Lean Six Sigma Black Belt Certification

Project 2: V-Tech Hydraulic Solutions

Learning Objectives

On completion of this project, you will be able to:

- Understand the V-Tech Hydraulic Solutions project background
- Analyze the various factors that led to the high replacement requests for the hydraulic car jacks manufactured by the company
- Infer how operator trainings, process monitoring, and regular maintenance improved the manufacturing quality

Pre-Define Phase

V-Tech: Replacement Extract from SAP

Months	1 Ton	1.5 Ton	2 Ton	3 Ton	Replacements
Jan-18	1598	1239	1165	1027	2515
Feb-18	1379	1321	1212	1025	2317
Mar-18	1403	1134	1377	1011	2018
Apr-18	1317	1265	1298	1023	2179
May-18	1397	1283	1229	1009	2095
Jun-18	1325	1246	1206	992	2021
Jul-18	1319	1167	1176	1001	1959
Aug-18	1297	1175	1152	984	1753
Sep-18	1253	1139	1103	987	1950
Oct-18	1218	1127	1109	989	1751
Nov-18	1211	1099	1097	1005	1699
Dec-18	1207	1103	1095	976	1513
Jan-19	1195	1095	1087	979	1688
Feb-19	1181	1093	1089	983	1721
Mar-19	1157	1071	1083	995	1519
Apr-19	1153	1083	1071	977	1619
May-19	1174	1089	1069	971	1711
Jun-19	1169	1881	1063	953	1892

Case Study

Mr. Jack Smith is the new business head of V-Tech Hydraulic Solutions.

He has been worried about the high replacement report for the new business line of **car lift hydraulic bottle jack.** These jacks are manufactured for the last 18 months. He observed that the replacement percent for the jacks have been 40.80% with an average replacement rate of 1884 per month as per data extracts from SAP.

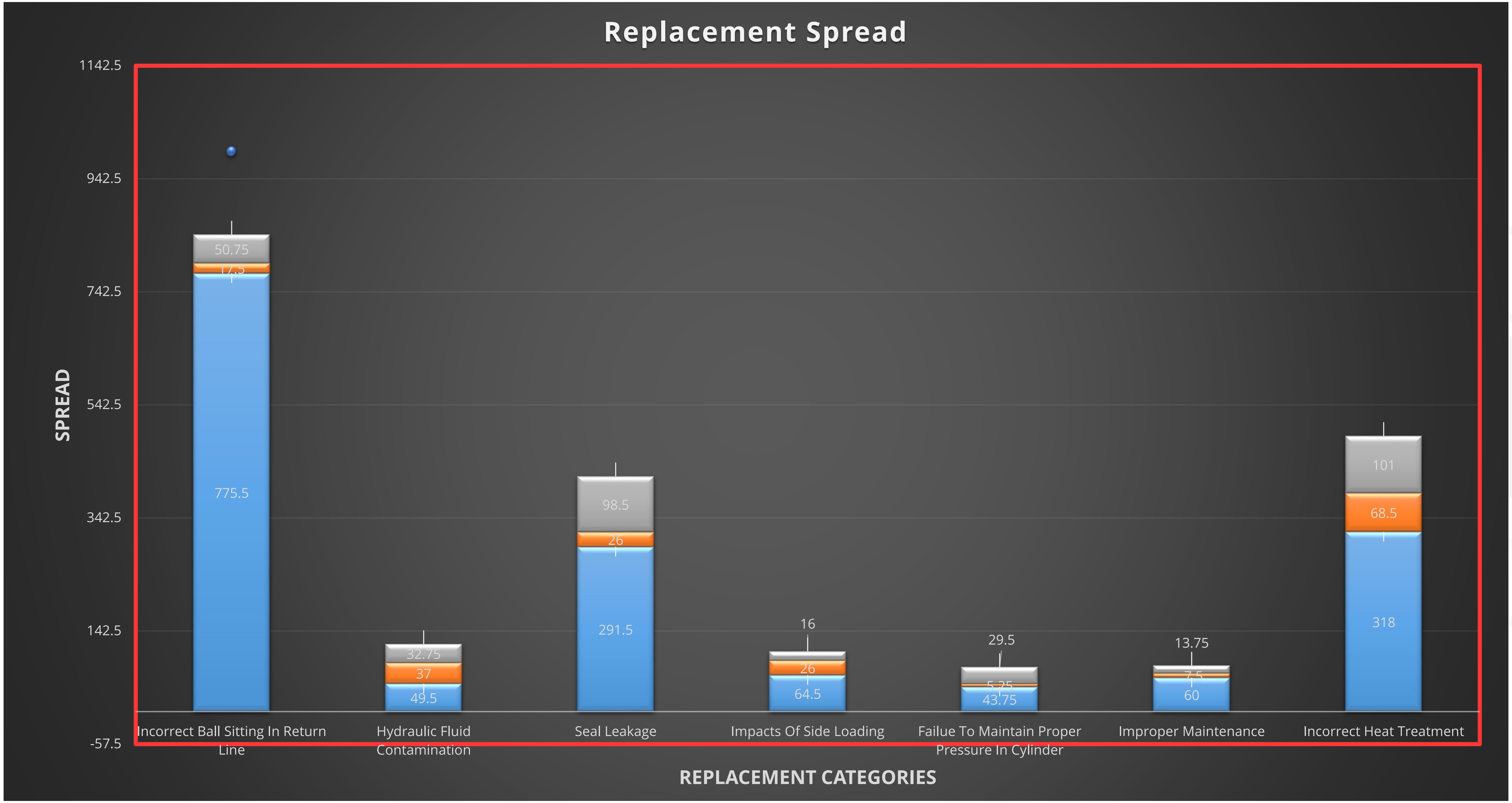
Mr. Smith hires Samuel Jonas, a Black Belt professional, to look into the situation and fix the problem.

The Data

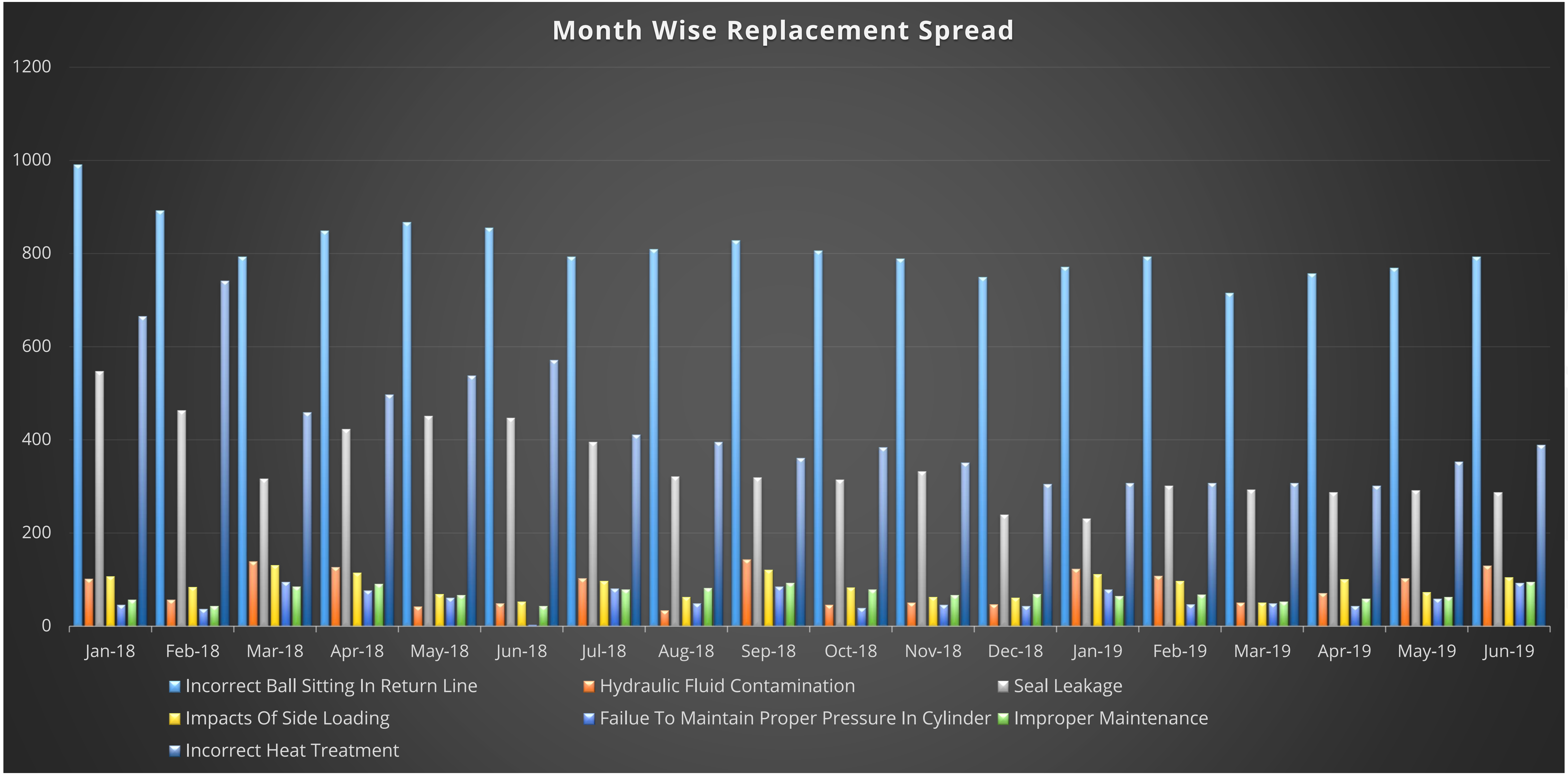
Samuel collects the rework data from the production unit, to get the insights on replacements.

