Induction Heating Technology for the Tube and Pipe Industry

Technical Presentation at:

7th Annual Steel Tube + Pipe Conference
PIPE & TUBE HOUSTON 2014

Topic 1: ATM (AjaxTocco Magnethermic) Overview
Topic 2: Induction Applications for Tube and Pipe
Ajax TOCCO Magnethermic (ATM)

Over 1,000 employees in 20 worldwide facilities

Staffed with Over 120 Mechanical, Electrical and Metallurgical Process Engineers

- Ajax Electrothermic Corp., 1916
- TOCCO Inc., 1935
- Ajax Engineering Corp., 1941
- Magnethermic Corp., 1948
- Ajax Magnethermic Corp., 1959
- Japan Ajax Magnethermic Corp., 1965
- Pillar Induction, 1966
- American Induction Heating in 1968
- Industrial Electric Heating in 1973
- Lectrotherm Inc., 1989
- Foundry Services, Gmbh 2000
- INTECH, Gmbh 2000
Topic #1 ATM Overview

Steel – 50% Bookings

Foundry – 20% Bookings

Steel Super Heaters

Heat Treat Quench and Temper

Coreless Furnace Systems

Vertical Channel Furnaces

LECTROTHERM
American
CycleDyne
Magnethermic
Ajax TOCCO
PILLAR
Westinghouse
Topic #1 ATM Overview

Forging – 10% Bookings

Heat Treating – 20% Bookings

Upsetting Systems

Billet and Bar Heaters

Automotive

CV Joints Case Hardening
Corporate

- Formed in 1908
- Sales approximately $1,200 Million (2011)
- Employees approximately 4,000
- NASDAQ as PKOH
- Headquarters in Cleveland, Ohio
Diverse Services for Tube and Pipe Manufacturing
Diverse Services for Tube and Pipe Manufacturing
Direct Local Support for Tube and Pipe Manufacturers

Location, Resources and Heritage

(3) Regional Service Technicians
(2) Aftermarket Support
(1) Regional Service Center
(2) System Sales Support
Topic #2
Applications for Induction Tube and Pipe Manufacturing
Typical Tube and Pipe Mfg. Applications for Induction Heating

- Heat Treat Quench and Temper of Tubing and Pipe
- Upset Processing for Heat Treating (in-line or pre-heaters)
- HF Seam Welding (*New Product Release 2014*)
- Weld Seam Annealing
- Full Body Annealing
- Pre-heating for Upsetting
- Sucker Rod Upsetting (Machines and Heaters)
- Sucker Rod Coupling Flame Spray Curing
- Swedge End Stress Relieving (Medium and Low Frequency)
- Tool Joint (Heat Treat, Tempering and Annealing)
- Curing & Pre-heating of Coatings
- Swivel Joint Bending (Machines and Heaters)
- Pipe Bending (Machines and Heaters)
- De-Bonding of Rubber (Round Stators)
- Continues Coiled Tube Processing
- Seamless Mill Billet Pre-heaters
- Seamless Finishing Taper Re-heaters
Complete Solutions for Heat Treat, Quench and Temper Lines

From 2 – 40 tons an Hour in Complete ERW Systems
Complete Material Handling Solutions to Include Installation
Upsetting Systems

- We offer a variety of upsetting systems. The most common utilized are the Channel and the Pigeon Hole systems as shown below. The coil efficiency is the primary difference.

Channel System
(45 – 50%)
Efficient

Pigeon Hole System
(65 – 70%)
Efficient
Sucker Rod Upsetting
Solid State RF Flame Spray Curing of Sucker Rod Couplings
ERW Weld Seam Annealing

• Through advanced FEA analysis we can precisely control the heat effected zone of the seam annealing process.

