength and safety, we must attach two square solid bars from the top to the bottom, as seen in figures 3.7 and 3.24. I must first drill and bolt two square plates at a distance of 5.3 feet from the center of the ladder. The ladder's top side will then need to have solid square bars welded to it, and the bottom side will need to be welded to the square plate that is fastened to the ground. Figure 3.24 displays the ladder's detailed dimensions. Table 3 lists the major equipments that will be used in the construction of the new shower tester.

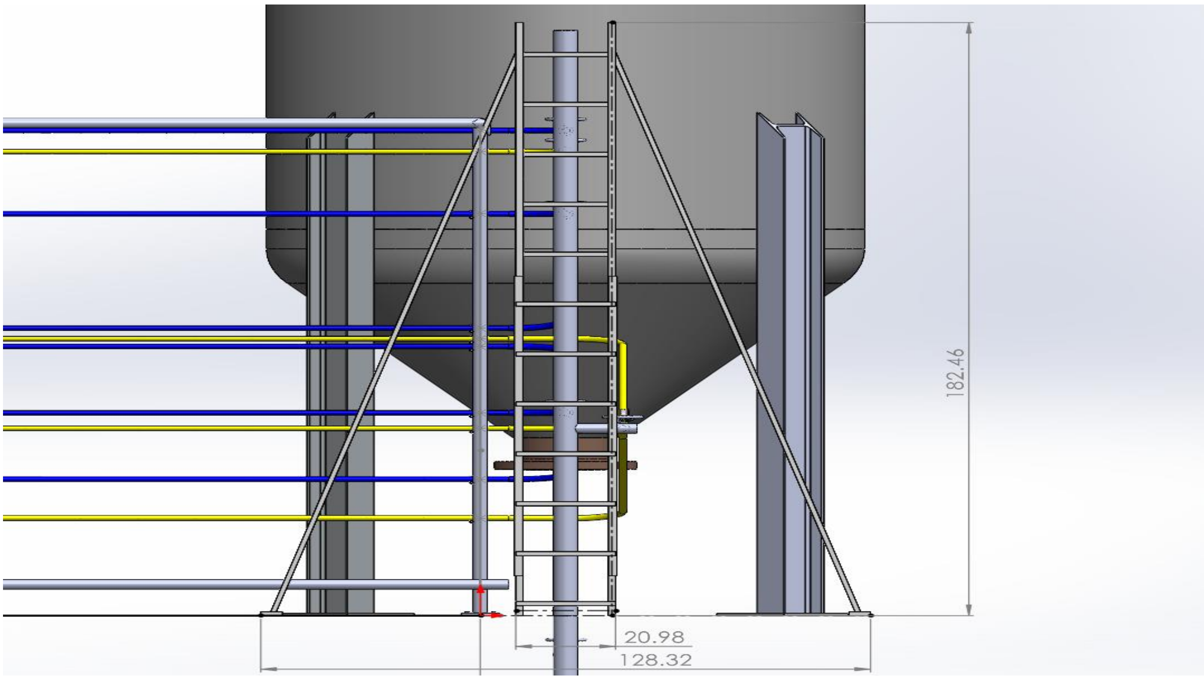


Figure 3.24: Dimension of the ladder of New shower tester booth

Table 3: Requirement of Major Equipment for New shower tester

<table>
<tr><th>Vehicle Type</th><th colspan="2">Branch GI pipe length (feet) & Quantity</th><th>Diameter of Branch Pipe (inch)</th><th>The number of Full cone nozzles</th><th>Nozzles successive distance (in)</th><th>Globe valve number (Shower input)</th><th>Pressure gauge number (Shower input)</th><th>Number of Pressure Gauges, Ball Valves & Gate Valves (Tank output)</th><th>Number of frame pipe (3 inch Diameter) & Square Plate (8*8 inch)</th><th>No of Pump</th></tr>
<tr><td rowspan="2">Bus</td><td>Lateral Side</td><td>L-40
Qt-10</td><td rowspan="2">1.5</td><td rowspan="2">544</td><td rowspan="2">14</td><td rowspan="2">6</td><td rowspan="2">6</td><td rowspan="4">Pressure Gauge-2
Ball Valve-4
Gate Valve-2</td><td rowspan="4">16
&
14</td><td rowspan="4">02</td></tr>
<tr><td>Top Side</td><td>L-40
Qt-06</td></tr>
<tr><td rowspan="2">SUV</td><td>Lateral Side</td><td>L-20
Qt-06</td><td rowspan="2">1.5</td><td rowspan="2">200</td><td rowspan="2">12</td><td rowspan="2">4</td><td rowspan="2">4</td></tr>
<tr><td>Top Side</td><td>L-20
Qt-4</td></tr>
</table>

3.7.4 Pit Preparation Procedure for Pump Installation:

To proceed with the centrifugal pump installation shown in fig. 3.25, I must prepare the pit area. I will be responsible for overseeing our civil engineer's construction of the pit in accordance with the design and drawing. The Reinforced Cement Concrete (RCC) floor area must first be dug out while taking the pit's dimensions into account. The dimension of the pit will be L-91.89inch, W-82.53inch and D-36.48inch shown in fig 3.26 and 3.27. Then we will have to prepare the ground slab reinforcement of the pit. Pump 1 have to be placed in the bottom level of the pit and Pump 2 have to be placed in the separate base of the pit which dimension shown in fig 3.26 and 3.27. Additionally, in accordance with the drawing, we must weld the anchor bolts (a total of eight) at precise locations in the slab reinforcement to secure the centrifugal pumps. The size of the anchor bolt will be L-12in and dia-0.63in shown in fig 3.28. Here I have to mention that, both pumps base bolt dimensions are similar. Furthermore we will have to recheck jointly the layout of slab reinforcement of the pit before pouring the Cement Concrete Paste. Then Cement Concrete paste will have to be poured into the slab reinforcement of the pit.

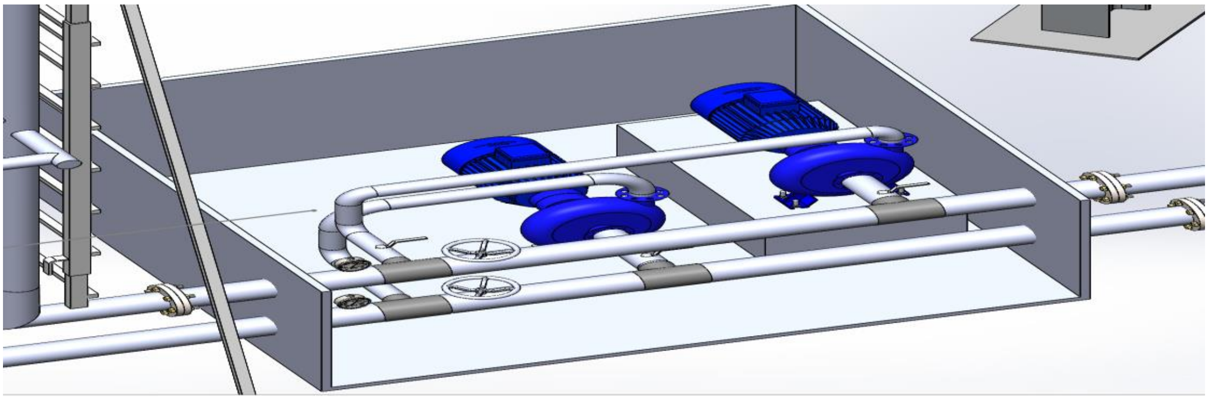


Figure 3.25: View of the Pump Pit area of New shower tester

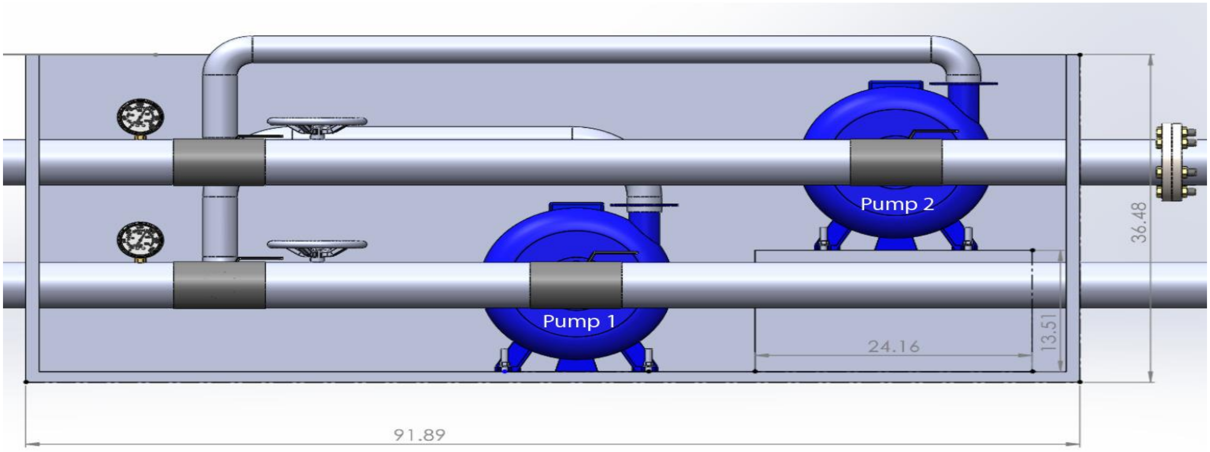


Figure 3.26: Dimension of the Pump pit (Front view)

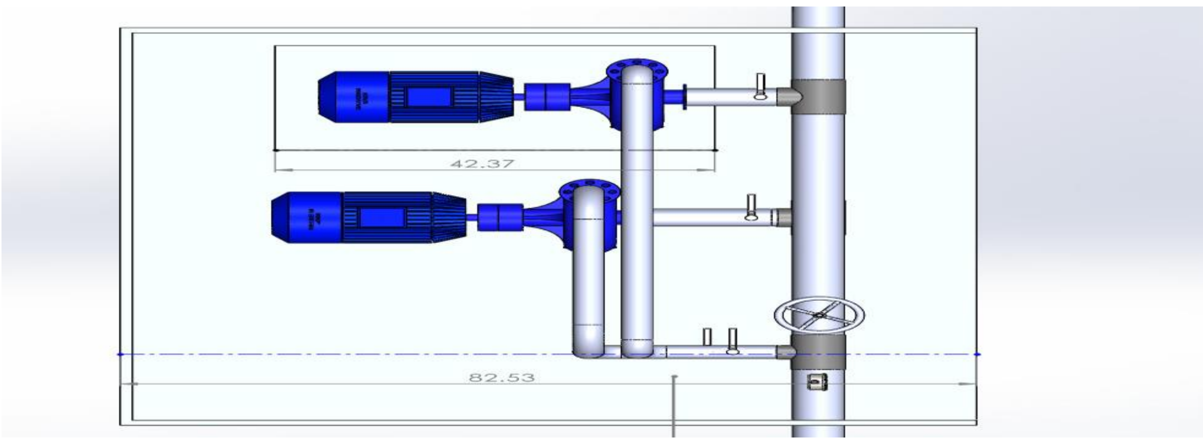


Figure 3.27: Dimension of the Pump pit (Top view)

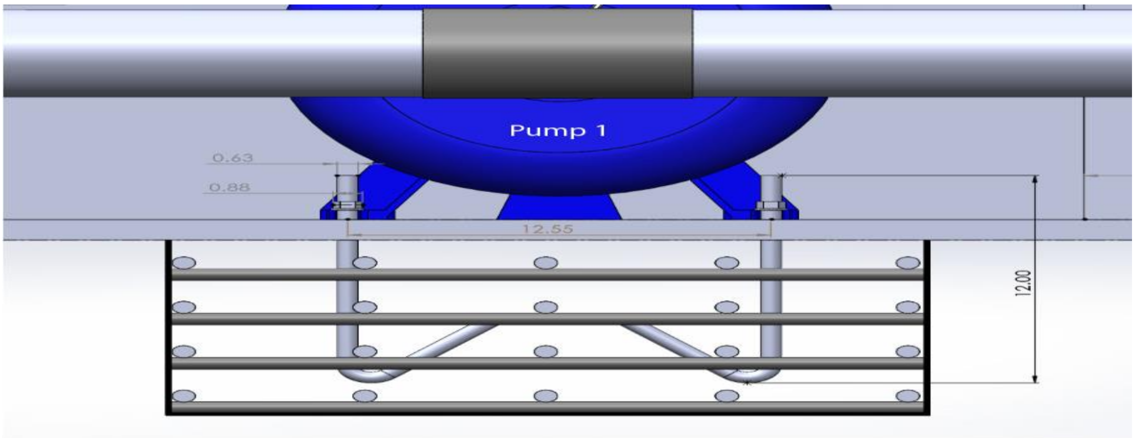


Figure 3.28: Dimension of the Pump anchor bolt (Pump base cross sectional view)

3.7.5 Installation Procedure of Centrifugal Pumps in Pit Area:

We should make the effort to install the centrifugal pumps inside the pit once the RCC structure has dried. To precisely position the pumps, we will first raise and lower them using a chain pulley block. Because there is a chance that the top of the bolt could be damaged when the pump is lifted down, we will need to work extremely carefully. By aligning the base hole of the pump with the centre of the bolt, we will gently raise the pump down. Next, we will connect the main transmission pipe T socket to the pump impeller's inlet using 4-inch pipes. Two ball valves, depicted in fig. 3.29, will be installed in the suction pipe. The main transmission pipe T socket and the pump impeller output will then be connected by means of 3-inch pipes. Six elbows in all will be utilised in the pump's delivery pipe to create the delivery line to the main transmission pipe. Two ball valves will be installed in the delivery pipe shown in fig 3.29. The distance between "T sockets" located in the upper and lower main transmission pipes are shown in fig 3.30 and 3.31. The vertical distances between the Delivery pipes of pump 1&2 are shown in fig 3.32 and 3.33. Furthermore, to guarantee correct alignment, we may need to place some shim plates at the pumps' bases. Following alignment confirmation, we will need to use a wrench to tighten the hexagonal nut (a total of eight nos.) with washer. The size of the nut is 0.88inch shown in fig 3.28. The pump Right hand side leg front bolt to left hand side leg front bolt distance is 12.55inch shown in fig 3.28. The pump right hand side leg rear bolt to left hand side leg front bolt distance is 3.67inch shown in fig 3.34

