Managing Melt Temperature in a Twin Screw Extruder

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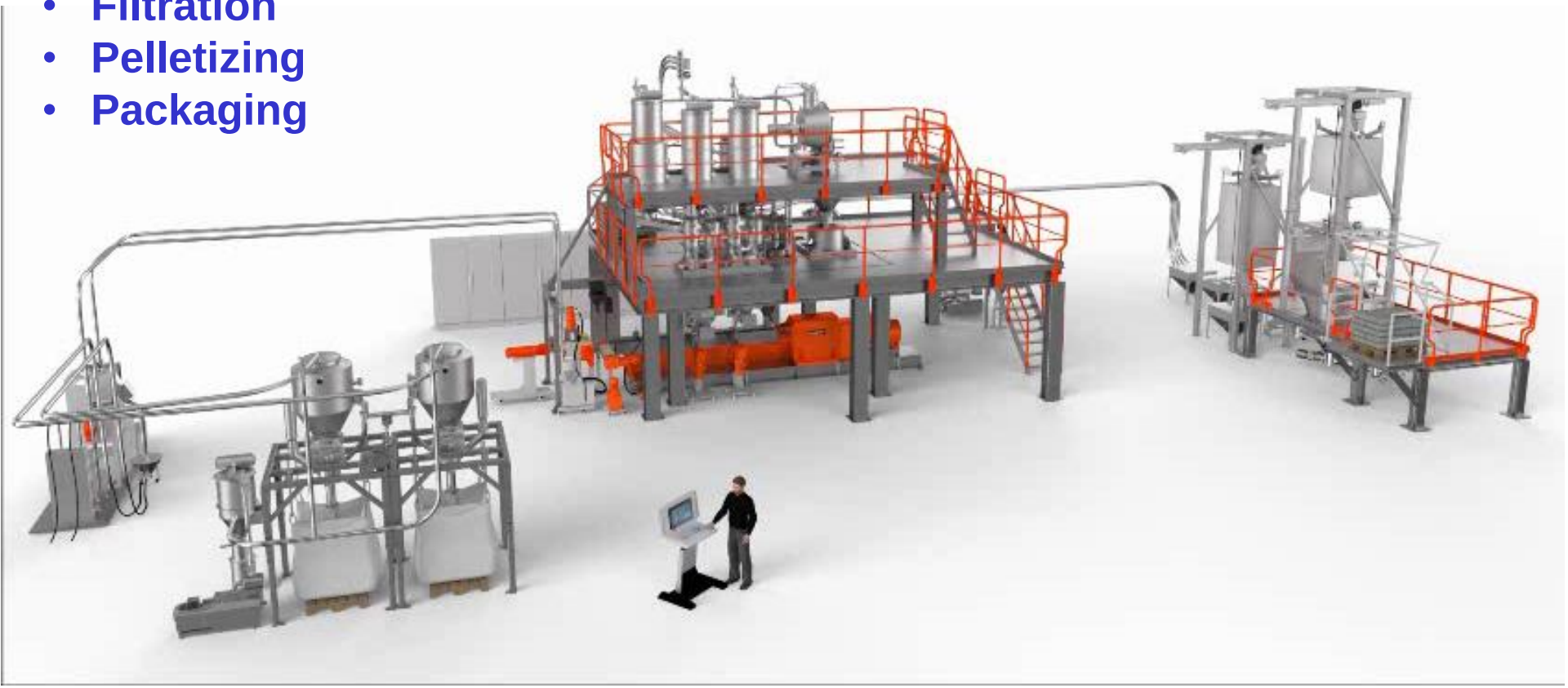
February 26, 2019
Prepared for SPE PO 2010

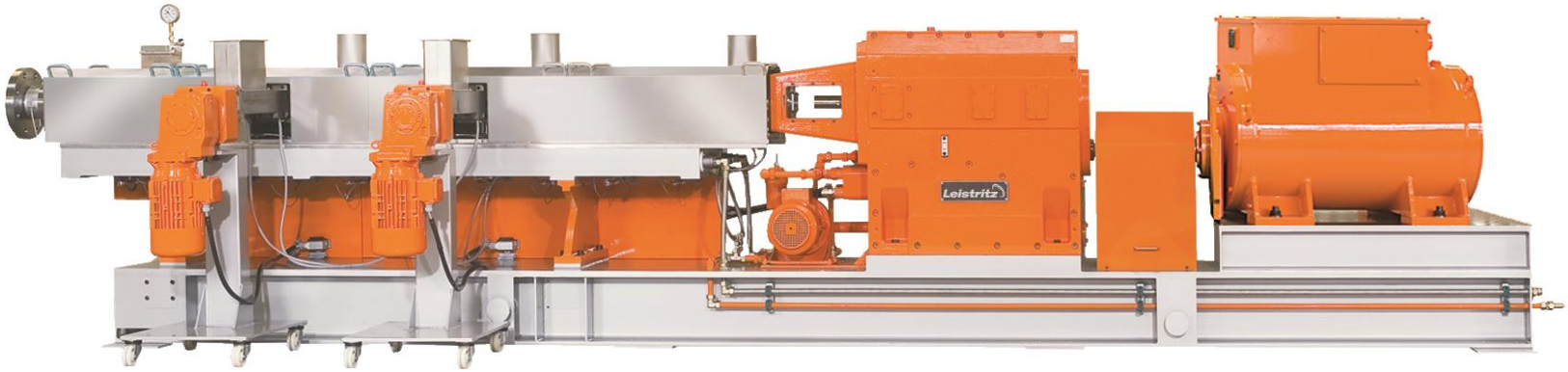
Twin screw compounding system

- Material handling
- LIW feeders
- Filtration
- Pelletizing
- Packaging



ZSE-MAXX twin screw extruder

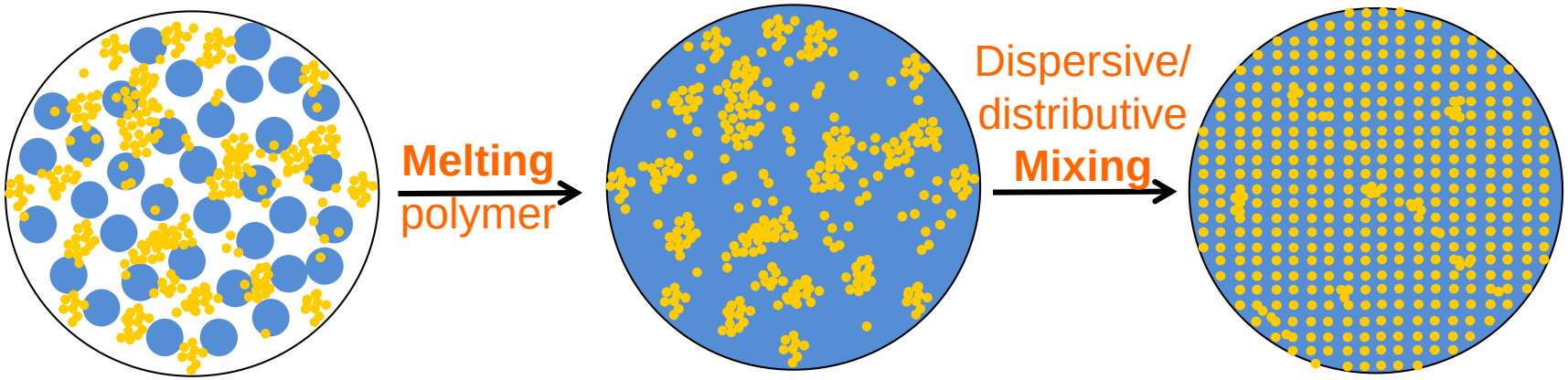
TSEs: compounding, devol and REX



- **Continuous mixer: polymer+ additives + fillers + liquids**
- **Managing melt temp: operating conditions, screw design, front-end configuration**

TPE/TPO/TPV Compounding

- Solid additives/particles
- Polymer granules/pellets



PP + rubber+ additives + oil fillers+++

Suspended in polymer melt

Uniformly mixed particles with a few agglomerates

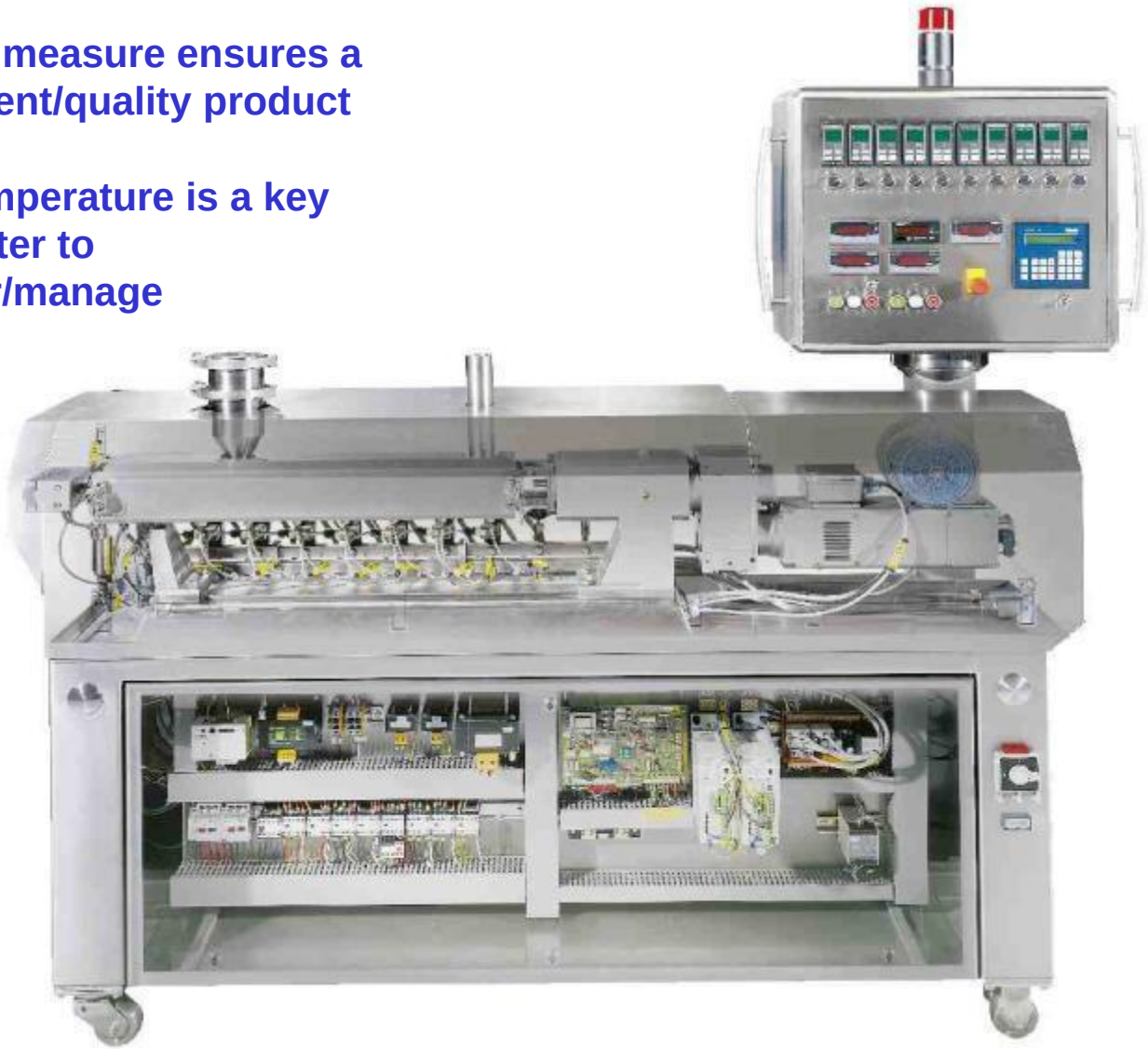
Gogos and Ioannidis

Controls and Instrumentation

Control: temps, rpm, feed rate, vacuum
Readouts: melt temp & pressure, torque, in-line optical sensors+

