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Transparent Flow Metering Skid: Innovative Methodology for Enhanced Flow Measurement

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Abstract. Flow metering skids constitute essential components across diverse industries, notably within the oil and gas sector, where accurate measurement of fluid flow is vital for ensuring operational efficiency, regulatory adherence, and the optimization of revenue. Conventional flow metering systems, frequently enclosed within non-transparent housings, may hinder real-time monitoring and diagnostic processes. The present study introduces a transparent flow metering skid, facilitating enhanced visibility for maintenance and ensuring measurement accuracy while concurrently maintaining operational efficiency. Offering visibility, reliability, and ease of maintenance, the transparent design allows for continuous flow monitoring, enabling timely maintenance and reducing downtime, thus providing an effective solution for industries aiming to optimize flow measurement.

1 Introduction

Accurate fluid measurements are critical in the oil and gas industry for production, transportation, and custody transfer. [1] Fluid flow metering skid systems manage this by integrating components like flow meters, filters, pressure regulators, control valves, and data acquisition equipment. Unlike conventional systems, skid systems are factory-built and rigorously tested for consistent quality. Their compact, modular design eases installation and minimizes space requirements. The pre-piped and prewired setup reduces on-site construction time and labor costs while increasing system reliability. These skids can be customized for various fluid types, with flow meters chosen based on fluid characteristics and measurement needs. The selection of supplementary components within the skid ensures appropriate conditioning of the fluid stream for accurate metering and protects the flow meter from damage due to particulates or pressure variations. Data acquisition equipment facilitates real-time monitoring and control of the flow rate, enabling process optimization and improved production efficiency.

The central component of a skid system is the turbine flowmeter, which has been the subject of extensive research, particularly regarding its application within the oil and gas industry. Previous studies on this topic include: The overall performance of turbine and propeller flow

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meters and their characteristics are influenced by factors such as viscosity, flow pattern, flow rate, and pressure level. [2] In this context, Higson presents the results of his research on the transient performance of a turbine flow meter, focusing on its electrical output. [3] Thompson et al. (1970) investigated a theoretical model of a turbine meter to understand the effects of delaying torques, propeller interference, and other relevant factors. [4] A computer software program calculates the actual rotor speed by numerically integrating the lift and drag forces on the rotor blades. The numerical analysis of the sample disclosed significant effects originating from the velocity profile and blade interference, while the delaying torques were found to be negligible within the large Reynolds number range. The wide range of metre designs that fall into the turbine, propeller, or paddle flow meter family and have been manufactured for commercial use have been detailed by Baker and co-authors. [5] Towards this line, they also did an experimental investigation to explore the flow meter performance under various input swirls and to validate the performance model. [6] A theoretical prediction model for turbine flow meters has been established in this line of research. [7] The driving torque on the flow meter rotor is assessed based on the aerodynamic characteristics of the blades, using the numerical model that has previously been developed for various flow conditions surrounding the flow meters of turbines.

Furthermore, the characteristics of an oval gear flowmeter that employs several fluids with varying viscosity were explored. [8] Ali and colleagues recently engineered and constructed a device designed to accurately and simultaneously measure the flow rate and temperature of various mediums, including liquids such as oil or water, as well as gases such as natural gas. [9] The results are presented on a liquid crystal display (LCD). The device operates by channeling the fluid through a turbine that spins at a speed directly correlated with the flow rate of the fluid. In addition, a temperature sensor is employed to determine the temperature of the fluid in motion. The study employs both modeling and experimental tests to validate the dynamic characteristics of a turbine flow meter (TFM). [10] The kinetic equation of the TFM is derived by analyzing the driving and resistance torques within the modeling component. Simulations conducted using the kinetic equation illustrate the robust dynamic performance of the TFM. Experimental investigations utilize a workbench designed to generate both step-type and sine-type flows for identification within the temporal and frequency domains. Subsequently, Husni and co-authors provide an exhaustive analysis of turbine flow meters (TFMs). [11] The study outlines the prevailing state-of-the-art advancements, elucidates the foundational principles that underlie TFMs, and highlights various parameters influencing their robustness. Furthermore, the research investigates diverse challenges pertinent to TFMs that may affect measurement accuracy. A crucial issue identified is the discrepancy in meter readings between manual metering or turbine stand meters and Electronic Volume Correctors (EVCs) employed in the oil and gas sector. This inconsistency can lead to potential losses for consumers or industries. The study proposes the introduction of a notification system, integrating an advanced intelligent mechanism to detect faults within the system.

