Digital Technology in the Wax Room

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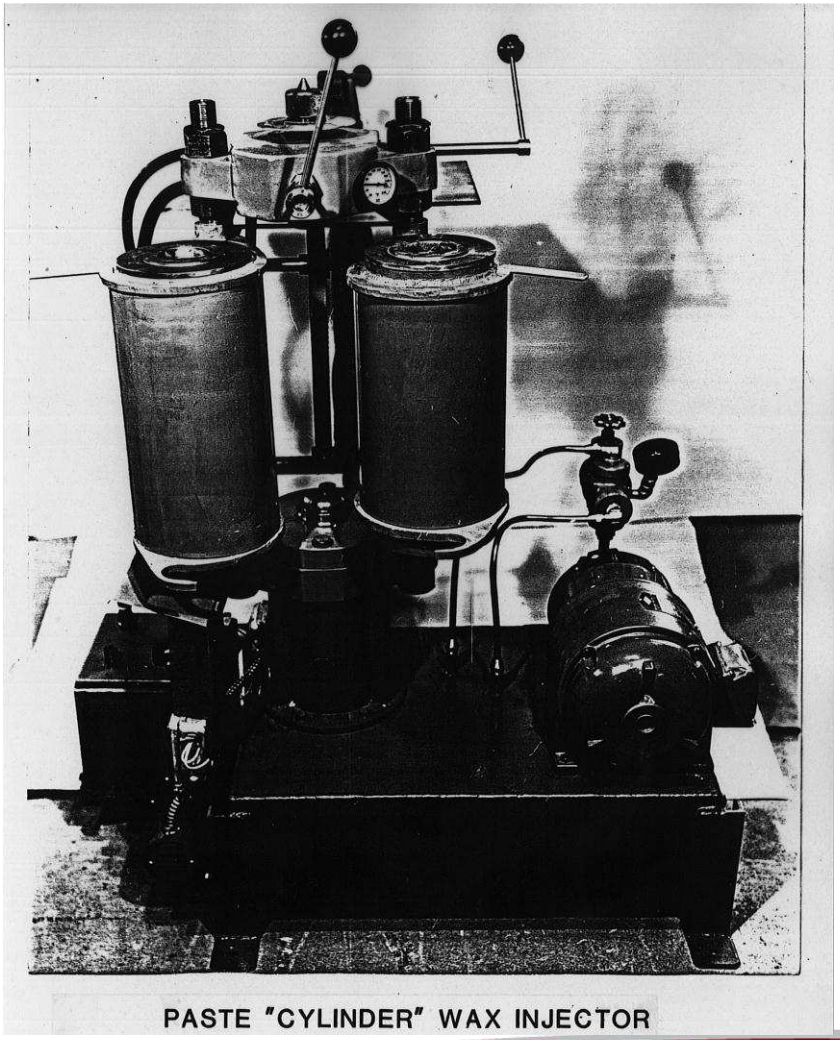
MPI Incorporated

Where we came from



PASTE "CYLINDER" WAX INJECTOR

- Trip down Memory Lane
- 40 years ago controls were minimal

Where are we going

- Today with Digital Controls we can have the opportunity to see what is happening with:
  - Wax Temperature
  - Wax Flow
  - Wax Pressure
- Hold tighter tolerances

Some things never change

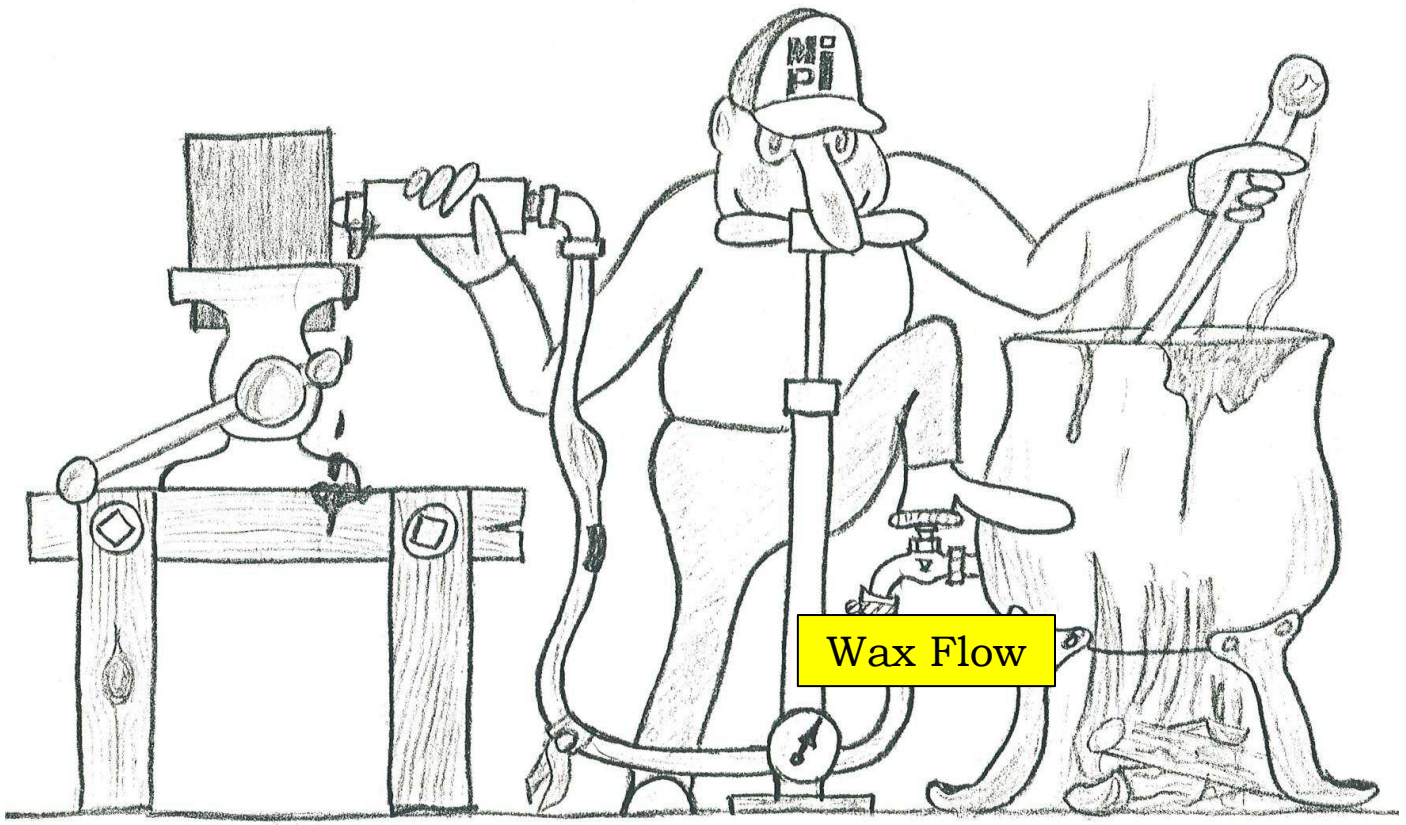
“No matter how sophisticated the instrumentation, the application of that instrumentation and how it is used to control the process is the real challenge.”

