Induction Heater 4 FLUIDS

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BRASCOELMA

BRASCOELMA – ELECTROMAGNETIC INDUCTION HEATER

Company History

Founded in May 1976, **BRASCOELMA** was established with the objective of supplying electro-electronic and electro-metallurgical industrial equipment. Since its inception, the company has continuously developed and applied its own technology, ensuring the production of high-quality equipment for the national market.

Operating from its own dedicated facilities, **BRASCOELMA** is equipped with state-of-the-art machinery, enabling complete in-house manufacturing and ensuring total control over production quality. The company is committed to continuous improvement in both production technique and supplier selection, maintaining the highest standards in its products.

Products Manufactured by BRASCOELMA

BRASCOELMA specializes in the production of a wide range of industrial equipment, including:

- Inductive Heaters for Fluids – Direct heating solutions for gases (including hydrogen and natural gas), oils, heat transfer fluids, water, corrosive liquids, and flammable liquids.
- Low Voltage Power Transformers – Up to 3000V, available in single-phase and three-phase configurations.
- Power Transformers for Industrial Furnaces – Designed for high-performance applications.
- Autotransformers – Reliable solutions for voltage regulation and adaptation.
- Oil-Cooled Power Transformers – Custom-built for special applications.
- Power Rectifiers – Suitable for galvanic processes and high-voltage electrostatic applications.
- Power Reactors, Inductor Coils, and Cores – Specifically designed for industrial furnaces.
- Special Furnaces – Tailored for reduction processes and thermal treatment.
- AC Power Controllers (SCR Control) – Used in machines, furnaces, and induction heaters for efficient energy management.
- Services and Maintenance – Expert repair and maintenance of power transformers, rectifiers, reactors, and related equipment.

With a strong commitment to innovation, quality, and reliability, BRASCOELMA continues to bea trusted leader in the electro-electronic and electro-metallurgical industries.

The Development of the Fluid Induction Heater

In **1983**, Engineer **Mário Di Giulio** presented the concept of inductive heating (the conversion of electrical energy into heat), driven by governmental incentives to expand the use of electrical energy, **BRASCOELMA** pioneered the development of an innovative electric heater that revolutionized the industry. This groundbreaking invention, known as the **Inductive Electrothermic Generator**, or simply the **Fluid Induction Heater**, has since become one of the most promising advancements in electrical heating technology.

The concept was first presented at the **Second Electrothermal Seminar** in June 1983, organized by **CNBE (Electrothermal Brazilian National Commission)**. Following initial research and development, the **Fluid Induction Heater** was awarded Brazilian patents **Nº 8300396, 8302583, 8506299-5, 96011181-1, and 0102550-3 (pending).** A group of international engineers recognized it as one of the most brilliant innovations of the 1980s.

Today, the **Fluid Induction Heater** is a well-established and proven technology, demonstrating exceptional versatility in heating various fluids with an impressive **98% overall efficiency**—without limitations on temperature or pressure. This places it among the most efficient electrical heating solutions ever developed.

Thanks to its outstanding performance in the electrothermal sector, the **Fluid Induction Heater** has achieved **energy savings of approximately 30%** compared to traditional electric resistance heating and even greater savings when compared to fossil fuel-based heating systems.

Induction Heating: Efficiency, Cost Reduction, and Environmental Benefits

The **BRASCOELMA Induction Heater** offers a **clean, efficient, and cost-effective** solution for fluid heating. Free from **pollutant emissions,** it enhances **energy efficiency,** boosts **productivity,** and significantly **reduces operational costs.**

BRASCOELMA Induction Heater

The **BRASCOELMA** Induction Heater **(DIFHEMI)** offers the best direct heating solution for fluids. Without pollutant emissions, it enhances energy efficiency, increases productivity, and reduces operational costs.

Instead of passing through multiple stages and losing significant energy, **why not achieve heating in just one stage while maximizing energy efficiency?**

To ensure **better and broader utilization of available Exergy***, DIFHEMI was developed to eliminate the **inefficiencies of conventional indirect heat exchange systems.** By avoiding energy losses in heat transportation, DIFHEMI can be **installed close to consumption points,** thanks to its **compact design and minimal space requirements.**

Principle of Operation

The **BRASCOELMA Induction Heater** generates heat **through electromagnetic induction in the walls of stainless-steel tubes**, which form a specially designed tubular coil. This **heat is then transferred to the fluid flowing inside the tubes** with maximum efficiency. The system is **suitable for heating any kind of fluid** while ensuring safety and reliability.

How It Works

The **DIFHEMI** (Direct Fluid by Electromagnetic Induction Heating) technology is rooted in the principles of an **electrical power transformer,** utilizing Exergy generated by magnetic induction*. This heating system surpasses conventional methods due to its **simplicity, safety, and thermodynamic efficiency,** rendering older technologies obsolete.

The heat generation process in the **BRASCOELMA Induction Heater** is based on electromagnetic induction within a **stainless-steel tubular coil system:**

The concept is simple yet highly efficient:

1. **Voltage is applied to the primary coil.**
2. **Heat is generated in the secondary coil tube bundle.**
3. **Through the Joule effect**, since the coil's terminals are short-circuited, **all energy applied to the primary is converted into thermal energy in the secondary.**
4. **The circulating fluid is instantly heated,** achieving an *exceptional Exergetic thermoelectric efficiency of at least 98%**.

This innovative system **eliminates energy losses** associated with traditional heating methods, making **DIFHEMI a smarter, more efficient, and cost-effective solution** for industrial fluid heating.

The **DIFHEMI system** is designed for **maximum safety and efficiency,** making it a superior choice for industrial heating applications.

Why DIFHEMI is a Safe and Reliable Solution:

✅ **Zero voltage risk** – The **tubular bundles are electrically isolated,** ensuring there is **no voltage** between the mains and the equipment.

✅ **Safe for hazardous areas** – Can be operated **without risk**, even in **sensitive environments.**

✅ **Maintenance-free – No moving parts,** ensuring **continuous 24/7, 365-day operation.**

✅ **Handles extreme conditions** – Operates **at high temperatures, high pressures, and high power levels.**

Additional Advantages:

- **Compact and modular design** – Can be **installed close to consumption points,** saving valuable space.
- **Prevents fluid degradation** – The **low inner tube wall temperature** prevents **hot spots, cracking, carbonization, or chemical alteration** of the heated fluid.
- **Stable operation** – Ensures **consistent temperatures** with **no fluctuations** during the process.
- **Dry, naturally cooled system** – Eliminates **the need for external cooling** while maintaining efficiency.
- **Non-corrosive and waste-free** – Produces **no waste** in the thermal fluid heating process.

