Rajshahi University of Engineering & Technology

Department of Mechatronics Engineering

Course No: MTE 3100

Course Title: Industrial Training

A Report on **Industrial Training in Forbes Marshall** is submitted to the Department of Mechatronics Engineering, Rajshahi University of Engineering & Technology for fulfilling the course named "Industrial Training" for the degree of Bachelor of Science in Mechatronics Engineering.

Prepared By

Avik Md Emtiaz Arefin: 2008013

Md Raihanul Haque Rahi: 2008011

Md. Nazib Abrar: 2008026

Industrial Supervisor

Engr. Md. Jainal Abedin

Sr. Manager - Steam System & Control Instrumentation

Forbes Marshall Bangladesh

Rajshahi University of Engineering & Technology

Department of Mechatronics Engineering

Certificate

This is to certify that the report on "Industrial Training" by Avik Md Emtiaz Arefin, Md Raihanul Haque Rahi, Nazib Abrar, bearing Roll no 2008013, 2008011 & 2008026 respectively, has been carried out under my supervision in fulfilment of the requirements of the course named "Industrial Training" for the degree of Bachelor of Science in Mechatronics Engineering.

Supervised By

....

Md Manirul Islam
Assistant Professor
Department Of Mechatronics
Engineering Rajshahi University of
Engineering & Technology,
Rajshahi - 6204

Prepared By

. . . .
Avik Md Emtiaz Arefin
id: 2008013

. . . .
Md Raihanul Haque Rahi
id: 2008011

. . . .
Nazib Abrar
id: 2008026

Rajshahi University of Engineering & Technology

Department of Mechatronics Engineering

DECLARATION

We hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. We also declare that, as required by the appropriate rules and conduct, we have fully written this report based on truth and cited all activities and dutiesthat we undertook while on attachment. We therefore declare that this material is original.

Authors

....
Avik Md Emtiaz Arefin
id: 2008013

....
Md Raihanul Haque Rahi
id: 2008011

....
Nazib Abrar
id: 2008026

Acknowledgement

At first all praise to the Almighty Allah, the most merciful and beneficent, who has given us the strength, knowledge and ability to complete this report.

Authors express their deepest revere, heartiest gratitude and produce respect to their faculty supervisor **Md Manirul Islam**, Department of Mechatronics Engineering, Rajshahi University of Engineering & Technology, for his valuable guidance, continuous support, and constructive suggestions throughout the attachment period. His insightful comments and suggestions have been invaluable in shaping this report.

All the honorable teacher of Mechatronics Engineering Department, RUET, will forever remain the memories of the authors for their inspiration.

We would like to express our gratitude to our parents for their continuous support and encouragement throughout our academic journey. We would like to thank our industry supervisor, **Engineer Md. Jainal Abedin** (EEE, RUET-04), Manager-Steam System & Control Instrumentation of Forbes Marshall, for his guidance and support in ensuring the success of our attachment at Forbes Marshall Private Limited. We would also like to thank the staff at Renaissance Apparel Ltd. for their assistance and cooperation during our attachment. Finally, we would like to thank our friends and classmates for their support and encouragement throughout this journey.

Avik Md Emtiaz Arefin

id: 2008013

Md Raihanul Haque Rahi

id: 2008011

Nazib Abrar

id: 2008026

Rajshahi University of Engineering & Technology, Rajshahi - 6204

Date: December 3, 2024

Abstract

This book offers a comprehensive overview of Forbes Marshall, a global industrial engineering company specializing in steam engineering and control instrumentation. It covers the company's history, global operations, products, services, and social initiatives. The report delves into various aspects of steam engineering, including steam generation, distribution, and applications across different industries. Key topics explored include:

Detailed examination of boiler systems, types, components, and efficiency considerations Steam traps and control valves, their types and importance in steam distribution Flow meters and their applications in industrial processes Pressure regulating systems and their role in steam management Instrumentation and control engineering in process industries

The report also includes insights from an industry visit to a textile facility, highlighting practical applications of Forbes Marshall's technologies in real-world settings. It concludes with a discussion on the future scope for mechatronics graduates within the company. This document serves as a valuable resource for understanding industrial steam systems, control instrumentation, and Forbes Marshall's contributions to these fields.

Contents

List of Figures

1 CHAPTER 1: INDUSTRIAL TRAINING OVERVIEW

Industrial attachment represents a crucial bridge between academic theory and professional practice. this program immerses students in real-world industry settings that align with their field of study, particularly benefiting engineering students who rely heavily on practical applications. during the attachment, students work as trainees under experienced professionals, gaining valuable insights into company operations and employee roles. the program begins with careful industry selection, considering factors such as:

Company robustness and stability, available research opportunities, organizational culture alignment, training capacity and expertise

Trainers provide comprehensive orientation covering: Sector-specific information, detailed work plans, safety protocols, company objectives, operational rules and regulations

1.1 Core Program Elements

The industrial attachment program encompasses several key components that ensure comprehensive learning: training structure:

Guided tours of various sectors, hands-on involvement in production processes, direct observation of employee roles, practical application of theoretical knowledge

Professional development: Technical skill enhancement, communication ability improvement, problem-solving capability development, understanding of industry standards

1.2 Program Objectives

The industrial attachment program aims to achieve the following goals: Technical development:

Enhancement of technical proficiency, exposure to current industry technologies, understanding of practical applications, development of specialized skills

Professional growth: Improvement of communication abilities, development of collaborative skills, understanding of organizational dynamics, enhancement of work ethics

Academic integration: Connection of theory with practice, application of classroom knowledge, development of research capabilities, understanding of industry standards

Career preparation: Facilitation of career transitions, development of professional networks, understanding of industry requirements, enhancement of employability

1.3 Training Report Requirements

The industrial training report serves as a formal documentation of the attachment experience and must include: Documentation elements:

Detailed record of activities undertaken, analysis of learning outcomes, assessment of skill development, reflection on professional growth

Report Objectives: Formal documentation of experiences, self-assessment of performance, feedback provision to stakeholders, demonstration of professional readiness and support for future career opportunities

1.4 Significance of Industrial Training

Industrial training holds paramount importance in student development through:

Practical Application: Implementation of theoretical knowledge, development of technical expertise, enhancement of problem-solving abilities and understanding of real-world challenges

Professional Development: Exposure to workplace dynamics, development of professional networks, understanding of industry standards and enhancement of career prospects

Research and Innovation: Participation in industry projects, development of innovative solutions, contribution to ongoing research and understanding of industry challenges.

Career Enhancement: Improvement of employability, Development of professional skills, Understanding of career paths and Creation of industry connections.

This comprehensive program ensures students graduate with both theoretical knowledge and practical expertise, ready to contribute effectively to their chosen fields.

2 CHAPTER 2: FORBES MARSHALL

2.1 Acquaintance

Forbes Marshall is a leading provider of energy conservation and automation solutions. The company specializes in steam engineering and control instrumentation, offering a wide range of products and services to improve efficiency and productivity in various industries.[7]

2.2 History of Forbes Marshall

In 1926, J N Marshall & Co was set up as a trading company, supplying steam accessories to the thriving textile industry in Ahmedabad. This marked the beginning of a legacy.

In 1946, J N Marshall & Co entered into the distribution of products for the efficient use of steam for energy and formed a tie-up with Cochran for selling packaged boilers.

The first manufacturing unit was established in Kasarwadi, Pune in 1958.

In 1959, Spirax Marshall was incorporated for the manufacture of steam system products.

In 1962, Forbes Marshall entered into the control instrumentation business and formed strategic alliances with Cambridge Instruments UK and Polymetron, France for the manufacture of water quality analyzers.

In 1984, Krohne Marshall was incorporated for the manufacture of flow and level equipment in a joint venture with KROHNE Messtechnik, Germany. Forbes Marshall also formed an association with Shinkawa Electric Co, Japan for vibration monitoring equipment.

In 1985, Forbes Marshall launched a range of control valves and desuperheating stations in collaboration with ARCA Regler, Germany.

In 1986, the operations for the control instrumentation business moved to Pimpri, Pune.

In 1997, Forbes Marshall introduced consultancy services for the layout and detailed engineering of new process plants.

In 2006, an internationally certified Krohne Marshall flowmeter calibration rig, the second largest in Asia, was set up.

In 2007, Forbes Marshall CODEL, a joint venture between Forbes Marshall and CODEL International, UK, was incorporated for the manufacture of emission monitoring systems.

In 2008, Forbes Marshall made its first overseas investment in CODEL International, UK.

In 2009, the Forbes Marshall and VYNCKE NV, Belgium joint venture Forbes Vyncke was incorporated for the manufacture of biomass solid fuel-fired boilers.

In 2012, Forbes Solar was incorporated in a joint venture with Azur Earth GmBH, Germany for the manufacture of solar cogeneration combined heat and power systems.

In 2013, boiler manufacturing began at the Forbes Marshall campus under the Mega Project Scheme of the Government of Maharashtra at Chakan, Pune. This manufacturing facility is certified by the prestigious American Society Of Mechanical Engineer's "ASME 'U' Designator & Certificate" for manufacturing. NBIL has also certified the facility.

In 2015, Forbes Marshall acquired the entire foreign shareholding of its JV partner in the steam systems business.

In 2021, Forbes Marshall celebrated its 75th anniversary and set up a manufacturing facility in Singapore.

2.3 Vision and Mission

Figure 1: Vision and Misison of Forbes Marshall

2.4 Products and Services

1. Boilers and boiler efficiency
2. Steam systems
3. Valves
4. Flow and level meters
5. Condition monitoring systems
6. Automation
7. Steam and water analysis systems
8. Process analytics
9. Emission quality analyzers
10. Gauges
11. Compressed air efficiency
12. Services
13. Energy audits
14. Plant asset management
15. Compressed air audits
16. Vibration consultancy services
17. Design consultancy

2.5 Global Operations of Forbes Marshall

Forbes Marshall operates in multiple countries, with a strong presence in Asia, Europe, and the Americas. The company has manufacturing facilities, sales offices, and service centers worldwide, ensuring that it can meet the needs of its diverse customer base. Forbes Marshall's global operations are depicted in Figure 2.

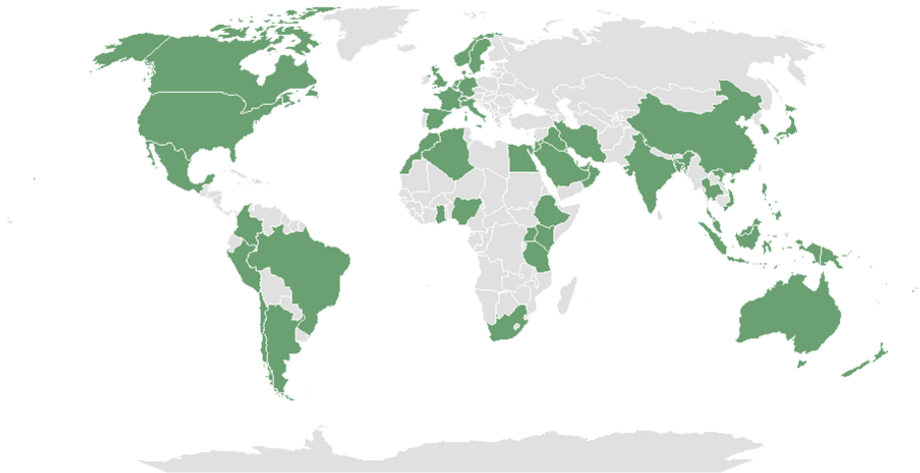


Figure 2: Countries of operation of Forbes Marshall

As of now, Forbes Marshall has established itself as a global leader in energy conservation and automation solutions. The company has a strong presence worldwide with 37 offices, 6 manufacturing units, and 18 distribution centers. This extensive network allows Forbes Marshall to effectively serve its diverse customer base.

To ensure excellent customer support, Forbes Marshall has a team of 500 dedicated sales and service engineers who work tirelessly to meet the needs of their 8,000 customers worldwide. The company values customer engagement and conducts 1,250 customer connects daily, fostering strong relationships and understanding their evolving requirements.

2.6 Research and Development

With a focus on continuous innovation, Forbes Marshall remains committed to research and development. The company's large R&D team is dedicated to developing new products and services that address the industry's future needs. By prioritizing energy and process optimization, Forbes Marshall aims to reduce energy consumption and make a positive impact on the environment.

2.7 Sustainability Initiatives

2.7.1 Energising Communities

Forbes Marshall is committed to giving back to the communities where it operates. As part of its corporate social responsibility initiatives, the company partners with local organizations that focus on education for children, skilling for youth, and mobilizing women through self-help groups. These initiatives aim to empower individuals and contribute to the long-term wellness of families by providing healthcare services.

2.7.2 Investing in a Better Future

In 2012, Forbes Marshall established the Forbes Foundation to invest in organizations and strategic social innovation projects in Maharashtra, India, and beyond its immediate geographic communities. The foundation focuses on addressing issues in education, building resilience in communities, and supporting good governance. By investing in future innovations, Forbes Marshall aims to collaboratively tackle pressing societal issues that are often unsupported.

2.7.3 Identifying Needs

Forbes Marshall actively engages with community members to identify their needs and work towards achieving a common goal of creating an equitable society.

2.7.4 Collaborating

The company collaborates with organizations and community members to co-design, monitor, and support solutions that address the identified needs. By working together, Forbes Marshall aims to create sustainable and impactful change within the community.

2.7.5 Catalyzing Change

Forbes Marshall strives to build awareness, provide perspective, and offer access to resources that can catalyze positive change within the community. Through its initiatives, the company has touched the lives of 150,000 individuals, impacted 35,000 people through its corporate social responsibility efforts, supported 50 NGOs through cohorts and incubators, reached 4,000 students, and economically empowered 3,000 women.

3 CHAPTER 3: STEAM ENGINEERING

3.1 What is Steam?

Steam is the gas formed when water passes from the liquid to the gaseous state. At the molecular level, this is when H_2O molecules manage to break free from the bonds (i.e. hydrogen bonds) keeping them together[8].

3.2 Types of Steam:

When water is heated to its boiling point, it transforms into steam. The temperature at which this transformation occurs is known as the boiling point. The boiling point of water is 100°C at atmospheric pressure. However, the boiling point of water changes with pressure. For example, at a pressure of 10 bar, the boiling point of water is 180°C. The relationship between pressure and temperature is illustrated in Figure 3.

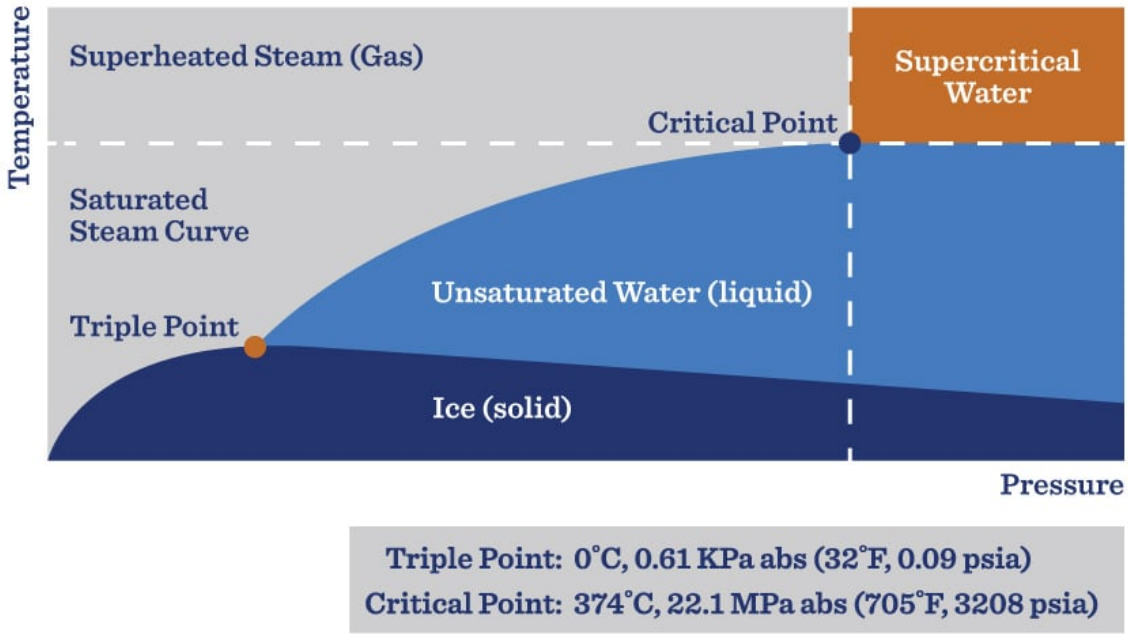


Figure 3: Pressure-Temperature Relationship of Water & Steam

Depending on the pressure, temperature, content of water different types of steam are produced. The most common types of steam are:

1. **Dry steam:** All its water molecules remain in the gaseous state. Hence, it's a trans-

parent gas[9].

