
Maximizing
RAP Use
ASTEC
INDUSTRIES, INC.

Overlays Can Experience Cracks and Re-Rutting

Rutting Often Occurs in Older Overlay Pavements

Milling and Inlays Prevent Re-Rutting

End of Load Segregation

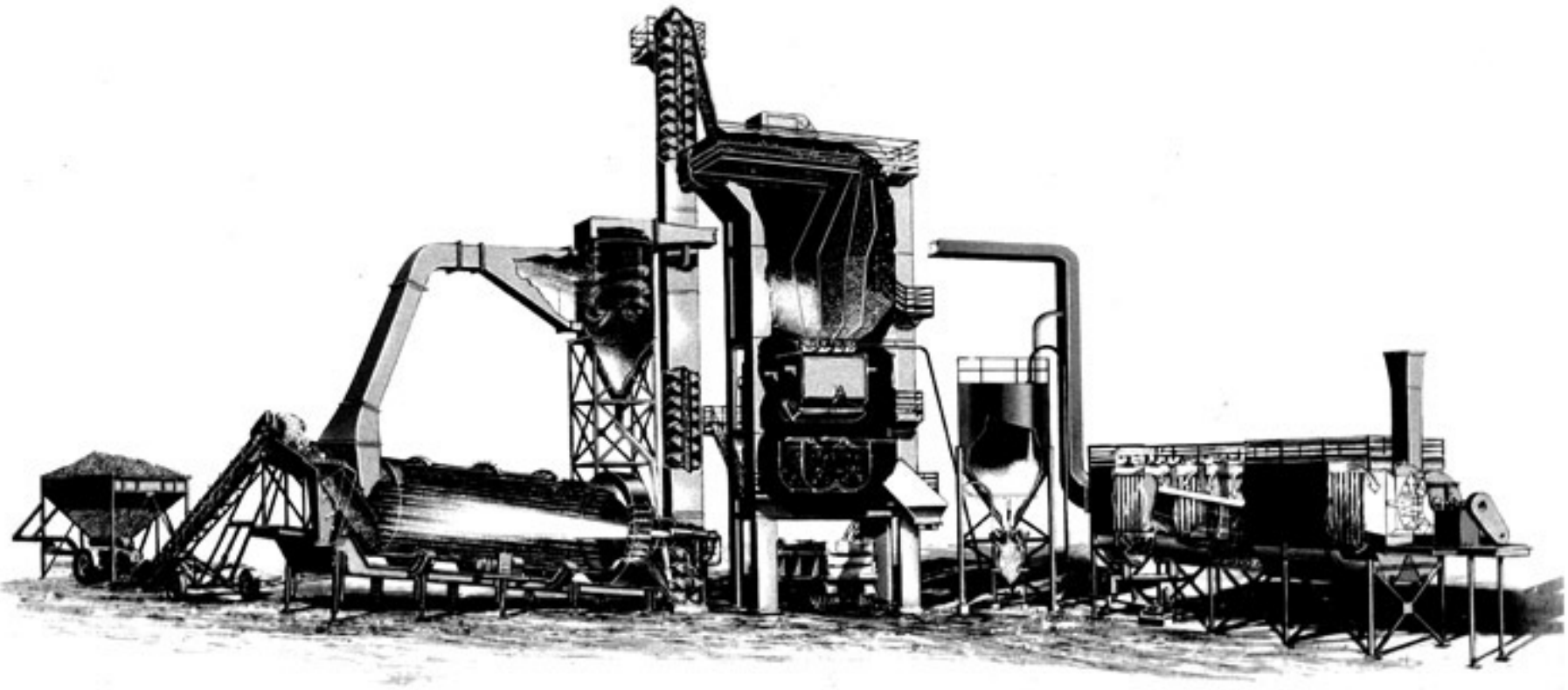
Rock Quarry

Barriers to increasing the use of more Recycle

- Meeting voids & asphalt content with Superpave Mix Design
- Meeting skid requirements
- Hardness of asphalt with high RAP - need to use softer virgin asphalt cement…fatigue cracking
- Special mixes like SMA
- Limit RAP to 15% when polymers are used

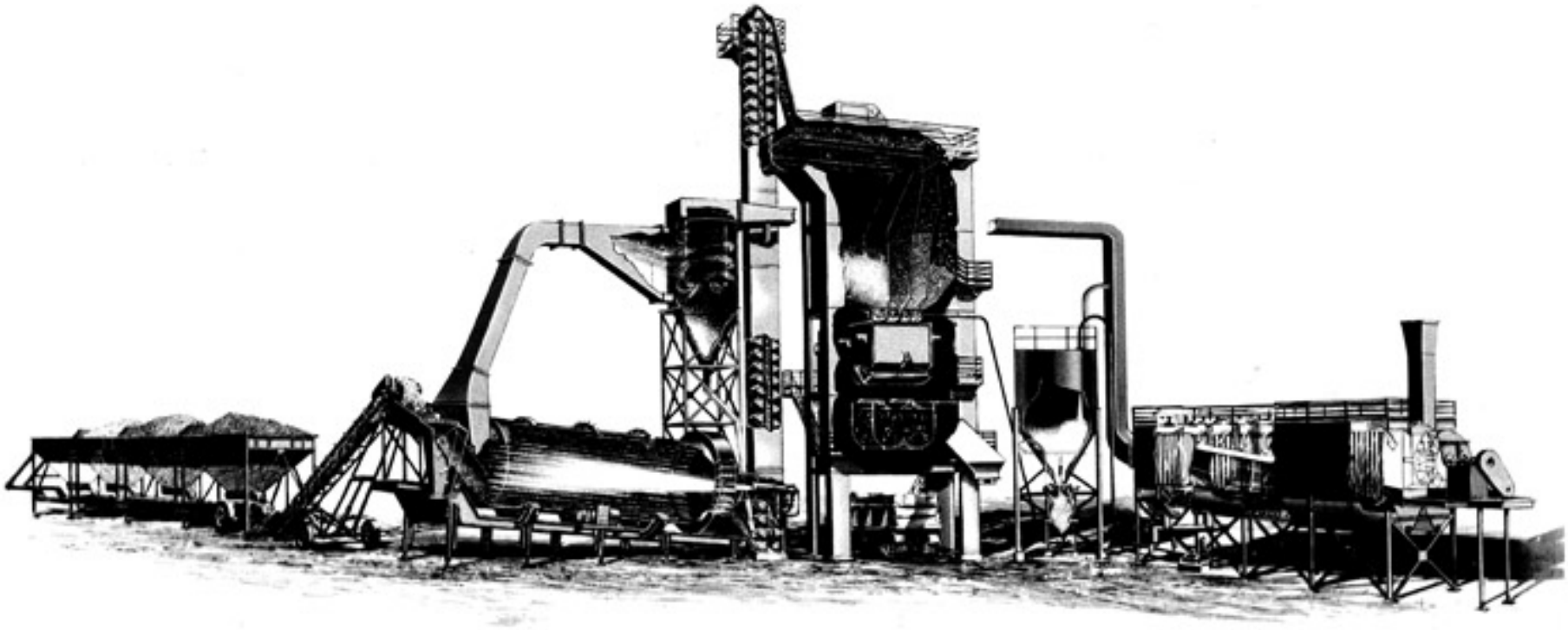
Meeting Superpave Mix Design requirements