This **innovative system** is designed to **ensure total safety for both operators and industrial processes,** setting a new standard in **efficient and risk-free heating solutions.**

Unlike traditional heating methods that require multiple stages, **DIFHEMI heats fluids in a single step.** By leveraging **electromagnetic induction**, the fluid is efficiently heated as it flows through the system, optimizing energy use and ensuring **precise temperature, pressure, and flow control.**

Key Advantages of DIFHEMI:

- ✅ **Single-stage heating process** – No need for multiple conversion steps.
- ✅ **Pollution-free operation** – Zero emissions or contaminants.
- ✅ **Silent and static –** No moving parts, eliminating mechanical wear.
- ✅ **No need for peripheral equipment** – Self-sufficient design.
- ✅ **Naturally cooled** – No external cooling systems required.
- ✅ **Minimal regulatory requirements –** No complex environmental or government permits needed.
- ✅ **Explosion-free and maintenance-free** – Safer and more reliable than traditional heaters.
- ✅ **Superior thermodynamic efficiency – 10-30% more efficient** than conventional heating systems.
- ✅ **Compact, automated, and cost-effective – Easy installation, low investment, and reduced operating costs.**

As illustrated in the image below (Fig.01), the fluid enters the **inlet tube**, passes through the **internal tube bundles**, and exits the **outlet tube**, immediately heated to the **desired temperature** with **high energy efficiency and operational simplicity**. **DIFHEMI redefines industrial heating,** offering a **smarter, cleaner, and more efficient solution** for fluid heating applications.

This **heat is efficiently transferred to the fluid** flowing inside the pipes.

FIG. 01: AN EXPLODED VIEW OF A DIFHEMI HEATER DESIGN, SHOWCASING BOTH INTERNAL AND EXTERNAL CONSTRUCTION DETAILS.

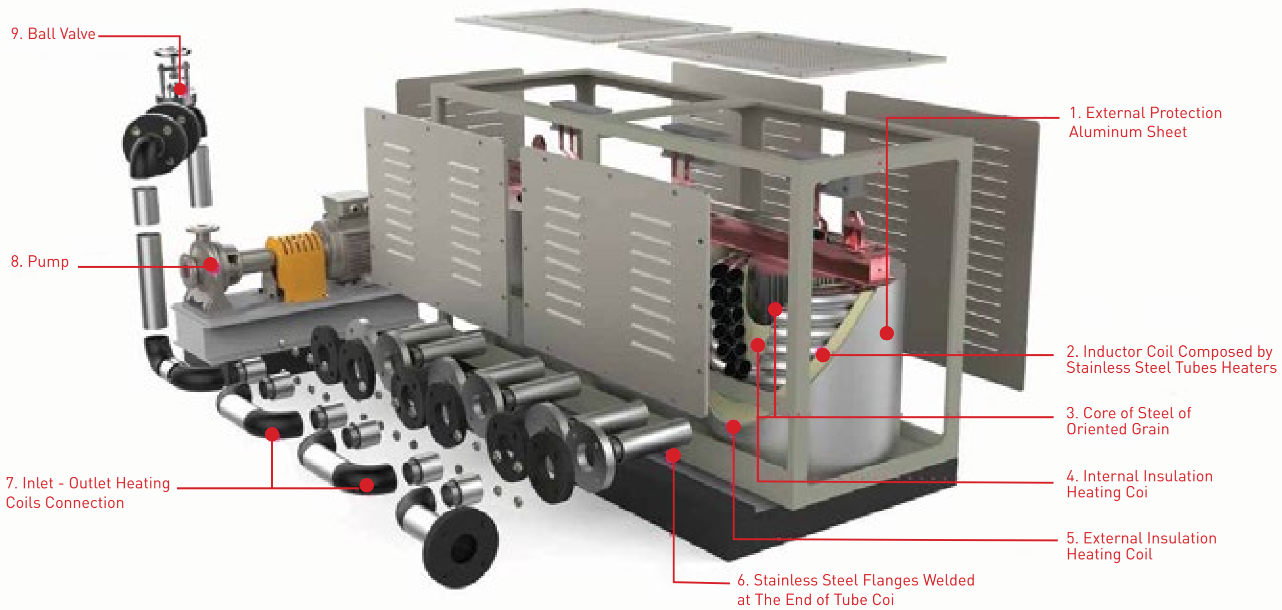

FIG. 02: PHOTO OF A TYPICAL MAGNETIC INDUCTION HEATER PRODUCED BY BRASCOELMA.

How long is a DIFHEMI inductive heater's working life?

Based on our practical experience, the working life of a DIFHEMI inductive heater is significantly longer than that of an electrical-resistance or fossil-fuel-burning heater. DIFHEMI heaters operate on the **transformer principle**, making their durability comparable to that of power transformers. Their lifespan depends primarily on proper operational care, as well as factors such as the **type of fluid used**, and the **quality specifications** defined during the initial design.

We have **DIFHEMI** heaters in operation for over **20 years without requiring maintenance.** To ensure such longevity, we always recommend **standard operational care**, just as is done with power transformers.

This system guarantees a **heat exchange efficiency of 98%** and maintains a **high-power** factor between **0.95 and 0.98 due to use they Exergy ****.

** **What is Exergetic Efficiency?**

From the perspective of **Exergy,** efficiency calculations take into account the thermodynamic conditions of the external environment surrounding the unit where the overall process occurs or the component where a specific process is carried out. This method provides a novel approach to efficiency measurement, establishing the ratio between:

1. The loss in the energy conversion capacity of the utilized energy to achieve the desired effect.
2. The loss in the energy conversion capacity of the required energy to perform the process.

The **conversion capacity** of a given amount of energy is measured relative to the external environment and applies to each form of energy. This c**onversion capacity** is called **Exergy**.

Why Use Exergy?

The advantage of using **Exergy** is that it standardizes different forms of energy onto a **single basis for comparison.** Unlike traditional energy analysis, Exergy considers the ability of energy to be converted into useful work, making it possible to directly compare the initial and final Exergy in any process.

This principle is the foundation of **Exergetic analysis**, which DIFHEMI employs in heater efficiency calculations. Exergetic analysis offers more **precise results**, enabling better decision-making when modifying designs or optimizing operating conditions. Additionally, it supports **thermos-economic analysis,** helping identify different energy quality and process options, ultimately leading to cost reductions.

Technical Definition Of Exergy

Technically, **Exergy**, or **maximum work content**, is defined as:

"The maximum amount of work obtainable when a system transitions from an initial to a final state, comparable to Gibbs free energy **(G = U + PV - TS).**"

Exergy measures the **degree of interaction** between a system, its environment, and the standard state.

Energy vs. Exergy

- **Energy** is a system property governed by the **First Law of Thermodynamics**, which states that energy cannot be destroyed, only converted. However, in each conversion, part of the energy becomes unavailable for work.

- According to Rant, **Exergy** represents the portion of energy that can be **converted into another form**, such as heat or work.

As Rant and Kotas describe:

ENERGY = EXERGY + ANERGY

- **Exergy:** The portion of energy that can be used.

- **Anergy:** The portion of energy that cannot be converted into useful work.

