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TECHNICAL RUBBER COURSE

Mixing Technology & Machinery

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.

1848 1998

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Topics

- **Commonly used Rubber Compounding machinery**
- **Basic mixing theory**
- **Intermeshing and tangential batch mixers**
- **Practical Aspects of Batch mixer operation**

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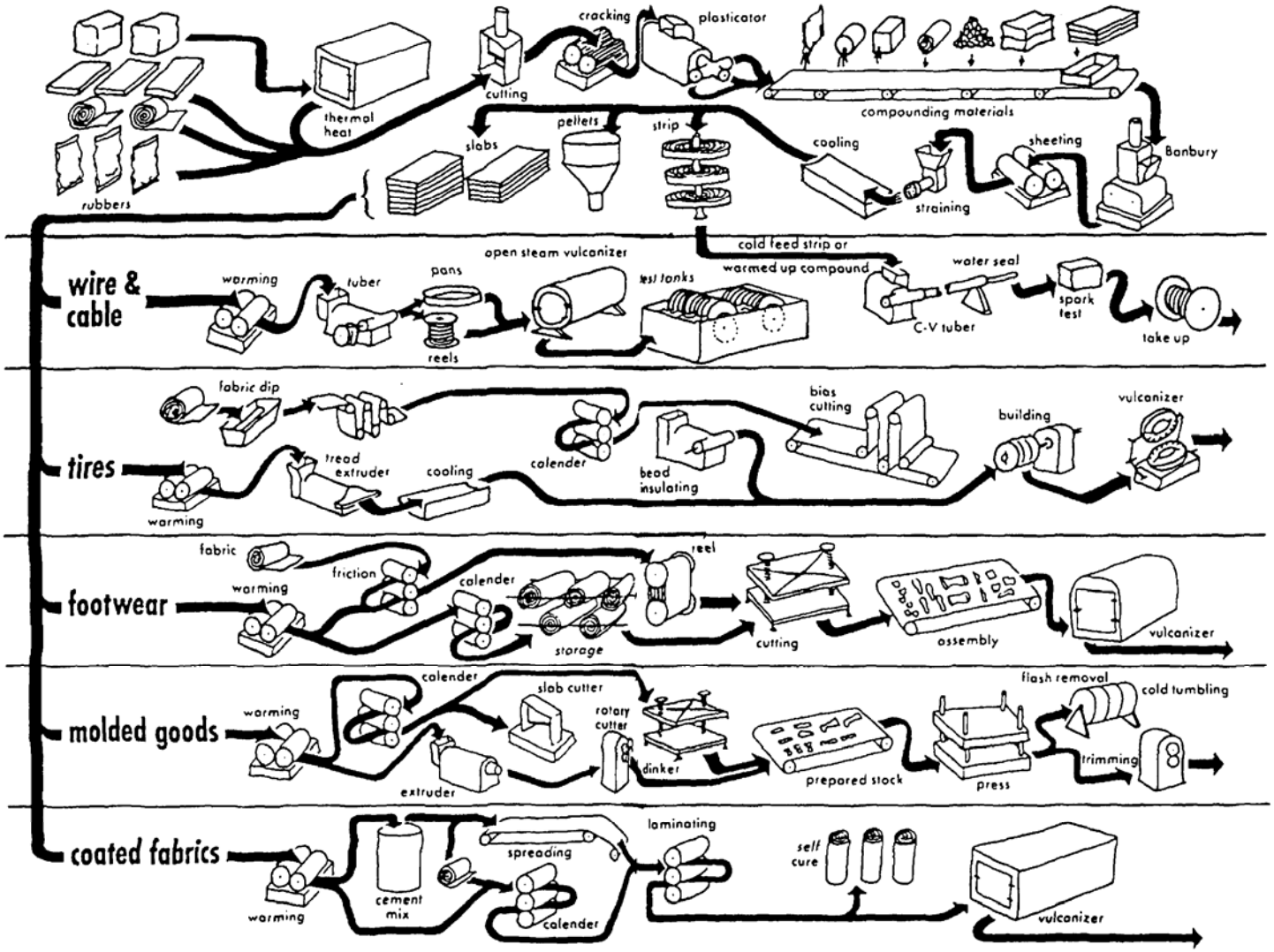
Typical Flow Diagram for Rubber Goods Manufacture



Primary Compounding Machinery

TYPE	General	Advantages	Disadvantages
MILLS 	First Rubber compounding machine (not generally a primary mixer they are used as a post mixer forming device)	- Very versatile - Broad range of shear capability - accepts all feed forms - good for short production runs	- difficult to control - difficult to automate - batch to batch variation (due to weighments, feeding ,&heat & shear history) - dirty operation - safety considerations - low output - varying power demand - labor intensive
BATCH MIXERS 	Most common Rubber compounding Machinery	- accepts all feed forms - high output - can be automated - good for short production runs - long life expectancy - broad range of shear capability	- varying power demand - batch to batch variation (mixer control & weighments) - post mixer variable product heat history - capital intensive - need post mixer forming - can be labor intensive
CONTINUOUS MIXERS 	Specialty applications	- high output - energy efficient - ease of process optimization - easily automated - uniform product shear & heat history	- need free flowing feed (particulate rubber) - require sophisticated weigh & feed systems - not applicable for short runs - difficult to clean - capital intensive - need post mixer forming
TWIN SCREW EXTRUDERS 	Newer technology Specialty applications	- energy efficient - ease of process optimization - easily automated - geometry optimized for use - uniform product shear & heat history	- need free flowing feed(particulate rubber) - require sophisticated weigh & feed systems - not applicable for short runs - difficult to clean - capital intensive - configuration changes required

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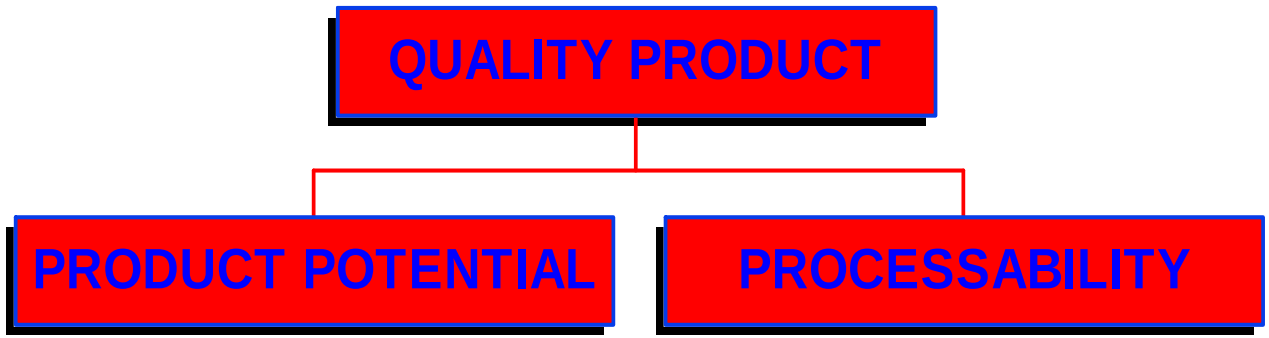
Compounding's Quality Objective



WHEN PROPERLY FABRICATED THE PART MUST MEET ALL PHYSICAL REQUIREMENTS

THE PRODUCT MIX MUST EASILY BE FORMED INTO THE FINAL PRODUCT SHAPE

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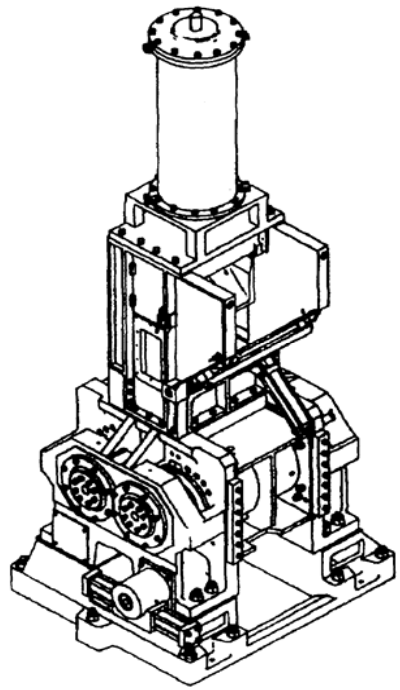
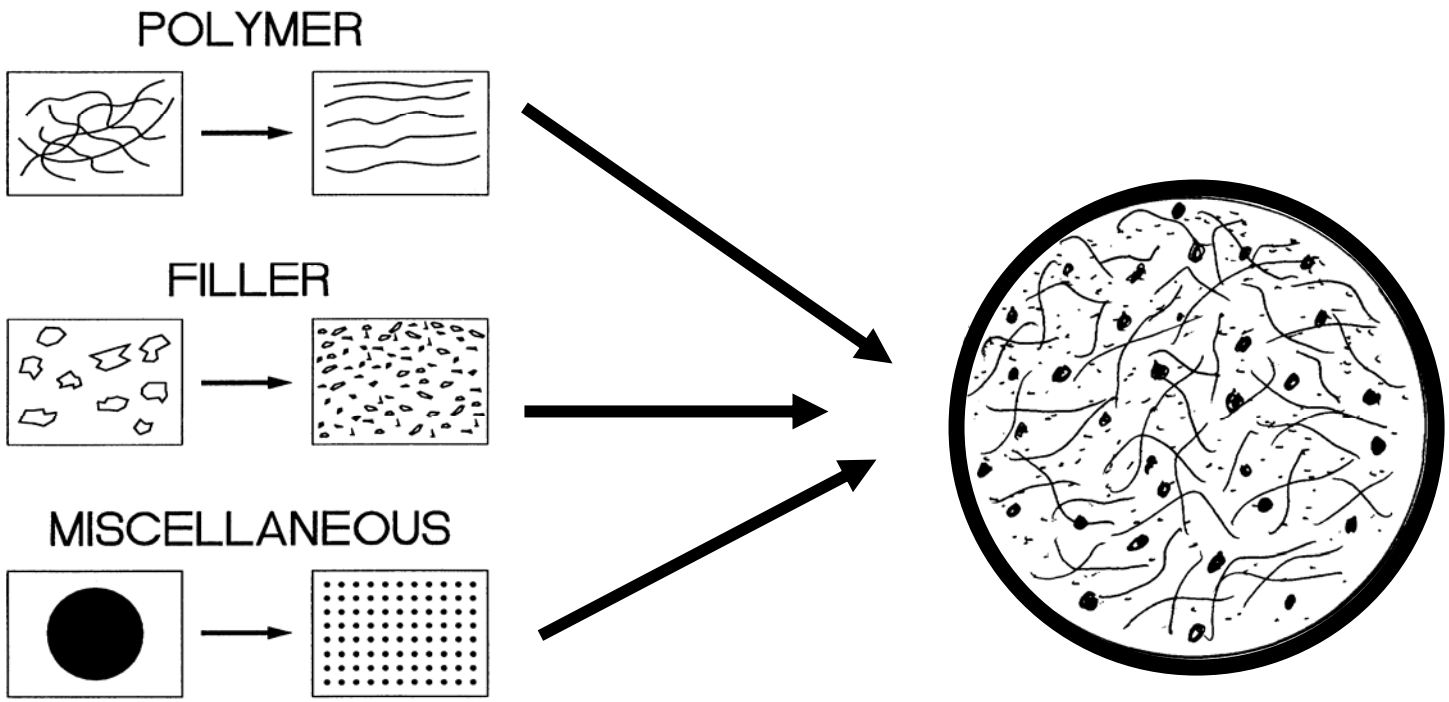
Process Technology



Compound Ingredients

Compounding Machinery

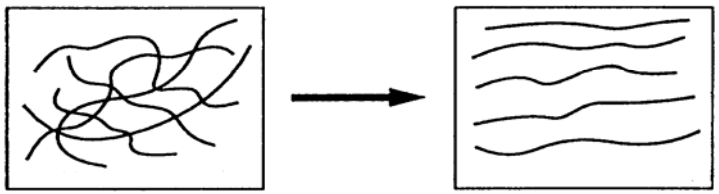
The Mixing Process



Raw Materials

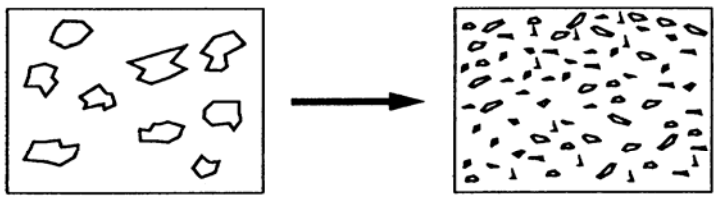
Typical Material Concerns

POLYMER



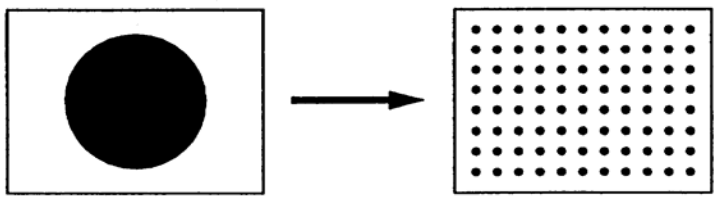
- Polymer type age, uniformity & purity
- MW & MWD
- entanglements
- thermal &oxidative characteristics
- homogenization of single or multiple polymers (phase morphological concerns-compatibly)
- environmental and geometric affect of polymers

FILLER



- filler type(extending,reinforcing,& reactive fillers)
- age,uniformity, purity,reactivity
- particle size and particle size distribution
- requirement to breakdown agglomerates or pellets
- the possible forming of agglomerates
- requirements for efficient filler/polymer interaction

MISCELLANEOUS



- type of plasticizers ,protective additives,reactive chemicals
- age,uniformity, purity,reactivity
- lubricating affects of liquid and melting additives
- threshold temperature affects for incorporation
- maximum temperature limitations

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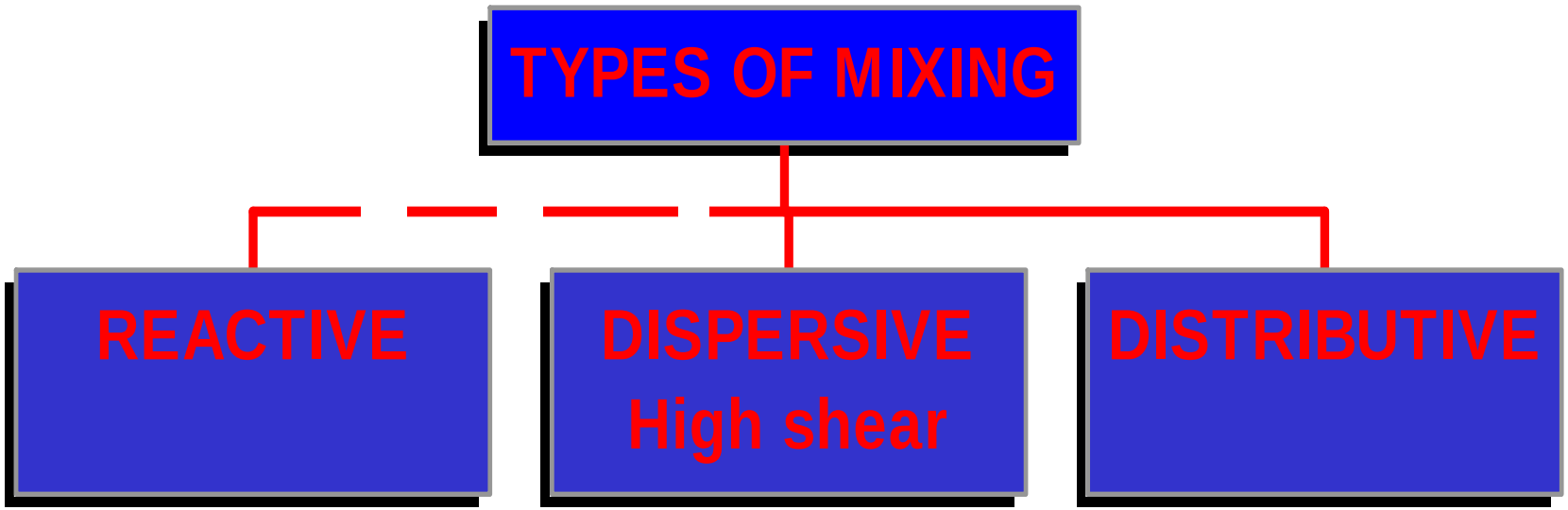
TYPES OF MIXING
REACTIVE
DISPERSIVE
High shear
DISTRIBUTIVE

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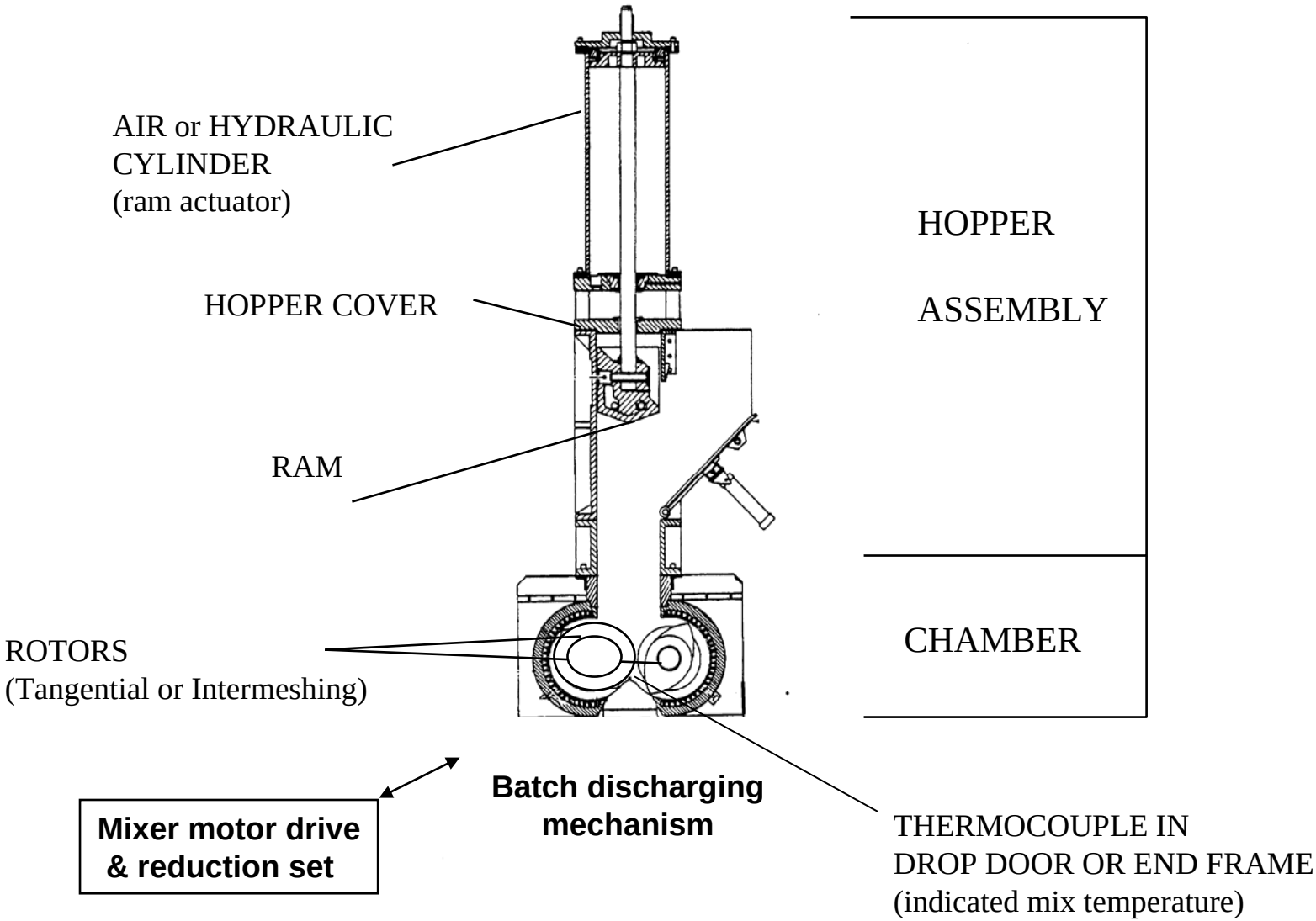
Batch Mixing Technology

Basic Components of The Batch Mixer



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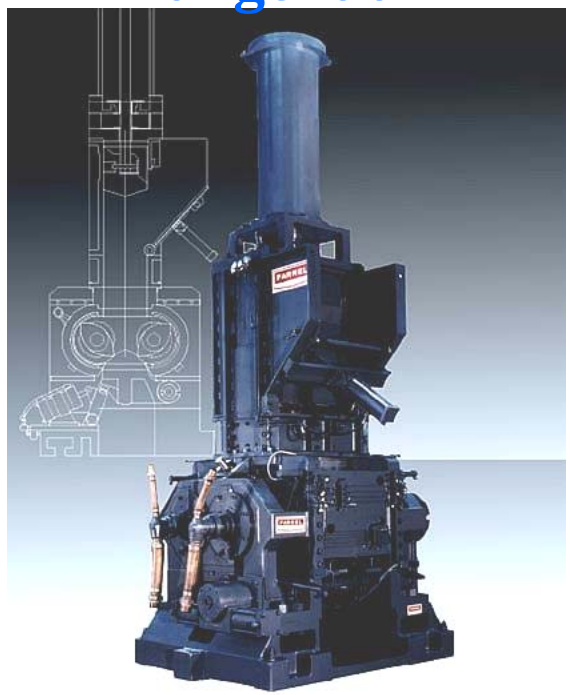
Batch Mixing Technologies

Intermeshing

Intermix® “Mark 5”

Tangential



Banbury® F series “ST”

