Improving Production Through Reliability – Assessment with Limited Information

9 Steps to Improved Manufacturing Reliability

Tutorial Outline – Reliability Assessment

- 9 Steps to More Reliable Equipment based on Performance Measurement and Corrective Action
- Relating measured performance to specified performance

9 Steps to More Reliable Equipment

- Step 1 – Basic Data Collection
- Step 2 - Investigate the Root Causes of the Identified Problems, Develop and Implement Corrective Action
- Step 3 – Re-interview the Operating and Maintenance Personnel
- Step 4 - Obtain Plant Maintenance Data
- Step 5 – Root Cause Identification and Corrective Action

9 Steps to More Reliable Equipment - 2

- Step 6 - Observe the Equipment
- Step 7 – Investigate the Root Causes of the Identified Problems, Develop and Implement Corrective Action
- Step 8 – Repeat the Observation Study
- Step 9 – Institute a Closed Loop Failure Reporting, Analysis, and Corrective Action System (FRACAS) and/or Condition Monitoring/On-Condition Repair System

Step 1 – Basic Data Collection

- Conduct structured interviews of plant personnel
  - Operators
  - Maintainers
  - Supervisors
  - Manufacturing Engineers

Step 1 – Basic Data Collection - 2

Reliability & Maintainability Survey

Customer Company X **Location** Indianapolis **Date** June 10 & 11, 1996_

Machine Type 5RE IW **Machine Quantity** 2

Machine S/Ns 907-08, 907-49

Machine Operation #s 130 A & B

Step 1 – Basic Data Collection - 3

1.Machine Reliability Issues

1.1. What are your expectations for machine Reliability? Does the machine meet your expectations?

Exceeds Expectations š; Meets Expectations š; Needs Improvement ■

1.1.1..Estimate of Machine Reliability (Mean Time Between Failures [MTBF] or %Uptime) **65-80%**

Comments: Fatal wheelhead fault on 130A - pump lube and it operates OK, trouble with wheelbase moving when grinding wheel gets down to minimum size; Cables on 130A workrest dry out and become brittle after exposure to coolant; lots of faults - machine will just stop running and show no fault; On 130B servo motor on dresser traverse locks up - reset drive and it works. 3rd shift: 90% of problems are cables on 130A, Company X mgt. has refused to buy replacement cables in the past; planned change from Motor U to Motor Z motors will improve servo performance and reliability as well as replace cables with more suitable cables for Company X environment; I/O cubes need to be reseated or replaced repeatedly due to heat - A/C is apparently set at 75 deg F. Some I/O cubes show discoloration from heat. Fatal wheelhead faults on 130B. Size changes (goes big) on all diameters of 130A. Encoders failing frequently. Wheel drive brake not working on 130A - Company X changed wheel drive type. 3rd Shift says reliability meets expectations

Step 1 – Basic Data Collection - 4

1.2..Does Machine Operate Without Need of Manual Assists?

No Manual Assists š; Some Manual Assists ■; Frequent Manual Assists š

Comments: Steady rests jam up 3 to 4 times/week on 130A; According to 3rd shift, steady rest gets lost from time to time, jams after wheel change, 1st Shift: steady rest not reset faults; 2nd shift: steady rest jams when it goes back to datum, need to remove motor to unjam. 2nd shift says machine needs frequent assists

1.3. Does Machine Operate Without Need of Manual Adjustments?

No Manual Adjusts š; Some Manual Adjusts ■; Frequent Manual Adjusts š

Comments: Gaging problems - have to continually readjust gage fingers on 130A - in particular left gage ; steady rests adjusted occasionally for runout or chatter. 2nd shift says machine needs frequent manual adjustments

Step 1 – Basic Data Collection - 5

2.Machine Maintainability Issues

2.1. What are your expectations for repair time?

Exceeds expectations š; Meets Expectations ■; Needs Improvement š

2.2. Does the machine meet your expectations?

Yes ■; No š

2.3. Estimated Mean Time To Repair (MTTR) 60 - 240 Minutes

Comments: Retaining ring on driver has too many screws which corrode and always have to be drilled out to remove - Gary H suggested changing to stainless screws to eliminate corrosion; wheel speed stepping switch difficult to setup, needs special screw driver to setup. 2nd shift says repair time needs improvement

Step 1 – Basic Data Collection - 6

2.4. Is Access Satisfactory?

Excellent Access š; Very Good Access ■; Satisfactory Access š; Fair Access š Poor Access š

Comments: 3rd shift says satisfactory access

2.5. Can Repairs Be Made With Available Tools?

Yes ■; No š

Comments: Needed to make one special screwdriver to adjust wheel speed stepping switches

2.6..Are Machine Diagnostics and Checkout Procedures Satisfactory?

Excellent š; Satisfactory ■; Needs Improvement š

Comments: Diagnostics are pretty good on MPC II E

Step 1 – Basic Data Collection - 7

2.7. Are Manuals Satisfactory for Needs?

Excellent š; Satisfactory ■; Needs Improvement š

Comments: Need training on sparkout grind feature

2.8. Are Recommended Spares Correct as to Type and Quantity?

No Shortages š; Some Shortages ■; Frequent Shortages š

Comments: Company X is not using Supplier Y list. Recommended spare parts list not adequate, mostly just parts for wear. Encoders in short supply. Many repaired encoders not repaired properly. Shortage of solenoids. 3rd shift has frequent shortages

Step 1 – Basic Data Collection - 8

3.Machine Quality Issues

3.1. Is Machine Producing Quality Parts?

Yes ■; No š

Comments: Quality - bad centers in parts is major problem; runout problem - some machine & some part Oversize parts. 2nd shift says machine is not producing quality parts. Steady rest causes most of problems. Operators use steady rest to control size (TRAINING???) This is not correct method - need to adjust profile bars

Quantity Good Parts Produced in previous 12 months________________.

Quantity Defective Parts Produced in previous 12 months_____________.

Step 1 – Basic Data Collection - 9

3.2. Is Machine Meeting Statistical Requirements?

Yes š; No ■

3.3. Estimated statistical performance of machine (i.e., C_{pk})______________

Comments: Quality problems primarily related to crank itself - bad centers.

4. Other Comments

Need more training in how to rework cranks; Gage W post-process gaging system is problematic

Step 2 – Root Causes and Corrective Action – Structured Problem Solving

- Establish a Corrective Action Team
  - Multidisciplinary
  - Supplier and user members, if possible
  - Identify team leader (Champion)
  - Facilitator can reduce conflict
  - Note taker can help team concentrate on problem solving
  - Use a separate session for each problem with separate teams, if possible

Step 2 – Root Causes and Corrective Action – Structured Problem Solving - 2

- Identify the Problem
  - Prioritize the effort toward BIG problems
  - Better problem definitions yield better solutions
  - Clarity and completeness count

Step 2 – Root Causes and Corrective Action – Structured Problem Solving - 3

- Contain the Problem
  - Temporary fix, stop gap measure, etc.
  - If problem is bleeding user resources, this reduces the cost until a permanent corrective action is developed
  - Can be process or design change
    - Usually quick and dirty fix, not complete resolution of problem
  - Don’t let this be final solution to problem
    - Problem will recur
    - Confidence in systemic approach to improved reliability will be destroyed

