Atlas of

Wax Pattern Defects

Investment Casting Institute

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Acknowledgments

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Section I

Defects in Wax Patterns

Introduction:

In the process of wax pattern manufacturing, there are a number of challenges the producer faces in making a consistent quality wax pattern. There can be problems associated with pattern dies, waxes, cores, equipment and process parameters that may result in defects that cause unnecessary rework and scrap. It is recognized that if the wax pattern is of good quality, the caster has a proper start toward meeting the goal of a quality casting.

This manual is provided to assist both process engineers and wax injection personnel to identify defects in wax patterns. It offers suggested remedies to reduce or eliminate the defect.

The manual is in an easy-to-use format. Photos provide a visual of the defect; text provides a list of probable causes and the suggested remedies. The most probable cause is listed first. The causes and remedies are categorized as “Equipment,” “Pattern Die,” “Wax,” and “Other.”

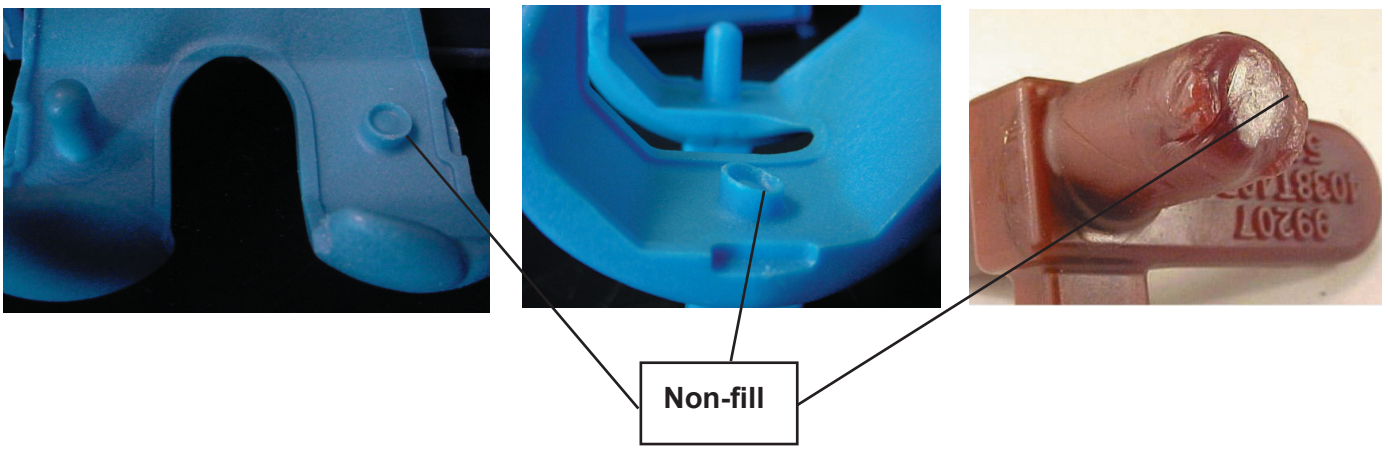
Several assumptions are made as follows:

- Wax injection die is of proper design and in good working condition.
- Wax injection machine is of proper size and in good operating condition.
  All controls such as temperature, injection pressure and flow controls are calibrated properly. If there is a question, consult equipment supplier.
- Wax is in proper condition and suitable for the application.
  If there is a question, consult wax supplier.
- Environment is suitable for wax pattern manufacturing, i.e. proper cleanliness, temperature and humidity.

If the above assumptions are not true, the manual will also provide direction to solve problems related to these issues.

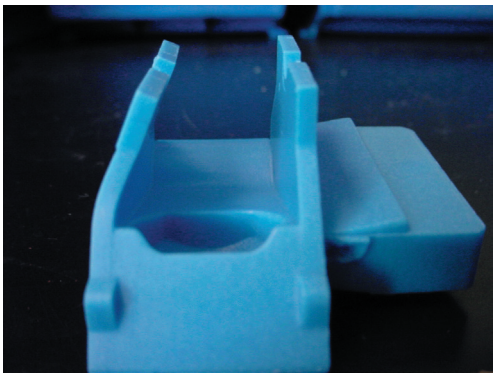
The manual is divided into three sections. **Section 1** relates to defects in wax patterns. **Section 2** is for defects related to the production of soluble cores. **Section 3** is for pattern defects that are related to the use of ceramic or soluble cores as well as wax chills.

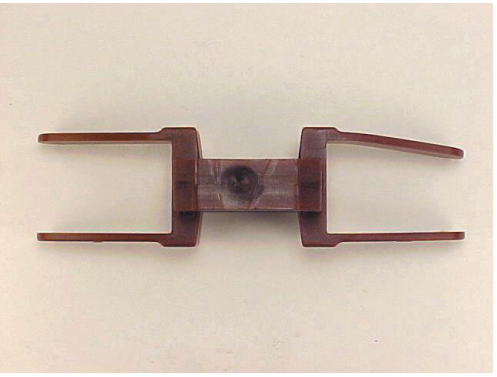
Non-fill



	Probable Cause	*Suggested Remedy*
Equipment	Improper shot size	*Make sure machine has proper shot size capacity. Increase shot size.*
	Wax flow rate insufficient	*Increase flow rate.*
	Wax flow rate too high causing air entrapment	*Decrease flow rate.*
	Acceleration (ramp-up) too low - machine unable to achieve proper flow rate *(Machines equipped with electronic injection control)*	*Increase acceleration (ramp-up) setting.*
	Insufficient injection pressure – machine unable to achieve flow	*Increase injection pressure.*
	Cold die	*Increase die temperature.*
	Cold slug of wax in nozzle	*Increase nozzle temperature or remove cold slug prior to injection.*
Pattern Die	Trapped air in die	*Add vents in the trouble area. If vents exist make sure they are clean.*
	Injection runner location	*Rework die as needed.*
	Injection runner too small *(particularly for paste)*	*Increase runner as needed.*
	Opposing wax flow	*Examine die design and relocate or add runners as needed.*
Wax	Cold wax	*Increase wax temperature.*
Other	Excessive mold release	*Clean die and use minimal mold release.*
	Wax or ceramic core size or location	*See Section 3.*

