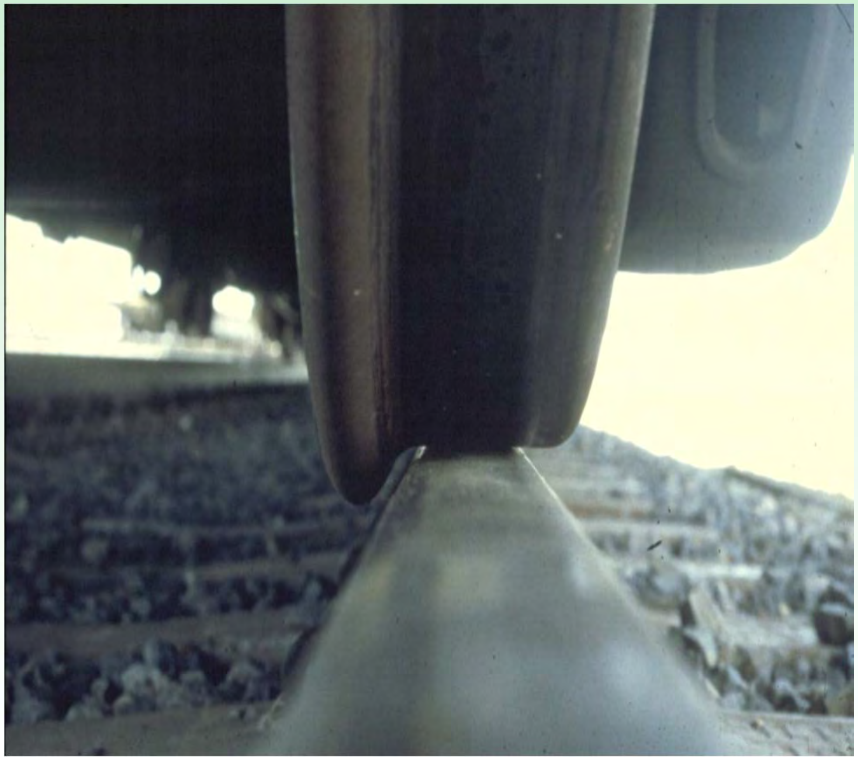
Understanding Why, When and How Rail Grinding is Performed

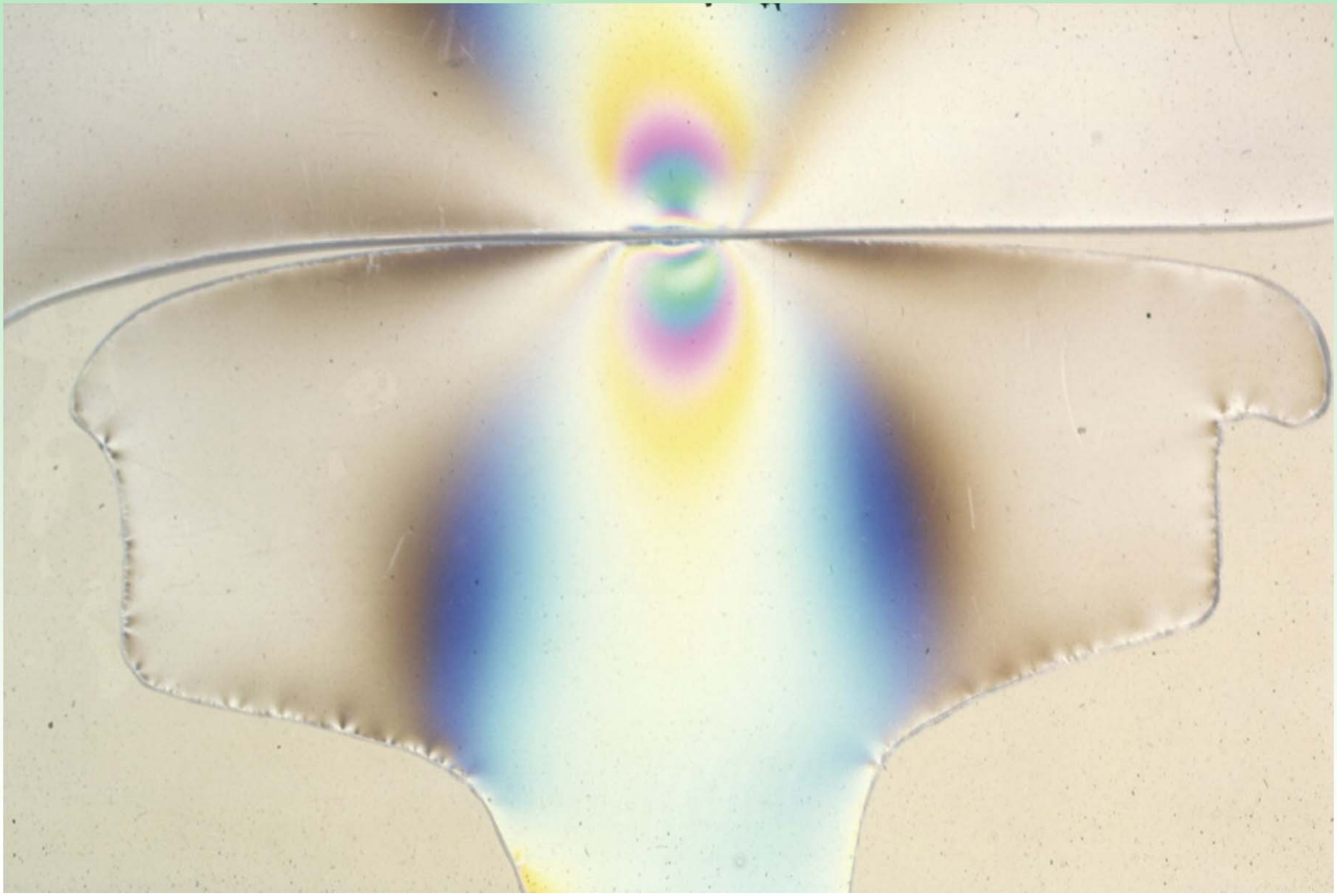
Outline

- WHY GRIND
  - Wheel/Rail Contact
  - Wheel/Rail Surface Defects
  - Broken Wheel Mark on Rail
- HOW AND WHEN
  - Philosophy of Grinding
  - Development of Templates
  - Surface Crack Measurement
  - Grinding Plan Development
  - Grinding Quality Control
  - Educating Different Departments