Key Input Variables

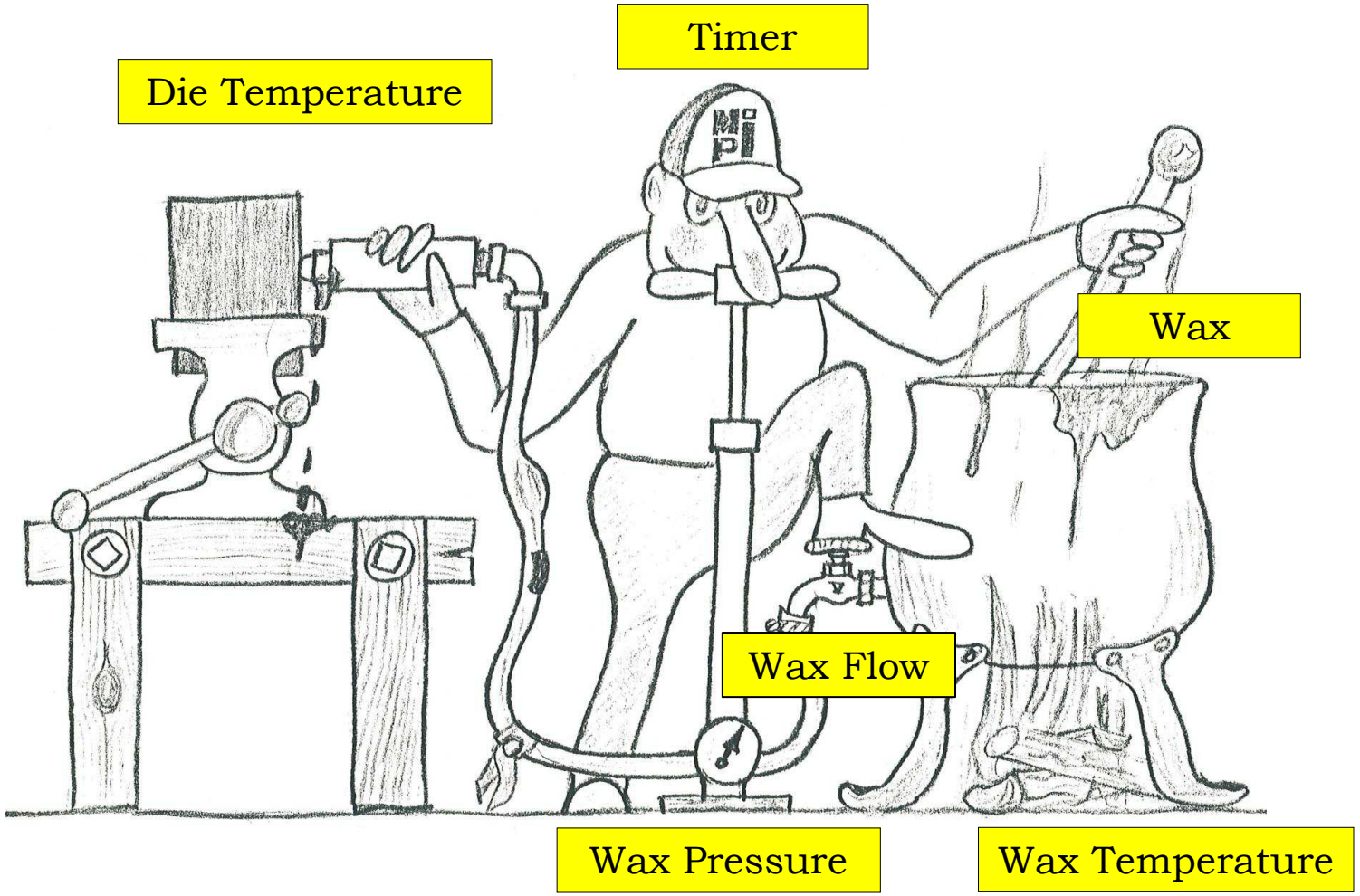
Key Input Variables:

- Temperature
- Flow
- Pressure
- Time
- Wax

Key Input Variables



Key Input Variables



Digital Technology in the Wax Room

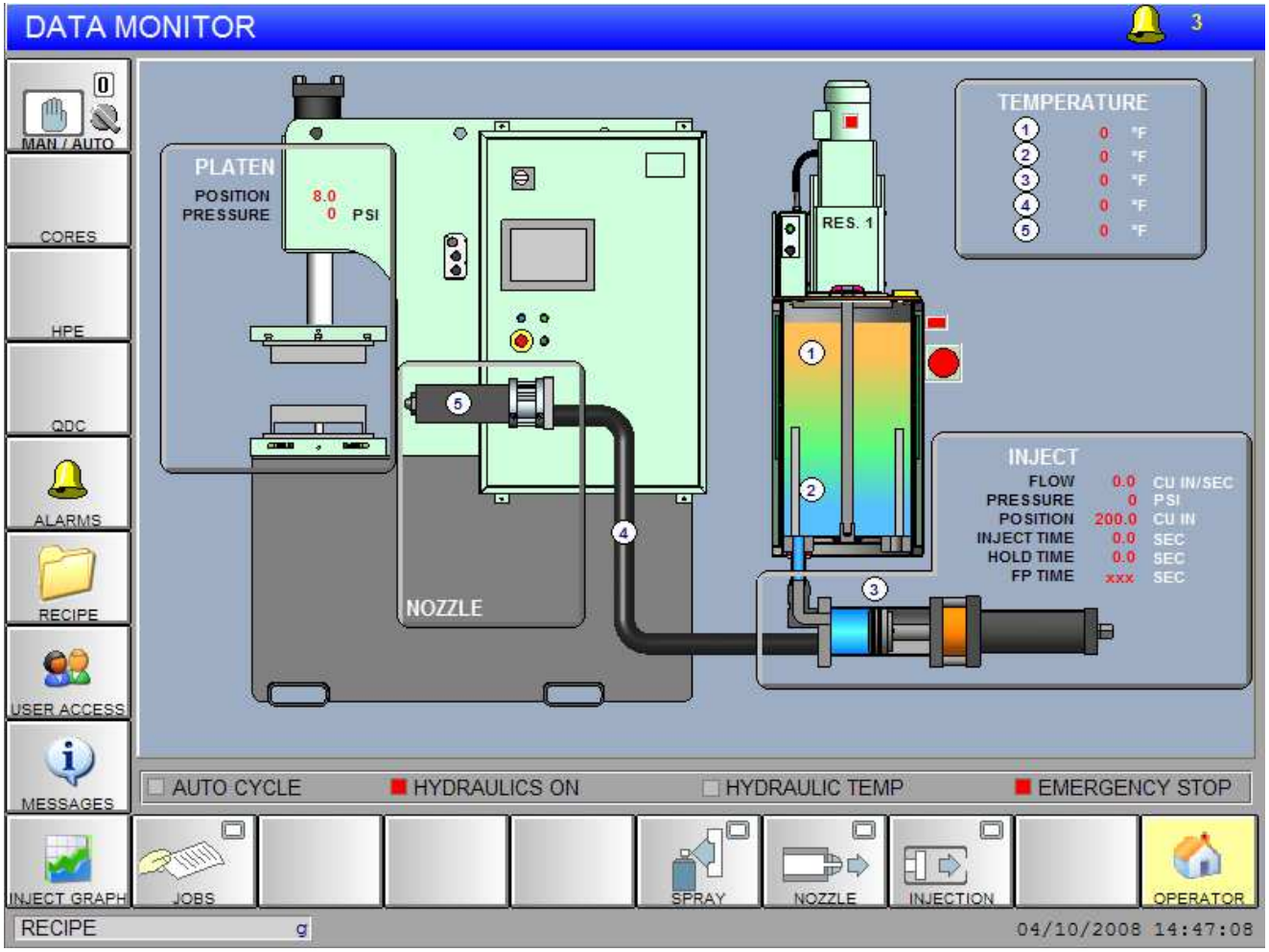
Digital Technology allows us to accurately control wax:

- Temperature
- Flow
- Pressure
- Time
- Wax

The Process of Wax Injection

- The goal of wax injection is to replace 100% of the air in the die with wax
- If you achieve this goal you will get a perfect wax pattern
- To be successful you need control

The Process of Wax Injection



Digital technology provides the control

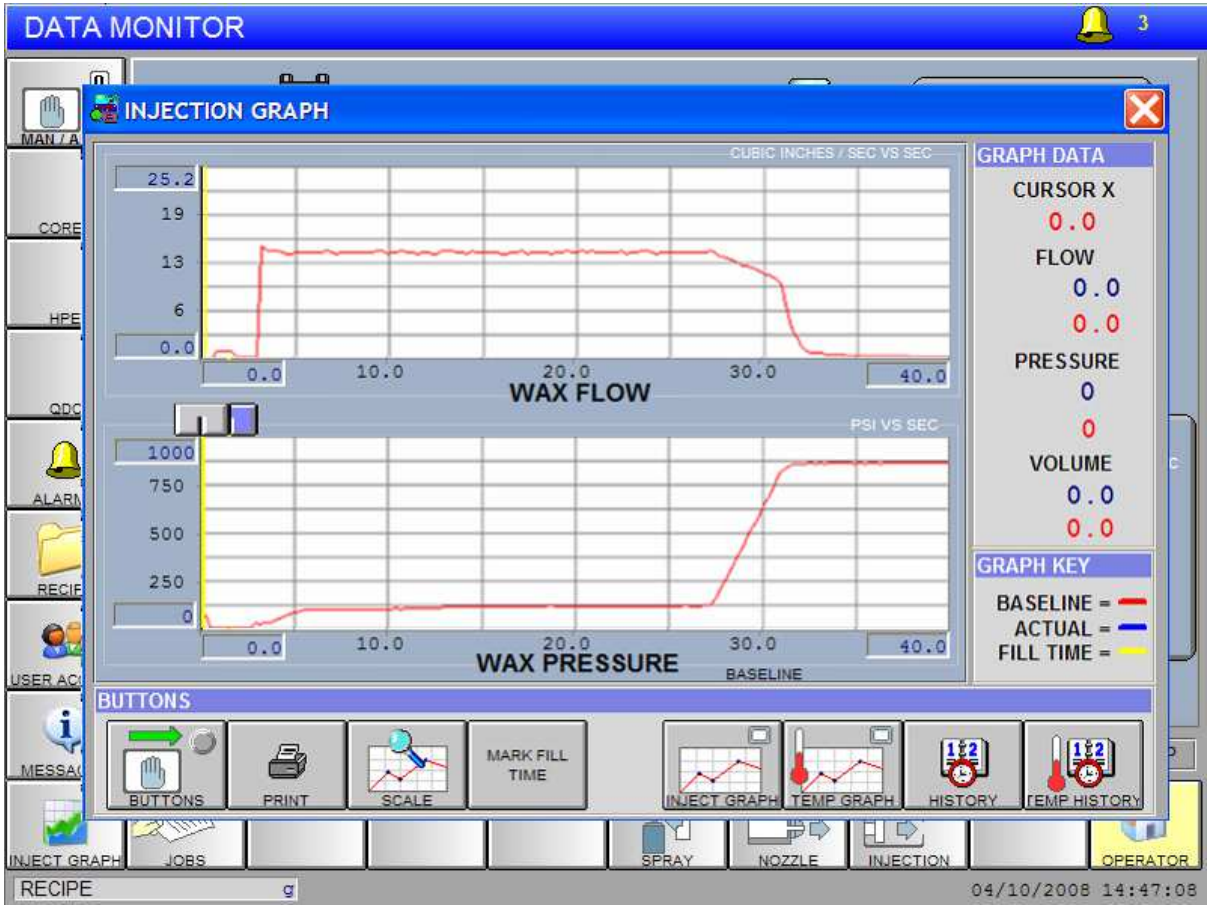
Digital Technology in the Wax Room

- Wax Temperature Control

Digital Technology in the Wax Room

- Wax Temperature Control
- Wax Flow and Pressure Control

Digital Technology in the Wax Room



Digital Technology in the Wax Room

- Wax Temperature Control
- Wax Flow and Pressure Control
- Die Temperature Control

Digital Technology in the Wax Room

- Wax Temperature Control
- Wax Flow and Pressure Control
- Die Temperature Control
- Injection Time

Digital Technology in the Wax Room

Digital Technology allows for:

- Store recipes

Digital Technology in the Wax Room

Digital Technology allows for:

- Store recipes
- Control and analysis of Key Input Variables

Digital Technology in the Wax Room

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- Repeatable setups

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Digital Technology allows for:

- Store recipes
- Control and analysis of Key Input Variables
- Repeatable setups
- Control who can make process changes
- Vary the flow and pressure during an injection cycle

Why Not Perfect Patterns?

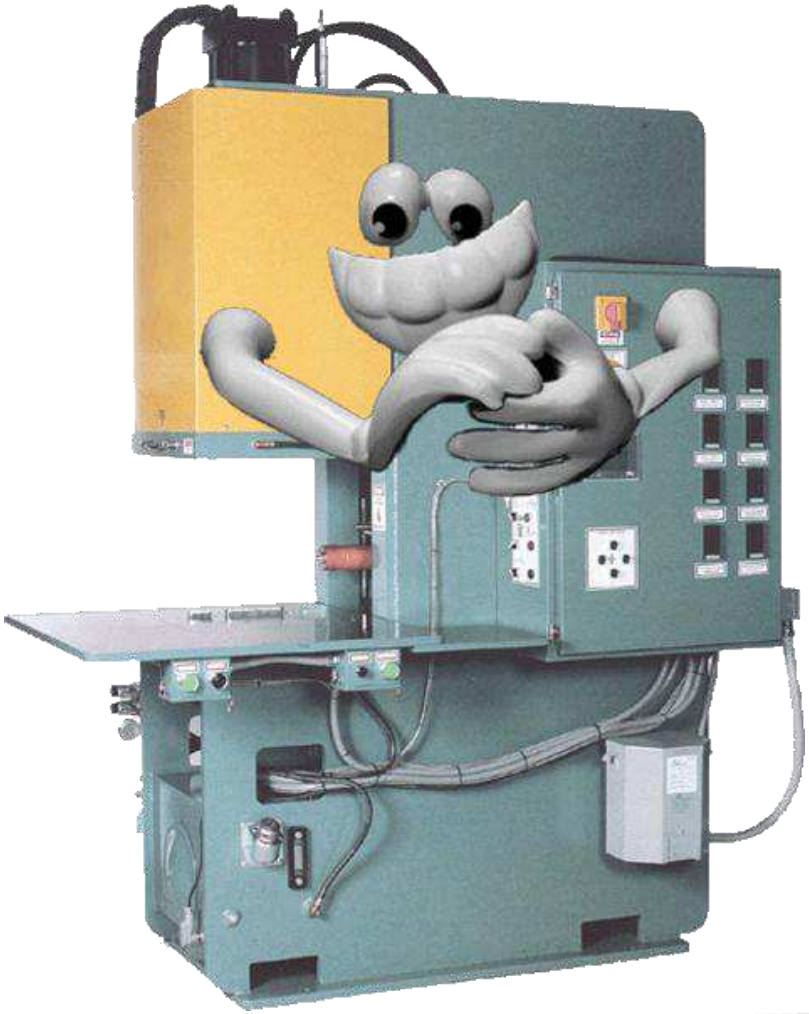
The controls have the ability to give you a perfect pattern each time.

