

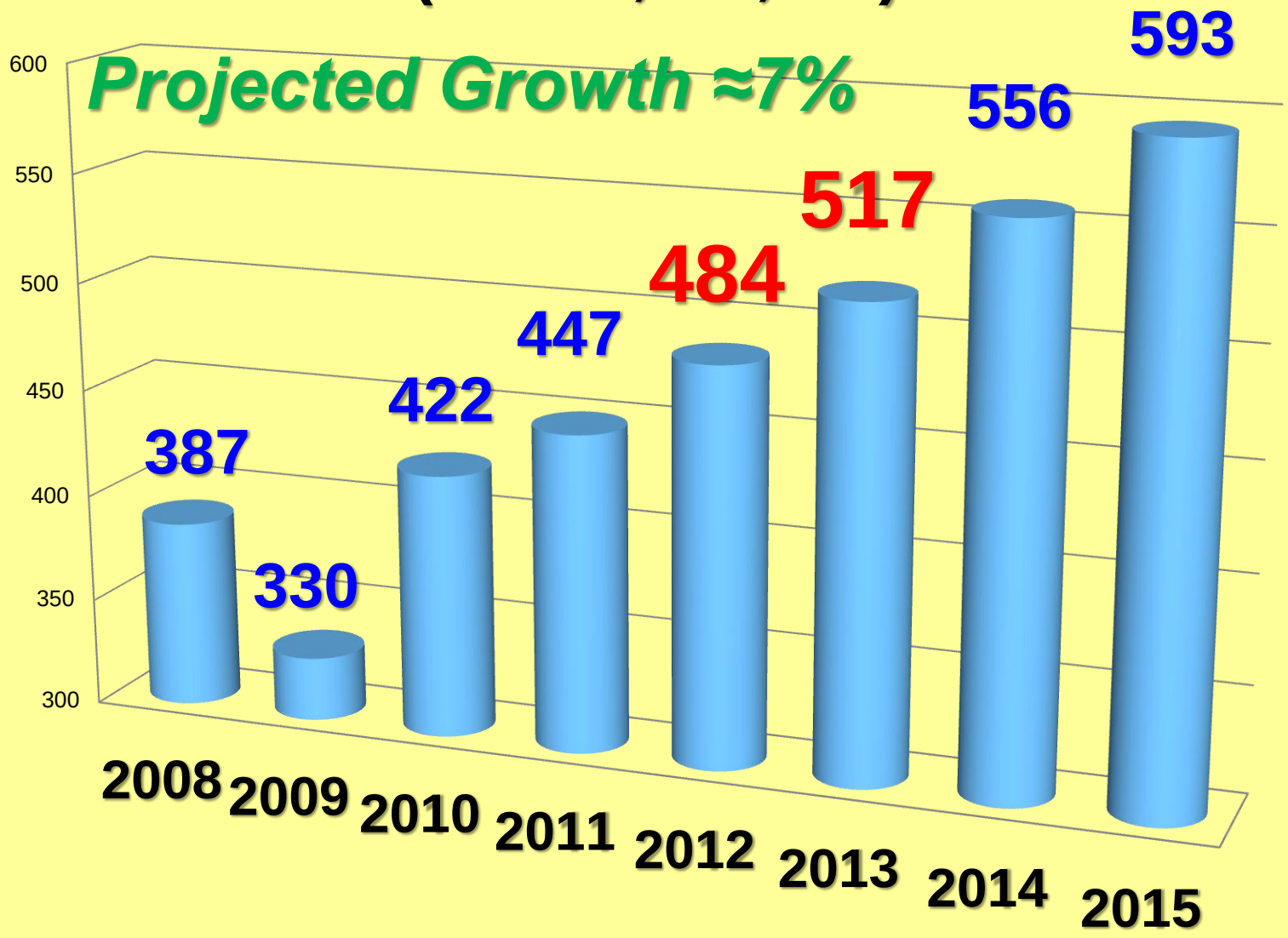
Straight Grate vs Grate Kiln

2013 Corem Pelletizing Conference

Ken Oja
Cliffs Technical Group

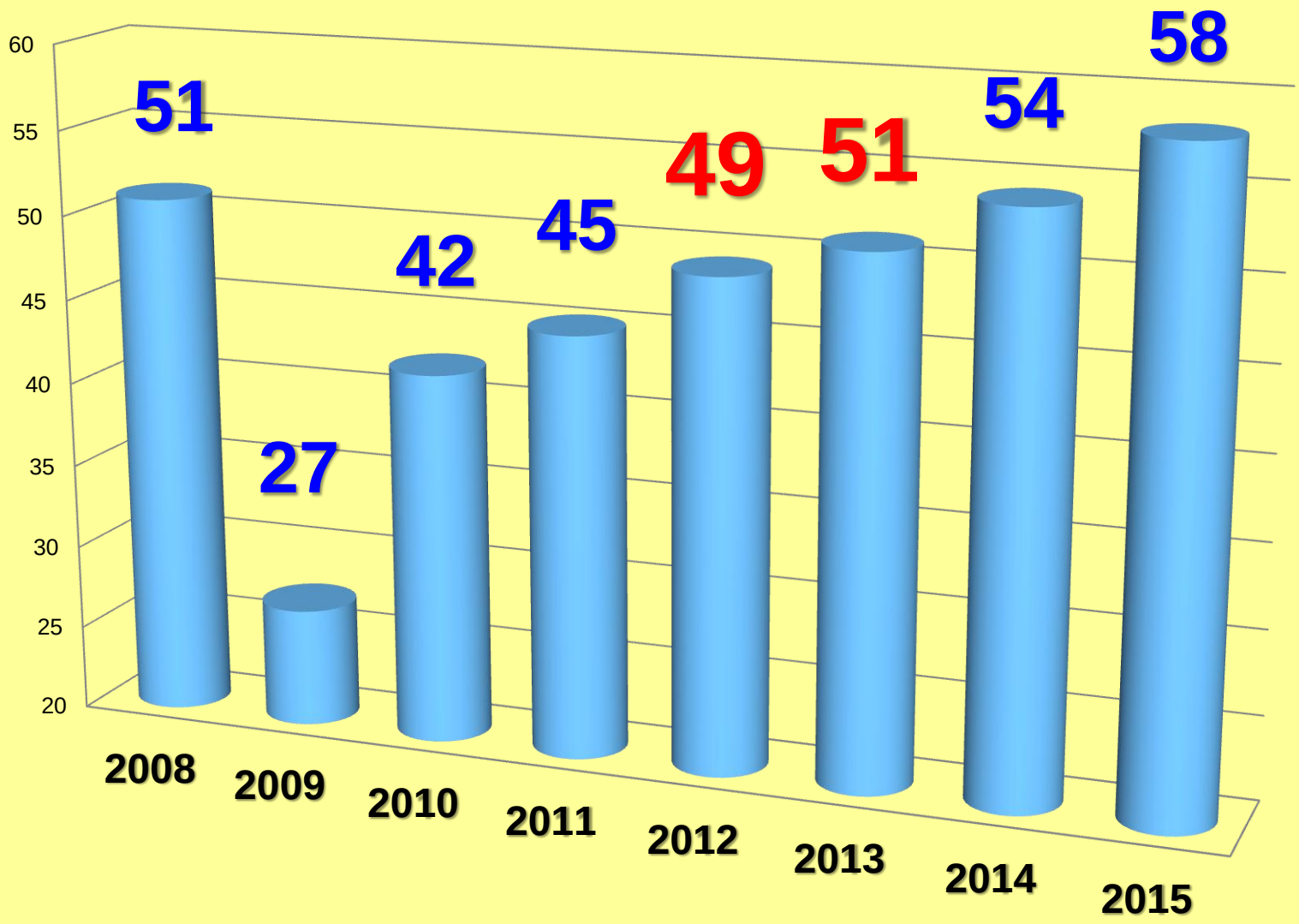
1. Cliffs has a long history in Pelletizing
2. Operating experience with straight grates, grate kilns and shaft furnaces
3. Goal will be to compare SG with GK
4. Some of the conclusions may surprise you

World Iron Ore Pelletizing Production
(MT x 1,000,000)



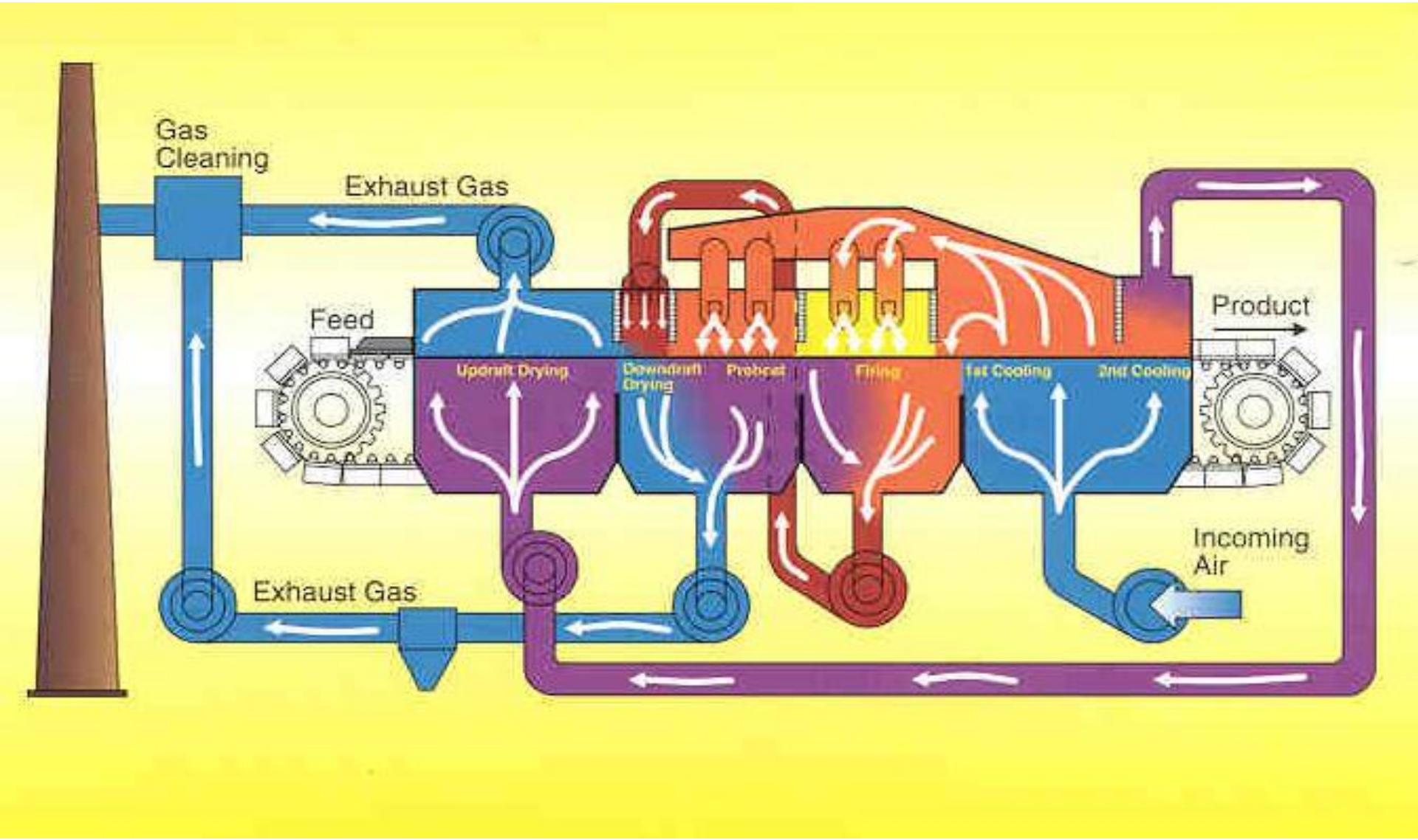
CLIFFS

USA Iron Ore Pelletizing Production (MT x 1,000,000)