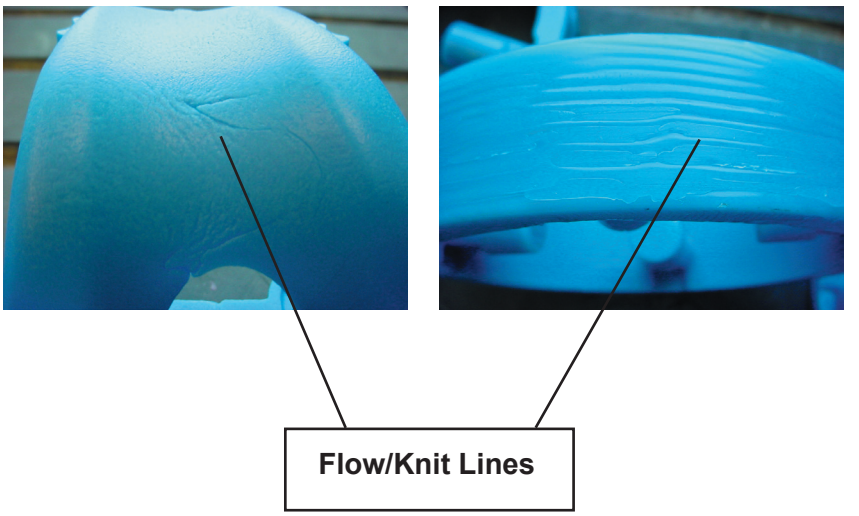
Distortion





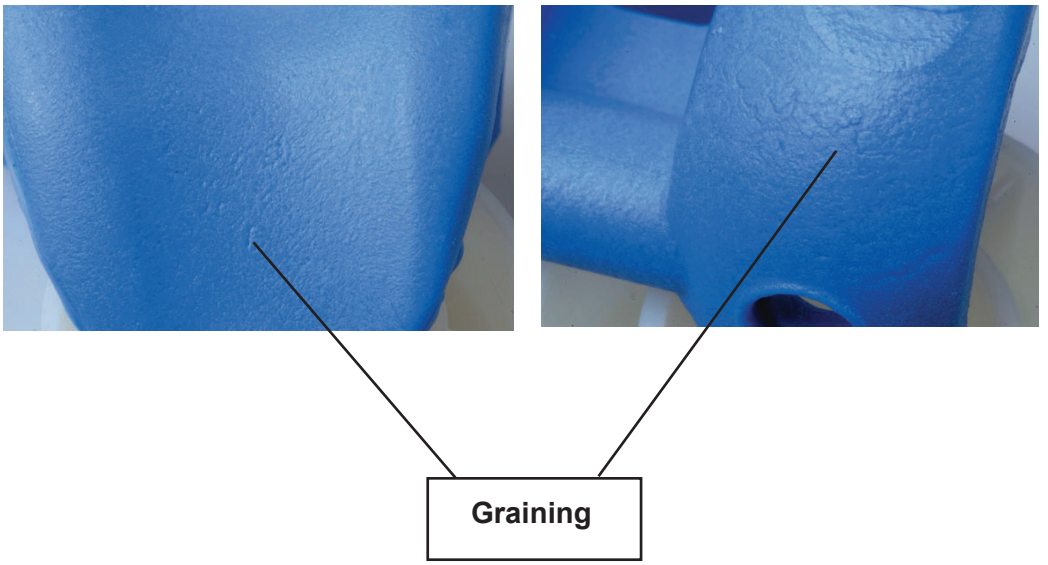
	Probable Cause	*Suggested Remedy*
Equipment	Short cycle time	*Increase cycle time. Cycle time must be adequate to allow sufficient pattern cooling.*
	High platen temperature	*Reduce platen temperature.*
	Clamp opening too fast	*Reduce clamp opening speed.*
	Hot wax	*Reduce wax temperature.*
Pattern Die	Die too hot	*Reduce temperature of die or platen to increase cooling.*
	Vacuum created	*If core pull is located in blind hole it should be withdrawn slowly to avoid producing a vacuum. At times a vent may be needed.*
	Ejector pin location or design	*Review die design and rework as needed*.
Other	Opening of die too fast	*Reduce speed of die opening.*
	Insufficient or improper mold release	*Use appropriate amount or type of mold release to ensure proper pattern removal.*
	Improper removal of pattern from die	*Proper training of personnel for pattern removal technique.* ***Note:*** *Use a gentle air assist by blowing along the parting line to loosen from die. Always make sure the pattern is being withdrawn evenly. Apply even hand pressure and avoid bending pattern.*
	Storage – placing pattern on uneven surface	*Use caution in storing pattern after injection. Make sure it is properly supported. In some cases, a fixture may be required*.
	Elevated temperature in wax room	*Maintain wax room at proper and consistent temperature as needed*.