On-line measure ensures a consistent/quality product

Melt temperature is a key parameter to monitor/manage



Feeders set rate: LIW feeders

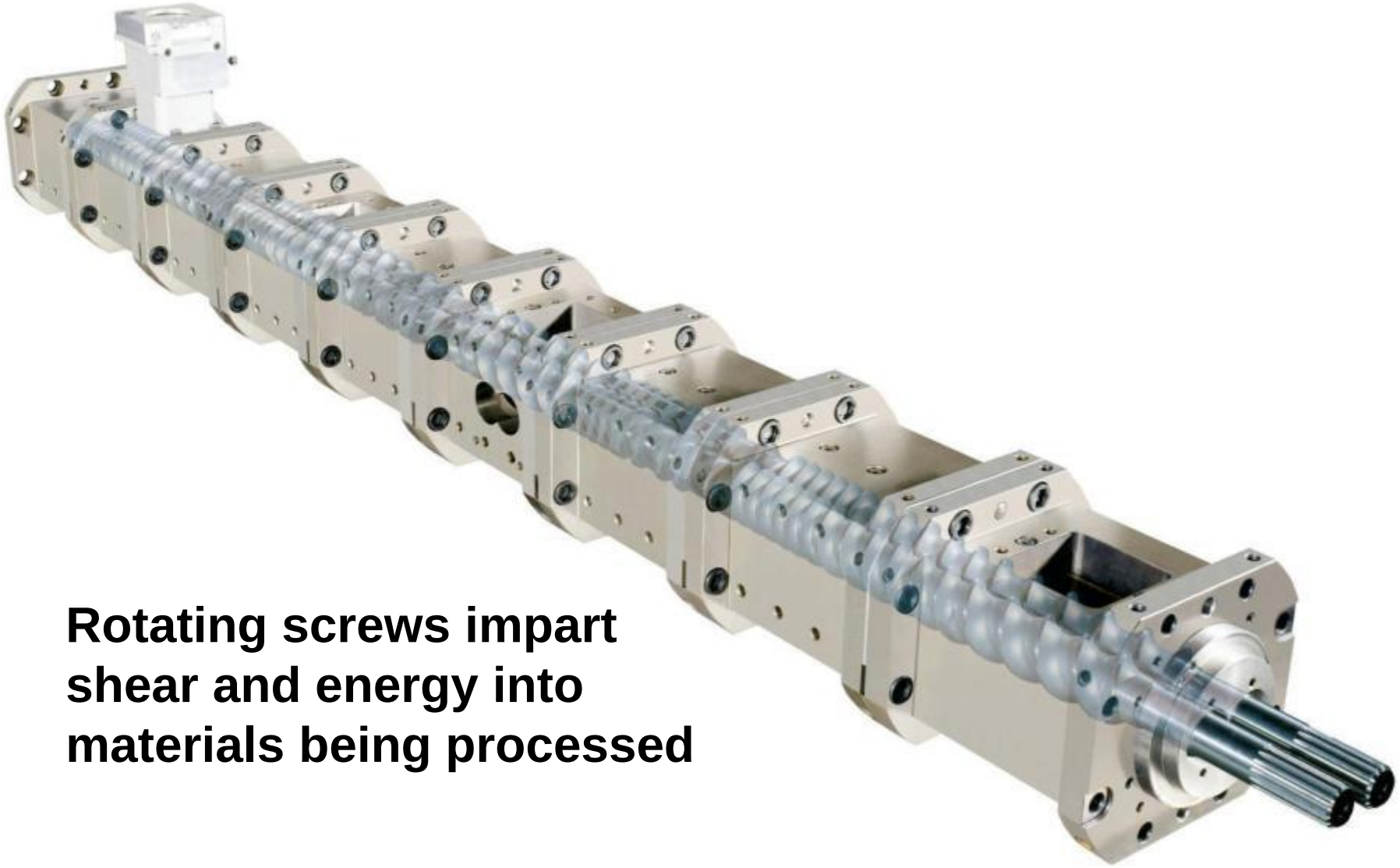
Feeder #1: 80% polymer

Feeder #2: 20% pigment/filler/additive+

Screw rpm independent....optimize mixing & devol

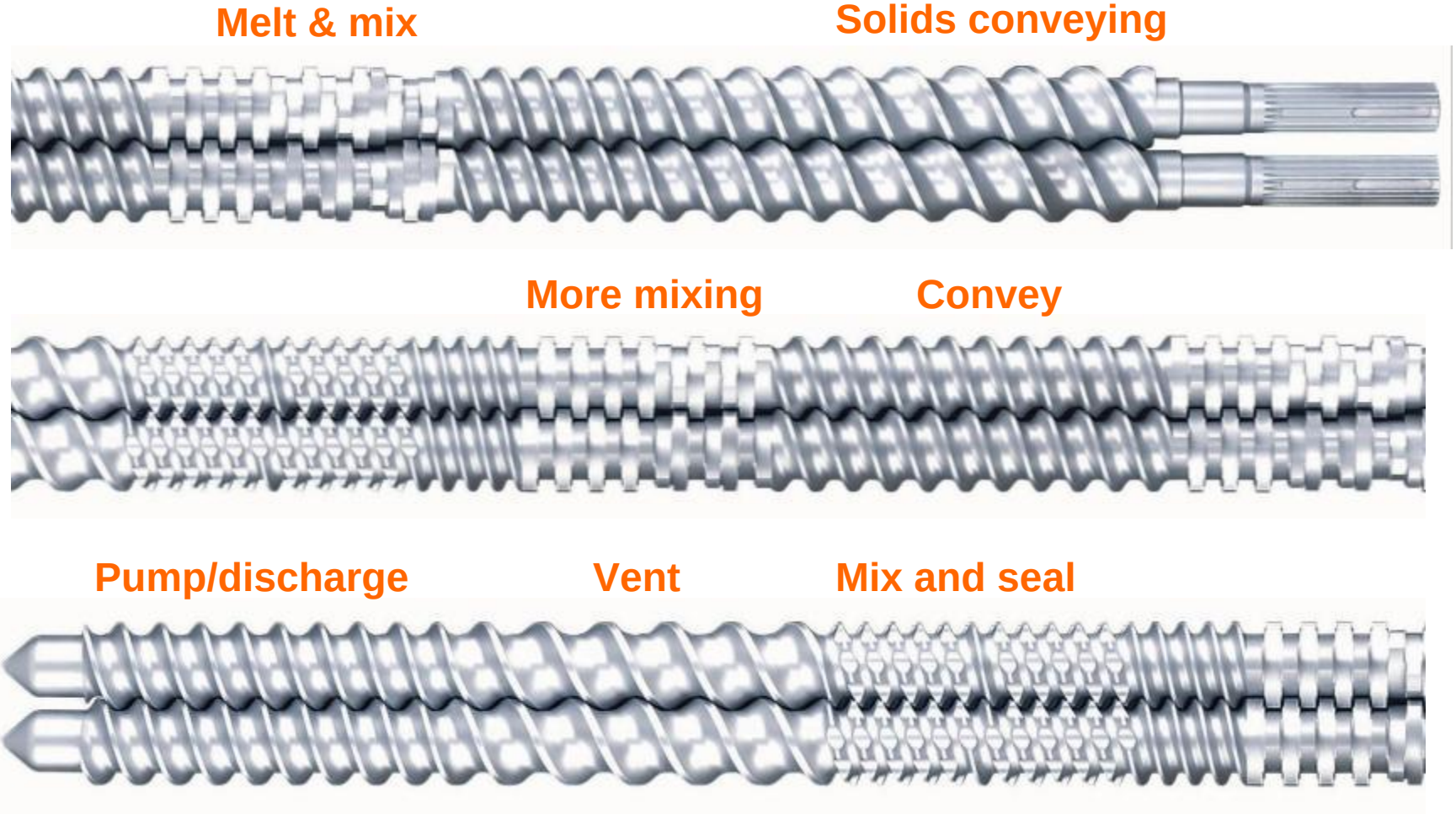
100 to 1200 rpms is typical

TSE Process Section



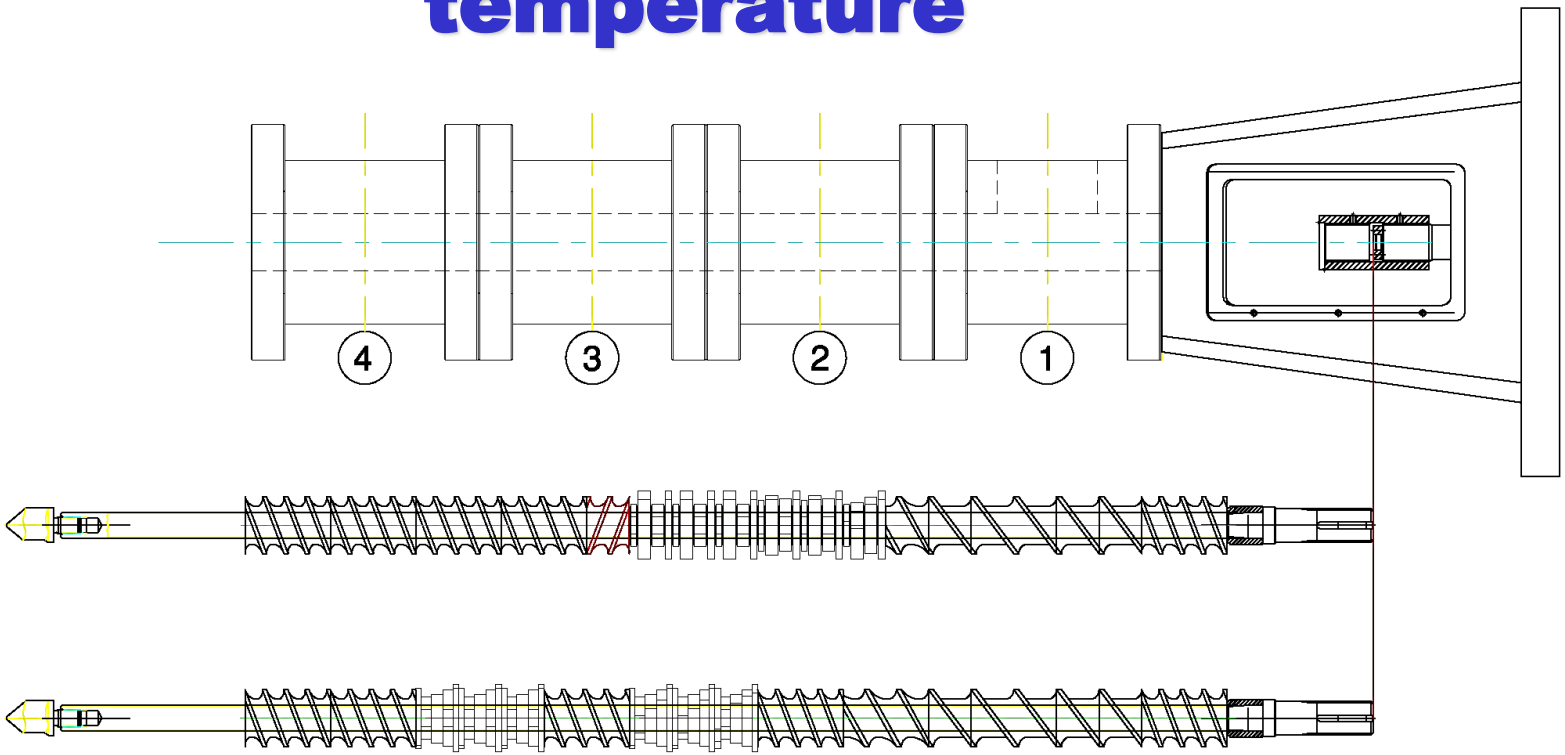
Rotating screws impart shear and energy into materials being processed

Co-rotating TSE design

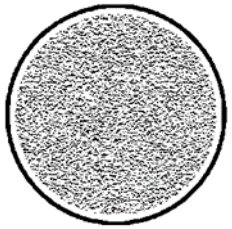


TSE’s are small mass, continuous mixers

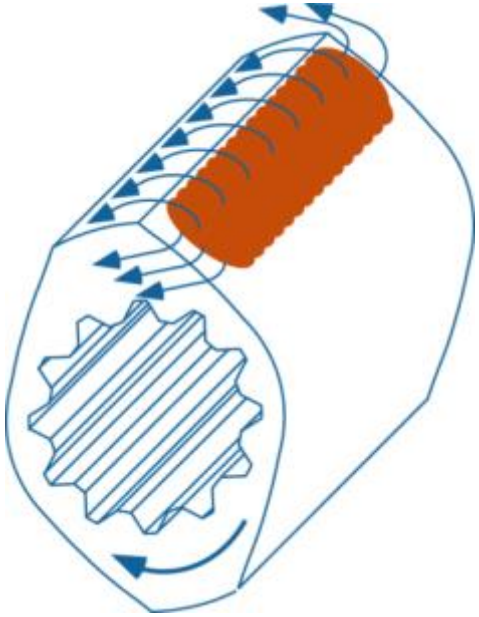
Melting zone directly effects melt temperature



Types of mixing elements

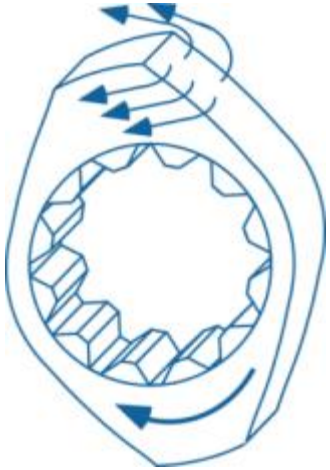


BROAD

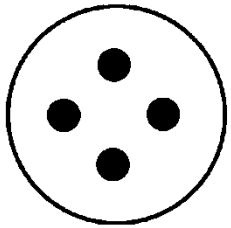


LOBAL POOL CAPTURE
(DISPERSIVE)

NARROW



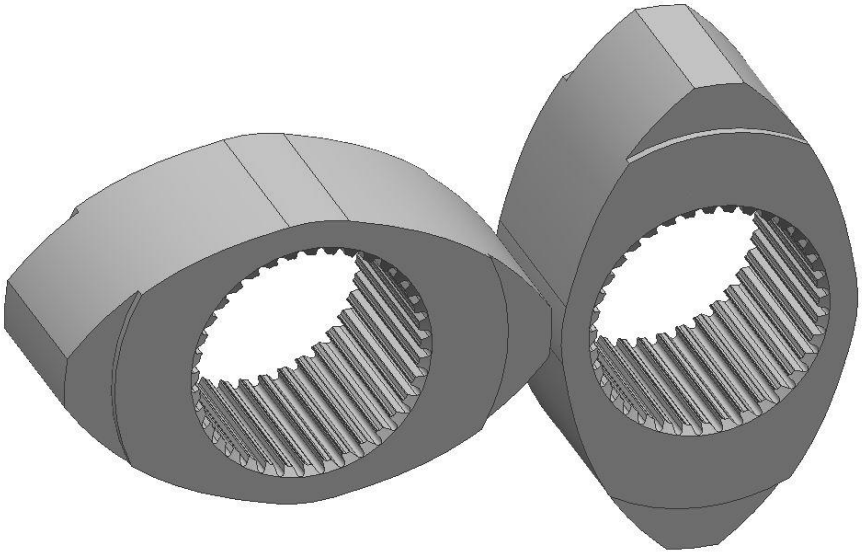
MELT DIVISION
(DISTRIBUTIVE)