CLIFFS

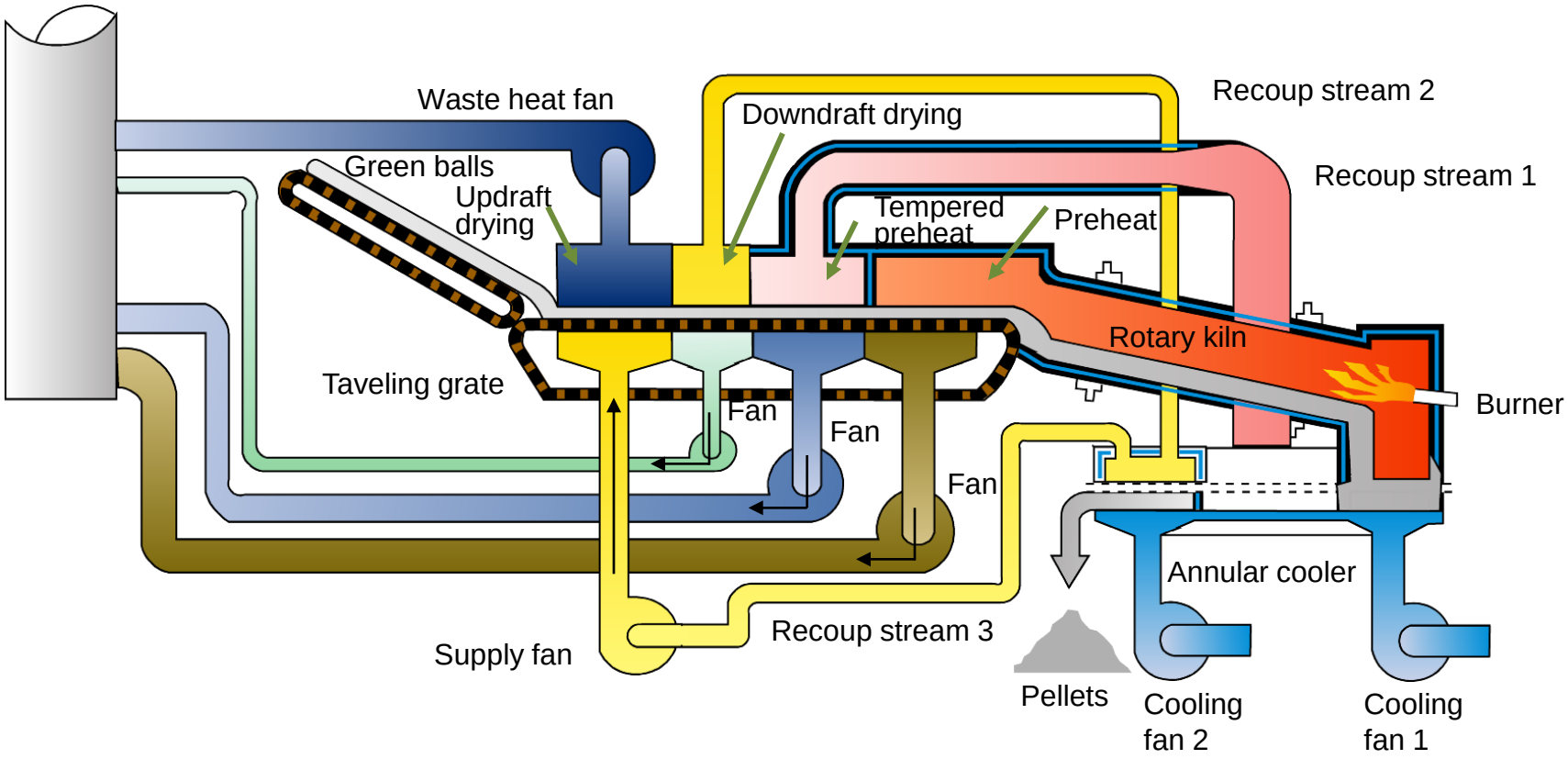
Straight Grate



Slides courtesy of Dean Conner- Metso

CLIFFS

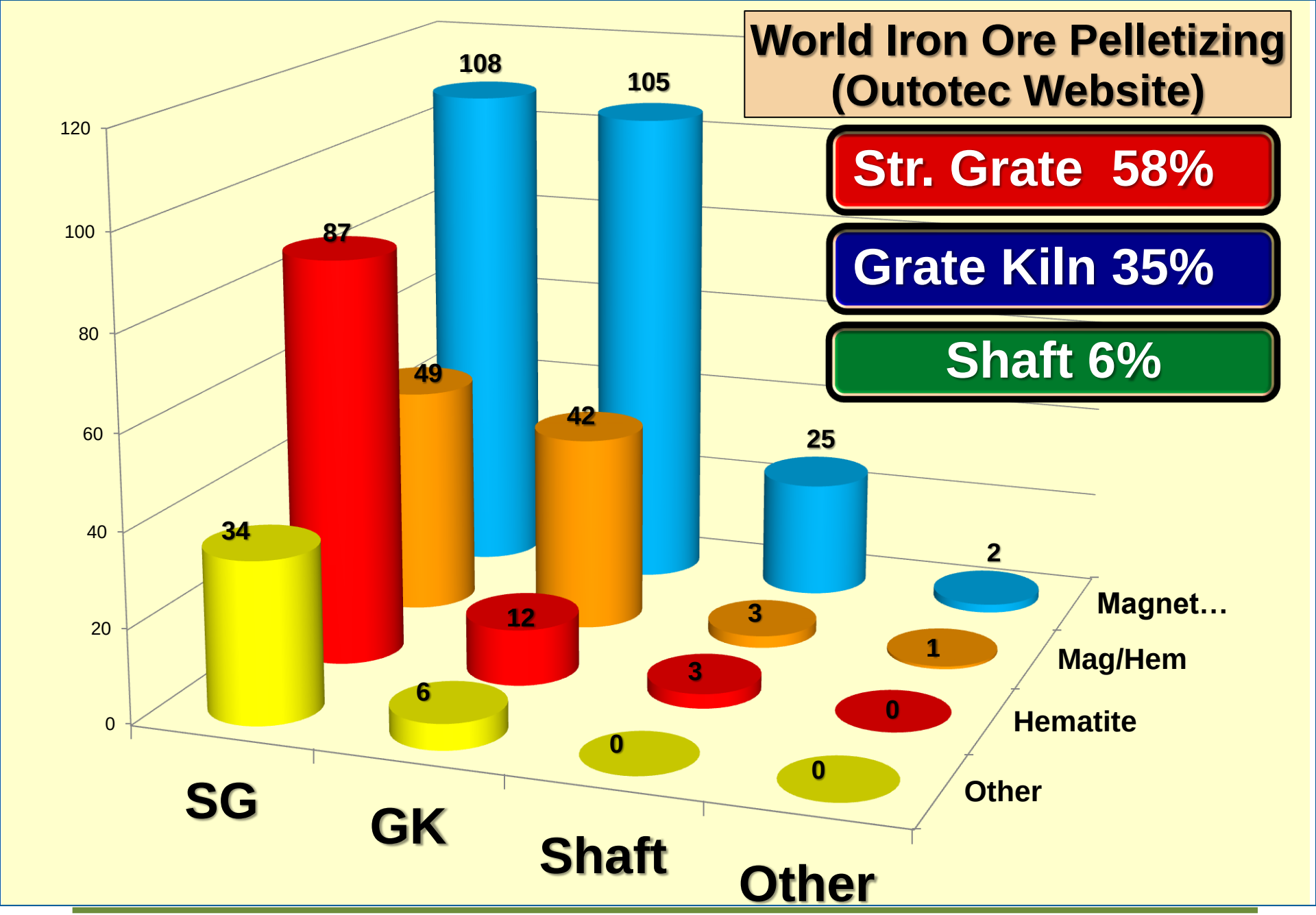
Simplified Grate Kiln System Flow



Slides courtesy of Dean Conner- Metso

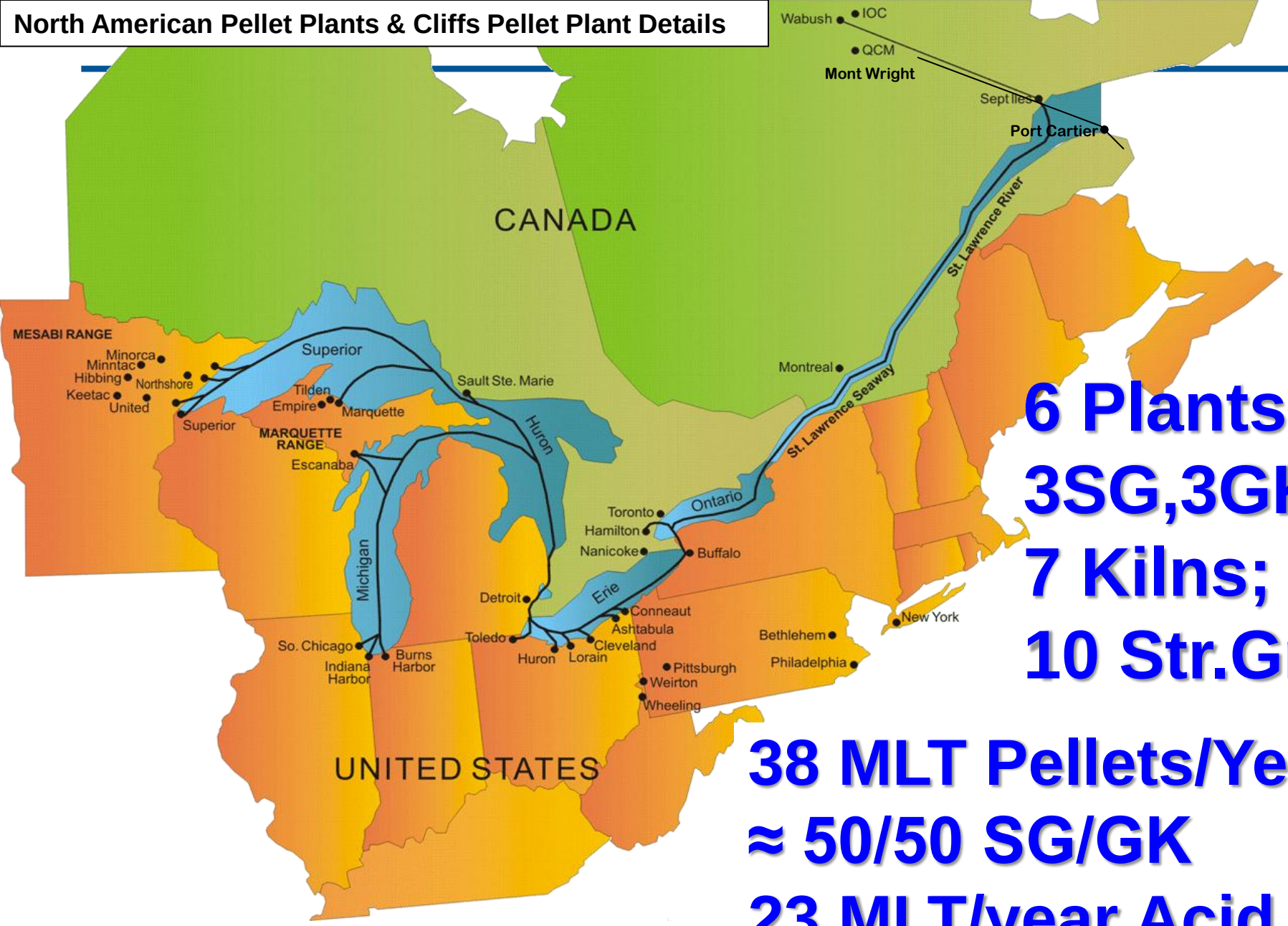
CLIFFS

World Iron Ore Pelletizing (Outotec Website)



CLIFFS

North American Pellet Plants & Cliffs Pellet Plant Details



6 Plants
3SG,3GK
7 Kilns;
10 Str.Gr.

38 MLT Pellets/Year
≈ 50/50 SG/GK
23 MLT/year Acid
15 MLT/Year Fluxed

Difficult comparison considering extreme differences feed and pellet types

Cliffs' Largest SG:	Cliffs' Largest GK:
• 100% Acid Pellets • Magnetite • Natural Gas	• 100% Fluxed Pellets • Hematite • Coal

A direct comparison will always be skewed

Straight Grate		Grate Kiln Cooler
	CAPEX	





CLIFFS

Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	
	Before Tumble Fines	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	
	Before Tumble Fines	
	Product Quality	





Straight Grate		Grate Kiln Cooler
	CAPEX	
	Annual Tonnage	
	Btu/LT	
	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	
	Before Tumble Fines	
	Product Quality	
	% Availability	





CLIFFS

CAPEX- STRAIGHT GRATE VS GRATE KILN



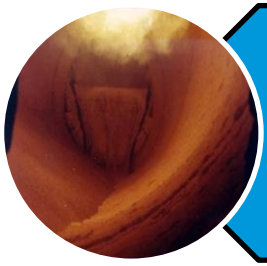
CAPEX: 5% to 10% higher with GK



SG has bigger fans and hearth layer system



GK building height greater



The 5-10% may vanish where kiln & cooler could be outside



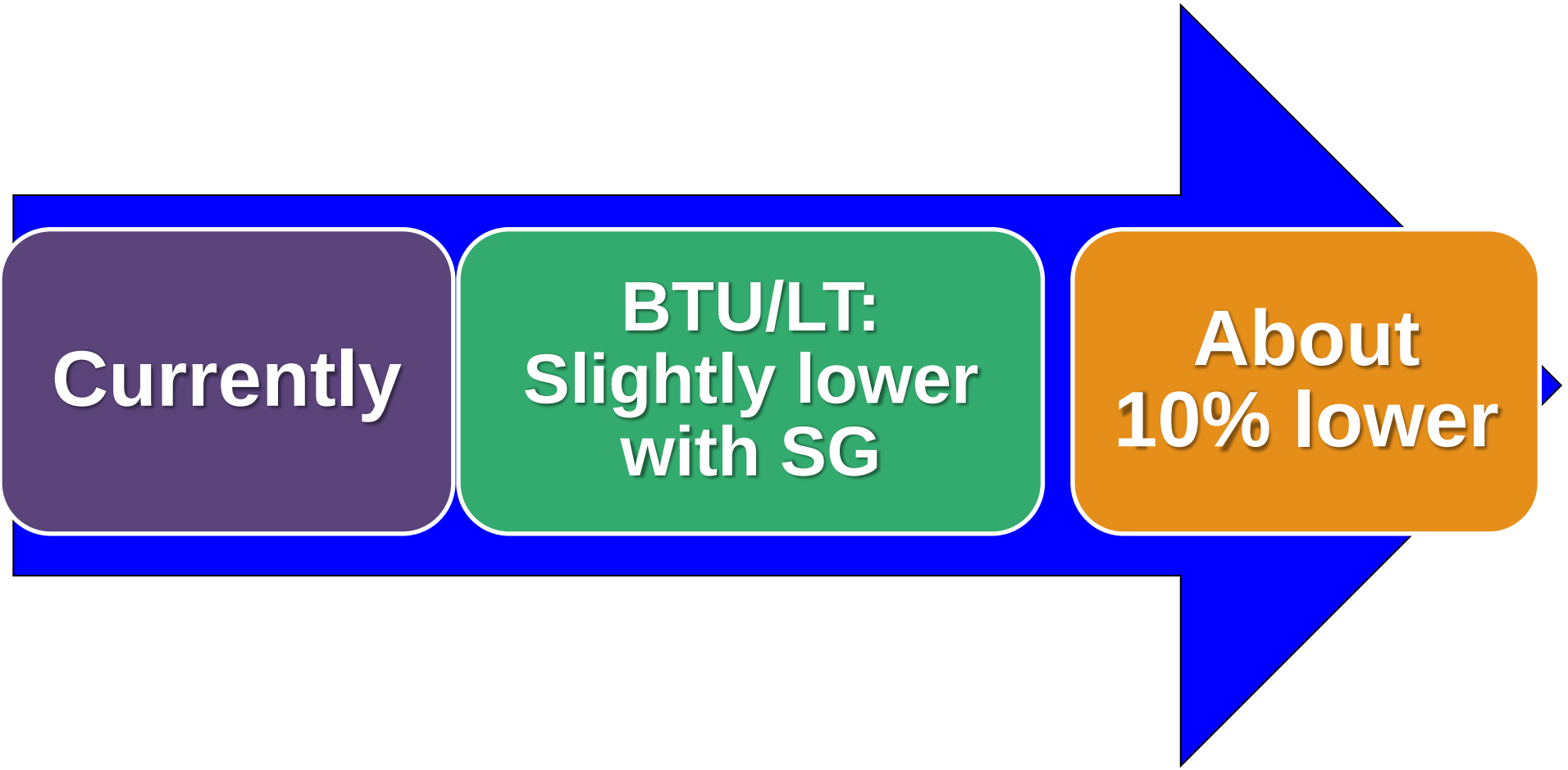
CLIFFS

Annual Tonnage slightly higher with SG

- Units of +7 MT/year with SG
- Units of 6-7 MT/year with GK
- No apparent limitation on either