Months	Incorrect Ball Sitting In Return Line	Hydraulic Fluid Contamination	Seal Leakage	Impacts Of Side Loading	Failure to Maintain Proper Pressure In Cylinder	Improper Maintenance	Incorrect Heat Treatment
Jan-18	991	102	547	107	46	57	665
Feb-18	892	57	463	84	37	43	741
Mar-18	793	139	316	131	95	85	459
Apr-18	849	127	423	115	77	91	497
May-18	867	42	451	69	61	67	538
Jun-18	855	49	447	53	3	43	571
Jul-18	793	103	395	97	81	79	411
Aug-18	809	34	321	63	49	82	395
Sep-18	828	143	319	121	85	93	361
Oct-18	806	46	314	83	39	79	384
Nov-18	789	51	332	63	46	67	351
Dec-18	749	47	239	61	43	69	305
Jan-19	771	123	231	112	79	65	307
Feb-19	793	108	301	97	47	68	307
Mar-19	715	51	293	51	49	53	307
Apr-19	757	71	287	101	43	59	301
May-19	769	103	291	73	59	63	353
Jun-19	793	130	287	105	93	95	389

Data Spread by Categories



Data Spread Month wise



Define Phase

Project Charter – Problem Statement

On an average, 40.80% of the car lift cylinder jacks are being replaced due to product failures, which on an average is draining out $471104 per month, making the line of business bleed and also making survival into business a big challenge.

Due to such huge rate of defectives, major clients viz. car manufacturers are highly dissatisfied and may cancel the contract in the next renewal.

Product failure is also causing injuries to the users which is bringing down the brand value.

Project Charter – Goal Statement

Replacements due to top 3 defects to be reduced in the following phased manner:

Target reduction in top 3 defects to be limited to 50% in Year 1

Target reduction in top 3 defects to be limited to 30% in Year 2

Target reduction in top 3 defects to be limited to 20% in Year 3

Project Charter – Business Case

Replacement cost saving analysis

Assumptions	Base timeline considered
Target reduction in top 3 defects to be limited to 50% in year 1	18 months
Target reduction in top 3 defects to be limited to 30% in year 2	Year 1
Target reduction in top 3 defects to be limited to 20% in year 3	Year 2
Status quo maintained for defect types apart from top 3	
*** Replacement cost saving being tracked from year 1 i.e. post full-scale completion of the project**	
Top 3 defects count contribution to replacement	28518
Top 3 defects contribution% to replacement in year 1	73%
Top 3 defects count contribution to replacement in year 2	44%
Top 3 defects count contribution to replacement in year 3	14%
*** Status quo maintained for defect types apart from top 3**	
Yearly replacement cost saving in year 1	$ 1526378
Yearly replacement cost saving in year 2	$ 3165820
Yearly replacement cost saving in year 3	$ 4861795
Total replacement cost saving	$ 9553993

Project Charter – Business Case (Contd.)

Cost Benefit Analysis

NPV and IRR				
Year	**Cost (in USD)**	**Benefits**	**Net Benefits (in USD)**	**Description**
			9.50%	Annual discount rates which management wants
0	-4567000	0	-4567000	Initial project investment
1	-8000	1526378	1534378	Returns
2	-4500	3165820	3170320	Returns
3	0	4861795	4861795	Returns
Totals	**-4579500**	**9553993**	**4999493**	
NPV			**2905338**	
IRR			**38.83%**	

Project Charter – Project Scoping

- Focusing on the top 3 defects
- Targeting to reduce the replacement occurring due to these top defects only
- Other reasons of replacements for the car lift cylinder jacks are beyond the scope of the project

Milestones

Define phase: 2 Months → Measure phase: 1 Month → Analyze phase: 1 Month → Improve phase: 1 Month → Control phase: 1 Month

Team Members

Samuel → Six Sigma BB

Sean → Process Owner

Michael → Production Manager

Jimmy → Six Sigma GB

Raphael → QC Inspector

RACI Model

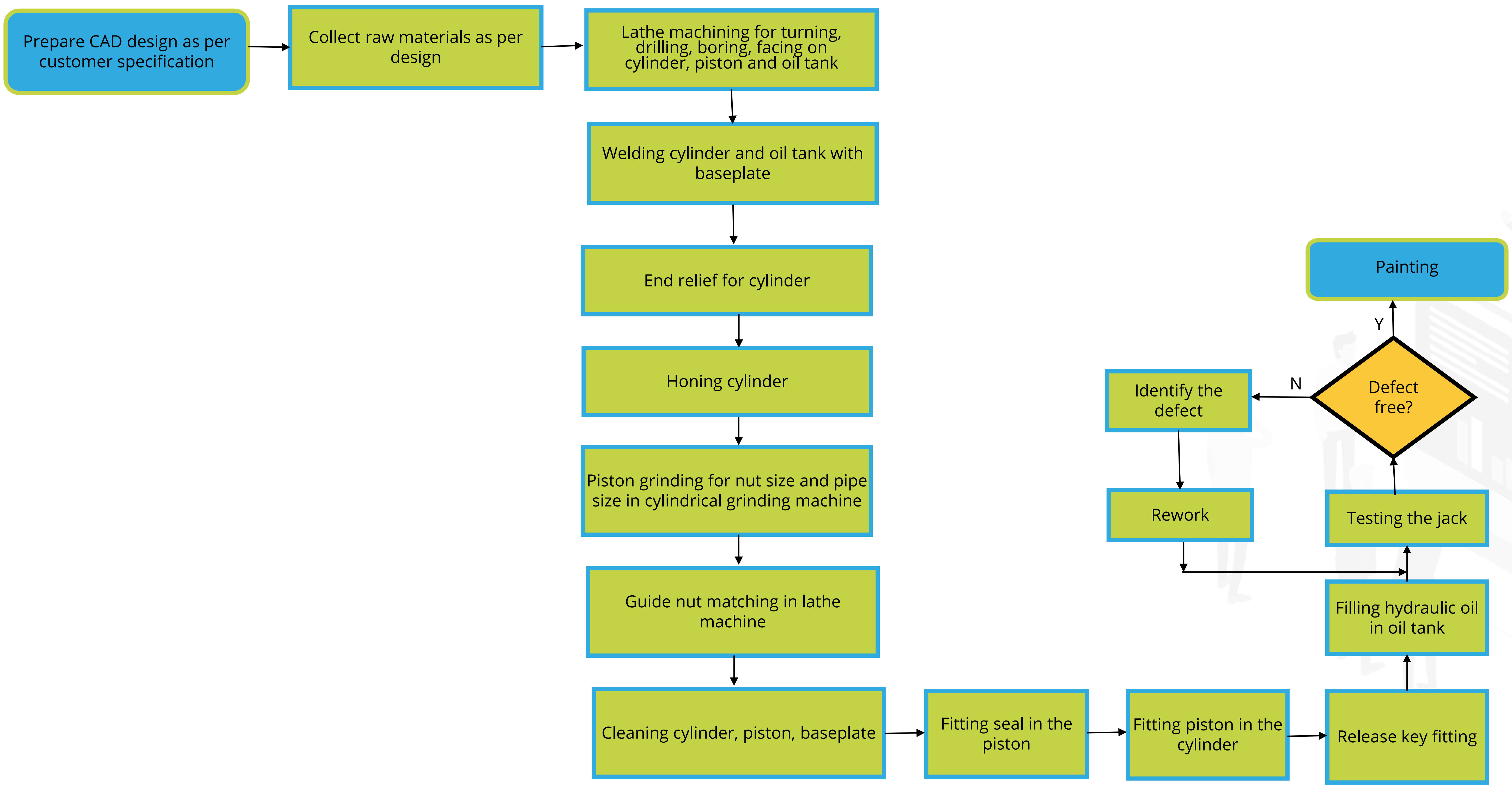
	Define	Measure	Analyze	Improve	Control
Samuel	A	R/A	R/A	R/A	A
Sean	C	C/I	I	C/I	A/I
Michael	C	C	I	I	R
Jimmy	R	R		R	A
Raphael	C	C	I	I	R

FMEA

System:	Cylinder Jack	Design Responsibility:			Samuel/Jimmy		FMEA Number:	Insert FMEA#		
Subsystem	Jack Malfunction						Page:	1		
Component	Car Lift Cylinder Jack						Prepared by:	Samuel		
Model:	model						FMEA Date:	9/6/2019		
Core Team:	Six Sigma Team									
Item/Part Function	**Potential failure mode**	**potential effect(s) of failure**	**Sev**	**Class**	**Potential cause(s) / mechanism(s) of failure**	**Occur**	**Current design controls prevention**	**Current design controls detection**	**Detect**	**R. P. N.**
Cylinder Jack	**Jack Bursting**	**Car resting on the jack getting damaged; operator may get injured**	**9**		**Failure to maintain pressure, incorrect heat treatment**	**9**	**None**	**None**	**9**	**729**
Cylinder Jack	**Jack Malfunction**	**Car resting on the jack getting damaged; operator may get injured**	**9**		**Incorrect ball sitting in return line; hydraulic fluid contamination; seal leakage; impacts of side loading; improper maintenance**	**8**	**None**	**None**	**9**	**648**