2. Wet steam: A portion of its water molecules have given up their energy (latent heat) and condense to form tiny water droplets. Hence, these droplets make the steam look white and opaque[9].

3. Saturated Steam: - Application Area: Indirect Heating - Process Application. Saturated steam refers to steam that is completely dry and has the same temperature as the water from which it is formed. When water is boiled, its temperature increases until it reaches the boiling point at that pressure.

If additional heat is applied to the water, it converts to steam by absorbing the latent heat of evaporation. This steam, which exists at the same temperature as the water, is known as saturated steam. If saturated steam does not contain any water droplets, it is called dry saturated steam[10].

4. Vacuum Steam: As we know, at a specific pressure, saturated steam always exists at the boiling point of water at that pressure. Saturated steam exists at approximately 100°C at atmospheric pressure. If the pressure is reduced, the temperature at which saturated steam is formed also decreases. This steam, generated under sub-atmospheric pressure (vacuum conditions), is called vacuum steam. Vacuum steam has a temperature below 100°C[10].

5. Superheated Steam: - Application Area: Power Generation. If saturated steam is further heated, its temperature continues to rise above the boiling point. Such steam, with a temperature higher than the boiling point at that pressure, is referred to as superheated steam[10].

6. Clean Steam: - Application Area: Injection (Direct Heating). Clean steam is steam that is free from impurities. It is generated using a clean steam generator. Clean steam is used in the pharmaceutical industry for injection purposes. It is also used in the food industry where steam comes into direct contact with the food product[10].

3.3 Steam As a Source of Heat

Steam played a crucial role in the industrial revolution. However, in modern times, steam has been largely replaced by internal combustion engines and electricity as a power source.

Nowadays, steam is primarily recognized for its applications in heating, serving as both a **direct** and **indirect** source of heat.

The concept behind using steam for cooking is that when steam comes into direct contact with the food being heated, the latent heat of steam is directly transferred to the food, while the condensation of water droplets provides moisture.

In industrial processes, direct steam heating is commonly employed for cooking, sterilization, steam smothering, vulcanization, and other procedures.

On the other hand, indirect steam heating refers to processes where steam does not directly contact the product being heated. This method is widely utilized in industry due to its ability to provide rapid and uniform heating. Typically, a heat exchanger is used to heat the product in this method.

One advantage of indirect steam heating over direct steam heating is that the formation of water droplets during heating does not affect the product. As a result, steam can be utilized in various applications such as melting, drying, and boiling.

Indirect steam heating finds extensive use in processes related to the production of food and beverages, tires, paper, cardboard, fuels like gasoline, and pharmaceuticals, among others.

3.4 Parts of Steam Engineering

1. **Boiler**: A vital part of the system, the boiler heats water to produce steam. Usually, it includes a combustion chamber, furnace, tubes, and a number of temperature and pressure control devices.

2. **Steam turbine**: High-pressure steam's thermal energy is transformed into mechanical energy using a steam turbine. It has a rotor with blades that the high-velocity steam rotates, creating power.

3. **Condenser**: By cooling down the turbine's exhaust steam, the condenser is in charge of transforming it back into liquid form. By producing a vacuum that allows steam to be used more effectively.

4. **Piping System**: Steam is transported from the boiler to the target destination via a pipe system called steam piping. To provide a secure and effective flow of steam, it contains pipes, fittings, valves, and insulation.

5. **Pressure Reducing Valve**: A pressure-reducing valve is used to regulate and lower the pressure of steam from high levels to lower, safer levels appropriate for a variety of applications.

Figure 4: Pressure Reducing Valve

6. **Steam Separator**: A steam separator is used to remove water droplets and moisture from the steam, ensuring that only dry steam reaches the point of use. This helps in improving the efficiency and effectiveness of the steam system.

7. **Steam control valves**: These valves control steam flow to manage pressure and temperature. They are essential for preserving the best process conditions and guaranteeing safe operation.

8. **Steam Traps**: Steam traps are used to get rid of the condensate (water) that builds up in the steam system. They guarantee that heat is transferred effectively and help prevent water from building up in the pipes.

9. **Steam Condensate Recovery System**: Condensate (condensed steam) is collected and returned to the boiler by the steam condensate recovery system. It lowers operating expenses and aids in energy and water conservation.

10. **Safety Valves**: Vital parts that guard the system from overpressure include safety valves. In order to avoid catastrophic failures or equipment damage, they automatically expel excess steam.

11. **Instrumentation and controls:** To monitor and manage steam characteristics like temperature, pressure, flow rate, and level, steam engineering needs a variety of instruments and control systems. These consist of sensors, gauges for measuring pressure and temperature, and automation systems.

3.5 Application of Steam

There are many industry verticles wheere steam is used, below are some of the areas where steam is used extensively.

1. Textile industry
2. Food & Beverage industry
3. Ceremic industry
4. Sugar industry
5. Pulp industry
6. Dairy industry

4 CHAPTER 4: STEAM GENERATION & DISTRIBUTION

4.1 Steam Generation

Steam generation is the process of producing steam from water. The steam generation process involves several steps, from water intake to the final production of high-pressure steam. Below is an overview of the typical steam generation that is done through the application of heat:

1. Water Intake: The process begins with the intake of water from a natural source, such as a river, lake, or reservoir.

2. Water Treatment: In industrial application in order to ensure the efficient and safe operation of the steam generation system, the water must undergo treatment. The treatment may involve processes such as filtration, ion exchange, chemical dosing, and demineralization to reduce impurities such as suspended solids, dissolved minerals, and organic matter that could cause scaling, corrosion, or damage to the equipment.

3. Boiler Feedwater Pumping: After treatment, the water is pumped from the water source or the treated water storage tank to the boiler feedwater system. The feedwater system is responsible for supplying water to the boiler.

4. Boiler: The boiler is the central component of the steam generation process. It is a closed vessel where water is heated to generate steam. The heat required to convert water into steam is typically provided by burning fuels like coal, natural gas, oil, or through other heat sources like nuclear reactors, solar energy, or waste heat from other processes.

5. Combustion and Heat Transfer: In the boiler, the fuel is burned, releasing energy in the form of heat. This heat energy is transferred to the water in the boiler's walls and tubes. The water absorbs the heat and begins to boil, producing steam. The process of water turning into steam is accompanied by a phase change, and the steam produced is saturated steam, which contains both water vapor and liquid water.

6. Steam Separation: Once the steam is formed in the boiler, it is separated from any remaining water droplets. This separation is achieved through devices like steam drums or separators. The dry steam is then directed to the steam distribution system for further use.

Figure 5: Moisture Separator

7. Superheating: The separated steam is directed to the superheater, where its temperature is increased, enhancing its thermal efficiency and energy content.

8. Steam Distribution: The steam is distributed through a network of pipes to various points of use within the industrial facility. These points of use can include turbines for power generation, process heating equipment, sterilization units, and more.

9. Condensation and Return: After performing its intended work, the steam loses its energy and condenses back into water. The condensate is collected and returned to the boiler feedwater system, completing the cycle.

Regular maintenance, water treatment, and optimization of the steam generation process contribute to increased system efficiency and cost-effectiveness. Fuel used for generating steam accounts for about 50% of total utility cost. Scarcity of Natural Gas, increase in cost of fuel and hence the steam costs. Effective steam management plays a role in various field like: Fuel Savings - which can be leveraged for cost competitiveness. Reducing fuel cost is the only route to cut costs substantially. Product Quality – Maintaining proper steam parameters ensures product quality, e.g. uniform color, print, brightness etc. Productivity -

Improving batch timings on equipment.

4.2 Components of a Steam Generator

There are several key components in a steam generator that work together to produce steam efficiently and safely. These components include:

1. Boiler Drum: The boiler drum serves as a reservoir for water and steam. It also separates the steam from the water, ensuring that only steam is sent to the superheater and turbines.

2. Furnace: This is where the fuel is burned to generate heat. The furnace is designed to ensure optimal combustion conditions.

3. Superheater: This component heats the steam produced in the boiler drum to a higher temperature, increasing its energy content and efficiency.

4. Economizer: Positioned after the superheater, the economizer preheats the water entering the boiler using residual heat from the flue gases.

5. Air Preheater: It preheats the air entering the furnace, improving combustion efficiency and reducing fuel consumption.

6. Feedwater Pump: This pump ensures a constant supply of water to the boiler, maintaining the required pressure and flow rate.

4.3 Types of Steam Generators

Few types of steam generators are used in industries. They are:

1. Fire-Tube Boilers: In these boilers, hot gases from the furnace pass through tubes submerged in water. The heat from the gases is transferred to the water, generating steam. Fire-tube boilers are generally used for low-pressure applications.

2. Water-Tube Boilers: In water-tube type boilers, water circulates through tubes heated externally by the furnace. These boilers can generate steam at higher pressures and temperatures, making them suitable for power generation and high-pressure industrial processes.

3. Electric Boilers: These boilers use electrical energy to heat water and produce steam. They are typically used in smaller applications where electricity is readily available and emissions must be minimized.

4. Once-Through Boilers: These boilers do not have a drum. Instead, water flows continuously through the tubes, absorbing heat and transforming into steam. Once-through boilers are highly efficient and respond quickly to changes in demand.

Figure 6: Boiler at Renaissance Apparel Ltd.

Boilers will be discussed in detail in the boilers chapter.

4.4 Technologies and Innovations

Several technologies and innovations have been developed to improve the efficiency and sustainability of steam generation systems. These include:

1. Combined Heat and Power (CHP): Also known as cogeneration, CHP systems simultaneously produce electricity and useful heat from the same energy source, improving overall efficiency.

2. Advanced Boiler Materials: The development of high-temperature alloys and coatings enhances boiler efficiency and longevity, allowing for higher operating pressures and temperatures.

3. Waste Heat Recovery: Systems that capture and reuse waste heat from industrial processes or exhaust gases improve overall energy efficiency and reduce fuel consumption.

4. Supercritical and Ultra-Supercritical Boilers: These advanced boiler designs operate at pressures and temperatures above the critical point of water, resulting in higher thermal efficiencies and reduced emissions.

4.5 Accessories for Steam Distribution System

4.5.1 Strainer

A strainer valve is a type of pipe fitting used to purify, filter, or separate liquid from solids while still allowing the liquid to flow through it. Most often, strain is employed to remove steam from a stream of mixed liquids.

4.5.2 Pipe

A pipe transports pressurized steam from a boiler to the functional components, like the steam engine or turbine. Such piping generally incorporates valves to control the flow of the steam or to stop it entirely.

4.5.3 Moisture Separator

Air with moisture is sent from the cooler to the separator. The is twirled around in air. As it is accelerated through it, a diffuser propels the separator's body. rotating force causes water droplets to hit the separator wall, where they are then gravitationally collected.

4.5.4 Thermodynamic Trap

The thermodynamic trap is a steam trap that operates simply but is exceptionally long-lasting. The trap works by utilizing the dynamic action of flash steam as it passes through the trap.

4.5.5 Ball Float Trap

Traps having a wide range of uses. Condensate loads of any weight can be efficiently handled. little in scale. Because of the high and continuous discharge capacity, maximum heat transfer is guaranteed. A ball float steam trap is the best solution for draining plants with automatic temperature control.

4.5.6 PRV

In spite of changes in demand and/or upstream (inlet) water pressure, a pressure-reducing valve (PRV) is an automatic control valve created to reduce higher unregulated input pressure to a constant, reduced downstream (outlet) pressure.

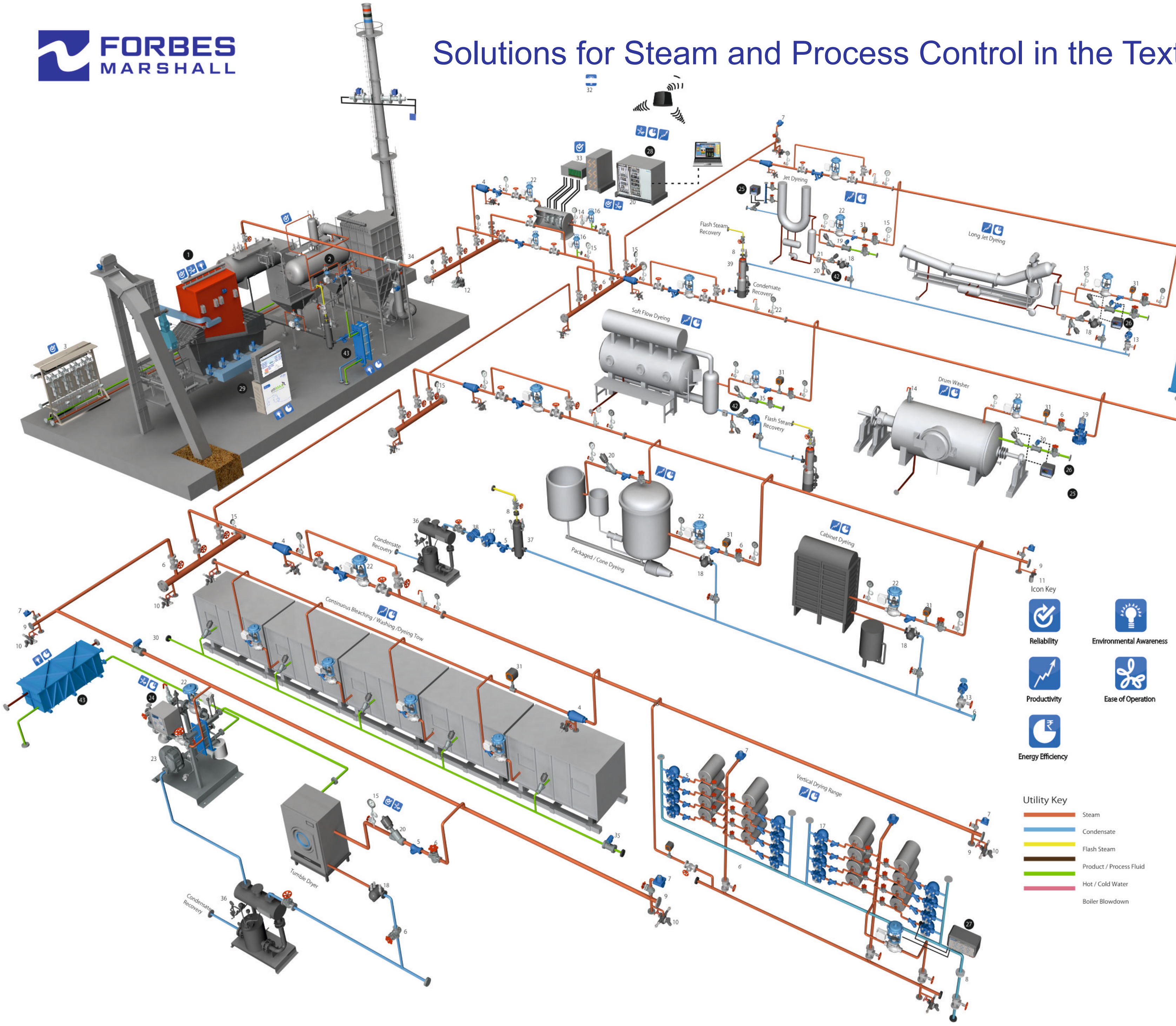
4.5.7 Safety Valve

Steam systems typically employ safety valves for downstream pressure-reduction devices and boiler overpressure protection, among other uses. Safety valves are used in process operations to prevent product damage due to excessive pressure even though their primary purpose is to ensure safety.

