PROGRESS REPORT

1. Project Title: “Determine the technical requirements of industrial oil-fired burners”	**Project Code:** MED 0177
2. PI (Name & Address): Dr. Sarbjot Singh Sandhu NI'I' Jalandhar	**Date of Birth** 10th Sept 1977
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4. Approved Objectives of the Proposal:

The objectives of the project for:

- To conduct a comprehensive assessment of industrial oil-fired burners focusing on functionality, efficiency, and operational aspects.
- To analyze combustion processes to understand their efficiency and emissions characteristics.
- To evaluate designs and components of oil-fired burners to identify strengths and weaknesses.
- To examine performance metrics including heat output, emissions levels, and fuel consumption.
- To study maintenance requirements to identify areas for improvement and optimize operational reliability.
- To explore optimization possibilities to enhance burner system efficiency and environmental sustainability.
- To utilize both research and practical experiments to gather data and insights for actionable recommendations.
- To provide detailed insights and recommendations to enhance the reliability, efficiency, and environmental sustainability of industrial oil-fired burner systems.

Date of Start: 25 June 2024	**Total cost of Project:** Rs. 08,36,127/-
Date of completion: Ongoing (26 Sept. 2024)	**Expenditure as on** Oct 4 2024: Rs. 73422/-

5. Literature Review

In refining, petrochemical, and chemical industries, process burners heat furnaces utilizing combustion. Air enters through a noise-reducing part, then an adjustable control, before reaching the plenum for distribution [1]. Fuel, often ignited by a pilot burner, is injected through tips into the air stream shaped by the burner tile. These burners are diverse, classified by factors like air draft, emissions, flame shape, placement, fuel type, and mixing methods, to best suit various heating needs in those industries [1], [2]. Oil-fired burners in industries are undergoing a transformation driven by research across multiple fronts including Efficiency, emissions reduction, and sustainability [2].

According to studies conducted on a Lynet burner, the swirl ratio of the hot gases at the burner exit must be taken as a similarity criterion when simulating the spread and entrainment of jets from the burner. Isothermal studies require distortion of the swirler [3]. Cold studies show that the variation of flame shape with swirler setting is determined by the interaction of combustion air flow and oil spray [3]. Data was collected from a full-size steam atomized burner operating on residual fuel oil while measurements were taken in a large burner test facility, including flame temperatures, gas analysis, and radiation measurements [4]. Three flame conditions were examined, showing variations in temperature and emissivity and a mathematical model was used to analyze heat release distribution in the flame and from that they concluded that there was exponentially decay in volumetric heat release with the downstream distance (x) from the burner [4].

S. Win Lee et. al studied the combustion of soy methyl ester fuel blended with petroleum distillate fuel in an oil burner of residential-scale hot water boiler to deduce its potential of reducing the emission and it was found that it burned normally, didn't require any changes to the equipment, and reduced some emissions compared to regular oil. The downside was slightly higher carbon monoxide during cold starts [5]. Further research for testing integrity of combustion equipment and the long- term chemical and thermal stability of the biofuel blends is required [5]. Young Gun Go et. al examined the uneven air distribution in a boiler's windbox (air supply chamber) for multi-burner power plants by employing a scaled model to assess air velocity at each burner exit and compared it with computer simulations (CFD) to determine how to establish a more uniform flow pattern for optimal combustion and reported that uneven airflow can create unstable flames, increased pollutants, and poorer efficiency [6]. Study examined an industrial oil-burner/furnace system with two flames at varying excess air levels with experimental measurements included temperature, velocity, NOx, and CO inside the furnace [7]. Numerical modeling (CFD) using two combustion models showed discrepancies near the burner but better agreement downstream and NO levels were predicted well by the model [7].