Process re-engineering is immediately required

High level Process Mapping



SIPOC

S	I	P	O	C
Suppliers	**Inputs**	**Process**	**Outputs**	**Customers**
Provider	Raw materials	**Start: prepare CAD design as per customer specification**	Hydraulic jack	Car manufacturers
V-tech hydraulic solutions	Lathe machine and operator			Stockist
Raw material vendors	Honing machine and operator	**High-level process description:**		Dealers
	Welding machine and operator	Collect raw materials as per design		Resellers
	Cylinder, piston, oil tank, baseplate, nut, pipe, seal, hydraulic oil	Lathe machining for turning, drilling, boring, facing on cylinder, piston and oil tank		End users
	Testing machines and operator	Welding cylinder and oil tank with baseplate		
	Paint	End relief for cylinder		
	Painter	Piston grinding for nut size and pipe size in cylindrical grinding machine		
		Guide nut matching in lathe machine		
		Cleaning cylinder, piston, baseplate		
		Fitting seal in the piston		
		Fitting piston in the cylinder		
		Release key fitting		
		Filling hydraulic oil in the oil tank		
		Testing		
		End: painting		

Measure Phase

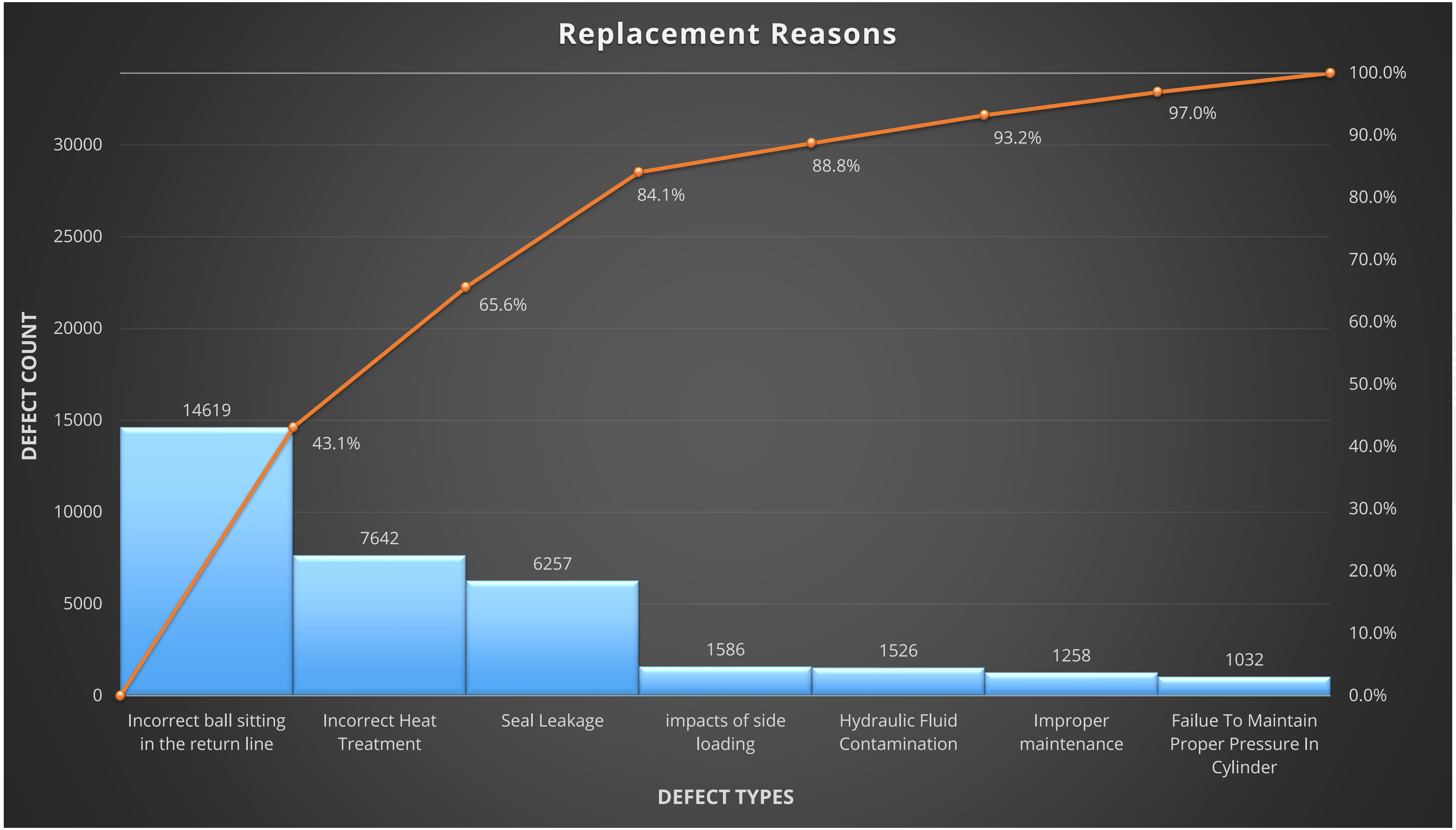
Current Process Sigma Level

Average replacement = 1884 ÷ { Average output per month = 4618 × Defect opportunities = 7 } = DPO = 0.0582812

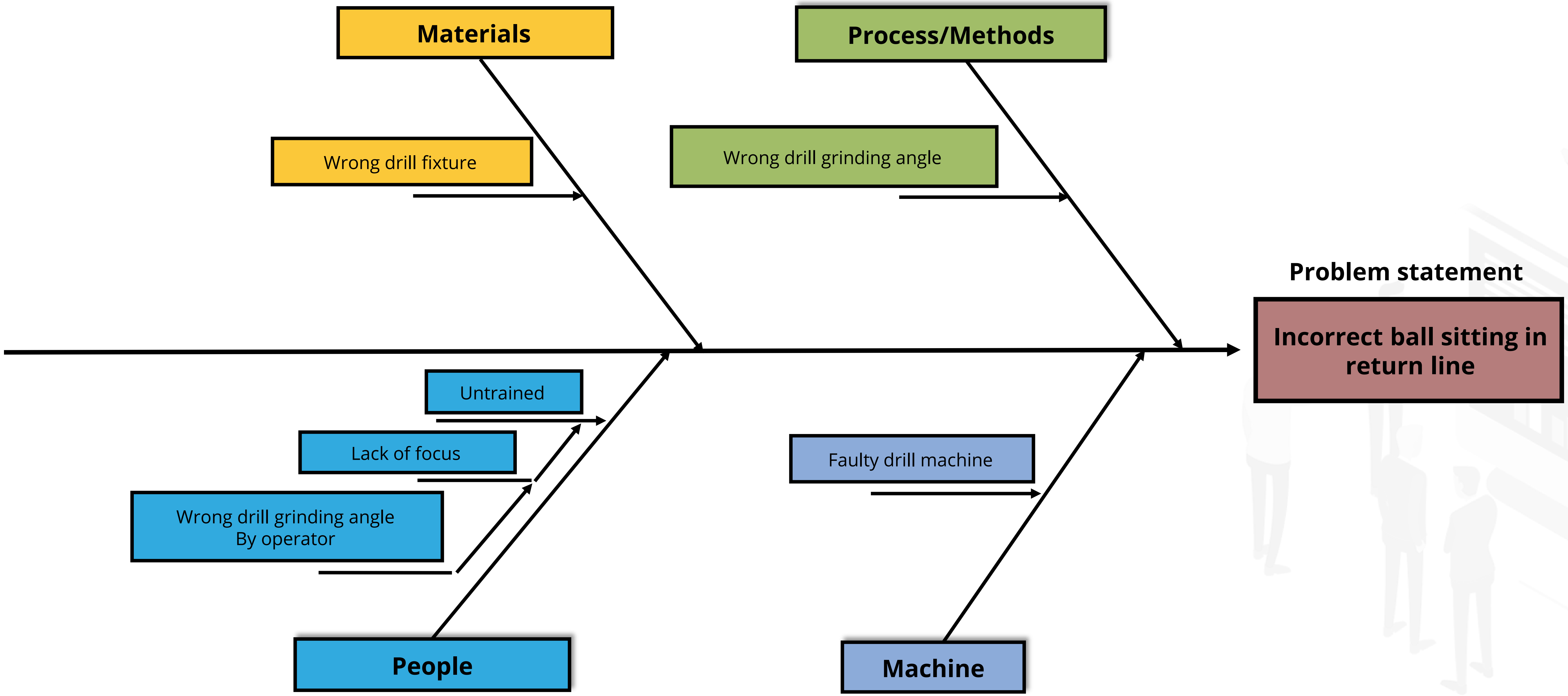
DPO = 0.0582812 × 1000000 = DPMO = 582821.26

