SPE South Texas section

SPE

2017 SPE INTERNATIONAL

POLYOLEFINS CONFERENCE

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REEDY

CHEMICAL FOAM

& SPECIALTY ADDITIVES

Speaker:

Peter Schroeck

President & CEO

A new introduction to Chemical Blowing Agents

- A lean method for creating cellular structures in thermoplastic injection and extrusion molding

REEDY
CHEMICAL FOAM
& SPECIALTY ADDITIVES

- Reedy International Corp. was founded in 1989 in Keyport NJ by Michael Reedy, a career-long supporter of the SPE – TPM&F
- Awarded 19 patents: Related to foam process, formulas and combining CO_2 with any other gas
- In partnership with Genpak, introduced CBA to meet newly implemented global emission requirements to replace CFC and HCFC in the production of foamed XPS
- In 2009 company moved its headquarters to Charlotte, NC
- In January 2015 Reedy International Corp. changed to **Reedy Chemical Foam & Specialty Additives**

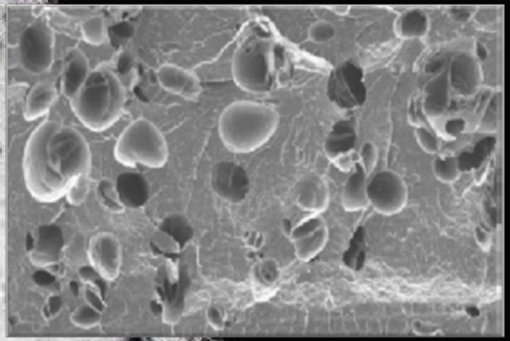
Foaming Agent

(Blowing Agent) A substance which is capable of producing a cellular structure via a foaming process in a variety of materials that undergo hardening or phase transition, such as polymers and plastics.

Two technologies:

Physical Blowing Agent

(Gas Injection)



Cellular structure created by injecting gas in a super critical state directly into the barrel through equipment modifications.

For high and medium density foams, gases utilized are usually N_2 or CO_2.

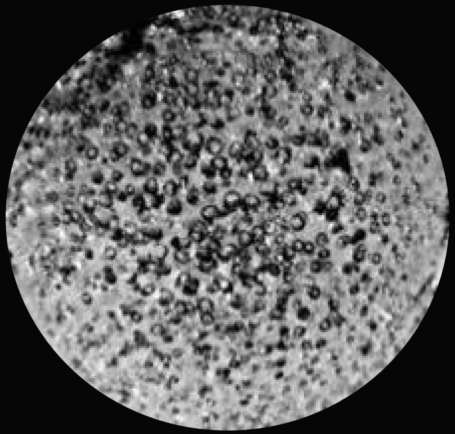
N_2 **or** CO_2

Chemical Blowing Agent

(Chemical Foaming Agent, CFA)

Cellular structure created by a chemical reaction and heat during the plasticating process.

Gas generated is usually CO_2, N_2, or a combination for high-to-medium density foams.



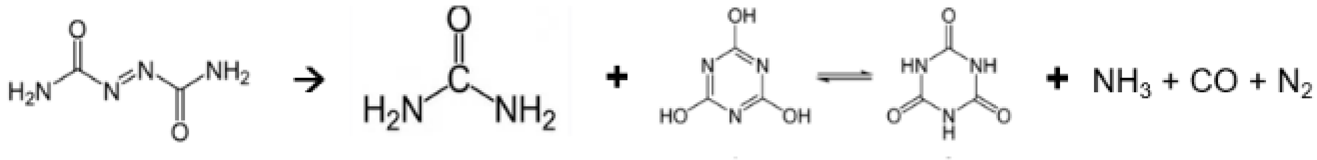
N_2 **And/or** CO_2

Primary CFA Types

Exothermics

Azodicarbonamide (ADC) : Creates Nitrogen and Ammonia, generates heat upon decomposition.

Typically best for PVC or ABS compounds. Heat up the System. Make Larger cells in Olefins, Styrenics, etc. Best suited for SFM or extruded plastic lumber.



- 50 years of use in rubber and plastics
- Slow gas diffusion rate - Positive for some applications and negative for others
- Rapid and Robust gas expansion
- N_2 is not as soluble in olefins and styrenes as CO_2

Endothermics

Carbonate / Acid Blends (SAFOAM® Endothermic) : Creates CO_2 and water, absorbs heat.

Most are FDA, Cool the system, usually make the best structure (small plentiful cells, white).

$3NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3CO_2 + 3H_2O$

(sodium bicarbonate) + (citric acid) → (sodium citrate) + (carbon dioxide) + (water)

- 30 Years of use in Thermoplastics
- Self Nucleating
- Rapid gas diffusion rate – Faster crystallization times due to CO_2 being a plasticizer
- Slow, controlled gas release (less pressure)
- CO_2 is more soluble in the polymer melt than N_2

Why Use Chemical Foam?

- Reduces Cost
  - Less Material Consumption
- Reduces Weight
- Eliminates Sink
  - Improved Printing on Flat Surfaces
- Higher Production Efficiency
  - Lower Processing Temperatures
  - Faster Cycle Time
  - Reduces Machine Energy

- Improves Thermal Insulation
- Improves Sound Insulation
- Easily Scalable
  - Stable and Repeatable
  - Simple Process, Easy to Feed
- Easy Startup Cost
  - Easy to use Additive
  - No Modifications to Equipment Needed
  - *Shutoff nozzles are a benefit in Injection Molding*

Expectations of Modern CFA

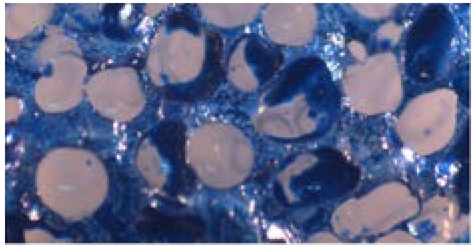
Early CFA Technology:

- 400-500 micron cells were common and acceptable in commodity parts
- High gauge variability and process challenges
- Closed-and-Open cells
- ADC is most common worldwide; Challenges due to potential toxicity
- No longer acceptable for use in food packaging, children's products

Modern CFA Technology:

- Process Friendly formulations – “Value Added” formulas for easy processing
- Uniform cell structure = more consistent physical properties, better surfaces
- Customers seek 200 microns cells and below, more **Closed-Cell content**
- Fine Cell structure = better retention of physical properties like impact strength and elongation at break

400 Micron

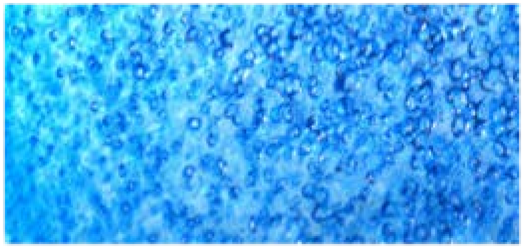


1980

200 Micron

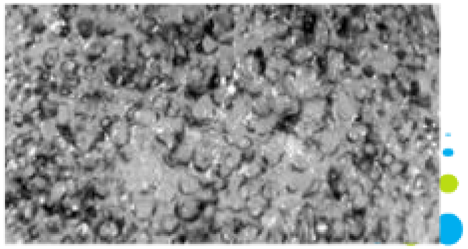
2000

100 Micron



2010

< 100 Micron



2015

Cost Savings of Safoam®

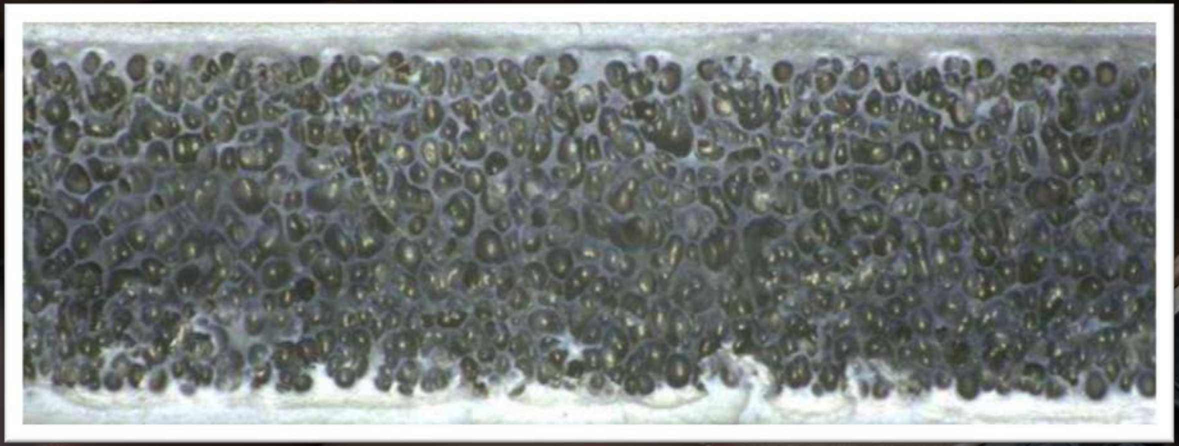
Injection Molding Case Study: Cosmetic Compact Case (2001)

Pre-foamed Production		SAFOAM® FPE-50 Evaluation	
Machine & Tool	650 Ton Clamp; 4 Cavity slide tool	SAFOAM® FPE-50	$4.28/lb. 454 grams per lb. = $0.0094/gram
Pre-Trial Machine Output	240 parts per hour	SAFOAM® FPE-50 Dose Rate	1.5%
Pre-Trial Part Weight	338 grams average	Part Weight	314 grams average
Pre-Trial Total Cycle Time	$65.00 per hour	Cycle Time Reduction	8% (38 grams average reduced to 314 grams average)
Machine Time Cost	59.53 seconds	Foamed Part Cost	Glass filled PP: 314 grams x $0.0009/gram = $0.2825
20% Glass Filled PP Cost	$0.41/lb.	Machine	$0.018/seconds x 48.5 seconds = $0.873
Machine	$0.018/second x59.53 seconds = $1.072	FPE-50	314 grams x 1.5% x $0.0094 = $0.0442

$1.38/part @ 240 parts/hour

$1.20/part @ 285 parts/hour

PP & TPO Auto Parts



CFA reduces part weight and improves part stability.

Automotive Applications

- Material: PP/LGF, PP/EPDM
    - Visible Parts
    - Door Panel
    - Overheads
    - Structural Parts
    - Dash Board Carrier

Chemical Foam Molding

- **Molding Machine:**
  1. Shut-off Nozzle ex. herzog®
  2. Pressure and accumulator for fast injection

- **Mold Design:**
  1. Gate Location and size
  2. Sufficient vent

- **Molding Parameters:**
  1. Temperature profile
  2. Fast injection speed
  3. Low or no pack and hold