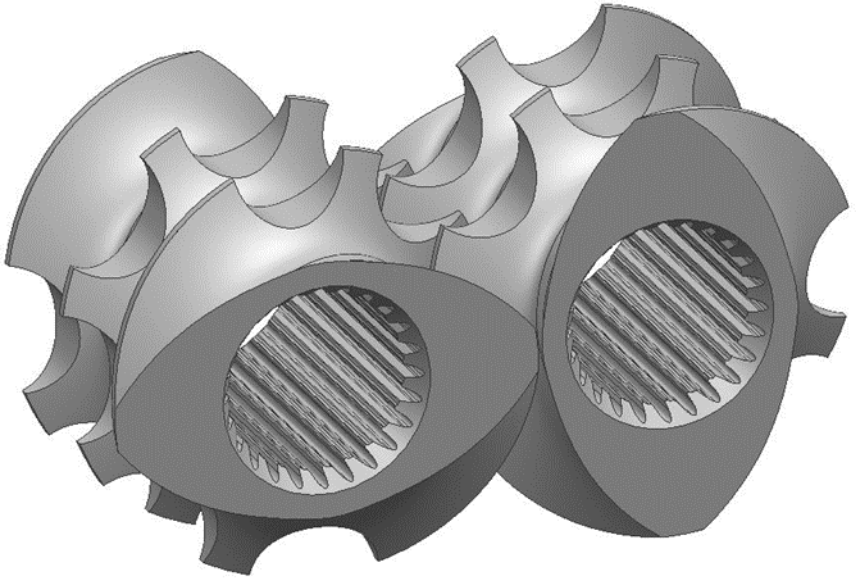


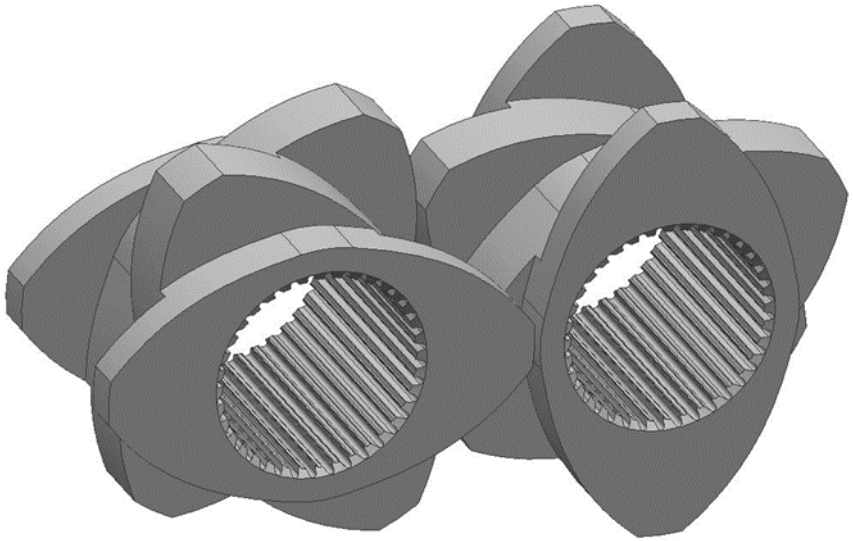
Wider disk = dispersive mixing

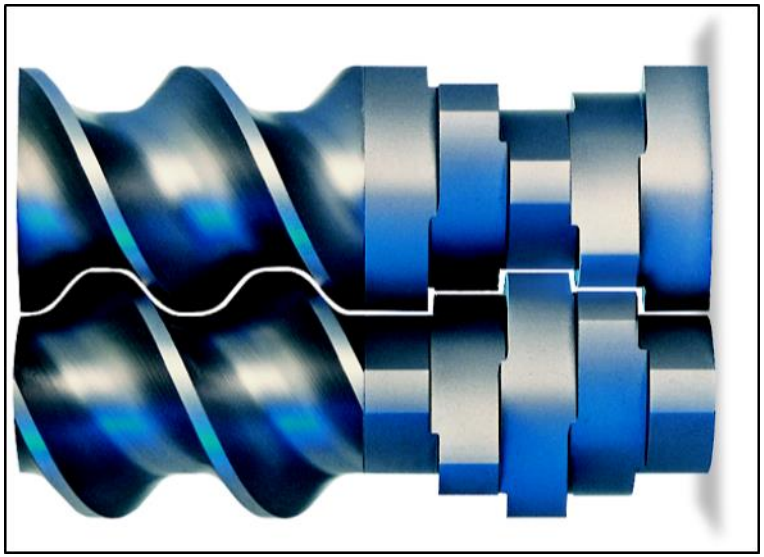
Narrower disk = distributive mixing

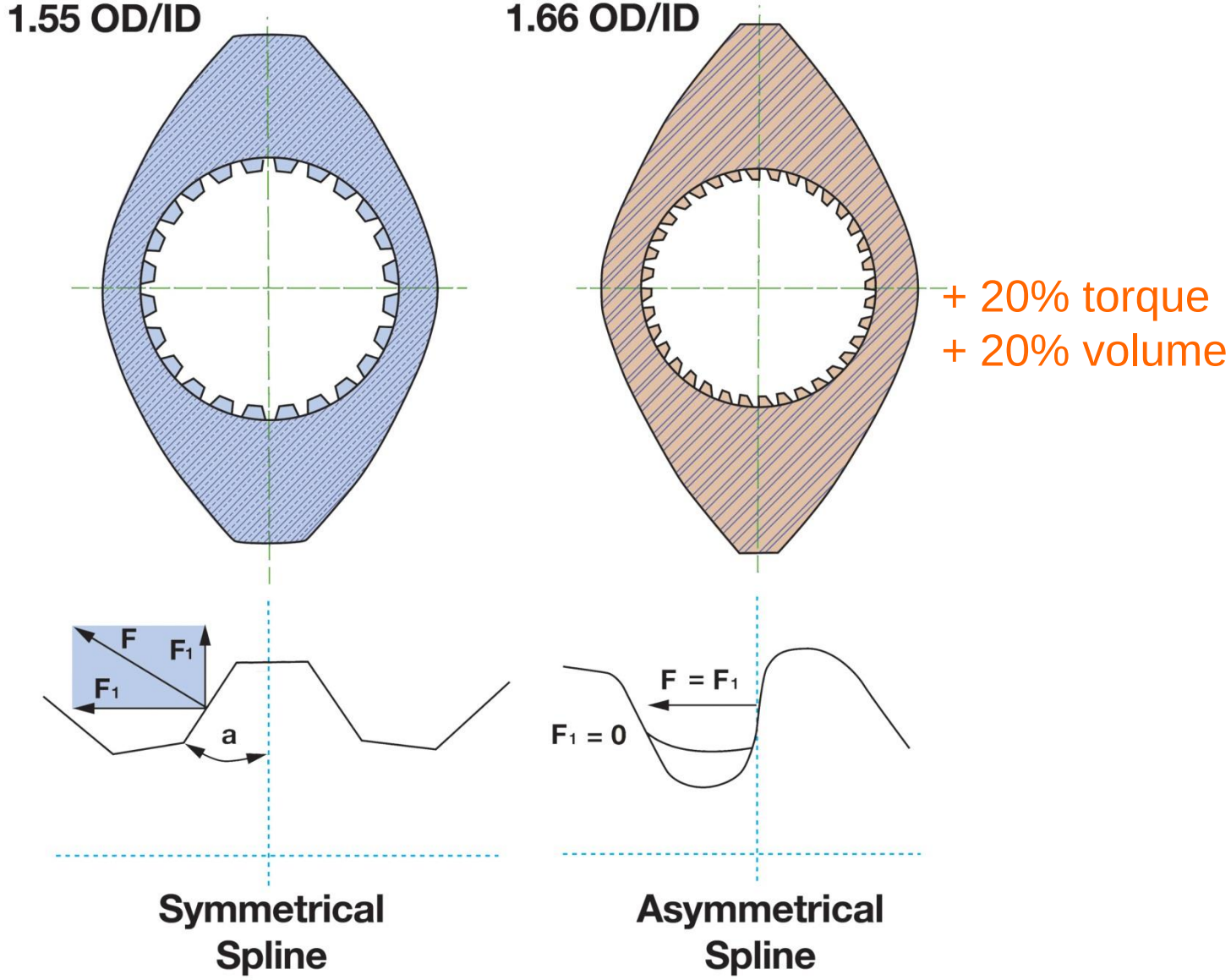
Mixing elements











Smaller diameter shaft can transmit more torque

ZSE-27 test: HP vs MAXX

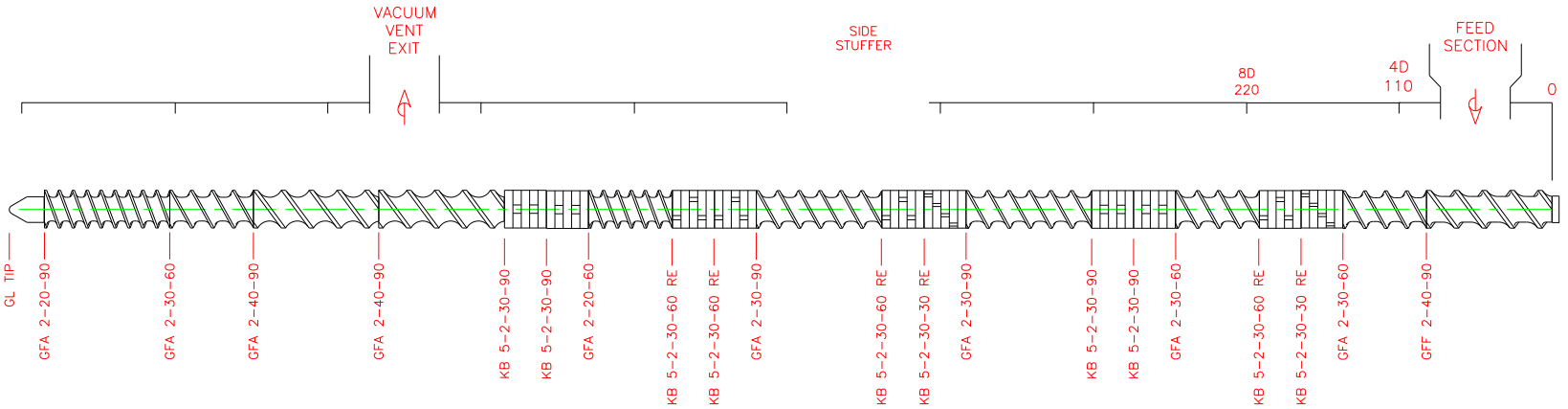
Test with PE powder 12 MFI

- **ZSE-27 HP**
- 1.5 OD/ID
- 27 mm screw dia.
- 4.5 mm flight depth
- 10.3 cc/dia. free vol.

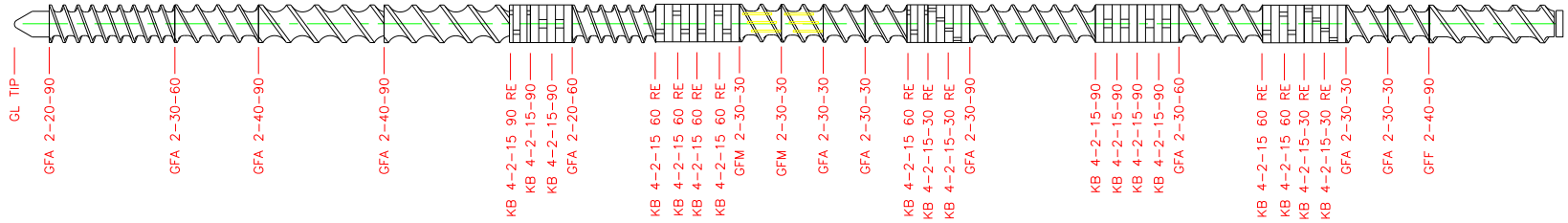
- **ZSE-27 MAXX**
- 1.66 OD/ID
- 28.3 mm screw dia.
- 5.7 mm flight depth
- 14.3 cc/dia. free vol.