Investigation on the excess air levels in boilers change depending on the firing rate was performed and it was found that excess air level increases significantly (30-80%) as the firing rate decreases [8]. It was reported that to have better control excess air which also impacted the boiler efficiency and frequently monitor and calibrate excess air levels through persistent maintenance or digital monitoring (O_2 trim) controls can be used to assess it [8]. A heavy-oil-fired burner was tested in a furnace with very hot air (1200 °C) with different atomizers and firing modes to reduce nitric oxide emissions and lower F_2 firing mode was reported the best for nitric oxide reduction and burner design simplification [9]. A comprehensive experimental program conducted on a model industrial burner to create a database of flame images for subsequent analysis and for this three methods were explored for flame identification such as feature extraction and analysis, self-organizing feature maps, and an adaptation of a speech recognition method [10]. These methods were tested for their success rate in identifying combustion regimes and estimating NOx emissions and based on the results, including testing in other combustion situations, these methods showed the potential for effective flame monitoring [10]. Computational Fluid Dynamics (CFD) analysis of a horizontal oil-fired air preheater's combustion chamber initially designed to operate with low excess air at 15%, the chamber experienced refractory overheating issues on its roof during start-up and it was discovered that the flame shape was short and wide, contributing to the overheating despite no flame impingement on the refractory wall [11]. At different configurations combustion performance was optimized and there was reduction in overheating for horizontal oil-fired air preheater's combustion chamber, concluding that increased air supply and strategic distribution between the main burner and bussle pipes proved operationally effective and economically feasible [11]. Study focused on the effect of physical and chemical properties of residual emissions reported that after monitoring emissions from a 432 GJ steam generator over three days, high combustion efficiency and the presence of fine aerosol containing sulfate coordinated to transition metals [12]. Gas chromatography-mass spectrometry analysis showed low levels of polycyclic aromatic hydrocarbons, with the majority of volatile organic gas emissions attributed to oxygenated compounds [12].

The researchers measured the temperature profiles and flame images inside the furnace to investigate how the axi-asymmetric conditions affected the flame shape and combustion efficiency and found that the flame shape was influenced by buoyancy and the location of the minimum flow rate in air distribution, and that the axi-asymmetric conditions had different impacts on the formation of incomplete combustibles and the overall combustion efficiency as combustion air was discharged less in the ascending region of the swirl flow, the flame shape was more deformed toward where the air was supplied less [13]. Afshin investigated the combustion of petrodiesel and various biodiesel blends (B100, B5, B10, and B20) in a semi-industrial boiler and evaluated the efficiency, exhaust emissions, and costs associated with each fuel [14]. Findings indicated that biodiesel blends, particularly B5, offered the efficiency comparable to petrodiesel with lower emissions and cost-based optimization approach identified optimal fuel blend and oxygen concentration for cost savings in boiler performance [14]. Another study that conducted experimental tests to determine optimal combustion conditions and emissions levels for soybean methyl ester, soybean oil, B5, and B20 blends and found that while pure biodiesel and vegetable oil are not economically feasible, B5 and B20 offer competitive performance and reduced total costs, with B5 emerging as the most favorable alternative fuel [15].

An expert system within Flame OP for flame data processing, enabling flame indexing and combustion stoichiometry inference and employed statistical analysis, shape factor, and probabilistic neural network algorithms for flame classification [16]. Initial testing at CTPALM Unit

1 showed promising results, indicating improved flame monitoring and combustion optimization and Further thorough testing under normal operating conditions is recommended, along with following the software recommendations for maintenance practices to enhance fuel efficiency and reduce pollutant emissions [16]. MHI conducted a detailed analysis of atomizers and swirlers, key components of burners, primarily through numerical methods and study confirmed a 38% reduction in particle size in spray tests and observed that the developed swirler remained intact even after a year of operation in real equipment [17]. Study measured the temperature, emissions, and combustor performance of WCO-LDO blends in a swirled oil burner and results showed that WCO-LDO blends had lower emissions and values than LDO, except for hydrocarbons and NOx [18]. WCO-LDO blends also had higher radial flame temperature and lower heat transfer to the combustor wall than LDO [18]. Study conducted on the geometry medication effects on NO_x emission and combustion instability in a heavy oil-fired swirl burner while using CFD simulations and 3D FEM analysis to predict the effects of different numbers of separation plates at the burner outlet. The results showed that more separation plates reduced NOx emission by over 100 mg/m^3, Six separation plates caused longitude pressure mode at 30 Hz in the boiler & 1D and 3D methods agreed on the negative growth rate region around 40 ms [19].

Comparison study on the effects of diesel fuel and palm oil biodiesel-diesel blend fuel on the flame characteristics and emissions of an oil burner showed that the blend fuel produced a larger, cooler, and more luminous flame than diesel fuel, with more soot particles and IR radiation and the blend fuel also reduced the NOx emission by more than half [20]. Investigation on the evaluation of the combustion of heavy fuel (HFO) and used motor (UMO) oils blends in a free-flames burner in an isothermal oven showed that UMO blends had higher heat transfer, combustion efficiency, and exergy balance than HFO and it was found that UMO blends could be used as fuel in free-flames combustion [21]. The researchers tested three different blends of bioethanol (10%, 15%, and 25%) and measured the flame shape, temperature, and emissions of each blend and found that bioethanol blends reduced CO, UH, NOx, and soot emissions by various percentages, but also lowered the flame and exhaust temperature compared to pure diesel [22]. Researchers applied the machine learning to classify flames in oil-fired burners and presented the method for selecting the most pertinent flame features from scanner signals to compute the flame index and gauge combustion stoichiometry in burners under specific conditions [23]. Using feature subset selection algorithms, redundant and noisy flame features are eliminated, reducing dimensionality and with probabilistic neural network employed for flame feature clustering demonstrated that only four key features (second principal component, autocorrelation sum, singular spectrum entropy, and aver- age period) were found to be sufficient for accurate flame classification (92.3% accuracy), aiding in burner combustion monitoring and optimization [23].