Step 2 – Root Causes and Corrective Action – Structured Problem Solving - 4

- Identify the Root Cause
  - Many methods for getting to root cause
    - Methods from Anderson and Fagerhaug or similar book
    - Possible Cause generation
      - Brainstorming
    - Cause and effect analysis (fishbone diagram)
    - Similar problems resolved in past
    - Consensus of Team necessary to assure buy-in by all parties

Step 2 – Root Causes and Corrective Action – Structured Problem Solving - 5

- Develop Corrective Action
  - Formal change to process or design to reduce or eliminate root cause recurring
  - Corrective Action dependent on Root Cause
    - Process related root cause requires process change
      - Process includes all personnel and training
    - Design related root cause requires design change
      - Design addresses hardware and software only
    - Hybrid (part process, part design) cause may require both process and design changes

Step 3 – Re-interview the Operating & Maintenance Personnel

- Repeat initial interview
  - after Corrective Action is implemented and stable
  - 2 to 3 months after completion of Corrective Action
  - If corrective action is ineffective, revisit structured problem solving
- Follow-up for Effective Corrective Action
- Final step for Structured Problem Solving
- May identify new issues for corrective action

Step 4 - Obtain Plant Maintenance Data

- May be informative
- Can be finding needle in a haystack
- Data assumes many forms
  - Repair tickets
  - Downtime logs
  - Automated downtime logs
  - Fault logs
  - Summaries of any of the above
  - Failure tags

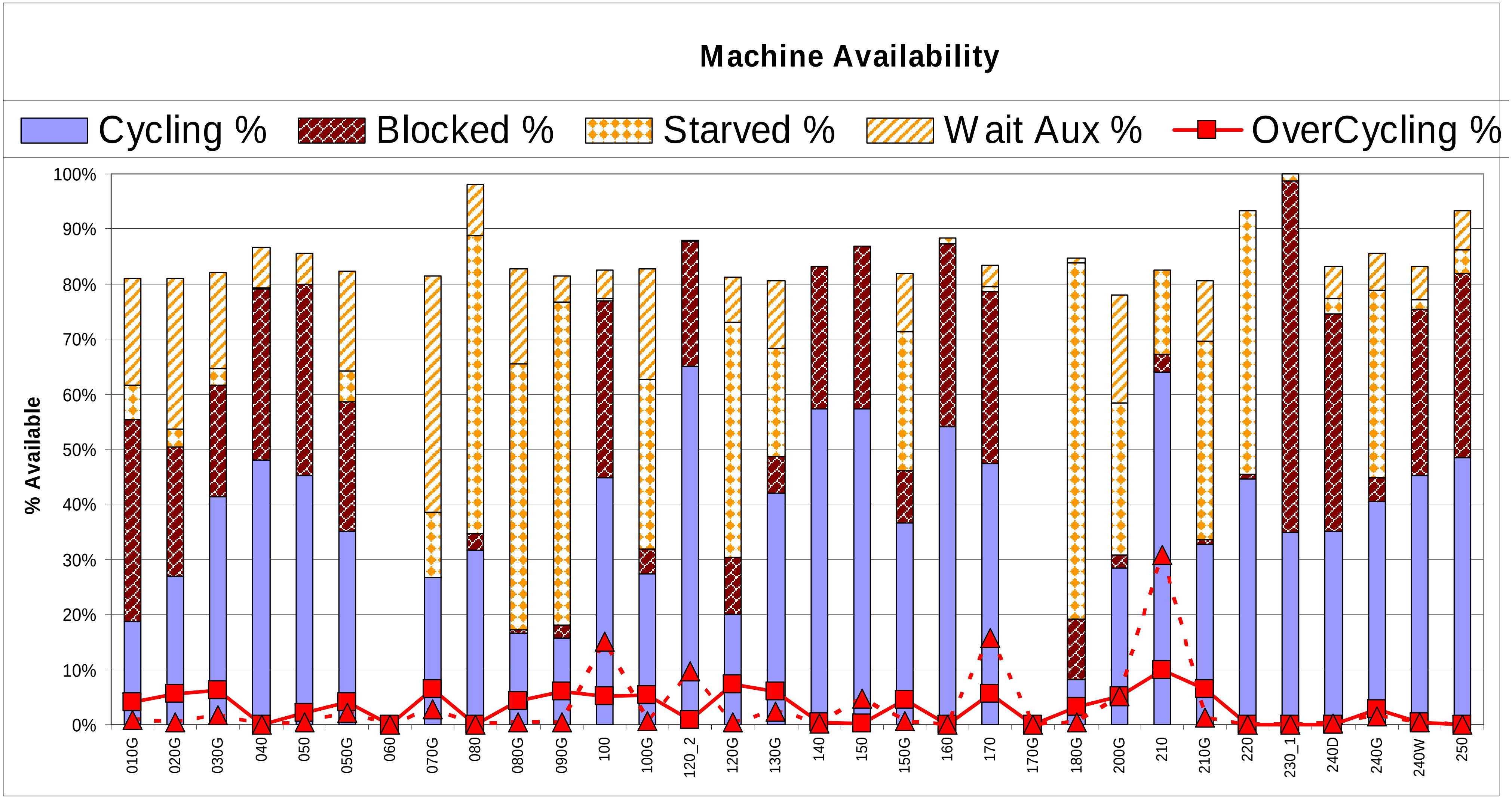
Sample Factory Fault Data

fac_id	job	event	fault-start-date	fault-start-time	fault-end-date	fault_end-time	fault_desc	A	shrt_desc	fault_secs_durn
609	0	E	11/18/2002	8:22:55	11/18/2002	8:25:57	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	182
609	0	E	11/18/2002	8:27:15	11/18/2002	8:31:07	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	232
609	0	E	11/18/2002	12:12:36	11/18/2002	12:17:34	OVERCYCLE_0:0:10	E	OVERCYCLE_0:	298
609	0	E	11/18/2002	17:26:43	11/18/2002	17:46:51	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	1208
609	0	E	11/18/2002	19:23:05	11/18/2002	19:23:19	OVERCYCLE_0:0:10	E	OVERCYCLE_0:	14
609	0	E	11/18/2002	19:26:50	11/18/2002	20:07:52	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	2462
609	0	E	11/18/2002	23:28:55	11/19/2002	8:15:07	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	31572
609	0	E	11/19/2002	8:20:11	11/19/2002	8:24:50	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	279
609	0	E	11/19/2002	11:34:17	11/19/2002	11:45:20	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	663
609	0	E	11/19/2002	11:54:06	11/19/2002	11:54:24	OVERCYCLE_0:0:10	E	OVERCYCLE_0:	18
609	0	E	11/19/2002	19:15:48	11/19/2002	22:14:42	NOT_IN_CYCLE_0:0:30	E	NOT_IN_CYCLE	10734