Annual
Tonnage
SG

BTU/LT- STRAIGHT GRATE VS GRATE KILN

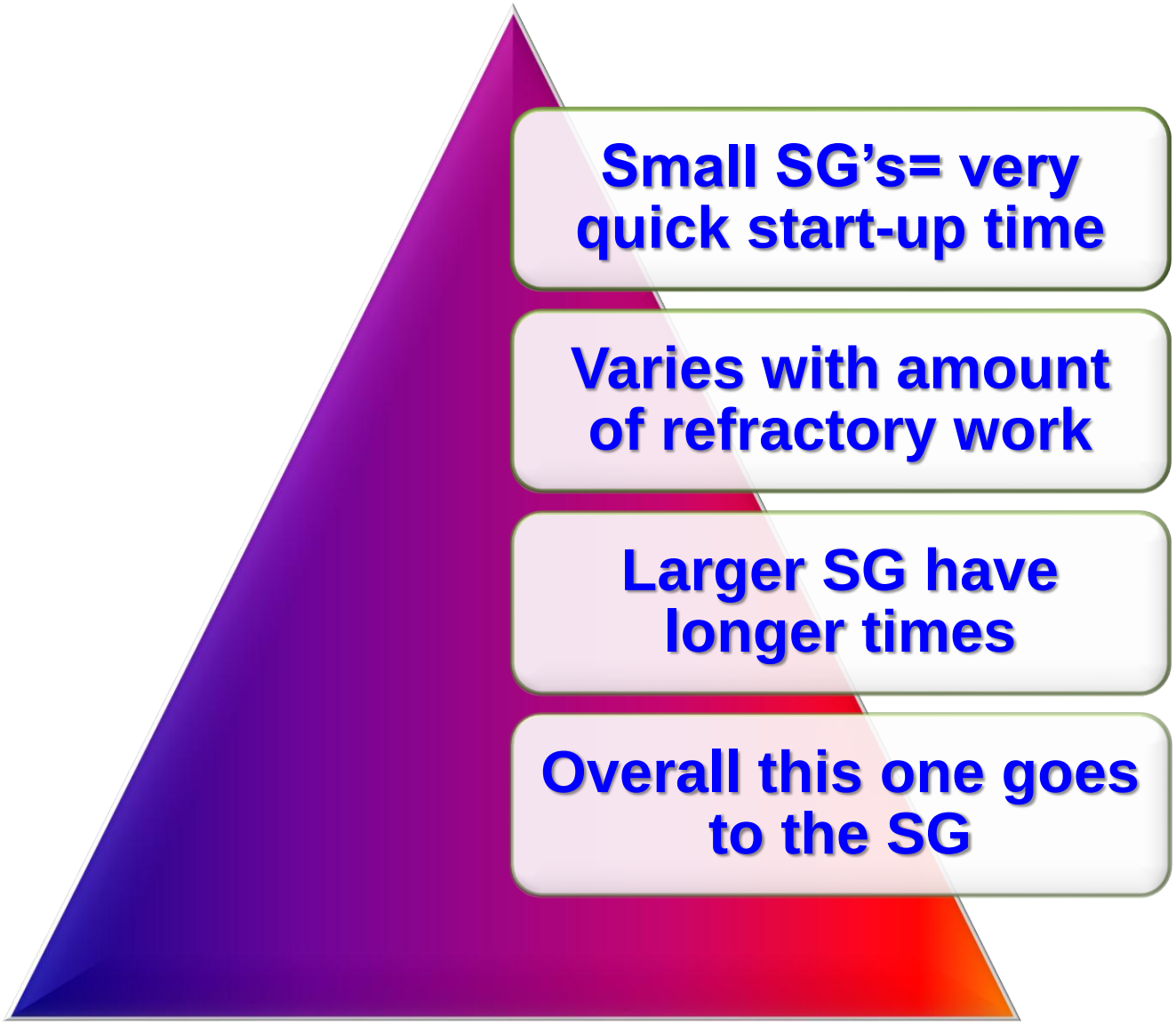


CLIFFS



CLIFFS

COLD START-UP TIME: STRAIGHT GRATE VS GRATE KILN



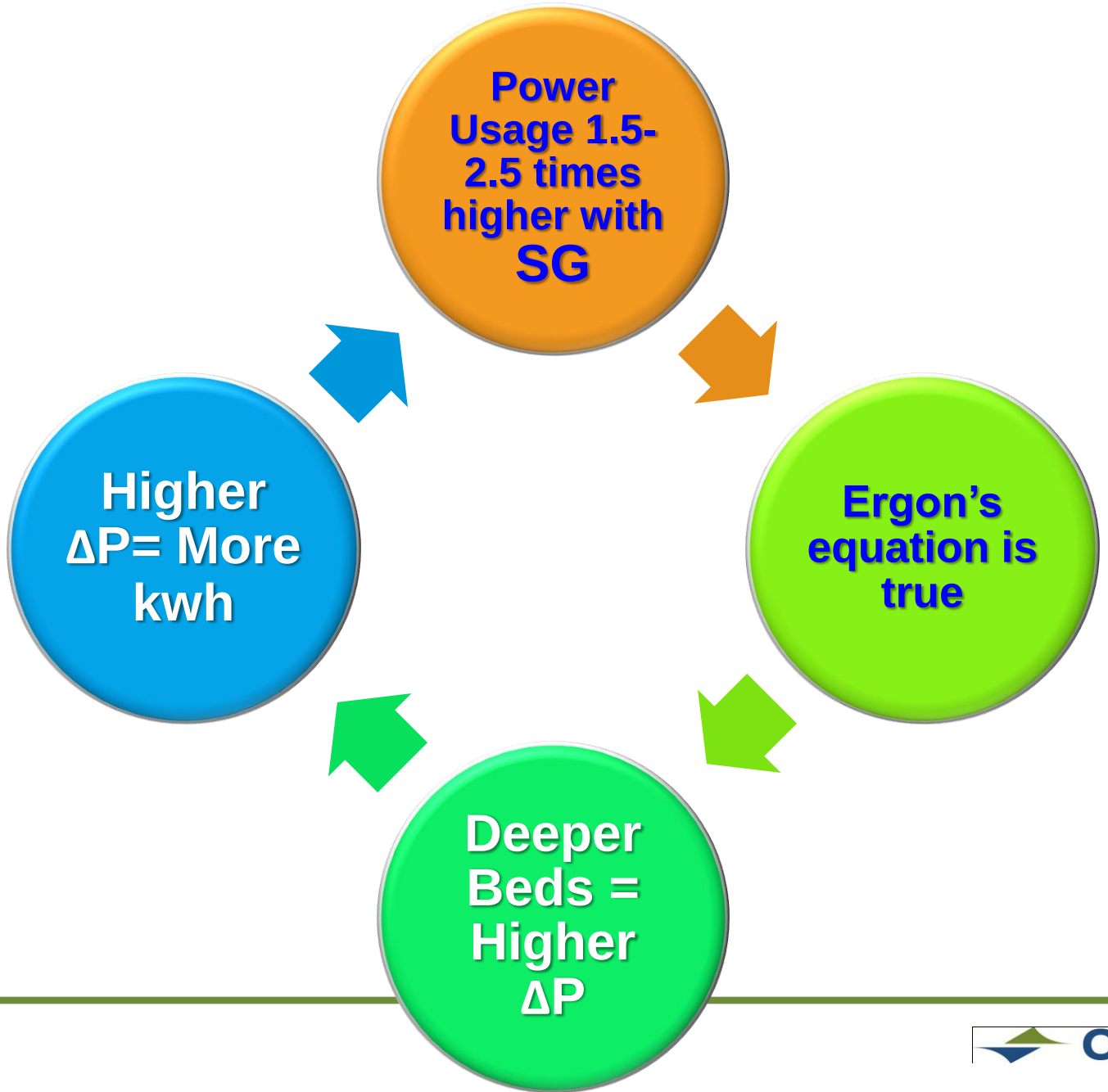
CLIFFS



CLIFFS

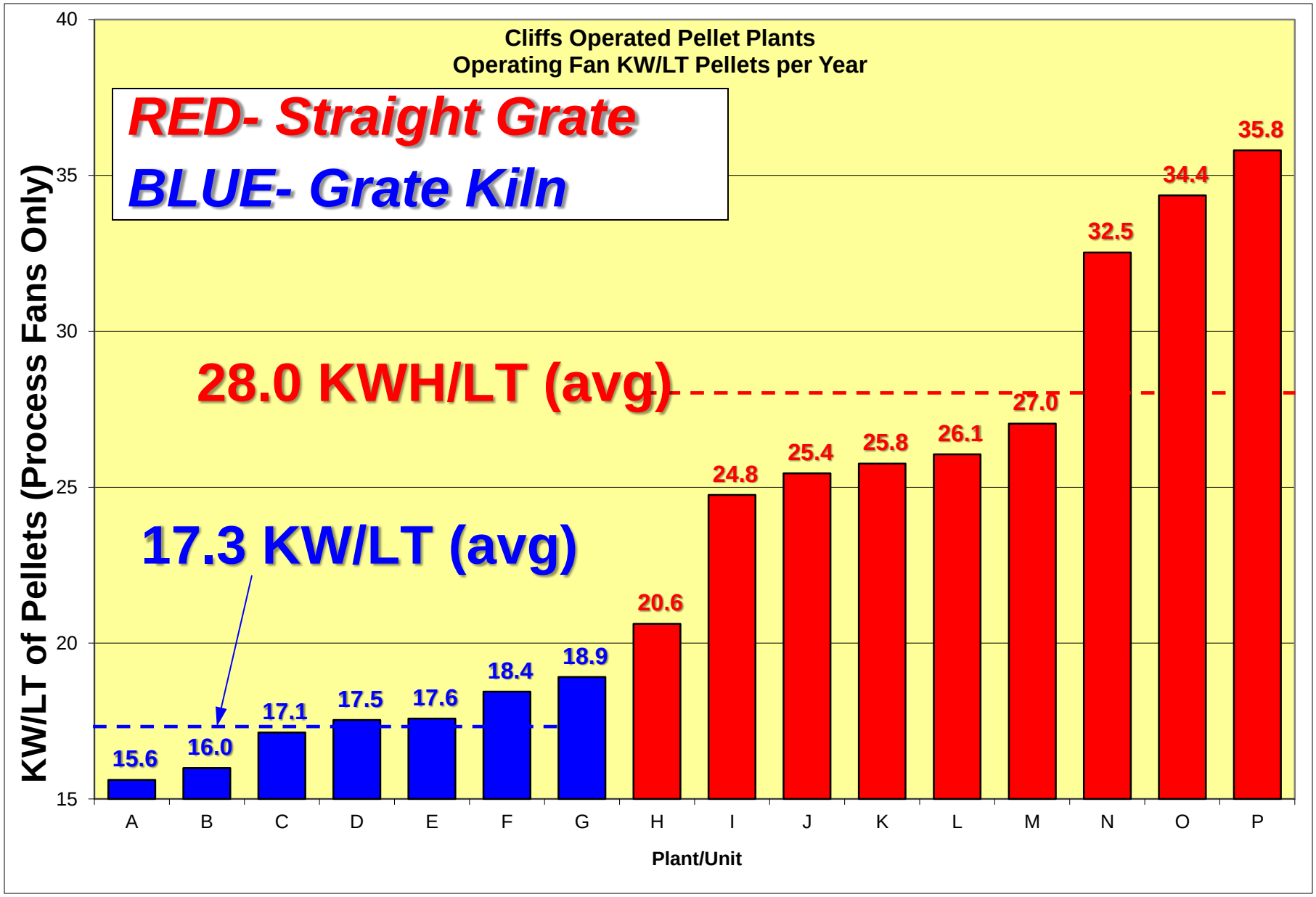
Straight Grate		Grate Kiln Cooler
✓	CAPEX	
✓	Annual Tonnage	
✓	Btu/LT	
✓	Cold Start Time	
	Power kwh/LT	
	Bentonite Rate	
	Organic Binder	
	Footprint	
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	
	Before Tumble Fines	
	Product Quality	
	% Availability	

POWER- STRAIGHT GRATE VS GRATE KILN



CLIFFS

Power- Straight Grate vs Grate Kiln



CLIFFS



CLIFFS


Bentonite Rate

Bentonite Rate



BENTONITE RATES-CLIFFS

Concentrate Moistures 7.5% to 11%

Concentrate Blaine's 1,500-4,000 cm^2/g

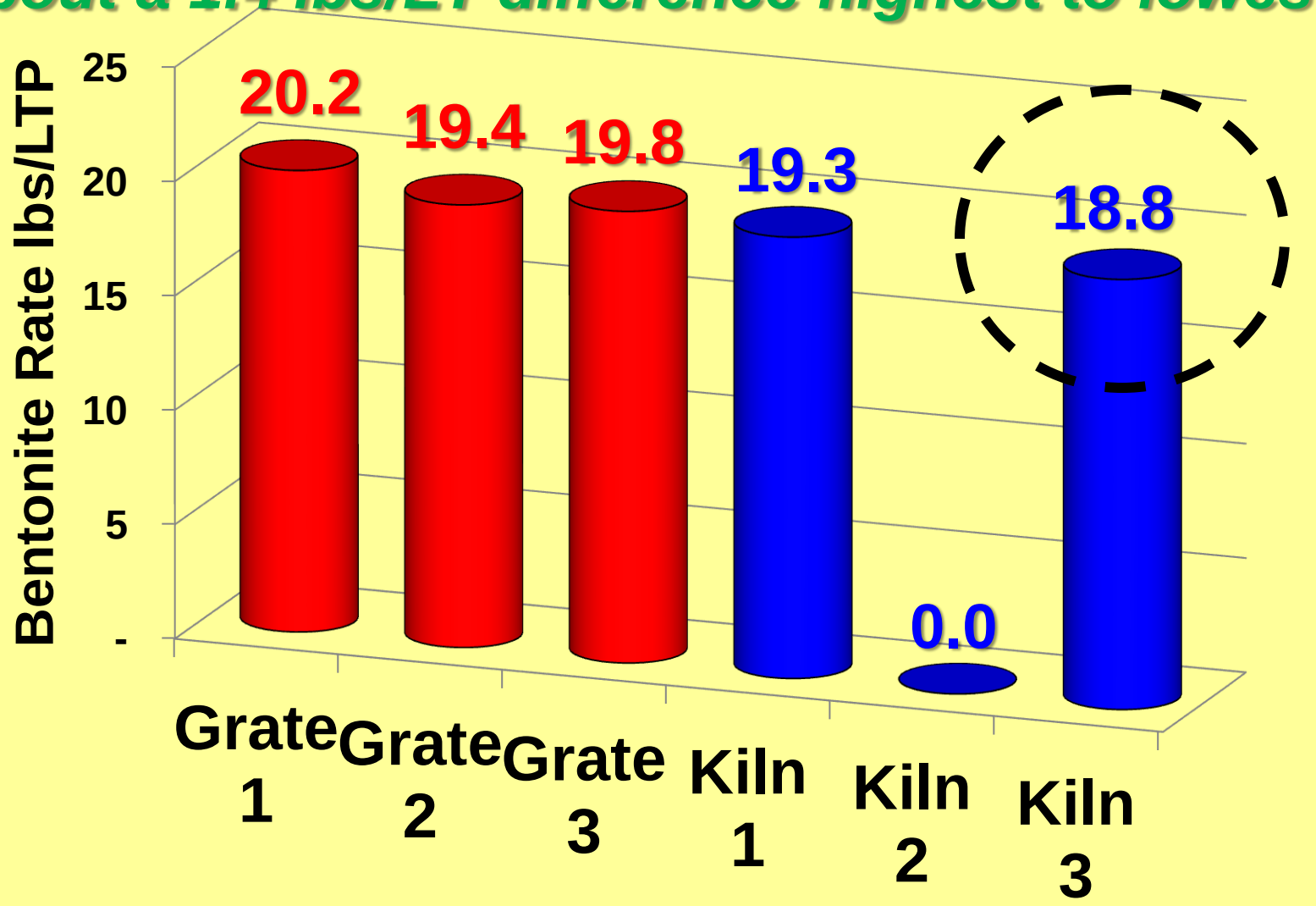
We have:

- intensive mixers
- non-intensive mixers
- no mixers

We should have a wide range of bentonite rates …

Cliffs Yearly Average Bentonite Rate lbs/LT of Pellets- by Plant

About a 1.4 lbs/LT difference highest to lowest

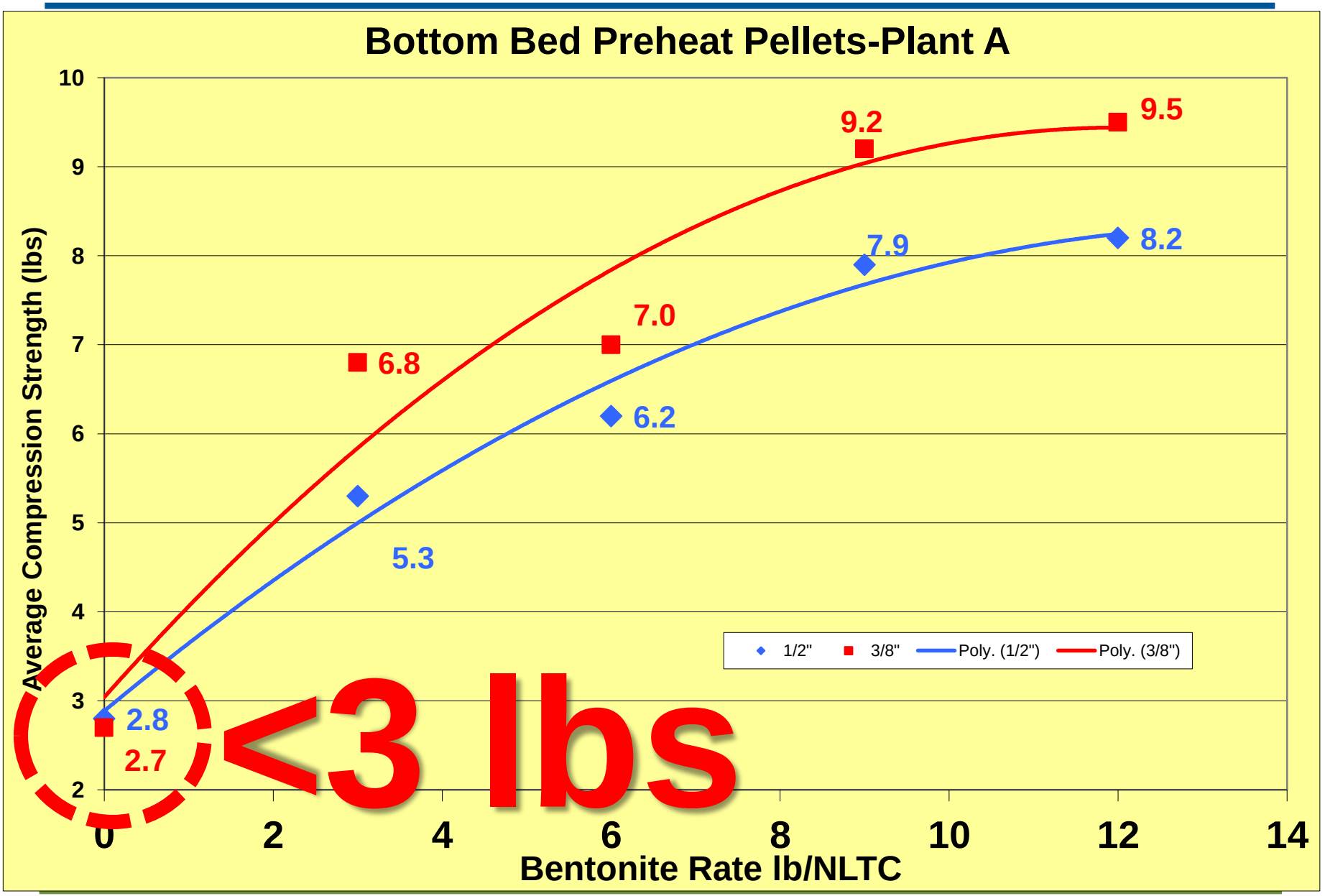


CLIFFS



CLIFFS

ORGANIC BINDER



CLIFFS

Deeper Beds require a higher bottom bed dry ball compressions to avoid fines

Cliffs has one GK plant on 100% OB

GK has been more successful with OB's



CLIFFS

FOOTPRINT- LARGER UNITS

1 GK= 3.632 MLT



72

Annual LT/ft²

1 GK= 50,361 ft²

1 SG= 2.67 MLT



48

Annual LT/ft²

1 SG= 55,428 ft²

CLIFFS

FOOTPRINT- ANNUAL LT/FT^2

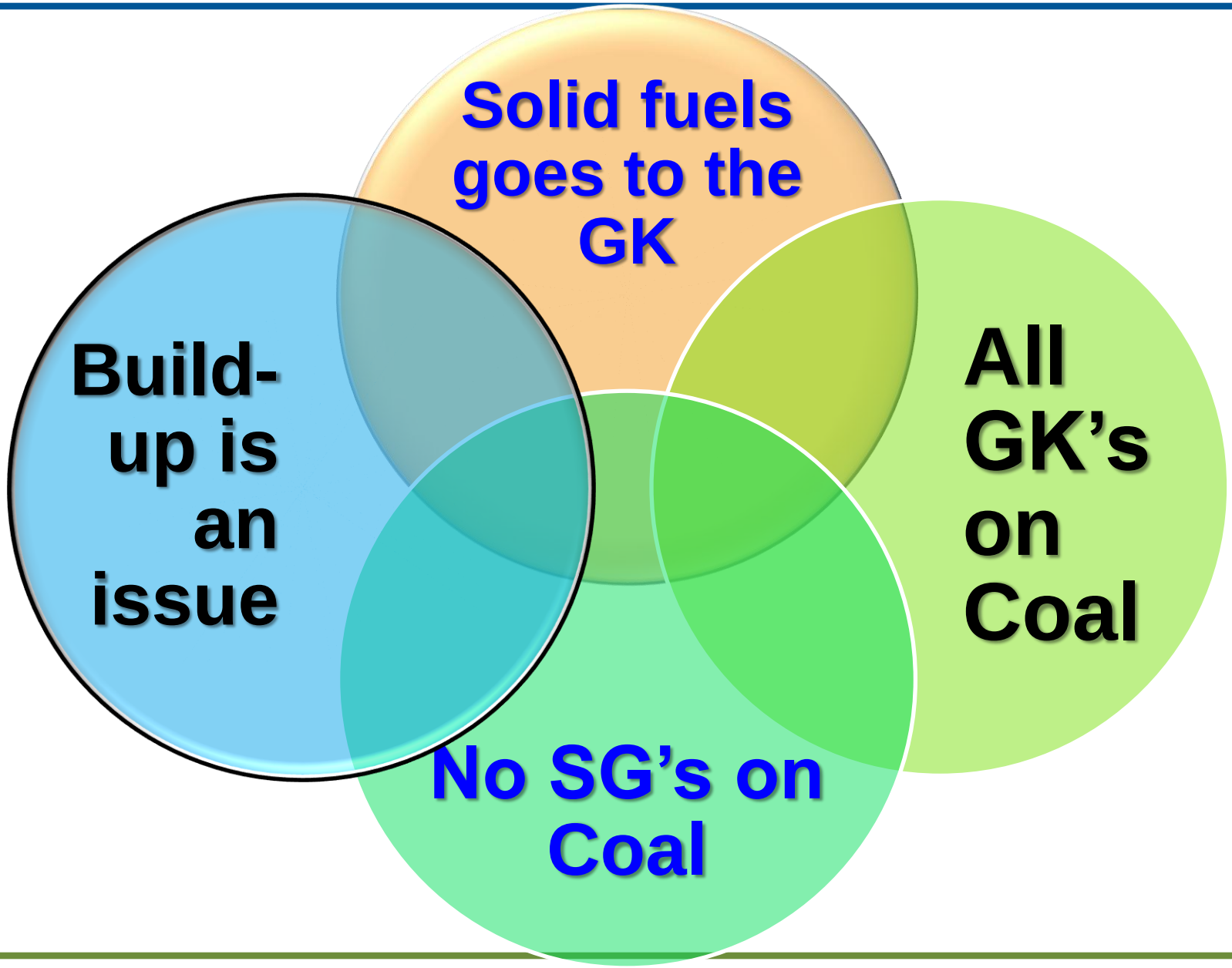
	GK	SG
Small Units	76	46
Big Units	72	48



CLIFFS

Straight Grate		Grate Kiln Cooler
✓	CAPEX	
✓	Annual Tonnage	
✓	Btu/LT	
✓	Cold Start Time	
	Power kwh/LT	✓
	Bentonite Rate	✓
	Organic Binder	✓
	Footprint	✓
	Solid fuels	
	Refractory Issues	
	Fluxed Pellets	
	Labor	
	Maint. Materials	
	Before Tumble Fines	
	Product Quality	
	% Availability	

SOLID FUELS



CLIFFS

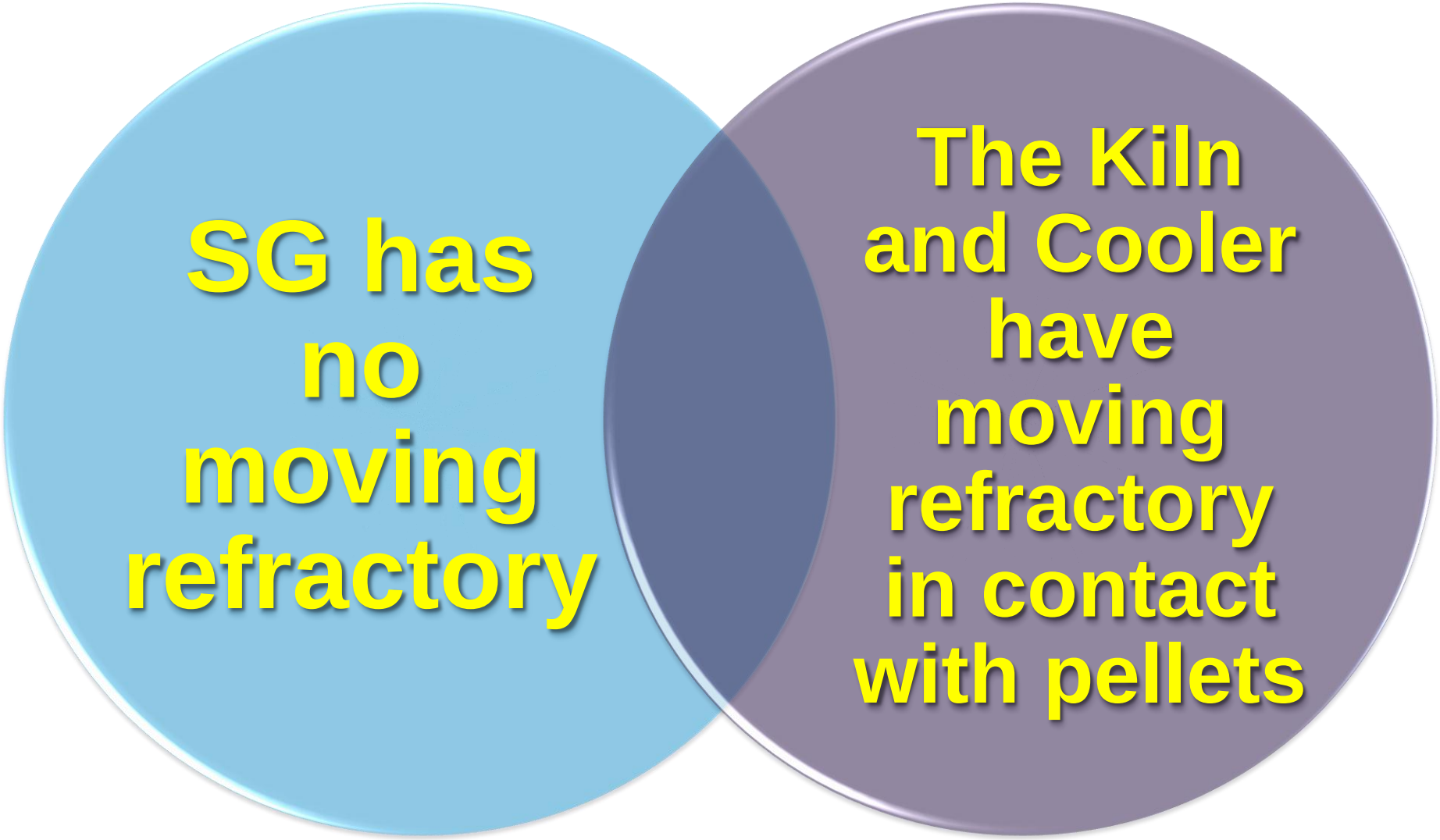




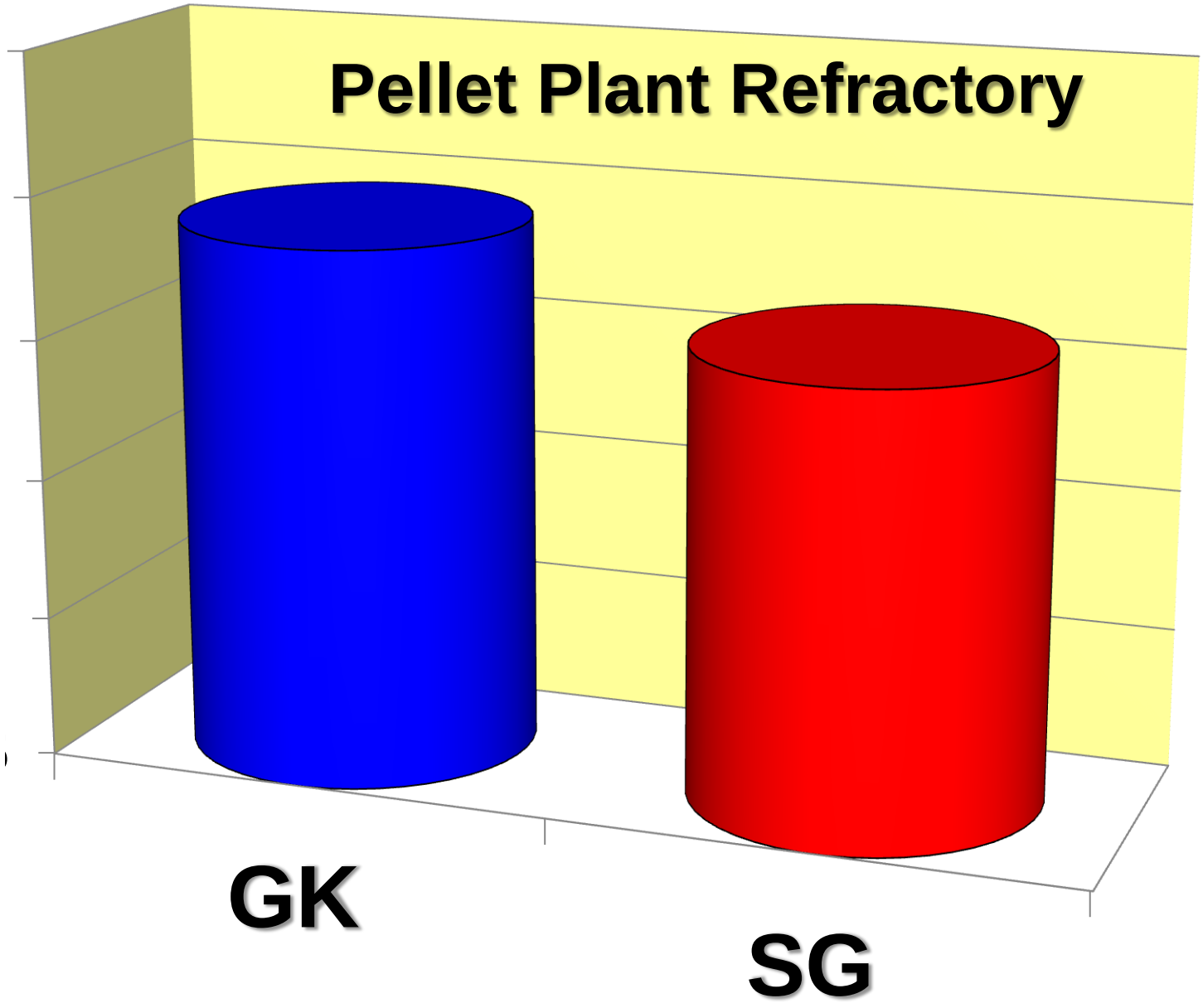


CLIFFS

REFRACTORY- STRAIGHT GRATE VS GRATE KILN



CLIFFS



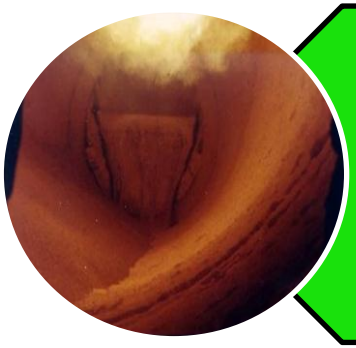
CLIFFS


Refractory
SG

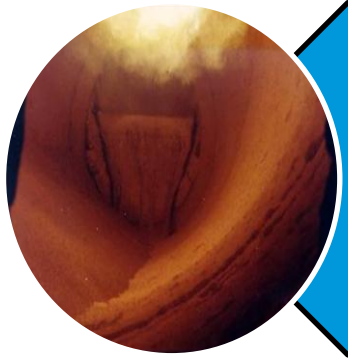
FLUXED PELLETS STRAIGHT GRATE VS GRATE KILN