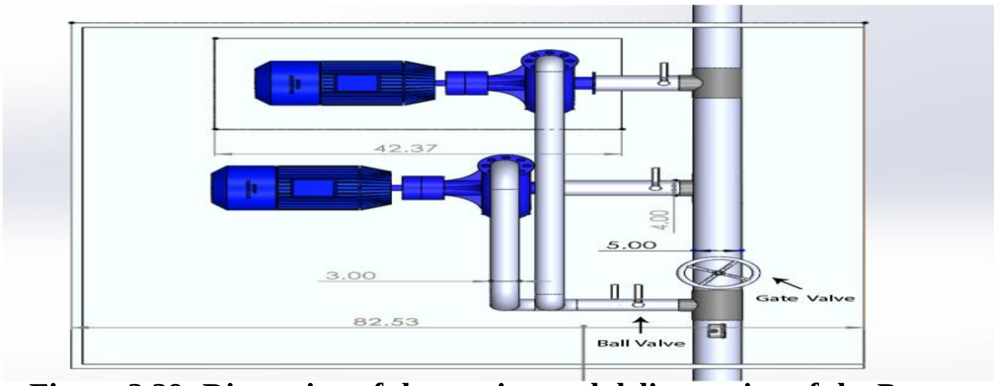


Figure 3.29: Dimension of the suction and delivery pipe of the Pump

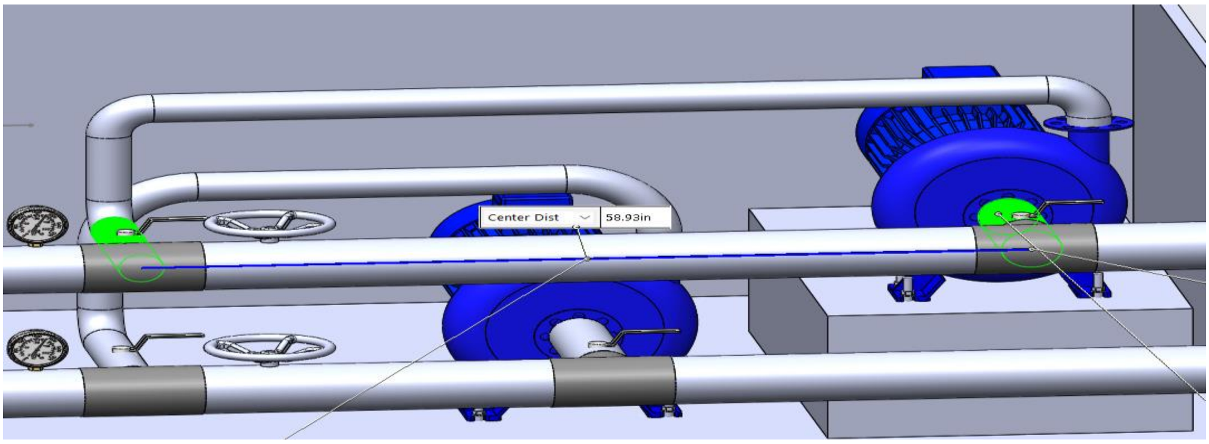


Figure 3.30: Distance between "T socket" of upper main transmission pipe

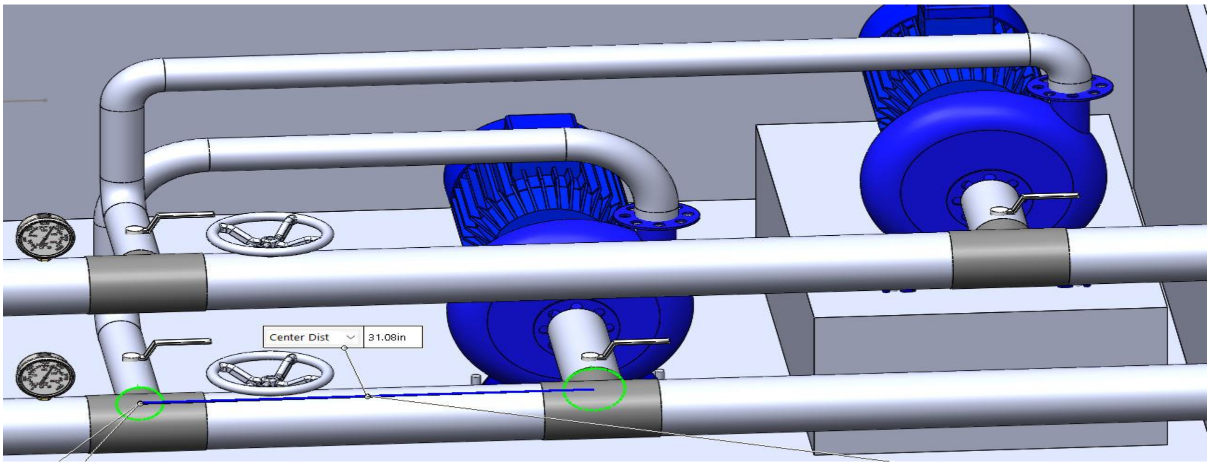


Figure 3.31: Distance between "T socket" of lower main transmission pipe

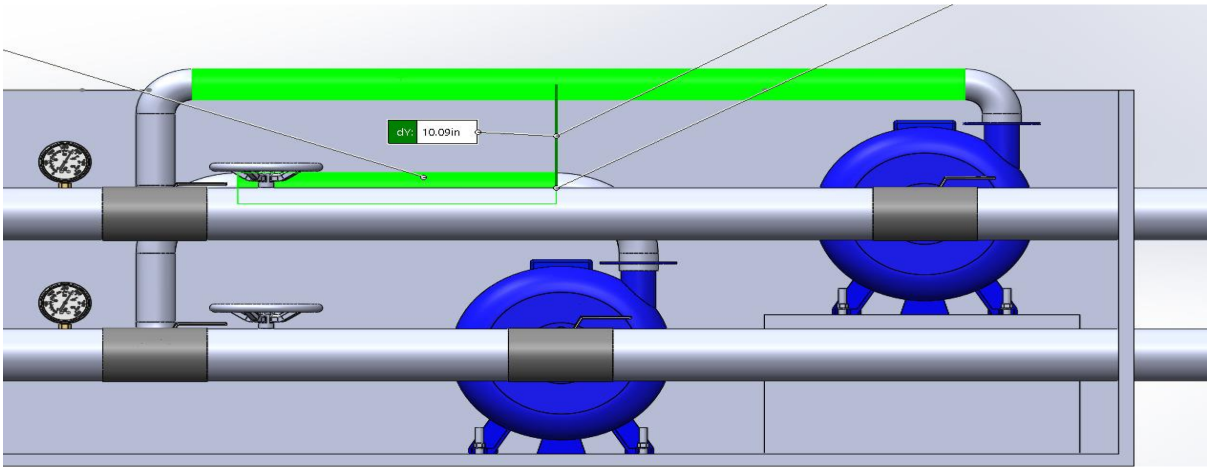


Figure 3.32: Vertical Distance between delivery pipe of Pump 1&2

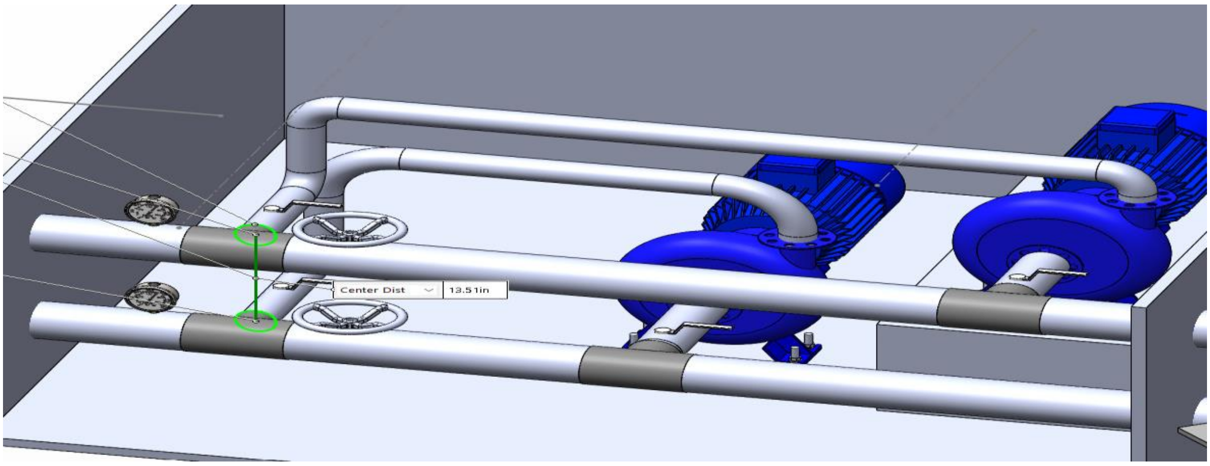


Figure 3.33: Vertical Distance between delivery pipe of Pump 1&2 Joining at Main Transmission Pipe.

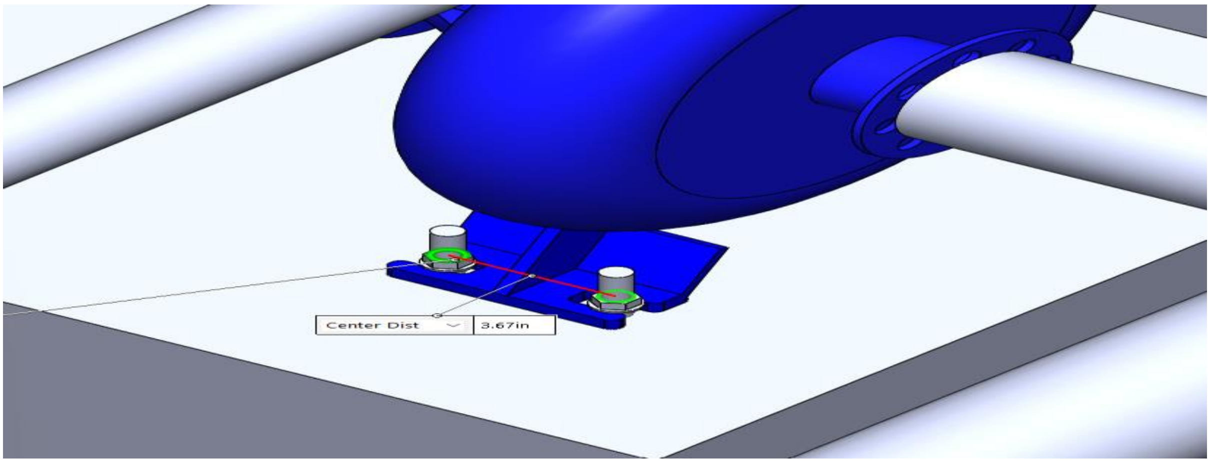


Figure 3.34: Dimension of the Pump right side leg bolt

3.7.6 Electrical Connections and Final Checking Procedure:

When the pump installation is finished, I will need to call an electrical engineer to do the electrical work so the pumps can be operated. We will do a trial run once he has finished installing the appropriate electric wiring and switching equipment. I have to operate the gate and ball valves to close and open before turning on the pumps. After turning on, I'm hoping that both centrifugal pumps will function without hiccups and that no strange noises or vibrations will be detected. Our electrical engineer would have operated the pumps and obtained the required electrical readings at the same time. In order to perform a shower test, I will then put a bus inside the shower tester. Tables 4 and 5 display the centrifugal pump and tank specifications, respectively.

Table 4: Specification of the Centrifugal Pump:

Model	Pedrollo F80/200B
Origin	Italy
Size Discharge	4”x3”
Power	30 kW/Three Phase
Voltage	415V
Flow Rate	3950 L/min
Head	34 m
RPM	2900
Frequency	50Hz
Liquid Temperature	25°C
Environment Temperature	20°C-35°C
Dimensions (L x W x H)	824mm x 360mm x 430mm
Weight	201.6kg

Table 5: Overhead tank specification:

Height (feet)	Capacity (Liter)
100	2,00,000

Table 6: Cost Estimate:

No.	Description	Quantity	Unit price (BDT)	Total price (BDT)
1	GI pipes (main Transmission)	(5" x 104')	230 Tk per feet	23920
2	GI pipes (Sub main Transmission)	(3" x 20')	180 Tk per feet	3600
3	GI pipes for SUV (Branch pipe)	(1.5" x 385')	90 Tk per feet	34650
4	GI pipes for Bus (Branch pipe)	(1.5" x 912.5')	90 Tk per feet	82125
5	Glove valves	10	1420 Tk	14200
6	Brass Gate valves	2	1600 Tk	3200
7	Adjustable cone nozzles	744	25 Tk	18600
8	Diaphragm pressure gauges	12	2000 Tk	24000
9	1.5′′ elbow	16	135 Tk	2160
10	Pedrollo Pump	02	395000Tk	790000
11	Miscellaneous			60000
	Total cost			1056455 Tk

Total Cost- Ten lac fifty six thousand and four hundred fifty five BDT only.

**** All expenditures of this project will be beared by Pragoti Industries Ltd.**

CHAPTER 4

DESIGN CALCULATIONS

4.1 Introduction:

All of the mathematical calculations needed to modify the shower tester booth so that it is bus compatible have been completed in this chapter. Both the older shower tester and the suggested modified shower tester cases have all of the terms—such as flow rate, head loss, power consumption, operation cost, water pressure, water consumption, etc.—calculated. However, because two centrifugal pumps have been added to the proposed design, pump power has been calculated in addition in the modified design. Below are the results of the calculations:

4.2 Calculations of the Shower Tester Booth for SUV in Pragoti Industries Ltd.:

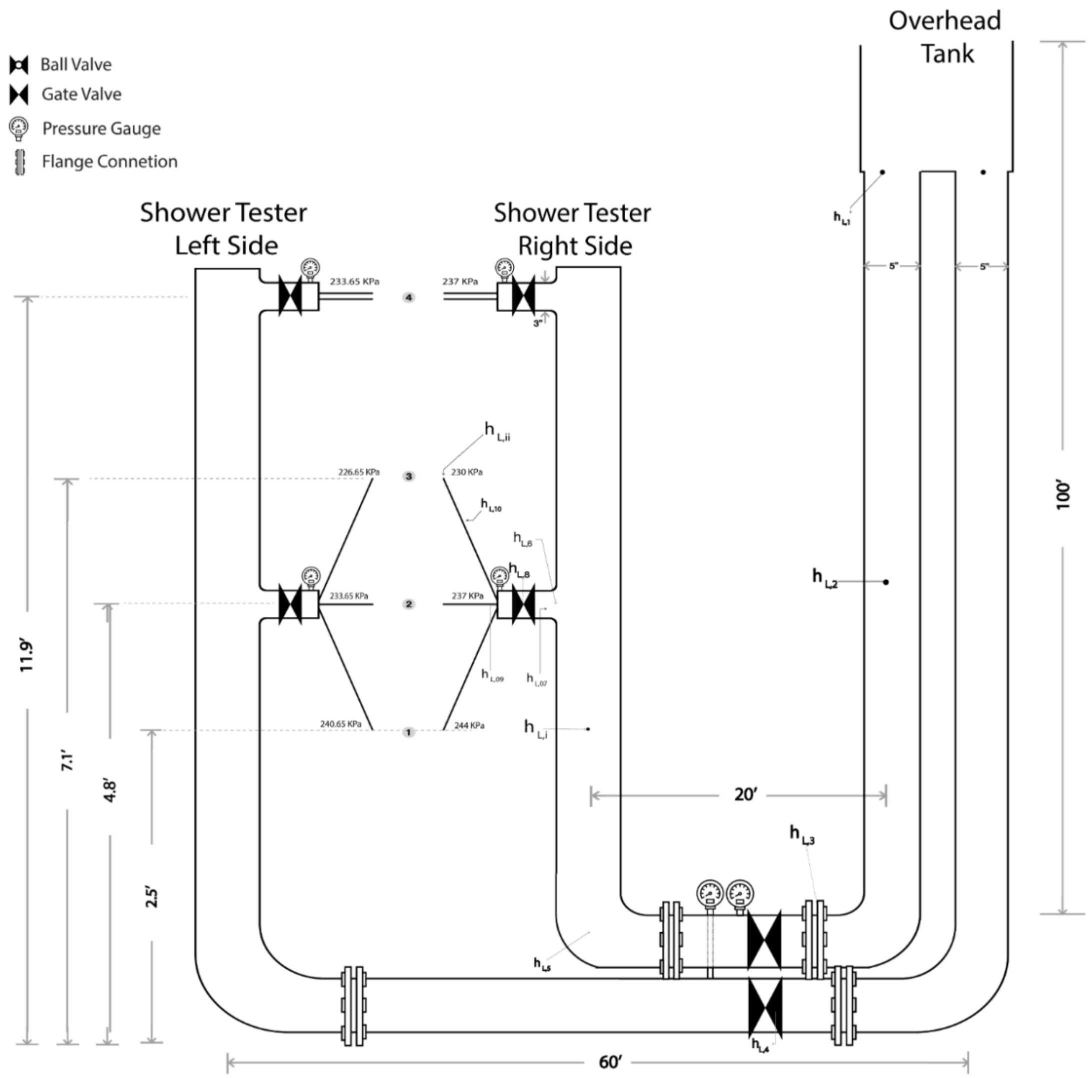


Figure 4.1: Front view of New shower tester pipe arrangement for SUV.