Thus, energy is the **sum** of exergy (usable energy) and anergy (unusable energy). According to Kotas, **Exergy** quantifies the **maximum work a system can perform** to reach equilibrium with its environment.

How are DIFHEMIs controlled?

DIFHEMI heaters are controlled by a **transistorized power-control panel** housed in a **carbon-steel cabinet.** The cabinet is **blasted back to bare metal** and coated with an **electrostatic powder paint** in **Munsell neutral color N 6.5.** Other colors can be applied upon request. The equipment is designed for both **indoor and outdoor applications.**

Key Characteristics of DIFHEMI Heaters:

- **Phase-angle control** for precise power regulation.
- **Soft-start module** to prevent power surges.
- **Inhibit-signal input** for external control integration.
- **Current feedback** for enhanced stability and efficiency.
- **ON-OFF control** with power contactors up to 80 kW.
- **Reliable operation** in aggressive environments.
- **Adjustable load response time,** ranging from **a few seconds to several minutes.**
- **Supply voltage capability** up to **760 V.**
- **Compatible control signals:**
- **0-20 mA, 4-20 mA, 0-5 V,** and **0-10 V.**
- **Adjustable firing angle** optimized **for inductive loads.**
- **Seamless interconnectivity** with major **PLCs** available on the market.

This robust design ensures **high performance, durability, and adaptability**, making DIFHEMI heaters an excellent choice for various industrial applications.

Advantages Over Traditional Heating Systems

✅ **Superior Temperature Control** – Due to its **low thermal inertia**, the **BRASCOELMA Inducti Heater** ensures **precise and responsive temperature regulation,** unmatched by conventional fluid heating systems.

✅ **Higher Energy Efficiency** – Despite using **electric energy,** many heating applications have proven **more cost-effective** with induction heating compared to **fuel oil or natural gas systems.**

✅ **Rapid Response to Temperature Changes** – The induction heating system delivers **quick adjustments** to variations in fluid temperature, improving process efficiency.

- ✅ **Safer & More Efficient for High-Viscosity Fluids** – The **BRASCOELMA Induction Heater** is the **optimal choice** for heating **ultra-viscous oils,** offering enhanced reliability and performance.

- ✅ **Energy Savings of Up to 15%** – In practical applications, replacing **resistance-based heaters** with **inductive heating technology** has resulted in energy savings of up to **15%.**

By adopting **inductive heating**, industries can achieve **lower energy costs, reduced environmental impact, and improved process efficiency,** making it the **smart choice for modern fluid heating applications.**

FEATURES OF THE BRASCOELMA INDUCTION HEATER

Safety

The **Electrical Induction Heater** offers several **safety advantages** due to its unique construction and operating principles:

- ✅ **Dry & Naturally Cooled Operation** – The system functions **without the need for external cooling,** ensuring **reliable performance** with minimal maintenance.

- ✅ **Flame-Free & Spark-Free** – Unlike traditional heating systems, the **Inductive Heater does not produce flames** or **spark-over**, making it an **ideal choice for hazardous environments.**

- ✅ **Zero Voltage on Heating Elements** – The entire **heating element remains at zero potential** relative to any external installation, enhancing safety during operation.

- ✅ **Efficient & Uniform Heating – The tubular heating elements** are heated by circulating currents within their walls, ensuring:

  - **Constant surface heat flux** for steady and efficient fluid heating.
  - **High convection heat transfer coefficient,** optimizing heat distribution.
  - **Minimal temperature difference** between the heating surface and the flowing fluid, preventing overheating and improving overall safety.

With its **high efficiency, reliability, and enhanced safety features**, the **BRASCOELMA Induction Heater** is the **ideal solution f**or a wide range of industrial fluid heating applications.

Efficiency of the BRASCOELMA Induction Heater

The **BRASCOELMA Induction Heater** delivers **exceptional efficiency** compared to conventional resistance heating, making it a **cost-effective and durable** solution for industrial heating applications.

Key Efficiency Advantages

✅ High Heat Transfer Efficiency

- The t**ubular heating elements** enable **highly efficient heat exchange**, ensuring **minimal temperature differences** between the heating surface and the fluid.
- The fluid flows at **high speed through the pipes**, maximizing heat transfer and optimizing energy use.

✅ **Lower Wall Temperatures = Greater Durability**

- The **high heat exchange coefficient** keeps the **pipe wall temperature low**, reducing thermal stress and extending the lifespan of both the heater and the fluid.
- This feature is especially beneficial for heating **thermal fluids (mineral or synthetic oils) and ultra-viscous oils.**

✅ **98% Global Efficiency**

- **Inductive heating achieves up to 98% efficiency,** significantly outperforming combustion based heating systems.
- Traditional **fuel-based systems** suffer from **substantial energy losses**, making the **Induction Heater a more economical option in many applications.**

✅ **Energy & Cost Savings**

- Despite using **electrical energy,** the **high efficiency of inductive heating** often makes it **cheaper to operate** than **mineral oil or natural gas combustion systems.**
- The **system's fast response time** allows **precise temperature control**, further reducing energy waste.

✅ **Ideal for Ultra-Viscous Oils**

- Among **countless industrial applications**, the **Induction Heater** has proven to be the **most efficient and safest solution** for heating **ultra-viscous oils.**

With its **unmatched efficiency, durability, and cost-effectiveness**, the **BRASCOELMA Induction Heater** sets a new **standard for industrial heating technology.**

Maintenance, Temperature, and Pressure Capabilities- Minimal Maintenance Requirements

The **BRASCOELMA Induction Heater** is designed for **long-term reliability** with **minimal maintenance,** thanks to its unique construction:

✅ **No Moving Parts** – Eliminates mechanical wear and tear, reducing maintenance costs.

✅ **No Conventional Electric Resistances** – Avoids common failure points associated with resistance heaters, increasing system longevity.

✅ **Robust Construction** – Designed for **continuous industrial use** with high durability.

Temperature & Pressure Capabilities

The **operating limits** of the Induction Heater are determined **only by the type of fluid used,** making it an extremely versatile heating solution.

✅ **Works at High Temperatures & Pressures** – Can handle extreme operating conditions based on fluid properties.

✅ **Adaptable to Various Applications** – Suitable for industrial processes requiring **precise thermal control** at elevated pressures.

With its **low-maintenance design and superior temperature/pressure adaptability**, the **BRASCOELMA Induction Heater** is an **ideal choice for demanding industrial heating applications.**
Immediate Availability, Modularity, and Compact Design

Rapid Heating & Immediate Availability

Unlike conventional heating systems or boilers, the **BRASCOELMA Induction Heater** provides:

✅ **Instant Heating** – Due to its **low thermal inertia**, it quickly reaches the desired fluid temperature.

✅ **Fast Startup** – Immediately begins heating after being energized, optimizing process efficiency.

✅ **Consistent Performance** – Ensures precise temperature control with minimal delays.