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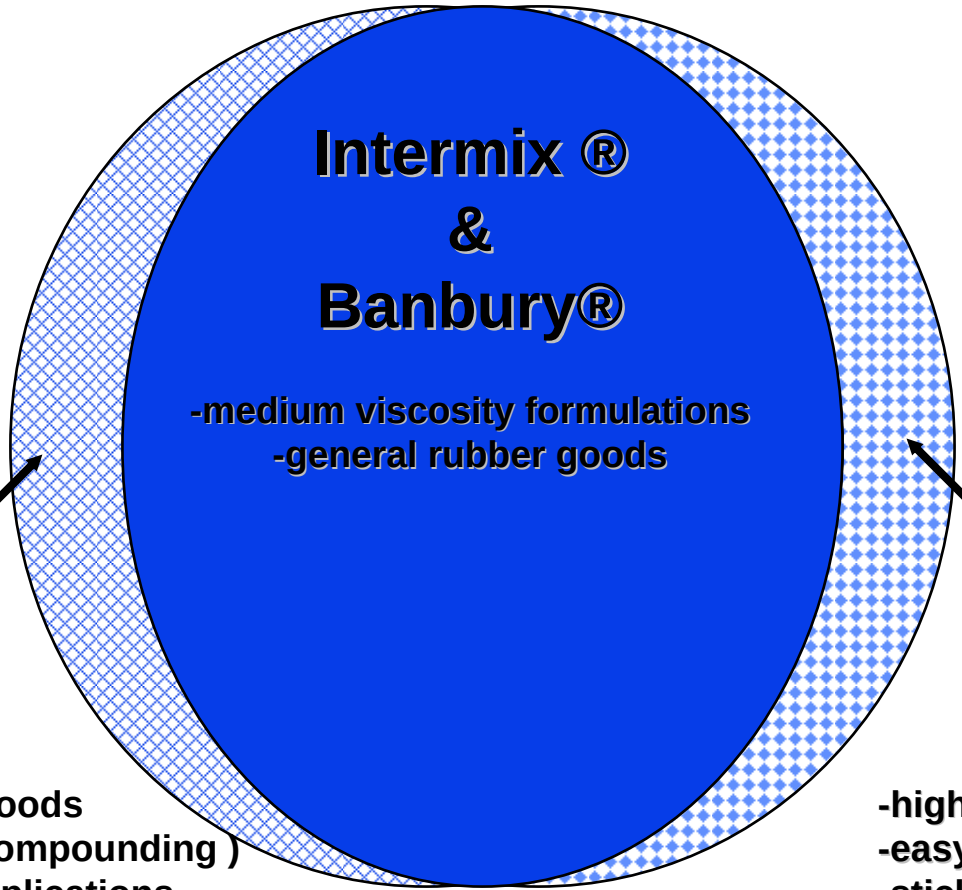
Machinery in Application

AREAS OF APPLICATION	% OF INTERMIX® BATCH MIXERS IN APPLICATION	% OF BANBURY® BATCH MIXERS IN APPLICATION
TIRE COMPOUNDS	5	57
TECHNICAL RUBBER GOODS ie,SEALS,HOSE , AND CUSTOM MIXING	79	23
WIRE AND CABLE	7	3
FLOORING	3	4
PLASTICS COMPOUNDING	6	13

Areas of mixer application



Intermix ®

-specialty rubber goods
(low temperature compounding)
-extreme quality applications

•reactive mixing applications (high viscosity)
•single step mixing applications

Banbury ®

-high volume applications
-easy to mix formulations
-sticky materials

•multiple step mixing applications
(especially final mix of high viscosity compounds)

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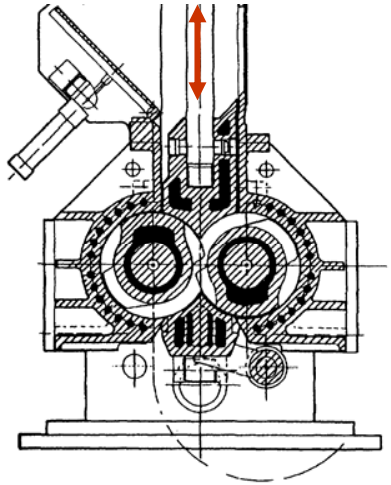
Selected Items of Comparison

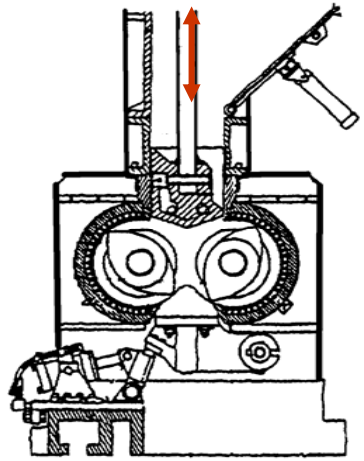
Mechanical

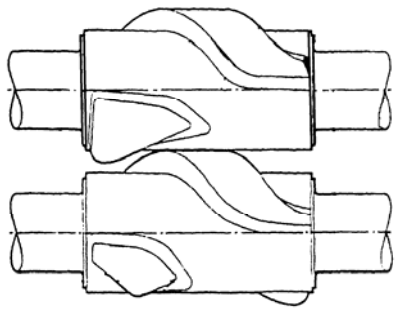
- Ram actuation
  (HYDRAULIC OR PNEUMATIC)
- Hopper door
- Ram or weight design
- Mixer sides
- Mixer rotor end plates
- Mixer rotors
- Drop door design
- Drop door latch mechanism
- Dust stops

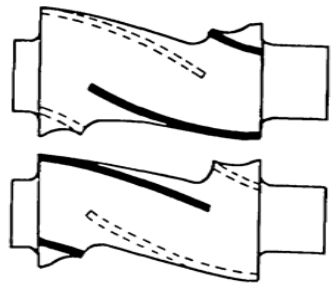
INTERMESHING ROTOR DESIGN



TANGENTIAL ROTOR DESIGN



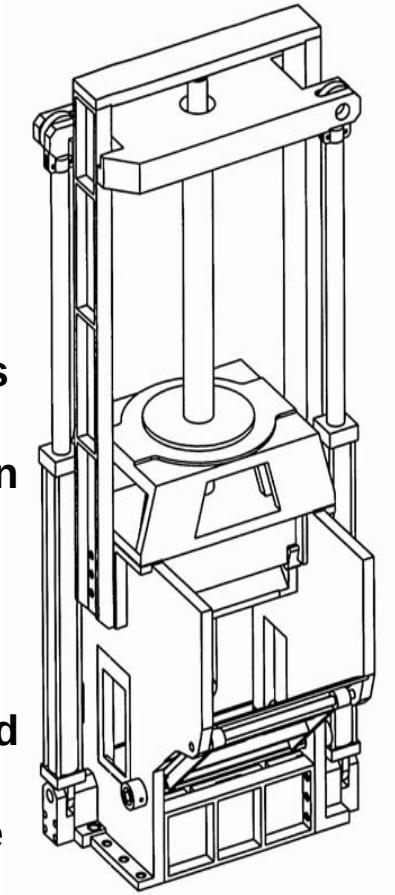


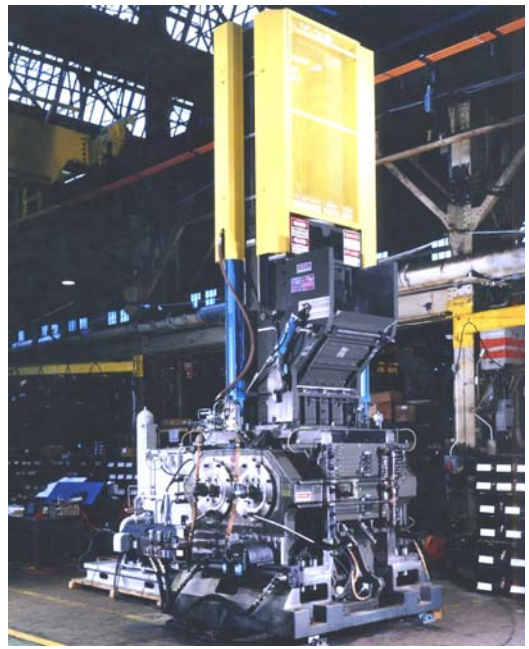


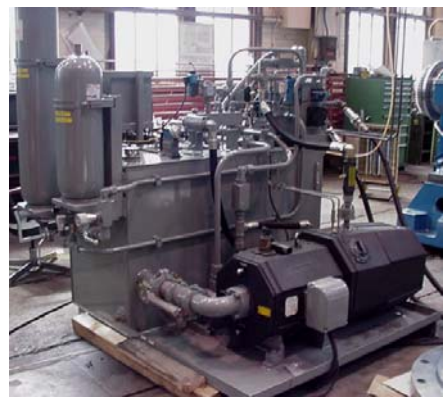
Hydraulic hopper Actuation

Potential Benefits

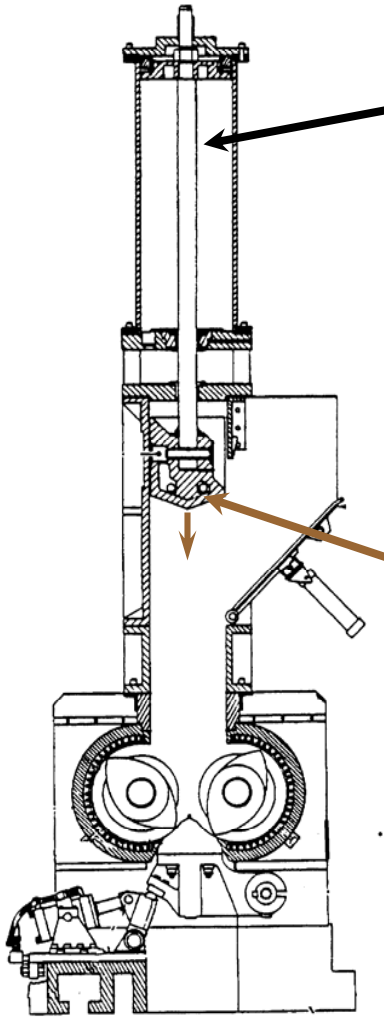
- Eliminates compressed air requirements
- Efficient application of high batch pressure
- Potential Increase of process repeatability due to the elimination of the variations in the plant air supply
- Potential reduction in plant operating expenses
- it allows position control and variation of pressure on the batch during the mixing cycle







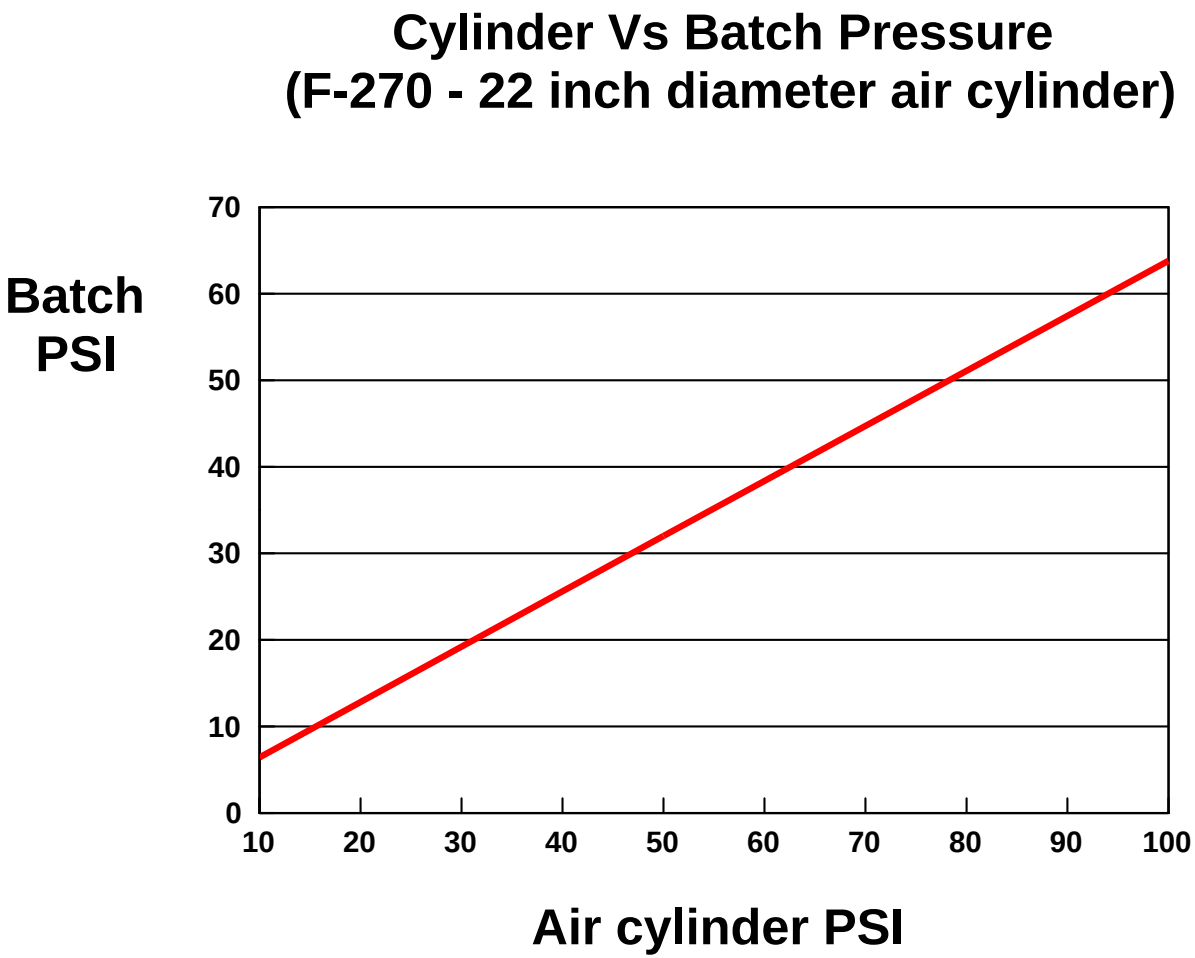
Batch & Cylinder Pressure



CYLINDER AIR PRESSURE
- air pressure applied to the piston in the cylinder forcing the weight down

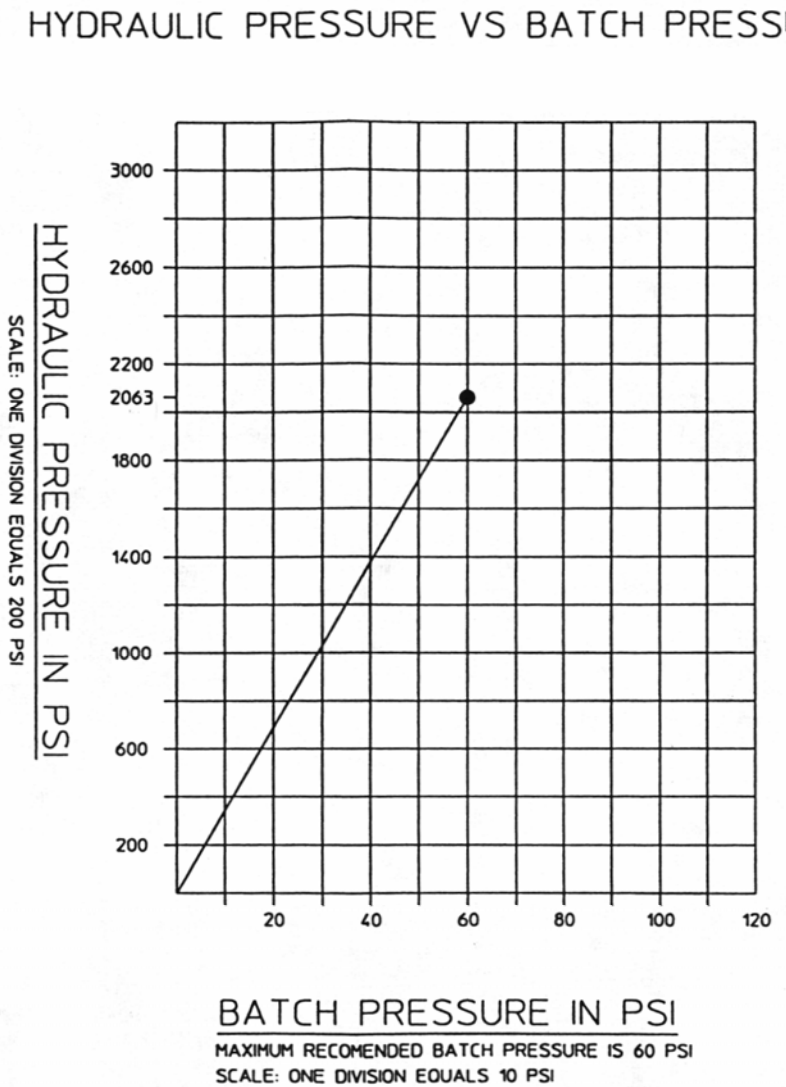
BATCH or RAM PRESSURE
- pressure applied by the bottom of the weight on the batch

Batch & Cylinder Pressure



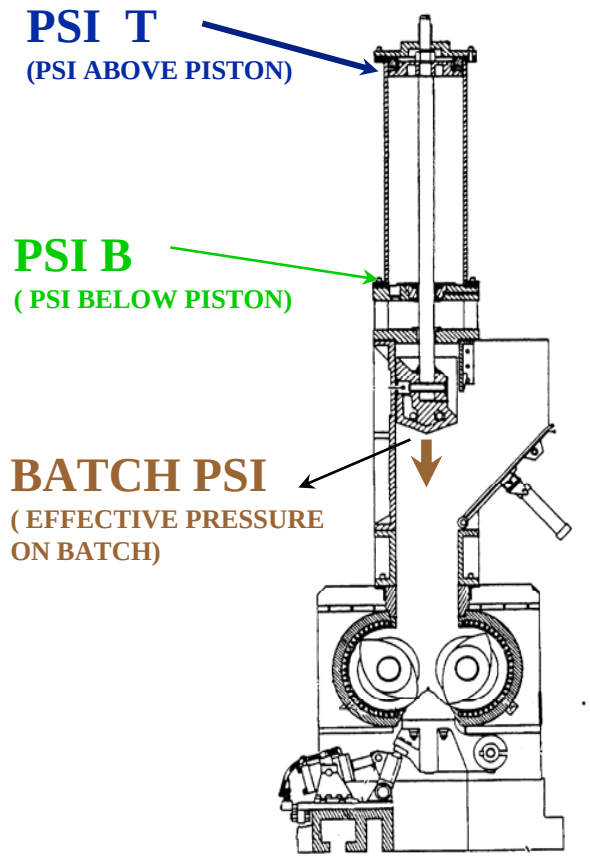
Batch & Cylinder Pressure

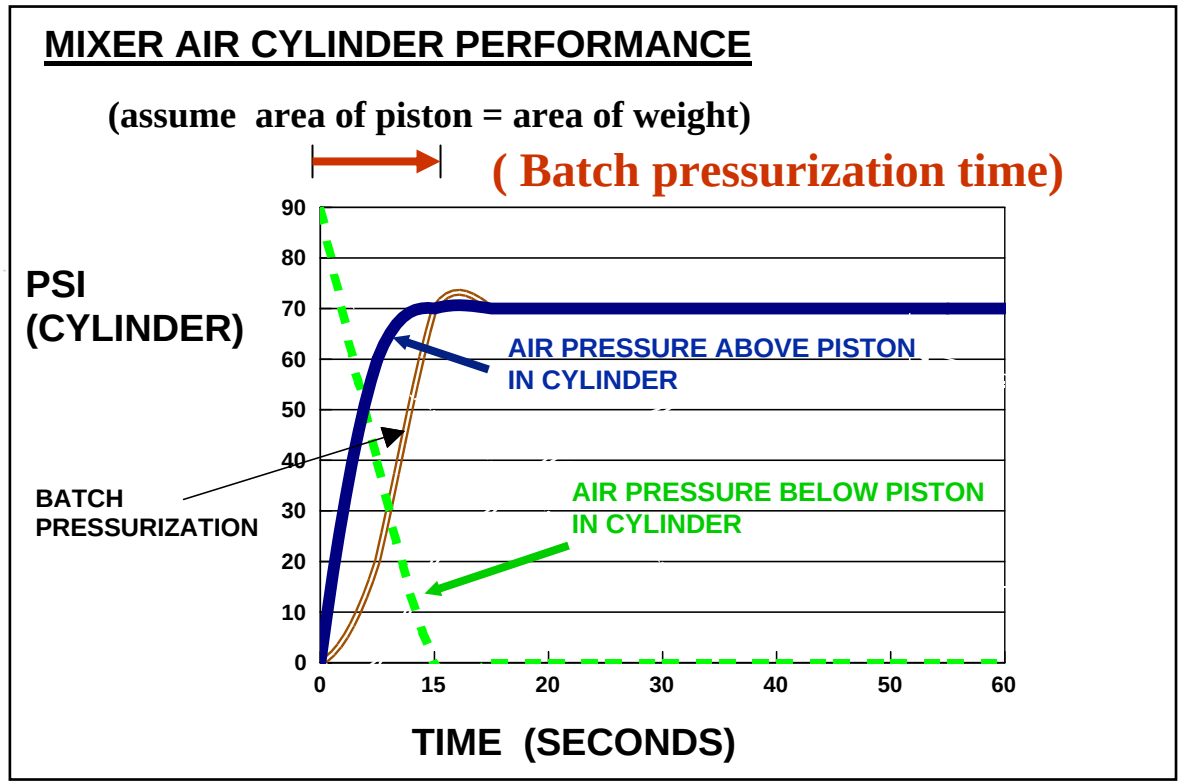
(hydraulic system for F-270 mixer)



"BATCH" AND "CYLINDER" PRESSURE

BATCH PSI = f (PSI T - PSI B) x AREA PISTON / AREA WEIGHT





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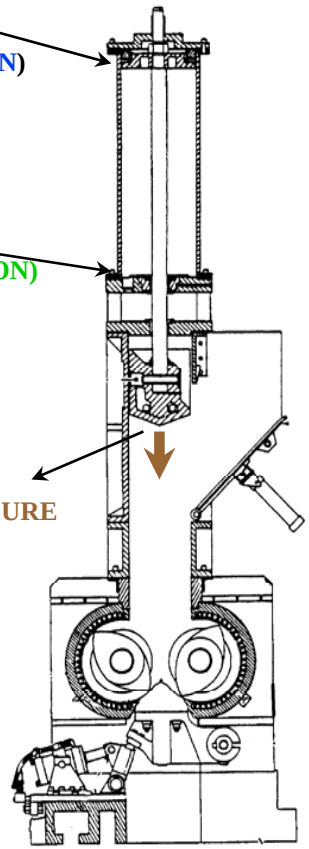
"BATCH" AND "CYLINDER" PRESSURE