Process Sigma Level: 1.2

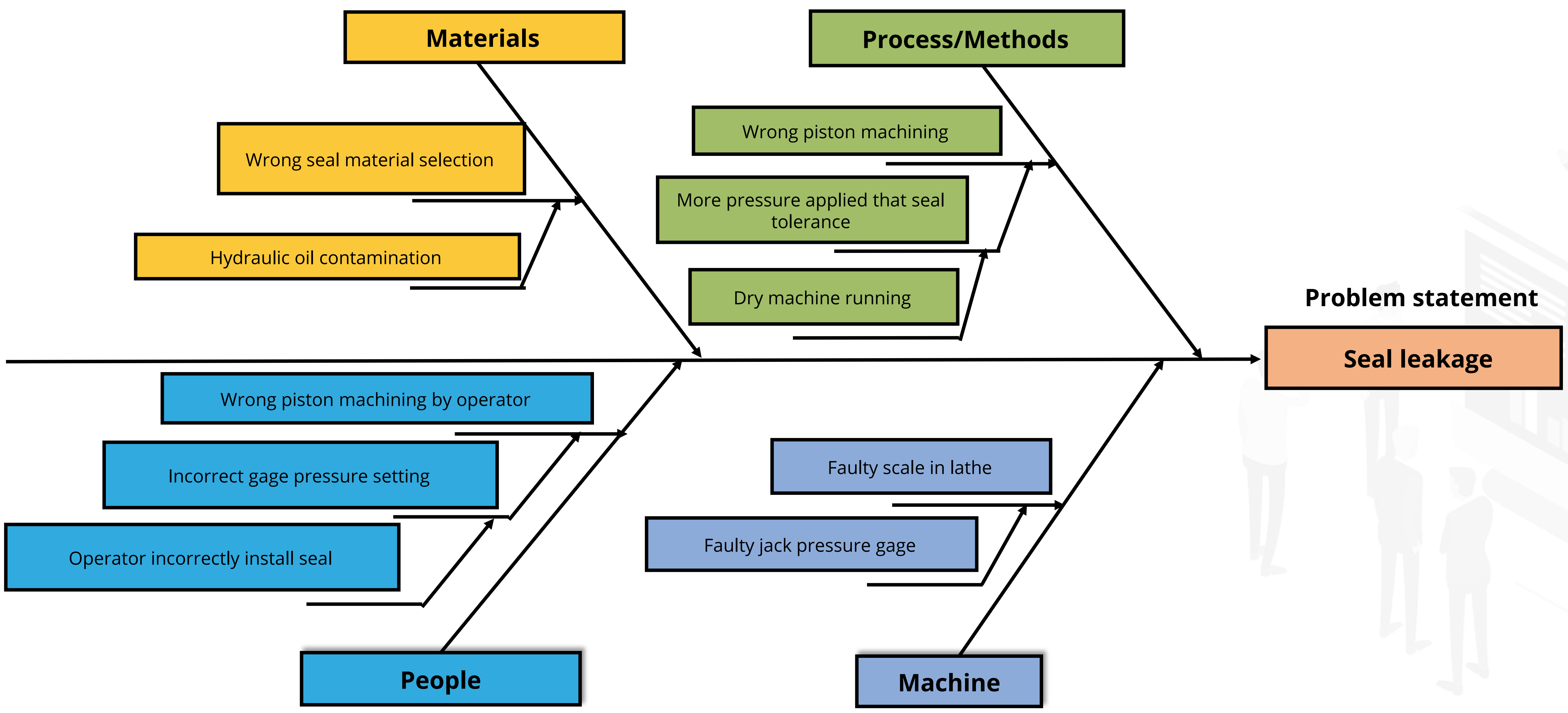
Vital Few


Replacement Reasons
DEFECT COUNT
30000
25000
20000
15000
10000
5000
0
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
14619
7642
6257
1586
1526
1258
1032
43.1%
65.6%
84.1%
88.8%
93.2%
97.0%
Incorrect ball sitting in the return line
Incorrect Heat Treatment
Seal Leakage
impacts of side loading
Hydraulic Fluid Contamination
Improper maintenance
Failue To Maintain Proper Pressure In Cylinder
DEFECT TYPES

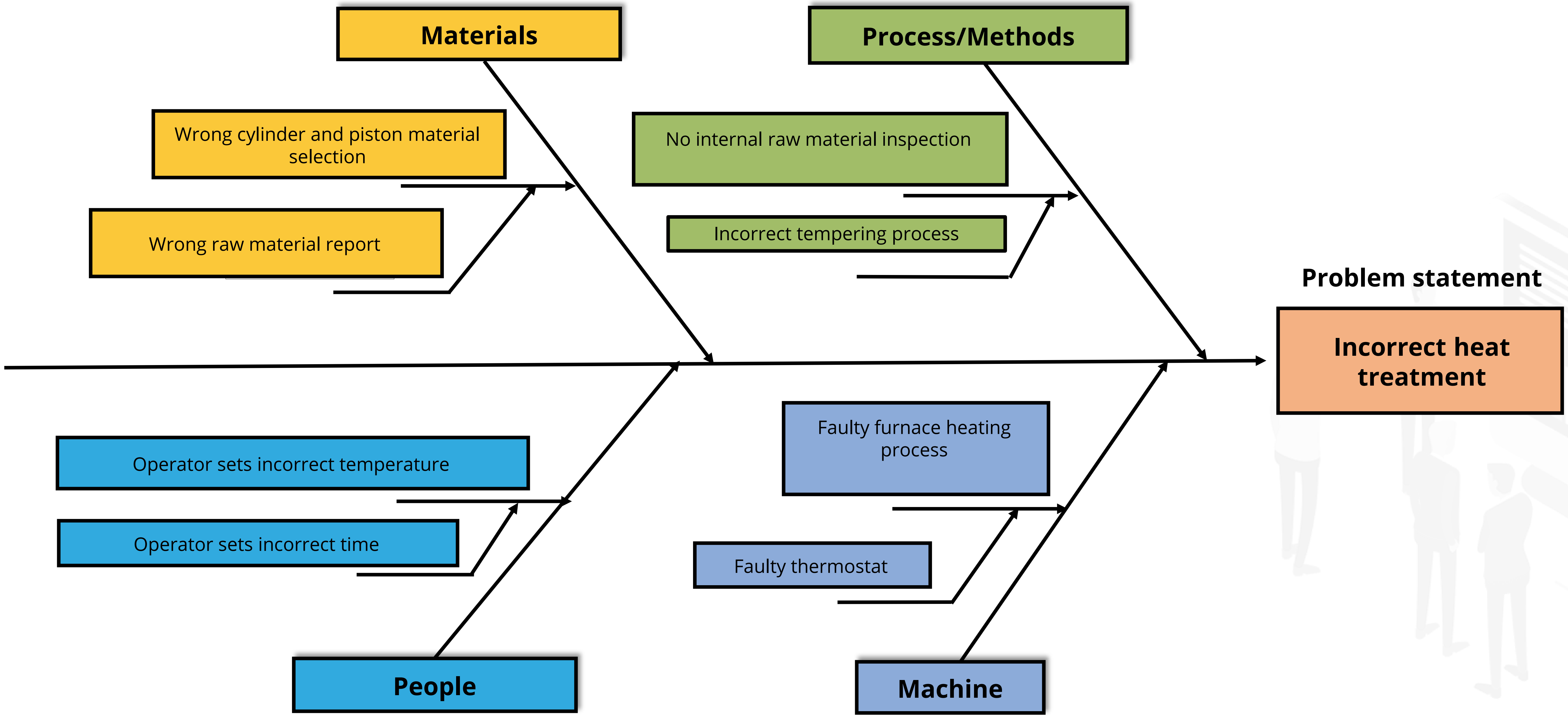
Cause and Effect



Cause and Effect (Contd.)



Cause and Effect (Contd.)



Gage R and R Test

Hardness heat treatment output

Gage R and R						Part Number								
Average and Range Method		1	2	3	4	5	6	7	8	9	10	Sum		
Appraiser 1	Trial 1	36.9	38.5	39.6	40.2	43.9	44.6	41.6	42.9	36.7	38.7	1203.400		
	Trial2	35.9	38.7	39.5	39.8	43.6	43.8	41.9	43	37.2	38.1			
	Trial3	36.7	37.9	39.6	40.1	42.7	43.2	40.8	42.1	36.3	38.9	398.300		
	Trial4												Xbar1	Reference
	Trial 5												40.11333	36.000
	Total	109.5	115.1	118.7	120.1	130.2	131.6	124.3	128	110.2	115.7			Bias
	Average-Appraiser 1	36.5	38.367	39.567	40.033	43.4	43.867	41.433	42.667	36.733	38.567		Rbar1	4.113
	Range1	1	0.8	0.1	0.4	1.2	1.4	1.1	0.9	0.9	0.8		0.86	
Appraiser 2	Trial 1	35.8	37.8	39.2	39.2	41.2	43.8	40.7	42.3	36.5	38.1	1181.800		
	Trial2	35.9	37.1	38.4	39.3	41.3	42.7	41.3	42.1	36.9	38.2			
	Trial3	35.8	37.9	38.9	39.1	41.1	42.9	41.5	41.7	37	38.1	394.000		
	Trial4												Xbar2	Reference
	Trial 5												39.39333	36.000
	Total	107.5	112.8	116.5	117.6	123.6	129.4	123.5	126.1	110.4	114.4			Bias
	Average-Appraiser 2	35.8333	37.6	38.833	39.2	41.2	43.133	41.167	42.033	36.8	38.133		Rbar2	3.393
	Range2	0.1	0.8	0.8	0.2	0.2	1.1	0.8	0.6	0.5	0.1		0.52	

Gage R and R Test (Contd.)

Hardness heat treatment output

		Constants					
Range Average	0.6900						
XDiff	0.7200	5 Trials	4 Trials	3 Trials	2 Trials	# Trials	3
UCL	37.0000	2.11	2.28	2.58	3.27	D4	2.58
LCL	36.0000	0	0	0	0	D3	0
Repeatability(EV)	0.4077	0.577	0.729	1.023	1.88	A2	1.023
Reproducibility(AV)	0.5036	0.4299	0.4857	0.5908	0.8862	K1	0.5908
Gage Capability(R and R)	0.6479	0.7071	0.5231			K2	0.7071
Spec Tolerance	8.8	2 Ops	3 Operators				

UCL represents the limit of the individual R's

Circle those beyond the limit.

