coperion

confidence through partnership

- compounding & extrusion
- materials handling
- service

Welcome

Open House

June 20th, 2017

Coperion Corporation - Wytheville, VA

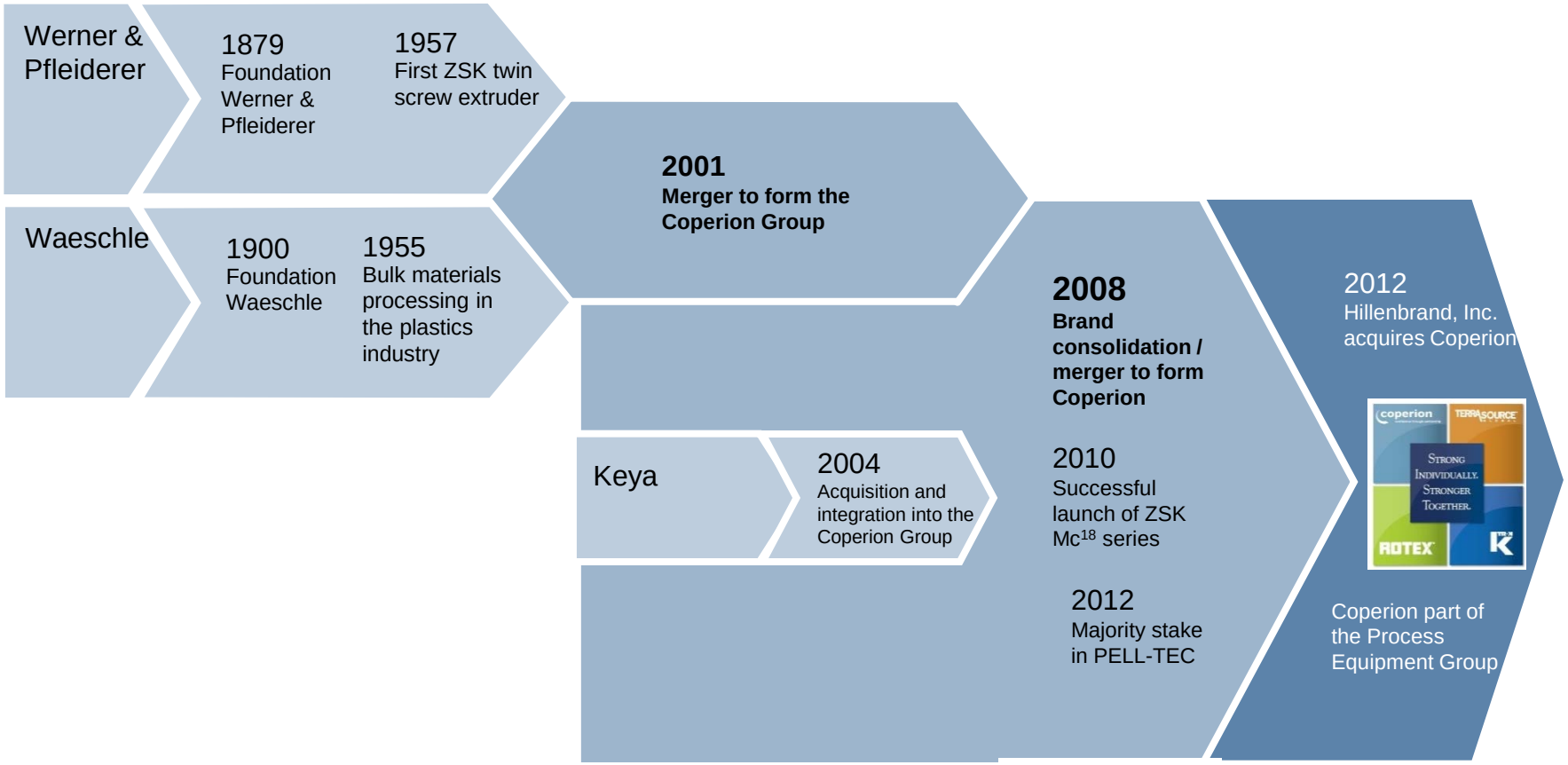
coperion
confidence through partnership

Agenda

8:00	Registration
8:30	Welcome & Safety Orientation Eberhard Dieterich I Business Unit Manager, Coperion Corporation, Sewell Bobby Epperson I Sr. Engineer	Coperion Corporation, Wytheville
9:00	Wytheville Expansion Project - Overview of our Capabilities: • Extruder Assembly Shop Robert DiMarino	General Manager and Vice President Operations	Coperion Corporation, Wytheville Alan Wood I Manager Production/Manufacturing	Coperion Corporation, Wytheville • Gear Box Shop Rich Taylor I Vice President Customer Service	Coperion Corporation, Sewell • FAT Robert DiMarino I General Manager and Vice President Operations	Coperion Corporation, Wytheville • Warehouse Robert Bolger I Strategic Sourcing Manager & Manager of Warehouse/Logistics Operations	Coperion Corporation, Wytheville
10:00	Coffee break
10:30	Process Technology Update: Latest technology to increase productivity, quality, operating flexibility and energy efficiency Alex Utracki I Director, Process Technology I Coperion Corporation, Sewell
11:15	Screw Element Technology Update • Wytheville screw manufacturing capability overview • Screw element technology and material types Rich Taylor I Vice President Customer Service	Coperion Corporation, Sewell
12:00	Lunch
13:00	Plant Tour Including Screw Manufacturing
15:00	Questions / Wrap-up
16:00	End of Event

coperion
confidence through partnership

Companies Are Changing



coperion
confidence through partnership

Hillenbrand, Inc.

(Hillenbrand Industries)

HILLENBRAND, INC.

HI LISTED NYSE

2007 | **2008** | **2010** | **2011** | **2012** | **2013**

Hillenbrand Industries announces a plan for the separation of Hill-Rom and Batesville Casket into two independent publicly traded companies

Hillenbrand, Inc. (parent of Batesville Casket Company) began operation as a public company traded on the New York Stock Exchange April 1, 2008

TR-N K

ROTEX

coperion confidence through partnership

TR-N K

TERRASOURCE GLOBAL

coperion K-TRON

coperion confidence through partnership

Coperion Business Divisions

compounding & extrusion

ZSK, STS and CTE – three letters embody modern processing machinery and plant design for compounding technology. Our twin screw compounders continually set new standards in the plastics, chemical and food processing industries.

feeding & weighing

Coperion K-Tron specializes in feeding and weighing solutions for any process – accurate down to the last detail, able to handle a variety of bulk materials in a variety of applications.

materials handling

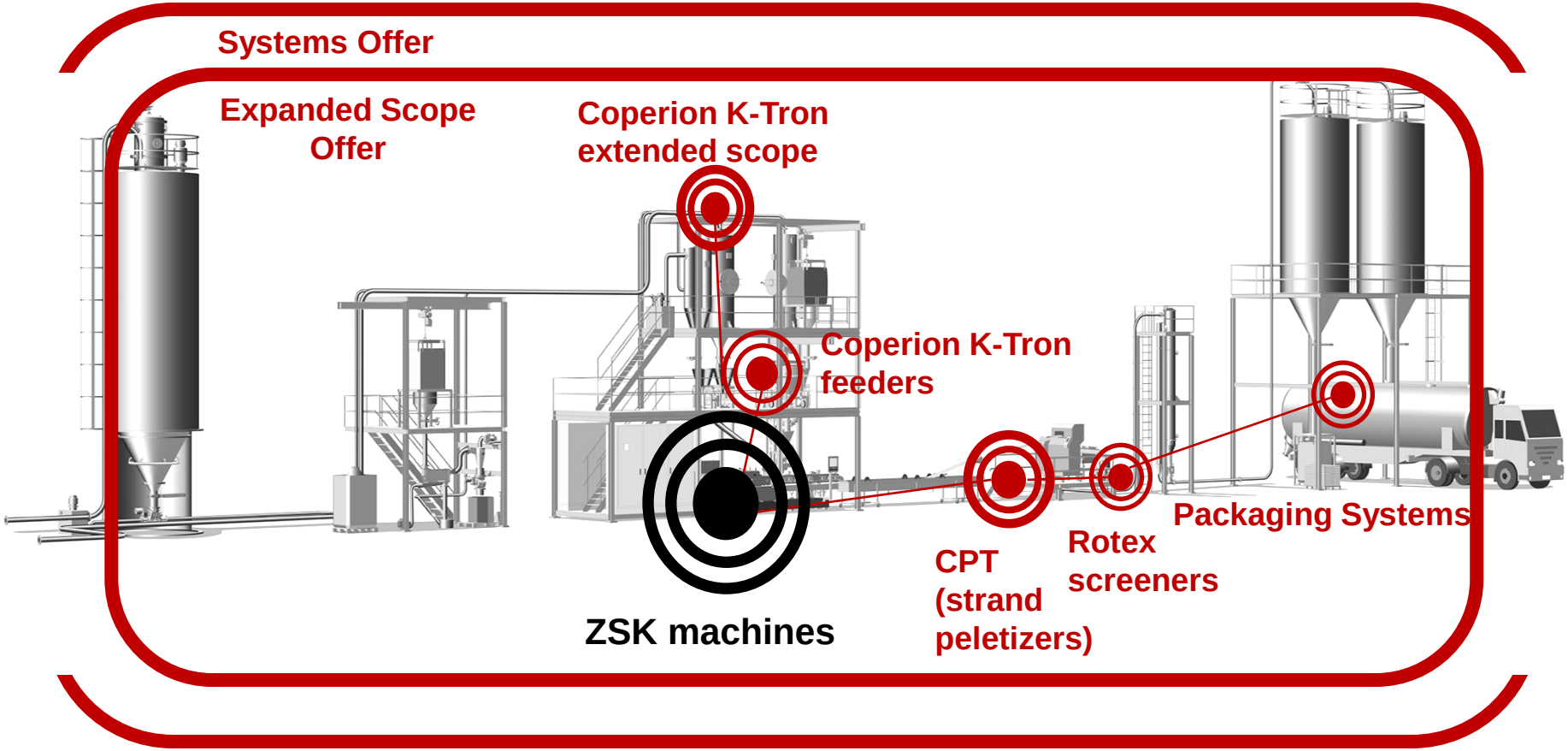
Hand in hand – we master all process steps in the treatment and handling of bulk materials. Quality is our benchmark when conveying, elutriating, homogenizing, storing, dosing, thermally treating or packaging products.

service

Your success is our success – already during installation and commissioning of a machine or plant a service team is on-site. Maintenance, spare parts service, service consulting, training and modernization – we use our experience and competence to the advantage of our customers.

coperion
confidence through partnership

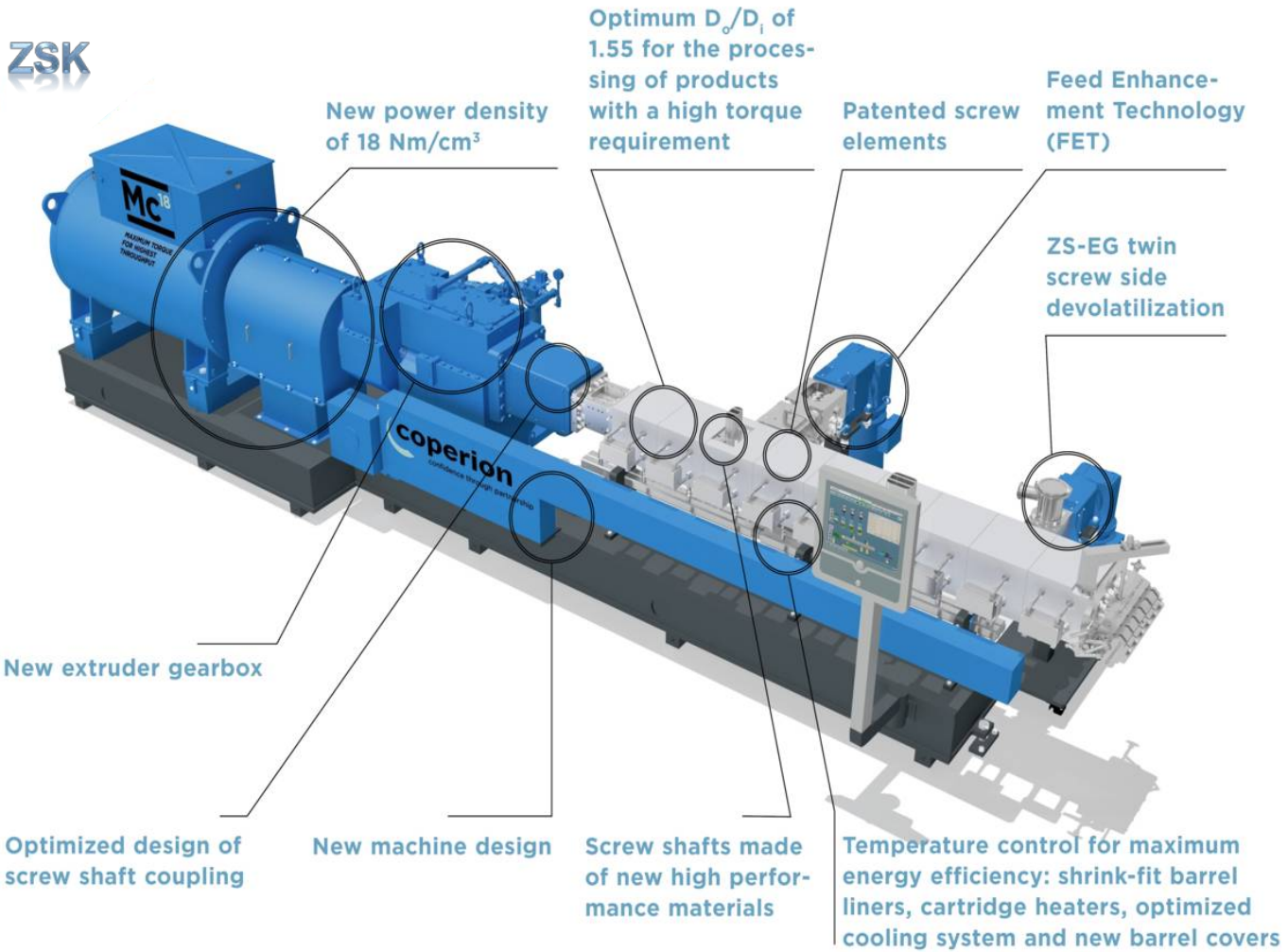
ZSK & STS Extruders as platform for Coperion System Solutions



coperion
confidence through partnership

ZSK Mc18 – machine technology – new power density of 18 Nm/cm³

60 YEARS ZSK



coperion
confidence through partnership

ZSK Mc^{18} – technical data

ZSK	Max. torque per shaft [Nm]	Specific torque Md/a^3 [Nm/cm^3]	Max. screw speed [min^{-1}]	Max. drive power N [kW]	Screw diameter [mm]
18 MEGAlab*	38	11.3	1,200	10	18
26 Mc*	106	11.3	1,200**	28	25
32 Mc^{18}	315	18	1,200	83	32
45 Mc^{18}	930	18	1,200	246	45
58 Mc^{18}	2,000	18	1,200	529	58
70 Mc^{18}	3,500	18	1,200	926	70
82 Mc^{18}	5,700	18	1,200	1,508	83
92 Mc^{18}	7,500	17	1,000	1,654	92
106 Mc^{18}	11,900	18	1,000	2,617	106
119 Mc^{18}	15,300	17	1,000	3,373	118
133 Mc PLUS	18,100	13.6	1,000	3,980	133

* Laboratory extruder. ** max. 1,800 min-1 at reduced torque. ZSK 32 - ZSK 82 available in compact version.

Coperion Standard Machine STS Mc11

Standard Twin Screw

for Compounding of

- Engineering Plastics
- Masterbatch
- Recycling

	Standard Twin Screw				
STS Mc^{11} Type	**35**	**50**	**65**	**75**	**96**
Screw diameter [mm]	36	51	62	71	94
Md/a^3	11.3	11.3	11.3	11.3	11.3
Motor power [kW]	60	165	315	483	706
Screw speed [1/min]	900	900	900	900	600
Expected capacity [kg/h]	260	800	1,400	2,200	4,200

coperion
confidence through partnership

Strand Pelletizing Equipment

Cooling → **Dewatering** → **Pelletizing**

Strand Cooling Trough Type CT

Strand Conveyance Type SC

Process Water Circulation Type PWK

Air Wipe Type AW

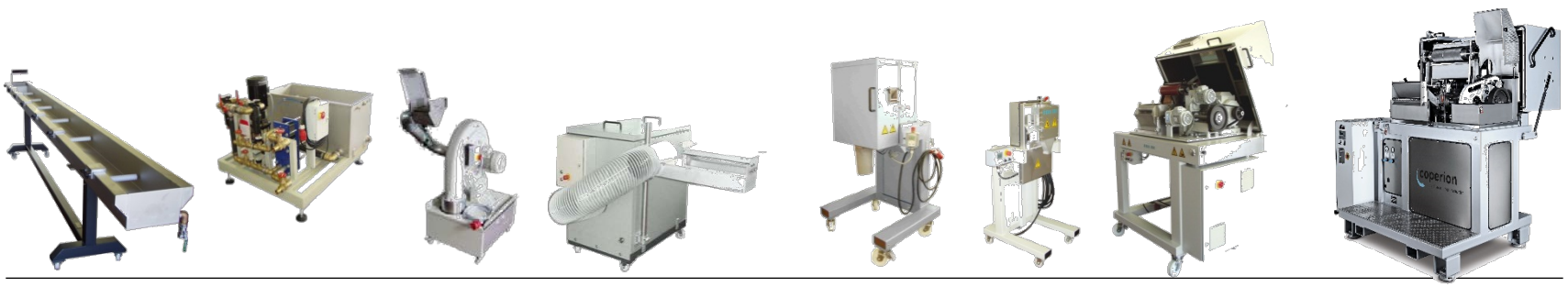
Suction Device Type SD easy

Suction Device Type SD mini – midi - maxi

Strand Pelletizer Type SP EN & SP Pure
working width 30, 50, 100 and 150 mm
throughput 30 to 1000 kg/h

Strand Pelletizer Type SP easy / SP U
working width 120, 220 and 320mm
throughput up to 2500 kg/h

Strand Pelletizer Type SP HD
working width 500 and 700mm
throughput up to 6300 kg/h



coperion
confidence through partnership

Coperion Wytheville Overview

Coperion Wytheville – Expansion History

Screw Elements and Barrel Mfg.:

- Wytheville has grown from 10,000 sq. ft. in the early 2000's to 49,000 sq. ft. today.
- 14,000 sq. ft. added 2012 slotted for a new product for this location, barrel manufacturing for NAFTA market.
- This growth was done in careful strategic steps over those years.
- Since October 2012 Wytheville manufactures screw elements for the world market for sizes 18-98 mm and some special larger sizes.

Coperion Wytheville – Expansion History

coperion
confidence through partnership

Coperion Wytheville – Expansion History

2015 Expansion:

- Added an additional 51,000 sq. ft. for a total of ~100,000 mfg., warehousing and office.
- Ramsey facility was relocated and all operations moved to this location with this expansion.
- Includes assembly, warehousing, gearbox repair, distribution.

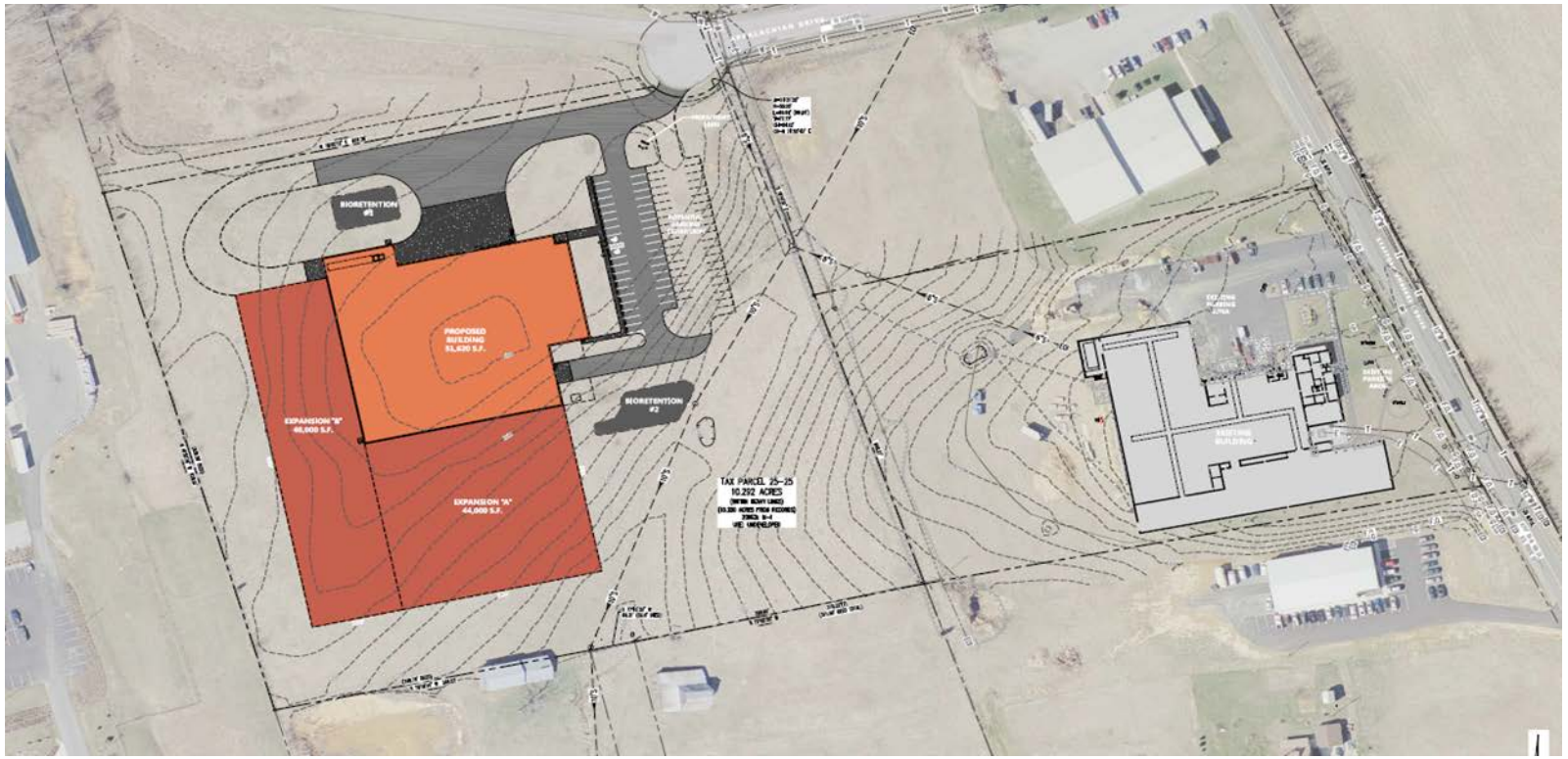
Wytheville, VA – Building 1

Total Building	49,000 sq. ft. / 4,600 sq. mtr.
Manufacturing	45,000 sq. ft. / 4,200 sq. mtr.
Office	4,000 sq. ft. / 400 sq. mtr.

Wytheville, VA – Building 2

Total for New Building	51,500 sq. ft. / 4,800 sq. mtr.
Manufacturing	46,000 sq. ft./ 4,300 sq. mtr.
Office	5,500 sq. ft. / 500 sq. mtr.

Wytheville, VA – Building 2



coperion
confidence through partnership

Coperion NAFTA Operations

Wytheville Screw Elements Manufacturing Capabilities

- Elements from ZSK-18 to ZSK-98
- Welded elements up to size ZSK-133
- Specialized welded elements up to ZSK-177
- Customized designs
- Screw shaft hardware
- R&D on new materials / coatings in conjunction with Coperion Stuttgart
- Re-engineering of elements of competitors elements (3rd brand)

Wytheville Extruder Barrel Overview

- Barrel manufacturing project Phase I is designed and installed to produce 500 barrels/year for the NAFTA market using the base barrel concept. Additional phases are planned to increase production to meet market demands.

- Presently the plant is actively providing new and refurbished barrels

- An extensive qualification process for new barrels with Coperion Stuttgart was completed.

Extruder Assembly

New Machine ZSK Assembly

Modular Unit Assembly

coperion
confidence through partnership

Extruder Assembly

Factory Acceptance Test (FAT): New Capabilities

FAT New Capabilities

- New building design included infrastructure for power to test machines
- $250,000 invested
- Implementation shortly
- Will test machines and peripherals with controls and drive to maximum extent possible
- 16,000 amps dedicated, 200, 400 & 600 amp circuits
- Test will be performed for internal use, but can be an option for customer witness

coperion

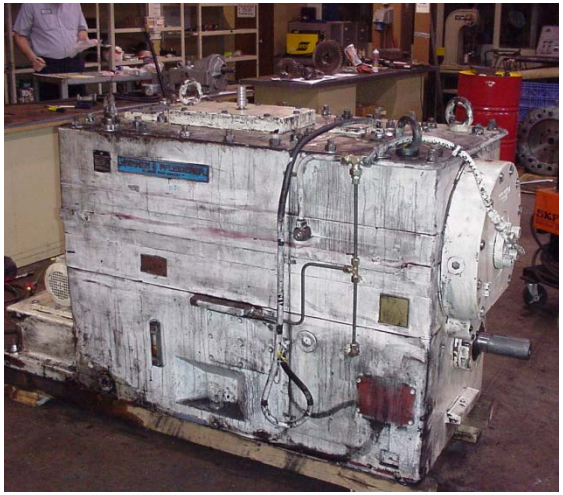
confidence through partnership

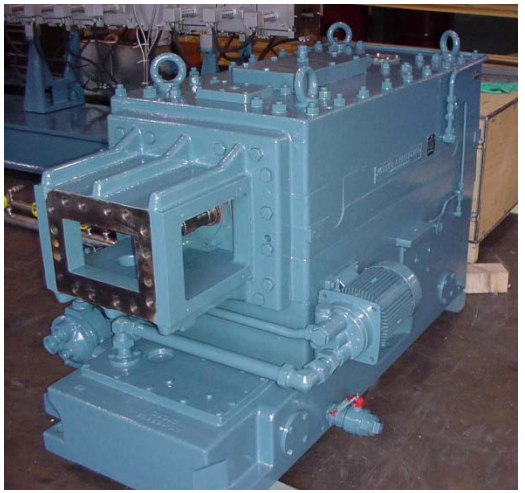
- compounding & extrusion
- materials handling
- service

Gearbox Shop and Refurbishing

Gearbox Refurbishment

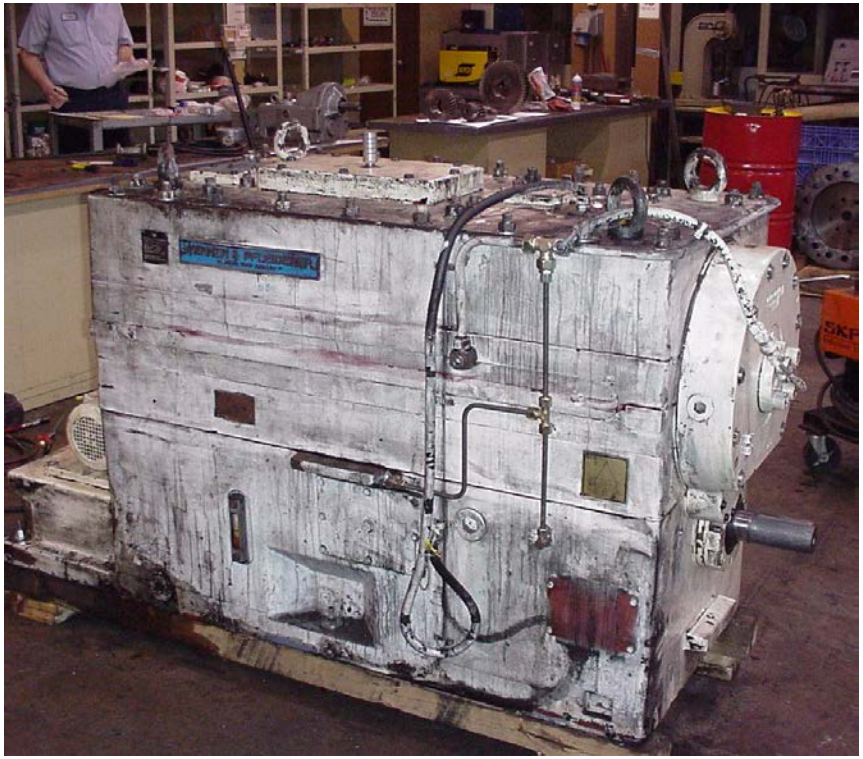
- All Coperion gearbox types
- Inspection normally within 3-5 days of receipt with cost and schedule recommendations
- Common overhaul kits, gear parts, and speed ratios in stock
- Typical turnaround time typically 6-8 weeks (if we have the parts)
  - Emergency turnaround priority for “down” production lines
  - Pre-scheduled 5 to 8 day quick turn-arounds for planned shutdowns
- For emergency situations – use the Gearbox Exchange Program





coperion
confidence through partnership

Gearbox Repair Procedure



Used gearbox to be refurbished as received from customer

coperion
confidence through partnership

Gearbox Repair Procedure & Q.C. Documentation

Required Action

Procedure/Specification

Delivery to repair shop

Shipping arrangements

Receiving documentation

Document External condition (Photos)

