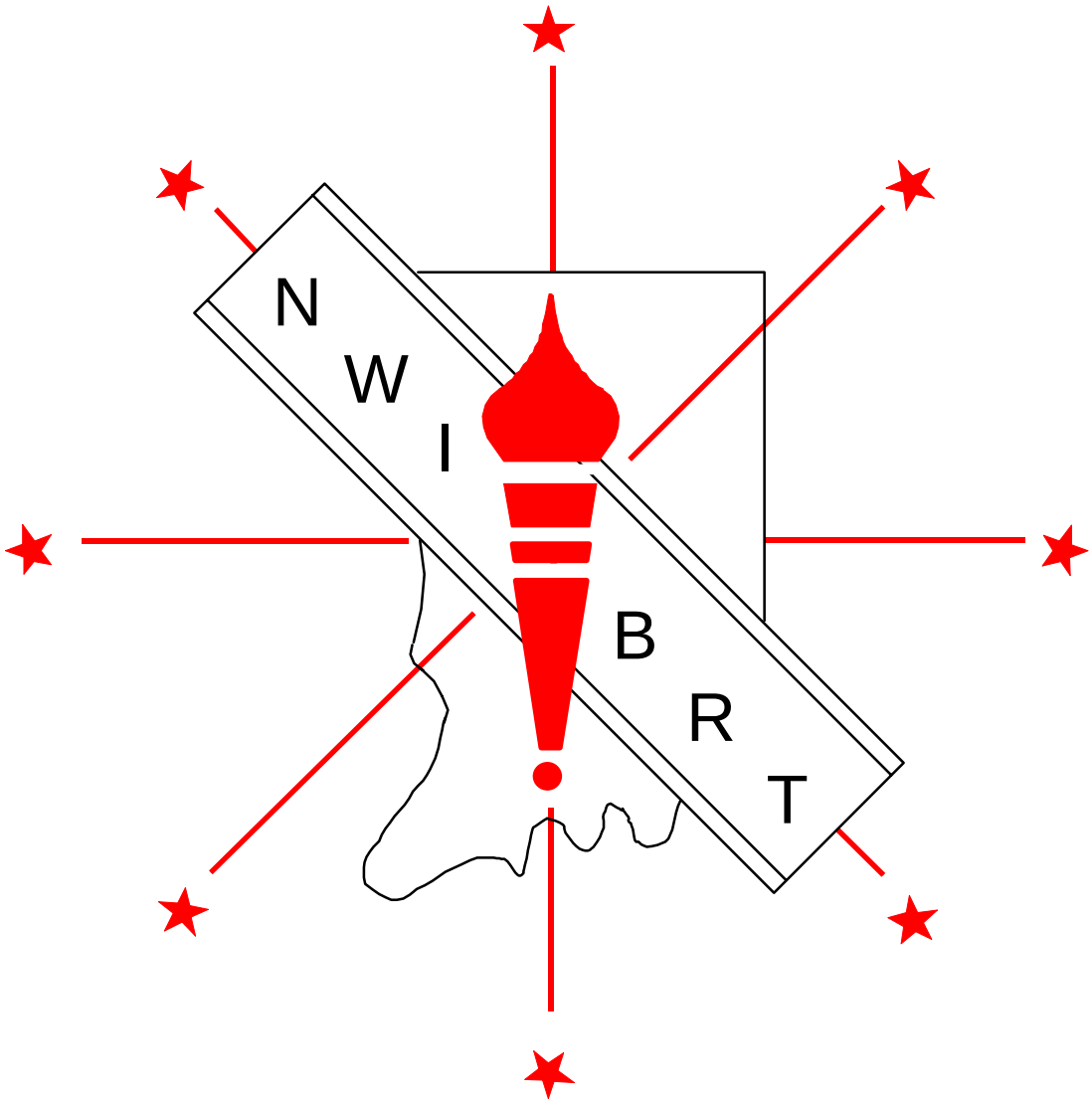

Minimum Acceptance Requirements for Equipment Reliability

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Northwest Indiana Business Roundtable
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Acknowledgements:

A great deal of knowledge, effort, and hard work has gone into the preparation of this "Minimum Acceptance Requirements for Equipment Reliability" document. It is not the thoughts of a single individual, but has drawn on the knowledge and experiences of many individuals working for a variety of different companies, each with a slightly different insight to maintenance and reliability issues, each with different talents, but all with a common vision of making our businesses more successful in this global economy.

We would like to acknowledge the Northwest Indiana Business Roundtable Reliability Subcommittee individuals for their contributions, and their employers for affording them the opportunity to work together on this team. We would also like to thank those outside of the NWIBRT that contributed their efforts to bring this specification into being.

Member and Subscriber Companies participating on the Reliability Subcommittee in the creation of this specification include:

BP - Whiting

Cornerstone Electrical Consultants, Inc.

Falk-PLI

Mittal Steel – Burns Harbor

Mittal Steel – Indiana Harbor

Morris Material Handling, LLC

NIPSCO (Northern Indiana Public Service Company)

Predict-DLI

Rimkus Consulting Group, Inc.

U.S. Steel – Gary Complex

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Preface:

This document fills a void; it addresses measurable reliability tests and quantifiable measures that can be employed on equipment to assess its current health and provide some degree of confidence that the machine is operating well and should have a long life. Without such testing and subsequent acceptance, the Purchaser may have little recourse than to place undesirable equipment into service and suffer the increased downtime, higher maintenance costs, and higher life cycle costs.

There are many other standards and specifications available that deal with in service measures of machine and system health to guide maintenance, replacement, or other remedial measures, but few address the acceptance levels associate with those measures. Levels for acceptance on new or rebuilt machines or systems are not the same levels which should drive maintenance activities on well used in service machine.

For example, you have the oil changed in your car and the oil level is left at the "full" mark. You routinely check the oil and its level continues to go down, yet you wait till it is 1 quart low before adding oil to bring it back to the "full". Your acceptance criterion is that the oil level be at the full mark (or very close to full). Your "maintenance required" criterion is that at 1 quart low and you take remedial action to bring the level back to within that acceptance specification. The same holds true for nearly all machines and processes. The design specification limit (acceptance limit) is not the same as the "maintenance required" limit; there is always a deadband.

The NWIBRT Reliability Subcommittee has endeavored to assemble a reasonable set of reliability tests and quantifiable measures that can be employed across a broad range of equipment to aid the Purchaser in obtaining good, reliable equipment.