- Why aren’t foundries producing perfect patterns all the time?
- Why do we still have pattern defects?

Why Not Perfect Patterns?

No matter how sophisticated the instrumentation is, the application of that instrumentation and how it is used to control the process is the real challenge.

Why Not Perfect Patterns?



How do you know that your machine is doing what it is supposed to do?

Data Collection

How do you compare one manufacturer’s machine to another?

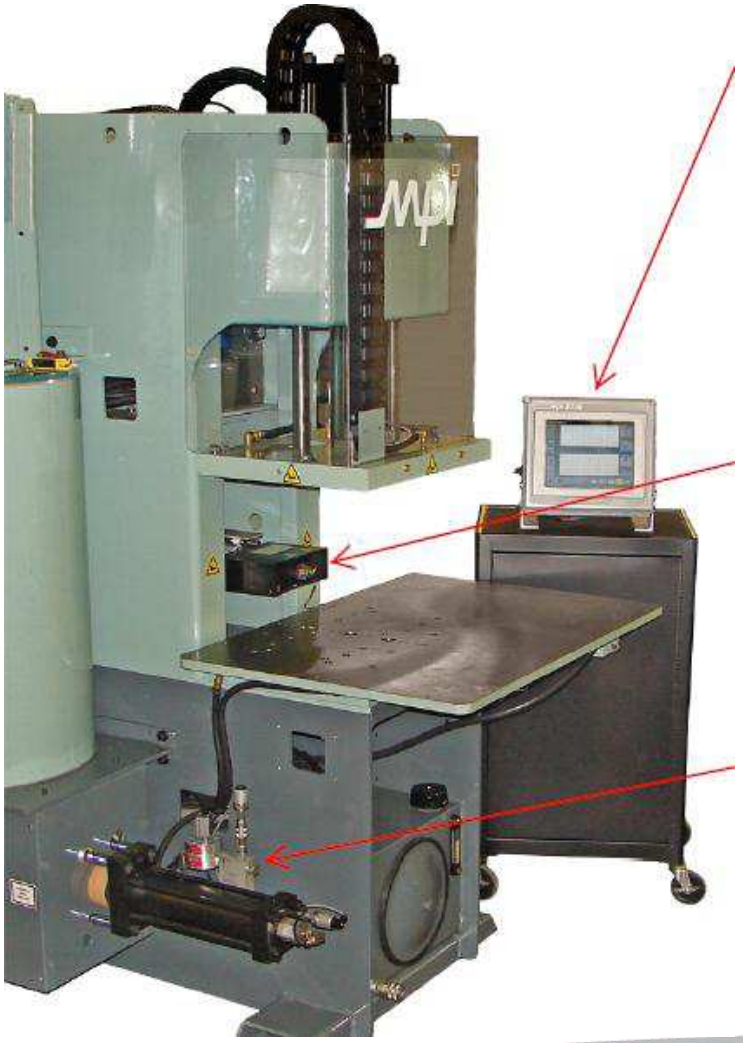
Data Collection

Pressure readout at the nozzle

MPI's 20-20 Process Vision

Through the use of digital data collection devices

Data Collection



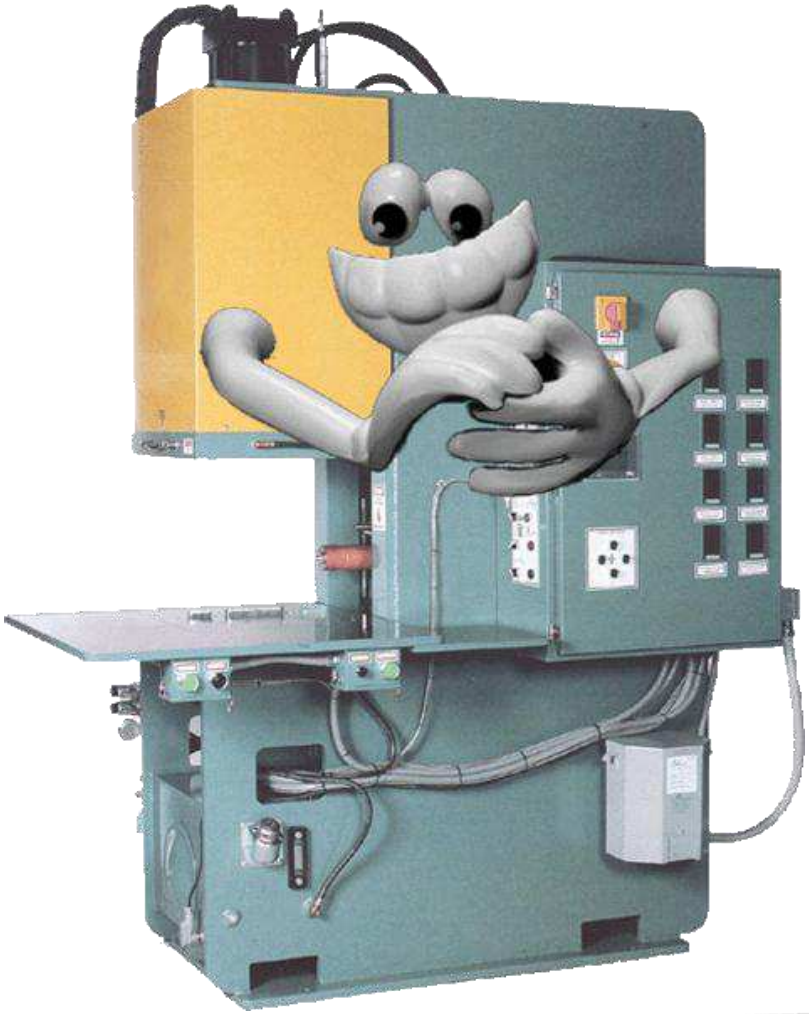
Data collection Device

Wax temperature sensing

Wax pressure sensing

Wax Flow sensing

Data Collection



Eliminate your machines personality

Achieve repeatability for all your machines

Data Collection

Example #1

A large foundry benefited from the use of a data collection device

- Collected Data from all machines
- Saw variations between machines
- Saw variations within the machines

Data Collection

Example #1

Compared data with a newer Digitally controlled machine

Data Collection

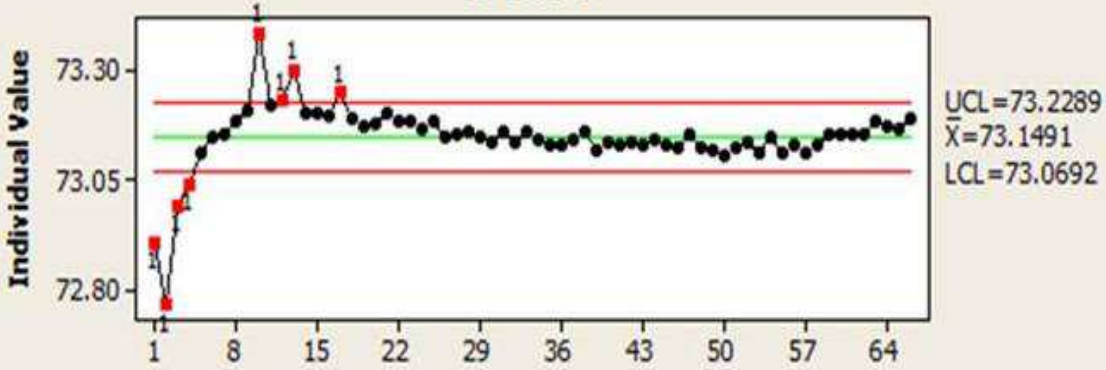
Example #1

In the above example, one of the data points being collected was the wax temperature.

