LA-UR-22-32912

Approved for public release; distribution is unlimited.

Title:	MMWG PdM Users Monthly call - Alignment and Balancing
Author(s):	Foster, Michelle Elizabeth
Intended for:	MMWG (Maintenance Manager's Working Group) PdM (Predictive Maintenance) Users Monthly call
Issued:	2022-12-13

Los Alamos NATIONAL LABORATORY

MMWG PdM User's Monthly Call Alignment and Balancing

Michelle E. Foster

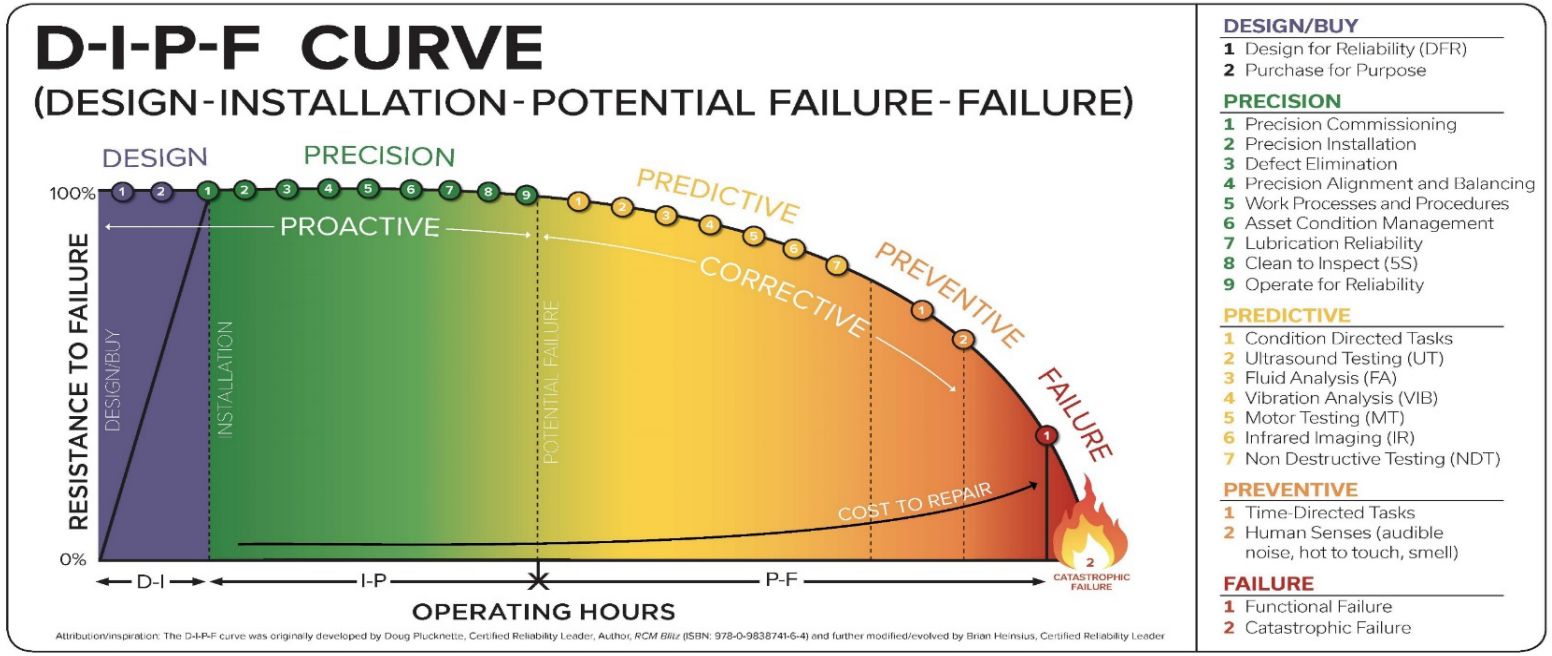
Reliability Engineer - Condition Monitoring and Analysis
Maintenance Site Services – Maintenance Programs

12.27.2022

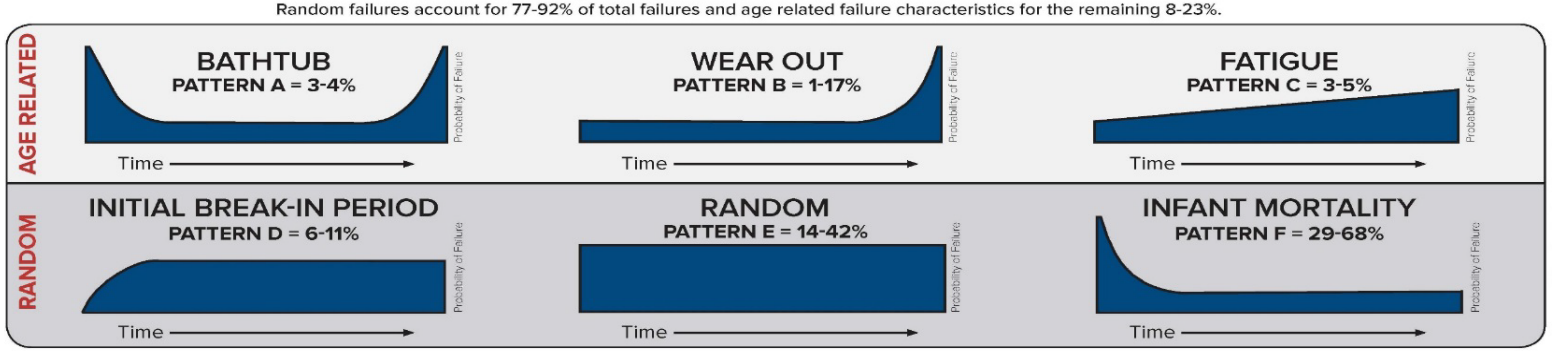
Alignment and Balancing

Alignment and Balancing

HOW FAILURE OCCURS



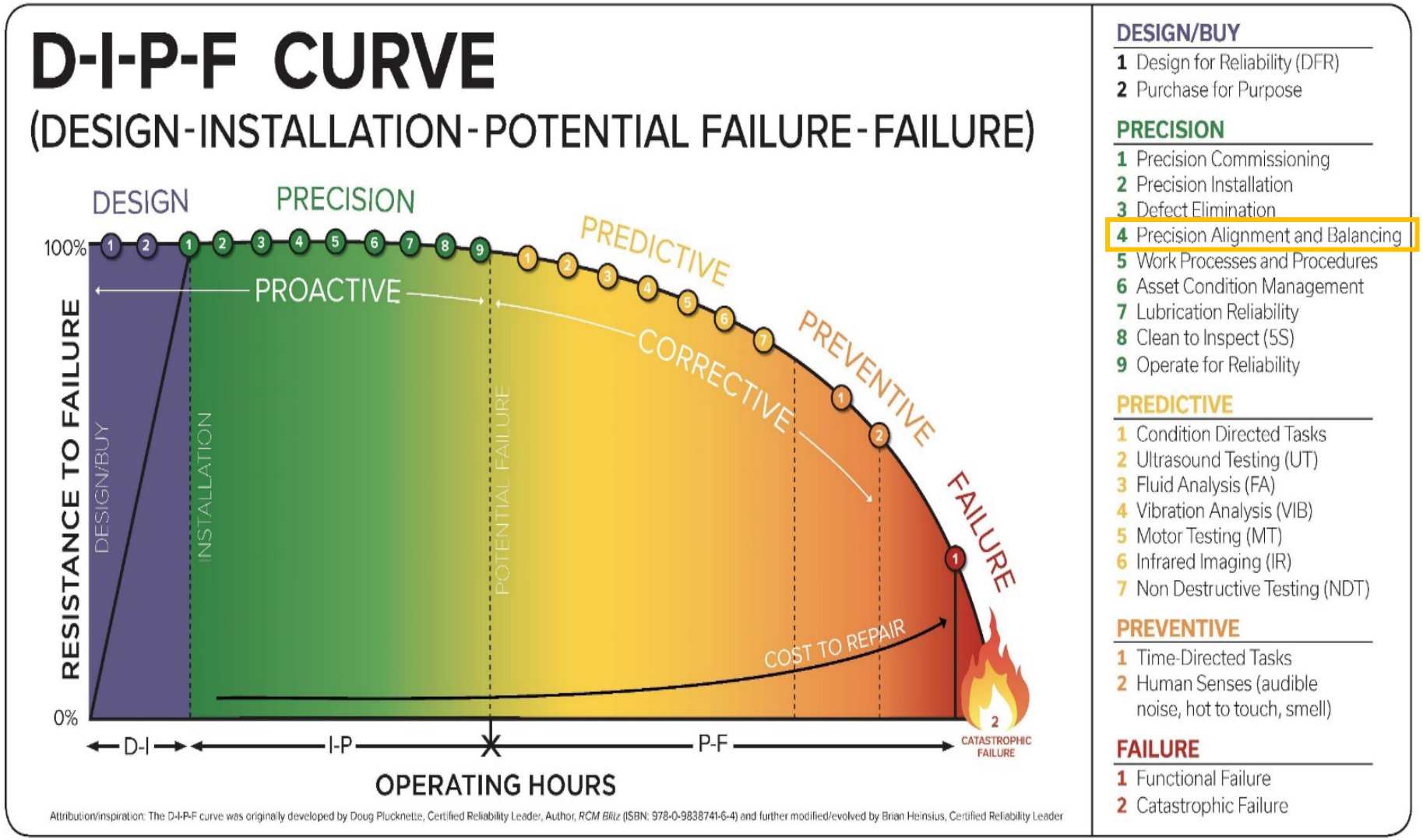
Attribution/inspiration: The D-I-P-F curve was originally developed by Doug Plucknette, Certified Reliability Leader, Author, *RCM Blitz* (ISBN: 978-0-9838741-6-4) and further modified/evolved by Brian Heinsius, Certified Reliability Leader