References:

1. ASNT SNT-TC-1A 1711 Arlingate Lane, Columbus, OH 43228
2. ASTM D 1264 100 Barr Harbor Drive, West Conshohocken, PA, 19428
3. ASTM D 130 100 Barr Harbor Drive, West Conshohocken, PA, 19428
4. ASTM D 1401 100 Barr Harbor Drive, West Conshohocken, PA, 19428
5. ASTM D 1743 100 Barr Harbor Drive, West Conshohocken, PA, 19428
6. ASTM D 217 100 Barr Harbor Drive, West Conshohocken, PA, 19428
7. ASTM D 2270 100 Barr Harbor Drive, West Conshohocken, PA, 19428
8. ASTM D 2272 100 Barr Harbor Drive, West Conshohocken, PA, 19428
9. ASTM D 2509 100 Barr Harbor Drive, West Conshohocken, PA, 19428
10. ASTM D 3427 100 Barr Harbor Drive, West Conshohocken, PA, 19428
11. ASTM D 4049 100 Barr Harbor Drive, West Conshohocken, PA, 19428
12. ASTM D 445 100 Barr Harbor Drive, West Conshohocken, PA, 19428
13. ASTM D 566 100 Barr Harbor Drive, West Conshohocken, PA, 19428
14. ASTM D 5950 100 Barr Harbor Drive, West Conshohocken, PA, 19428
15. ASTM D 665 A/B 100 Barr Harbor Drive, West Conshohocken, PA, 19428
16. ASTM D 892 100 Barr Harbor Drive, West Conshohocken, PA, 19428
17. ASTM D 92 100 Barr Harbor Drive, West Conshohocken, PA, 19428
18. ASTM D 974 100 Barr Harbor Drive, West Conshohocken, PA, 19428
19. ASTM D-1403 100 Barr Harbor Drive, West Conshohocken, PA, 19428
20. ASTM D-2266 100 Barr Harbor Drive, West Conshohocken, PA, 19428
21. ASTM D-2782 100 Barr Harbor Drive, West Conshohocken, PA, 19428
22. ASTM D-5182 100 Barr Harbor Drive, West Conshohocken, PA, 19428
23. ASTM D-6304 100 Barr Harbor Drive, West Conshohocken, PA, 19428
24. ISO 18436-2 1 rue de Varembe, 1211 Geneva 20, Switzerland
25. ISO 1940/41 1 rue de Varembe, 1211 Geneva 20, Switzerland
26. ISO 4406:1999 1 rue de Varembe, 1211 Geneva 20, Switzerland

I General

The purpose of this "Minimum Acceptance Requirements for Equipment Reliability" document is to aid both the Seller and Purchaser by outlining documented testing methods & measures related to equipment health & reliability along with acceptance parameters for those measures. It benefits the Seller by setting reasonable minimum expectations which could influence the design, manufacture, and installation of the equipment or system. It benefits the Purchaser by ensuring the equipment performs within these Acceptance Requirements which should lead to longer in-service life and greater equipment reliability. It benefits both Seller and Purchaser by ensuring documented acceptance testing and approval has taken place.

Generally, all sections of this document shall apply, but on smaller contracts, installations, and purchases, some sections may not be applicable due to the particular equipment or systems installed or touched. Sections, paragraphs, or items which are not applicable must be agreed to in writing by both Seller and Purchaser prior to contract or sale.

The following items in this document refer to testing, correcting, retesting, logging, and documentation of items, equipment, and systems as installed or in use at the Purchasers facility with the exception of shop surge testing and some specific spares (spare motors, delivered oils & lubricants, etc.) supplied with the project. The Seller shall perform these acceptance tests. Any equipment not meeting the acceptance criteria shall be corrected at Seller's expense and re-tested until all acceptable levels are met*. **All tests shall be documented, signed, and forwarded to the Purchaser for final acceptance.** Documentation and acceptance shall be either hard copy or secure electronic means. Neither verbal communication of test results for approval nor verbal communication of final acceptance are permitted.

With the exception of spares noted above, all acceptance testing shall take place at the Purchasers facility on installed, operating equipment. This does not preclude the supplier or manufacturer from testing their components or systems offsite to give assurances that the equipment will perform well when installed, but such tests shall not qualify as acceptance testing as required by this document. Spare motors noted above shall be tested unloaded on isolation pads for acceptance. Delivered lubricants shall be sampled on site. Each section of this document may have additional criteria describing factory calibration requirements, test methods, acceptance criteria, reporting, and additional document requirements, but they are all in addition to the requirements stated here.

*Special circumstances may apply within specific sections, such as vibration & thermography, for "with cause" anomalies or exceptions to stated acceptance criteria. Please review those sections for additional information.

II Hydraulic Oil System Cleanliness Level Specifications

All hydraulic systems shall meet specific cleanliness conditions as noted below. The sampled locations (reservoirs, systems, loops, etc.), sampling port physical locations, and sampling procedures shall be agreed to between Purchaser and Seller. ISO 4406:99 testing methods shall be used. The Seller shall sample the systems initially and test to verify conditions. The Seller shall subsequently, each month for 6 months, resample the systems and test to verify these conditions are maintainable. All sample test results shall be documented and submitted for approval to Purchaser (Section I. General).

ISO Cleanliness Requirements at Different System/Component Operating Pressures, PSI			
Equipment	**< 1500 PSI**	**1500-2500 PSI**	**> 2500 PSI**
Servo Control Valves	16/14/11	15/13/11	14/12/10
Proportional Valves	17/15/12	16/14/11	15/13/11
Variable Volume Pumps	17/16/13	16/15/12	16/14/11
Cartridge Valves	18/16/13	17/16/13	16/15/12
Fixed Piston Pumps and Motors	18/16/13	17/16/13	16/15/12
Vane Pumps	18/16/13	17/16/13	16/15/12
Directional, Pressure, and Flow Control	18/16/13	17/16/13	16/15/12
Solenoid Valves	18/16/13	17/16/13	16/15/13
Gear Pumps and Motors	19/17/14	18/16/13	18/16/13
Cylinders	20/18/15	20/17/14	19/17/14

III Lubricating Oil Specifications

Lubricants received "as new" to be used in equipment or as spare should be tested for particulate and water contamination as well as basic performance capabilities. Each lubricant has a technical specification sheet that specifies various performance properties depending on desired duty. Lubricants are divided into several groups according to their use and base oil properties:

1. Turbine
2. Hydraulic
3. Gear
4. Grease
5. Special function lubricants

Turbine lubricants are generally highly refined and are required to be clean, free of water, resist water contamination and possess high oxidation stability.

If the Turbine lubricant does not meet its corresponding technical specification, it is not acceptable. If the Turbine lubricant does not meet its cleanliness specification, at supplier's expense, it may be recirculated and filtered in the reservoir until the target cleanliness is met. Normal RPVOT values are 1,000 minutes or greater for new lubricants.

The following tests shall be performed on Turbine lubricants:

Turbine Lubricant New Specification Tests and Limits			
Test Method	**Expressed Value**	**ASTM #**	**Optimum Value**
Viscosity @ 40ºC & 100ºC	Centistokes (cSt)	D 445	+ or – 5% of VG
Viscosity Index	Number with no units	D 2270	> or = 95
Water	Ppm water	D-6304	< 50 ppm
Flash Point	ºF & ºC	D 92	> 450ºF
Pour Point	ºF & ºC	D 5950	< = - 10ºF
Neutralization #	Milligrams of KOH	D 974	< or = 0.1
Rust Prevention Test	Pass/Fail	D 665 A/B	Pass/Pass
Copper Strip Corrosion	1-4	D 130	< 1B
Rotary Pressure Vessel Oxidation Test	Minutes	D 2272	> 400
Foaming Sequence I/II/III	Milliliters of foam	D 892	Pass/Pass/Pass
Air Release	Minutes	D 3427	< or = 5
Water Separability	Milliliters of oil, water, and emulsion	D 1401	40/40/0
ISO Cleanliness Code	Three #'s xx/xx/xx	ISO 4406:1999	17/14/11

Hydraulic lubricants are used primarily to transfer power or direction in machines and as such encounter more sliding action. For servo control systems these lubricants can operate at high temperatures and therefore need to be stable to oxidation. They must be clean and some have fire suppression requirements that must also be addressed.