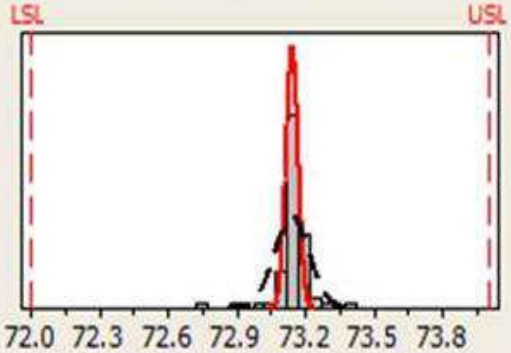
- Used data collected to analyze, through Statistical Process Control, wax temperature variation at the nozzle
- Data was gathered every 0.1 second
- See illustration 2

Process Capability Sixpack of Average Temp of injections

I Chart

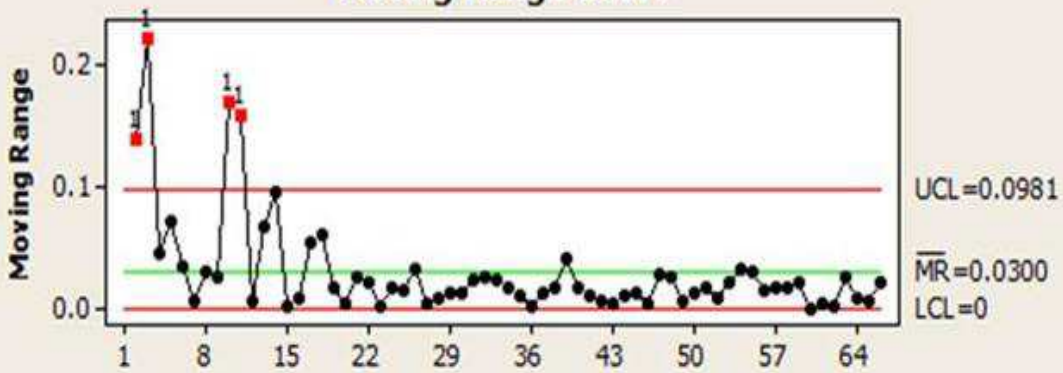


Capability Histogram



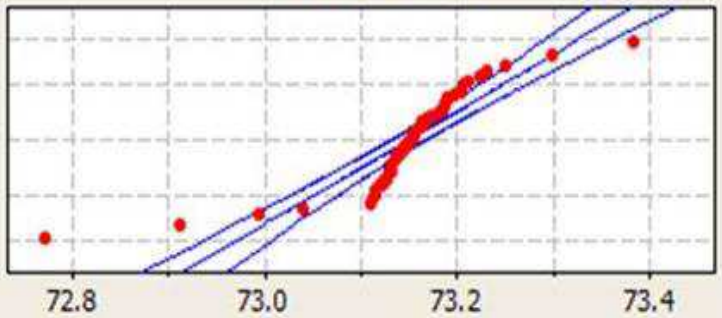
Specifications	
LSL	72
USL	74

Moving Range Chart

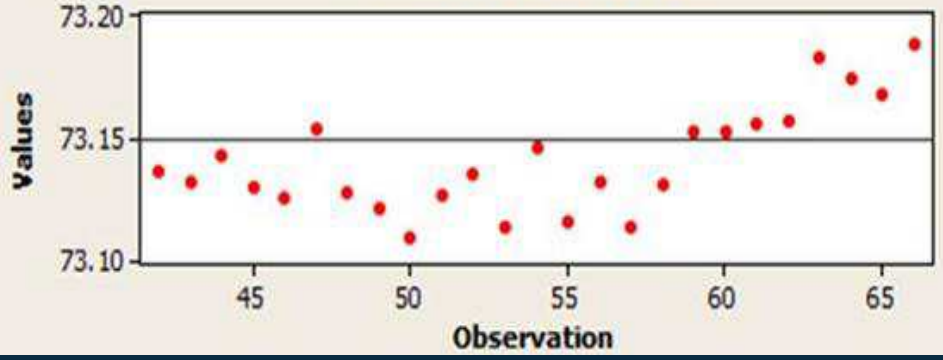


Normal Prob Plot

AD: 4.882, P: < 0.005

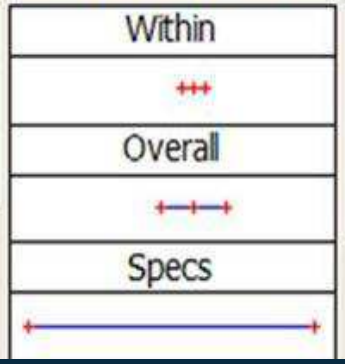


Last 25 Observations



Capability Plot

Within	
StDev	0.02661
Cp	12.53
Cpk	10.66
PPM	0.00



Overall	
StDev	0.07603
Pp	4.38
Ppk	3.73
Cpm	*
PPM	0.00

Data Collection

Example #2

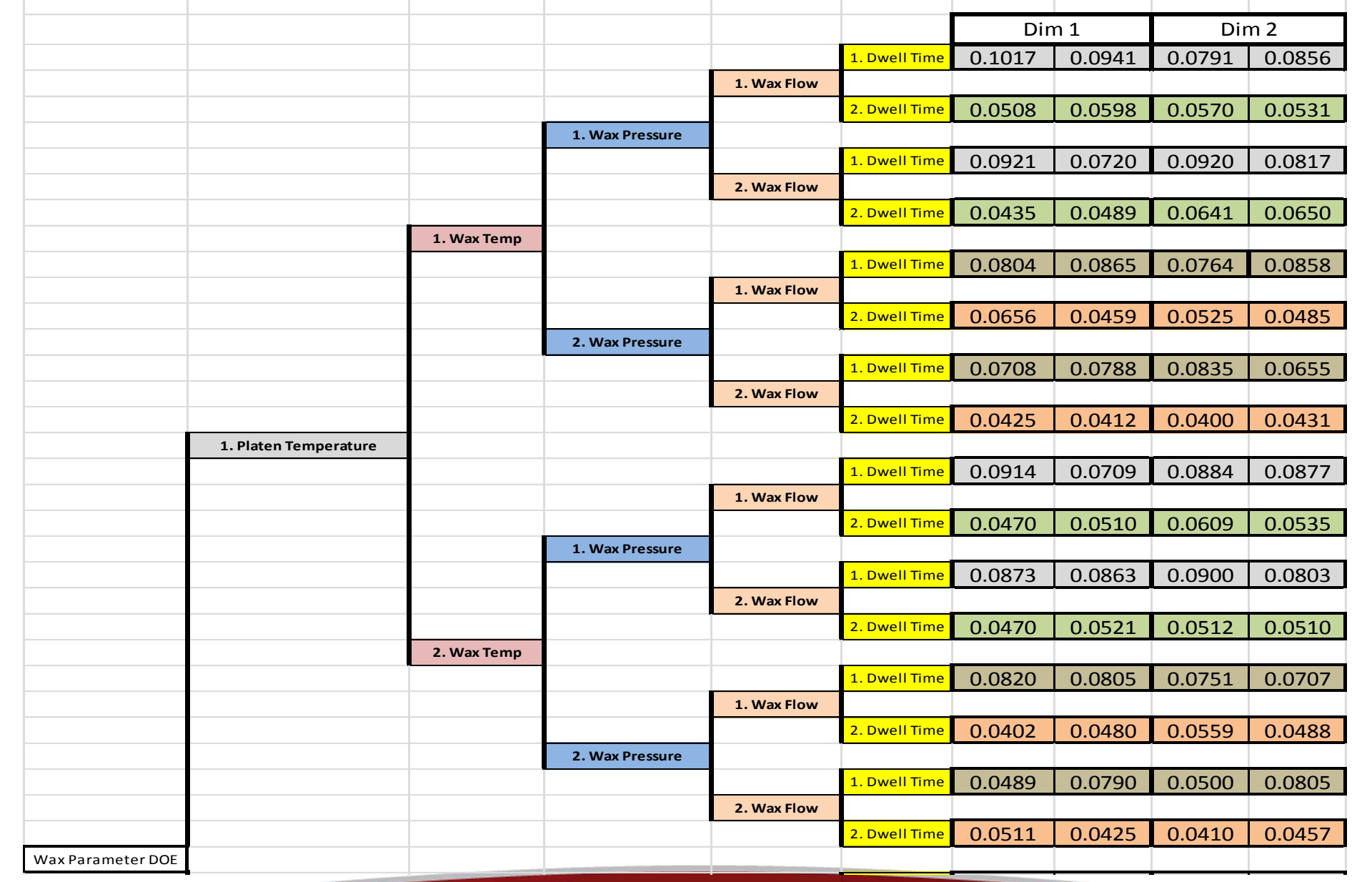
- It is difficult to predict the outcome of an injection recipe
- Start with a similar recipe of a know part
- What happens if your part has dimensional variation from specification?

Data Collection

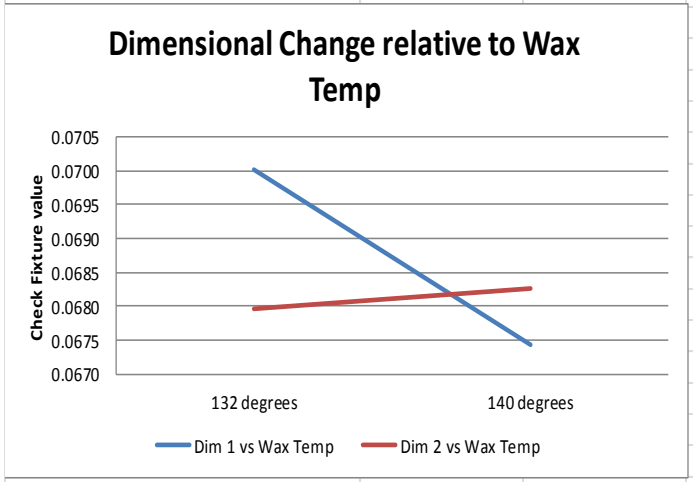
Example #2

Using Data to drive your injection recipe

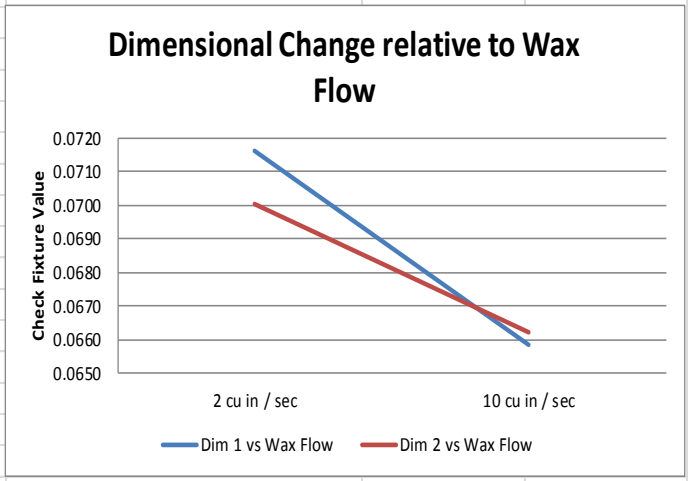