reliabilityweb.com • maintenance.org • reliabilityleadership.com

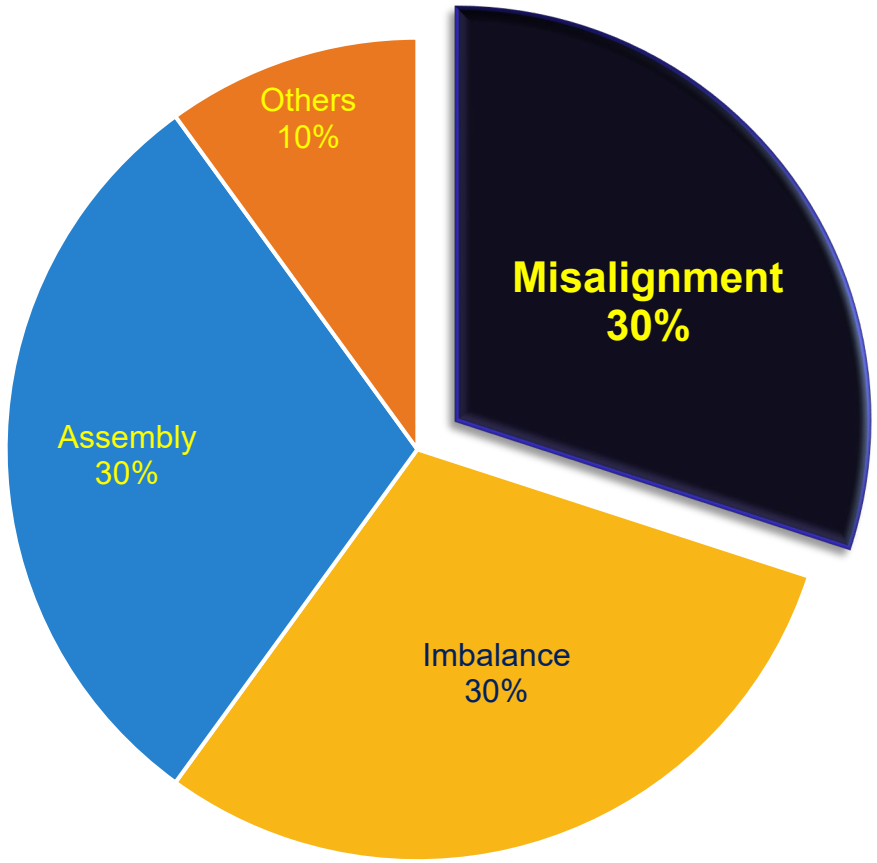
Alignment and Balancing

HOW FAIL



Alignment and Balancing

Mechanical Failure - Rotating Equipment

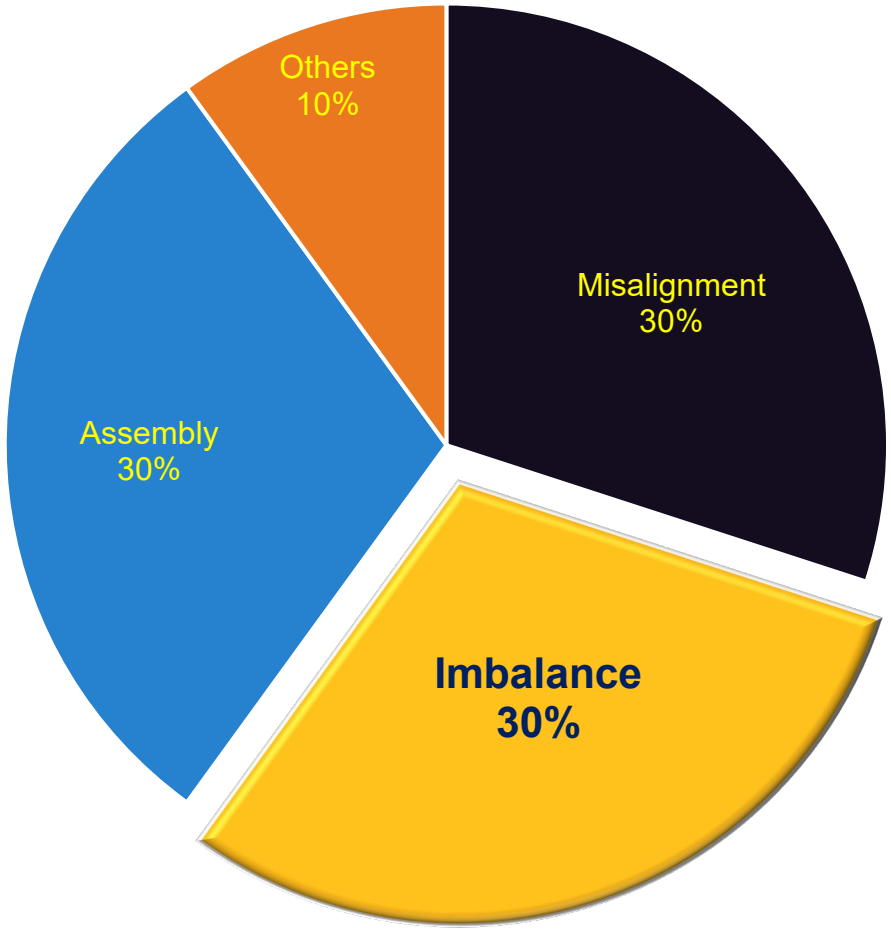


Alignment Misconceptions

- Not accounting for angled and short leg soft foot
- Improper torque and torque sequence
- Loss of bearing radial internal clearance
- Coupling will accept the misalignment
- Thermal growth on smaller machines doesn't matter
- Other machines in the area will not affect
- Natural frequencies will not affect alignment
- Aligning to published tolerances
- Case Deflection is equal in all directions
- Our laser gave us smiley faces ☺

Alignment and Balancing

Mechanical Failure - Rotating Equipment

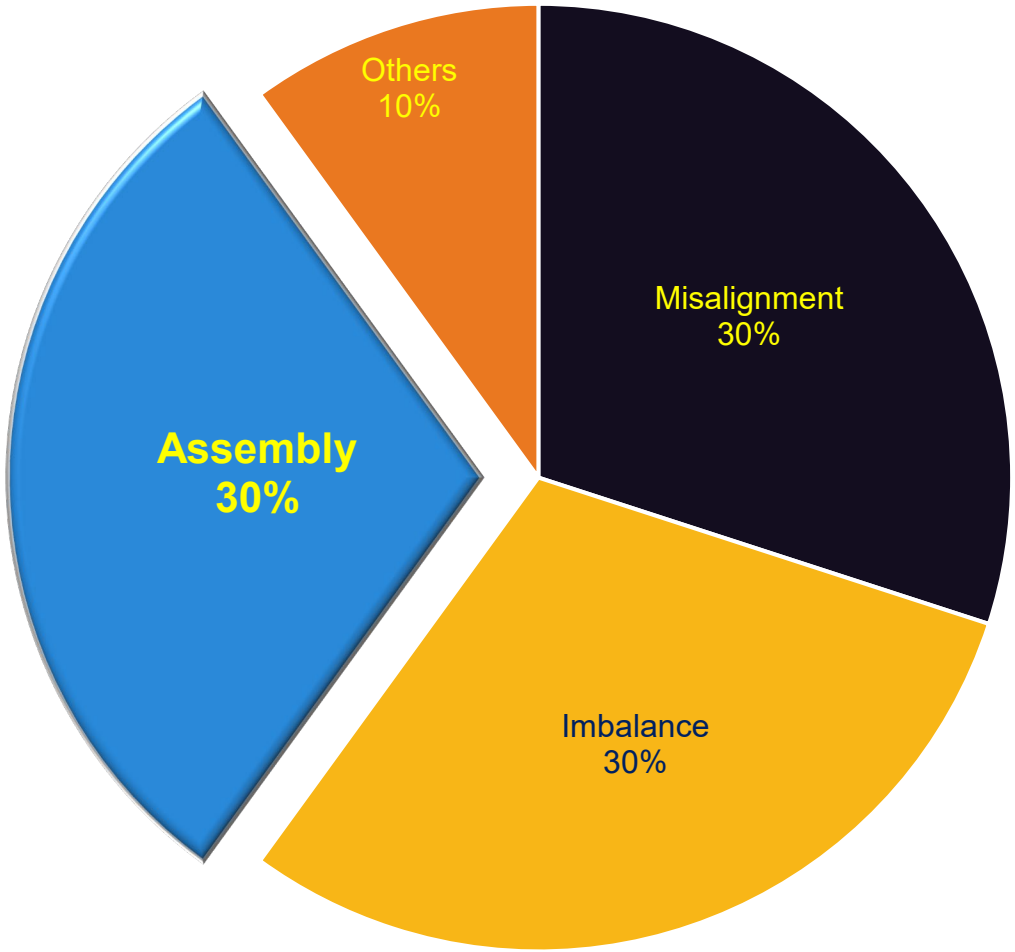


What can affect impeller Balance

- Homogeneity of parent material
- Was the system bored true to the periphery?
- Was the system bored square to the periphery?
- Is the cast the same thickness, width, breadth, and length.
- What is the final acceptance tolerance used?