Modular Application & Flexible Integration

The **Induction Heater** is designed for **seamless integration** into existing industrial layouts:

✅ **Easy Installation** – Can be adapted to **existing infrastructure** without requiring major modifications.

- ✅ **Scalability** – Modular design allows **expansion per production sector or specific equipment.**
- ✅ **Interconnectivity** – Multiple modular units can be linked to **existing consumer equipment**, improving system efficiency.

Compact & Space-Saving Design

Compared to traditional heating systems of equivalent power, the Induction Heater offers:

- ✅ **Smaller Footprint** – Maximizes available workspace.
- ✅ **Easier Placement** – Compact structure simplifies installation.
- ✅ **Optimized Layout Usage** – Efficient use of industrial space, ideal for restricted environments.

Inductive Heater: Advantages & Applications

The **BRASCOELMA Inductive Heater** is the **most efficient and versatile solution** for direct fluid heating. With **zero emissions**, it optimizes energy use, boosts productivity, and significantly **reduces operating costs.**

How It Works

The Inductive Heater transfers heat to the fluid via electromagnetic induction in the walls of stainless-steel pipes. This ensures:

- ✅ **Maximum efficiency (98%)**
- ✅ **Prevention of fluid cracking**
- ✅ **Direct and uniform heating**
- ✅ **What Fluids Can Be Heated?**

Heat Transfer Fluids

- ✅ **Water & Steam Generation**
- ✅ **Fuel Oils (for burners, turbines, etc.)**
- ✅ **Natural Gas & Hydrogen**
- ✅ **Tars & Corrosive Liquids**
- ✅ **High-Purity Fluids & Lubricants**

- ✅ Nitrogen & Other Industrial Gases
- ✅ Any Process Fluids Requiring Heating

Key Advantages

- ✅ **Works Dry & Naturally Cooled** – No additional cooling system required.
- ✅ **High Accuracy Temperature Control** – Ensures **stable and precise heating.**
- ✅ **Immediate Heat Availability** – No startup delays.
- ✅ **Fast Response to Temperature Changes** – Ideal for dynamic industrial processes.
- ✅ **98% Efficiency** – Significant energy savings compared to other heating systems.
- ✅ **High Power Factor (93-98%)** – Reduces energy losses.
- ✅ **Handles High Temperatures & Pressures** – Versatile across various industries.
- ✅ **Eliminates Heat Exchangers** – Simplifies system design.
- ✅ **Safe for Pure or Corrosive Fluids** – No contamination risk.
- ✅ **Compact & Modular Design** – Easy integration into existing setups.
- ✅ **Zero Maintenance** – No moving parts, no wear-and-tear.
- ✅ **Low Investment Cost** – Affordable and **long-lasting.**
- ✅ **Minimal Temperature Difference** Between **Tube Wall & Fluid** – Prevents **fluid degradation.**

Industries & Applications

- ✅ **Petrochemical & Oil Refineries** – Heating crude oil, fuel oils, and lubricants.
- ✅ **Power Plants** – Steam generation and fuel heating.
- ✅ **Chemical & Pharmaceutical** – Heating high-purity and corrosive fluids.
- ✅ **Food Processing** – Heating edible oils and liquid ingredients.
- ✅ **Gas Processing** – Natural gas, hydrogen, and nitrogen heating.
- ✅ **Industrial Manufacturing** – Various heating applications across industries.

Additional Key Features

- ✅ **Fast Temperature Response** – Reacts quickly to process demands.
- ✅ **Modular Installation & Space-Saving** – Compact design allows easy integration.
- ✅ **Ideal for Process Innovations** – Adapts to new and evolving industrial needs.

- ✅ **Zero Pollution** – Environmentally friendly with no emissions.
- ✅ **Direct Connection to Local Electrical Grid** – No need for additional infrastructure.
- ✅ **High Power Capacity** – **Up to 5000 kW** for large-scale industrial applications.
- ✅ **Flexible Voltage Options** – Available in **220V / 380V / 440V / 480V** and **higher** as needed.

It sounds like **BRASCOELMA's Induction Heater** is highly versatile and suitable for a broad range of **industrial applications**. With**1000+ installations** worldwide, it's a well-proven technology for heating **fuel oils, heat transfer fluids**, **compressed air, water, and heavy oils** or other fluids.

Technical Document: Induction Heater Applications

Mains Applications

The Induction heater is a highly efficient and versatile heating solution for a wide range of industrial applications. It provides direct heating for various fluids, ensuring optimal energy use, improved productivity, and reduced operational costs.

Ideal Applications for Heating:

- **Ultra-viscous fuel oils** – Ensures effective heating and flow improvement.
- **Heat transfer fluids** – Used in vulcanization, molding, chemical reactors, or thermal traces.
- **Gases** – Suitable for hydrogen, nitrogen, compressed air, air, and other gases.
- **Surface treatment baths** – Used in pickling, washing, and related processes.
- **Resin pigment and fiber production** – Efficiently heats process fluids.
- **Pitch heating (395ºC)** – Ensures stable heating at high temperatures.
- **High purity water** – Used in specialized industrial processes.
- **Vapor generation** – Enables effective steam production.
- **Plastic molding and extrusion** – Provide precise temperature control.
- **Chemical distillation and concentration** – Optimize processing efficiency.
- **Lubricating oil refining and re-refining** – Enhances product quality.
- **Fluid pasteurization (e.g., milk processing)** – Ensures safety and consistency.
- **Food dehydration** – Facilitates efficient moisture removal.
- **Food product distillation and concentration** – Supports food processing industries.

- **Pharmaceutical processes** – Enables accurate and controlled heating.
- **Resin and pigment manufacturing** – Ensures high-quality production.
- **Fractionization of crude oil asphalt, bitumen, and high viscosity oil heating, also pyrolysis** – Enhances refining and processing efficiency.
- **Pickling and phosphating** – Used in metal treatment and finishing.
- **Manufacture of Ethylene and Glycols** – Ensures stable processing conditions.
- **Deodorization of edible oils** – Improves oil quality and shelf life.
- **Manufacture of fibers, polyester, etc.** – Supports textile and polymer industries.
- **Vulcanization and rubber processing** – Enables precise temperature control.
- **Fatty acid manufacturing** – Ensures stable and efficient heating.
- **Degreasing bath heating** – Used in industrial cleaning and surface preparation.
- **All industrial processes requiring fluid heating** – Offers a versatile and efficient heating solution.

Tests and Inspections

Tests and inspections applied to the induction heater were developed by **BRASCOELMA** because there are no specific standards. The minimum tests required and performed in our own laboratory are the following:

1. Penetrating Liquids Test

- Applied to all welds of stainless-steel tubes, following ASTM Section III Vol.3 and JIS-Z2343 standards.

2. Pressure Test

- Conducted at 1.5 times the working pressure applied to heating elements to ensure stru-tural integrity and safety.

3. Performance Test

- Conducted with reduced voltage and power applied to the induction heater to verify operational efficiency.