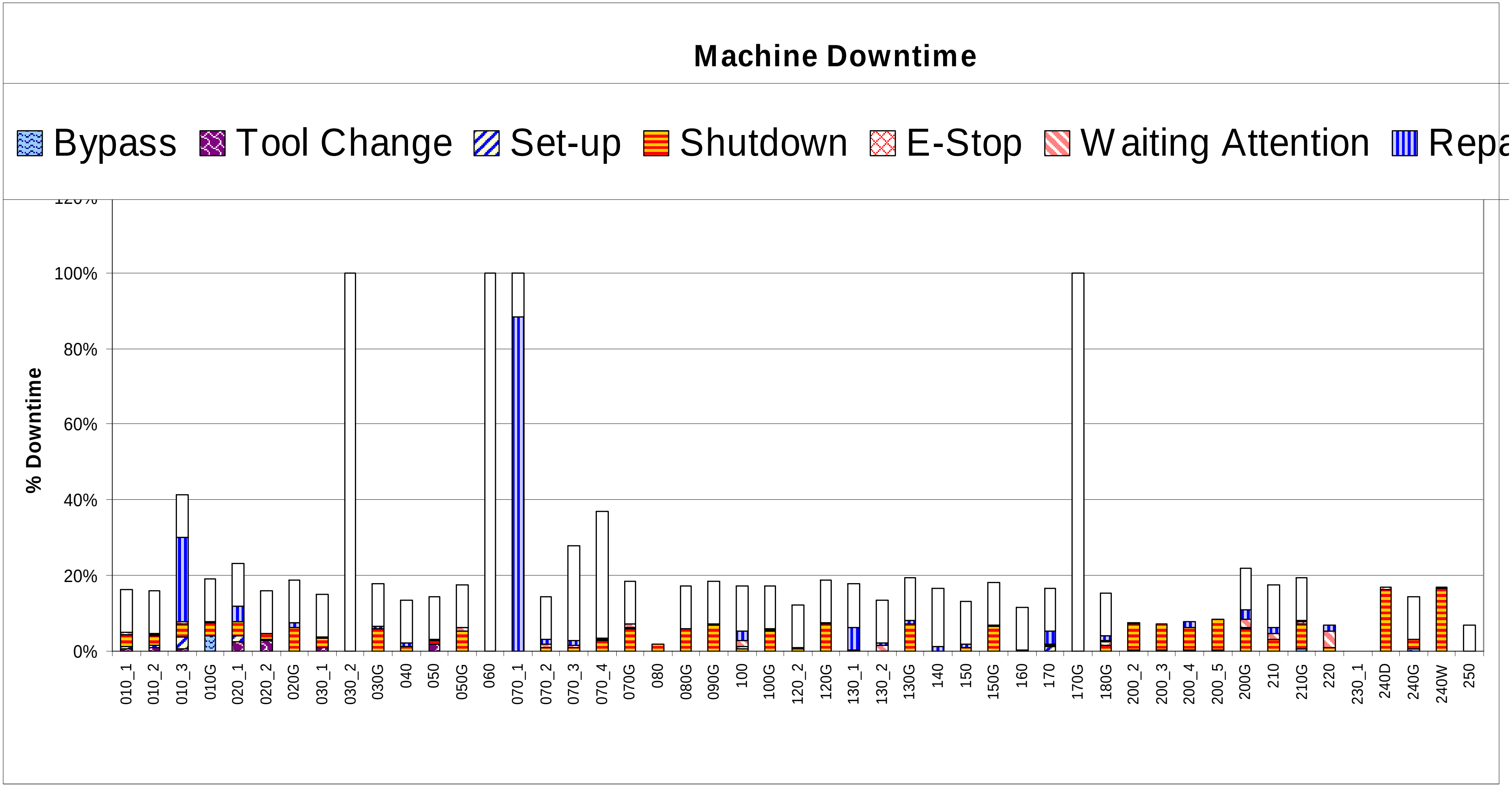
"Top 20" Faults

Date: 14-Feb-2005 To 18-Feb-2005	Feb 14 - Feb 18		Feb 07 - Feb 11		Jan 31 - Feb 04		Jan 24 - Jan 28	
Shift(s): 1026,1027	Occ/shift	Dur/shift	Occ/shift	Dur/shift	Occ/shift	Dur/shift	Occ/shift	Dur/shift
Fault Description	/Mod	/Mod	/Mod	/Mod	/Mod	/Mod	/Mod	/Mod
OP070-PROBE CYCLE - TOOL MISSING SPINDLE 2 CHECK TOOL	0	3780.4	1	799.2	2	280.2		
OP100-(35240) Communication RTC with HPI not built up	2	2087.3	3	42.4	8	172.7	2	213.4
OP070-ARS1(115) E-E13007 HVR MODULE SUPPLY VOLTAGE MISSING I182.54.4 PIN X7-3,	1	600.5	1	426.4				
OP130-SCRUBBER COOLANT PRESSURE FAILED	61	389.4	96	523.5	9	111.1	14	124.1
OP200G-LIMIT SWITCH FAULT LOADING HATCH 2 SQ2302,SQI2125	8	359	4	46.3				
OP140-System Program reports that a Grind Cycle was interuppted for some reason	14	354.3	27	544.5	8	254	14	105.2
OP240G-SAFETY DOOR NOT CLOSED OUTGOING CONVEYOR	9	329	19	270.4	1	16.5		
OP150-System Program reports that a Grind Cycle was interuppted for some reason	8	292.9	8	289.4	8	163.9	1	12.7
OP160-System Program reports that a Grind Cycle was interuppted for some reason	6	288.7	27	357.3	15	194.1	10	78.6
OP100G-E-STOP SYSTEM KA2801	1	286			4	0.7	1	0.1
OP130-System Program reports that a Grind Cycle was interuppted for some reason	16	283.2	26	452.3	15	148.1	7	228.7
OP210-BLOW-OFF ROTATION AT HOME BWD. SWITCH NOT ON	1	141.7						
OP210G-NO PART IN MACHINE 5 WHILE UNLOADING	11	140.8						
OP210-CONTROL VOLTAGE OFF	2	133.8	1	0.7	4	6.6	6	21.7
OP210G-SAFETY RELAY DRIVES NOT OK KA2901	8	129.6	2	3.6	6	31	2	18
OP130G-CLEAR/AUTOMATIC SIGNAL DISABLED DURING PART CHANGE MACHINE 3	2	122.7			2	9.8	1	2.2
OP140-COOLANT RETURN PUMP FAULT	5	116.9			1	4.2	1	5.1
OP030-F344 PROGRAM IS NOT GENERATED PROPERLY	2	114	2	76.3	1	179.9	1	10.5
OP220-Sta.2 Return Film Flag Reset Fault	24	112.5						
OP130-LH HYDRAULIC LIFT OIL PRESSURE LOW	1	109.2			1	282		
OP130G-E-STOP SYSTEM KA2801	2	108.6						
OP210G-SAFETY DOOR NOT CLOSED MACHINE 1	2	105.6	1	13.3	4	97.9		
OP220-Sta.1 E-Stop	10	98.2	10	146.9	13	64.5	6	89.5
OP150G-E-STOP SYSTEM KA2801	2	96.1	1	0.1				
OP010-	4	95.8	1	81.6	8	144.2	3	89.3
OP030-F192 STEADY TOP 1: CLAMPING PRESSURE NOT OK	11	94.5						
OP220-Gantry Emergency Stop Fault	9	89.9	2	53.6	3	56.9	5	70.4
OP150G-SAFETY DOOR NOT CLOSED BUFFER 1	17	88						
OP140-WHEEL SCRUBBER COOLANT PRESSURE FAILED	13	86.9	4	83.2	6	34.2	2	3.8
OP130G-SAFETY DOOR NOT CLOSED BUFFER 2	16	84.4						
OP210-VERTICAL VISIT DOOR NOT CLOSED SAFETY SWITCH	1	83.1						
OP220-Sta.2 Extend Film Flag Reset Fault	22	80.1						
OP130-WORK PUSHER NOT RETRACTED	15	78.5	5	45.7			29	285.7
OP130G-PART PRESENT SWITCH FAULT NEST 2	4	77.7	1	3.8	1	6.2		
OP030-F193 STEADY TOP 1: COMMAND NOT EXECUTED (TIME)	6	75.6						
OP230-LEFT AND RIGHT GATES OPENED - IW3.0.10:X2	7	57.7	0	7.8	1	2		
OP220-Sta.1 Broken Film	16	55.2	36	64.9	94	232.3	23	54.8
OP230-EMERGENCY PUSHBUTTON PRESSED FROM LEFT GATE - IW3.0.10:X9	0	55.1	1	11.8	4	47.6	1	56.9
OP210G-E-STOP MACHINE 2	7	54.9	1	0.4	5	30.3	2	0.2
OP210-PALLET MUST TO BE LOADED ONTO THE FORK LIFT	18	54.3			5	17.3		