Flow Lines / Knit Lines



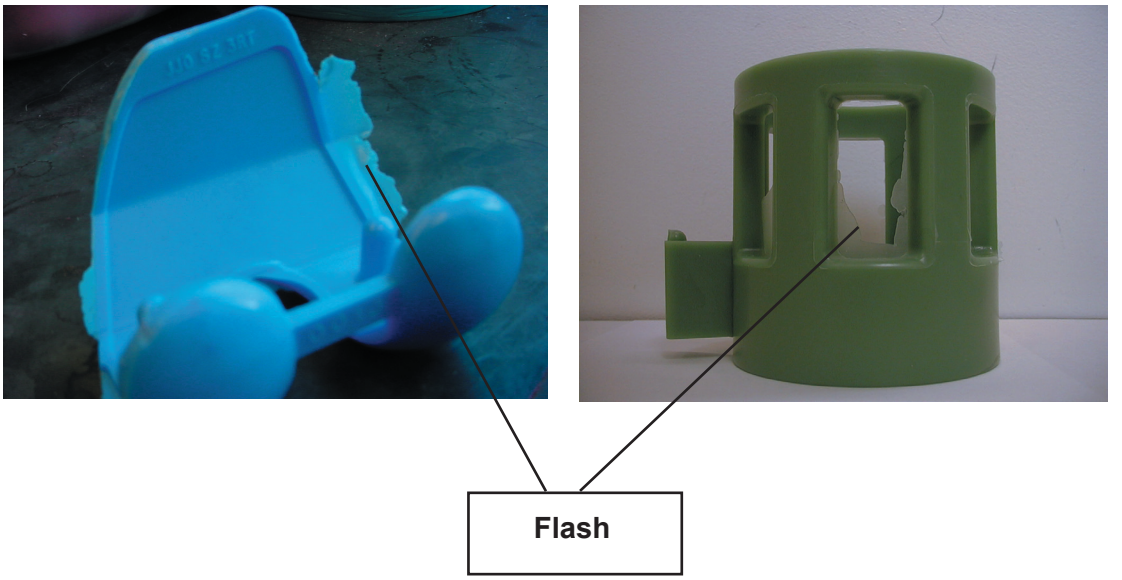
	Probable Cause	*Suggested Remedy*
Equipment	Cold wax	*Increase wax temperature.*
	Wax flow rate	*Adjust flow rate as required.*
	Low injection pressure	*Increase injection pressure*.
	Cold die	*Change die temperature. Turn platen water temperature off or adjust die temperature controller settings.*
	Low acceleration – machine unable to achieve proper flow rate. *(Machines equipped with electronic injection control)*	*Review acceleration setting. Increase acceleration setting to correspond better with wax flow rate.*
	Cold wax in nozzle	*Increase nozzle temperature.*
Pattern Die	Injection runner design	*Review location of runner. Use single injection port if possible. Complex injection port can prevent proper flow of wax into cavity.*
	Poor venting in die	*Clean vents or add vents as necessary.*
Other	Excessive mold release	*Clean die and ensure minimal amount of mold release is applied. Excessive mold release can accumulate ahead of the wax flow and result in lack of fusion.*

Graining



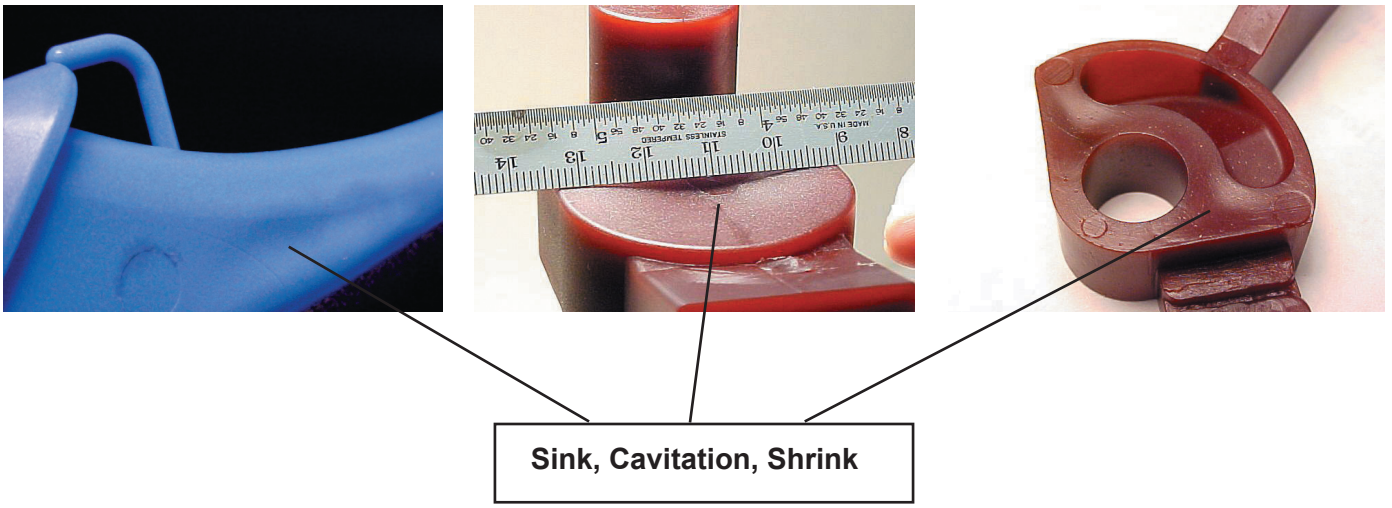
	Probable Cause	*Suggested Remedy*
Equipment	Low wax temperature	*Increase wax temperature.*
	Low injection pressure	*Increase injection pressure in reasonable increments.*
	Wax flow insufficient	*Increase flow rate.*
	Filler separation	*Use proper conditioning parameters including appropriate agitation in melting tank and in holding tank. Consult wax supplier for proper conditioning and melting procedure.*
Pattern Die	Cold die	*Reduce cooling water. Preheat die before injection.*
	Poor surface finish in die	*Polish die cavity.*
Other	Excess mold release	*Reduce amount of mold release.*