If the Hydraulic lubricant does not meet its corresponding technical specification, it is not acceptable. If the Hydraulic lubricant does not meet its cleanliness specification, at supplier's expense, it may be recirculated and filtered in the reservoir until the target cleanliness is met. Normal RPVOT values are 1,000 minutes or greater for new lubricants.

The following tests shall be performed on Hydraulic lubricants:

Hydraulic Lubricant New Specification Tests and Limits			
Test Method	**Expressed Value**	**ASTM #**	**Optimum Value**
Viscosity @ 40ºC & 100ºC	Centistokes (cSt)	D 445	+ or – 5% of VG
Viscosity Index	Number with no units	D 2270	> or = 95
Water	Ppm water	D-6304	< 100 ppm
Flash Point	ºF & ºC	D 92	> 450ºF
Pour Point	ºF & ºC	D 5950	< = - 20ºF
Neutralization #	Milligrams of KOH	D 974	< or = 0.2
Rust Prevention Test	Pass/Fail	D 665 A/B	Pass/Pass
Copper Strip Corrosion	1-4	D 130	< 1B
Rotary Pressure Vessel Oxidation Test	Minutes	D 2272	> 400
Foaming Sequence I/II/III	Milliliters of foam	D 892	Pass/Pass/Pass
Air Release	Minutes	D 3427	< or = 5
Water Separability	Milliliters of oil, water, and emulsion	D 1401	40/40/3 max
ISO Cleanliness Code	Three #'s xx/xx/xx	ISO 4406:1999	18/15/12

Gear lubricants are special in that they are generally much higher in viscosity grade and have certain expected anti-wear capabilities. Since they are also heavier, they also tend to have higher particle counts even when new.

If the Gear lubricant does not meet its corresponding technical specification, it is not acceptable. If the Gear lubricant does not meet its cleanliness specification, at supplier's expense, it may be recirculated andfiltered in the reservoir until the target cleanliness is met. Normal RPVOT values are 1,000 minutes or greater for new lubricants.

The following tests shall be performed on Gear lubricants:

Gear Lubricant New Specification Tests and Limits			
Test Method	**Expressed Value**	**ASTM #**	**Optimum Value**
Viscosity @ 40ºC & 100ºC	Centistokes (cSt)	D 445	+ or – 5% of VG
Viscosity Index	Number with no units	D 2270	> or = 85
Water	Ppm water	D-6304	< 200 ppm
Flash Point	ºF & ºC	D 92	> 325ºF
Pour Point	ºF & ºC	D 5950	< = - 20ºF
Rust Prevention Test	Pass/Fail	D 665 A/B	Pass/Pass
Copper Strip Corrosion	1-4	D 130	< 1B
Foaming Sequence I/II/III	Milliliters of foam	D 892	Pass/Pass/Pass
ISO Cleanliness Code	Three #'s xx/xx/xx	ISO 4406:1999	19/17/12
Timken Extreme Pressure	Max load in pounds or kg	D-2782	60 lbs
Four Ball Wear	Scar diameter wear reading in millimeters	D-2266	< or = 0.5
FZG	Highest stage (1-13) achieved	D-5182	12

Greases are comprised usually of a gear lubricant with a thickener added to suspend the lubricant in a matrix which releases the lubricant when some type of dynamic action occurs.

If the Grease does not meet its corresponding technical specification including Worked Penetration Range Test, it is not acceptable. If the Grease does not meet its cleanliness specification, it is not acceptable. Supplied grease thickeners shall be consistent and compatible with the greases normally used by the Purchaser. Any incompatibilities required for technical reasons shall be communicated and agreed to by the Purchaser prior to delivery.

Typical specifications for new greases are:

New Grease Tests			
Test Method	**Expressed Value**	**ASTM #**	**Optimum Value**
Cone Penetration Unworked & 60 x	Millimeters/10	D 217	See NLGI Grease Classification table below
Worked Penetration 10,000 & 100,000 x	Millimeters/10	D 217	> or = +1 NLGI grade level
Dropping Point	Temperature in ºC & ºF	D 566	> or = 300ºF
Corrosion Prevention	Pass/Fail	D 1743	Pass
Water Washout	% grease washed out	D 1264	< or = 4 %
Water Spray-Off Resistance	% grease sprayed off	D 4049	< or = 6%
Timken OK Load	Maximum weight in Kg or Lbs	D 2509	> or = 40 lbs

The table below lists all NLGI (National Lubricating Grease Institute) grease grades from 000 to 6. Each of the grease ratings shall fall within the specifications when tested under ASTM D-217.

NLGI Grease Classification		
Grade	**Worked Penetration Range @ 77F, mm/10**	**Consistency**
000	445 to 475	Semifluid
00	400 to 430	Semifluid
0	355 to 385	Very Soft
1	310 to 340	Soft
2	265 to 295	Common Grease
3	220 to 250	Semihard
4	175 to 205	Hard
5	130 to 160	Very Hard
6	85 to 115	Solid

Special function lubricant specifications shall be addressed in a future revision.

IV Vibration Specifications

A. General Requirements

Vibration acceptance testing shall be performed on all rotating equipment by ISO 18436-2 certified persons in a manner consistent with sound vibration collection, analysis, and diagnostic practices using suitable, calibrated instruments, transducers, and software. The instrument systems and practices shall be suitable for the intended frequency ranges, possess adequate amplitude resolution needed for these tests, and employ anti-aliasing filtering.

In order to maximize the value of this information as benchmark data, the Seller shall utilize the same, or Purchaser preferred, vibration data collector instrument(s) and software currently being used by the Purchaser. The use of alternate instruments, software, and configuration may be permitted by the Purchaser on a case by case basis. When available, the Seller shall also set up appropriate machine locations and measurements following the Purchaser's guidelines complete with acceptance, warning, and critical alarm levels for the equipment prior to performing and storing the vibration measurements in the vibration software. The database shall also include information on the equipment such as bearing type, number of gear teeth, etc. to allow future analysis of equipment vibration problems. The database and test results may be built in the Purchaser's CBM software system or in a compatible system where the Seller shall seamlessly import the information into the Purchaser's CBM system or export the information into an acceptable interim format, such as MIMOSA (Machinery Information Management Open System Alliance), which can be imported into the Purchaser's CBM system.

Data collection shall be performed by ISO 18436-2 Category 2 certified persons or trained persons under the direct guidance of a Category 3 supervisor. Test plans, measurement/database setup, result interpretation, and analysis shall be performed by a Category 3 analyst or trained persons under the direct guidance of a Category 4 supervisor.

B. Test Conditions

All acceptance testing (other than spare motor only unloaded/loaded shop tests and spare gearbox only unloaded/loaded shop tests) will take place on equipment installed at the Purchaser's site and operating under typical speed and load as described below. Seller may elect to pre-test equipment at an alternate location to increase their confidence they have manufactured a satisfactory machine, but those (factory) tests will not be used as a basis for Purchaser's acceptance. One should note that if a

machine under factory test cannot meet the "as installed" acceptance criteria, it is unlikely it will be acceptable in the field.

Rotating equipment shall meet the specific vibration criteria listed below for all speeds and loads from 0% to 100% of design. The Seller shall take and store vibration readings at design speed for constant speed equipment. The Seller shall take and store vibration readings at MAX speed, 90% speed, and 75% speed for variable speed equipment. The vibration acceptance vibration levels and absolute frequency ranges may change based on rotating speed; care must be taken to apply the appropriate criteria at each speed. All tests shall take place under normal operating conditions/parameters. If high vibration is suspected at other speeds, additional acceptance testing shall be performed at these speeds to verify acceptance.