Currently, metering skid systems are not without drawbacks. The intricate pipe structures and enclosed instruments contribute to a lack of transparency, complicating real-time monitoring of the flow process. This lack of visibility might cast doubt on the integrity of data, particularly in custody transfer scenarios, where precise measurements are crucial for financial transactions. In addition, maintenance is often cumbersome due to restricted access to internal parts. This research seeks to develop and build a skid system to overcome the previously stated disadvantages. While transparent flow setups are common in academia, their integration into practical flow metering skids with dual metering (turbine and oval gear) for enhanced accuracy and redundancy is rare, particularly for diagnostics and training.

2 Components of the skid system

The final product consists of the following individual components:

2.1 Flow straightener

A flow straightener in a piping system organizes the fluid flow to minimize turbulence, ensuring accurate readings from downstream instruments such as flow meters. This improves the accuracy of the measurement and the function of the system. The CAD representation of the flow straightener used in this study is presented in Fig. 1.

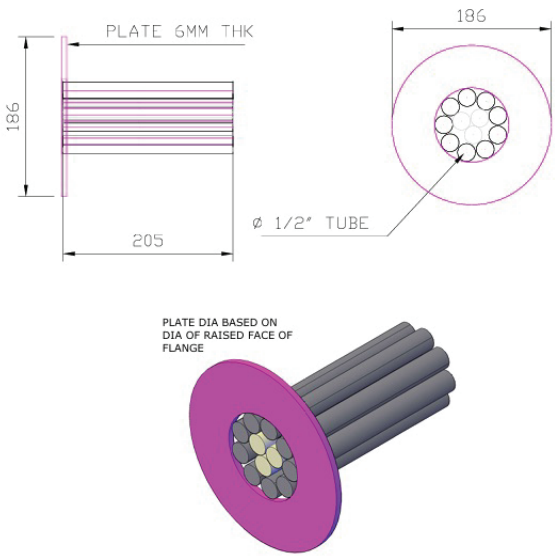

Figure 1. CAD & 3D Model of Flow Straightener

2.2 Flow stainer

A flow strainer constitutes an essential element within piping systems, tasked with the filtration of unwanted particulates and debris from liquid or gas streams transiting through the pipes. Such contaminants may originate from rust, welding slag, or fragments of pipe scale that may become dislodged during the operational process. If not properly managed, these particulates could potentially harm or obstruct downstream equipment, including pumps, control valves, or precision instruments. The strainer incorporates a mesh or a perforated basket designed to capture these particles, thereby ensuring a clean and unimpeded flow to the sensitive apparatus located further along the piping network.

2.3 Turbine flow meter with pulse output

A turbine flow meter with pulse output is a device used to measure the volumetric flow rate of a liquid or gas. It works based on the principle that a freely rotating turbine spins within the meter in proportion to the flow rate passing through it. This rotation is then converted into a series of electrical pulses for easy quantification. The components comprise a turbine, which is a multi-bladed rotor strategically situated within the flow path; a magnetic pickup, which

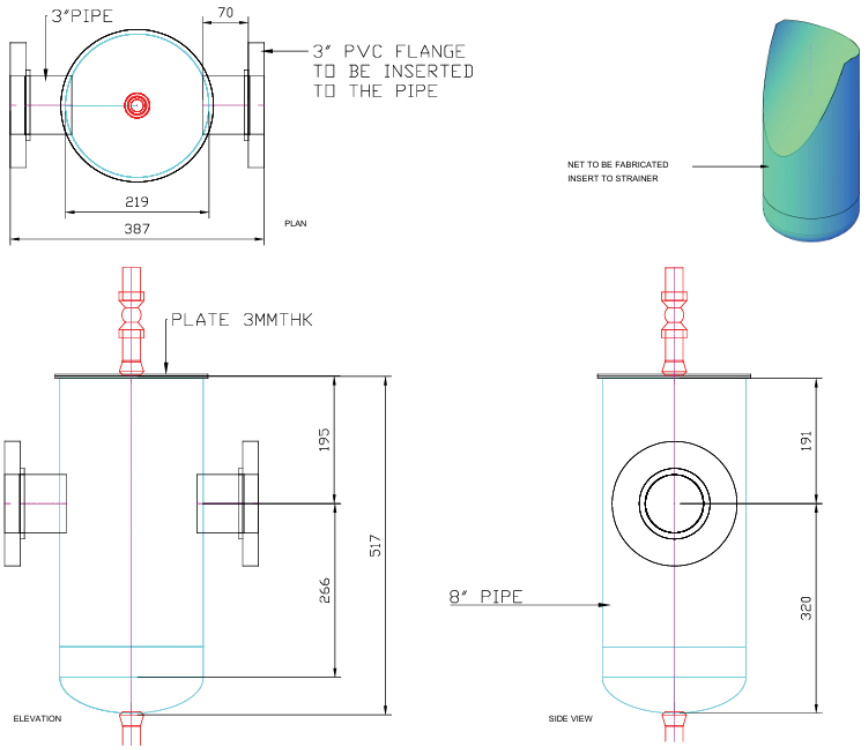

Figure 2. CAD & 3D Model of Strainer

serves as a sensor to detect the turbine's rotation; and the pulse output, which constitutes the electrical signal generated with each rotation of the turbine.