A good fluxed pellet can be made with both

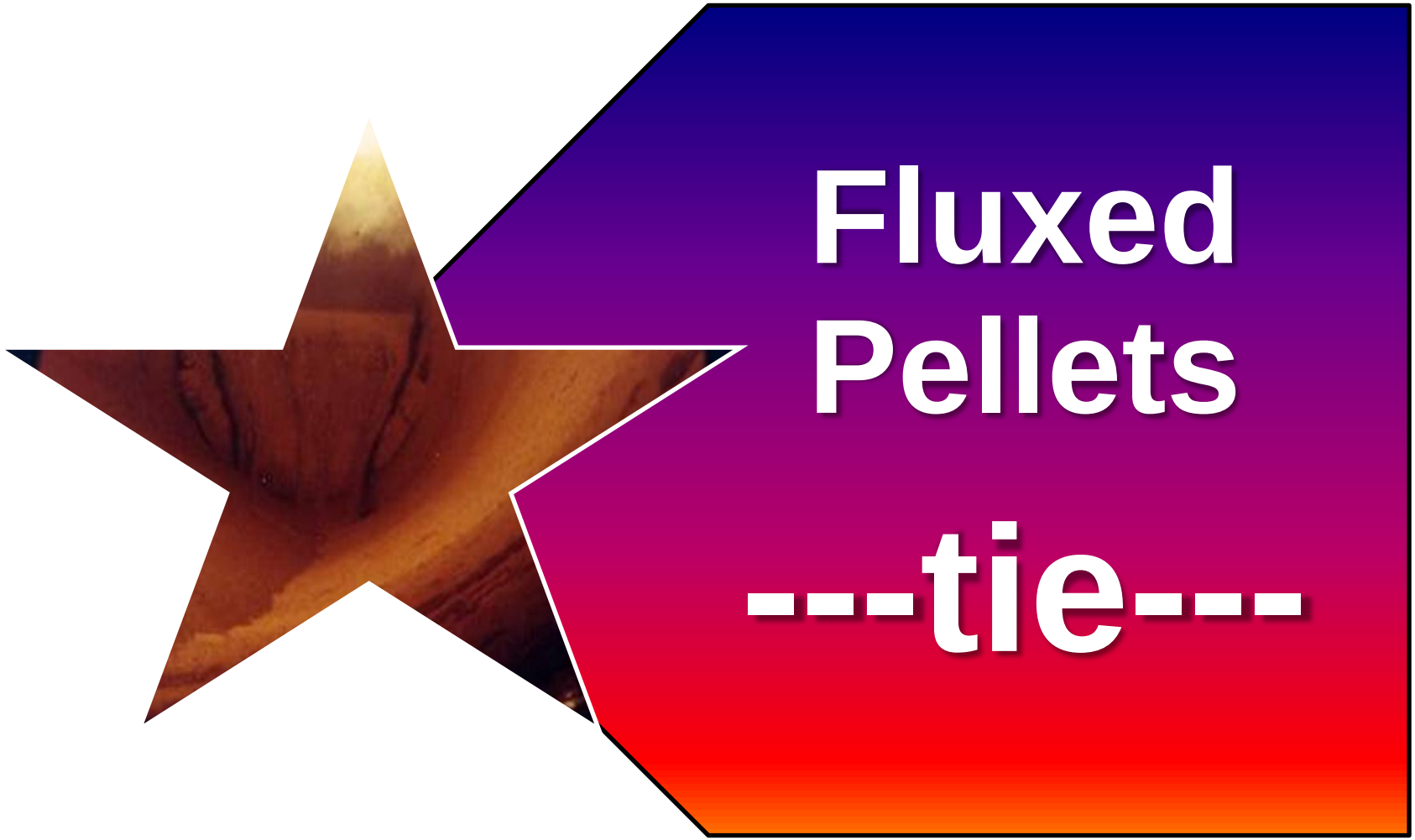


The GK Plants make the majority

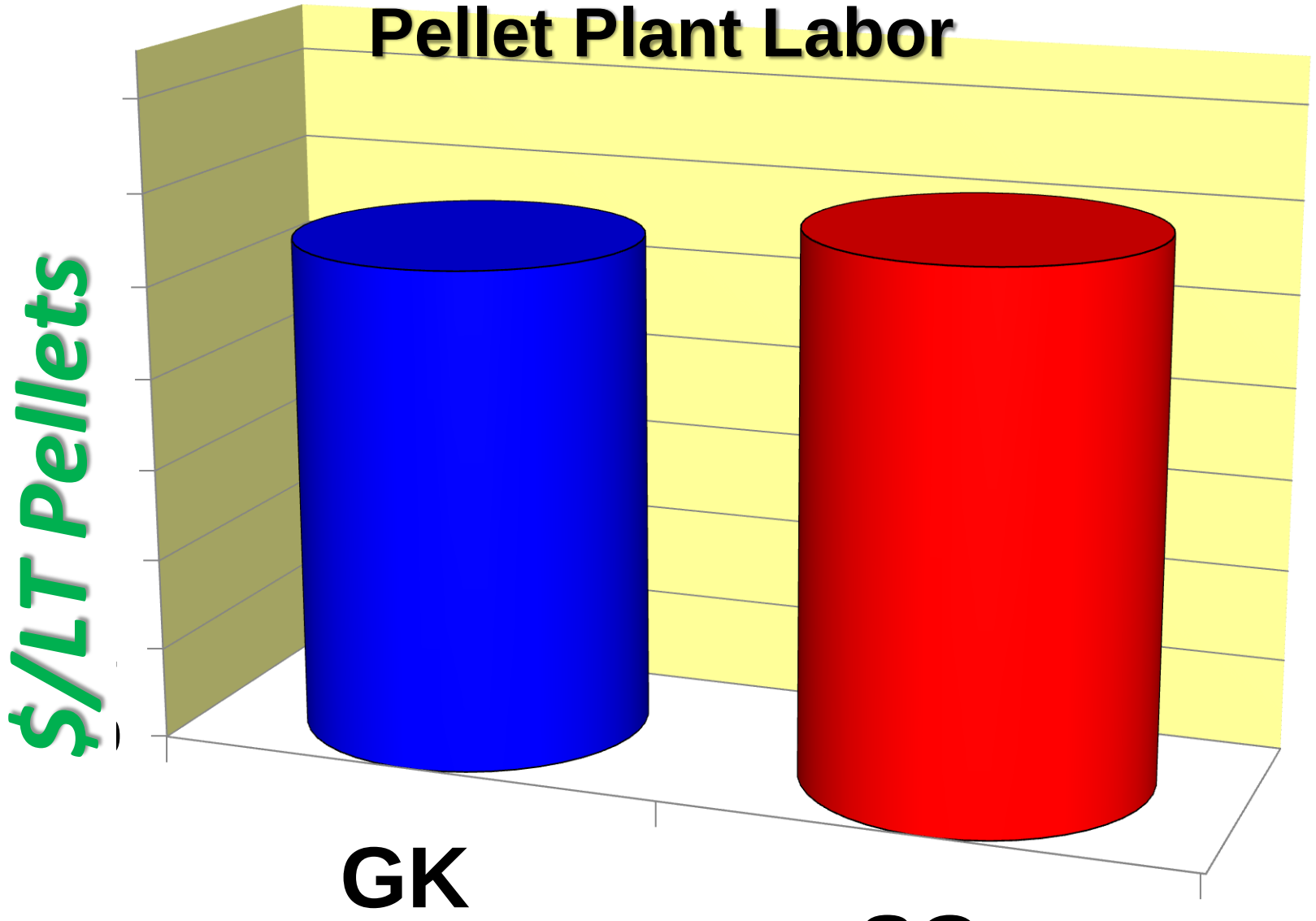


No clear winner

CLIFFS


Fluxed
Pellets
---tie---

Pellet Plant Labor



RED- Straight Grate
BLUE- Grate Kiln

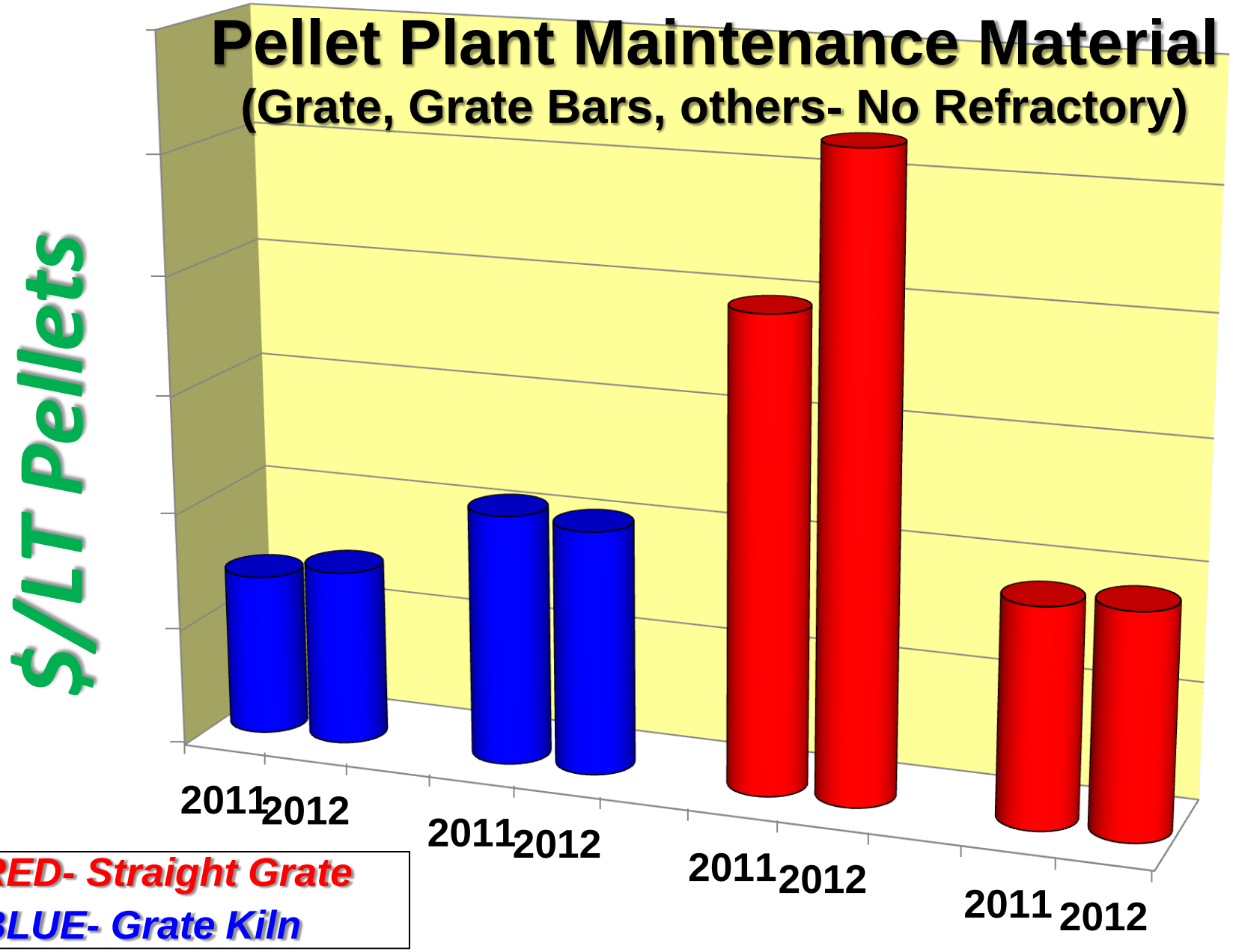
CLIFFS


Labor
---tie---

Straight Grate		Grate Kiln Cooler
✓	CAPEX	
✓	Annual Tonnage	
✓	Btu/LT	
✓	Cold Start Time	
	Power kwh/LT	✓
	Bentonite Rate	✓
	Organic Binder	✓
	Footprint	✓
	Solid fuels	✓
✓	Refractory Issues	
-----	Fluxed Pellets	-----
-----	Labor	-----
	Maint. Materials	
	Before Tumble Fines	
	Product Quality	
	% Availability	

CLIFFS

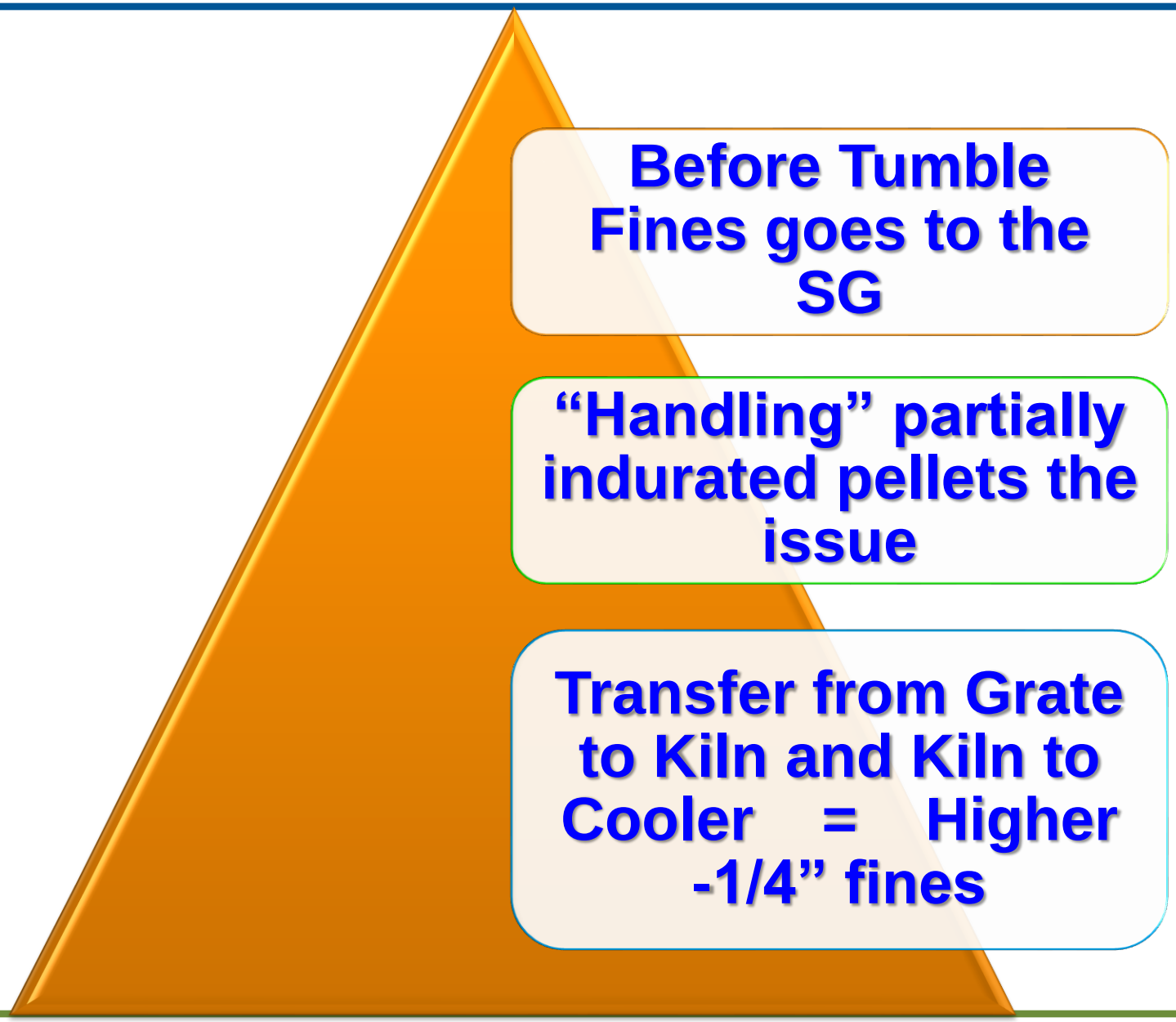
Pellet Plant Maintenance Material
(Grate, Grate Bars, others- No Refractory)