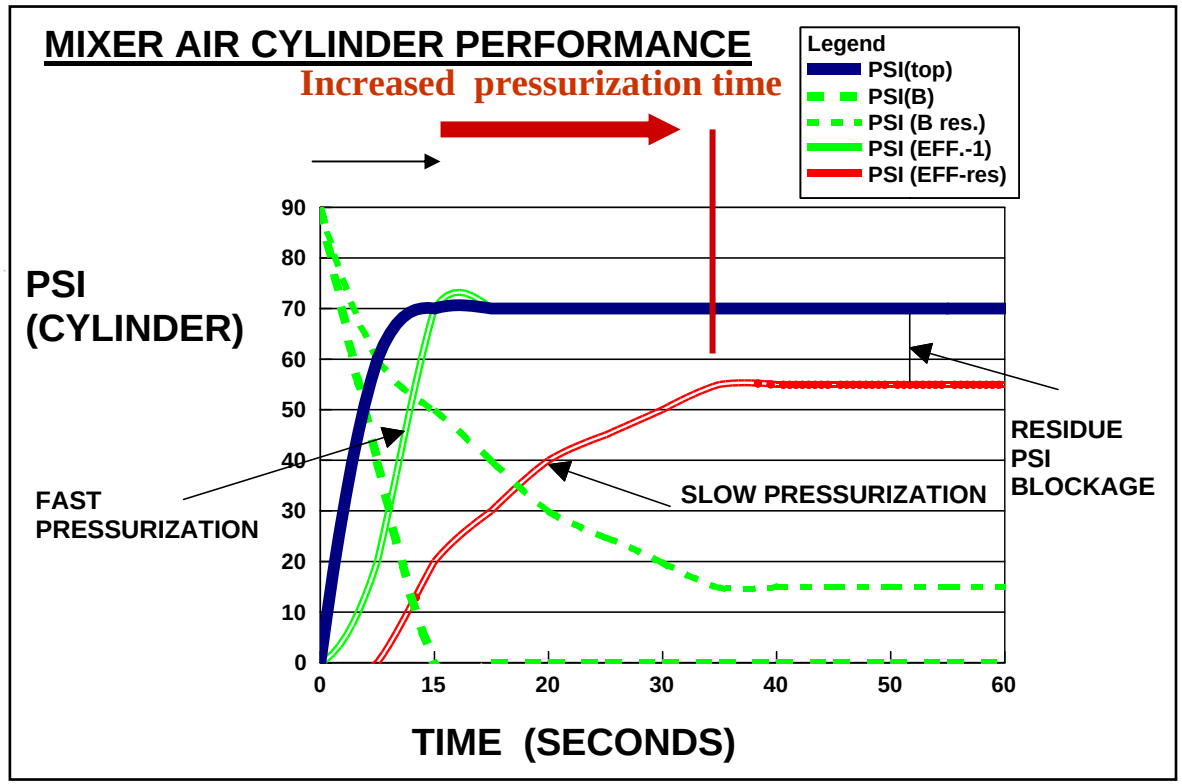
BATCH PSI = f (PSI T - PSI B) x AREA PISTON / AREA WEIGHT

PSI T
(PSI ABOVE PISTON)

PSI B
(PSI BELOW PISTON)

BATCH PSI
(EFFECTIVE PRESSURE ON BATCH)





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Selecting a Hydraulic or Pneumatic actuated ram

Topics to be addressed

- Tangential Vs Intermeshing rotor mixer
- Consistency of air pressure to mixer
- Quality & quantity of supplied air
- Operating cost
- Environmental considerations
- System Maintenance costs
- Capitol investment
- Knowledge of system operating characteristics

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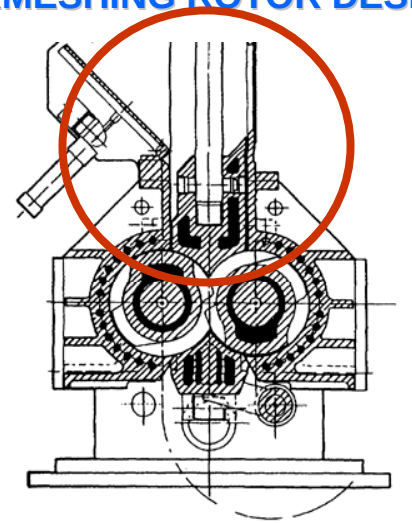
Selected Items of Comparison

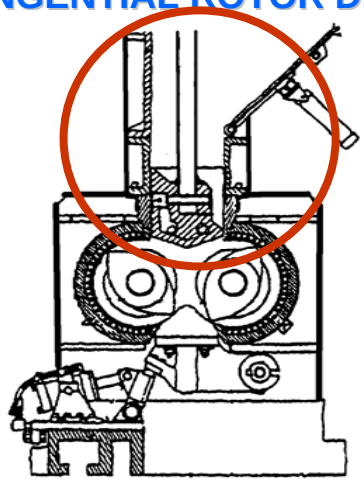
Mechanical

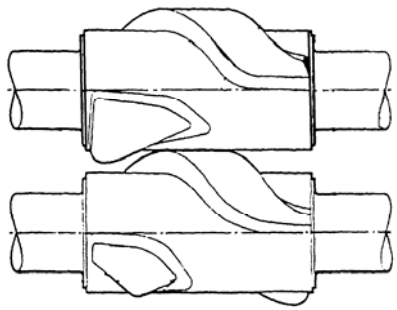
- Ram actuation
- Hopper door
- Ram or weight design
- Mixer sides
- Mixer rotor end plates
- Mixer rotors
- Drop door design
- Drop door latch mechanism
- Dust stops

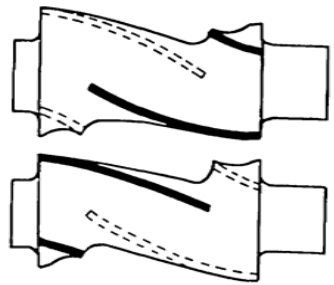
INTERMESHING ROTOR DESIGN



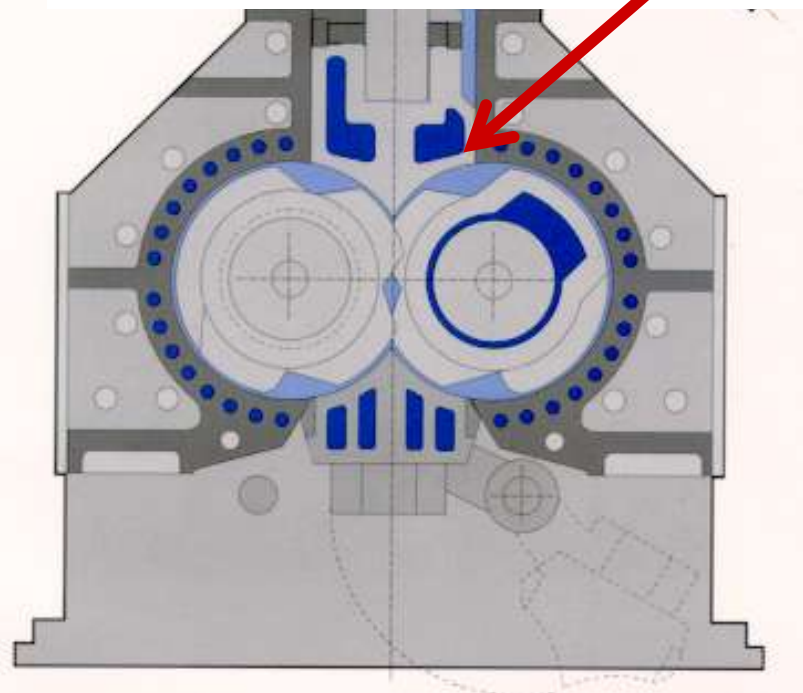
TANGENTIAL ROTOR DESIGN





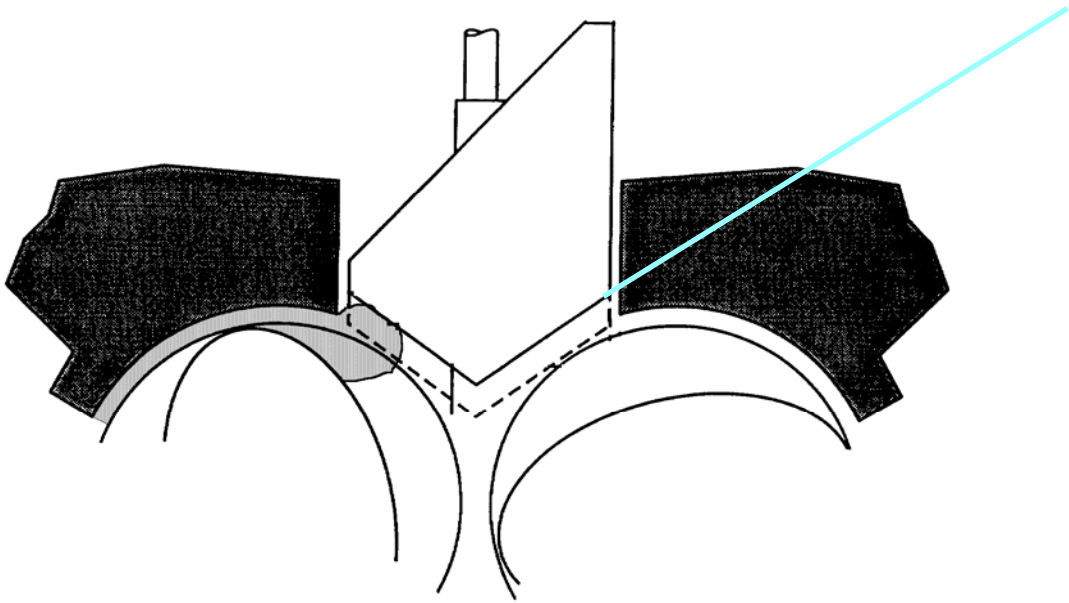


Intermix® full down weight position



The ram when full down is an extension of the body bore (the bottom becomes a working surface)

Banbury® full down weight position



The ram full down position is elevated.The Elevated Position is necessary for efficient venting and material flow within the mixing chamber

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Selected Items of Comparison

Mechanical

- Ram actuation
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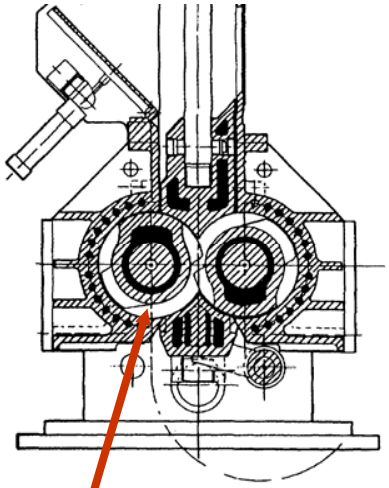
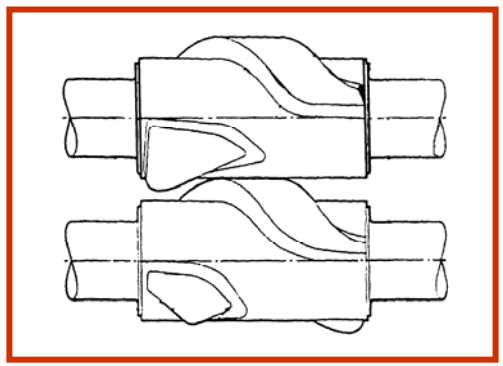
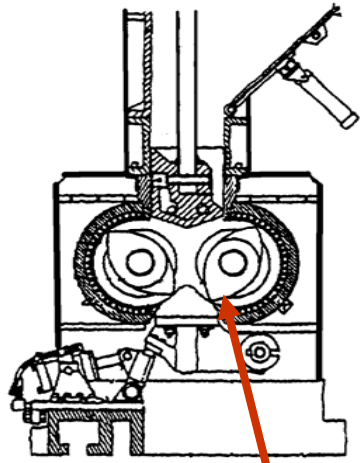
- Ram or weight design
- Mixer rotors
- Mixer rotor end plates
- Mixer sides
- Drop door design
- Drop door latch mechanism
- Dust stops

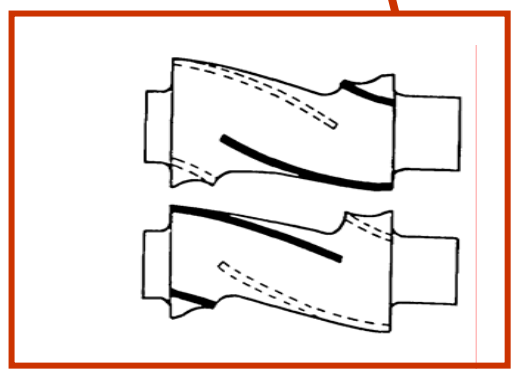
INTERMESHING ROTOR DESIGN





TANGENTIAL ROTOR DESIGN





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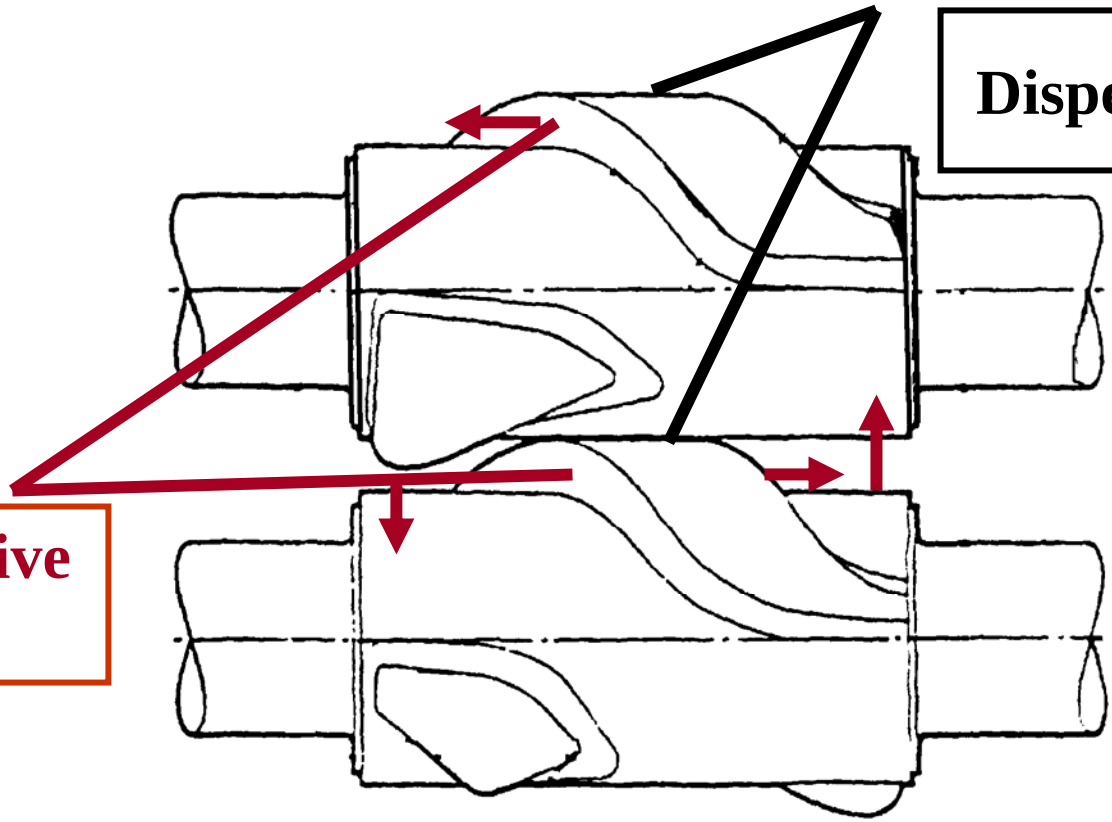
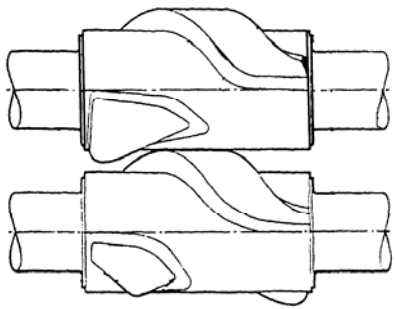
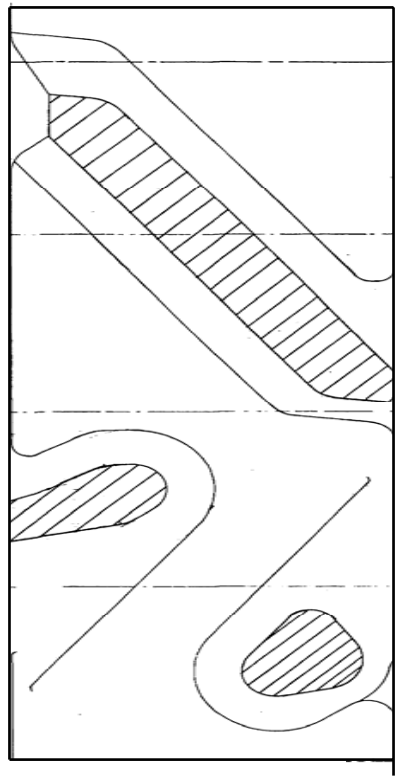
Intermix ®
Dispersive and Distributive Mixing



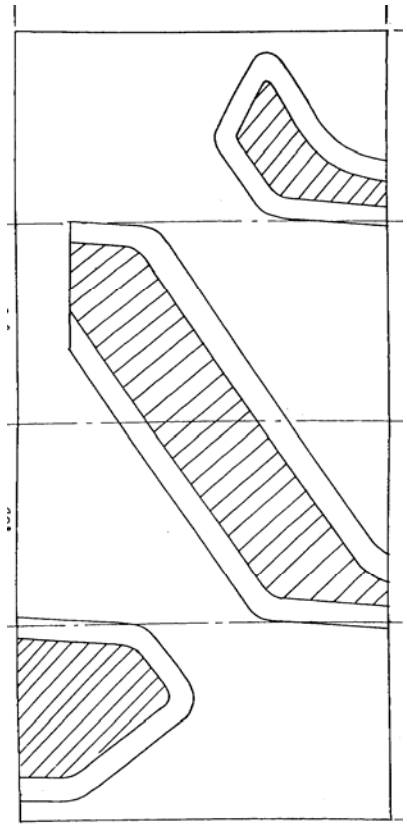
Intermix rotor designs
(increased fill factor and shear flow)



NR 5



NR 2



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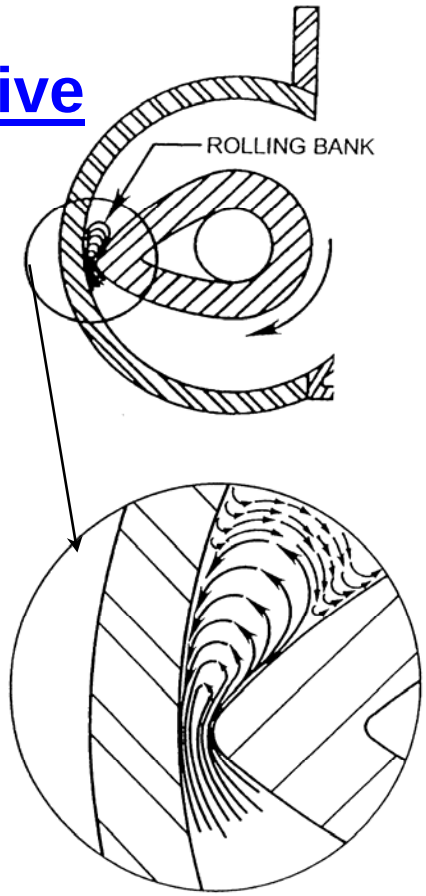
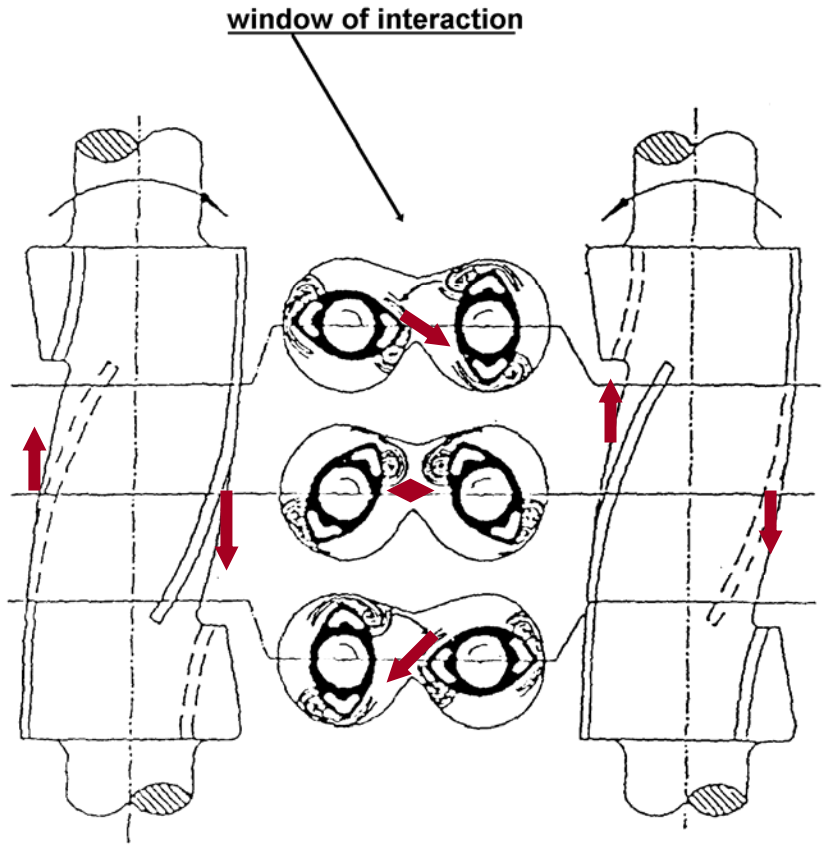
Mixing Action "Banbury ®"