Identify and correct causes

LCL = 0 D3=0 for up to 7 trials

Gage system may be acceptable based on importance of application and cost

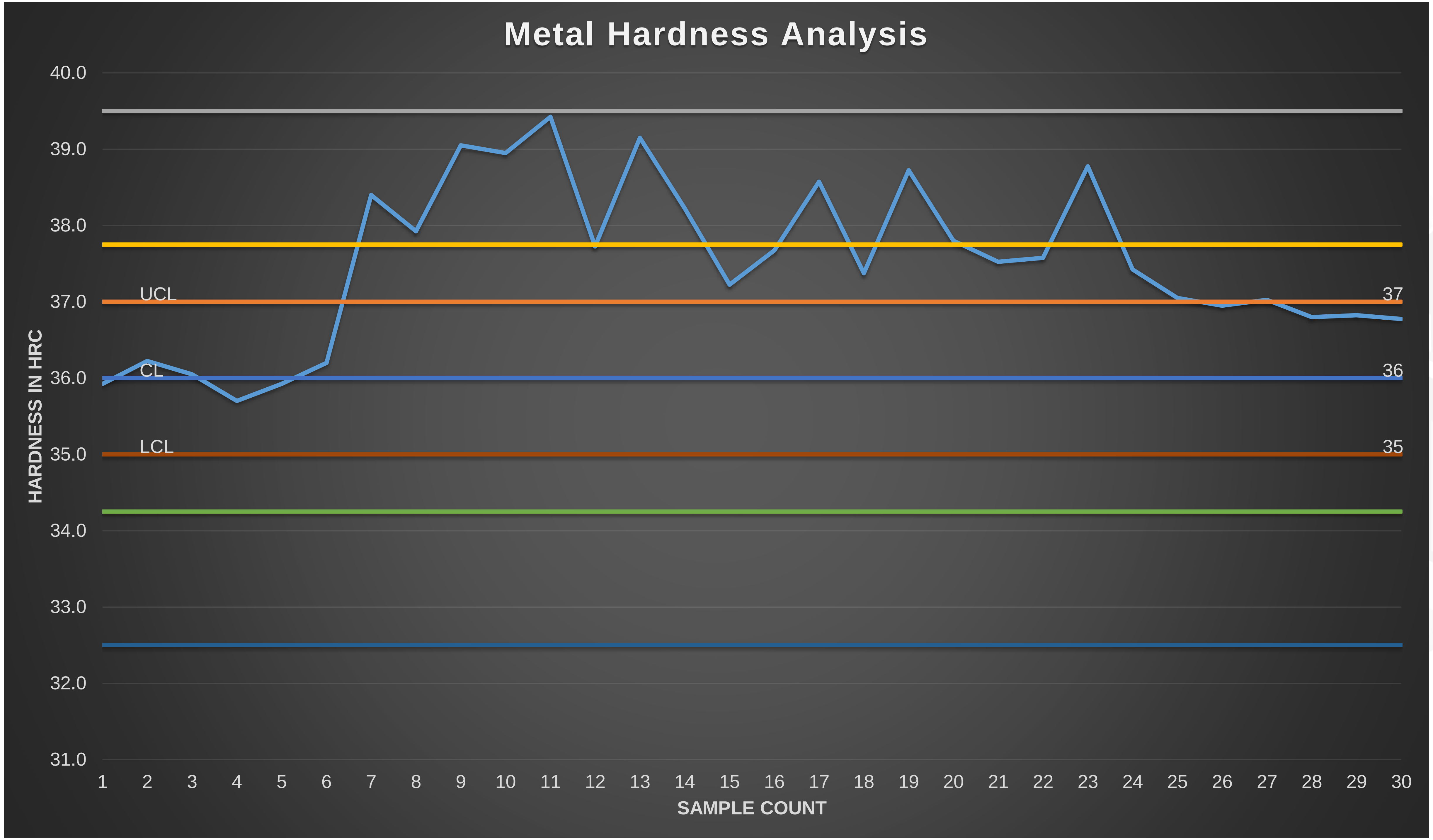
Operator may need to be better trained or gage is hard to read

	% Using TV	% Using Tolerance
AIAG - Automotive Industry Action Group Formulas		

		% Using TV	% Using Tolerance				
EV (Equipment Variation)		0.4077					Equipment Variation (EV)
%EV		**17.0%**	**27.8%**	#Parts	#Trials	#Ops	% of Total Variation (TV)
AV: (Appraiser Variation)		0.50364		10	3	2	Appraiser Variation(AV)
%AV		**21.0%**	**34.3%**				% of Total Variation (TV)
R and R (Gage Capability)		0.6479					Repeatability and Reproducibility (R and R)
%R and R		**27.0%**	**44.2%**		**NDC5**		% of Total Variation (TV)
PV (Part Variation)		2.3071					Part Variation (PV)
%PV		96.3%	157%				% of Total Variation (TV)
TV (Total Variation)		2.3963					Total Variation (TV)

No Booking: Reasons

Metal Hardening (in HRC)
35.7
36.9
36.2
34.8
35.7
36.8
45.6
43.7
48.2
47.8
49.7
42.9
48.6
44.9
40.9
42.7
46.3
41.5
46.9
43.2
42.1
42.3
47.1
41.7
40.2
39.8
40.1
39.2
39.3
39.1

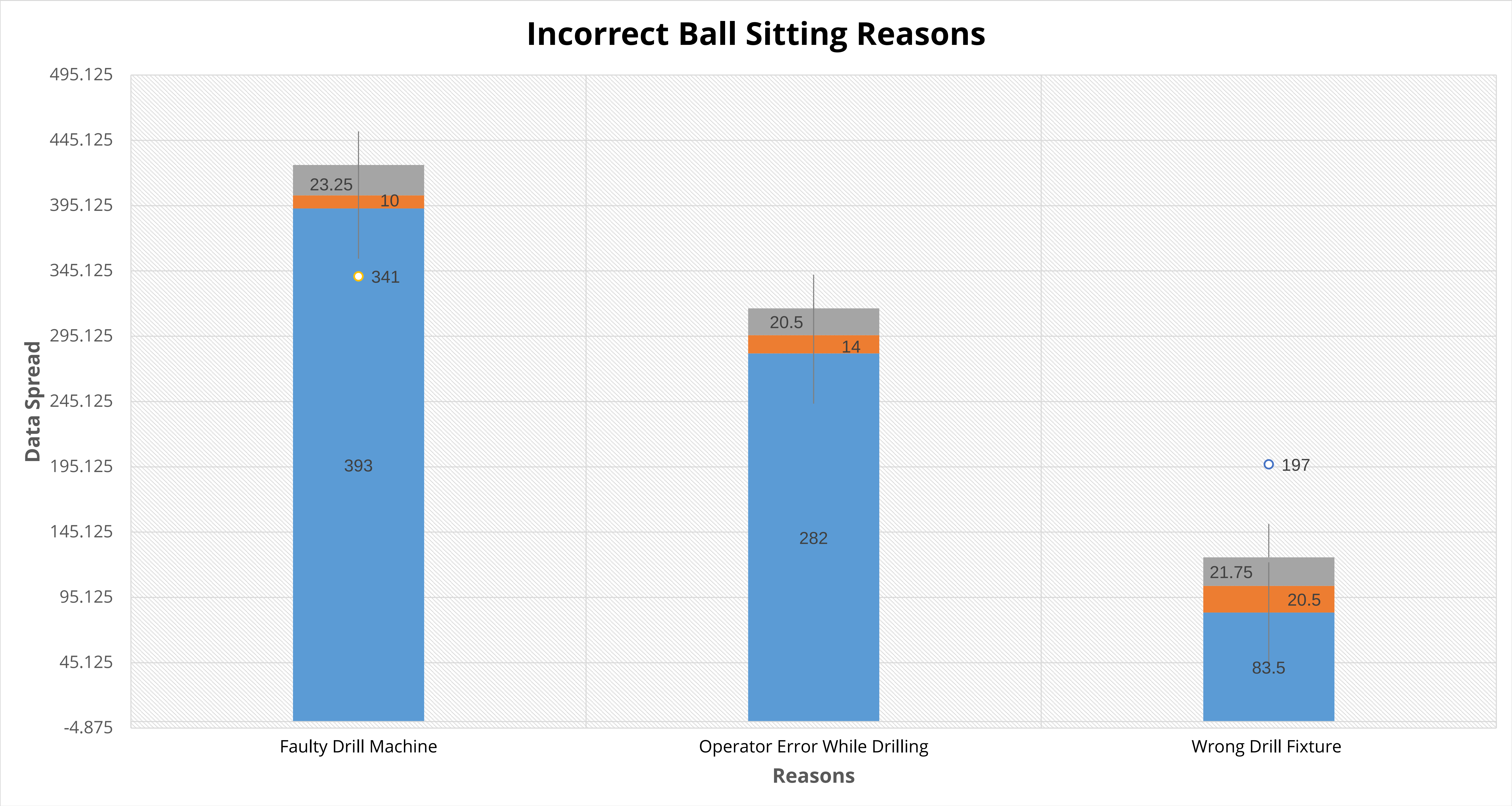


Analyze Phase

Incorrect Ball Sitting In Return Line

Faulty drill machine	Operator error while drilling	Wrong drill fixture
452	342	197
431	319	142
415	301	77
421	309	119
437	288	142
449	305	101
401	279	113
405	307	97
428	321	79
411	267	128
397	286	106
383	285	81
389	291	91
370	321	102
393	277	45
341	281	135
393	261	115
395	321	77

Incorrect Ball Sitting In Return Line (Contd.)