4.5.8 Deaerator Head

The current boiler feed water tank now has a Deaerator Head addition that has mixing nozzles for new make-up water, flash steam, and plant area condensate. The stainless-steel perforated mixing pipe is immersed in feed water. This makes it possible for the feed water tank to uniformly mix hot condensate, flash steam, and make-up water.

Solutions for Steam and Process Control in the Textile Industry



Product Key

Steam Generation:

	Product Family	Model Name
1	Biomass Boilers	Forbes Vyncke
2	Pressurized Deaerators	Oxycal
3	Steam & Water Analysis System	SWAS

Steam Distribution:

	Product Family	Model Name
4	Forbes Marshal Moisture Separator	FMSEP34, FMSEP54
5	Forbes Marshall Cast Strainers	FMSTR34, FMSTR54
6	Piston Valves	PSVAL
7	Forbes Marshall Air Vent	FMAV53
8	Forbes Marshall Spring Loaded Disc Check Valve	FMDCV, FMDCVANSI
9	Forbes Marshall Pipeline Connector Series	FMPC50, FMPC51, FMPC52, FMPC53
10	Forbes Marshall Universal Thermodynamic Trap	FMTD64-U
11	Forbes Marshall Universal Inverted Bucket Trap	FMBT50-U
12	Compact Module - Thermodynamic Trap	CMTD42M-F, CMTD62M-S,CMTD62M-F CMTD250M
13	Forbes Marshall Air Eliminators	FMAE31 , FMAE53
14	Forbes Marshall Safety Relief Valve	FMSRV, VSR series
15	FM Pressure Gauges	PG
16	DeSuperheater	Variable Nozzle

Process Control Efficiency:

	Product Family	Model Name
17	Single Orifice Float Trap	SOFT31, SOFT53
18	Compact Module - Two Orifice Float Trap	CMTOFT
19	Forbes Marshall Pilot Operated Pressure Reducing Valve	FMPRV41, FMPRV53, DSPRV41
20	Forbes Marshall Piston Actuated Valves	FMPAV
21	Forbes Marshall Sensor Chamber	SC31 , SC53
22	Forbes Marshall Control Valves	Ecotrol series
23	Steam Operated Pumping Trap	SOPT
24	HeatMax	HEATMAX
25	Level Control System	BM26
26	Liquor Control System	Optiflux 4000, FMPAV
27	Moisture Control System	--
28	Distributed Control Systems	Microcon

Metering and Monitoring Systems:

	Product Family	Model Name
29	Boiler Efficiency Monitoring System	Effimax 500,1000,2000, 3000, 4000, Xmax
30	Vortex Steam Flowmeter	Flowirl 8700, Accuflow
31	Vortex Steam Flowmeter	SteaMon
32	Opacity Monitoring	DCEM2100
33	Vibration Monitoring System	Kenjin KJ-2000
34	Orifice type Steam Flowmeter	Orifice steam flowmeter
35	Electromagnetic Meters	Optiflux 4000, Aquamag

Condensate & Flash Steam Recovery System:

	Product Family	Model Name
36	Pressure Powered Pump Packaged Unit	PPPPU-C, PPPPU, MV55
37	Forbes Marshall Flash Vessel	FMFV
38	Forbes Marshall View Glass	VU10, VU30, VU50
39	Flash Jet Pump	FJP
40	Thermocompressor Systems	TC Series
41	Condensate Contamination Detection System	CCDS-C, CCDS-PC
42	Utility Automation System	UAM

Heat Recovery Solutions:

	Product Family	Model Name
43	Heat Recovery systems	BHRS, VHRS, WHRS , DHF

5 CHAPTER 5: PRODUCTION

5.1 Overview:

The production process using Forbes Marshall components at Renaissance Apparel is a comprehensive sequence of operations that transforms raw knit fabric into finished dyed textile products. The system requires of a steam distribution system, boilers from Forbes Marshall. The facility operates 22 hours per day across three shifts, maintaining a production capacity of 30 tons per day (20 tons in Phase 1 and an additional 10 tons in Phase 2).

In the production section there is Dyeing, Knitting, Printing and Washing. There was a soft flow machine for dyeing which produces 30 tons of products in a day. There was a Slitting machine to make the round fabric into an open form. Then there was a stenter machine for the dryer and heat setting of the fabric. Thermic Oil used for stenter. There was a Compacting machine as well for fabric shrinkage control. There were also knitting machines producing 25 tons of products in a day. Fabric made in a round shape here. This fabric is called Greig Fabric. The printing machine was screen print type and 50 tons of products can be printed per day. There were several washing machines whose capacity was 2000 per day.[11]

5.2 Knitting Machine:

The production journey begins with knitting, where yarns are interlaced to create fabric. These are on the second floor of the factory of the production line. Mayer & Cie Circular Knitting Machines are employed for this stage.

5.2.1 Description:

Knitting machines come in various types, including flatbed, circular, and warp knitting machines. They consist of a needle bed, yarn feeders, carriage or cam system, and controls for adjusting stitch size and pattern.

Figure 8: Knitting Machine

Figure 9: Knitting Machine Close Up

5.2.2 Functionality:

1. Yarn Feeding: Yarn is fed into the machine from multiple feeders or cones, depending on the type of knitting machine.

2. Stitch Formation: Needles or hooks on the machine interlock the yarn to form loops or stitches, creating the fabric.

3. Fabric Formation: The carriage or cam system moves across the needle bed, manipulating the needles to form rows of stitches and build up the fabric.

4. Control: Knitting machines may have controls for adjusting stitch size, tension, and

pattern to create different textures, designs, and structures.

5.2.3 Advantages:

1. Versatility: Knitting machines can produce a wide range of fabrics, including jerseys, rib knits, and jacquards, with various textures, patterns, and thicknesses.

2. Efficiency: Knitting machines can achieve high production speeds, making them suitable for mass production of knitted garments, textiles, and accessories.

3. Customization: Knitting machines offer flexibility in design and customization, allowing for the creation of unique and personalized knitted products.

5.2.4 Disadvantages:

1. Complexity: Operating and maintaining knitting machines require specialized skills and knowledge. Troubleshooting and repairing technical issues can be challenging.

2. Cost: Knitting machines can be expensive to purchase and maintain, especially advanced models with computerized controls and features.

3. Fabric Limitations: Knitting machines may have limitations in terms of fabric width, gauge, and complexity, restricting the types of fabrics and designs that can be produced.

5.3 Dyeing Machine:[1]

The greige fabric proceeds to the dyeing stage. Fongs Soft Flow Dyeing Machines are used to achieve gentle and uniform dyeing, capable of handling up to 30 tons of fabric daily. Machines Used: Fongs Soft Flow Dyeing Machines (Model: THEN Airflow® Synergy 8).

It is a textile processing device used in the dyeing of fabrics, primarily made from natural or synthetic fibers.

Figure 10: Dyeing Machine

Figure 11: Dyeing Machine 2

5.3.1 Description:

These machines are designed to provide a gentle and uniform dyeing process for delicate fabrics, ensuring minimal damage or creasing. They operate by circulating a dye liquor through the fabric in a controlled manner, allowing for even penetration of the dye solution into the fibers.

5.3.2 Functionality:

1. Fabric Loading: Fabrics are loaded into the dyeing machine, either in loose form or on perforated rollers, to ensure even dye distribution.

2. Dye Liquor Circulation: The dye liquor, consisting of water, dye, and auxiliary chemicals, is circulated through the fabric using a combination of pumps, nozzles, and a specially designed flow system.

3. Temperature and Pressure Control: Soft flow dyeing machines maintain precise control over temperature and pressure parameters to ensure optimal dyeing conditions for different types of fabrics and dyes.

4. Dyeing Cycle: The dyeing process typically involves multiple cycles of dyeing, rinsing, and draining to achieve the desired color depth and uniformity.

5. Versatility: Soft flow dyeing machines are suitable for a wide range of fabrics, including cotton, polyester, wool, and blends, making them versatile for various textile applications.

5.4 Slitting Machine:

After dyeing, the tubular fabric undergoes slitting to convert it into an open-width form using the Stanta Cut Slitting Machine. It cuts large rolls or coils of material into narrower strips.

5.4.1 Description:

Machine Used: Stanta Cut Slitting Machine.

Specifications: Brand Name: Stanta Cut Origin: Switzerland Power Consumption: 10 kW Speed: 60–70 m/min

1. Unwinder: Where the large roll or coil of material is loaded for processing.

2. Slitting knives or blades: These are used to cut the material into narrower strips.

Figure 12: Slitting Machine

3. Rewinder: Where the slit strips are rewound into smaller coils or spools.

4. Tension control system: Ensures proper tension is maintained on the material throughout the slitting process.

5. Control panel: Allows operators to adjust settings such as cutting width, speed, and tension.

5.4.2 Functionality:

1. Material feeding: The roll or coil of material is loaded onto the unwinder and fed into the slitting machine.

2. Slitting: The material passes through the slitting knives or blades, which cut it into narrower strips. The number of blades and their spacing determine the width of the strips.

3. Rewinding: The slit strips are rewound onto individual cores or spools on the rewinder.
4. Quality control: Operators monitor the slitting process to ensure the strips are cut accurately and without defects.

5.5 Stenter Machine:[2]

Figure 13: Stenter at Renaissance Apparel Ltd

Figure 14: Stenter Machine

The open-width fabric is thn subjected to stentering in the stentering machine, Dilmenler Stenter Machine, Model DLN-2100, involving drying and heat-setting to stabilize fabric dimensions.

5.5.1 Description:

A stenter machine typically consists of the following main components:

1. Entry and exit sections: Where the fabric enters and exits the machine.
2. Tentering chains: Continuous chains with clips or pins that hold the fabric edges taut and straight throughout the process.
3. Frame: Supports the tentering chains and other components of the machine.
4. Heating chambers: Where the fabric is subjected to heat to remove moisture and apply treatments or finishes.
5. Air circulation system: Ensures even distribution of heat and airflow across the fabric.

5.5.2 Functionality:

1. Fabric feeding: The fabric is fed into the stenter machine from a roll or other source.
2. Tentering: The fabric is held taut and straight by the tentering chains, which stretch it to the desired width.
3. Heat treatment: The fabric passes through heating chambers, where it is subjected to controlled temperatures to remove moisture and apply treatments such as drying, curing, or coating.
4. Cooling: After heat treatment, the fabric may pass through cooling chambers to reduce its temperature and stabilize the applied treatments.
5. Finishing: Additional processes such as brushing, shearing, or calendering may be performed to achieve specific surface textures or finishes.
6. Fabric winding: The finished fabric is wound onto a roll or other suitable form for further processing or packaging.

5.6 Compacting Machine:

The fabric moves to compacting, where shrinkage is reduced, and dimensional stability is enhanced. It is particularly used for knitted fabrics.

5.6.1 Description:

Compacting machine used in Renaissance consisted of the following main components:

1. Entry and exit sections: Where the fabric enters and exits the machine.

Figure 15: Compacting Machine.

1. Compacting rollers: These rollers compress the fabric, reducing its thickness and improving its dimensional stability.

2. Tension control system: Ensures proper tension is maintained on the fabric throughout the compacting process.

3. Heating system (optional): Some compacting machines may include a heating system to soften the fabric fibers, allowing for better compression.

5.6.2 Functionality:

1. Fabric feeding: The fabric is fed into the compacting machine from a roll or other source.

2. Compression: As the fabric passes through the compacting rollers, it is subjected to pressure, which compresses the fibers and reduces the thickness of the fabric.

3. Heat treatment (optional): In some cases, the fabric may be subjected to heat during the compacting process to soften the fibers and enhance the compression effect.

4. Cooling: After compression, the fabric may pass through cooling chambers to reduce its temperature and stabilize its properties.

5. Fabric winding: The compacted fabric is wound onto a roll or other suitable form for further processing or packaging.

5.7 Printing Machine:

The treated fabric undergoes printing using the Zimmer Rotary Screen Printing Machine (Model: Magnoprint), capable of processing up to 50 tons of fabric daily.

Figure 16: Printing Machine

5.7.1 Description:

The machines in Renaissance consists of the following main components:

1. Screen frame: A frame made of wood, aluminum, or steel, with a stretched mesh screen tightly attached.

2. Squeegee: A rubber or plastic blade used to push ink through the mesh screen onto the substrate.
3. Printing bed: The surface where the substrate is placed for printing.
4. Registration system: Guides or stops to ensure accurate alignment of the substrate for multiple-color printing.
5. Ink reservoir: A container for holding the printing ink, typically located above the screen frame.

5.7.2 Specifications:

Printing Width: Up to 3200 mm Number of Colors: Up to 12 Speed: Up to 120 m/min

5.7.3 Functionality:

1. Preparation: The design to be printed is first transferred onto a stencil or mesh screen using a photographic process or manually applied emulsion.
2. Setup: The substrate is placed onto the printing bed, and the screen frame is positioned over it.
3. Ink application: Ink is poured onto the screen frame, and a squeegee is used to spread the ink evenly across the screen.
4. Printing: The squeegee is then pulled across the screen, forcing the ink through the mesh and onto the substrate, creating the desired design or pattern.
5. Curing: After printing, the substrate may pass through a curing or drying process, typically involving heat or UV light, to set the ink and ensure durability.

5.8 Washing Machine:

A washing machine is a textile processing device used to clean and finish fabrics after dyeing, printing, or other treatments.

Machine Used: Yilmak Washing Machine (Model: HNS 405)

Figure 17: Washing at Renaissance Apparel Ltd

5.8.1 Specifications:

Load Capacity: 500 kg per batch Steam Utilization: Steam Pressure: 8.5 - 10.5 BarG Steam heats the wash water to temperatures up to 98°C for efficient cleaning.

6 CHAPTER 6: GENERATOR [3]

Figure 18: Generator machine

Generators play a crucial role in the textile industry by providing a reliable uninterrupted source of power. At the textile manufacturing facility, the significance of reliable power sources in maintaining seamless operations was observed.

The generator machine shown in Figure 18 is the gas-powered generator J420 LEANDX, installed on the second floor of the energy building.

The generator offers an electrical output between 1,411 kW and 1,562 kW and a thermal output of 1,422 kW to 1,906 kW. Operating within a voltage range of 480V to 13.8kV, it achieves an electrical efficiency of up to 44.0% and a thermal efficiency of up to 50.5%. Such specifications make it well-suited to meet the high energy demands of the facility.

Figure 19: Gas powered generator J420 LEANDX

7 CHAPTER 7: BOILERS

7.1 Acquaintance

Boilers are integral components of modern industrial processes and residential heating systems, designed to convert water into steam or hot water using various fuel sources such as natural gas, oil, coal, or electricity. This thermal energy is then utilized for heating, power generation, and a multitude of other applications. Having evolved from simple fire-tube designs to the advanced and efficient water-tube and electric boilers of today, boilers play a crucial role in multiple sectors, including manufacturing, power generation, and food processing. Their significance lies in their ability to provide consistent and reliable heat and steam, essential for numerous industrial processes. Modern boilers are engineered for greater efficiency, environmental friendliness, and safety, incorporating technologies like condensing capabilities to recover heat from exhaust gases and sophisticated control systems for optimal operation and safety. Understanding the various types of boilers, their components, and operating principles is vital for anyone involved in their maintenance, operation, or design. This report explores the different classifications of boilers, their working mechanisms, and the latest advancements in boiler technology, highlighting their critical role in contemporary industry and daily life.

Figure 20: Boiler

7.2 Types of Boilers [4]

Boilers can be classified into various categories based on different criteria. Below is a detailed overview of the primary types:

7.2.1 Based on the position of water and hot gases

1. **Fire Tube Boiler**: In this type, hot gases pass through tubes surrounded by water.

2. **Water Tube Boiler**: Here, water flows through tubes that are heated by external hot gases.