Distributive

Dispersive

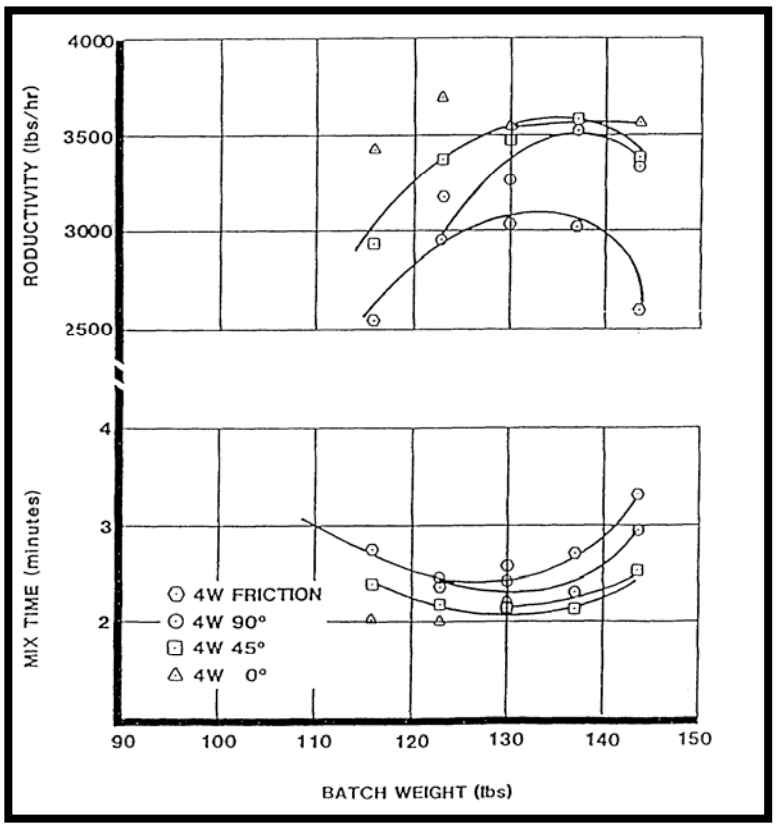


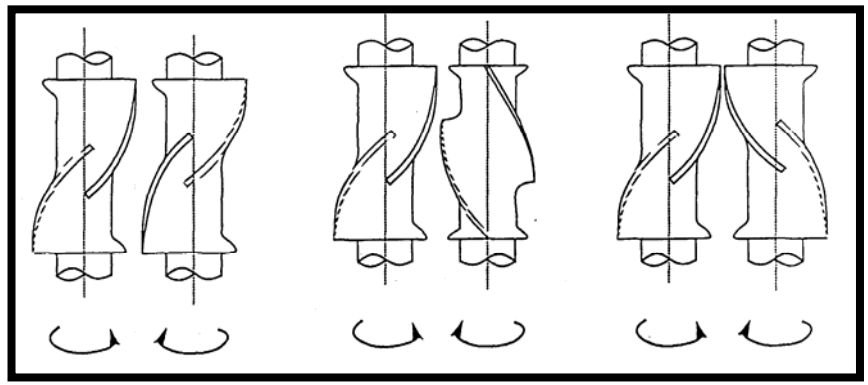


Even speed or friction operation

F-Series Banbury Mixers (tangential mixers)

Even speed Rotor Alignments





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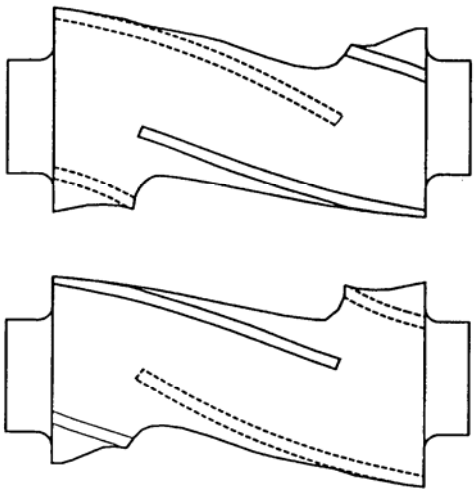
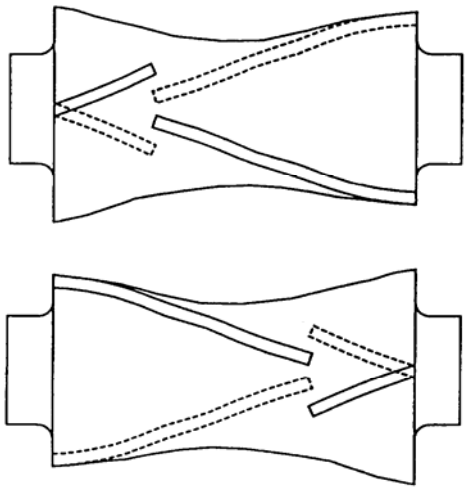
F-Series Banbury® Mixers (tangential mixers)

F series Banbury rotor types

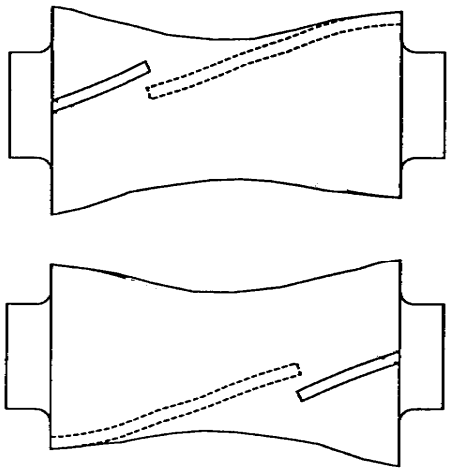
ST™ / SN4T

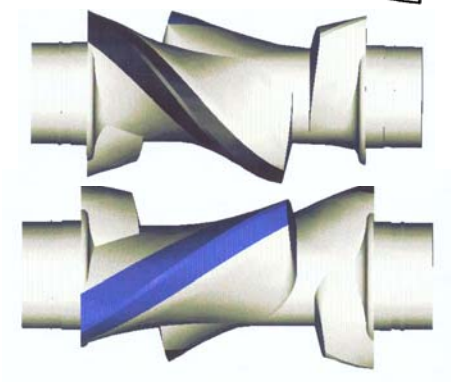


4 wing / SK



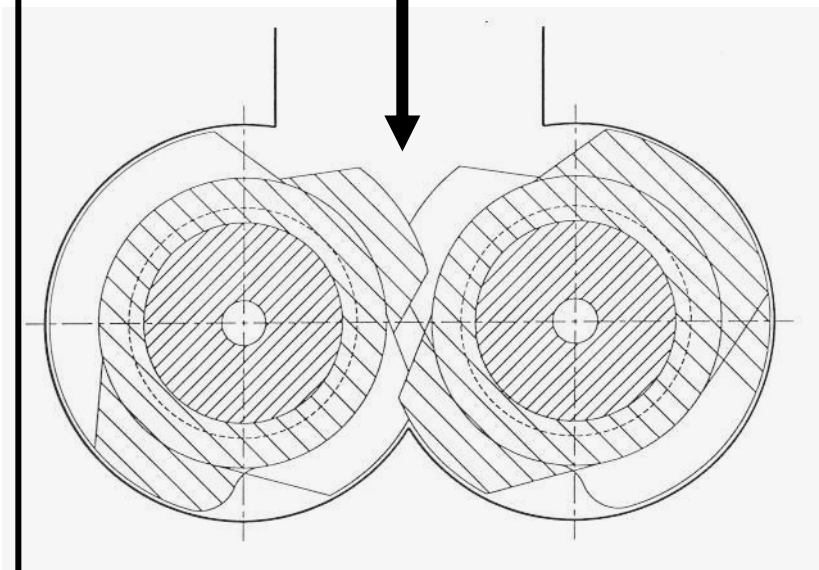
2 wing

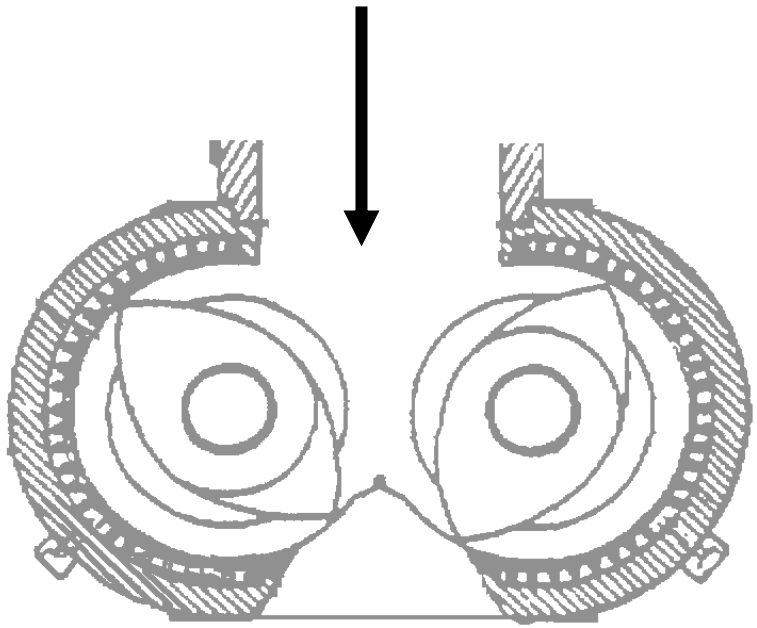




WFT

Feeding Efficiency
Intermix ® Vs. Banbury ®





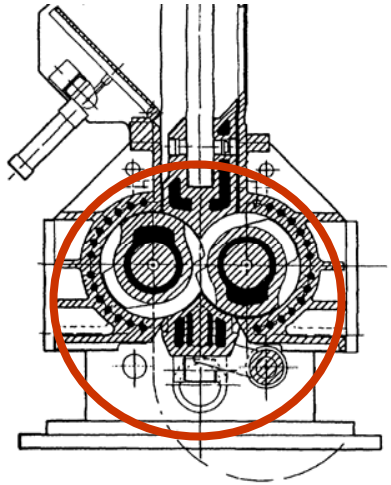
FARREL

Selected Items of Comparison

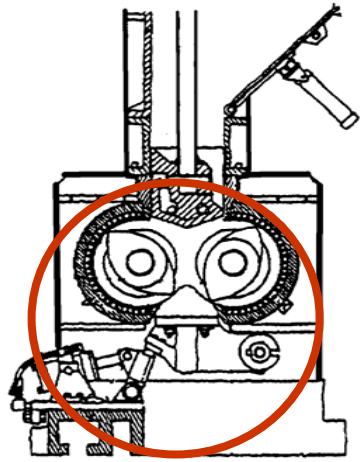
Mechanical

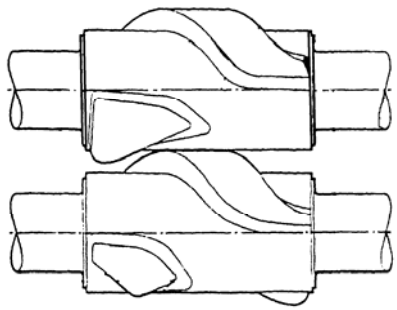
- Ram actuation
- Hopper door
- Ram or weight design
- Mixer rotors
- Mixer rotor end plates
- Mixer sides
- Drop door design
- Drop door latch mechanism
- Dust stops

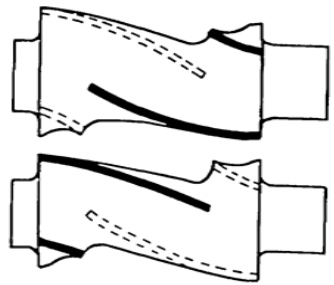
INTERMESHING ROTOR DESIGN



TANGENTIAL ROTOR DESIGN

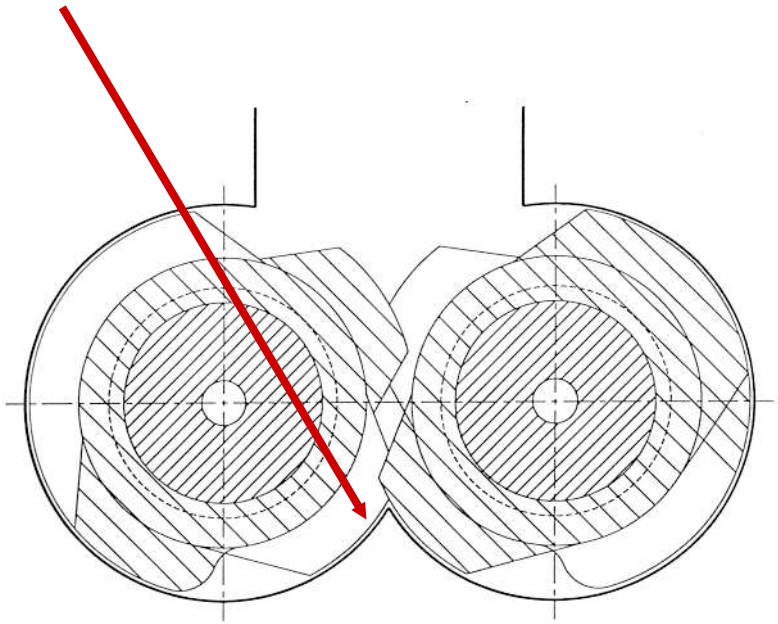






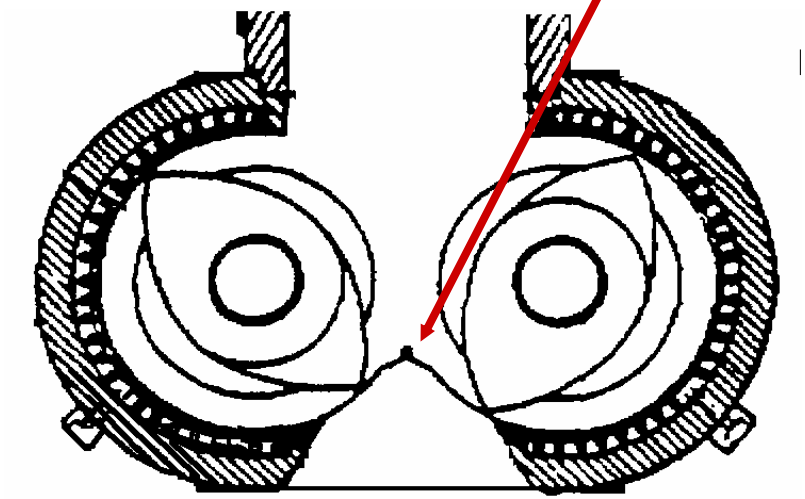
Drop door designs of the Intermix ® Vs. Banbury ®

a full extension of the body bore for maximum shear work and heat transfer



Intermix ®

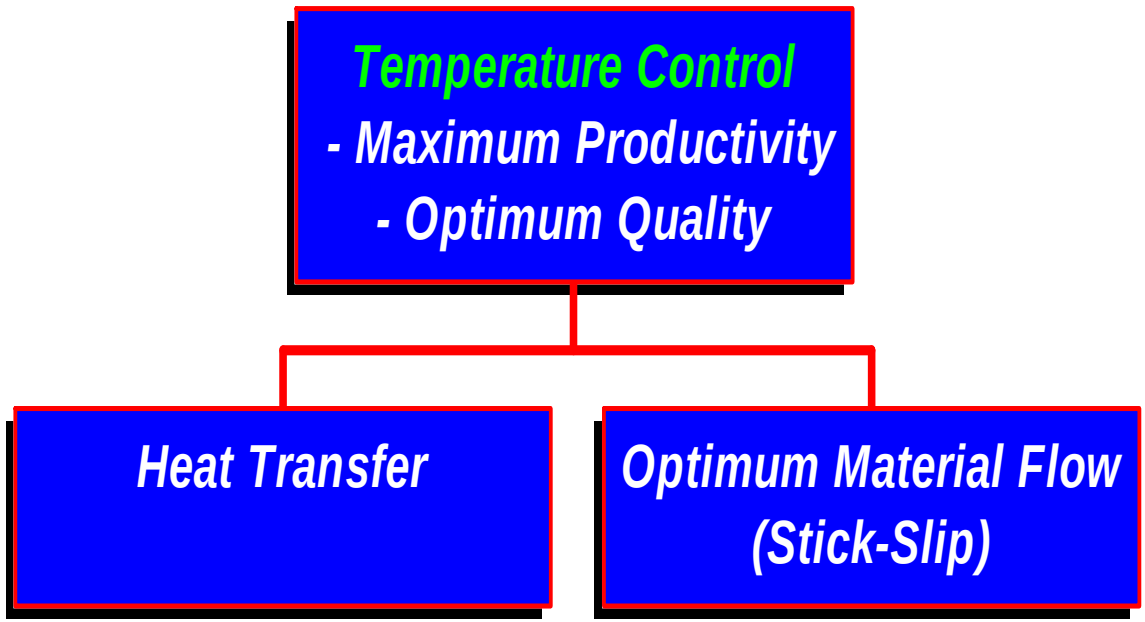
Contoured to be an extension of the body bore and relieved to permit material transfer



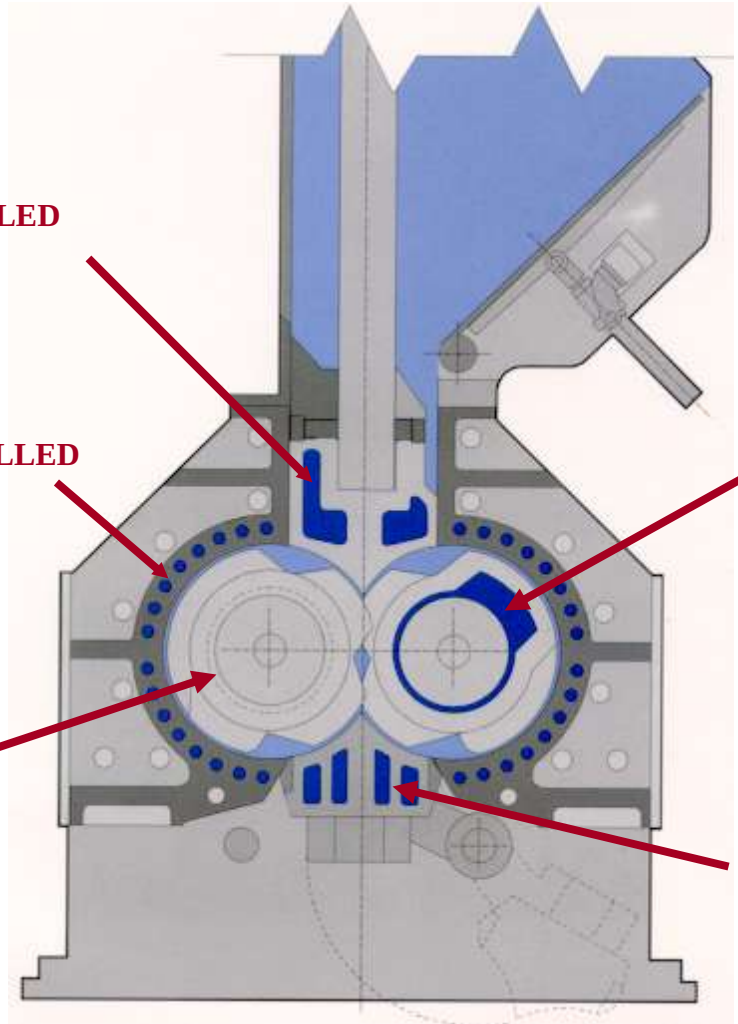
Banbury ®

FARREL

Mixer Metal Temperature



Intermix® Chamber Water Cooled Cavities



TEMPERATURE CONTROLLED
WEIGHT STANDARD

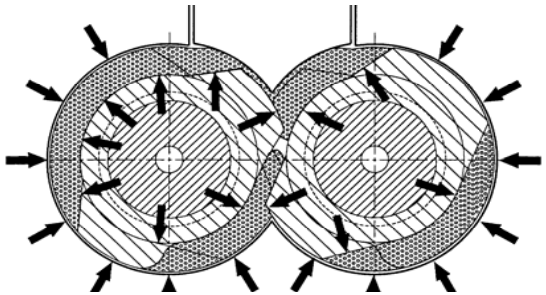
HIGH EFFICIENCY
TEMPERATURE CONTROLLED
SIDES

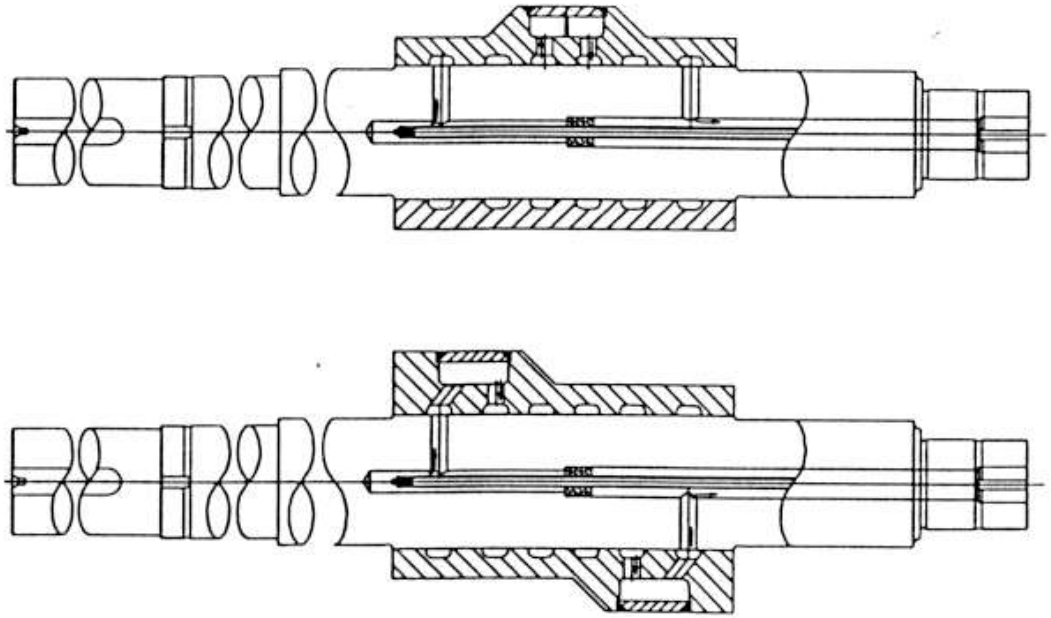
HIGH EFFICIENCY
TEMPERATURE CONTROLLED
ROTORS

