Wax Room 101A for Investment Castings

Overview : Best Practices Pre & Post Pattern Injection

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Subjects

1. IC Wax Composition: Pattern & Water soluble core wax.
2. Handling Procedures: Melt, Condition & Injection
3. Wax Injection Characteristics
4. Wax Injection Influences: Temperature, Viscosity, Mold fill

Wax pattern quality and yield determines the ability to produce consistent casting quality & reduce costs
**What is in IC Wax (IC)?**

*Typically comprised of Petroleum Waxes, Resin, Fillers, Additives & Natural Waxes*

**Waxes**  Parafins, Microcrystalline
- flow, die release, dewaxing, melt & congealing point

**Resins**  Natural & Synthetic resins
- dimensional stability, body, mechanical, properties, flow, dewaxing, setting

**Fillers**  Polystyrene (XLPS), Acid (PTA), Bisphenol-A (BPA), Neutral “O”, Water
- Dimensional, Mechanical, Bulking, Setting

**Additives**  Polymers
- Setting, melt & congealing point, mechanical properties
What is in Water Soluble Wax (WS)?

Typically comprised of a Binder, * Filler & an Effervescing Carbonate

**Binder**  Polyethylene Glycols (PEG’s) - Various Molecular Weights
  •  Melt Points, Flow, Hardness & Surface Characteristics

**Fillers**  Powder, Fibrous materials
  •  Dimensions, Mechanical properties, Hardness, Elastic properties

**Effervescing agent**  Powder, high Density
  •  Aid in dissolution rate of Soluble, Dimensions – bulking agent

**Additives**
  •  UV markers, special polymers , UV light quality checking, setting

* Inorganic nature of Fillers = Adhere to **Best Practice Handling Procedures**
**Filler: facts**

- Very fine particles: no effect on surface finish
- Shape: ground or spherical
- Particle size distribution key
- Solid particles in suspension, so mild agitation is needed to prevent settling
Physical, Rheological & Thermal Material Properties related to IC Process

<table>
<thead>
<tr>
<th>Ash Content</th>
<th>Volumetric Expansion</th>
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<tbody>
<tr>
<td>Hardness</td>
<td>Melt Points</td>
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<tr>
<td>Viscosity</td>
<td>Thermal Conductivity</td>
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<tr>
<td>Surface Tension</td>
<td>Thermal Diffusivity</td>
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<tr>
<td>Ductility</td>
<td>Set Speed</td>
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<tr>
<td>Dimensions</td>
<td>Congealing Point</td>
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All materials used to produce a casting are part of a **system** and must work together to produce a quality casting.
Handling Procedures: Melt, Condition & Injection

The way IC waxes are handled during the melting, conditioning, and injection stages of pre-pattern production will directly reflect the quality of wax pattern produced in the wax room.
Melting and Conditioning Process

Conditioning takes a long time due to the low thermal conductivity of the wax.
Wax Melting

Melting wax at too high of a temperature (overheating) can alter the wax characteristics.

- Generally, Most IC & WS waxes should be melted between 180-190°F / 82-87°C.
  - Soluble waxes Temperature Set Point at lower limit
  - Direct melt unit above reservoir or, manual fill?

- Temperature should not exceed 98°C for extended period of time - breakdown of RM constituents.

- Constant slow speed agitation a must - prevent fillers from separating from base wax.
- Typical agitation speed between 12-17 RPM’s – not to induce / entrap air.
What happens when you melt your wax at too low a temperature?

- Not all of the higher melt point components will fully blend into the solution to meet the proper state for optimum performance. Result - certain wax properties will be effected.

- If properly melted and conditioned, the viscosity, flow, surface finish and dimensions will benefit most by this practice.
## Melting – too low

Melting at too cold a temperature changes the wax properties – Post Injection

<table>
<thead>
<tr>
<th></th>
<th>Preparation Temperature</th>
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<tbody>
<tr>
<td></td>
<td>93C</td>
</tr>
<tr>
<td>Ring and Ball – Degrees C</td>
<td>82</td>
</tr>
<tr>
<td>Drop Melt Point – Degrees C</td>
<td>92</td>
</tr>
</tbody>
</table>

If improperly melted, components will not reach their true melt point and fully blend back into the mixture – the physical and rheological properties can impact quality of soluble wax core.
Melting Equipment

- Cylindrical wax tank (Manual filling)
- Wax melt plate unit (Direct Melt: above wax reservoir)
- Wax melt plate unit (Direct Melt: above reservoir, paste press)
Melting in cylindrical tank – Manual Loading

➢ Check melt tank - clean and no residue.
➢ Add material to create “melt pool” on initial Melt of material. Agitation a constant, slow speed. Prevents excess air, hot spots and filler separation.
➢ When tank is full, check actual wax temperature to ensure material has reached recommended temperature for 45 Min.
➢ Add material when level of tank is 1/3 empty – liquid not below agitator.