4. Power Factor Measurement

- Evaluation of the power factor to ensure optimized electrical performance and energy efficiency..

5. Ohmic Resistance Measurement

- Conducted using a Wheatstone bridge to calculate copper coil losses and verify the electrical efficiency of the heater.

6. Effective Power Rating Measurement

- Determination of the real power output of the induction heater to validate performance specifications.

7. Insulation Resistance Measurement

- Measured between the inductors and grounded tubular coils using a 5000-volt megger to ensure electrical insulation quality.

8. Applied Voltage Test

- A voltage of 2,500 volts is applied between the primary inductors and grounded tubular heating elements for 1 minute to check dielectric strength.

9. Operational Electronic Panel Tests

- Assessment of electronic panel functionality, including thyristor performance, to verify control system efficiency and reliability.

These rigorous tests ensure the induction heater meets the highest standards of efficiency, reliability, and safety before deployment in industrial applications.

Conclusion

The induction heater is an advanced heating technology that provides a reliable, safe, and cost-effective solution for a wide range of industrial applications. With its high efficiency, rapid temperature response, and pollution-free operation, it stands out as the preferred choice for fluid heating in diverse industries.

ADVANTAGES IN USING THE INDUCTIVE HEATER FOR DIFHEMI FLUIDS, REPLACING STEAM BOILERS HEATED BY FOSSIL FUELS

The inductive heater, Difhemi, offers numerous advantages in steam generation without polluting emissions, increasing productivity and reducing operating costs. Below are the key benefits of using Difhemi instead of conventional steam boilers:

1. Exemption from Governmental Approvals

- Steam boilers heated by fossil fuels (gas, oil, tar, coal, etc.) require exclusive housing and plant approval by multiple government agencies, such as Environment, Fire, Ministry of Labor, and City Hall.

- **Difhemi is exempt from these governmental approvals.**

2. Simplified Installation and Reduced Infrastructure

- Boilers require an extensive piping network, increasing both investment costs and maint-nance needs, as they cannot be installed near production machines due to safety regulations.

- **Difhemi does not need a pipe network because it can be installed near the point of use.**

3. Lower Administrative Expenses

- Boilers necessitate various administrative expenses, including operation reports, supply acquisition, and maintenance part purchases.

- **Difhemi eliminates all these administrative expenses.**

4. Minimal Maintenance Costs

- Boilers require continuous maintenance and the purchase of accessories, adding to operational costs.

- **Difhemi requires minimal maintenance, with only occasional thyristor replacement due to improper operation.**

5. Elimination of Operator and Management Costs

- Boiler operations require dedicated personnel for continuous monitoring and maintenance.

- **Difhemi eliminates these labour costs, operating autonomously.**

6. No Need for steam traps and Water Treatment

- Boilers require regular maintenance of steam traps and water treatment systems to ensure efficiency and longevity.

- **Difhemi eliminates these costs and maintenance tasks.**

7. Immediate Heat Availability

- Due to its low thermal inertia, **Difhemi provides nearly instant heat upon energization, elim-nating the long warm-up times required for boilers to reach operational temperatures.**

- Connecting water to the inlet tube immediately results in steam at the desired temperature or even superheated steam at the outlet.

8. Superior Energy Efficiency

- **Difhemi offers a 98% thermal efficiency, ensuring optimal energy utilization and cost savings.**

9. No Water Consumption

- Unlike boilers, which consume large amounts of water for steam generation**, Difhemi ope-ates without direct water consumption, reducing overall resource expenditure.**

10. Silent Operation

- Boilers generate significant noise during operation.
- **Difhemi is completely silent during the production of steam.**

11. Compact Design and Space Efficiency

- Due to its innovative construction, **Difhemi requires minimal space, making it an ideal solution for industrial environments with limited space availability.**

12. Elimination of Maintenance Logs and Regulatory Compliance

- Boilers require detailed maintenance and operation logs, which must be regularly reported to authorities.
- **Difhemi does not require maintenance logs or regulatory filin**gs.

13. Reduced Heat Loss and Leakage

- Boilers lose steam through leaks in the piping network, leading to energy waste.
- **Difhemi, installed near the point of use, eliminates heat loss associated with long piping networks.**

14. No Need for Fuel Additives

- Boilers require fuel additives for combustion efficiency and maintenance.
- **Difhemi operates without any need for chemical additives.**

15. Precise and Uniform Temperature Control

- **Difhemi ensures constant and precise temperature regulation, preventing fluid degradation and maintaining process stability.**

16. Safe and Low-Pressure Operation

- Boiler operation involves high pressures, increasing safety risks.
- **Difhemi operates at the pressure equivalent to the pump, reducing the risk of high-pressure hazards.**

17. No Governmental Registration Required

- Boilers must be registered with labour and environmental authorities.
- **Difhemi does not require registration with any government agency.**

18. Enhanced Safety

- Boiler systems pose potential risks to operators, facilities, and production processes.
- **Difhemi ensures total safety for operators and the manufacturing environment.**

19. Cost Savings on Steam Transportation

- Boiler-generated steam requires extensive piping networks, adding to infrastructure and maint-nance costs.
- **Difhemi eliminates the need for steam transportation infrastructure, reducing costs.**

20. No Need for Maintenance Contracts

- Boilers require service contracts for equipment maintenance, fuel storage tanks, hydraulic systems, fuel injectors, pressure tanks, NR13 compliance, and round-the-clock operators.
- **Difhemi eliminates all these costs, making it a more economical and efficient heating solution.**

Conclusion:

By replacing traditional fossil fuel-powered steam boilers with the **Difhemi Inductive Heater**, industries can significantly reduce operational costs, improve efficiency, eliminate pollution, and enhance workplace safety while achieving superior heating performance. Difhemi provides a **highly efficient, cost-effective, and environmentally** friendly alternative to traditional steam boilers. With **immediate heat availability, low maintenance, high efficiency, and enhanced safety,** Difhemi is the ideal solution for fluid heating across various industries.

THERMAL ENGINEERING: THE PROBLEM OF "HOT-POINTS"

Maintaining fluid temperature within precise tolerances is crucial in many industrial processes. A significant challenge in this regard is the occurrence of "**hot-points**" (or "**hot-spots**" in technical terminology), particularly in liquid-based systems. A **hot point** refers to small, localized areas where temperatures significantly exceed the specified limit, which can negatively impact process quality, safety, and the physical and chemical properties of the fluid.

One of the most critical applications where hot-spot control is essential is in **nuclear reactors**, where excessive localized heating can compromise reactor integrity. Generally, hot-points occur at the **fluid-surface boundary** of heat-exchanging components, such as tubes or plates, where heat is transferred from a solid surface to the fluid.

Role of Turbulent Flow in Temperature Uniformity

A **turbulent flow regime**—characterized by high Reynolds numbers—helps in **temperature homogenization** by improving heat distribution. This occurs through **convective heat transfer**, where the fluid absorbs heat from the solid surface, preventing extreme local temperature variations.