Incorrect Ball Sitting In Return Line (Contd.)

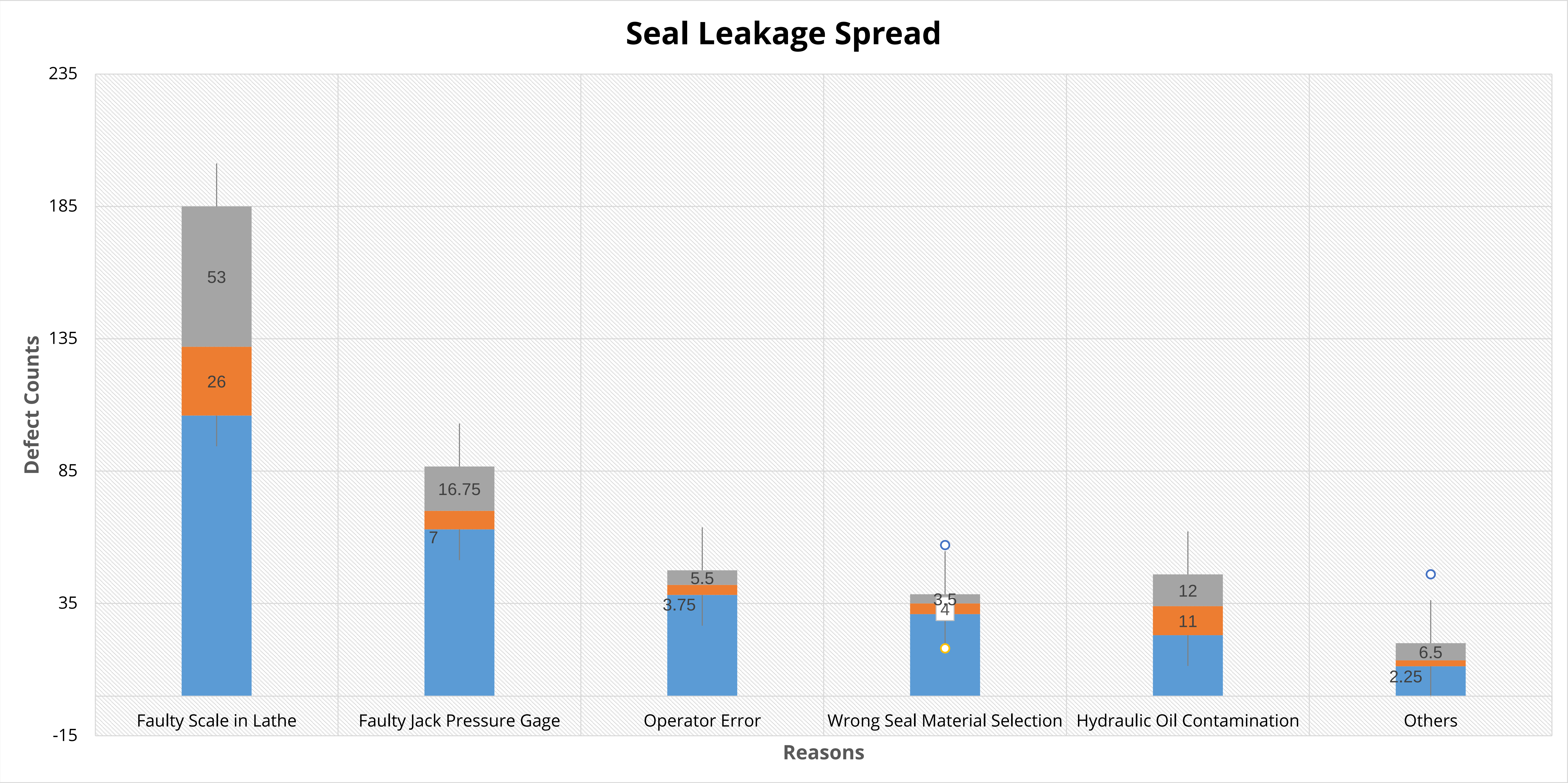
Proposed Solutions

- Maintenance of drill machine/change drill machine
- Operator equipment handling and behavioral training
- Drill bit testing prior use

Seal Leakage

Faulty scale in lathe	Faulty jack pressure gage	Operator error	Wrong seal material selection	Hydraulic oil contamination	Others
243	109	45	39	65	46
210	97	48	42	35	31
191	65	31	18	2	9
179	88	49	37	53	17
187	95	53	47	49	20
199	93	61	35	37	22
167	82	39	39	51	17
148	71	43	35	19	5
133	63	38	31	43	11
115	74	37	29	39	20
131	83	41	36	29	12
97	59	31	23	18	11
89	54	29	21	29	9
117	67	53	32	19	13
115	63	46	35	21	13
103	69	39	31	31	14
95	51	43	57	33	12
93	51	39	35	47	22

Seal Leakage (Contd.)



Seal Leakage (Contd.)

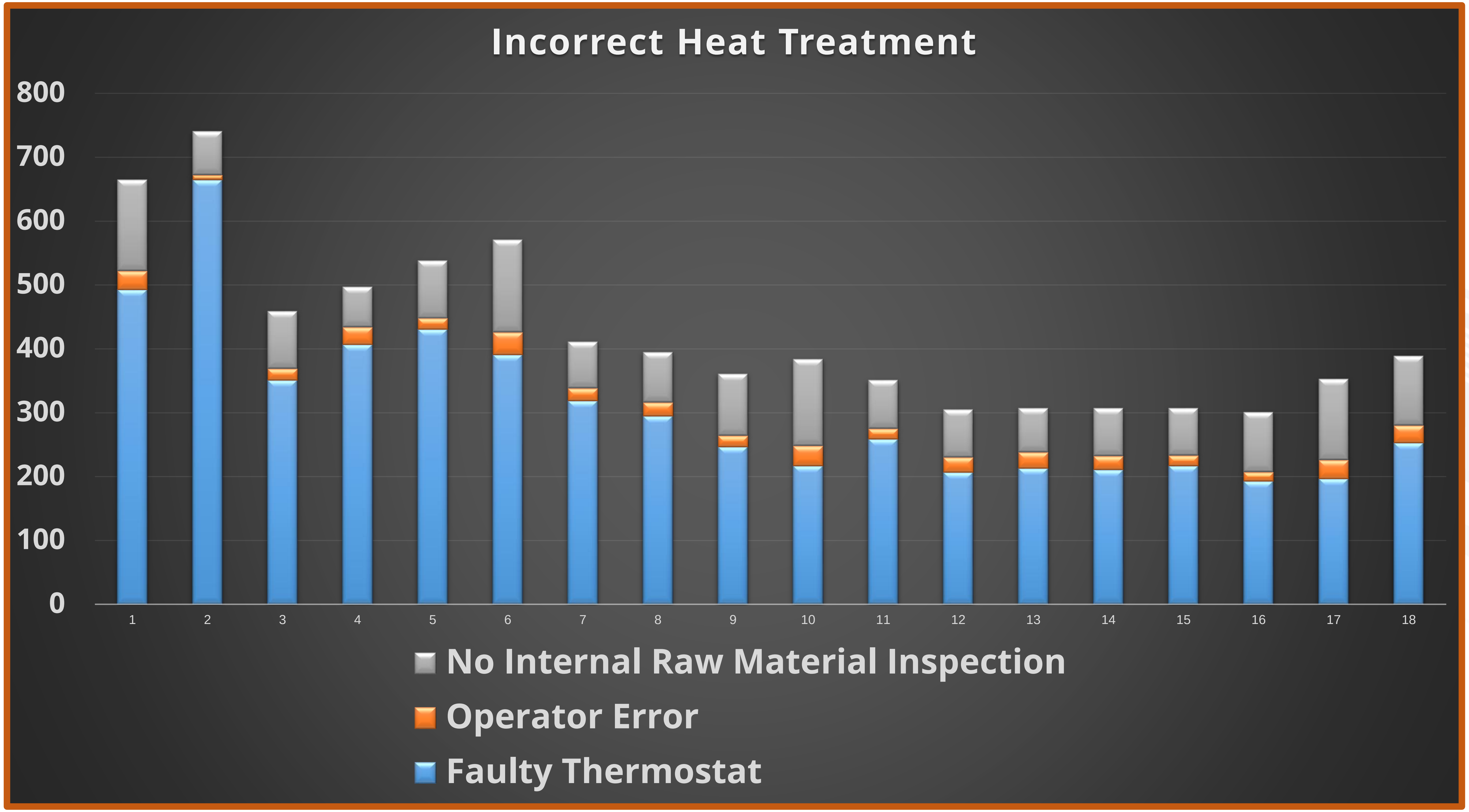
Proposed Solutions

- Maintenance of scale in lathe/change lathe scale
- Regular hydraulic oil maintenance prescribed
- Maximum pressure limit set at 700 bar

Incorrect Heat Treatment

Faulty thermostat	Operator error	No internal raw material inspection
493	29	143
665	7	69
351	18	90
407	27	63
431	17	90
391	35	145
319	19	73
295	21	79
247	17	97
217	31	136
259	16	76
207	23	75
213	25	69
211	21	75
217	16	74
193	14	94
197	29	127
253	27	109

Incorrect Heat Treatment (Contd.)



Incorrect Heat Treatment (Contd.)