Controlling Air Voids and Asphalt Content = Controlling Segregation



BATCH PLANT

ONE BIN COLD FEED

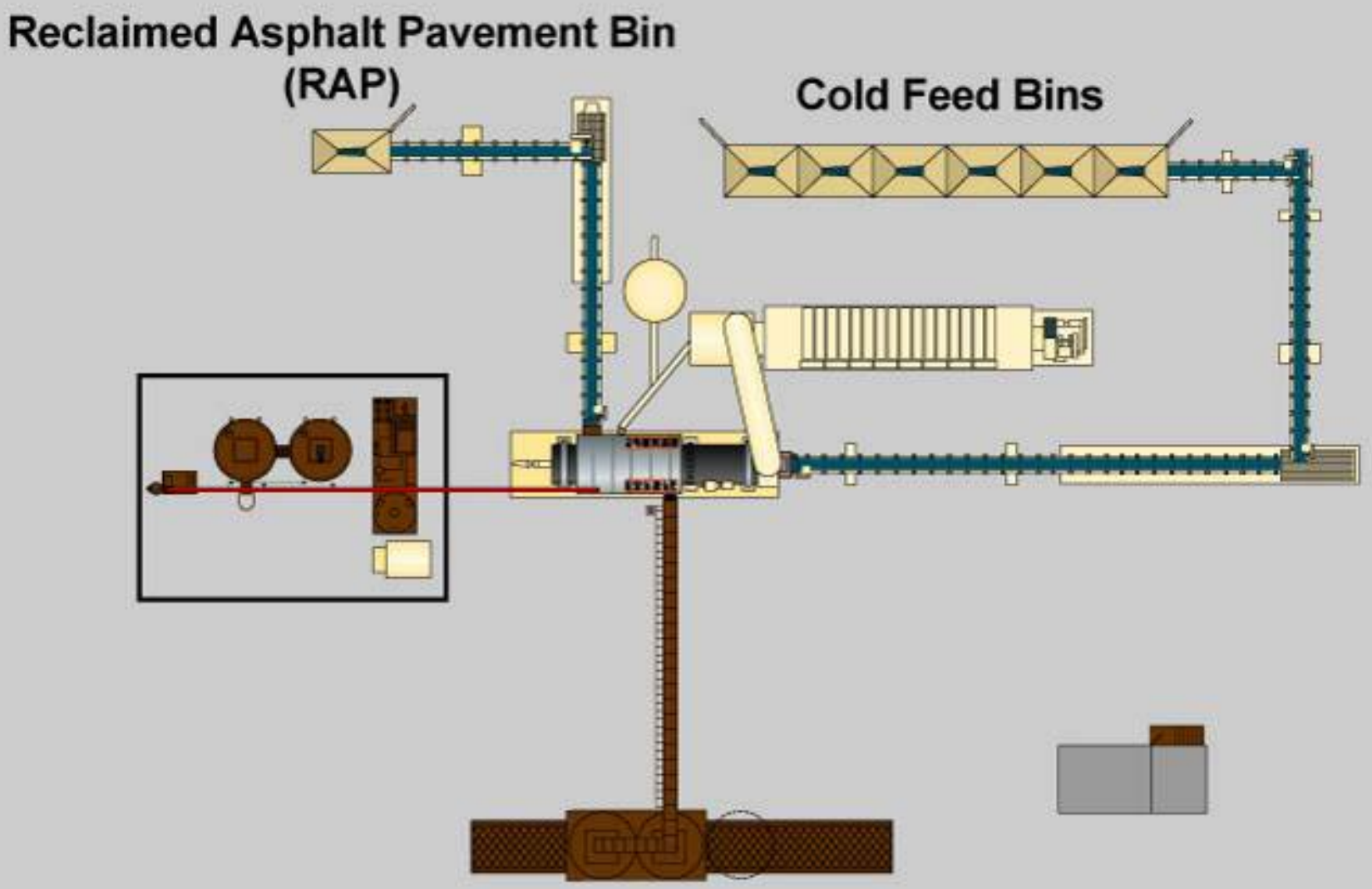


BATCH PLANT

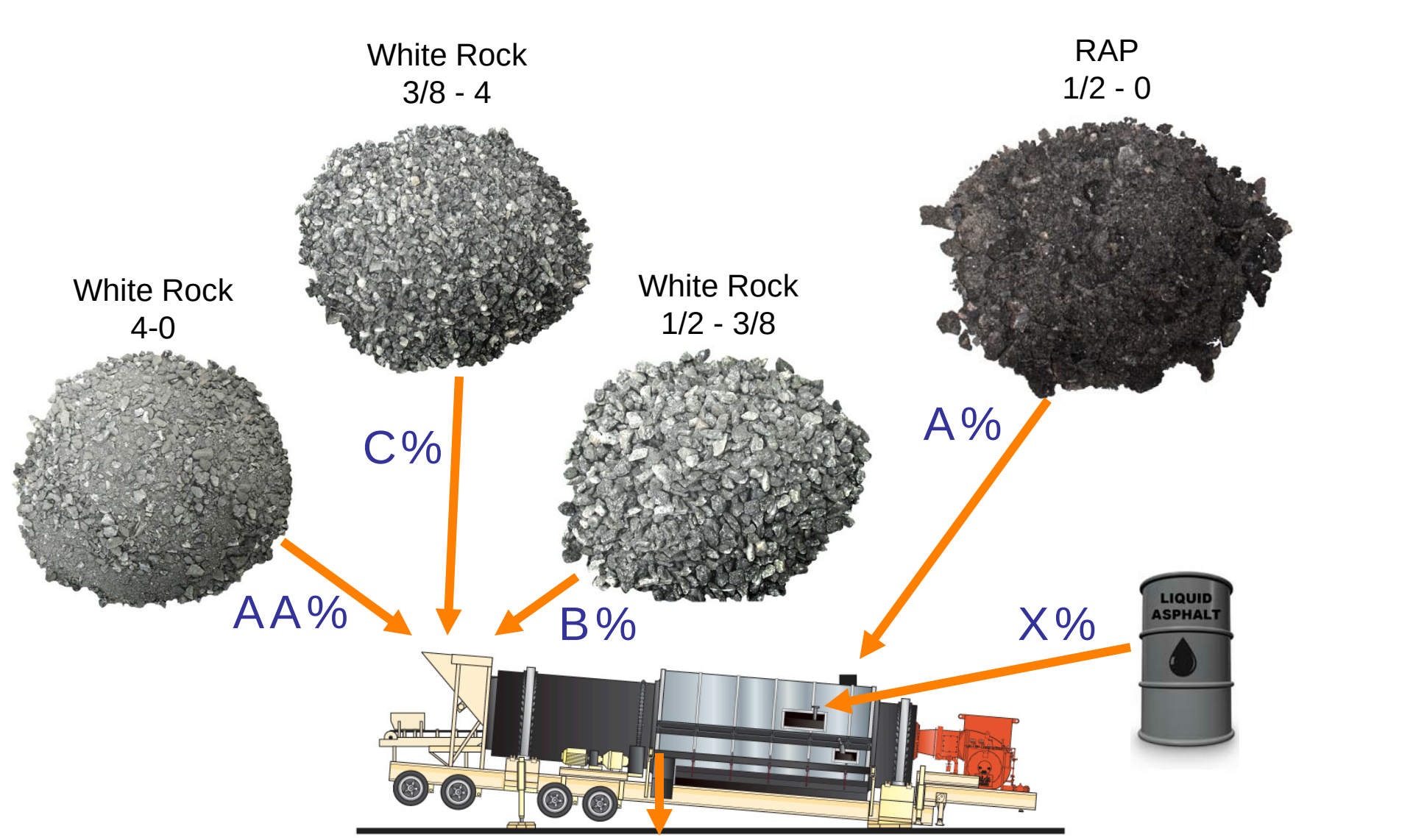
FOUR BIN COLD FEED

Full-Lane Milling Machine

RAP Pile With 1/2” Minus to 3/4” Minus Aggregate



1980-1990's HMA Facility with Single RAP Bin



SUPERPAVE MIX WITH 1/2 RAP

1/2 x 0

6% AC

1/2 x 4

4% AC

4 x 0

7% AC

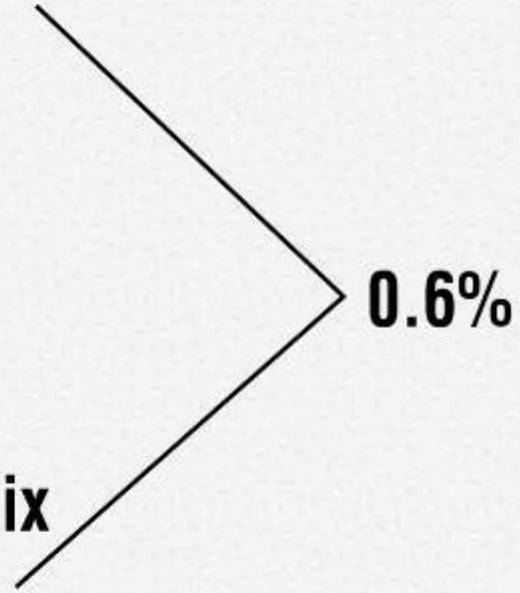
Surface Area

- **1 lb. of ⅜” Aggregate = 1 sq. ft.**
- **1 lb. of -200 mesh = 150 sq. ft.**

Liquid Asphalt coats Surface Area

@ 20% RAP Coarse AC Contribution to Mix

= 0.20 x 4% = 0.8%



Fine AC Contribution to Mix

= 0.20 x 7% = 1.4%

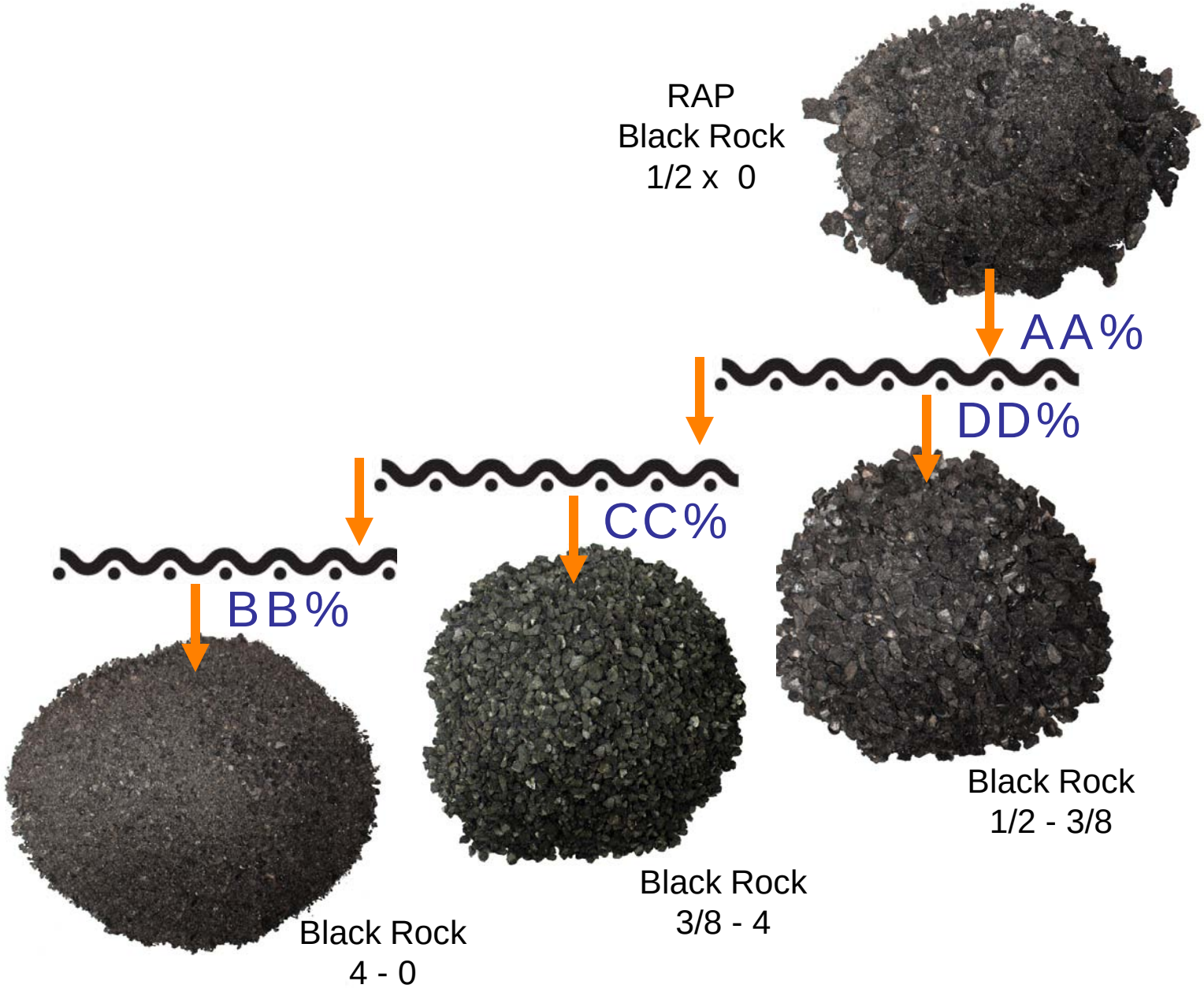
@ 40% RAP Coarse AC Contribution to Mix

= 0.40 x 4% = 1.6%

Fine AC Contribution to Mix

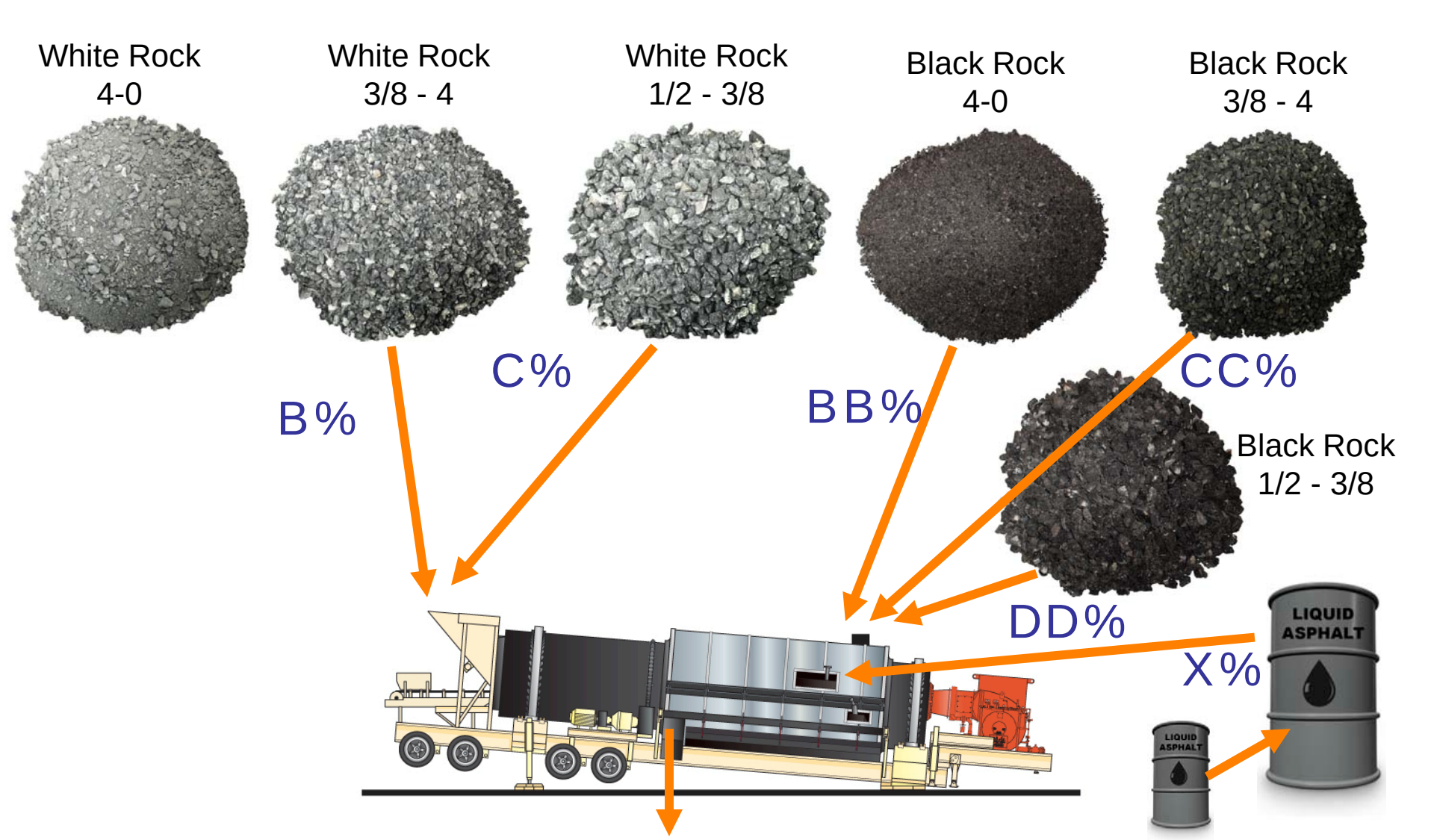
= 0.40 x 7% = 2.8%

1.2%



PROCESSED RAP SCREENED TO ORIGINAL INGREDIENTS


2007 6 7



SUPERPAVE MIX WITH PROCESSED RAP - CHOICE #2

Use of RAP for High Traffic Surface Mixes