Wheel/Rail Contact

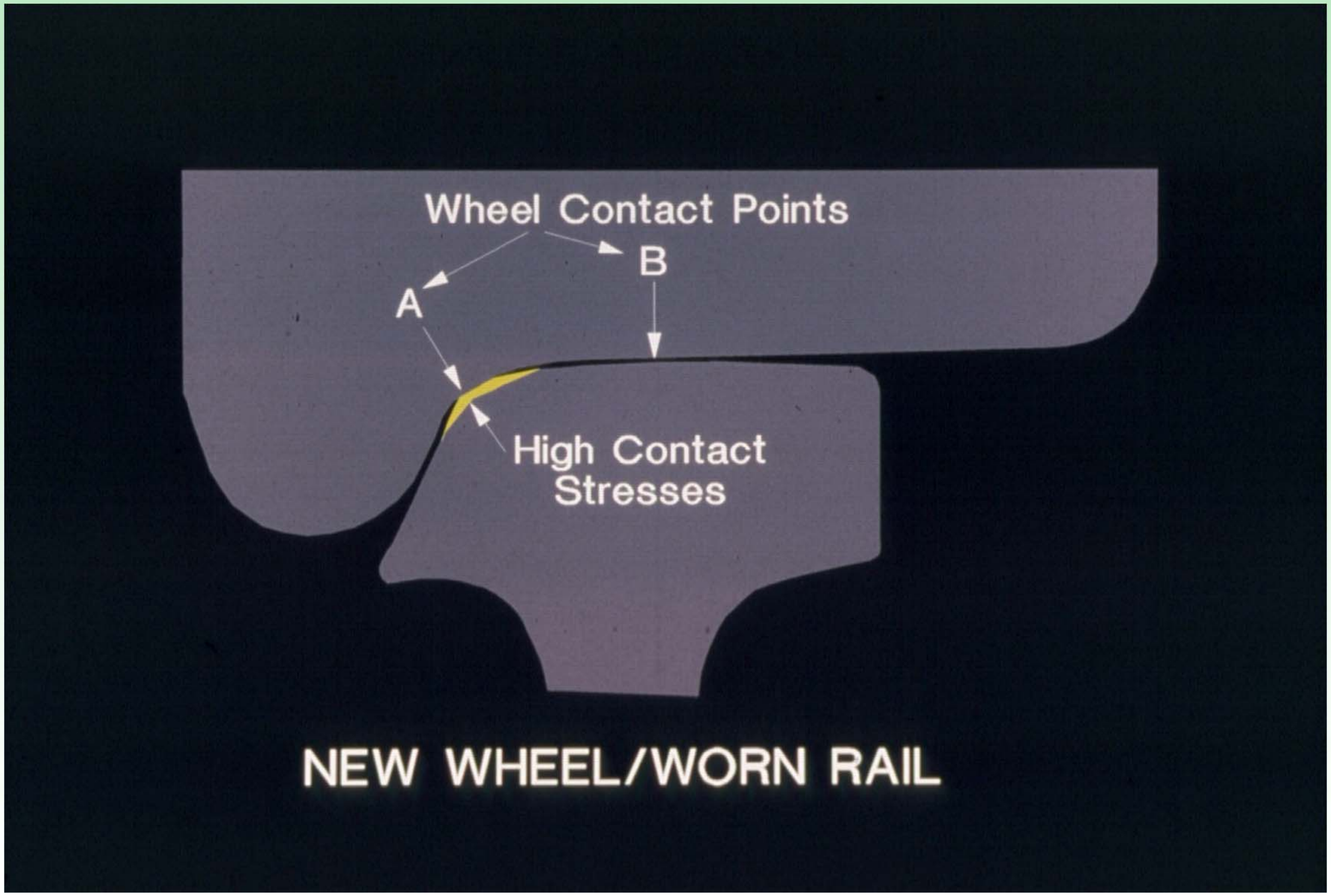


Narrow Contact Patch

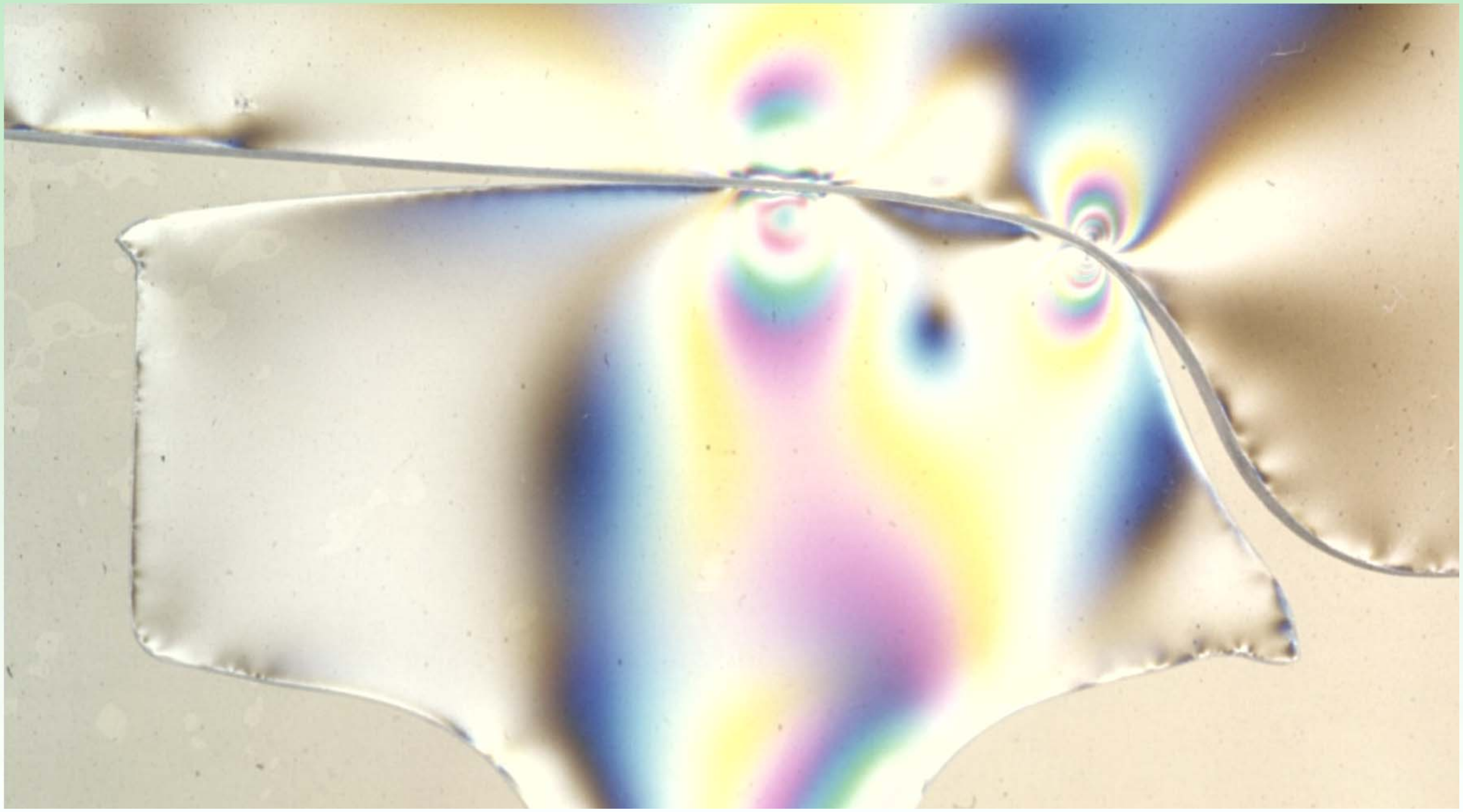


New Rail with New Wheels

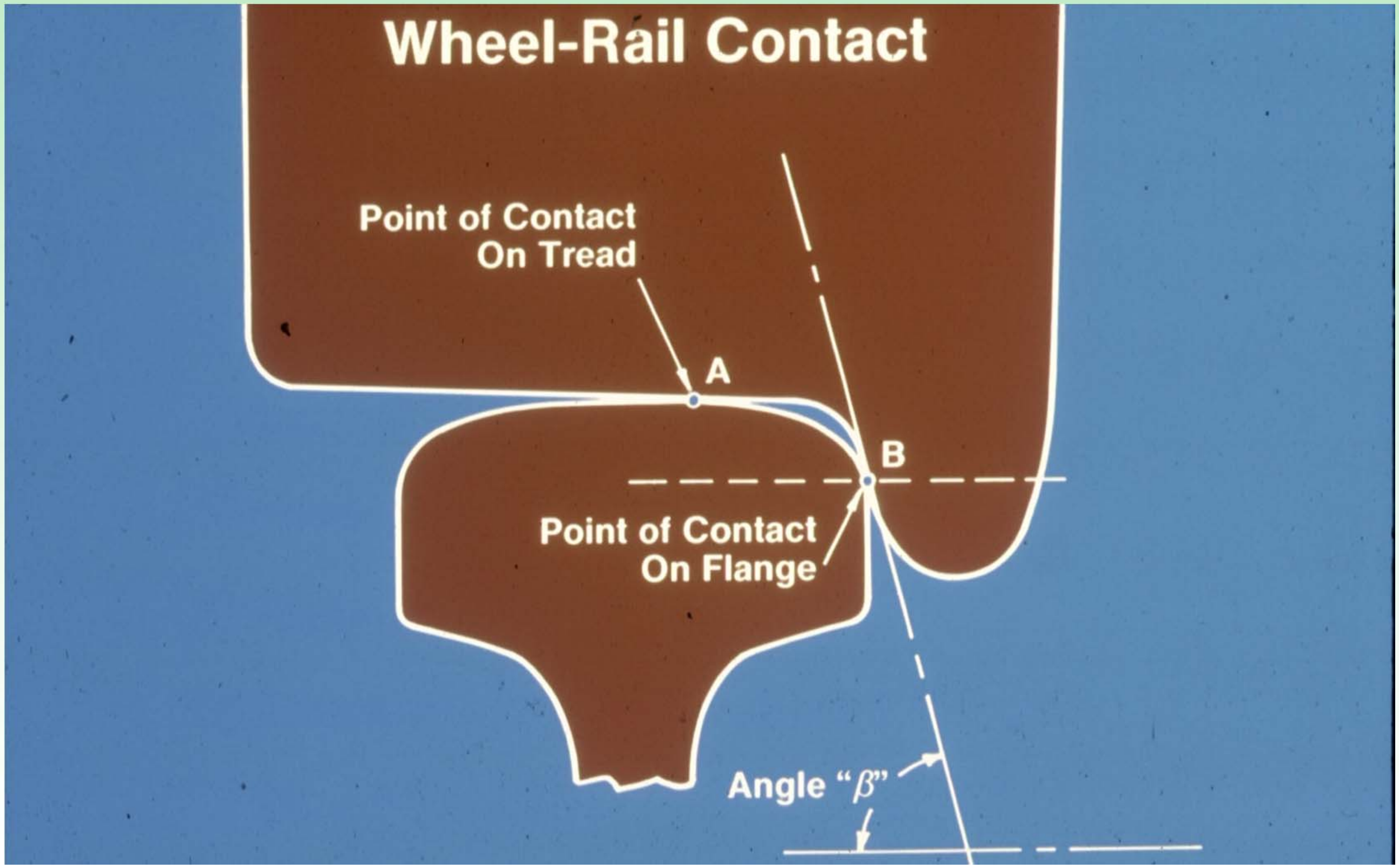
New Wheel Worn Rail



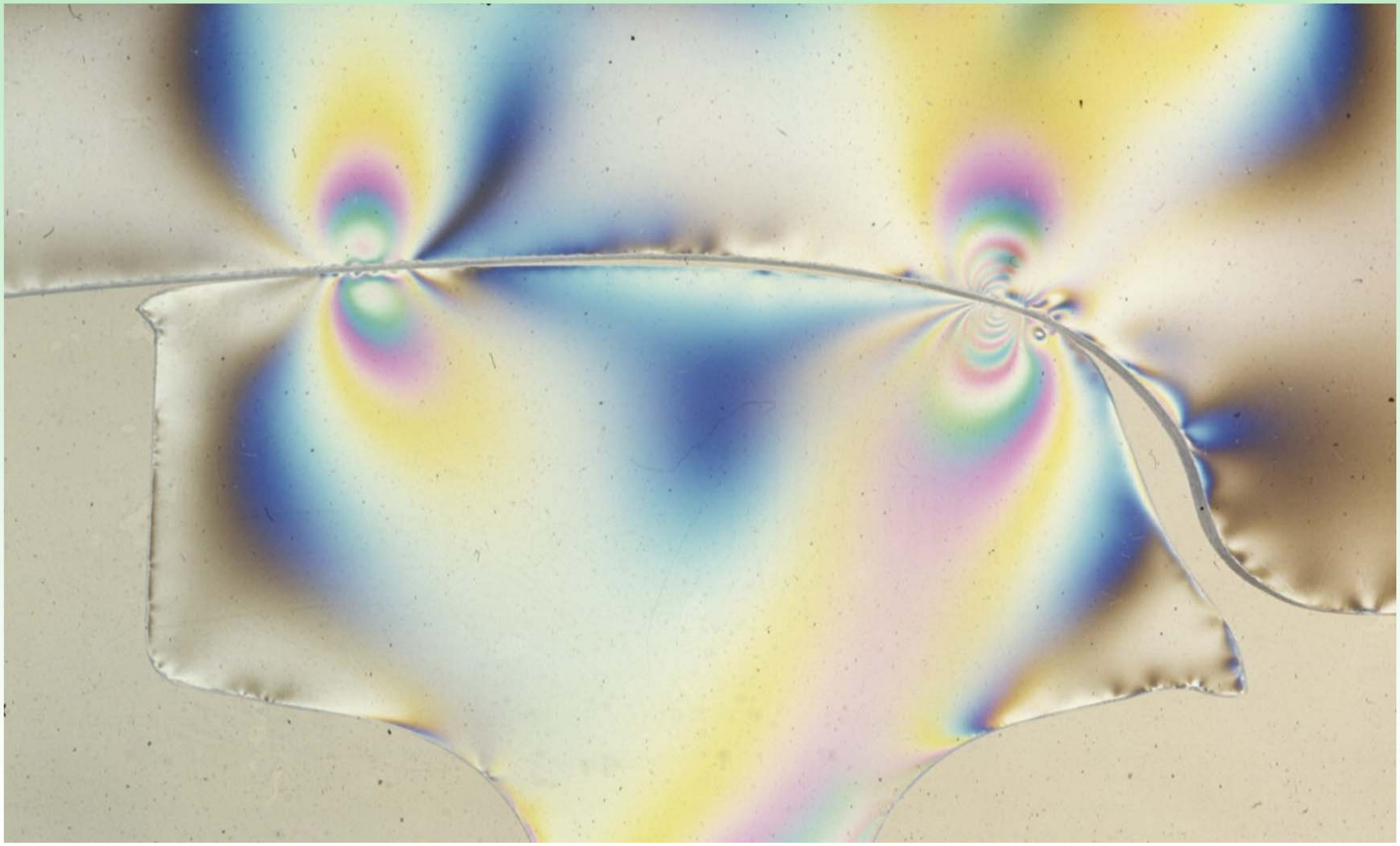
Curve Worn Rail Gage Corner Relief



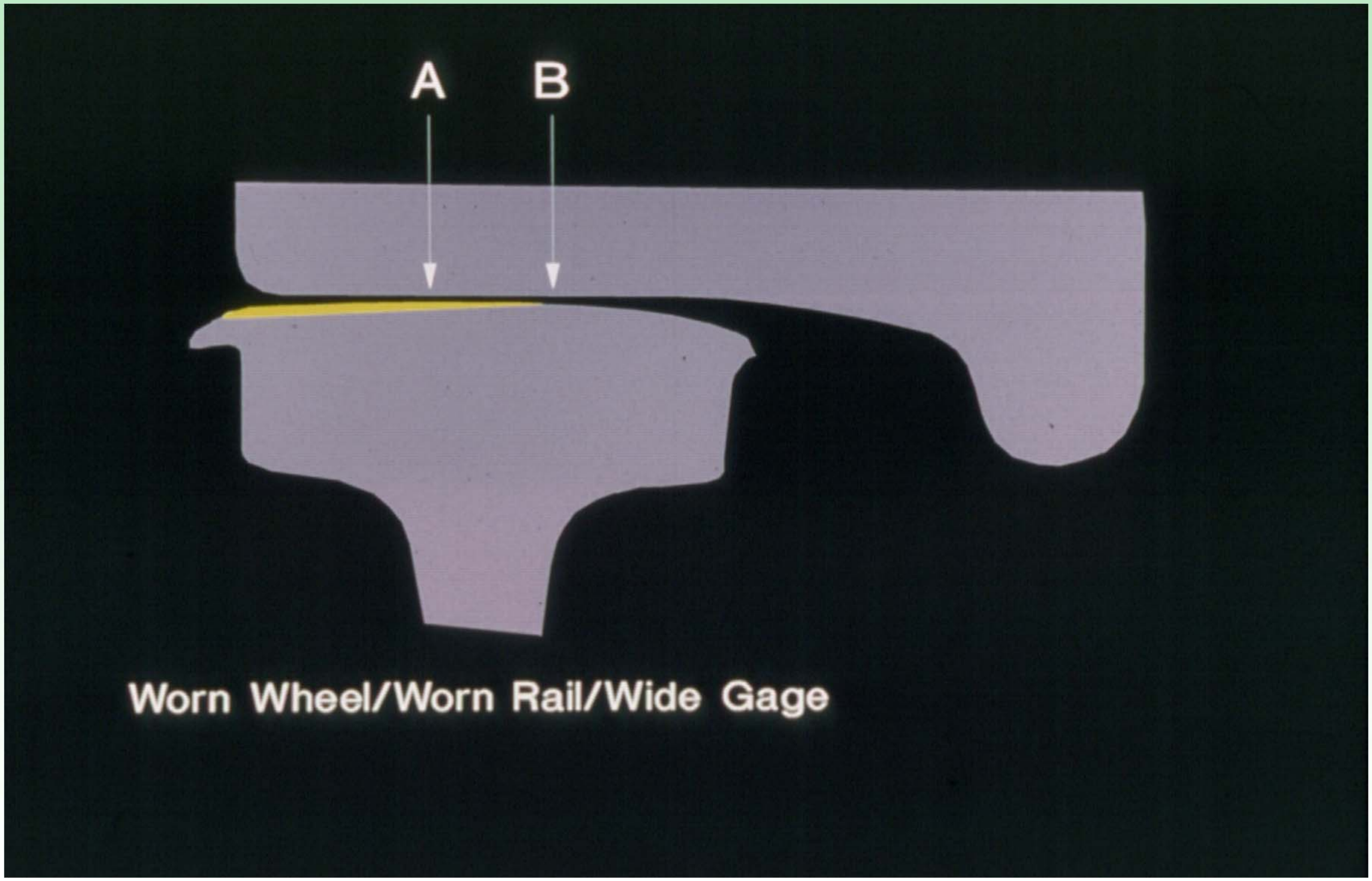
New Wheel New High Rail – 2 pt Contact



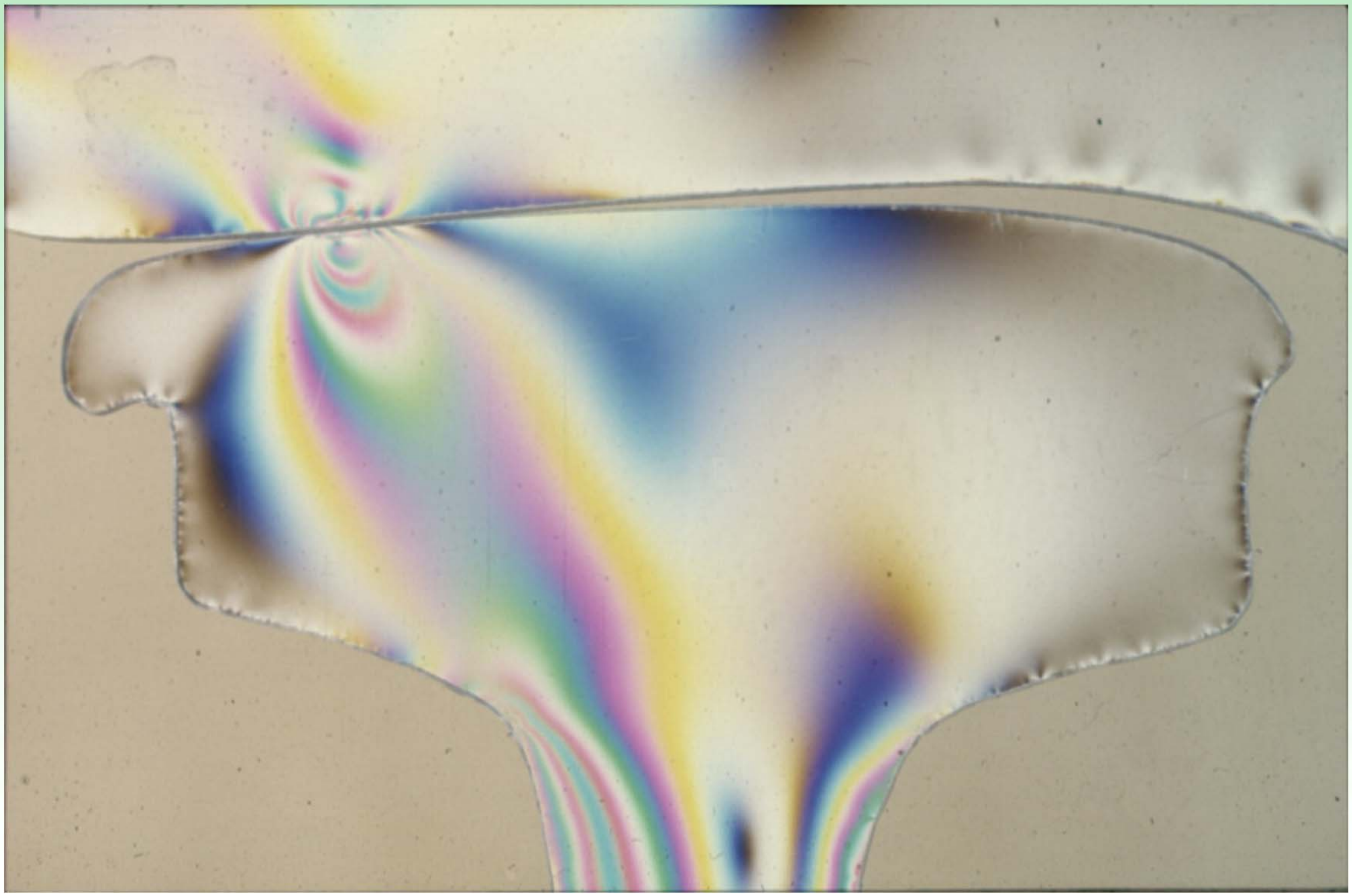
High Side Worn Rail - Severe
2 point Contact