Plant Availability Data



Plant Downtime Data



Step 5 – Root Cause Analysis and Corrective Action

- Analyze the data to provide input to a Corrective Action Team
  - Weibull analysis if failure times are provided
  - Pareto analysis for fault and repair summaries
- Identify the BIG Problems
- Perform similar structured problem Solving as in Step 2
- Follow up with review of Plant Maintenance Data 2 to 3 months after Corrective Action implemented

Step 6 – Observe the Equipment

- **Set up a fixed time observation of the equipment in operation**
- **Establish methodology and ground rules**
  - Observers are present whenever manufacturing time is scheduled
  - Total observation time is predetermined, usually 100 hours of scheduled time
  - Observers do not assist plant personnel
  - Downtime codes are predefined
  - All operational events as well as faults are documented
- Summarize downtime and uptime data
  - Graphically present results
- Identify high priority negative events

Step 6 – Observe the Equipment – 2

Downtime Codes

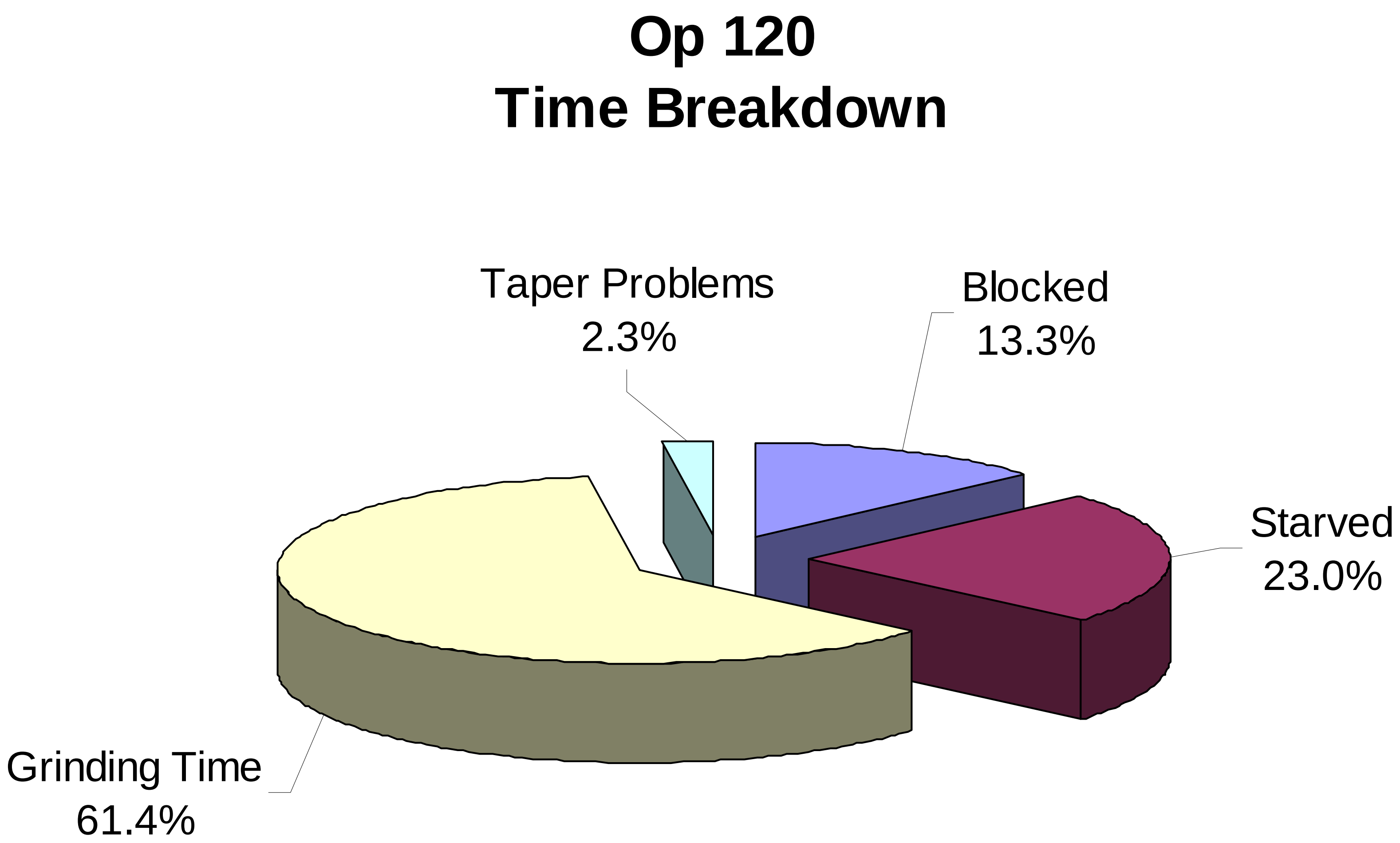
Coolant Codes		Gage Codes		Mat'l Hndlng		Machine Codes		Operator Codes		Stock Codes		Tooling Codes		Quality Defect Codes	
D01	Coolant Flow Inadequate	G01	Gage not Advanced	H01	Machine Automation fault	M01	Servo Failure	O01	Start of Shift	S01	Conveyor Full	T01	Unscheduled Wheel change	QA	Runout
		G02	Gage Won't Retract			M02	Limit Switch Failure	O02	End of Shift	S02	Conveyor Empty	T02	Wheel Broken	QB	Roundness
						M03	Control failure	O03	Break	S03	Loader Stuck in Machine	T03	Diamond Worn	QC	Profile
						M04	Proximity Switch Failure	O04	Lunch	S04	Loader not Serving Machine	T04	Bad Center	QD	Taper
						M05	Motor Failure	O05	Meeting			T05	Bad Workrest	QE	Size O.D.
						M06	Footstock Won't Advance							QF	Size I.D.
						M07	Headstock Won't Advance							QG	Surface Finish High
						M08	Dresser not up to speed							QH	Surface Finish Low
						M09	Dresser too fast							QI	Excessive Size Variation
						M10	Out of Balance							QJ	Size Length
						M11	Workrest not advanced							QG	Cylindricity
						M12	Workrest not retracted							QH	Parallelism