4.2.1 Flowrate of Water:

Flow rate per nozzle, $Q = 15\ lpm = 2.5 \times 10^{-4} m^3/s$ [70]

The Shower Tester Booth features 200 nozzles for SUVs.

Total Flow Rate, $\boldsymbol{Q_t = 0.05 m^3/s}$

[Total flow = flow per nozzle × nozzle number]

Water will be delivered to the booth via two 5" pipes from the overhead tank.

Flowrate for each 5" pipe, $\boldsymbol{Q_5} = Q_t/2 = \boldsymbol{0.025 m^3/s}$

On the lateral side, every 5" pipe splits into two 3" pipes.

Flowrate of 3" pipe, $\boldsymbol{Q_3} = Q_5/2 = \boldsymbol{0.0125 m^3/s}$

The lateral side has five 1.5" pipes that will receive water from 5" pipes,

Flowrate in 1.5" pipes, $\boldsymbol{Q_{1.5}} = Q_5/5 = \boldsymbol{5 \times 10^{-3} m^3/s}$

4.2.2 Average velocity of water:

Average velocity in 5" pipes, $v_5 = \frac{Q_5}{\pi\left(\frac{D}{2}\right)^2}$

Flow Rate (Q) = Velocity (V) × Area (A = pi × r^2)

Here, $Q_5 = 0.025 m^3/s, D = 5" = 0.13m$
Therefore, $\boldsymbol{v_5 = 1.88 m/s}$

Average velocity in 3" pipes, $\boldsymbol{v_3} = Q_3/(\pi(D/2)^2) = \boldsymbol{3.248\ m/s}$

Here, $Q_3 = 0.0125 m^3/s, D = 3" = 0.07m$

Average velocity in 1.5" pipes, $\boldsymbol{v_{1.5}} = Q_{1.5}/(\pi(D/2)^2) = \boldsymbol{7.07 m/s}$

Here, $Q_{1.5} = 5 \times 10^{-3} m^3/s, D = 1.5" = 0.03m$

4.2.3 Calculation of Head Loss:

- $\boldsymbol{h_{L,1}}$ **Loss due to Water Inlet:**

$$\boldsymbol{h_{L,1}} = K_L \times (v_5{}^2/2g) = \boldsymbol{0.021m}$$

For slightly rounded inlet, $K_L = 0.12, v_5 = 1.88 m/s$ [71]

- $\boldsymbol{h_{l,2}}$ **Constant Head Loss in 5" Pipe:**

- Before it bends 90 degrees a second time and enters the booth, It would take the head loss for 5" pipes into account.
- Different for left and right side of shower tester.

$$R_e = \frac{\rho v_5 D}{\mu} = 3.06 \times 10^5 \quad [71]$$

Here, D $= 5" = 0.13$m$, v_5 = 1.88 m/s, \mu = 0.797 \times 10^{-3} Pa.s$

For **Galvanized Iron (GI)** Pipe,

Roughness $\varepsilon = 0.15$ [71]

Relative Roughness $\varepsilon/D = 0.0011$

From Moody chart, Friction Factor, f = 0.021 [71]

For the right side of shower tester:

L = 120 feet = 36.576 m, D = 0.13 m, v_5= 1.88 ms^{-1}

$$h_{L,2} = f\frac{L}{D}\frac{v_5^2}{2g} = 1.01 \text{ m}$$

For the left side of shower tester:

L = 160 feet =48.76m

$$\acute{h}_{L,2} = f\frac{L}{D}\frac{v_5^2}{2g} = 1.352\ m$$

The Pressure differential between the shower tester's left and right sides:

$$\Delta p = \rho g(\acute{h}_{L,2} - h_{L,2})$$

$$= 3351.6 \text{Pa} = 3.35 \text{kpa}$$

The pressure differential between the shower tester's left and right sides would be 3.35 kPa. Everything in the two towers is symmetrical except for this. Accordingly, the pressure calculation for the right side of the shower tester has been shown, and the pressure for the left side would be 3.35 kPa (0.033 bar) lower for the corresponding branches, which is insignificant.

- **$h_{L,3}$ & $h_{L,5}$ →90° bend in 5 in. pipe:**

For, flanged connection, K_L= 0.3 [71]

$$h_{L,3} = h_{L,5} = K_L\frac{v_5^2}{2g} = 0.054 \text{ m} \qquad v_5 = 1.88\ ms^{-1}$$

- **$h_{L,4}$→ Gate valve in 5 in. pipe:**

$$h_{L,4} = K_L\frac{v_5^2}{2g} = 0.036 \text{ m}$$

Valve while fully open, K_L= 0.2

v_5= 1.88 ms^{-1}

- **$h_{L,6}$ → Sudden Contraction (from 5 inch to 3 inch)**

  $\frac{d^2}{D^2} = \frac{3^5}{5^2} = 0.36$

  From table- 8.4 (Cengel)

  $K_L = 0.34$

  $h_{L,6} = K_L \frac{v_3^2}{2g} = 0.1\text{m}$ v_3=3.248 ms^{-1}

- **$h_{L,7}$→ Head Loss for 2 feet 3" pipe:**

  $h_{L,7} = f \frac{L}{D} \frac{v_3^2}{2g}$

  $R_e = \frac{\rho v_3 D}{\mu}$ D=0.07 m; v_3=3.248 ms^{-1}

  $= 2.85 \times 10^5$ L= 2 feet = 0.6 m

  $\frac{\epsilon}{D} = 0.0021$

From Moody Chart, f = 0.024

  $h_{L,7}$ = **0.1107 m**

- **$h_{L,8}$ Globe Valve in 3" pipe:**

  $h_{L,8} = K_L \frac{v_3^2}{2g} = \mathbf{0.107\ m}$ v_3=3.248 ms^{-1}; K_L= 0.2

- **$h_{L,9}$ → Sudden Contraction from (3inch to 1.5inch pipes)**

  $h_{L,9} = K_L \frac{v_{1.5}^2}{2g}$

  for $\frac{d^2}{D^2} = \frac{1.5^5}{3^2} = 0.25$

  K_L= 0.4 $v_{1.5}$ =7.07 ms^{-1}

  $h_{L,9}$ = 1.02 m

- **$h_{L,10}$: Head Loss in 1.5″ Pipes**

$$Re = \frac{\rho v_{1.5} D}{\mu} = 2.66 \times 10^5$$

$$\frac{\varepsilon}{D} = 0.005$$

From Moody Chart, friction factor $f = 0.003$

$$h_{L,10} = f \frac{L}{D} \frac{{v_{1.5}}^2}{2g}$$

Putting $L = 10' = 3.048m$,

$$\boldsymbol{h_{L,10}} = f\frac{L}{D}\frac{{v_{1.5}}^2}{2g} = \mathbf{7.77}\boldsymbol{m}$$

Total Constant Head Loss:

- Every branch of the shower tester booth would have the same procedure.

$$\boldsymbol{h_{L,C} = h_{L,1} + h_{L,2} + h_{L,3} + h_{L,4} + h_{L,5} + h_{L,6} + h_{L,7} + h_{L,8} + h_{L,9} + h_{L,10}}$$

$= 0.021 + 1.01 + 0.054 + 0.36 + 0.1 + 0.1107 + 0.107 + 1.02 + 7.77 = \mathbf{10.28}\boldsymbol{m}$

➢ **$h_{L,i}$: Additional Head Loss for 5″Pipe:**

- The head loss in a 5″ pipe as it reaches 3″ branches has taken into account.
- At 4.8′ and 11.9′, It would be different for 3″ branches.

At 4.8′,

$h_{L,i} = f\frac{L}{D}\frac{{v_5}^2}{2g} = 0.034m$ [71]

Here, $v_5 = 1.88m/s, L = 4.8' = 1.24m, f = 0.02, D = 0.13$m

At 11.9',

$$h_{L,i} = f\frac{L}{D}\frac{{v_5}^2}{2g} = \mathbf{0.10}\boldsymbol{m}$$

Here $L = 11.9' = 3.62m$

➢ **$h_{L,ii}$: Head Loss due to 90^0 Bend in 1.5″ Pipe:**

- It had been applied for branch 1, 2, and 3

$$h_{L,ii} = f\frac{L}{D}\frac{{v_{1.5}}^2}{2g} = \mathbf{2.29}\boldsymbol{m}$$

Here, $K_L = 0.9(threaded), v_{1.5} = 7.07m/s$

4.2.4 Water Pressure Calculation:

➢ **The Pipes at 2.5′ (branch 1):**

Total Loss, $\boldsymbol{h_L} = h_{L,C} + h_{L,i} + h_{L,ii} = 10.28 + 0.034 + 2.29 = \mathbf{12.6}\boldsymbol{m}$

From Bernoulli's Principle, [71]

$$P_1 + \frac{1}{2}\rho{v_1}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho{v_2}^2 + \rho g h_2 + \rho g h_L$$

Point 1: Water at the surface of overhead tank

$$P_1 = 101325Pa, v_1 = 0, h_1 = 100' = 30.48m$$

Point 2: Water in 1.5″ pipes before entering nozzle at 2.5′

Here, $h_2 = 2.5' = 0.76m$

And $\frac{1}{2}\rho {v_1}^2 = 0$, as water on the surface of overhead tank barely moves

$\rightarrow 101325 + 0 + 1000 \times 9.8 \times 30.48 = P_2 + 0.5 \times 1000 \times 7.07^2 + 1000 \times 9.8 \times 0.76 + 1000 \times 9.8 \times 12.6$

$\rightarrow P_2 = 251556.56 - 1000 \times 9.8 \times 0.76$

P_2 = 244 kPa = 2.44 bar (Pressure at branch 1)

- **For Pipes at 4.8′ (branch 2):**

Here, $h_2 = 4.8' = 4.8 \times 0.3048 = 1.463m, h_L = 12.6\,m$

$P_1 = \frac{1}{2} \times \rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2 + \rho g h_L$

P_2 $= 251556.55 - 1000 \times 9.8 \times 4.8 \times 0.3048$

=**2.37 kPa = 2.37 bar (Pressure at branch 2)**

- **For pipes at 7.1’ (branch 3):**

$\boldsymbol{h_2}$=7.1′=$\mathbf{7.1 \times 0.3048}$=2.16m

h_L =12.6m

$P_1 = \frac{1}{2} \times \rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2 + \rho g h_L$

$P_2 = 251556.55 - 1000 \times 9.8 \times 7.1 \times 0.3048$

P_2 =230 kPa = 2.3 bar (Pressure at branch 3)

- **For pipes at 11.9′ (branch 4):**

$h_L = h_{L,C} + h_{L,I}$ =10.28+0.10 =10.38 m

h_2=11.9′ =11.9 × 0.3048=3.62 m

$P_1 = \frac{1}{2} \times \rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2 + \rho g h_L$

$\rightarrow$101325+ 0 + 1000 9.8 30.48 = P_2 + 1/2×1000×7.07^2 + 1000×9.8×3.62 + 1000×9.8×10.38

P_2 = 237.8 kPa = 2.37 bar (Pressure at branch 4)

4.2.5 Consumption of Water for Shower Testing of a SUV:

15 L/min of water would be sprayed from each nozzle. In the Shower Tester Booth, there are 200 nozzles specifically designed for SUVs.

Therefore, water usage by the booth in 1 minute $= 15L/min \times 200 = \mathbf{3000L}$

We spent perhaps six to seven minutes using the earlier shower tester. However, a car's shower test typically takes four to five minutes. We adhere to this standard time in the new one.

If we continue the shower testing for 4 minutes then total water consumption will be,

$$(3000L \times 4) = \mathbf{12,000L}$$

If we continue the shower testing for 5 minutes then total water consumption will be,

$$(3000L \times 5) = \mathbf{15,000L}$$

As previously stated, the tank has a capacity of 2,00000 liters. Therefore, for SUVs only, we can run at least 13–16 units till the tank runs out if we fill it up once.