Typical Foam IM challenge - surface splay

Joint study

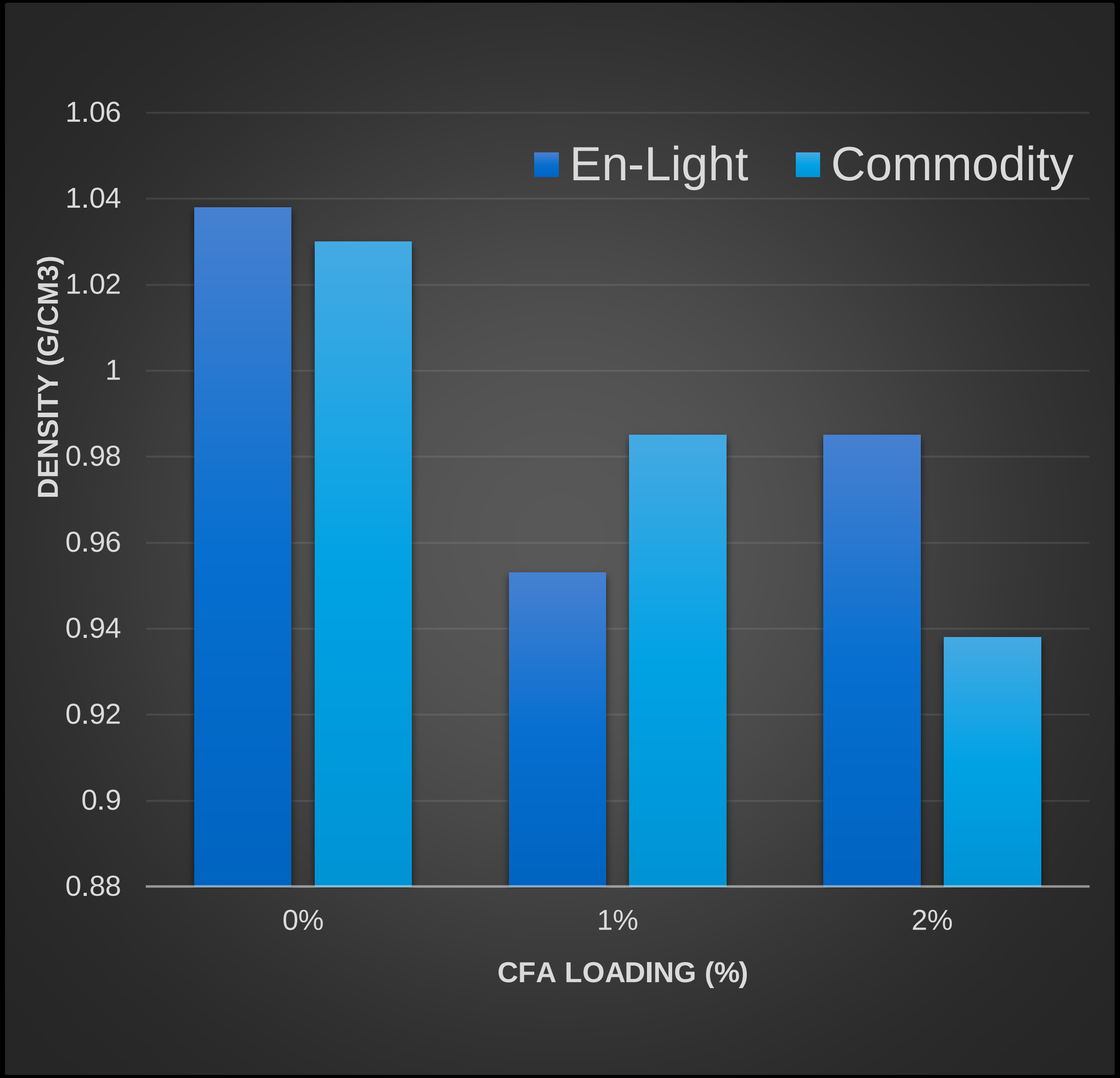
AK Plastics developed a class A surface PP product but were unprepared for the effects of a blowing agent on the surface.

Reedy encourages material suppliers to research and explore the effect of chemical foam with their products. As we will state in the following graphs, results will vary between materials.

Weight reduction comparison

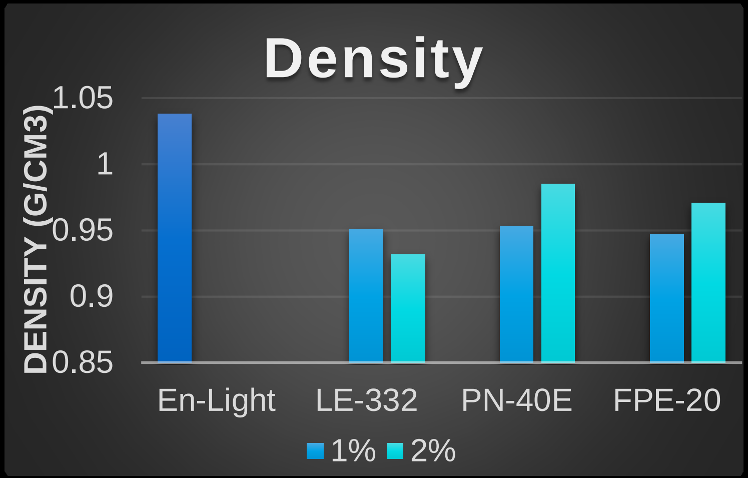
- **En-Light™ PP**
  1. Addition of 1% PN-40E helps reduce density by 8%
  2. Similar weight reduction on commodity 20% GF-PP requires 2% PN-40E
  3. Lower dosage of CFA needed to maximize weight reduction

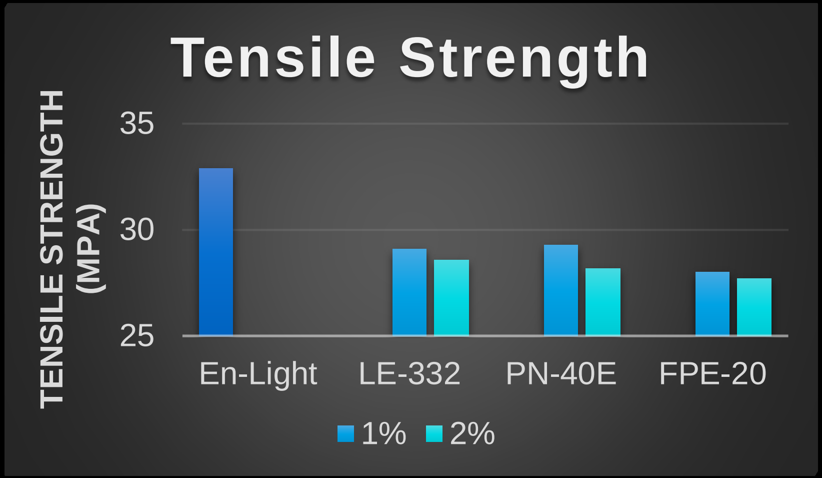
Compatibility of resin and foaming agent is crucial for performance balance.