Proposed Solutions

- Change furnace thermostat and heating coil
- Raw material internal inspection SOP before using
- Operator equipment training

Improve Phase

Metal Hardening (in HRC)

Before furnace parts changed	After furnace parts changed
35.7	35.2
36.9	36.3
36.2	36.1
34.8	35.7
35.7	36.8
36.8	35.3
45.6	35.5
43.7	36.02
48.2	36.3
47.8	35.01
49.7	36.7
42.9	35.5
48.6	36.4
44.9	36.6
40.9	35.4
42.7	35.9
46.3	35.6
41.5	36.8
46.9	35.42
43.2	36.49
42.1	36.89
42.3	35.46
47.1	36.6
41.7	35.8
40.2	35.1
39.8	35.09
40.1	36.91
39.2	36.33
39.3	35.87
39.1	36.29

Hypothesis Testing

Null hypothesis:
Metal hardness remains similar before and after furnace part change

Proposed Solutions

Alternate hypothesis:
Metal hardness changes after furnace part change

T-test Results

T-test: paired two sample for means		
	Before furnace parts changed	**After furnace parts changed**
Mean	41.99666667	35.97933333
Variance	18.11136782	0.359792644
Observations	30	30
Pearson correlation	0.095934944	
Hypothesized mean difference	0	
Df	29	
T stat	7.772366749	
P(t<=t) one-tail	7.14995e-09	
T critical one-tail	1.699127027	
P(t<=t) two-tail	1.42999e-08	
T critical two-tail	2.045229642	

Ha: Metal hardness changes after furnace part change

Key Inputs and Output For Heat Treatment

KP_IV_1
X_1:
Temperature
(In degree centigrade)

\+

$KPIV_2$
X_2:
Time
(In hours)

=

KPOV
Y:
Hardness
(In HRC)

Key Inputs and Output Relation For Heat Treatment

AT 5 HOURS

Temperature (In Degree C)	Metal Hardness (In HRC)
510	35.2
520	36.3
520	36.1
515	35.7
515	36.8
510	35.3
510	35.5
520	36.02
520	36.3
510	35.01
515	36.7
510	35.5
520	36.4
515	36.6
510	35.4

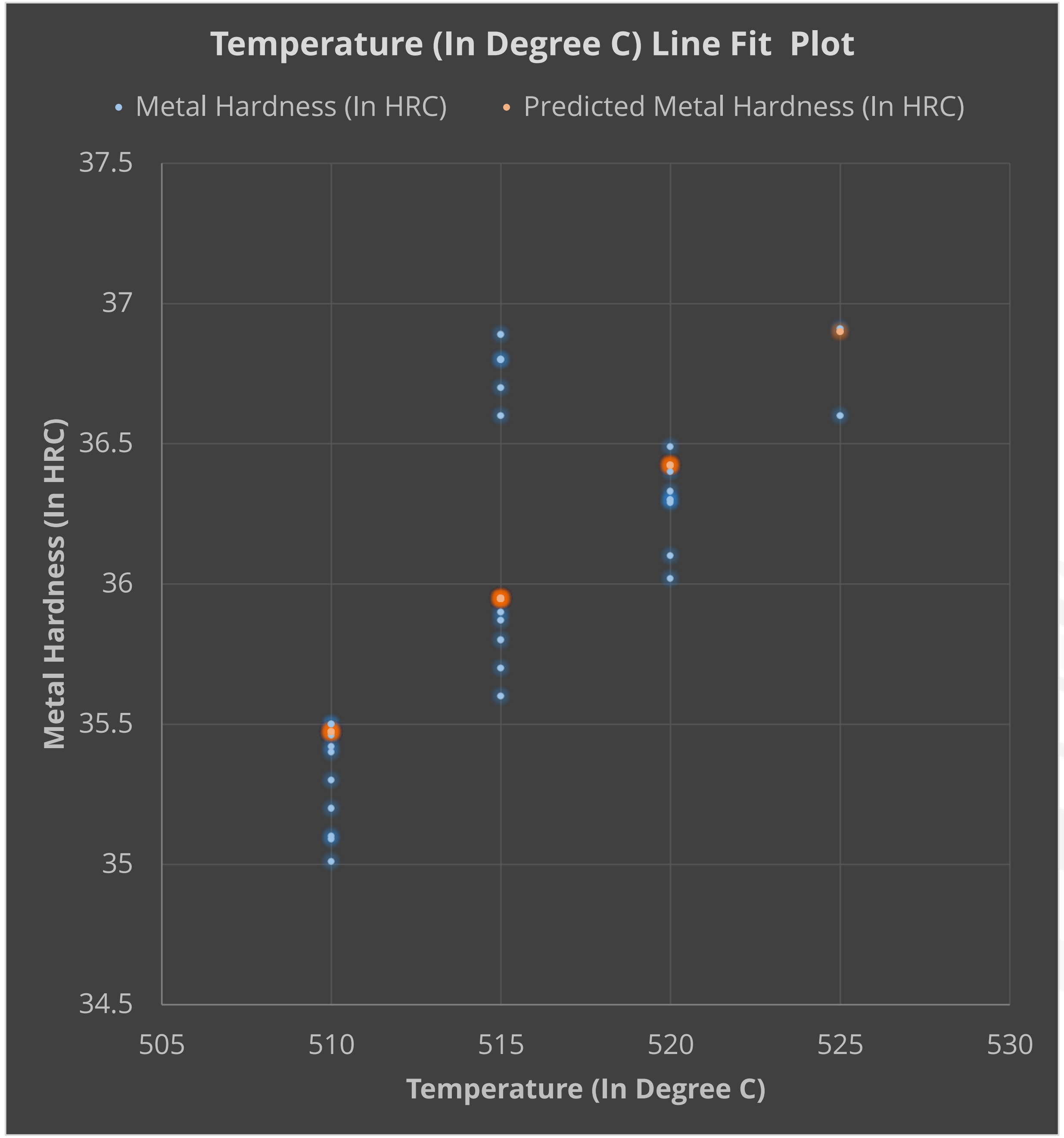
Temperature (In Degree C)	Metal Hardness (In HRC)
515	35.9
515	35.6
515	36.8
510	35.42
520	36.49
515	36.89
510	35.46
525	36.6
515	35.8
510	35.1
510	35.09
525	36.91
520	36.33
515	35.87
520	36.29

Key Inputs and Output Relation For Heat Treatment (Contd.)

AT 5 HOURS

Summary output	
Regression statistics	
Multiple R	0.749393149
R Square	0.561590091
Adjusted R Square	0.545932594
Standard Error	0.404190688
Observations	30

	Coefficients	Standard Error
Intercept	-13.07561856	8.191282907
Temperature (In Degree C)	0.095190722	0.015894471



Y= – 13.0761 + 0.095X1 + 0.404

simplilearn

Key Inputs and Output Relation For Heat Treatment (Contd.)

AT 500ºC

Time (In Hours)	Metal Hardness (In HRC)
5.16	35.2
5.66	36.3
5.66	36.1
5.33	35.7
5.83	36.8
5.16	35.3
5.16	35.5
5.66	36.02
5.66	36.3
5.16	35.01
5.83	36.7
5.16	35.5
5.66	36.4
5.83	36.6
5.16	35.4

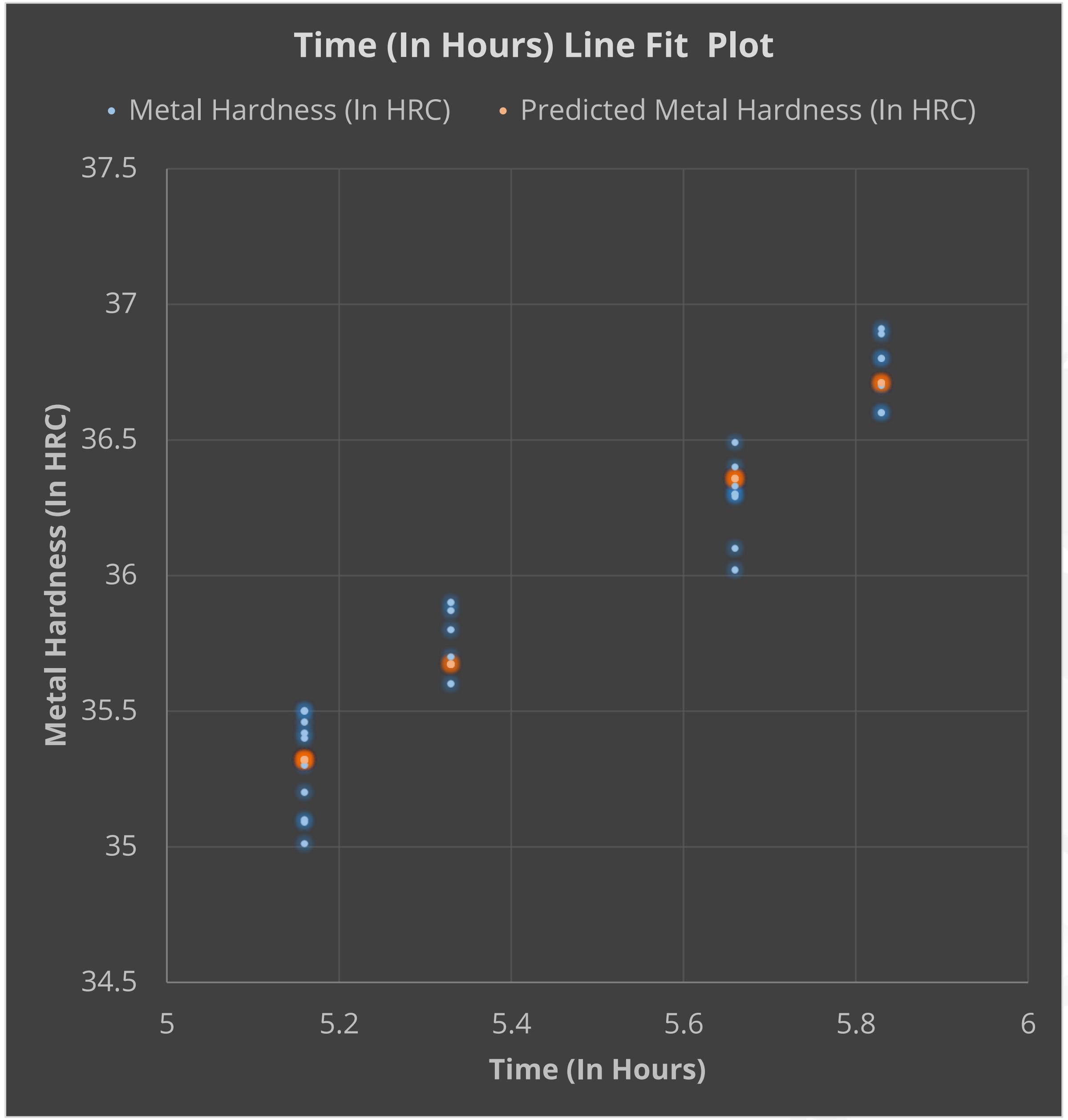
Time (In Hours)	Metal Hardness (In HRC)
5.33	35.9
5.33	35.6
5.83	36.8
5.16	35.42
5.66	36.49
5.83	36.89
5.16	35.46
5.83	36.6
5.33	35.8
5.16	35.1
5.16	35.09
5.83	36.91
5.66	36.33
5.33	35.87
5.66	36.29