40 to 1 L/D process section
40 HP AC motor
Same temperature profile

Screw designs: ZSE-27 HP vs MAXX



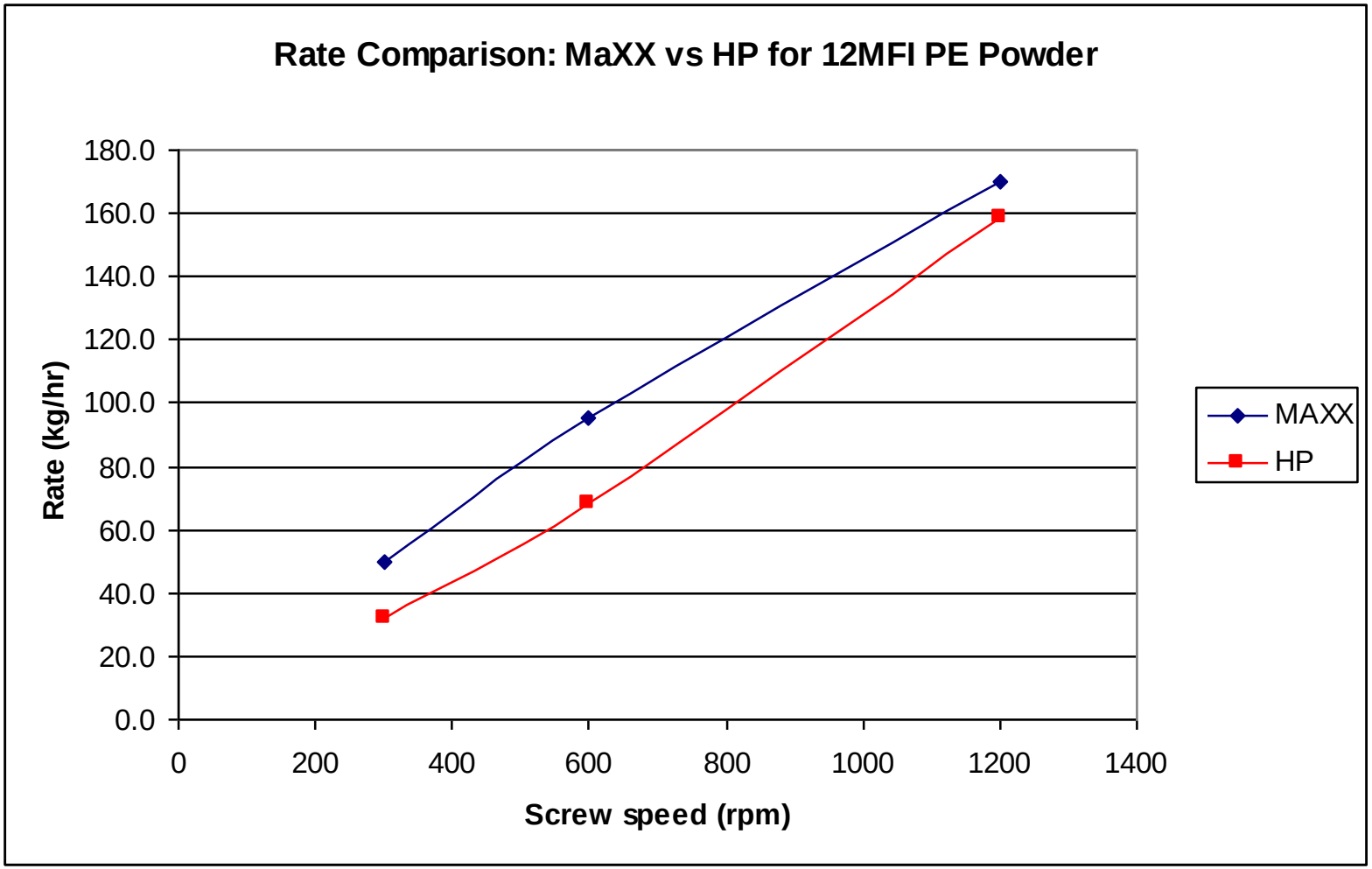
ZSE-27 HP

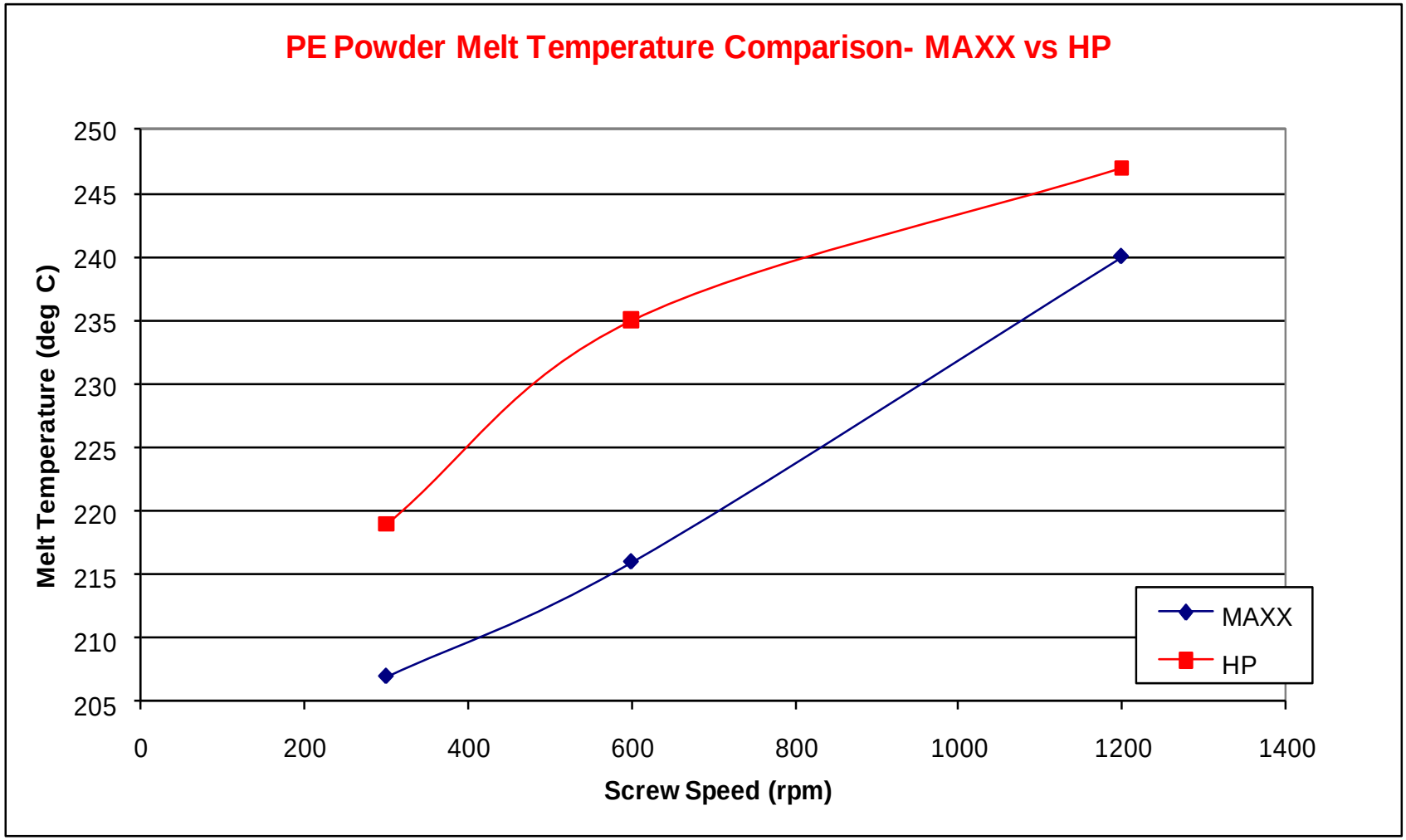


ZSE-27 MAXX

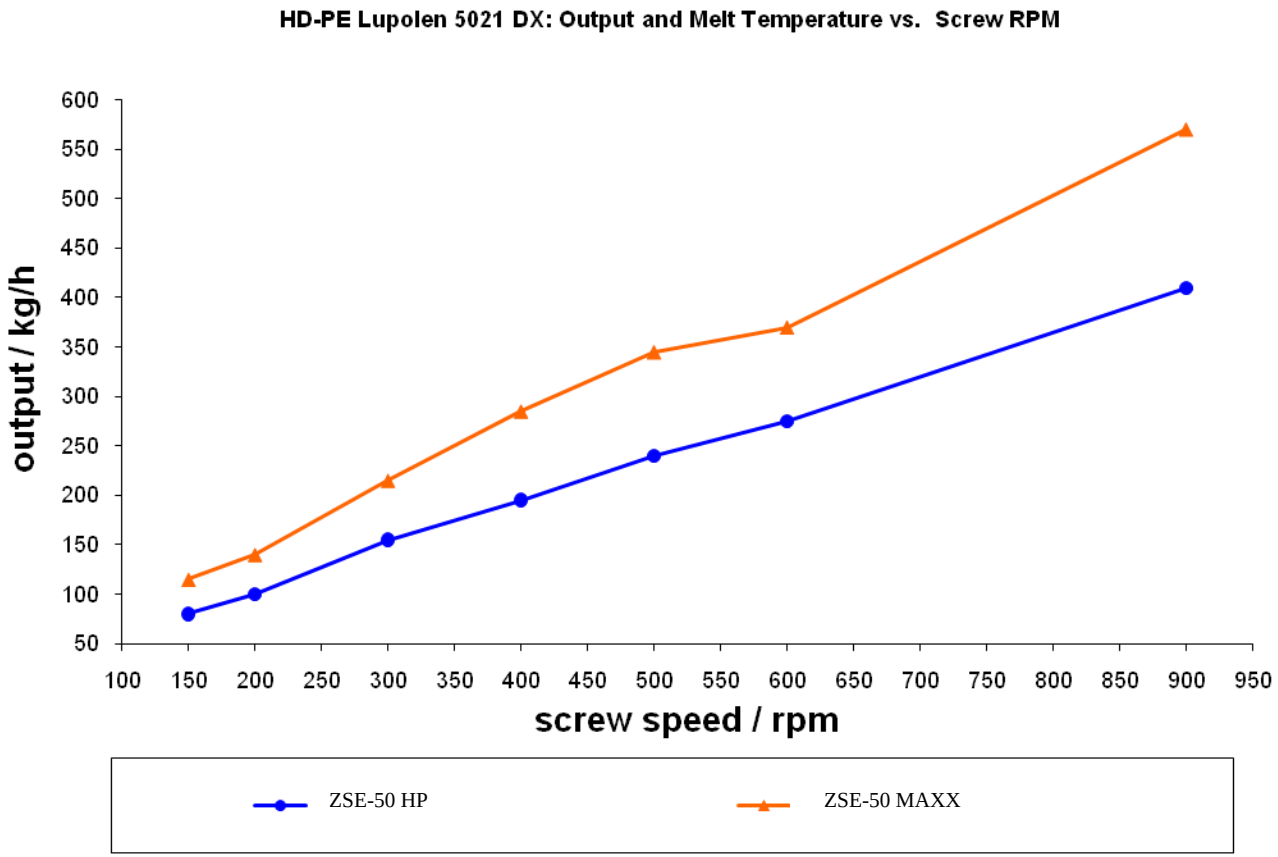
Tests used open end discharge, less than 100 psi pressure

Process Comparison - ZSE 27




PE Powder Melt Temperature Comparison- MAXX vs HP
Melt Temperature (deg C)
250
245
240
235
230
225
220
215
210
205
0
200
400
600
800
1000
1200
1400
Screw Speed (rpm)
MAXX
HP