- Is RAP made from skid resistance aggregate?
  - Yes! - No problem
  - No! - By fractionating RAP the minus ¼", it can be used in any mix since aggregates finer than ¼" do not effect skid numbers

White Rock
4-0

White Rock
3/8 - 4

White Rock
1/2 - 3/8

Black Rock
4-0

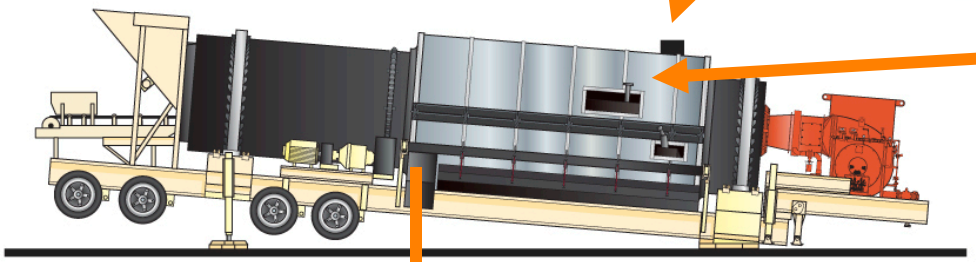
Black Rock
3/8 - 4

B%

C%

BB%

Black Rock
1/2 - 3/8



X%

SUPERPAVE MIX WITH PROCESSED RAP - CHOICE #1

Changing the grade of liquid when RAP increases…WHY?

- **To obtain density in mix**
- **“Is this beneficial or necessary?”**
  Perception has been that it is necessary to extend pavement life


HEATEC
HEATEC

With Warm Mix (hot foam), we can achieve density without changing grades at 50% RAP

Foam Liquid Asphalt
How much water?

1 ton mix – 2,000 lb.

20 cu ft. (25% void or 5 cu. ft.)

5.3% liquid – 106 lb.

Volume of liquid – 1.63 cu. ft.

1 lb. H_2O when converted to steam = 30 cu. ft.

$$\text{Expansion} - \frac{30}{1.63} = 18$$

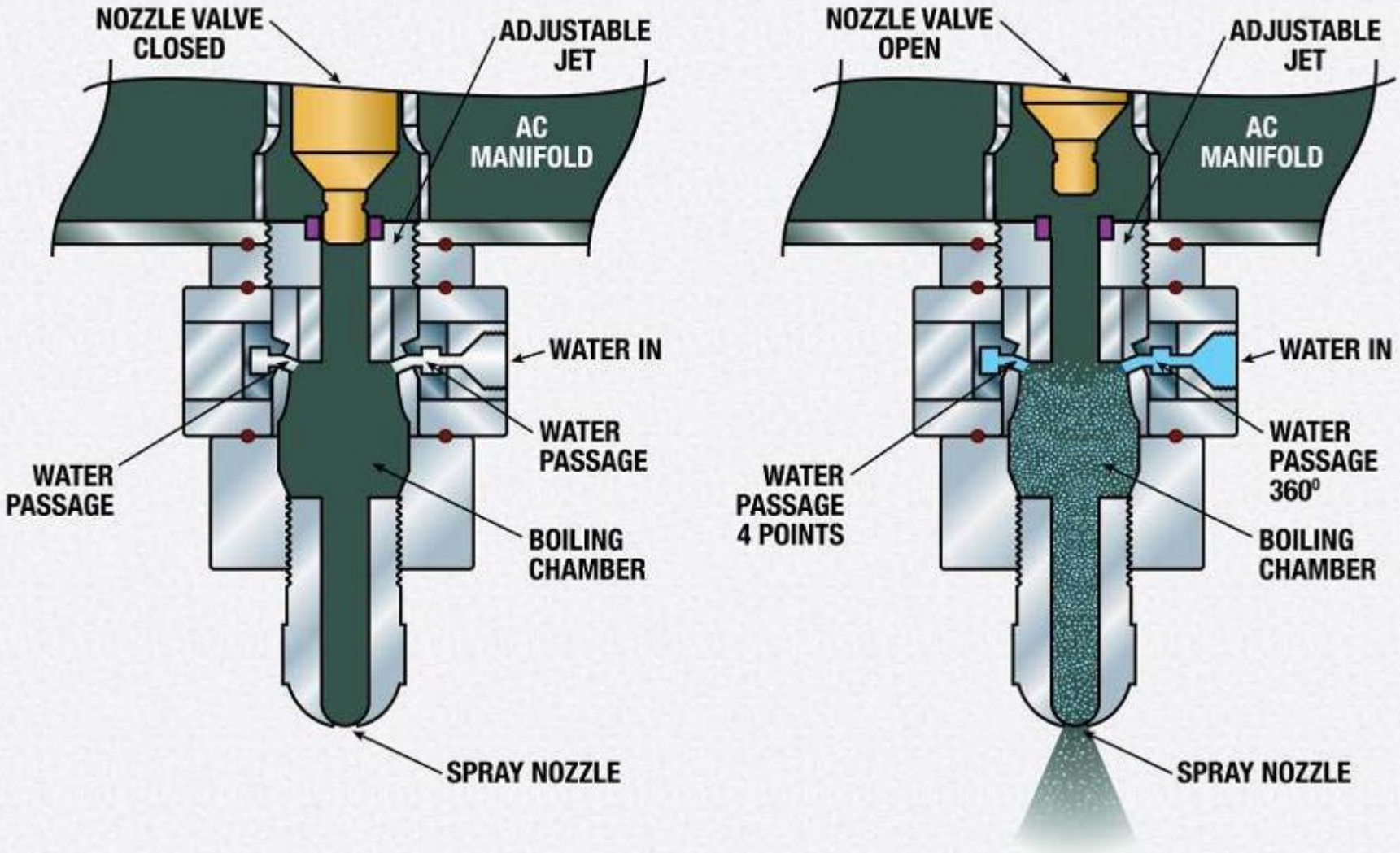
However only room for 5 cu. ft.