7.2.2 Based on the position

1. **External Fired Boiler**: The furnace is outside the boiler shell.

2. **Internally Fired Boiler**: The furnace is inside the boiler shell.

7.2.3 Based on Axis

1. **Horizontal Boiler**: These boilers have a horizontal axis.

2. **Vertical Boiler**: These boilers have a vertical axis.

7.2.4 Based on Pressure

1. **Low-Pressure Boiler**: Operates at lower pressures, typically below 15 psi.

2. **High-Pressure Boiler**: Operates at pressures above 15 psi.

7.2.5 Based on the Furnace

1. **Single Furnace Boiler**: Contains one furnace.

2. **Dual Furnace Boiler**: Contains two furnaces.

7.2.6 Based on the Method of Circulation

1. **Natural Circulation Boiler**: Water circulates naturally due to convection currents.

2. **Forced Circulation Boiler**: Water circulation is forced by a pump.

7.2.7 Based on Fuel Burning

1. **Solid Fuel-Fired Boiler**: Uses solid fuels like coal or wood.

2. **Oil and Gas Fired Boiler**: Uses oil or gas as fuel.

3. **Dual Fired Boiler**: Can use both oil and gas.

4. **Exhaust Gas Boiler**: Primarily uses the waste heat from exhaust gases, making them a unique category in terms of fuel usage.

7.2.8 Based on the Furnace

1. **Single Furnace Boiler**: Contains one furnace.

2. **Dual Furnace Boiler**: Contains two furnaces.

Fire-tube Boilers: Fire-tube boilers operate by passing hot gases produced from fuel combustion through tubes that are submerged in water. The heat from these gases transfers to the water, generating steam. These boilers are valued for their straightforward design and reliability, making them suitable for various heating applications.

Water-Tube Boilers: In water-tube boilers, water circulates within the tubes, and these tubes are heated externally by hot gases from the combustion process. This setup allows for higher efficiency and the ability to operate at higher pressures, making water-tube boilers a common choice for power generation and industrial processes.

Electric Boilers: Electric boilers utilize electricity as their heat source. They contain electric resistance elements to heat the water, making them compact and easy to install. These boilers are often found in residential and commercial settings where traditional fuel sources might not be feasible.

Combi Boilers: Combination boilers, or combi boilers, are designed to provide both space heating and hot water from a single unit. These boilers are especially popular in residential settings due to their ability to supply hot water on demand, eliminating the need for a separate water heater.

Figure 21: Electric Boiler

7.3 Components of a Boiler

Boilers are complex systems composed of several key components, each serving a specific function to ensure efficient and safe operation. Below is a detailed description of these components:

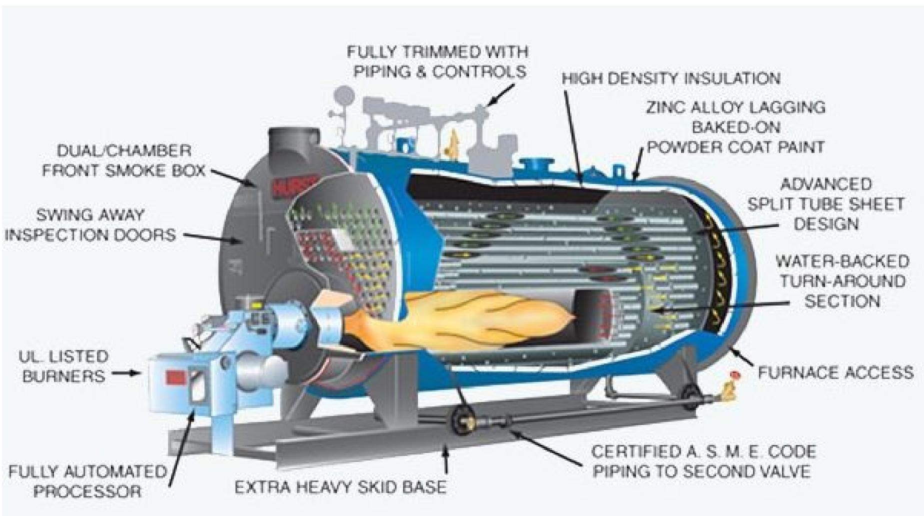


Figure 22: Components of a Boiler

1. **Furnace Tube**

   The furnace tube is where the fuel combustion occurs, generating the necessary heat for the boiler's operation.

2. **Tubes (2nd Pass)**

   These tubes facilitate the second pass of flue gases, transferring heat to the water as the gases move through the boiler.

3. **Tubes (3rd Pass)**

   These tubes enable the third pass of flue gases, ensuring maximum heat transfer and efficiency.

4. **Combustion Chamber**

   The combustion chamber is where the fuel and air mixture is burned, releasing heat energy. It is designed to facilitate efficient combustion and may include features such as baffles or refractory materials to optimize heat transfer.

5. **Front Smoke Box**

   The front smoke box collects flue gases from the front end of the boiler, directing them through the system for further heat exchange.

6. **Rear Outlet Box**

   The rear outlet box collects and directs flue gases out of the boiler at the rear end, aiding in efficient gas flow and heat transfer.

7. **Sight Glass**

   A sight glass allows operators to monitor the water level inside the boiler, ensuring it remains within safe and operational limits.

8. **Safety Valve**

   The safety valve prevents overpressure by releasing steam if the pressure exceeds safe limits, ensuring the boiler operates safely.

9. **Crown Valve**

   The crown valve is a high-pressure steam valve situated at the top of the boiler, controlling the release of steam.

10. **Feed Check Valve**

    This valve regulates the flow of feedwater into the boiler and prevents backflow, maintaining the proper water level.

11. **Level Controls [12]**

    Level controls maintain the correct water level within the boiler, ensuring efficient operation and preventing damage due to low water levels.

12. **Manhole**

    The manhole provides access to the boiler's interior for inspection and maintenance, allowing for regular checks and servicing.

13. **Spare**

    Reserved for future use or additional components as needed for specific applications.

14. **Feed Pump**

    The feed pump supplies feedwater to the boiler, ensuring a consistent water level and maintaining operational efficiency.

15. **Control Panel**

    The control panel houses the controls and monitoring instruments for the boiler's operation, allowing operators to manage and adjust the system as needed.

16. **Burner**

    The burner is responsible for the combustion of fuel (such as gas, oil, or coal) in the boiler. It mixes the fuel with air and ignites it to generate heat. The burner's design and control system plays a crucial role in achieving efficient and clean combustion. It must atomize the fuel, supply the correct quantity of air, properly mix the fuel and air, and maintain the temperature required for ignition.

17. **FD Fan (Forced Draft Fan)**

    The FD fan provides air for combustion and maintains proper draft within the boiler, ensuring efficient fuel burning.

18. **Fan Inlet Silencer**

    The fan inlet silencer reduces noise from the forced draft fan inlet, contributing to a quieter operation.

7.3.1 Combustion Chamber

The combustion chamber is a critical component where the fuel and air mixture is burned to release heat energy necessary for the boiler's operation. The design of the combustion chamber can vary significantly depending on the type of boiler and the fuel used. Common shapes include cylindrical, rectangular, or conical configurations.

Key Aspects of the Combustion Chamber:

1. **Shape and Design:** The shape and design influence the efficiency of combustion and heat transfer. Cylindrical shapes are common in many industrial boilers due to their ability to withstand high pressures. Rectangular designs might be used in large utility boilers to accommodate more extensive heat transfer surfaces.

2. **Refractory Materials:** These are heat-resistant materials that line the walls of the combustion chamber. Refractory materials like firebrick, castable refractories, and ceramic fibers insulate the chamber, protect surrounding boiler components from excessive heat, and reflect heat back into the chamber to enhance combustion efficiency.

3. **Baffles and Flame Holders:** These devices are installed within the combustion chamber to create turbulence, promoting better mixing of the fuel and air. Proper mixing ensures complete combustion, which increases efficiency and reduces emissions. Baffles and flame holders also help stabilize the flame within the chamber.

4. **Burner Mounting:** The burner introduces and mixes fuel with air. Its precise location within the combustion chamber ensures proper fuel dispersion and flame stability, which is crucial for efficient combustion and heat generation.

5. **Heat Transfer Optimization:** The combustion chamber is designed to maximize heat transfer from the burning fuel to the surrounding heat exchanger surfaces. Efficient design ensures that the maximum amount of heat is absorbed by the water or steam, improving overall boiler efficiency.

6. **Combustion Air Supply:** Adequate air supply is essential for complete combustion. The combustion chamber receives preheated air to enhance combustion efficiency and reduce energy losses. The preheated air also helps in maintaining a stable flame.

7. **Exhaust Gas Path:** After combustion, the exhaust gases need to be efficiently removed from the combustion chamber. This path typically leads to a flue or chimney, ensuring that gases are safely expelled to the outside environment. Proper design of the exhaust path minimizes heat loss and enhances boiler efficiency.

7.3.2 Heat Exchanger

The heat exchanger is a core component of the boiler, responsible for transferring heat from the combustion gases to the water or steam. Its design and construction are crucial for the boiler's overall efficiency. Key Aspects of the Heat Exchanger:

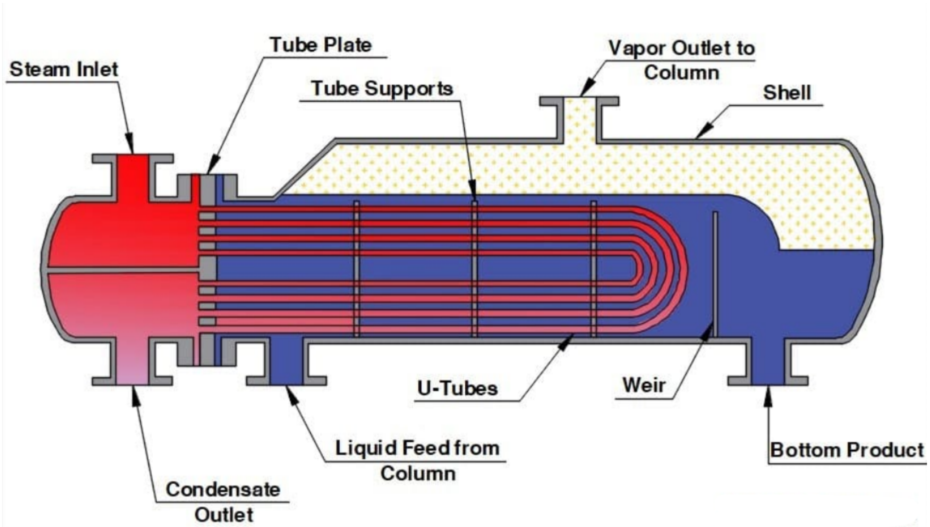


Figure 23: Heat Exchanger

1. **Function:** The heat exchanger facilitates the exchange of thermal energy, raising the

temperature of the water or steam within the boiler. This process is essential for producing the steam or hot water needed for various applications.

2. **Construction:** Heat exchangers in boilers are typically made of metal, such as steel or cast iron, chosen for their durability and excellent heat transfer properties. They consist of a series of tubes or passages through which the hot combustion gases flow. In fire-tube boilers, the hot gases flow through the tubes, while in water-tube boilers, the water flows inside the tubes.

3. **Heat Transfer Mechanism:** Heat transfer occurs through conduction and convection. As the hot combustion gases pass over the surface of the heat exchanger tubes, heat is conducted through the metal walls of the tubes, transferring it to the water or steam inside. Convection also plays a role as the movement of the water or steam helps distribute the heat evenly within the heat exchanger.

4. **Water or Fluid Circulation:** The heat exchanger is designed to allow water or steam to circulate through the tubes or passages, maximizing heat transfer. In fire-tube boilers, water surrounds the tubes, whereas in water-tube boilers, water flows inside the tubes. Circulation is driven by pumps or natural convection, depending on the boiler's design.

5. **Efficiency Considerations:** The design and condition of the heat exchanger significantly impact the boiler's efficiency. A clean and well-maintained heat exchanger allows for efficient heat transfer, minimizing energy losses. Proper water treatment and regular maintenance prevent scale or sediment buildup that can impair heat transfer efficiency.

6. **Combustion Gas Exhaust:** After transferring heat to the water or steam, the combustion gases exit the heat exchanger and are typically expelled through a flue or chimney. Condensing boilers have additional heat exchanger surfaces that cool the flue gases further, allowing water vapor in the gases to condense and release additional heat, thereby increasing the overall efficiency of the boiler.

7.3.3 Water Vessel

The water vessel, also known as the boiler shell, is a sealed container that holds water or steam, providing a safe and controlled environment for heat transfer and pressure containment. Key Aspects of the Water Vessel:

1. **Pressure Containment:** Designed to withstand the pressures generated during boiler operation, ensuring safety and preventing leaks or explosions.

2. **Heat Transfer Surface:** The vessel's interior surfaces are designed to maximize the heat transfer from the combustion gases to the water, enhancing the boiler's efficiency.

3. **Material:** Typically made from high-quality steel or alloy, capable of withstanding high temperatures and pressures.

7.3.4 Pressure Vessel

The pressure vessel is designed to contain the high pressures generated in the boiler. It ensures safe operation by maintaining controlled conditions for the steam or hot water. Key Aspects of the Pressure Vessel:

1. **Design Standards:** Constructed according to strict industry standards and regulations to ensure safety and reliability under high-pressure conditions.

2. **Safety Features:** Includes pressure relief valves and other safety devices to prevent overpressure and ensure safe operation.

7.3.5 Controls and Safety Devices

Boilers are equipped with various controls and safety devices to monitor and regulate the operation, maintaining safe and efficient performance. Key Aspects of Controls and Safety Devices:

1. **Pressure Switches:** Monitor and control the pressure within the boiler, ensuring it stays within safe limits.

2. **Temperature Sensors:** Track the temperature of the water or steam, helping to maintain optimal operating conditions.

3. **Safety Valves:** Release steam or water if pressure exceeds safe levels, preventing explosions.

4. **Flame Safeguards:** Ensure the burner operates safely, shutting it down if a flame is not detected.

5. **Control Panels:** Centralize the control and monitoring of the boiler's operation, providing operators with the ability to make adjustments as needed.

7.3.6 Pumps

Pumps circulate water or other fluids through the boiler system, maintaining proper flow and pressure. Key Aspects of Pumps:

1. **Feedwater Pumps:** Supply water to the boiler, maintain the water level, and ensure continuous operation.

2. **Circulation Pumps:** Circulate water within the boiler system, enhancing heat transfer and efficiency.

3. **Condensate Pumps:** Remove condensed water from the system, returning it to the feedwater supply.

7.3.7 Expansion Tank

An expansion tank accommodates the expansion and contraction of water as it heats and cools, maintaining constant pressure within the system. Key Aspects of the Expansion Tank:

1. **Pressure Regulation:** Prevents excessive pressure build-up by allowing water to expand and contract safely.

2. **System Protection:** Reduces the risk of damage to the boiler and associated piping from pressure fluctuations.

7.3.8 Chimney or Flue

The chimney or flue exhausts combustion gases and by-products from the boiler to the outside environment, ensuring safe and efficient operation. Key Aspects of the Chimney or Flue:

1. **Gas Removal:** Efficiently removes waste gases from the boiler, preventing backdrafts and leaks.
2. **Material:** Constructed from materials resistant to high temperatures and corrosive gases to ensure durability.
3. **Design:** Optimized to minimize heat loss and ensure the safe expulsion of gases, enhancing overall boiler efficiency.

7.4 Components of a Boiler System

A boiler's design consists of three primary systems:

7.4.1 Feed Water System

The feed water system prepares and supplies water to the boiler, comprising:

1. Deaerator: It heats boiler feedwater, removing dissolved gases like oxygen to prevent corrosion.
2. Feedwater Control System: Regulates water flow to maintain optimal levels and pressure.
3. Condensate Recovery System: Collects and returns condensed steam to conserve water and energy.

