Integrated Melt-Stream Heating

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Melt-stream Heating Methods and Evolution

Melt-stream heating is used on barrels, transfer pipes, etc. to melt feed-stock prior to extrusion or injection. Referring to Figures 1 and 2, our industry has used conventional band-heaters since its inception, and only now, after 40+ years of minimal change, have a series of radically-new technologies been introduced, including infrared, induction and integrated heating. This paper reviews the drivers for these changes followed by the motivations, advantages and benefits of the new integrated heating approach.

Band-heaters are resistive “contact” heating elements. They generate heat by passing current through a resistive circuit then drive that heat across a contact resistance into the process. Referring to Figure 3, the resistance to heat transfer presented by the casing of the band-heater, and the contact resistance ($R_C$) between it and the process, requires the heating element to run at an elevated

![Figure 1. Melt-stream heating technology evolutionary timeline](image)

![Figure 2. Conventional band-heaters](image)

![Figure 3. Band-heater heat flow illustration](image)
temperature \( (T_h) \). This elevated temperature increases heat losses \( (Q_L) \) to the environment, reduces the band-heater’s life-span and increases its thermal inertia, retarding temperature control response.

With increasing energy costs, motivation to reduce or eliminate the environmental heat losses \( (Q_L) \) is quickly increasing. Blended electricity rates vary globally from under $0.05/kW-hour to over $0.25/kW-hour, and will continue rising. Referring to the example in Figure 4, a heat loss of 4.8 kW/m\(^2\) (450 watts/feet\(^2\)) of un-insulated surface, combined with an electricity rate of $0.10/kW-hour and 8000 hours of operation, translates to a significant thermal-insulating savings of $3900/m\(^2\)/year ($360/feet\(^2\)/year).

Thermally insulating band-heaters is relatively inexpensive and also improves safety by protecting operators from hot surfaces and electrical contacts. However, thermally insulating band-heaters requires compromises. Doing so raises the temperature of the heater’s outer casing \( (T_o) \) and terminations, reducing reliability and lifespan. It also captures the thermal inertia of the band-heater against the process, making it more difficult to attain and maintain optimal temperature control. The reduced heater access (due to the surrounding thermal insulation) is another negative in view of reduced heater reliability.

Concurrent with the increased focus on energy savings is the growing desire for process sustainability, which requires process optimization in addition to improved reliability, safety and efficiency.

The circuitry within band-heaters is typically not uniformly distributed, and the contact pressure and resulting thermal resistance between them and the process is not uniform either, nor does it remain constant (because thermal cycling causes repeated expansion and contraction of the band-heaters).

The result, as illustrated in Figure 5, is non-uniform process heating that also changes over time.

Any consideration of new heating methods to improve efficiency thus also provides an opportunity to improve the heating uniformity, both spatially (circumferentially and axially) and over time.
Consequently, in spite of the strong motivation to insulate band-heaters and the apparent simplicity and low cost of doing so, the industry has continued to look for better methods that will force fewer compromises. Specifically, the search has been on for heating methods that can reduce or eliminate heat losses to the environment while also improving reliability, temperature controllability and uniformity.

**Integrated Melt-Stream Heating**

Integrated melt-stream heating (patents pending) uses a thin (1 to 1.5 mm thick) extremely robust plasma-sprayed heater coating (see Figure 6) applied directly to the exterior surface of the cylindrical process component (i.e. barrel, transfer pipe, etc.).

Comparing Figures 7 and 3, this new technology’s “heater” coating is bonded directly to the process component to eliminate thermal contact resistance. The coating is also comprised of aluminum oxide, an excellent electrical-insulating material with high thermal conductivity, low density and low specific heat.

The coating’s minimal thermal inertia combined with maximum efficiency when thoroughly insulated then permits faster, more stable temperature control at reduced amperages, as shown in Figure 8.

**Figure 6.**
Plasma-spray application of heater coating

**Figure 7.**
Integrated technology heat flow illustration

Efficiency \(= \frac{Q_P}{Q_P + Q_L}\)

The Standard Bayonet Thermocouple in Cylinder Wall

- 90 mm diameter cylinder with 36 mm bore (3.54” OD, 1.42” ID)
- 38 mm thick thermal insulation
- 23% less amperage
- 30% faster to target
- Stabilizes 75% faster
And, because the heater coating is bonded to the process component, minimal temperature gradients ($\Delta T = T_H - T_P$) are needed to rapidly drive heat from one to the other (see Figure 9). In comparison, band-heaters require elevated temperature gradients between the heater and the process.

The heater coating’s uniform thickness and direct bonding to the process also ensures uniform spatial heating, both circumferentially and axially. The stark difference in heating uniformity between band-heaters and this new integrated heating technique is illustrated by Figures 10 and 11.

As illustrated next in Figures 12 and 13, initial development of this new technology focused on proof-of-reliability, with the typical test regimen entailing over 5,000 rapid heating and cooling cycles from ambient to 455°C/850°F and higher (up to 1093°C/2000°F). All production installations have since performed without failure.
While most applications to-date have been on injection molding barrels (see Figure 14), this new technology is applicable to the heating of other cylindrical machine components, including transfer pipes or melt pipes (as shown in Figure 15), where the plasma-sprayed heater coating withstands cleaning in fluidized beds or ovens to 455°C/850°F.

Referring again to Figure 14, inexpensive and efficient sheet-type thermal insulation wraps tightly around the process and is held in place by easily-removable Velcro straps. Compact threaded (M5/10-32) electrical connections as shown in Figures 16 and 17 also permit rapid disconnection and re-connection.

These practical features allow transfer pipes with integrated heating to be quickly cleaned in the maintenance shop. The pipe can be suspended, connected to a power source, and then self-heated to 455°C/850°F for internal cleaning using a wire brush.
Reliability is further enhanced by the inert coating’s resistance to contamination (hardened resin pops right off the diamond-ground surface, as shown in Figure 18) and the ability to install band-heaters over top of the heater coating provides a simple backup heating method.

**Conclusions**

The designed technical advantages of Integrated Melt-Stream Heating are:

- Eliminates heater-to-process contact resistance to minimize heater temperature elevation
- Prevents heater oxidation
- Virtually eliminates heater thermal inertia
- Ensures extremely uniform heating that never degrades or changes
- Provides a smooth contour that is easily wrapped with high-performance inexpensive insulation

The expected practical benefits of these technical advantages are:

- Extended heater life (design expectation is infinite life) for reduced downtime and maintenance
- Minimized temperature control response time for better process recovery and stability
- Improved process and product uniformity
- Maximized energy efficiency
- Improved operator safety