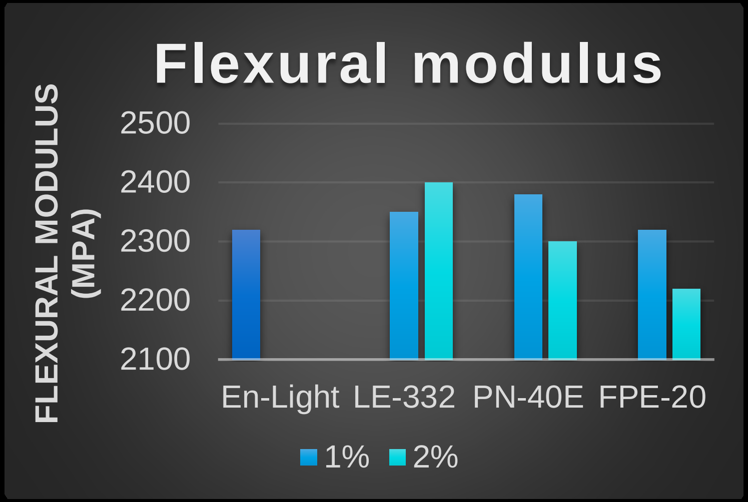


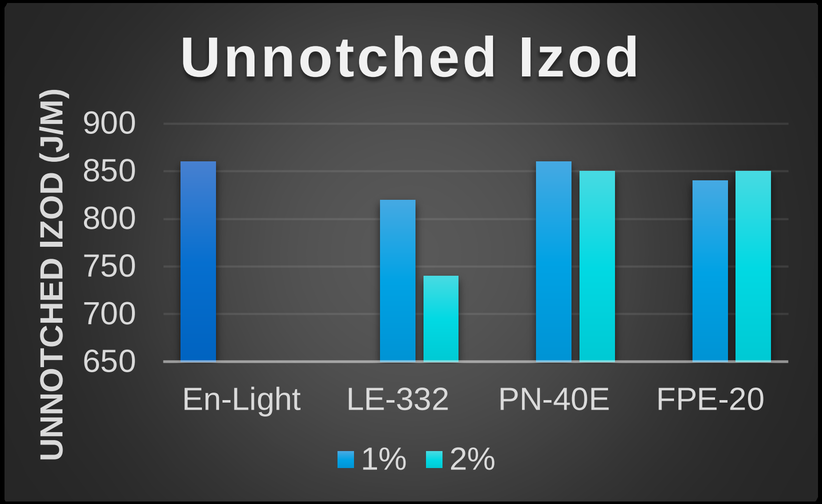
Properties with different CFAs

AsahiKASEI









- En-Light helps retain > 85% tensile strength and > 95% flexural modulus and Izod impact at presence of CFA.
- Increasing CFA dosage on commodity PP gradually reduces stiffness and strength.
- 1% PN-40E in En-Light PP has balanced weight reduction and mechanical properties

Surface aesthetics

AsahiKASEI

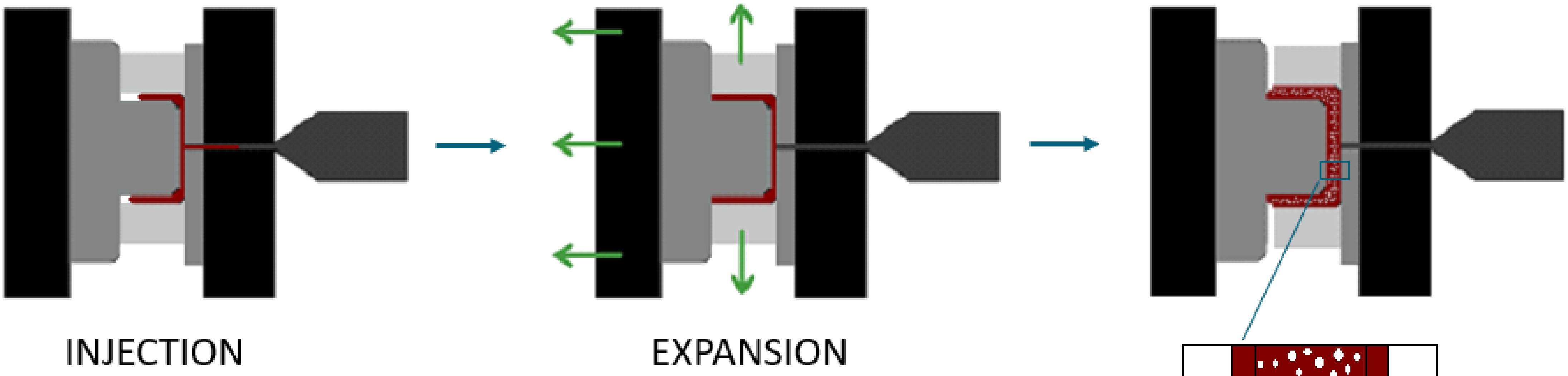
Thermylene w. PN-40E
DE=2.59
Grayscale change=3.5