Key Findings:

- Research emphasizes swirl ratio as a crucial factor for simulating jet spread and entrainment.
- Investigation into biofuel blends in a boiler found B5 and B20 to be economically feasible with reduced emissions. Evaluation of soybean methyl ester, waste cooking oil, palm oil and biodiesel blends showed competitive performance and reduced costs compared to petrodiesel. Testing of bioethanol blends in burners showed reduced emissions but lower flame and exhaust temperatures compared to diesel. Evaluation of heavy fuel and used motor oil blends demonstrated higher heat transfer and combustion efficiency compared to conventional fuel
- Examining air distribution in a boiler's windbox highlighted the importance of uniform airflow for stable combustion. CFD analysis of an oil-fired air preheater identified improved combustion with increased air supply and strategic distribution.
- Flame shape and combustion efficiency in a furnace were affected by axi-asymmetric conditions, impacting flame formation and efficiency. Research on burner components demonstrated improved performance and reduced particle size in spray tests.
- CFD simulations and experimental tests on heavy oil-fired burners revealed reduced NOx emissions with optimized burner geometry. Machine learning applied to flame classification in oil-fired burners identified key features for accurate flame monitoring and optimization.

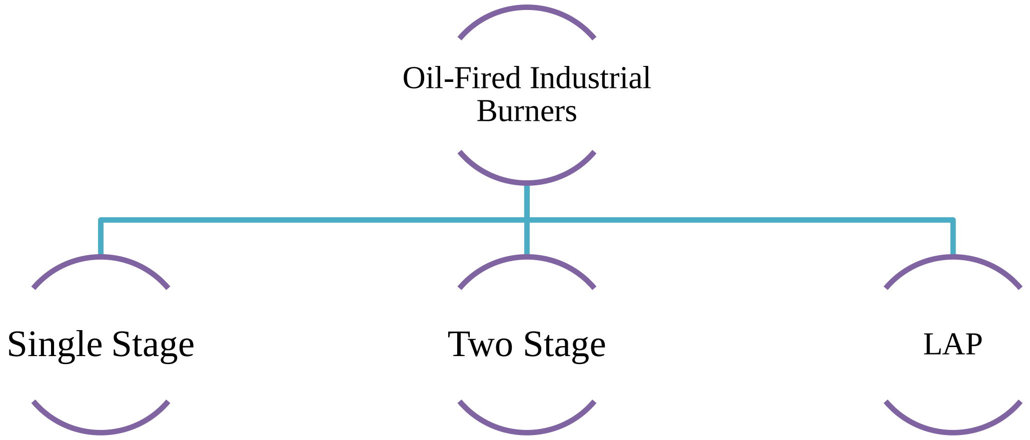
6. Industrial Visits done:

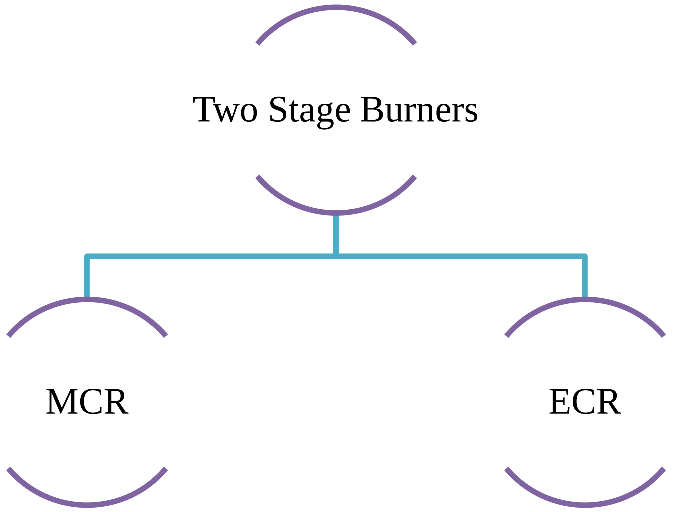
S.No.	Name	Location	Date of Visit
1.	Burners India	Mehsana, Gujrat	15/07/2024, 16/07/2024
2.	Ecotech Burners	Surat, Gujrat	17/07/2024
3.	Unitech Combustion	Ahmedabad, Gujrat	18/07/2024
4.	Flame India	Ahmedabad, Gujrat	18/07/2024
5.	Techno Therm Engineers	Ahmedabad, Gujrat	18/07/2024

6.1 Data collection

It was carried out using a structured questionnaire, designed to capture detailed information on various aspects of the manufacturing and usage of industrial oil-fired burners. The questionnaire sought to gather data on the types of burners manufactured, types of users, quality control practices, and the raw materials used in production.