HDPE : ZSE-50 1.55 vs 1.66 OD/ID
Output & Melt Temperature vs. Screw Speed



HDPE : ZSE-50 1.55 vs 1.66 OD/ID
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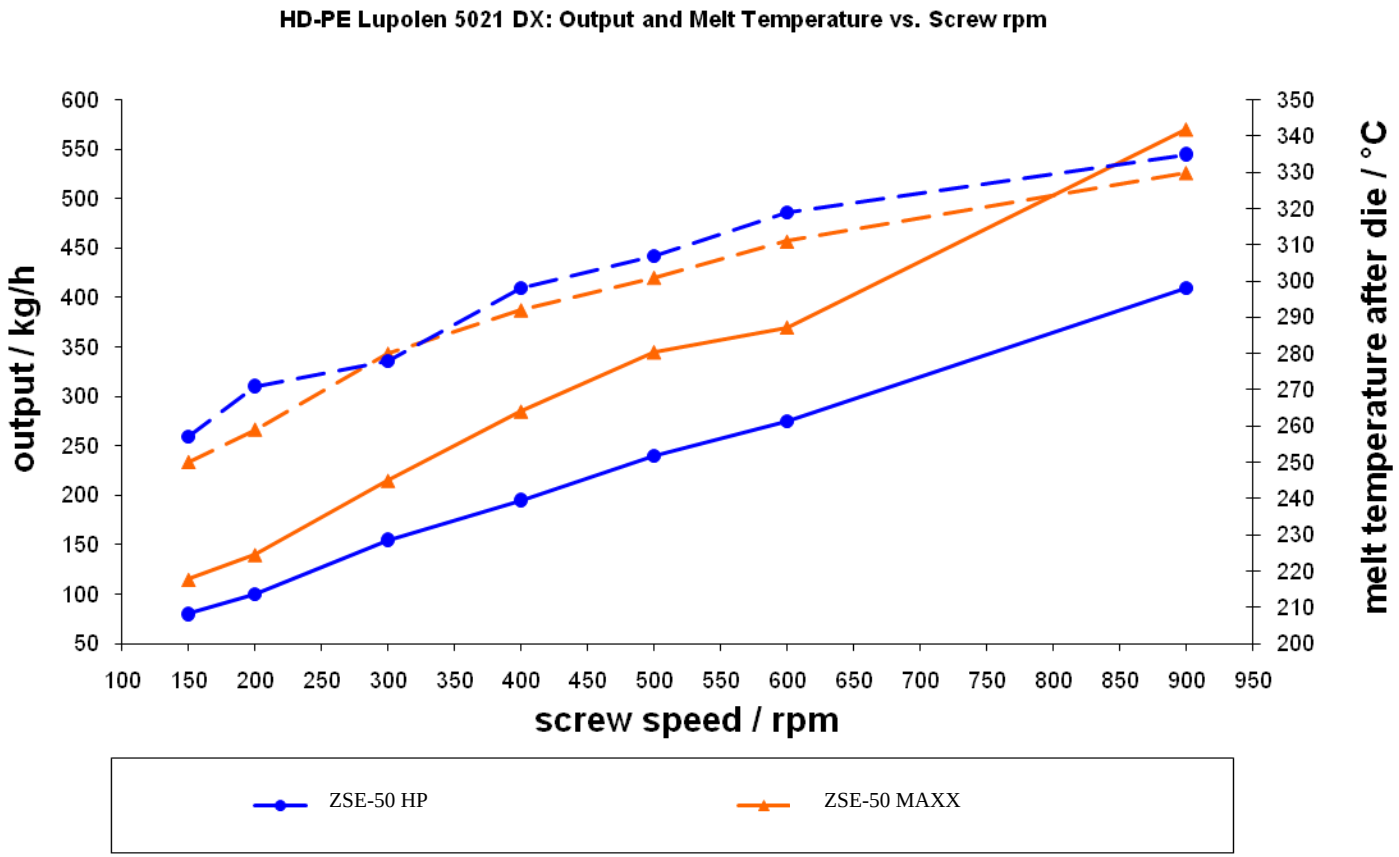
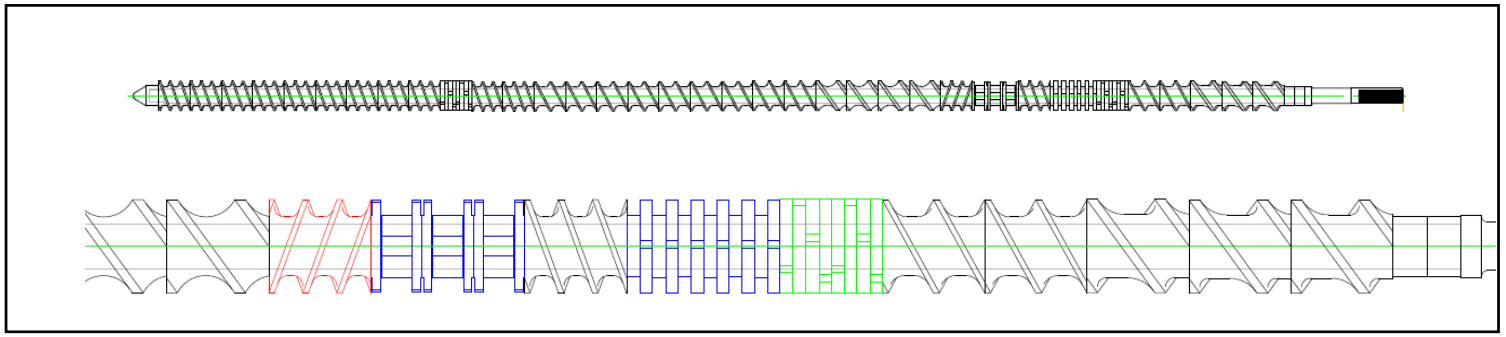
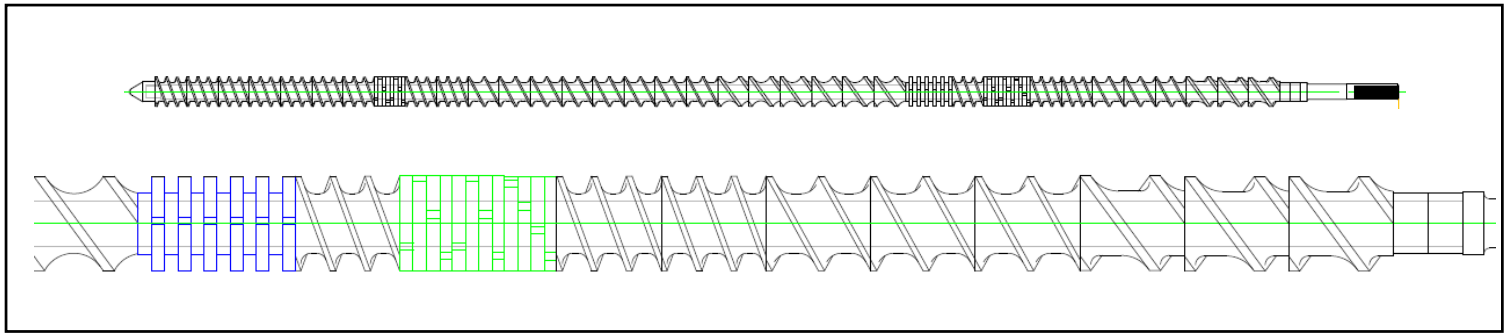


Managing melt temperature – ZSE-27 mm MAXX Screw Designs

- Aggressive melting zone



- Extended melting zone



Managing melt temperature – Processing Parameters

Processing conditions:

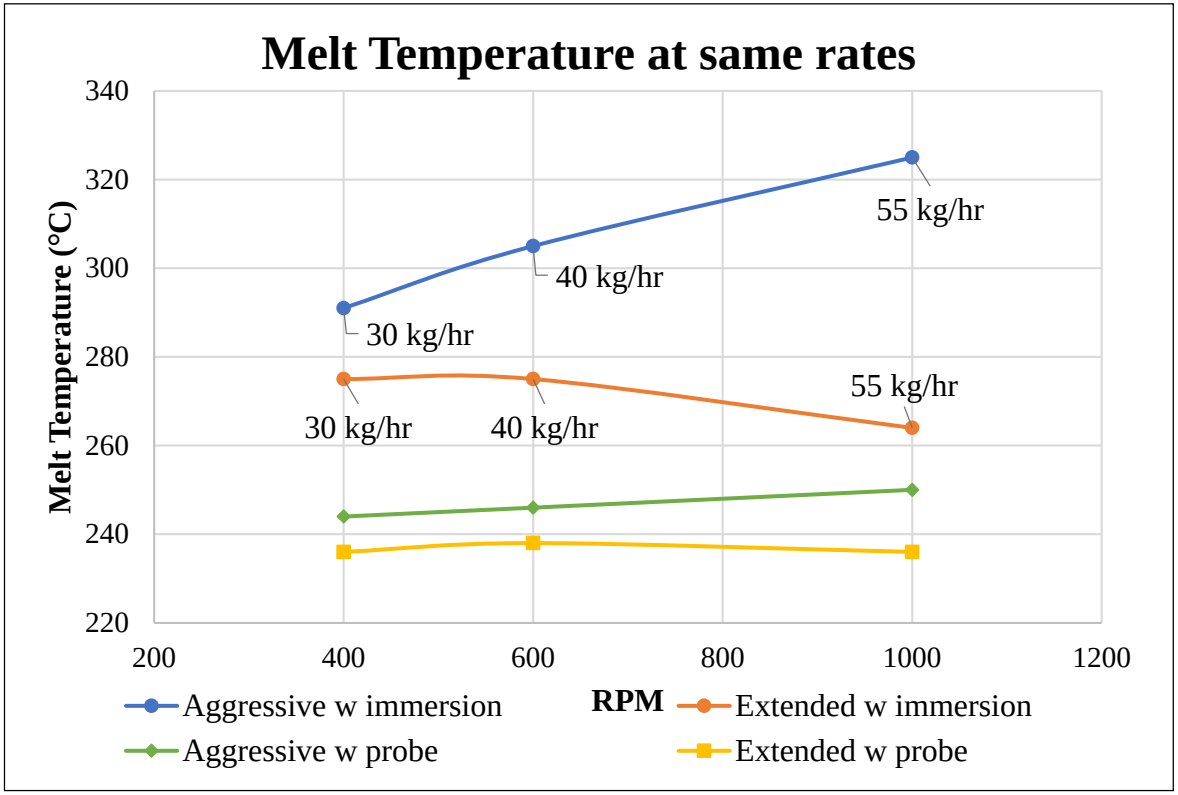
- 400, 600, 1000 rpm
- Max rate at 85% torque
- 2 MFI PP

Machinery setup:

- ZSE 27 mm MAXX, 40:1 L/D
- 28.3 mm diameter screws
- 1.66 OD/ID ratio
- Unrestrictive die
- Flush temperature probe and immersion temperature probe

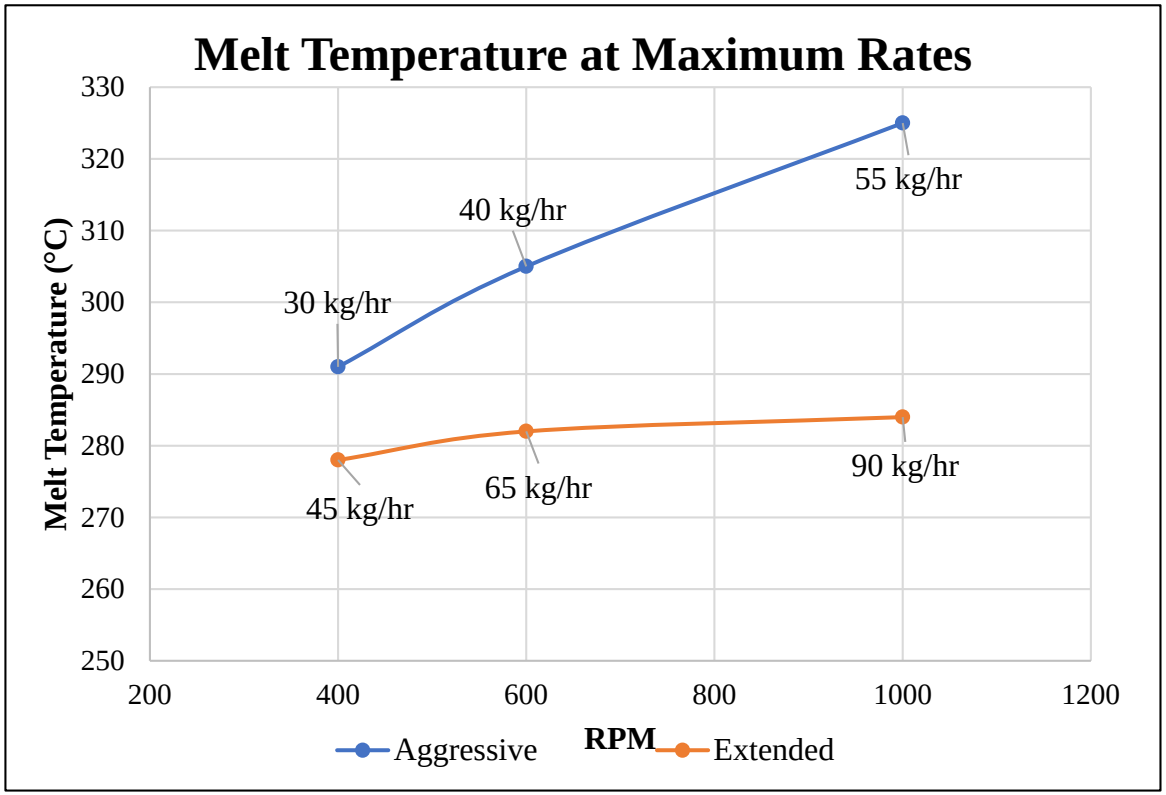
Temperature Setpoints (°C)										
ZONE 0	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6	ZONE 7	ZONE 8	ZONE 9	ZONE 10
Main Feed	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Vent (atm.)	Solid	Swing Gate
COLD	255	266	266	255	244	244	233	233	233	233

Managing melt temperature



- Higher melt temperature with aggressive screw design
  - Reverse elements
  - Wide disk/neutral KB's
- Higher temperatures with immersion probe vs. flush probe for all conditions
- Shorter RT's with extended design