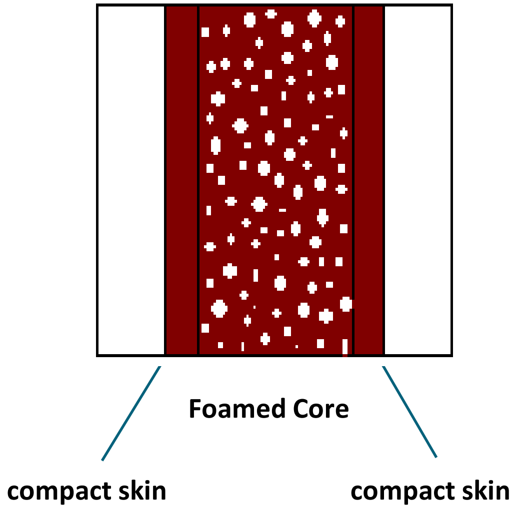
En-Light™ w. PN-40E
DE=0.18
Grayscale change=5

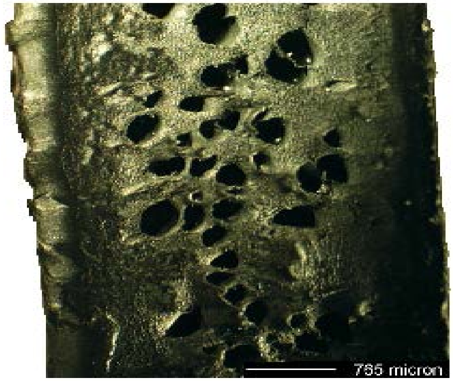
- Foaming agent poses little effect on color and grayscale on En-Light™
- En-Light™ technology works synergistically with foaming agents and helps retain surface aesthetics.

Core Back Injection

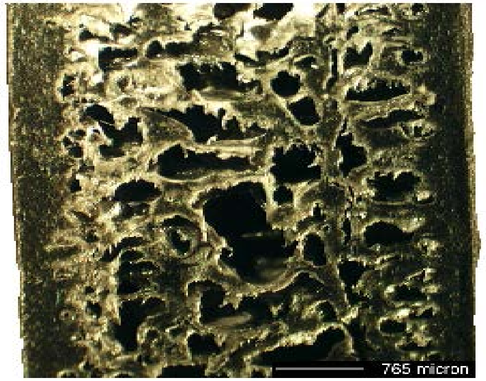
- Very high degree of foaming possible
- Excellent weight to strength relation







Conventional TSG



Core Back Expansion

Safoam®

Injection Molding – CORE BACK Process with TPO (Automotive Application)

Incumbent CFA 4% Loading
(Actual CFA content **10,000 ppm**)

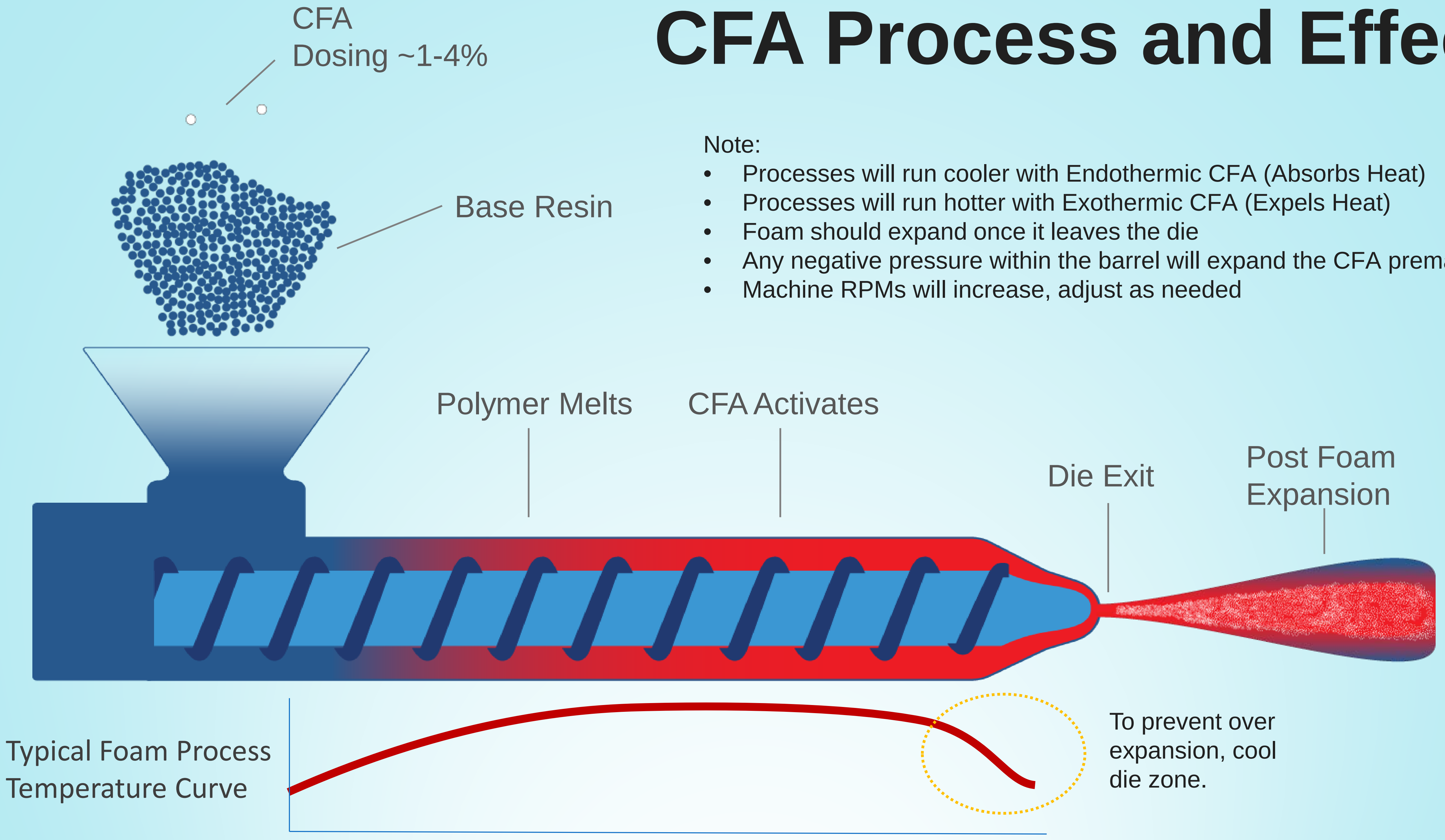
Reedy CFA 1.7% + KN 0.4% Loading
(Actual CFA content **4,000 ppm**)

In this trial, the Kinetic Nucleator made more efficient use of the CO_2 gas generated by the CFA (No Direct Gas).