CLIFFS


Maint.
Mat'l
GK

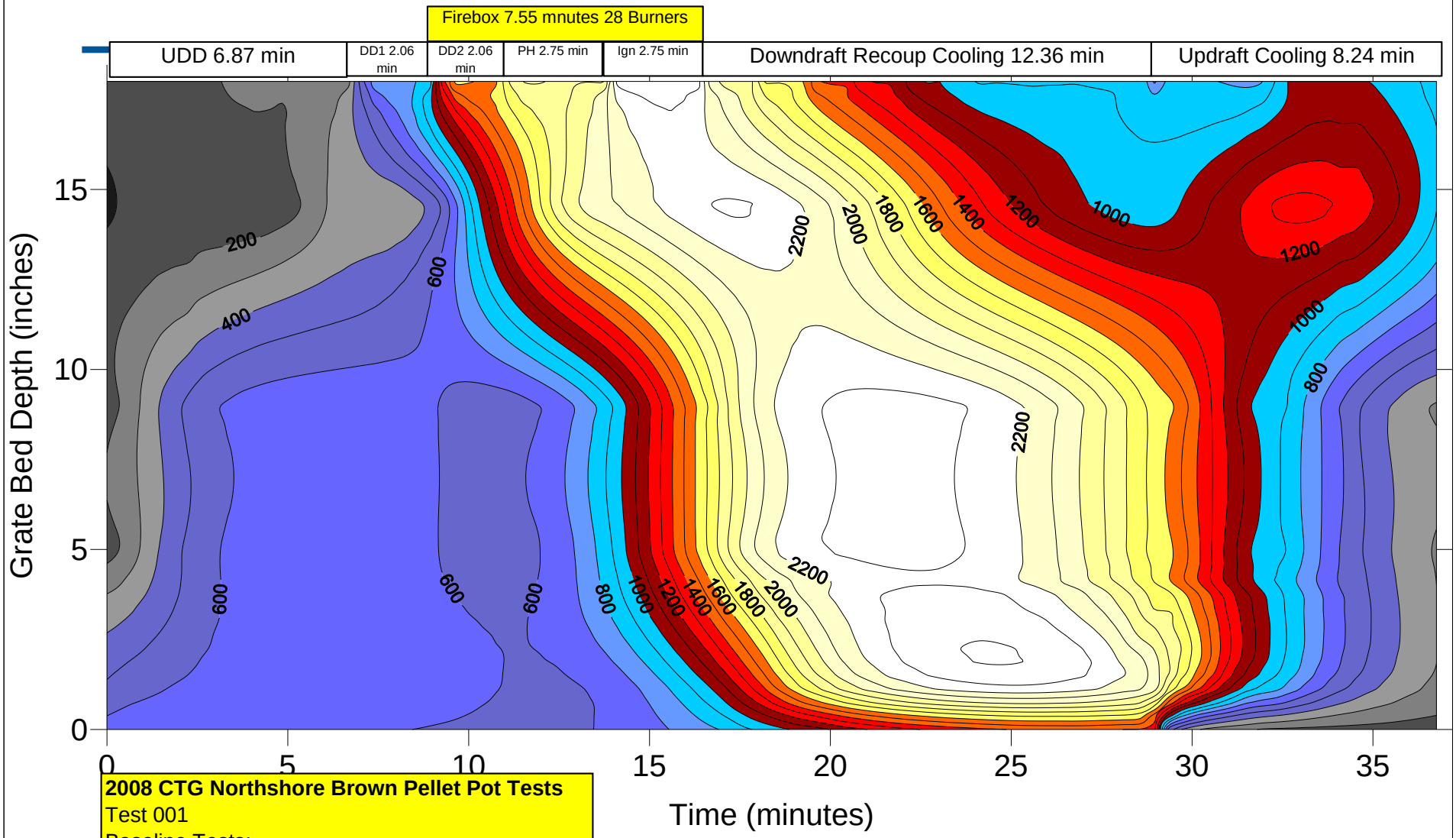
BEFORE TUMBLE FINES



CLIFFS



CLIFFS

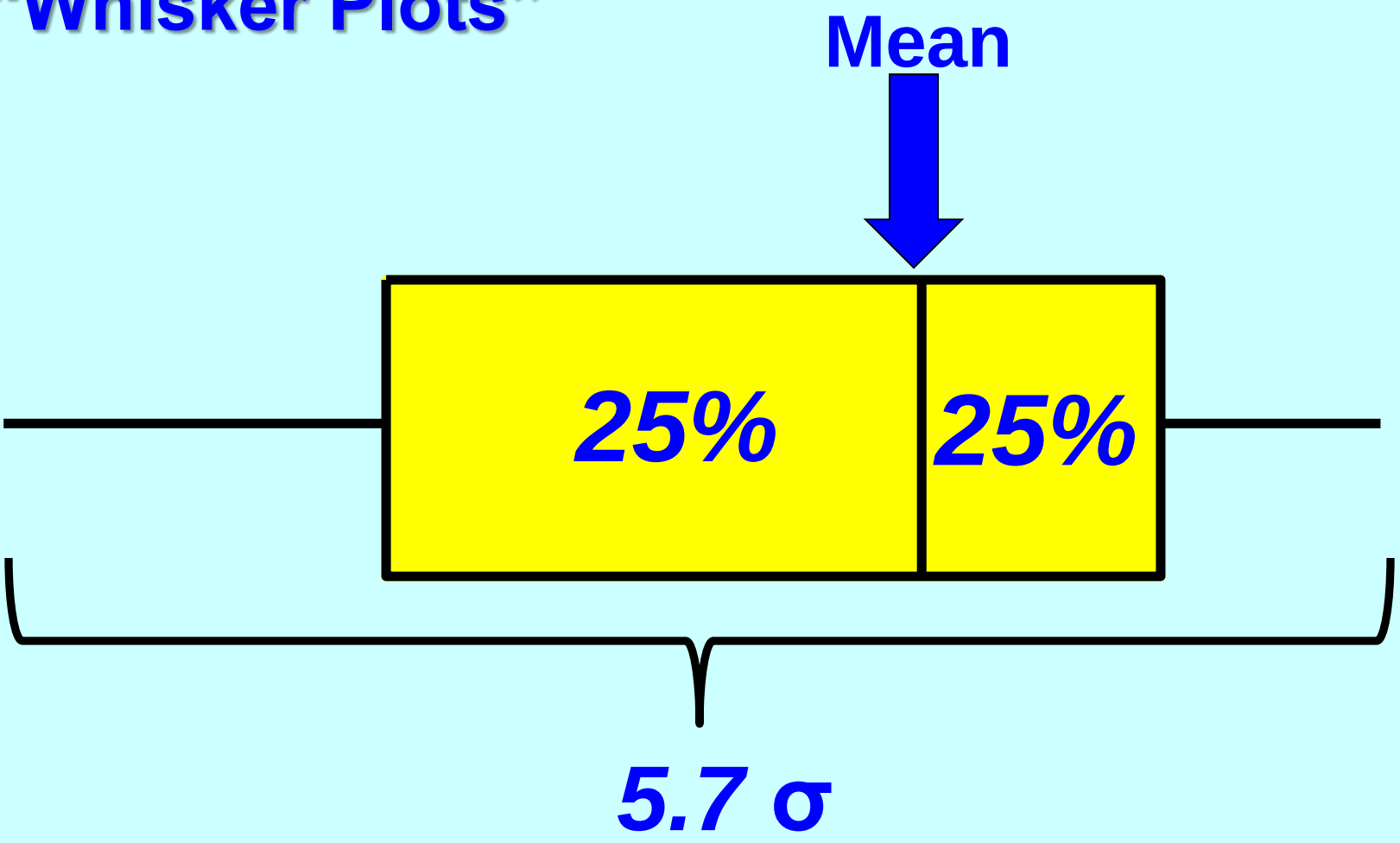


2008 CTG Northshore Brown Pellet Pot Tests
Test 001
Baseline Tests:
16" Green Balls, 2" Hearth Layer
1,600°F DDD2, 1,900°F Preheat, 2,325°F Ignition

Lab Bench Test

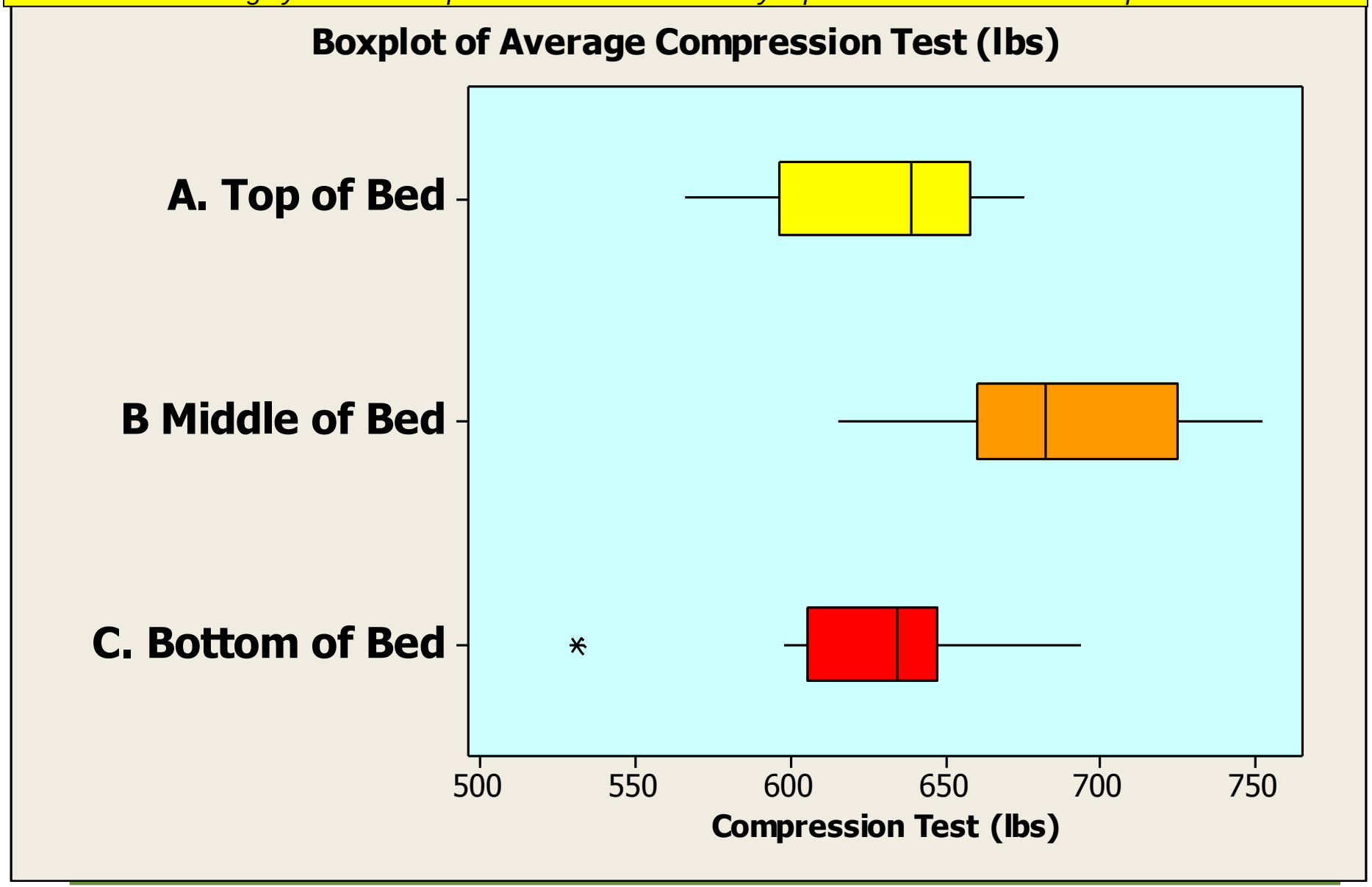
CLIFFS

"Whisker Plots"



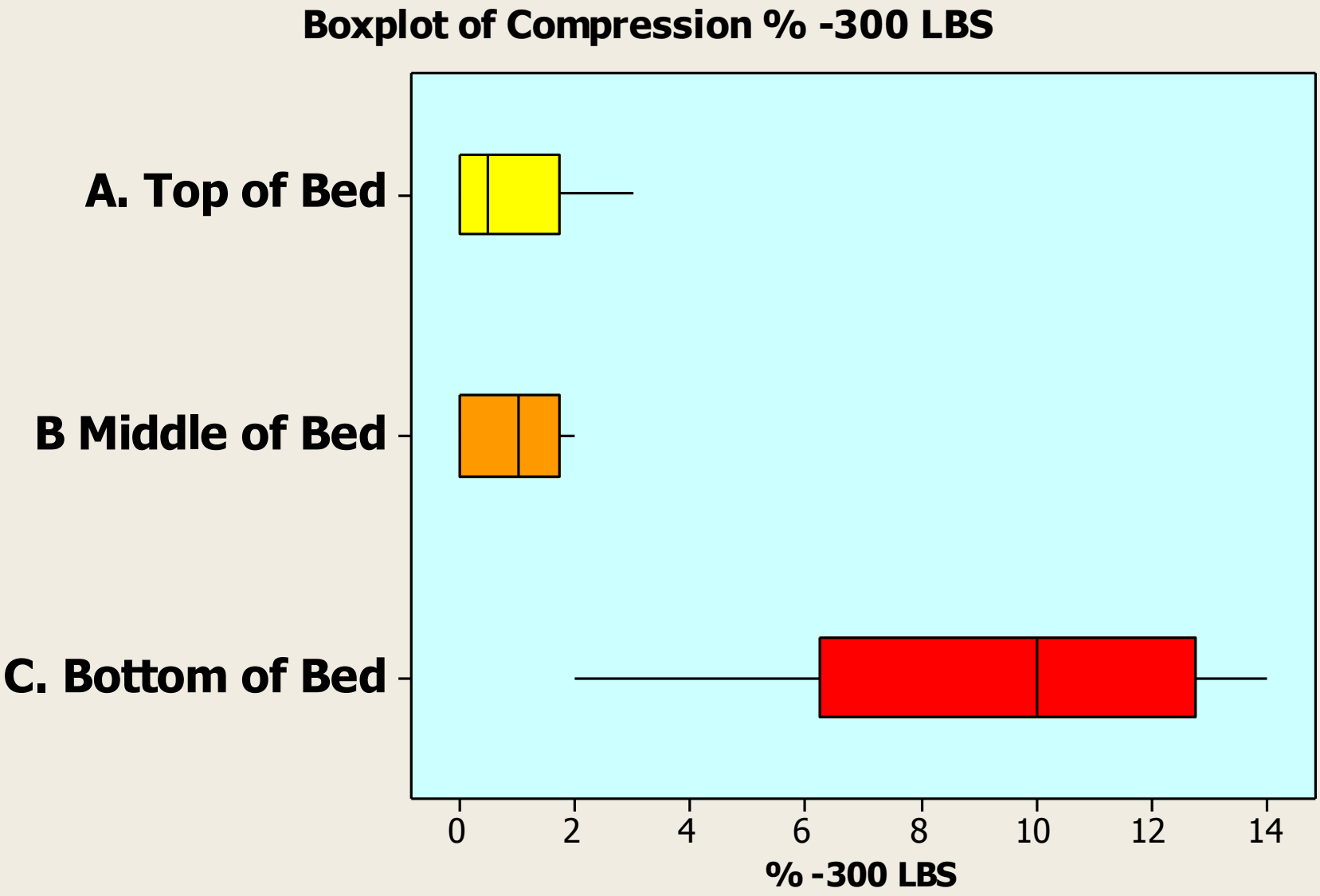
CLIFFS

8 Pot Grate Tests Minnesota Magnetite; 16” GB; 2” Hearth Layer; Separated the bed by hand into 3 equal layers after the normal firing cycle was completed. Hearth and side layer pellets not included in samples.