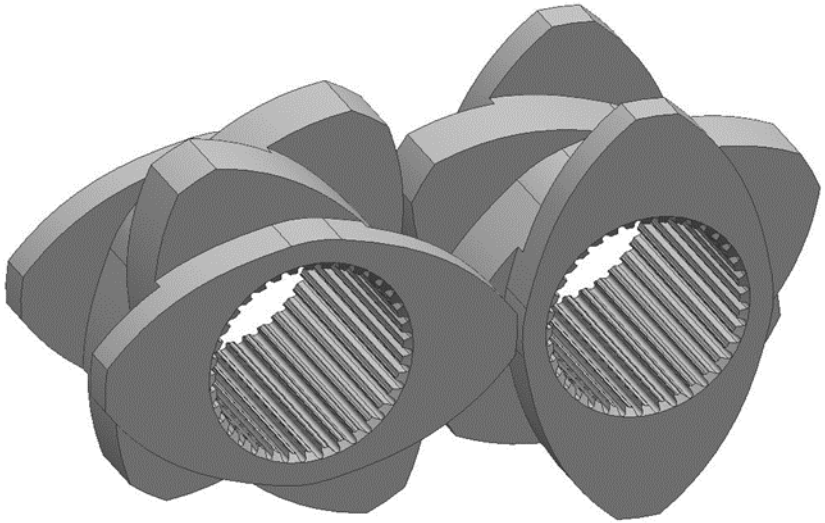
Managing melt temperature

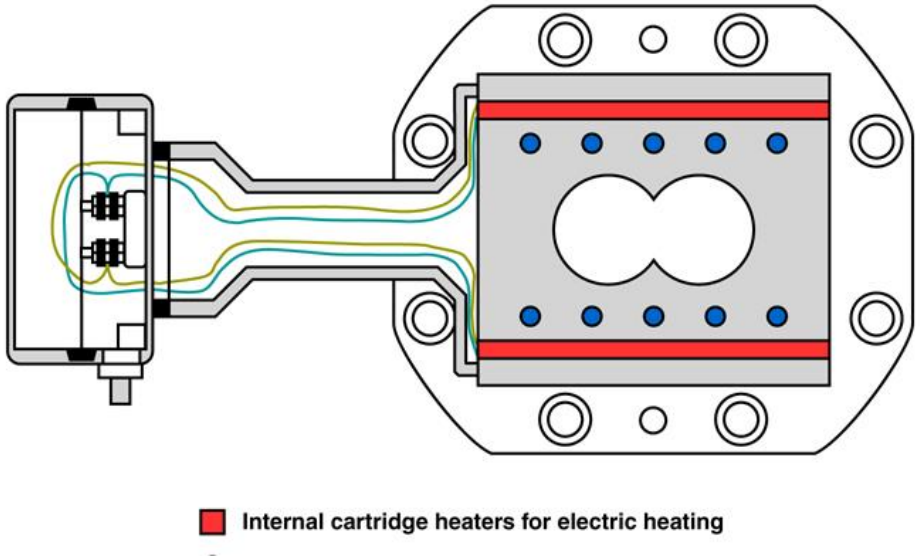


- Restriction in rate with the aggressive design
- Still higher melt temperatures at maximum rates with the aggressive design
  - Reverse elements
  - Wide disk/neutral KB's

Purposeful degradation of HDPE*

Increase MFI by a factor of 3 to 6 times





Beat up the polymer!!

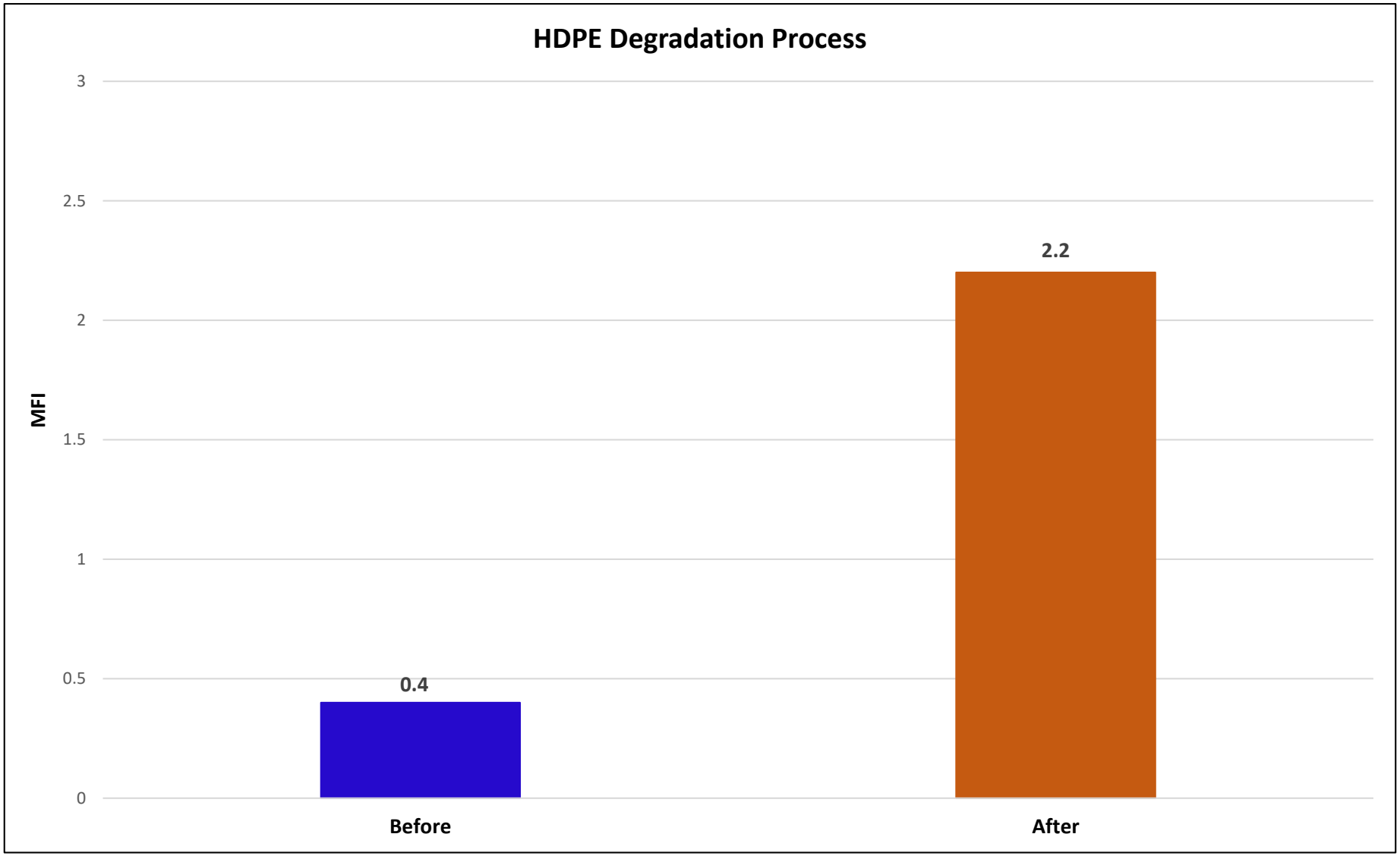
Increase screw rpms- Let it rip!

Jack up the temps!!

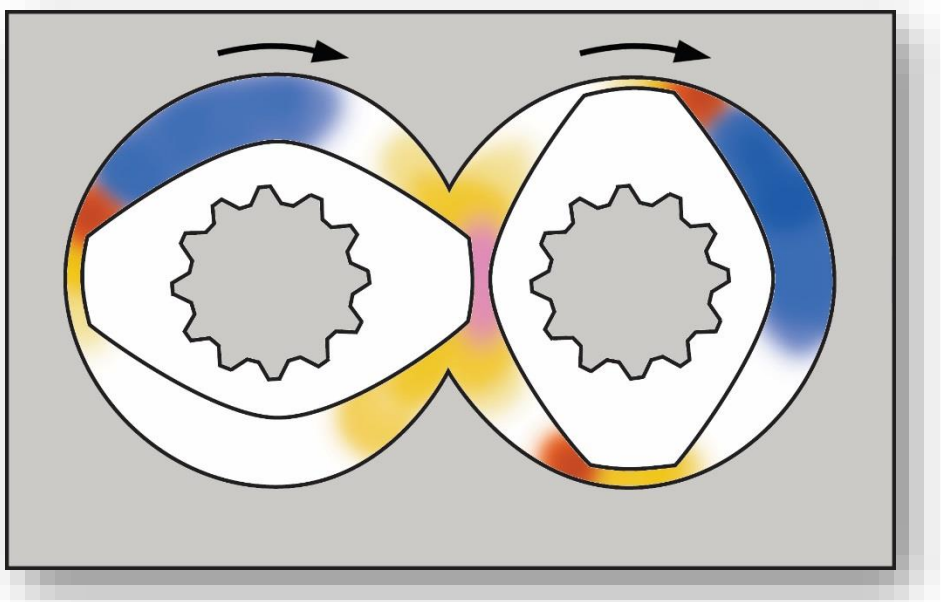
Who cares about melt temp???

* Atypical TSE system

Not a mixing job…
Beat up the polymer- make it flowable
Increase MFI by a factor of 3 to 6 times



Peak shear rate



Shear rate = (π*D*n)/(h *60)

D = screw dia.

n = screw rpm

h = overflight gap

Scale up example: ZSE-27 = (π*27*400)/(.2 * 60) = 2827 sec.-1

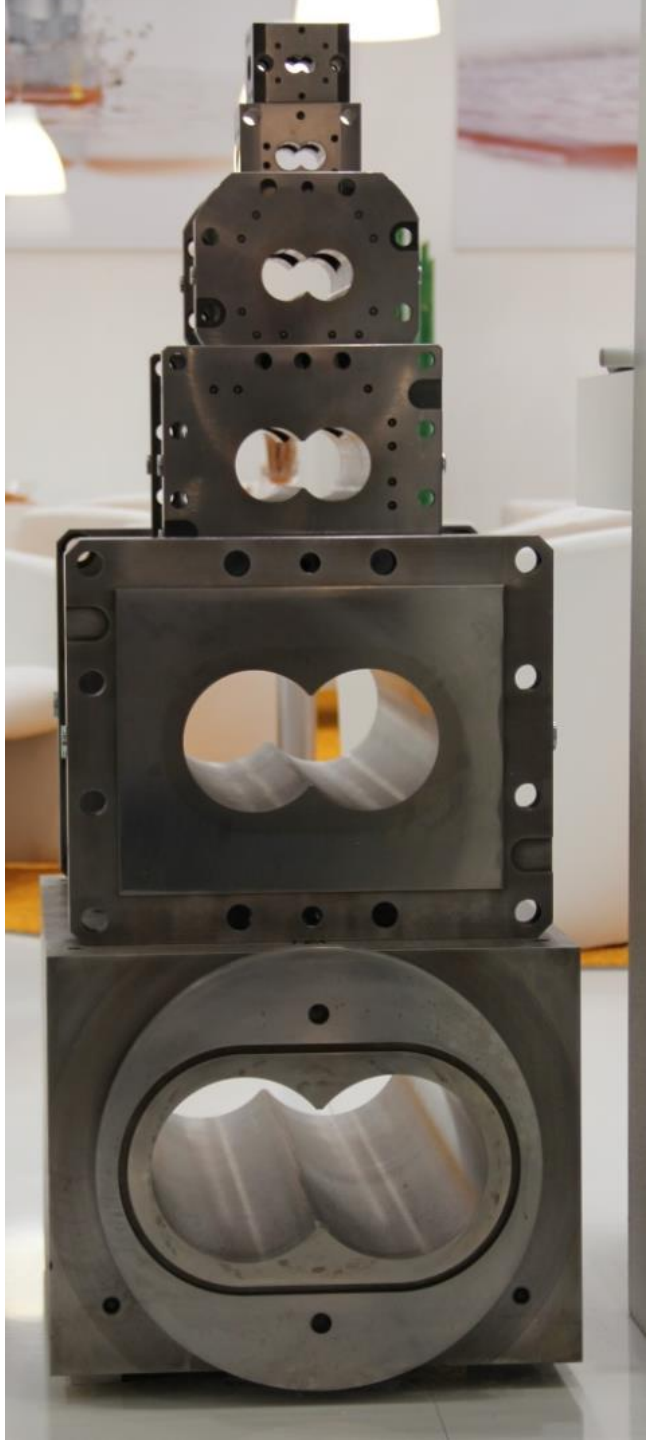
ZSE-60 = (π*60*270)/ (.3* 60) = 2827 sec.-1