However, even with ideal mixing, a **hot point** can only be **completely eliminated** if the **solid surface temperature (t)** remains within a safe limit. Specifically, for a **hot point** to be prevented, the temperature of the heat source must not exceed the **maximum allowable fluid temperature (t_2)**, accounting for the system's positive tolerance **Δt.**

Mathematical Condition for Hot-Point Elimination

If:

- **t** = target fluid temperature
- **t_1** = minimum allowable temperature
- **t_2** = maximum allowable temperature
- **Δt** = positive tolerance

A **hot-point** is effectively eliminated when the heat-exchanging surface temperature satisfies the condition:

$$(t+\Delta t)\leq t_2$$

By ensuring this condition is met, localized overheating is prevented, maintaining system efficiency and safety.

To achieve this ambitious goal, a **Special Fluid-Flow Maintenance Equipment** was studied, designed, manufactured, and **prototyped**. This advanced system **ensures a constant temperature throughout the fluid flow, eliminating hot spots by leveraging state-of-the-art technology** and probability-based calculations.

Maintaining uniform temperature in all components of a **fluid-flow system** requires addressing two essential factors. The first is **preventing any localized maximum temperature t2t_2t2** within the industrial system. In this context, an **industrial system follows the Classical Thermodynamics definition**—a material set with **defined boundaries**, within which state variable transformations occur. This factor will be the subject of a **forthcoming scientific analysis.**

An important factor—but only relevant once the first factor is assured—**is the homogenization of fluid temperatures throughout the entire system.**

1. THE RUNOFF RATE

To achieve uniform fluid temperature across all parts of the system, it is crucial to first eliminate **hot points** (Factor **a**). Once this condition is met, **temperature homogenization** (Factor **b**) can be effectively implemented.

A key aspect of achieving this homogenization is ensuring a **high Reynolds number**, which corresponds to a **turbulent flow regime**. Turbulent flow enhances **heat distribution** and prevents localized overheating by promoting efficient mixing.

To maintain the necessary turbulence, the **fluid velocity** must meet a **minimum threshold**. This minimum velocity is determined based on the **Continuity Equation**, ensuring that the flow rate is sufficient to sustain turbulence and facilitate uniform heat transfer.

In practical applications, this minimum velocity is expressed in **meters per second (m/s)** and serves as a critical design parameter for fluid flow systems.

The **continuity equation** is based on the **principle of mass conservation** and can be expressed as:

$$Q = A.v$$

or, in a more general form:

$$D = A.v/ \rho$$

where:

- Q = volumetric flow rate (m^3/ s)
- D = mass flow rate (kg/s)
- A = cross-sectional area (m^2)
- v = fluid velocity (m/s)
- ρ = fluid density (kg/m^3) (*)

If the fluid is **incompressible**, the equation simplifies to:

$$A_1v_1 = A_2v_2$$

where indices 1 and 2 represent two different points in the flow.

(*) **The density (ρ\rhoρ) of a liquid** is typically expressed in **kg/m³** and depends primarily on **temperature** (and, to a lesser extent, pressure).

For most **liquids**, as **temperature increases**, **density decreases** because the liquid expands. The relationship between density and temperature is often given in tables or empirical equations specific to the liquid.

Example: Density of Water (kg/m³) at Different Temperatures

Temperature (°C)	Density (kg/m³)
0°C	999.84
20°C	998.21
50°C	988.03
100°C	958.40

For other liquids like **oil, alcohol,** the density varies differently with temperature and often follows an approximate linear equation:

$$\rho(T)=\rho0.\ (1-\beta(T-T_0))$$

where:

- ρ(T) = density at temperature T
- ρ0 = reference density at T0
- β = thermal expansion coefficient (1/K1)

Describing the concept of **flow distribution in parallel pipes** to manage high flow rates.

We start with the equation:

$$S = D.v/c$$

For pipes, the cross-sectional area S is given by:

$$S=\pi.d^2/4$$

where:

- d = inner diameter of the pipe
- v = flow speed
- D = total flow rate
- c= a proportionality factor

Why Split the Flow into Parallel Pipes?

When **d** becomes too large, practical issues arise:

1. **Structural limitations** – Manufacturing and installing very large pipes is costly.
2. **Flow velocity constraints** – Higher diameters may cause very low speeds, leading to sediment-tion in some applications.
3. **Pressure drop management** – Multiple smaller pipes can reduce pressure loss compared to a single large one.

Thus, engineers **split the total flow D** into **multiple smaller parallel pipes**, ensuring each handles a portion of the total flow while maintaining an optimal **Reynolds number** and pressure conditions.

The **Reynolds number** (Re) is a crucial parameter that considers **fluid velocity, viscosity, and pipe diameter** to determine the flow regime.

The formula for the **Reynolds number** is:

$$Re=\rho.v.D/\mu$$

or alternatively, using **kinematic viscosity (ν):**

$$Re=v.D/\nu$$

where:

- Re = Reynolds number (dimensionless)
- ρ = Fluid density (kg/m3)
- v = Flow speed (m/s (which must be optimized for the system)
- D = Pipe diameter (m)
- μ = Dynamic viscosity (Pa*s or N·s/m2 or Kg/ms)
- ν = Kinematic viscosity (m2/) where ν=μ/ρ

How to Determine a Minimum Reynolds Number?

- To ensure efficient flow, **a minimum Reynolds number** is often required.
- For fully **turbulent** flow, engineers typically **aim for Re>4000.**
- If the flow is too slow **(low Re)**, the system may suffer from **higher viscosity effects**, causing exce sive pressure to drop or inefficient heat transfer.

Thus, the **desirable speed** should be **high enough** to maintain a good **Re** value, but not too high to cause excessive energy loss due to turbulence.

PELICULAR COEFFICIENT

The **Coefficient of Film** (or **Convective Heat Transfer Coefficient, h**) is a key parameter in heat transfer by convection. It represents the rate of **heat transfer per unit area per unit temperature difference** between a solid surface and a fluid.

Relationship with the Nusselt Number

The **Nusselt number (Nu)** is a dimensionless quantity that relates the convective heat transfer to conductive heat transfer within a fluid layer. It is expressed as:

$$Nu = h.D/k$$

where:

- Nu = Nusselt number (dimensionless)
- h = convective heat transfer coefficient (W/m^2K)
- D = characteristic length (e.g., pipe diameter for internal flow) (m)
- k = thermal conductivity of the fluid (W/mK)

Dependency on Reynolds and Prandtl Numbers

The Nusselt number is typically correlated with the **Reynolds number (Re)** and **Prandtl number (Pr)** as:

$$Nu = C.Re^m .Pr^n$$

where **C**, **m**, and **n** are empirical constants that depend on the flow condition (laminar, turbulent, internal, or external).