Step 6 – Observe the Equipment – 3

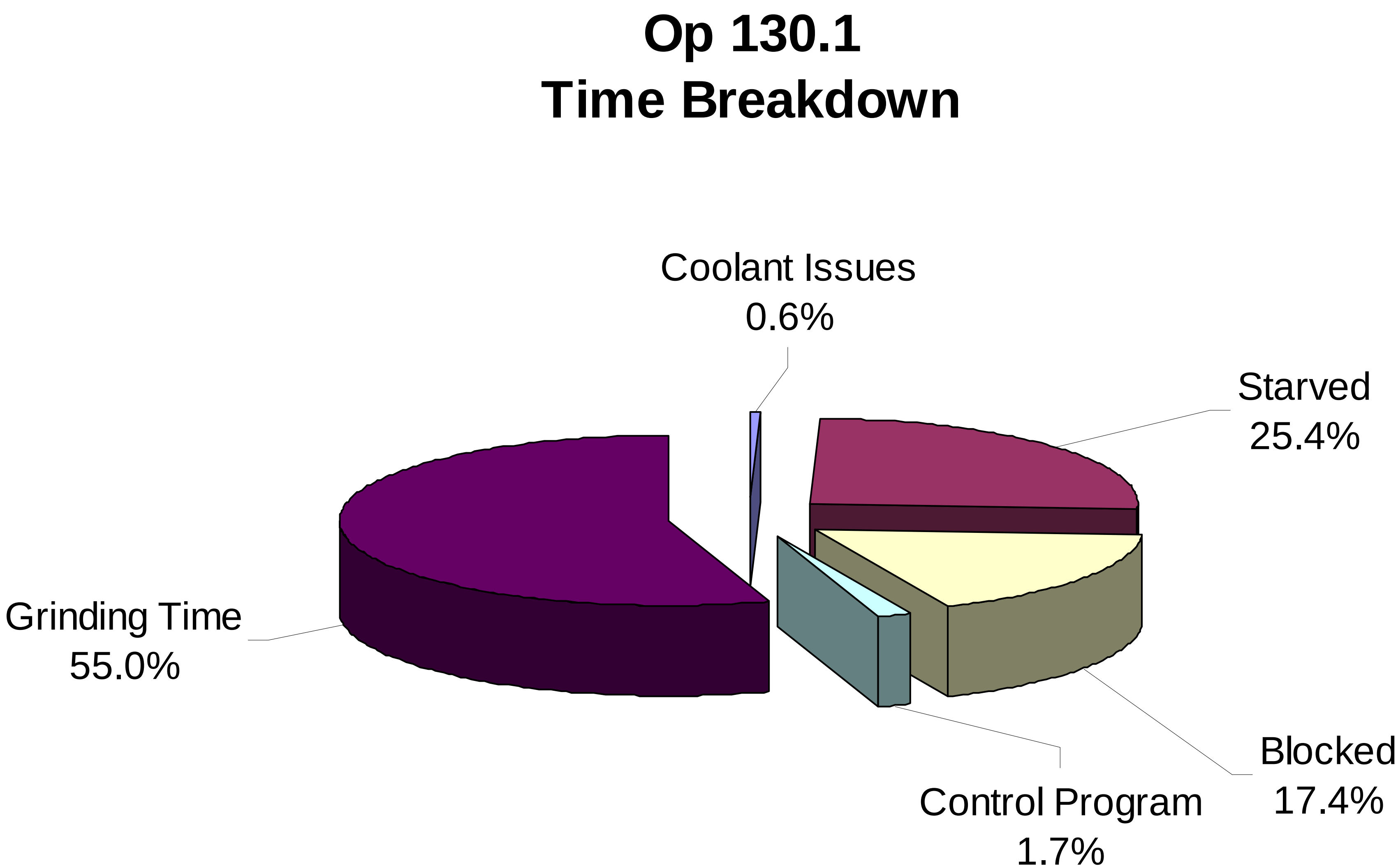
Sample Data Sheet

Date	Shift	Downtime Code	Time of Event	Start Repair Time	End of Event Time	Repair Time	Repair Time	Response Time	Response Time	Failure Report Number	Comments
20-Aug	**1**	**QE**	**5:00**	**5:00**	**12:40**	7:40	460	0:00	0		
		O07	**15:00**	**15:00**	**15:00**	0:00	0	0:00	0		
21-Aug		**O06**	**5:00**	**5:00**	**5:00**	0:00	0	0:00	0		
		O04	**5:00**	**5:00**	**5:10**	0:10	10	0:00	0		
		O01	**10:30**	**10:30**	**11:00**	0:30	30	0:00	0		
		S02	**12:27**	**12:27**	**12:30**	0:03	3	0:00	0		Gantry cannot move parts to OP200
		O07	**15:00**	**15:00**	**15:00**	0:00	0	0:00	0		
22-Aug		**O06**	**5:00**	**5:00**	**5:00**	0:00	0	0:00	0		
		O04	**5:00**	**5:00**	**5:10**	0:10	10	0:00	0		
		M02	**6:15**	**6:15**	**6:30**	0:15	15	0:00	0		Footstock Overtravel Fault-
		S02	**9:40**	**9:40**	**9:49**	0:09	9	0:00	0		
		O01	**11:00**	**11:00**	**11:30**	0:30	30	0:00	0		
		O07	**15:00**	**15:00**	**15:00**	0:00	0	0:00	0		
23-Aug		**O06**	**5:00**	**5:00**	**5:00**	0:00	0	0:00	0		
		O04	**5:00**	**5:00**	**5:10**	0:10	10	0:00	0		
		T02	**9:13**	**9:13**	**13:43**	4:30	270	0:00	0		Excessive runout-Changed wheels
		O05	**14:25**	**14:25**	**14:30**	0:05	5	0:00	0		
		O07	**15:30**	**15:30**	**15:30**	0:00	0	0:00	0		
24-Aug		**O06**	**5:00**	**5:00**	**5:00**	0:00	0	0:00	0		
		O04	**5:00**	**5:00**	**5:35**	0:35	35	0:00	0		
		M16	**7:00**	**7:00**	**7:20**	0:20	20	0:00	0		Reduced cycle time
		M16	**7:30**	**7:30**	**7:36**	0:06	6	0:00	0		Reduced cycle time
		D01	**7:45**	**7:45**	**8:00**	0:15	15	0:00	0		
		M16	**8:23**	**8:23**	**8:25**	0:02	2	0:00	0		Reduced cycle time