This allowed the same density and cycle time with half the LDR of the standard CFA.

CFA Process and Effect

Note:
- Processes will run cooler with Endothermic CFA (Absorbs Heat)
- Processes will run hotter with Exothermic CFA (Expels Heat)
- Foam should expand once it leaves the die
- Any negative pressure within the barrel will expand the CFA prematurely
- Machine RPMs will increase, adjust as needed



Safoam® in Foam Core Extrusion

How did we do it?

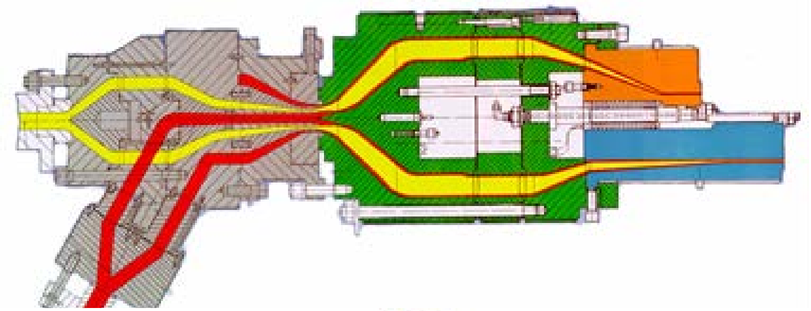
Actual customer extrusion case study
HIPS Extruded Sheet: ABA Structure -

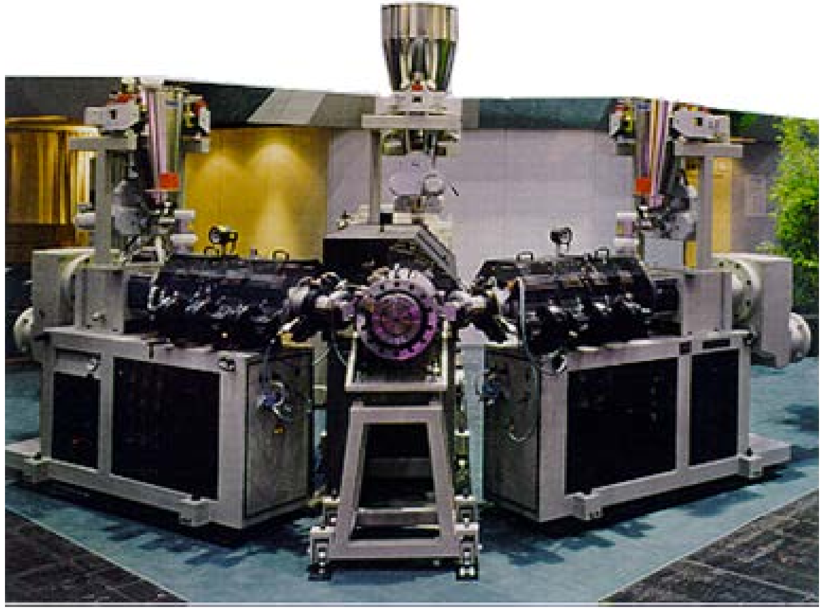
- Increased extrusion rates by 26%
- Reduced weight by 20% on first trial; with equipment upgrades, weight reduction has improved to 40%
- Improved surface quality
    - Smoother, whiter surface with less TiO_2
    - Improved stamp printing
    - Less colored dye to achieve same tint
    - Stiffer sheet with strong cells that did not collapse during thermoforming; die-cutting saw less "fuzz"
- Thicker gauge; tighter gauge control edge to edge
    - Both 180mm and 125mm sheet achieved greater consistency across entire width of sheet

Safoam® Level	Melt Temp	Ft/Min	Notes
N/A	193°C	20	Start up
2%	192°C	20	Too much gas
1%	190°C	25	Still too much gas; blistering on surface
0.5%	190°C	23	Surface improvements
0.5%	187°C	26	White surface staying consistent; reduced TiO_2
0.5%	184°C	27	Open gap; gauge up from 56mm to 76mm

Customer reported 50% of new business directly related to SAFOAM®

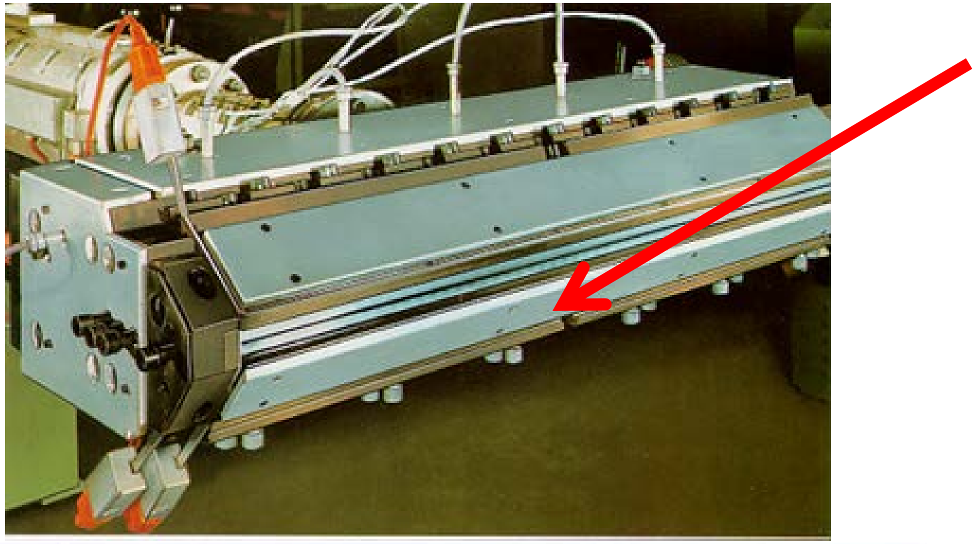
Monolayer versus Multilayer Sheet





- There are two basic sheet structures: a single layer or two or more layers
- Safoam works best in three layer structure in center layer
- Layers are identified by letters:
  - A: single layer, monolayer
  - AB: two layers, two extruders
  - ABA: three layers, two extruders
  - ABC: three layers, three extruders