TEMPERATURE CONTROLLED
ROTOR END PLATES STANDARD

TEMPERATURE CONTROLLED
DOOR TOP

Intermix ® Rotor Cooling



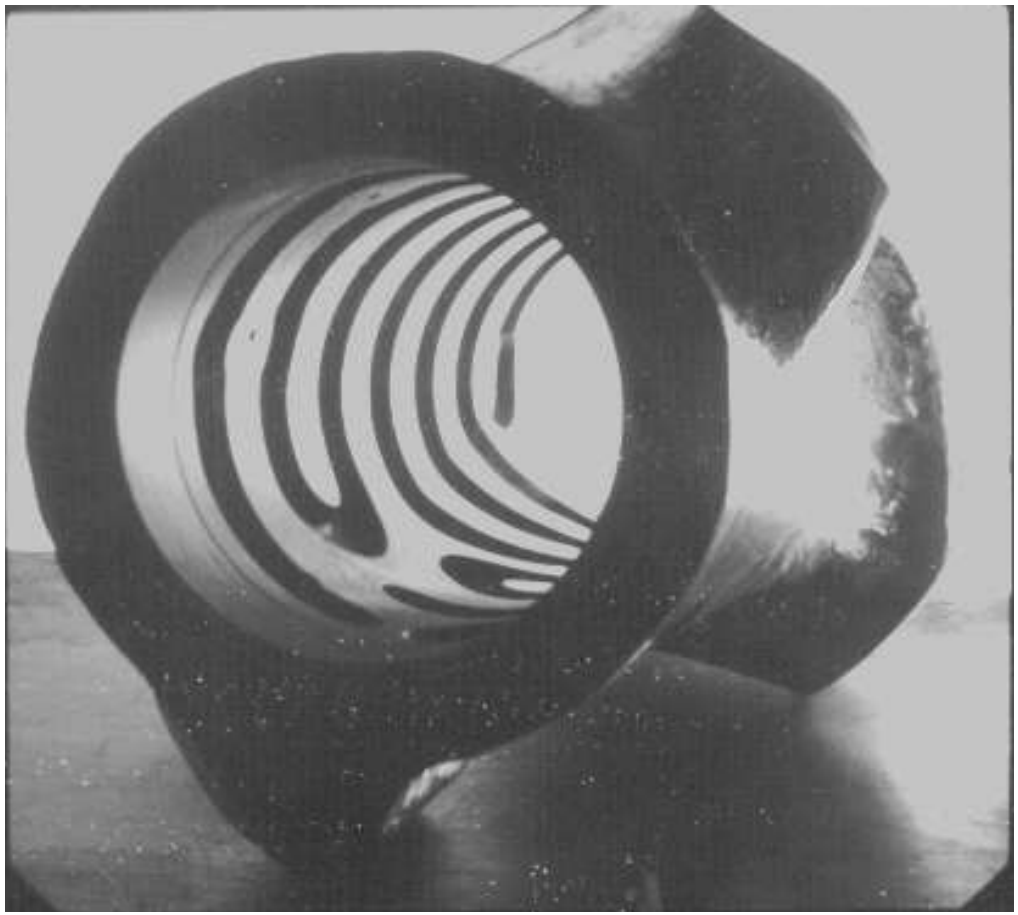


Enhanced spiral cooling passages over whole length of rotor body

Enhanced cooling of Nog

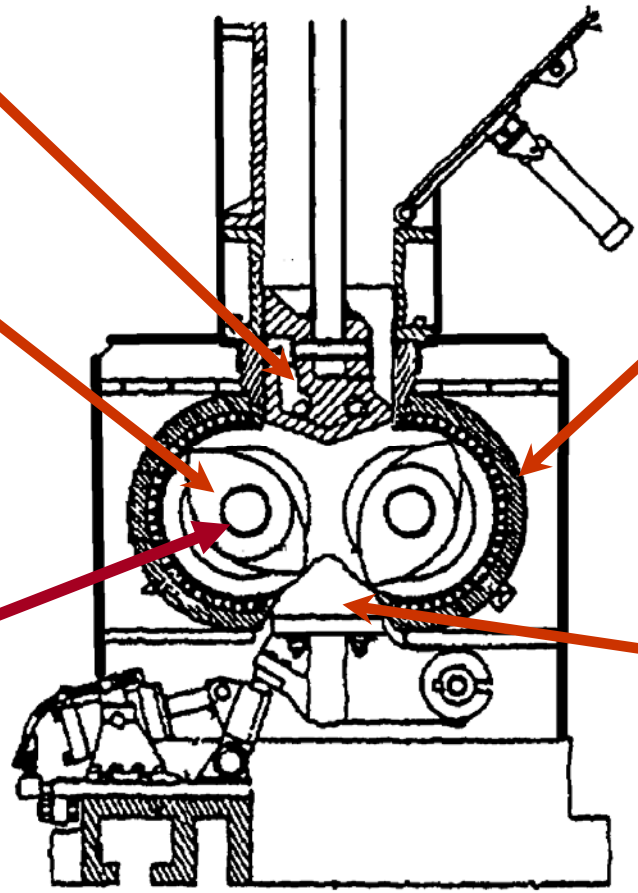
FARREL

NR5 Rotor Spiral Cooling

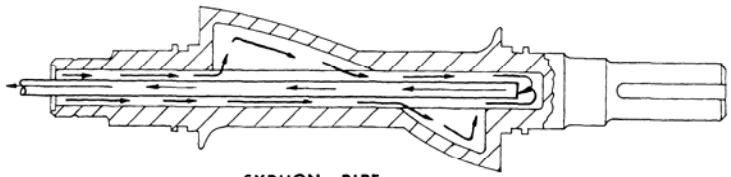


FARREL

Banbury ® Mixer Heating / Cooling

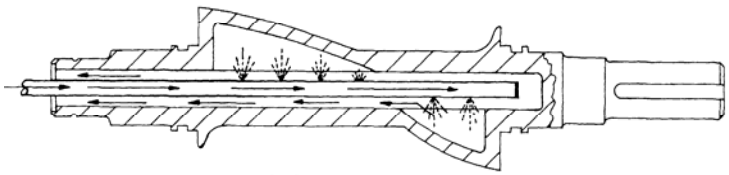


Banbury® Rotor Cooling

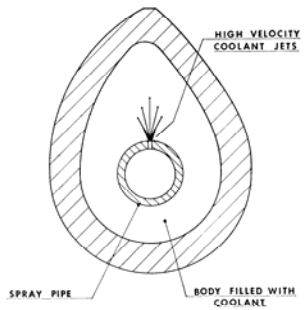


SYPHON PIPE

ROTOR COOLING DESIGNS

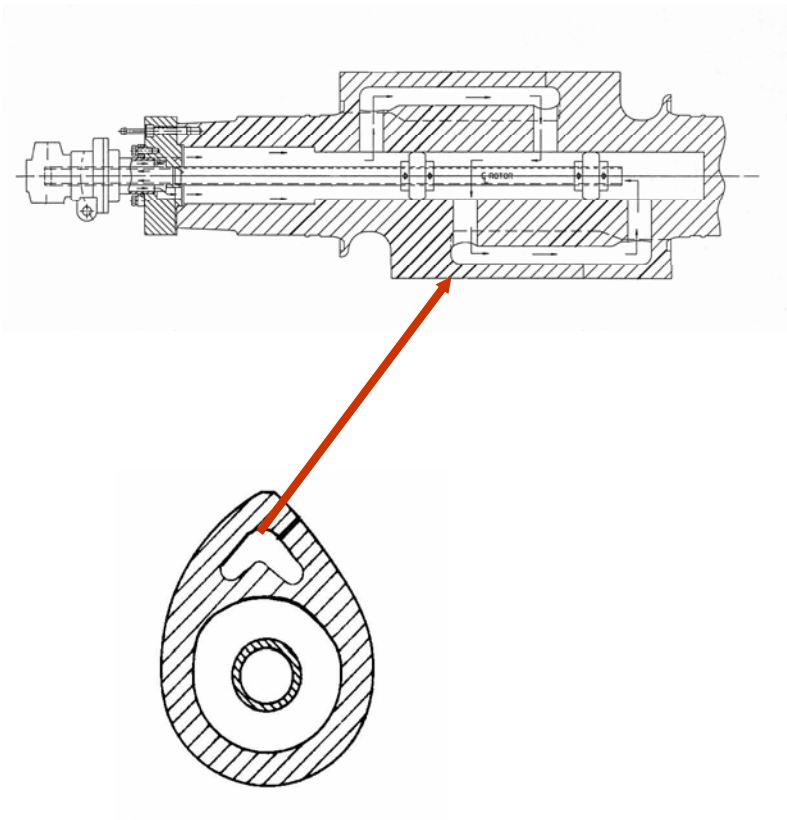


SPRAY PIPE



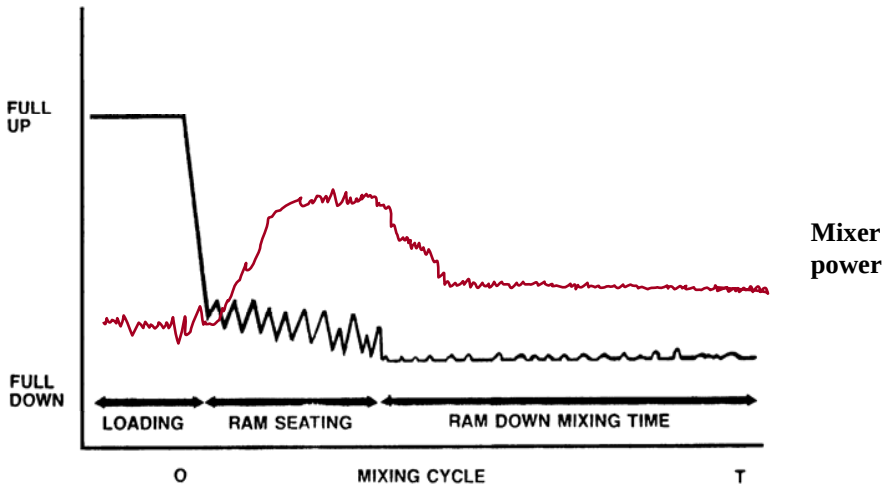
ROTOR COOLING

(Tip Cooled Design)

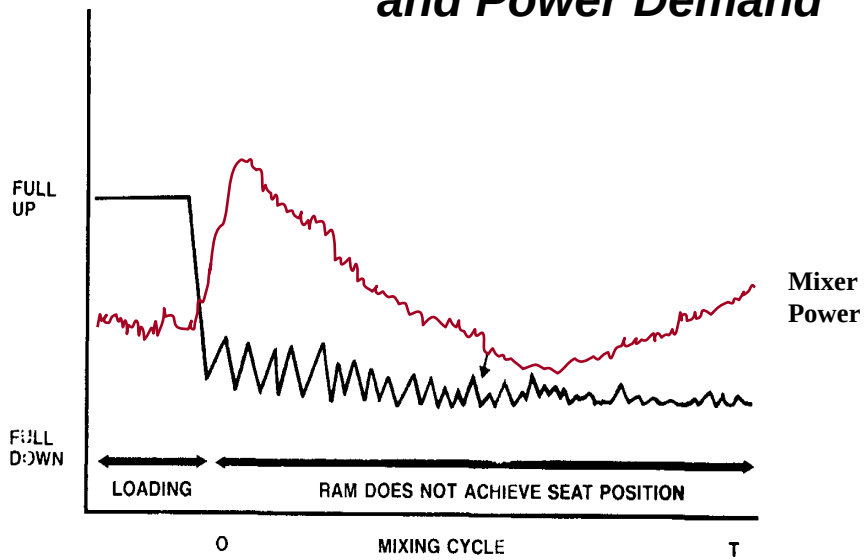


Typical Ram Action and Power Demand

Banbury ® Ram Action and Power Demand



Intermix ® Ram Action and Power Demand



FARREL

PRIMARY VARIABLES AFFECTING BATCH MIXERS

- compound formulation
- batch weight / fill factor
- mixing steps and procedures
- mixer applied batch pressure
- mixer rpm
- mixer temper (metal temperature control)
- compound component considerations
- environmental effects

FARREL

Batch Size Calculation

BATCH SIZE

(THEORETICAL)

batch wt. = (net mixer volume) (density compd.) (fill factor)

Fill factor (Intermix) = 0.85 (fill factor(Banbury))

BANBURY® Mixer
Net Chamber Volume& Rotor Type (liters)

NET MIXER VOLUME " LITERS "

rotor type	Br- 1600	1D	F-50
2 wing	1.6	16.5	-
4wing ST™	-	-	50

rotor type	F-80	F-200	F-270	F-370	F-620
2 wing	80	200	270	-----	----
4 wing	70.5	156	257	414	652
4 wing ST™	70.5	156	257	414	704

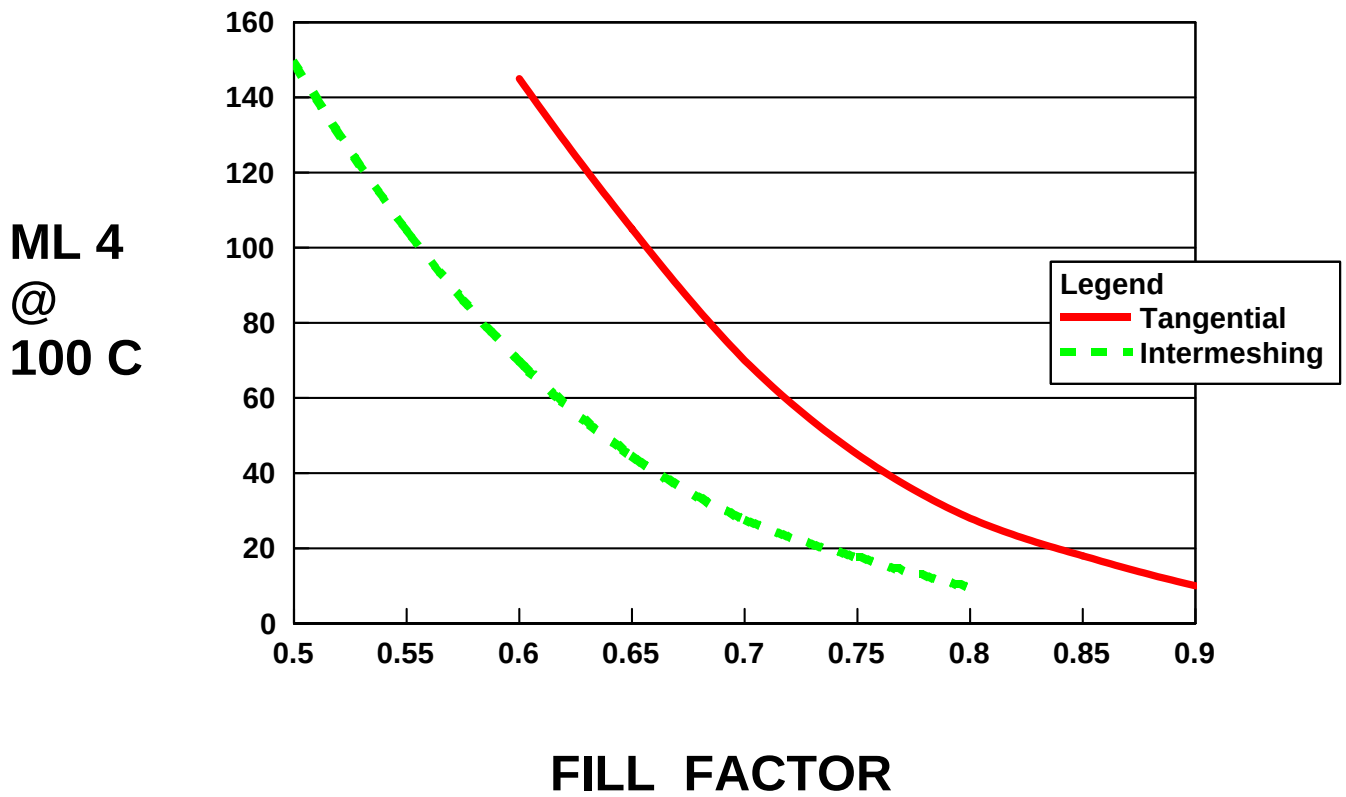
Intermix ® Mixer
Net Chamber Volume (nr-5) rotors (liters)

Net Mixer volume “liters”

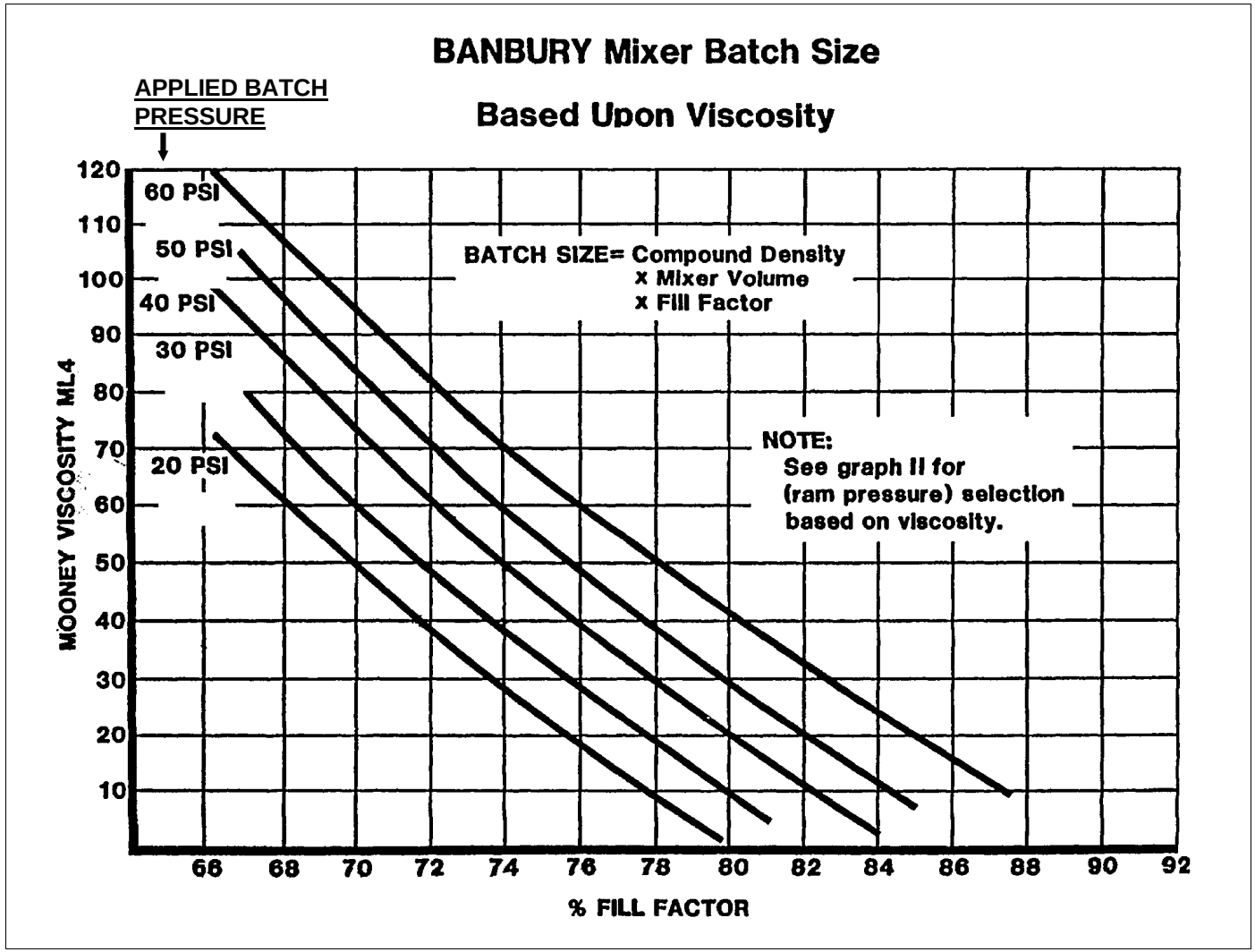
Machine size	K-0	K-1	K-2	K-2A	K-4	K-5	K-6	K-6A	K-7	K-8	K-10
NR-2 rotors	1.64	5	18	44	82	126	185	231	330	436	783
NR-5 rotors	1.82	5.5	20	49	91	140	205	257	330	484	870