C. Testing Parameters

Vibration measurements consisting of overall magnitude, time domain records, and frequency domain FFT spectra shall be made as close to the bearing as possible in at least two radial directions 90 degrees apart and in at least one axial location at each bearing location.

The magnitude measurements and FFT measurements shall use a Hanning window and at least 4 linear/rms averages with up to 50% overlap processing. FFT measurements shall employ enough lines of resolution to adequately resolve vibration frequencies for diagnostic purposes, but not so many as to mask or hide vibration spectral peaks. Multiple measurements may be required to attain the information required. The FFT frequency resolution between similar amplitude signals (<20d**B** difference**)** with a Hanning window applied should be calculated based on this formula:

Resolution = [3 x (Frequency Span)]/Number of FFT Lines

Time domain records typically do not require windowing. If a window is applied to the instrument setup, it shall be a Hanning window, but the time record shall not reflect the effects of the windowing function. All time domain records shall use a sampling rate of at least 12,800 samples/sec (typical 5000 Hz Fmax setup). The length of the time block (often controlled by the 'number of lines' setting) shall reflect at least 6 rotations of the shafts. No time domain averaging is required. These measurements will not employ filtering or other methods to reduce the vibration amplitudes within the desired frequency range of interest.

Units of operating speed are acceptable in either RPM or Hz (cycles per second). Units of vibration frequency are acceptable only in Hz.

Units of vibration acceleration shall be in terms of G_{peak} where 1 G is defined as 386.1 inch/sec^2. G's overall values may be obtained from the time domain or from a wide band limited overall (typically 2 Hz – 20 kHz) based on the FFT results and scaled to G_{peak}. G's spectral line amplitude values or band limited overall amplitude values are based on the FFT results and are scaled to G_{peak}. G's PEAK values will be obtained from the time domain and shall reflect the maximum excursion from the mean (typically 0.0 G's), whether positive or negative.

Units of vibration velocity shall be in terms of IPS_{peak} (inches per second). IPS overall values may be obtained from the time domain provided a velocity transducer or analog integration is used. IPS overall values may also be obtained from a wide band limited overall (typically 2 Hz – 2 kHz) based on the integrated FFT results and scaled to IPS_{peak}. IPS spectral Line Amplitude values or band limited overall amplitude values are based on the FFT results and are scaled to IPS_{peak}.

D. Acceptance Criteria

Vibration acceptance limits are based on the general equipment type, overall G's acceptance values, peak G's acceptance values, overall IPS acceptance values, and IPS line amplitude frequency bands. The corrected acceptance values from the "Overall Vibration Magnitude Guidelines" apply to all measurement locations and orientations. If machines are outfitted with proximity probe (relative displacement) type transducers or of a construction (speed, bearing type, rotating mass, bearing stiffness, etc.) which generally should employ relative displacement vibration transducers, additional acceptance criteria will be agreed upon between Seller and Purchaser. At no time shall acceptance displacement limits exceed 25% of the shaft/bearing diametrical clearance.

The following tables identify the criteria that will be used for acceptance. The acceptable amplitudes of each item ("Band Name") are a percentage of the "Corrected Acceptance Level" for a given machine/train type. The table "Overall Magnitude Vibration Guidelines" lists machine/train types, their general acceptance, warning, and critical levels. The associated "Table Notes, Modifiers, and Exceptions" clarifies the methods to adjust or correct those acceptance levels to the particular train/machine.

If there is any question as into which equipment type a particular machine falls, it should be discussed with the Purchaser. In those cases where the equipment cannot reasonably fit within an existing Equipment Type, the Purchaser may, on a case by case basis, create an additional Equipment Type along with its uncorrected Acceptance, Warning, and Critical levels.

Vib Acceptance Limits: Bands vs. % of Corrected Acceptance Levels

Units	Band Name	Frequency Range	% of Corrected Acceptance Level	Criteria
IPS_{peak}	Overall IPS	Overall or 2hz – 2khz	100%	OA or Band Limited OA
IPS_{peak}	Subsynchronous	(0.3 – 0.8) x Running Speed	50%	Line Amplitude
IPS_{peak}	Running Speed	(0.8 – 1.2) x Running Speed	80%	Line Amplitude
IPS_{peak}	Lower harmonics	(1.2 – 3.5) x Running Speed	50%	Line Amplitude
IPS_{peak}	Mid harmonics	(3.5 – 8.5) x Running Speed	30%	Line Amplitude
IPS_{peak}	Upper harmonics	8.5 x Running Speed – 1000 Hz	30%	Line Amplitude
IPS_{peak}	Midband	1000 Hz – 2000 Hz	30%	Line Amplitude
IPS_{peak}	Highband	2000 Hz – 5000 Hz	20%	Line Amplitude
G_{peak}	Overall G's	Overall or 2hz – 20khz	125%	OA or Band Limited OA
G_{peak}	Wideband G's	0.3 x Running Speed – 5000 Hz	100%	Band Limited OA
G_{peak}	Max G's PEAK	(From Time Domain Data)	250%	Max. Excursion from Mean

Each spectrum shall meet the overall magnitude acceptance level as well as each band acceptance level. Each time domain measurement shall meet the Max G's PEAK acceptance level.

For most machines, the values directly from the "Overall Vibration Magnitude Guidelines" must be corrected or adjusted for speed, bearing type, mounting considerations, and other noted factors. Speed corrections are in the last section of the "Overall Vibration Magnitude Guidelines" table. Notes regarding these potential adjustments are in the "Table Notes, Modifiers, and Exceptions" section after the table. . You **MUST** review the instructions and apply the appropriate adjustments in order to use the proper "Corrected Acceptance Level" rather than the nominal value alone.

A spreadsheet "calculator" to assist the Seller in calculating the appropriate acceptance values per band, frequency band limits, based on machine type, speed, bearings, mounting, etc. is available. This calculator is available at the NWIBRT web site (http://www.nwibrt.org) in the STANDARDS section. This calculation spreadsheet is available only as a convenience to the Seller. If any irregularities between the calculator, vendor softwares, and this document exist, the values derived directly from this document shall prevail.

NOTE: It is important that you use the calculator revision which matches this document revision to reduce the chances of irregularities. The calculator also contains major software vendor specific tabs of sample implementations to ease the creation of the required measures and alarms. Please inform us of any irregularities you find in the calculator as well as offer suggestions and help in creating additional vendor specific tabs.