A SolidWorks 3D model, developed from an AutoCAD design of a flow metering skid, substantially assists in the accurate positioning and assembly of equipment within the skid. This model functions as a comprehensive digital twin, providing an integrative perspective of the skid's layout, component dimensions, and spatial relationships. By visualizing the entire assembly in three dimensions, engineers and technicians can identify potential collisions or interferences early in the design process, thereby averting expensive rework during physical assembly. The model supports precise equipment placement by offering exact coordinates and reference points, ensuring that each component is strategically positioned for optimal functionality and maintenance access. Additionally, the 3D model is capable of generating detailed assembly instructions, which guide technicians through the process methodically, thereby reducing errors. This digital methodology not only streamlines the assembly process but also enhances overall quality control. Such a 3-D CAD model depicting the efficient positioning of the pump is illustrated in Fig. 3.

3 Steps from design to operation

Proceeding to the fabrication procedure of the transparent flow metering skid, this section delineates the stages from initial design to the completion of the functional unit. The procedure encompasses the selection of materials, machining, welding, and assembly, with an emphasis on ensuring a leak-proof system, a transparent flow pathway, and maintaining structural integrity.

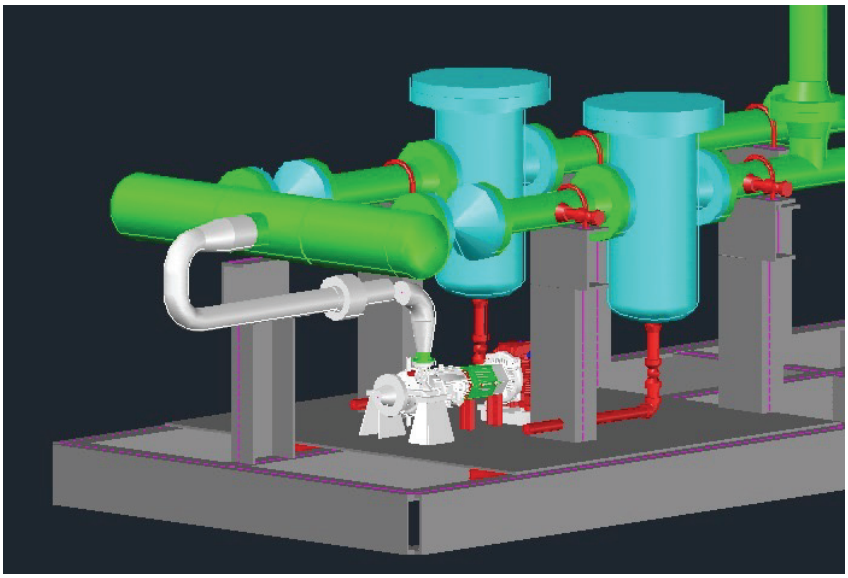

Figure 3. Representation of Pump positioning in the skid system.

1. Material Procurement and Pipeline Fabrication: The fabrication process begins with the procurement of materials as specified in the Bill of Quantities (BOQ). These are transported to the workshop, where the transparent pipeline is assembled using acrylic tubes for visual inspection and high-pressure fittings to ensure leak-proof, durable joints.

2. Base Skid Fabrication: A structural base is fabricated using C-channel beams ($100mm \times 50mm \times 5mm$), chosen for their strength and lightness. Spot welding is used for initial alignment, followed by MIG welding for permanent joints. A protective paint coating is applied to resist corrosion and improve appearance.

3. Pipeline Mounting and Alignment: The constructed pipeline is precisely aligned and affixed onto the foundational skid. High-quality fasteners, chosen according to engineering specifications, ensure the components are securely held to endure operational stresses and vibrations.

4. Functional Testing and Leak Inspection: The operational efficacy of system components, such as flow meters and pressure sensors, is meticulously scrutinized. Leak detection is performed employing pressure gauges, ultrasonic instruments, or tracer gases, with any identified deficiencies addressed expeditiously.