Flash



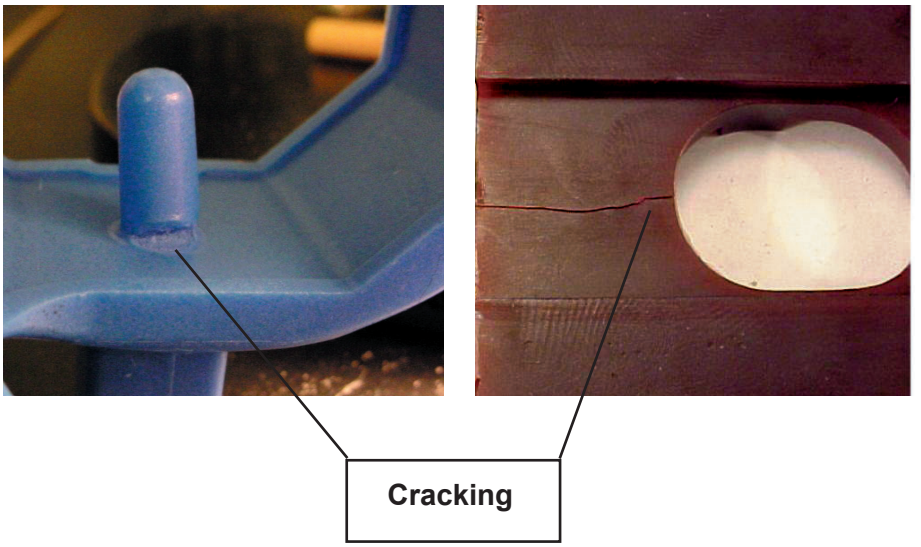
	Probable Cause	*Suggested Remedy*
Equipment	High injection pressure	*Decrease injection pressure. Injection pressure can open the die by overcoming the available clamping pressure.*
	Low clamp pressure	*Increase clamp pressure.*
	High wax temperature	*Decrease wax temperature.*
	Unequal clamping of die	*Clamp die evenly. Balancing blocks may be required. Die may flash if it extends beyond the platen plates.*
	High injection flow rate	*Reduce injection flow rate.*
	Excessive acceleration rate *(Machines equipped with electronic injection control)*	*Reduce acceleration rate.*
Pattern Die	Die wear or damage	*Correct as required. Inspect for worn inserts or damage due to excessive pressure on die closure. Inspect for worn edges at parting line. Inspect for damage. (e.g. raised impact seams)*
	Die not completely closed	*Remove wax chips or other interference between die faces.*

Sink, Cavitation, Shrink



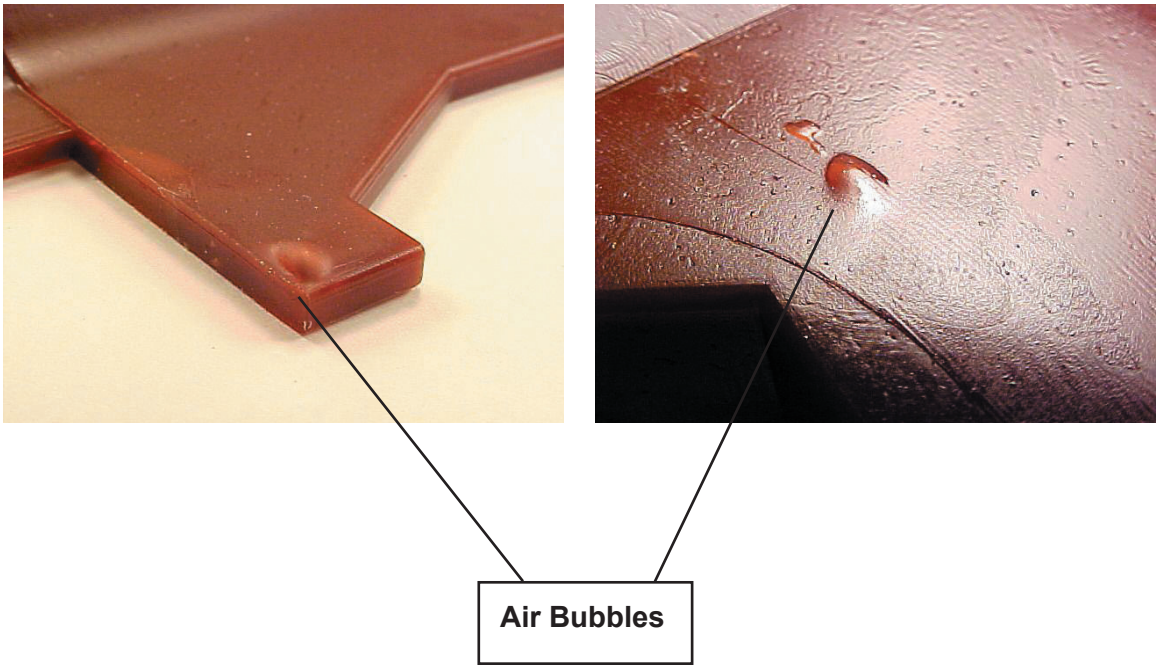
	Probable Cause	*Suggested Remedy*
Equipment	High wax temperature	*Reduce wax temperature.*
	Low injection pressure	*Increase injection pressure.*
	Short injection time	*Increase injection time.*
	Incorrect die temperature	*Review die temperature and determine if cooling platen or die would improve condition.*
	Insufficient wax flow	*Increase flow rate.*
	Wax press not suitable for application	*If possible, inject pattern on different equipment (liquid, paste or billet).*
Pattern Die		
	Injection runner too small	*Increase cross section of injection runner.*
	Incorrect injection runner location	*Ensure that wax is entering die as close as possible to the largest unchilled volume section of the pattern.*
	Injection runner too long	*Shorten the length of the runner.*
Wax	Wax selection not suitable for application	*Consider changing wax to one less prone to sink, cavitation and shrink.*
		Consider using wax chills.
		Consult wax supplier.