- Create a 2k full factorial Design of Experiment (DOE)
- One of our customers conducted such and experiment


Dim 1
Dim 2
1. Dwell Time 0.1017 0.0941 0.0791 0.0856
1. Wax Flow
2. Dwell Time 0.0508 0.0598 0.0570 0.0531
1. Wax Pressure
1. Dwell Time 0.0921 0.0720 0.0920 0.0817
2. Wax Flow
2. Dwell Time 0.0435 0.0489 0.0641 0.0650
1. Wax Temp
1. Dwell Time 0.0804 0.0865 0.0764 0.0858
1. Wax Flow
2. Dwell Time 0.0656 0.0459 0.0525 0.0485
2. Wax Pressure
1. Dwell Time 0.0708 0.0788 0.0835 0.0655
2. Wax Flow
2. Dwell Time 0.0425 0.0412 0.0400 0.0431
1. Platen Temperature
1. Dwell Time 0.0914 0.0709 0.0884 0.0877
1. Wax Flow
2. Dwell Time 0.0470 0.0510 0.0609 0.0535
1. Wax Pressure
1. Dwell Time 0.0873 0.0863 0.0900 0.0803
2. Wax Flow
2. Dwell Time 0.0470 0.0521 0.0512 0.0510
2. Wax Temp
1. Dwell Time 0.0820 0.0805 0.0751 0.0707
1. Wax Flow
2. Dwell Time 0.0402 0.0480 0.0559 0.0488
2. Wax Pressure
1. Dwell Time 0.0489 0.0790 0.0500 0.0805
2. Wax Flow
2. Dwell Time 0.0511 0.0425 0.0410 0.0457
Wax Parameter DOE

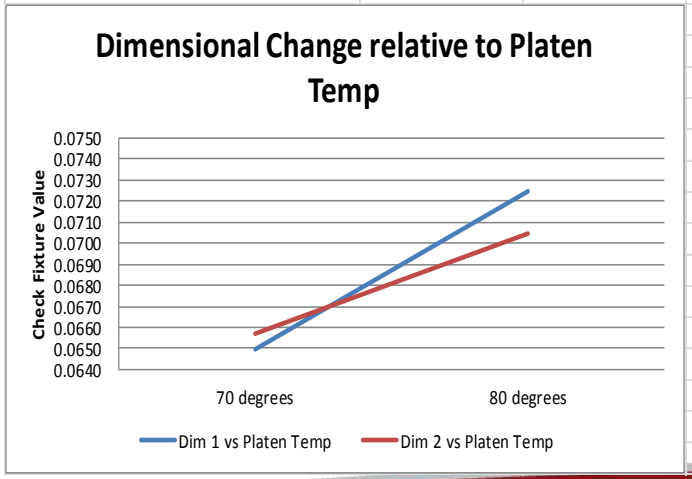
	132 degrees	140 degrees
Dim 1 vs Wax Temp	0.0700	0.0674
Dim 2 vs Wax Temp	0.0680	0.0683