Intermix ® Vs Banbury ®
Batch Weight & fill Factor

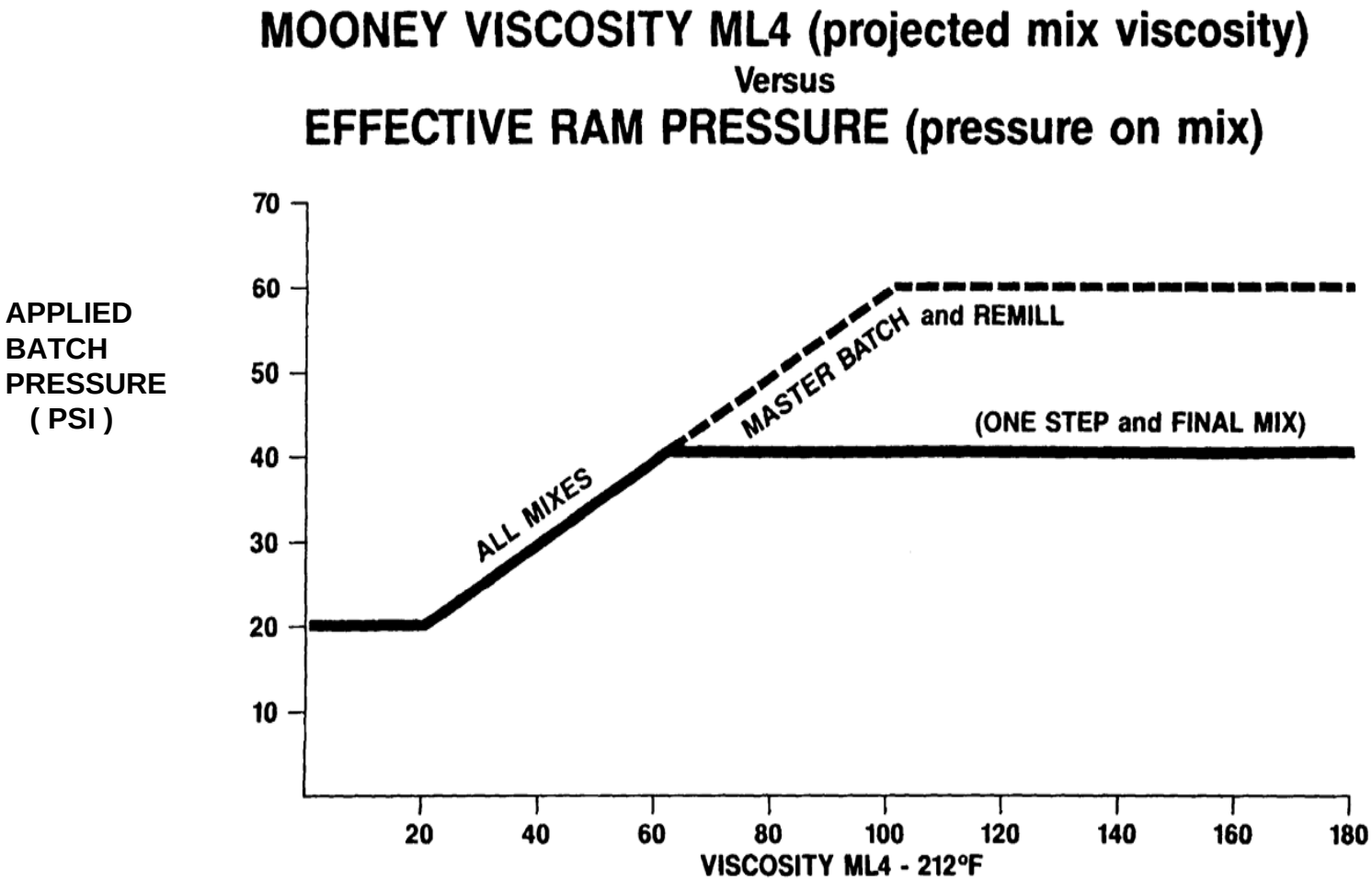
Banbury ® ST equipped mixer @ 50 psi batch pressure
Intermix ® NR5 equipped mixer @ 75 psi batch pressure



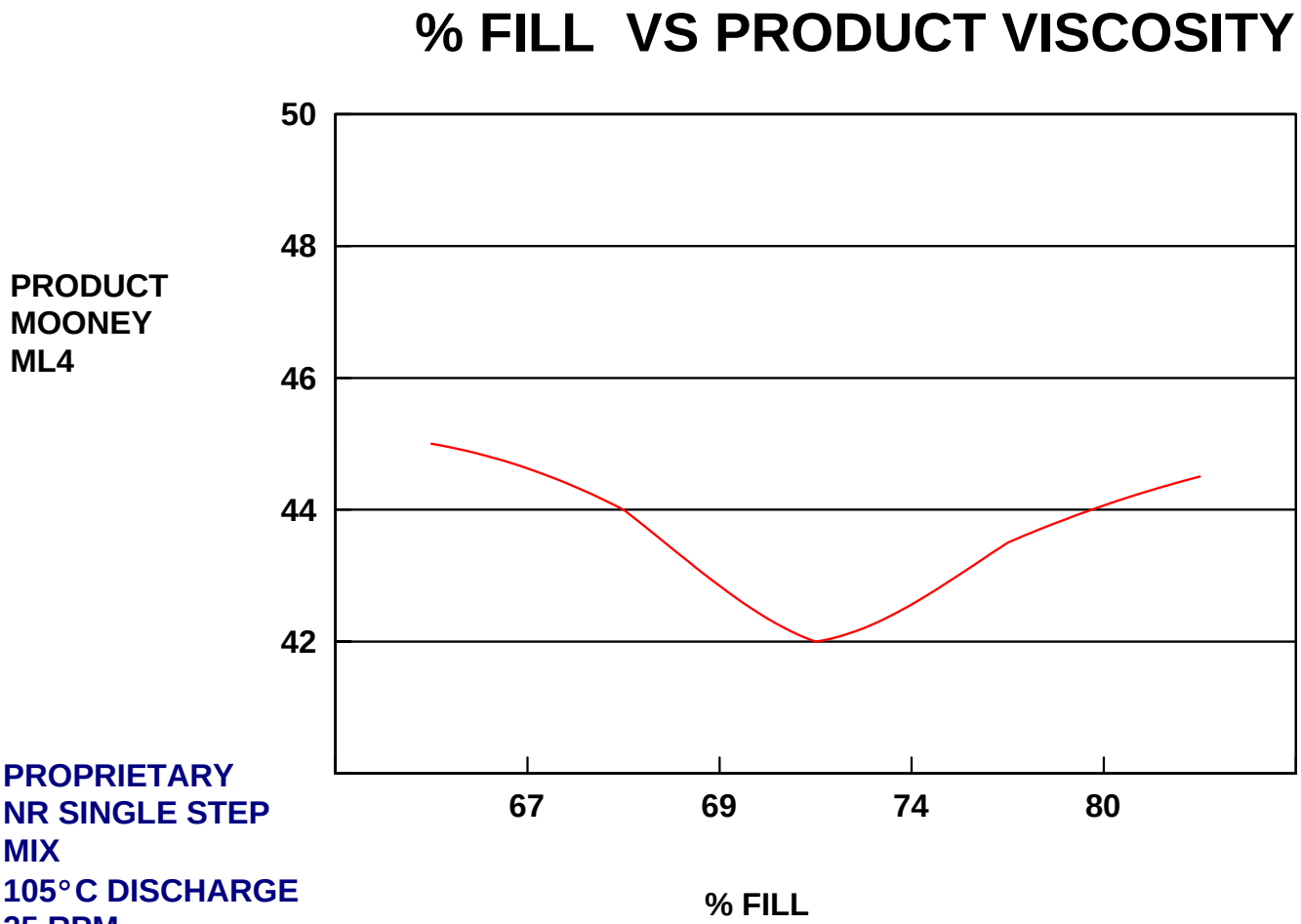
BANBURY®
BATCH WEIGHT & FILL FACTOR



BANBURY®
Batch Pressure & Viscosity

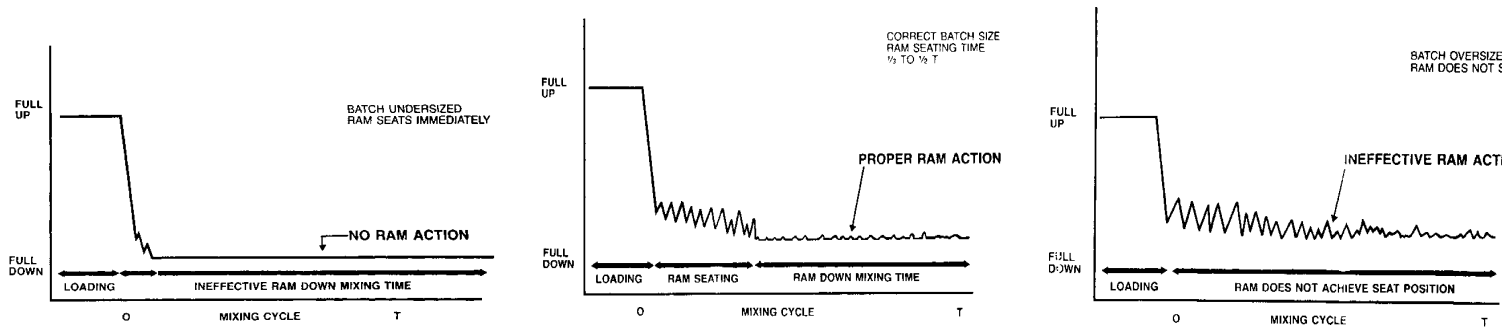


Optimum fill factor (Banbury)



“RPI” DATA
(Banbury Data)

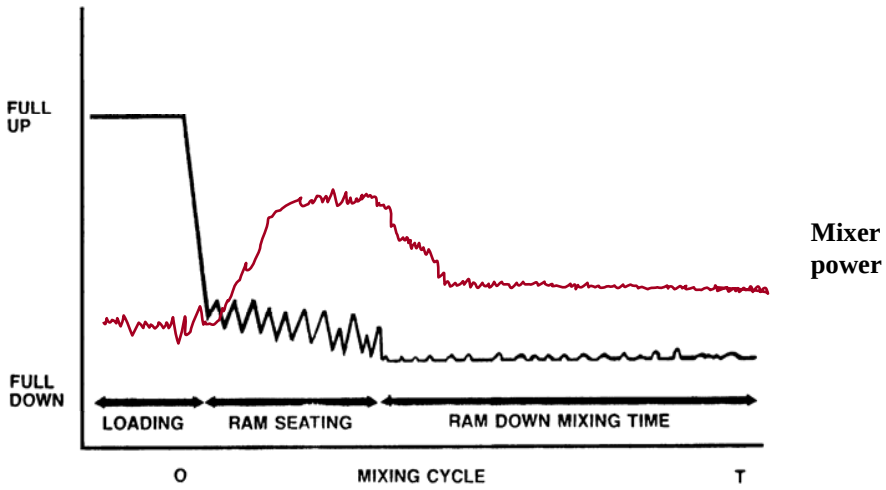
1A *1B* *1C*



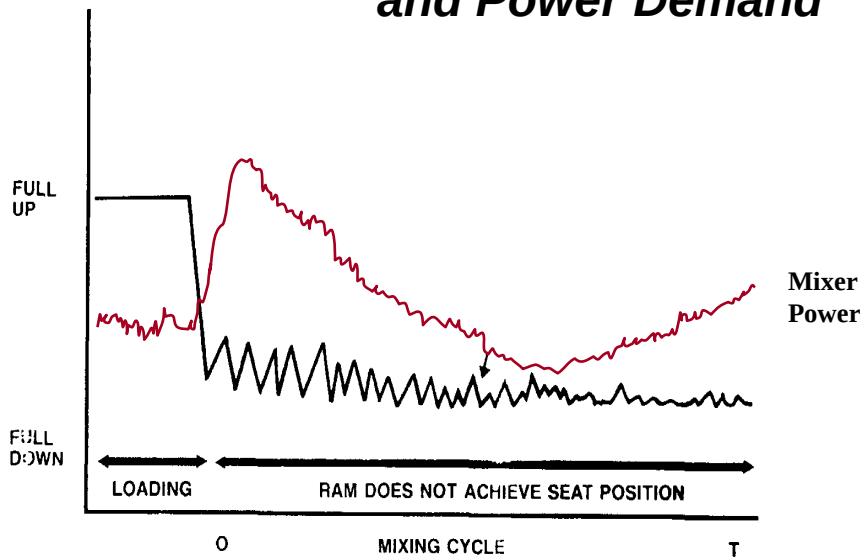
ram position Vs time small batch weight	ram position Vs time optimum batch weight	ram position Vs time large batch weight