4.3 Calculations of the Modified Shower Tester Booth for BUS in Pragoti Industries Ltd:

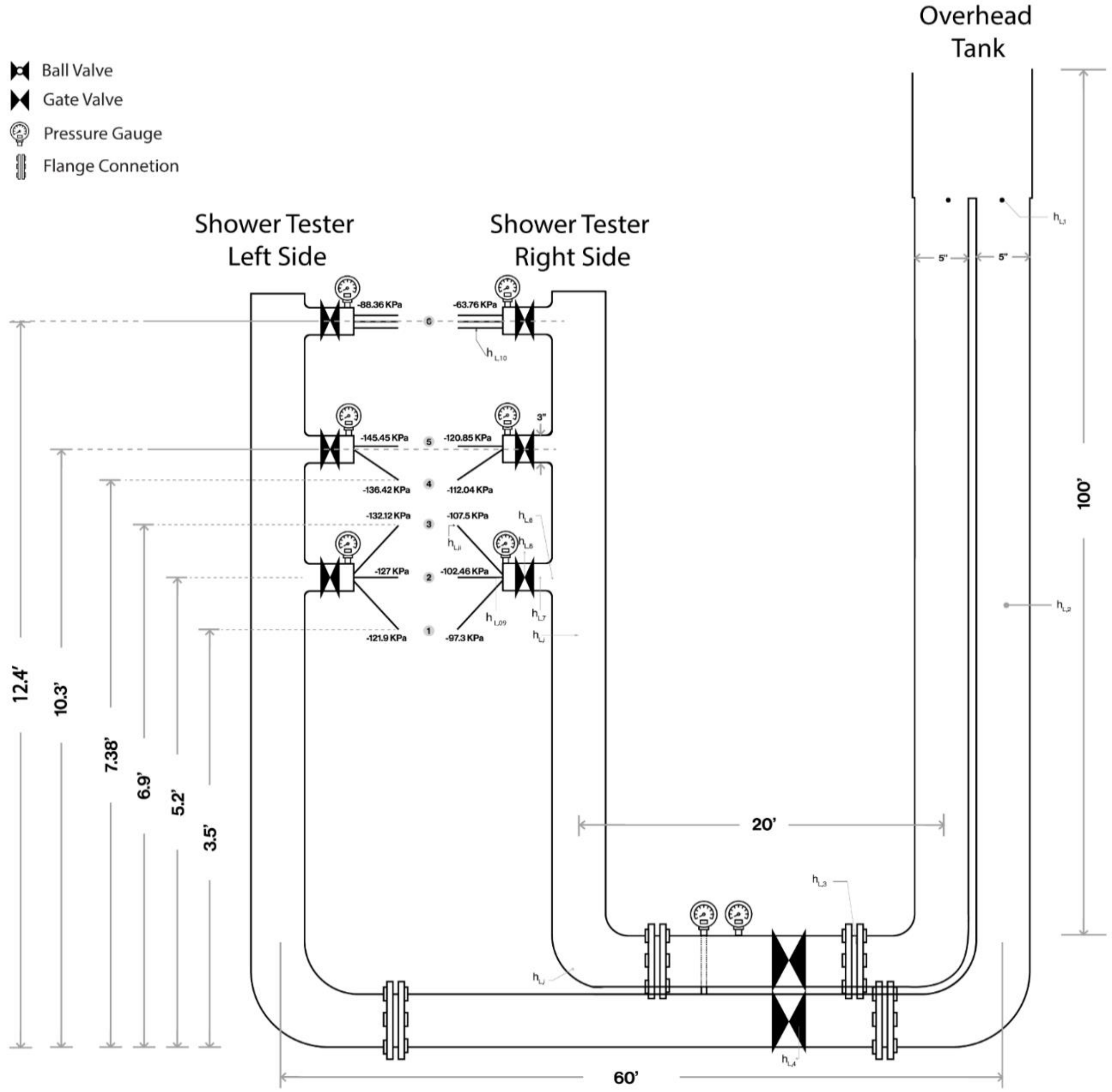


Figure 4.2: Front view of New shower tester pipe arrangement for Bus without pump.

4.3.1 Flowrate of Water:

Flow rate per nozzle, $Q = 15\ lpm = 2.5 \times 10^{-4} m^3/s$ [70]

The Shower Tester Booth features 544 nozzles for Bus.

Total Flow Rate, $\boldsymbol{Q_t = 0.136\ m^3/s}$

[Total flow = flow per nozzle × nozzle number]

Water will be delivered to the booth via two 5" pipes from the overhead tank.

Flowrate for each 5" pipe, $\boldsymbol{Q_5} = Qt/2 = \boldsymbol{0.068 m^3/s}$

On the lateral side, every 5" pipe splits into three 3" pipes.

Flowrate of 3" pipe, $\boldsymbol{Q_3} = Q_5/3 = \mathbf{0.0226}\boldsymbol{m^3/s}$

Eight 1.5" pipes on lateral side will receive water from 5" pipes,

Flowrate in 1.5" pipes, $\boldsymbol{Q_{1.5}} = Q_5/8 = \mathbf{8.5 \times 10^{-3}}\boldsymbol{m^3/s}$

4.3.2 Average velocity of water:

Average velocity in 5" pipes, $v_5 = \frac{Q_5}{\pi\left(\frac{D}{2}\right)^2}$

Flow Rate (Q) = Velocity (V) × Area (A = pi× r²)

Here,$Q_5 = 0.068m^3/s, D = 5" = 0.13m$

Therefore, $\boldsymbol{v_5} = \mathbf{5.123}\boldsymbol{m/s}$

Average velocity in 3" pipes $\boldsymbol{v_3} = Q_3/(\pi(D/2)^2) = \mathbf{5.872}\ \boldsymbol{m/s}$

Here, $Q_3 = 0.0226m^3/s, D = 3" = 0.07m$

Average velocity in 1.5" pipes, $\boldsymbol{v_{1.5}} = Q_{1.5}/(\pi(D/2)^2) = \mathbf{12.025}\boldsymbol{m/s}$

Here, $Q_{1.5} = 8.5 \times 10^{-3}m^3/s, D = 1.5" = 0.03m$

4.3.3 Calculation of Head Loss:

- **$\boldsymbol{h_{L,1}}$ Loss due to Water Inlet:**

$$\boldsymbol{h_{l,1}} = K_l \times (v_5{}^2/2g) = \mathbf{0.16}\boldsymbol{m} \qquad [71]$$

For slightly rounded inlet, $K_L = 0.12$ [71]

- **$\boldsymbol{h_{l,2}}$ Constant Head Loss in 5" Pipe:**

- Before it bends 90 degrees a second time and enters the booth, It would take the head loss for 5" pipes into account..
- Different for left and right side of shower tester.

$$R_e = \frac{\rho v_5 D}{\mu} = 8.35 \times 10^5 \qquad [71]$$

Here, D = 5" = 0.13m, $v_5 = 5.123m/s, \mu = 0.797 \times 10\text{^} - 3Pa.s$

For **Galvanized Iron (GI)** Pipe,

Roughness $\varepsilon = 0.15$ [71]

Relative Roughness $\varepsilon/D = 0.0011$

From moody chart, Friction Factor, f=0.02 [71]

For the right side of shower tester[71]:

$$h_{L,2} = f\frac{L}{D}\frac{{v_5}^2}{2g} = \mathbf{7.534}\boldsymbol{m}$$

For the left side of shower tester:

$$h'_{L,2} = f\frac{L}{D}\frac{{v_5}^2}{2g}$$

Here, $L = 100' + 60' = 160' = 48.768m$

$$h'_{L,2} = \mathbf{10.046}\boldsymbol{m}$$

The Pressure differential between the shower tester's left and right sides:

$$\Delta\text{P} = \rho\text{g}\left(h'_{L,2} - h_{L,2}\right)$$
$$\Delta\text{P} = 24617.5\text{Pa} = 24.6\text{kPa}$$

There will be 24.6 kPa pressure difference between left and right tower. Except this, everything is symmetrical for two towers. Thus, the **right tower's pressure calculation is shown above and the left tower's pressure will be 24.6 kPa lower for the corresponding branches.**

- **$\boldsymbol{h_{L,3}}$; $\boldsymbol{h_{L,5}}$ 90^0 Bend in 5" Pipe:**

For flanged connection, K_L= 0.3 [71]

$h_{L,3} = K_L\frac{{v_5}^2}{2g}$

$\boldsymbol{h_{L,3} = h_{L,5} = 7.534m}$

- **$\boldsymbol{h_{L,4}}$ Gate valve in 5" pipe:**

While gate valve fully open, $K_L = 0.2$

$$h_{L,4} = K_L\frac{{v_5}^2}{2g} = \mathbf{0.267}\boldsymbol{m}$$

- **$\boldsymbol{h_{L,6}}$ Sudden contraction (from 5 inch to 3 inch):**

$$\frac{d^2}{D^2} = \frac{3^2}{5^2} = 0.36 \quad [71]$$

From Table 8.4, $K_L = 0.34$ [71]

$$h_{L,6} = K_L\frac{{v_5}^2}{2g} = \mathbf{0.45}\boldsymbol{m}$$

- **$h_{L,7}$: Head Loss in 3″ Pipe:**

$$Re = \frac{\rho \boldsymbol{v_3} D}{\mu} = 5.15 \times 10^5$$

Here D=3″=0.07m, $\boldsymbol{v_3} = 5.872\text{m/s}, \mu = 0.797 \times 10^{-3}\text{Pa. s}$

Relative Roughness, $\frac{\varepsilon}{D} = \frac{0.15\times10^{-3}}{0.07} = 0.0021$

From moody chart, Friction Factor, f=0.024

Here, L = 2′ = 0.6 m, D = 3″ = 0.07m

$$h_{L,7} = f\frac{L}{D}\frac{{v_5}^2}{2g} = \mathbf{0.361}\boldsymbol{m}$$

- ➢ $\boldsymbol{h_{L,8}}$ **Globe Valve in 3" Pipe:**

Here, K_L = 0.2

$$h_{L,8} = K_L\frac{v_3^2}{2g} = \mathbf{0.351}\boldsymbol{m}$$

- ➢ $\boldsymbol{h_{L,9}}$ **Sudden Contraction (3" to 1.5" pipes):**

$$h_{L,9} = K_L\frac{v_{1.5}^2}{2g}$$
$$\frac{d^2}{D^2} = \frac{1.5^2}{3.0^2} = 0.25\text{m}$$

From Table 8.4, $K_L = 0.4$ [71]

here. $v_{1.5} = 12.025\ m/s$

$$\boldsymbol{h_{L,9}} = \mathbf{2.95\ m}$$

- ➢ $\boldsymbol{h_{L,10}}$ → **Head Loss in 1.5" Pipes:**

Here,$D = 1.5$"=0.03 m

$$v_{1.5} = 12.025\ m/s$$

$$R_e = \frac{\rho v_{1.5} D}{\mu} = 4.52 \times 10^5$$

Here, $\text{D} = 1.5" = 0.03\text{m}, v_{1.5} = 12.025 m/s, \mu = 0.797 \times 10^{-3} Pa.s$

$$\frac{\varepsilon}{D} = \frac{0.15 \times 10^{-3}}{0.03} = 0.005$$

From Moody Chart, $f = 0.03$

Here, $L = 10' = 3.048\text{m}$

$$h_{\mathrm{L},10} = f\frac{L}{D}\frac{v_{1.5}^2}{2g} = \mathbf{22.48\ m}$$

Total Constant Head loss, $h_{L,C}$:

- would be same for all branches

$h_{L,C} = h_{L,1} + h_{L,2} + h_{L,3} + h_{L,4} + h_{L,5} + h_{L,6} + h_{L,7} + h_{L,8} + h_{L,9} + h_{L,10}$
$= 0.16 + 7.534 + 0.401 + 0.267 + 0.40 + 0.45 + 0.361 + 0.351 + 2.95 + 22.48$
$\boldsymbol{h_{L,C} = 35.35m}$

➢ **$h_{\mathrm{L},i}$ → Additional Head Loss for 5′′ pipe:**

- It has taken into account, the head loss in 5′′ pipe as it reached 3inch branches following the second 90 degree bends..
- For the 3′′ branch at $5.2'$, $10 \cdot 3'$ and $12.5'$, it would be different.

At $5 \cdot 2'$,

$h_{L,i} = f\frac{L}{D}\frac{v_5^2}{2g} = 0.325$ m $\qquad v_5 = 5.123\ m/s$
$\qquad L = 5.2' = 1.58m$

At $10 \cdot 3'$

$h_{L,i} = f\frac{L}{D}\frac{v_5^2}{2g} = 0.646$ m $\qquad L = 10.3' = 3.139m$

At $12 \cdot 4'$

$h_{L,i} = f\frac{L}{D}\frac{v_5^2}{2g} = 0.776$ m $\qquad L = 12.4' = 3.77$m

➢ **$h_{L,ii}$ → Head Loss due to 90° bend in 1.5" pipes:**

- It applied for branch (1), (2), (3), (4) & (5).

$h_{L,ii} = K_L\frac{v_{1.5}^2}{2g} = 6.639$ m $\qquad K_L = 0.9$[threaded]
$\qquad v_{1.5} = 12.025$ m/s

4.3.4 Water Pressure Calculation:

➢ **For the pipes at 3.5′ (branch 1):**

Total loss, $h_L = h_{L,c} + h_{L,i} + h_{L,ii}$ = 42.314m

From Bernoulli's Principle,[71]

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

101325 + 1000×9.8×30.48 = P_2 + 0.5 ×1000 × 12.025^2 + 1000×9.8×1.06+1000×9.8×42.314

P_2 = -97.3 KPa = -0.97 bar (Pressure at branch 1, shown in fig 1)

- **For the pipes at 5.2′ (branch 2):**

h_L = 42.314m [same as branch1]

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

P_2 = -86948.51 – 1000×9.8× (5.2×0.3048)

P_2 = -102.4 kPa = -1.02 bar (Pressure at branch 2, shown in fig 1)

- **For the pipes at 6.9′ (branch 3):**

h_L = 42.314m [same as branch1]

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

P_2 = -86948.51 – 1000×9.8× (6.9×0.3048)

P_2 = -107.559 kPa = -1.07 bar (Pressure at branch 3, shown in fig 1)

- **For the pipes at 7.38′ (branch 4):**

Total loss, $h_L = h_{L,c} + h_{L,i} + h_{L,ii}$ = 42.635m

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

101325 + 1000×9.8×30.48 = P_2 + 0.5 × 1000 ×12.025^2 + 1000×9.8×2.24+1000×9.8×42.635

P_2 = -112.04 kPa = -1.12 bar (Pressure at branch 4, shown in fig 1)

- **For the pipes at 10.3′ (branch 5):**

h_L = 42.635m [same as branch 4]

h_2 = 10.3′ = 3.129m

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

P_2 = -90094.31 – 1000×9.8×3.139

P_2 = -120.85 kPa = -1.2 bar (Pressure at branch 5, shown in fig 1)

- **For the pipes at 12.4’ (branch 6):**

Total loss, $h_L = h_{L,c} + h_{L,i}$ = 35.35 + 0.776 = 36.126 m

h_2 = 12.4′ = 3.77 m

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g h_L$

101325 + 1000×9.8×30.48 = P_2 + 0.5×1000×12.025^2 + 1000×9.8×3.77+1000×9.8×36.126

P_2 = -63.252 KPa = -0.632 bar (Pressure at branch 6, shown in fig 1)

4.3.5 Consumption of Water for Shower Testing of a Bus:

15 L/min of water would be sprayed from each nozzle. In the Shower Tester Booth, there are 544 nozzles specifically designated for buses.
Consequently, the booth's water consumption in one minute $= 15L/min \times 544 = \mathbf{7960L}$

We spent perhaps six to seven minutes using the earlier shower tester. However, a bus shower test typically takes four to five minutes. We adhere to this standard time in the new one.

If we continue the shower testing for 4 minutes then total water consumption will be,

$$(7960L \times 4) = \mathbf{31,840L}$$

If we continue the shower testing for 5 minutes then total water consumption will be,

$$(7960L \times 5) = \mathbf{39,800L}$$

As previously stated, the tank has a capacity of 2,00000 liters. Therefore, if we fill the tank once for the bus, we can run at least five or six units till the tank is empty.