Start Project

Drawing + B.O.M

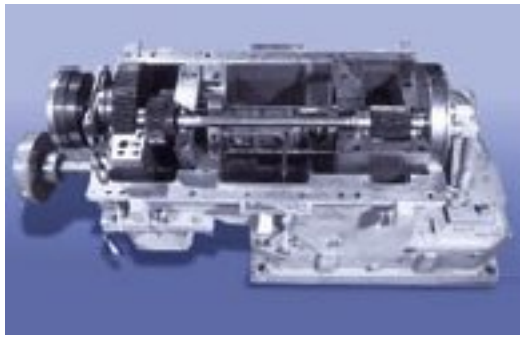
Confirm Parts availability

Schedule repair shop

Dis-assembly

Mark parts
Initial inspection

Inspection Checklist



Clean

Parts OK

Pre-select parts visually inspected

OK = Yes

Detailed Inspection (➔ next sheet)

Parts with visible damage – pitting, spalling, tooth fracture other damage

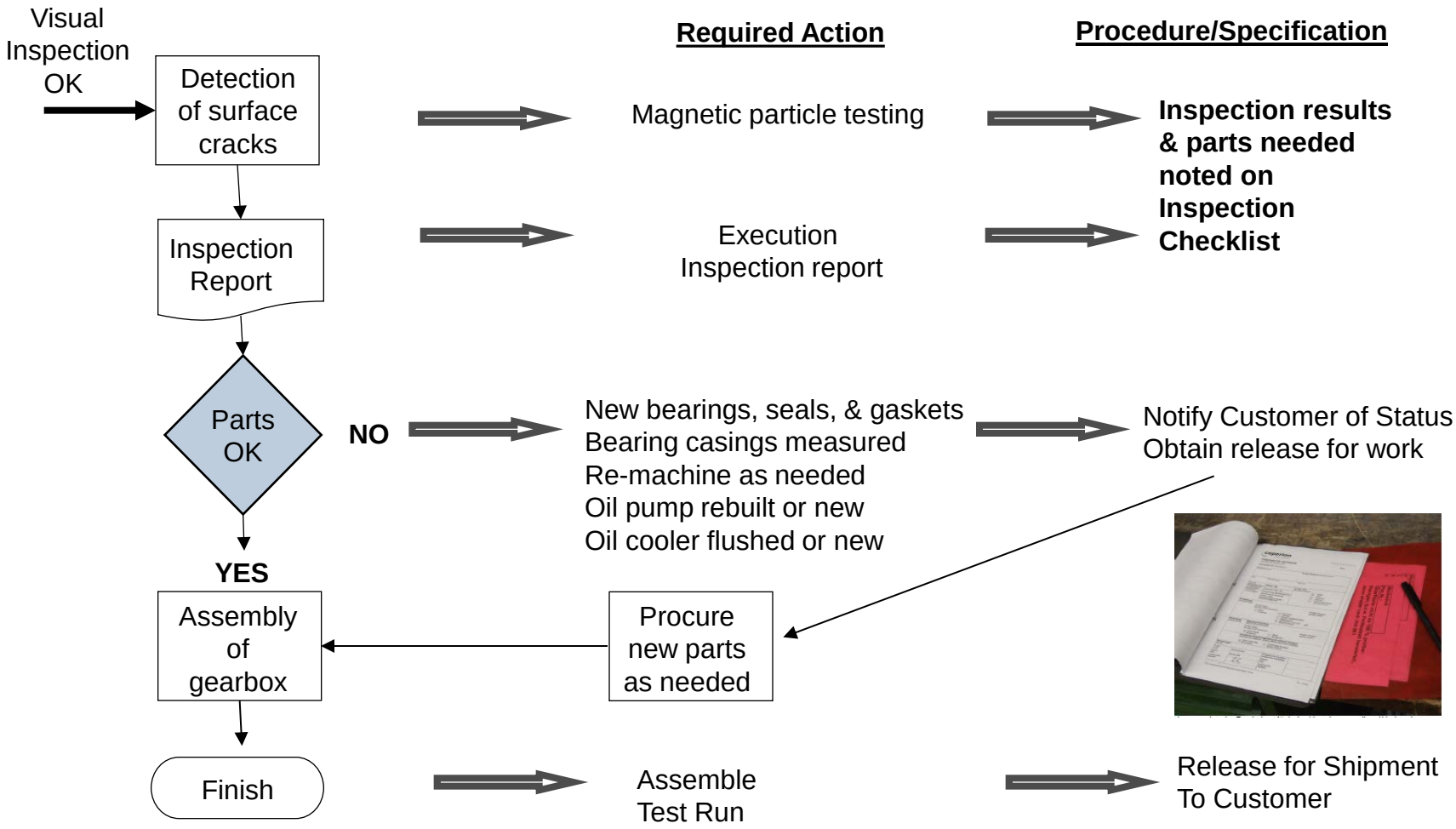
NO

Failure analysis

Scrap

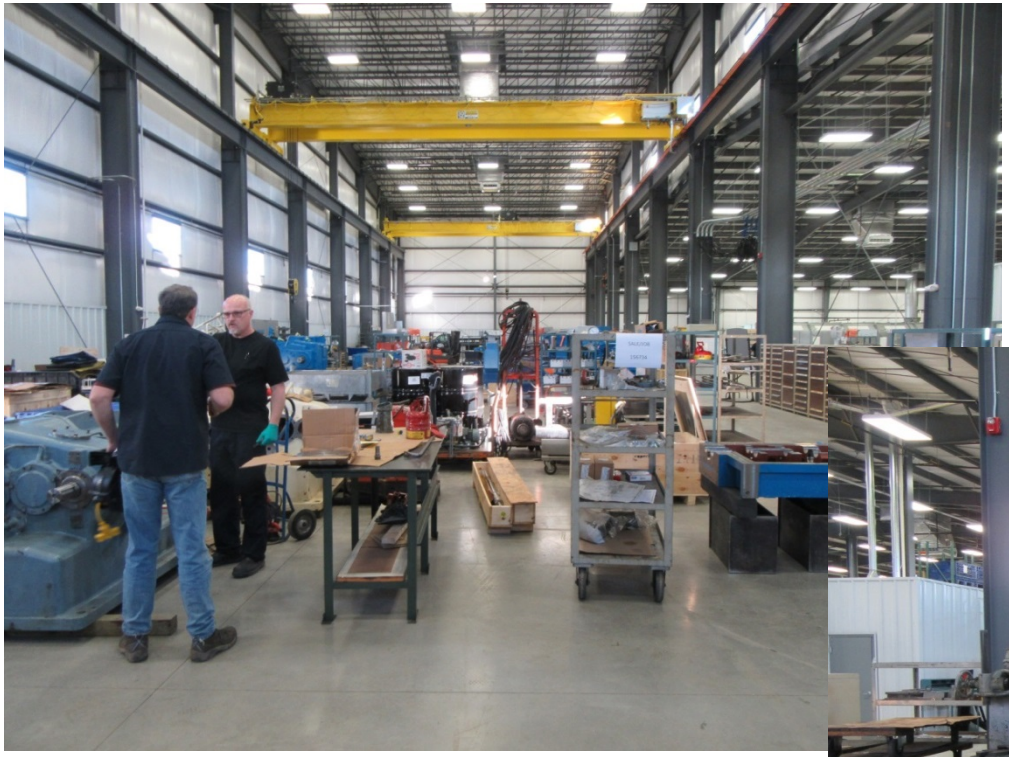
coperion
confidence through partnership

Gearbox Repair Procedure & Q.C. Documentation



coperion
confidence through partnership

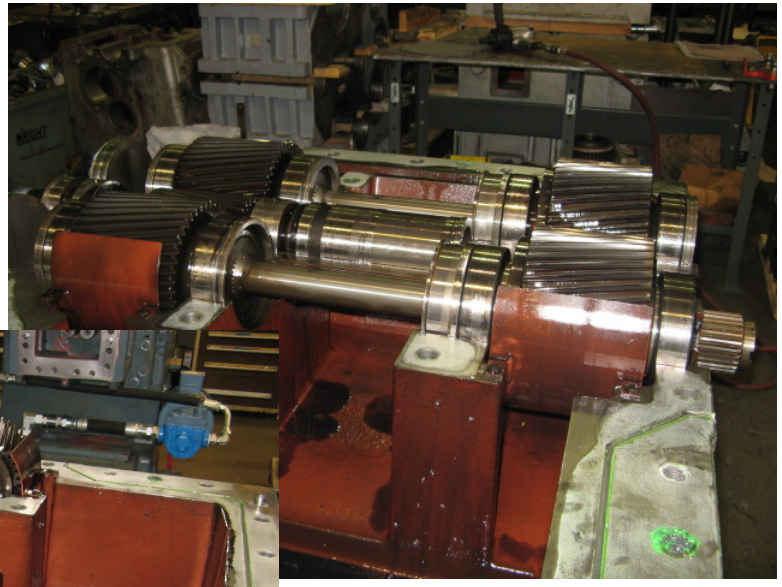
Coperion Wytheville, VA Gearbox Shop



coperion
confidence through partnership

Gearbox Repair

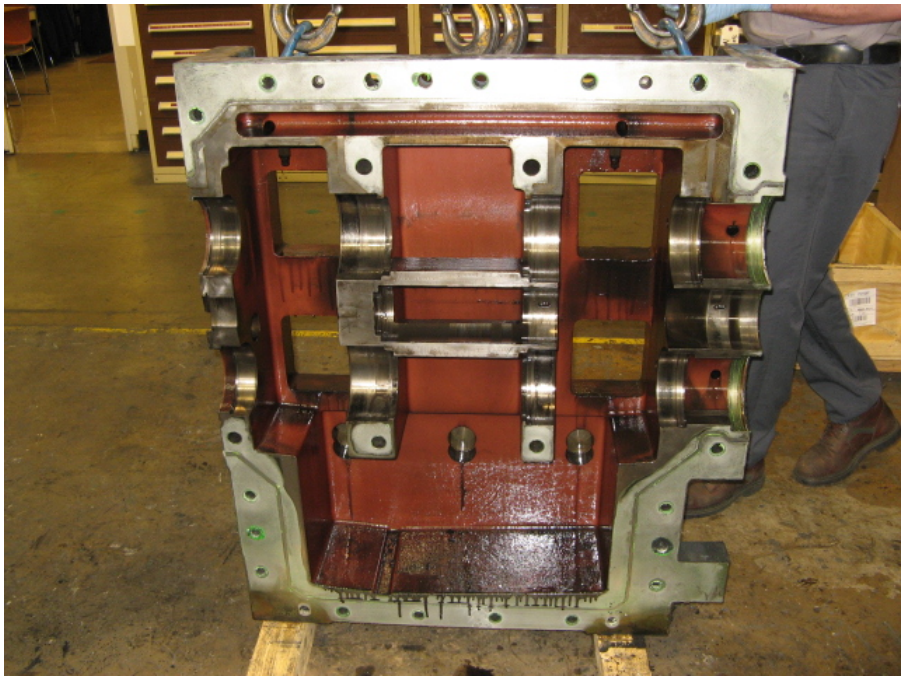
Used gearbox disassembly and inspection



coperion
confidence through partnership

Gearbox Repair

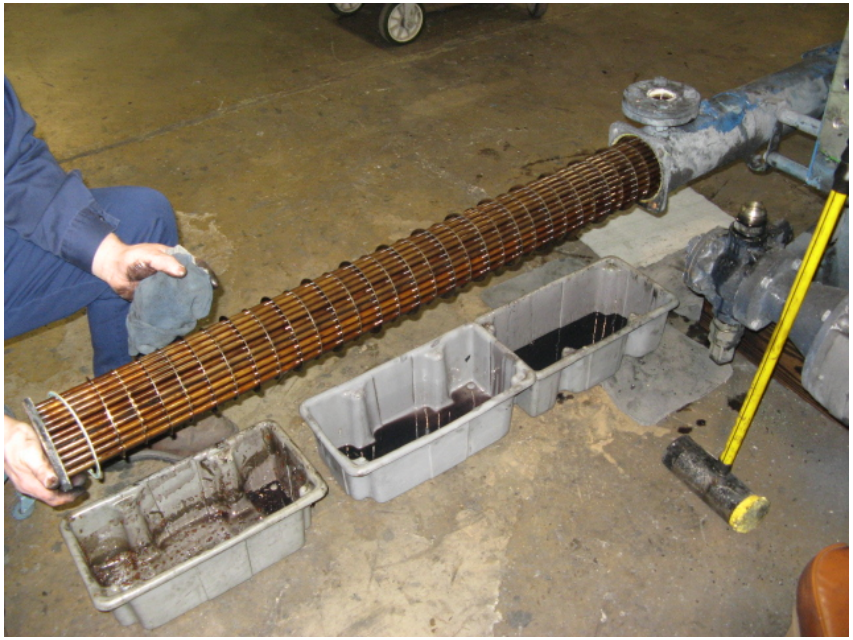
Gearbox housing washing and inspection



Gearbox Repair

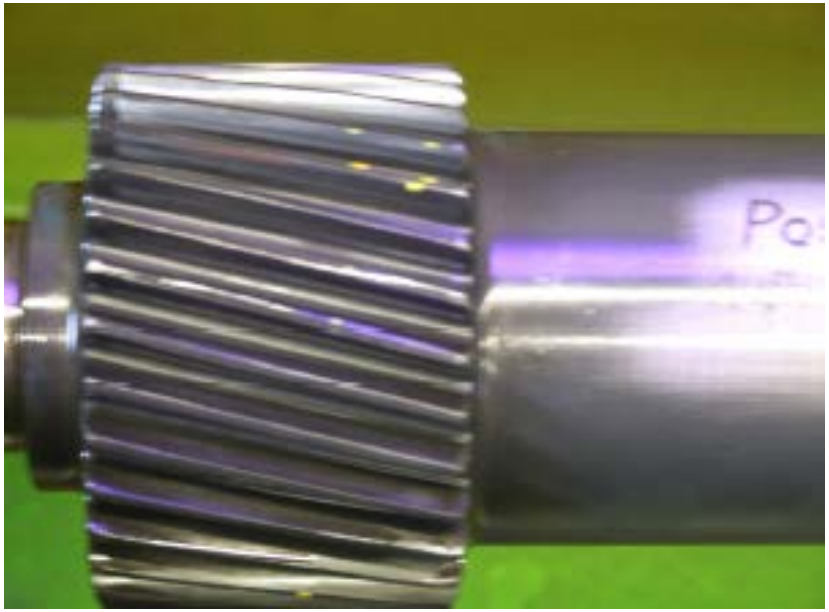
Gearbox heat exchanger inspection and testing

Gearbox gear and shaft inspection



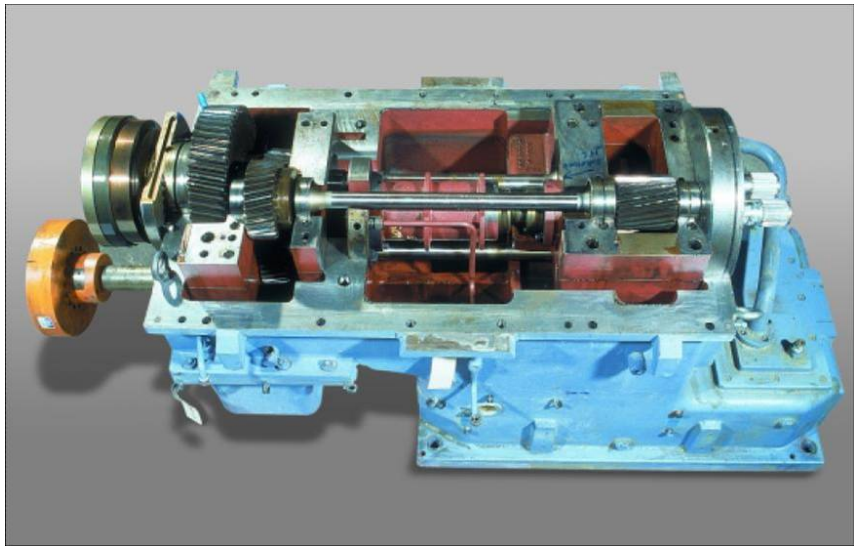
Gearbox Repair

Gearbox gear and shaft magnetic particle inspection process

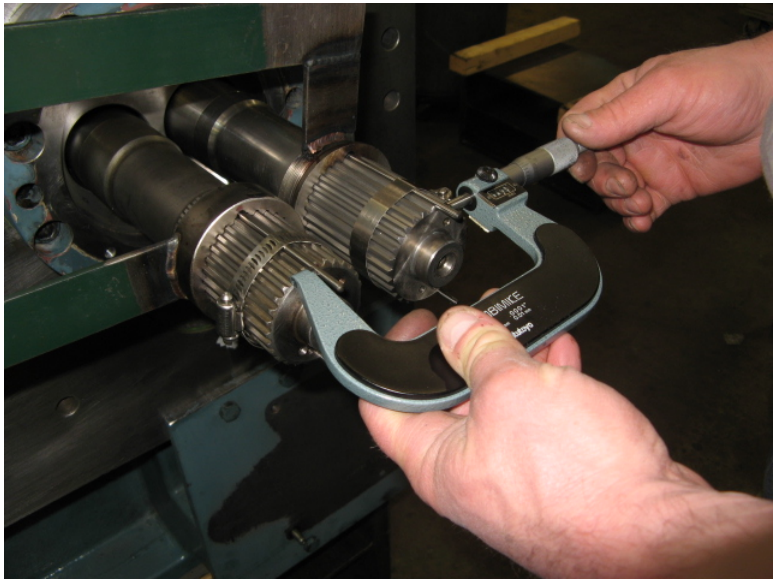


Gearbox Repair

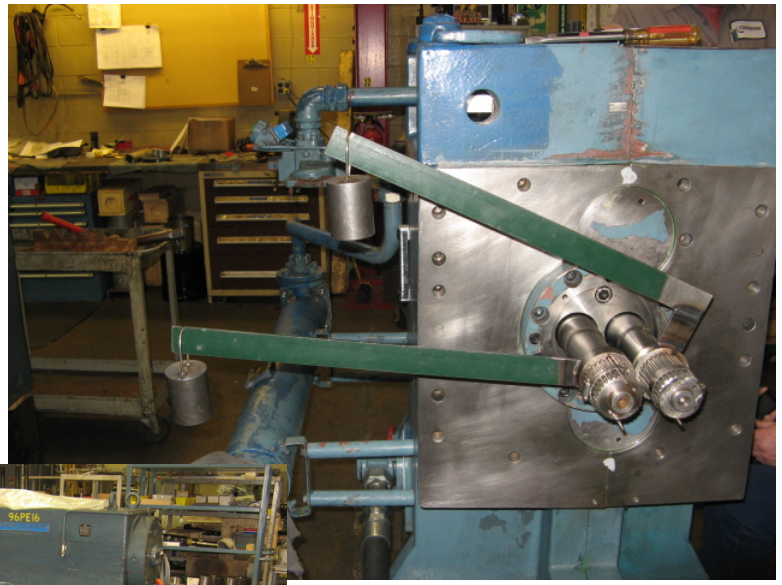
Gearbox re-assembly

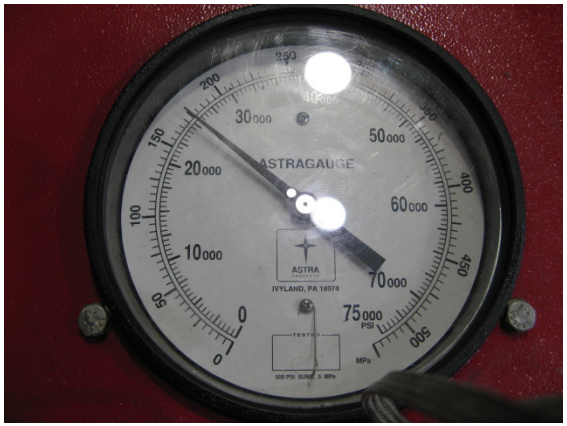


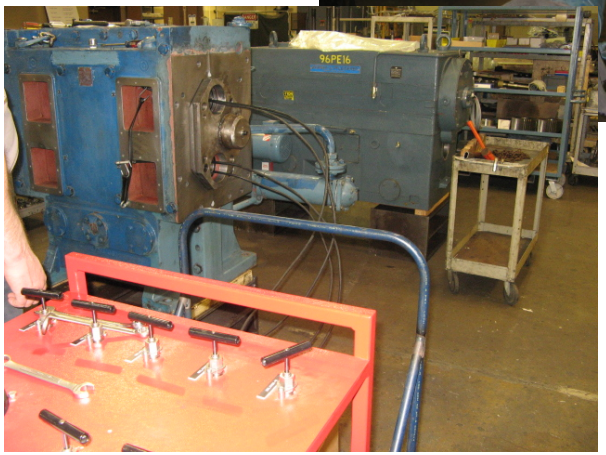
Gearbox Repair



Gearbox re-assembly timing adjustments







Pumping-up the gears

coperion
confidence through partnership

Gearbox Refurbishing Assembly Quality Checklist

coperion
confidence through partnership

Coperion Corporation
663 E. Crescent Ave. Ramsey, NJ 07446

Gearbox Refurbishing Check List

Project Number: _____ Date: _____

QR Number: _____ Employee: _____

ID Number: _____ _____

Customer: _____ Location: _____

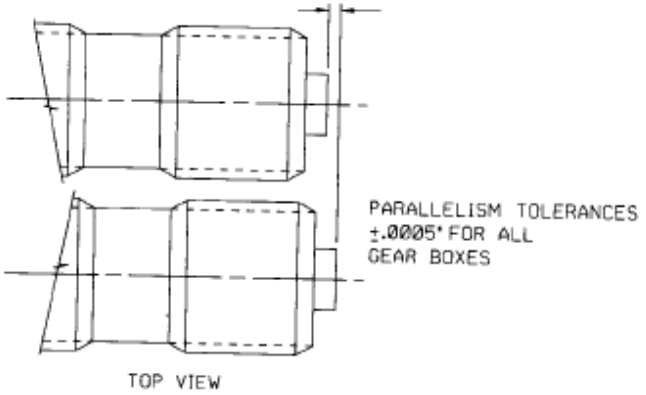
Gearbox Manufacturer: _____

Gearbox Size: _____

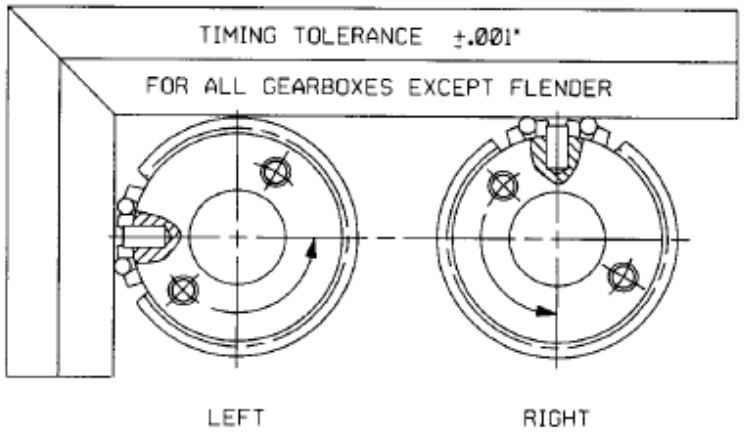
Gearbox Serial Number: _____

Gearbox Ratio when Received: _____

Parallelism Tolerances for all Gearboxes

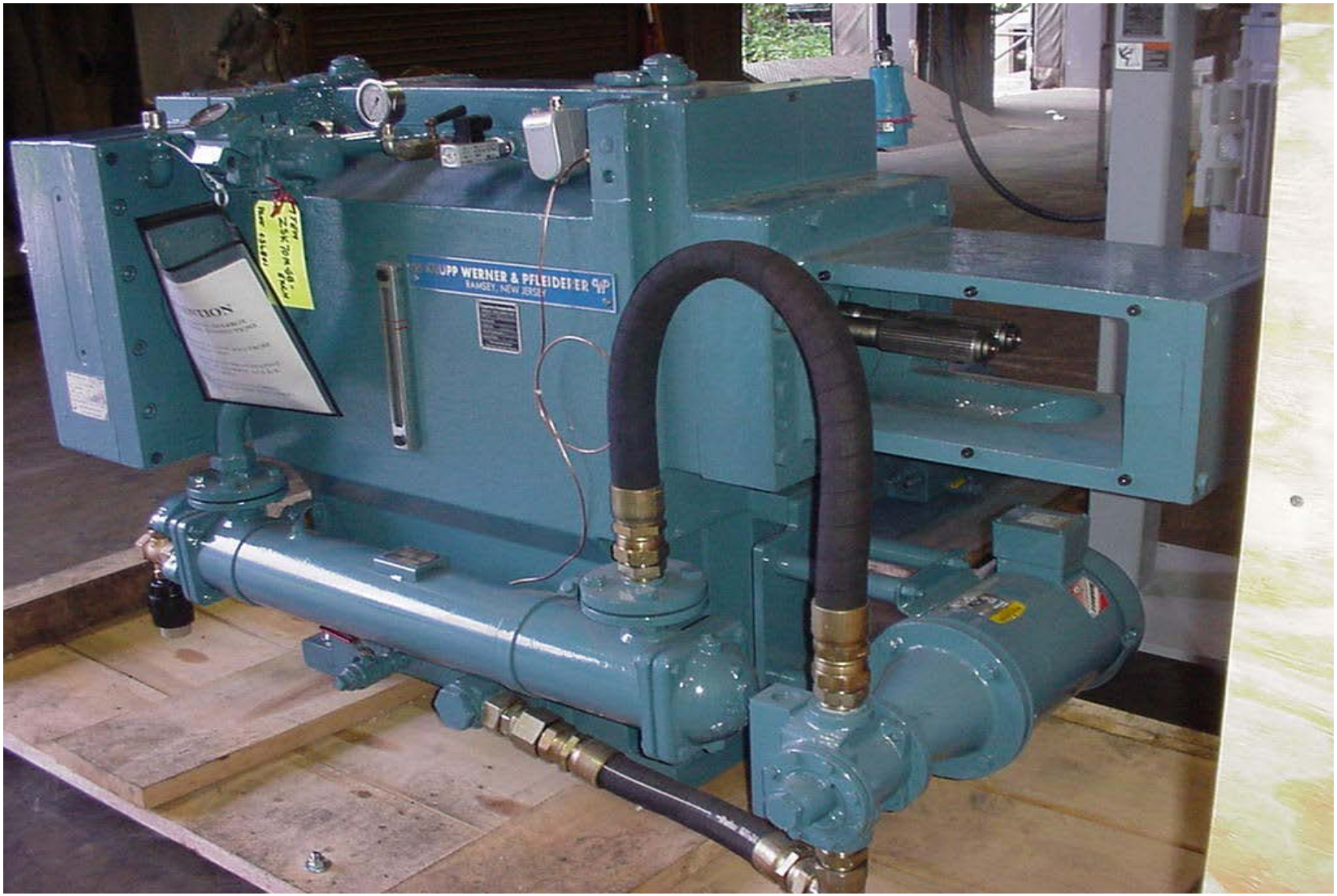


Timing Tolerance for Non-Flender Gearboxes



coperion
confidence through partnership

Completed Gearbox After Refurbishing



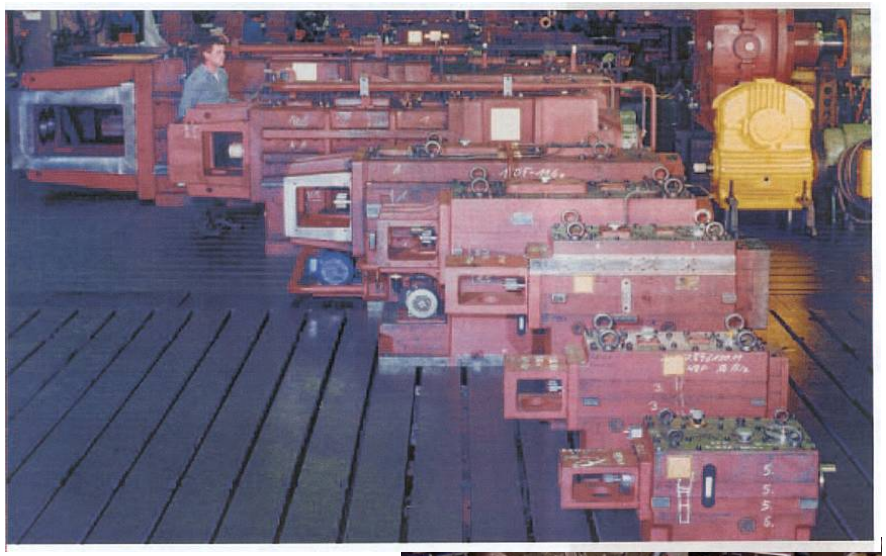
coperion
confidence through partnership

Gearbox Exchange Program

- Coperion's gearbox exchange (replacement) program was developed to minimize downtime in the event of an emergency gearbox failure.