Typical Ram Action and Power Demand

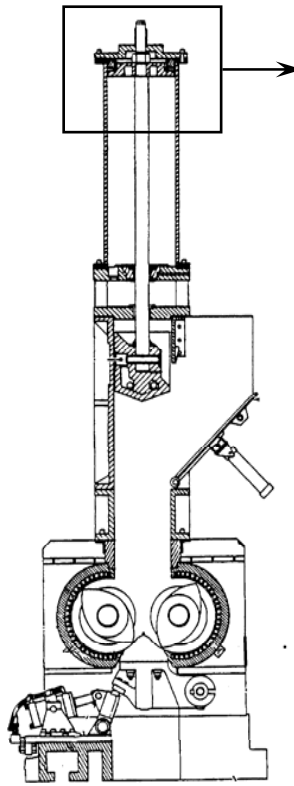
Banbury ® Ram Action and Power Demand

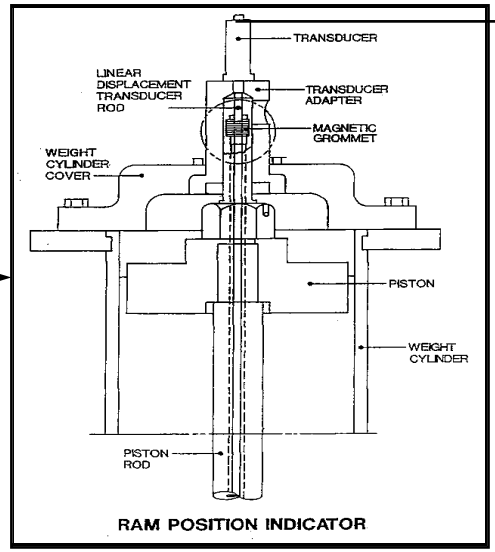


Intermix ® Ram Action and Power Demand



“RPI” SYSTEM

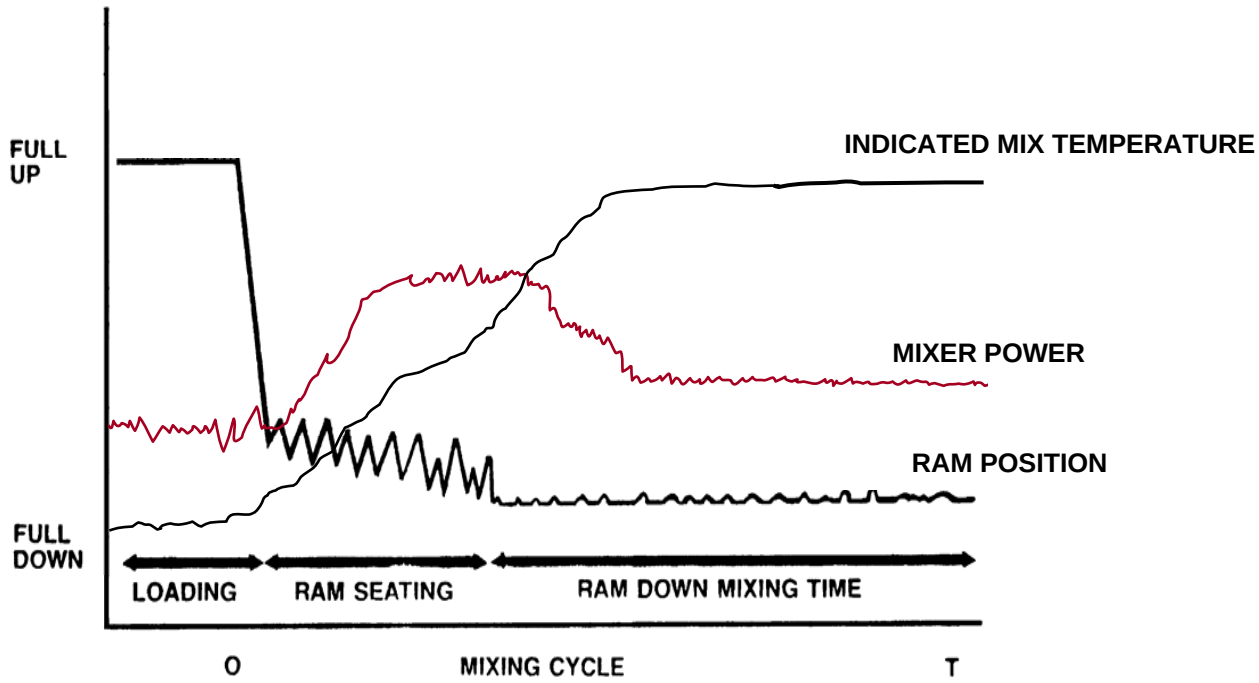




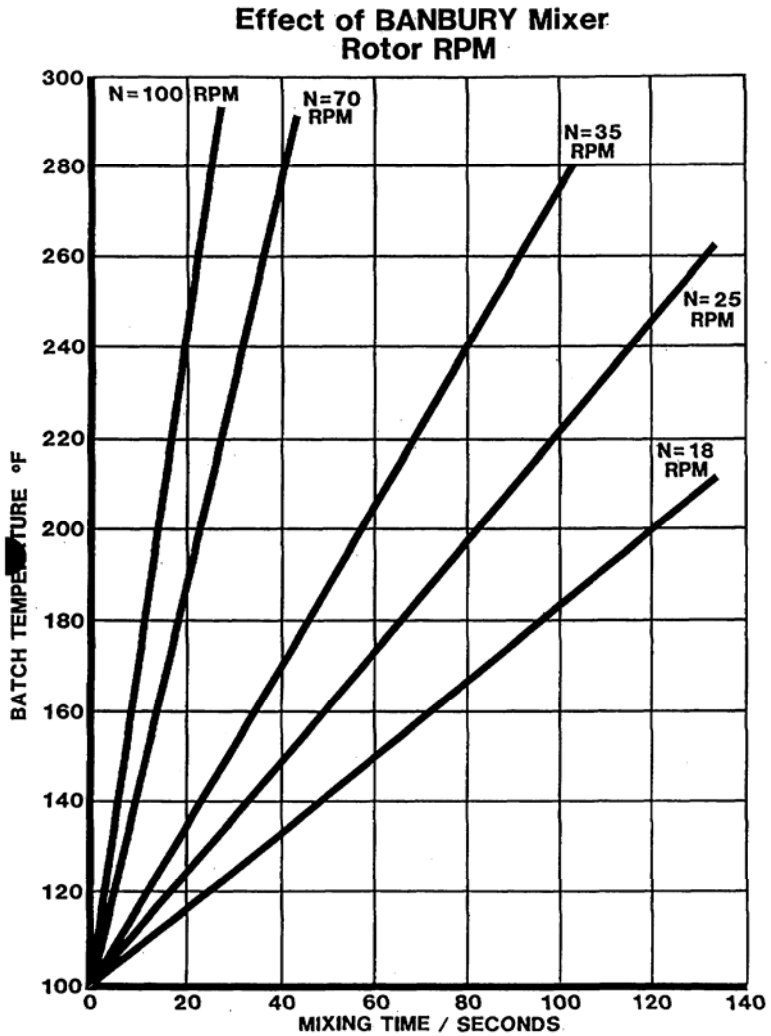
signal conditioner

RECORDER

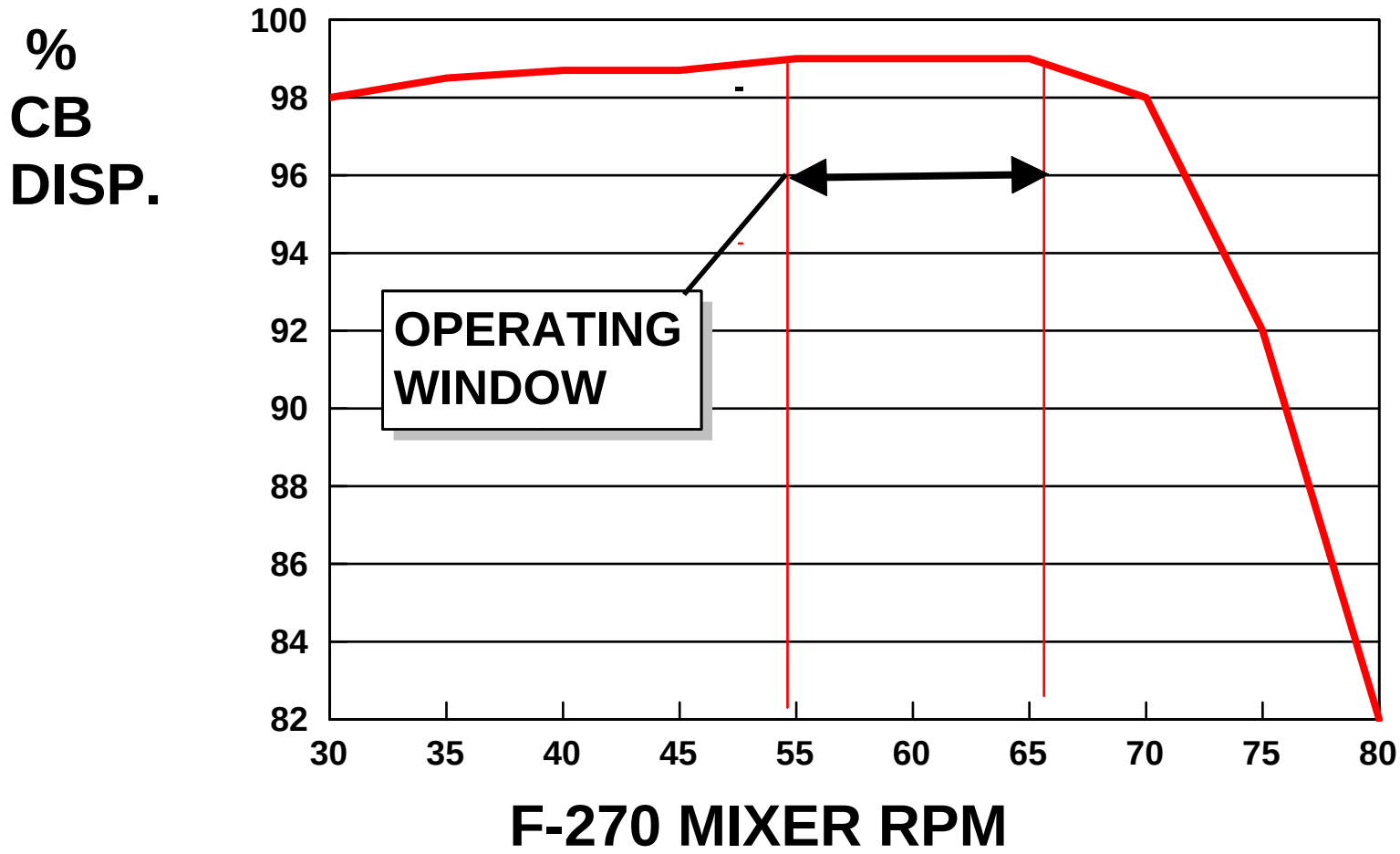
Mix Topography & Process Optimization



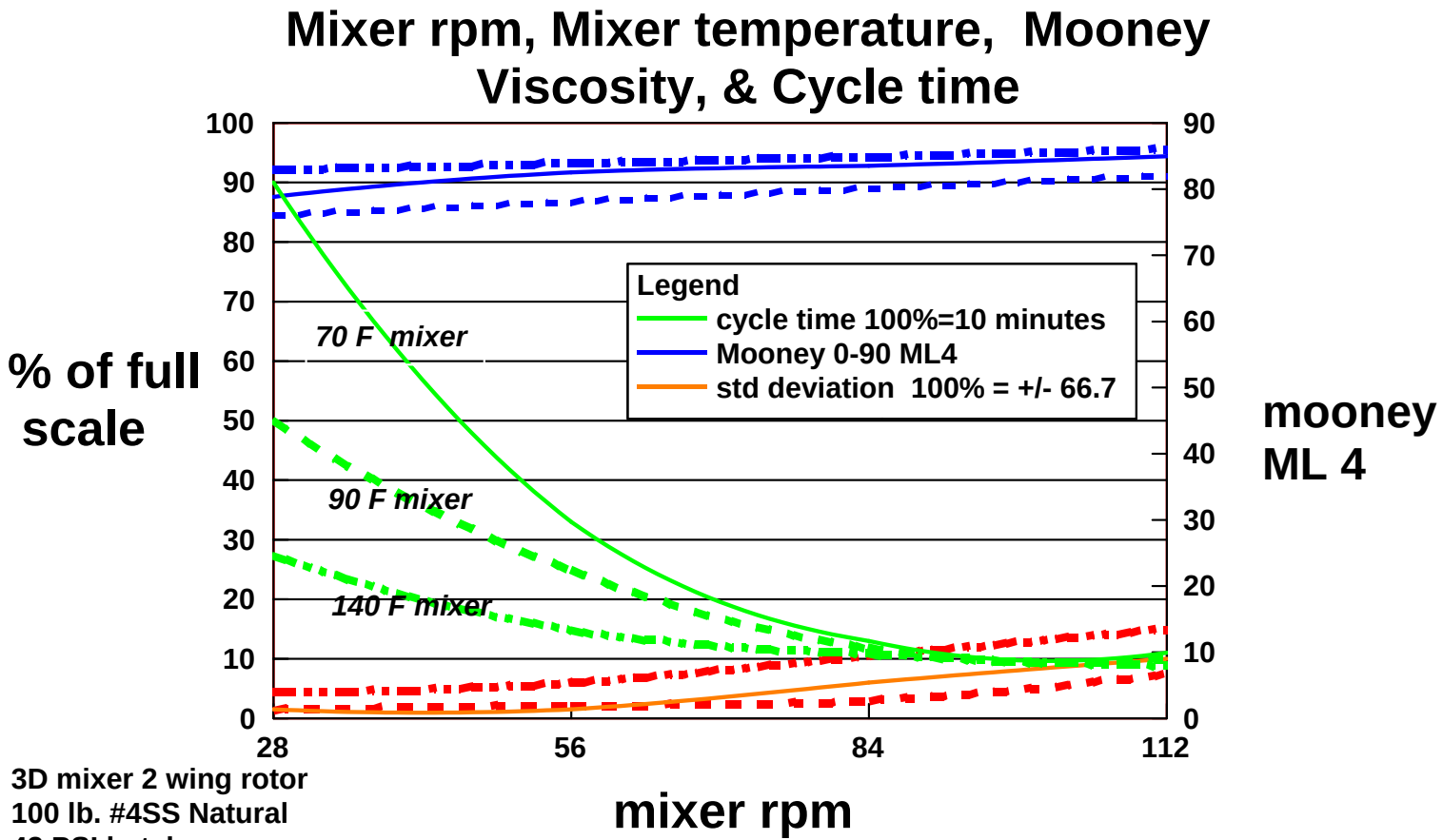
Banbury Mixer RPM & Mix time



Mixer RPM & CB Dispersion



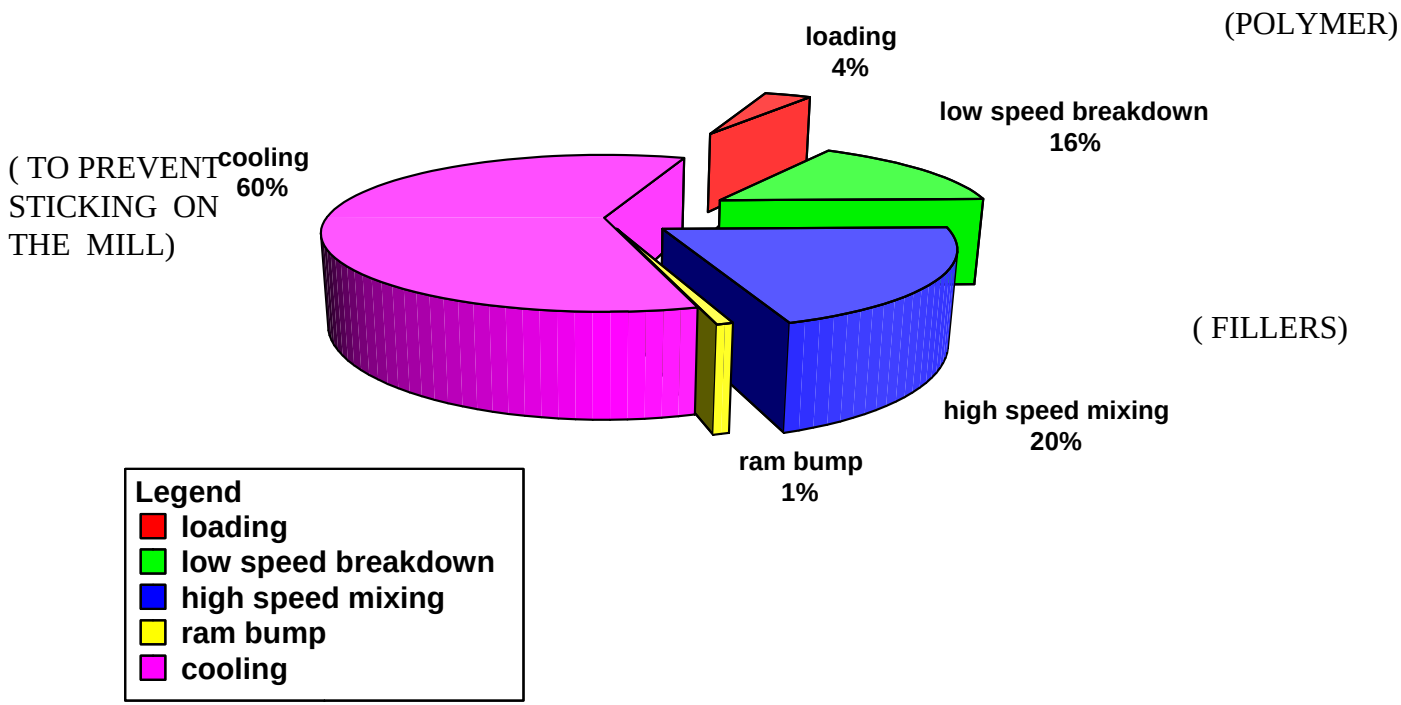
Mixer RPM,TCU settings & Mooney Viscosity



3D mixer 2 wing rotor
100 lb. #4SS Natural
43 PSI batch pressure
uniform feed @ approx. 10 Lb. chunks
70 F feed temperature
discharge @ 285 -300F

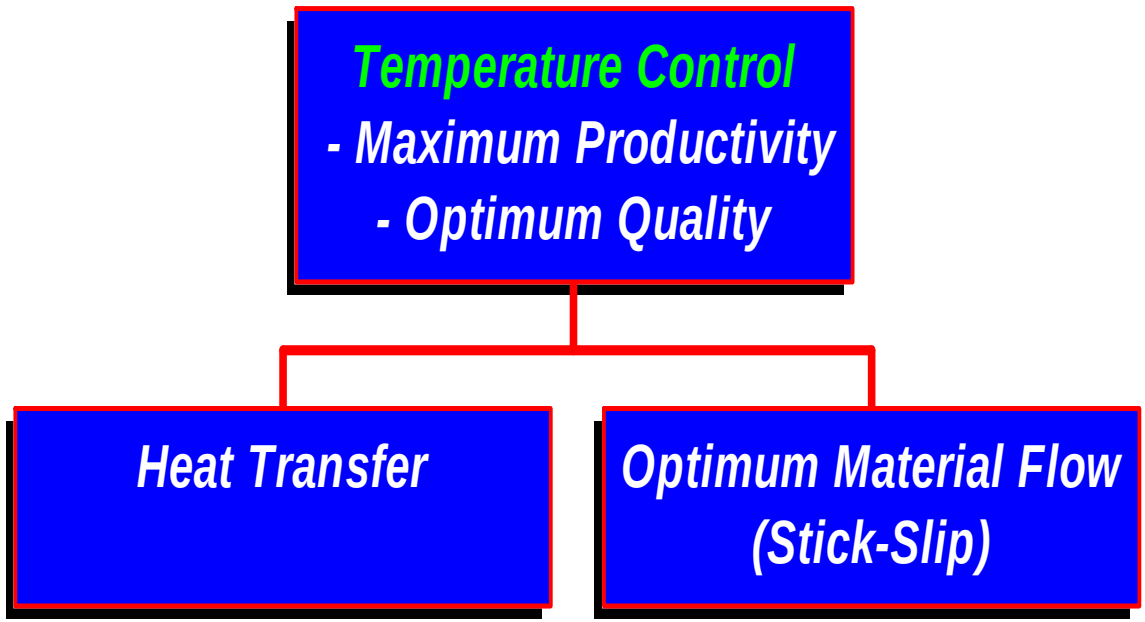
Mix Cycle and Mixer RPM

MIX CYCLE FUNCTION DISTRIBUTION

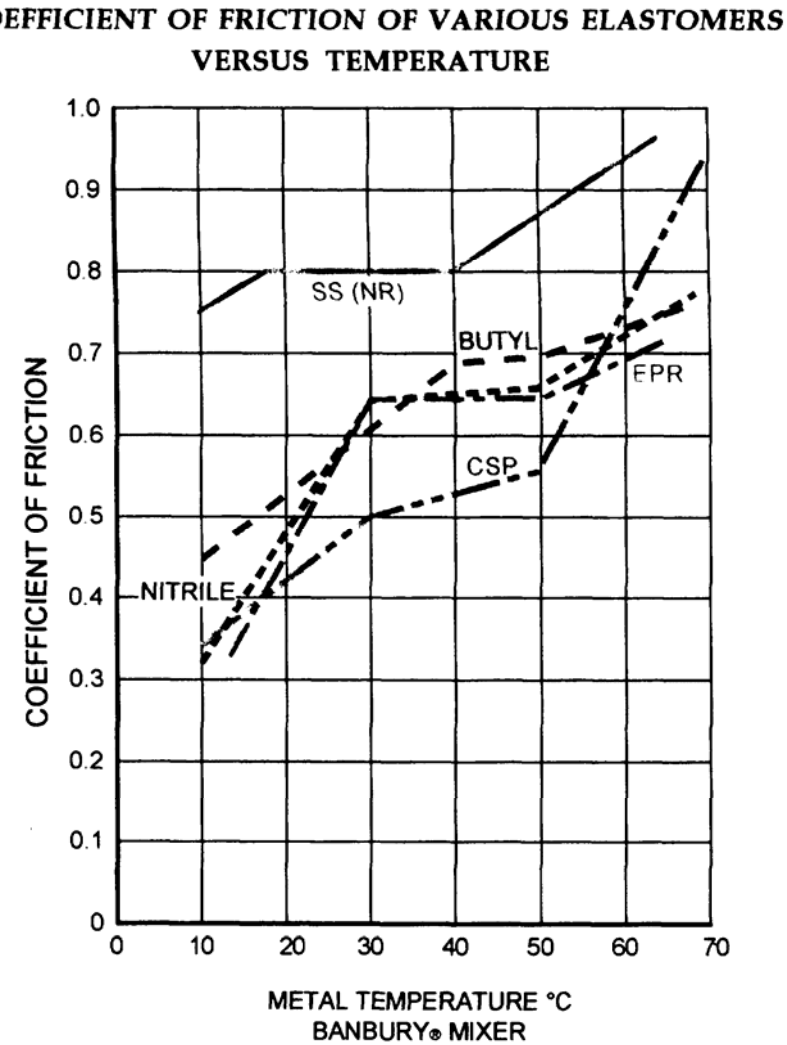


FARREL

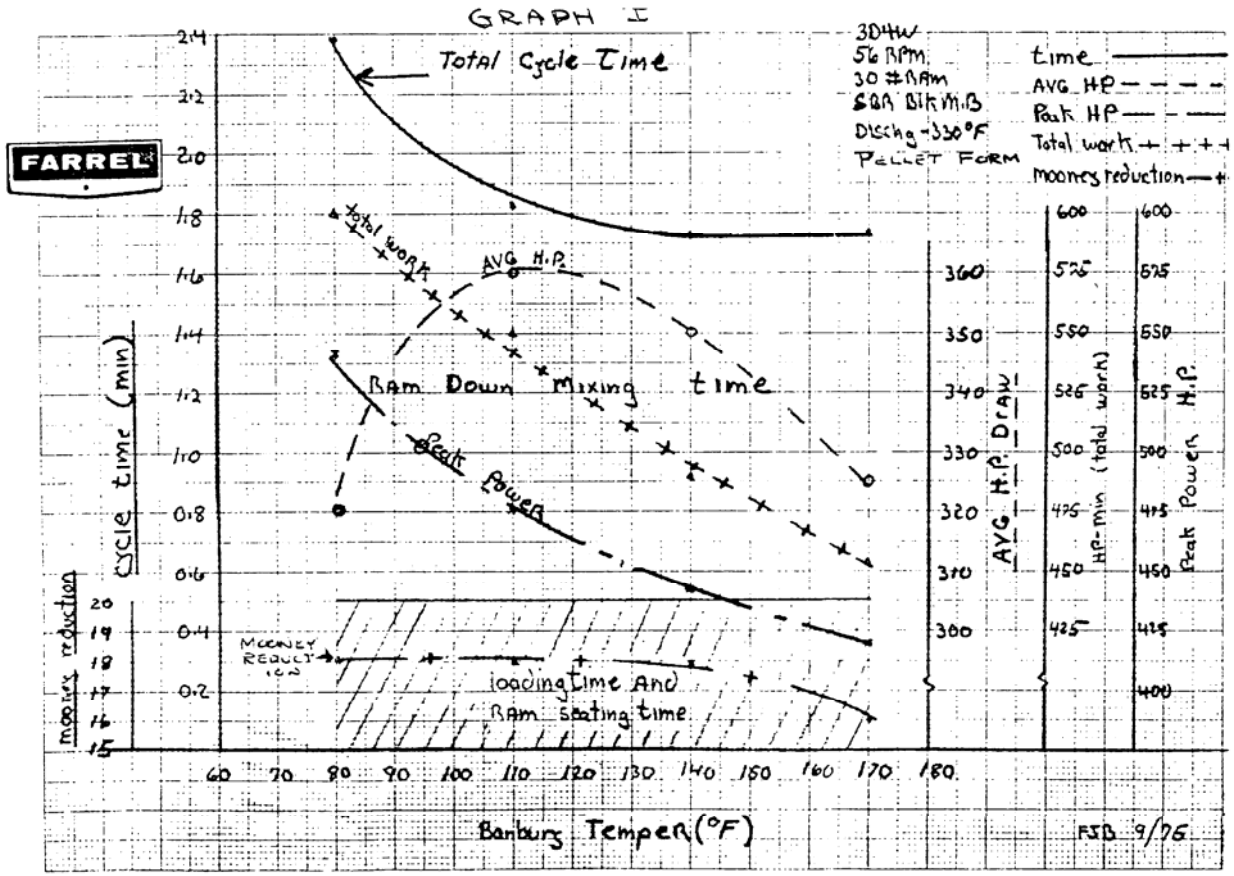
Mixer Metal Temperature



Metal Temperature & Interfacial friction effects



SBR mixing,TCU settings & mix efficiency

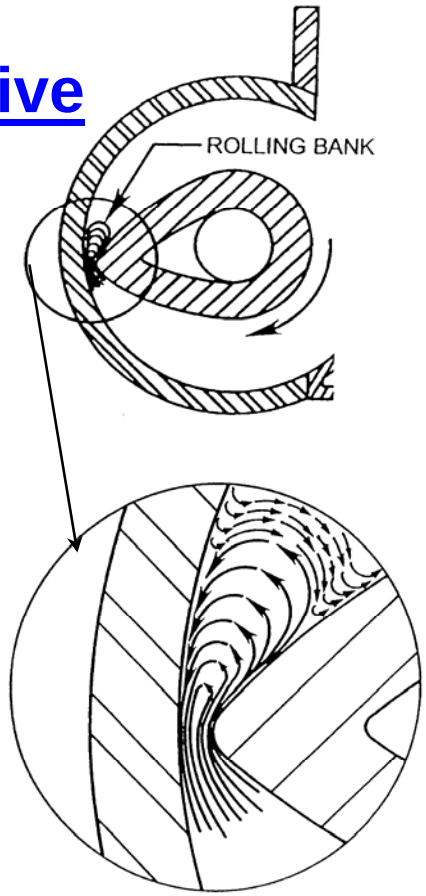


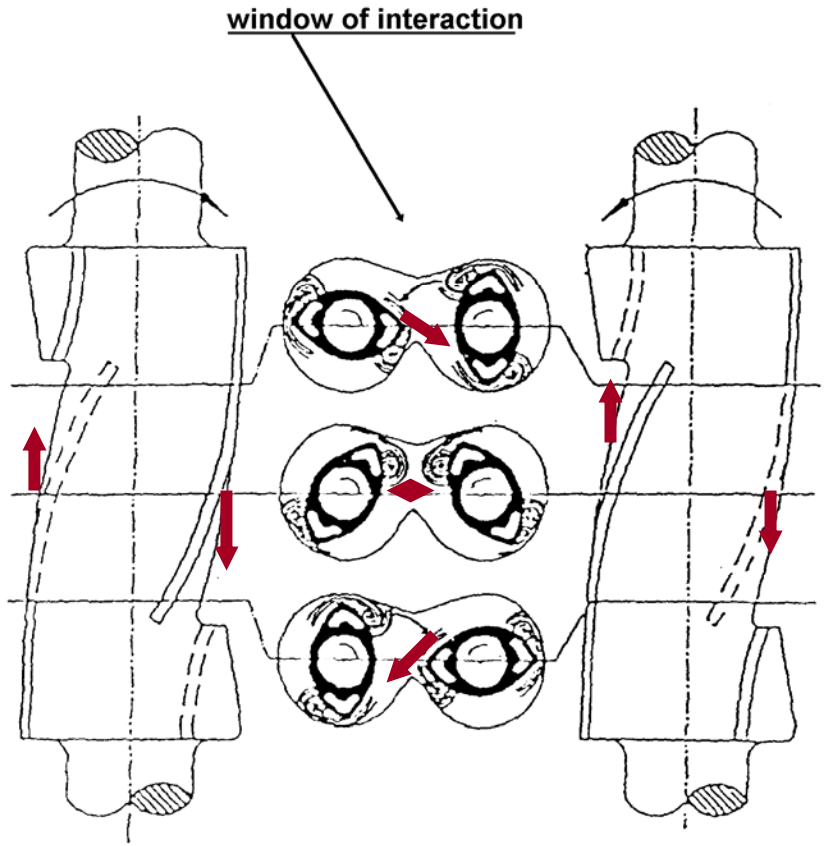
FARREL

Mixing Action "Banbury ®"

Distributive

Dispersive



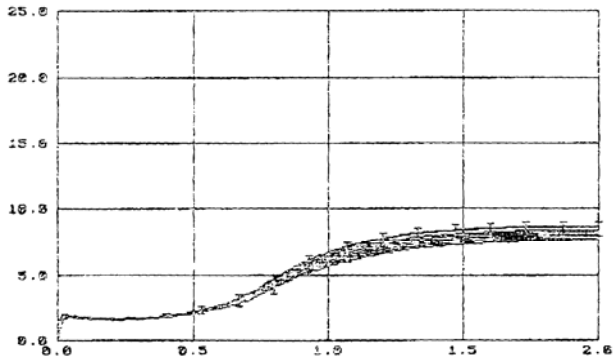


Even speed or friction operation

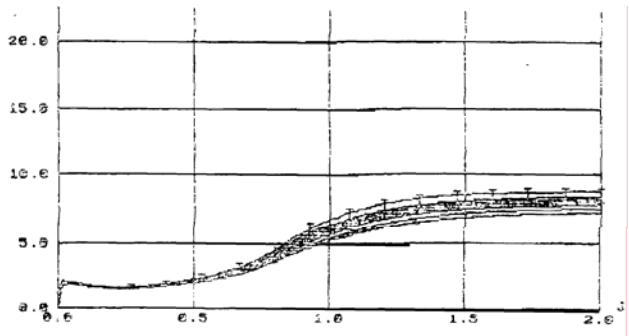
ST Rotor Performance

Cure Uniformity and Rotor Temperature
Tread Compound - Final Mix

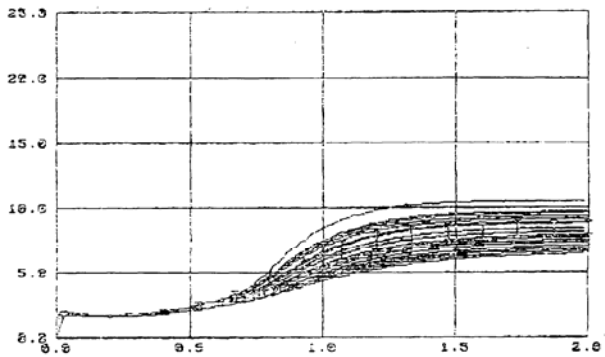
F-270 4wST
mixer body @49 C (120 F)
mixer door @ 27 C (81 F)
fill factor @ 75%
batch Pressure @ 4.1 bar (60 psi)
mixer @ 30 rpm
70 sec rm dn mix time



rotor water @ 71 C (160 F)