Extrusion Die



- Adjustable die lips help maintain controlled gauge

When foaming, post foamed expansion will expand the thickness of the final product. Die lips and roller stacks will need to be adjusted to prevent the compression subsequent collapse of the newly created and malleable cellular structure.

HDPE Extrusion Case Study

HDPE: Bapolene 3255, MI 8.0, Density 0.960

Extruder: 1.25” single screw, 30:1 L/D, 3:1 compression ratio.

Melt Temp at clamp
362°F (183°C)
Melt Pressure:
2250 psi (155 bar)

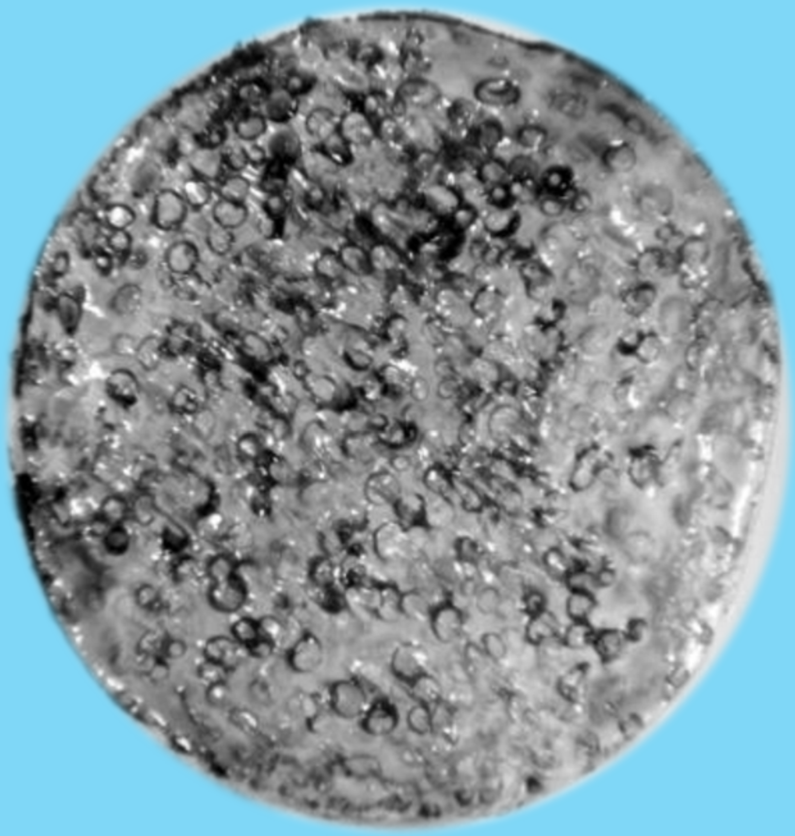
CFA Endo Blend: 0.50% by weight of a sodium bicarbonate/citric acid blend.

Nucleated samples contained 0.25% by weight of K-nucleator.

Extrusion profile:

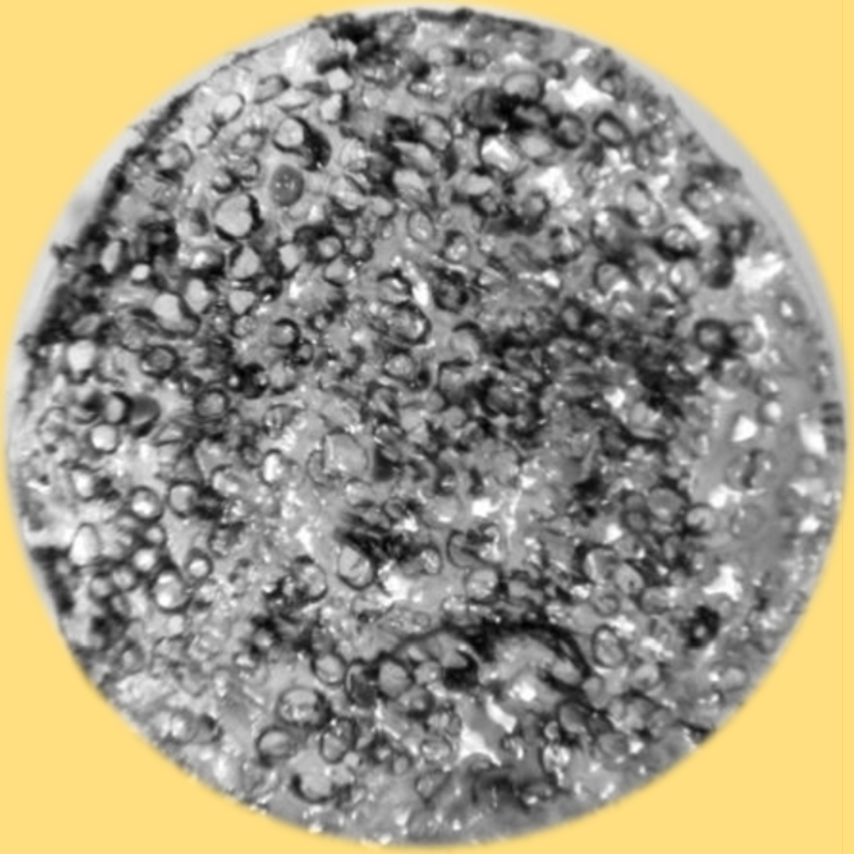
ZONE 1	ZONE 2	ZONE 3	ZONE 4	CLAMP	HEAD	DIE
345°F 174°C	385°F 196°C	385°F 196°C	355°F 179°C	345°F 145°C	320°F 160°C	320°F 160°C