Alignment and Balancing

Mechanical Failure - Rotating Equipment

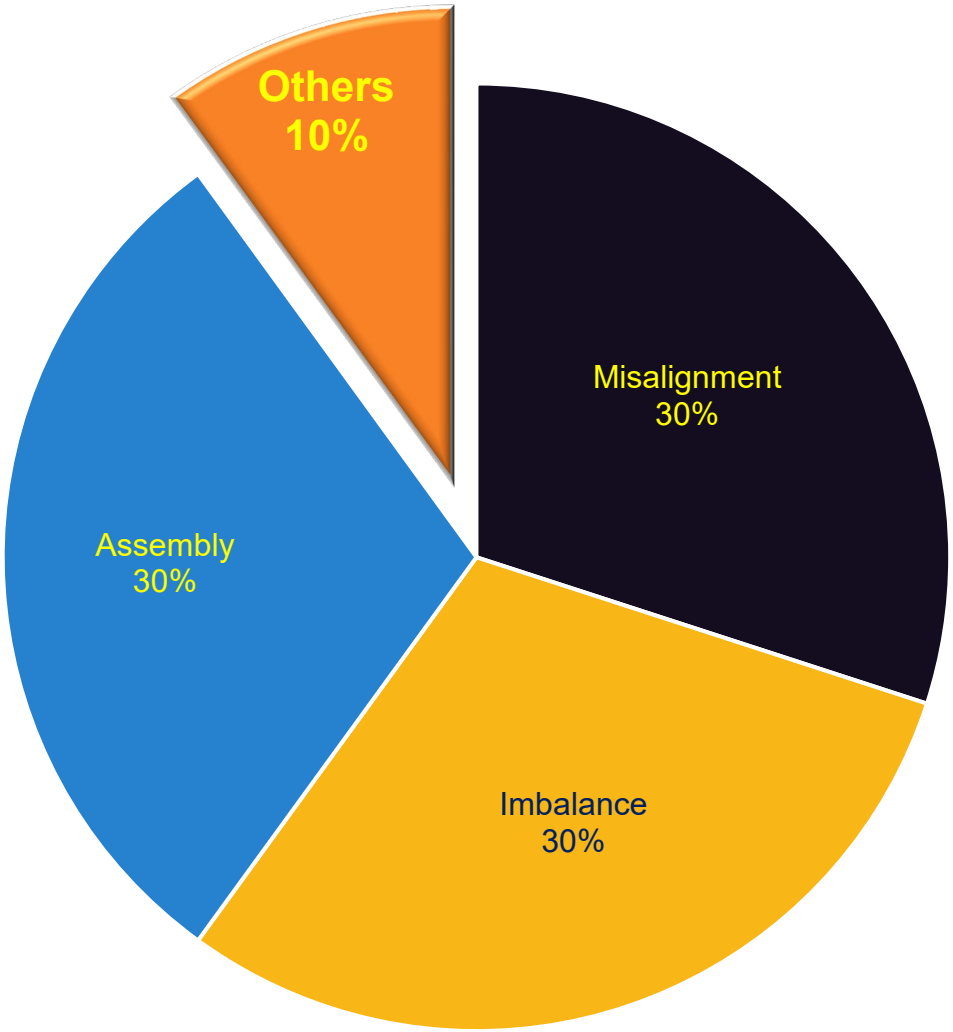


Assembly Concerns and how it effects Reliability

- Torqueing of bolts – Misalignment
- Bolt torque pattern sequence – Misalignment
- Electrical termination box hard piping – Misalignment
- Key length and positioning – Unbalance
- Setscrews – Unbalance
- Pulled Threads – Misalignment
- Offset collars – Unbalance
- Grease quantities – Unbalance
- Position of grease in couplings - Unbalance

Alignment and Balancing

Mechanical Failure - Rotating Equipment



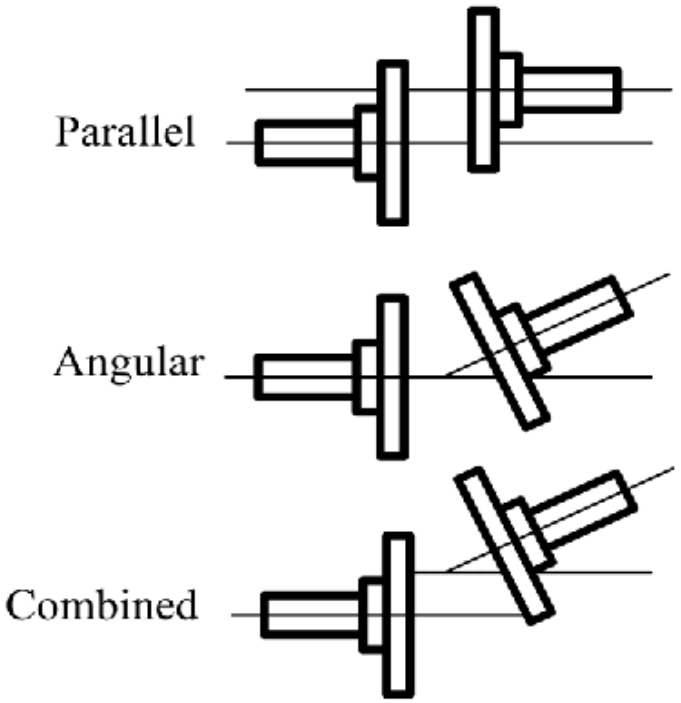
Other Issues…

- Bearing problems
- Electric rotor bar problems
- Electrical air gap problems
- Gear mesh noise and early failure
- Pump pulsations
- System overloading

Alignment

Alignment and Balancing

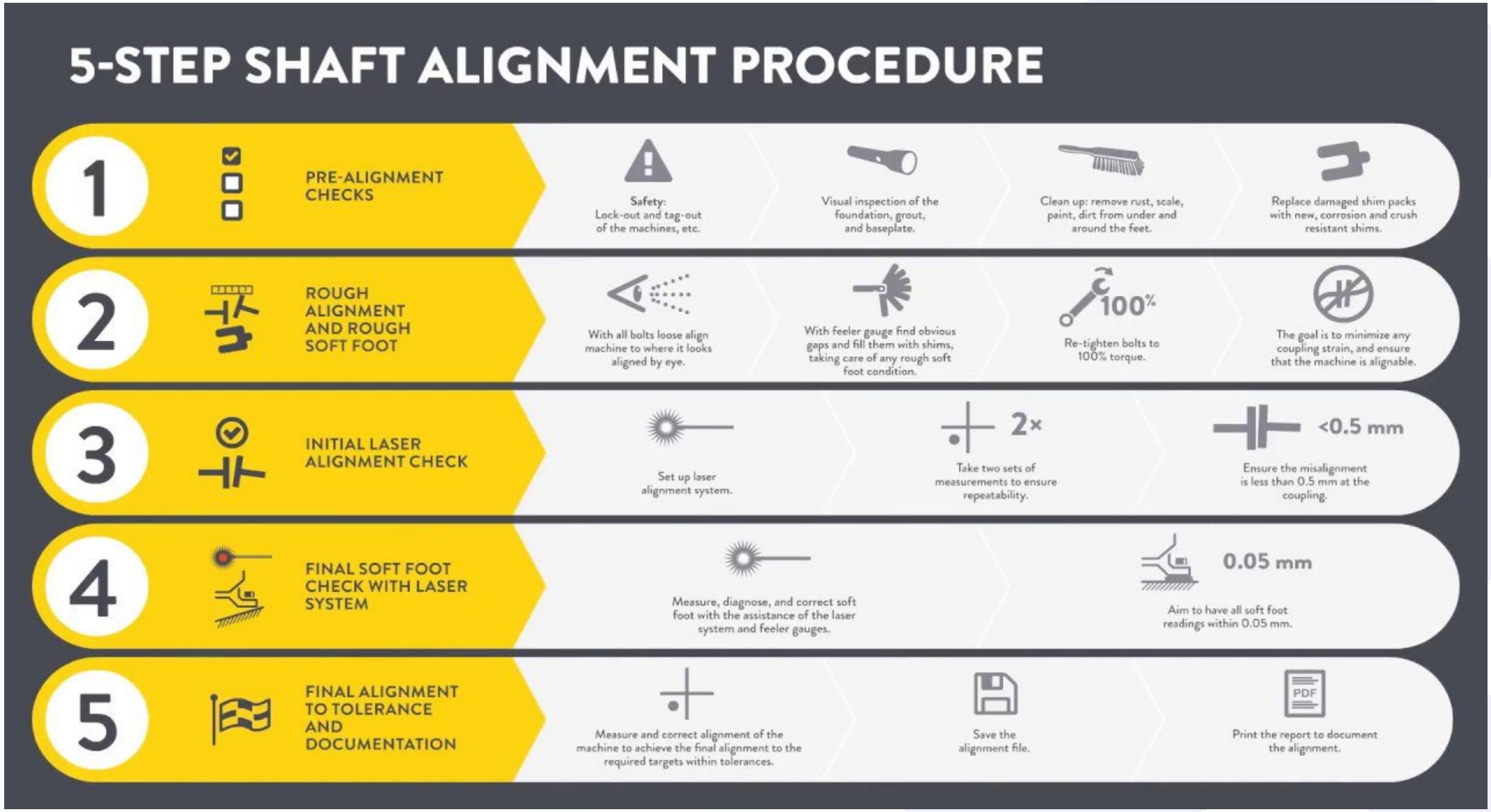
Types of Misalignment…



Alignment Methods

- Straight-edge
- Dial indicators
  - Rim and face
  - Cross dial
  - Reverse dial
- Laser alignment tools

Alignment and Balancing



Alignment and Balancing

SHAFT ALIGNMENT TOLERANCES

RPM	OFFSET (mils)		GAP (mils/10")		SPACER SHAFT (mils/in.)	
	EXCELLENT	FAIR	EXCELLENT	FAIR	EXCELLENT	FAIR
600	5.0	9.0	10.0	15.0	1.8	3.0
900	3.0	6.0	7.0	10.0	1.2	2.0
1200	2.5	4.0	5.0	8.0	0.9	1.5
1800	2.0	3.0	3.0	5.0	0.6	1.0
3600	1.0	1.5	2.0	3.0	0.3	0.5
7200	0.5	1.0	1.0	2.0	0.15	0.25

All Speeds: Maximum Soft Foot Reading 2.0. Use OEM or in-house tolerances if available.

Alignment and Balancing

Alignment Special considerations

- Soft foot
  - Soft foot causes frame defection and that can wreak havoc on bearings.
  - When using a laser – remember that the laser is showing you the reaction at the shaft centerline.
- Spacer couplings – make sure you are using the correct setting in the alignment software.
- Long shafts – again there is a consideration when using the laser tool.