Therefore only 1/6 lb. of H_2O ends up in foam

AFTER COMPACTIONS

Air voids = 5% or 1 cu. ft.

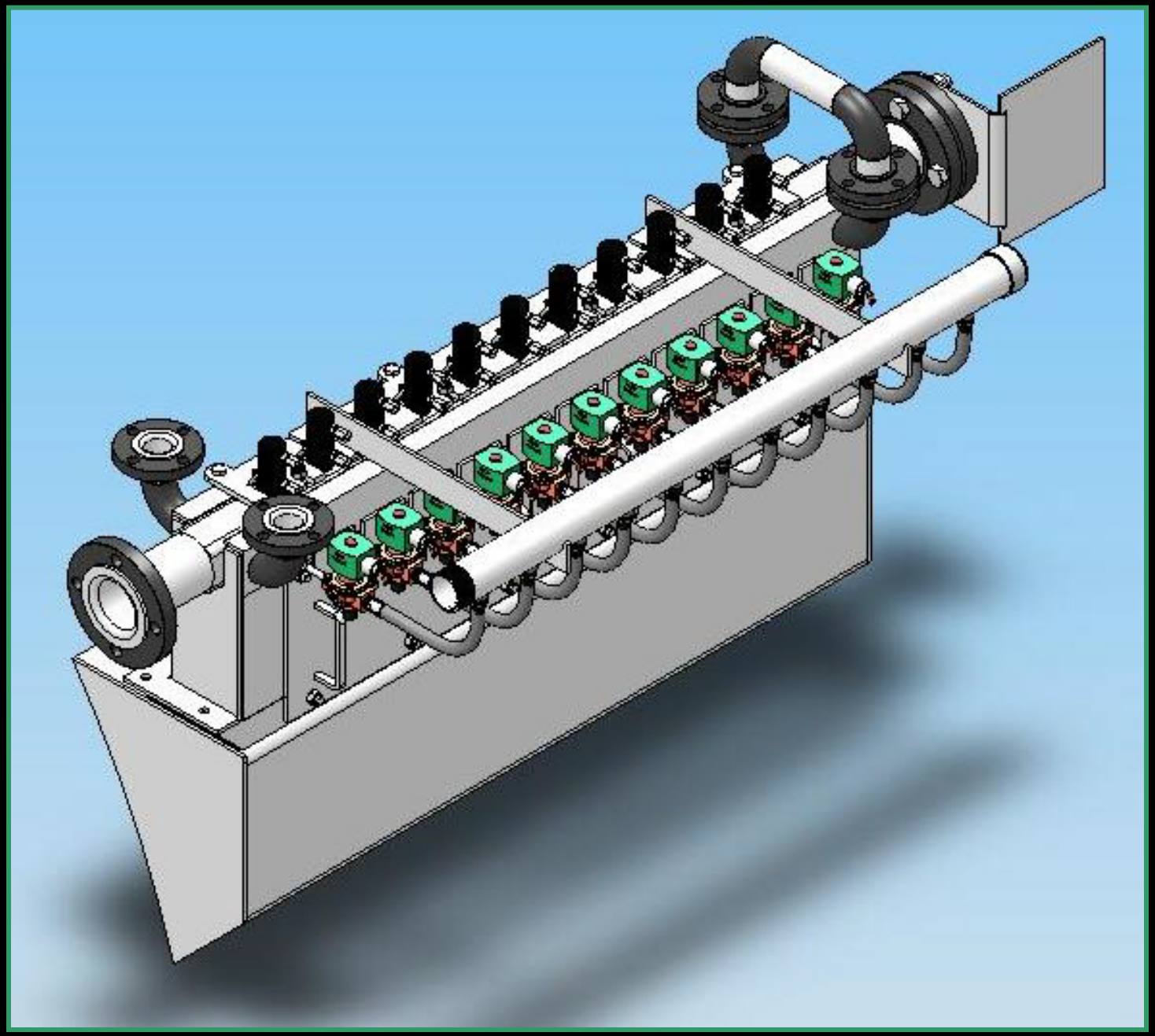
Therefore only 1/30 lb. of H_2O remains in liquid

