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Daphne Marcyan, PE Principal Engineer

Parametrix

Jen Murphy, PE, CSE Senior Consultant

What's the Big Deal with Big Pumps? May 4, 2023

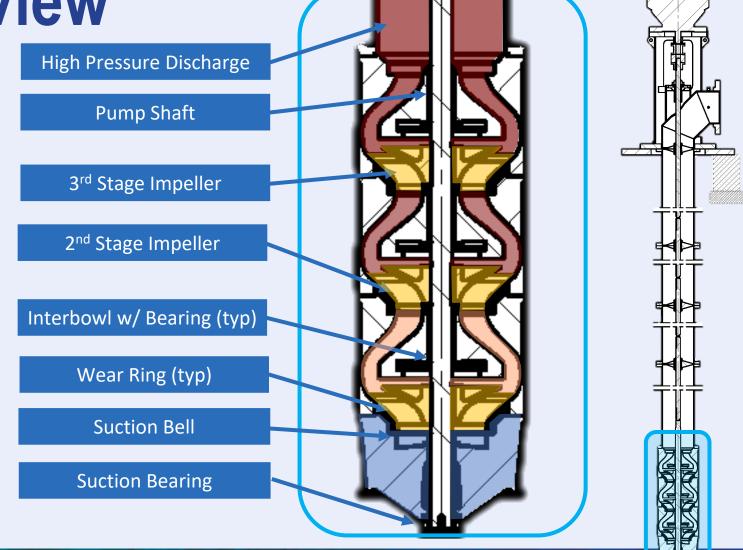
Presentation Overview

- Goals
 - Understand key design elements
 - Small items that make a BIG difference
- Vertical Turbine (VT) Pump Overview
- Specifying Large Vertical Turbine Pumps
 - Hydraulic Considerations
 - Vibration / Structural
 - Electrical and Controls
- Case Study



Pump Components

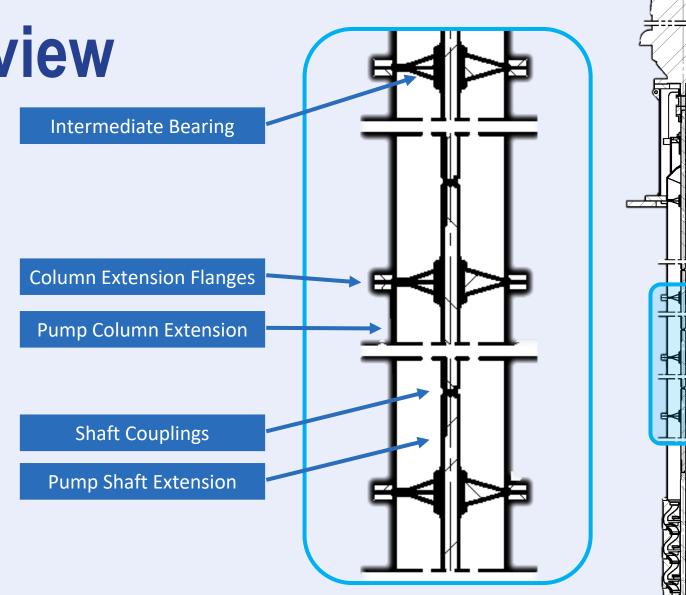
• Multi-stage impeller and volute assembly



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Pump Components

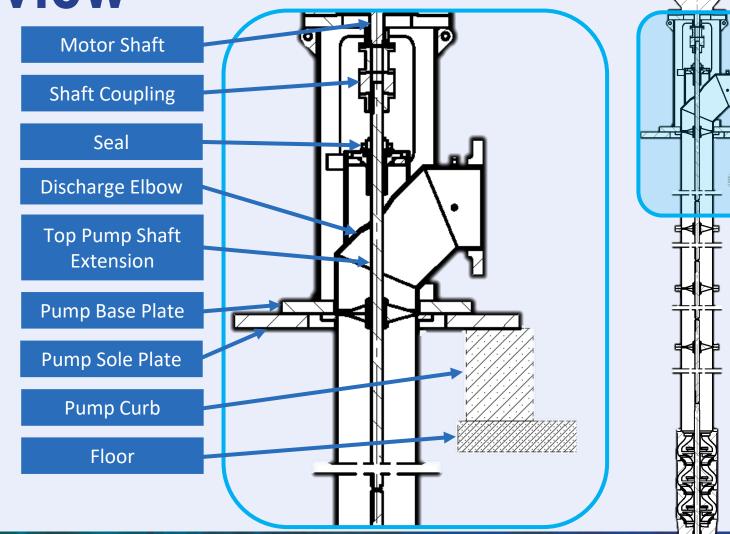
- Multi-stage impeller and volute assembly
- Column and shaft
 extensions