Low Side Worn Rail Worn Wheel

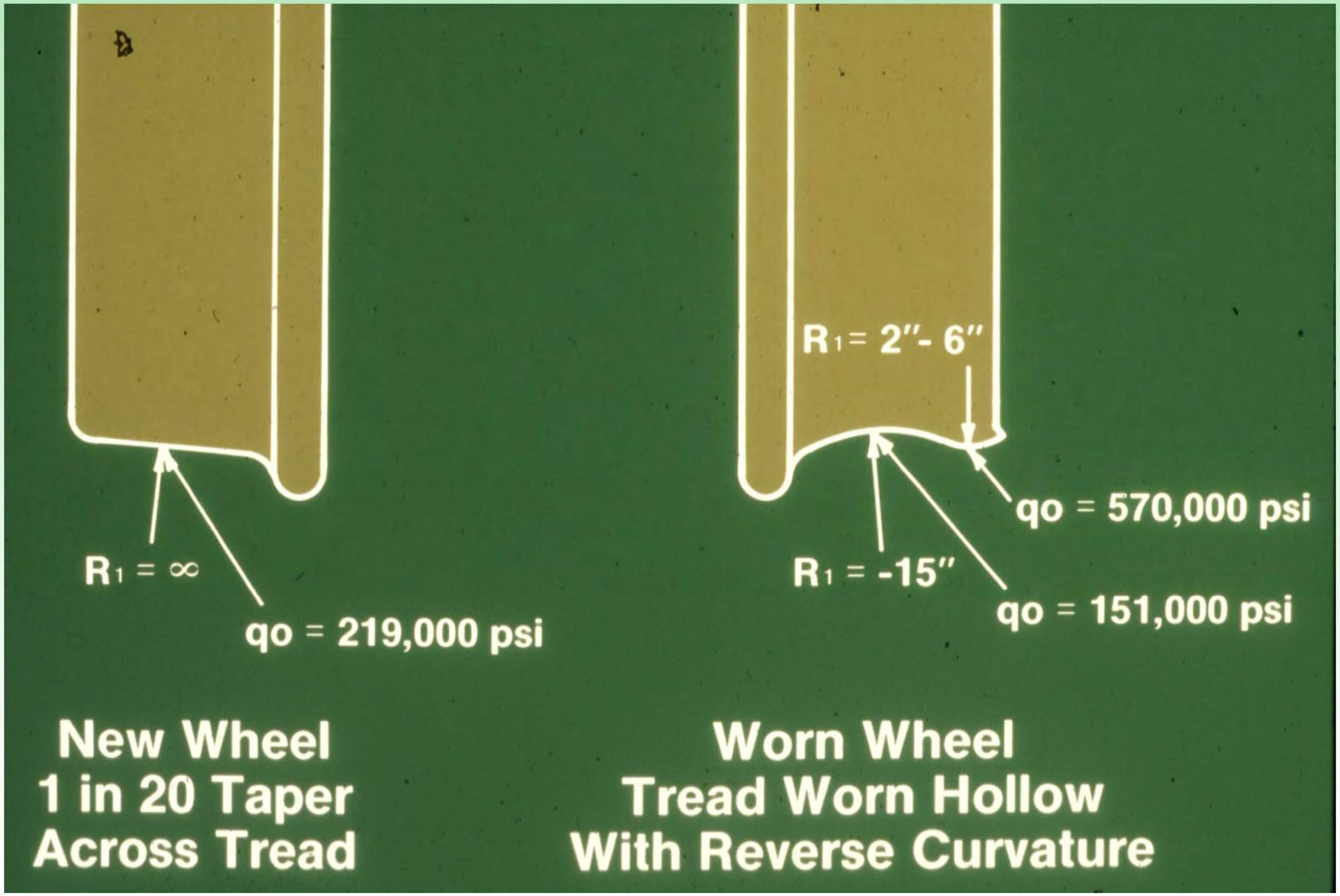


Low Side Worn Rail Worn Wheel

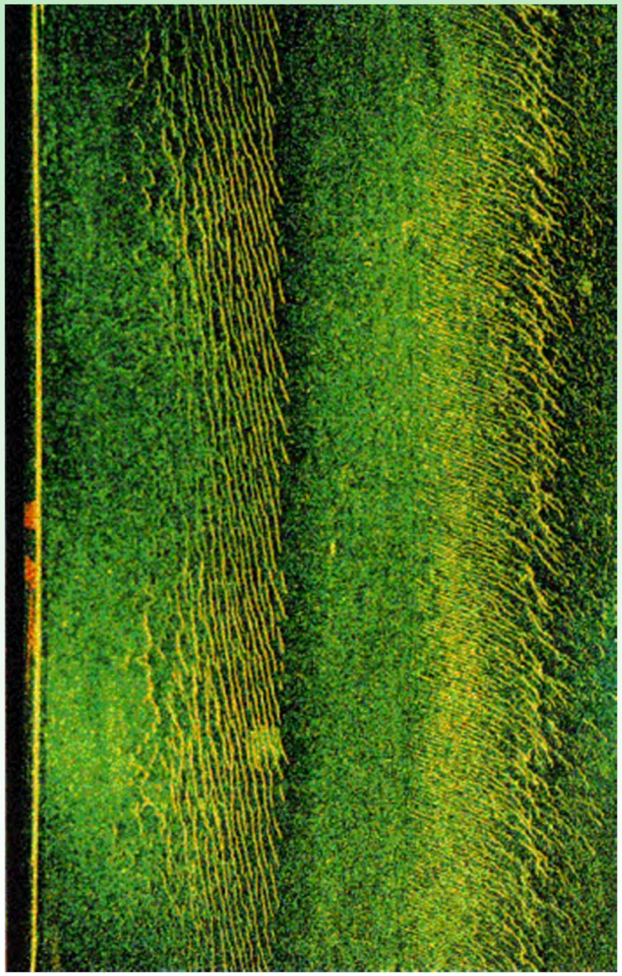


Low Side Worn Rail Worn Wheel

Wheel Stress Points



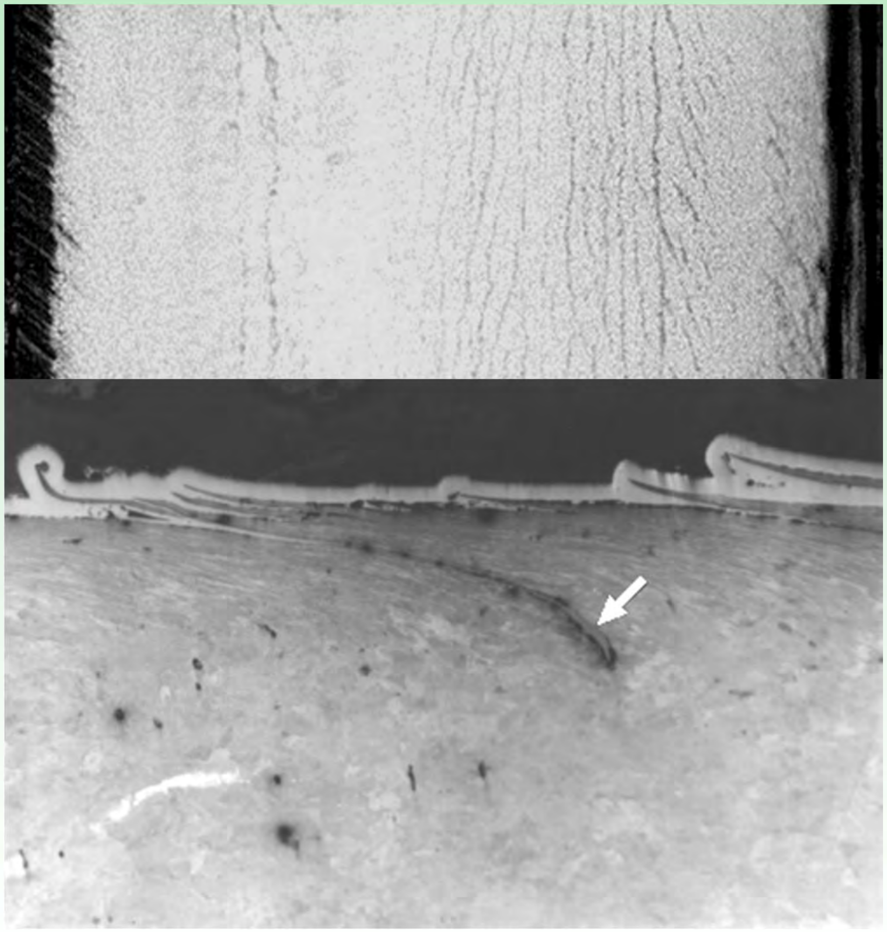
RCF - appearance on wheels



Incipient cracks

Fully grown cracks

RCF – appearance on rail



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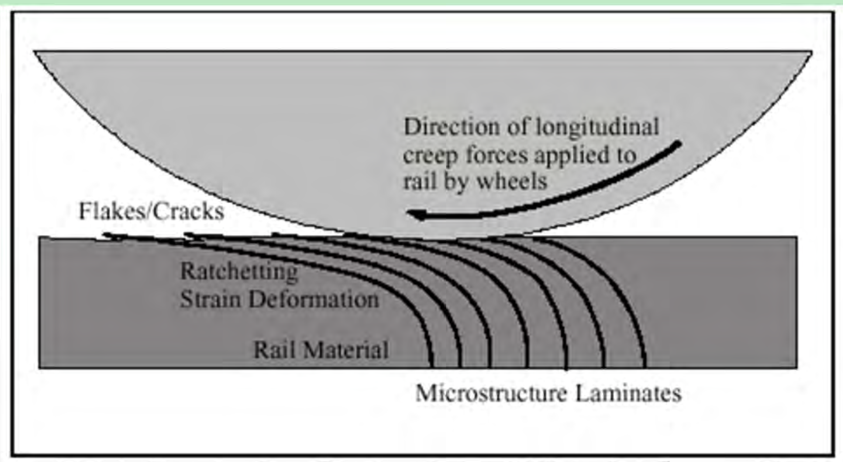
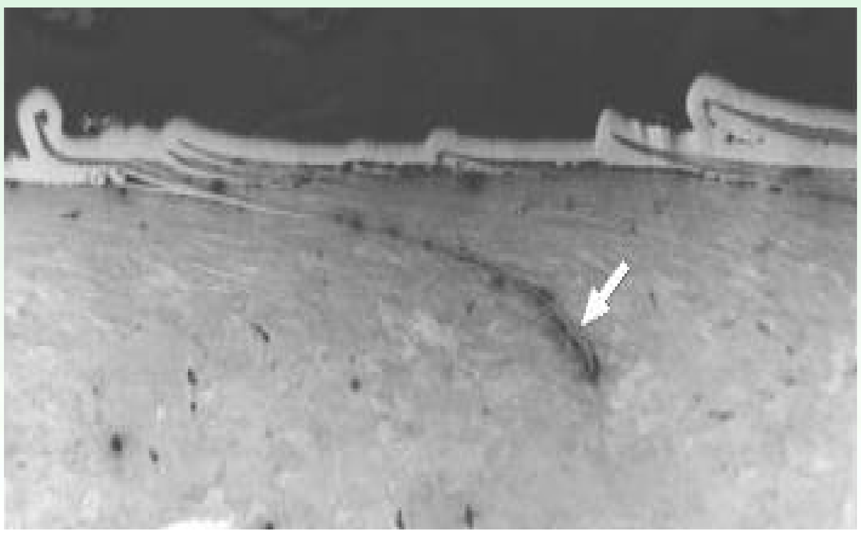
Fully grown cracks

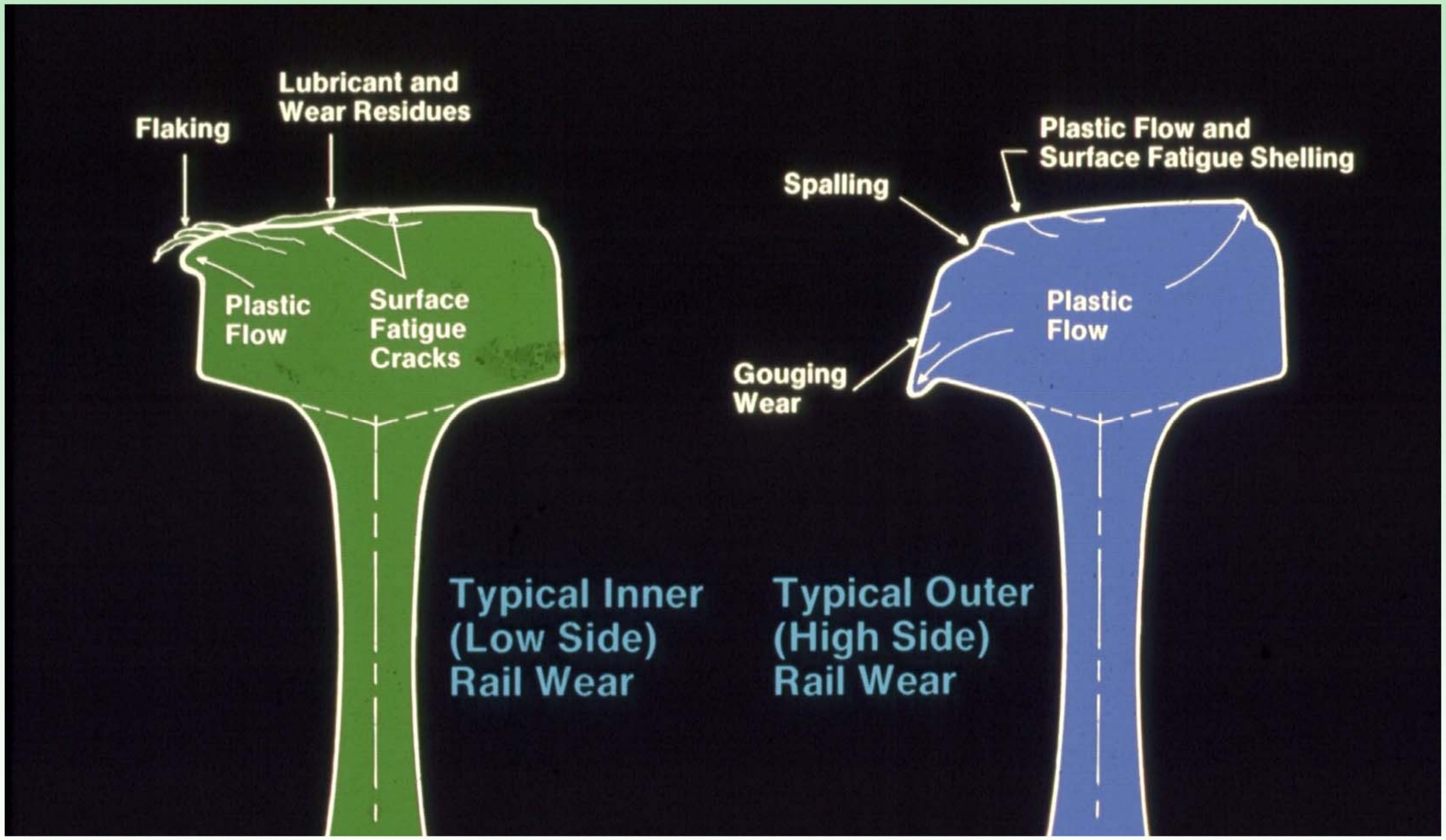
How Do RCF Cracks Form?



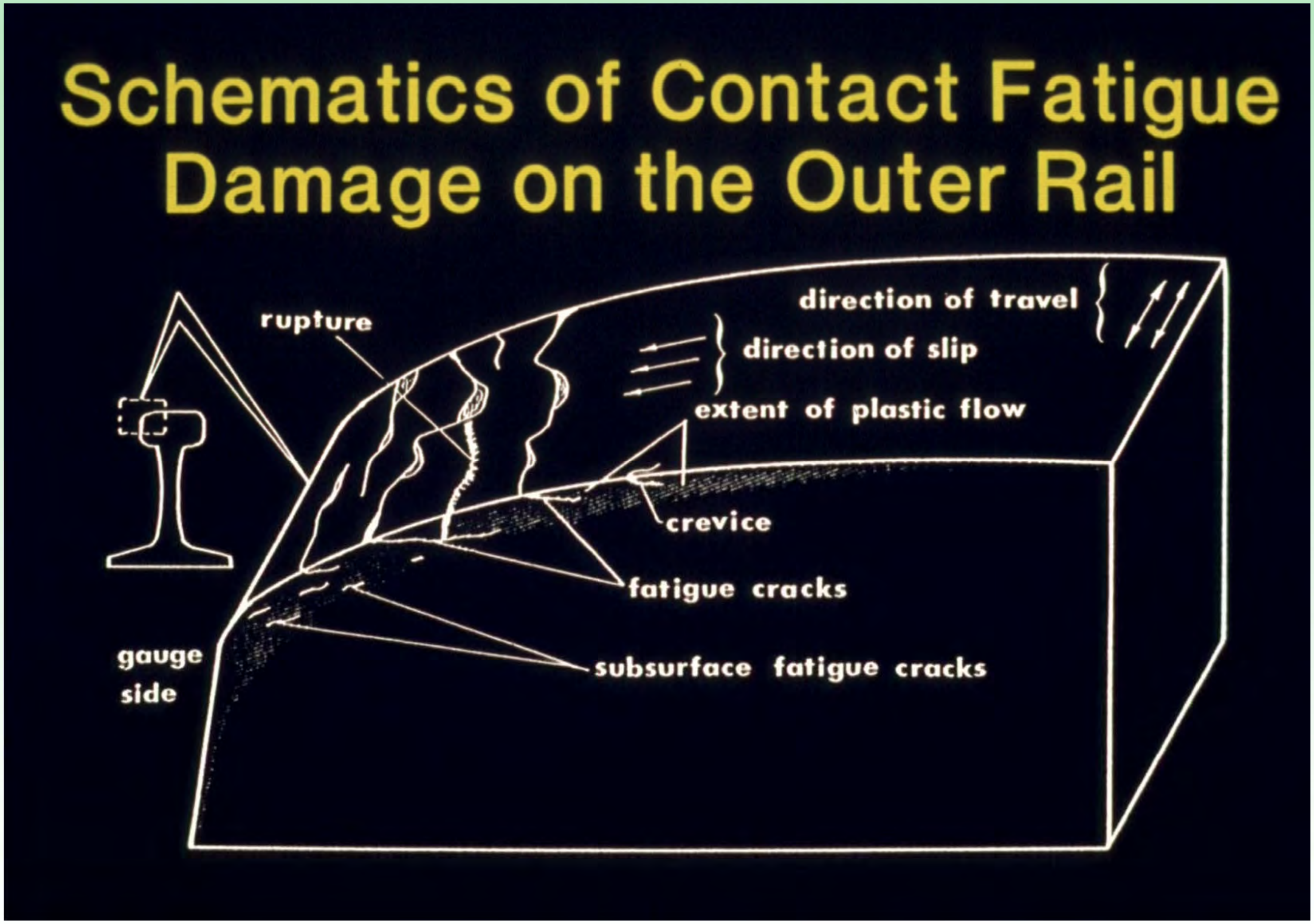


- 33 MGT = 1 million wheels passes on heavy haul track
- A certain fraction of wheels plastically deform the rail in the direction of applied tractions (due to ΔR and AOA).
- Each loading cycle "ratchets" the surface layer until the ductility of the steel is exhausted
- Eventually an incipient crack is generated (usually within 1 to 5 MGT)

Typical Rail Fatigue in Curves



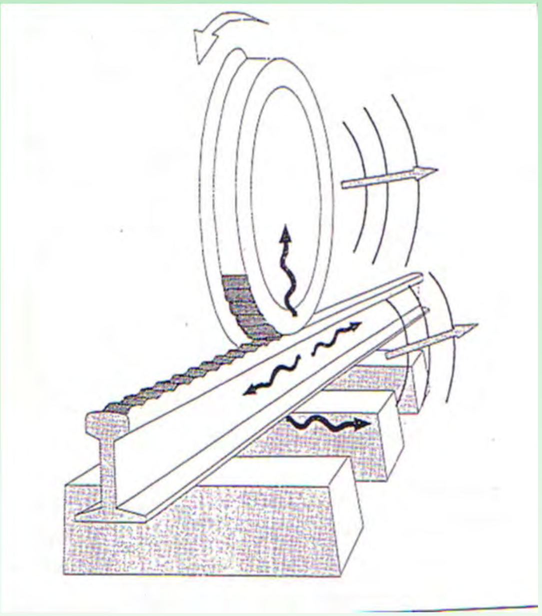
RCF High Rail



Surface Defects

- Corrugations
- Surface Fatigue
    - Shelling
    - Spalling
    - Surface Cracking/Head Checks
- Engine Burns
- Joint/Weld Batter