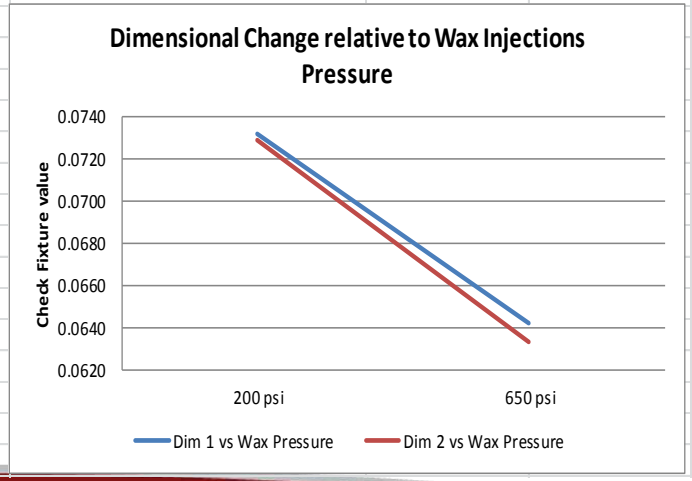
	2 cu in / sec	10 cu in / sec
Dim 1 vs Wax Flow	0.0716	0.0658
Dim 2 vs Wax Flow	0.0700	0.0662



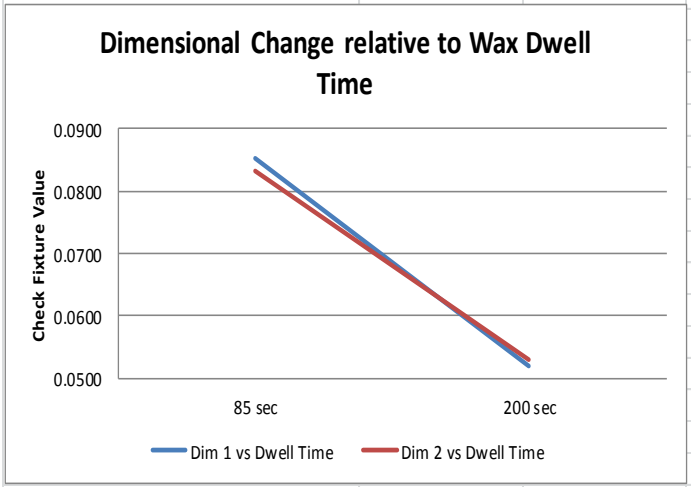
	70 degrees	80 degrees
Dim 1 vs Platen Temp	0.0650	0.0725
Dim 2 vs Platen Temp	0.0657	0.0705



	200 psi	650 psi
Dim 1 vs Wax Pressure	0.0732	0.0643
Dim 2 vs Wax Pressure	0.0729	0.0633



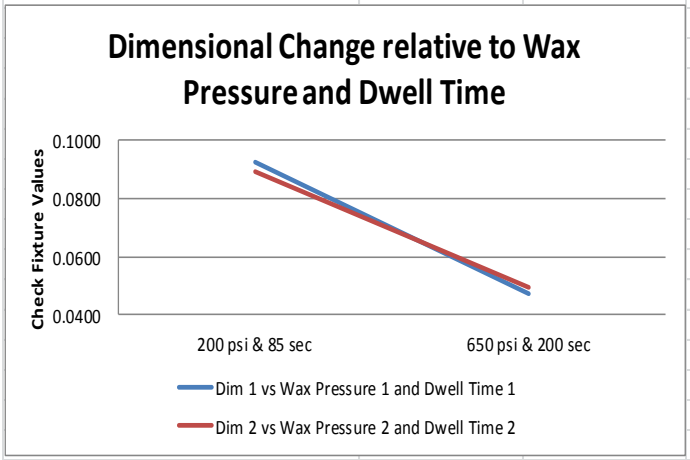
	85 sec	200 sec
Dim 1 vs Dwell Time	0.0854	0.0521
Dim 2 vs Dwell Time	0.0833	0.0530

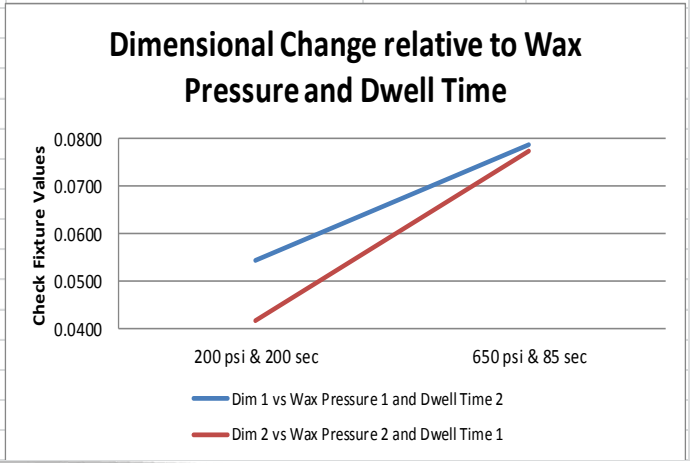


Note: The larger number denotes a smaller part

	200 psi & 85 sec	650 psi & 200 sec
Dim 1 vs Wax Pressure 1 and Dwell Time 1	0.0922	0.0473
Dim 2 vs Wax Pressure 2 and Dwell Time 2	0.0892	0.0493

	200 psi & 200 sec	650 psi & 85 sec
Dim 1 vs Wax Pressure 1 and Dwell Time 2	0.0542	0.0786
Dim 2 vs Wax Pressure 2 and Dwell Time 1	0.0416	0.0774





Train Your Personnel

Having your personnel adapt to the new digital technology of the wax room is key to success.

- Need to be trained on it’s operation
- Understand the differences between old and new
- The operator may be reluctant to change

Train Your Personnel

It is not uncommon to find a new digitally controlled machine setup incorrectly:

Example #1: Temperature variations in the machine due to improper setup, especially in the injection nozzle

Train Your Personnel

It is not uncommon to find a new digitally controlled machine setup incorrectly:

Example #1: Temperature variations in the machine due to improper setup

Example #2: Machine designed to run paste wax but is used as a liquid machine

Train Your Personnel

It is not uncommon to find a new digitally controlled machine setup incorrectly:

Example #1: Temperature variations in the machine due to improper setup

Example #2: Machine designed to run paste wax but is used as a liquid machine

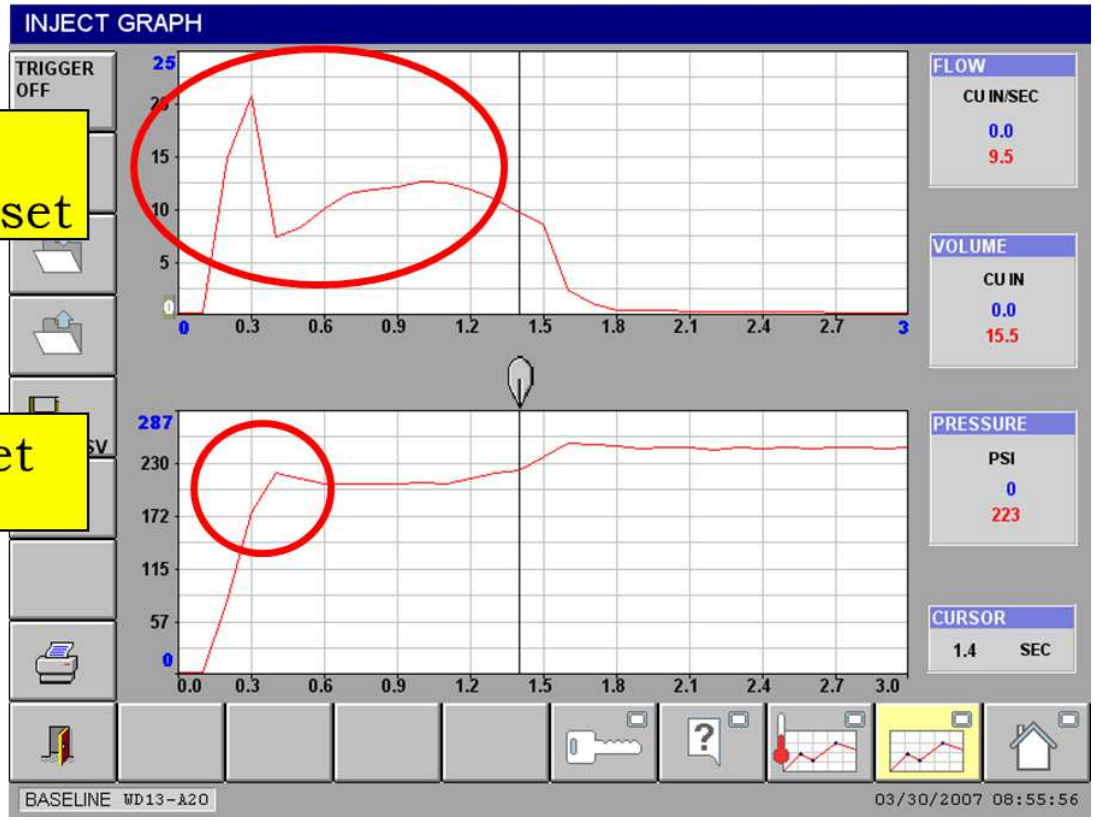
Example #3: Wax flow control being controlled with wax pressure and not understanding why

Train Your Personnel

Poorly Controlled Injection Cycle

Flow is unsteady
Flow does not match preset

Pressure is close to preset during fill



Robotic Integration

Robotic Integration in the wax room:

Robots have become a reality in the wax room

Robotic Integration

Robotic Integration in the wax room:

Robots have become a reality in the wax room

- Automated wax injection cell using a 6 axis robot

Automated Injection: 6 Axis Robot

Robotic Integration

Robotic Integration in the wax room:

Robots have become a reality in the wax room

- Automated wax injection cell using a 6 axis robot
- Automated pattern assembly, multiple patterns per runner bar

Robotic Integration

Robotic Integration

Robotic Integration in the wax room:

Robots have become a reality in the wax room

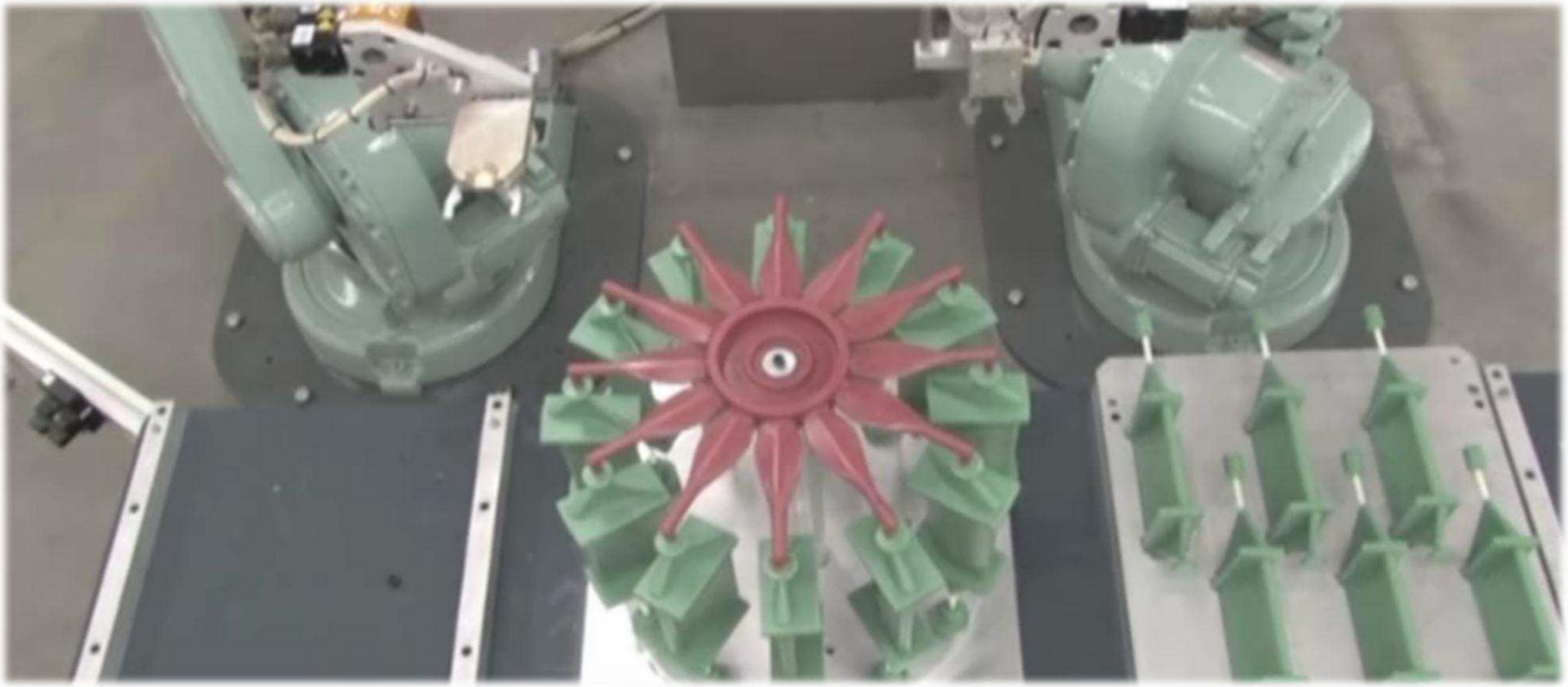
- Automated wax injection cell using a 6 axis robot
- Automated pattern assembly, multiple patterns per runner bar
- Automated pattern assembly using two 6 axis robots for single crystal assemblies

Automated Assembly: Two 6 Axis Robots

Single Crystal Turbine Blade Assembly

Automated Assembly: Two 6 Axis Robots

Automated Assembly: Two 6 Axis Robots



Digital Technology in the Wax Room

- Digital technology is awesome
- Yes it can be frustrating
- Gains out way the setbacks
- Robotic integration in the wax room

Digital Technology in the Wax Room

Embracing digital technology through proper education will achieve long term gains in:

- **Productivity**
- **Accuracy**
- **Casting Yields**
- **Bottom Line**

Digital Technology in the Wax Room

Thank You