- Inventory consists of our most popular gearbox models.

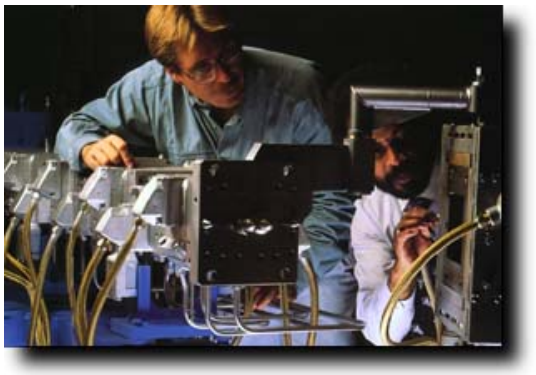
- The gearboxes are factory reconditioned and equipped with the most common speed ratio.

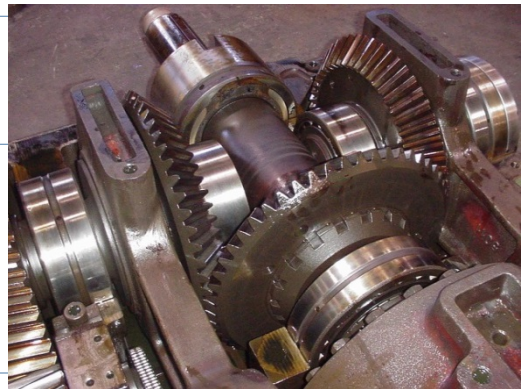


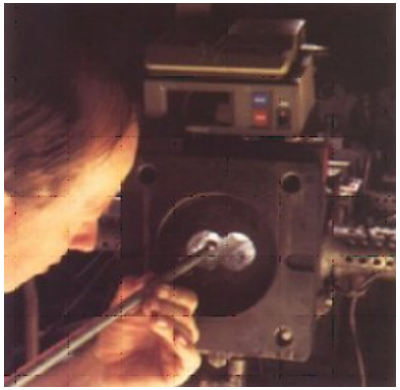
coperion
confidence through partnership

Reconditioning Services

- Barrel Refurbishment
- Screw Stack Out
- Gearbox Refurbishment
- Gearbox Exchange Program
- Machine Upgrades
- Refurbished – Second Hand Equipment
- Used Machine Appraisal







coperion
confidence through partnership

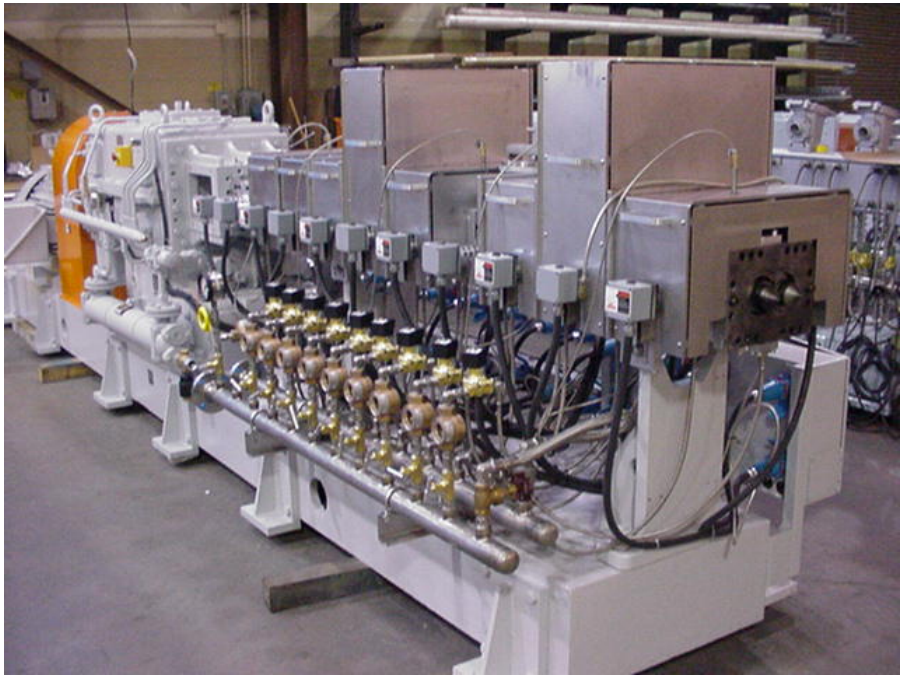
ZSK Extruder Upgrades

Convert three (3) lobe to two (2) lobe design
Replace motor, drive, couplings and associated items for the speed and torque increase
Control panel upgrade or replacement
Torque coupling upgrade
Convert a foundation mounted to a based frame design
Change the machine L/D
Screw shaft and element upgrade
Replace old generation gearboxes with current design
Replace Super Compounder gearbox with Mega Compounder (today's standard gearbox)

ZSK Extruder Upgrades

Before

After



coperion
confidence through partnership

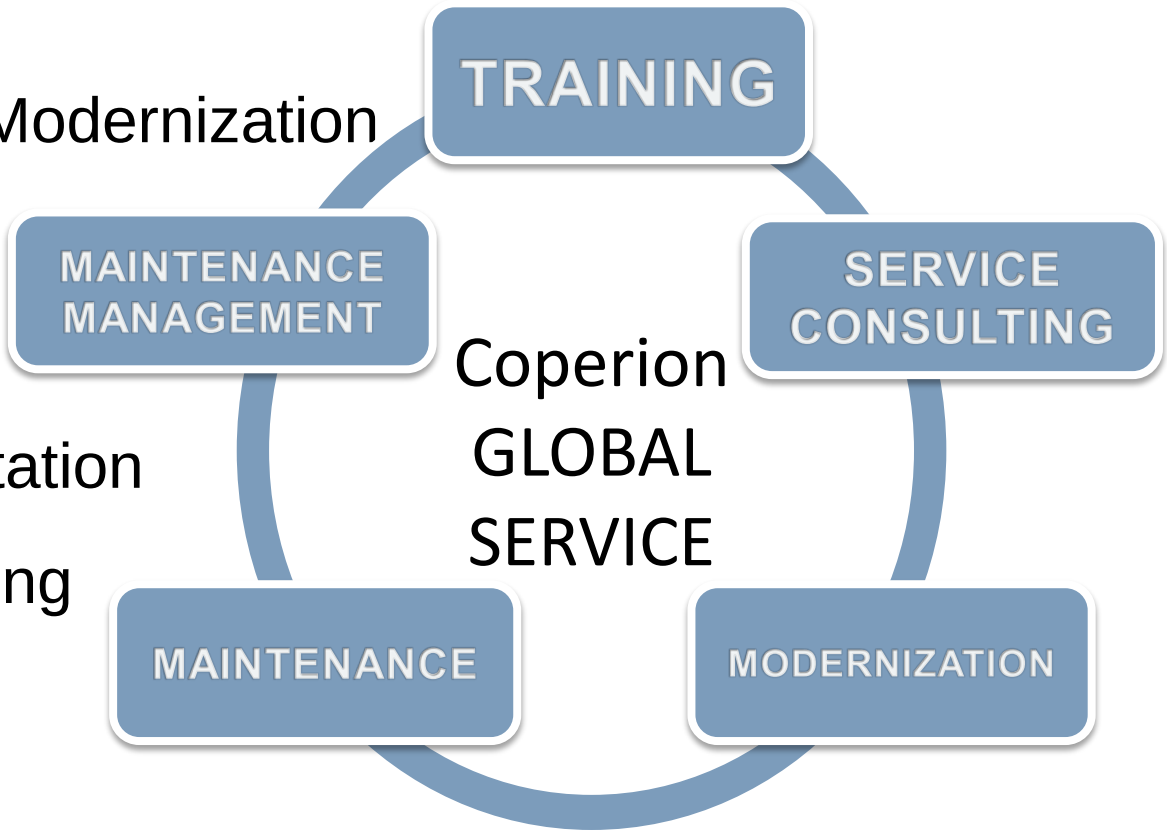
ZSK Extruder Upgrades

ZSK-58 MC+ Gearbox Upgrade Project

Gearbox, baseframe, motor, & coupling pre-assembled for plant retrofit installation

Coperion Customer Service

- Spare Parts
- Refurbishing & Modernization
- Maintenance
- Field Service
- Process Consultation
- Service Consulting
- Training



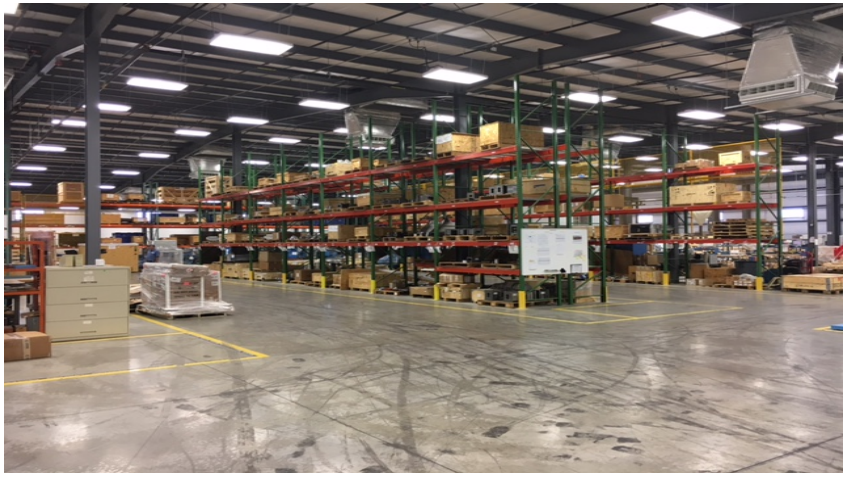
Coperion – Global Distribution Overview

Bob Bolger

Strategic Sourcing Manager/Manager of Warehouse Operations

coperion
confidence through partnership

Coperion – 8,800 square foot Global Distribution Center handling NAFTA, European and Asian market.



coperion
confidence through partnership

Coperion US Capabilities

- Coordinate and distribute for all Coperion locations; Stuttgart, Weingarten Nanjing and India.
- Continued 20+ year relationship with our current Import/Export broker; ensuring timely delivery of product; air and ocean options; assistance with NAFTA requirements.
- Coperion inventory: all inventory parts and locations bar coded;

  all inventory transfers performed electronically;

  daily transfer of finished elements from Building 1
- We carry over $8 million in inventory
- Cycle counts performed daily maintaining 95% accuracy per month
- Supply Chain OTD metrics for fiscal 2017 is currently 91%
- Utilization of lean manufacturing processes: 5S, PFEP, Safety Stock, Purchase/Make lead times

Process Technology Update:
Latest technology to increase productivity, quality, operating flexibility and energy efficiency

Alex Utracki
Director, Process Technology

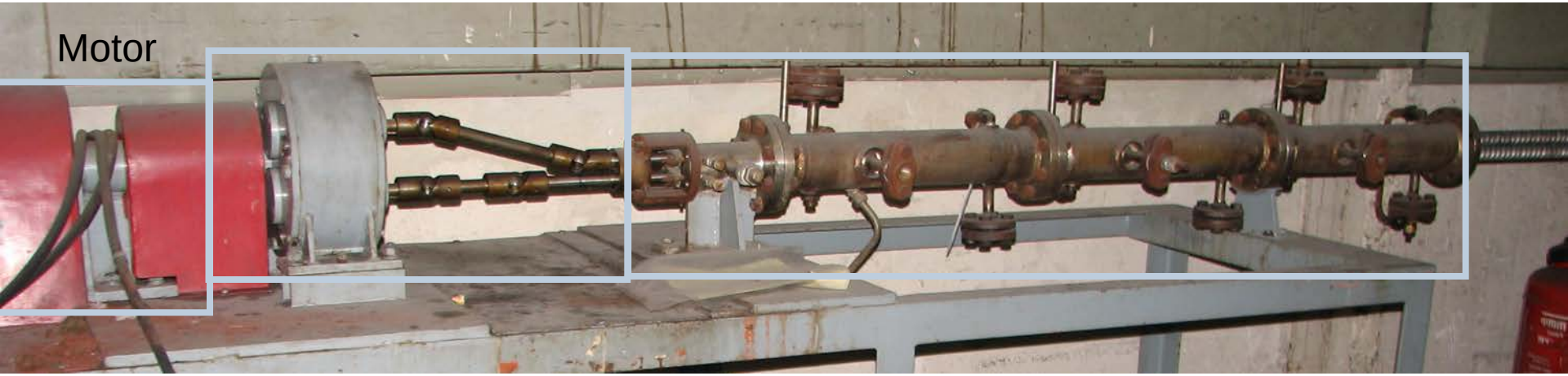
Tel.: +1 (856) 256-3019
alex.utracki@coperion.com

coperion
confidence through partnership

Twin-screw Modular Design History

Gear box

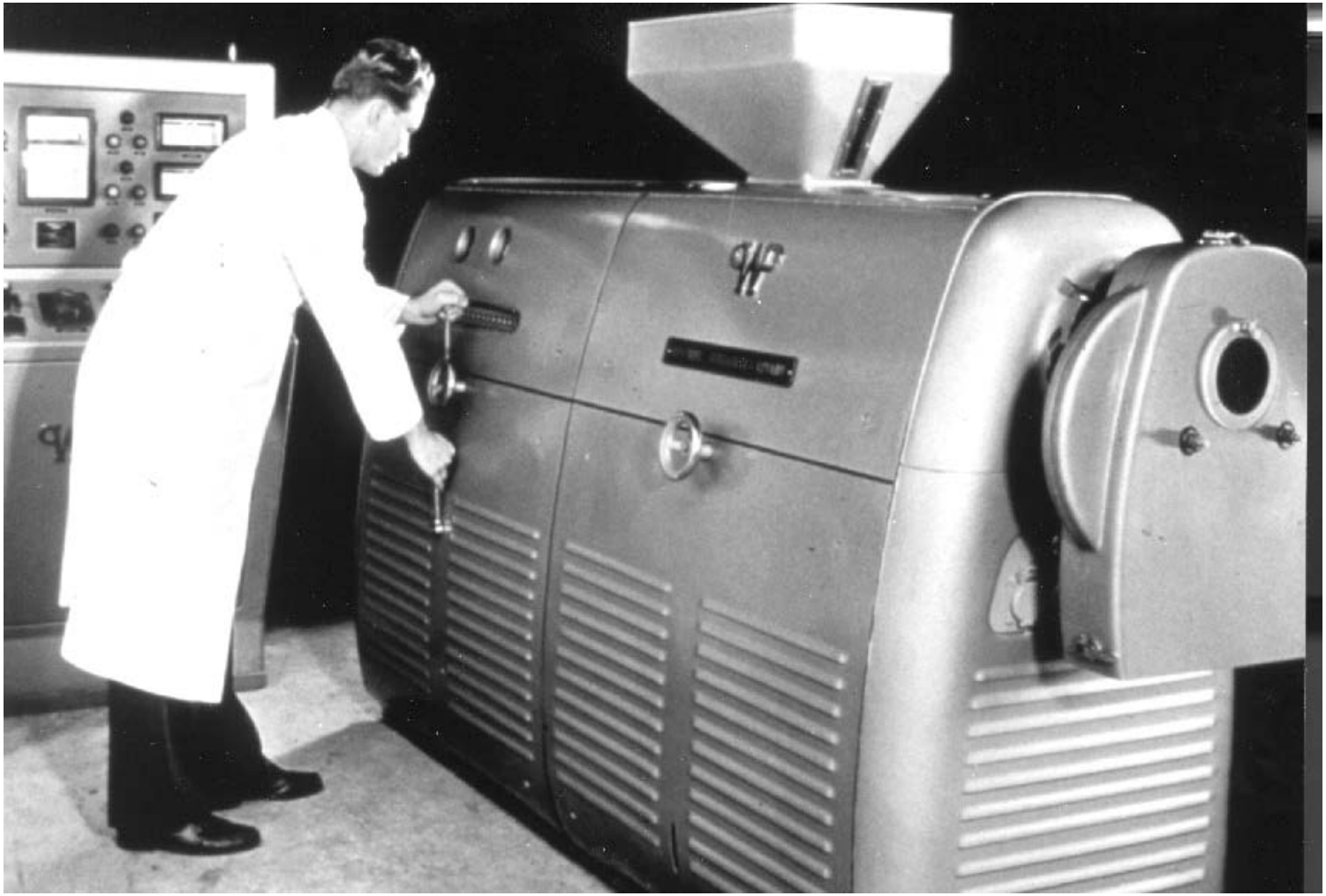
Modular Process section



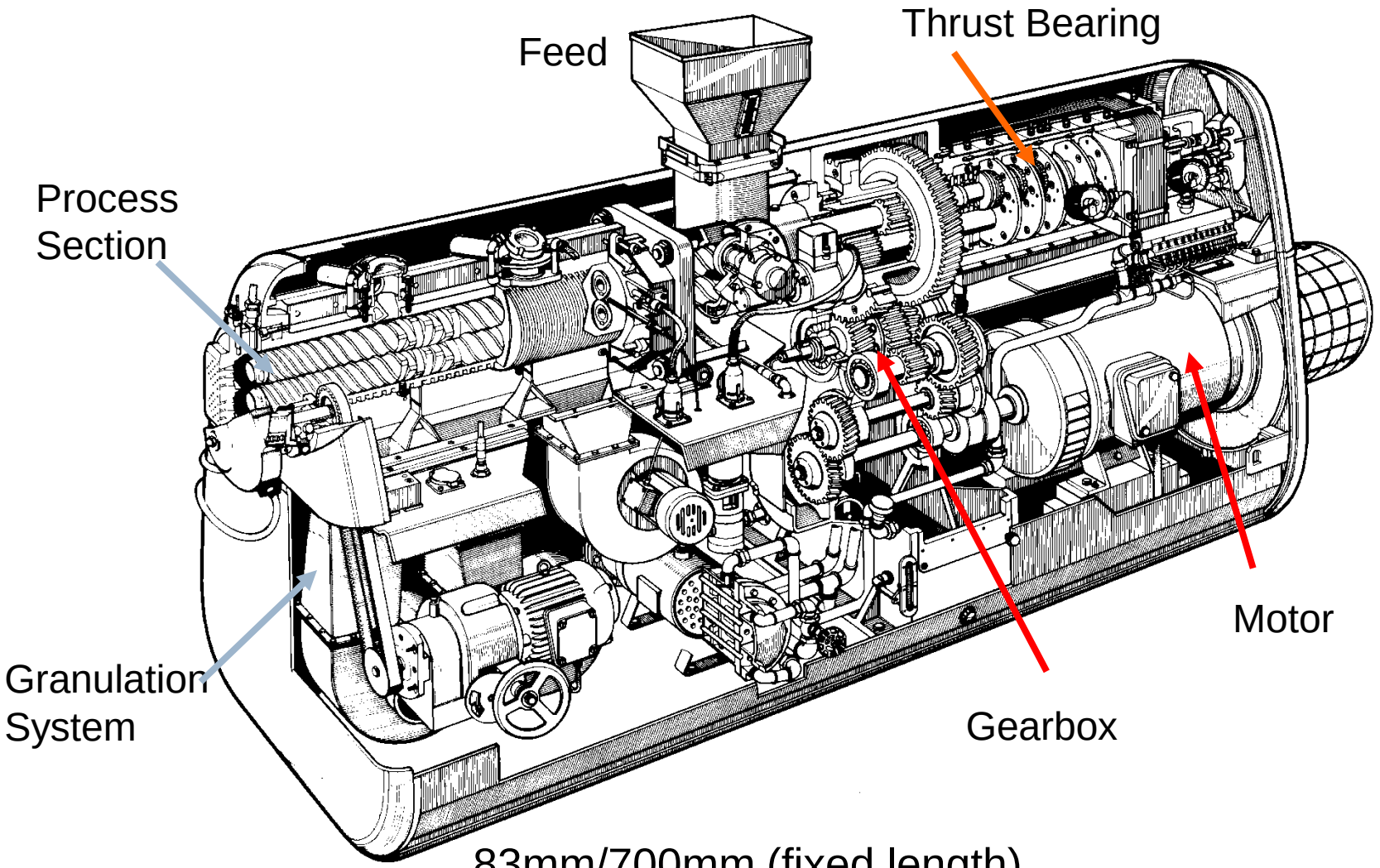
Lab Extruder 1940's, R. Erdmenger Bayer

coperion
confidence through partnership

First Commercial Co-rotating Twin Screw Extruder: ZSK-83



ZSK-83: 1957

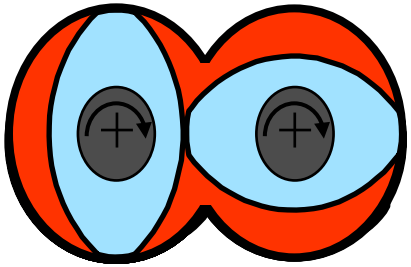


coperion
confidence through partnership

ZSK: Modular Design

Drive power of 10 kW up to 12 MW for rates from 0.5 kg/h and 100 t/h

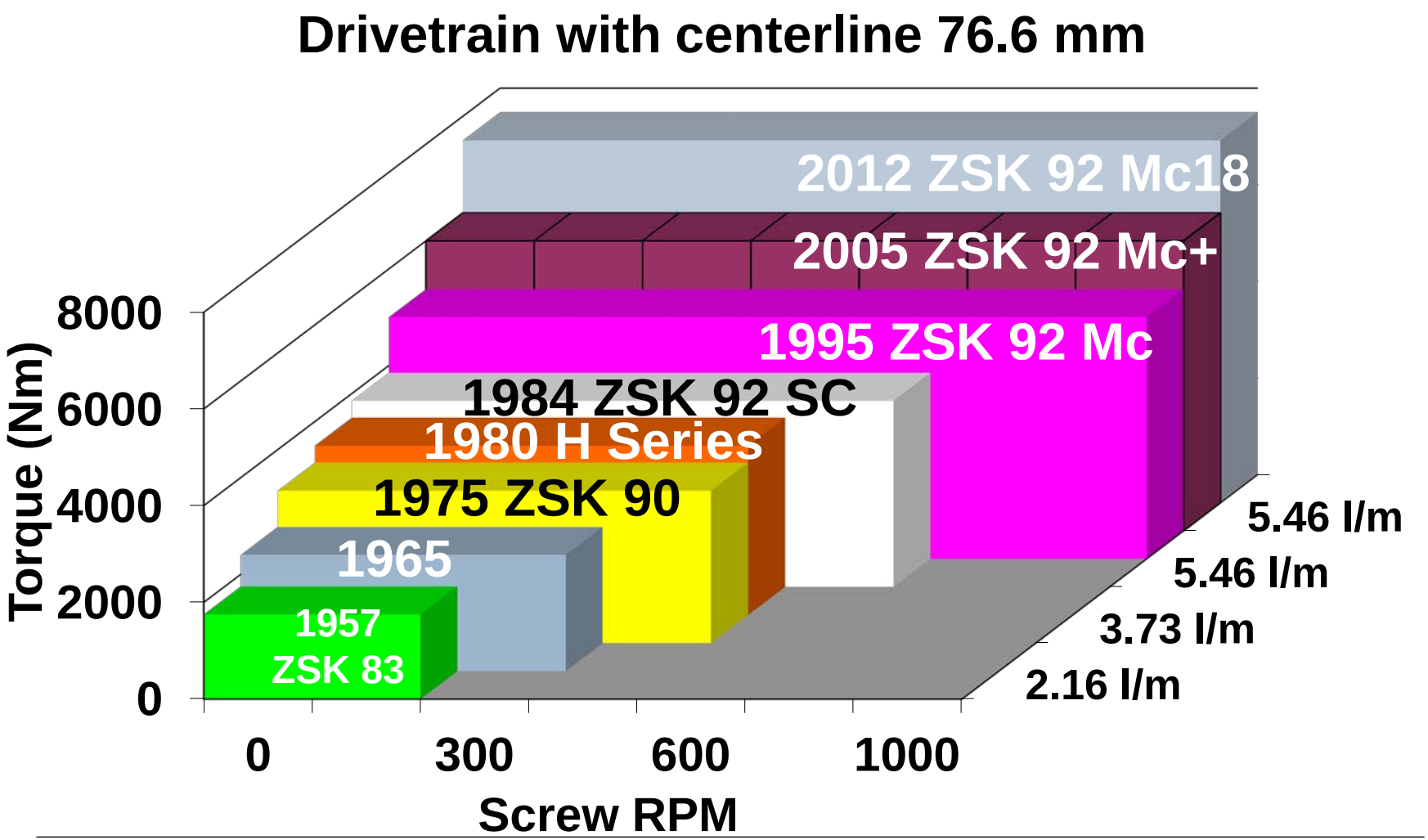
Operating principle



Modular design
for screw elements and kneading blocks

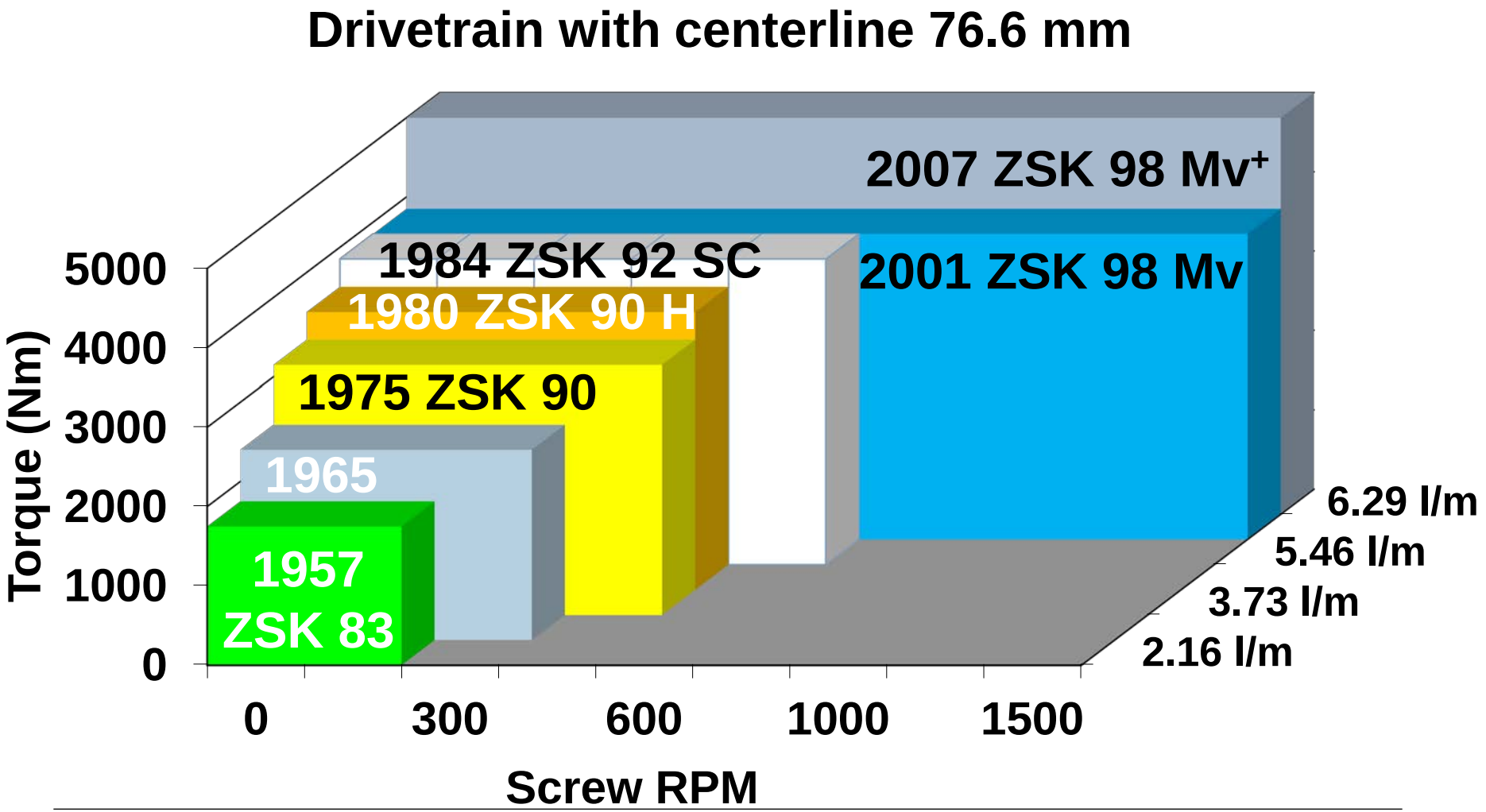
coperion
confidence through partnership

Pushing the Process 1957-2015: Torque + RPM



coperion
confidence through partnership

Pushing the Process 1957-2015: Volume and RPM



coperion
confidence through partnership

ZSK – Evolution of Torque and Volume

1955: Generation 1
$D_o / D_i = 1.22$
$M_d / a^3 = 5.0$ Nm/cm³
$n = 150$ min⁻¹

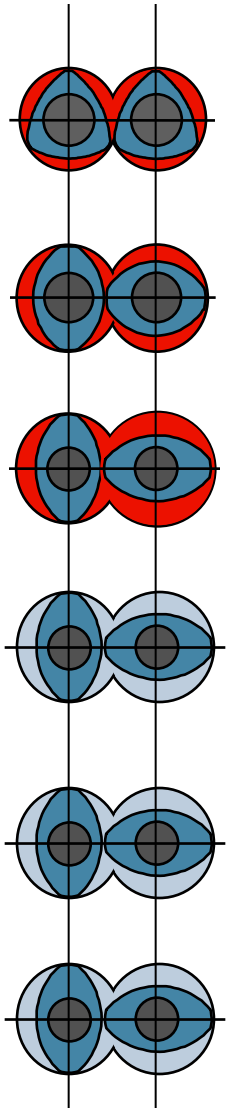
1970: 2-flighted
$D_o / D_i = 1.44$
$M_d / a^3 = 5.0$ Nm/cm³
$n = 300$ min⁻¹