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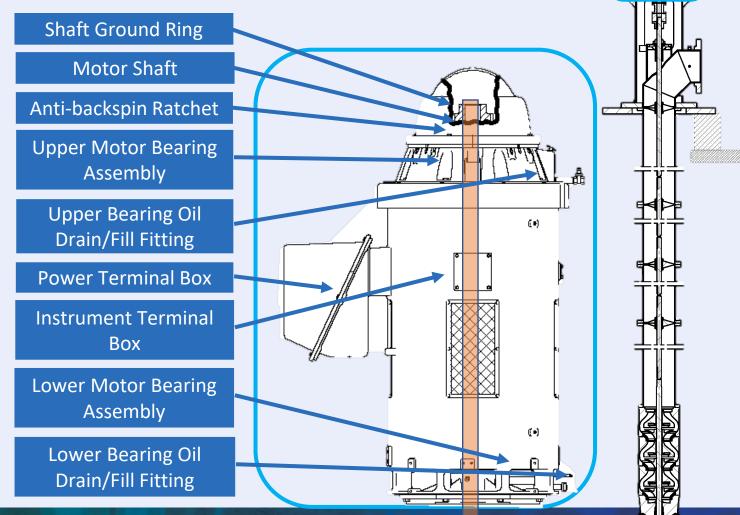
Pump Components

- Multi-stage impeller and volute assembly
- Column and shaft
 extensions
- Pump base



Pump Components

- Multi-stage impeller and volute assembly
- Column and shaft extensions
- Pump base
- Motor



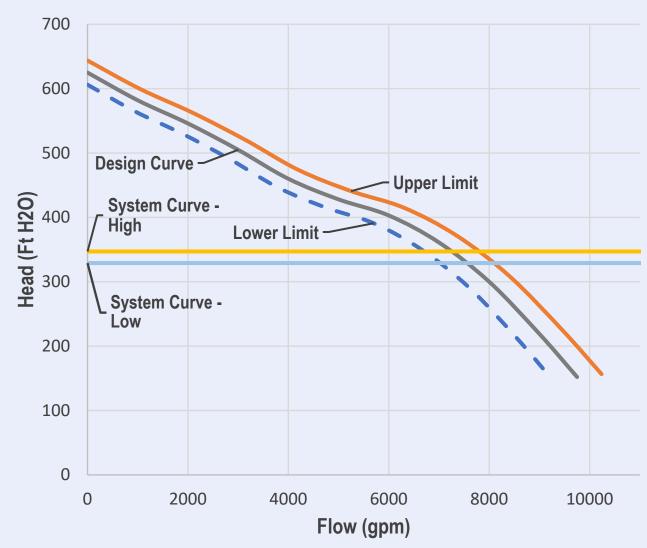
Specifying Large Vertical Turbine Pumps

ANSI/HI 14.6-2022 Pump Acceptance Tests

		Grade	Grade 1			Grade 2		Grade 3
		Δt_Q		109	6	16%		18%
		Δt_H	6%			10%		14%
Test	Guarantee	Acceptar			nce grad	е		
. parameter	requirement	Symbol	1B	1E	. 1U	2B	2U	ЗB
Rate of flow	Mandatory	t _Q (%)	± 5%	± 5%	0% to + 10%	± 8%	0% to +16%	± 9%
Total head	Mandatory	t _H (%)	± 3%	± 3%	0% to + 6%	± 5%	0% to +10%	± 7%
Power]	Optional ^a	t _P (%)	+ 4%	+ 4%	+ 10%	+ 8%	+ 16%	+ 9%
Efficiency ^b	(either/or)	t _η (%)	- 3%	- 0%	- 0%	- 5%	- 5%	- 7%

Table 14.6.3.4 — Pump test acceptance grades and corresponding tolerance band

Pump Acceptance Criteria 1B



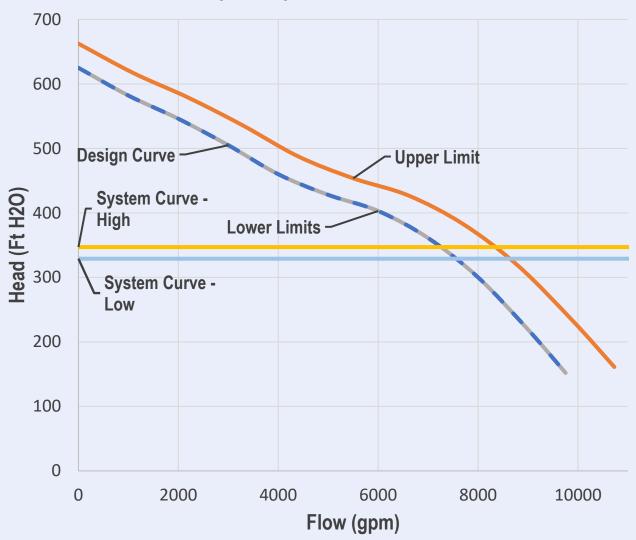
Specifying Large Vertical Turbine Pumps

ANSI/HI 14.6-2022 Pump Acceptance Tests

		Grade	Grade 1			Grade 2		Grade 3
		Δt_Q		10%			16%	18%
		Δt_H	6%				10%	14%
Test	Guarantee		Acceptar			nce grad	e	
. parameter	requirement	Symbol	1B	1E	. 1U	2B	2U	3B
Rate of flow	Mandatory	t _Q (%)	± 5%	± 5%	0% to + 10%	± 8%	0% to +16%	± 9%
Total head	Mandatory	t _H (%)	± 3%	± 3%	0% to + 6%	± 5%	0% to +10%	± 7%
Power]	Optional ^a	t _P (%)	+ 4%	+ 4%	+ 10%	+ 8%	+ 16%	+ 9%
Efficiency ^b	(either/or)	t _η (%)	- 3%	- 0%	- 0%	- 5%	- 5%	- 7%