Common Engineering Correlations

For **laminar flow in a pipe** (Re<2300)

$$Nu=3.66$$

For **fully developed turbulent flow** (Re>4000, **Dittus-Boelter equation** applies:

$$Nu=0.023.Re^{0.8} *Pr^{0.3}$$

where:

- Pr = Prandtl number (dimensionless), given by Pr=cpμ/k
- cp = specific heat capacity (J/kgK)
- μ = dynamic viscosity (Pa·s)

Conclusion

The **film coefficient h** can be determined using the Nusselt number formula once Re and Pr are known. These correlations have been extensively verified in engineering applications for heat exchangers, cooling systems, and industrial processes. Since the **thermal conductivity (k), specific heat capacity (cp)**, and **dynamic viscosity (μ)** are all **temperature-dependent**, their variation affects the heat transfer performance.

Why is a High Heat Transfer Coefficient (h) Essential?

1.Prevents Hot Spots ("Hot-Points")

- In **induction heating**, local overheating can occur if heat is not efficiently transferred away from the surface.
- A **high convective heat transfer coefficient (h)** ensures better heat dissipation, reducing the risk of thermal stress and material degradation.

2.Temperature Dependence of Fluid Properties

- **Thermal conductivity (k)** generally **increases** with temperature for gases but **decreases** for liquids.
- **Viscosity (μ)** typically **decreases** with temperature for liquids, reducing resistance to flow.

- **Specific heat (cp)** changes depending on the fluid but impacts the Prandtl number (Pr), which influences heat transfer.

Ensuring a High (h) Value

To maximize **convective heat transfer**, engineers focus on:

1. **Increasing Flow Speed (v)** → Higher **Reynolds number (Re)** promotes turbulence, improving heat transfer.

2. **Enhancing Fluid Properties** → Using fluids with high k and optimal Pr**Using Surface Enhancements** → Fins, ribs, or coatings can increase effective heat transfer.

3. **Optimizing Flow Geometry** → Using multiple smaller pipes instead of one large one to improve heat exchange efficiency.

Conclusion

Maintaining a **high heat transfer coefficient (h)** is **critical in induction heating systems** to avoid **hot spots** and ensure **uniform temperature distribution**. The **Nusselt number correlation** helps in selecting the right conditions for better cooling and thermal management.

The Inductive Heat Exchanger: A Specialized Solution

Maintaining the temperature of a fluid relies on controlling the **wall temperature (t')** of the pipe through which it flows. To prevent the formation of **hot points**, this temperature must not exceed **$t + \Delta t_2$.**

A straightforward solution to this challenge is to measure **power density**—first during **engineering design** and later in **operating practice**—ensuring that t' remains within the desired limits. For precise temperature control in both industrial design and operation, **inductive heating** provides the most accurate and effective solution.

Limitations of Traditional Heating Methods

Conventional heating methods, such as **fuel combustion**, create extreme temperature gradients **(t'' - t)**, where **t''** represents the temperature of flames or combustion gases. While this may be acceptable in applications like **steam boiler pipes**, where high temperatures are expected, it is unsuitable for processes requiring precise thermal control.

Similarly, for **ultra-low temperature oils, immersed electrical resistors** are not recommended. These systems create **low-velocity regions** around the resistors, leading to localized overheating and temperature inconsistencies.

Why Inductive Heating is the Optimal Solution

For industrial processes where hot points could compromise product quality, **electric inductive heating** offers several key advantages:

1. **Efficient Power Regulation** – It releases only slightly more power than the thermal load, ensuring minimal energy losses (maximum **4% total: 2% power factor loss and 2% thermal loss)**.

2. **Optimized Heat Transfer** – By applying the equation:

$$Q/A = h.(t' - t)$$

where **Q/A** is the power density and **h** is the film heat transfer coefficient, inductive heating achieves a l**ow temperature difference (t' - t)** while maintaining a **high heat transfer rate.**

This precise control ensures uniform fluid temperature distribution, eliminating **hot-points** and maintaining process efficiency.

SUMMARY

A **hot-point** always occurs at the **boundary** between the heat-yielding surface and the fluid film in direct contact with it. Naturally, **swirl flow** (characterized by high Reynolds numbers) aids in **fluid temperature homogenization**, ensuring a more uniform heat distribution via convection.

However, even with perfect homogenization, a hot point can only be completely eliminated when **the temperature of the solid surface (e.g., tubing wall)** does not exceed the **maximum permissible temperature of the fluid.**

In **conventional heating systems**, this level of control is **impossible**. The occurrence of hot-points is both **common and disastrous**, as it leads to fluid degradation—first causing **carbonization**, followed by **coking.**

The Advantage of Inductive Heating

Thanks to the **design of induction heating systems** and careful engineering considerations—such as the **ideal Reynolds number, Film Coefficient, and Power Density**—hot-points are **completely eliminated** in these specialized systems.

Unlike standard **off-the-shelf** industrial heaters, **electric inductive heating systems** are **custom designed** for each application, **based on specific requirements such as:**

- **Fluid type**
- **Maximum and minimum flow rates**

- **Target temperatures for heating and maintenance**

A **tailored thermal engineering solution** is developed.

High Efficiency & Cost-Effectiveness

Despite this high level of customization, inductive heating systems do **not** incur excessive material costs. This is because the **technical design parameters** dictate the **optimal physical configuration**, ensuring maximum efficiency. As a result, these systems achieve an **exceptionally high thermal efficiency of approximately 95%**—a performance level unmatched by conventional **indirect heating methods**.

Thus, in every **BRASCOELMA** project, the specifications are carefully determined based on:

- **The number and diameter of the pipes**, which define the **desired flow velocity.**

- **The ideal Film Coefficient**, which is crucial for **energy flow optimization** to prevent the occurrence of **hot points.**

Every aspect of engineering and design is precisely calculated and faithfully translated into the **manufacturing** and **operation** of the equipment. This ensures that **industrial thermal requirements** are met with **high accuracy and reliability.**

Therefore, in the design of the **Inductive Electrothermal Heater**, the **electrical energy** required to generate the necessary **thermal energy** at any given moment is considered a **consequence** rather than a **cause**. However, during operation, this relationship is naturally reversed, as electrical input drives the thermal output.

Heating of Ultra-Viscous Oils

The Best Technology for Heating Ultra-Viscous Fuel Oils

It is well known that to achieve efficient combustion of any type of fuel oil, proper atomization is essential. The fundamental parameter that determines the degree of difficulty in atomizing oil is its viscosity, which is directly related to temperature. The higher the oil's burning temperature, the lower its viscosity, and the greater its atomization efficiency.

While heating ultra-viscous oils poses significant challenges for resistance, gas, or fuel-oil heaters—due to the high likelihood of oil cracking—the introduction of the **Inductive Fluid Heater** has made heating ultra-viscous oils a simple and safe operation, even when accounting for the high viscosities of these oils at elevated temperatures. For example, the kinematic viscosity of a **9A oil at 275°C** (the recommended temperature for atomization and combustion) is **20.12 centistokes**, approximately **20 times higher than water at room temperature.**

When applying the commonly used empirical correlations (such as **Hausen, Sieder-Tate, and others)** to calculate the **Nusselt number** and, consequently, the average heat transfer coefficient by convection, extremely high wall temperatures for the tubes of **Inductive Fluid Heaters** are obtained. However, these results are completely inconsistent with practical field measurements.