1985: ZSK Sc
$D_o / D_i = 1.55$
$M_d / a^3 = 8.7$ Nm/cm³
$n = 600$ min⁻¹

1995: ZSK Mc
$D_o / D_i = 1.55$
$M_d / a^3 = 11.3$ Nm/cm³
$n = 1200$ min⁻¹

2004: ZSK Mc PLUS
$D_o / D_i = 1.55$
$M_d / a^3 = 13.5$ Nm/cm³
$n = 1200$ min⁻¹

2010: ZSK Mc^{18}
$D_o / D_i = 1.55$
$M_d / a^3 = 18.0$ Nm/cm³
$n = 1200$ min⁻¹

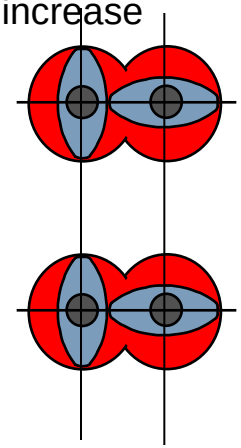


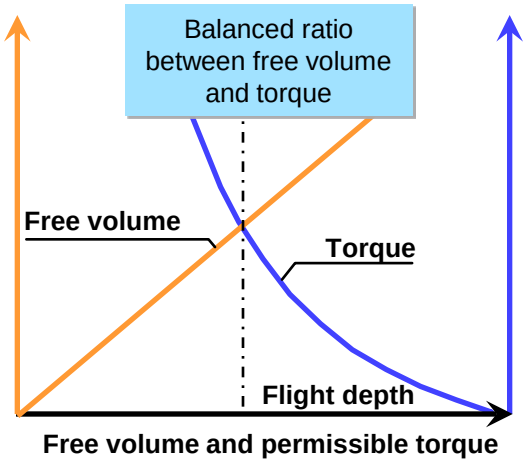
Increase of
free volume (100%)
and of specific torque

Free volume increase
(40%)

Torque
increase

Torque
increase





2001: ZSK Mv
$D_o / D_i = 1.80$
$M_d / a^3 = 8.7$
Nm/cm³ $n = 1800$
min⁻¹

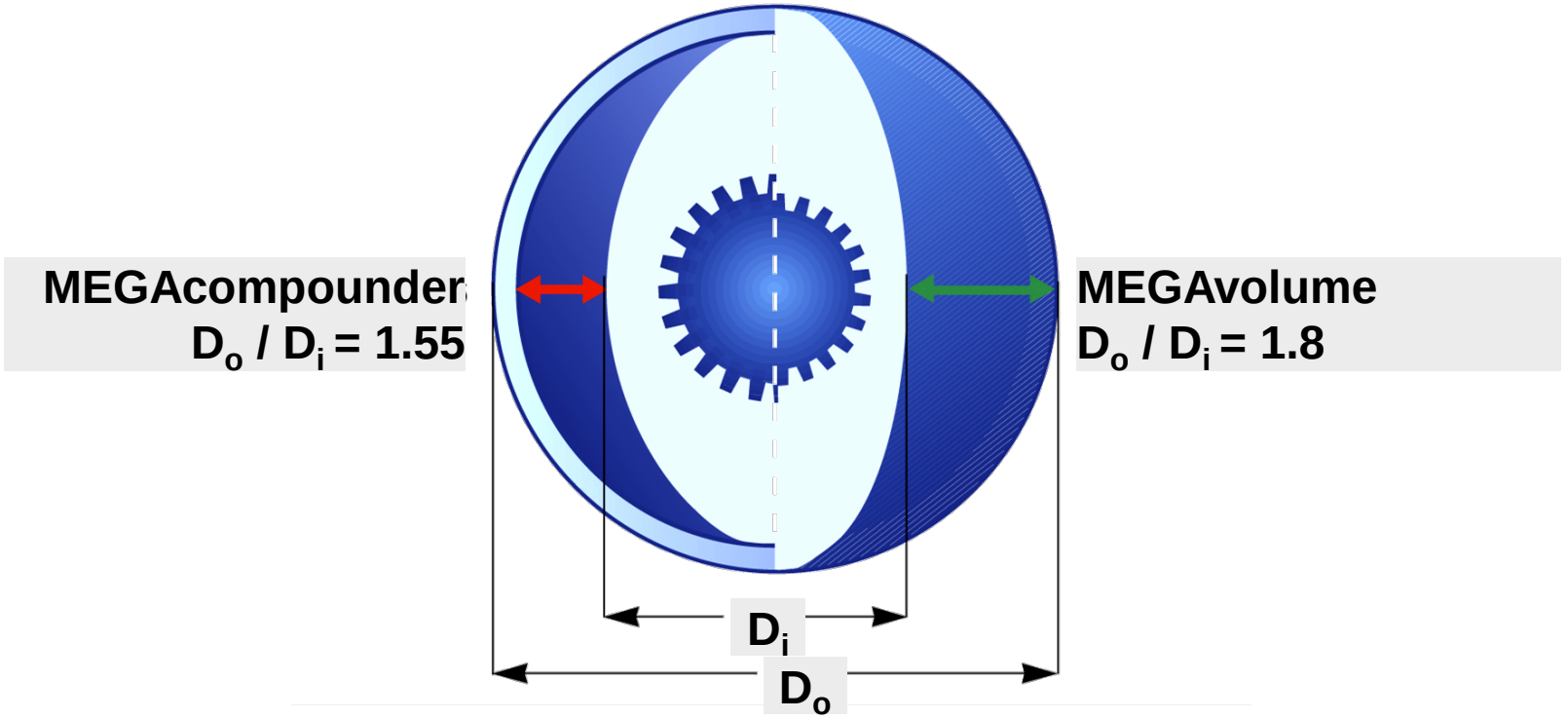
2007: ZSK Mv PLUS
$D_o / D_i = 1.80$
$M_d / a^3 = 11.3$ Nm/cm³
$n = 1800$ min⁻¹

D_o / D_i = Outer / Inner diameter
M_d / a^3 = Specific torque

coperion
confidence through partnership

Changes in Screw Geometry

Larger channel volume has been achieved by increasing barrel bore and deeper screw channels



Typical Specific Energy Input Values for Compounding Tasks

Compounding of Polymers

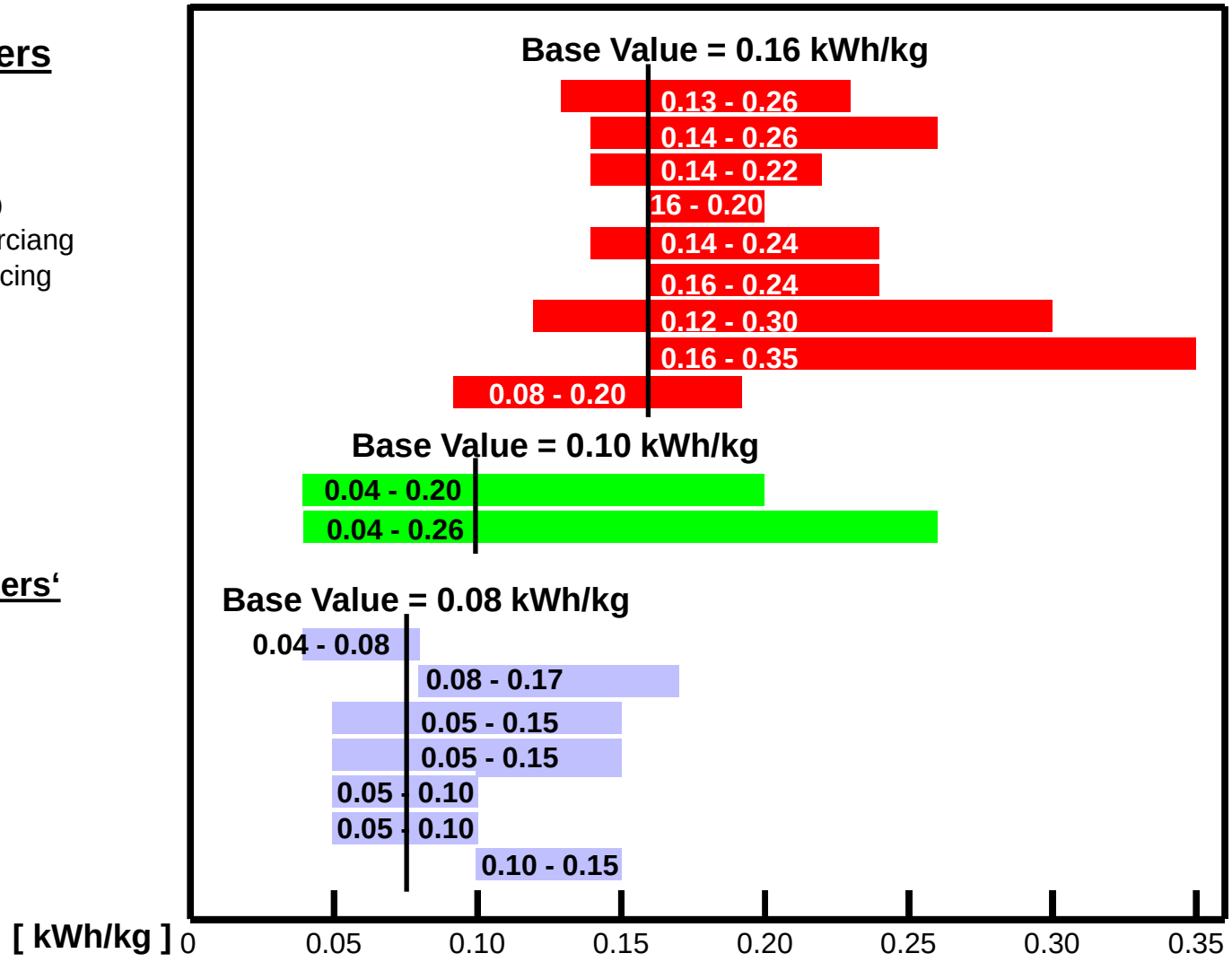
Polyolefins with Gear Pump
Polyolefins without Gear Pump
ABS, PVC
Polymerblends (PC/ABS; PC/PBT)
PP, PBT normal level filling / Reinforciang
PA, PET normal level filling / Reinforcing
White- / Color - Masterbatch
Black - Masterbatch
PP high level filling

Reactions, Degassing

Polymerisation (TPU, POM)
Concentrating of Polymer Solutions

Compounding of ‚Non-Polymers‘

Powder Coatings
Toners
Food Stuffs
Catalyst Carriers
Detergents
Adhesives
Active coal



coperion
confidence through partnership

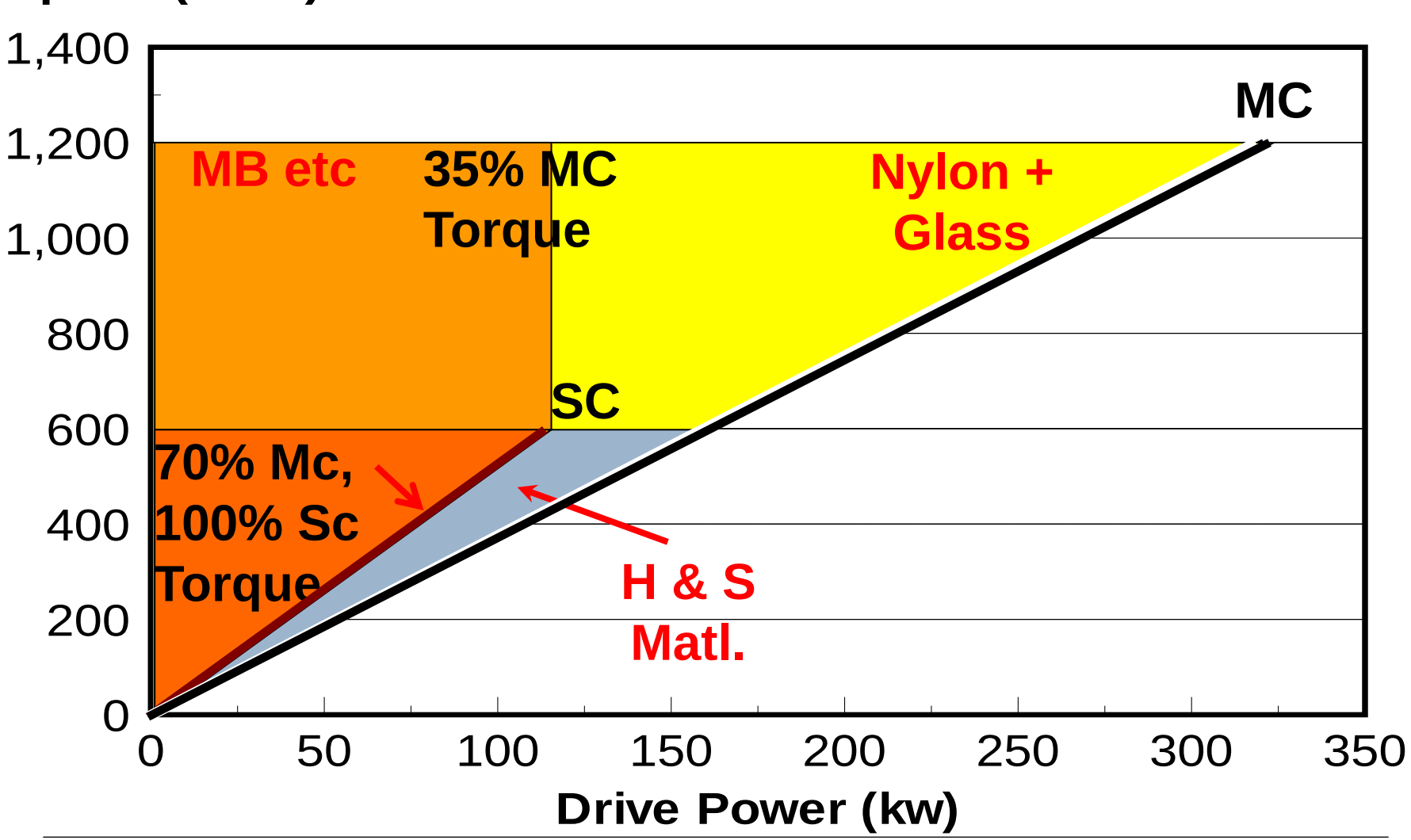
Market Demands transformed into the “Mega Concept”

- Increased Productivity
- Improved Product Quality
- More Operating Flexibility
- Greater Energy Efficiency

MEGA Concept

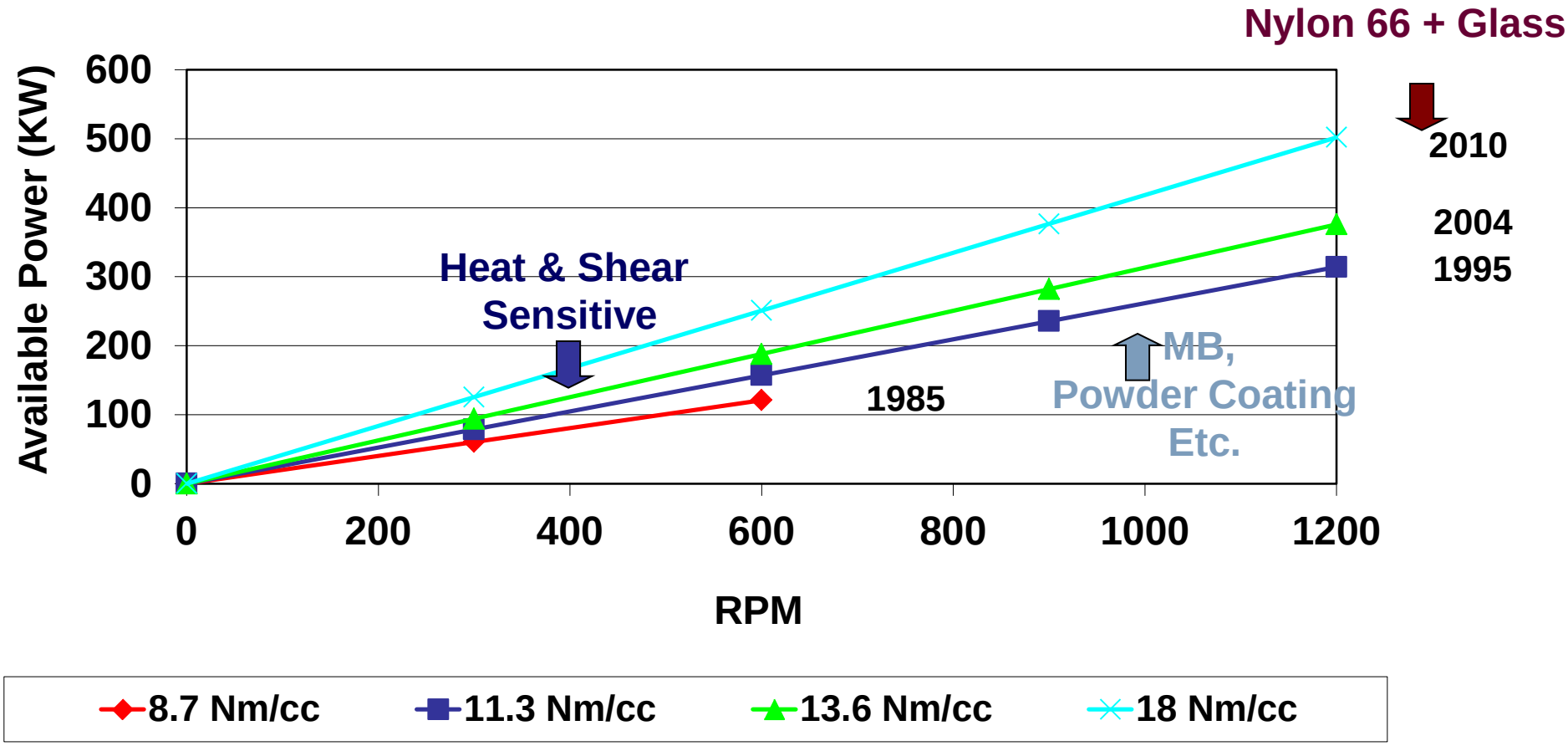
- Combined high torque & high RPM
  - Nylon 66 + Glass
- High torque at more standard RPM
  - Heat & Shear Sensitive Products
- High RPM at standard torque
  - MB, Powder Coating, & Toner

MEGA (1995) vs. SC - Available Power @ RPM: ZSK 58



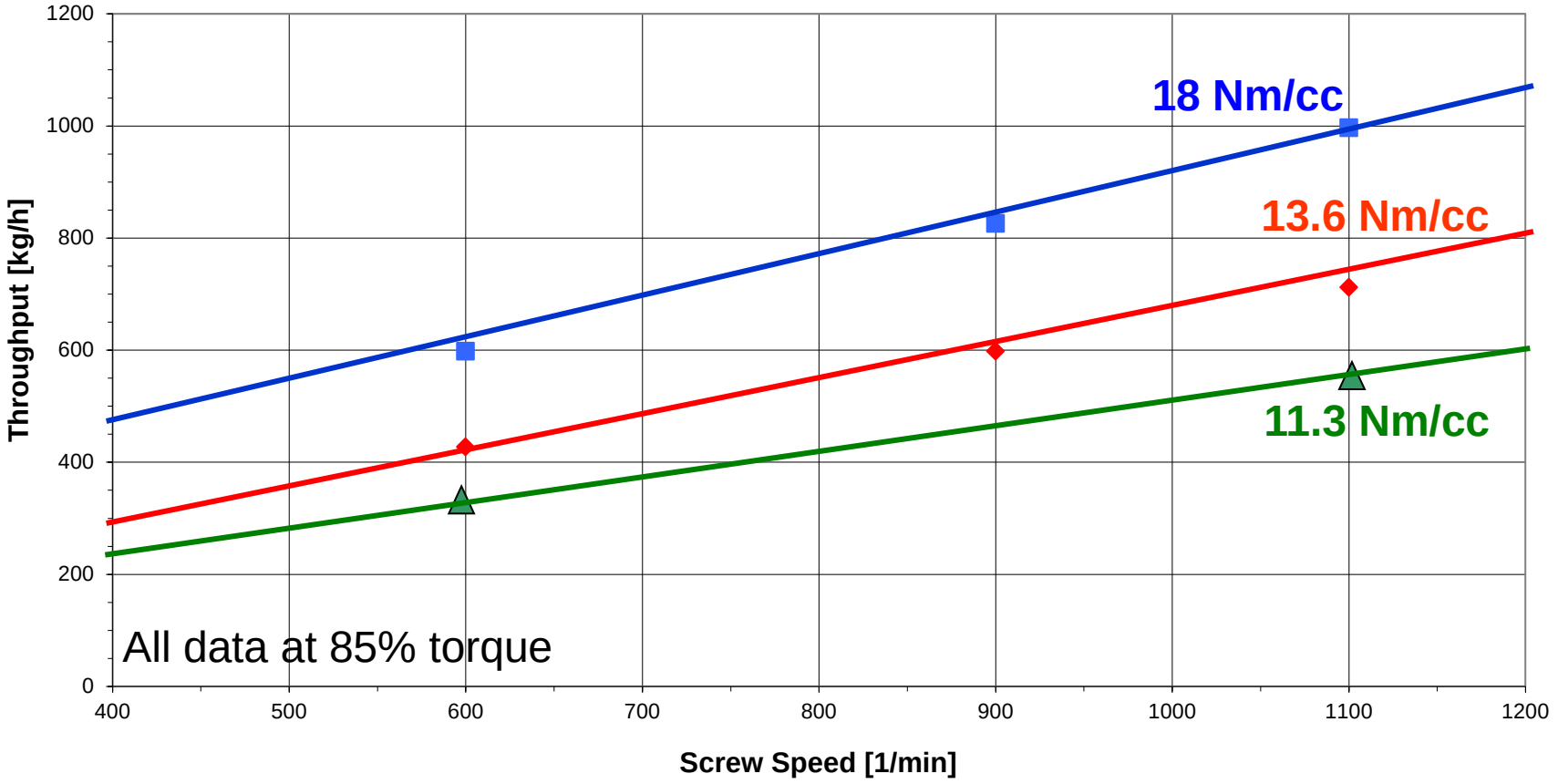
coperion
confidence through partnership

Continued Growth of Drive Power (Torque): ZSK 58mm, 1995-2017



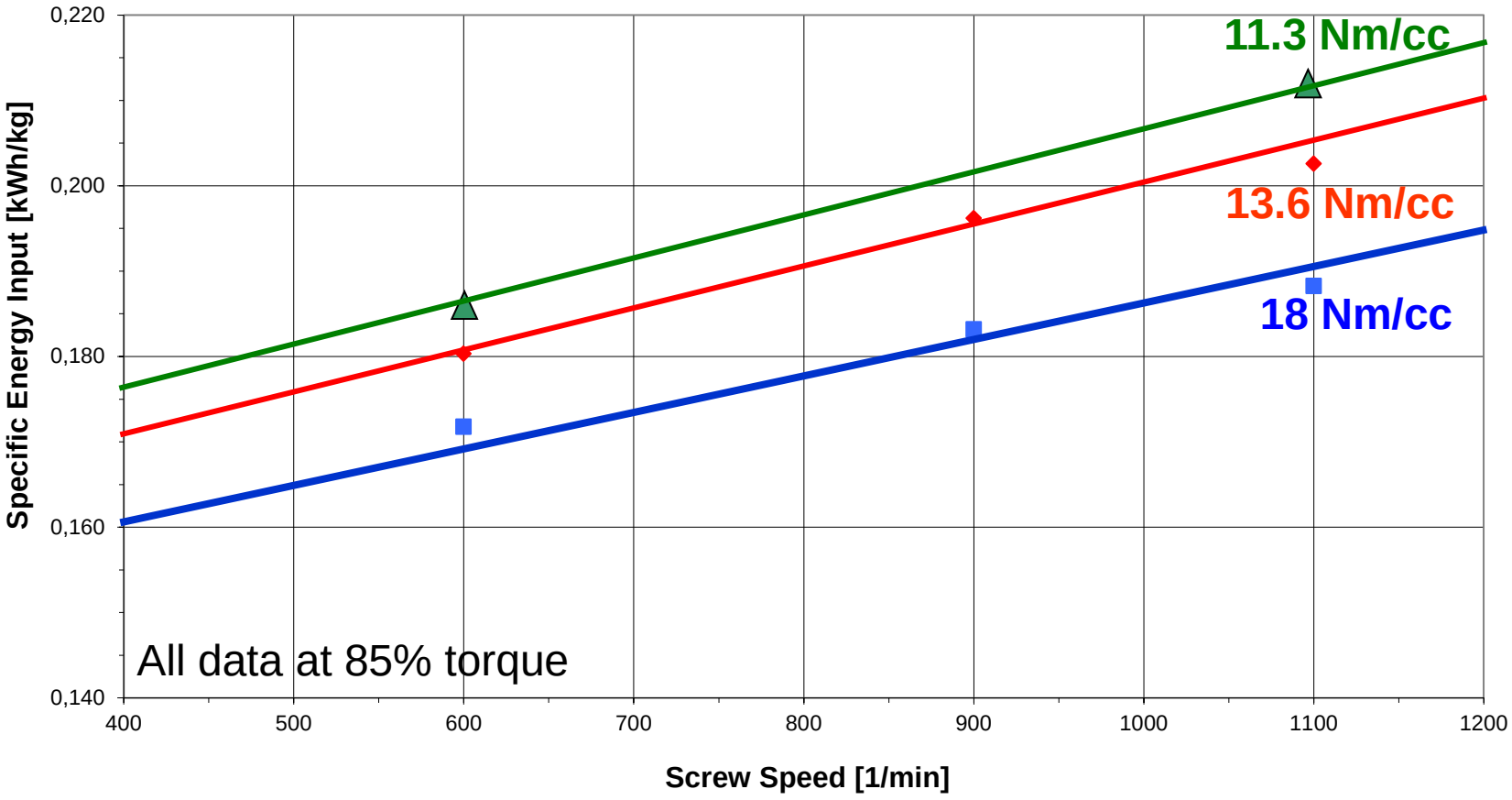
coperion
confidence through partnership

PA6 + 30% GF
ZSK 45 mm: Throughput Increase Comparison



coperion
confidence through partnership

PA6 + 30% GF
ZSK 45 mm: Energy Savings > 5%

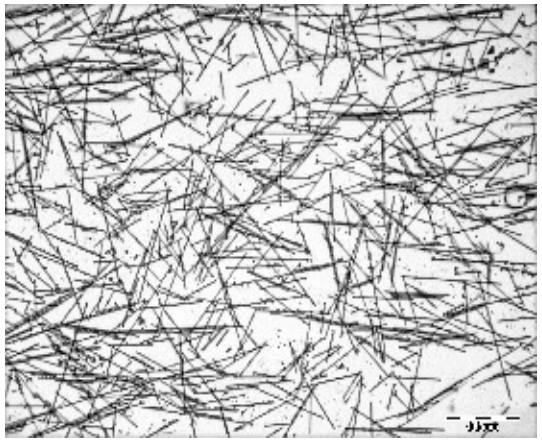


coperion
confidence through partnership

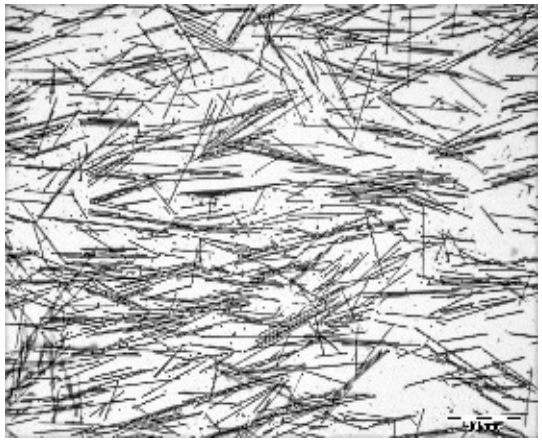
Microscopy of Glassfibers for PA6 + 30% GF (ZSK 45 mm)