Overall Vibration Magnitude Guidelines (Uncorrected)

Equipment Type	Acceptance		Warning	Critical
	IPS_{peak}	G_{peak}	IPS_{peak}	IPS_{peak}
COOLING TOWER DRIVES				
Long, Hollow Drive Shaft	.185 IPS	.80 g	.375 IPS	.600 IPS
Close Coupled Belt Drive	.135 IPS	.70 g	.275 IPS	.425 IPS
Close Coupled Direct Drive	.100 IPS	.80 g	.200 IPS	.300 IPS
COMPRESSORS				
Reciprocating	.160 IPS	1.20 g	.325 IPS	.500 IPS
Rotary Screw	.135 IPS	1.50 g	.275 IPS	.425 IPS
Centrifugal with or without External Gearbox	.085 IPS	1.50 g	.175 IPS	.275 IPS
Centrifugal with Integral Gearbox (Axial)	.085 IPS	6.00 g	.175 IPS	.275 IPS
Centrifugal with Integral Gearbox (Radial)	.075 IPS	5.00 g	.150 IPS	.225 IPS
BLOWERS (FANS)				
Lobe Type Rotary	.150 IPS	1.20 g	.300 IPS	.450 IPS
Belt Driven Blower	.135 IPS	.80 g	.275 IPS	.425 IPS
General Direct Drive Fans (with Coupling)	.110 IPS	1.00 g	.225 IPS	.350 IPS
Primary Air Fans	.100 IPS	1.00 g	.200 IPS	.300 IPS
Large Forced Draft Fans	.100 IPS	1.00 g	.200 IPS	.300 IPS
Large Induced Draft Fans	.085 IPS	1.00 g	.175 IPS	.275 IPS
Shaft Mounted Integral Fans	.085 IPS	.80 g	.175 IPS	.275 IPS
Vane Axial Fan (Measurement on Bearing Frame)	.075 IPS	.80 g	.150 IPS	.225 IPS
MOTOR/GENERATOR SETS				
Belt Driven	.135 IPS	.80 g	.275 IPS	.425 IPS
Direct Coupled	.100 IPS	1.00 g	.200 IPS	.300 IPS
CHILLERS				
Reciprocating	.125 IPS	1.20 g	.250 IPS	.400 IPS
Centrifugal (Open Air)	.100 IPS	1.20 g	.200 IPS	.300 IPS
Centrifugal (Hermetic)	.075 IPS	1.20 g	.150 IPS	.225 IPS
LARGE TURBINE GENERATORS				
1800 RPM Turbine Generators	.085 IPS	.60 g	.175 IPS	.275 IPS
3600 RPM Turbine Generators	.125 IPS	.60 g	.250 IPS	.375 IPS
CENTRIFUGAL PUMPS				
Vertical Pumps (12' to 20' Height Above Base)	.185 IPS	.80 g	.375 IPS	.600 IPS
Vertical Pumps (8' to 12' Height Above Base)	.160 IPS	.80 g	.325 IPS	.500 IPS
Vertical Pumps (5' to 8' Height Above Base)	.125 IPS	.80 g	.250 IPS	.400 IPS
Vertical Pumps (0' to 5' Height Above Base)	.100 IPS	.80 g	.200 IPS	.300 IPS
General Purpose Horizontal Pumps	.100 IPS	1.50 g	.200 IPS	.300 IPS
Boiler Feed Pumps	.100 IPS	1.50 g	.200 IPS	.300 IPS
Hydraulic Pumps	.060 IPS	2.00 g	.125 IPS	.200 IPS
ROLLS				
Idler (driven by surface friction only)	.050 IPS	.80 g	.100 IPS	.150 IPS
Driven (coupled or belt)	.050 IPS	1.00 g	.100 IPS	.150 IPS
RECIPROCATING PUMPS				
Crankshaft Type	.150 IPS	1.20 g	.300 IPS	.450 IPS
Axial Piston Type	.135 IPS	3.00 g	.275 IPS	.425 IPS
MACHINE TOOLS				
Motors	.035 IPS	.40 g	.075 IPS	.125 IPS
Gearbox Input	.050 IPS	.80 g	.100 IPS	.175 IPS
Gearbox Output	.037 IPS	.60 g	.075 IPS	.125 IPS
Spindle, Roughing Operations	.030 IPS	.50 g	.060 IPS	.100 IPS
Spindle, Machine Finishing Operation	.020 IPS	.35 g	.040 IPS	.070 IPS
Spindle, Critical Finishing Operation	.010 IPS	.20 g	.020 IPS	.040 IPS

Table continues on next page.

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STANDARD MOTOR ONLY – Spare Shop Test (unloaded, full speed, on isolation pads)				
Less than 6 HP	.100 IPS	1.00 g	n/a	n/a
6 HP – 60 HP	.080 IPS	.80 g	n/a	n/a
61 HP – 600 HP	.080 IPS	.80 g	n/a	n/a
More than 600 HP	.070 IPS	.70 g	n/a	n/a
SPECIAL MOTOR ONLY – Spare Shop Test (unloaded, full speed, on isolation pads)				
Less than 6 HP	.080 IPS	.80 g	n/a	n/a
6 HP – 60 HP	.050 IPS	.60 g	n/a	n/a
61 HP – 600 HP	.050 IPS	.60 g	n/a	n/a
More than 600 HP	.040 IPS	.50 g	n/a	n/a
PRECISION MOTOR ONLY – Spare Shop Test (unloaded, full speed, on isolation pads)				
Less than 6 HP	.060 IPS	.50 g	n/a	n/a
6 HP – 60 HP	.030 IPS	.35 g	n/a	n/a
61 HP – 600 HP	.030 IPS	.35 g	n/a	n/a
More than 600 HP	.020 IPS	.25 g	n/a	n/a
STANDARD MOTOR ONLY – Spare Shop Test (>90% load, full speed, clamped down)				
Less than 6 HP	.100 IPS	1.00 g	n/a	n/a
6 HP – 60 HP	.080 IPS	.80 g	n/a	n/a
61 HP – 600 HP	.080 IPS	.80 g	n/a	n/a
More than 600 HP	.070 IPS	.70 g	n/a	n/a
SPECIAL MOTOR ONLY – Spare Shop Test (>90% load, full speed, clamped down)				
Less than 6 HP	.080 IPS	.80 g	n/a	n/a
6 HP – 60 HP	.050 IPS	.60 g	n/a	n/a
61 HP – 600 HP	.050 IPS	.60 g	n/a	n/a
More than 600 HP	.040 IPS	.50 g	n/a	n/a
PRECISION MOTOR ONLY – Spare Shop Test (>90% load, full speed, clamped down)				
Less than 6 HP	.060 IPS	.50 g	n/a	n/a
6 HP – 60 HP	.030 IPS	.35 g	n/a	n/a
61 HP – 600 HP	.030 IPS	.35 g	n/a	n/a
More than 600 HP	.020 IPS	.25 g	n/a	n/a
GEARBOX – [future] Spare Shop Test (unloaded)				
Less than 100 HP	tbd IPS	tbd g	n/a	n/a
100 HP – 1000 HP	tbd IPS	tbd g	n/a	n/a
More than 1000 HP	tbd IPS	tbd g	n/a	n/a
GEARBOX – [future] Spare Shop Test (>90% load)				
Less than 100 HP	tbd IPS	tbd g	n/a	n/a
100 HP – 1000 HP	tbd IPS	tbd g	n/a	n/a
More than 1000 HP	tbd IPS	tbd g	n/a	n/a
"Corrections" to Guideline values based on operating speed at the measured shaft.	**% of Acceptance IPS Limit**	**% of Acceptance G's Limit**	**% of Warning IPS Limit**	**% of Critical IPS Limit**
12 - 49 RPM Operating Speeds	10%	10%	10%	10%
50 - 99 RPM Operating Speeds	20%	10%	20%	20%
100 - 199 RPM Operating Speeds	35%	20%	35%	35%
200 - 349 RPM Operating Speeds	50%	30%	50%	50%
350 - 499 RPM Operating Speeds	70%	40%	70%	70%
500 - 799 RPM Operating Speeds	90%	60%	90%	90%
800 - 1399 RPM Operating Speeds	100%	80%	100%	100%
1400 - 1999 RPM Operating Speeds	100%	100%	100%	100%
2000 – 3999 RPM Operating Speeds	120%	130%	120%	120%
4000 RPM and Higher Operating Speeds	140%	160%	140%	140%

Table notes follow below.