Corrugation



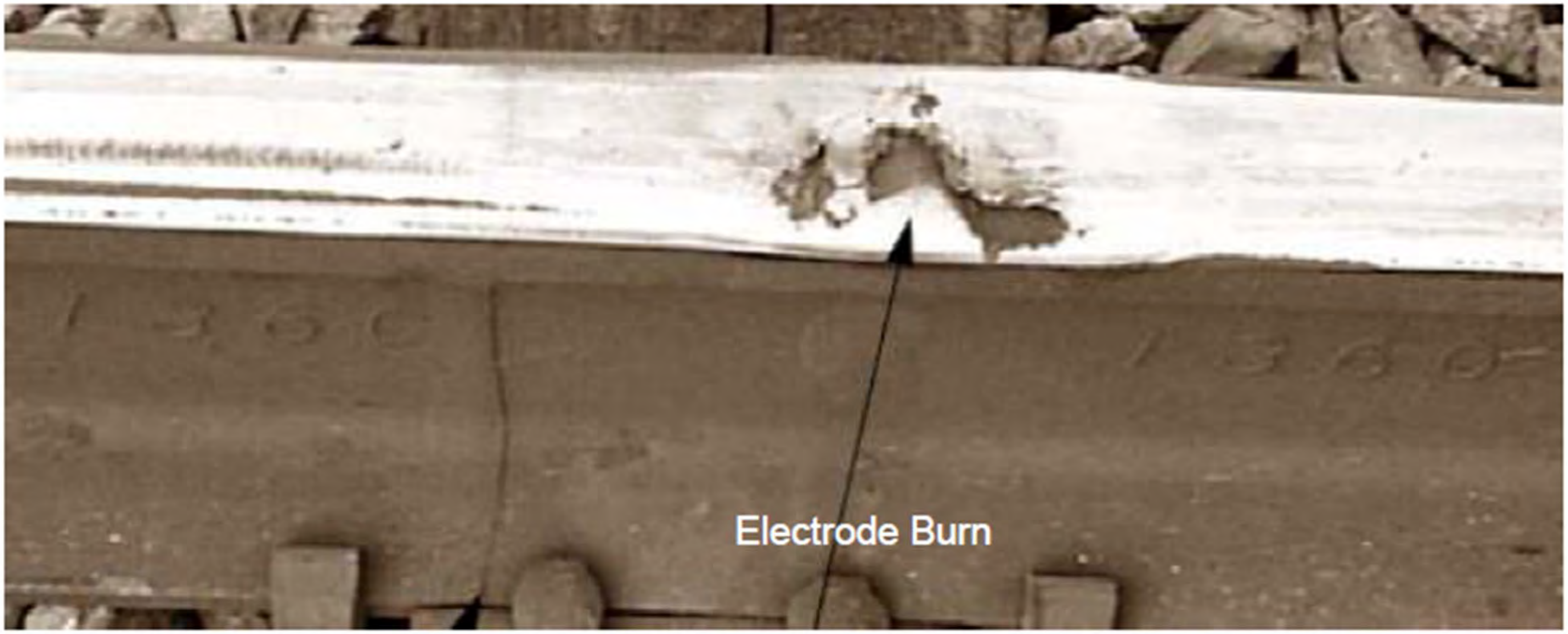
Corrugated Rail

Corrugation

Corrugation increases surface degradation

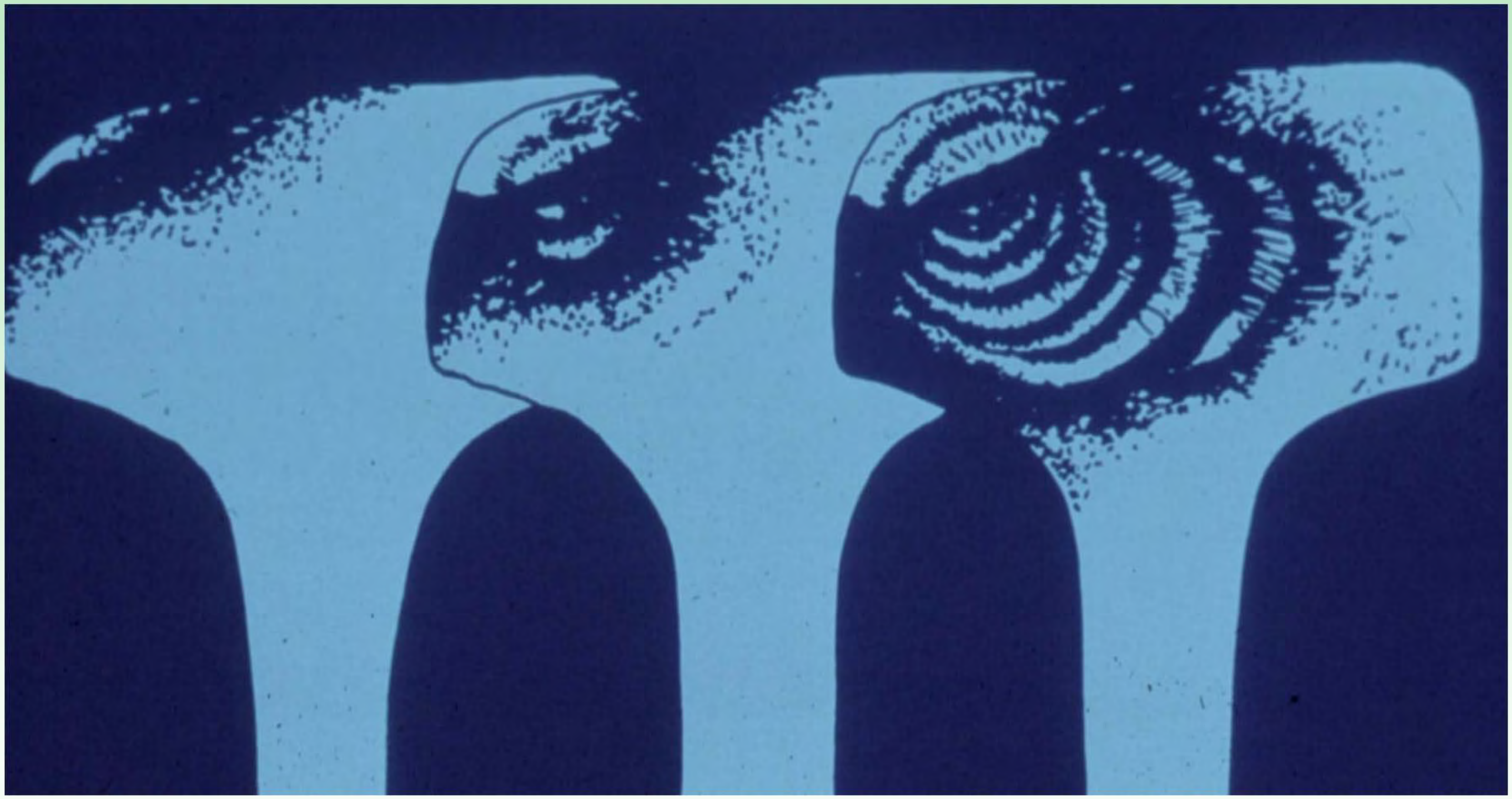
Short Wave Corrugation

Flash Butt Weld Electrode Burn



Shell Defects

Shell Fracture Growth Stages



Severe Shelling in track

Gage Corner Checking/Spalling

Broken Wheel Damage

Broken Wheel Damage

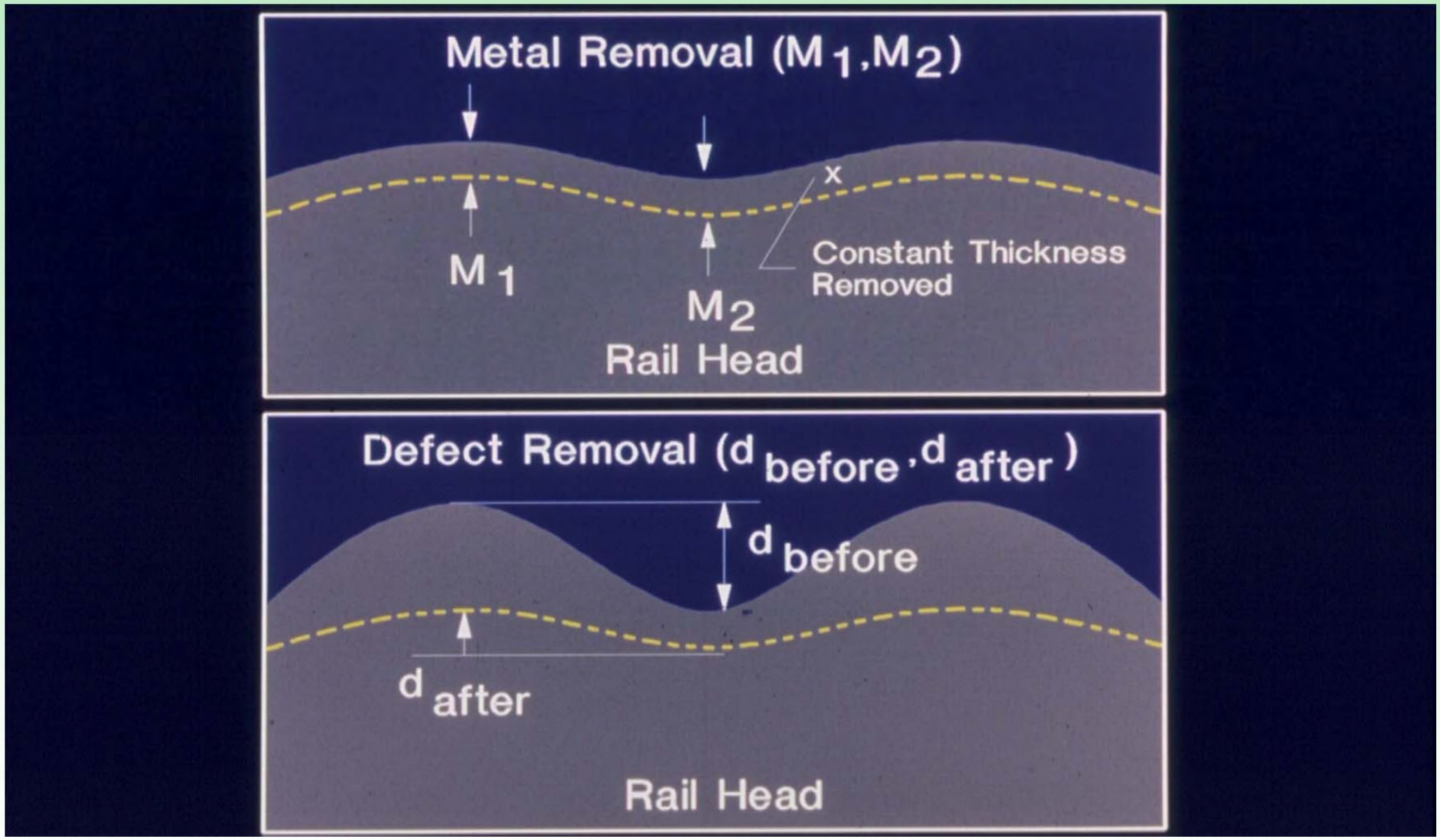
Before and After Grinding

Before and After Grinding

Grinding Philosophies

- Corrective
  - Defect Removal
  - Remedial Action
  - Heavy Metal Removal
- Preventive/Maintenance
  - Before Onset of Significant Defects
  - Light Frequent Grinding at Higher Speeds
  - Profile Grinding
- Preventive Gradual
  - Use of Maintenance Grinding to Address Large Defects
  - Use a Series of Preventive Grinding Passes Over Time

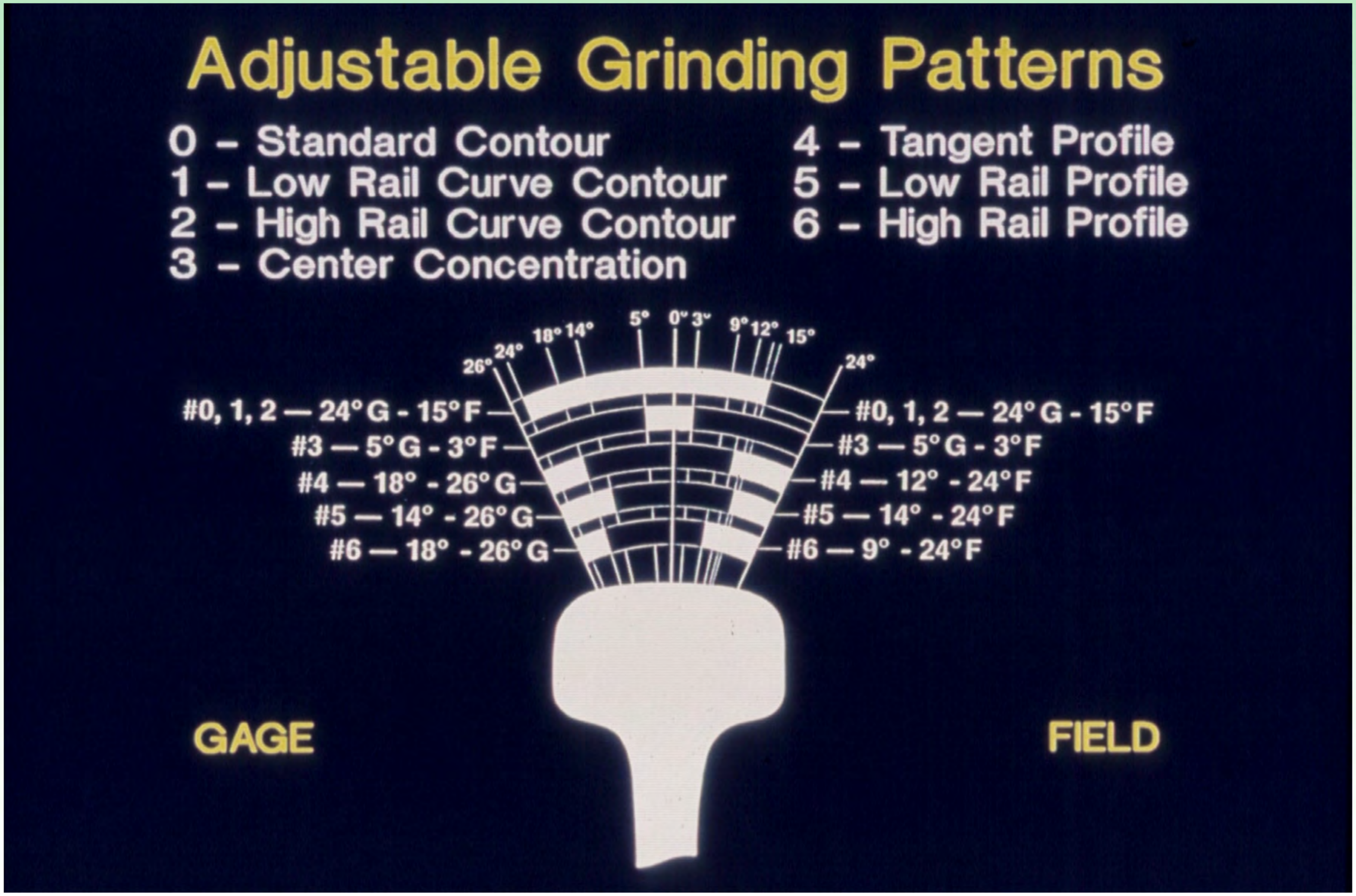
Preventative vs Corrective



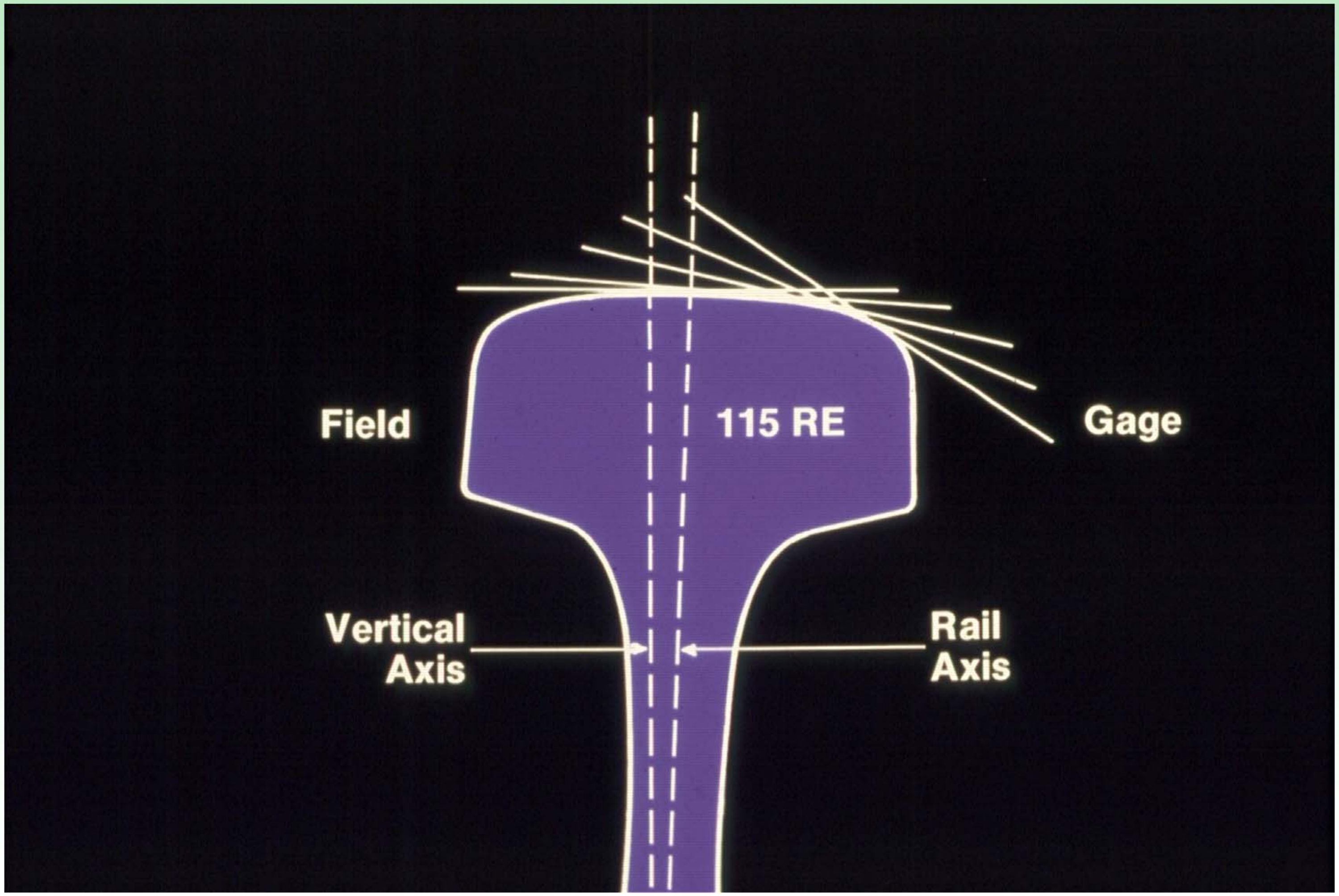
Metal Removal Factors

- Grinding Power
  - — Number of Motors
  - — Size of Motors
- Grinding Speed
- Power Setting of Individual Motors
- Location on Rail Head
- Specific Type of Defect (For Isolated Defects)
- Grinding Stone Composition
- Effectiveness of Grinding Equipment
  - — Active Long Wave
  - — Automatic Load Control