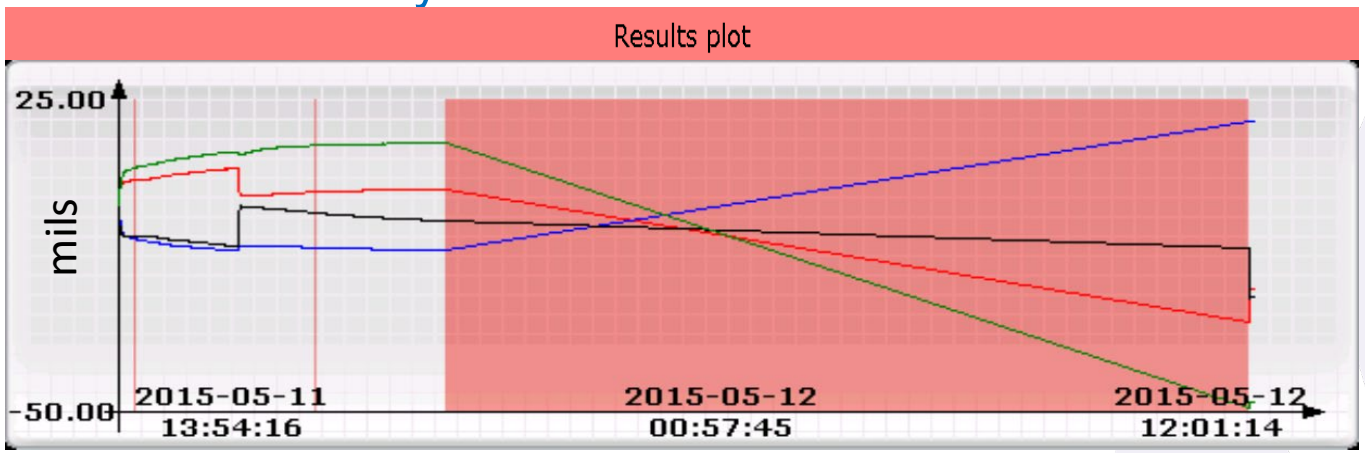
Alignment and Balancing

"Live Trend" Measurement

- Machine placed in safe running condition.
- Laser alignment heads are placed on the machine – not the shaft.
- Machine turned on and measured.
- Machine turned off and locked out.
- Laser alignment heads are placed on shaft and "realigned" based on measurement.

Alignment and Balancing

“Live Trend” Study



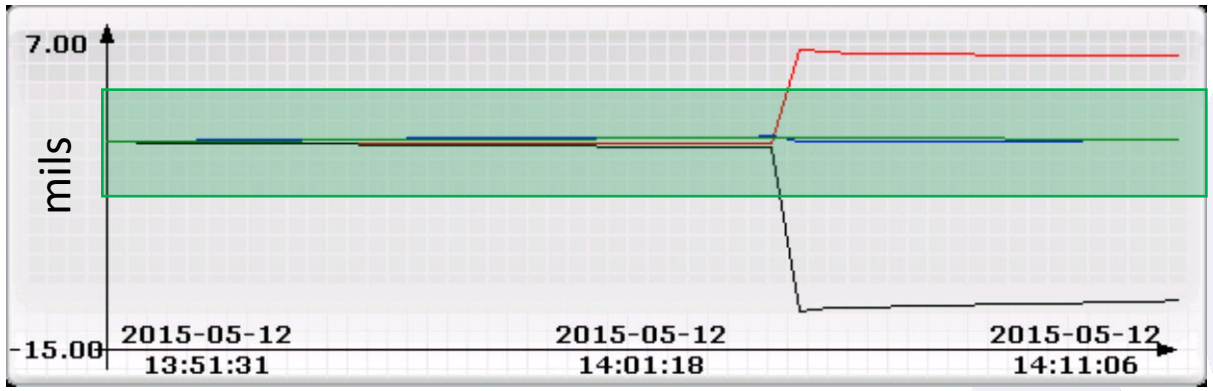
Vertical Gap
Vertical Offset
Horizontal Gap
Horizontal Offset

The “Live Trend” Graph from the alignment machine.
This is a graph of the 1st measurement ***and*** after the first adjustment.

- “Live Trend” is a measurement of how the machine moves after it is started or shut down.
- It considers thermal movement as well as movement due to dynamic loading.
- It measures actual movement and is not a calculated value.
- The machine is *intentionally misaligned* to the measured values.

Alignment and Balancing

Next “Live Trend” Measurement



Vertical Gap
Vertical Offset
Horizontal Gap
Horizontal Offset

The “Live Trend” Graph from the alignment machine.
This is a graph of the final measurement after the final adjustment.

Final measurement were:

0.4 mils angular and 1.2 mils offset horizontal ☺

5.3 mils angular and -9.5 mils offset vertical ☹

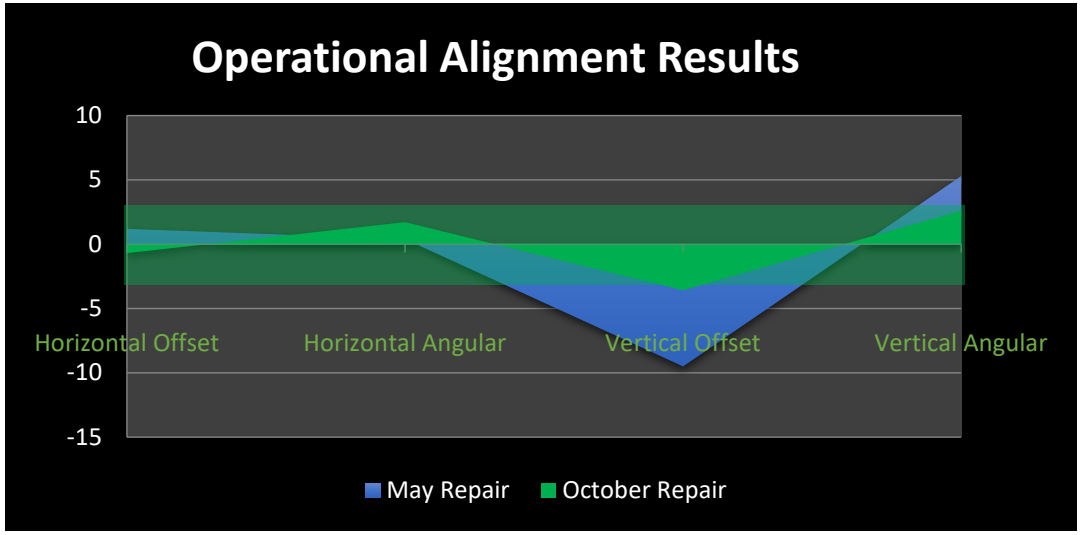
Recommended alignment tolerances are < 3.0 Mils angular and < 1.5 mils offset for a 3600 RPM machine.

The vertical numbers are still high.

Alignment and Balancing

Recommended alignment tolerances
for a 3600 RPM machine:
< 3.0 mils angular; < 1.5 mils offset

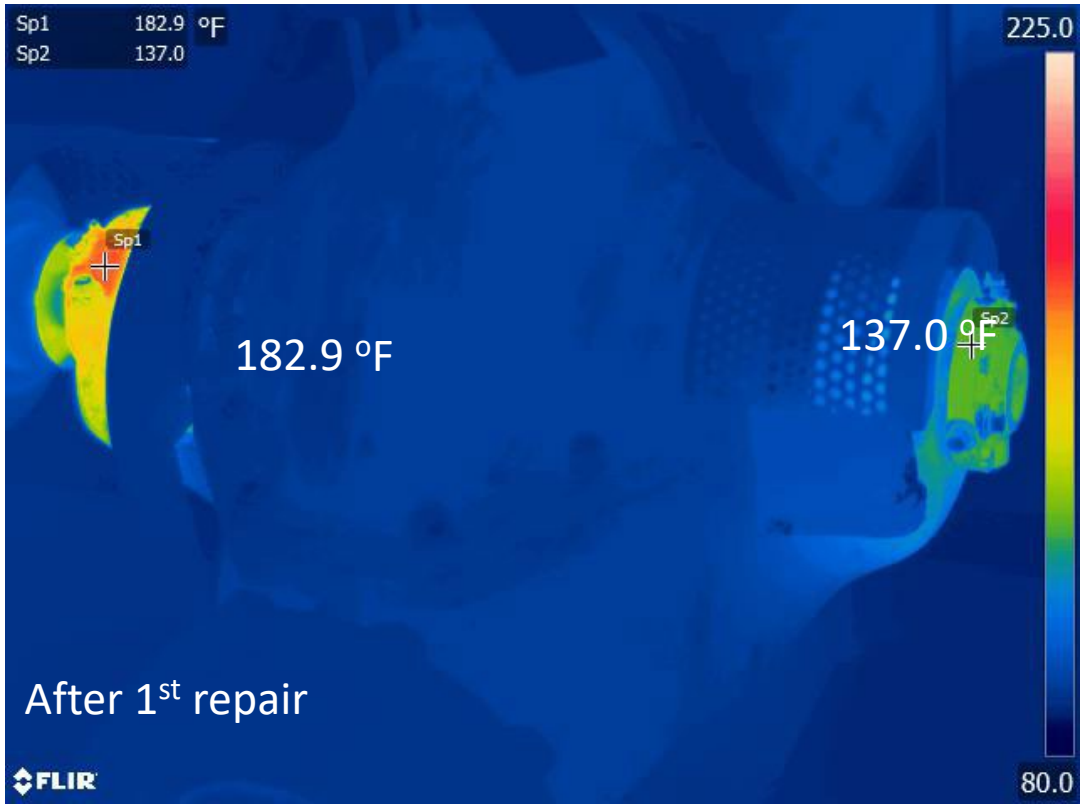
	Horizontal Offset	Horizontal Angular	Vertical Offset	Vertical Angular
May Repair	1.2 ☺	0.4 ☺	-9.5 ☹	5.3 ☹
October Repair	-0.7 ☺	1.7 ☺	-3.6 ☺	2.6 ☺