- Types of Burners Available: The data revealed that manufacturers in the region produce a variety of burners, including Two-Stage Burners, MCR Modulating Burners, ECR Modulating Burners, and LAP Burners. Among these, LAP Burners are produced less frequently and are typically supplied on demand, specifically for furnace applications.





- User Types: The questionnaire helped identify different user categories, ranging from small-scale industries to large manufacturing units, each with varying requirements for burner specifications and quality standards.
- Quality Control Practices: Information was gathered on the types of quality control measures employed by manufacturers, revealing significant variation in practices, often influenced by the scale of operations and resource availability.
- Raw Materials: Data on the raw materials used highlighted a reliance on both local and imported components, with specific standards adhered to for materials and packaging, though not universally applied across all manufacturing processes.

6.2 Industrial Observations:

- Lack of Specific Standards: It was observed that there are no particular standards specifically followed for every oil-fired burner. Manufacturers largely rely on their internal guidelines or adopt practices based on imported burner designs.

- Unorganized Sector: The sector is predominantly unorganized, with almost no variability in manufacturing practices and quality control. Smaller manufacturers often lack the resources to implement comprehensive standards.
- Reliance on Imported Burners: Some manufacturers has reported that users prefer the imported burners, especially from European markets, due to the perceived superior quality and adherence to stringent international standards.
- Material and Packaging Compliance: For materials and packaging, manufacturers generally adhere to the existing BIS standards. However, these do not extend to the entire burner system but are limited to specific components.
- Emissions Testing: Emissions testing is not a regular practice among manufacturers. Tests are usually carried out only on demand. Otherwise, it is usually carried out by the users, who installed these burners in furnace or boilers, on the plant to fulfil the state board requirements.

7. International Standards

Information was collected on international standards governing industrial oil-fired burners. These standards provide comprehensive guidelines on:

- Emissions control and testing.
- Safety measures and user instructions.
  A range of international standards relevant to industrial oil-fired burners was identified for review. The selected standards will help benchmark Indian practices against global best practices and guide the development of comprehensive technical requirements tailored to the Indian industry. EN 298:2022 standard has been purchased for detailed study.

S.No.	Standard Name	Agency	Detail
1	ISO 23553-1:2022	ISO	Safety and control devices for oil burners and oil-burning appliances
2	EN 298:2022	EN	Automatic burner control systems for burners and appliances burning gaseous or liquid fuels
3	EN 267:2020	EN	Forced draught burners for liquid fuels
4	NFPA 31	NFPA	Standard for the Installation of Oil-Burning Equipment

5	EN 13611:2019	EN	Safety and control devices for burners and appliances burning gaseous and/or liquid fuels

8. Work which remains to be done under the project (for on-going project)

a) Engagement with Industry Users:

- Further visits are planned for various regions. A visit to Cheema Boilers (Mohali) has been confirmed, providing an opportunity to gain insights from a key player in the industry. Follow-ups will continue with potential users in Ludhiana who have yet to confirm their participation.

b) Manufacturer visits:

- Plan and execute visits to other manufacturers. Some in Maharashtra have been contacted and waiting for their response.

c) Additional Standards:

- Acquire and study the remaining selected international standards.
- The insights gained from these standards will be integrated to meet global requirements

S.No.	*Activities*	*Progress*					
1	Literature review	*Done*					
2	Visits		*Done*	*In-Progress*			
3	*Mid term review*			*In-Progress*			
4	Data Analysis			*In-Progress*			
5	Report submission						

9. Budget Utilization and Expenditure

S.No.	Project Head	Sanctioned Funds	Total Released Funds	Utilization	% Utilization
1.	Consumables	₹ 59390	₹ 16034	9346	
2.	Equipment	₹ 276737	₹ 0		
3.	Travel	₹ 300000	₹ 155720	64076	

4.	Overhead	₹ 200000	₹ 54000		

S.No.	Project Head	Item	Detail	Price	Remarks
1.	Consumables	International Standard	EN 298:2022	$ 106.89	-
2.					

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