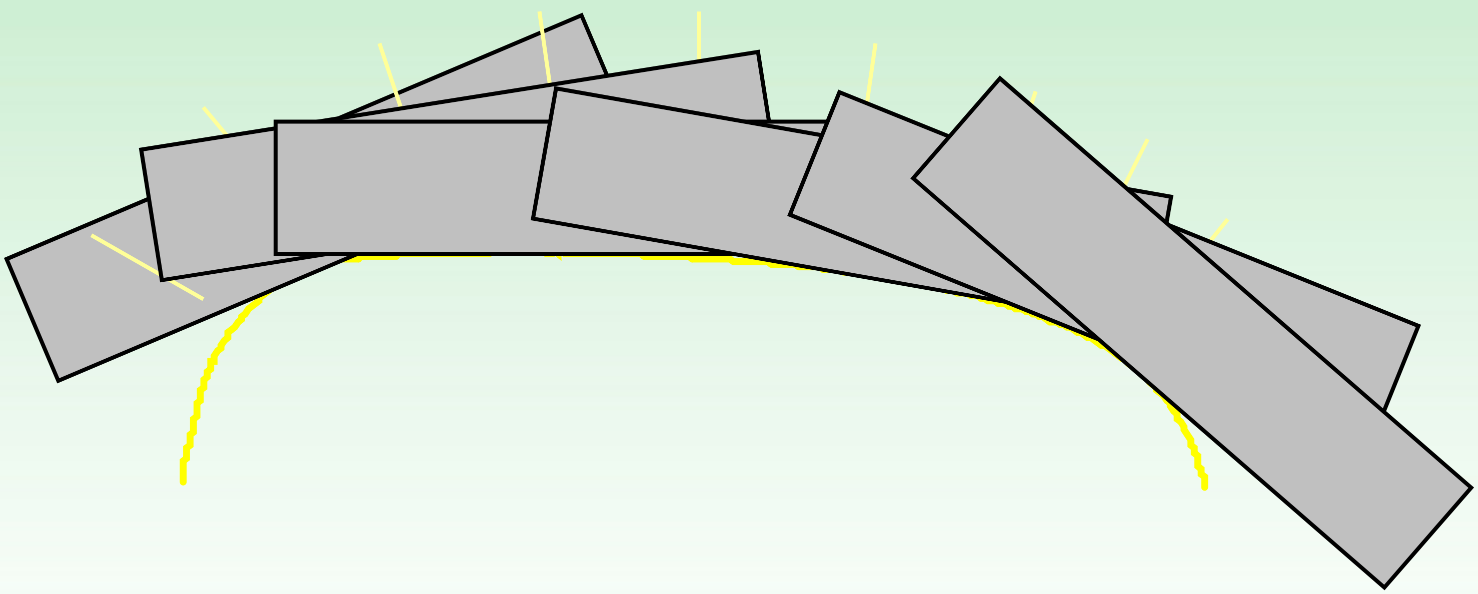
Grinding Patterns



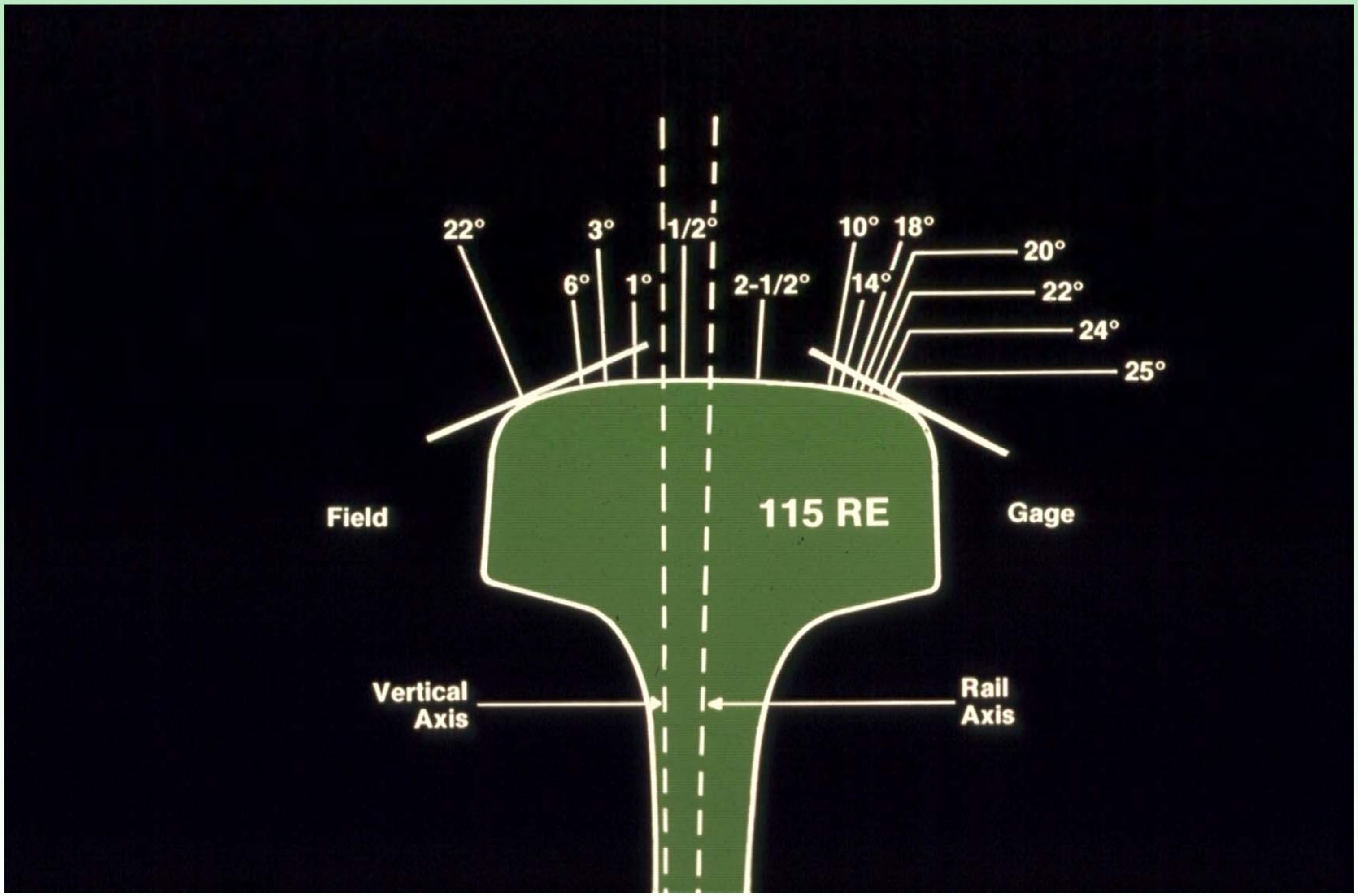
Grinding Angle Facets



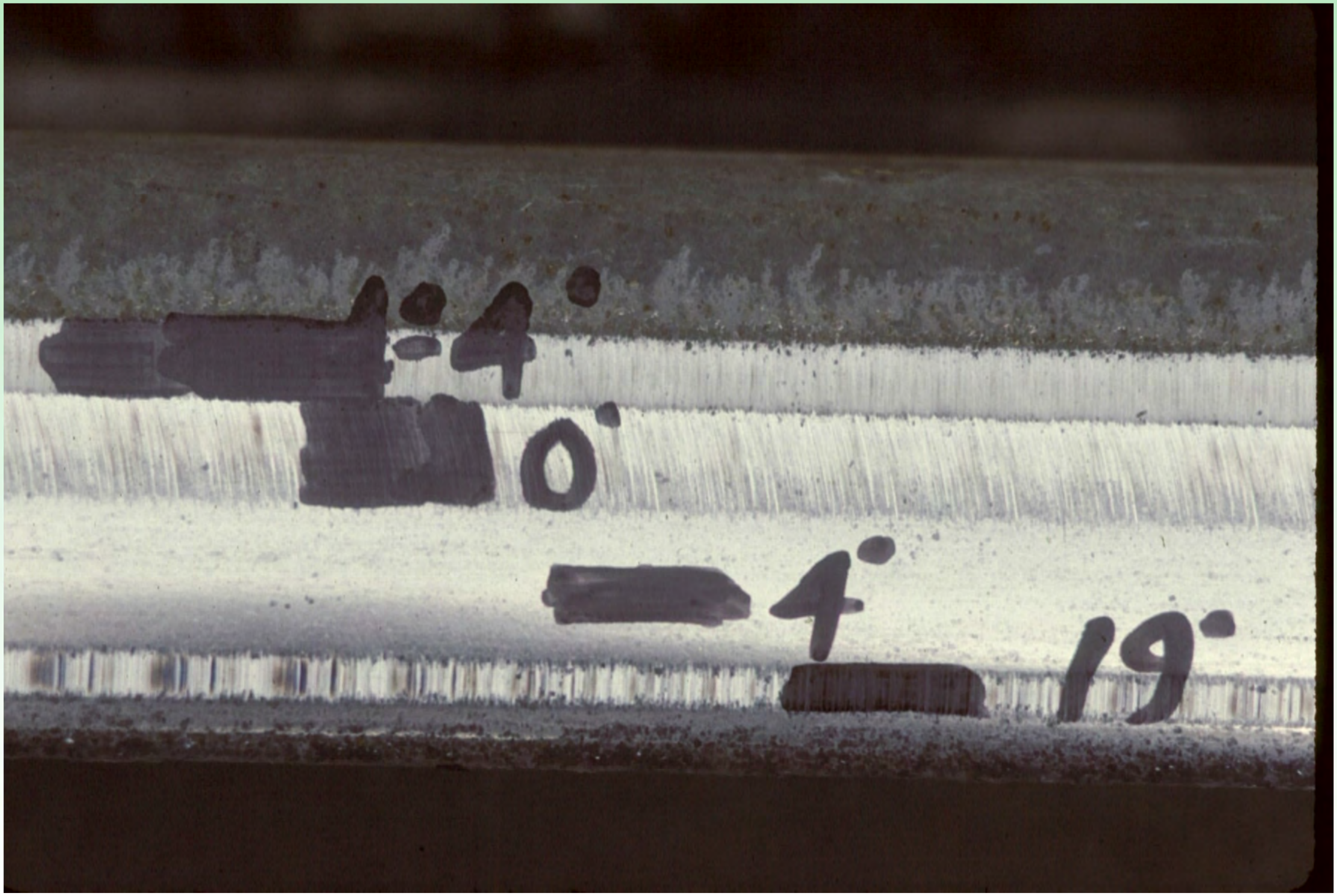
Grind Motor Placement



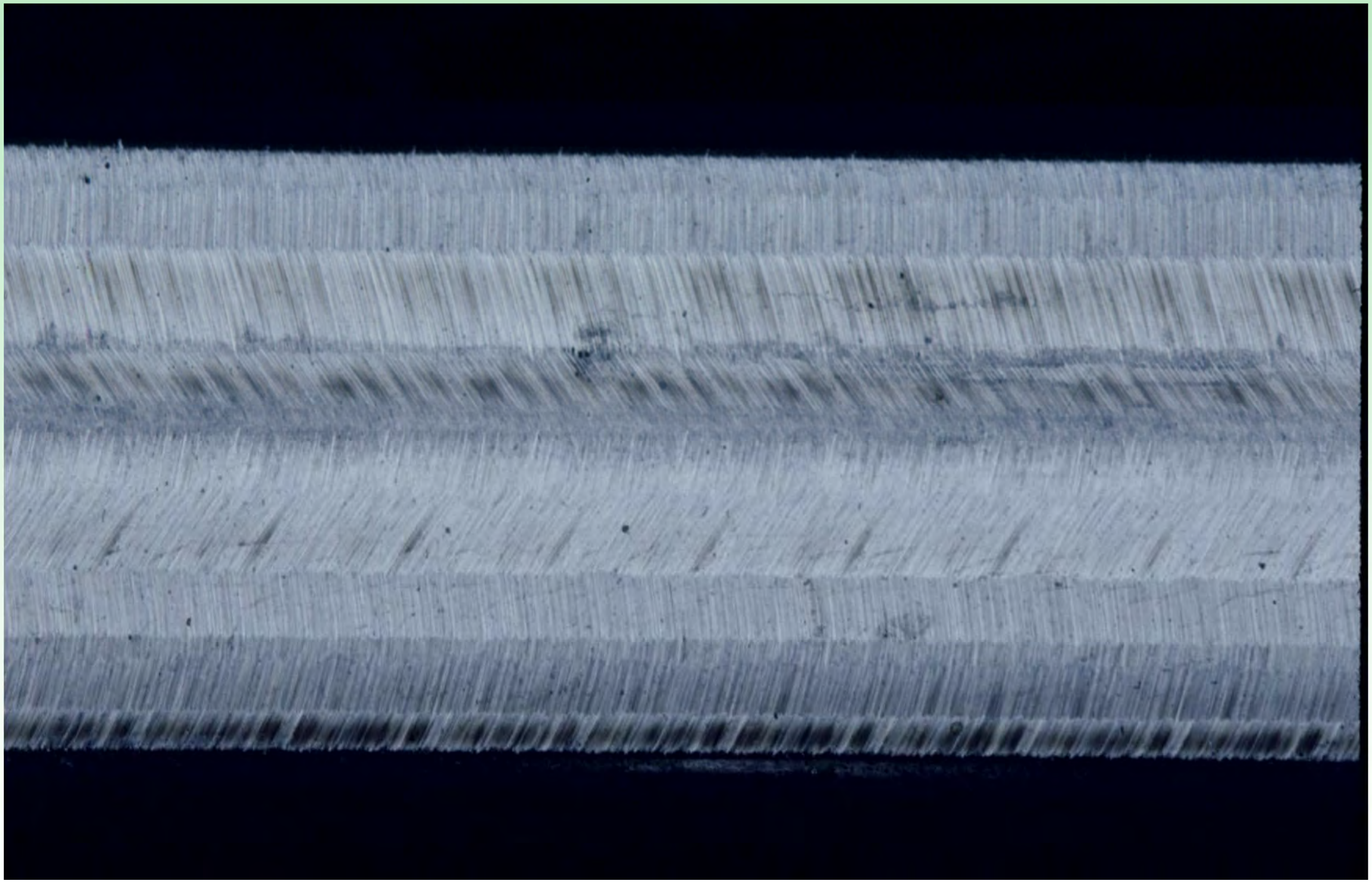
Grinding Angle Facets



Grinding Angle Facets



Grinding Angle Facets



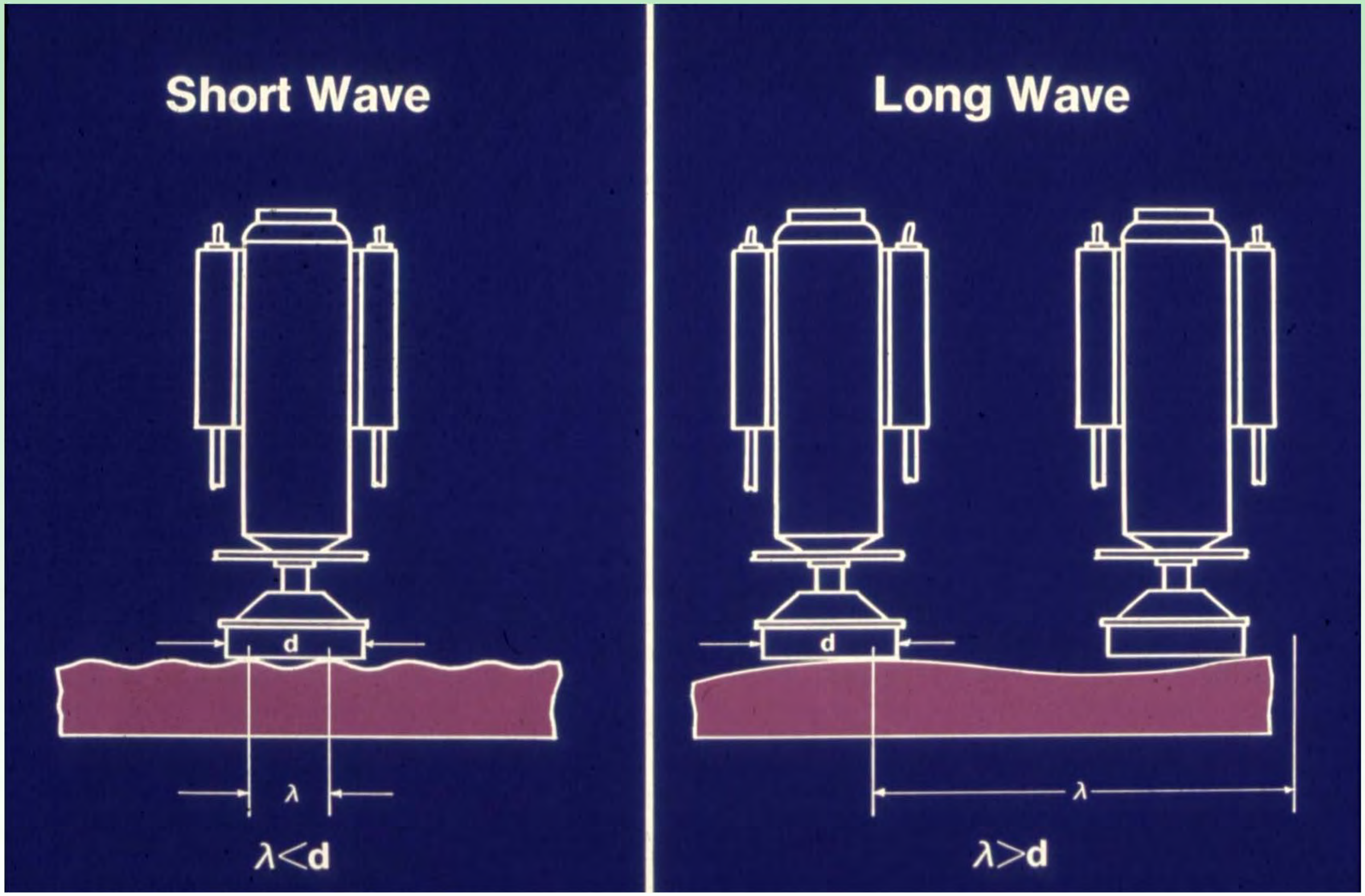
Defect Removal

- Key role of grinding is to control and remove rail surface defects
  - Grinding templates and patterns to address class of defects
- NOT ALL DEFECTS HAVE TO BE COMPLETELY REMOVED
- Important to know when to stop grinding
  - Do not want to grind away all of the work hardened rail head
  - Grinding on a regular cycle allows for long term defect control