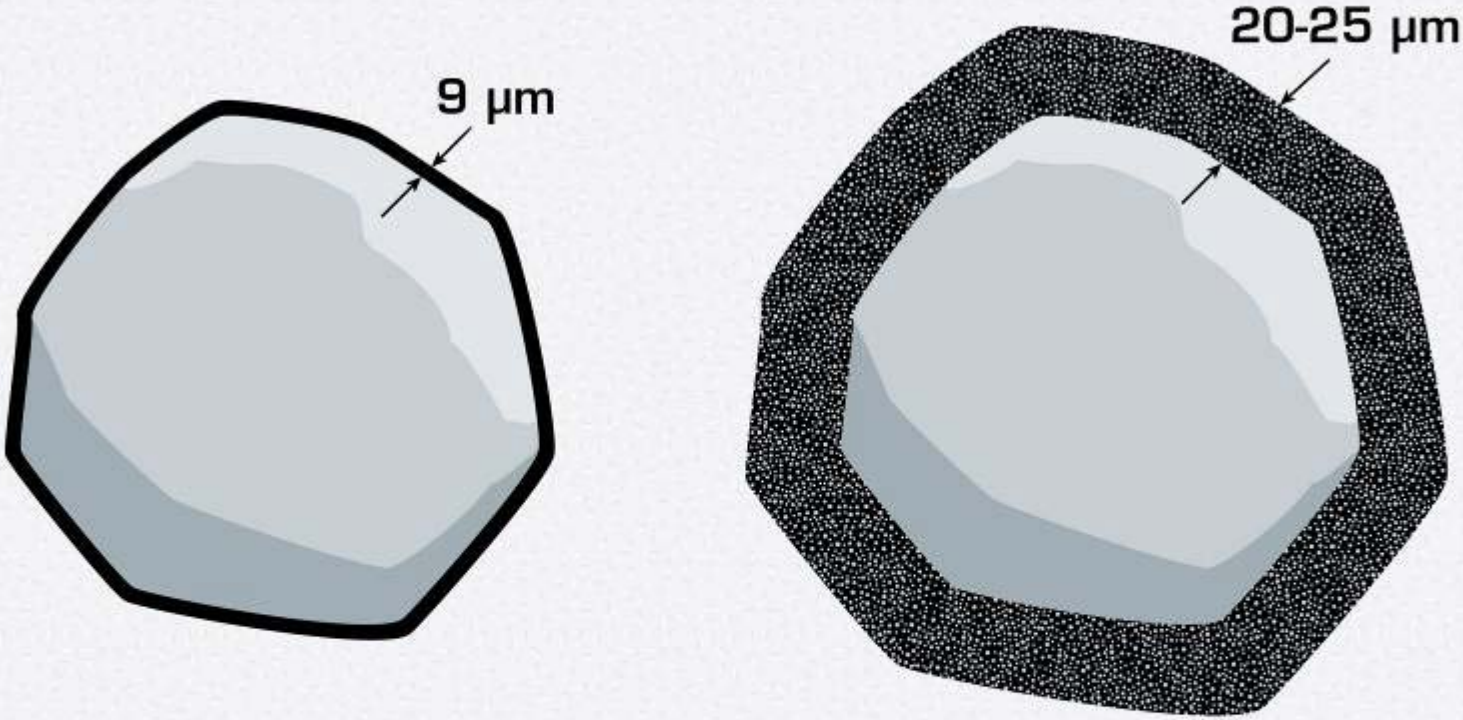


FOAM NOZZLE CLOSED

FOAM NOZZLE OPEN

FOAM NOZZLE

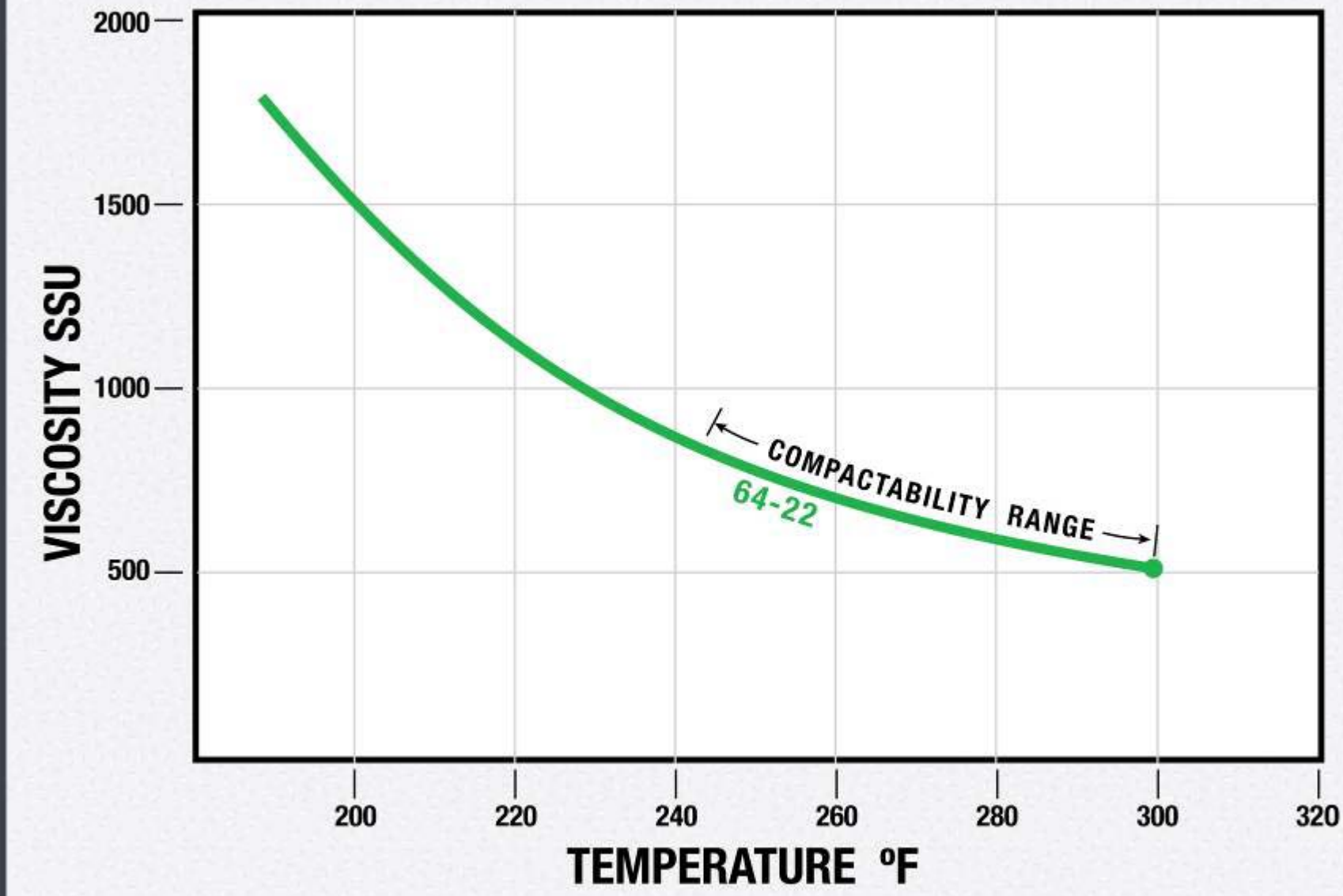




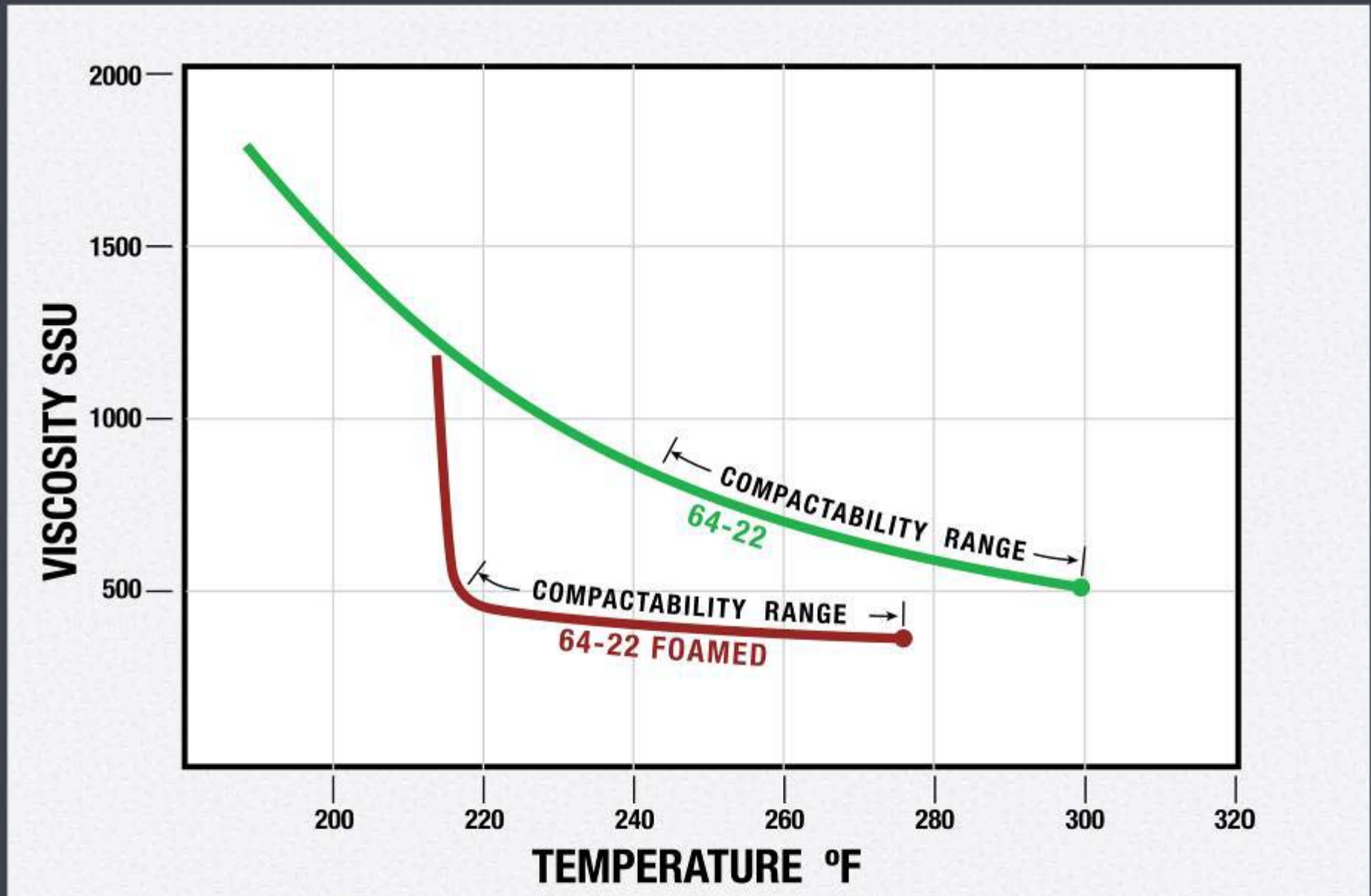
NORMAL COATING

DB GREEN FOAM COATING

COATING THICKNESS



VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)



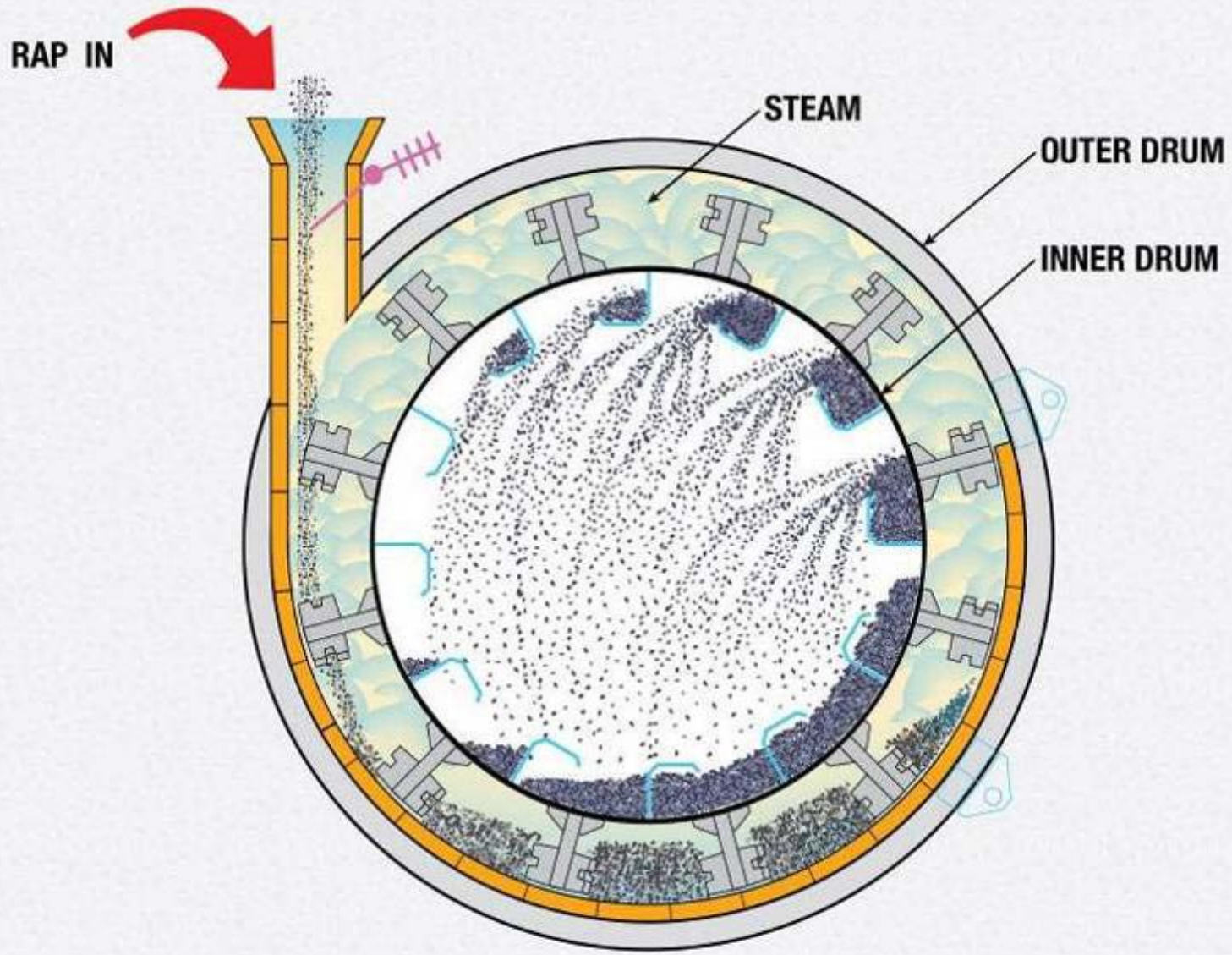
VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)

No Smoke – No Smell…Why?

- Light oils are either put in asphalt or left in asphalt during refining
- These light oils boil at above 285ºF
- By mixing at below 285ºF, the boiling point is never reached…eliminating smoke (vapor) and corresponding smell

High Percentage Recycle Mix with Standard Grade of Asphalt

- To achieve compaction (density)…run 275°F and foam virgin liquid
- By using a standard liquid 64-22, you produce a much softer product than with virgin mix due to:
  - Lower temperature results in less oxidation
  - Light oil remains in liquid
  - Steam produced from drying the RAP creates an inert atmosphere



RAP GENERATES STEAM IN OUTER DRUM

What AC hardness do we really need?

- France
  uses 30/50 penetration (76 or 82-22) in virgin mix and the same in 50% RAP
- Sweden
  uses 70/100 penetration (64-22) in both virgin and 50% RAP

Is Changing a Grade Beneficial?