Key Inputs and Output Relation For Heat Treatment (Contd.)

AT 5 HOURS

Summary output	
Regression statistics	
Multiple R	0.963389705
R Square	0.928119723
Adjusted R Square	0.92555257
Standard Error	0.163663183
Observations	30

	Coefficients	Standard Error
Intercept	24.62240563	0.598036228
Time (In Hours)	2.073188702	0.109034186



Y= 2.073 + 24.625X2 + 0.163

Control Phase

Implementations

Operators' equipment handling trainings

SOP adherence regular monitoring

Total productive maintenance of machines

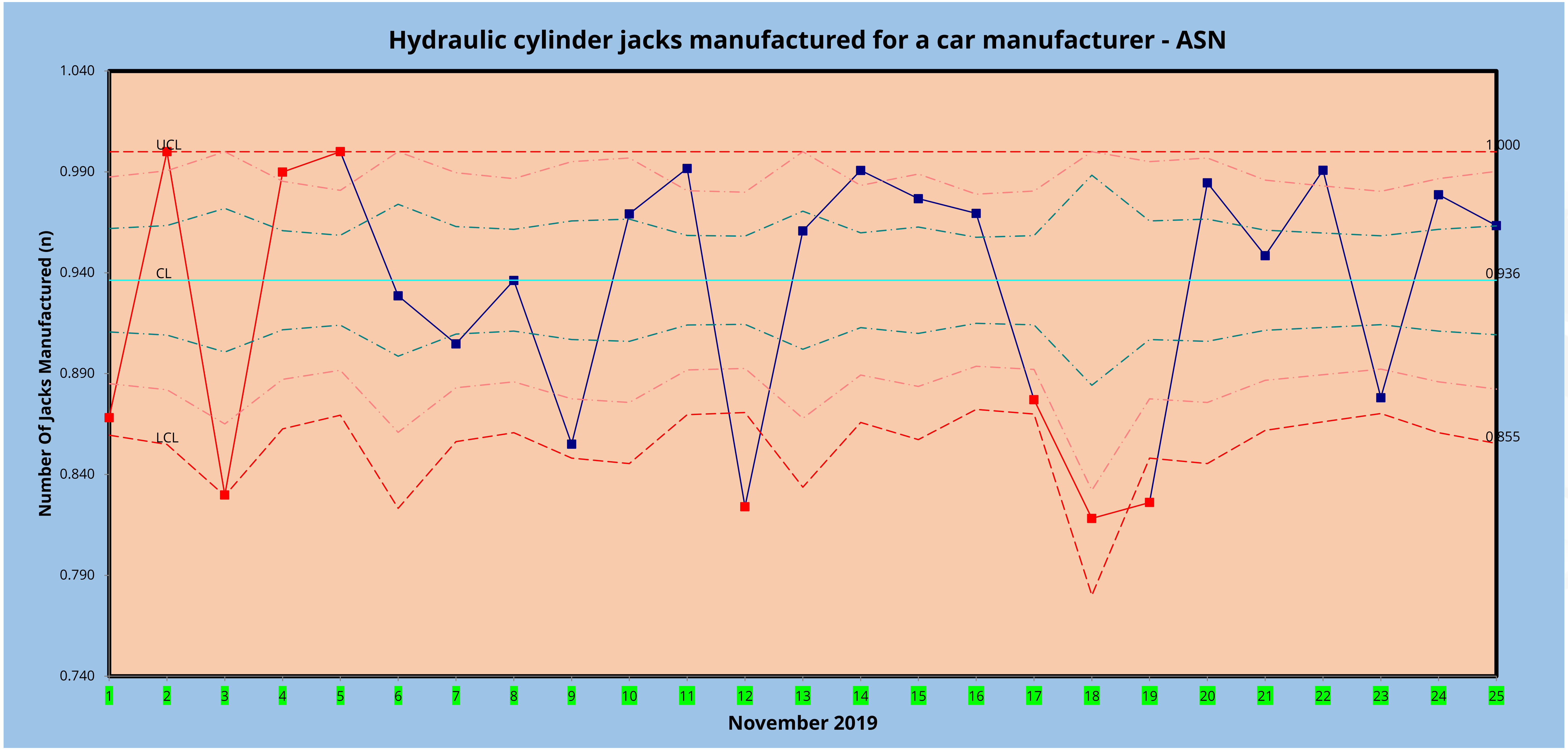
FMEA

System:	Cylinder Jack	**Design Responsibility:**			Samuel/Jimmy		**FMEA Number**	Insert FMEA#								
Subsystem	Jack Malfunction						**Page**	1			1					
Component	Car Lift Cylinder Jack						**Prepared by:**	Samuel								
Model:	model						**FMEA Date:**	9/6/2019								
Core Team:	Six Sigma Team															
Item/Part Function	**Potential Failure Mode**	**Potential Effect(s) of Failure**	**Sev**	**Class**	**Potential Cause(s) / Mechanism(s) of Failure**	**Occur**	**Current Design Controls Prevention**	**Current Design Controls Detection**	**Detect**	**R. P. N.**	**Potential Failure Mode**	New Measures	Sev	Occur	Detect	R. P. N.
Cylinder jack	Jack bursting	Car resting on the jack getting damaged; operator may get injured	9		Failure to maintain pressure, incorrect heat treatment	9	None	None	9	729	**Jack bursting**	**Furnace coil and thermostat changed, raw material inspection SOP adherence, operator equipment training**	**9**	**2**	**2**	**36**
Cylinder jack	Jack malfunction	Car resting on the jack getting damaged; operator may get injured	9		Incorrect ball sitting in return line; hydraulic fluid contamination; seal leakage; impacts of side loading; improper maintenance	8	None	None	9	648	**Incorrect ball sitting in the return line seal leakage**	**Drill machine changed; correct drill bit usage, operator trained, lathe scale changed, pressure limit set at 700 bar**	**9**	**3**	**2**	**54**

Output Post the Implementation Phase

Day	Number Of Jacks Manufactured (n)	Yield (np) Defect Free Jacks	Yield % (p)	LCLp	UCLp
1	91	79	86.80%	93.60%	101.30%
2	81	81	100.00%	93.60%	101.80%
3	47	39	83.00%	93.60%	104.30%
4	99	98	99.00%	93.60%	101.00%
5	120	120	100.00%	93.60%	100.30%
6	42	39	92.90%	93.60%	104.90%
7	84	76	90.50%	93.60%	101.60%
8	94	88	93.60%	93.60%	101.20%
9	69	59	85.50%	93.60%	102.40%
10	65	63	96.90%	93.60%	102.70%
11	121	120	99.20%	93.60%	100.30%
12	125	103	82.40%	93.60%	100.20%
13	51	49	96.10%	93.60%	103.90%
14	108	107	99.10%	93.60%	100.70%
15	86	84	97.70%	93.60%	101.50%
16	131	127	96.90%	93.60%	100.00%
17	122	107	87.70%	93.60%	100.30%
18	22	18	81.80%	93.60%	109.30%
19	69	57	82.60%	93.60%	102.40%
20	65	64	98.50%	93.60%	102.70%
21	97	92	94.80%	93.60%	101.10%
22	109	108	99.10%	93.60%	100.60%
23	123	108	87.80%	93.60%	100.20%
24	94	92	97.90%	93.60%	101.20%
25	82	79	96.30%	93.60%	101.70%

Output Post the Implementation Phase: Example



Summary

You should now be able to:

- Understand the V-Tech Hydraulic Solutions project background
- Analyze the various factors that led to the high replacement requests for the hydraulic car jacks manufactured by the company
- Infer how operator trainings, process monitoring, and regular maintenance improved the manufacturing quality