Cracking



	Probable Cause	*Suggested Remedy*
Equipment	Excessive Injection time	*Decrease injection time. If pattern cools excessively in die, it will become hard and brittle and have a tendency to crack before or during removal.*
	Cold die	*Increase die and /or platen temperature.*
	High injection pressure, pattern difficult to remove from die.	*Reduce injection pressure.*
Pattern Die	Improper mold opening	*Slow down opening rate. Check opening sequence of die carefully without forcing pattern.* ***Note:*** *When draw is deep, make sure parting line is separated evenly. Add or extend guide pins.*
	Improper removal of pattern	*Check pattern handling and removal techniques. Consider using air assist.*
	Draft, burr or rough surface	*Have tool maker check the die. Correct or polish as necessary.*
	Improper adjustment of knock-out pins	*Locate pins to avoid a bending stress on the pattern during removal and add more pins if necessary. Check adjustment of pins for even actuation and speed.*
	Sharp inside corners	*Check with engineering for possible addition of fillet.*
Wax	Brittle wax	*Consider changing wax to Increase toughness in order to reduce brittleness. Consult your wax supplier.*
Other	Insufficient mold release	*Check for adequate mold release in area of difficulty. Change mold release as necessary.*

Air Bubbles



	Probable Cause	*Suggested Remedy*
Equipment	Excessive injection flow rate	*Reduce wax flow rate.*
		Note: *Excessive flow rate causing turbulence can entrap air during injection of wax.*
	Excessive acceleration rate *(Machines equipped with electronic injection control)*	*Reduce acceleration rate.*
	Incorrect nozzle temperature	*Adjust nozzle temperature.*
	Improper wax conditioning	*Condition wax according to manufacturer's instructions.*
	High wax temperature	*Reduce wax temperature.*
	High clamping pressure	*Reduce clamping pressure. High clamp pressure may shut off vents.*
	Injection system seal leakage	*Replace defective seals.*
	Injection chamber fill rate too fast	*Reduce fill rate; consult equipment manufacturer.*

Air Bubbles

	Probable Cause	*Suggested Remedy*
Pattern Die	Improper use of vents	*Add or relocate vent(s) in die cavity; ensure that existing vents are kept clean.*
	Improper size and/or location of wax injection sprue	*Correct size and/or location of wax injection sprue to reduce or eliminate turbulence.*
	Die orientation to press	*Turn die upside down.*
	High die temperature	*Decrease die temperature.*
	Low die temperature	*Increase die temperature*
Wax	Defective billets	*Ensure that billets are produced without air.*
	Damaged billets	*Repair or replace damaged billets.*
		***Note:** Billets that have rough surfaces or are damaged can entrain and trap air which can be transferred to wax patterns.*
Other	Improper loading of wax	*Air can be entrapped by careless filling of the wax press with hot wax.*
		***Note:** Melted wax should be poured into reservoir slowly, creating as little turbulence as possible.*
	Excessive mold release	*Reduce use of mold release*.
		***Note:** Excessive amounts of mold release on surface of mating halves can act as a “gasket"; clean die halves to remove excess mold release.*

Dimensional Variations

Introduction

There are many areas of a pattern that can be affected by variation in dimensions, and because of this, it is difficult to present photos to cover every possible situation. The dimensions can be affected by a number of controllable variables within the process. The following causes and remedies will apply to the vast majority of dimensional variations and will allow the wax technician to identify and correct the variation.

	Probable Cause	***Suggested Remedy***
Equipment	Injection pressure variation	*Maintain consistent injection pressure.* ***Note:*** *Low pressure will reduce dimensions. High pressure will increase dimensions.*
	Injection time variation	*Maintain consistent cycle time.* ***Note:*** *Short cycle will reduce dimensions. Long cycle will increase dimensions.*
	Wax temperature variation	*Maintain uniform wax temperature.* ***Note:*** *Low temperature will increase dimensions. High temperature will reduce dimensions. Check wax temperature calibration.*
	Die temperature variation	*Provide proper cooling / heating to maintain consistent die temperature.*
	High nozzle temperature	*Decrease nozzle temperature.* ***Note:*** *High nozzle temperature can lead to dimensional variation on small parts.*
	Clamp pressure variation	*Maintain sufficient clamp pressure to prevent opening of die.*

Dimensional Variations

	Probable Cause	*Suggested Remedy*
Pattern Die	Runner size too small or improperly designed	*Ensure proper size and design of runner system to adequately feed pattern before solidifying.*
	Die cleanliness	*Clean die as needed and perform routine die maintenance.*
	Die mismatch	*Check guide pins for wear or proper alignment. Add additional guide pins.*
	Die manufacturing errors	*Check die dimensions.*
Wax	Incorrect shrink factor	*Ensure that wax properties are within specifications. For filled waxes ensure proper melting and agitation to maintain uniform filler dispersion.*
	Contaminated wax	*Check condition of the wax. Replace wax as necessary.*
	Filler separation	*Use proper conditioning parameters including appropriate agitation in melting tank and in holding tank. Consult wax supplier for proper melting and conditioning procedures.*
Other	Ambient temperature variation	*Maintain consistent wax room temperature*.
	Distortion of wax patterns	*See "Distortion."*
	Missing chills	*Ensure that required chills were used.*
	Uneven clamping of die	*Use proper injection press or balancing blocks.*

Section 2

Defects in Soluble Cores

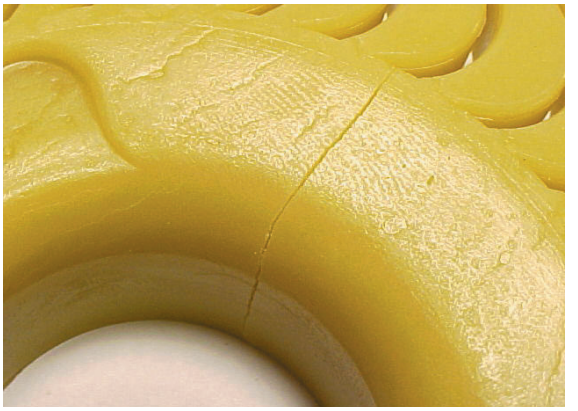
Introduction

There are occasions when internal details of a component are created using a core produced from a soluble wax which is commonly referred to as a soluble core. Soluble cores are produced using techniques similar to regular wax patterns and are therefore subject to similar defects.