13.6 Nm/cc : 600 rpm

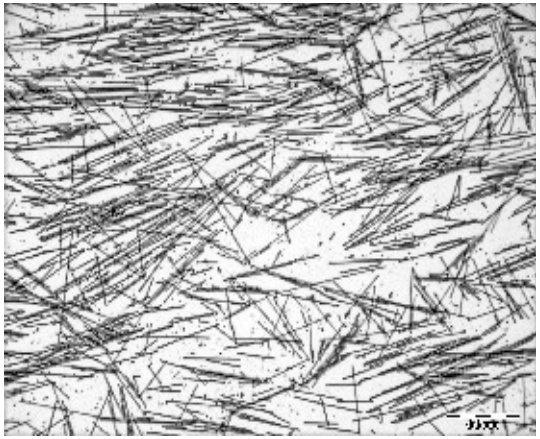
900 rpm



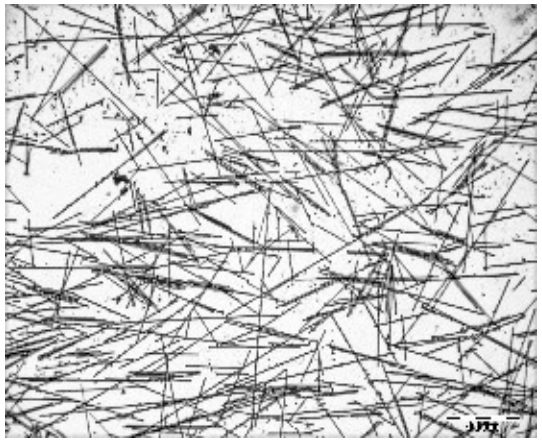
1100 rpm



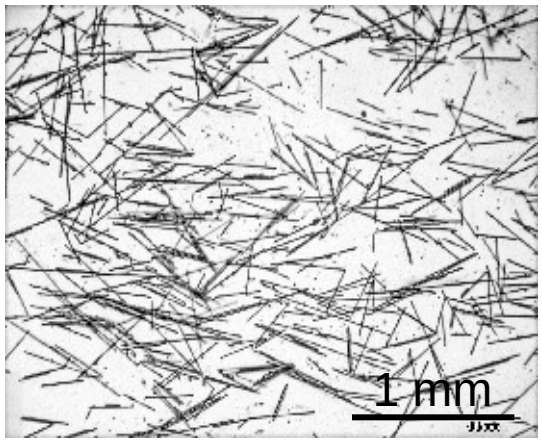
18 Nm/cc: 600 rpm



900 rpm

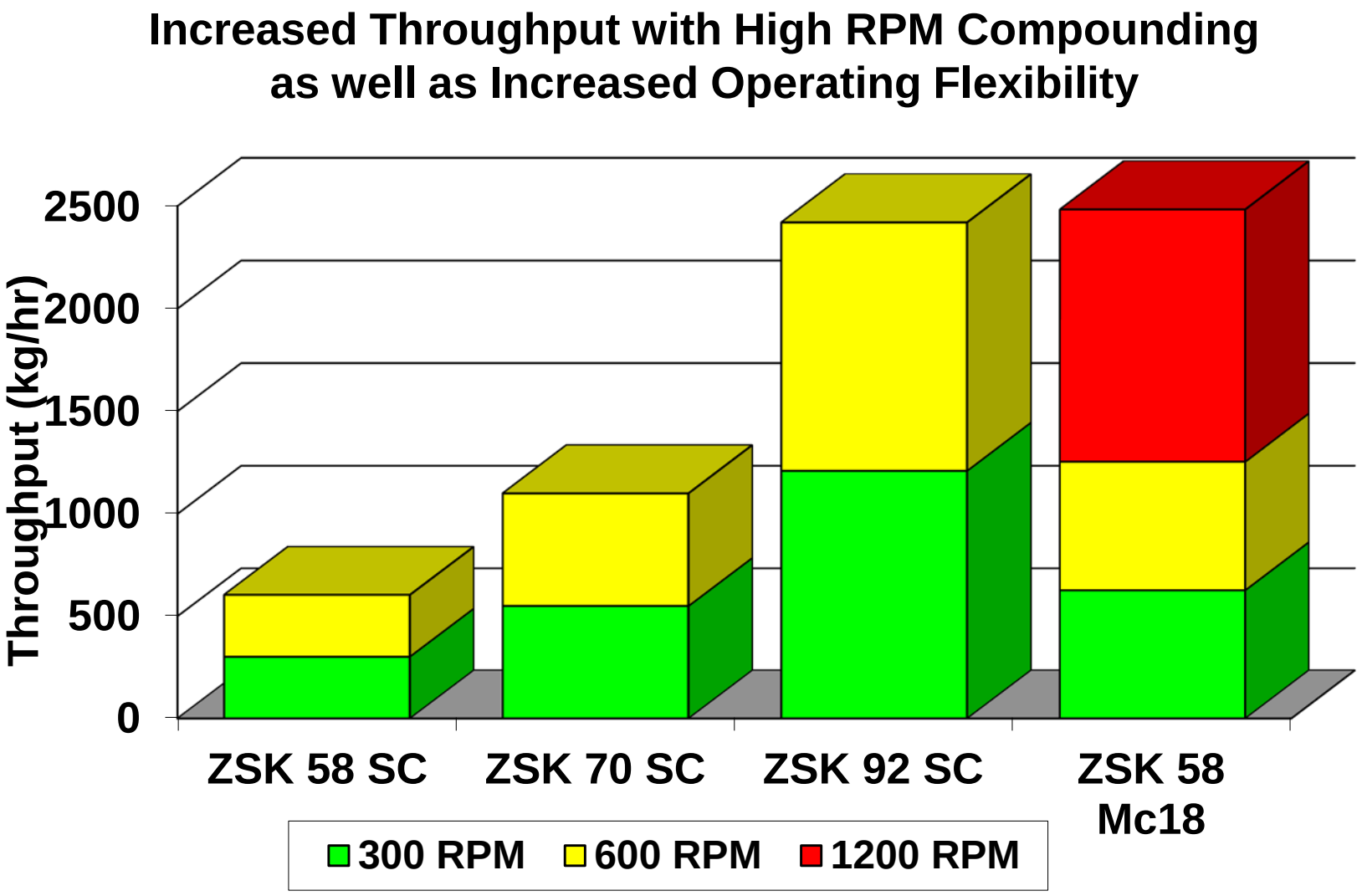


1100 rpm



coperion
confidence through partnership

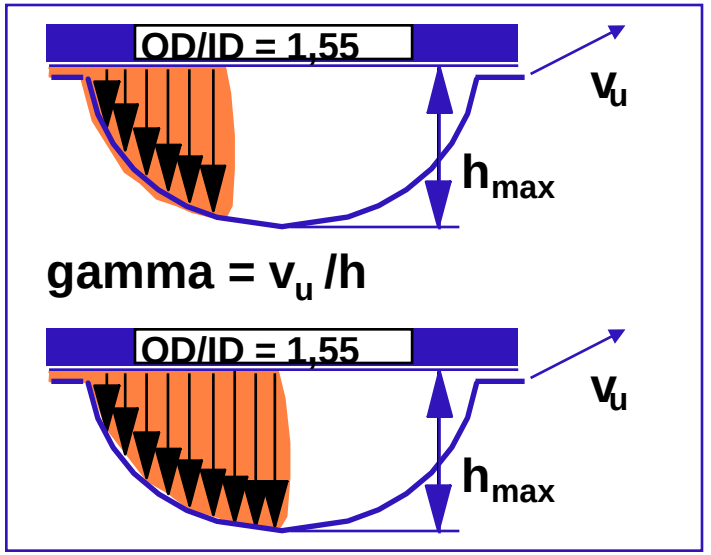
Compounding of Filled Engineering Resins



coperion
confidence through partnership

Advantages of Higher Torque

- Utilize higher % fill factor
- Reduced average shear
- Lower material temperature
- Typically lower residence time

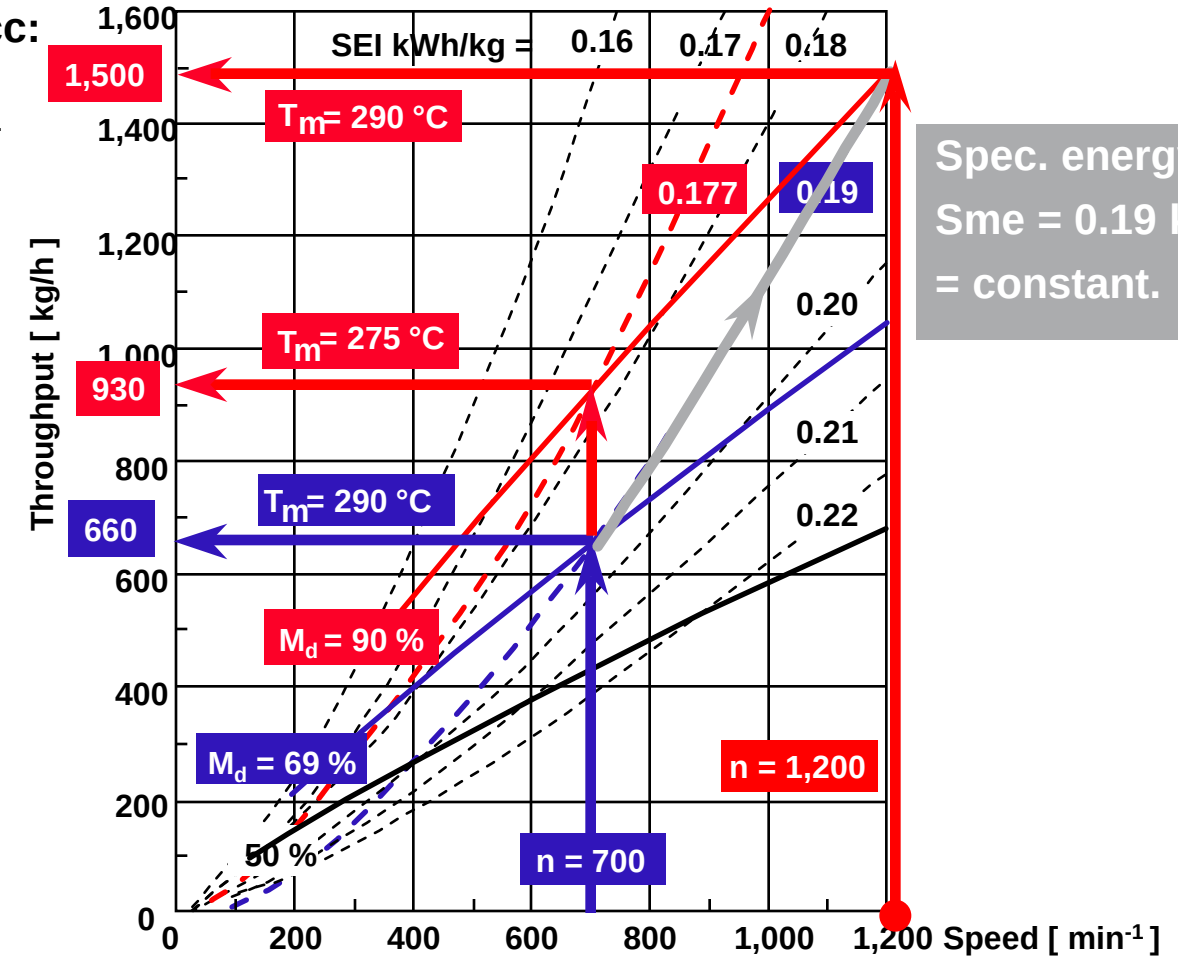


- Reduced stress on product: Improved Product Quality/Energy Efficiency
- Enables utilization of higher screw rpm: Improved Productivity

Impact of Torque on Performance
High Torque Lowers SME (SEI) and Improves Quality

ZSK 58 11.3 Nm/cc:
P = 314 kW
n_{max} = 1,200 min^{-1}

Product:
ABS

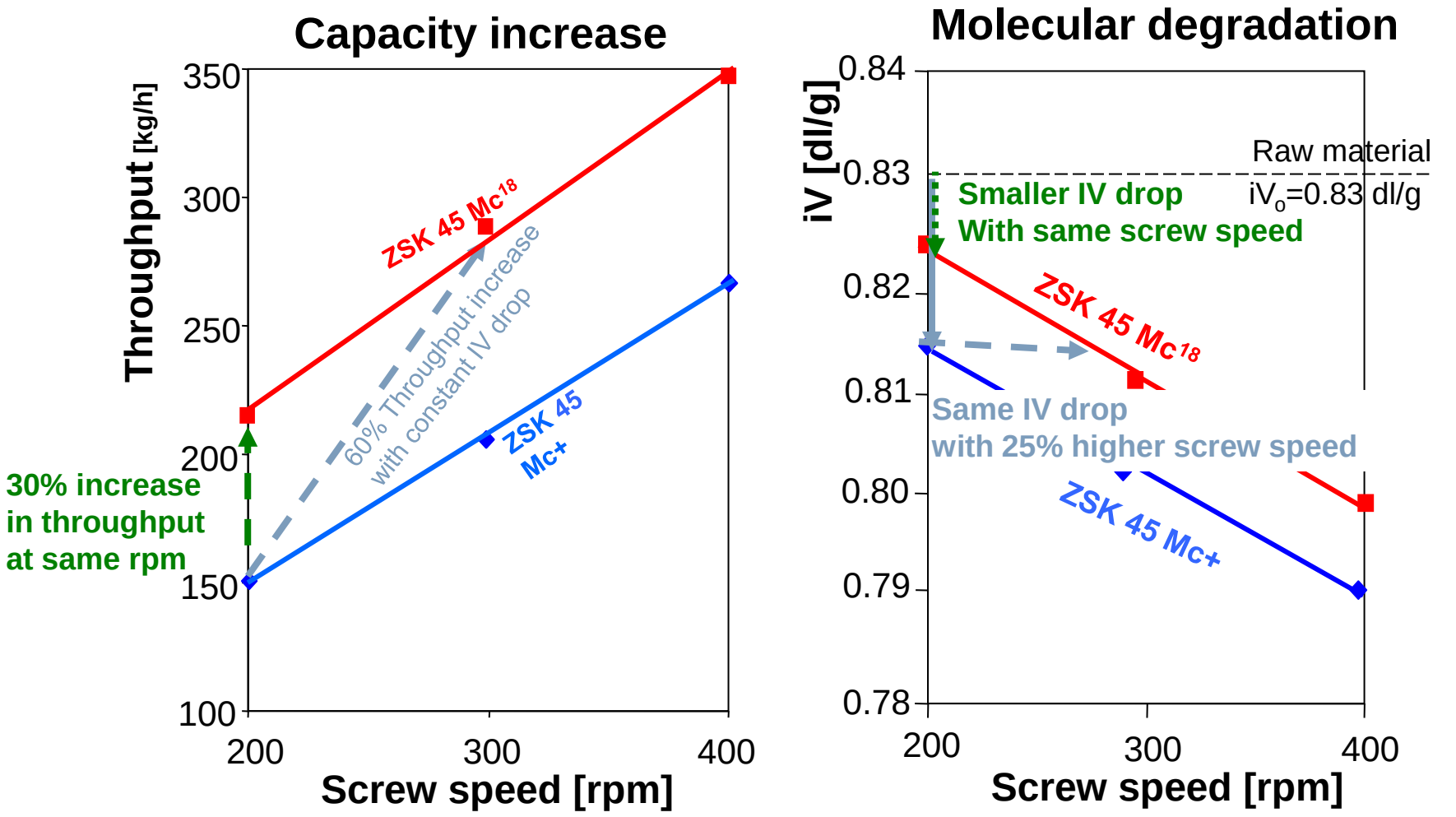


Spec. energy
Sme = 0.19 kWh/kg
= constant.

coperion
confidence through partnership

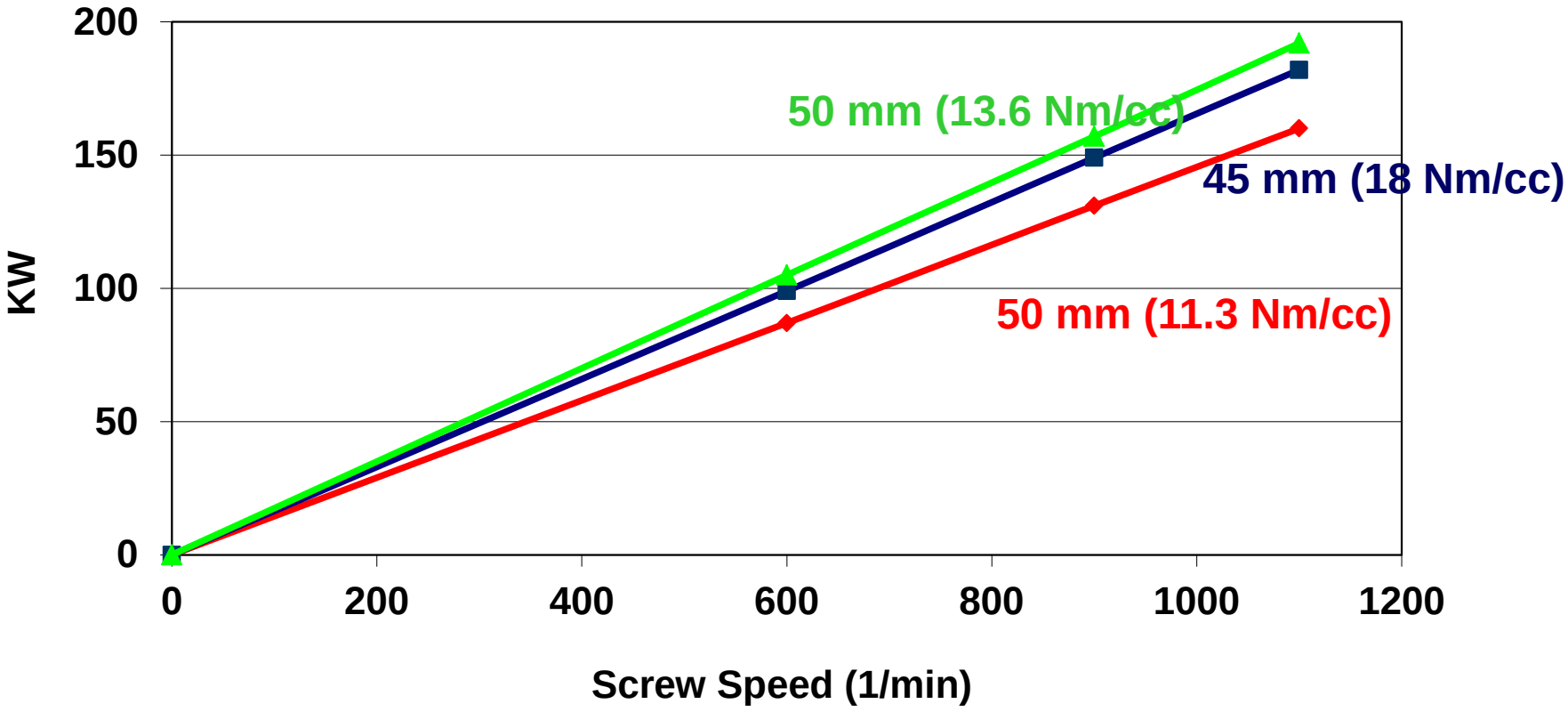
Basics for producing and compounding of PET

ZSK 45 Mc^{18} – 60% throughput increase in PET compounding



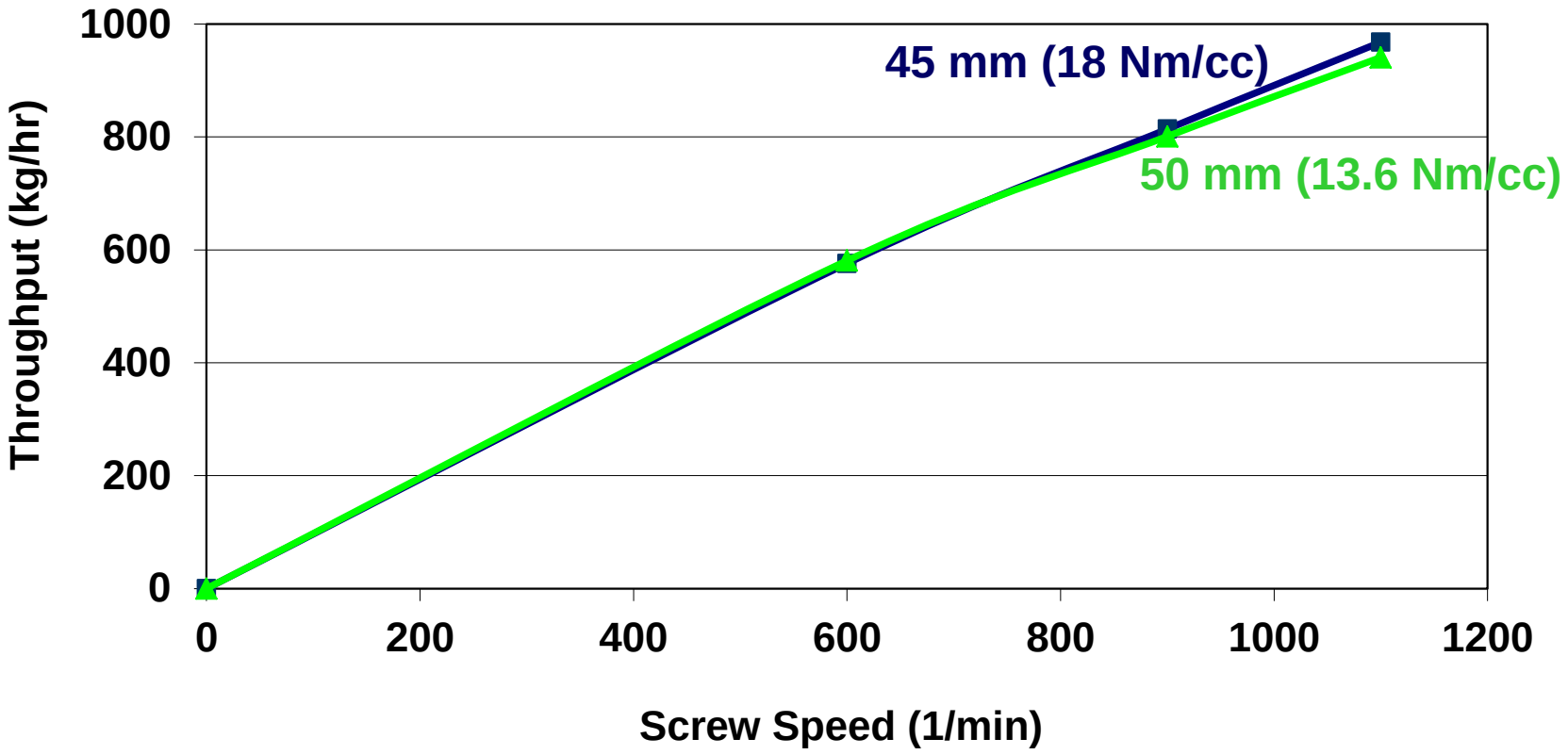
coperion
confidence through partnership

Impact of Torque on Compounding Line Extruder Size
KW vs. rpm at 85% Torque



coperion
confidence through partnership

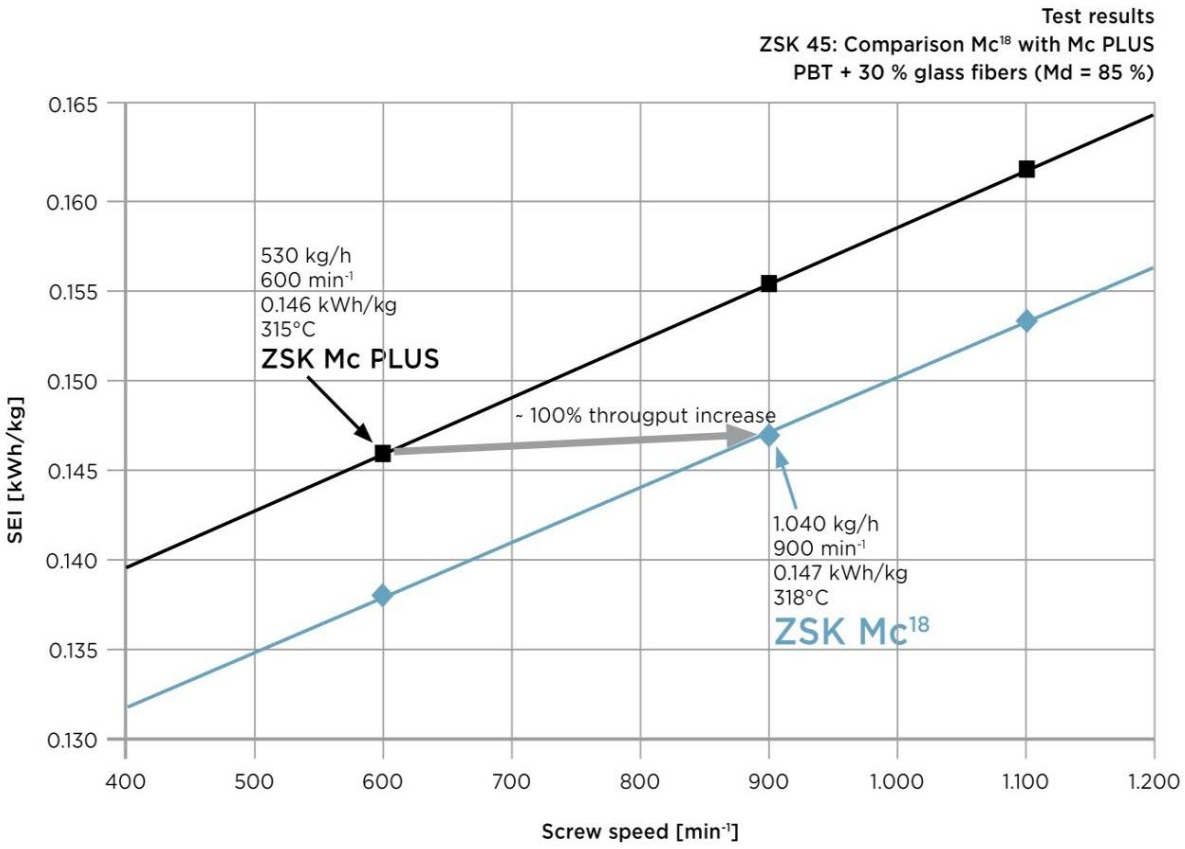
Impact of Torque on Compounding Line Extruder Size Rate vs. rpm at 85% Torque