The pressure in each branch pipe was obviously negative based on the higher water pressure calculation. In order to get the standard pressure for shower testing, we have to install two centrifugal pumps in the 5-inch main transmission pipe that could increase the network's pressure by at least 315 kPa. The following is the result of the pump's power calculation:

4.3.6 Power of Pump Calculation:

Hydraulic Power of the pump, $P_{kWh} = \frac{qp}{3.6\times10^6}$ [72]

Here, $q = 0.068m^3/s = 244.8m^3/h, p = 315000Pa$

Thus, Hydraulic Power

$$P_h = 21.42kW$$

Large centrifugal pumps have BEP of 70-80% [73]

If the overall efficiency of the pump is 71%, then

Total Power needed for the pump, $P_t = \frac{P_h}{\eta} = 30.16kW \approx 30kW$

Two centrifugal pumps, which would work efficiently around **31.6 m (100 feet) Head** and could supply **7960L/min Flow Rate**, are highly recommended for connecting with 5″ main transmission pipe. Then we selected a 30kw centrifugal pump which model is Pedrollo

F80/200B.Though our single pump flow rate is (3950 L/min) so it could be easily manageable to meet the requirement of almost 7960L/min by using two centrifugal pumps operating at the same time. The specification of the pump shown in the table 4.

4.3.7 How a Pump Increases Pressure:

Each branch of the new shower testing booth would get 315 kPa of pressure from the Pump. Pressures in every branch pipe are calculated below and after calculation all the branch pipe pressures shown in fig 2.

<u>Pressure at Right Side Shower Tester:</u>

Pressure at First Branch: $-97.3 + 315 = 217.7\text{kPa} = 2.17\text{bar}$

Pressure at Second Branch: $-102.46 + 315 = 212.54\text{kPa} = 2.12\text{bar}$

Pressure at Third Branch: $-107.5 + 315 = 207.5kPa = 2.07bar$

Pressure at Fourth Branch: $-112.04 + 315 = 202.96\text{kPa} = 2.02\text{bar}$

Pressure at Fifth Branch: $-120.85 + 315 = 194.15kPa = 1.94bar$

Pressure at Sixth Branch: $-63.76 + 315 = 251.24\text{kPa} = 2.51\text{bar}$

<u>Pressure at Left Side Shower Tester:</u>

Pressure at First Branch: $-121.9 + 315 = 193.1\text{kPa} = 1.93\text{bar}$

Pressure at Second Branch: $-127 + 315 = 188\text{kPa} = 1.88\text{bar}$

Pressure at Third Branch: $-132.12 + 315 = 182.88kPa = 1.82bar$

Pressure at Fourth Branch: $-136.42 + 315 = 178.58\text{kPa} = 1.78\text{bar}$

Pressure at Fifth Branch: $-145.45 + 315 = 169.55kPa = 1.69bar$

Pressure at Sixth Branch: $-88.36 + 315 = 226.64\text{kPa} = 2.26\text{bar}$

The calculation above showed that branch pipe negative pressure has been removed following the addition of two centrifugal pumps.

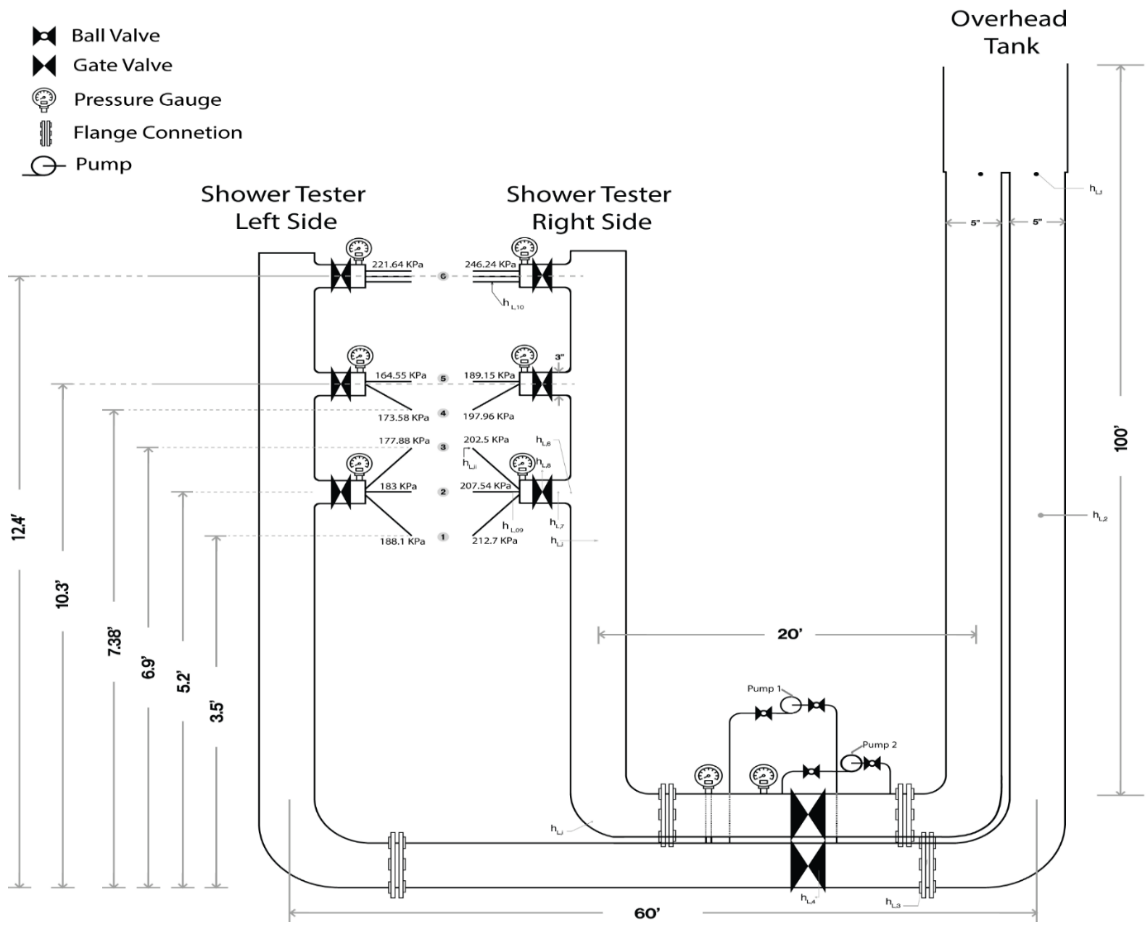


Figure 4.3: Front view of New shower tester pipe arrangement for Bus with pump

4.3.8 Energy Consumption and Cost Calculation of Pumps:

A vehicle's shower test typically takes four to five minutes.

The total energy used if we carry out the shower test for four minutes will be,

$$W = P_t \times t = 30kW \ \times \frac{4}{60} h$$

$$= 2kWh = 2Unit$$

The total energy used if we carry out the shower test for five minutes will be,

$$W = P_t \times t = 30kW \ \times \frac{5}{60} h$$

$$= 2.5kWh = 2.5Unit$$

In Bangladesh, for industrial use the unit cost of power is **13.6 taka / 0.1 dollar**

For 4 minutes operation, Total Cost of energy $= (2Unit \times 13.6) = \mathbf{27.2\ tk}$ / **0.2 dollar**

For 5 minutes operation, Total Cost of energy $= (2.5\ Unit\ \times 13.6)\ = \mathbf{34.05\ tk}$ / **0.28 dollar**

CHAPTER 5

ANSYS ANALYSIS OF MODIFIED SHOWER TESTER

5.1 Introduction:

In this chapter, an ANSYS simulation was conducted to evaluate the performance of the fabricated shower tester design for both bus and SUV models. The simulation aimed to analyze the structural integrity and fluid dynamics involved in the testing process, ensuring that the design functions effectively under various operating conditions. The results provided valuable insights into the performance variations between the bus and SUV configurations, helping to optimize the shower tester for both vehicle types. This simulation approach allowed for a detailed understanding of potential improvements before physical testing, saving time and resources.

5.2 Ansys Analysis of New Shower Tester for SUV:

5.2.1 Geometry Preparation:

The Assembly was designed in SOLIDWORKS and imported to ANSYS. The assembly is part of the Right-side SUV section of the whole shower tester which has been shown by Figure-5.1.

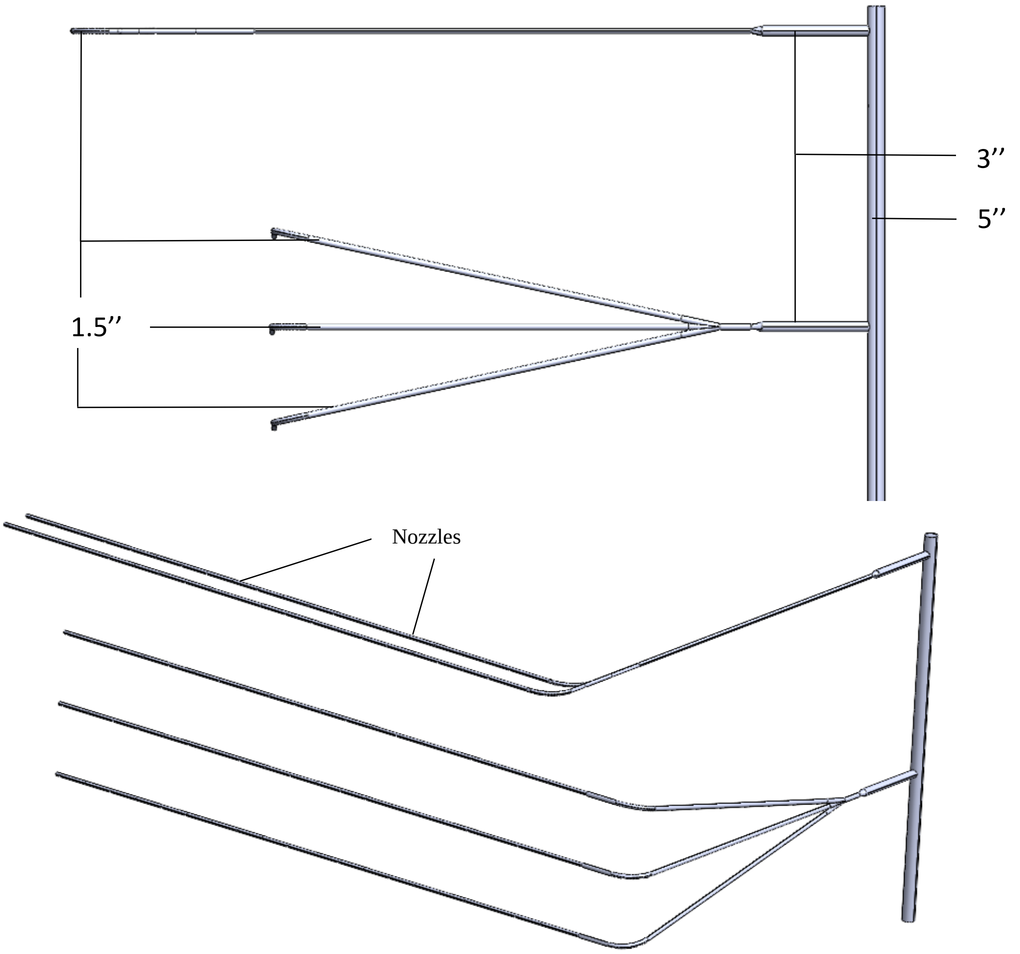
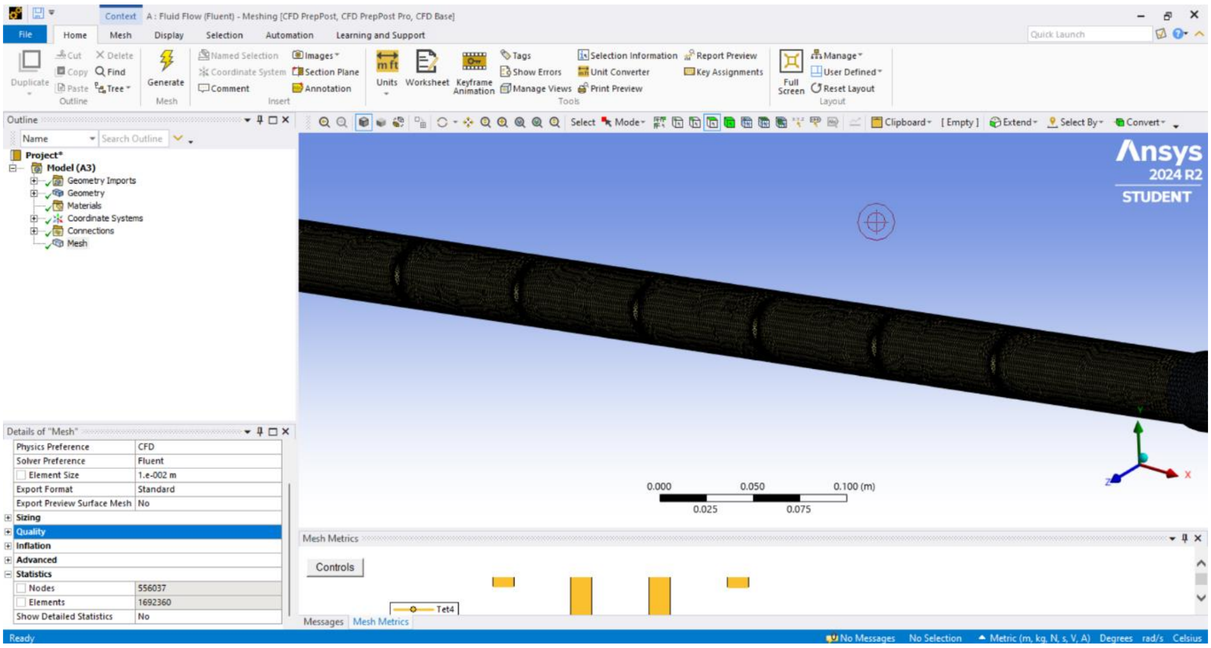


Figure 5.1: Simulation Part

5.2.2 Meshing:

The mesh consists of approximately 550,000 nodes and 1.7 million elements. To ensure higher accuracy, special attention was given to capturing the curvature and proximity in critical areas, particularly around the nozzle regions. This refinement allowed for better resolution of complex geometry and improved the quality of the simulation results. Figure-5.2 is showing mesh analysis.