There are a variety of issues associated with the production and use of soluble cores that can result in defective soluble cores or nonconforming wax patterns.

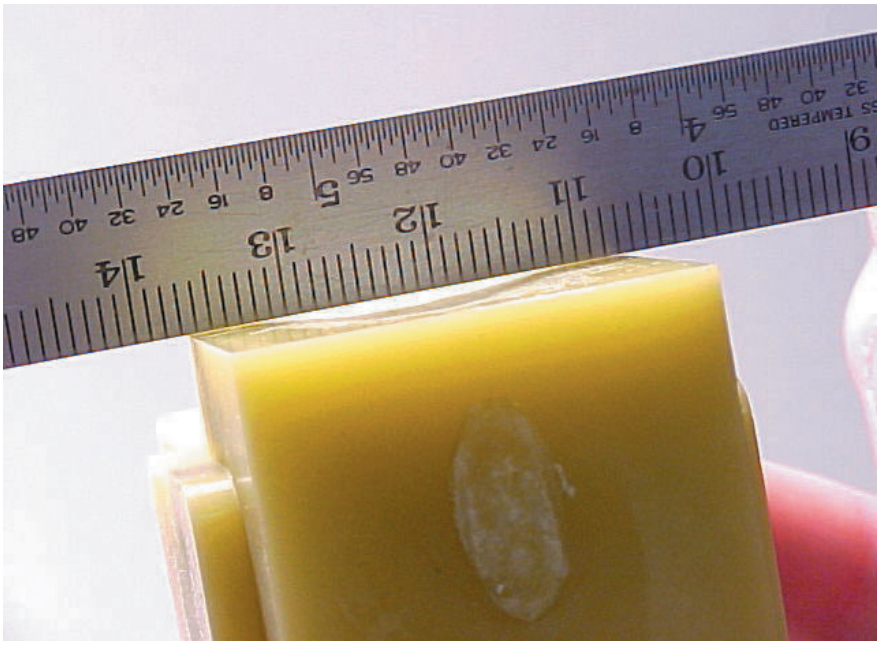
This section will follow the same format as the foregoing, except the material will now be specific to the production of soluble cores.

Cracking



	Probable Cause	*Suggested Remedy*
Equipment	Cold platen	*Increase platen temperature.*
	Excessive cycle time	*Decrease cycle time.*
	Hot wax	*Reduce wax injection temperature.*
	Clamp opening too fast	*Reduce clamp opening speed.*
Pattern Die	Cold die	*Increase die temperature.*
	Burr in die	*Have toolmaker remove burrs.*
	Die mismatch	*Check guide pins for wear or improper alignment.*
Wax	Filler separation	*Check for proper agitation of wax. Discard defective wax. Check temperatures during conditioning process.*
Other	Opening die too fast	*Reduce speed of die opening.*
	Improper removal of pattern	*Proper training of personnel for pattern removal technique.* ***Note:*** *Use a gentle air assist by blowing along the parting line to loosen from die. Always make sure the pattern is being withdrawn evenly. Apply even pressure and avoid bending pattern.*

Sink, Cavitation, Shrink

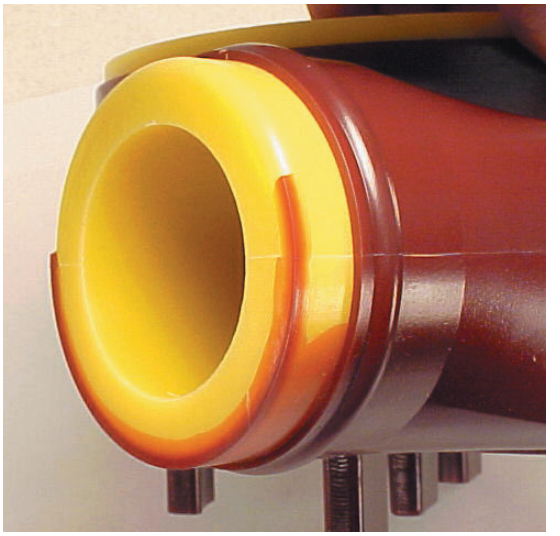


	Probable Cause	*Suggested Remedy*
Equipment	Hot wax	*Reduce wax temperature.*
	Short cycle time	*Increase cycle time.*
	Low injection pressure	*Increase injection pressure.*
	Insufficient shot size	*Increase shot size.*
	Improper platen temperature	*Adjust platen temperature.*
Pattern Die	Improper die temperature	*Adjust die temperature.*
	Insufficient sprue size	*Increase sprue size.*
	Inappropriate sprue location	*Change sprue location.*

Air Bubbles

	Probable Cause	*Suggested Remedy*
Equipment	Improper melting and/or conditioning	*Review melting and/or conditioning process.*
	Hot wax	*Decrease wax temperature.*
	Excessive wax flow	*Reduce wax flow.*
	Excessive acceleration rate *(Machines equipped with electronic injection control)*	*Reduce acceleration rate.*
	High injection pressure	*Decrease pressure.*
	Improper nozzle pressure	*Adjust nozzle pressure.*
Pattern Die	Improper die venting	*Clean and/or add die vents.*