Magnitude Guidelines Table Notes, Modifiers, and Exceptions:

A. The velocity and acceleration limit values must be corrected for shaft speed. For shafts operating between 12 RPM and 3999 RPM, use the correction values in the last section of the table for these adjustment factors for each measure. Limits for machines slower than 12 RPM or faster than 3999 RPM shall be set by Purchaser on a case by case basis.

B. These limits apply to casing measurements on machines which also include relative shaft to casing vibration (proximity probe) instruments. Additional acceptance limits for these relative measurements shall be determined by the Purchaser on a case by case basis. Typically, acceptance displacement limits will not exceed 25% of the shaft/bearing diametrical clearance. Warning will not exceed 40% and Critical will not exceed 55% of said design clearance.
C. Velocity and Acceleration limits in this table apply to measurements made by accelerometer and/or velocity probes as close as possible to the bearing housings.
D. These values are based on machines using antifriction type bearings. Due to reduced transmissibility and inherent damping in plain (plain, sleeve, fluid film, tilting pad, etc) bearings, velocity limits shall be reduced by 35% and acceleration limits by 50%.
E. These limits assume the machine is not on vibration isolators. Increase velocity limits by 30% if machine is mounted on a compliant isolation system. This does not apply to shop tests on temporary isolation pads.
F. Acceptance and alarm values for installed drive motors are 100% of their particular driven machine. If there is any question, please consult Purchaser.
G. Alarm values for individual gearboxes are 125% of their particular driven machine unless otherwise noted.
H. The terms "Warning" and "Critical" in this table are not necessarily related to any annunciate nor shutdown actions. As used here, the intent of the term “Warning” is an in service limit used by the purchaser which when exceeded is cause for concern and should trigger a heightened awareness for the health of the machine. The intent of the term “Critical” is an in service limit used by the purchaser which when exceeded is cause for great concern and should trigger additional testing and/or remedial actions. Although the Purchaser may specify multipliers other than 2x and 3x for the creation and inclusion of the “Warning” and “Critical” limits in their CBM software system, the 2x multiplier will always apply with regard to the "General Testing, Acceptance, & Resolution Procedures of this document.

Acceptance Criteria Example 1:

1190 RPM, 200 HP, single speed, direct drive fan centrifugal fan, moving ambient air in a product cooling application. The motor is fitted with ball bearings and the fan with spherical roller bearings. The fan and motor assembly are mounted on a spring isolation system to reduce fan vibration entering the structure. What are the vibration acceptance limits at the fan bearings for each band?

Looking up this fan type in the fan in the table gives us nominal acceptance values of 0.110 ips and 1.00 g's.

Per Note A. Speed corrections from the table for 1190 RPM are 100% for velocity and 80% for acceleration.

Per Note B. Not applicable to this machine.

Per Note C. Informational, does not alter acceptance limits.

Per Note D. Anti-friction bearings so no change for velocity or acceleration limits.

Per Note E. Machine is on vibration isolators. Increase velocity limits by 30%, no change for acceleration.

Per Note F. We are dealing with the fan bearings, but the motor bearings would be the same for this machine.

Per Note G. Not applicable, this is direct drive, no gearbox is involved.

Corrected velocity acceptance limit = 0.110 x 100% x 130% = 0.143 ips.

Corrected acceleration acceptance limit = 1.00 x 80% x 100% = 0.80 g's.

Below are the band acceptance levels and frequency ranges…

Units	Band Name	Frequency Range	%C	Value	Criteria
IPS_{peak}	Overall IPS	OA or 2 Hz – 2 kHz	100%	.143	OA/Band OA
IPS_{peak}	Subsynchronous	5.95 – 15.87 Hz	50%	.072	Line Amplitude
IPS_{peak}	Running Speed	15.87 – 23.80 Hz	80%	.114	Line Amplitude
IPS_{peak}	Lower harmonics	23.80 – 69.42 Hz	50%	.072	Line Amplitude
IPS_{peak}	Mid harmonics	69.42 – 168.58 Hz	30%	.043	Line Amplitude
IPS_{peak}	Upper harmonics	168.58 – 1000.00 Hz	30%	.043	Line Amplitude
IPS_{peak}	Midband	1000 Hz – 2000.00 Hz	30%	.043	Line Amplitude
IPS_{peak}	Highband	2000 Hz – 5000.00 Hz	20%	.029	Line Amplitude
G_{peak}	Overall G's	OA or 2 Hz – 20 kHz	125%	1.000	OA/Band OA
G_{peak}	Wideband G's	5.95 – 5000.00 Hz	100%	.800	Band OA
G_{peak}	Max G's PEAK	From Time Domain Data	250%	2.000	Max. Excursion

E. General Testing, Acceptance, & Resolution Procedures

Note: Each stage of the process is subject to Purchaser audit.

1. Seller will develop the database in an acceptable vibration/CBM software system, follow acceptable database/measurement standards for each piece of equipment, and take the initial vibration readings using methods & instruments acceptable to the Purchaser as outlined previously.
2. Seller will review these readings. Optionally, the Seller may collect a second set of readings to insure repeatability or accuracy. Equipment that is entirely within the acceptable levels of vibration will be documented and communicated as previously described to Purchaser for their acceptance. When accepted, no further acceptance work shall be required on that particular equipment provided there are no further equipment modifications, changes, or interactions. Equipment that is above acceptable levels will be identified, communicated to the Purchaser, and be subject to additional countermeasures and testing.
3. If the Seller believes the vibration is coming from an outside source that is not present during normal operation of the system, the Supplier may take steps to isolate the equipment from this source to more closely represent actual conditions of the operating equipment. A Purchaser representative must be present and sign off on the isolation methods, testing procedures, and actual test conditions. The Seller will review these readings as in Step #2 above.

4. The Seller shall take additional analysis type measurements if necessary, analyze the data, develop countermeasures, and then implement necessary countermeasures to reduce the vibration to acceptable levels. Additional vibration testing will be performed. The Seller will review these readings as in Step #2 above. The Purchaser or Purchasers representative may be available to assist the Seller in identifying the source cause.
5. If the equipment is still above acceptable levels, at Seller's expense, Seller and Purchaser (pr Purchaser's representative) shall perform additional diagnostic measures and analysis. Additional countermeasures will be identified and implemented by the Seller, followed by testing and evaluation as in Step #2 above. This process will continue until all countermeasures have been exhausted and no root cause for the unacceptable vibration levels is identified. Purchaser will then reevaluate the data in an attempt to identify a probable root cause to be addressed by the Seller. If a possible root cause cannot be identified and the vibration levels do not exceed the "warning" level, this vibration level may be accepted by Purchaser on a case by case basis as a baseline and no further work will be required. Acceptance under these circumstances should not be considered the "norm" and its occurrence should be quite rare.

F. Spare Parts

1. Spares that are supplied with the project shall be of equal design specification and performance as the installed equipment. If any installed equipment is field modified to meet vibration acceptance criteria, the Seller shall modify the appropriate spare(s) at Seller's expense and note changes on the prints.
2. Spare motors supplied with the project shall be tested and must pass the appropriate "Motor Only – Spare Shop Test" criteria for unloaded conditions. At Purchasers option and expense, specific motors shall also be tested and pass the appropriate "Motor Only – Spare Shop Test" criteria for loaded conditions.