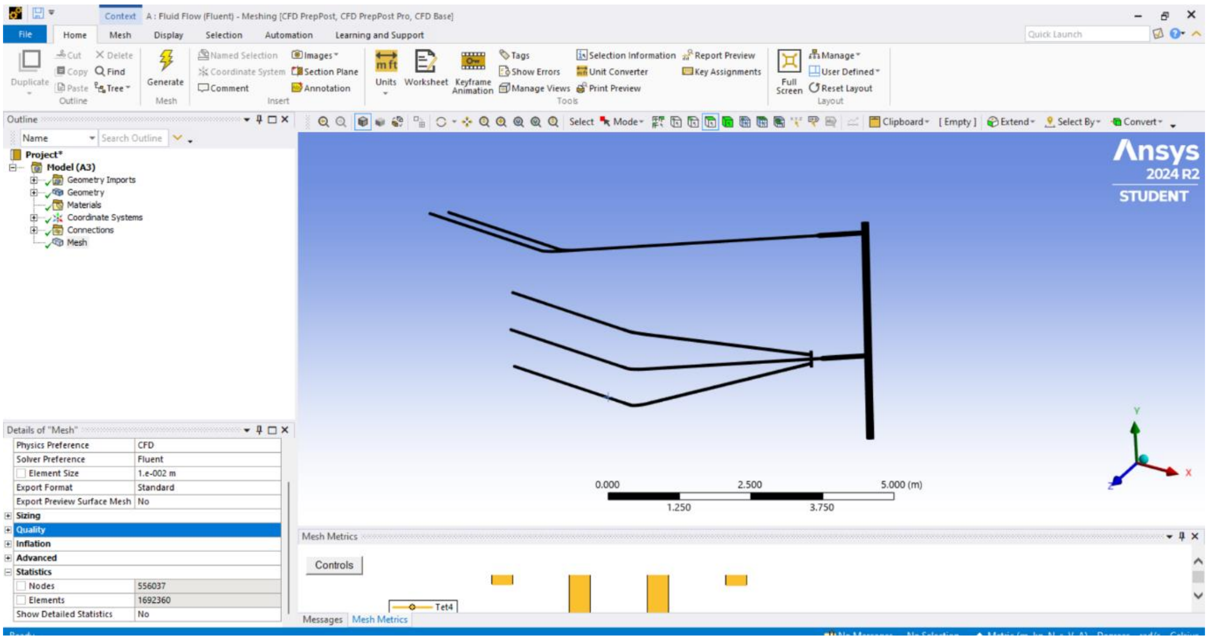


Figure 5.2: Mesh

5.2.3 Skewness:

Skewness is the difference between the cell's form and that of an equilateral cell with the same volume. Excessively skewed cells might cause the solution to become unstable and reduce accuracy.

In Figure-5.3, The mesh has a skewness value of 0.84972, which falls within the acceptable range for mesh quality. This value is below the generally accepted maximum skewness limit of 0.9, indicating that the mesh is well-formed and suitable for accurate simulations.

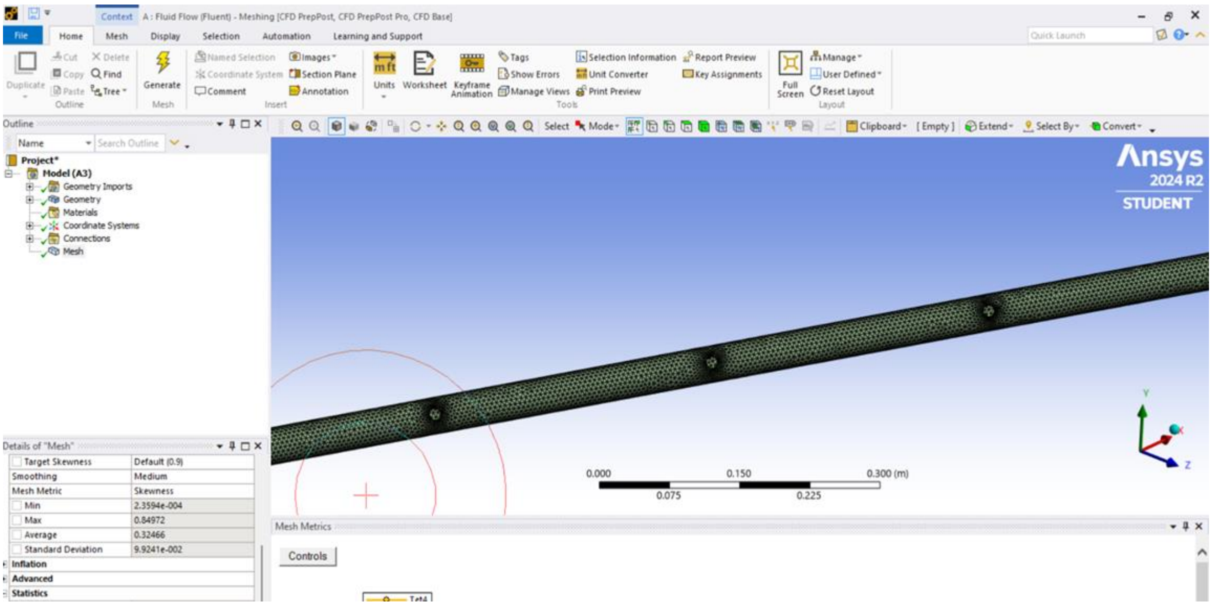


Figure 5.3: Skewness

5.2.4 Orthogonal Quality:

Orthogonal Quality in ANSYS is a measure of how aligned or "orthogonal" the elements of the mesh are relative to the geometry and the adjacent elements. It is a key indicator of mesh quality, particularly for structured meshes (e.g., hexahedral or quadrilateral elements).

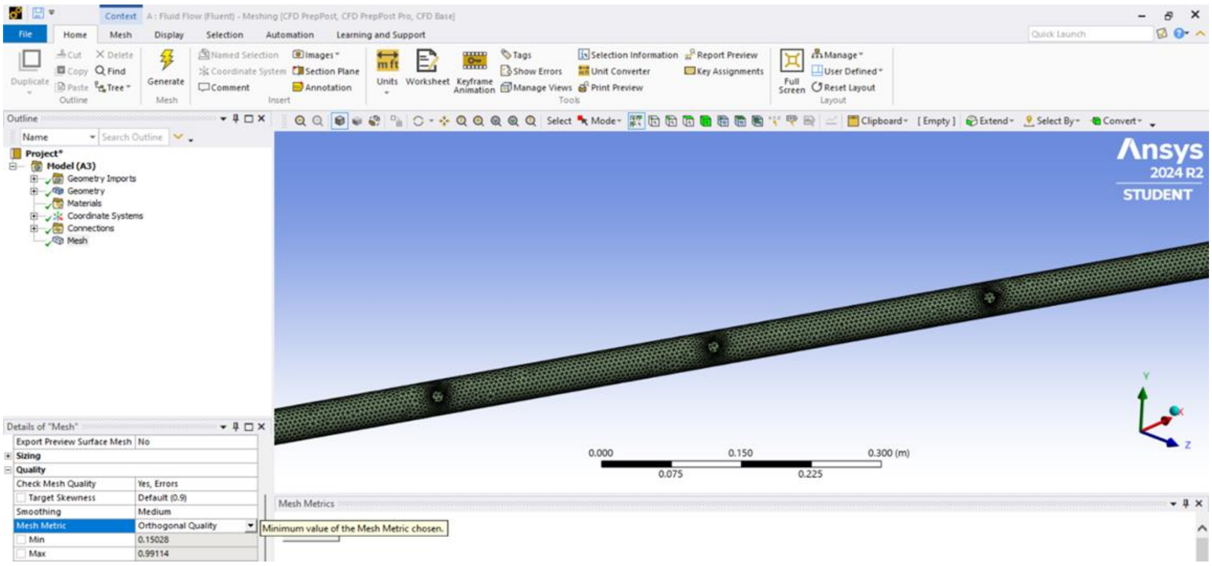


Figure 5.4: Orthogonal Quality

For structured meshes with hexahedral or quadrilateral elements, maintaining good orthogonality is essential for accurate results. Typically, the orthogonal quality should be kept above 0.1. In this case, the mesh has an orthogonal quality of 0.15028, which falls within the acceptable range, indicating that the mesh is of adequate quality for reliable simulations. Figure-5.4 is showing Orthogonal Quality in this case.

5.2.5 Simulation Model:

A well-liked two-equation turbulence model for simulating the effects of turbulence in fluid flow in computational fluid dynamics (CFD) is the SST (Shear Stress Transport) k-omega model. It works especially well for flows with complicated boundary layers, separation, and unfavorable pressure gradients. This model was applied to the problem that is depicted in Figure 5.5.

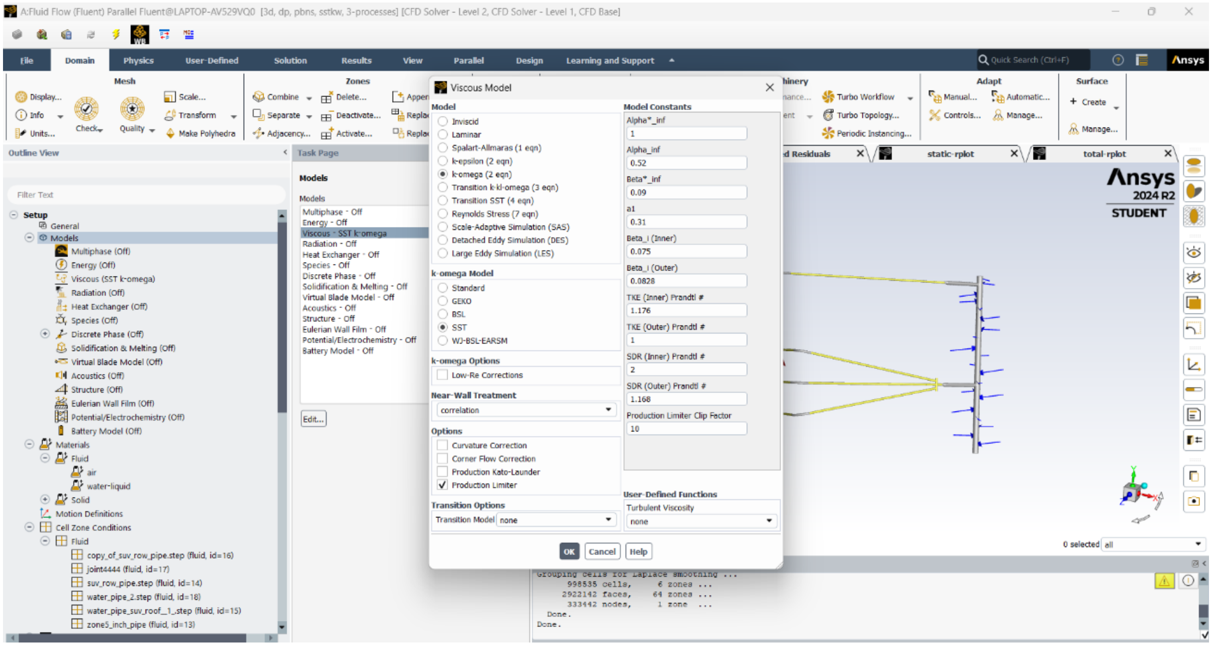


Figure 5.5: Simulation Model

5.2.6 Input:

Inlet Velocity: 2 m/s (taken from Calculation for flowrate in 5-inch pipe)

The inlet velocity defines the speed at which the fluid enters the computational domain through the inlet boundary. In ANSYS, we can set this as a boundary condition, which influences how the fluid flows through the system. The velocity of **2 m/s** for water is derived based on flowrate calculations for a 5-inch pipe, which is shown in Figure-5.6(a).

Fluid: Water-liquid was applied in the cell zone conditions.

The cell zone conditions in ANSYS describe the characteristics of the domain inside which the fluid moves. By specifying **water-liquid** as the fluid, ANSYS recognizes the properties of water, such as its density and viscosity, allowing it to simulate fluid dynamics accurately. This is essential for solving the governing equations and understanding interactions like drag or pressure changes within the domain. This is shown in Figure-5.6(b).

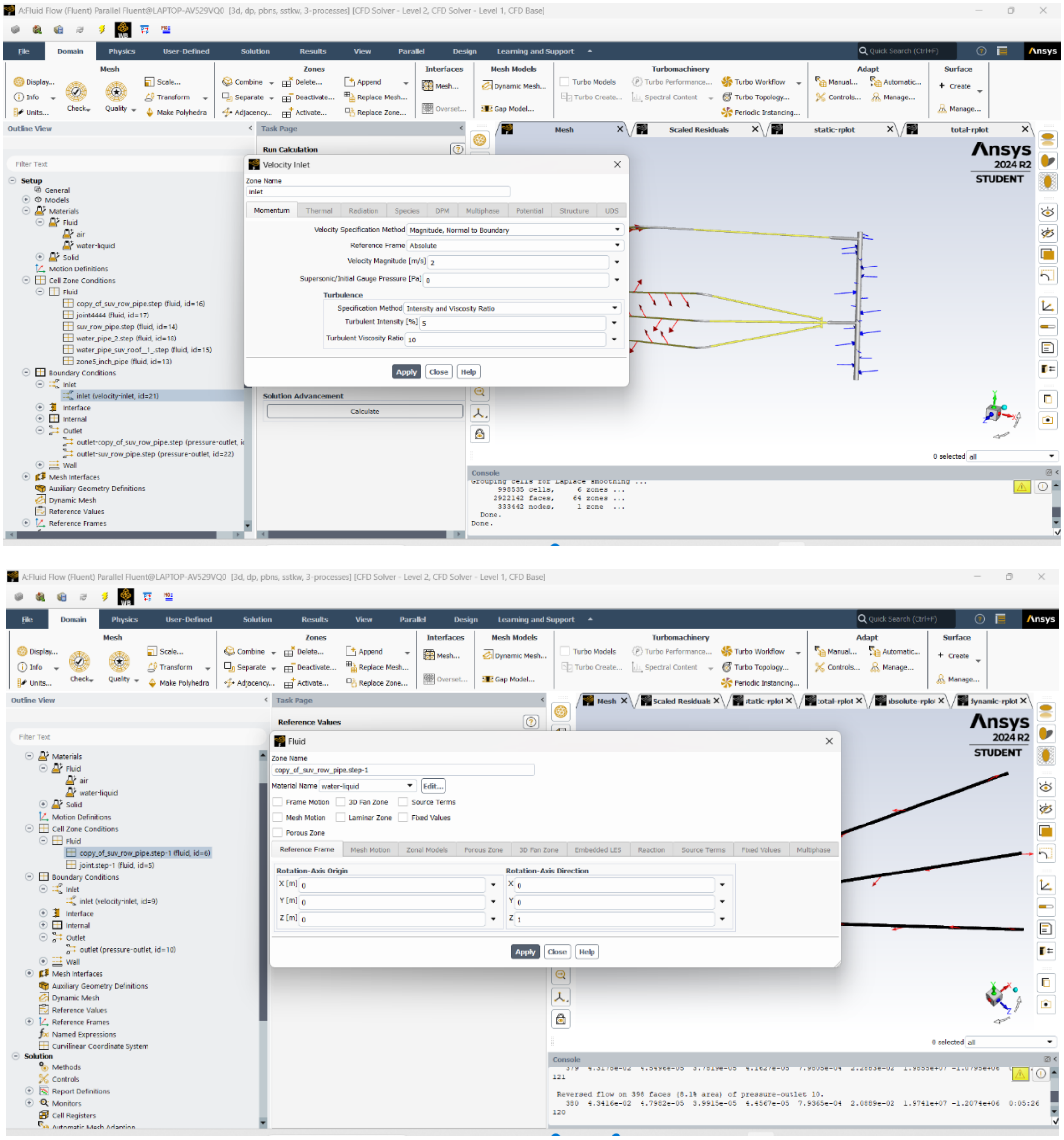
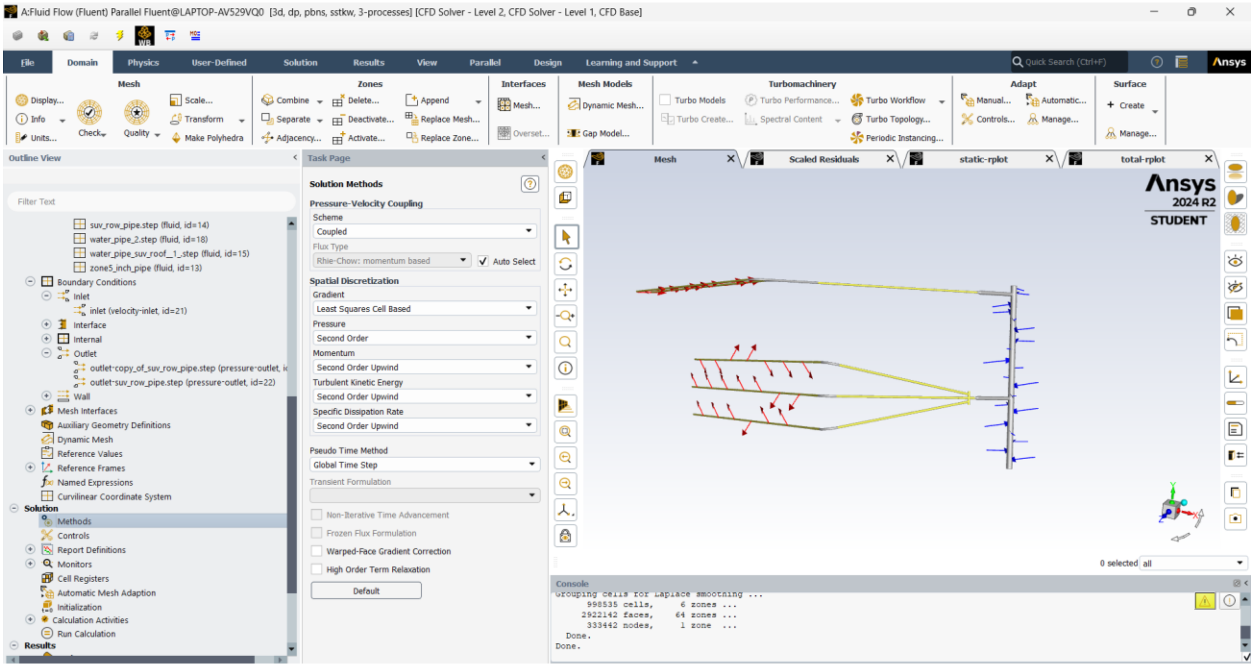