1983 Florida DOT Test on Asphalt Hardness

Batch Plant Produced Mixes

Long Range Effect on Rutting

Date	Section 3 (High Light Ends) Viscosity - 2000* Rutting (in.)	Section 7 (Steam Distilled) Viscosity - 4000* Rutting (in.)
12/27/84	0.00	0.00
03/19/85	0.04	0.00
08/06/85	0.03	0.00
09/27/85	0.06	0.00
12/03/85	0.06	0.03
12/22/86	0.08	0.07
11/30/88	0.14	0.06
02/28/91	0.35	0.16
12/24/92	0.46	0.15
01/26/95	0.60	0.18
03/22/99	0.60	0.27

Long Range Effect on Cracking

Date	Cracking sq. ft./1,000 ft.*	Cracking sq. ft./1,000 ft.*
12/27/84	0.0	0.0
03/19/85	0.0	0.0
08/06/85	0.0	0.0
09/27/85	0.0	0.0
12/03/85	0.0	0.0
12/22/86	3.0	2.5
11/30/88	2.0	1.6
02/28/91	61.1	2.0
12/24/92	49.0	1.1
01/26/95	175.6	38.6
03/22/99	120.2	207.5

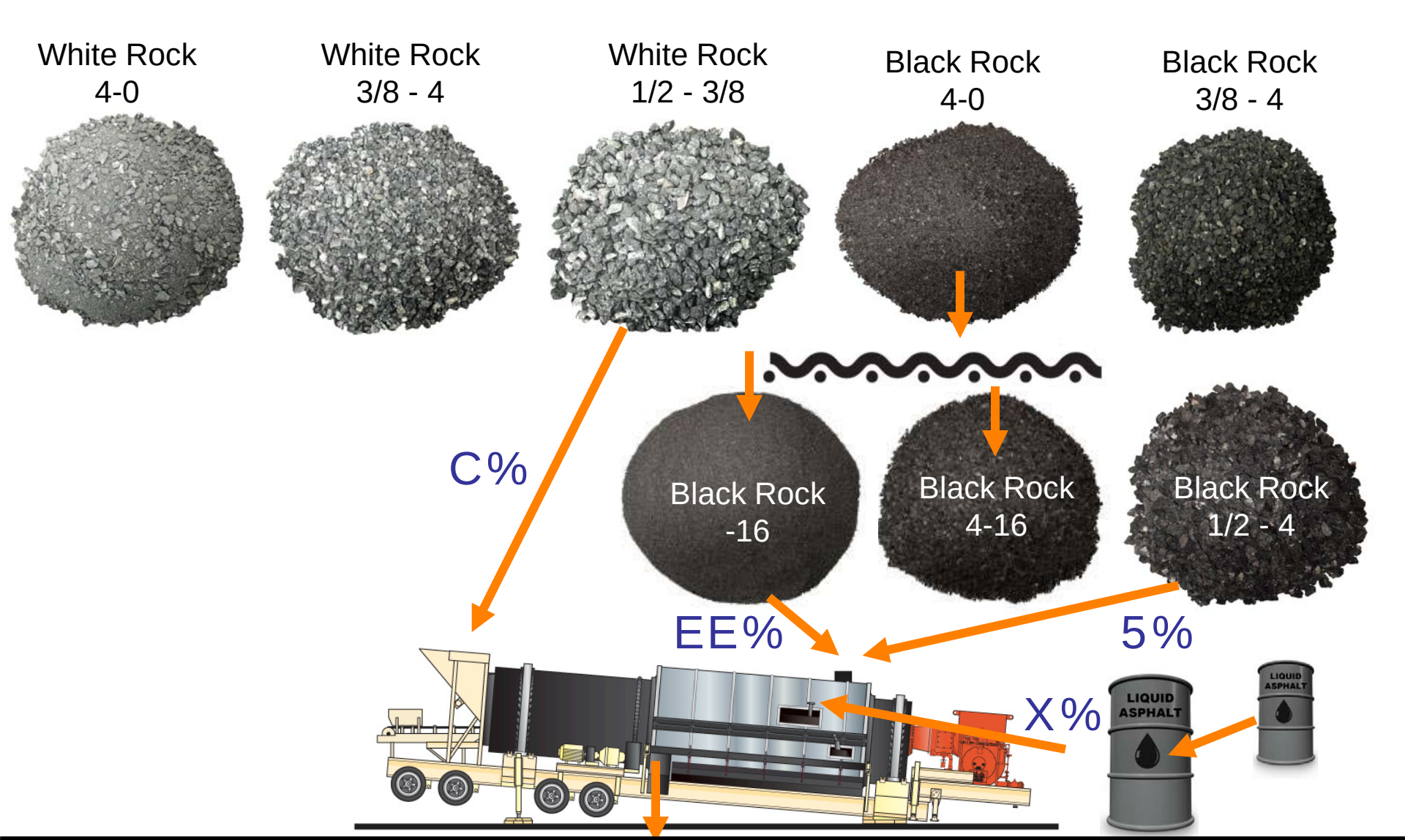
* In each inspection period - 1,000 ft. of the 4,000 ft. test sections were analyzed. Each time the same 1,000 ft. was not analyzed; therefore, the overall average results are more meaningful.

Will high RAP in surface mix effect the Life of the Pavement?

Yes…It will

- **Reduce rutting and**
- **Give at least as long life in fatigue**

Can RAP be used in SMA mixes?

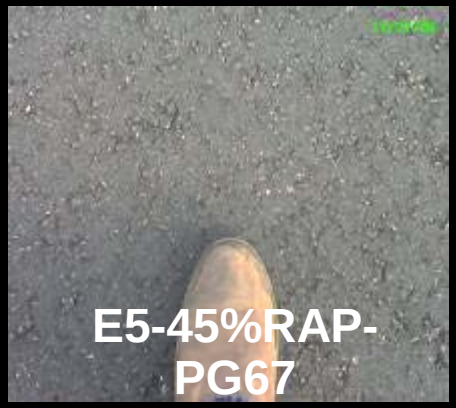


SUPERPAVE MIX

WITH PROCESSED RAP - CHOICE #3

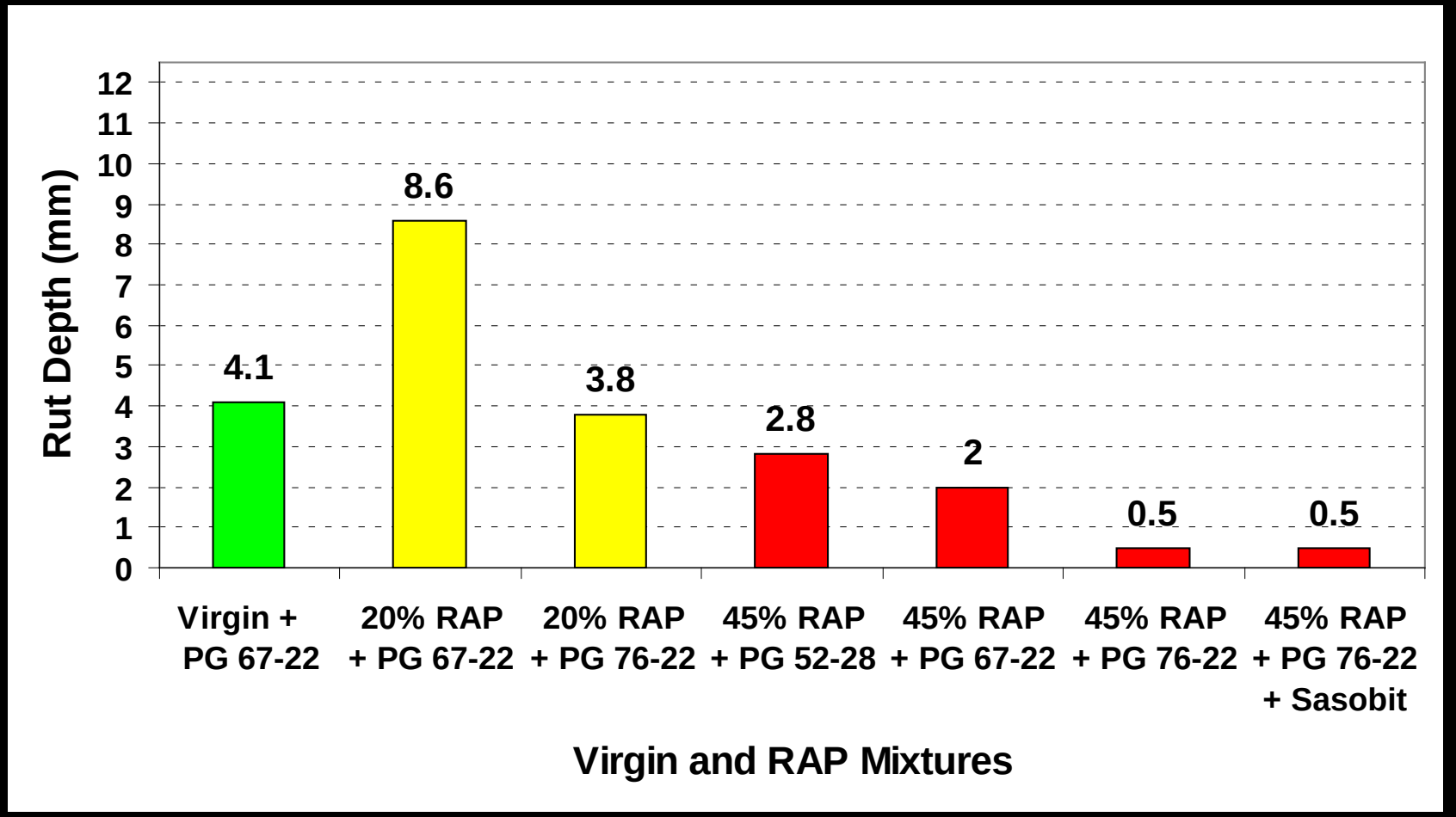
Should the RAP be limited to no more than 15% when using Polymers?