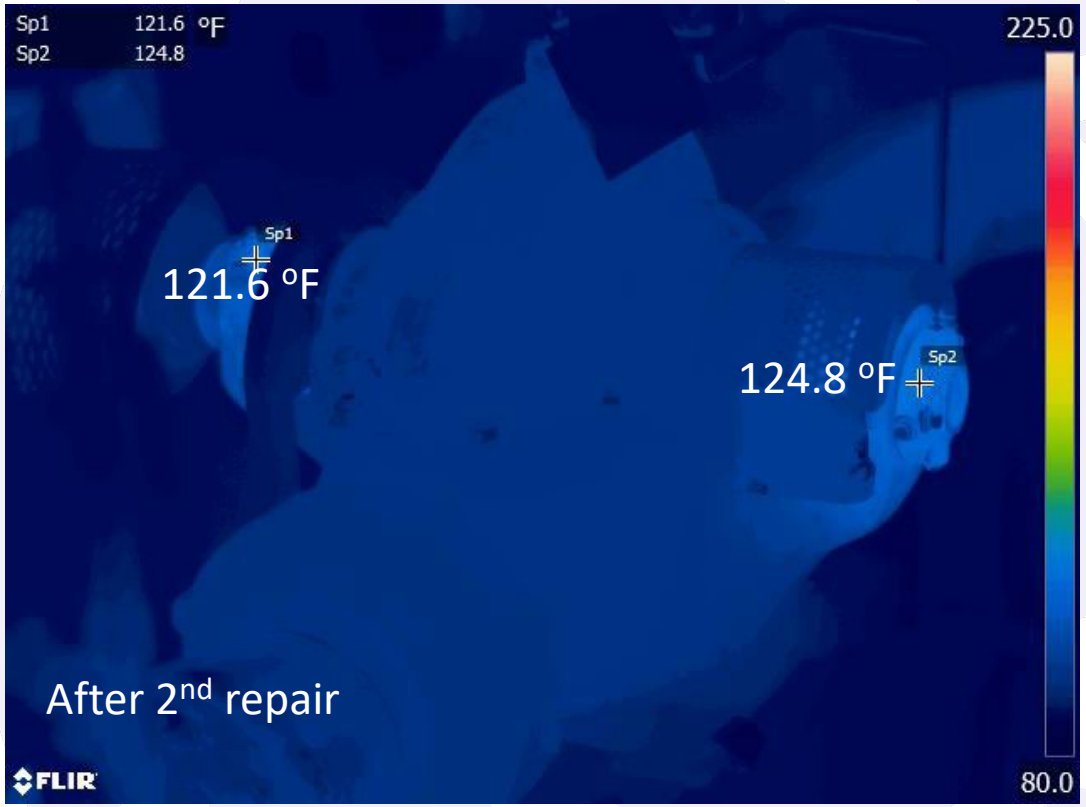


- The motor was moved in order to work on the pump bearing.
- The motor feet and base were cleaned up.
- The shim pack from the alignment in May was labeled and reused.
- The original “misalignment” was maintained with an additional adjustment.

Alignment and Balancing

Thermal Images



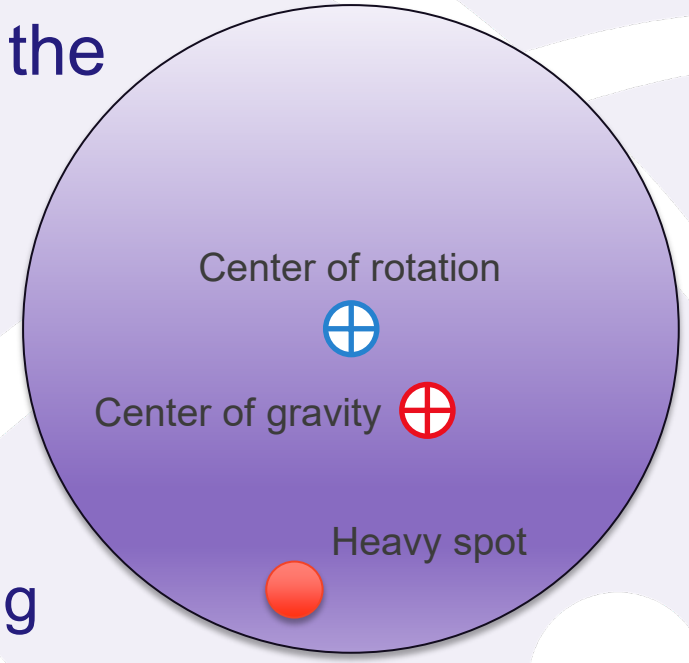


Balancing

Alignment and Balancing

Balancing definition

An impeller is balanced when the center of geometry (hopefully it's the same as the center of rotation) and the center of mass is coincident (in line) especially when running.

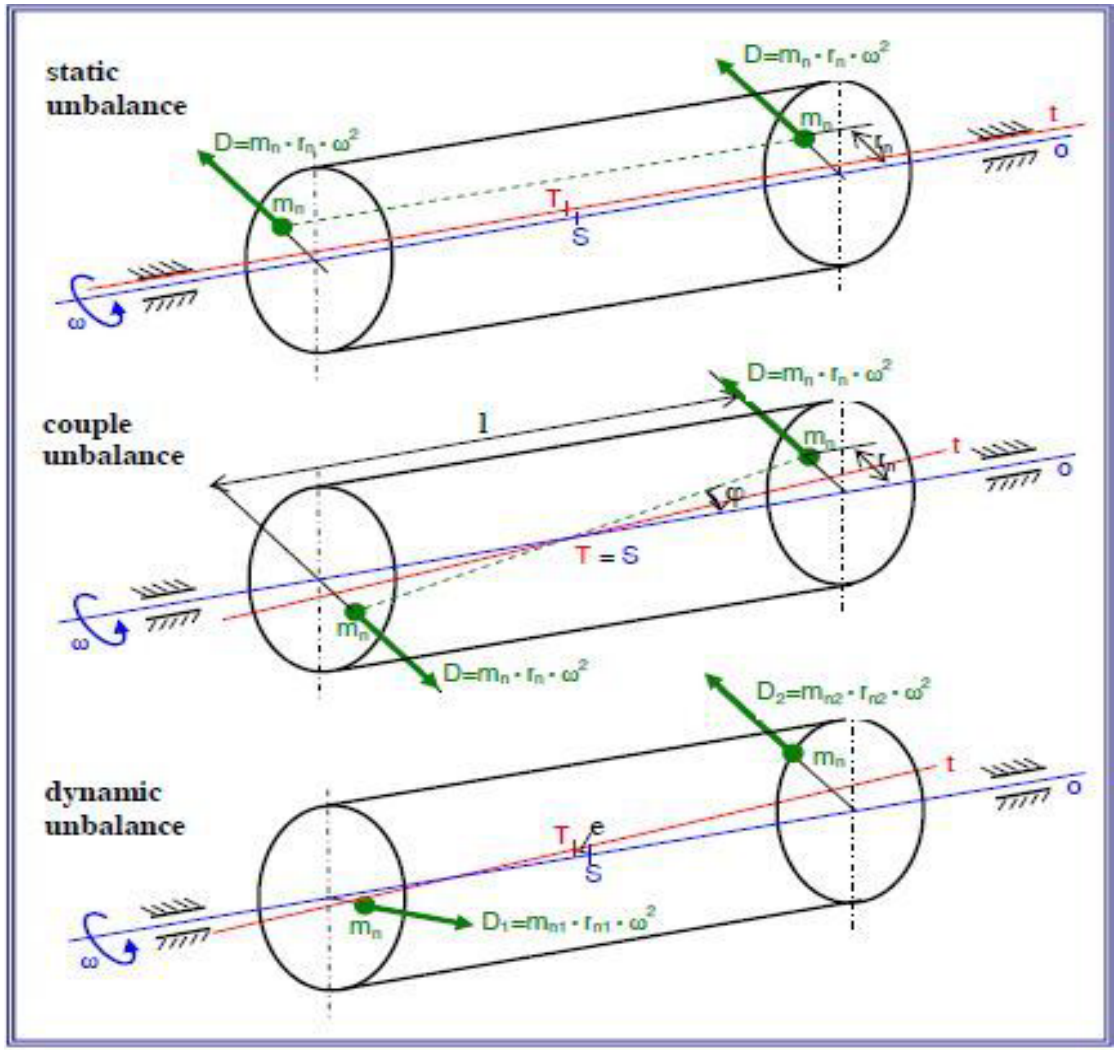


Causes of imbalance

- Casting – mass distribution
- Machining – errors during radial, bore cutting and squaring
- Assembly – multiple component positioning
- Operation – temperature warping, adhesion, erosion, corrosion
- Maintenance – repair welding, lubrication etc.

Alignment and Balancing

Types of Unbalance



Types of balancing solutions

- Single plane
- Two plane
- Multiplane

When to check balance

- After a bearing repair
- New install
- After an impeller replacement
- After a rebuild

Balance Units

- oz-inches
- g-mm

Alignment and Balancing

Balancing procedure (High Level)

1. Make sure balance is the problem.
2. Go over lock-out procedures with appropriate personnel because balancing requires applying and releasing the lock-out a minimum of 3 times and probably more. Everyone needs to be on the same page.
3. Set up equipment.
4. Reference run – initial readings for analyzer.
5. Trail run – attach trial weight
6. Trim run (with or without trial weight)
7. Repeat trim runs until balance tolerance is achieved

Alignment and Balancing - Balance Tolerances per ISO 1940

Table 1 — Guidance for balance quality grades for rotors in a constant (rigid) state

Machinery types: General examples	Balance quality grade G	Magnitude $e_{per} \cdot \Omega$ mm/s
Crankshaft drives for large slow marine diesel engines (piston speed below 9 m/s), inherently unbalanced	G 4000	4 000
Crankshaft drives for large slow marine diesel engines (piston speed below 9 m/s), inherently balanced	G 1600	1 600
Crankshaft drives, inherently unbalanced, elastically mounted	G 630	630
Crankshaft drives, inherently unbalanced, rigidly mounted	G 250	250
Complete reciprocating engines for cars, trucks and locomotives	G 100	100
Cars: wheels, wheel rims, wheel sets, drive shafts Crankshaft drives, inherently balanced, elastically mounted	G 40	40
Agricultural machinery Crankshaft drives, inherently balanced, rigidly mounted Crushing machines Drive shafts (cardan shafts, propeller shafts)	G 16	16
Aircraft gas turbines Centrifuges (separators, decanters) Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds up to 950 r/min Electric motors of shaft heights smaller than 80 mm Fans Gears Machinery, general Machine-tools Paper machines Process plant machines Pumps Turbo-chargers Water turbines	G 6,3	6,3
Compressors Computer drives Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min Gas turbines and steam turbines Machine-tool drives Textile machines	G 2,5	2,5
Audio and video drives Grinding machine drives	G 1	1
Gyroscopes Spindles and drives of high-precision systems	G 0,4	0,4

NOTE 1 Typically completely assembled rotors are classified here. Depending on the particular application, the next higher or lower grade may be used instead. For components, see Clause 9.