7.4.2 Steam System

Responsible for transporting steam throughout the facility, including:

1. Piping Network: Transports steam to where it's needed, ensuring efficient delivery.

2. Steam Control Devices: Valves, gauges, and regulators manage steam flow and pressure.

3. Steam Traps: Remove condensate to maintain system efficiency.

7.4.3 Fuel System

Provides heat energy for steam generation through:

1. Fuel Storage and Handling: Stores and delivers fuel (gas, oil, coal) to the boiler.

2. Burners: Mix fuel with air and ignite it in the combustion chamber for heat generation.

3. Fuel Control System: Regulates fuel and air supply for efficient combustion.

7.5 Boiler Safety Features

Boilers are equipped with essential safety features designed to ensure safe operation and mitigate potential hazards. These safety components play a critical role in maintaining operational integrity and protecting against risks. Here are key safety features commonly found in boiler systems:

1. Pressure Relief Valve (PRV): Automatically releases excess pressure to prevent the boiler from reaching unsafe levels, safeguarding against rupture or explosion.

2. Low Water Cut-Off (LWCO): Detects low water levels in the boiler to prevent overheating and damage by shutting down the burner until water levels are restored.

3. Flame Safeguard System: Monitors and ensures the stability of the flame in the combustion chamber. It shuts down the fuel supply if the flame becomes unstable or extinguished, preventing potential hazards.

4. High Limit Control: Monitors water or steam temperature and shuts down the burner if temperatures exceed safe limits, preventing overheating.

5. Overheat Protection: Devices such as temperature sensors or thermal fuses detect excessive temperatures and initiate shutdowns to protect the boiler from damage and maintain safety.

6. Safety Shutoff Valve: Installed on the fuel supply line, it shuts off fuel during emergencies or maintenance, ensuring safety during service operations.

7. Venting and Flue Gas Monitoring: Ensures proper venting of combustion by-products like carbon monoxide, maintaining safe air quality. Flue gas monitoring devices detect abnormal gas levels, alerting to potential safety issues.

These safety features are vital for compliance with safety standards and regulations, varying based on boiler type, size, and specific operational requirements. Regular inspection, maintenance, and adherence to safety protocols are essential to ensuring these features function effectively, ensuring the overall safety and reliability of boiler systems.

7.6 Recommended Boiler Water Quality

The quality of water used in boilers is critical for ensuring efficient and safe operation. To maintain optimal performance and longevity of the system, the following recommendations for boiler water quality should be observed:

1. Water Purity: Use relatively pure water to prevent scale buildup and corrosion. Demineralized or deionized water, with low mineral content, is recommended to enhance heat transfer efficiency and prevent scale formation.

2. pH Level: Maintain the pH of boiler water within the range of 8.5 to 9.5 to prevent corrosion of boiler components. Extreme pH levels can accelerate corrosion, impacting the boiler's lifespan and performance.

3. Total Dissolved Solids (TDS): Monitor and control the concentration of total dissolved solids (TDS) in boiler water. High TDS levels can lead to scale formation and reduce heat transfer efficiency. Regular monitoring and appropriate water treatment methods

are essential to managing TDS levels effectively. TDS is kept minimum to reduce blow down quantity

4. Oxygen Levels: Manage dissolved oxygen levels in boiler water to prevent corrosion. Oxygen scavengers or deaeration systems are used to maintain low oxygen levels, protecting against oxygen-related corrosion.

5. Water Hardness: Control water hardness, which is caused by calcium and magnesium ions, to prevent scale formation. Water softening methods such as ion exchange or chemical treatment help reduce water hardness and mitigate scale buildup.

6. Suspended Solids and Contaminants: Ensure boiler water is free from suspended solids, dirt, debris, and organic matter that can cause fouling. Implement effective filtration and treatment processes to remove contaminants and maintain clean boiler water.

Sr. No.	Characteristics	Value
1	Total hardness (max. ppm as $CaCO_3$)	5
2	pH value	8.5-9.5
3	Dissolved Oxygen max. mg/lit	Nil
4	Total Dissolved Solids (ppm)	Minimum

Table 1: Boiler Water Quality Table

7.7 Boiler Blowdown

Boiler blowdown is a critical process in maintaining water quality and operational efficiency by removing impurities and concentrated solids from the boiler water. Here's a detailed overview of boiler blowdown:

7.7.1 Purpose of Boiler Blowdown

Boiler blowdown serves several essential purposes:

1. **Removal of Impurities:** Blowdown helps to remove dissolved solids, suspended particles, and other impurities from the boiler water that can lead to scale formation and corrosion.

2. **Control of Total Dissolved Solids (TDS):** By periodically discharging a portion of the boiler water, blowdown helps control the concentration of total dissolved solids (TDS). High TDS levels can impair heat transfer efficiency and boiler performance.

3. **Prevention of Scale Buildup:** Blowdown reduces the likelihood of scale formation on heat transfer surfaces, which can decrease boiler efficiency and increase maintenance requirements.

7.7.2 Types of Boiler Blowdown

There are two main types of boiler blowdown:

1. **Continuous Blowdown:** This involves the continuous discharge of a small volume of boiler water containing concentrated impurities. Continuous blowdown helps control the buildup of dissolved solids and maintains TDS levels within acceptable limits.

2. **Intermittent (or Manual) Blowdown:** Intermittent blowdown is performed manually or semi-automatically to remove sludge and sediment that settle at the bottom of the boiler. It helps remove suspended solids and maintain water clarity.

7.7.3 Blowdown Procedure

The blowdown procedure typically involves the following steps:

1. **Measurement:** Regular monitoring of boiler water quality parameters, such as TDS levels, to determine the need for blowdown.

2. **Valve Operation:** Opening blowdown valves to discharge boiler water either continuously or intermittently based on operational requirements and water quality standards.

3. **Discharge:** Directing the discharged boiler water to a blowdown tank or suitable drain to safely remove impurities from the system.

4. **Monitoring and Adjustment:** Monitoring blowdown frequency and volume to optimize water treatment efficiency and minimize water and energy waste.

7.7.4 Benefits of Proper Boiler Blowdown

1. **Improved Boiler Efficiency:** By maintaining clean boiler water with controlled TDS levels, blowdown contributes to enhanced heat transfer efficiency and overall boiler performance.

2. **Extended Equipment Lifespan:** Reduced scale buildup and corrosion help prolong the lifespan of boiler components, reducing maintenance costs and downtime.

3. **Compliance with Regulations:** Proper blowdown practices ensure compliance with water quality standards and regulatory requirements, promoting safe and environmentally responsible boiler operation.

7.7.5 Blowdown Frequency and Amount

Boiler blowdown refers to the process of removing impurities and concentrated solids from the boiler water to maintain water quality and system efficiency. The frequency and amount of blowdown are crucial aspects of boiler operation:

1. **Frequency:** The frequency of boiler blowdown depends on factors such as boiler water quality, operating pressure, and steam demand. Typically, continuous or intermittent blowdown is performed:

   (a) **Continuous Blowdown:** This involves the continuous discharge of a small volume of boiler water to control the concentration of dissolved solids.

   (b) **Intermittent Blowdown:** This is conducted periodically to remove sludge and sediment that settle at the bottom of the boiler.

2. **Amount:** The amount of blowdown is determined based on the boiler's water quality parameters, particularly the concentration of total dissolved solids (TDS). Excessive blowdown can lead to energy and water waste, while insufficient blowdown can result in scale buildup and reduced boiler efficiency.

7.7.6 Importance of Automatic Boiler Blowdown Control System

Automatic boiler blowdown control systems play a pivotal role in industrial boiler operations, combining mechanical and electronic engineering principles to enhance efficiency, reliability, and safety. Here's why automation is crucial in this context, viewed through the lens of a mechatronics engineer:

1. **Efficiency and Optimization**
   (a) **Precision Control:** Ensuring blowdown occurs at the optimal time and volume based on water quality parameters like Total Dissolved Solids (TDS). This prevents under or over-blowdown, maximizing energy and water efficiency.
   (b) **Energy Savings:** Reducing unnecessary blowdown cycles minimizes the energy loss associated with heating and treating excess water. This efficiency directly translates to cost savings and environmental benefits.
2. **Reliability and Maintenance**
   (a) **Continuous Monitoring:** Sensors continuously monitor boiler water quality, detecting changes that could lead to scale buildup or corrosion. This proactive approach prevents equipment damage and extends operational lifespan.
   (b) **Predictive Maintenance:** Automated systems facilitate predictive maintenance by providing data insights into boiler health. This allows engineers to schedule maintenance based on actual operational conditions, reducing downtime and repair costs.
3. **Innovation and Adaptability**
   (a) **Smart Systems Integration:** Leveraging IoT (Internet of Things) and data analytics to optimize boiler performance and operational efficiency.
   (b) **Adaptive Control:** Implementing AI (Artificial Intelligence) algorithms for adaptive control strategies that learn and adjust to varying operational conditions, improving system resilience and responsiveness.

7.8 Boiler Efficiency

The efficiency of a boiler can be calculated using the following formula:

$$\eta = \frac{Q \times H \times h}{q \times GCV} \times 100 \tag{1}$$

Where:

1. Q = Steam Generation
2. H = Enthalpy of steam
3. h = Enthalpy of water
4. q = Amount of fuel (m^3/hr)
5. GCV = Gross Calorific Value

7.9 Used Automation and Mechatronics Systems in Boiler

Modern boiler systems leverage advanced automation and mechatronics to enhance efficiency, safety, and control. These integrated systems ensure optimal performance through precise monitoring and regulation of various parameters. Here's an overview of the key components and their functions:

7.9.1 Programmable Logic Controller (PLC)

PLCs are integral to boiler operation, managing critical parameters like temperature, pressure, and water levels. They ensure precise control over the entire system, including water level regulation and safety mechanisms. PLCs provide robust and flexible control solutions, essential for maintaining optimal boiler performance.

7.9.2 Burner Management System (BMS)

The BMS is crucial for controlling the combustion process. It manages fuel delivery, air-to-fuel ratio, ignition sequences, and flame monitoring. By continuously checking the flame status, the BMS can detect anomalies and take safety measures such as shutting off fuel or halting the burner to prevent hazards.

7.9.3 Combustion Control

Combustion control systems optimize the fuel-air mixture to achieve maximum efficiency while minimizing emissions. These systems adjust fuel and air supplies dynamically, ensuring complete combustion. Advanced algorithms adapt to changing load demands, maintaining optimal combustion performance and reducing fuel consumption.

7.9.4 Feedwater Control

Feedwater control systems regulate water flow into the boiler according to steam demand and water levels. By maintaining water levels within safe ranges, these systems prevent overfilling or low-water conditions. Incorporating sensors, flow meters, and control valves ensures precise and reliable water management.

7.9.5 Water Treatment and Monitoring

Automated systems monitor and maintain water quality by tracking parameters such as pH, dissolved oxygen, conductivity, and total dissolved solids (TDS). They use automated dosing systems to add chemicals like oxygen scavengers and pH adjusters, preventing scale buildup and corrosion, thereby extending boiler life.

7.9.6 Safety Interlocks and Alarms

Safety interlocks and alarms protect the boiler from hazardous conditions by monitoring pressure, temperature, water levels, and flame status. These systems trigger alarms and initiate safety protocols, such as shutting off fuel supply or activating emergency shutdowns, to maintain safe operation.

7.9.7 Data Acquisition and Monitoring

Automation systems gather and analyze data from sensors and instruments, covering parameters like temperature, pressure, and flow rates. This real-time data enables operators to monitor boiler performance, identify trends, diagnose issues, and plan maintenance activities effectively, ensuring continuous optimization and reliability.

7.10 Future Scopes of Automation in Boilers

As a mechatronics engineer, exploring future automation opportunities in boilers can lead to significant advancements in efficiency and performance. Here are key areas for future improvement:

7.10.1 Advanced AI and Machine Learning Integration

Incorporating AI and machine learning algorithms can enable predictive analytics for maintenance and operational optimization. These systems can learn from historical data to predict equipment failures, optimize fuel consumption, and adjust parameters in real-time for maximum efficiency.

7.10.2 IoT and Smart Sensors

Utilizing IoT-enabled smart sensors can provide real-time data on various boiler parameters, such as temperature, pressure, and water levels. This data can be used for continuous monitoring, enabling instant adjustments and proactive maintenance to prevent inefficiencies.

7.10.3 Robust Digital Twins

Developing digital twin technology for boilers can create real-time digital replicas of physical systems. This allows for comprehensive simulations, performance tracking, and predictive maintenance, enhancing overall system efficiency and reducing downtime.

7.10.4 Enhanced Automated Combustion Systems

Future combustion control systems can be designed to automatically adapt to varying fuel qualities and environmental conditions. This would ensure optimal combustion efficiency and lower emissions, regardless of changes in fuel type or external factors.

7.10.5 Integrated Renewable Energy Sources

Integrating boilers with renewable energy sources, such as solar or geothermal energy, can be automated to optimize energy use. Automated systems can manage the switch between conventional and renewable energy sources based on availability and demand, improving overall energy efficiency.

7.10.6 Advanced Water Treatment Automation

Future advancements in water treatment automation can include real-time water quality monitoring and automated chemical dosing systems. This would ensure optimal water quality, prevent scale and corrosion, and enhance the longevity and efficiency of the boiler.

7.10.7 Self-Optimizing Systems

Developing self-optimizing boiler systems that use advanced algorithms to continuously assess and adjust operations for peak performance can lead to substantial efficiency gains. These systems would autonomously adapt to changing operational conditions, ensuring optimal performance at all times.

8 CHAPTER 8: TRAPS AND CONTROL VALVES

8.1 Acquaintance

Steam traps and control valves are essential components in industrial steam systems. Steam traps are automatic valves designed to remove condensate (condensed steam and non-condensable gases) without letting steam escape. Control valves, on the other hand, are used to regulate the flow and pressure of steam, ensuring optimal performance and safety in various industrial processes. Together, these components play a crucial role in maintaining efficiency and preventing energy wastage in steam systems.

8.2 Types of Steam Traps

8.2.1 Single Orifice Float Trap

Description: The Forbes Marshall Single Orifice Float Trap is a condensate drain trap with a single orifice, optimal for process applications.

Figure 24: Single Orifice Float Trap

Features:

1. Efficient drainage of condensate.

2. There is no steam loss during regular operations, reducing the carbon footprint.

3. Erosion deflectors with simplified flow paths enhance resistance to erosion and impact.

4. Self-aligning primary valve and water hammer-resistant float assembly.

8.2.2 Compact Module Two Orifice Float Trap

Description: This trap is engineered to manage substantial discharge capacity during system initiation and peak condensate loads.

Figure 25: Compact Module Two Orifice Float Trap

Features:

1. Dual orifice system is controlled by a lever and float mechanism.

2. Integrated air vent and steam lock release mechanism.

3. Compact design with a strainer, non-return valve, inlet, outlet, and float.

4. Piston valves to prevent loss in the inline due to the gland.

8.2.3 Thermodynamic Trap

Description: Forbes Marshall Thermodynamic Steam Traps are known for their superior resistance to corrosion and effective condensate removal.

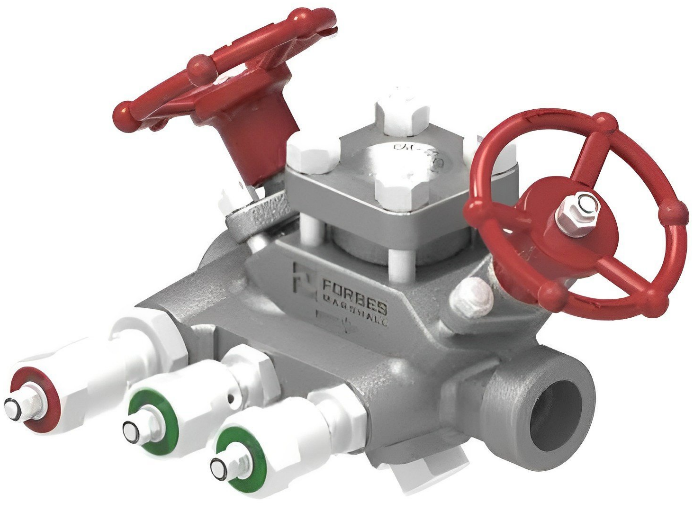


Figure 26: Thermodynamic Trap

Features:

1. Various sizes and end connections are available for installation flexibility.
2. Anti-air binding discs are available upon request.
3. Suitable for all pressure ranges.
4. Induction-hardened seating area for an extended lifespan.