RAP STUDY MATS



NCAT Pavement Test Track

Rutting Performance @ 9.0M ESALs



National Center for Asphalt Technology
NCAT
at Auburn University

Substitute 50% RAP for 4% polymers can achieve practically the same results

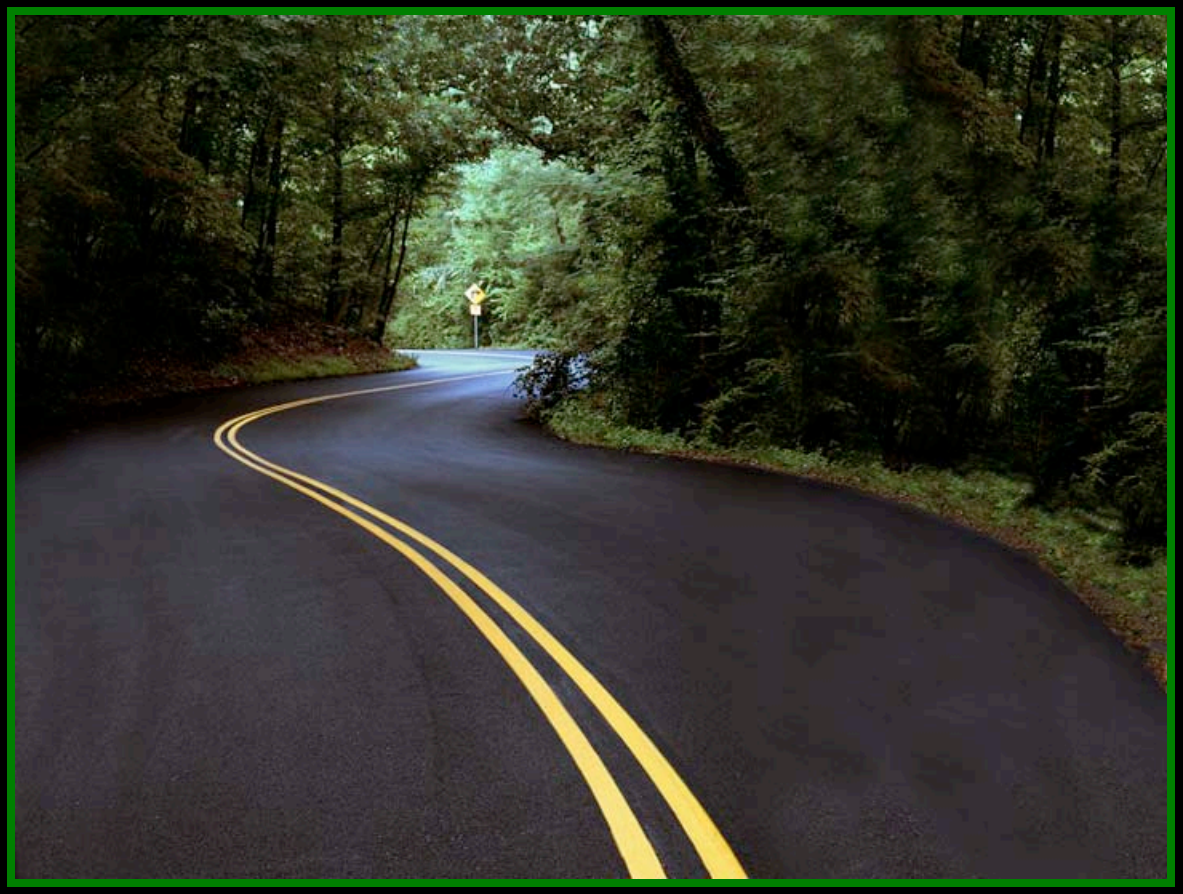
Benefits of High RAP & Warm Mix

For the Producer / Contractor

- Improved Workability
- No Smoke – No Smell
- High Percentage Recycle Mix with Standard Grade of Asphalt
- 14% Less Fuel
- 14% Higher Production
- Reduces Cost

For the Worker

- **Comfort & Safety**



For the DOT/Public

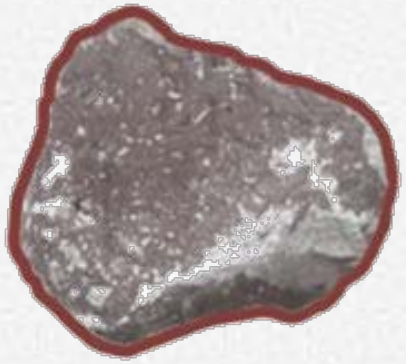
- Comfort & Safety of workers
- Improve Mixes

Why will we have a Longer Life Pavement?

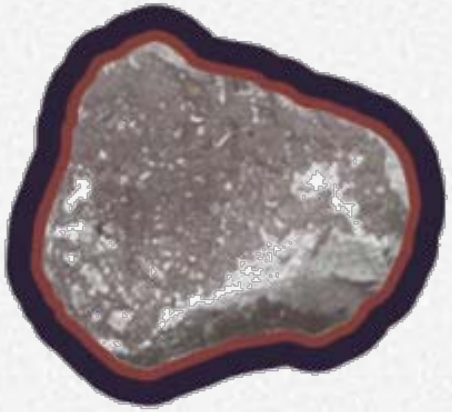
- Less oxidation of mix
- More uniformity of compaction
- With fractionating RAP…more uniform

Longer Life

VIRGIN
AGGREGATE



HARDER LIQUID
TRANSFERRED FROM
RAP PREVENTS
STRIPPING

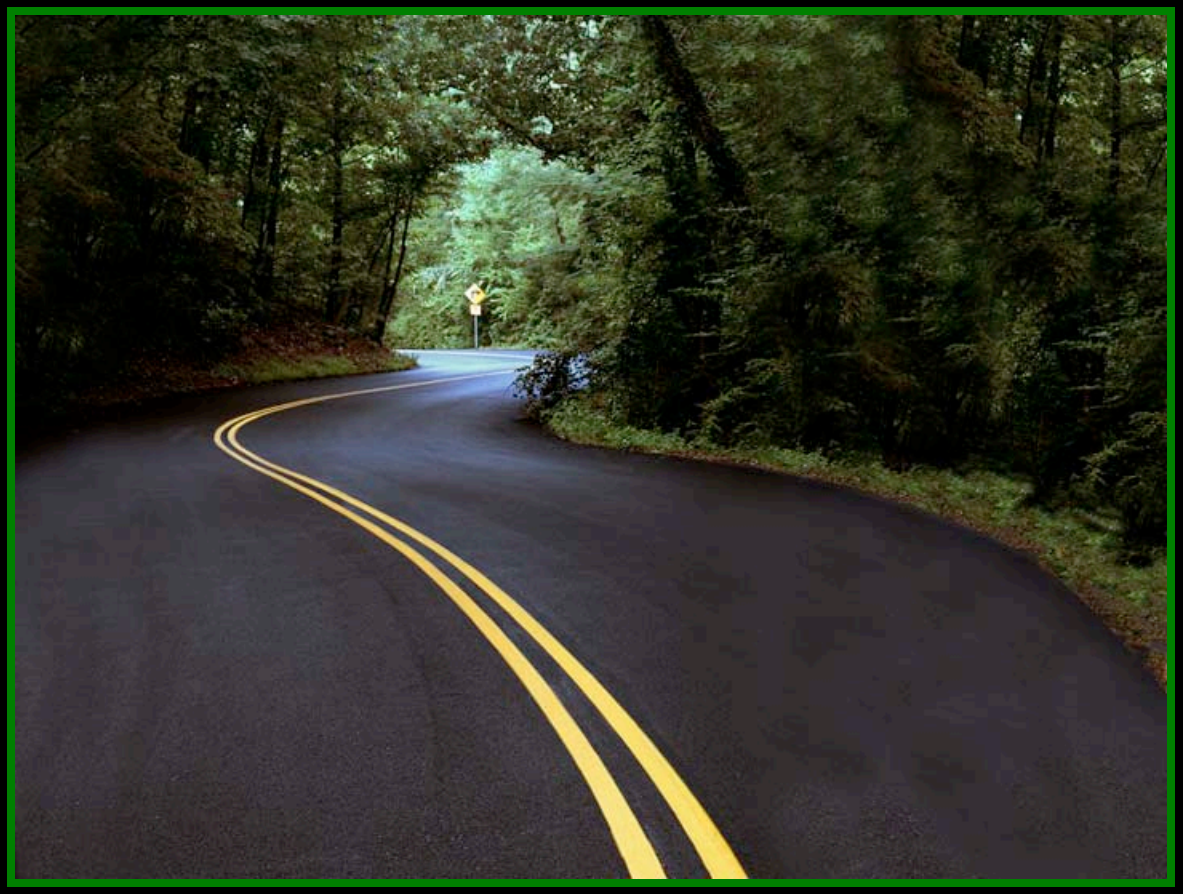


NEW
HOT FOAM AC
HELPS DURABILITY

Moisture Susceptibility

Mix Type	Average Air Void Content Dry (%)	Dry Indirect Tensile Strength (kPa)	Average Air Void Content Conditioned (%)	Conditioned Indirect Tensile Strength (kPa)	Tensile Strength Ratio (%)
Virgin	7.2	806.7	7.2	625.2	**77.5**
15% RAP	6.5	878.1	6.5	769.5	**87.9**
15% RAP / 5% MSM	6.8	985.1	6.5	818.6	**83.1**
50% RAP	7.2	1166.2	7.1	1124.7	**96.4**

- **ASHTO T-283**
- **Aggregate temperatures >200°C**
- **Aggregate moisture contents 0.04% - 0.1%**
- **Mix moisture contents <0.1%**