V Guidelines for Achieving Vibration Acceptance Levels

The Purchaser recommends these practices to Seller to assist in achieving acceptable vibration levels. These practices will not necessarily result in acceptance, but not heeding these good practices will likely prevent the equipment from being accepted.

1. All rotating equipment and spare parts such as rotors, fan wheels, impellers, shafts, sheaves, couplings, etc. should be balanced to an ISO 1940/1941 G 1.0 or better in multiple planes.
2. Coupling bore to exterior eccentricity at both ends of the hub should not exceed 0.001" + 0.0002"/inch of shaft diameter.
3. Sheaves, as installed, will not have more than 0.005" radial TIR at the pitch line of the groove nor more than 0.002" axial runout at the pitch line of the groove.
4. On any machine which may operate above 1800 RPM, reduced tolerances and additional design steps should be taken to insure smooth and reliable operation. Separate balancing of components and final trim balancing of the assembly to ISO G 0.4 may be required. Coupling bore eccentricity should be kept to 0.001" or less, coupling fitment to the shaft should be designed to reduce eccentricity as well as allow reduced coupling size and weight. Extended/spool type flexible couplings should be considered to reduce the affects of angularity and offset. Bearings should be chosen to provide concentric fitment to shaft, reduced internal clearances, and reduced bearing to housing allowable clearances. Care should be taken to insure that the operating speed vibration and other expected vibration defect frequencies do not excite the natural frequency of the shaft, supporting structure, nor the system.

VI Alignment Specification

All coupled rotating equipment will be laser-aligned, using a dual receiver coupling laser aligner or other Purchaser approved laser alignment equipment after installation. Thermal growth calculations

shall be made where appropriate to reflect operating conditions. If applicable, equipment, structure, and attached piping thermal growths shall be considered in addition to operational effects such as oil wedge, pressure/vacuum pull-down, etc. to insure in service alignment tolerances are achieved. The acceptable in service alignment tolerances for short couplings are shown in the table below. Acceptance tolerances for long coupling machines shall be set by the Purchaser on a case by case basis. The installation contractor must check for and correct any soft foot conditions before attempting the laser alignment of any coupled rotating equipment. The soft foot tolerance is the differential at any foot on the equipment. Fluid film bearing machine shafts shall be level while in service.

A record of the final alignment settings, alignment setup, alignment tolerances, machine ID/Name, date of alignment, and alignment technician ID shall be printed and signed by the technician responsible for the alignment. Calculations for thermal effects and other operational considerations shall be attached to this printout. A copy of this record shall be retained by the Seller, a copy shall be forwarded to the Purchaser for retention, and a copy shall be submitted to Purchaser for acceptance as outlined in the General portion of this document.

Two jacking bolts will be installed at each hold-down bolt position to facilitate controlled movement in the axial (in line with the shaft, perpendicular to the bolt body) direction and "horizontal" (perpendicular to hold-down bolt body and axial direction). The jacking bolts must be positioned so that they do not interfere with the installation and removal of shim packs. For a typical "4 hold-down bolt" machine, 8 jacking bolts will be required. If more than 4 hold down bolts are used, additional jacking bolts will be required. If unclear, please consult Purchaser as to specific requirements on a case by case basis.

Hold-down bolts shall be tightened using a calibrated torque wrench in at least three stages (50%, 80%, and 100% of final torque value), each stage following a "cross" pattern much like the pattern used for automotive wheels. After alignment and tightening of hold-down bolts, all jacking bolts will be backed-off ~0.100" and locked with jam nuts.

Short Coupling Shaft Alignment Guidelines

	Shaft RPM	Acceptance Criteria
Soft Foot	<= 1200 > 1200	0.003" 0.002"
Parallel Offset (1/2 TIR)	<= 600 <= 900 <= 1200 <= 1800 <= 3600 > 3600	0.0030" 0.0030" 0.0030" 0.0020" 0.0015" 0.0010"
Angularity	<= 600 <= 900 <= 1200 <= 1800 <= 3600 > 3600	0.00100"/inch 0.00075"/inch 0.00075"/inch 0.00050"/inch 0.00025"/inch 0.00010"/inch
Shaft Level (fluid film bearings)	All	0.0005"/inch

VII Infrared Thermography

All thermographic testing shall be performed by an ASNT Level II Certified Thermographer or better to provide assurance in the accuracy of quantitative temperature measurements. Instruments used shall be in calibration and shall be appropriate for the environment and measurement conditions. Testing shall be performed in a safe manner following all applicable codes.

All tests shall be done while the facility is above 80% of normal operating conditions and has maintained said rate for at least 3 continuous hours. Electrical loads should be at least 30% of component rated capacities.

Acceptable temperature rise over ambient or suitable referenced temperature on electrical equipment is based on equipment, voltage level, and criticality. Values are tabulated in the "Electrical Testing: Acceptable Rise & Delta, Deg Centigrade" table below. "Acceptable" and "Acceptable with cause" limits are acceptance limits applied to new, repaired, and rebuilt equipment and should not be confused with ongoing routine thermographic surveys to identify in service faults.

Electrical Testing: Acceptable Rise & Delta, Degrees Centigrade

Type	Vrms/DC	System Criticality	Acceptable		Acceptable with cause		Critical	
			Rise	Delta	Rise	Delta	Rise	Delta
Motor Starter	<600 V	High	3	3	4	4	25	12
Motor Starter	<600 V	Low	4	4	6	6	35	18
Motor Starter	>600 V	High	2	2	3	3	20	10
Motor Starter	>600 V	Low	3	3	4	4	25	12
Switchgear	<600 V	High	2	2	3	3	20	10
Switchgear	<600 V	Low	3	3	4	4	25	12
Switchgear	>600 V	High	1.5	1.5	2	2	10	5
Switchgear	>600 V	Low	2	2	3	3	10	10

Regarding this table, the following definitions shall apply:

Vrms/DC – in-service maximum Vrms AC or Peak DC voltage value of the system component.
System Criticality – estimate of the impact a failure of this system has on safety & productivity.
Acceptable – maximum rise & delta for in service equipment acceptance.
Acceptable With Cause – if there is just cause for the rise or delta to exceed normal acceptable values but are within "Acceptable with cause" limits, "With Cause" Acceptance may be granted at the sole discretion of the Purchaser, in writing, on a case by case basis.
Critical – temperature rise or delta values which should be communicated immediately and prompt consideration of immediate repair.
Rise – the difference between apparatus temperature and ambient or reference temperature.
Delta – the difference between apparatus temperature and similar (other phase) temperature.

A. Motor Starter Equipment

Infrared thermography scanning equipment shall be used to check all new, repaired, or rebuilt motor control centers for thermal anomalies. This will include an infrared scan of the bus connections typically in the back of the motor control center as well as the motor starter/drive compartments. Unacceptable thermal anomalies shall be addressed by the Seller.

B. Switchgear equipment

Infrared thermography scanning equipment shall be used to check all new, repaired, or rebuilt switchgear equipment and buswork. Unacceptable thermal anomalies shall be addressed by the Seller.