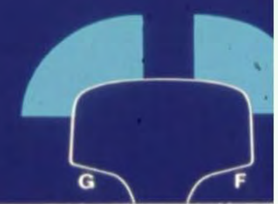
Pattern Selection and Depth

Situation and Objective	Defect Depth (.000)	Pattern and Relative Effort
New Rail — Mill Scale/Welds Surface Blemishes Delay Corrugation and Defects	4-6	±18± 
Corrugations Dynamic Loads	10-120	±18± 
Engine Burns, etc. Dynamic Loads	50-250	±18± 
Welds/Joints Dynamic Loads	20-250	±18± 

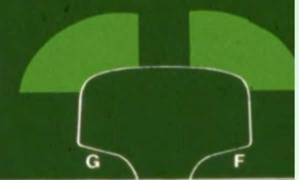
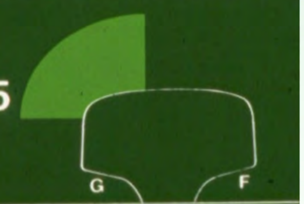
Corrugation Correction



Pattern Selection and Depth

Situation and Objective	Defect Depth (.000)	Pattern and Relative Effort
Gage Corner (Shells) Delay Fatigue Defects (Detail Fractures)	10-100	–45/+0 
Field Flow Preparation for Relay	25-50	–10/–45 
Head Crushing Preparation for Relay and Delay Fatigue Defect		+60/–60 

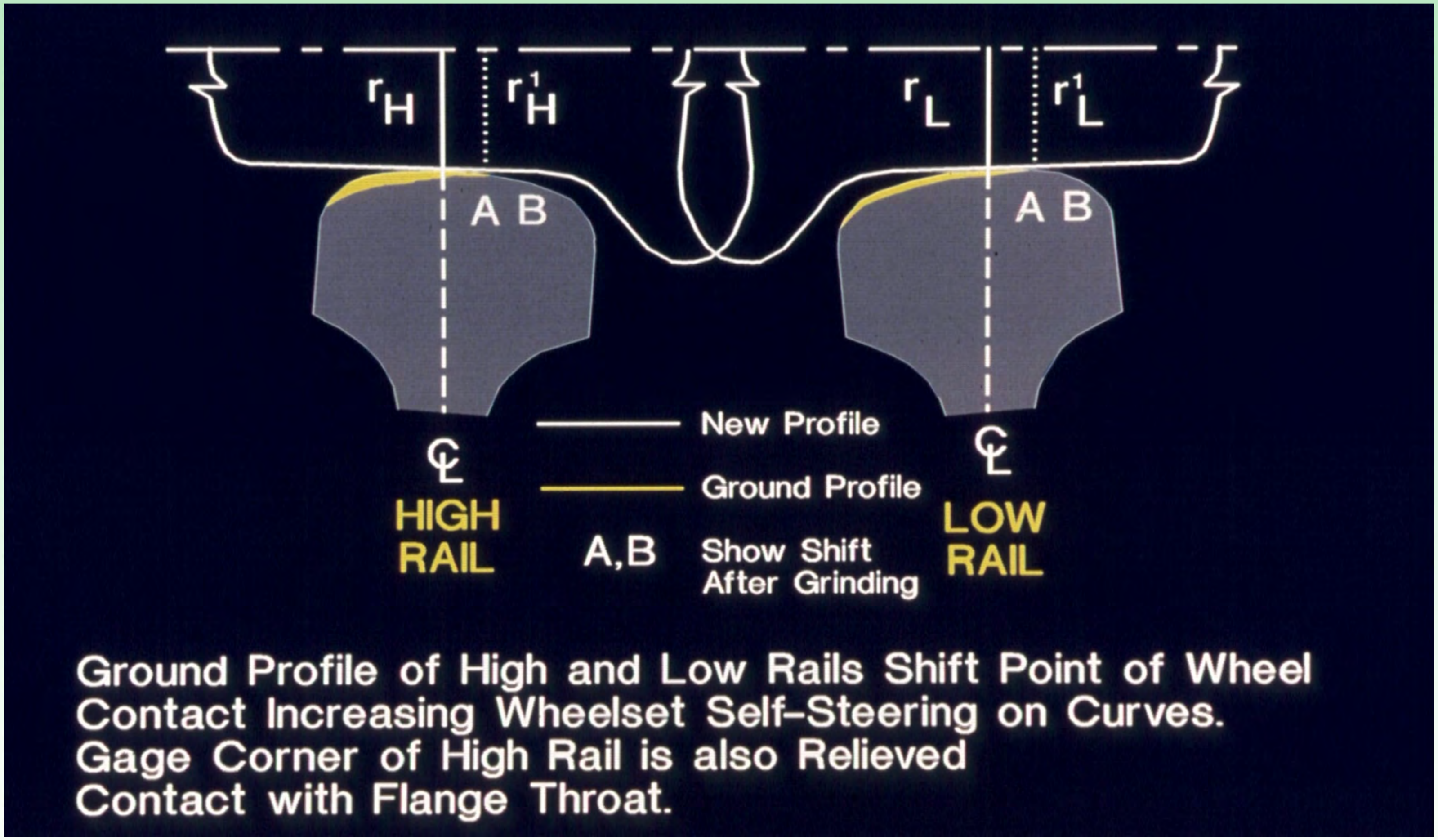
Pattern Selection and Depth

Situation and Objective	Defect Depth (.000)	Pattern and Relative Effort
Reprofiling Worn Profile Decreased Wear and Fatigue/ Decreased Curve Resistance	20-50	+70/−60 
Australia Decreased Wheel Wear		+60/−60 
Gage Face Wear Reduce Derailment Problems and Wheel Problems	250-700	+70/+45 

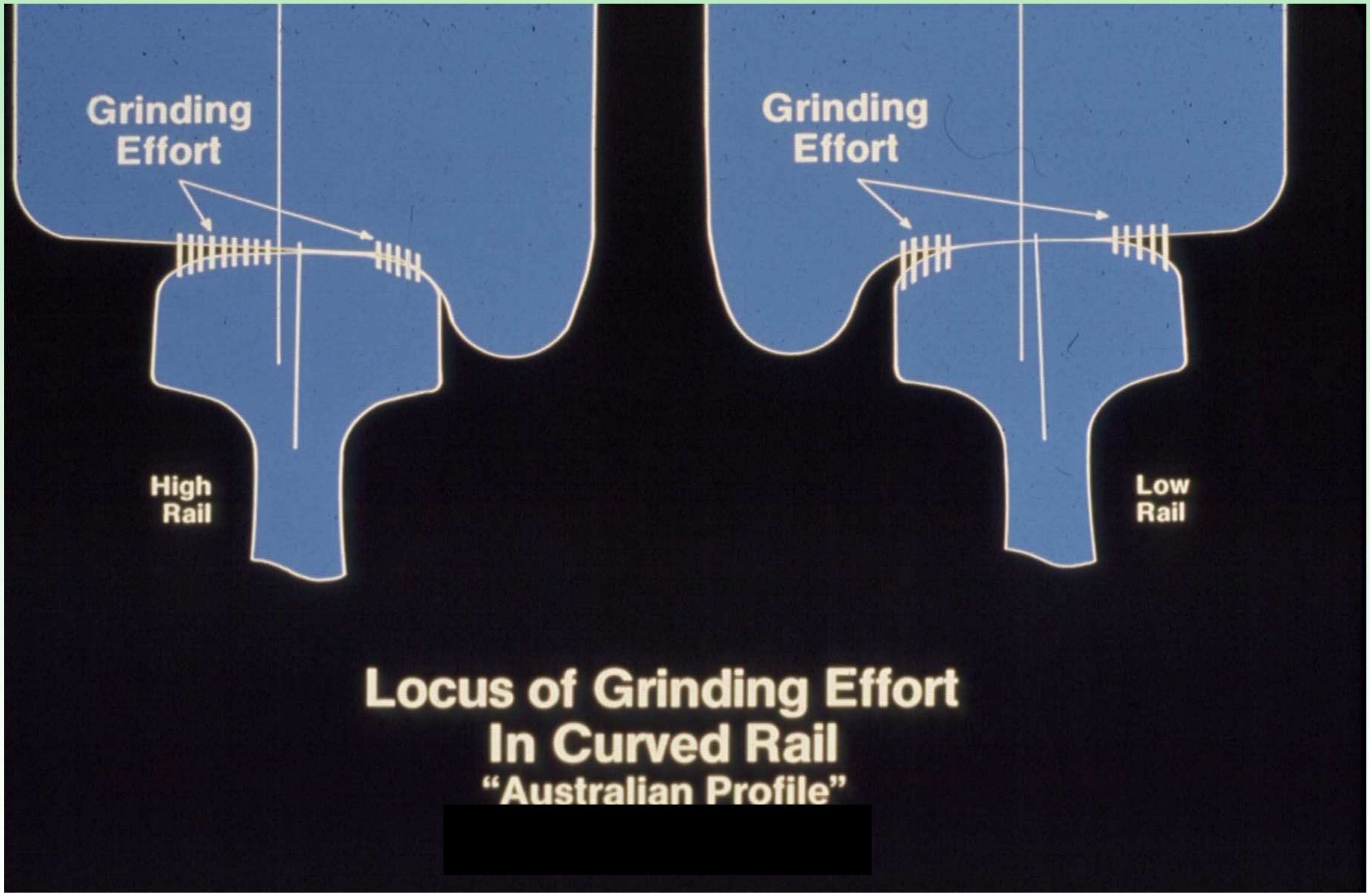
Rail Profile Grinding

- Control Gage Corner Fatigue
  - Addresses High Contact Stresses on High Rail Gage Corner
  - One Point vs Two Point Contact
  - Reduces Rate of Fatigue Defect Development
- Control Gage Face Wear
  - Enhanced Freight Car Truck Steering
  - Reduction in Lateral Wheel/Rail Forces and Gage Face Wear
  - Eliminates Flanging on Shallow Curves
- Control Corrugations
  - Heavy Axle Load Corrugations
  - Low Rail of Curves
  - Eliminate False Flange Contact
  - Delay Return of Corrugation