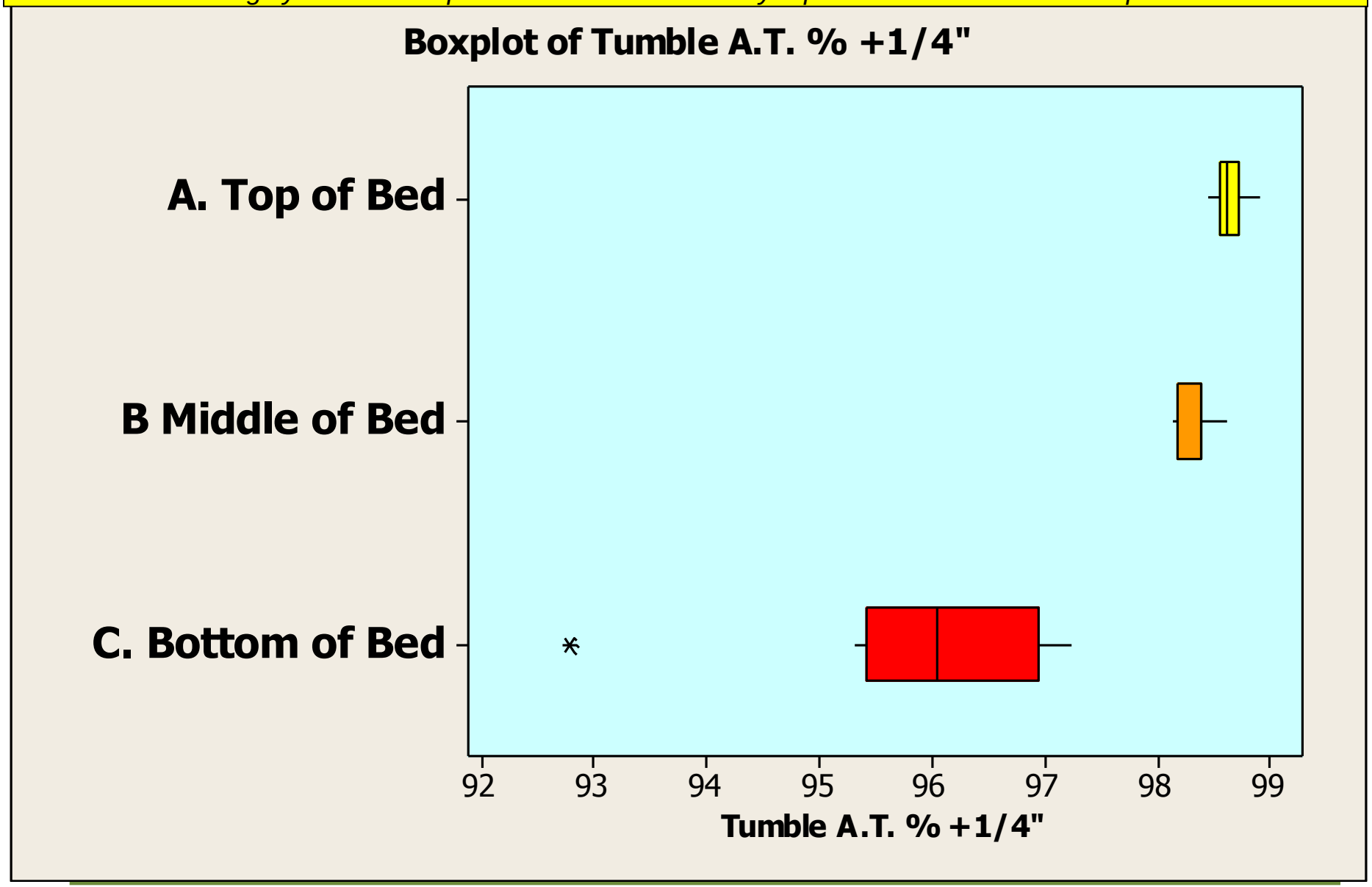


CLIFFS

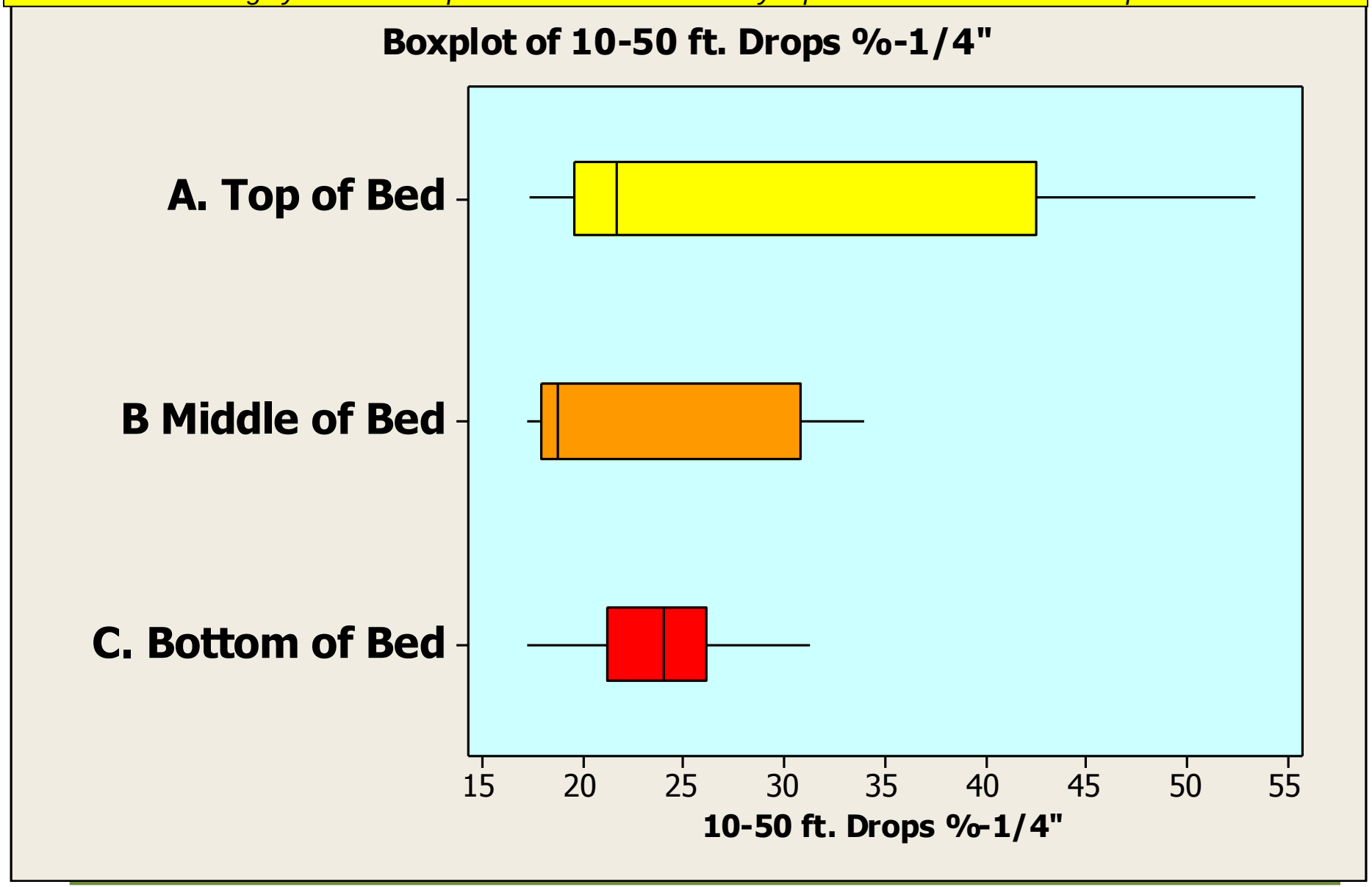
8 Pot Grate Tests Minnesota Magnetite; 16” GB; 2” Hearth Layer; Separated the bed by hand into 3 equal layers after the normal firing cycle was completed. Hearth and side layer pellets not included in samples.



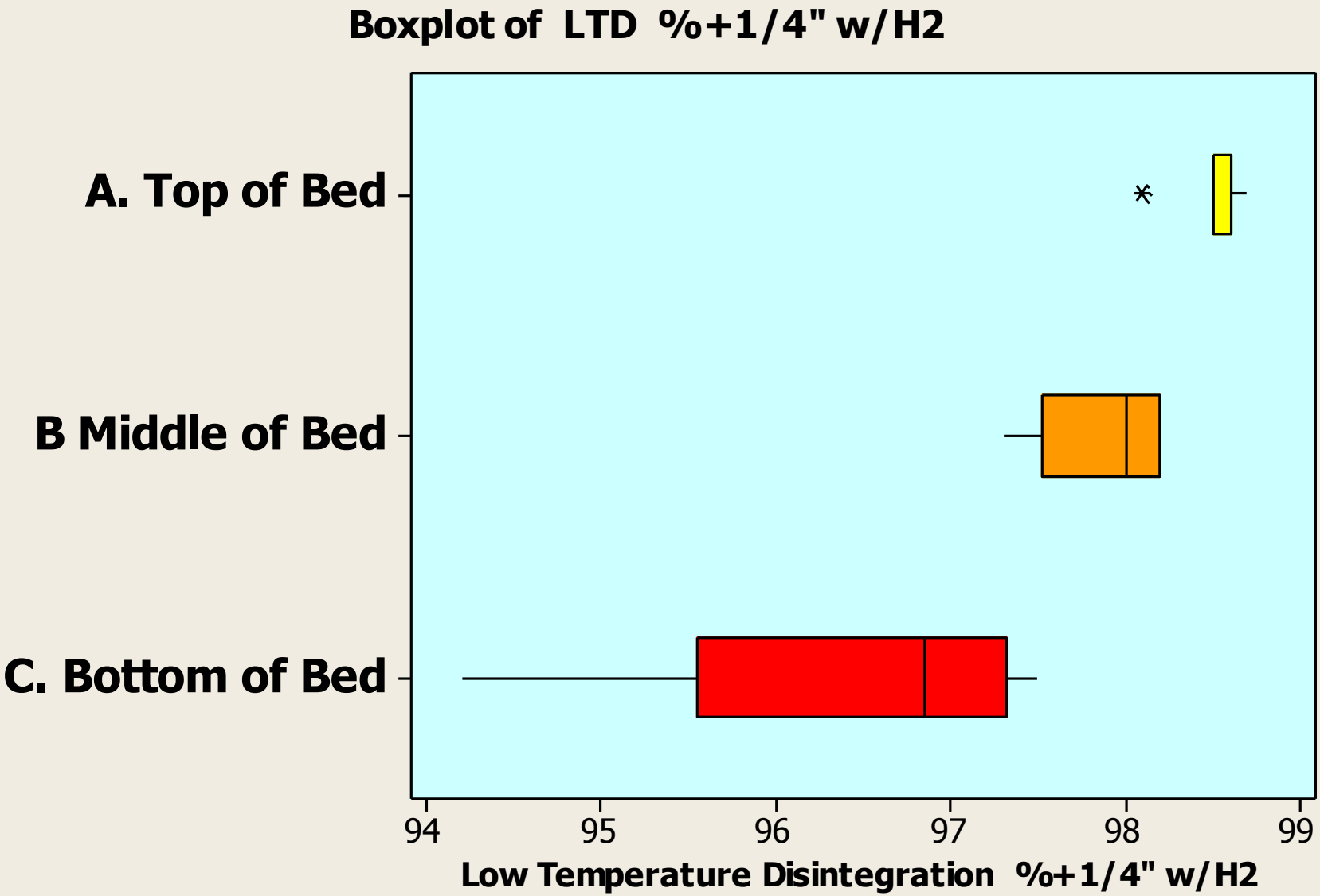
8 Pot Grate Tests Minnesota Magnetite; 16” GB; 2” Hearth Layer; Separated the bed by hand into 3 equal layers after the normal firing cycle was completed. Hearth and side layer pellets not included in samples.



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8 Pot Grate Tests Minnesota Magnetite; 16” GB; 2” Hearth Layer; Separated the bed by hand into 3 equal layers after the normal firing cycle was completed. Hearth and side layer pellets not included in samples.



CLIFFS

Straight Grate vs Grate Kiln- Plant Pellets

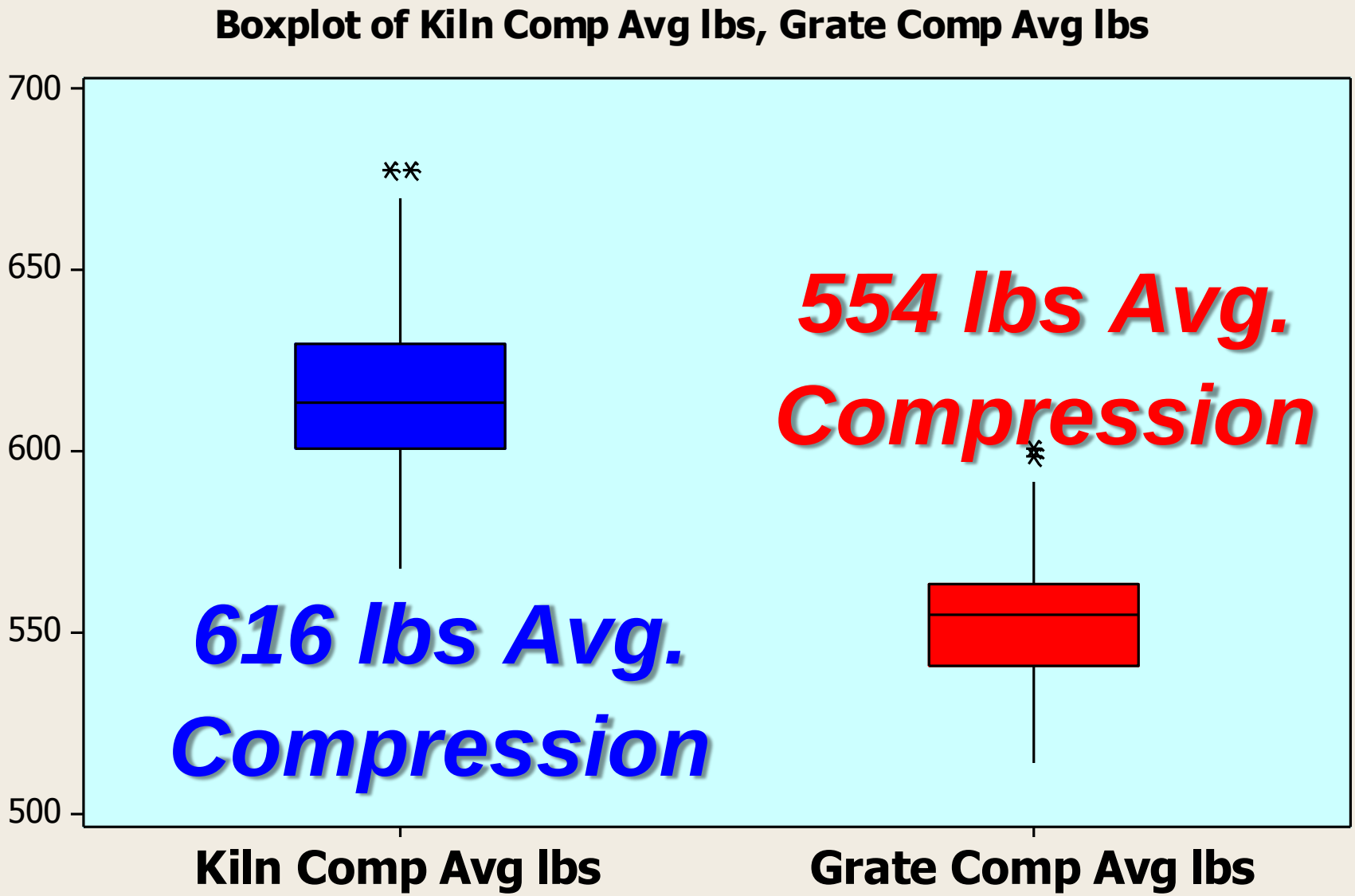
Quality Comparison with 2012 Cargoes:

1. Kiln Plant 4.1 MLT

2. Grate Plant 2.9 MLT

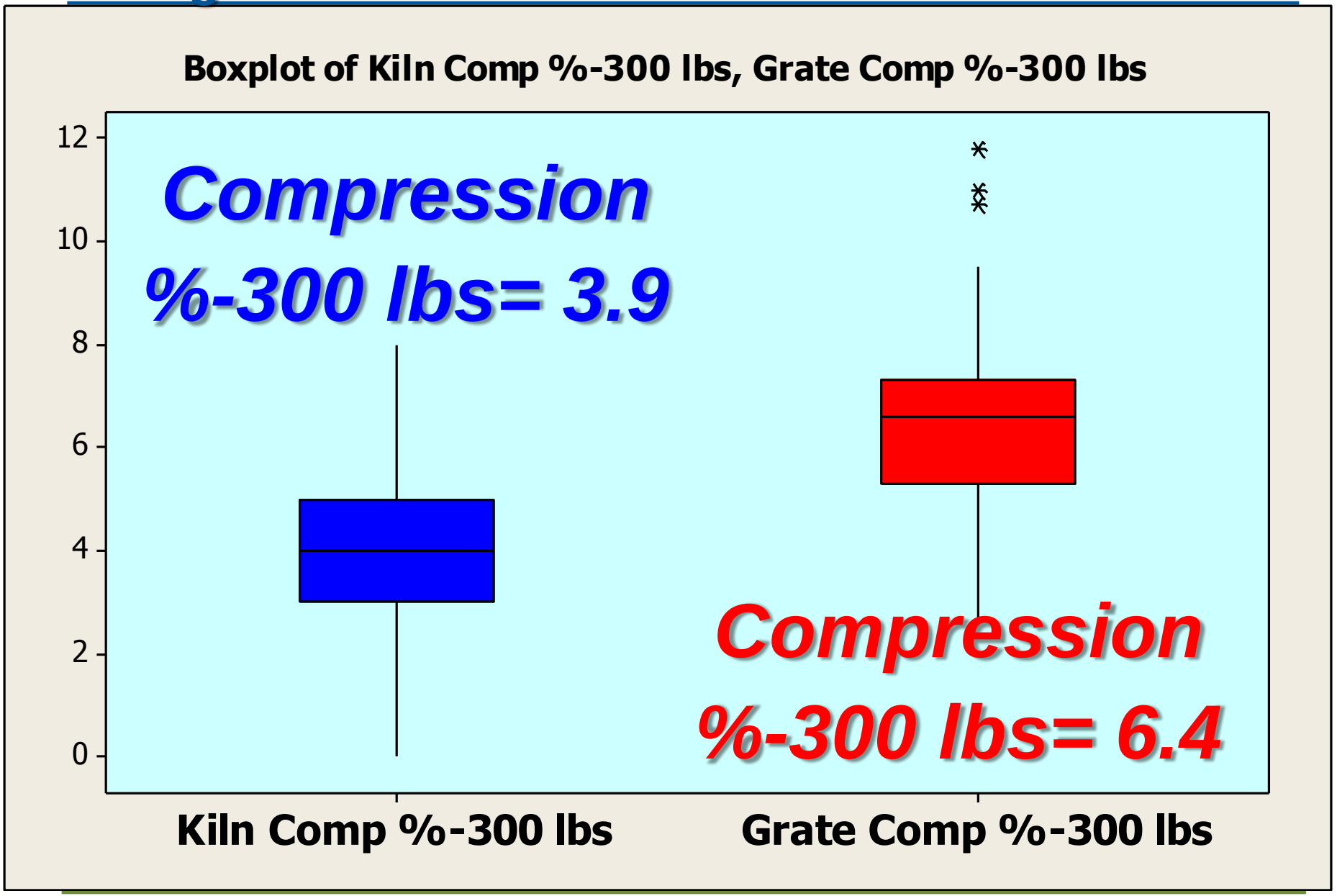
3. Both plants magnetite, Standard pellets & similar concentrates

Straight Grate vs Grate Kiln- Plant Pellets



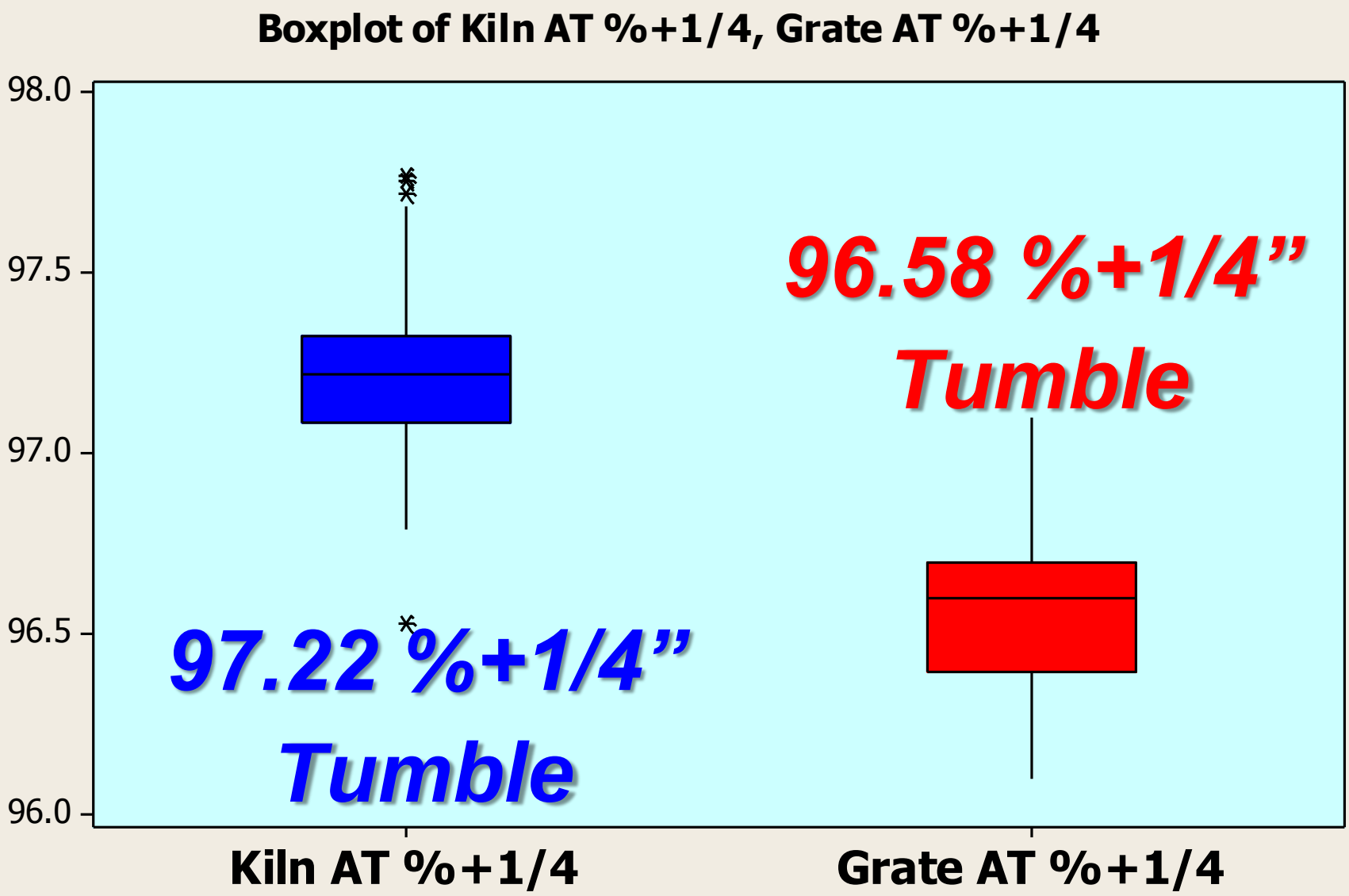
CLIFFS

Straight Grate vs Grate Kiln- Plant Pellets



CLIFFS

Straight Grate vs Grate Kiln- Plant Pellets



CLIFFS

No Cargo Data for Metallurgical Tests

Bottom Line:

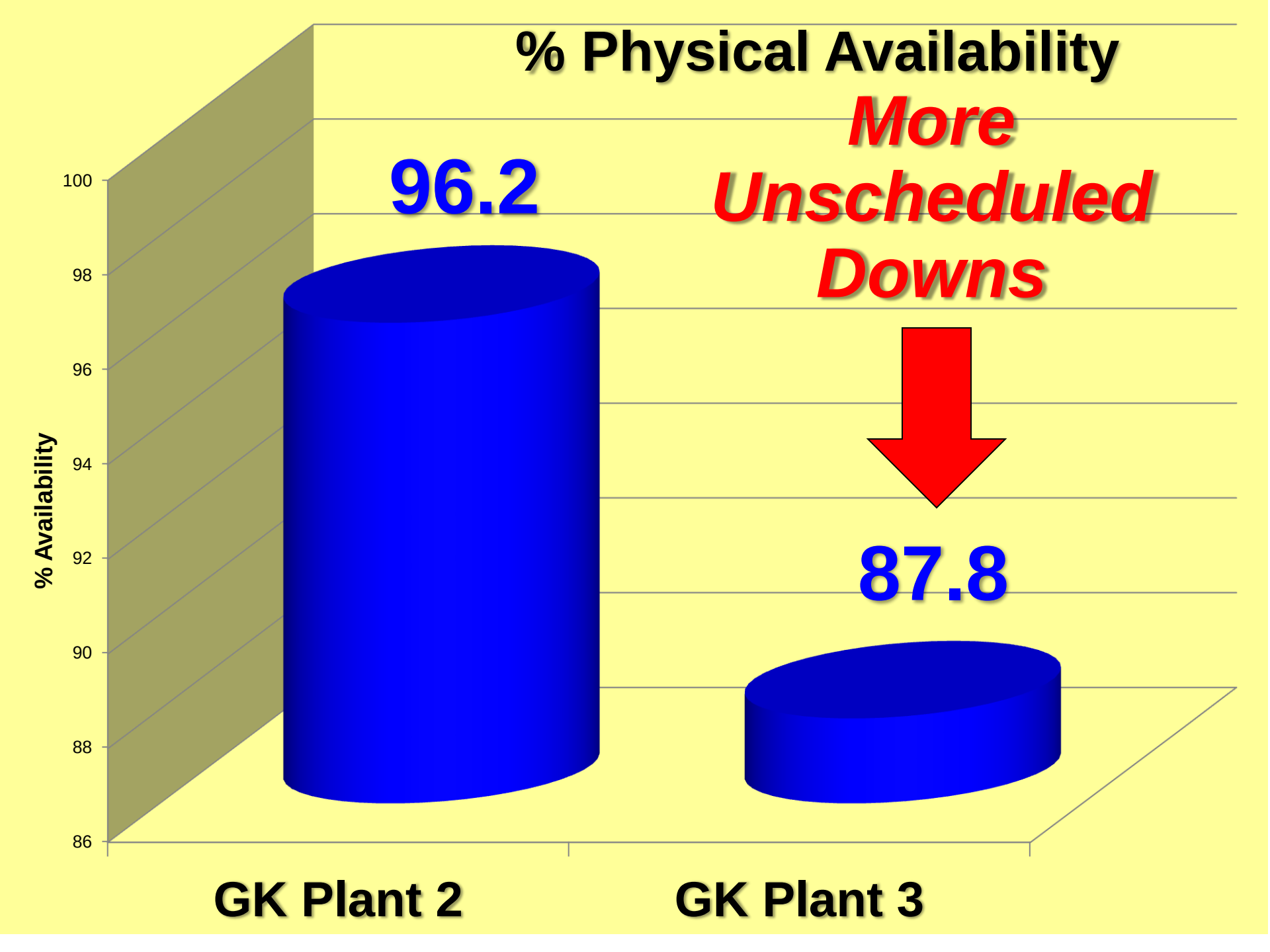
- Both make good pellets
- GK pellet quality better

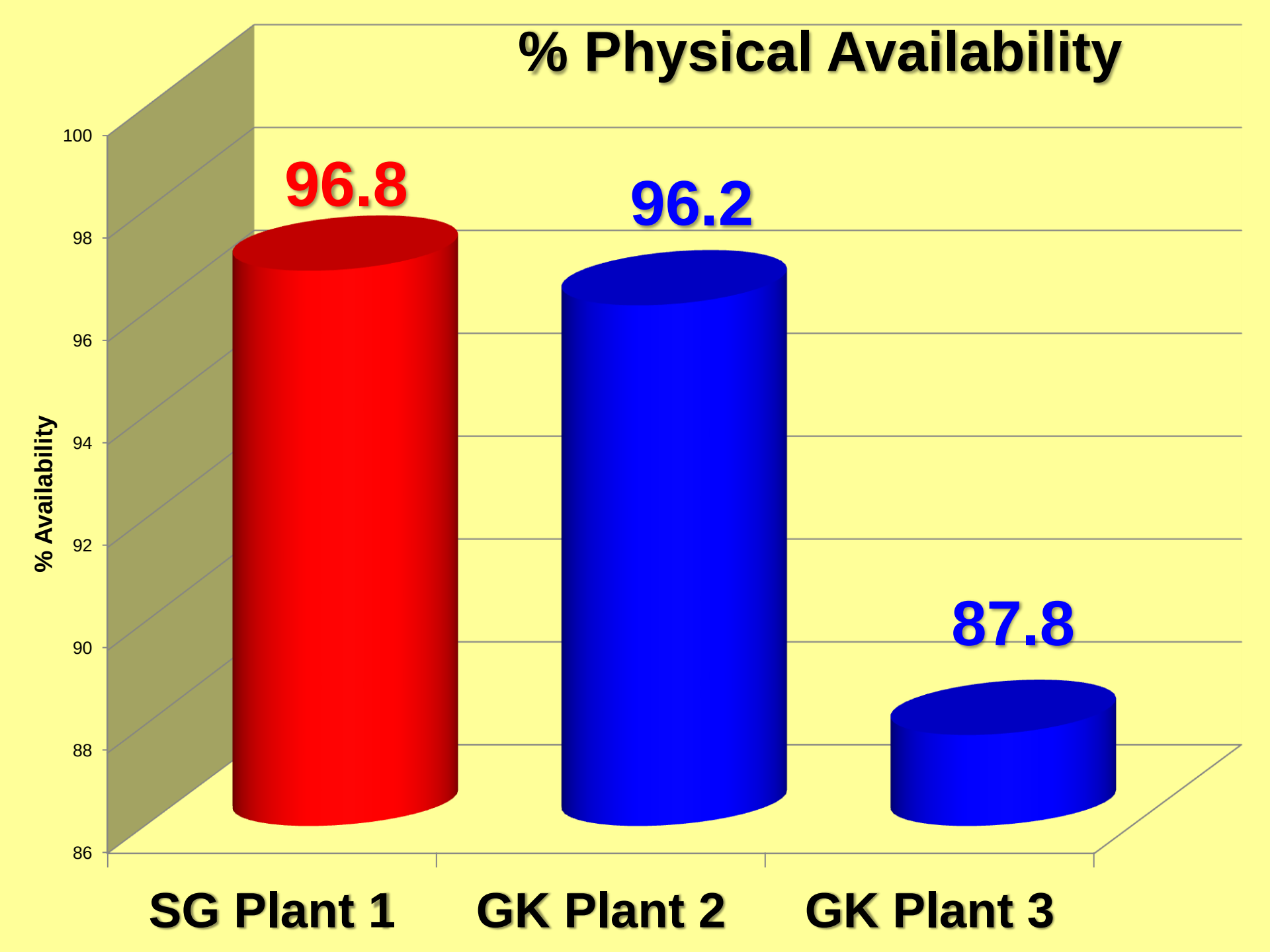


CLIFFS

Comparison Sketchy:

- GK pellet plants over designed
- Concentrator's are the bottleneck
- Grate Kilns have morphed: Longer Repair Periods
- Availability varies plant to plant


% Physical Availability
More Unscheduled Downs
96.2
87.8
% Availability
100
98
96
94
92
90
88
86
GK Plant 2
GK Plant 3


% Physical Availability
% Availability
100
98
96
94
92
90
88
86
96.8
96.2
87.8
SG Plant 1
GK Plant 2
GK Plant 3



CLIFFS

Straight Grate		Grate Kiln Cooler
✓	CAPEX	
✓	Annual Tonnage	
✓	Btu/LT	
✓	Cold Start Time	
	Power kwh/LT	✓
	Bentonite Rate	✓
	Organic Binder	✓
	Footprint	✓
	Solid fuels	✓
✓	Refractory Issues	
-----	Fluxed Pellets	-----
-----	Labor	-----
	Maint. Materials	✓
✓	Before Tumble Fines	
	Product Quality	✓
✓	% Availability	

FINAL CONCLUSIONS:

What is best depends on the value or weight you place on each category

Both types have strong and weak points:

SG- Lower CAPEX & Btu/LT, higher annual tonnage, lower BT fines, higher operating time

GK- Pellet quality better, more flexibility with binders & fuels, and lower power costs

Everything else is needle quiver


Thank You for
Your Attention