Figure 5.6: (a) Input Inlet Velocity and (b) Fluid domain

5.2.7 Solution Method:

Coupled with second-order upwind scheme. (For better accuracy). After 1200 Iterations convergence was achieved. Shown in Figure-5.7.



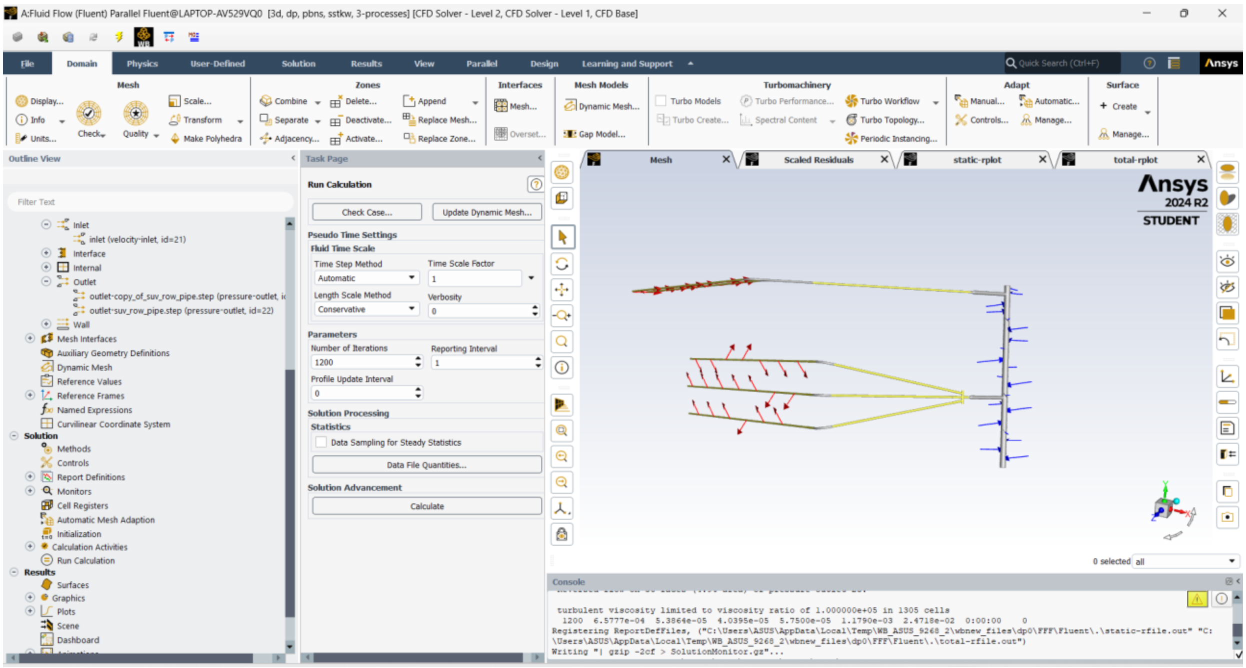
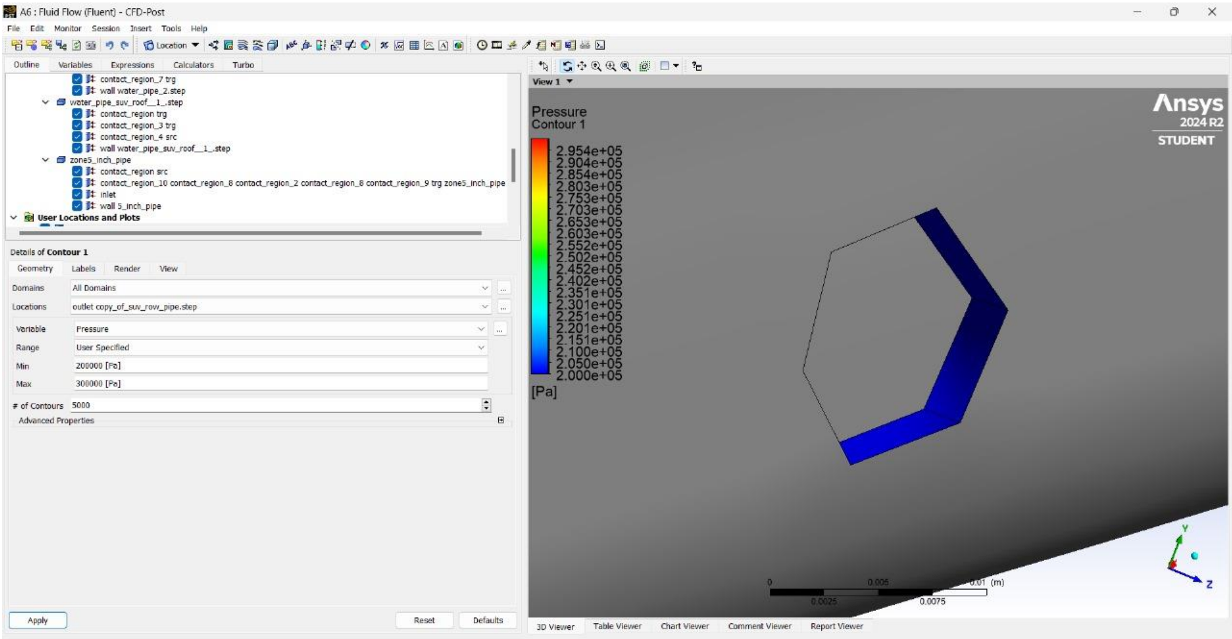


Figure 5.7: Solution Method

5.2.8 Results:

○ **Pressure for Section 1 (Lower section of pipes):**

The Figure-5.8(a) below shows a vertical bar which is representing pressure at the specific parts. At nozzle part the simulation is showing deeper blue, which indicates approximately 2 bars from the vertical bar. Again, the Figure-5.8(b) shows the pipe flow pressure also with a vertical bar. The pipe flow is showing red color which indicates the pressure about 3 bars from the bar.



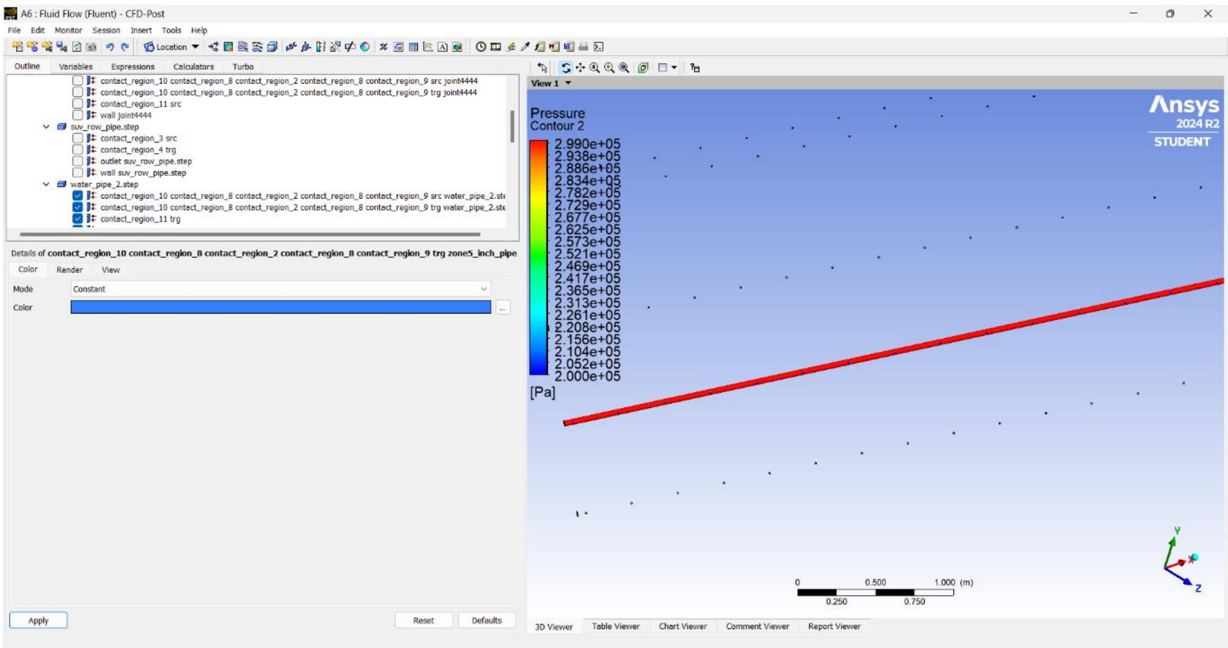


Figure 5.8: Pressure for Section 1 (a) Nozzle (b) Pipe

- **Pressure for Section 4 (Upper section of pipes):**

The Figure-5.9 below indicates that the pressure for upper section pipes, near the nozzle is about 2 bars, whereas in the pipes, it is roughly 3 bars.

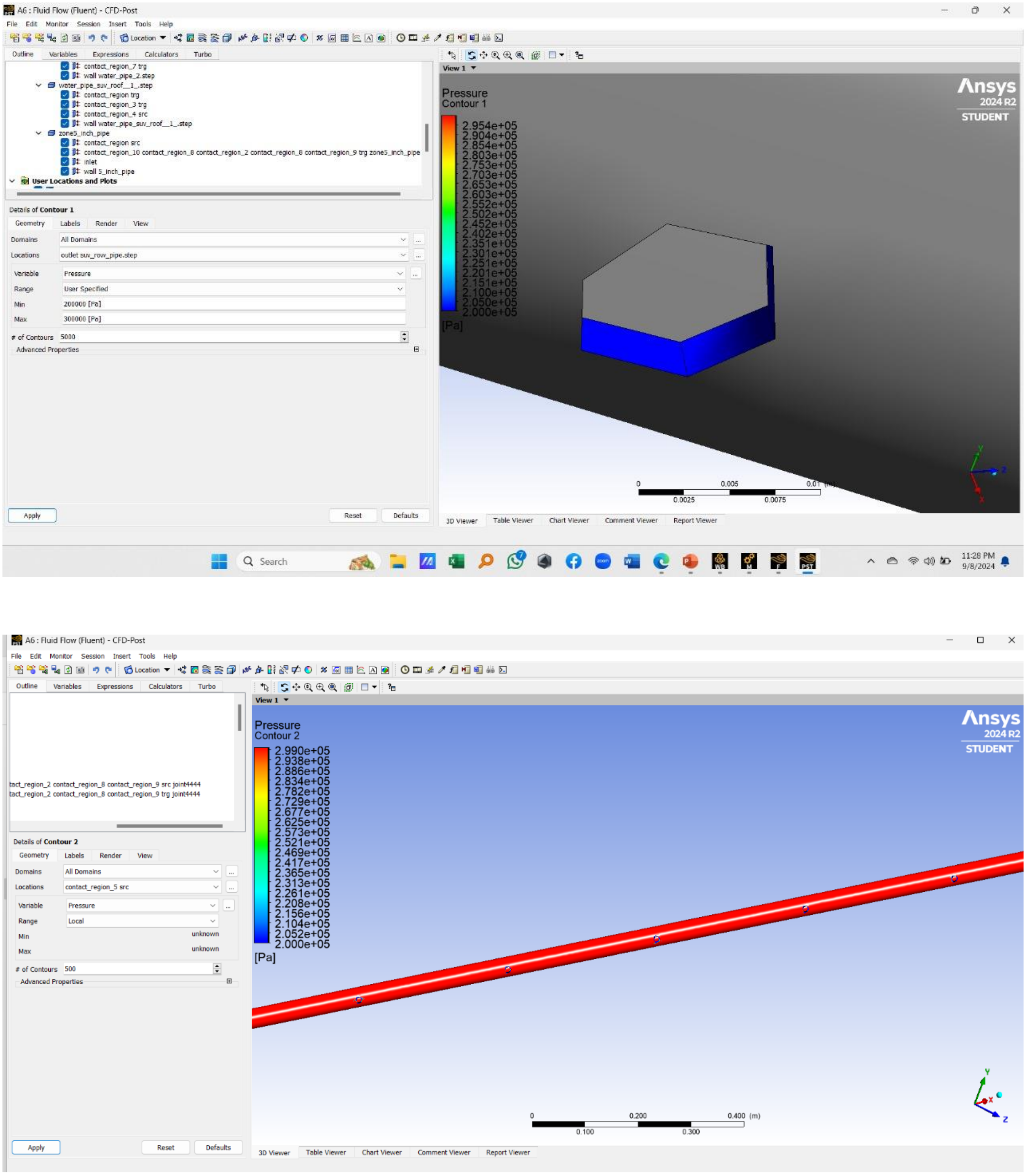


Figure 5.9: Pressure for Section 4 (a) Nozzle (b) Pipe

- **Pressure for BUS shower tester:**

The Figure-5.10 below shows that the pressure near the nozzle in the BUS pipe sections is approximately 2.2 bars.