Finite Element Analysis video
ERW Weld Seam Annealing

Movement 15° from coil center

Welded Seam

96.00 [2438]
24.38 [619]
32.00 [813]
.35 [9] GAP
Full Pipe Annealing / Normalizing

Full Pipe

750 – 1500 kW
1000 Hz

3 or more Coils in Parallel or Series / Parallel
Stress Relieving

Medium Frequency
1 – 10 kHz and
Low Frequency
60 – 200 HZ
Product Offerings.
NEW PRODUCT RELEASE
LATE 2014
Austenitizing (Tool Joint)

- Austenitizing for focused tool joint weld re-hardening. Re-hardening of tool joints is required after welding and machining for these processes change the base material hardness.

Welded and Machined Tool Joint.

1& 2-turn Induction Coils
Tempering Systems (Tool Joint)

- Tempering of tool joint heat effected zone. Multiple turn coils are used to temper the entire heat effect area from Friction Welding, Austenitizing and cutting and/or grinding.
Coating Systems

- Induction heating provides a fast, efficient means of drying off surface moisture from pipes. Curing of water based anti corrosion coatings or epoxy can also be accomplished in-line versus in a furnace. Ajax has over 54,000 KW of installed Curing and Drying systems.

TYPICAL TEMPERATURE RISE:
- PAINT/VARNISH CURING IS AMBIENT TO 200 °F
- EPOXY (FBE) IS AMBIENT TO 500 °F
Rubber De-Bonding / Residue and Moisture Removal After Water Jetting

Rubber De-bonding for Round Stators to break the bond between rubber on the ID of the tube. Typical OD temperatures are 850 °F with ID temperatures of 750 °F.
Swivel Joint Complete Systems

Bending machine capable of tooling for bending up to a 90 degree elbow, sizes range from 1” through 4” swivel joints.
Tube & Pipe Bending

Typical working temperatures are between 1900 – 2100 °F. A typical power supply would be 500 – 3 MW in power.
Seamless Mills - (Between Roughing and Finishing) In-Line Tapered Heat Re-Heaters & Ingot Pre-Heaters
Hybrid Induction Pre-Heaters for Existing Gas Fired Furnace Lines
Hybrid Pre-Heaters for Existing Gas Fired Furnaces Lines.
Hybrid Pre-Heaters for Gas Fired Furnaces. (Austenitize)

GAS FURNACE

5.5 OD, 0.304 wall, Tube 15 TPH

Tave, Tcore, Tsurf

Time (Sec)
Hybrid Pre-Heaters for Fossil Fuel Furnaces. (Temper)

7 OD, 0.408 wall, Tube 15tph

Temperature vs. Time Graph:
- Tave, Tcore, Tsurf
- GAS FURNACE

X-axis: Time (Sec)
Y-axis: Temp (Deg F)
Topic #3
Technology Comparison of Fossil Fuel Furnaces to Induction
Competitive Technologies -
Induction to Fossil Fuel heating for the Manufacturing of Tube and Pipe

● Primary Operational Difference

● Efficiency Considerations Between Technologies

● Cost Comparison Worksheets

● Additional Considerations between Gas and Induction Technologies
Primary Operational Difference

Traditional radiant furnace heating must wait for heat to conduct from the surface. Induction generates heat within the workpiece.
Induction cost differential is typically offset with the efficiency average of

Heat Treating =
65% – 75% for Induction
40% to 55% for a typical fossil fuel furnace.

Tempering =
65% – 75% for Induction
60 – 70% efficient for a typical fossil fired furnace.

Source = ASM
American Society of Metals
Efficiency Analysis of Typical In-line Fossil Fired Furnaces

Losses in a typical fossil fuel furnace.

Source = U.S Dept. Of Energy - A source Book for Industry
Efficiency Analysis of Typical In-line Fossil Fired Furnaces

Because of their high temperature, furnaces are large users of fossil-fuel energy. The following simple diagram lists the main losses on a typical furnace. Flue gases usually represent the main source of wasted energy.