In practice, for ultra-viscous oils, the measured **temperature difference between the tube wall and the fluid** in various **Inductive Fluid Heaters** in operation ranges between **8 and 25°C.**

Although none of the well-known empirical correlations for calculating the **Nusselt number** adequately explain the **low temperature differential** between the wall and the ultra-viscous oil flowing through the stainless-steel tubes of the **Inductive Heater, detailed studies conducted at Brascoelma** have confirmed the **excellent measured results.**

As previously mentioned, due to the **non-negligible viscosity** of ultra-viscous oils—even at atomization temperature—it is practically impossible to achieve a **high Reynolds number** flow. For instance, in the case of **4A oil**, when entering the heater at **120°C** and exiting at **180°C**, the viscosity values are **156.56 centistokes and 22.84 centistokes, respectively**, with a **mean viscosity of 51.54 centistokes at 150°C**.

In a specific project for a **750-kW heater designed for heating 4A oil**, if we assume:

- A **maximum pressure drop of 2 Kgf/cm^2,**
- A **power density of 0.9 W/cm^2,**
- A **flow rate of 21 m^3/h,**

Regardless of the tube diameter used in the heater, it is **impossible** to achieve an oil flow with a Reynolds number above **4000**, which is the **minimum condition** for transitioning from laminar to turbulent flow in ultra-viscous oils. (For the given parameters, a specific tube configuration resulted in a **Reynolds number of 835).**

It is well known that a **high convection heat transfer coefficient** is associated with **turbulent flow**, which reduces the thickness of the boundary layer and enhances heat transfer from the tube wall to the fluid.

How Do We Explain the Low Temperature Difference Between the Tube Wall and the Oil Flowing Through the Tubes?

By applying an **intuitive concept** to **long tubes**, Brascoelma has simplified the **analytical treatment** of the subject and successfully justified the **low temperature differential** between the wall and the fluid in **Inductive Heating of Ultra-Viscous Oil**. It is important to highlight that **only the Inductive Heater possesses the unique design characteristics that enable this simplified treatment**.

The **Inductive Heater** generates **induced currents within the tube walls**, ensuring an **extremely uniform heat flow** throughout the internal surface of the tube. This eliminates any physical possibility of localized hot spots.

When combined with a **well-designed heat exchange surface**, along with optimized tube **length and diameter**, this uniform heat distribution explains the **low temperature difference between the tube wall and the fluid.**

Since the **heat flow is perfectly uniform**, both the **wall temperature and the fluid temperature** increase **linearly with slight convergence in the flow direction**. For sufficiently **long tubes**, this convergence results in the **oil temperature at the heater outlet being very close to the internal tube wall temperature**, which explains the **low temperature differentials observed in practice**.

Comparison with Resistance Heaters

Compared to **electric resistance heaters**, which also use electricity to heat ultra-viscous oils, the **Inductive Heater** has several **key advantages**:

- **Energy savings of 25-30%**
- **Higher heat transfer efficiency**
- **Much lower tube wall temperatures**

The **greater energy efficiency** of the **Inductive Heater** compared to resistance heaters arises from a fundamental design difference. In resistance heaters:

- The heating element is **isolated** from the outer tube by a **magnesium oxide** layer.
- The heat must **overcome** both the **thermal barrier** of the **magnesium oxide** and the **metallic barrier** of the heater's protective tube.

This means that when calculating the **overall heat transfer coefficient** for an **immersed resistance heater**, three separate **partial heat transfer coefficients** must be considered before the heat **finally reaches the oil.**

In contrast, the **Inductive Heater** has **only one heat transfer coefficient (convection)**, which is identical to its **overall heat transfer coefficient**.

To maintain a given heat flux in resistance heaters, the heating element must **operate at a much higher temperature**, leading to **increased energy consumption**.

With the **Inductive Heater**, however, **no thermal barriers exist**. Even the **tube wall itself does not act as an obstacle** to heat transfer because the heat is **generated directly within the tube wall**.

Comparison with Gas and Fuel-Oil Heaters

Another major advantage of the **Inductive Heater** over **gas or fuel-oil heaters** is its **extremely low thermal inertia** and **fast response time** to temperature variations—**no other fluid heating system offers this capability.**

For **ultra-viscous fuel oil heating**, this ensures:

- **Stable atomization temperature and viscosity**, leading to **more efficient fuel combustion** with **higher efficiency.**
- The ability to **increase atomization temperature beyond supplier recommendations without the risk of cracking**, further enhancing combustion efficiency.

The Most Modern and Efficient Energy-to-Heat Conversion Technology

Due to brevity, we have not detailed the **electromagnetic design** required for the **Inductive Heater's development**. However, it is important to note that **austenitic stainless-steel tubes (non-magnetic)** play a crucial role in the heater's construction.

This innovation has led to the creation of the **most advanced and efficient machine for converting electrical energy into heat**, with an **overall efficiency of 98%**, as confirmed by **international companies**.

- **Uniform heat distribution eliminates localized hot spots, preventing oil cracking**—a risk inherent in **resistance heaters** and even greater in **fossil fuel combustion heaters**.
- **Rapid temperature response** ensures **stable fuel atomization**, leading to **higher combustion efficiency** and **greater fuel savings**.
- **Superior energy efficiency** provides **significant cost savings** compared to traditional heating systems.

In **most cases**, the **Inductive Heater replaces resistance heaters with 25-30% lower installed power requirements**, offering **better performance** while significantly **reducing operating costs.**

Conclusion

The **Inductive Heater** represents the **most efficient, safest**, and **economically viable** solution for heating **ultra-viscous fuel oils**, **outperforming** both **electric resistance heaters** and **gas/fuel-oil heating systems.**

Its **innovative design**, based on **electromagnetic induction**, ensures **uniform heat distribution**, **low wall temperatures, and rapid temperature response**, making it the **ultimate choice** for applications requiring **precise and efficient thermal processing.**

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is the result of a joint venture between
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AA Consultrade (the sales partner).

AA Consultrade

International Sales Address:

AA Consultrade Ltd
2nd Floor, 164 New Cavendish St.
W1W 6YT – London – UK
+39 339 734 7133
Phone Brasil: +55 11 4056 3350
www.inductionheater4fluids.com
contact@inductionheater4fluids.com

BRASCOELMA

Factory Address:

BRASCOELMA Construção Brasileira de
Aquecedores Indutivos Ltda.
Rua da Primavera, 108, Jd. Ruyce
09980-040 Diadema – SP - Brazil
Phones: +55 11 4056 3688 - Fax: +55 11 4056 3350
www.brascoelma.com.br