Flash



	Probable Cause	*Suggested Remedy*
Equipment	High injection pressure	*Decrease injection pressure. Injection pressure can open die by overcoming the available clamping pressure.*
	Low clamp pressure	*Increase clamp pressure.*
	High wax temperature	*Decrease wax temperature.*
	Unequal clamping of die	*Clamp die evenly. Balancing blocks may be required. Die may flash if it extends beyond platen.*
	High injection flow rate	*Reduce injection flow rate.*
	Excessive acceleration rate *(Machines equipped with electronic injection control)*	*Reduce acceleration rate.*
Pattern Die	Die wear or damage	*Correct as required.*
		Note: *Inspect for worn inserts or damage due to excessive pressure on die closure. Inspect for worn edges at parting line. Inspect for damage on closing die (e.g. raised impact seams).*
	Die not completely closed	*Remove wax chips or other interference between die faces.*

Graining

	Probable Cause	*Suggested Remedy*
Equipment	Low wax temperature	*Increase wax temperature.*
	Low injection pressure	*Increase injection pressure in reasonable increments.*
	Insufficient wax flow	*Increase flow rate.*
	Filler separation	*Use proper conditioning parameters including appropriate agitation in melting tank and in holding tank. Consult wax supplier for proper conditioning and melting procedure.*
Pattern Die	Cold die	*Reduce cooling rate. Preheat die before injection.*
	Poor surface finish in die	*Polish die cavity.*
Other	Excess mold release	*Reduce amount of mold release.*

Distortion

	Probable Cause	*Suggested Remedy*
Equipment	Cycle time too short	*Increase cycle time. Cycle time must be adequate to allow sufficient pattern cooling.*
	High platen temperature	*Increase cooling water.*
	Clamp opening too fast	*Reduce clamp opening speed.*
	Hot wax	*Reduce wax temperature* .
Pattern Die	Die too hot	*Adjust temperature of die or platen to increase cooling.*
	Vacuum created by core pull	*If core pull is located in blind hole* , *it should be withdrawn slowly to avoid producing a vacuum. At times, a vent may be needed.*
	Ejector pin location or design	*Review die design and rework as needed*.
Other	Opening of die too fast	*Reduce speed of die opening.*
	Insufficient or improper mold release	*Use appropriate amount or type of mold release to ensure proper pattern removal.*
	Improper removal of pattern from die	*Proper training of personnel for pattern removal technique.* ***Note:*** *Use a gentle air assist by blowing along the parting line to loosen from die. Always make sure the pattern is being withdrawn evenly. Apply even hand pressure and avoid bending pattern.*
	Storage – placing pattern on uneven surface	*Use caution in storing pattern after injection. Make sure it is properly supported. In some cases, a fixture may be required*.
	Elevated temperature in wax room.	*Maintain wax room at proper and consistent temperature as needed*.

Section 3

Defects in Patterns Related to the Use of Ceramic, Soluble Cores and Wax Chills

Introduction

There are occasions when internal details of a component are required to be cast around ceramic or soluble cores. It is necessary therefore to inject wax around the ceramic or soluble core during the wax injection process.

There are a variety of problems associated with this type of process that result in nonconforming wax patterns or damage to the ceramic or soluble core.

This section will follow the same format as the foregoing, except the material will now be specific to the use of ceramic or soluble cores.

Helpful hints:

Ceramic Cores

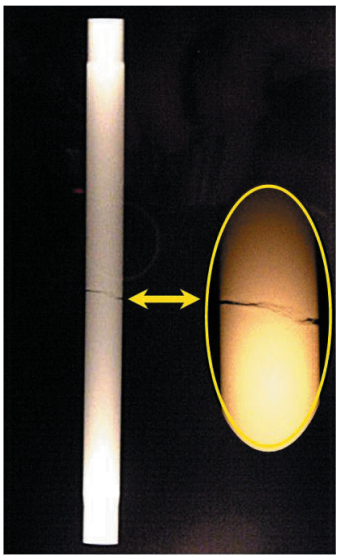
- Make sure that the ceramic core is properly prepared prior to injection.
- Where there are deeper design slots or holes, it is best to fill them with wax prior to injection. This will prevent sink/cavitation in these areas.
- To prevent the wax from lifting from the ceramic core, it may be an advantage to coat the core with a substance that will promote adhesion.
- For fragile cores that have yield problems:
    - Consideration should be given to X-raying cores prior to and after injection to ensure core integrity.
    - Prior to injection, do a pre-clamping of the die with core installed. Open die and examine core. If no crack, then continue. If cracked, then check core dimension or the die to see which one is causing the problem.

Soluble Cores

- Make sure soluble cores are prepared properly prior to injection.
- Be sure to completely remove all soluble core pattern material to avoid potential casting inclusions or improperly formed core cavities in the casting.
- Soluble cores will “grow” in size and deteriorate in the presence of high humidity; it is recommended that soluble cores be used as soon as possible after production and stored, if necessary, in a controlled environment until used.
- It is important to avoid contamination of waxes. To avoid pattern wax contamination with soluble wax, mixing and injection equipment used interchangeably must be completely cleaned and flushed prior to the change over.