8.2.4 Compact Module Thermodynamic Trap

Description: This module integrates a thermodynamic steam trap with a pipeline connector through a universal connector.

Features:

1. In-line components for easy specification and installation.
2. Forged carbon steel construction for longevity.

3. Quick installation process, taking less than 45 minutes.
4. Can be installed in any angular direction without an angled trap position.

8.2.5 Bimetallic Trap

Description: The Bimetallic Steam Trap, designed by Forbes Marshall, efficiently discharges steam lines operating at high pressure and temperature levels.

Figure 27: Bimetallic Trap

Features:

1. Stainless steel insert for resilience against erosion and corrosion.
2. Condensate section with a check valve for precise control.
3. Integrated strainer screen for debris filtration.
4. External adjustment screw for regulating discharge temperature.

8.2.6 Bucket Traps

Description: Forbes Marshall Bucket Traps are ideal for recovering high-pressure condensate in horizontally oriented pipelines.

Features:

Figure 28: Bucket Trap

1. Resistance to water hammer.
2. Suitable for high-pressure applications.
3. Built-in strainer screen to prevent debris.

8.3 Types of Control Valves

8.3.1 Globe Valves

Description: Globe valves are widely used for regulating flow in a pipeline. They offer good shutoff capability and are suitable for throttling services.

Features:

1. Precise flow control.
2. Low leakage rates.
3. Suitable for high-pressure applications.
4. Available in various sizes and materials.

8.3.2 Ball Valves

Description: Ball valves are known for their durability and ability to provide tight shutoff. They are used in applications requiring quick on/off control.

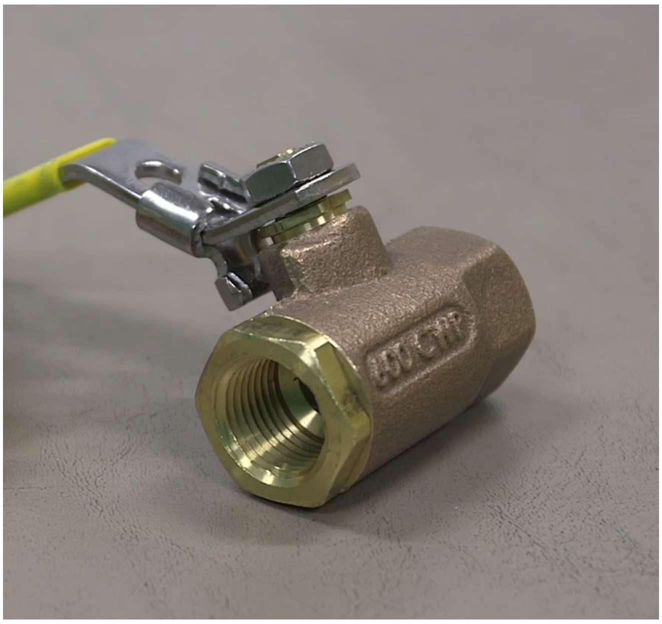


Figure 29: Ball Valve

Features:

1. Quick operation with a quarter-turn movement.
2. Minimal pressure drop when fully open.
3. Suitable for high-temperature and high-pressure applications.
4. Available in various configurations, such as two-way and three-way.

8.3.3 Butterfly Valves

Description: Butterfly valves are used for regulating and isolating flow in pipelines. They are lightweight and offer a compact design.

Features:

1. Quick operation with a quarter-turn movement.
2. Low cost and maintenance.

Figure 30: Butterfly Valve

3. Suitable for large valve applications.

4. Available in various materials to handle different types of fluids.

8.3.4 Diaphragm Valves

Description: Diaphragm valves are used in applications requiring corrosion resistance and tight shutoff. They are ideal for handling slurries and viscous fluids.

Features:

1. Leak-proof sealing.

2. Suitable for abrasive and corrosive fluids.

3. Easy to maintain and repair.

4. Available in various materials, including rubber and plastic linings.

8.3.5 Check Valves

Description: Check valves are designed to allow flow in one direction and prevent backflow. They are essential for protecting equipment and maintaining system integrity.

Features:

1. Simple operation without the need for manual intervention.
2. Low-pressure drop.
3. Available in various types, such as swing check and lift check valves.
4. Suitable for horizontal and vertical installations.

8.3.6 Control Valves

Description: Control valves are used to regulate flow, pressure, temperature, and fluid level in industrial processes. They are critical for process automation.

Features:

1. Precise control of process variables.
2. Integration with control systems for automation.
3. Available in various types, including linear and rotary motion control valves.
4. Suitable for a wide range of applications and operating conditions.

9 CHAPTER 9: FLOW METERS

9.1 Overview:

A flow meter in a steam system is a device operated to assess the rate of steam flow through pipelines or channels. It provides essential data for monitoring and controlling steam consumption, optimizing energy efficiency, and ensuring proper operation of steam-driven equipment. Flow meters for steam systems come in various types, including differential pressure flow meters, vortex type flow meters, ultrasonic type flow meters, and thermal mass flow meters. These meters operate based on different principles such as pressure differential, fluid momentum, ultrasonic waves, or thermal conductivity. By accurately measuring steam flow rates, flow meters enable operators to assess system performance, detect leaks or inefficiencies, and make informed decisions to optimize steam usage and reduce energy costs.

9.2 Electromagnetic Flow meter:

An electromagnetic flow meter is that type of flow meter which is used to estimate the flow rate of conductive fluids, such as water or aqueous solutions, in various industrial processes. It operates on the principle of Faraday's electromagnetic induction law, where a magnetic field is generated by coils within the meter and applied to the fluid flowing through a non-conductive pipe. As the conductive fluid passes through the magnetic field, an

Figure 31: Electromagnetic Flow Meters (a) Compact version; (b) Remote display.

Electromotive force (EMF) is induced in the fluid, which is directly proportional to its velocity. By measuring this induced EMF, the flow meter calculates the flow rate of the fluid. One of the primary advantages of electromagnetic flow meters is their accuracy and reliability, even in demanding industrial environments with fluctuating flow rates, temperatures, and pressures. They have no moving parts, which minimizes wear and tear, reduces maintenance requirements, and ensures long-term stability and durability.

9.3 Vortex Flow meter:

A vortex flow meter is that type of flow meter which is used to assess the flow rate of liquids, gasses, or steam in industrial applications. It operates on the principle of the von Kármán effect, where vortices are generated as a fluid flows past a bluff body installed into the flow stream. These vortices alternate on either side of the bluff body, and their frequency is directly proportional to the flow velocity.

The vortex flow meter detects these vortices using sensors, typically piezoelectric sensors, and calculates the flow rate based on the frequency of vortex shedding. Vortex flow meters provide advantages such as its higher accuracy, wide turndown ratio, suitability for a variety of fluids, and minimal pressure loss.

Figure 32: Various types of Vortex Flow Meters

9.4 Coriolis Mass Flow meter:

A Coriolis mass flow meter is that type of flow meter which is used to estimate the rate of flow of liquids or gases based on the Coriolis effect. In this meter, the fluid flows through a vibrating tube or tubes. As the fluid flows, it causes the tubes to twist due to the Coriolis effect, which is a result of the fluid's inertia and the Earth's rotation. Sensors detect this twisting motion, and the amount of twist is directly proportional to the mass flow rate of the fluid. Coriolis mass flow meters are known for their high accuracy, wide turndown ratio, and ability to measure mass flow directly, regardless of fluid properties such as density, viscosity, or temperature.

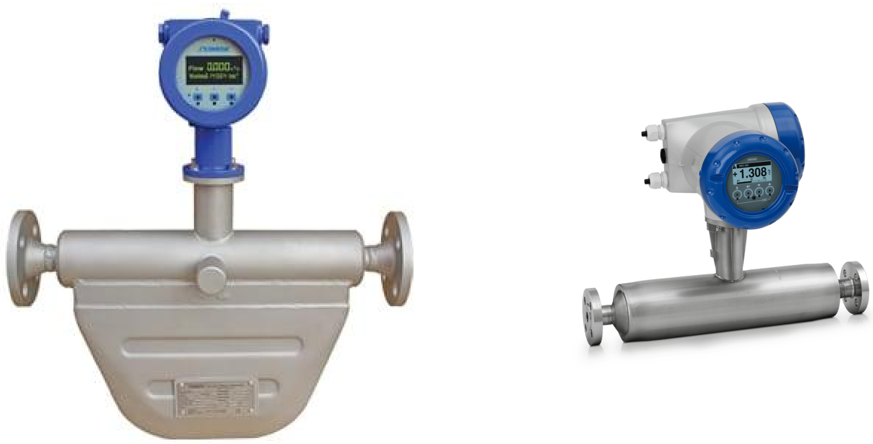


Figure 33: Various types of Coriolis Mass Flow meter.

9.5 Variable Area Flow meter:

A variable area flow meter, also known as a Rota meter, is a type of flow meter used to measure the flow rate of liquids or gases in industrial applications. It consists of a tapered tube with a float inside that moves vertically in response to the flow rate. As the flow rate increases, the float moves upward, and as it decreases, the float moves downward. The position of the float within the tapered tube indicates the flow rate, with higher flow rates corresponding to higher float positions.

Variable area flow meters are simple, cost-effective, and easy to install. They offer visual indication of flow rate and can be used for both high and low-pressure applications. However, their accuracy can be affected by changes in fluid density, viscosity, and temperature.

Figure 34: Variable Area Flow Meters (Rota Meter)

9.6 Orifice Type Flow meter:

An orifice type flow meter is a commonly used differential pressure flow meter which asses the rate of flow of liquids or gases in a pipeline. It has a plate with a hole (or orifice) installed in the pipeline, creating a pressure drop across the orifice plate as fluid flows through it. Pressure taps located downstream and upstream of the orifice plate measure the pressure differential, which is proportional to the flow rate according to Bernoulli's principle. By measuring the pressure drop across the orifice plate, the flow rate can be determined using empirical equations or calibrated charts. Orifice flow meters are relatively simple, cost-effective, and suitable for a variety of flow rates and fluid types. However, they can cause permanent pressure loss in the system and may require frequent recalibration for accurate measurements.

Figure 35: Orifice type flow meter.

9.7 Positive Displacement Flow meter:

It is a type of flow meter that estimates the rate of flow of liquids by repeatedly filling and emptying a chamber or chambers of known volume. As the fluid flows through the meter, it displaces a known volume of fluid, which is then estimated to calculate the flow rate.

Figure 36: Positive Displacement Flow meter

9.8 Open channel Flow meter:

An open channel flow meter is a type of flow meter that estimates the rate of flow of liquids in open channels, such as rivers, streams, canals, or partially filled pipes. Unlike closed pipe flow meters, which measure flow in pressurized pipes, open channel flow meters are designed to measure flow in channels where the fluid surface is exposed to the atmosphere. These meters typically use various methods to determine flow rate, such as velocity-area method, ultrasonic sensors, or pressure sensors.

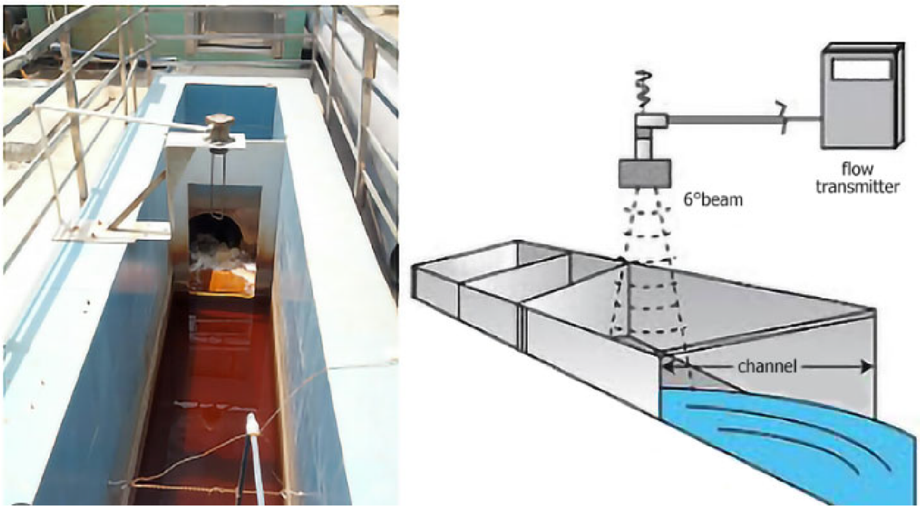


Figure 37: Open channel flow meters

9.9 Turbine type Flow meter:

It is a type of flow meter that estimates the rate of flow of liquids in various industrial applications. It consists of a rotor with turbine blades inserted into the flow stream. The fluid gives the turbine blades kinetic energy as it passes through the meter, which causes them to rotate. The rotation of the blades is proportional to the flow rate of the fluid, allowing for accurate measurement of flow rate.

Figure 38: Turbine type flow meter.

10 CHAPTER 10: ETP[5]

Figure 39: ETP (Top) at the Industrial Tour

Figure 40: ETP (Bottom) at the Industrial Tour

During the visit to Forbes Marshall, the Effluent Treatment Plant (ETP) was observed as an essential system for wastewater management. The ETP process, integral to industries like pharmaceuticals, textiles, and chemicals, was demonstrated to treat highly contaminated water effectively. In this case, it was noted that Figure 39 and Figure 40 depicted biological treatment processes specifically from the textile industry.

The significant role of the ETP in managing industrial wastewater and domestic sewage was emphasized. Contaminants such as organic matter, inorganic matter, heavy metals, oil and grease, suspended particles, and other pollutants were shown to be systematically treated. Various stages of treatment were introduced to ensure the removal of impurities, including suspended particles, dissolved organic matter, and sludge disposal.

The process was described as either chemical, biological, or a combination of both methods. At Forbes Marshall, the biological type of treatment was highlighted through practical observation and explanation. The following steps were outlined as part of the wastewater treatment process:

Equalization: The purpose of the equalization tank was explained as balancing the raw effluent from different processing units. The effluent was collected in a mixed tank and subsequently pumped into an aeration tank functioning as an equalization tank. A floating aerator was utilized to homogenize the effluent before transferring it to the neutralization tank for further treatment.

pH Control: It was ensured that the pH value of the effluent remained within the range of 5.5 to 9.0, adhering to the standards set by the Bureau of Indian Standards (BIS). For acidic waste (low pH), bases were added to adjust the pH, while for alkaline waste (high pH), acids were employed for modification.

Coagulation: The process of coagulation was observed, where liquid aluminium sulphate was added to untreated water. This led to the aggregation of dirt particles, forming larger, heavier particles that were easier to remove through settling and filtration.

Sedimentation: Water movement was slowed during sedimentation, allowing heavy particles to settle at the bottom. The collected particles were referred to as sludge, which was subsequently managed in the next stages of treatment.

Filtration: Filtration was carried out by passing water through layers of sand and gravel filters, effectively removing particulates. Regular backwashing was performed to maintain the filters' efficiency.

Disinfection: Before entering the distribution system, the water was disinfected. Chlorine was introduced to eliminate any remaining microorganisms, ensuring the water's safety and hygiene.

Sludge Drying: The settled solids from sedimentation were transported to drying beds. Once the sludge thickness reached approximately 300 mm, the sludge charging was stopped, and the bed was left for natural evaporation. It was noted that the drying process typically took about 10 days.

Through this visit to Forbes Marshall, the importance of the ETP in ensuring environmentally responsible practices was highlighted. Each stage of the treatment process was carefully observed, demonstrating a commitment to sustainability and regulatory compliance in wastewater management.