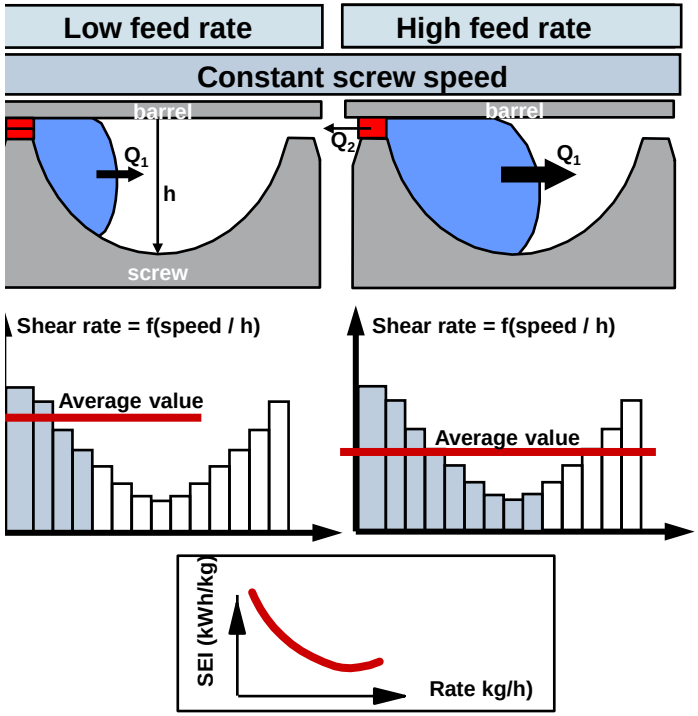


coperion
confidence through partnership

ZSK Mc^{18} – Advantages Summary

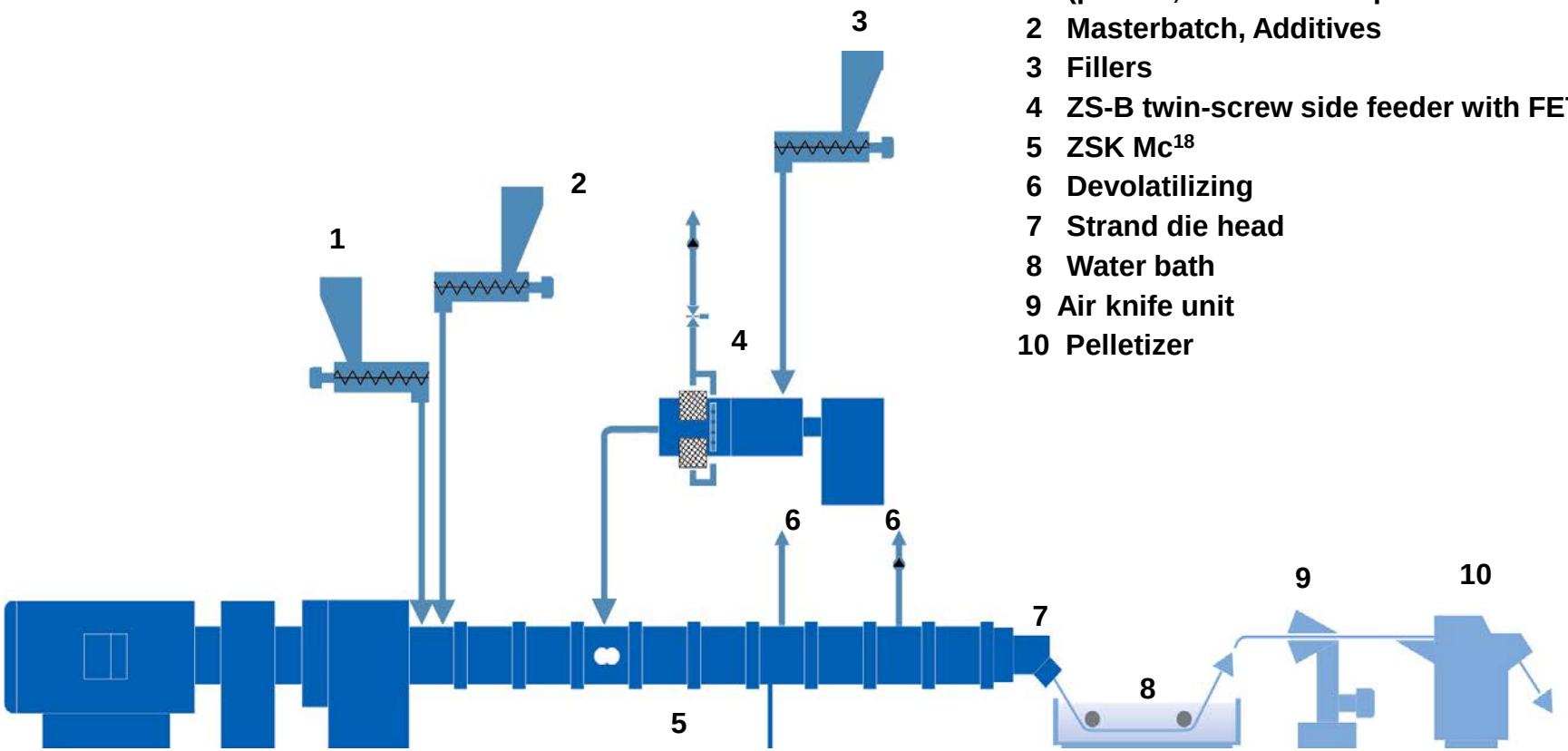
Throughput increase of up to 100% for constant Specific Energy Input (SEI)





coperion
confidence through partnership

Feed Enhance Technology
Example: Talc Filled PP

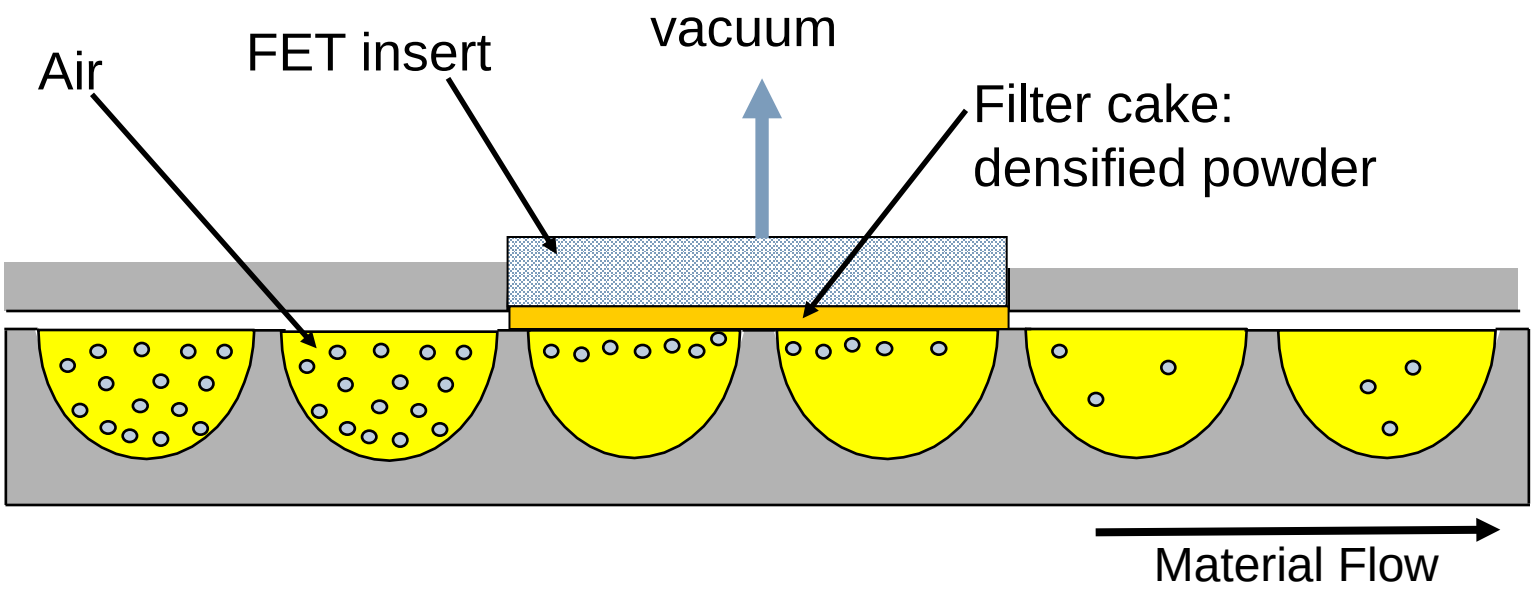


1 Polymer
(premix, alternative separate feeders)
2 Masterbatch, Additives
3 Fillers
4 ZS-B twin-screw side feeder with FET
5 ZSK Mc^{18}
6 Devolatilizing
7 Strand die head
8 Water bath
9 Air knife unit
10 Pelletizer

coperion
confidence through partnership

Feed Enhancement Technology (FET):

Solids conveying is improved by applying vacuum in the feed zone to a wall section which is porous and permeable to gas.

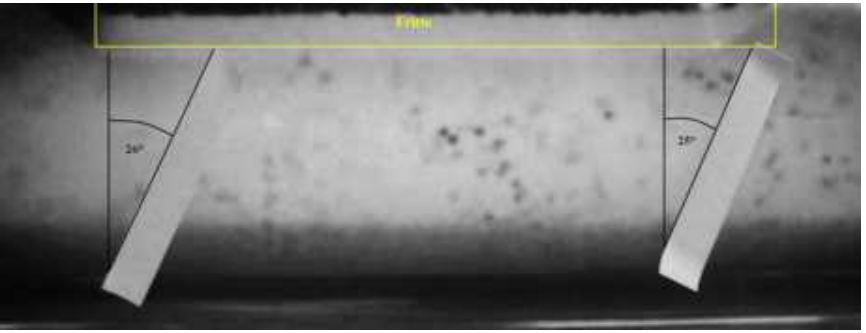


Effects:

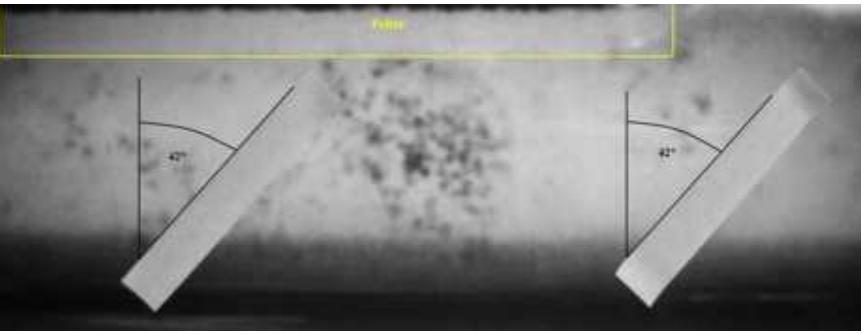
- air is removed → higher bulk density
- friction is changed in the area of insert

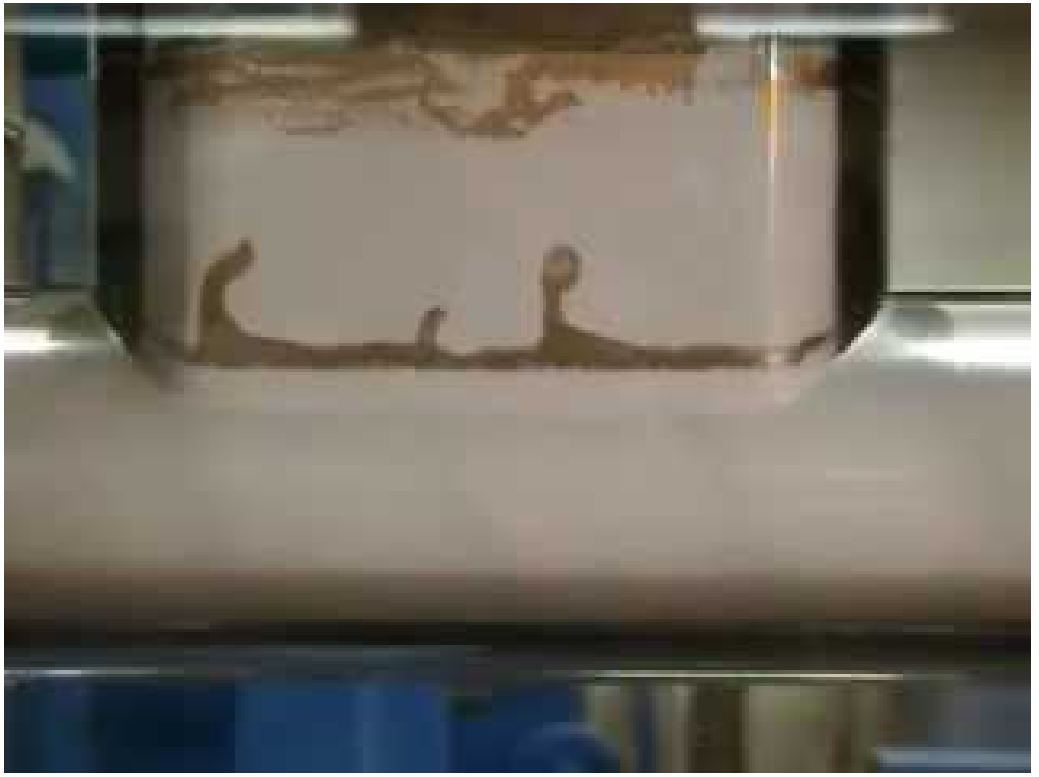
Feed Enhancement Technology: Demonstration

FET Off: Conveying angle ~ 20°



FET On: Conveying angle ~ 40°

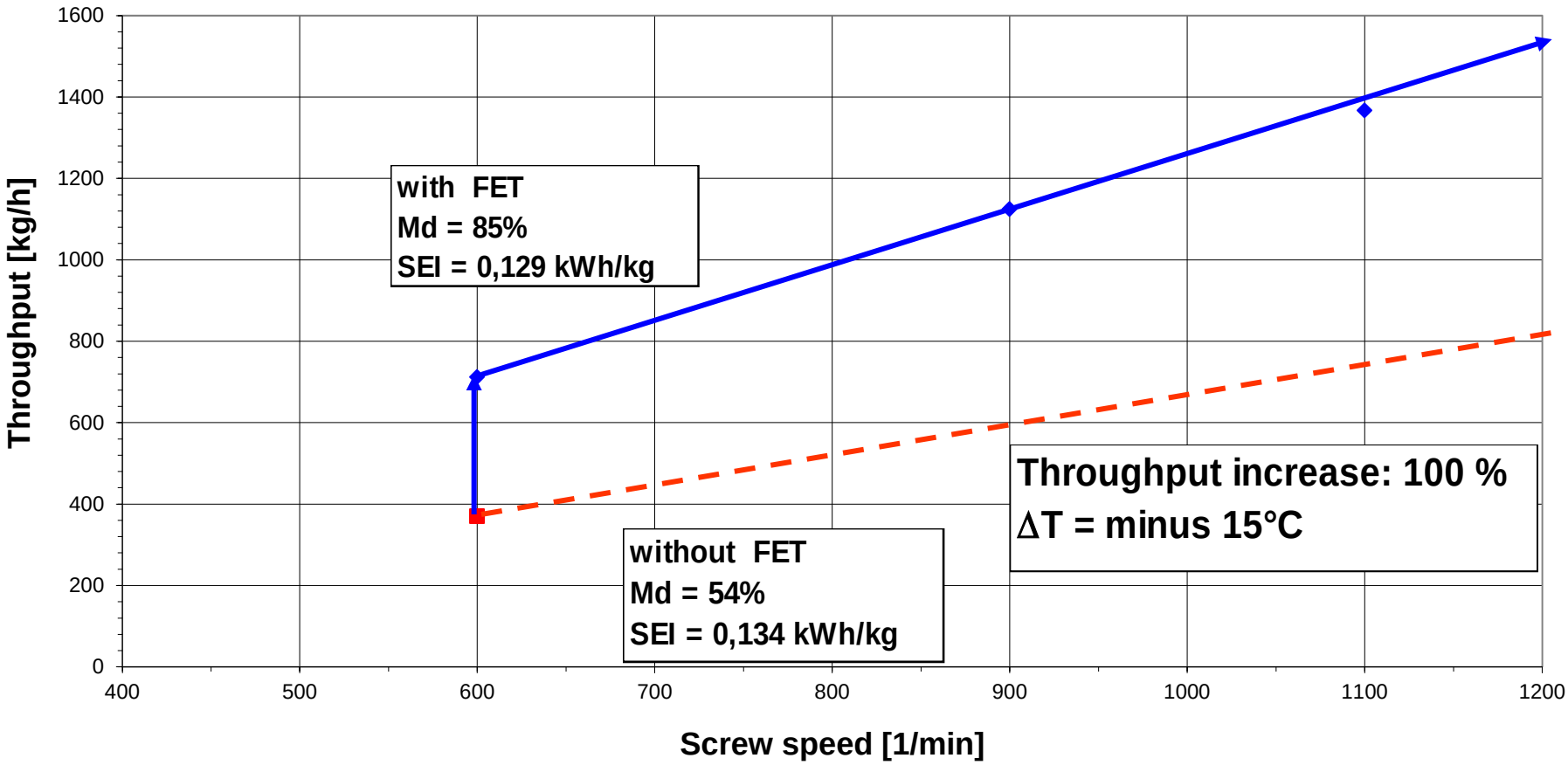




Flow Direction

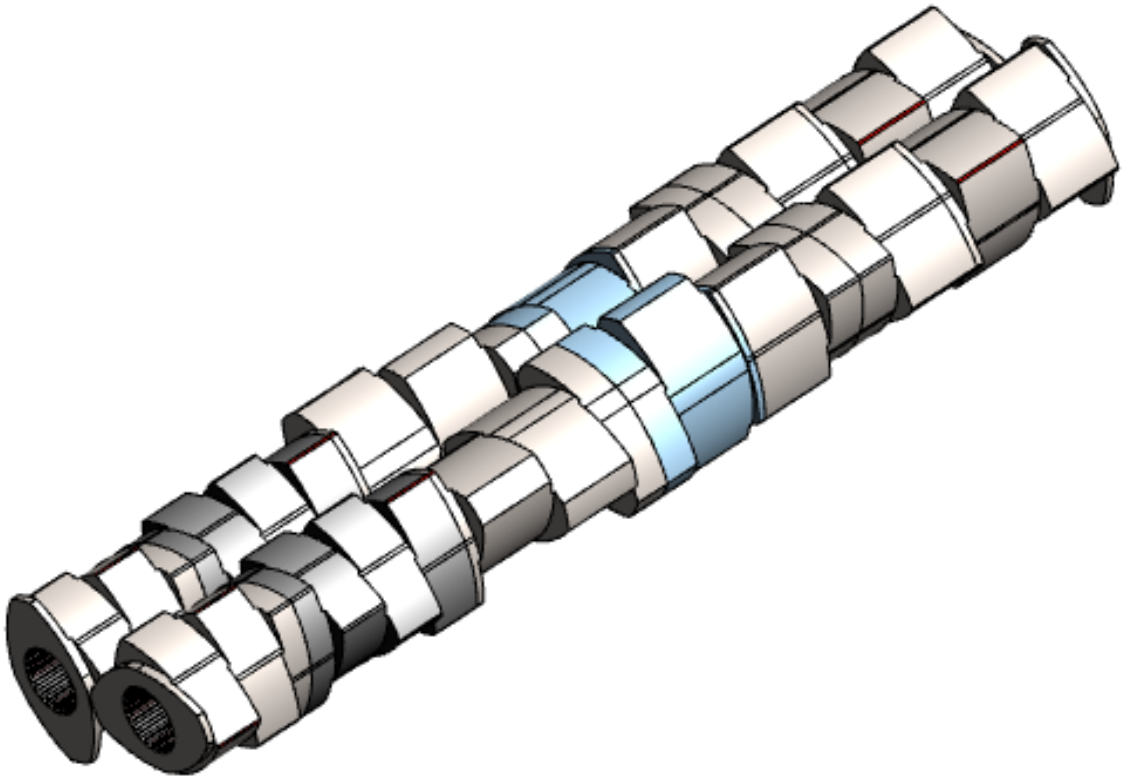
coperion
confidence through partnership

PP + 40% talc (Luzenac 1445)
45 mm (18 Nm/cc) with FET: Double the Rate!

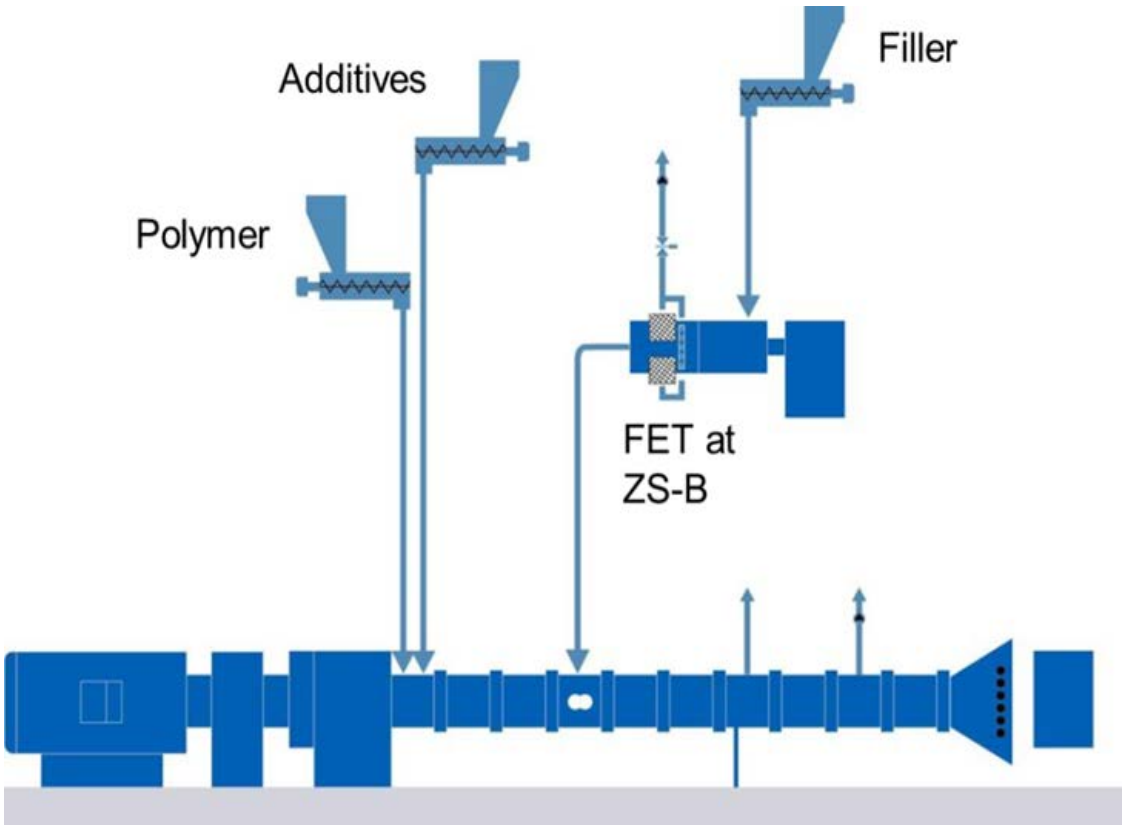


coperion
confidence through partnership

Involuted screw elements for increasing throughput of highly filled materials



Impact of process conditions and screw design
PP compounding



ZSK 58 Mc^{18}:

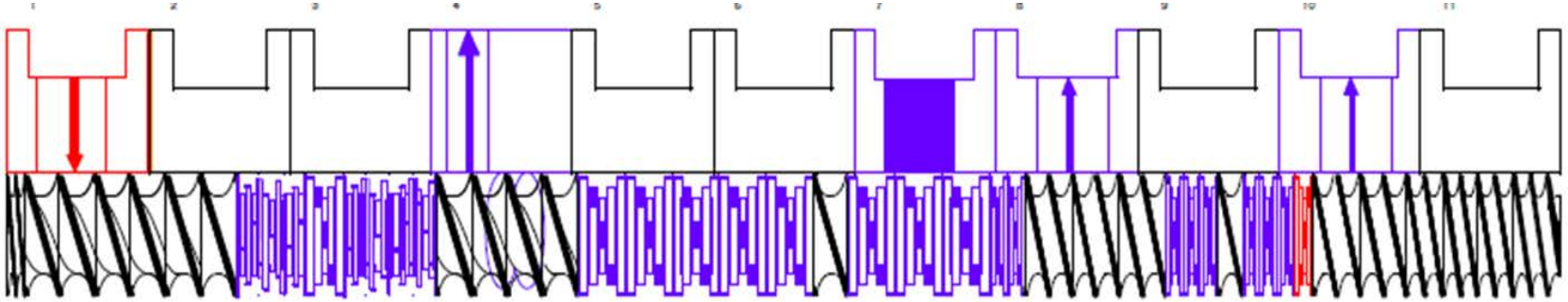
PP MI 8 + 70 % CaCO3

(1,3 µm, Coating 1,6%)

coperion
confidence through partnership

Impact of process conditions and screw design

Significant influence of screw configuration (Rate & Quality)



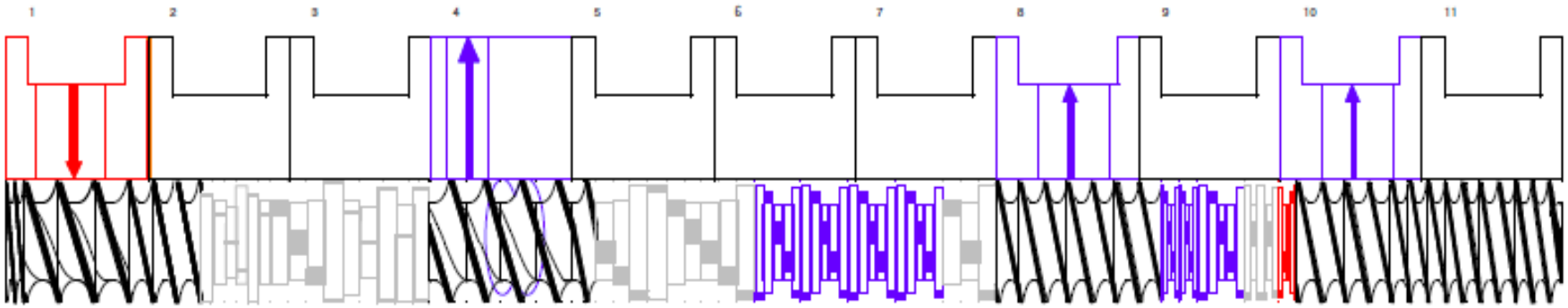
Standard Screw Elements

Max 550 kg/h

coperion
confidence through partnership

Impact of process conditions and screw design

Significant influence of screw configuration (Rate & Quality)



Max 900 kg/h

coperion
confidence through partnership

Summary

ZSK58Mc^{18}

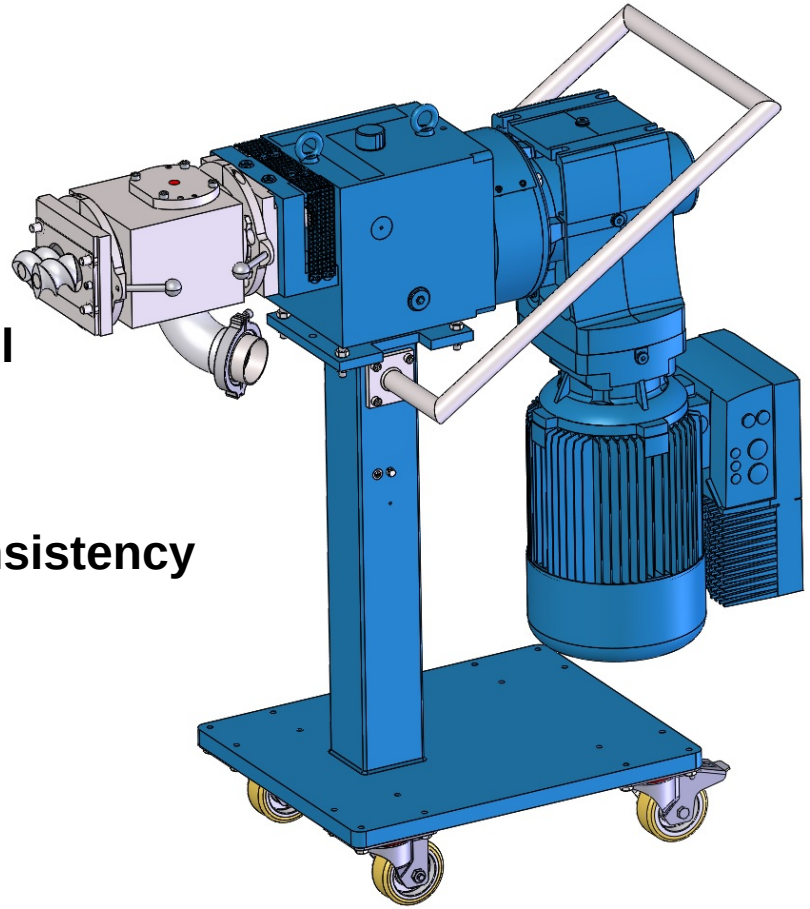
Recipe No.	Recipe	Max. Rate Standard-Screw profile	Max. Rate New Screw profile (Involute)	Rate increase
4	PP MI 8 + 70% CaCO3	550 kg/h	900 kg/h	+60 %

ZSK92Mc^{18}

Recipe No.	Recipe	Max. Rate Standard-Screw profile	Max. Rate New Screw profile (Involute)	Rate increase
5	PE MI 20 + 80% CaCO3	2200 kg/h	3000 kg/h	+35 %

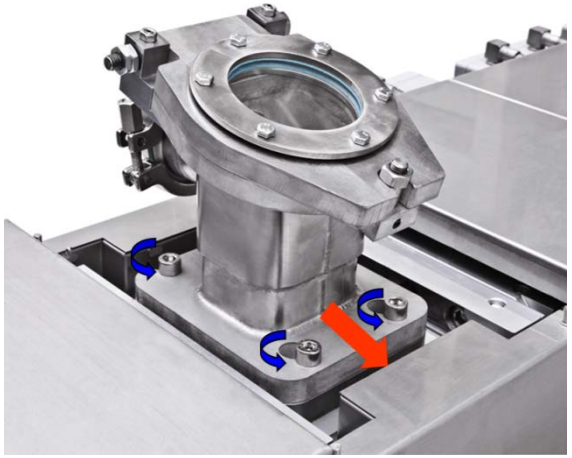
Twin-screw Side Venting (ZS-EG)

- **Effective Degassing**
- **Safe operation at higher degree of fill**
- **Improves compound quality and consistency**
- **Lowers production costs**