Model for Heat Treating
Recovery with a Recuperator

- 49% Efficient
- 68% Efficient

Fuel Input

- Heat to Load: 49%
- Losses in Furnace Structure – Insulation losses: 2%
- Water Cooling Losses (stock transport systems): 1% (Barrel)
- Radiation Losses (doors, inspection ports): 3%
- Material Losses e.g. evaporation, spillage, scaling
- Flue Losses

Sensible Energy

- 45% HT

Potential Energy

- 32% Temper
- 11 - 19% Recovery
Efficiency Considerations Between Technologies

Losses in a typical Induction System.

- ≈ 3% Transformer
- ≈ 4% Frequency Converter
- ≈ 3% Cap Losses
- ≈ 5% Transmission Lines
- ≈ 20% Coil I^2R and Thermal Radiation Losses
## ATM Technology Comparison Worksheets

### Economic Study - Induction vs Gas Heat Treatments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Induction Heating</th>
<th>Gas Heating (20°C to 650°C)</th>
<th>Gas Heating (20°C to 800°C)</th>
<th>Gas Heating (20°C to 1000°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity Consumption (kWh/HR)</strong></td>
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<tr>
<td><strong>Demand Charge per MwH</strong></td>
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<tr>
<td><strong>Gas Rate per Gigajoule (GJ) including delivery and consumption</strong></td>
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<tr>
<td><strong>Annual Production (Tons per Year)</strong></td>
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<tr>
<td><strong>Utilization</strong></td>
<td></td>
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<tr>
<td><strong>System Power Rating (kW) for Induction Heat Treatments</strong></td>
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<tr>
<td><strong>Yield Loss Value (t/m) used to determine losses due to scale</strong></td>
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</tbody>
</table>

### Energy Consumption (kWh/HR) per Tonne

<table>
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### Energy Cost per Tonne

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<th>Gas Heating (20°C to 800°C)</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Cost per Tonne ($)</strong></td>
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<tr>
<td><strong>Scale Loss (%)</strong></td>
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<tr>
<td><strong>Scale Loss (Ton/Year)</strong></td>
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<tr>
<td><strong>Yield Loss in Scale per Tonne</strong></td>
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<tr>
<td><strong>Energy Cost per Year</strong></td>
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<tr>
<td><strong>Annual Demand Cost</strong></td>
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<tr>
<td><strong>Installed Investment Cost</strong></td>
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<tr>
<td><strong>Number of Years</strong></td>
<td></td>
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<tr>
<td><strong>Annual Amortization</strong></td>
<td></td>
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<tr>
<td><strong>Annual Interest</strong></td>
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<tr>
<td><strong>Total Cost per Year</strong></td>
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<tr>
<td><strong>Average Cost per Tonne</strong></td>
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<tr>
<td><strong>Annual Savings Using Induction</strong></td>
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</tbody>
</table>
## Case Study of Annual Operating Cost Comparison (2013)

Summary Sheet of Annual Operating Cost of Gas and Induction for 36 Tons/hr. Heat Treat Quench and Temper Lines.

<table>
<thead>
<tr>
<th></th>
<th>Max Utilization Scenario</th>
<th>Min Utilization Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Available Hours</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Available Hrs./ Yr.</td>
<td>8760</td>
<td>8760</td>
</tr>
<tr>
<td>Planned Downtime</td>
<td>1584</td>
<td>1584</td>
</tr>
<tr>
<td>Actual Operating Hours</td>
<td>7176</td>
<td>7176</td>
</tr>
<tr>
<td>Demand Cost</td>
<td>?</td>
<td>2.5</td>
</tr>
<tr>
<td>Power Factor</td>
<td>?</td>
<td>9000</td>
</tr>
</tbody>
</table>

### Utilization

<table>
<thead>
<tr>
<th>Historical Utilization Percentages</th>
<th>86%</th>
<th>97%</th>
<th>60%</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Operating Hrs. Based on utilization</td>
<td>6171.36</td>
<td>6960.72</td>
<td>4305.6</td>
<td>5740.8</td>
</tr>
<tr>
<td>Design Tons per Hr.</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Annual Production Tons</td>
<td>222168.96</td>
<td>250585.92</td>
<td>155001.6</td>
<td>206668.8</td>
</tr>
</tbody>
</table>