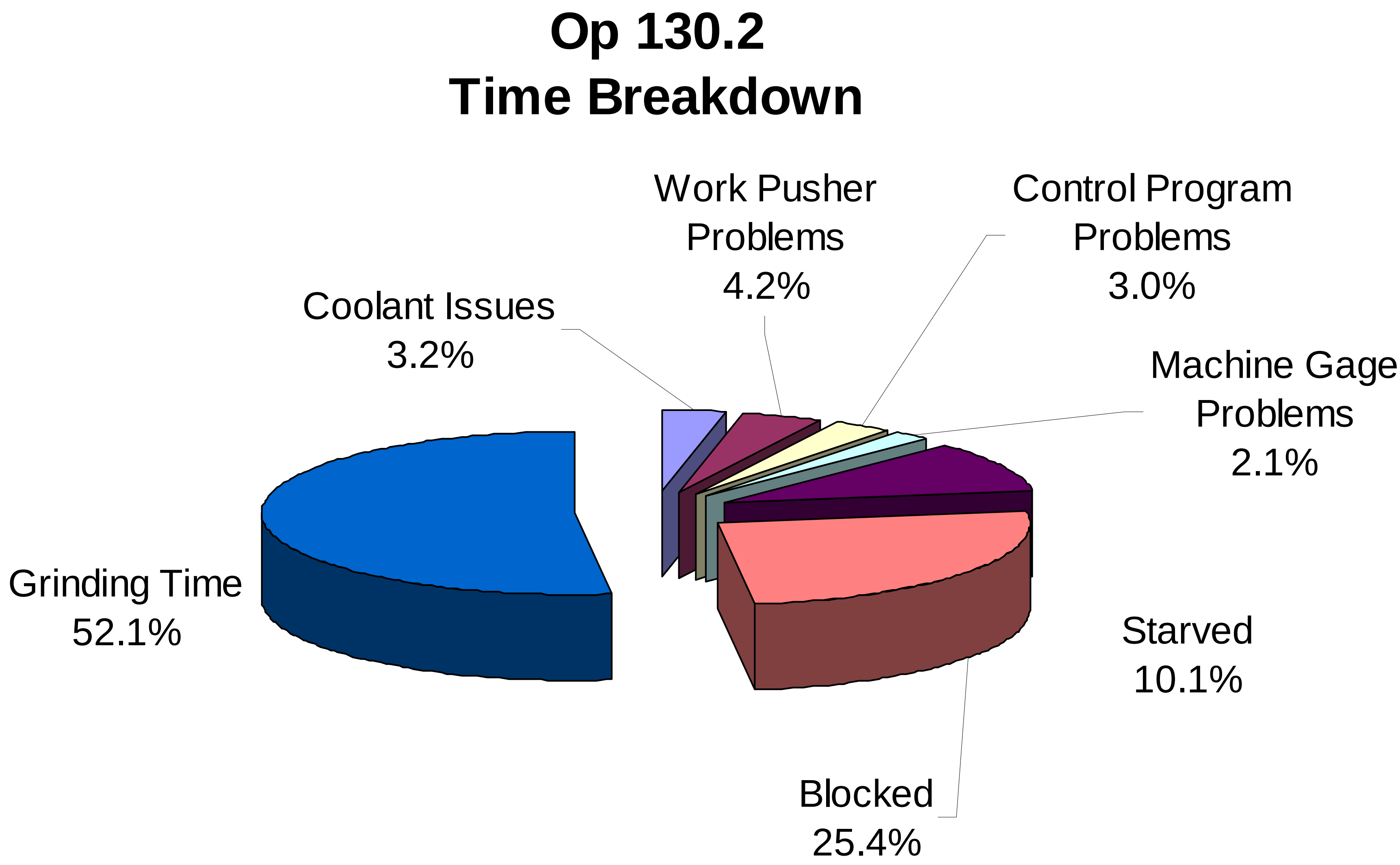
Step 6 – Observe the Equipment – 4



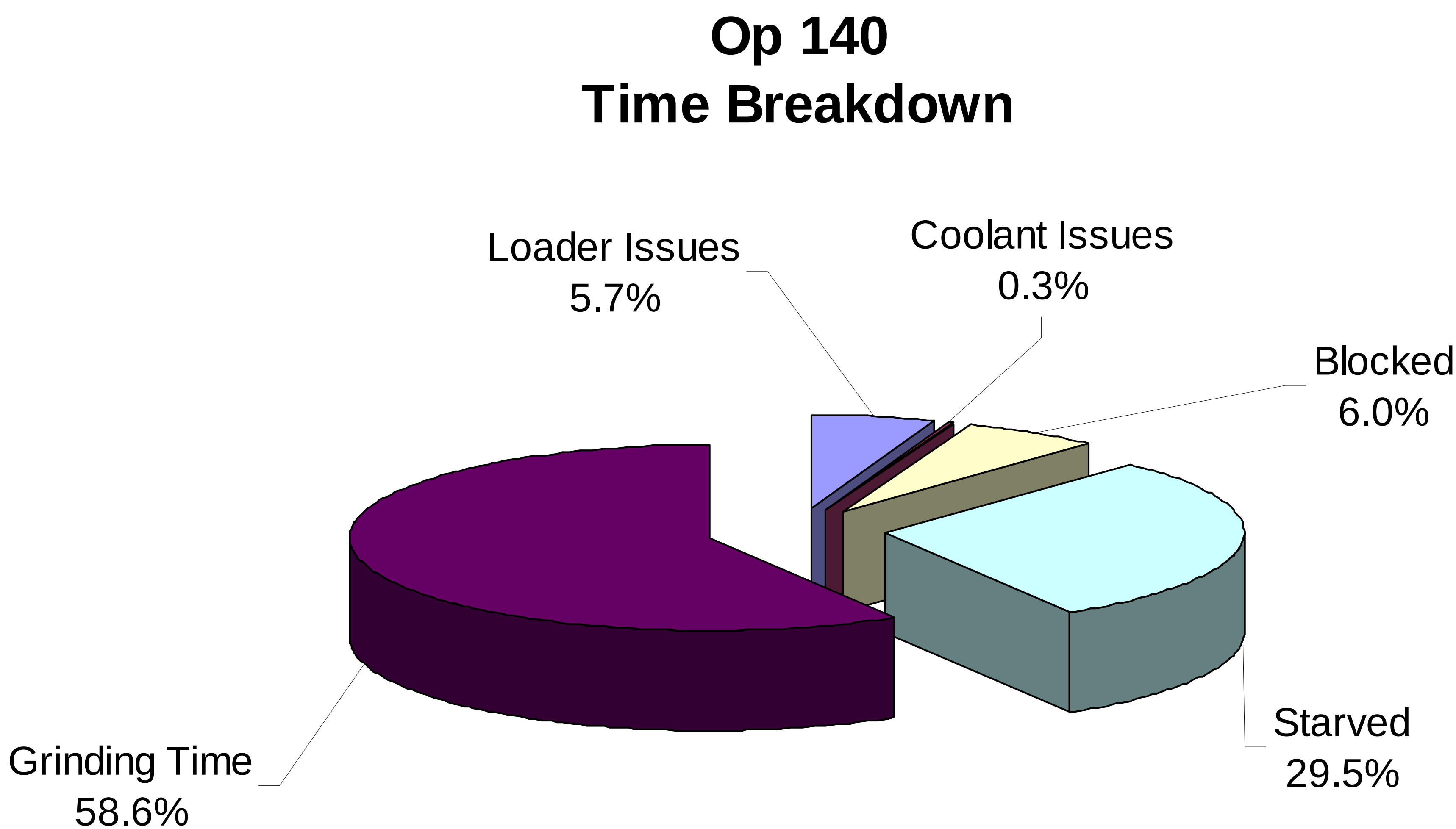
Step 6 – Observe the Equipment - 5



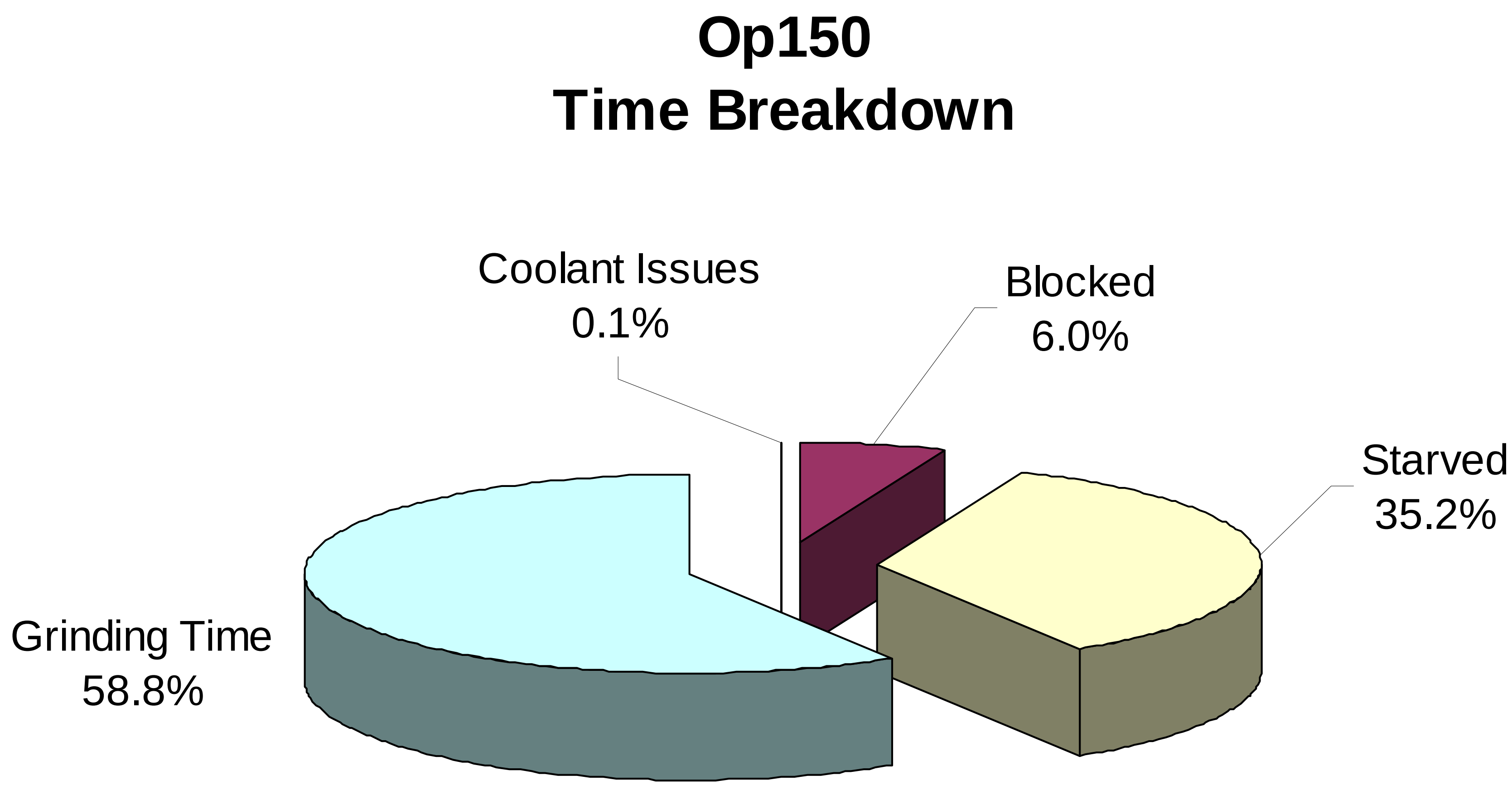
Step 6 – Observe the Equipment - 6



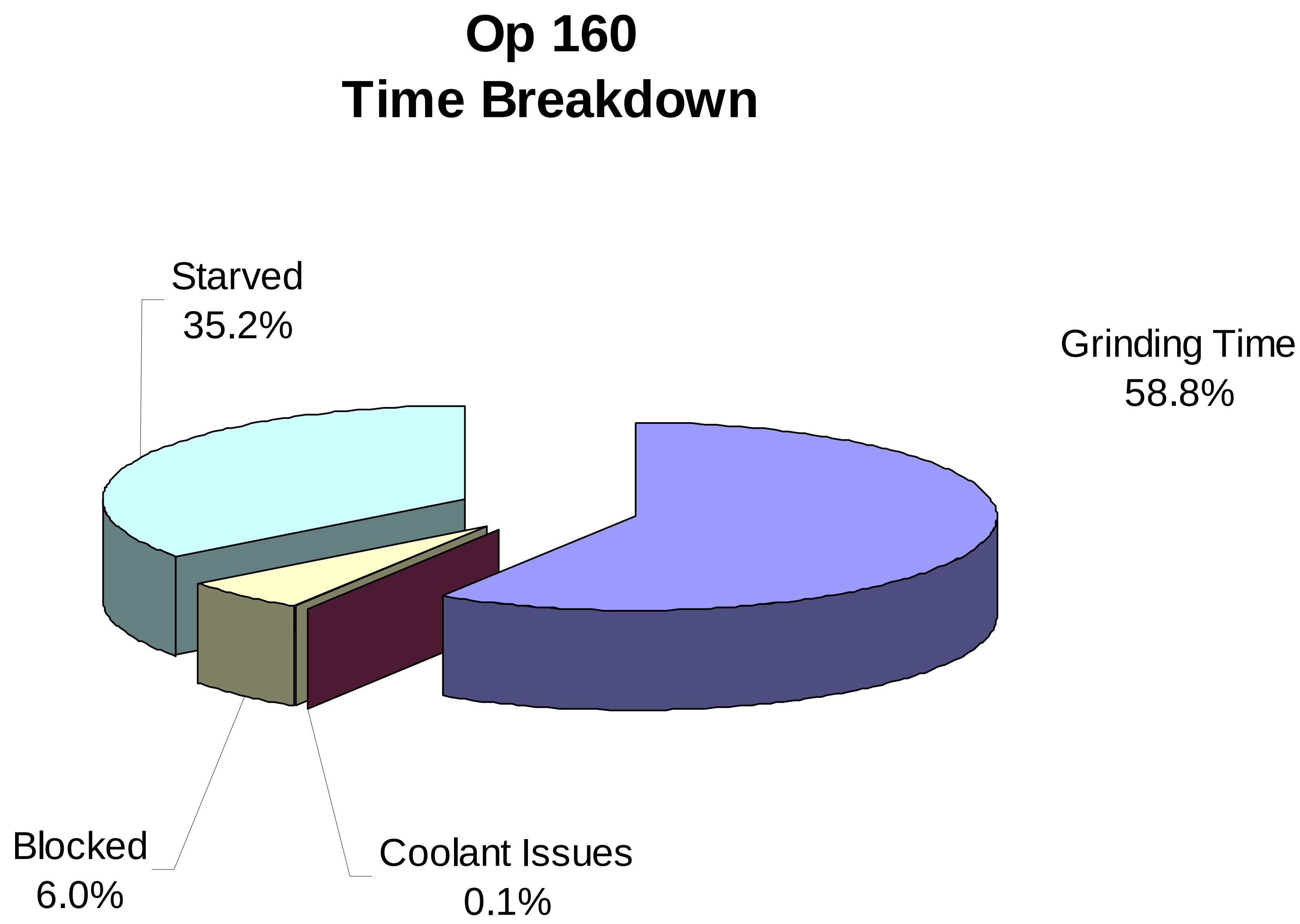
Step 6 – Observe the Equipment - 7



Step 6 – Observe the Equipment - 8



Step 6 – Observe the Equipment - 9



Step 6 – Observe the Equipment – 10

Identify Problems for Corrective Action

- Significant Downtime Events other than Blocked and Starved
  - Excessive Runout due to damaged wheel – 430 minutes
    - Wheel change to cure excessive runout – 270 minutes
  - Reprogramming Control for cycle time and other control issues - 73 minutes
  - Gantry Problems – 178 minutes