HDPE Extrusion Case Study



Endo blend

CELL RANGE (MICRONS)	NOMINAL SIZE (MICRONS)	DENSITY (G/CC)	DENSITY REDUCTION
60-120	100	0.533	44.5%



Endo Blend + Reedy KN

CELL RANGE (MICRONS)	NOMINAL SIZE (MICRONS)	DENSITY (G/CC)	DENSITY REDUCTION
50-160	105	0.464	51.7%

Polypropylene Rod Extrusion

Polypropylene: Exxon PP4712E1, 2.8 MFI
1.25" single screw extruder, 30:1 L/D, 3:1 compression ratio.

Chemical Foaming Agent (CFA) Endo Blend: 0.36% by weight of a sodium bicarbonate/monosodium citrate blend. An equal weight of mineral oil was used to coat the pellets with the additives.

All nucleated samples contained 0.36% by weight of nucleator.

Talc particle size:	1 micron
Calcium carbonate particle size:	1 micron
Reedy KN:	30 micron

Melt Temperature:
380°F at the clamp

Melt Pressure:
1850 psi

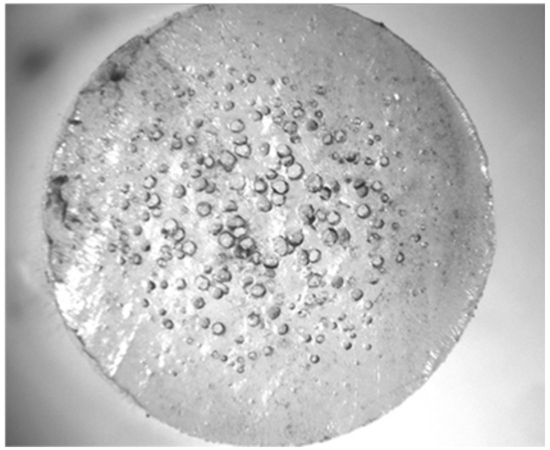
Extrusion profile:

ZONE 1	ZONE 2	ZONE 3	ZONE 4	CLAMP	HEAD	DIE
390°F	420°F	395°F	370°F	350°F	340°F	350°F

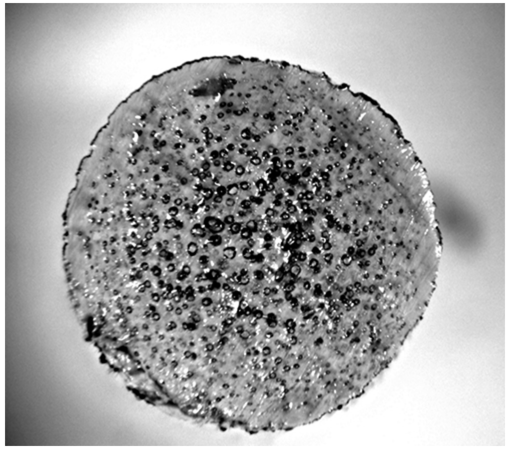
Polypropylene Rod Extrusion

SAMPLE	CELL RANGE (MICRONS)	NOMINAL SIZE (MICRONS)	DENSITY (G/CC)	DENSITY REDUCTION
CFA	50-130	100	0.837	8.1%
CFA + $CaCO_3$	30-100	80	0.754	17.2%
CFA + Talc	30-135	100	0.694	23.8%
CFA + Reedy KN	30-100	85	0.675	25.9%

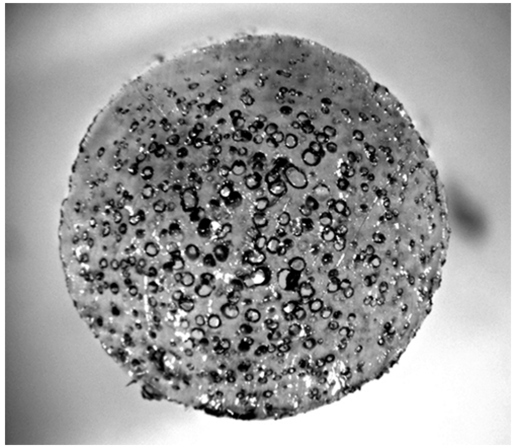
CFA



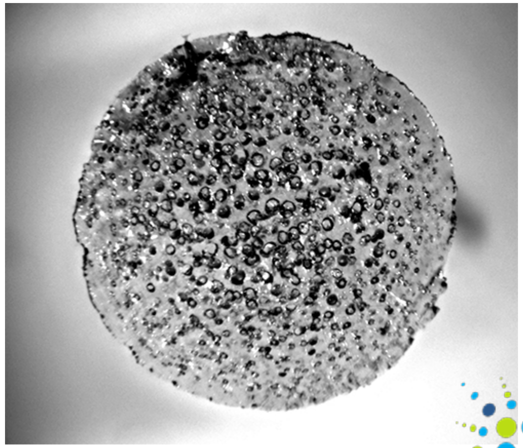
CFA+ $CaCO_3$



CFA+ Talc



CFA+ Reedy KN



Real world Examples: HIPS Extrusion

Multilayer: ABA Structure with Foamed “B” Layer

Goal: Better Density reduction.

Established foam process, weight reduction 23-27%

Addition of KN, with no process changes, 32%

Unanticipated findings: Gauge variation went from 12.5% down to 1.7%!

Better mixing of the formula and CFA allowed better heat distribution and more efficient use of the gas generated by the CFA.