Core Breakage

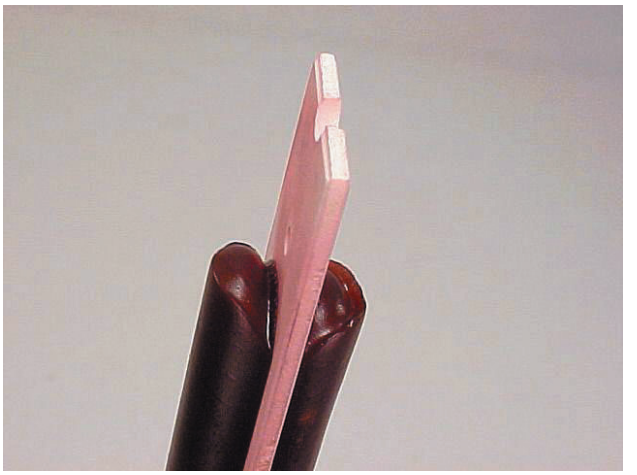
	Probable Cause	*Suggested Remedy*
Equipment	High injection pressure	*Reduce pressure.* ***Note:*** *Ceramic cores should be injected using minimal injection pressure.*
	Excessive flow rate	*Reduce flow rate.*
	Excessive acceleration *(Machines equipped with electronic injection control)*	*Reduce acceleration.*
	Excessive clamp pressure	*Reduce clamp pressure to the minimum that is needed.*
	Low wax temperature	*Increase wax temperature.* ***Note:*** *Low wax temperature will cause high wax viscosity*



Broken core inside wax pattern.

Pattern Die	Core location	*Have locator pins properly adjusted by a qualified technician.* ***Note:*** *The core locator pins may be too high causing breaks when shutting die. If the pins are too low the core is not supported and may break during wax injection.*
	Ejector pins moving fast	*Reduce ejector pin speed to insure smooth operation.*
Core	Oversize cores	*Check core dimensions.* ***Note:*** *If core is oversized contact core supplier. In some cases it is possible to sand the area that is oversized. The proper fix for long term is make the core to proper dimensions.*
Other	Improper removal of wax pattern from die	*Proper training of operators in removal techniques.*
	Insufficient mold release	*Increase mold release*.
	Excessive mold release	*Clean die and use minimal mold release.*

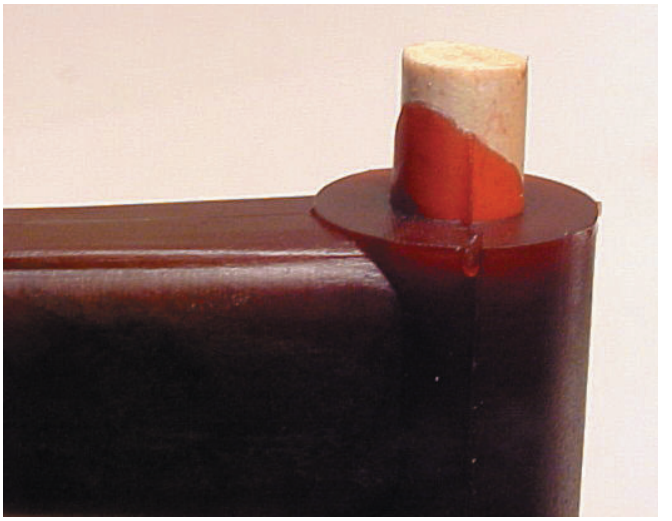
Non-Fill Using Cores*



	Probable Cause	*Suggested Remedy*
Equipment	Low injection pressure insufficient	*Increase injection pressure in small increments.*
	High clamp pressure	*Reduce clamp pressure.*
Pattern Die	Core location	*Adjust core location pins to assure proper location of core in die.*
	Cold die	*Warm die to promote better wax flow.*
Core	Core oversized	*Check dimensions and contact core supplier*. **Note:** *May be able to sand down core.*
Other	Cold core	*Warm core to promote better wax flow.*

***For additional information see causes and remedies in Section I, page 9.**

Flash Using Cores*

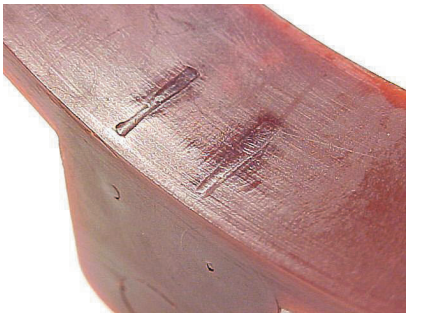


Flash around core

	Probable Cause	***Suggested Remedy***
Equipment	High injection pressure	*injection pressure.*
	High wax flow rate	*Reduce wax flow rate.*
	High acceleration rate *(Machines equipped with electronic injection control)*	*Reduce acceleration rate.*
	High wax temperature	*Reduce wax temperature.*
Pattern Die	High die temperature	*Reduce die temperature.*
	Die worn or damaged	*Correct wear or damage to die. Replace if problem is severe.*
Core	Oversized core	*Check dimensions and correct accordingly*.
	Damaged or broken core	*Determine cause for failure and correct accordingly.*

***For additional information see causes and remedies in Section I, page 13.**

Defects Using Wax Chills



There are occasions when wax chills are required to compensate for wax cavitation in thick cross sections. A variety of problems associated with the use of wax chills can result in nonconforming wax patterns. The following are helpful hints.

Helpful Hints:

- High injection flow rates or injection pressure can cause the chills to break, move to the pattern surface (commonly called “kiss out”) and/or entrap air with resulting pattern surface defects that will scrap the wax pattern. Reduce flow rate and/or injection pressure to minimize these problems.

- Chills must cool completely prior to use in pattern making to avoid shrinkage or distortion in the wax pattern.

- Chill may be too large or improperly located. The wax may not properly encapsulate the chill during pattern injection. Review location or chill design. Another solution is to add holes or reduce the size of the chill to allow the wax to flow through and around the chill.

- For the production of wax chills please refer to Section I. For the use of and injection around chills, refer to Section 2.

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