Step 7 – Investigate the Root Causes of the Identified Problems, Develop and Implement Corrective Action

- Observation should identify causes of significant downtime
- Root cause analysis should be developed using same team approach as steps 2 and 5
- Follow-up will be to repeat Observation as Step 8

Step 8 – Repeat the Observation

- Use same rules as original observation
- Schedule at least 3 months after corrective action implemented
- If significant issues still exist, repeat step 7

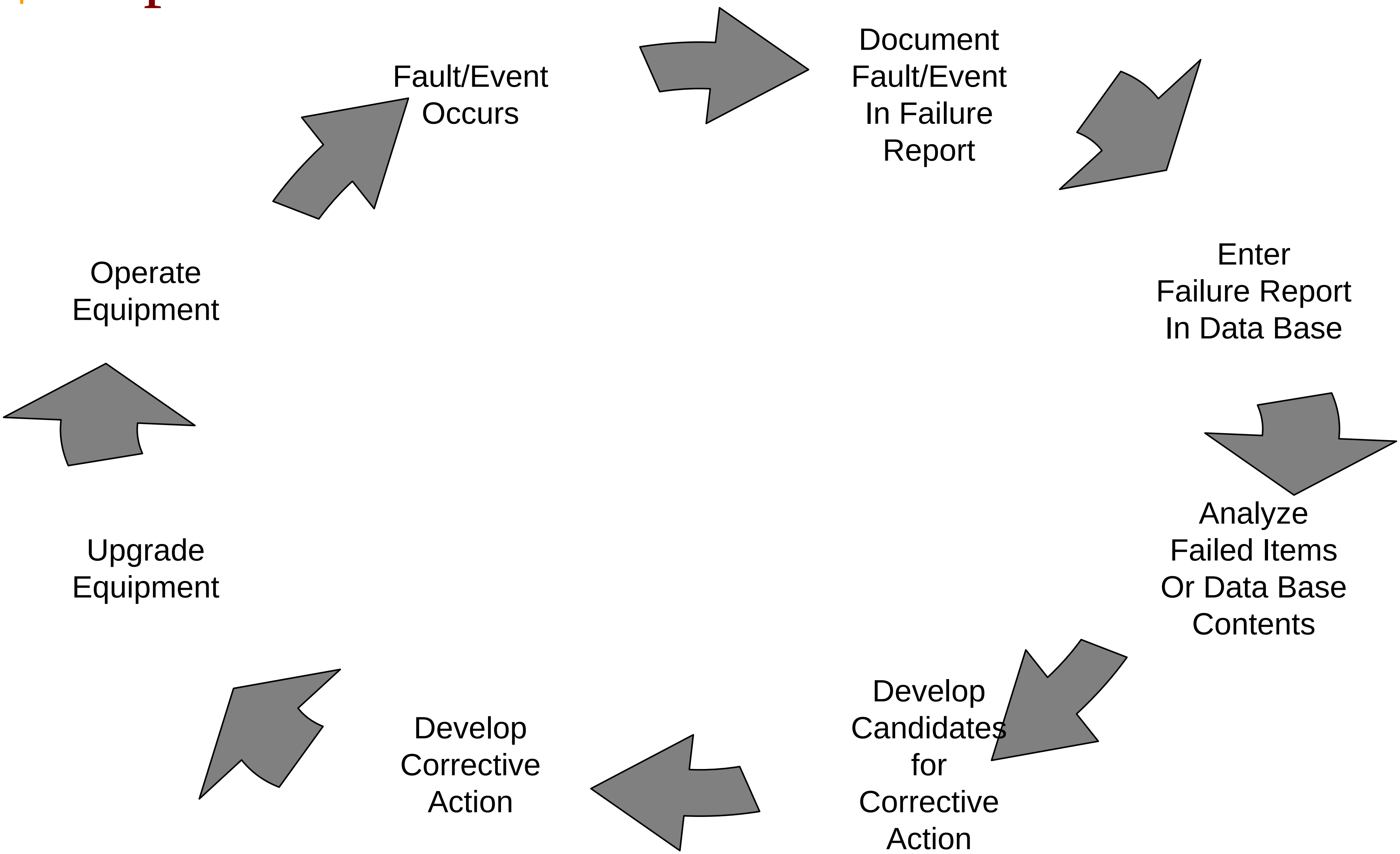
Step 9 – Institute a Closed Loop Failure Reporting and Corrective Action System (FRACAS)

- Almost all Maintenance and Failure Reporting Systems masquerade as a Closed Loop FRACAS
- Almost all of these systems miss the target by a large margin
- These systems are rarely "closed loop"
- Many occurrences are not documented
- Consistency of documentation leaves much to be desired
- Failure Analysis is rarely performed

Step 9 – Institute a Closed Loop Failure Reporting and Corrective Action System (FRACAS) - 2

- Requirements
  - Document all occurrences, even minor ones
  - Document all symptoms
  - Document all repair actions, including “None Taken”
  - Analyze removed components, fluids, etc.
    - Chemical and Physics of failure analysis
  - Document system state at failure occurrence
  - Digital photography of failed items when words may be inadequate
  - Feedback results to process and equipment designers

Step 9 – FRACAS - 3



Step 9 – Condition Monitoring/ On-Condition Repair

- Maintenance on condition
  - Vibration monitoring and Analysis
    - Built-in sensors
    - “Portable” equipment
  - Temperature monitoring and analysis
    - Built-in sensors
    - IR guns
  - Chemical monitoring and analysis
    - Sample and analyze all fluids
    - In-tank continuous fluid monitoring

Step 9 – Condition Monitoring/ On-Condition Repair

- Perform condition monitoring continuously for built-in sensors
- Perform condition monitoring periodically for "portable" monitors
  - Establish frequency sufficient to identify condition change early enough to avoid unscheduled maintenance
- Establish thresholds for monitored systems
- Perform maintenance when threshold is exceeded
  - Schedule maintenance on maintenance shift, or to minimally impact production

Relating Measured Performance to Specified Requirements

- Operational (Equipment) Availability or % Uptime are rational requirements for manufacturing equipment
- Performance measurements should be compared to the specified requirements
- Process and Design Improvements are necessary until measured performance consistently meets or exceeds specified performance
- Do not let perfection become the enemy of good, very good or excellent
- Cost of each % improvement increases as overall performance increases
  - More $ to go from 98% to 99%, than from 95% to 96%

Summary

- Any and All information can be used to solve Manufacturing Reliability problems
- All data can be valuable, but consistent, complete data can be more valuable
- Solving one problem will open the doors to solve more problems
- Thoroughness and consistency of approach will win the confidence of manufacturing personnel and provide more and better data
- Closed-loop FRACAS and/or Condition-monitoring Maintenance are the goals of any Availability Improvement Program