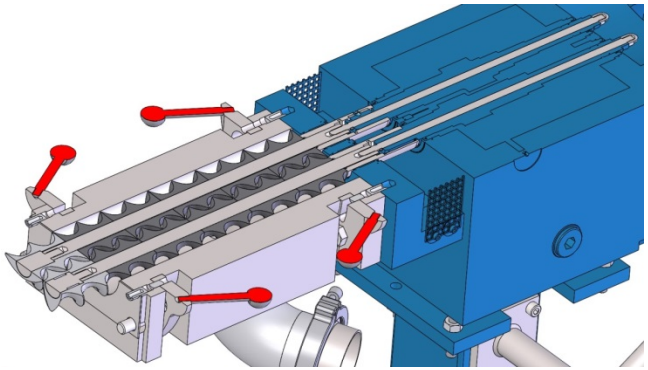


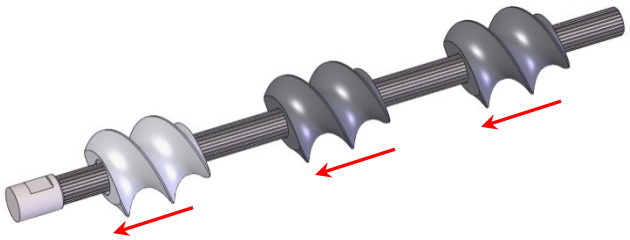
coperion
confidence through partnership

Side degassing unit: type ZS-EG

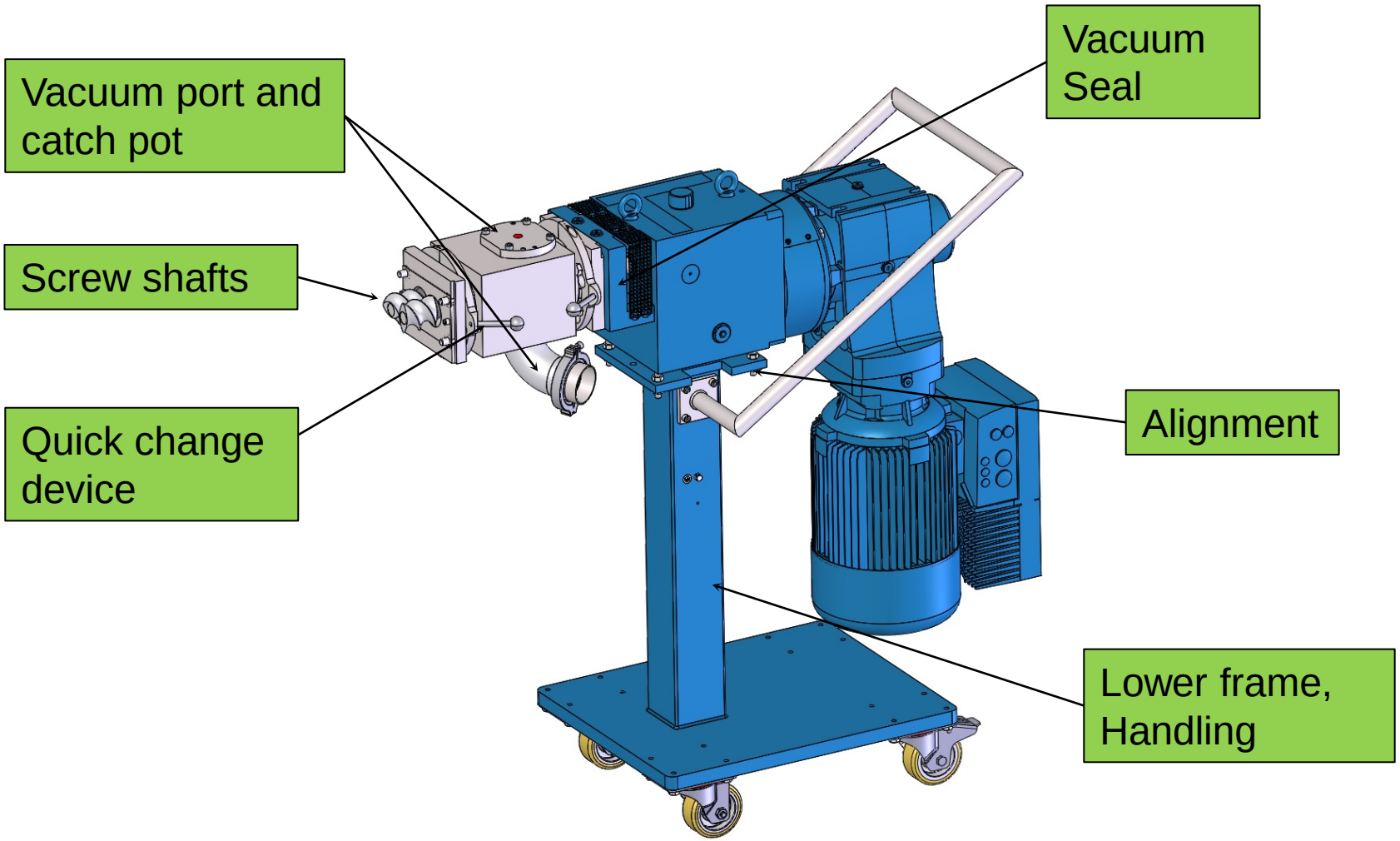


- Standardized unit
- Higher throughput
- Lower downtimes for cleaning and maintenance
- High and uniform product quality
- Lower production costs (faster/simpler color changes)
- Increased machine safety





Side Vent Stuffer (ZS-EG)



Twin Screw Side Degassing Unit (ZS-EG): Customer Feedback

"**Higher throughput** when processing through the use of a twin screw degassing unit because the gas flow channel is constantly open".

"In addition the new ZS-EG generation increases plant output due to **lower downtimes for cleaning and maintenance**".

"We achieve **high and uniform product quality** in the manufacture of polycarbonate compounds using a ZS-EG since material cannot accumulate in the twin screw degassing unit and fall back into the processing zone".

"**Production costs are also lower** since colour changes are simpler and quicker with **less clean-down work**".

"We benefited from the **increased machine safety** offered by the new ZS-EG configuration".

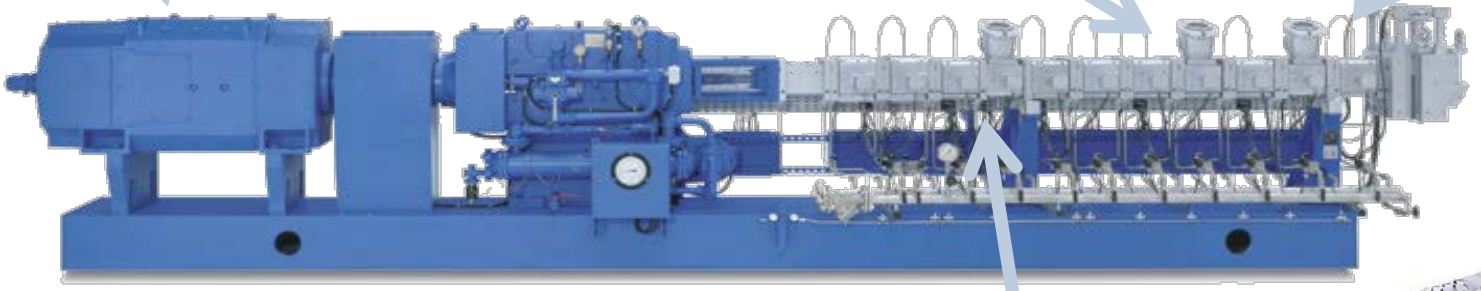
Extruder Screw Elements

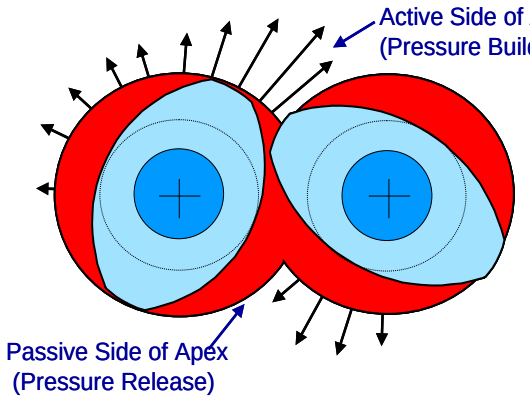
Coperion ZSK Extruder Wear
Complex Process & Mechanical System in Motion

High Speed & Torque

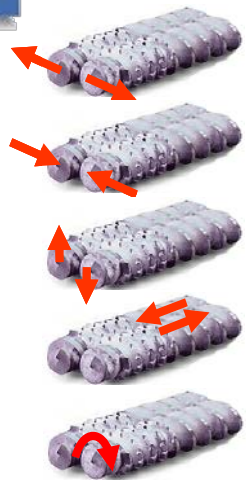
Barrel Wear

Discharge Pressure



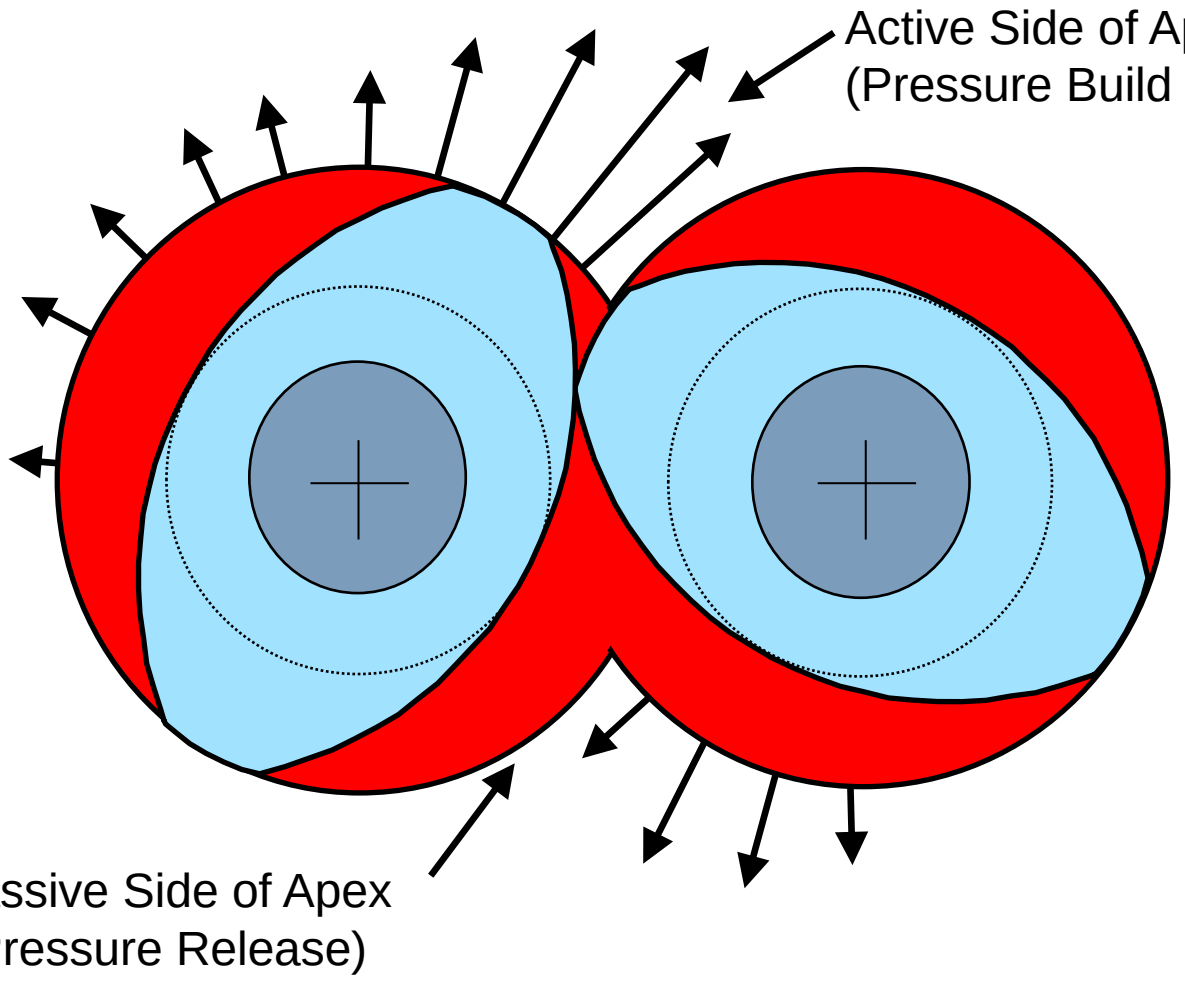


Screw Wear



coperion
confidence through partnership

Schematic Representation -
Radial Pressure Profile of the ZSK Extruder



ZSK Twin Screw Extruder Screw Wear

Wear pattern	Displacement of screw shafts	Explanation
		**Outward forces**
		**Inward forces due to the elasticity of the melt**
		**When the diameter of the screw is reduced very much, screws tend to climb up onto each other.**
		**Axial displacement of screw shafts.**
		**Twisting of one screw shafts.**

coperion
confidence through partnership

ZSK Screw Element Materials
The Types of Wear

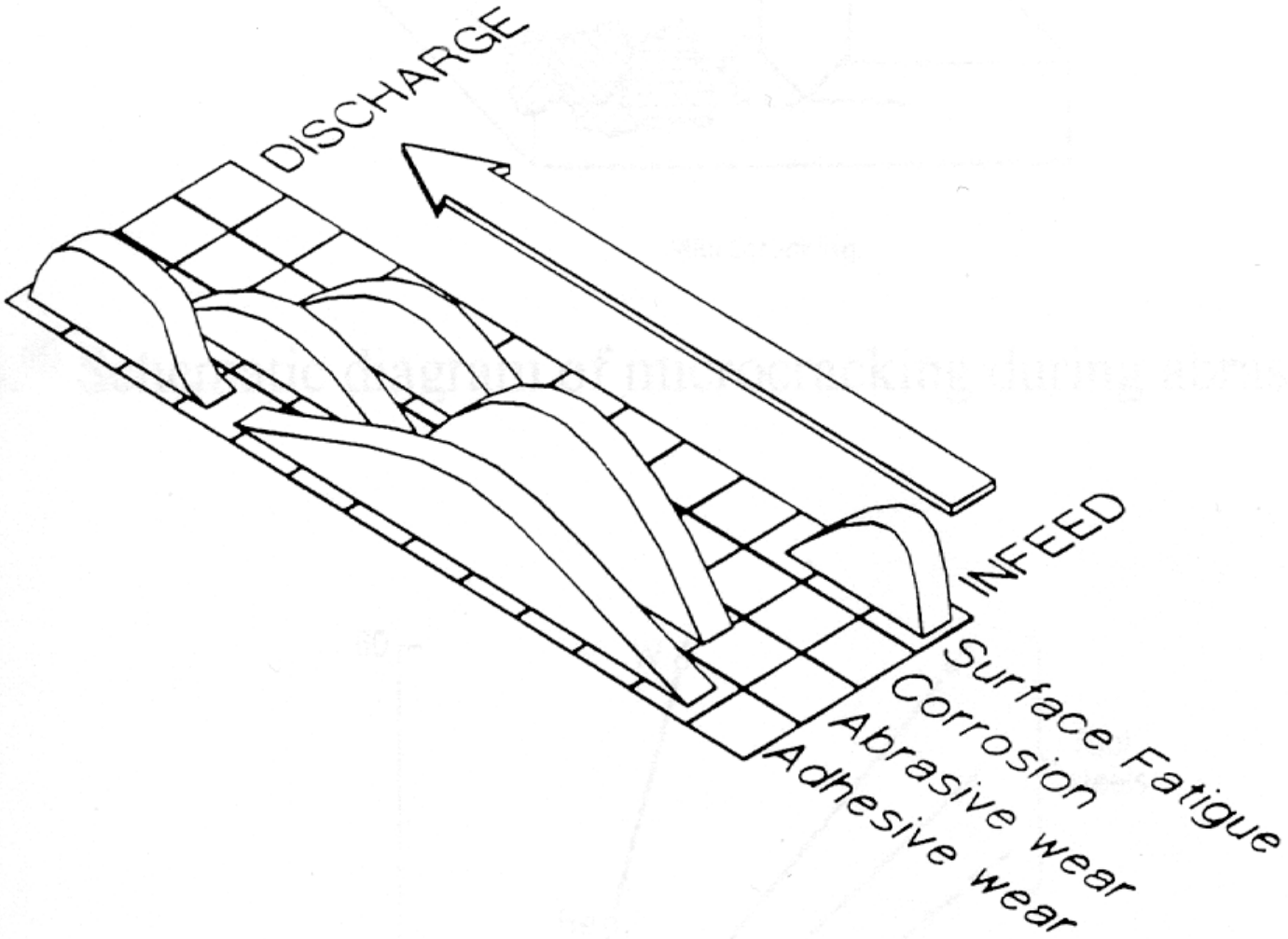
Mechanical Wear

- abrasion (product/metal)
- erosion (product stream)
- adhesive (metal/metal)
- surface fatigue (product/metal)

Chemical Wear

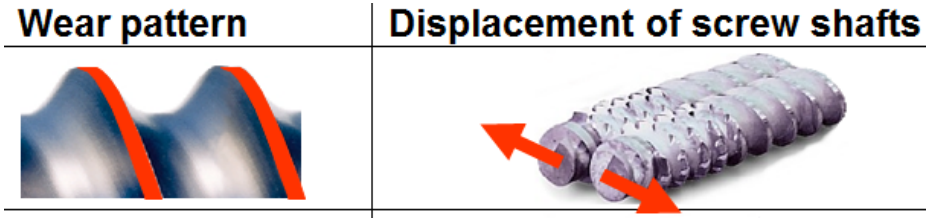
- corrosion (product)

Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length



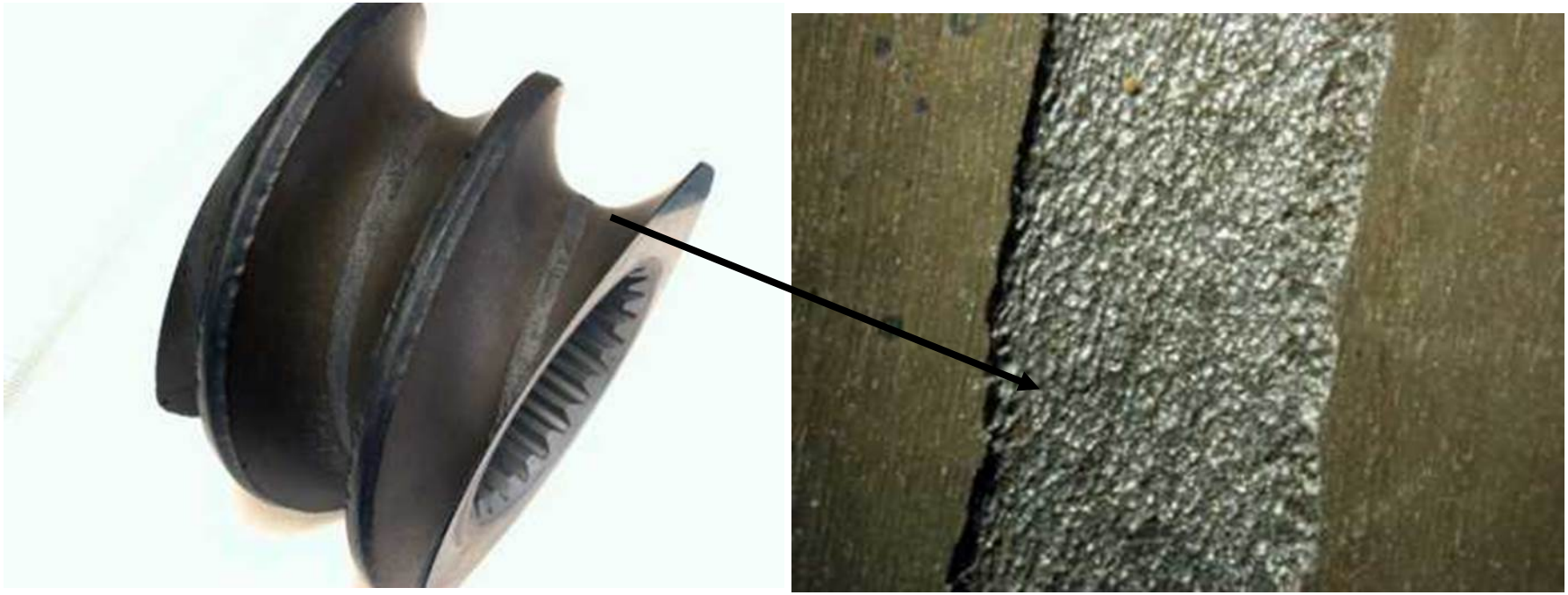
Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length

Wear at the discharge of the ZSK

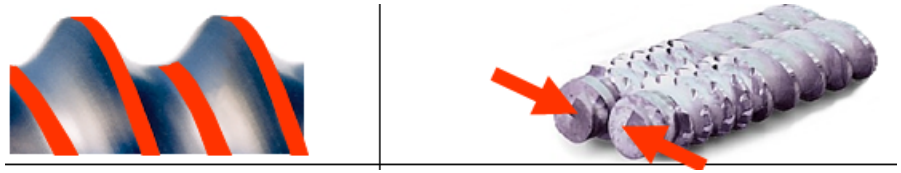


coperion
confidence through partnership

Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length

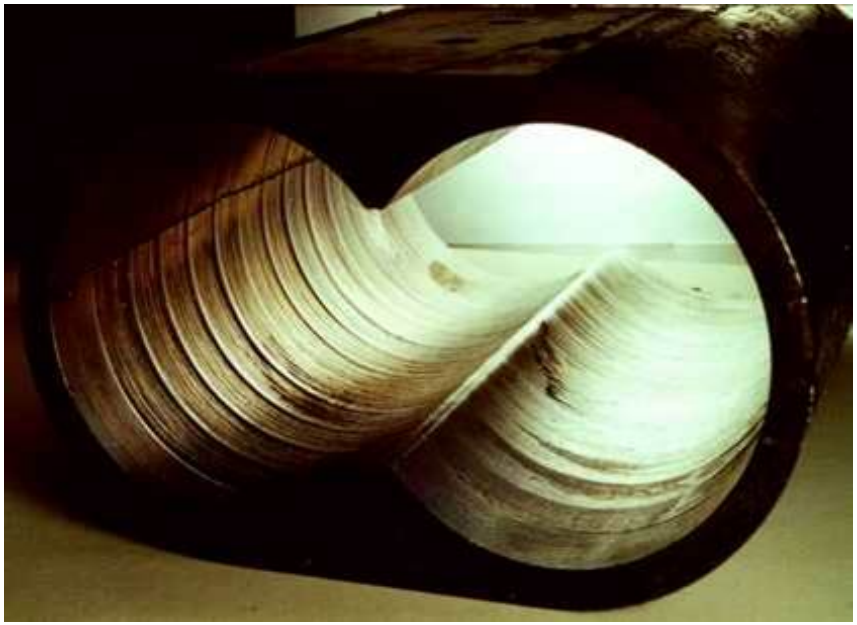


ZSK-92 running technical plastics



coperion
confidence through partnership

Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length



melting zone from runnning PA (polyamide) + 30% glass fiber

Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length

ZSK-58 running PVC + fillers

ZSK-32 running technical plastics + additives

coperion
confidence through partnership

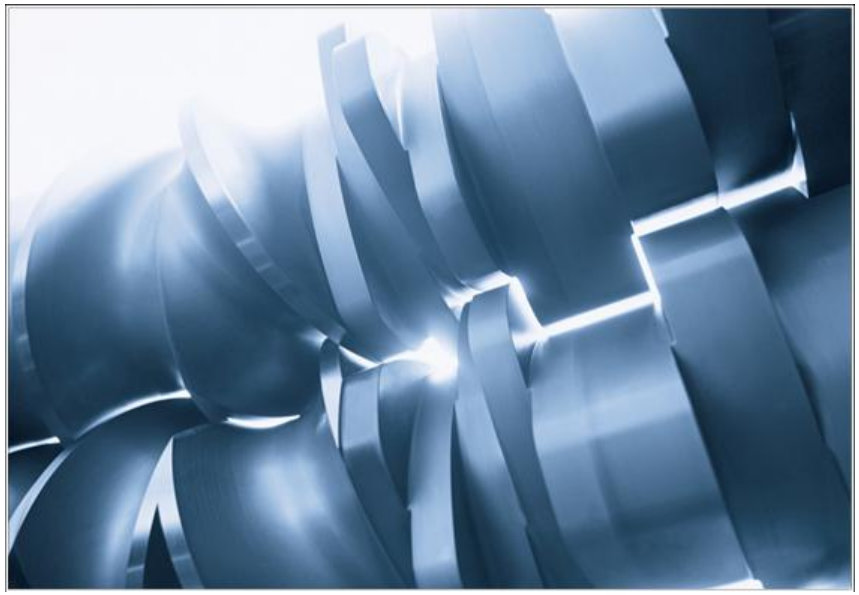
Coperion ZSK Screw Element Materials
Typical Wear Mechanisms Along the Barrel Length

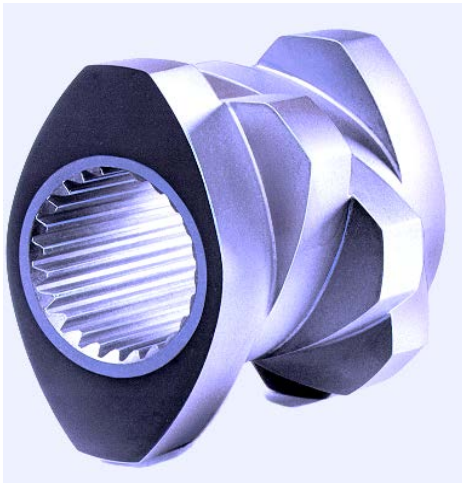
Combination of abrasive wear and corrosion

coperion
confidence through partnership

Coperion Corporation
Extruder Screw Elements

- Nitrided
- Stainless
- Thru Hardened
- Powder Metallurgical
- Crest Welded





coperion
confidence through partnership

Coperion ZSK Screw Element Materials
Screw Wear Protection Processes

Process	Application Examples
Nitriding	Nitralloy Steel
Solid thru-hardened	Stainless Steel, Tool Steels
HIP Material	CPM9V, CPM10V, S90V, Coperion Material “25” (usually bi-metalic with a soft core)
Solid Screw with Welded Coating	CS base material with Tungsten Carbide weld
	Stainless Steel with Colmonoy 4 welded crests
	Inconel with Colmonoy 4 welded crests

Screw Elements Styles

coperion
confidence through partnership

Coperion ZSK Screw Element Materials

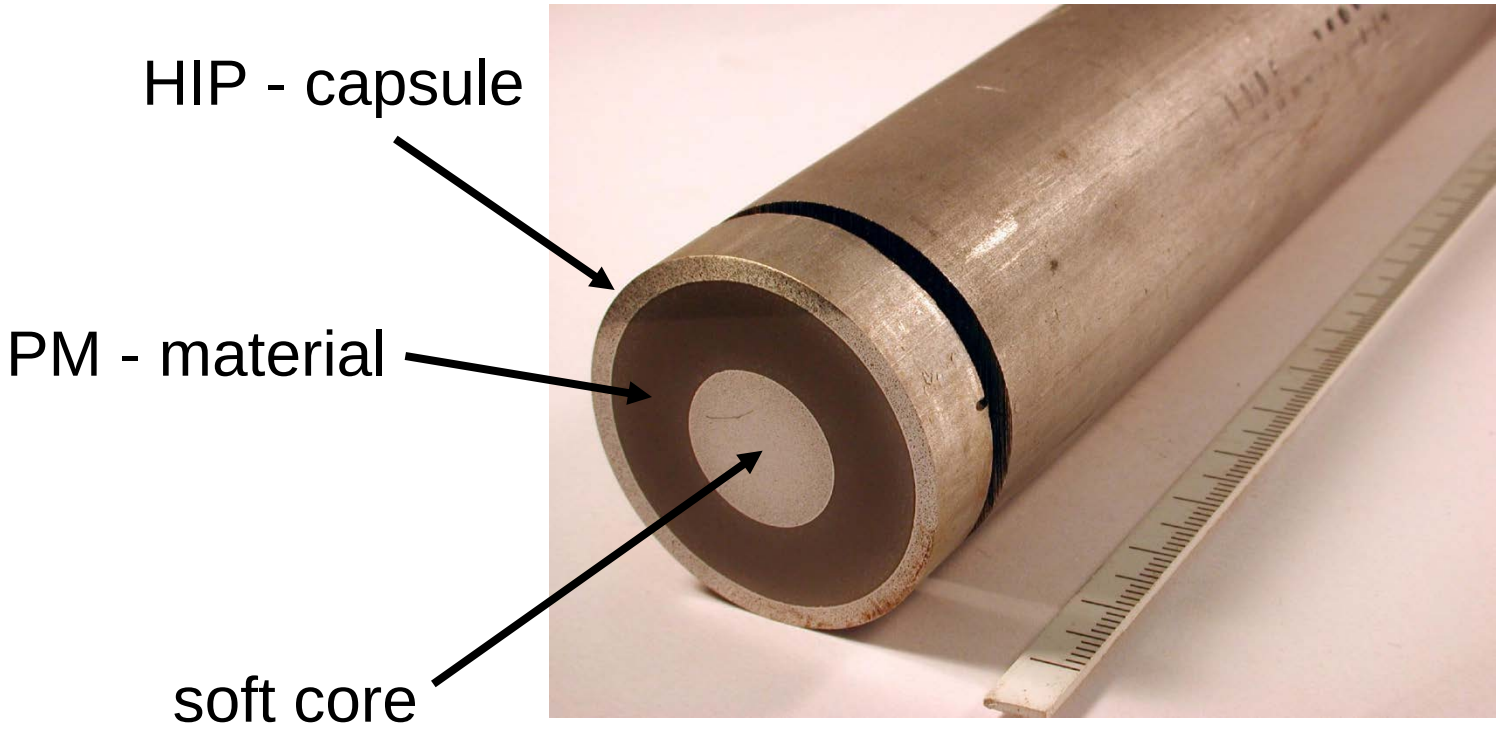
Material Code	Description	Hardness HRC	Wear Resistance	Corrosion Resistance
00	Nitraloy 135 (nitrided)	65-70	X	X
05	Thru-Hardened Stainless Steel	48-52	XX	XXX
39	PM Tool Steel CPM9V (solid)	53-56	XXXX	XX
15	PM Composite Tool Steel CPM10V with soft core	59-61	XXXX	XX
25	PM Corrosion Resistant Tool Steel X235 with Stainless Steel soft core	59-61	XXXX	XXXX
212	Nitraloy with WPR25 (carbide filled) crestweld	58-60	XXX	X
229 (16)	Inconel 625 with WPR22 (Colmonoy 4) crestweld	40-44	XXX	XXXXX
245 (28)	17-4 PH SST with WPR22 (Colmonoy 4) crestweld	40-44	XXX	XXXX
236	Carbon Steel Body fully welded with WPR25 (carbide filled)	59-61	XXXXX	XXX
271 / 272	PM Composite Tool Steel CPM420V (272 with soft core)	56-58	XXXX	XXXX