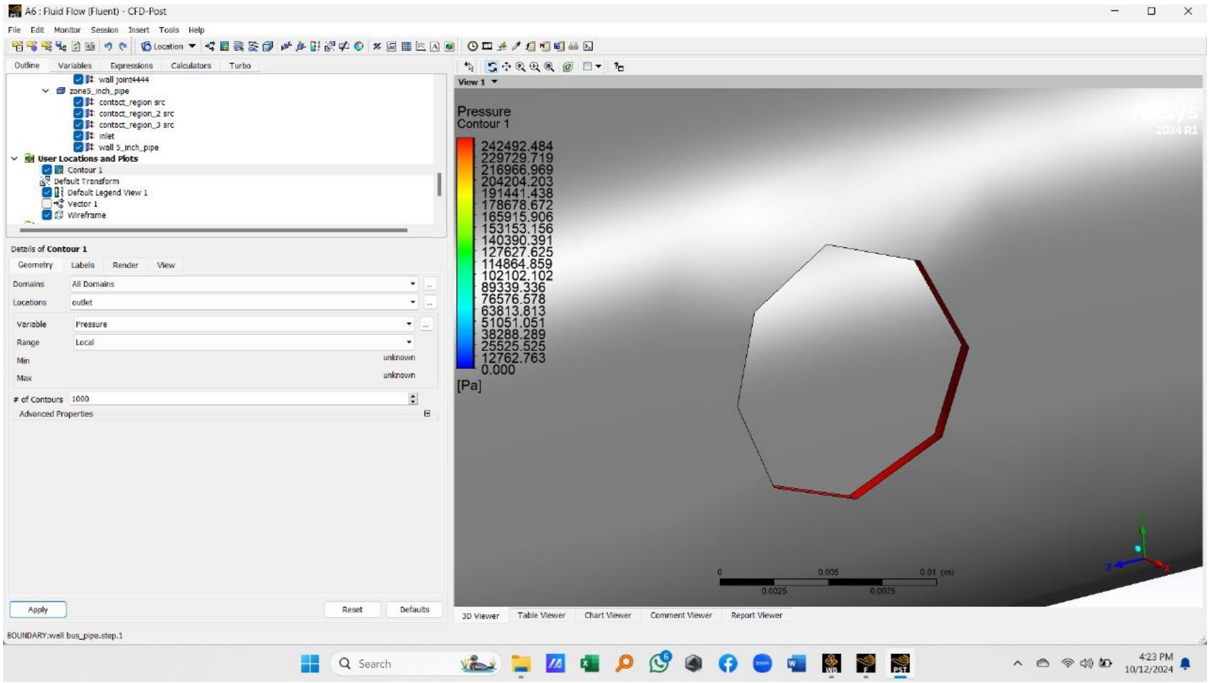


Figure 5.10: Pressure in Nozzle for BUS shower tester

Saswat Sambit et al.[74] Simulated a 25.4 mm or 1 inch straight pipe with a length of 1m and found the velocity contour with a inlet velocity of 2.56 m/s and outlet velocity of 2.94 m/s. They also found total pressure contour and inlet pressure of 0.059 bar and outlet pressure of 0.036 bar.

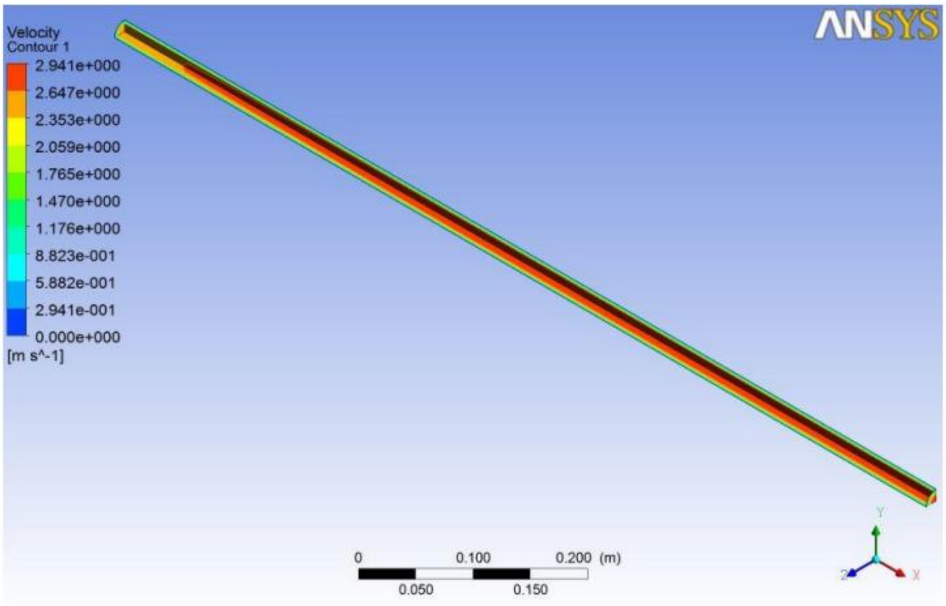


Figure 5.10: Velocity Contour

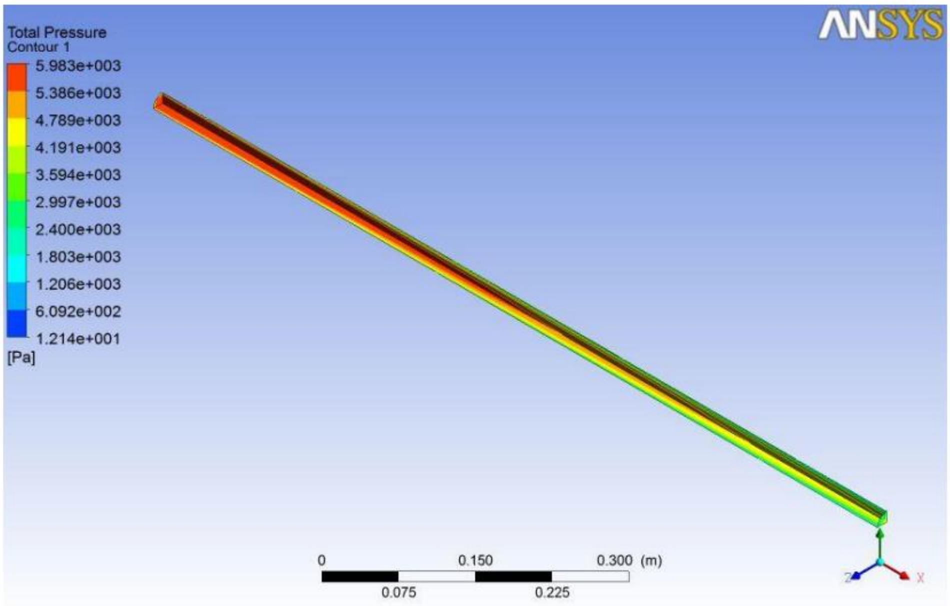


Figure 5.11: Total Pressure Contour

Abish Lamsal et al.[75] Simulated a straight pipe having a length of 8 meter and dia of 0.2m or 7.874 inch and found velocity contour with the inlet velocity of 3.5 m/s and outlet velocity of about 3.06 m/s. Velocity profiles of the flow at 6 distinct locations were also shown by them.

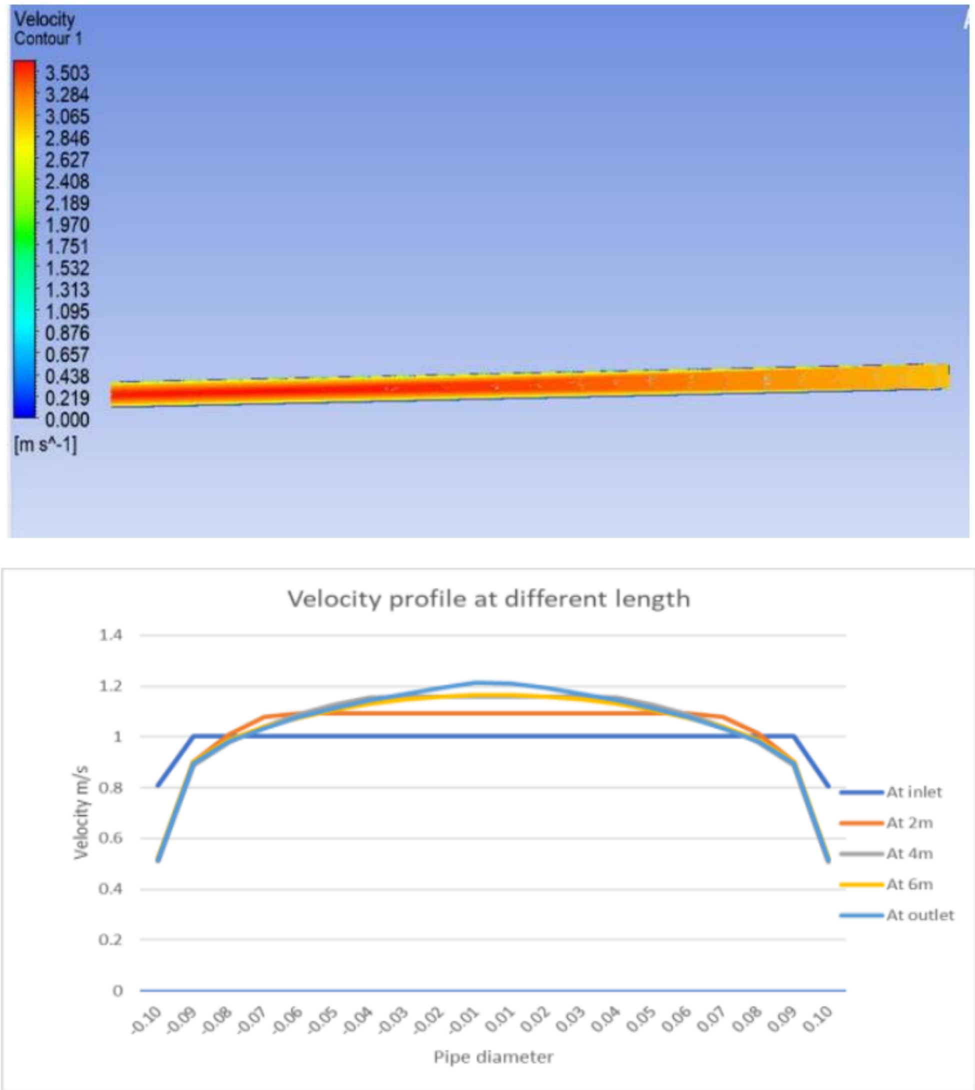


Figure 5.12: Velocity Contour and Velocity Profile in Six Locations

CHAPTER 6

CONCLUSION

6.1 Introduction:

In conclusion, the thesis project "Modification of a Car Shower Tester Booth to a 52 seated Bus-Compatible Shower Tester Booth" successfully addresses the challenges of adapting a facility designed for smaller vehicles to meet the demands of larger ones, such as buses. The project not only achieved the necessary structural and functional upgrades, but also utilized advanced simulation techniques through ANSYS to ensure that the modifications were efficient and reliable. By expanding the booth's capabilities, the project paves the way for broader applications and improved testing efficiency. Additionally, the modifications were validated through simulations that confirmed the booth's effectiveness in delivering accurate waterproof testing for larger vehicles. This project demonstrates significant practical value, but there are also numerous opportunities for future work to further refine and expand upon the design and functionality.

6.2 Summary of the work done:

This thesis project of modification of a Car/SUV Shower Tester Booth to a Bus-Compatible Shower Tester Booth, demonstrates-

1. **Practical Design Modification**: A practical approach to repurposing and upgrading an existing vehicle testing facility for larger vehicles. The project likely involves redesigning the shower tester booth's dimensions, structural integrity, underground tank, overhead tank and water distribution system, transmission system to accommodate the size and unique needs of buses, ensuring that the booth can simulate realistic weather and environmental conditions for waterproof testing.
2. **Advanced Control Mechanisms**: The integration of more advanced control mechanisms with different nozzles and valves, angle of spray, adding centrifugal pumps were the significant part of this modification to ensure uniform coverage over the bus's surface, especially around its higher roof and larger surface area. This necessitates reinforcing the structure to support the increased water volume and pressure that larger vehicles demand during testing.
3. **ANSYS Simulations**: In addition to these modifications, ANSYS simulations were conducted for both the original SUV shower tester and the modified Bus-compatible shower tester. These simulations provided critical insights into the performance and efficiency of the redesigned booth, allowing us to assess the structural integrity, water flow patterns, and pressure distribution in both versions. The ANSYS results confirmed that the modified booth could maintain the same high standards of waterproof testing for buses, with appropriate adjustments to water pressure and distribution angles to

cover the larger surface area of buses effectively, ensuring that the new design meets industry standards for vehicle waterproof testing.

4. **Resource Optimization & Cost-Effective Solution:** This project showcases resource optimization by utilizing an already-existing facility instead of building an entirely new booth, thereby minimizing expenses and optimizing operations. Ultimately, this means that a wider variety of vehicles can be tested within the same infrastructure thanks to a more adaptable testing facility that can house Buses and SUVs alike. The original Car/SUV shower tester booth's usefulness is expanded to include buses with this project, which improves its functionality. By making this change, the testing procedure is now more effective and the facility design is more flexible. The project helps the automotive industry find cost-effective solutions and maximizes its resources by matching the booth's capabilities with the increasing demands of larger vehicles.

6.3 Future Work Directions:

For this project several areas of future work could further enhance the design, performance, and utility of the modified facility. These future works can address both technical improvements and broader industry applications:

1. **Optimization of Water Efficiency**: Explore water recycling and filtration systems to reduce water usage and enhance sustainability.
2. **Advanced Automation and Control Systems**: Develop an intelligent system with sensors and AI for real-time adjustments in water pressure, angles, and flow, making the booth adaptable to various vehicle sizes and conditions.
3. **Expansion to Other Vehicle Types**: Modify the booth to test a wider range of large vehicles, such as trucks, RVs, and minibuses, expanding its applicability.
4. **Integration of Acoustic and Wind Tunnel Testing**: Add capabilities for noise and aerodynamic performance testing in addition to waterproofing, making the booth a multi-functional testing environment.
5. **Durability Testing of Booth Components**: Study the long-term performance of water nozzles, pumps, and structural elements under high-demand testing conditions to improve durability.
6. **Enhancement of Safety Features and Ergonomics**: Improve safety protocols for operators, vehicle entry, and exit processes, and strengthen the booth's structure for testing larger, heavier vehicles.
7. **Comprehensive Cost-Benefit Analysis**: Conduct an in-depth analysis of the financial and operational benefits of converting Car/SUV shower tester to bus-compatible versions, including ROI and maintenance costs.

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