Figure 41: LAB for measuring the condition of effluent water

11 CHAPTER 11: CONTROL AND INSTRUMENTATION

11.1 Pressure Control: Pressure reduction – pneumatic

11.1.1 Description

These control systems may include:

1. P + I + D functions to improve accuracy under varying load conditions.

2. Set point(s), which may be remotely adjusted.

11.1.2 Advantages:

1. Incredibly precise and adaptable.

2. Within the bounds of the valve range, there is no maximum valve size.

3. Capable of handling a 50:1 flow range (usually for a globe control valve).

4. Appropriate for dangerous settings.

5. There is no need for an electrical supply.

6. Their quick operation allows them to adapt efficiently to sudden variations in demand.

7. Incredibly strong actuation that can handle large pressure differentials across the valve.

11.1.3 Disadvantages:

1. More costly than regulations that act on their own.

2. More intricate than self-regulating mechanisms.

3. Not programmable in a straightforward manner.

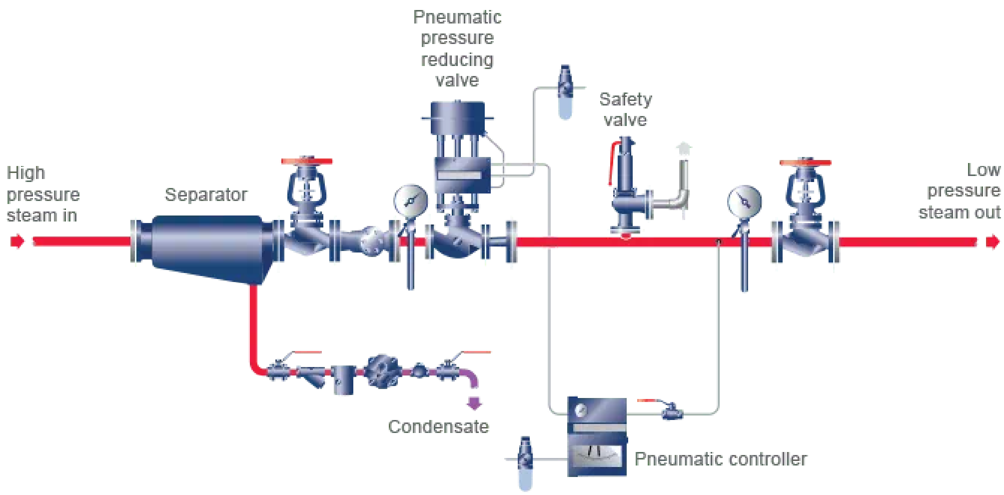


Figure 42: Pressure reduction system with pneumatic controller.

11.2 Pressure reduction – electro pneumatic

11.2.1 Description:

These control systems may include:

1. P + I + D functions to improve accuracy under varying load conditions.
2. Set point(s) which may be remotely adjusted, with the possibility of ramps between set points.

11.2.2 Advantages:

1. Very precise and adaptable.
2. Readout and remote adjustment.
3. Within the bounds of the valve range, there is no maximum valve size.
4. Capable of handling a 50:1 flow range (usually for a globe control valve).
5. Quick operation: quick reaction to demand variations.
6. Very strong actuation that can handle large pressure differentials across the valve.

11.2.3 Disadvantages:

1. More costly compared to pneumatic or self-acting controllers.

2. More intricate than pneumatic or self-acting controls.

3. Requires an electrical control signal. Expensive in dangerous locations.

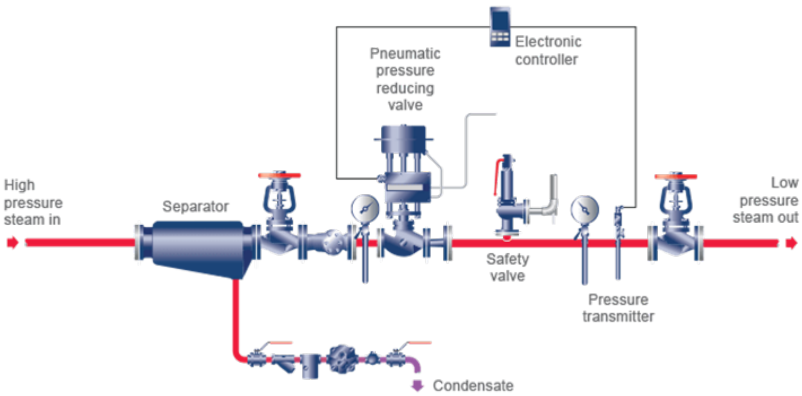


Figure 43: Pressure reduction system with electro-pneumatic controller.

11.3 Pneumatic temperature control

11.3.1 Description:

These control systems may include:

1. P + I + D functions to improve accuracy under varying load conditions.

2. Set point(s), which may be remotely adjusted.

11.3.2 Advantages:

1. Very precise and adaptable.

2. Within the bounds of the valve range, there is no maximum valve size.

3. Outstanding ratio of turndowns.

4. Appropriate for dangerous settings.

5. There is no need for an electrical supply.

6. Their quick operation allows them to adapt efficiently to sudden variations in demand.

7. Very strong and resilient to large differential pressures.

11.3.3 Disadvantages:

1. Costlier than running controls that are direct.

2. More intricate than simple operational controls.

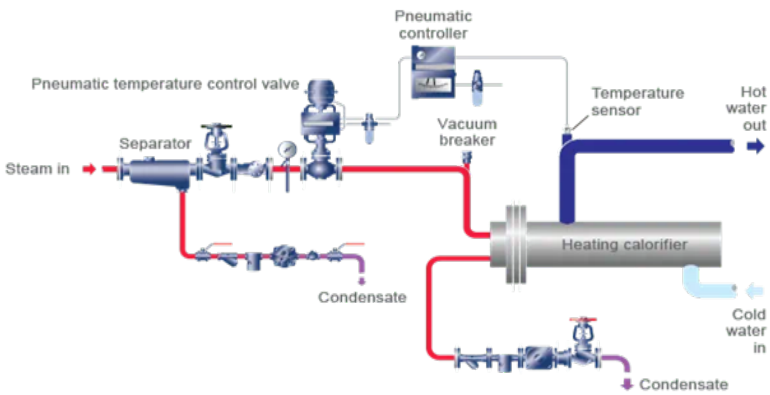


Figure 44: Temperature (pneumatic) controller

11.4 Electro pneumatic temperature control

11.4.1 Description

These control systems may include:

1. P + I + D functions to improve accuracy under varying load conditions.

2. Set point(s) may be remotely adjusted, with the possibility of ramps between set points.

11.4.2 Advantages:

1. Very precise and adaptable.

2. Readout and remote adjustment.

3. Within the bounds of the valve range, there is no maximum valve size.

4. Outstanding ratio of turndowns.

5. Their quick operation allows them to adapt efficiently to sudden variations in demand.

6. Very strong and resilient to large differential pressures.

11.4.3 Disadvantages:

1. More costly compared to pneumatic or self-acting controllers.

2. More intricate than pneumatic or self-acting controls.

3. An electrical source is necessary.

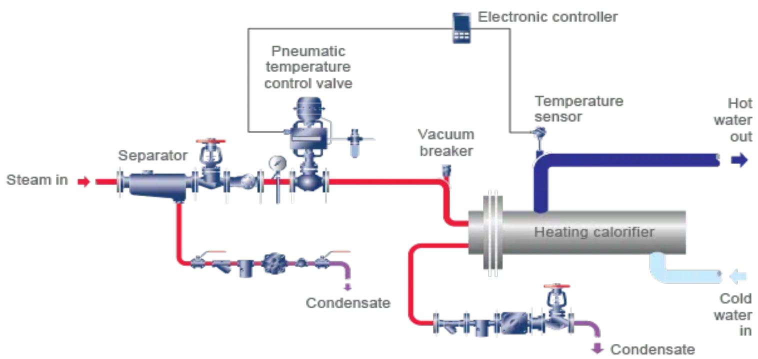


Figure 45: Electro-pneumatic temperature controller

11.5 Level Control

Adjustable on/off level control

11.5.1 Description

An adjustable on/off level control system consists of a controller and a capacitance probe (see Figure 46), and provides:

1. One alarm point in addition to an open/closed valve control.

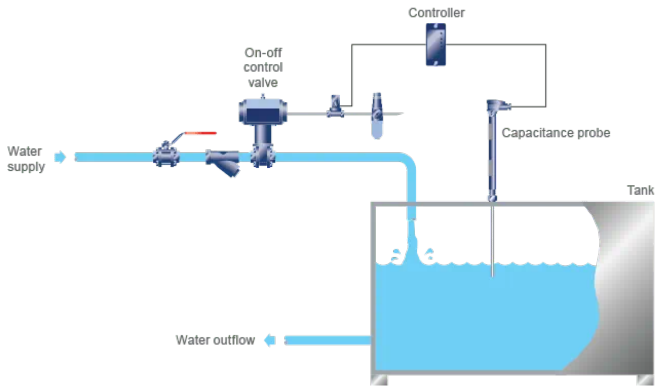


Figure 46: On/off level controller

2. As an alternative, set a low and a high alarm.

3. The controller functions allow for the adjustment of the valve's operating levels.

11.5.2 Advantage:

1. The operation may be stopped without changing the level settings thanks to the adjustable on/off level control.

11.5.3 Disadvantage:

1. More costly than an on/off switch that isn't changeable.

2. Applications: Suitable for a wide range of liquids, including those with poor conductivities.

3. Noteworthy: It may be utilised in conditions when the liquid surface is turbulent, and the built-in electronics can be modified to stop the pump (or valve) from cycling rapidly on and off.

11.6 Modulating level control

11.6.1 Description:

A capacitance probe and suitable controller, which generates a modulating output signal, usually 4–20 mA, make up a modulating level control system. Several devices may be impacted by this output signal, including:

1. Modulating a control valve.

2. Operating a variable speed pump drive.

11.6.2 Advantage:

1. The scale of the application is unlimited as the probe and controller don't really supply the power to run a device—rather, they only send out a signal that other devices react to.

2. Steady regulation of the tank's level.

11.6.3 Disadvantage:

1. More expensive than a conductivity probe system.

2. More complex than a conductivity probe system.

3. Supply system must be permanently charged.

4. Less suitable for ‘stand-by’ operation.

5. Possibly greater electricity consumption.

11.7 Desuperheaters

Desuperheating is the process of lowering the superheated temperature of steam or returning it to its saturated condition. A direct contact type pipeline desuperheater and a pressure lowering station are arranged in the system shown in Figure 47.

In its simplest form, high-quality water, usually condensate, is injected into the flow of superheated steam, which removes heat and lowers the temperature of the steam. Because the control system cannot distinguish between saturated and wet steam at the same temperature, it is not practicable to lower the steam temperature to its saturated value. As a result, the

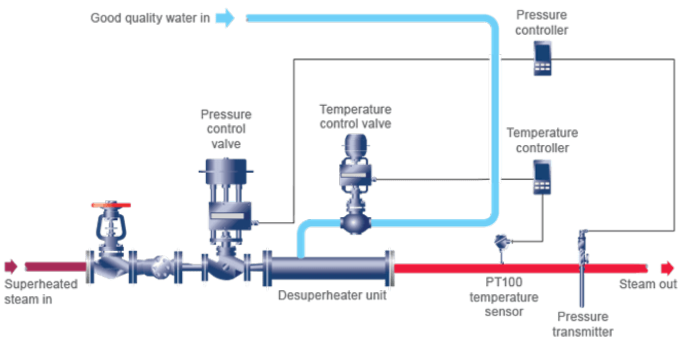


Figure 47: Desuperheating unit.

temperature is constantly maintained at a level that is greater than the applicable saturation temperature, often between 5 and 10 degrees Celsius above saturation.

This illustrates a simple setup that will function well for most purposes. The set setting on the temperature controller only has to be set slightly above the matching saturation temperature since the pressure control loop maintains the downstream pressure at a constant value.

If the downstream pressure fluctuates, as it sometimes does with certain industrial operations, a modification in the water/steam flow ratio will also be necessary.

The pressure transmitter's 4–20 mA signal is sent to the saturation temperature computer and pressure controller. The computer uses this information to continuously determine the downstream pressure's saturation temperature and sends a 4–20 mA output signal to the temperature controller based on that temperature.

The temperature controller is set up to detect its set point at 5°C to 10°C above saturation by accepting a 4–20 mA signal from the computer. In this manner, the temperature set point will automatically change if the downstream pressure changes for any of the previously listed causes. This will ensure that, regardless of load or downstream pressure, the proper ratio of water to steam is maintained.

11.8 PID Controller:[6]

One popular kind of feedback control system in industrial control systems is the PID controller. Proportional-Integral-Derivative, or PID, is the acronym for the three words used to modify the control signal sent to the system:

Proportional (P): The output value generated by this term is proportionate to the error value that is now present. It responds to the current mistake. By multiplying the error by a constant called the proportional gain (Kp), one may modify the proportional response. The system may respond violently when the Kp is high, but a Kp that is too high may induce instability.

Integral (I): The accumulation of previous mistakes is the subject of this word. The integral term accumulates the mistake if it continues over time, and this accumulation is amplified by the integral gain (Ki). It assists in removing steady-state error residue that the proportional term is unable to remove.

Derivative (D): This term uses its rate of change to anticipate future inaccuracy. It is modified by the derivative gain (Kd) and responds to the rate at which the error is changing. The derivative term contributes to increased stability by reducing overshoot and damping down the system response.

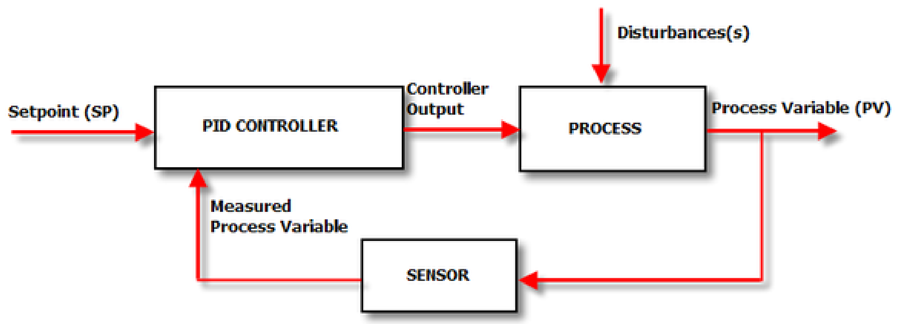


Figure 48: Work flow diagram of PID controller

11.9 Programmable Logic Controller (PLC)

Definition: A PLC is an industrial digital computer that is used to manage robotic devices, assembly lines, and other production processes that need to be highly dependable and simple to program.

Key Features:

1. Robust and robust: Designed to endure challenging industrial settings.

2. Real-time operation: Able to react in real-time to changes in input.

3. Programmable: Makes use of structured text, ladder logic, and function block diagrams, among other programming languages.

4. I/O Modules: Actuator and sensor interfaces.

Applications: Used in automation of machinery on factory assembly lines, amusement rides, light fixtures, and more.

11.10 Supervisory Control and Data Acquisition (SCADA)

Definition: SCADA is a control system architecture that provides high-level process supervisory management via the use of computers, networked data transmission, and graphical user interfaces.

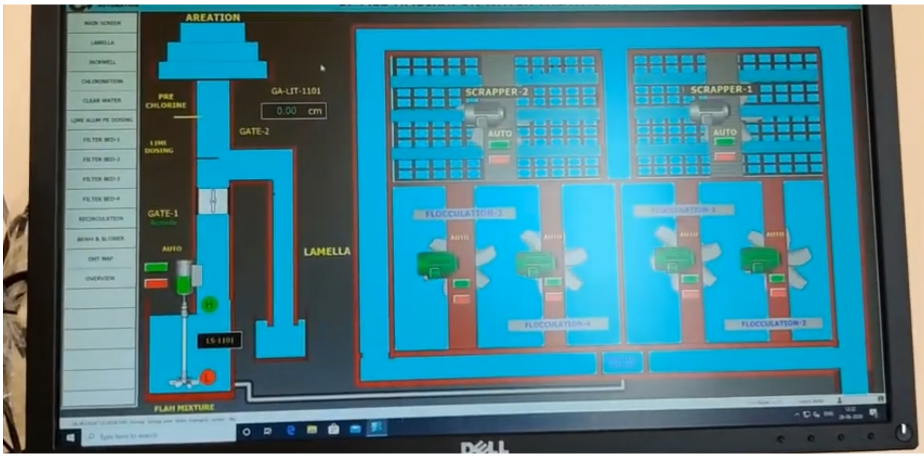


Figure 49: SCADA system for water level control

Key Features:

1. Monitoring, obtaining, and processing real-time data is known as real-time data collection.

2. Remote control: Offers process monitoring and control from a distance.

3. Alarms and data logging: Records data for analysis and sounds an alert when certain criteria are met.

4. Graphical user interface used by operators to communicate with the system is known as the Human-Machine Interface (HMI).