C. Electrical Transmission Equipment

Infrared thermography scanning equipment shall be used to check all new, repaired, or rebuilt electrical transmission equipment, distribution equipment, buswork, and conductors for thermal anomalies. Thermal anomalies without just cause shall be addressed by the Seller

D. Refractory Continuity

Infrared thermography scanning equipment shall be used to check the insulation and refractory continuity on all furnace areas. Acceptable temperature rise on the furnace surfaces shall be based on

the manufacture's stated cold wall temperature. The cold wall temperature shall be uniform and free of thermal anomalies due to refractory discontinuities. Anomalies shall be addressed by the Seller.

E. Hydraulic Systems

Infrared thermography scanning equipment shall be used to scan all pumps, valves, cylinders, and other hydraulic system components where practical. Thermal anomalies without just cause shall be addressed by the Seller.

F. Mechanical Systems

Infrared thermography scanning equipment shall be used to scan all motors, couplings, gearboxes, bearings, and other power transmission equipment where practical. Thermal anomalies without just cause shall be addressed by the Seller.

VIII Ultrasonic Testing

The Seller shall use ultrasonic testing to test the equipment noted below

A. Compressed Gas Line Leak Specification

Airborne ultrasonic equipment shall be used to check for leaks in all pressurized gas lines and compressed air lines.

B. Vacuum Line Leak Specification

Airborne ultrasonic equipment shall be used to check all vacuum lines for leaks.

C. Steam Line and Trap Leak Specification

Airborne ultrasonic equipment shall be used to check for leaks in steam lines where practical. Airborne ultrasonic equipment shall be used to check the operation of steam traps in new and repaired/rebuilt steam distribution systems.

IX Electrical Surge Testing

The Seller shall use a comparative surge tester to test the equipment noted below.

A. AC Motors

A high-frequency comparative surge tester will be used to check the reliability of all wire insulation on AC motors that are 50 hp and above. Any motor that fails the surge test will not be accepted. All motors, including spares, shall be tested prior to shipment.

All AC motors that are 50 hp or more must be phase balanced to within a 3 percent differential between all phases in the motor. Any motor that that exceeds this phase imbalance tolerance will not be accepted.

B. DC Motors

All DC motors of 50 hp or more must have the wire insulation tested using high-frequency surge testing techniques. All field coils and inner poles must be surge-tested. The armature must have a bar-to-bar surge test. Any DC motor that fails the surge test will not be accepted. All DC motors, including spares, shall be tested prior to shipment.

C. General Surge Testing Specification

The motor supplier will provide certified copies of the surge test results with the motor when it is shipped to the project site. The Owner may use its own high-frequency surge tester to check the reliability of the wire insulation. Any motor that fails the high-frequency surge test shall be returned to the equipment supplier for correction at no cost to the Owner.

X Induction Motor Current Analysis

Seller shall perform Motor Current Analysis on AC induction motors for the purposes of assessing rotor bar condition and confirmation of phase balance. Extremely critical motors over 3 HP shall be tested. Critical motors over 15 HP shall be tested. All motors over 40 HP shall be tested. The results of MCA shall be documented and reported to Purchaser. Referring to the "Motor Current Analysis Severity and Recommended Corrective Actions" table, MCA Severity Ranking of 1 and 2 are acceptable, others are not acceptable.

Note: Often, it is not necessary to use a dedicated instrument to perform Induction Motor Current Analysis. Most of the instrument as used for vibration data collection can be used for MCA, but the transducer shall be a current transformer based device rather than an accelerometer. Often MCA data can coexist and be included in the same Vibration/CBM database as in the vibration section of this document. Motor Current Analysis is a technique which looks at the frequency content of the motor stator currents and assesses the depth of modulation based on the relative amplitudes of the sidebands around applied line frequency. The sidebands of interest are at PolePass (Slip x Number of motor poles) spacing from the applied current line frequency.

Motor Current Analysis Severity and Recommended Corrective Actions

CAT #No.		Fabricated Bar/Ring Cage		Cast as One Bar/Ring Cage		Condition Assessment	Recommended Actions
		I_L/I_P dB	I_P/I_L %	I_L/I_P dB	I_P/I_L %		
Acceptable	1	> 60 dB	< 0.10%	> 54 dB	< 0.20%	Excellent.	Continue annual surveys
	2	54 - 60	0.10 - 0.20%	49 - 54	0.20 - 0.35%	Good.	Continue annual surveys
Unacceptable	3	48 - 54	0.20 - 0.40%	44 - 49	0.35 - 0.63%	Moderate.	Perform semi-annual surveys to trend change.
	4	43 - 48	0.40 - 0.71%	40 - 44	0.63 – 1.00%	Rotor bar crack may be developing. Possible high resistance joints.	Reduce survey intervals to quarterly or monthly depending on motor service. Trend for change. Review vibration.
	5	37 - 43	0.71 - 1.41%	34 - 40	1.00 – 2.00%	Two rotor bars likely cracked or broken. Possible high resistance joints.	Reduce survey intervals to monthly or weekly depending on motor service. Trend closely. Perform vibration diagnostics to confirm problem source & severity
	6	31 – 37	1.41 – 2.82%	28 - 34	2.00 - 3.98%	Multiple cracked or broken rotor bars & possible broken end rings. Likely high resistance joints.	Overhaul or replace motor ASAP
	7	< 31 dB	>2.82%	< 28 dB	>3.98%	Multiple broken rotor bars & likely broken end rings. Very likely severe rotor problems through out.	Shutdown NOW. Overhaul or replace motor NOW.

NOTES

1. Minimum Induction Motor Load= 75 %
2. Minimum Motor Size= 3 HP; Desired Motor Size >= 40 HP
3. I_L = Amplitude of stator current at F_L (in dBr or Amps)
4. I_P = Amplitude of stator current at greater 1st Pole Pass Sideband of F_L (dBr or Amps)
5. F_L = Line Frequency, nominal 50Hz or 60 Hz.
6. Fs = Slip Frequency = Synchronous Frequency – Actual Motor Speed (Hz or CPM)
7. F_P = Pole Pass Frequency = # Motor Poles Times x Fs (Hz or CPM)

"CAT. No" = Severity Ranking or Category Number.

XI System and Process Measurement Devices

Process control and product quality measurement devices (including, scales, width and thickness gauges, gas analyzers, load cells, non-contact temperature measurement devices, dew point measurement instruments, etc.) shall be qualified for accuracy & repeatability. After equipment is assembled and prior to shipment it shall be tested, calibrated, and adjusted. The accuracy & repeatability of all control and measurement instruments & devices shall be confirmed by using the manufacturer's standard calibration and adjustment procedures or Purchaser's Standards & Procedures (Purchaser's decision). All calibration and adjustment procedures shall be forwarded to the Purchaser for approval prior to final equipment testing. The Seller shall provide certified test results for each instrument or device when it is shipped to the project site. After the installation of the complete system, the Seller shall perform the necessary Gauge R & R tests to verify the overall performance accuracy and repeatability of all instrumentation as a total integrated system. Results of the Gauge R & R Tests shall be submitted to Purchaser for acceptance.

XII General Test Equipment

All equipment used to perform tests as outlined in this document shall be regularly maintained and calibrated to manufacturers standards. All calibrations shall be traceable to N.I.S.T. Standards or applicable industry standards. Documentation indicating calibration frequency and traceability shall be presented to Purchaser upon request. While not a requirement, ISO Certification is recommended.

In addition, individuals using this test equipment shall have up to date training on the proper use and application of the equipment.

Change Log

2006-09-29
NWIBRT Minimum Acceptance Requirements for Equipment Reliability
Initial release (revision number 01.00) dated 2006-09-29