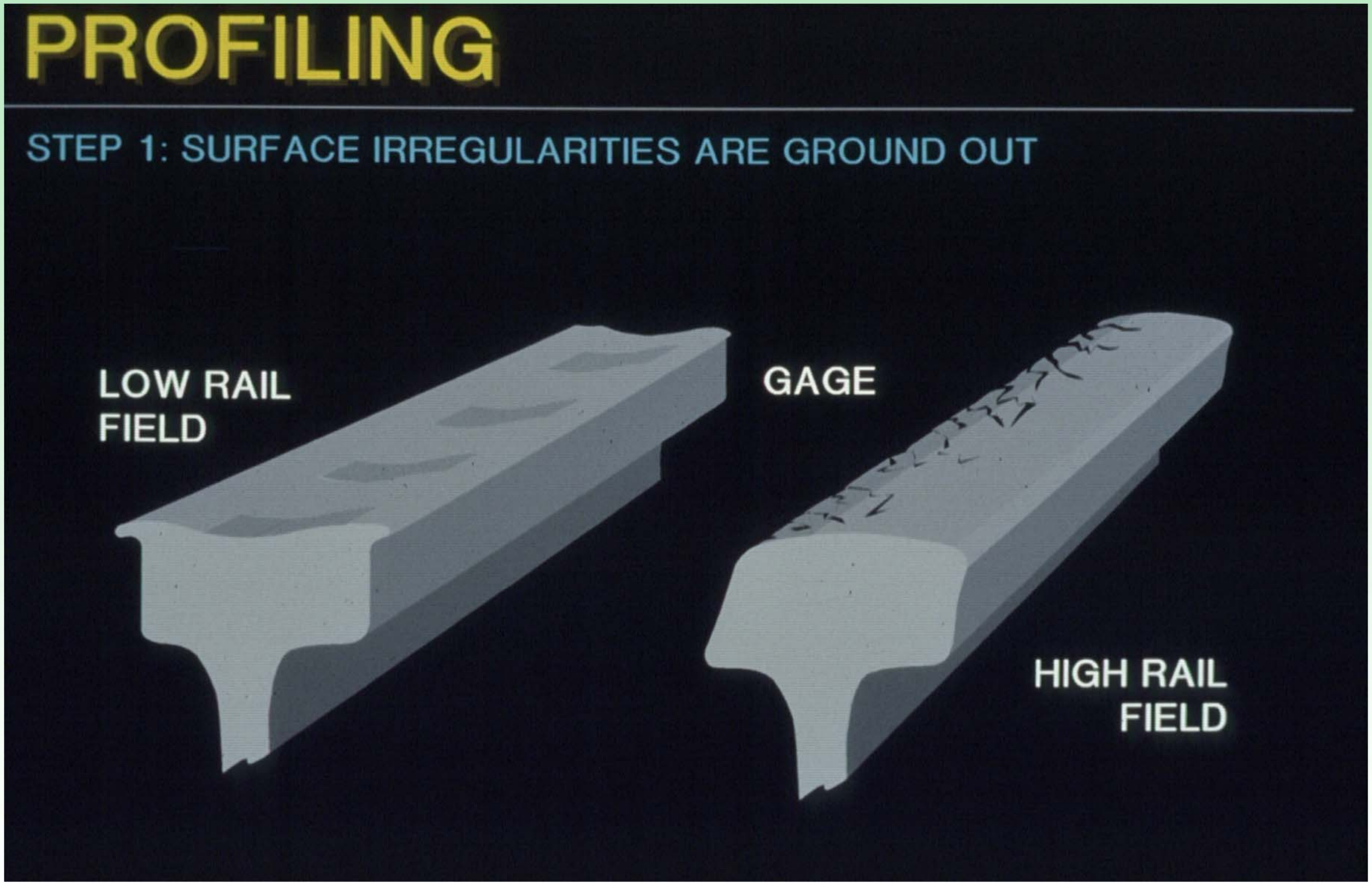
Rail Profile Grinding



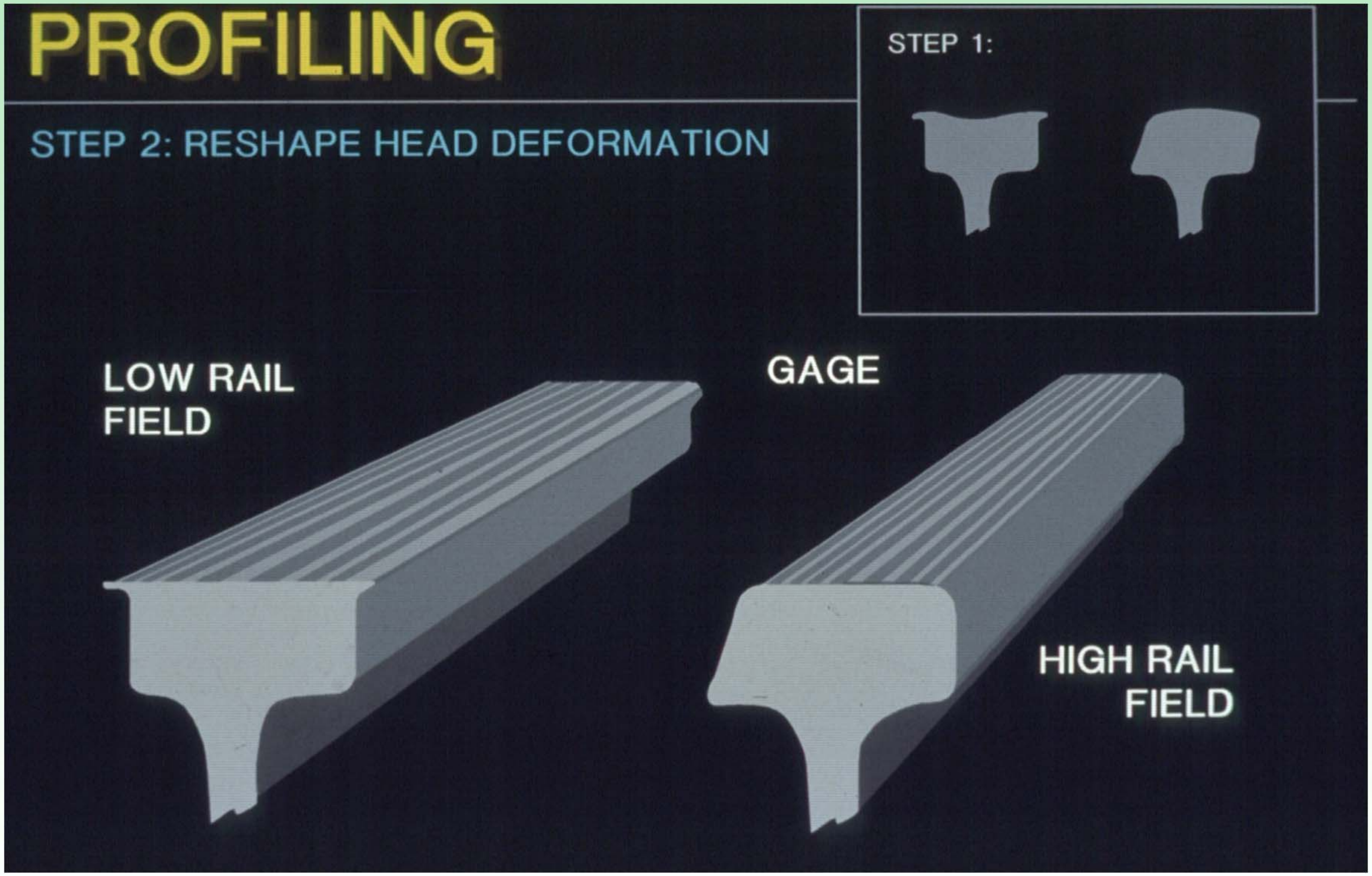
Rail Profile Grinding



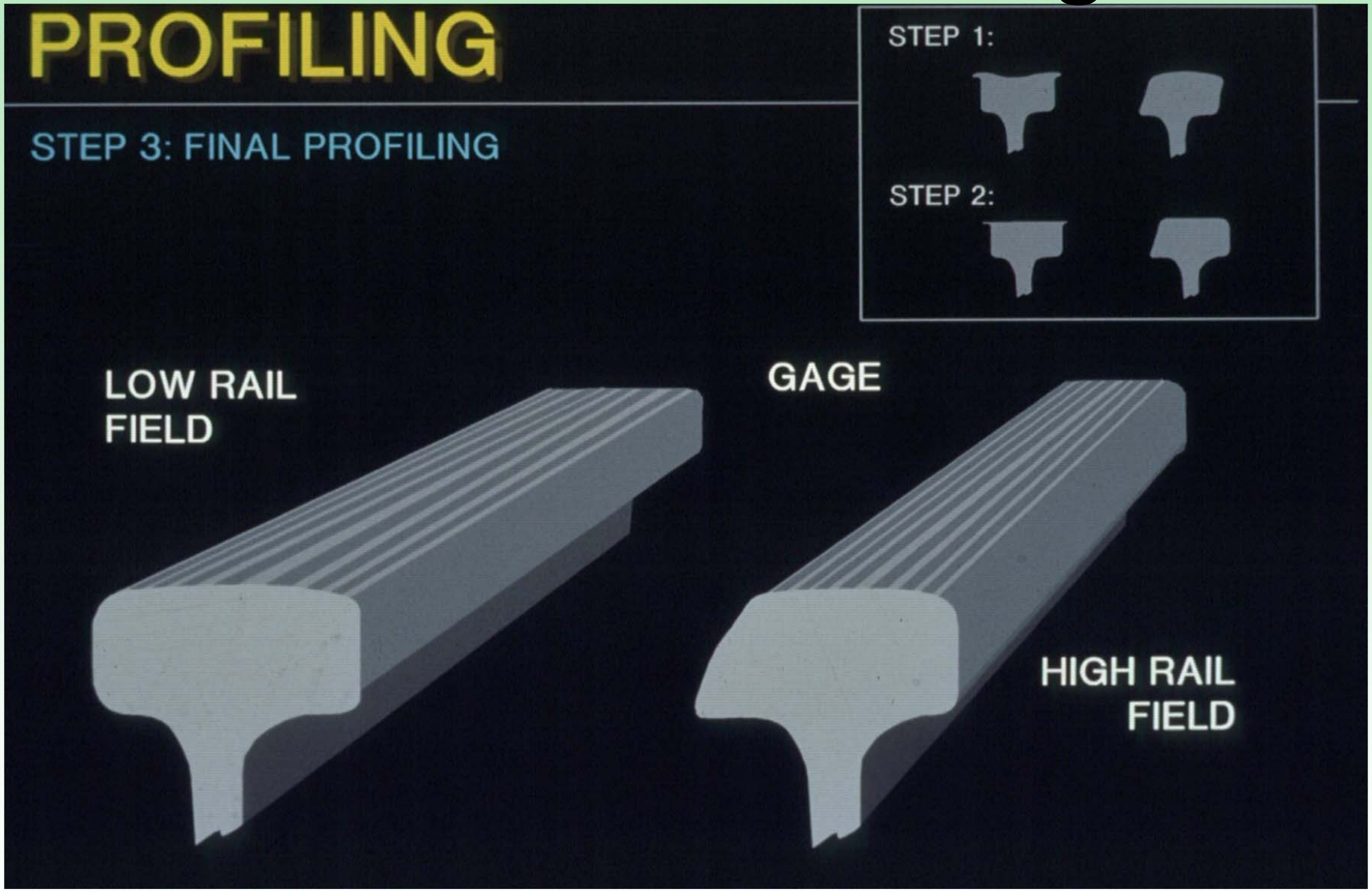
Rail Profile Grinding



Rail Profile Grinding



Rail Profile Grinding



Profile Grinding Goals

- Top of rail should never have a radius less than 8”
  - Reduced running band can result in high stresses and rail surface fatigue (spalling)
  - Running band should be between 1 1/4 and 1-3/4 inch on all rails
    - Reduce plastic deformation and metal surface fatigue
- Tangent rail tends to flatten over time
  - Needs to be contoured to 10-inch radius

Result of Grinding to less than an 8 inch head radius

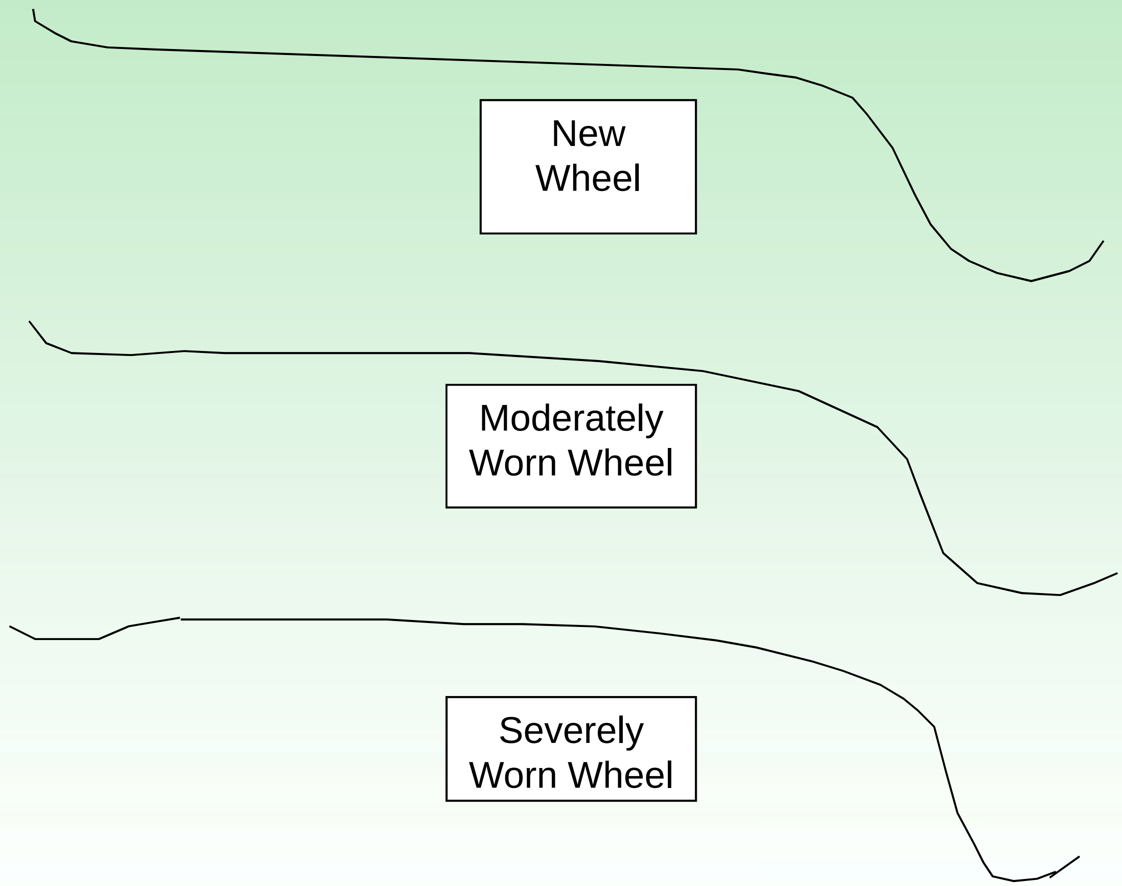
Spalling From Peaked Grinding

Template Development

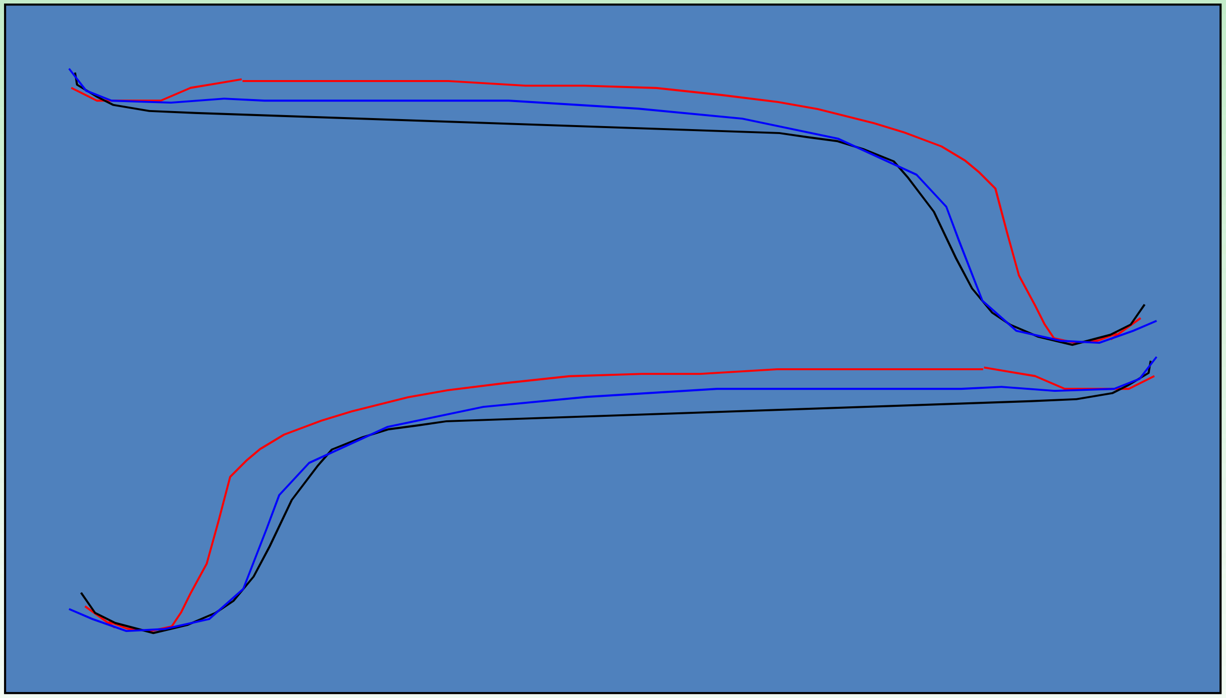
- CSX Rail grinding templates originally developed 2006 from wheel wear and rail profile data sets

- CSX grinding profiles modified to produce better wheel/rail contact :
  - Increased rail life
  - Increased wheel truing life
  - Reduced top of rail fatigue failures

Wheel Profile Examples

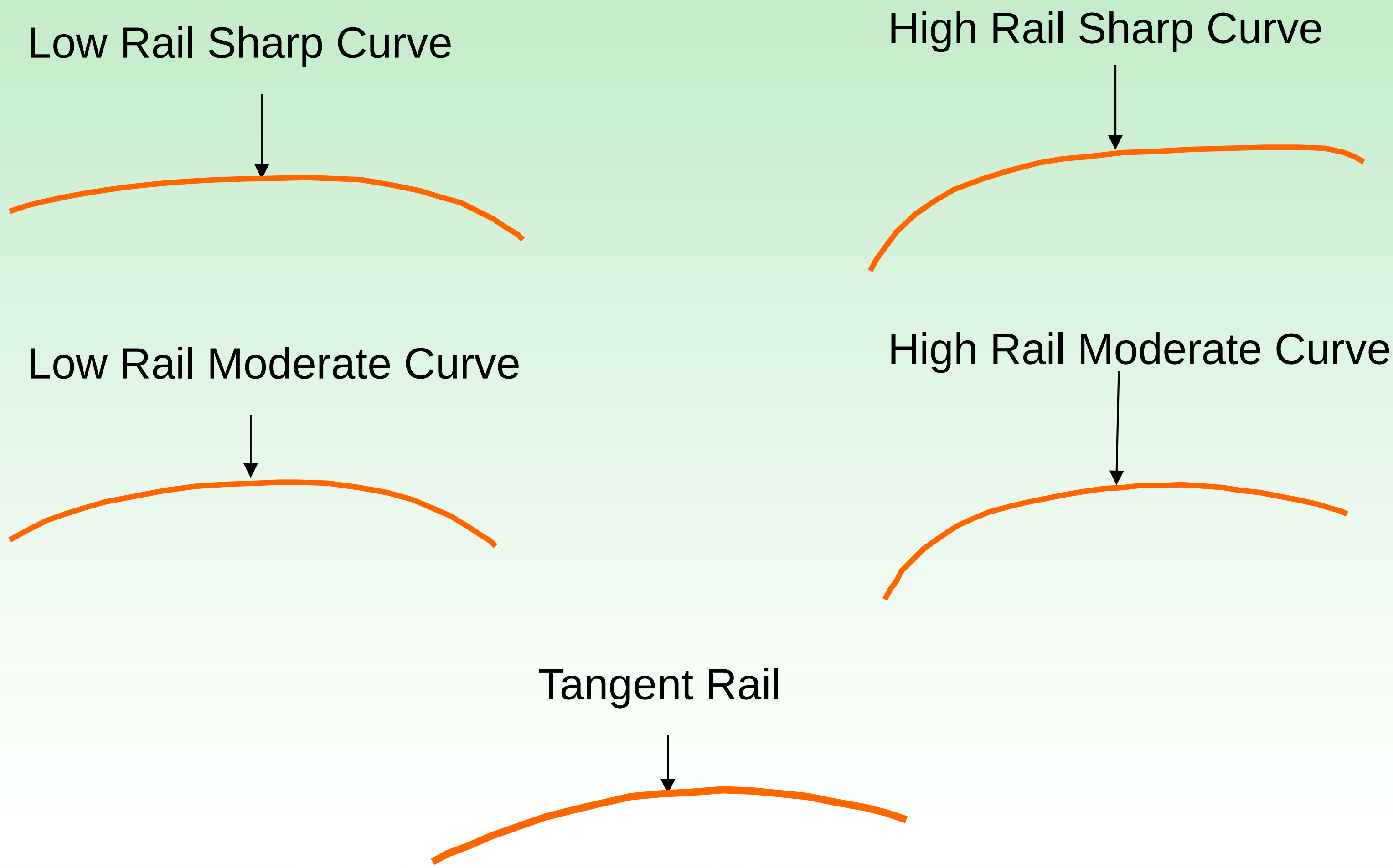


Wheel Profile Overlays



New Wheel in Black
Medium Worn Wheel in Blue
Worn Wheel in Red

Grinding Templates



Development of Grinding Plan

- Offline Data Analysis
  - Rail Profile
  - Annual Tonnage
  - Rail Surface Defects
- Online Analysis
  - Rail Profile
  - Grinding Quality
- Post Analysis
  - Production
  - Key Performance Indicators
  - Metal Removal

Surface Crack Analysis

Cycle Analysis by MGT

- MGT categorized by Subdivision / Prefix
- Preliminary Grinding Cycles utilize MGT breakdown by curvature
- Final Cycles based on actual MGT and curvature data

Subdivision MGT

- Multiple MGT segments within Subdivision
- Annual Prefix Tonnage weighted by segment length determines Subdivision MGT

SubMGT = [$\sum$(Weighted Segment MGTs) / Total Sub Track Miles]