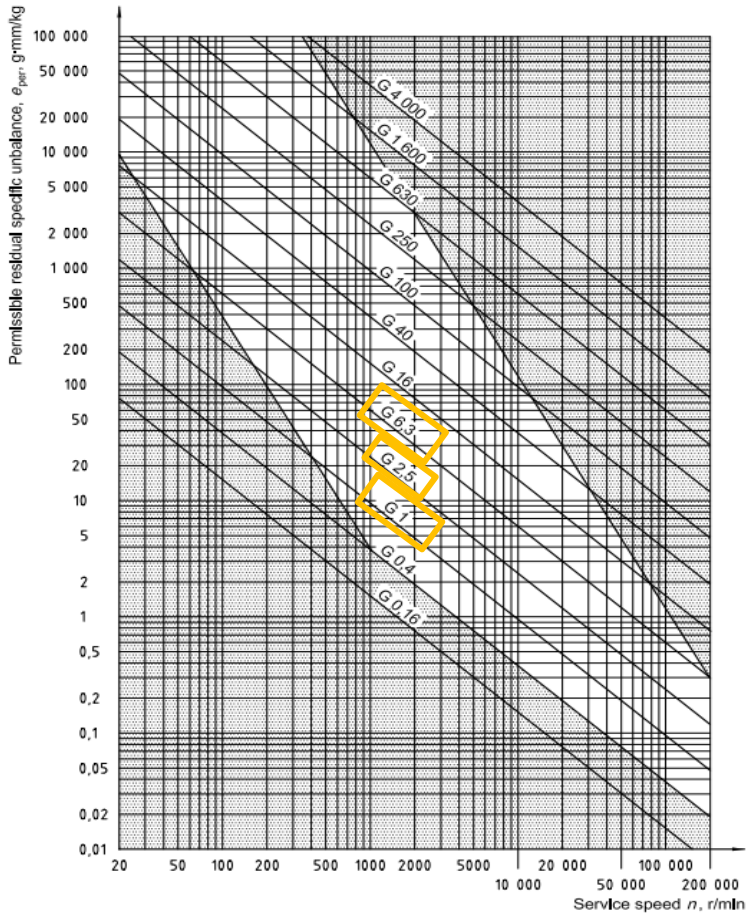
NOTE 2 All items are rotating if not otherwise mentioned (reciprocating) or self-evident (e.g. crankshaft drives).

NOTE 3 For limitations due to set-up conditions (balancing machine, tooling), see Notes 4 and 5 in 5.2.

NOTE 4 For some additional information on the chosen balance quality grade, see Figure 2. It contains generally used areas (service speed and balance quality grade G), based on common experience.

NOTE 5 Crankshaft drives may include crankshaft, flywheel, clutch, vibration damper, rotating portion of connecting rod. Inherently unbalanced crankshaft drives theoretically cannot be balanced; inherently balanced crankshaft drives theoretically can be balanced.

NOTE 6 For some machines, specific International Standards stating balance tolerances may exist (see Bibliography).



NOTE The white area is the generally used area, based on common experience.

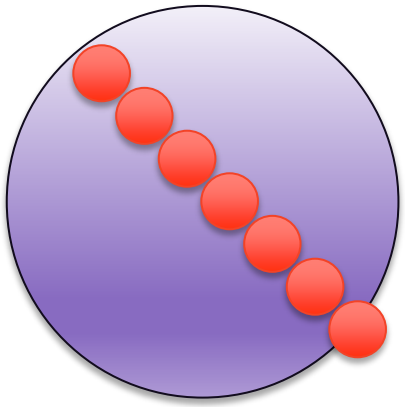
Figure 2 — Permissible residual specific unbalance based on balance quality grade G and service speed n (see 6.2)

Alignment and Balancing

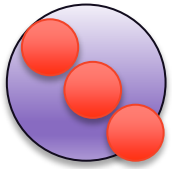
Balance Tolerances per ISO 1940		
Metric	Imperial (Peak)	Imperial (RMS)
G 6.3 mm/sec	0.25 in/sec	0.17 in/sec
G 2.5 mm/sec	0.10 in/sec	0.07 in/sec
G 1.0 mm/sec	0.04 in/sec	0.03 in/sec