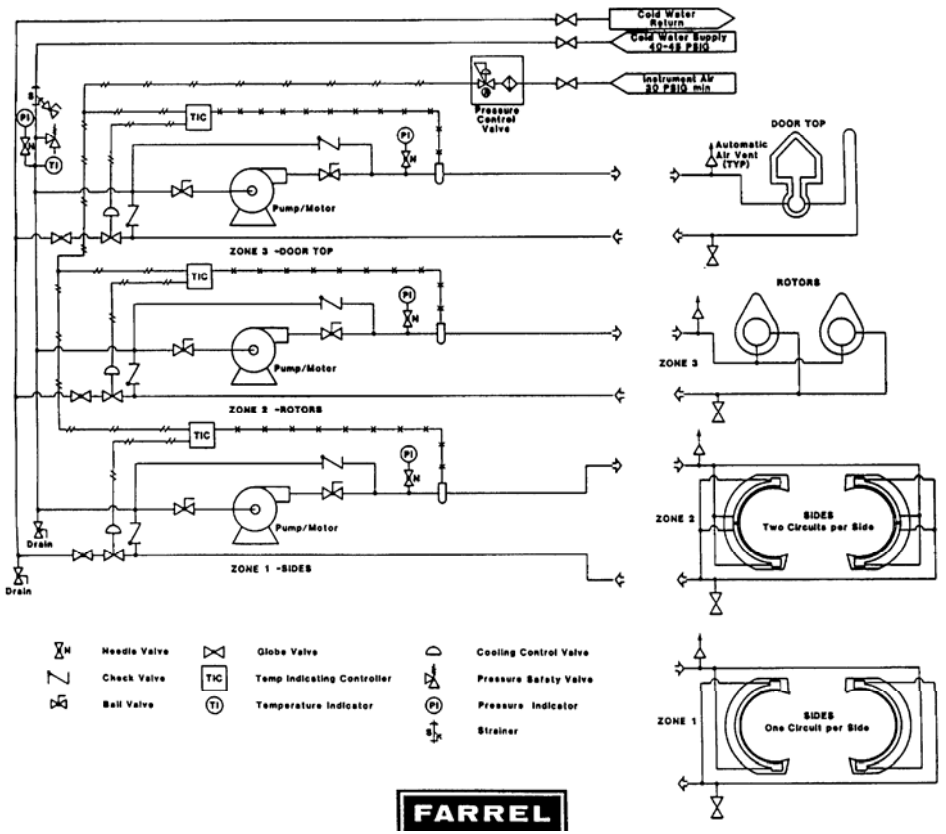


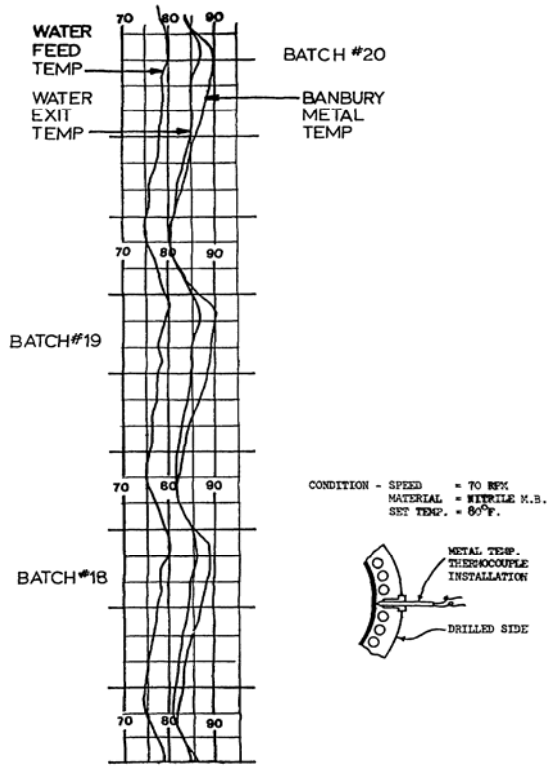
rotor water @ 60 C (140 F)



rotor water @ 49 C (120 F)

Temperature Control Unit "TCU"

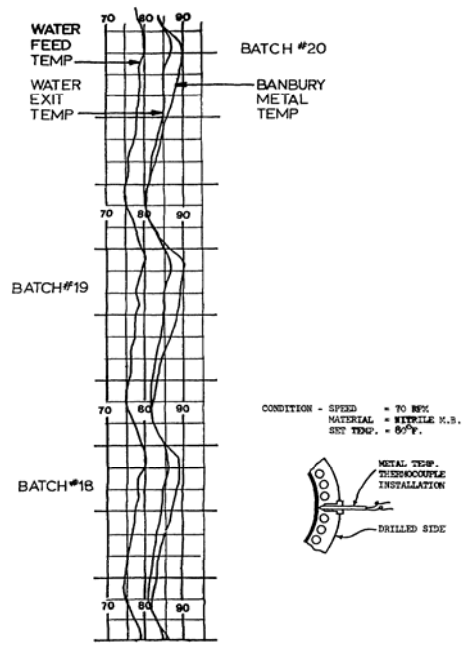




Banbury® Water Flow Rates (for maximum heat transfer)

FLOW RATES – BANBURY MIXERS
GPM

	1	3D	9/9D	F 80	F270/ 11D	F370	F620/ 27D
SIDES	30	60	60	120	120	140	180
ROTORS	20	35	40	40	60	100	150
DOORTOP	10	10	10	10	15	30	30

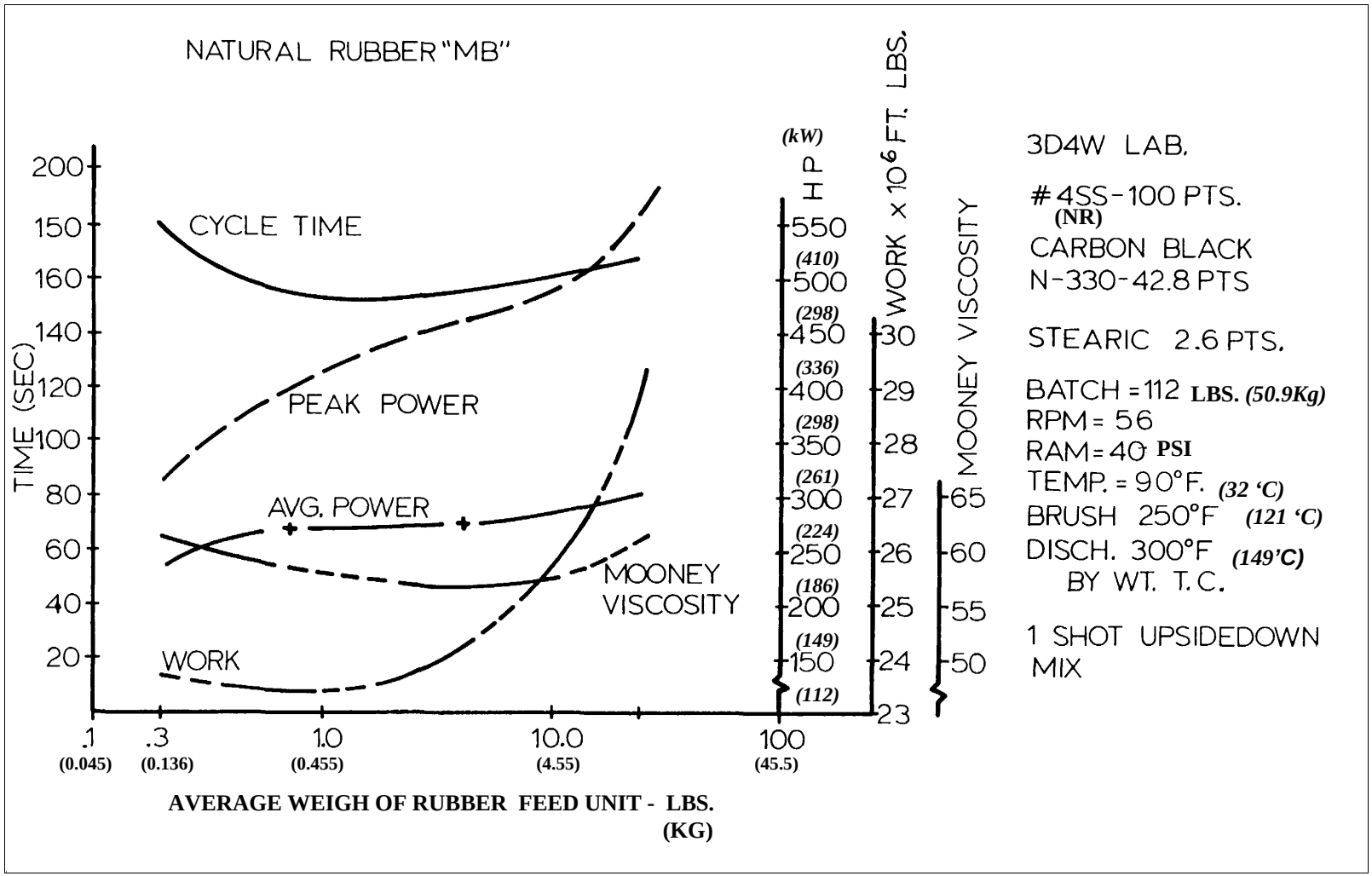


Banbury® TCU settings (starting points)

Polymer type	TEMPERATURE °F		
	rotors	sides	door
Natural rubber	90	150	90
Synthetic	140	150	150
Natural / Synthetic blends	150	150	150
EPDM / EPT	150	190	150
Nitrile (NBR)	90	90	90
Chloroprene (CR)	140	90	140
Butyl (BR)	90	90	90

COMPONENT CONSIDERATIONS

"Feed Form"



3D4W LAB.

#4SS-100 PTS.
(NR)
CARBON BLACK
N-330-42.8 PTS

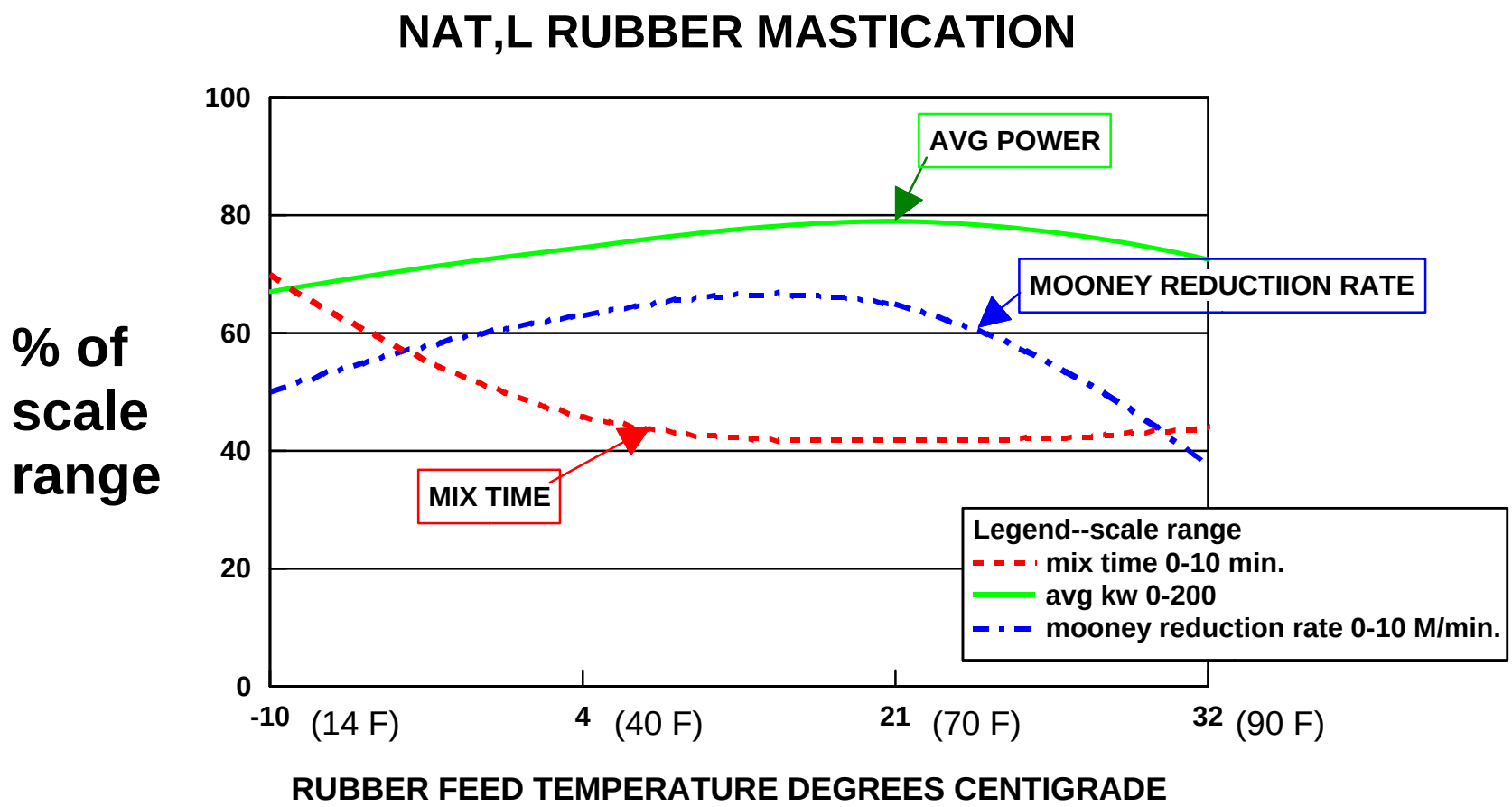
STEARIC 2.6 PTS.

BATCH = 112 **LBS.** ***(50.9Kg)***
RPM = 56
RAM = 40 **PSI**
TEMP. = 90°F. ***(32 'C)***
BRUSH 250°F ***(121 'C)***
DISCH. 300°F ***(149'C)***
BY WT. T.C.

1 SHOT UPSIDEDOWN
MIX

FARREL

COMPONENT CONSIDERATIONS
"environmental effects"



Mixing Parameters, Steps and Procedures
"The Art of Mixing Rubber"

I MIXING STEPS

SINGLE STEP MIX
- conventional single step
- upside down single step
- process specific single step

MULTIPLE STEP MIX
- premastication (optional)
- masterbatch
  - -simple single step mix
  - -process specific single step mix
- remill (optional)
- final mix

II MIXING PROCEDURES

- order of additions
- number of additions
- number of ram cleanings (brushes)
- discharging procedures
- rpm and batch pressure settings
- means of control

III MIXER OPERATING PARAMETERS

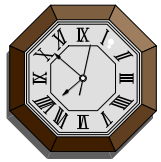
- % fill(batch weight)
- temper
- ram pressure
- mixer speed

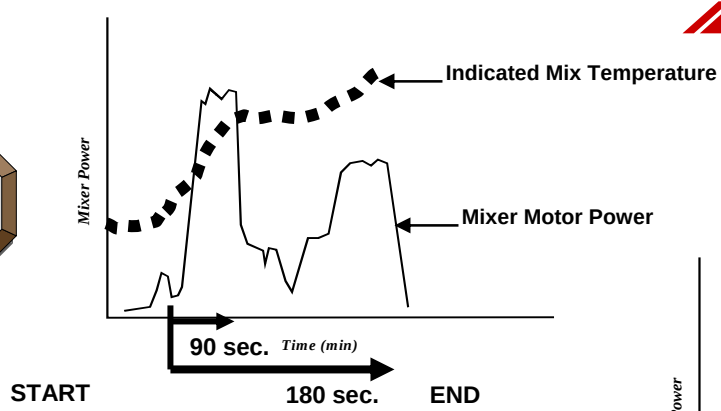
CYCLE CONTROL

-time
- indicated temperature
- energy (kwh)
- torque (power hp or kw)

FARREL

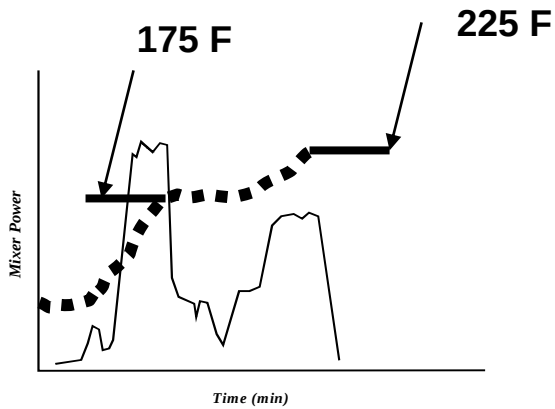
- Time





- Indicated Mix Temperature

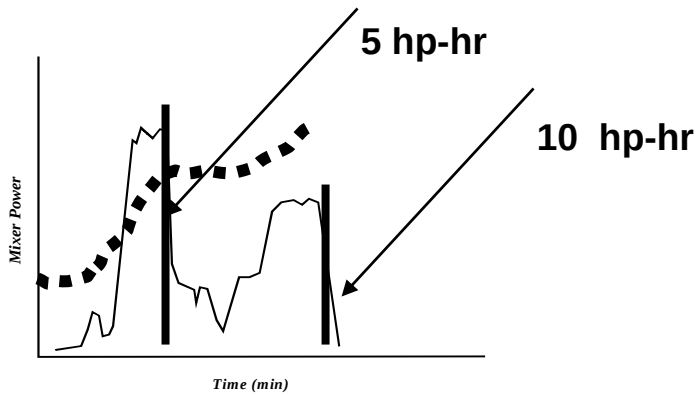
  (end frame or drop door T.C.)



- Mix Energy (hp-hr)

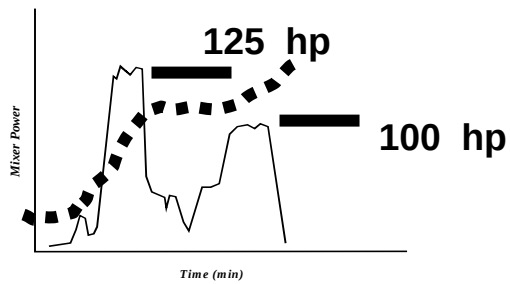
  (Power x time)

  (area under the power Vs time curve)



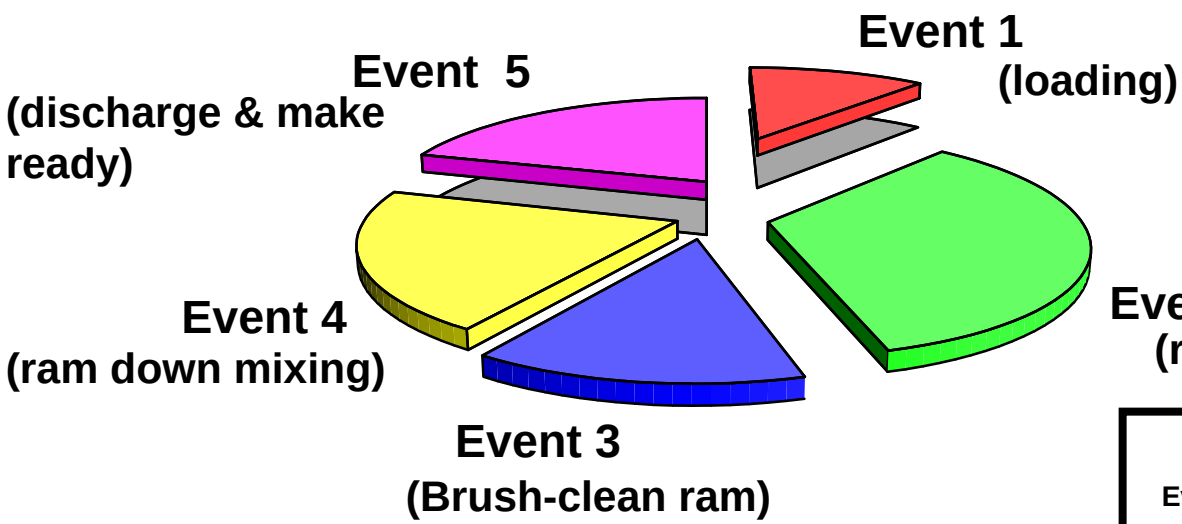
- Mixer Motor power

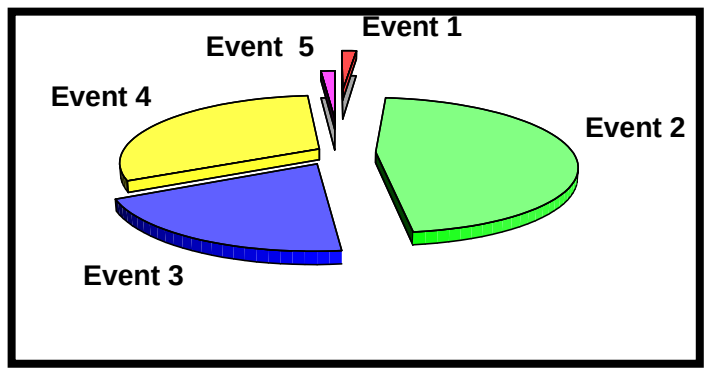
  (mixer motor torque)



Single step mixing

Event	Description	rpm	batch PSI	time (sec.)	Kwh
1	load polymer,all black,chemicals ,oils ,fillers ,cures	10	up	17	0.09
2	ram down mix to 175 F	50	50	50	2.66
3	raise ram and brush	30	up	20	1.01
4	ram down mix to 225 F	25	30	30	1.87
5	discharge batch- float ram open, drop door& dwell 15 sec	30	up	30	0.00
	close drop door and raise ram			147	5.72





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The End

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Banbury® Technical Data

Banbury® designation	Br	00C	1D	F-50	F-80	F-120	F-200	F-270	F-370	F-620
Net Chamber volume (liters)	1.57	4.24	18.7	47.4	80 /70	124 / 106	220 / 200	270 / 257	414	650 / 711
Rotor type	2w	2w	2w	ST	2w/4w&ST	2w/4w	2w/4w&ST	2w/4w&ST	4w & ST	4w / ST

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Intermix ® Technical Data

Capacities with the NR5 Rotors (liters)

Intermix type	K0	K1	K2	K2A	K4	K5	K6	K6A	K7	K8	K10
Net Chamber volume (liters)	1.8	5.5	20	49	91	143	206	257	306	484	870

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