Final Cycles

Account for variables affecting MGT data

- MGT Data includes yard tonnage
- Factors of Rail Type and Condition
- Multiple track (directional) tonnage differences

Master Plan Atlanta Division

ATLANTA	Abbeville (441.9 - 561.0)	SG	31	1.5	137.9	206.9	1.3	268.9
	Atlanta Terminal (0.0 - 6.5)	0WA	60	1	12.8	12.8	1.4	17.9
	Atlanta Terminal (6.5 - 22.4)	0WA	60	3	24.1	72.3	1.2	86.8
	Atlanta Terminal (827.0 - 865.0)	ANB	29	1	41.7	41.7	1.4	58.4
	Atlanta Terminal (561.0 - 575.3)	SG	32	1.5	14.3	21.5	1.4	30.03
	Atlanta Terminal (6.2 - 16.4)	XXB	32	1	12.4	12.4	1.4	17.4
	Atlanta Terminal (148.8 - 170.9)	YYG	17	1	22.1	22.1	1.2	26.52
	Awp W Of A (16.4 - 175.5)	XXB	42	2	173.5	347.0	1.3	451.1
	Birmingham Mineral (388.5 - 404.1)	0LB	12	0.5	15.6	7.8	1.4	10.9
	Birmingham Mineral (403.9 - 421.4)	0LC	15	0.5	17.5	8.7	1.4	12.2
	Birmingham Mineral (421.3 - 429.2)	0LK	8	0.5	7.8	3.9	1.4	5.5
	Birmingham Mineral (394.7 - 404.1)	00L	9	0.5	9.4	4.7	1.4	6.6
	Boyles Terminal (379.8 - 404.1	000	121	2	48.6	97.2	1.3	126.4
	Camak (0.0 - 47.0)	YYM	3	0.25	47.0	11.7	1.2	14
	Etowah (333.4 - 422.7)	00C	33	2	98.9	197.8	1.1	217.6
	Georgia (0.0 - 148.8)	YYG	14	0.5	148.8	74.5	1.2	89.4
	Lineville (788.3 - 816.0)	ANJ	38	1	30.9	30.9	1.2	37.1
	Lineville (816.0 - 967.4)	ANJ	51	2	172.5	345.0	1.3	448.5
	Lineville (XXB 69.1 - 71.2)	XXB	65	2	4.2	8.4	1.2	10.1
	M And M (485.0 - 665.2)	000	39	2	205.2	410.4	1.2	492.5
	Manchester (786.1 - 827.0)	ANB	28	1	44.7	44.7	1.3	58.1
	N O And M (665.2 - 803.7)	000	30	1	154.5	154.5	1.1	170.0
	PD (607.2 - 645.0)	00K	16	0.5	37.8	18.9	1.3	24.6
	S And N A South (404.1 - 485.0)	000	36	2	86.5	173.0	1.2	207.6
	W And A (48.6 - 137.3)	0WA	43	2	94.9	177.2	1.3	230.4
	W And A South (22.06 - 48.64)	0WA	61	3	33.3	100.1	1.3	130.0
Totals					1696.9	2606.1	1.25	3248.6

Grinder Schedule

ZT-CSX Rail Grinding Schedule - RMS 9 01/01/2006 thru 12/31/2006

Program	Division	Subdivisior Prefix	Station MP	- -	Station MP	ck Work T	Cycle	Route Miles	Track Miles 4887	Pass Miles 6700	PM/TM Ratio 1.37	No. Days 226.0	Dates	Trk Hrs per Day 2.8	Sprk Tm per Day 166
RMS 9	Florence	Columbia S	Elmwood 359	- -	Central Jct 499.9	SG OF	1	150.9	140.9	217.7	1.54	7.0	5/15/06 - 5/22/06	3.7	225
RMS 9	Jacksonville	Savannah S	Central Jct 499.9	- -	Burroughs 509.6	SG OF	1	9.7	9.7	13.2	1.36	1.0	5/22/06 - 5/23/06	1.5	91
RMS 9	Jacksonville	Savannah A	Burroughs 503	- -	Central Jct 490.4	#2 OF	1	12.6	12.6	2.2	0.17	1.0	5/23/06 - 5/24/06	0.3	19
RMS 9	Florence	Charleston CH	Central Jct 490.4	- -	Florence 292.7	SG OF, #2 OF	1	194.5	197.7	395.4	2.00	10.0	5/24/06 - 6/3/06	4.0	237
RMS 9	Florence	South End A	Florence 292.7	- -	:harlie Bake 119.9	SG OF, Track 2	2	172.8	172.8	214.3	1.24	7.0	6/3/06 - 6/10/06	3.9	232
RMS 9	Florence	North End A	0	- -	119.9	SG OF, Track 2	2	119.9	119.9	119.2	0.99	4.0	6/10/06 - 6/14/06	3.7	221
RMS 9	Florence	North End ARN	MEADOW 0	- -	2	Track 1 OF, Track	2	2.0	2.0	3.4	1.72	1.0	6/14/06 - 6/15/06	0.9	56
RMS 9	Florence	mond Tern CFP	1	- -	SOUTH AY 4.8	Track 3 OF,	2	3.8	3.8	3.8	1.00	1.0	6/15/06 - 6/16/06	0.4	23
RMS 9	Baltimore	mond Fred CFP	4.8	- -	114.64	Track 3 OF,	2	109.8	109.8	32.9	0.30	1.0	6/16/06 - 6/17/06	3.9	232
RMS 9	Baltimore	Capital CFP	114.8	- -	121.15	SG Curves &	3	6.4	6.3	7.4	1.17	1.0	6/17/06 - 6/18/06	1.5	91
RMS 9	Baltimore	Metropolitan BA	1	- -	oint Of Rocl 69	Track 1 OF, Track	2	68.0	68.0	136.0	2.00	3.0	6/18/06 - 6/21/06	4.5	272
RMS 9	Baltimore	Metropolitan BA	69	- -	Weaverton 78.8	Track 1 Curves &	2	9.8	9.8	10.2	1.04	1.0	6/21/06 - 6/22/06	1.3	75
RMS 9	Baltimore	Cumberland BA	78.8	- -	173.4	Track 1 OF, Track	2	94.6	94.6	290.6	3.07	9.0	6/22/06 - 7/1/06	3.9	233
RMS 9	Baltimore	Cumberland BAQ	0	- -	11.66	Track 4 Curves &	2	11.7	11.7	5.1	0.43	1.0	7/1/06 - 7/2/06	0.7	40
RMS 9	Baltimore	berland Ter BA	Mexico 173.4	- -	Beal st. 179.5	Track 1 OF, Track	2	6.1	6.1	17.0	2.80	1.0	7/2/06 - 7/3/06	2.2	135
RMS 9	Baltimore	Keystone BF	Viaduct Jct 178.9	- -	Rockwood 227	Track 1 OF, Track	2	132.7	48.1	138.6	2.88	4.0	7/3/06 - 7/7/06	4.1	245
RMS 9	Baltimore	Old Main Lin BAC	Point of Ro 64.8	- -	P Halethorp 5.9	SG Curves &	2	58.9	58.9	52.5	0.89	1.0	7/7/06 - 7/8/06	6.0	358
RMS 9	Baltimore	imore Term BAC	5.9	- -	TIS BAY JU 2.8	SG Curves &	4	3.1	3.1	2.2	0.70	1.0	7/8/06 - 7/9/06	0.2	14
RMS 9	Baltimore	imore Term BAK	96.2	- -	CP Bay View 89.6	SG Curves &	4	6.6	6.6	19.8	3.00	1.0	7/9/06 - 7/10/06	2.0	119
RMS 9	Baltimore	Philadelphia BAK	CP Bay View 89.6	- -	CP Vine St. 0	SG Curves &	2	89.6	89.6	100.9	1.13	4.0	7/10/06 - 7/14/06	3.7	223
RMS 9	Baltimore	Trenton QA	Park Jct. 0	- -	Port Read 57.33	SG Curves &	2	57.3	57.3	55.7	0.97	2.0	7/14/06 - 7/16/06	4.0	242
RMS 9	Baltimore	Bergen QR	1.68	- -	7.59	SG Curves &	2	5.9	5.9	5.9	1.00	1.0	7/16/06 - 7/17/06	0.6	35
RMS 9	Albany	River QR	CP 7 7.59	- -	CP SK 132.36	SG Curves &	2	124.8	124.8	120.4	0.96	4.0	7/17/06 - 7/21/06	3.8	226
RMS 9	Albany	River QR	CP SK 132.36	- -	CP 7 7.59	Travel back to	1		124.8	124.8	1.00	1.0	7/21/06 - 7/22/06		
RMS 9	Baltimore	imore Term BAK	CP Bay View 89.6	- -	96.2	SG Curves &	4	6.6	6.6	19.8	3.00	1.0	7/22/06 - 7/23/06	2.0	119
RMS 9	Baltimore	imore Term BAC	TIS BAY JU 2.8	- -	5.9	SG Curves &	4	3.1	3.1	2.2	0.70	1.0	7/23/06 - 7/24/06	0.2	14

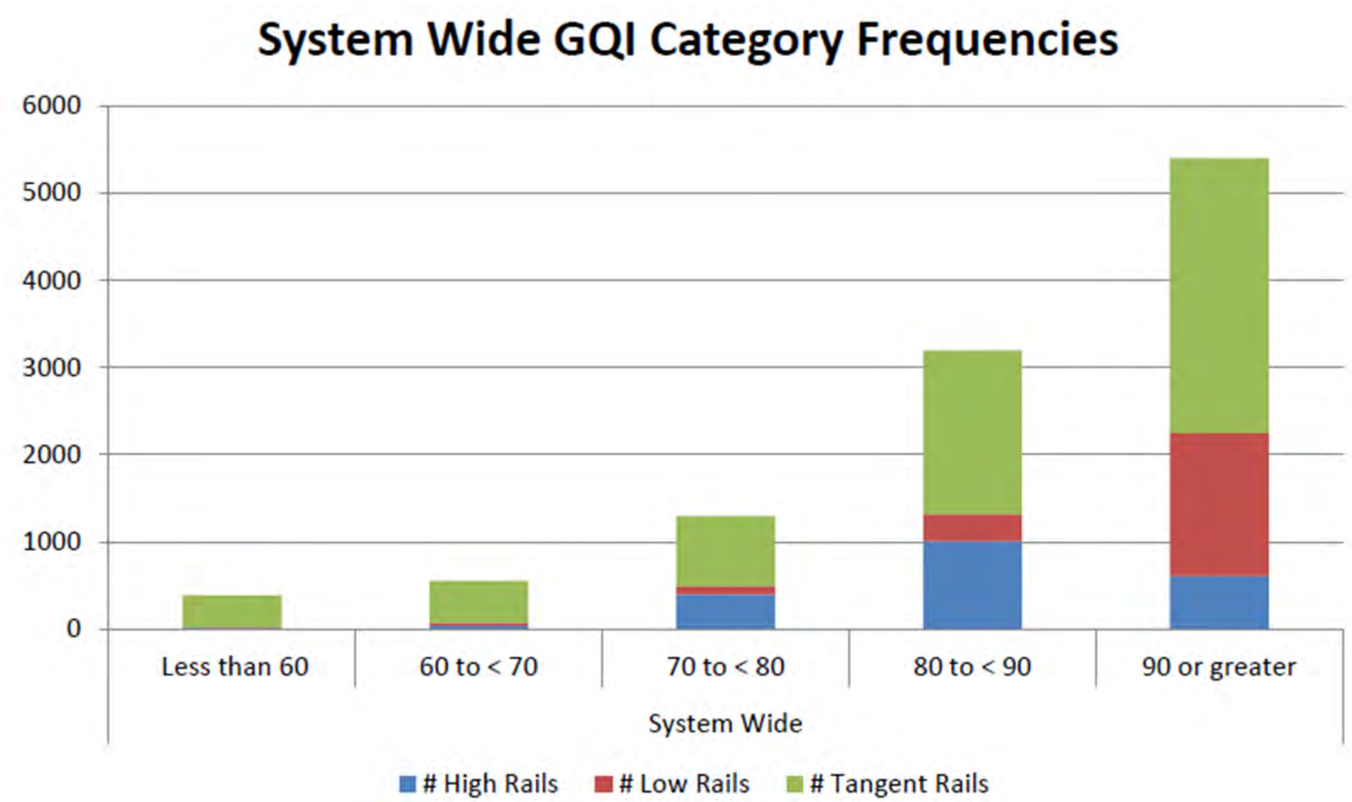
Grinding Plan

Track Information								Planned Grind							Work Time		
MP From	MP To	Track	Curve Name	Degree of Curve	Direc tion	Length (mi)	Features	GQI	High Rail Pattern (Tan-L)	Low Rail Pattern (Tan-R)	High Rail Passes	Low Rail Passes	Speed	Comments	Work Time (min)	Total Time (min)	Control Point
442	442.82	SG		0		0.82	DED @ MP442.7	9 // 78	3	41	1	1	11	55 // 93	4.5	4.5	
442.82	442.98	SG	SG-SG-442-1	3.1	L	0.16		1 // 9	**3**	**3**	2	1	7	26 // 100	1.4	5.9	
									3				7	100 // 100	1.4	7.3	
442.98	443.07	SG		0		0.08	Lube @ MP443	43 // 84	41	9	1	1	12	94 // 98	0.4	7.7	
443.07	443.37	SG	SG-SG-443-1	4.05	R	0.29		26 // 32	**3**	**41**	1	1	7	100 // 100	2.5	10.2	
443.37	443.47	SG		0		0.09		20 // 9	41	21	1	1	7	65 // 62	0.8	11	
443.47	443.66	SG	SG-SG-443-2	3.3	L	0.18		2 // 1	**3**	**3**	1	1	7	92 // 80	1.5	12.5	
443.66	443.83	SG		0		0.16		25 // 0	41	3	1	2	7	88 // 32	1.4	13.9	
										41			7	88 // 77	1.4	15.3	
443.83	444.08	SG	SG-SG-443-3	4.1	L	0.24		1 // 6	**3**	**42**	2	1	7	23 // 91	2.1	17.4	
									41				7	80 // 91	2.1	19.5	
444.08	444.5	SG		0		0.42		20 // 0	41	3	1	2	7	69 // 13	3.6	23.1	
										41			7	69 // 39	3.6	26.7	
444.5	444.91	SG	SG-SG-444-1	4	R	0.41		36 // 46	**42**	**41**	1	1	7	99 // 98	3.5	30.2	
444.91	445.73	SG		0		0.82		28 // 49	41	41	1	1	7	96 // 97	7	37.2	
445.73	446.49	SG	SG-SG-445-1	2	L	0.75		41 // 65	**43**	**14**	1	1	10	98 // 99	4.5	41.7	
446.49	446.66	SG		0		0.16		1 // 72	3	41	3	1	10	2 // 94	1	42.7	
									3				7	34 // 94	1.4	44.1	
									41				7	79 // 94	1.4	45.5	
446.66	446.96	SG	SG-SG-446-1	5	R	0.29		64 // 29	**42**	**41**	1	1	7	100 // 96	2.5	48	
446.96	447.37	SG		0		0.41		0 // 7	3	3	1	1	9	94 // 53	2.7	50.7	
447.37	447.75	SG	SG-SG-447-1	2	L	0.38	Lube @ MP447.5,	62 // 98	**46**	**41**	1	1	8	99 // 100	2.9	53.6	
447.75	448.78	SG		0		1.02		17 // 1	3	3	1	2	11	98 // 42	5.6	59.2	
										41			7	98 // 90	8.7	67.9	
448.78	449	SG	SG-SG-448-1	2	L	0.21		0 // 92	**3**	**9**	1	1	7	100 // 100	1.8	69.7	
449	449.94	SG		0		0.94	ck 449.05, Lube @	23 // 100	41		1	0	7	73 // 100	8.1	77.8	
449.94	450.44	SG	SG-SG-449-1	2	R	0.44		91 // 1	**12**	**3**	1	2	7	100 // 7	3.8	81.6	
										3			7	100 // 76	3.8	85.4	
450.44	451.83	SG		0		1.31		0 // 30	3	41	1	1	7	80 // 81	11.2	96.6	
451.83	451.98	SG	SG-SG-451-1	0.5	R	0.15		9 // 1	**3**	**3**	1	3	10	89 // 17	0.9	97.5	
										41			7	89 // 69	1.3	98.8	
										41			10	89 // 95	0.9	99.7	
451.98	452.37	SG		0		0.38		1 // 16	3	3	3	1	11	10 // 71	2.1	101.8	OUN FALLS
									3				7	43 // 71	3.3	105.1	
									22				7	75 // 71	3.3	108.4	
452.37	452.5	SG	SG-SG-452-1	0.55	L	0.12		6 // 58	**3**	**41**	1	1	7	80 // 100	1	109.4	
452.5	454.67	SG		0		2.16		45 // 83	41	41	1	1	7	99 // 98	18.5	127.9	OUN FALLS
454.67	454.92	SG	SG-SG-454-1	4	L	0.25		1 // 8	**3**	**3**	2	1	7	23 // 100	2.1	130	

Grind Quality Monitoring - GQI Report

System Wide GQI Category Frequencies

The table below gives the frequencies of the GQI categories (less than 60, 60 to < 70, 70 to < 80, 80 to < 90, and 90 or greater) in the third quarter of 2014 system wide.



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