G is Geschwindigkeit
German for velocity

G 6.3



G 2.5

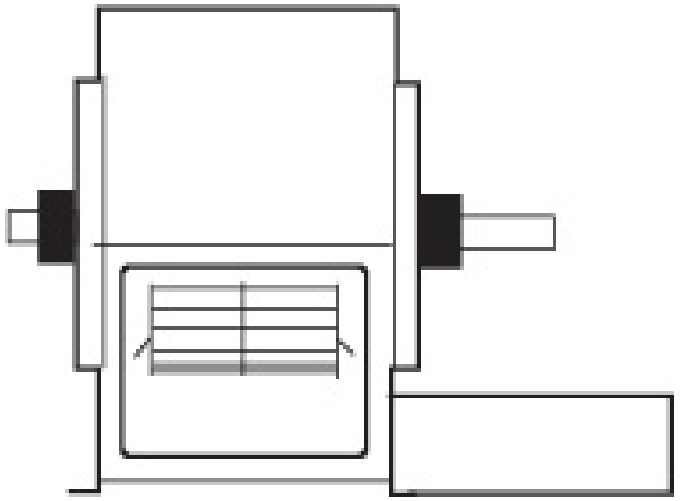


G 1.0

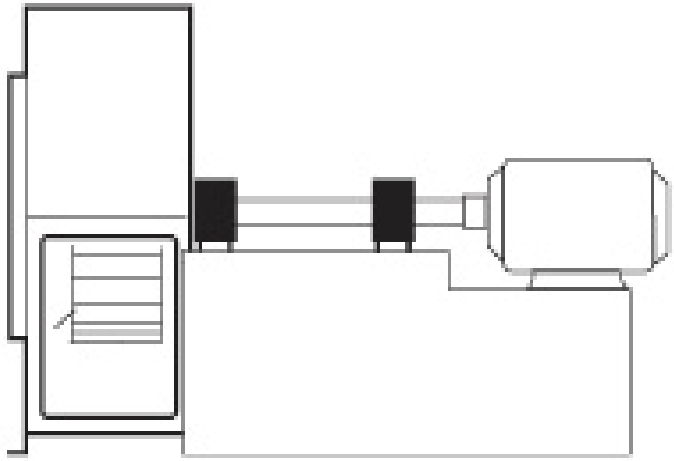
Alignment and Balancing

Special Considerations - Overhung Fans

Center hung Fan

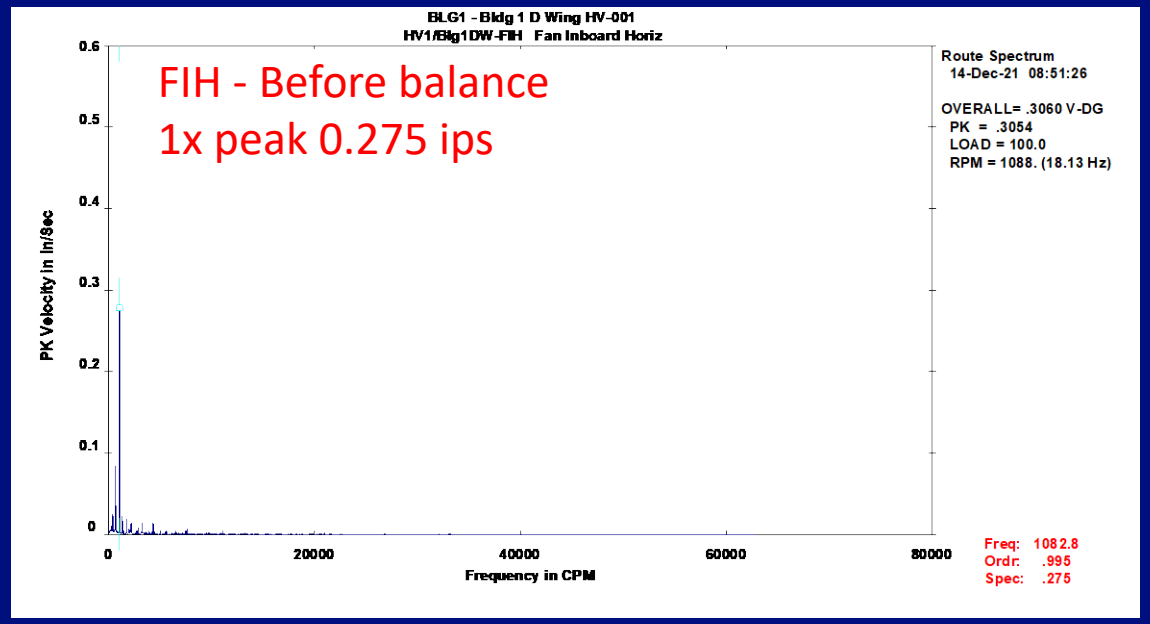


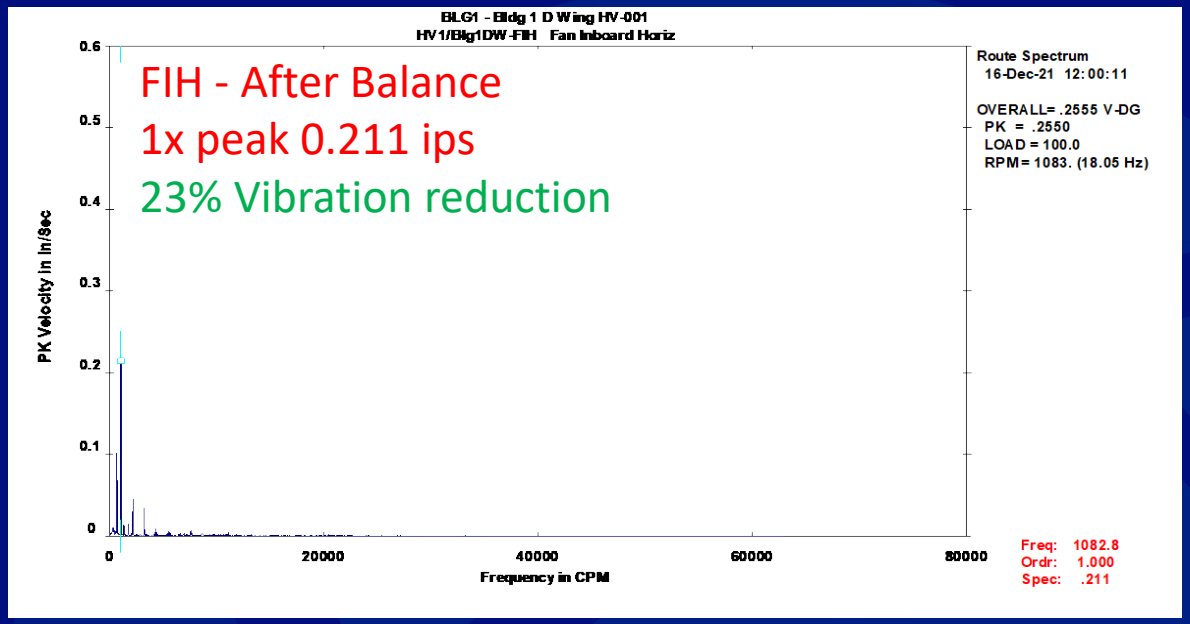
Overhung Fan

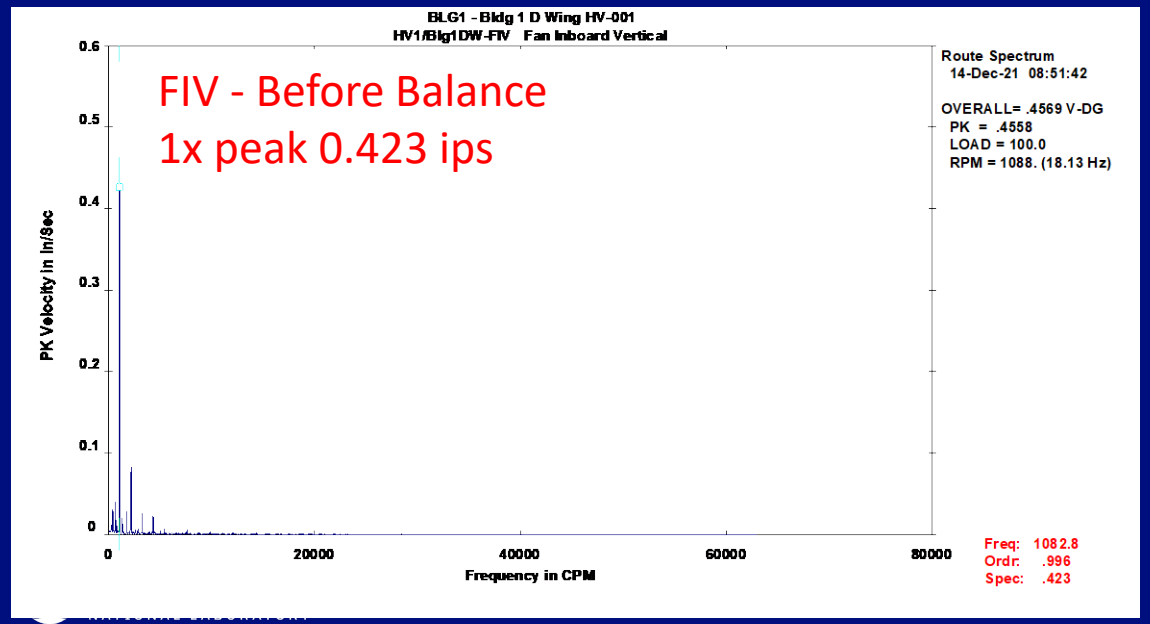


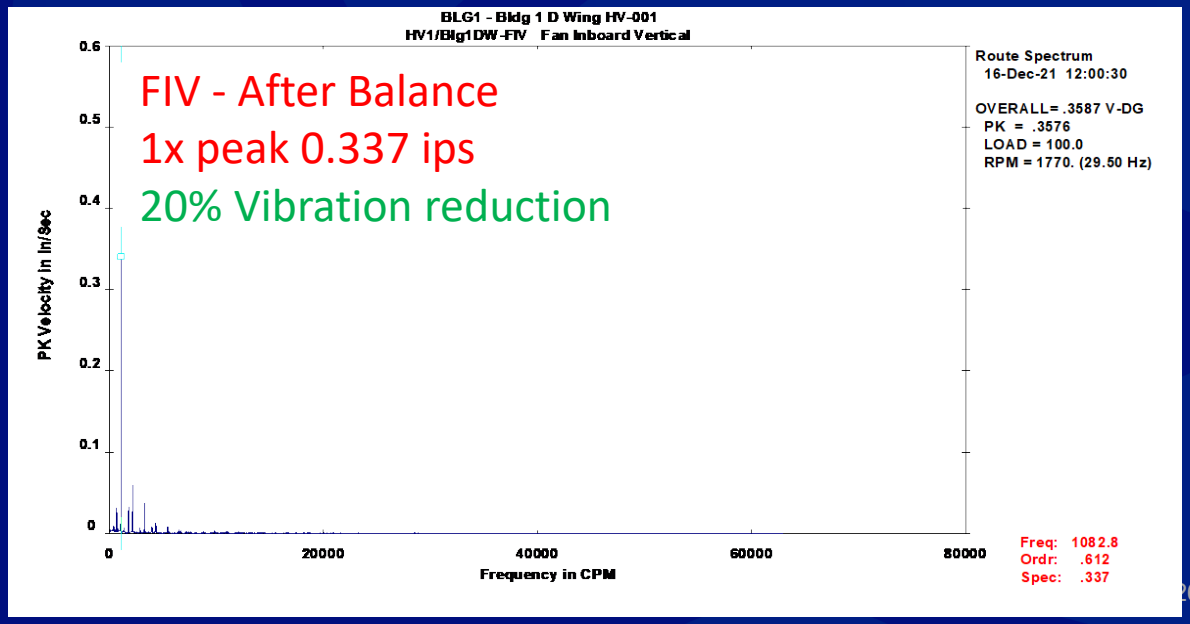
Imbalance can show up in the axial direction in an overhung fan.