Discharge element comparison

Open meshing elements = better heat transfer/cooling

Close meshing elements = more viscous heating

ZSE-27 @ 60 to 1 L/D



18mm to 180mm

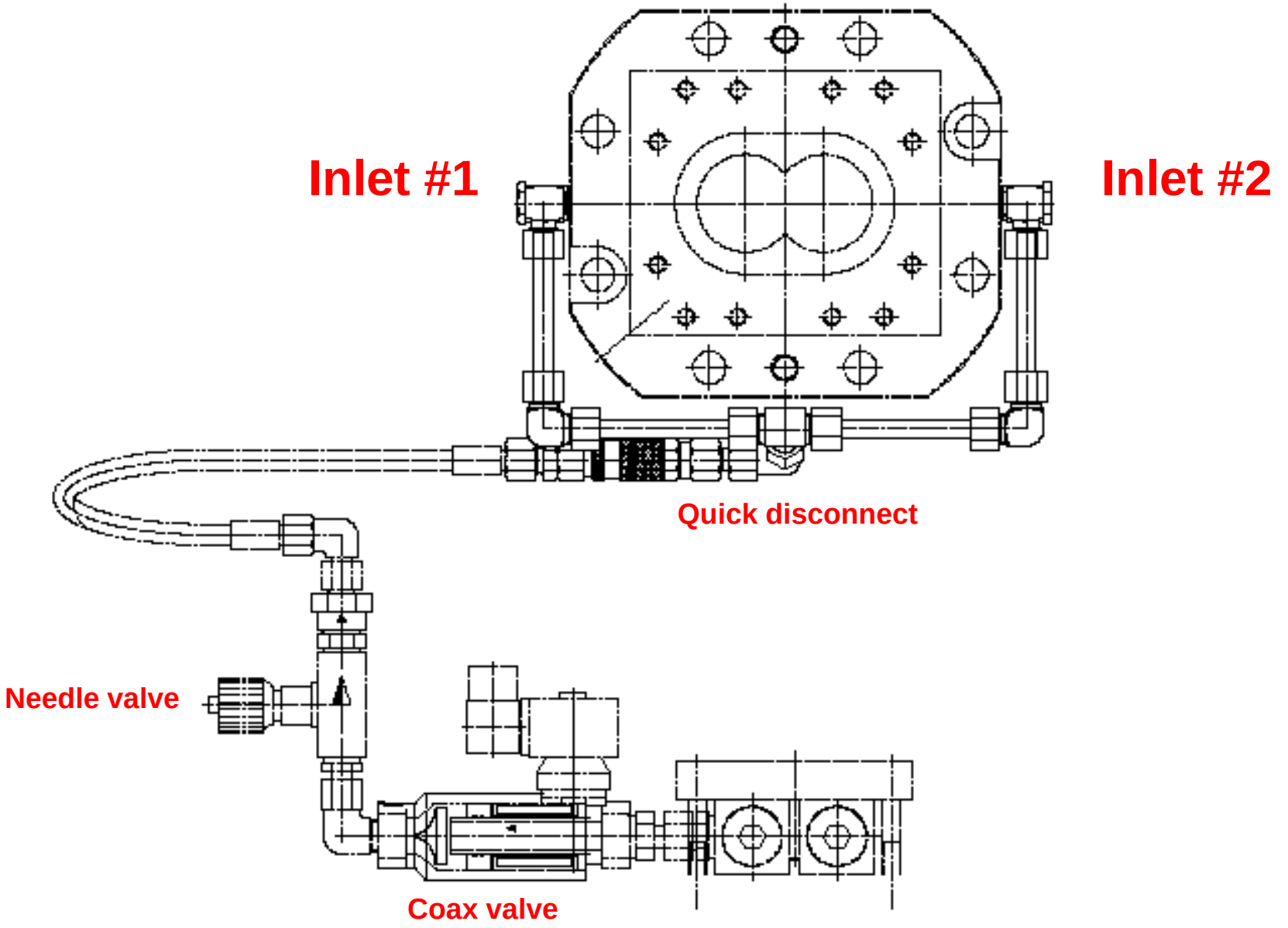
ZSE-18 = 3 cc/dia free volume

ZSE-40 MAXX = 48 cc/dia

ZSE-75 MAXX = 300 cc/dia

ZSE-180 MAXX = 3642 cc/dia

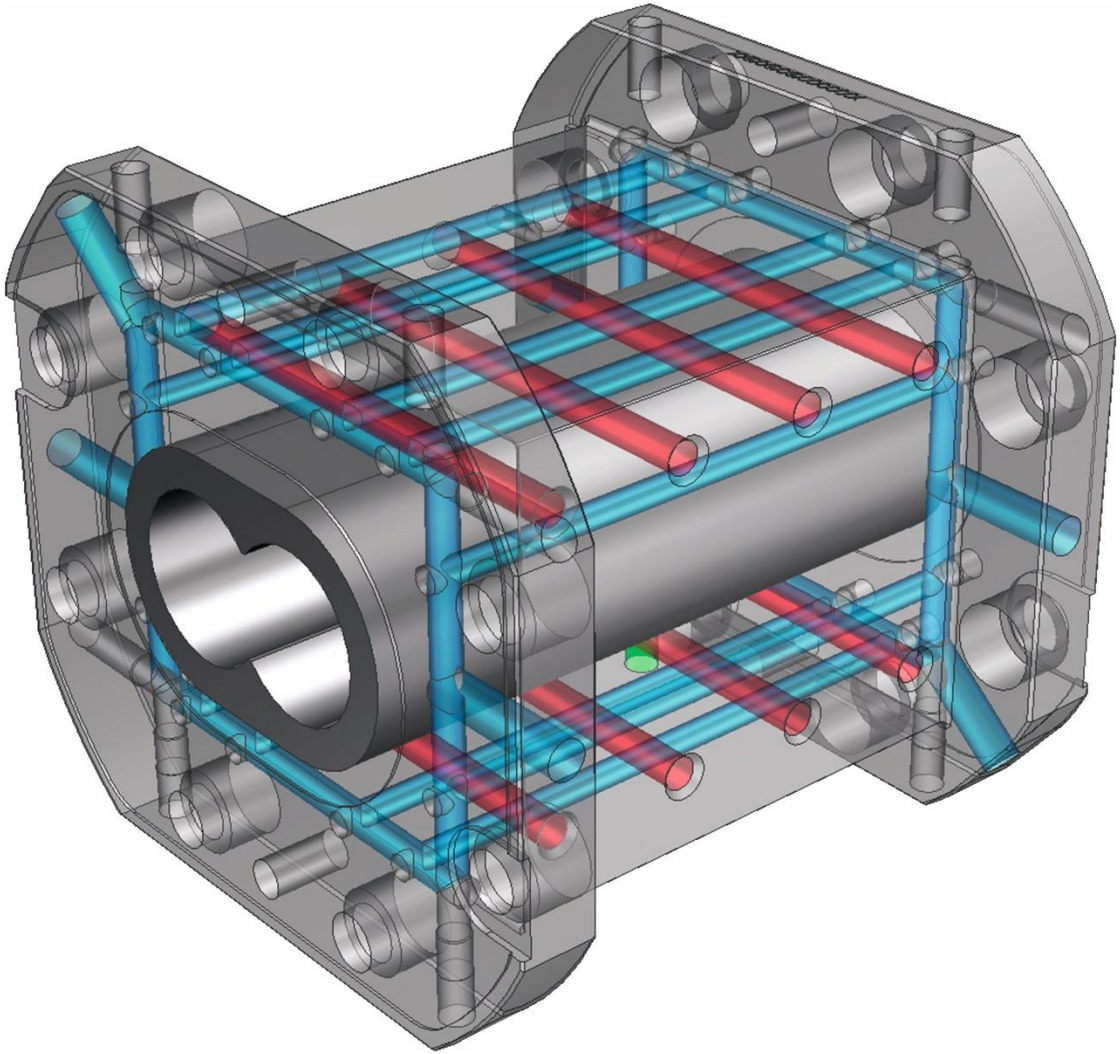
Barrel Cooling plays role in Tm



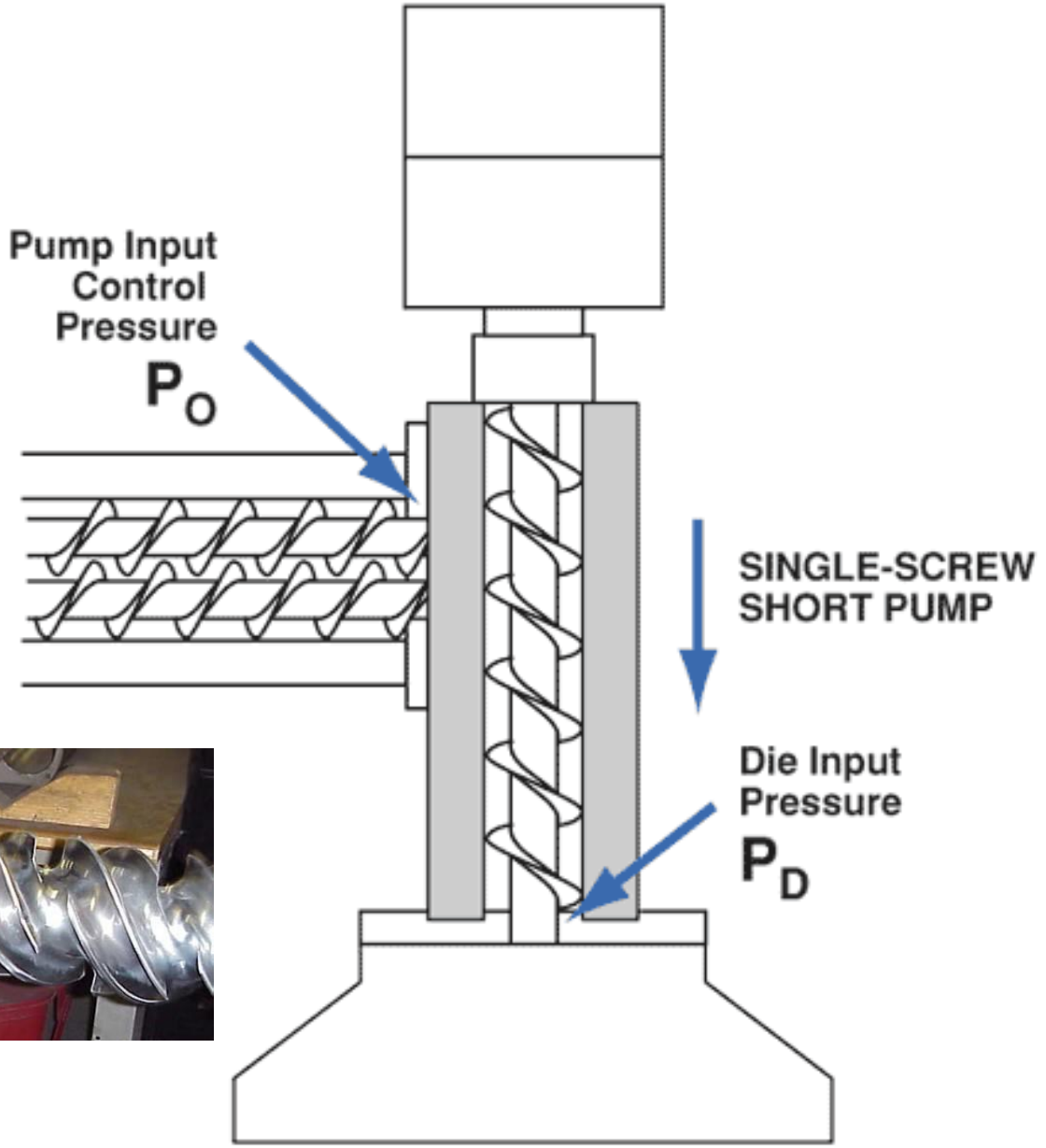
Barrel design

Electric cartridge heaters

Internal cooling bores- 2 inlets/outlets



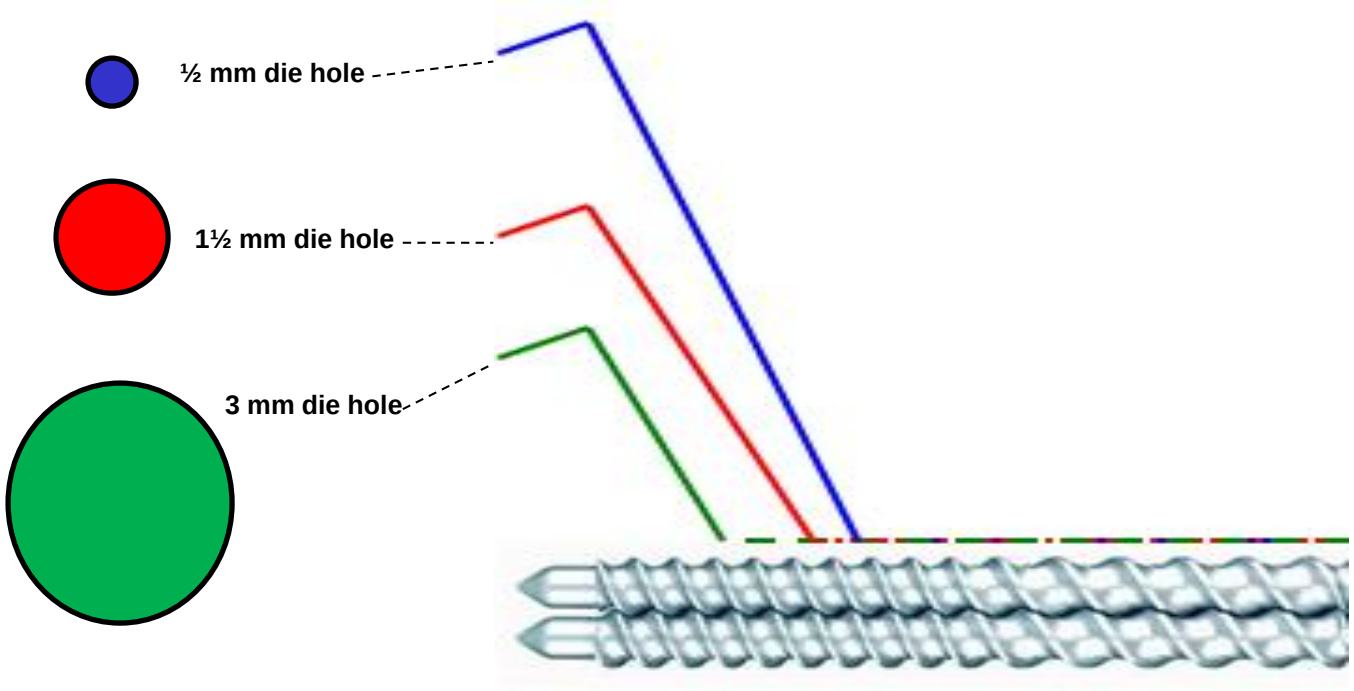
Single Screw Pump/ Cooling Extruder



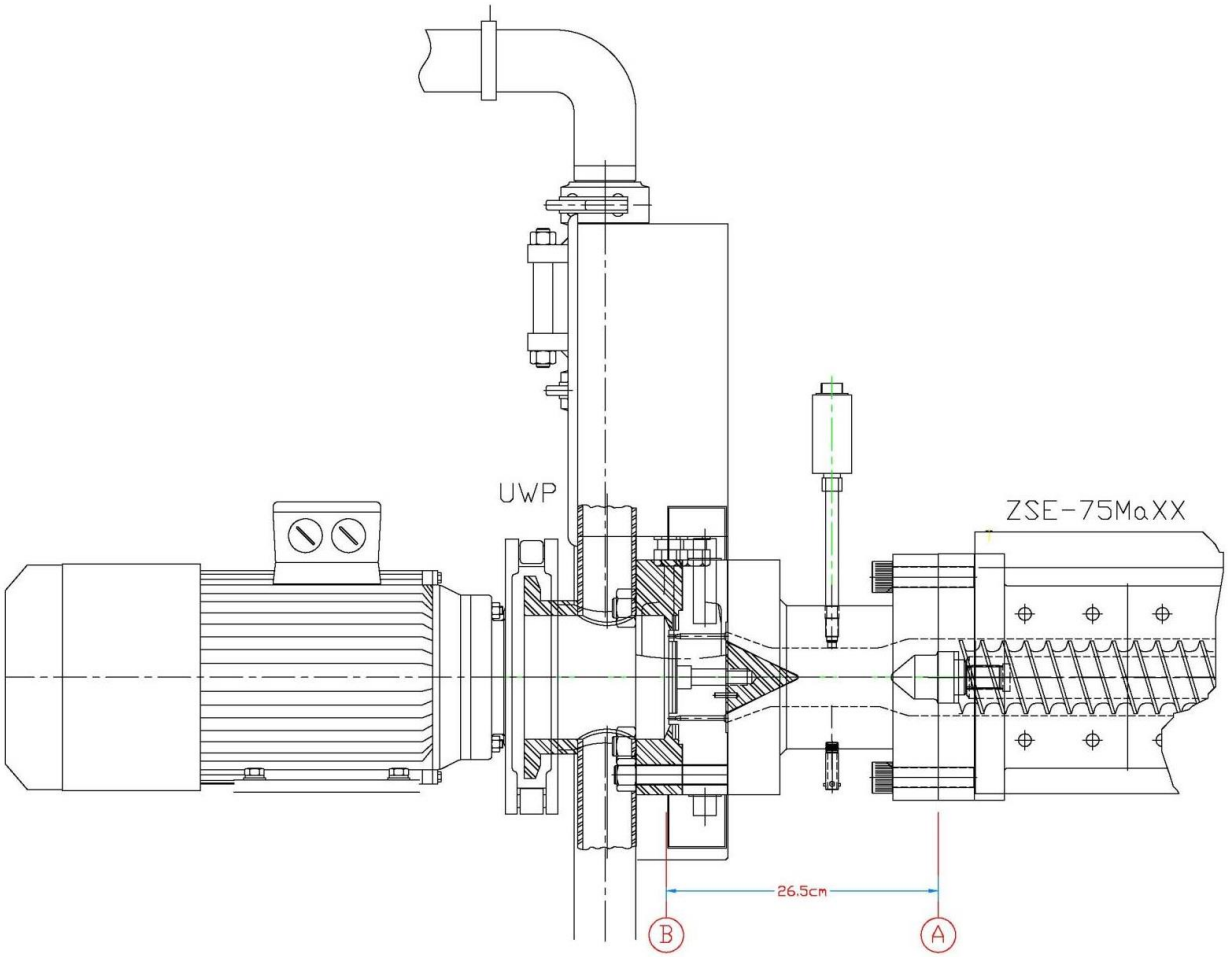
Temperature rise during pressure generation

$$\Delta T\ (°C) = \Delta P\ (bar) / 2\ (+/-\ 50\%)$$

- 40 Bar (580 PSI) Pressure results in a 20°C melt temperature rise (40/2)
- Restrictive front-end designs may adversely effect the product
- RPM, discharge screw elements & materials play a role in Tm

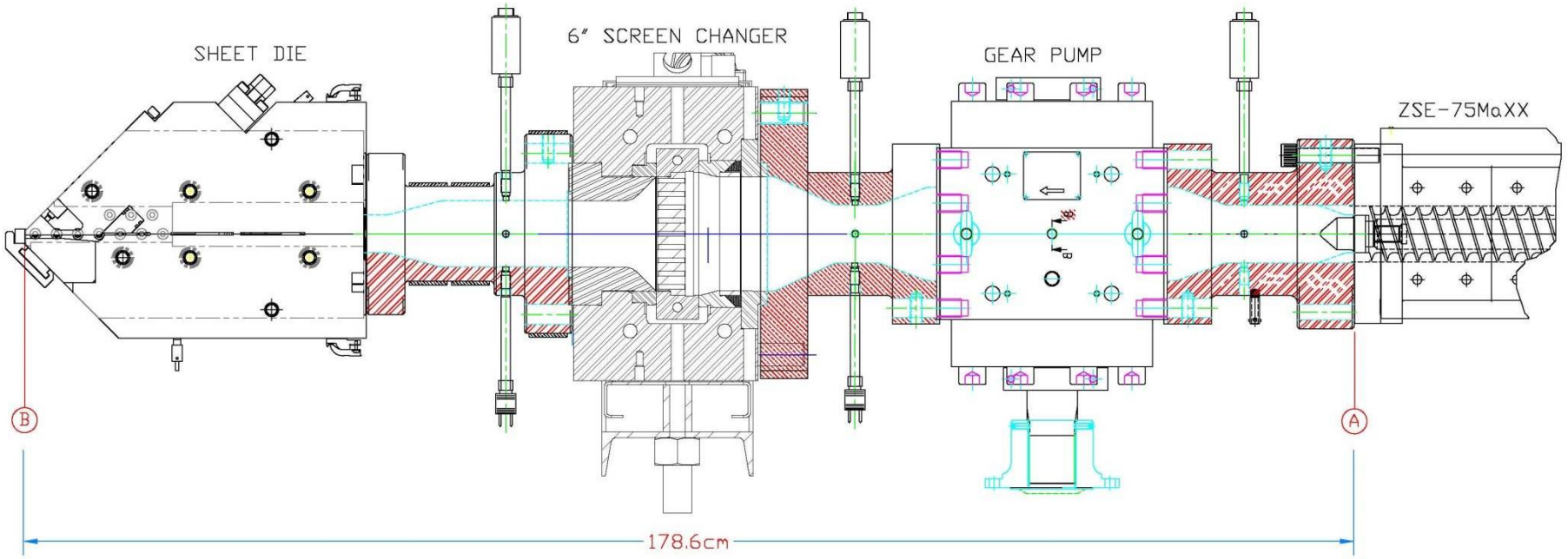


ZSE-75 MAXX Underwater pelletizer



RT for 1000 kgs/hr = 4 seconds