5. Calibration and Accuracy Adjustment: The flow meters are evaluated under standardized conditions, with their outputs being compared against established reference standards. Any observed discrepancies are rectified by adjusting the calibration to assure precise and consistent flow measurements.

6. Final Commissioning and Delivery Readiness: Upon the successful completion of testing and calibration, the skid is considered operationally prepared. This denotes the finalization of the fabrication and commissioning phases, affirming that the system conforms to all prescribed design and performance criteria.

4 Operation procedure

A photograph of the assembled final product is shown in Fig. 4. This apparatus has been installed at the civil laboratory of Amity University Dubai to facilitate further research endeavors. The fabricated transparent metering skid is designed to emulate the functionality of an actual, fully operational metering skid utilized in the oil and gas sector. This constructed skid is intended to operate analogously to the authentic one; however, due to the distinct configuration of inlet and outlet connections present in the actual skid, a direct adaptation for a demonstration recirculating skid is unfeasible. Consequently, the fluid flow is arranged in a closed loop, originating and returning to a water tank serving as both the inlet and the outlet. The fluid from the tank is initially directed to the inlet headers, where it is evenly distributed among the lines, including the main line with the duty meter and optionally redirecting to the prover line utilizing ball valves as necessary. From the header, the fluid progresses through a basket strainer where it undergoes filtration to remove debris and particles that could potentially damage the flow meters. Subsequently, the fluid crosses a flow straightener, constructed in compliance with applicable standards, which conditions the flow by eliminating turbulence, thus facilitating smooth entry into the flow meter. Upon entering the turbine flow meter, the fluid volume is quantified and the generated pulse is transmitted to flow computers to display the volume being transferred between parties, simultaneously measuring the temperature and pressure of the fluid through attached transmitters. Should any party necessitate confirmation or verification of the accuracy of the custody transfer along the main line, the flow is diverted through a secondary line equipped with a highly accurate flow meter (oval gear) to periodically verify and calibrate the turbine meter, ensuring precision as required. Although the oval gear meter provides enhanced accuracy, it requires periodic calibration by an accredited laboratory. Following measurement, the fluid is redirected to the fluid tank, acting as the outlet for the actual skid and facilitating recirculation of the fluid.

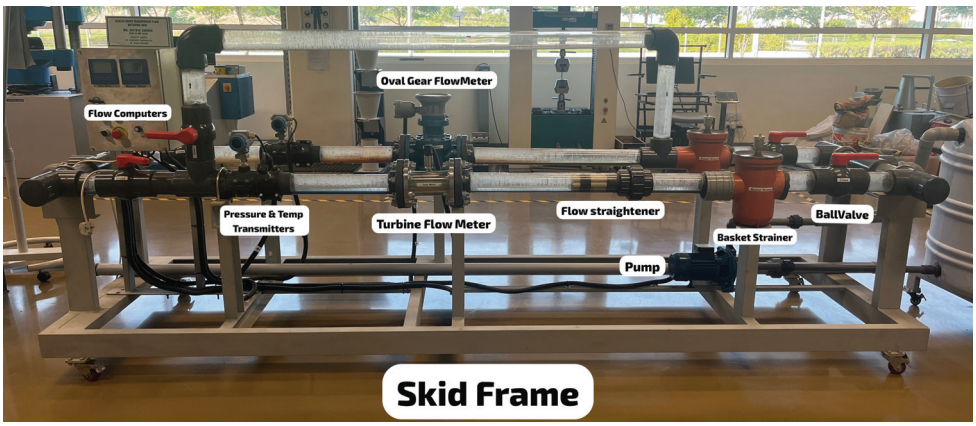

Figure 4. A photograph of the assembled transparent skid system at Amity University Dubai.

5 Summary

Fluid flow metering skid systems are pre-fabricated and autonomous configurations engineered to provide precise measurement of fluid flow rates and characteristics within industrial processes. This study investigates the development and evaluation of scaled-down transparent flow metering skids intended to improve clarity and understanding in applications involving flow measurement. Testing uncovered leaks in the PVC and acrylic materials used,

which, although transparent, lacked the pressure resistance of metal, but these issues were successfully resolved by applying epoxy sealant. Subsequent testing identified variations in performance between distinct meter types, specifically turbine and oval gear meters, necessitating calibration modifications via a K-factor within the flow computer to standardize the readings. Although transparency offers significant educational benefits, existing limitations of materials, especially their susceptibility to leaks and low-pressure endurance, limit their industrial use. Progress in material science and a strategic choice of materials that consider environmental variables are crucial to overcoming these obstacles. Transparent flow metering skids present promising opportunities for educational and industrial applications, and further research is essential to realize their potential.

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