Alignment and Balancing – Before and After Balance

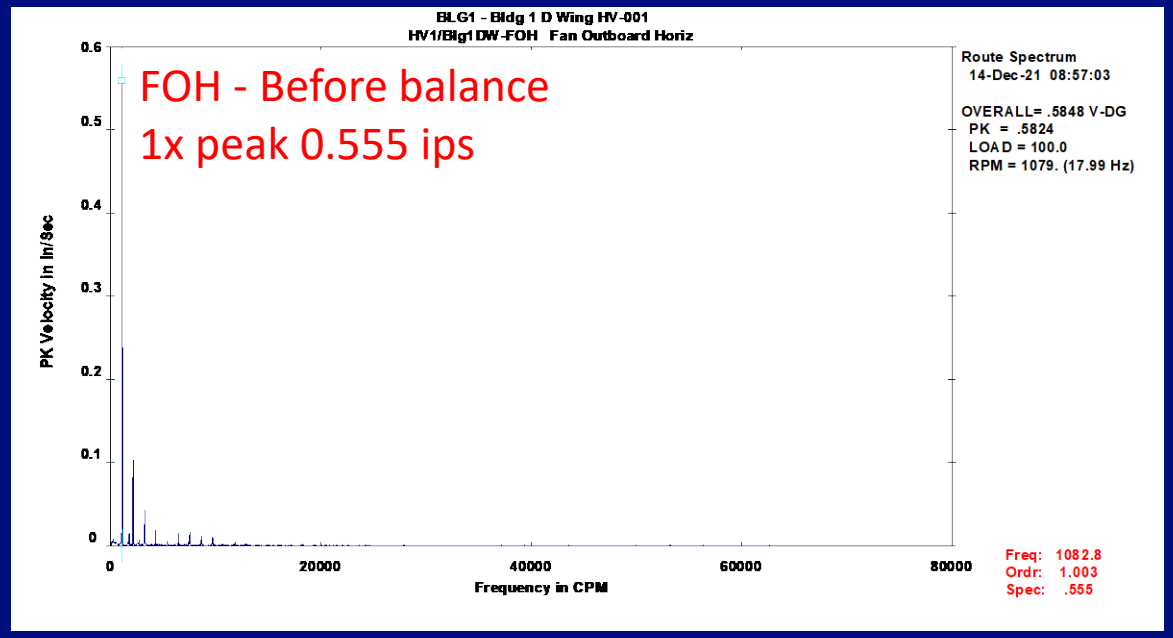


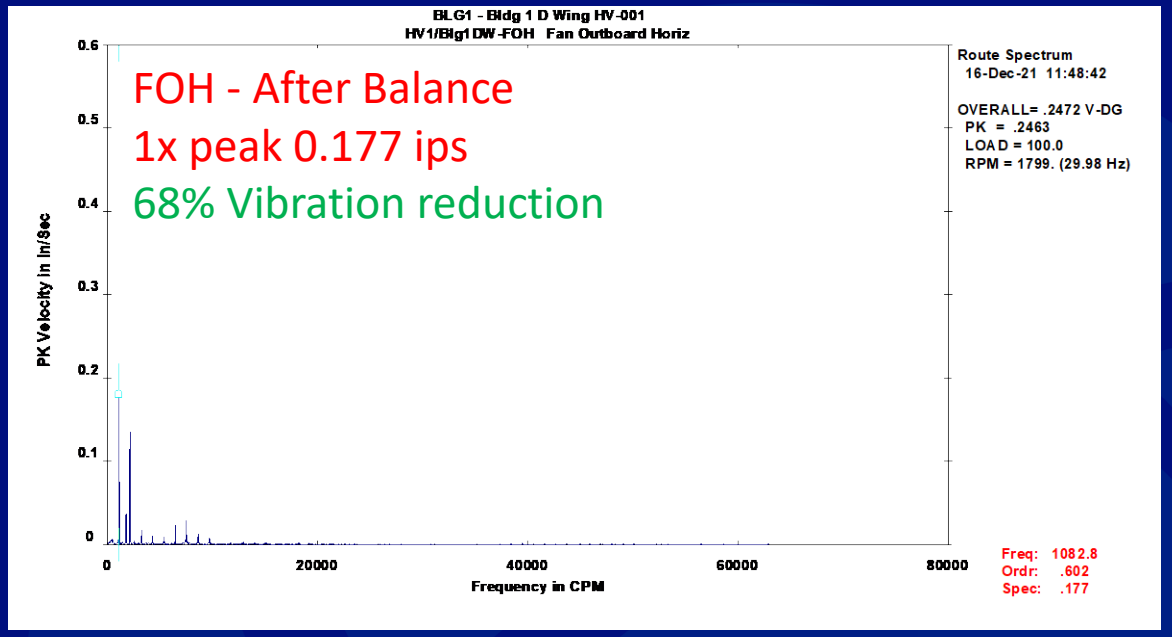


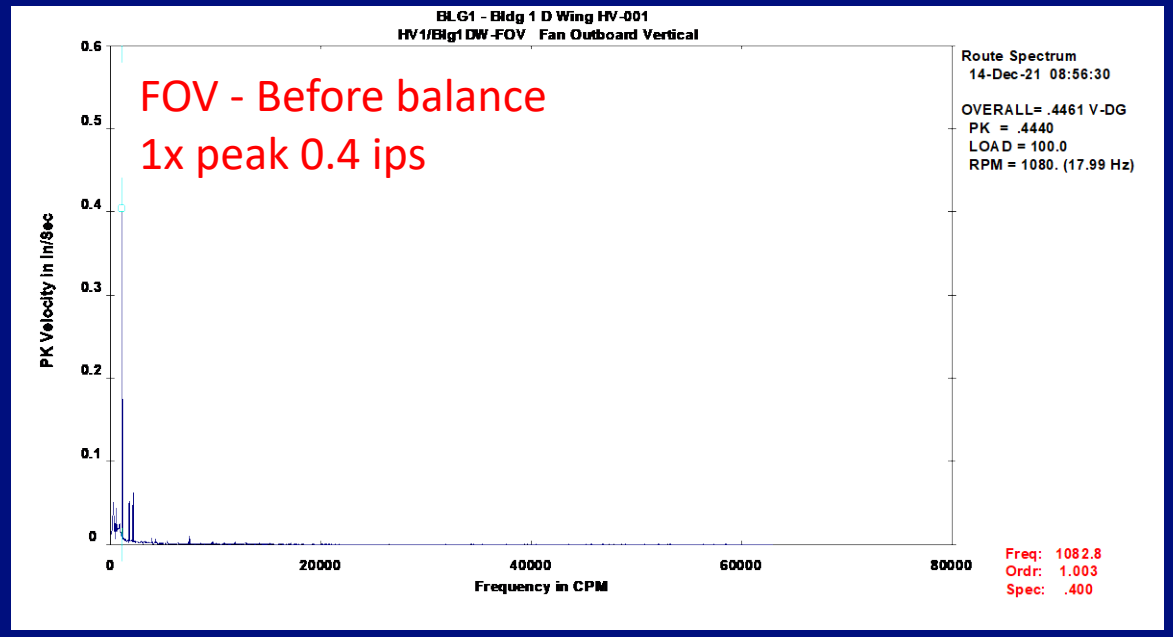


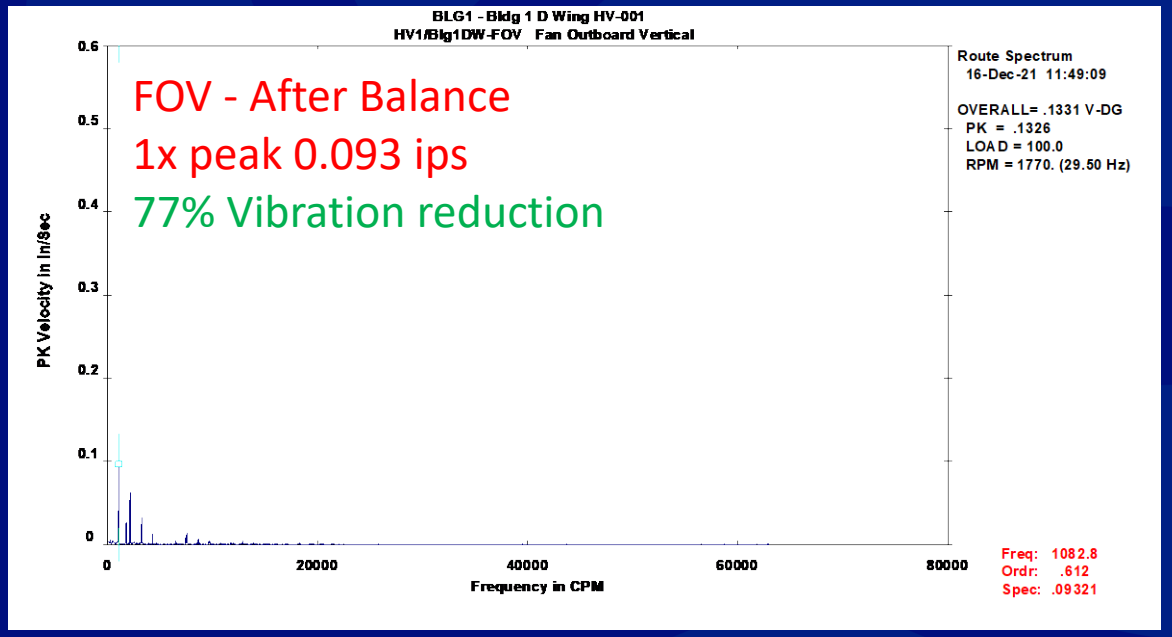


Alignment and Balancing – Before and After Balance





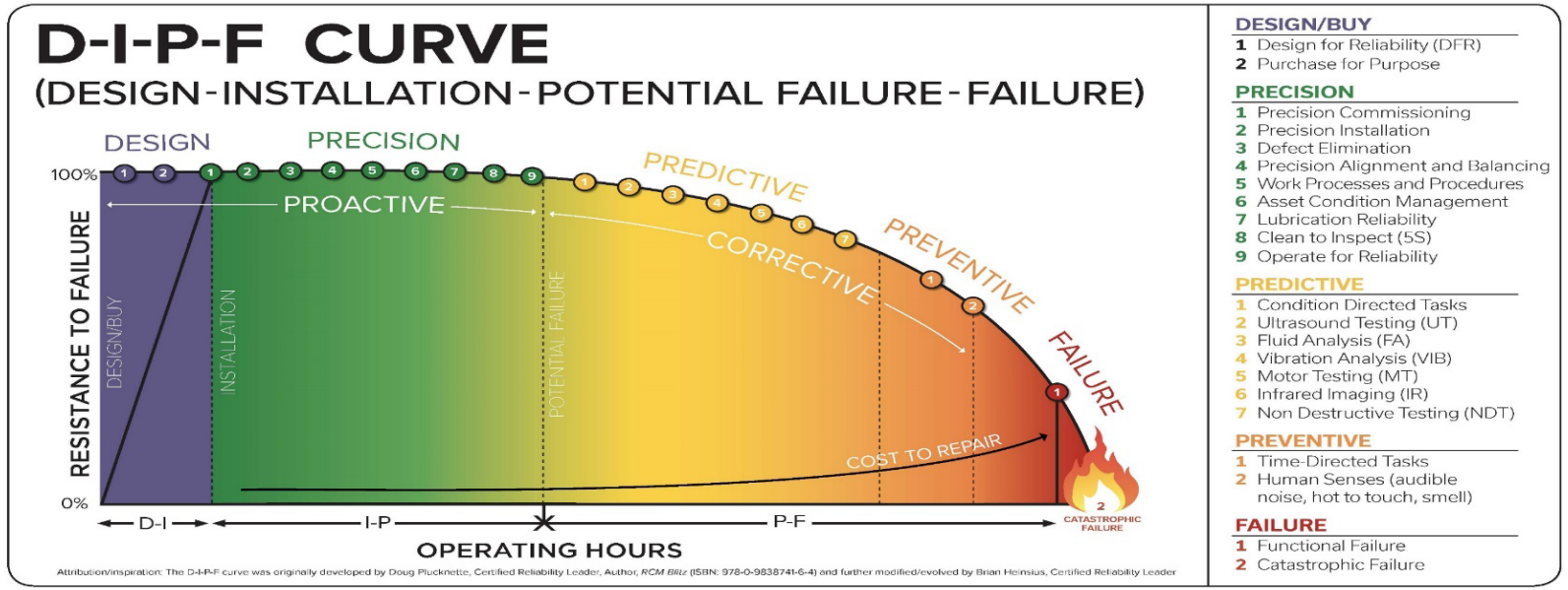




Alignment and Balancing

Benefits Aligning and Balancing Machines

- Saves bearings
- Increases Reliability
- Machines run at their happy place
- Reduce Energy Consumption
- Bad Actors list is shortened (hopefully)



Alignment and Balancing

Questions or Comments

Thank You

Michelle E. Foster

Reliability Engineer - Condition Monitoring and Analysis
Maintenance Site Services – Maintenance Programs
Mobile: 865.300.5824
505.660.8137

E-mail – mefoster@lanl.gov