ZSK Extruder Screw Element Material Details

Type	Description
Material “05”	Solid thru-hardened stainless steel Special proprietary DIN Grade 1.4122-WPH (special formulation with over 15% Chrome and additives for corrosion resistance and high temperature)
Material “15”	CPM10V (DIN Fe69, AISA A11) with carbon steel soft core Nominal base composition: C 2.5%, Cr 5.3%, Mo 1.3%, V 9.8%, Fe balance
Material “39”	Solid CPM9V (only for low torque applications (keyed shafts) or side feeders) Nominal base composition: C 1.8%, Cr 5.3%, Mo 1.3%, V 9%, Fe balance
Material “272”	CPM S90V with a carbon steel soft core Nominal base composition: C 2.3%, Cr 14%, Mo 1%, V 9%, Fe balance
Material “25”	Proprietary powder metallurgical stainless grade material HIPed onto a stainless steel soft core High Chrome content (over 20%) with Vanadium produces post HIP carbides for wear resistance concurrently with the high corrosion resistance

Coperion ZSK Screw Element Materials
Screw Element Composite Barstock with a soft core

Powder Metallurgical HIP Barstock



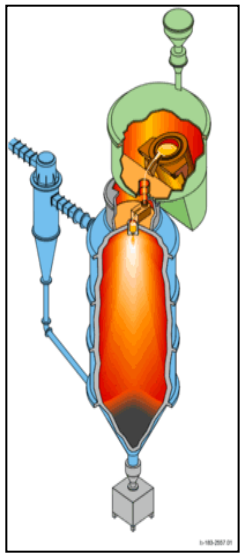
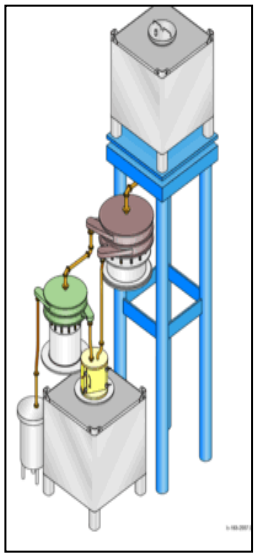
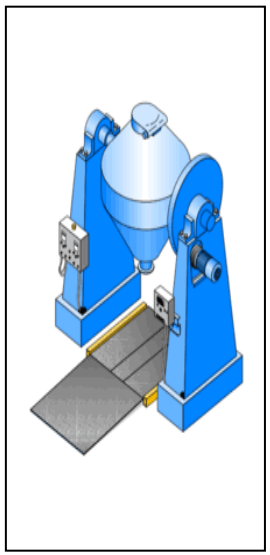
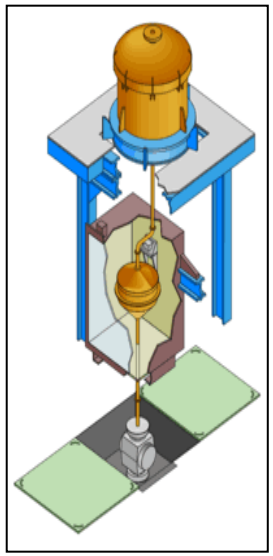
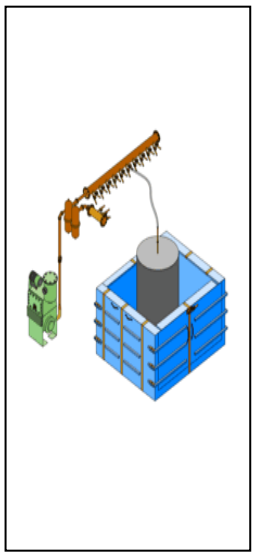
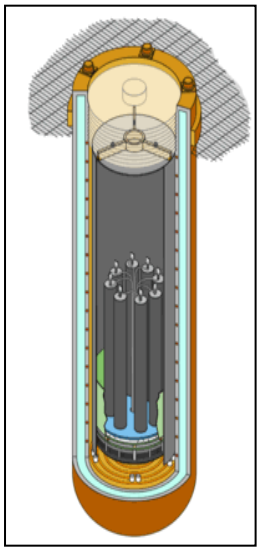
Coperion Screw Element Materials
HIP Manufacturing Technology

Hot Isostatic Pressing (HIPing) Process

> High Pressure (1,000 bar / 14,500 PSI)

> High Temperature (> 1,000 °C / 1,832 °F)

Atomization | Screening | Blending | Loading | Outgas | HIP Consolidation

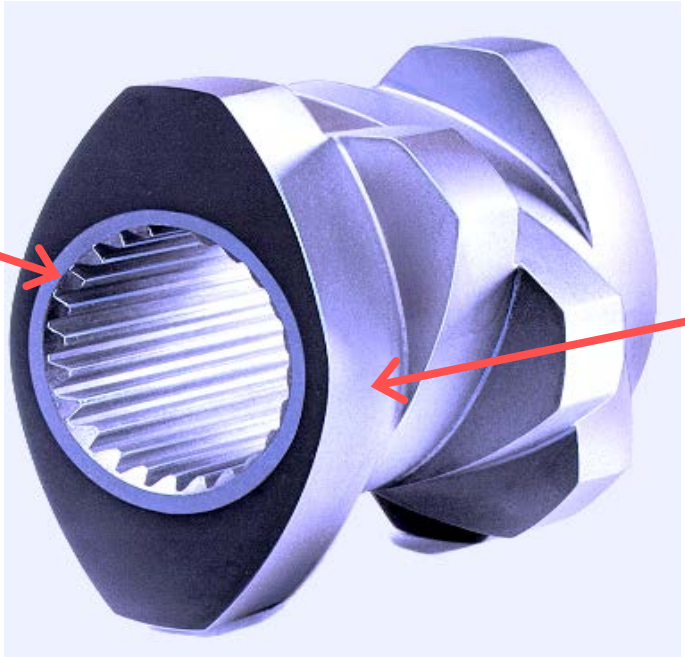







coperion
confidence through partnership

Coperion ZSK Screw Element Materials
Popular Softcore Screw Element Types

Material Code	Soft core	Outside PM Steel
15	Carbon steel	CPM 10V
272	Carbon Steel	S90V Stainless Steel
25	Stainless Steel	X235 Stainless Steel

Soft core steel sleeve



Through-hardened powder metallurgical (PM) steel, chromium and vanadium carbide based for wear life

ZSK Screw Element Materials
Screw Element Material “25”

- Basic wear and corrosion resistant screw element material for Coperion high torque ZSK extruders.
- Wear Resistance of this through-hardened Powder Metallurgical Stainless Steel material:
  - Over 20% Chrome and over 4% Vanadium content forming vanadium and chrome carbides after HIPing in the steel structure.
  - Hardness: 60 +5 HRC.
- Resistance to corrosion is based on the high chromium content.
- The elements are equipped with a metallurgical bonded Stainless Steel soft sleeve for spline accuracy and avoidance of cracking.

ZSK Screw Element Materials
Recommends for Soft core vs Solid Construction

- The high stresses of the extrusion process must be introduced uniformly from the screw shaft to the elements in order to avoid stress concentrations.

- Coperion first invented special design provisions so this uniform loading is assured. Coperion's wear resistant PM (powder metallurgical) elements are provided with **a soft sleeve in the area of the spline bore which is not hardened**. This assures that the spline is exactly straight and not distorted during the hardening process. As a result, the fit of the element on the spline provides **maximum contact surface and a minimum of stress concentrations**.

- Use of “solid” elements without the soft spline can result in serious shaft damage, and possibly extruder lock-up during operation, breaking shafts and gearbox internals. The “solid” inexpensive solution may end up costing much more in the long run.

ZSK Screw Element Materials
Risks for Soft Core vs Solid Construction

A through-hardened element without a soft core experienced a catastrophic cracking failure due to the high stress concentrations

ZSK Screw Element Materials
Recommends for Soft core vs Solid Construction

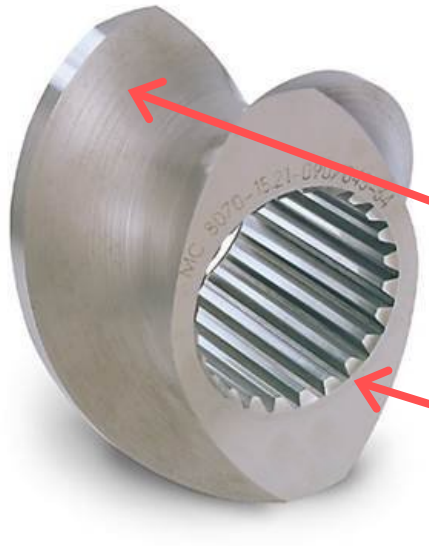
Material Application Chart		Keyway Shafts	SC Spline Shafts		MC Spline Shafts	
Material Type			SE	KB	SE	KB
39	CPM9V (solid)	OK	X* (low torque)	X* (low torque)	NO	NO
15 or 25	CPM10V or “25” with soft core	OK	OK	OK	OK	OK

SE = Screw Element KB = Kneading Block

X* = Use only for low torque applications or by prior experience

Coperion ZSK Screw Element Materials
Welded Screw Element Types

Material Code	Body	Weld Overlay
236	Carbon steel	Full TC body weld
245	17-4pH SS	Colmonoy 4 crest weld
229	Inconel 625	Colmonoy 4 crest weld

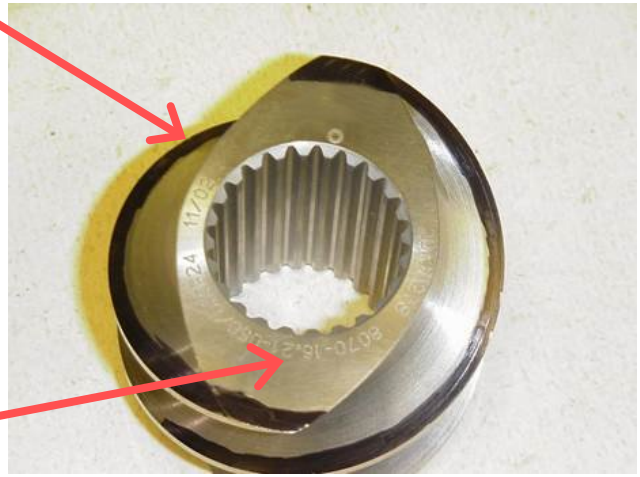


Crest Weld

or

Full Body &
Crest Weld

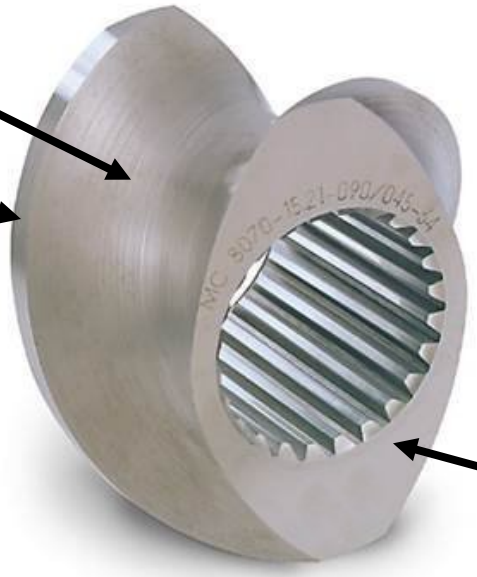
Body
Material



coperion
confidence through partnership

Coperion ZSK Screw Element Materials
Screw Element with fully welded overlay

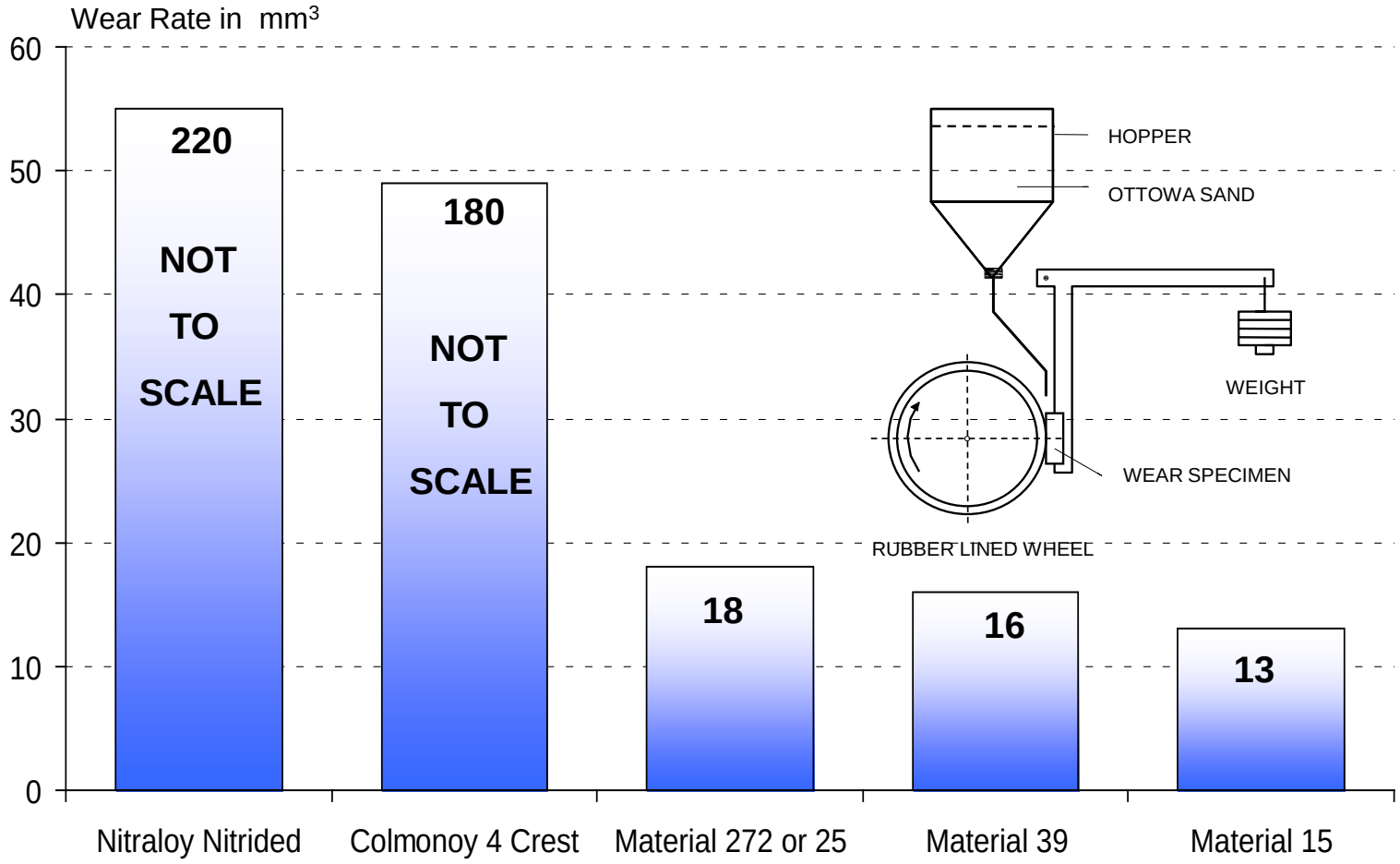
> Fully welded flights and fully welded crests
> Weld material is high tungsten carbide (>60%) in a corrosion resistant Ni-based matrix
> Weld overlay ~2.5 - 3mm



carbon steel body

- Wear resistance is based upon large tungsten carbide particles which are embedded in the NiCrBSi matrix
- Crest and body weldment is for extreme wear resistance
- Although ASTM wear test data is similar to Coperion Material Code “15”, actual wear resistance is superior, outperforming other materials by multiple lifetimes

Abrasive Wear Tests for Screw Material
ASTM-G65 Sand Abrasion Test



Note: The wear data are based on tests performed in our Materials Lab.
The exact wear rate relationships may vary for different applications.

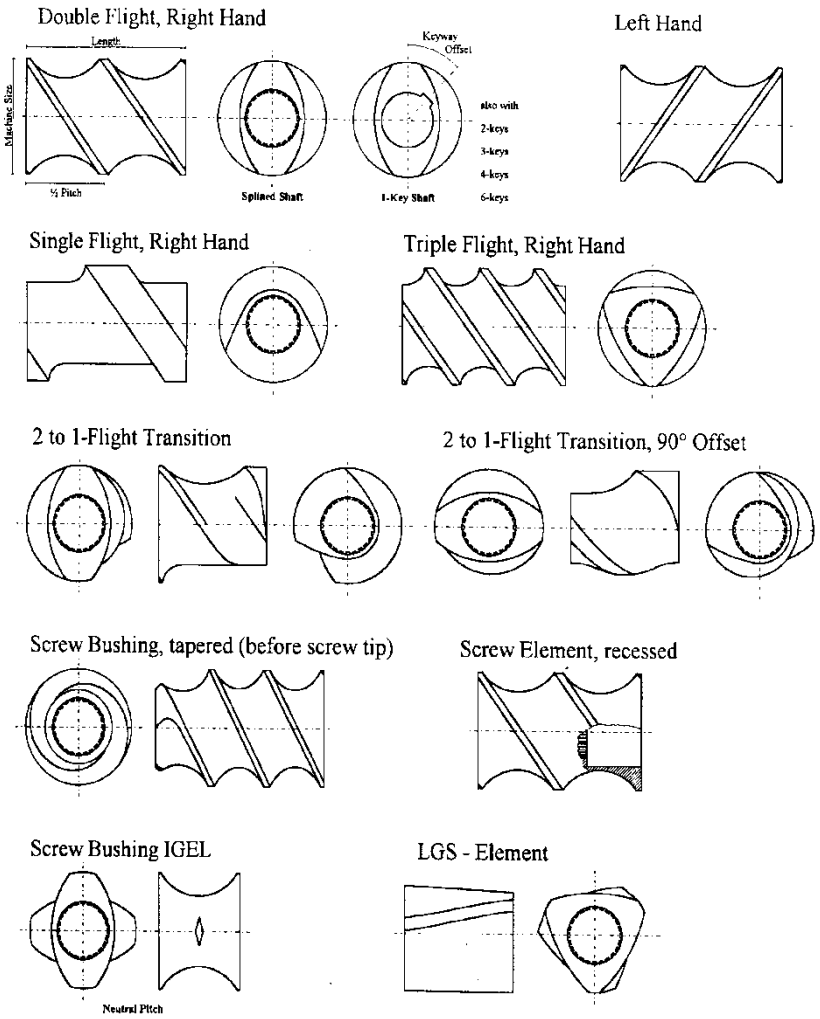
coperion
confidence through partnership

Coperion ZSK Screw & Barrel Material Adhesive Wear Compatibility

Screw Element Material			Barrel Adhesive Wear Compatibility					
Material Code	Description		Nitrided Steel	Cast "Vautid"	CPM10V	WPR-29	Ni-50/60 or Col 4	Supermet 60+ or 65
00	Nitralloy 135 (Nitrided)				Caution	Caution		Caution
05	Thru-Hardened Stainless Steel				NO	NO		
15	CPM-10V with soft core		NO					
25	MV 11K with 316SS soft core		NO					
272	CPM S90V with soft core		NO					
39	PM Tool Steel CPM 9V (solid)		NO					
212	Nitraloy with carbide crest weld		NO	Caution			NO	
229	Inconel 625 with Col 4 crest weld							
245	17-4 PH SSl with Col 4 crest weld							
236	Carbon Steel fully carbide welded		NO	Caution			NO	

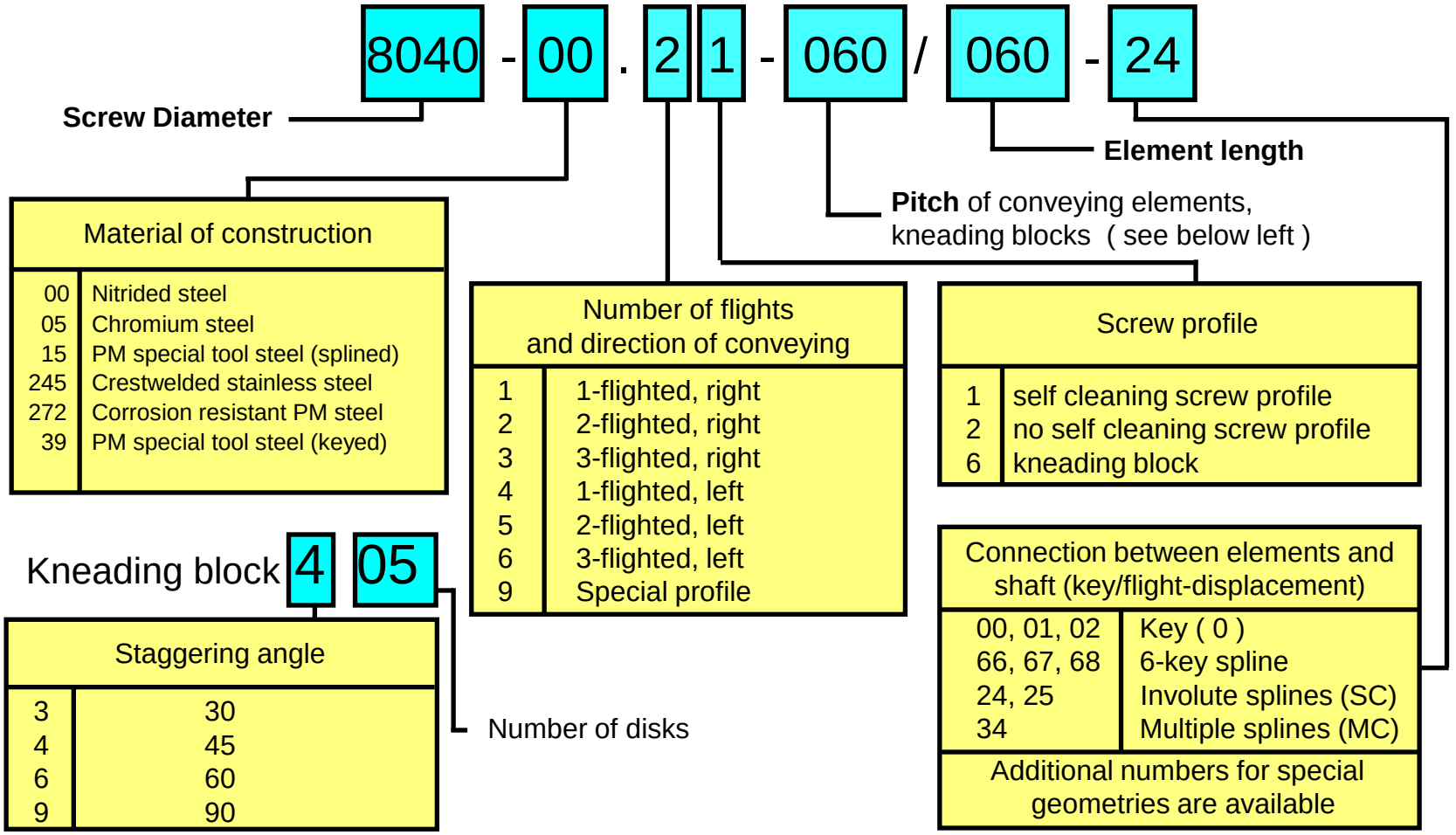
coperion
confidence through partnership

Coperion ZSK Screw Elements



coperion
confidence through partnership

ZSK Extruder Part Numbers for Screw Elements & Kneading Blocks



coperion
confidence through partnership

Coperion 3rd Brand Screw Elements

Coperion 3rd Brand Screw Elements

Berstorff	APV	Leistritz	Century	Prism	B & P
ZE 25	MP2019	ZSE 27	CX 40	16	30 BP
ZE 40A	MP2030	ZSE 34GG	CX 50	24	50 BP
ZE 60A	MP2040	ZSE 34GL	CX 58		80 BP
ZE 75A	MP2050	ZSE 50	CX 70		100 BP
ZE 90A	MP2065	ZSE 67	CX 92		125 BP
ZE 90A-UT	MP2080	ZSE 75	CX 133		CT 40
	MP2100	ZSE 96			CT 58
					CT 70
					CT 92
					CT 133

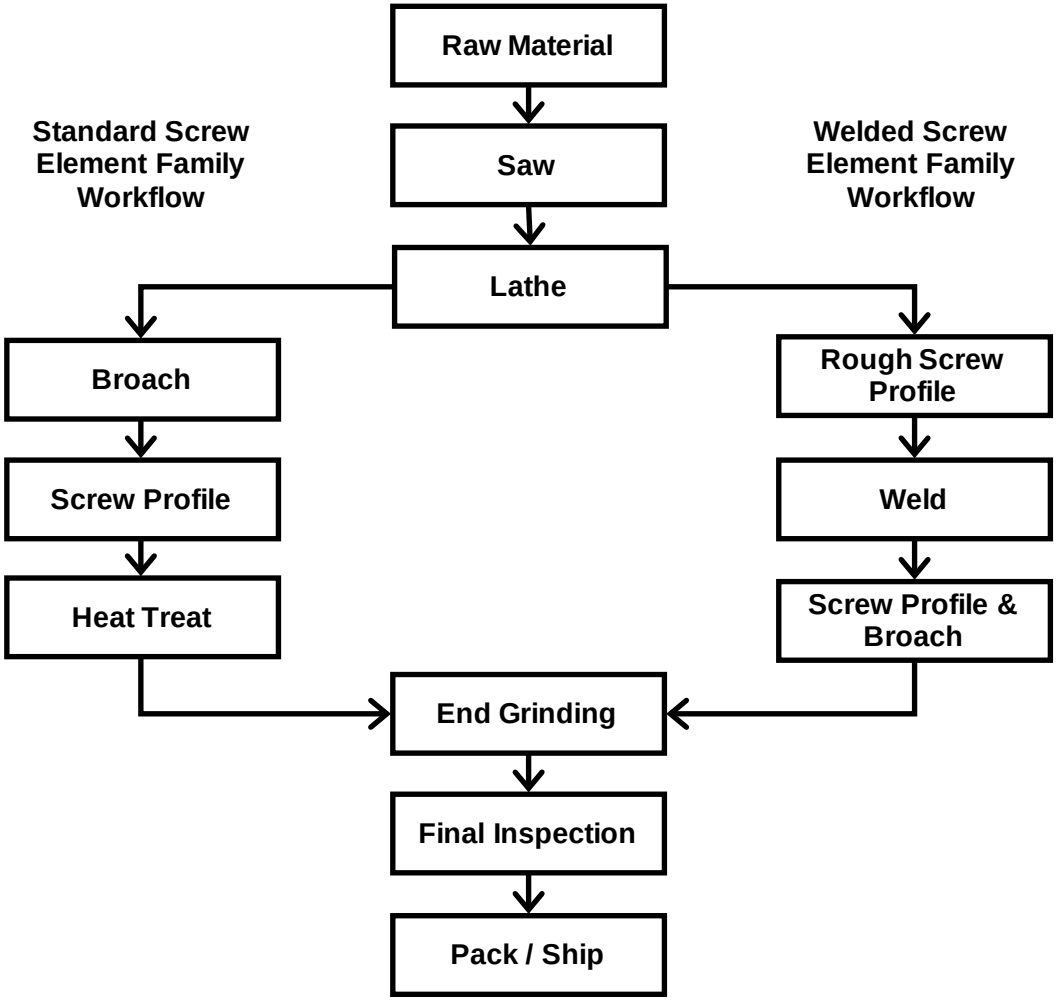
JSW	Davis Standard	Toshiba	Theysohn	Maris
TEX 65	DTEX 129.5	TEM 58	TSK 20	TM40W
JSW 128			SST 50	TM58W
			SST 60	TM70W

Kurimoto	Clextral	Pomini
KEX65	EV88	LCMAX1000
KUR125		

Also some elements for: Farrel, Ikegai, and others

coperion
confidence through partnership

Coperion
Screw Element Manufacturing Workflow



coperion
confidence through partnership


coperion
confidence through partnership
compounding & extrusion
materials handling
service