➢ All components of the wax must be thoroughly melted or “brought into solution” to achieve the designed wax characteristics for optimum results.
➢ Added care must be taken when transfer from melter to conditioning tank/injection machine to prevent air entrapment during pouring!!
Investment Casting Process Map

1. Wax injection
2. Mold preheat
3. Cast
4. Wax injection
5. Visual inspection
6. Pattern OK?
7. Wax cool
8. Dimensional inspection
9. Pattern OK?
10. Assembly
11. Mold inspection
12. Mold repair
13. Dewax
14. Final dry
15. Shell build
16. Knockout
17. Clean
18. Cutoff
19. Grind
20. Visual inspection
21. Yields, defects, etc.
Injection Parameters

- Injection time
- Dwell Time
- *Wax temperature*
- Wax pressure
- *Flow or velocity control*
- Mold & Platen temperature
- Spray instructions
- Air vs. water cooled
- Chill placement – photos
- Clamp Pressure
- Special instructions

Number of patterns
- Pattern surface quality
- Pattern dimensions
- Pattern distortion
- Wax feeder length
- Missing features
- Pattern identification
- Ejector pin marks
- On time production
**Wax Injection – Viscosity / Temperature relationship**

- The measure of the resistance of a fluid which is being deformed by either shear or stress
- The practical definition is the **THICKNESS** or **FLUIDITY** of something
- Temperature influences Viscosity, Measured in centipoises
- High viscosity fluids (**paste**) do not flow well but with the right combination of flow and pressure it makes a beautiful pattern
- Low viscosity fluids (**liquid**) flow easily this too needs control of flow and pressure to achieve an acceptable pattern.

- Pattern quality is highly dependent on the viscosity of the wax
- Wax temperature and viscosity are linked
- Injecting on a very **steep slope** where minor temperature changes drastically effect wax viscosity
- Virgin, reclaimed and reconstituted waxes all have different viscosity curves. Must control wax blends
- Low viscosity fluids flow easily – risk of turbulence/air
- High viscosity fluids pour slowly or not at all - risk of non fill

  Foundries (should) measure and calibrate temperature at key process points
If the wax is not consistently and properly handled upon Meltdown – Injection, a shift in viscosity can occur.

Understanding wax rheology and effects under injection, is key to obtaining the best performance from your IC wax materials.

Data shows the dramatic effect that shear rate has on the apparent viscosity of an Aerospace grade wax.
Temperature Effect on Viscosity

Liquid wax has a viscosity typically below 10,000 cps

Paste wax has a viscosity of 10,000-300,000 cps

Changes in wax temperature create changes in viscosity

55°C - 130°F

60°C - 140°F
Change in wax temperature = Change in Viscosity

Viscosity Versus Temperature

\[ \text{Viscosity} = \frac{\Delta T}{\text{Temperature}} \]

- \( f \) values range from 16,000 to 2,000 units.
- Temperature range from 128 to 138 units.
Temperature of the wax is critical

Minor Changes in Wax Temperature create significant changes to the viscosity of the Wax

Wax Viscosity changes the wax flow path in the wax die
Wax Injection Fill Characteristics – Tool Fill

Ideal Tool Fill – First at Nozzle, the progressively to the farthest point of the mold acting as a high surface tension hydraulic piston moving air and leveling nodules of lubricant ahead of it.

- Fill the tool slowly or “quietly” controlled parameters
- Avoid turbulence and air entrapment

BUT, We must also fill the tool fast enough to avoid:
- Solidification of the runner before the tool is full
- Solidification of the runner will cause pattern defects (non-fill, sink)
- Typically, a wax press fills a tool within a few seconds
- Need packing time to keep maintain pressure - dimensions and avoid pattern distortion

* See Video on Ideal Tool Fill
Wax Characteristics – Liquid & Paste

- Semi solid (paste) materials injected at lower temperatures & higher pressure
- Semi-solid material 75% through its plastic range when injected.
- Greater tolerance for temperature variation allows for wider window of control for rate and speed of material filling the tool.
- Faster set wax, shorter dwell times, cavitation

- Liquid components extended plastic range – injection to setup of material
- Lower viscosity and surface tension
- More control of flow, velocity and pressure of material entering the tool
- More prone to air inclusions, flash etc., during injection.
Wax Characteristic: Mold Filling & Temperature Influence

- Slow injection used – extended time during injection for material to cool & increase in viscosity
- Slow injection usually requires higher pressure for fill – due to setup and resistance to flow during injection.
- Fast fill a minimal amount of temperature change takes place
- Lower average viscosity requires less pressure to fill.
- The rate of pressure drop depends on the speed of set and fluidity of material
- Initial pressure must be high enough to be maintained to the most distant pattern section
Wax Characteristics: Mold filling & Temperature Influence

- The mold temperature influences the pressure required to fill the mold at a given injection pressure in pattern material.
- If mold temperature is too low, material may freeze and impede the flow of material into the mold before complete fill.
- If mold temperature is too high, excess dwell times, pattern distortion, and excess flash.
- Slow setting fluid waxes require colder molds.
- Fast setting waxes require a warmer mold.
- With a fast setting wax, best to run mold at warmer temperature as opposed to raising wax temperatures.
Mold Filling & Temperature Influence

The heat from the wax must be removed for the pattern to solidify

- Platen Cooling
- Die Cooling

70°F / 21.1°C

Wax Pattern Cross Section

140°F / 60°C
What is meant by stable condition - die temperature conditions?

- Constant conditions
- Not necessarily uniform conditions

Temperature gradient across the die; warm cavity (heated by the wax) and cold platen
Thank You

“Uncontrolled variation is the enemy of quality”.  
E.D.

“Continuous improvement is better than delayed perfection”.  
M.T.