ZSE-75 MAXX Sheet system front-end



RT for 1000 lbs/hr = 120+ seconds

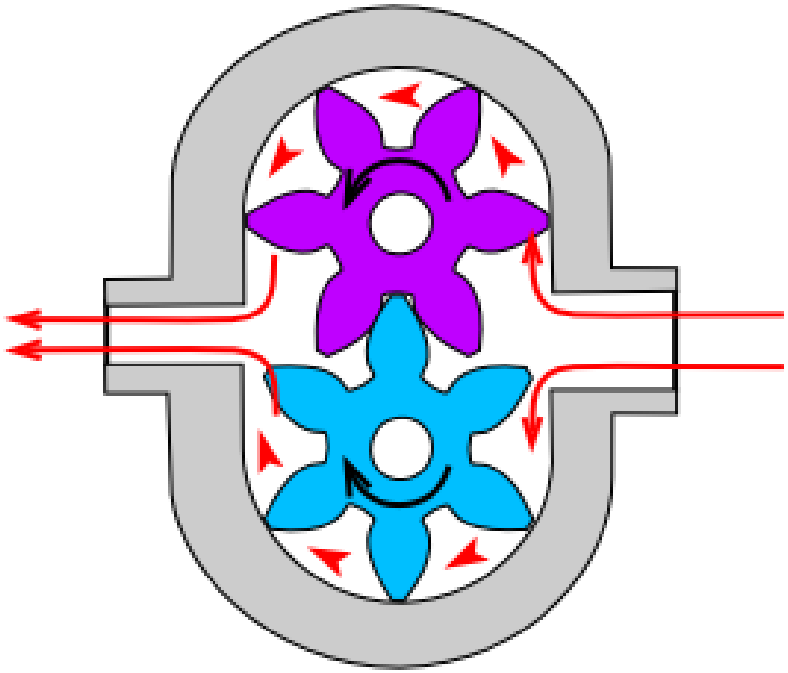
Gear Pump Front End

4000 PSI pressure differential possible

3500 PSI

DISCHARGE:

Anything that requires pressure generation



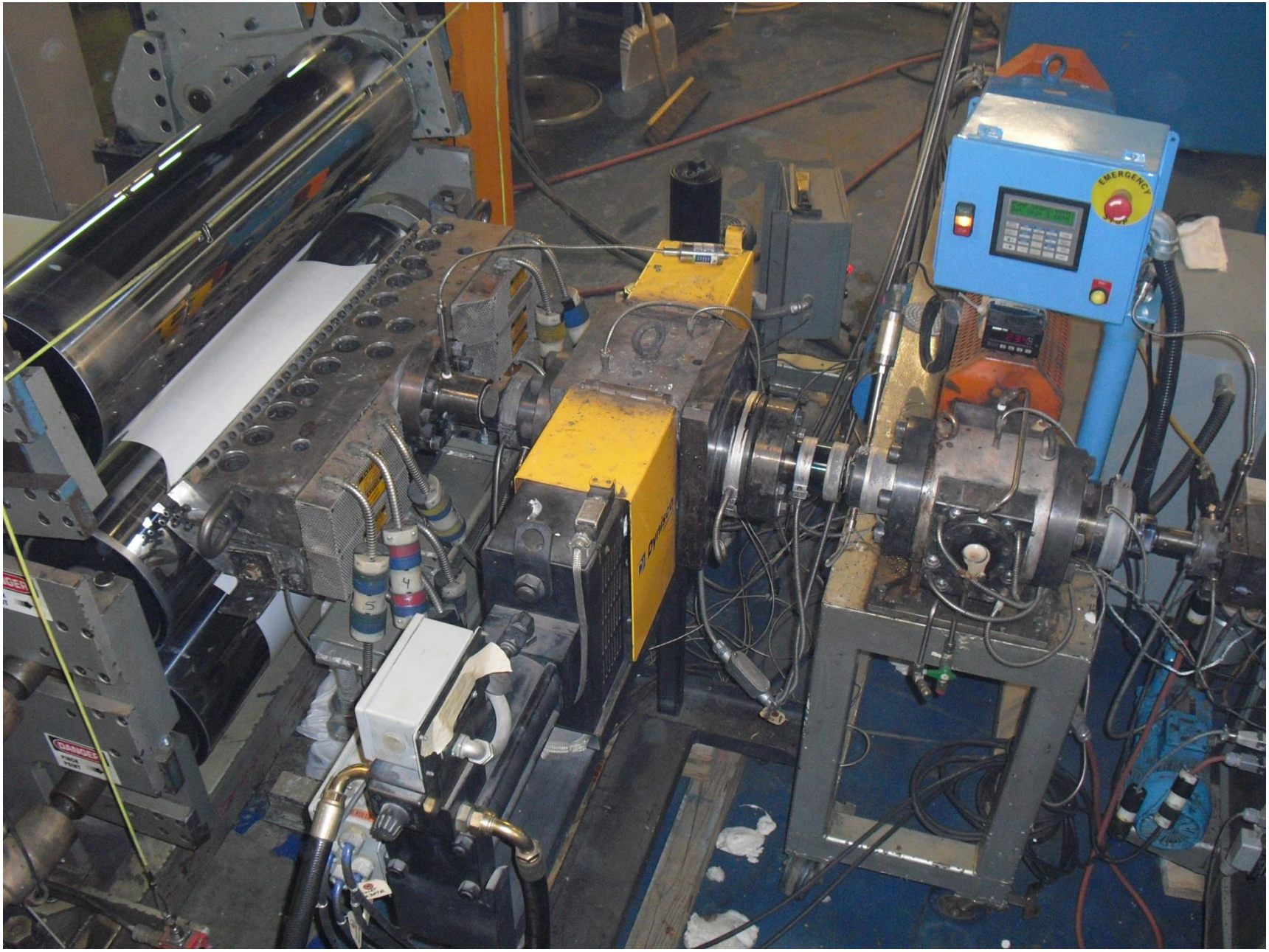
400 PSI

INLET:

TSE & coarse filtration (maybe)

ZSE-40 MAXX > SC > GP > SC/DV > UWP

Gear pump, screen changer, 800 mm die & roll-stack



Managing melt temperature – Summary

Comparing aggressive vs. extended melting zones:

- Aggressive design caused a dramatic temperature rise and restriction in rate
- Both screws resulted in molten polymer
- Higher temperatures from the aggressive design

Factors impacting melt temperature:

- Zone temperatures
  - Reverse profile was utilized
- Specific elements in the melting zone, mixing zones
  - Reverse vs. forward conveying elements
  - Wide vs. narrow disk kneading blocks
  - Forward vs. neutral conveying kneading blocks
- Pressure at the die
- Source of measurement
  - Immersion vs. flush temperature probe
- Material time at temperature

Leistritz