### Energy Cost

<table>
<thead>
<tr>
<th>Annual Operating Cost Per Ton</th>
<th>$ 15.48</th>
<th>$ 21.45</th>
<th>$ 22.19</th>
<th>$ 26.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Operating cost</td>
<td>$ 3,440,000</td>
<td>$ 5,375,000</td>
<td>$ 3,440,000</td>
<td>$ 5,375,000</td>
</tr>
</tbody>
</table>
Case Study of Annual Operating Cost Comparison (2013)

Summary Sheet of Annual Operating Cost of Gas and Induction for 36 Tons/hr. Heat Treat Quench and Temper Lines.

**Page-2**

<table>
<thead>
<tr>
<th></th>
<th>Gas HT</th>
<th>Induction HT</th>
<th>Gas Temper</th>
<th>Induction Temper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adjusted Operating Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted operating cost</td>
<td>$5,661,689.60</td>
<td>$5,976,406.21</td>
<td>$5,300,019.20</td>
<td>$6,201,675.20</td>
</tr>
<tr>
<td><strong>Adjusted Cost per ton</strong></td>
<td>$25.81</td>
<td>$23.92</td>
<td>$34.19</td>
<td>$30.01</td>
</tr>
<tr>
<td><strong>Capital Investment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital investment (2013 Quotes)</td>
<td>$18,750,000.00</td>
<td>$7,150,000.00</td>
<td>$/MBTU $3.76</td>
<td></td>
</tr>
<tr>
<td>Installation Cost (Estimate)</td>
<td>$3,131,073.00</td>
<td>$1,897,620.00</td>
<td>$/kWh $0.05</td>
<td>$0.05</td>
</tr>
<tr>
<td>(Gas installation multiplier = .65)</td>
<td></td>
<td></td>
<td>Power Factor 6000</td>
<td>9000</td>
</tr>
<tr>
<td><strong>Total Investment (Estimate)</strong></td>
<td>$21,881,073.00</td>
<td>$9,047,620.00</td>
<td>$2.50</td>
<td>$2.50</td>
</tr>
</tbody>
</table>

*Consider that gas process DOES requires electrical power for ancillary components*
Additional Considerations – Cost Comparison in $/ton at Reduced Production Rates.

This figure outlines the cost per ton difference between the technologies at reduced throughputs.

Source = Induction heating source Book ASM
The power supplies are controlled by IR temperature controller feedback throughout the line. Power is adjusted automatically by Power proportional controls.
System Controls with Computer Generated Simulations

Line speed and power can be adjusted electronically during production in response to changing conditions / alloys.

The line can lose utilities or be shut down and restarted as required with a minimum loss product.
AUSTENTIZING SYSTEM Design Simulations 36 tons/hr

4.5 OD, 0.25 wall, Tube, 36 TPH

Temp (Deg F) vs. Time (Sec)

- Tave
- Tcore
- Tsurf
TEMPERING SYSTEM Design Simulations 36 tons/hr

4.5 OD, 0.25 wall, Tube, 36 TPH

Tave, Tcore, Tsurf

Temp (Deg F) vs Time (Sec) graph
Additional Considerations - In-line Upset Tube and Pipe Uniform Heating

- Modeled two upset pipes, end to end
Additional Considerations - Reduced Cost of Environmental Compliance with Induction

With induction combustion emissions of a furnace heating systems are eliminated. The corporation sees the benefits of fewer incidences of emission-related penalties.

-OR –

In Some areas getting permitting is difficult and expensive.
Induction reduces the exposure of operators to the direct heat of fuel fired furnace systems. The corporation benefits from more employee comfort and a reduction in heat related safety incidences.
End of presentation

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