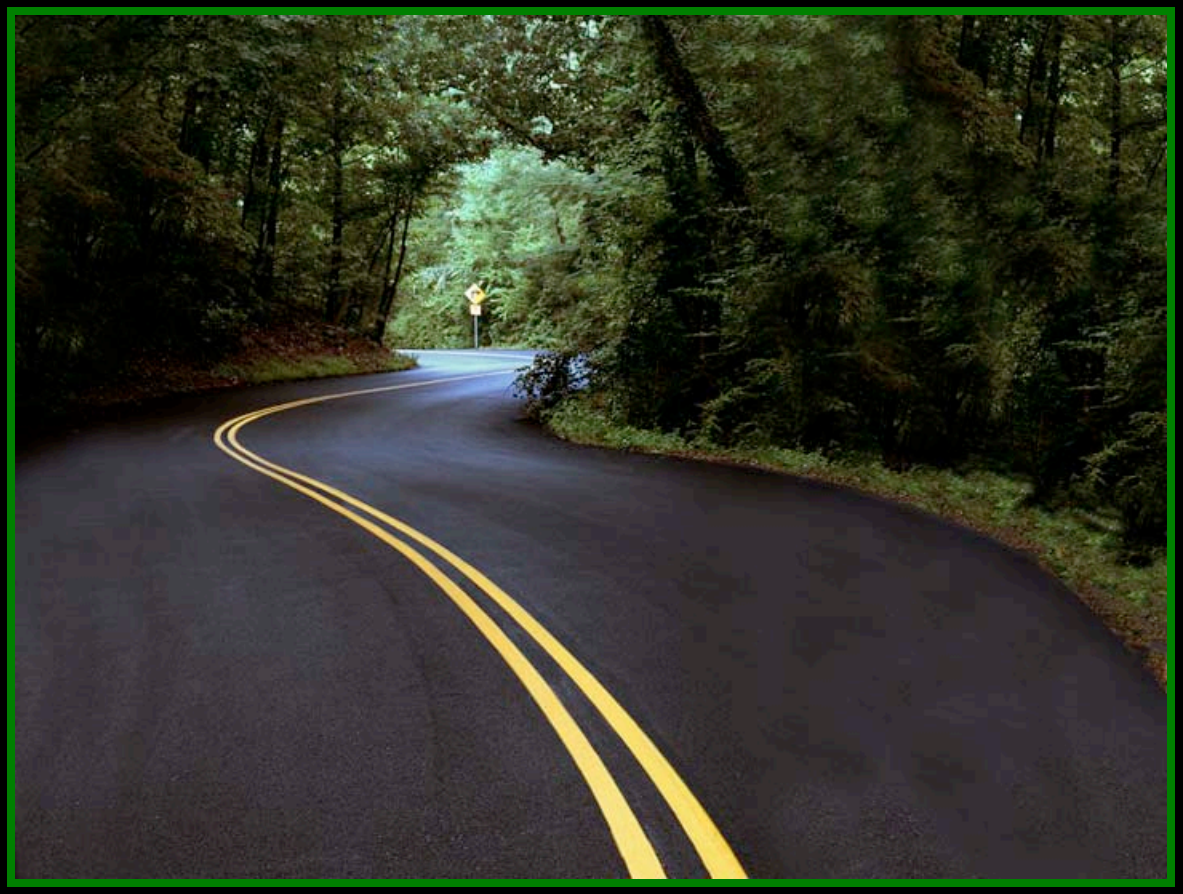


For the DOT/Public

- Comfort & Safety of workers
- Improve mixes
- Sustainability

Why Sustainability?

- By Milling & Recycling – 100% of the material can be re-used
- Reduce new aggregate requirement by 245,000,000 tons/year…annually (from 15% to 50%)
- Reduce oil consumption by 80,000,000 bbl/year…approximately 7 days of imported oil

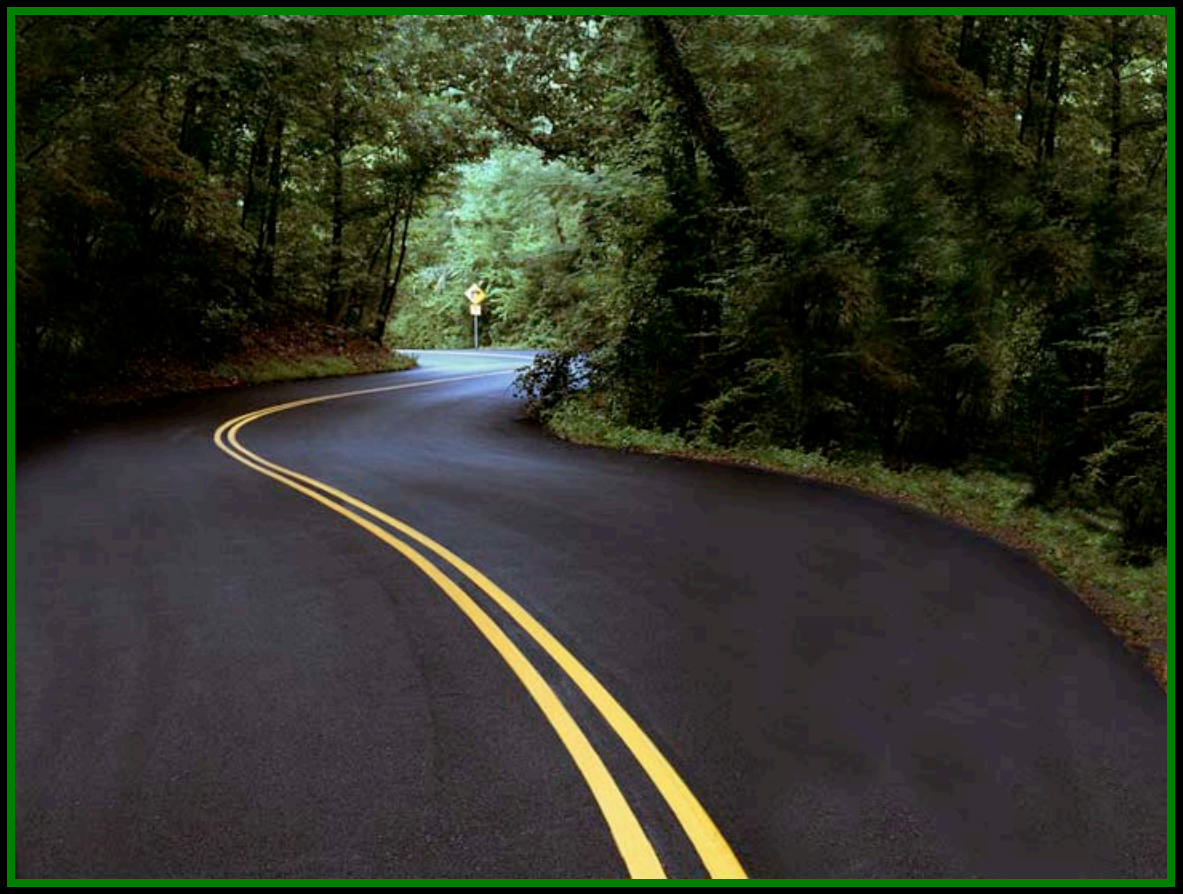


For the DOT/Public

- Comfort & Safety of workers
- Improve mixes
- Sustainability
- Green

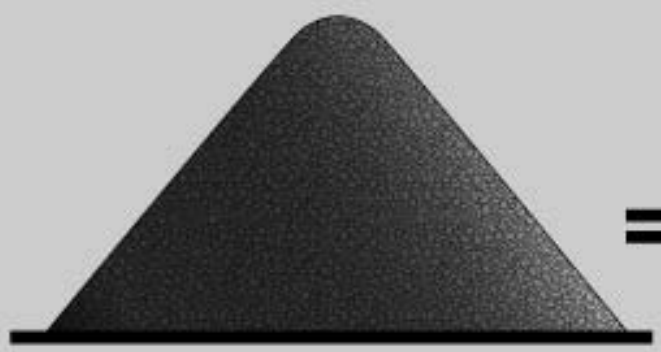
It's Green!

- Use 14% less fuel due to 50°F lower temperature
- No volatiles
- Use more recycle



For the DOT/Public

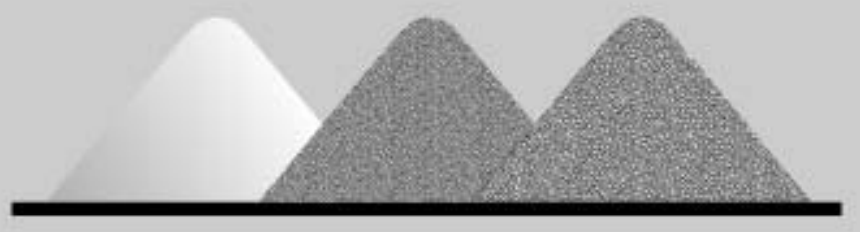
- Comfort & Safety of workers
- Improve mixes
- Sustainability
- Green
- Reduce Cost



30,000 Tons of RAP

=

70 - 6,000 Gallon Transport Trailers
and 28,200 Tons of Clean Aggregate



RAP is Worth the Virgin Material It Replaces

BID: $5,000,000.00

Aggregate	$ 15.00	
AC @ 600.00		
x 0.55	33.00	
		$ 48.00
Plant Cost	$ 10.00	
Trucking	4.00	
Laydown	3.00	
	$ 17.00	
Overhead & Profit	6.00	
		23.00
		$ 71.00 Price / ton

Tons = $\frac{\$5{,}000{,}000.00}{\$71.00}$ = 70,422 tons

Agg. tons = 66,549 tons

ASTEC INDUSTRIES, INC.

When paying 50% of the value of RAP less Milling, Trucking and Processing Cost

Milling……	$ 3.^{00} / ton
Trucking……	3.^{00} / ton
Processing……..	3.^{00} / ton
	$ 9.^{00} / ton

$$\text{Tons} = \frac{\$5{,}000{,}000.^{00}}{0.5(48.^{00}) + 0.5(9.^{00}) + 23.^{00}} = 97{,}087 + 38\%$$

- Plus 48,543 tons at $9.^{00} / ton cost of RAP left over to use in other mix
- Tons of stone used 45,873
- If RAP is used at 50% on other jobs and an additional 45,873 tons of stone will be used…Total stone used 91,946 tons

ASTEC INDUSTRIES, INC.

What we have done to date

- Installed over 100 units to create hot foam mechanically
- Produced between 1 and 2 million tons from 30 to 50% RAP with warm mix
- Stored in silo for 4 days
- Produced 76-22 (Polymers) and placed at 270ºF
- Produced rubber mix at 270ºF

What we have done to date

- Demonstration Projects
  - North Carolina
  - South Carolina
  - Tennessee x 4
  - Alabama
  - Texas
  - Arkansas
  - California
  - Kentucky
  - British Columbia
  - Ohio x 2
  - Illinois
  - Maryland
  - Louisiana
  - Florida x 2
  - Massachusetts

Conclusions:

1. HMA is 100% Recyclable
2. Milling corrects road profile, corrects drainage, eliminates raising shoulders and guardrails, and maintains bridge clearances…and generates RAP
3. By fractionating RAP and using Warm Mix (hot foam) with 50% RAP, it will produce a rut resistant, longer life pavement. It can be produced with a standard grade of AC. Density can be achieved with one less roller and centerline joint density is substantially improved
4. More miles can be paved at substantially less cost
5. Greenhouse emissions and imported oil are greatly reduced