Applications: Used in various industries like water treatment plants, oil and gas pipelines, power generation, and distribution.

11.11 Distributed Control System (DCS)

Definition: A distributed control system (DCS) is a process or plant control system in which the control components are dispersed throughout the system instead of being centralized at a single point.

Key Features:

1. Decentralized control: Every area of the plant has a controller that connects to other controllers via communication.

2. Scalability: Large and sophisticated operations can be easily scaled.

3. Integration: For higher-level monitoring, integrates often with other systems, including SCADA.

4. System dependability is increased by having redundant communication channels and controllers.

Applications: Commonly used in large-scale industrial processes such as chemical plants, oil refineries, and power stations where continuous and complex operations are required.

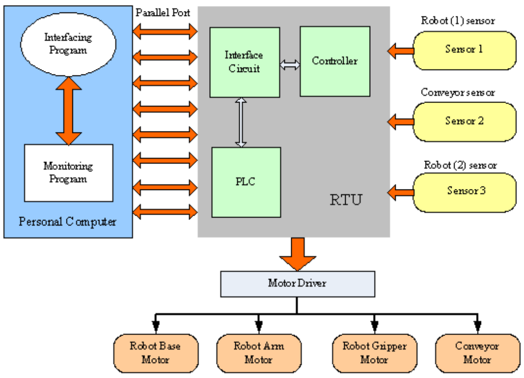


Figure 50: Block diagram of DCS for manufacturing plant.

12 CHAPTER 12: Scope of Mechatronics Engineering

The integration of mechatronic systems holds significant potential for enhancing the efficiency, productivity, and quality of operations at Renaissance Apparel. By combining mechanical engineering, electronics, computer science, and control engineering, mechatronics facilitates intelligent control and monitoring of industrial processes. This chapter outlines specific recommendations for incorporating mechatronic solutions into various stages of the production process to achieve performance optimization.

12.1 Knitting Process Automation and Monitoring

1. Implementation of Smart Sensor Networks
   (a) Yarn Tension Monitoring: Install tension sensors on the Mayer & Cie Circular Knitting Machines to continuously monitor yarn tension. Real-time data can prevent defects caused by inconsistent tension.
   (b) Machine Health Monitoring: Equip machines with vibration and temperature sensors to detect anomalies indicative of mechanical wear or failure. Early detection enables predictive maintenance, reducing downtime.
2. Integration with Central Control Systems
   (a) Programmable Logic Controllers (PLCs): Utilize PLCs to automate machine start/stop functions, pattern control, and fault detection.
   (b) Human-Machine Interface (HMI) Panels: Install touch-screen interfaces for operators to easily monitor machine parameters and receive alerts.

12.2 Advanced Dyeing Process Control

1. Precision Temperature and Flow Management
   (a) Temperature Sensors and Actuators: Integrate high-precision temperature sensors within Fongs Soft Flow Dyeing Machines. Use actuators to adjust heating elements, maintaining optimal dyeing temperatures.

    (b) Flow Rate Monitoring: Implement flow meters with IoT capabilities to monitor dye liquor circulation. Adjust flow rates automatically based on fabric type and desired dye penetration.

2. IoT Integration for Data Analytics

    (a) Cloud Connectivity: Connect dyeing machines to a cloud platform for data collection and analysis. Utilize machine learning algorithms to optimize dyeing recipes and reduce resource consumption.

    (b) Energy Consumption Monitoring: Track energy usage in real-time to identify opportunities for energy savings and cost reduction.

12.3 Slitting Process Enhancements

1. Automated Fabric Alignment and Tension Control

    (a) Optical Sensors: Install optical sensors to detect fabric edges and ensure precise slitting. This reduces material waste and enhances product quality.

    (b) Tension Control Systems: Use load cells and motorized actuators to maintain consistent fabric tension during slitting, preventing distortions.

2. Safety Improvements

    (a) Emergency Stop Systems: Incorporate safety light curtains and emergency stop buttons to enhance operator safety.

12.4 Stentering Process Optimization

1. Environmental Parameter Monitoring

    (a) Temperature and Humidity Sensors: Place sensors throughout the Dilmenler Stenter Machine to monitor and control drying conditions accurately.

    (b) Feedback Control Loops: Implement closed-loop control systems to adjust heating elements and airflow based on real-time sensor data.

2. Predictive Maintenance

    (a) Machine Learning Models: Analyze sensor data to predict component failures before they occur, scheduling maintenance proactively.

12.5 Compacting Process Automation

1. Smart Pressure and Temperature Control

    (a) Pressure Sensors: Integrate sensors to monitor roller pressure, allowing automatic adjustments for different fabric types.

    (b) Roller Temperature Control: Use temperature sensors and actuators to maintain optimal roller temperatures, improving fabric quality.

2. Automated Recipe Management

    (a) Control Software: Implement software that stores compacting parameters (recipes) for different fabrics, enabling quick setup and reduced errors.

12.6 Printing Process Precision

1. Real-Time Quality Inspection

    (a) Machine Vision Systems: Use high-resolution cameras and image processing algorithms to inspect print quality in real-time, detecting defects immediately.

    (b) Automatic Correction Mechanisms: Enable printers to adjust ink flow and pattern alignment automatically based on feedback from vision systems.

2. Enhanced Control Systems

    (a) Advanced HMI: Provide operators with intuitive interfaces displaying print quality metrics and machine status.

    (b) Remote Monitoring: Allow technical teams to monitor printing processes remotely, facilitating rapid response to issues.

12.7 Washing Process Efficiency

1. Water Usage Optimization

   (a) Flow Sensors: Install sensors to monitor water consumption, identifying opportunities to reduce usage without compromising wash quality.

   (b) Automated Chemical Dosing: Use dosage control systems to add detergents and chemicals precisely, improving consistency and reducing waste.

2. Temperature Control and Energy Management

   (a) Steam Flow Control: Implement valves and flow meters with actuators to regulate steam input based on real-time temperature requirements.

   (b) Heat Recovery Systems: Explore the use of heat exchangers to recover and reuse energy from hot wastewater.

13 Centralized Monitoring and Control

1. Industrial Internet of Things (IIoT) Platform

   (a) Unified Data Collection: Aggregate data from all machines into a centralized database for comprehensive analysis.

   (b) Dashboard Visualization: Develop dashboards displaying key performance indicators (KPIs), production metrics, and maintenance alerts.

2. Predictive Analytics and Maintenance

   (a) Data Analytics Tools: Use analytics software to identify patterns and predict maintenance needs across the production line.

   (b) Scheduled Alerts: Set up automated alerts for maintenance schedules, inventory replenishment, and performance deviations.

14 Energy Management Systems

1. Steam System Optimization
   (a) Smart Flow Meters: Upgrade to IoT-enabled steam flow meters for real-time monitoring and control of steam distribution.
   (b) Automated Control Valves: Install actuators on control valves to adjust steam flow automatically based on process demands.
2. Energy Consumption Analysis
   (a) Software Integration: Use energy management software to analyze consumption patterns, identify inefficiencies, and recommend optimization strategies.

15 Implementation Strategy

1. Phased Integration Approach
   (a) Pilot Projects: Begin with small-scale implementations in critical areas to evaluate benefits and refine solutions.
   (b) Scalability Considerations: Choose systems and technologies that can scale across the facility without significant additional costs.
2. Training and Skill Development
   (a) Operator Training Programs: Ensure that staff are trained to operate new systems effectively.
   (b) Technical Support Teams: Establish in-house teams capable of maintaining and troubleshooting mechatronic systems.

16 Expected Benefits

1. Increased Productivity: Automation and precise control reduce processing times and increase throughput.

2. Improved Quality: Real-time monitoring and adjustments lead to consistent product quality and reduced defects.
3. Cost Savings: Energy optimization and predictive maintenance lower operational costs.
4. Enhanced Safety: Automated safety systems protect workers and equipment.
5. Data-Driven Decision Making: Access to detailed operational data enables informed strategic decisions.

17 CHAPTER 13: GENERAL DISCUSSION & RECOMMENDATIONS

17.1 Health and Safety

The integration of mechatronics in textile engineering necessitates comprehensive health and safety protocols, particularly when dealing with automated systems and industrial equipment like boilers.

17.1.1 Automated Safety Systems

1. Implementation of emergency shutdown systems
2. Automated pressure monitoring in boilers and steam systems
3. Smart sensors for hazardous gas detection
4. Automated ventilation control systems
5. Real-time monitoring of machine guards and safety barriers

17.1.2 Personal Protection Systems

1. Smart PPE (Personal Protective Equipment) with embedded sensors
2. Automated access control to hazardous areas
3. Real-time monitoring of worker exposure to chemicals
4. Automated warning systems for excessive noise levels
5. Smart dust collection and filtration systems

17.1.3 Risk Management

1. Automated risk assessment systems
2. Digital safety audit tools

3. Real-time accident prevention monitoring
4. Smart maintenance scheduling
5. Automated compliance tracking systems

17.2 Research and Development

R&D in textile mechatronics focuses on advancing automation and improving efficiency while ensuring sustainability and safety.

17.2.1 Process Innovation

1. Development of smart fiber processing systems
2. Research into energy-efficient boiler systems
3. Advanced control algorithms for textile machinery
4. Innovation in automated quality inspection
5. Development of sustainable processing technologies

17.2.2 Material Technology Integration

1. Smart sensors for new material development
2. Automated testing systems for innovative textiles
3. Research into smart fabric production
4. Development of nano-textile processing
5. Integration of wearable technology in textiles

17.2.3 Sustainable Technologies

1. Research into energy-efficient heating systems
2. Development of water recycling technologies
3. Smart waste management systems
4. Green manufacturing processes
5. Eco-friendly dyeing technologies

17.3 Integration with Industrial Systems

Similar to the boiler systems discussed in the main text, modern R&D focuses on:

1. Advanced combustion chamber designs for energy efficiency
2. Smart control systems for optimal fuel usage
3. Integration of IoT sensors for real-time monitoring
4. Development of advanced safety valve systems
5. Research into automated maintenance protocols

17.4 Future Research Directions

1. Artificial Intelligence in process control
2. Machine learning for predictive maintenance
3. Advanced robotics for hazardous operations
4. Smart factory implementation strategies
5. Development of autonomous quality control systems

17.5 Safety Standards and Compliance

1. Development of automated compliance monitoring
2. Research into advanced safety protocols
3. Integration of digital safety management systems
4. Smart emergency response systems
5. Automated documentation and reporting systems

17.6 Recommendations

1. Implement comprehensive safety monitoring systems
2. Invest in sustainable technology research
3. Develop integrated training programs
4. Establish cross-functional R&D teams
5. Create standardized safety protocols

A Appendix 1: Organogram of the company

The company structure is as follow:

1. Country Manager

   Engr. Kazi Musa

   (a) Sr. Manager - Steam System & Control Instrumentation

       Engr. Md. Jainal Abedin

   (b) Team Lead - Boiler & Project

       Engr. Sayedur Rahman

   (c) Product Manager - Control Instrumentation

       Eng. Rajat Chakroborti

   (d) Customer Service Manager - Steam System & Boiler

       Engr. Moniruzzaman Bhuiyan

   (e) Customer Service Manager - Flowmeter & Control Instrumentation

       Engr. Amirul Islam

   (f) Accounts

       Parvej Bhuiyan

   (g) Manager, Admin & commercial

       Shams Al Arefin

The full organogram of Forbes Marshall, Bangladesh Division, is shown next page:

FORBES MARSHALL

- Country Manager, Forbes Marshall Bangladesh Operations (Engr. Kazi Musa)
  - Sr. Manager - System System & Control Instrumentation (Engr. Md. Jainal Abedin)
    - Energy Specialist - Energy Services Division- Team Lead (Engr. Monayam Masum)
    - Sr. Engineer - Technical Sales (Engr. Kazi Pavel Rahman)
    - Sr. Engineer - Technical Sales (Engr. Riaduzzaman Ridoy)
    - Sr. Engineer - Technical Sales (Engr. Sakil Ahmmed)
    - Sr. Engineer - Technical Sales (Engr. Nurul Hasan Chowdhury)
    - Engineer - Technical Sales (Engr. Kazi Redwanul Fahim)
    - Engineer - Technical Sales (Engr. Siam E Rabby)
    - Engineer - Technical Sales (Engr. Mahedi Azad)
    - Sr. Engineer - Control Instrumentation (Engr. CST Bony)
  - Team Lead - Boiler & Project (Engr. Sayedur Rahman)
    - Sr. Engineer - Boiler & Project (Engr. Faisal Rahman)
    - Sr. Engineer - Boiler & Project (Engr. Kamrul Islam)
  - Product Manager - Control Instrumentation (Engr. Rajat Chakroborti)
  - Customer Service Manager (Steam System & Boiler) (Engr. Moniruzzaman Bhuiyan)
    - Service Engineer - Boiler (Engr. Abul Bashar)
    - Service Engineer - Boiler (Engr. Rana)
    - Service Engineer - Steam System (Shah Alam)
    - Sr. Technician- Steam System (Mohammad Yusuf)
  - Customer Service Manager (Flowmeter & Control Instrumentation) (Engr. Amirul Islam)
    - Service Engineer - Flowmeter
  - Accounts (Parvej Bhuiyan)
    - Accounts Assistant (Hafizur Rahman)
  - Manager, Admin & Commercial (Shams Al Arefin)
    - Office Assistant (Mohammad Farid)

B Appendix 2: Group Photos & Environment

Figure 52: Group Photo at Forbes Marshall

Figure 53: RAL Group Intitial Meeting

Figure 54: Group Photo at Renaissance Apparel Ltd

Figure 55: Environment at Renaissance Apparel Ltd

Figure 56: Fabric Unit at Renaissance Apparel Ltd

References

[1] “Textile dyeing machines - thies textilmaschinen,” https://www.thiestextilmaschinen.com/product-portfolio/textile-dyeing-machines/, Oct. 2020, accessed: 2024-12-1.

[2] https://textilelearner.net/stenter-machine-types-functions/, accessed: 2024-12-1.

[3] “J420,” https://www.jenbacher.com/en/gas-engines/type-4/j420, accessed: 2024-12-1.

[4] “Steam boilers,” https://www.bosch-industrial.com/global/en/ocs/commercial-industrial/steam-boilers-669471-c/, accessed: 2024-12-1.

[5] https://textilelearner.net/effluent-treatment-plant-etp-in-textile-industry/, accessed: 2024-12-1.

[6] R. Paz, “The design of the pid controller,” 01 2001.

[7] V. Rishi Kumar, “Forbes marshall plans to step up export business,” http://www.thehindubusinessline.com/companies/forbes-marshall-plans-to-step-up-export-business/article6558007.ece, Nov. 2014, accessed: 2024-7-11.

[8] TLV, “What is steam?” https://www.tlv.com/steam-info/steam-theory/steam-basics/what-is-steam, Nov. 2022, accessed: 2024-7-12.

[9] TLV, “Types of steam,” https://www.tlv.com/steam-info/steam-theory/steam-basics/types-of-steam, Aug. 2022, accessed: 2024-7-12.

[10] “Different types of steam,” https://www.forbesmarshall.com/Knowledge/SteamPedia/About-Steam/Types-of-Steam11, accessed: 2024-7-12.

[11] S. Maity, S. Rana, P. Pandit, and K. Singha, “Advanced knitting technology,” 09 2021.

[12] https://www.sciencedirect.com/topics/engineering/level-control-system, accessed: 2024-12-1.