Table 14.6.3.4 — Pump test acceptance grades and corresponding tolerance band

Pump Acceptance Criteria 1U



Specifying Large Vertical Turbine Pumps

ANSI/HI 14.6-2022 Pump Acceptance Tests

		Grade	Grade 1			Grade 2		Grade 3
		Δt_Q		109	6		16%	18%
		Δt_H	6%				10%	14%
Test	Guarantee		Acceptar			nce grad	e	Lar
. parameter	requirement	Symbol	1B	1E	. 1U	2B	2U	ЗB
Rate of flow	Mandatory	t _Q (%)	± 5%	± 5%	0% to + 10%	± 8%	0% to +16%	± 9%
Total head	Mandatory	t _H (%)	± 3%	± 3%	0% to + 6%	± 5%	0% to +10%	± 7%
Power]	Optional ^a	t _P (%)	+ 4%	+ 4%	+ 10%	+ 8%	+ 16%	+ 9%
Efficiencyb	(either/or)	t _n (%)	- 3%	- 0%	- 0%	- 5%	- 5%	- 7%

Table 14.6.3.4 — Pump test acceptance grades and corresponding tolerance band

Testing and Inspection

Qty Description

1 Testing and Inspection

Performance Testing Details

Test Acceptance Criteria: ANSI/HI 14.6 Grade 1U

Test Tolerance: Flow = -0/+10%, Head = -0/+6%, Power = -0/+10%, Efficiency -0/+0%

Performance Test Options

Complete Unit Test With Job Driver - 1 units

Capacity	: 7150.0 USgpm
Head	: 350.00 ft
Density / Specific gravity	: - / 1.000
Pump speed	: 1780 rpm
Ns / Nss	: - / 11810 (US units)
Test tolerance	: ANSI/HI 14.6 Grade 1B

Take Away: Incorrect tolerances can cause underperformance, incorrect pump submission, or system damage

NSF 61 Compliance vs. Certification

NSF 61: *Drinking Water System Components* Primarily focused on materials in contact with water

NSF 61 COMPLIANCE

- (OAR) 333-061-0050
- Designed for potable water
- All components meet
 NSF 61

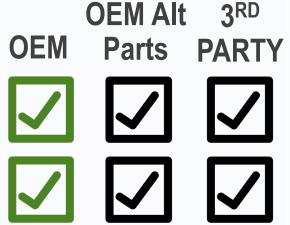
NSF 61 CERTIFICATION

- Applies to pump assembly
- 3rd party certification
- Limits available pumps and features
- Must use spare parts matching original certification

NSF 61 Compliance vs. Certification

NSF 61: *Drinking Water System Components* Primarily focused on materials in contact with water

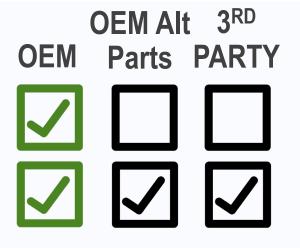




Pump Internals

Motor, shaft coupling, etc.

NSF 61 CERTIFICATION

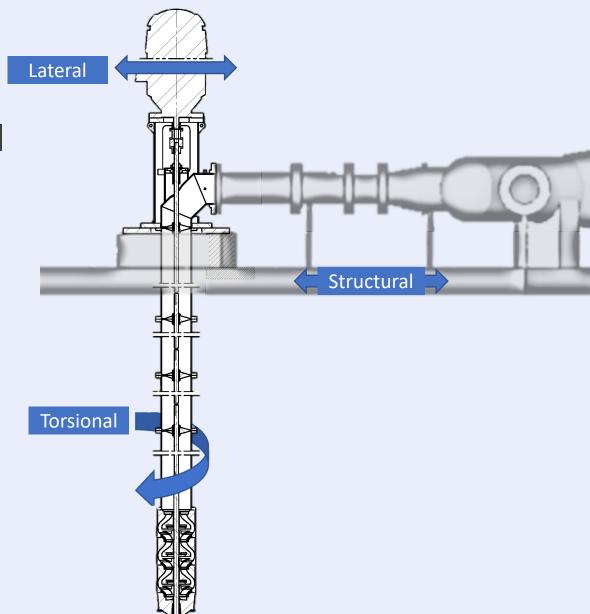


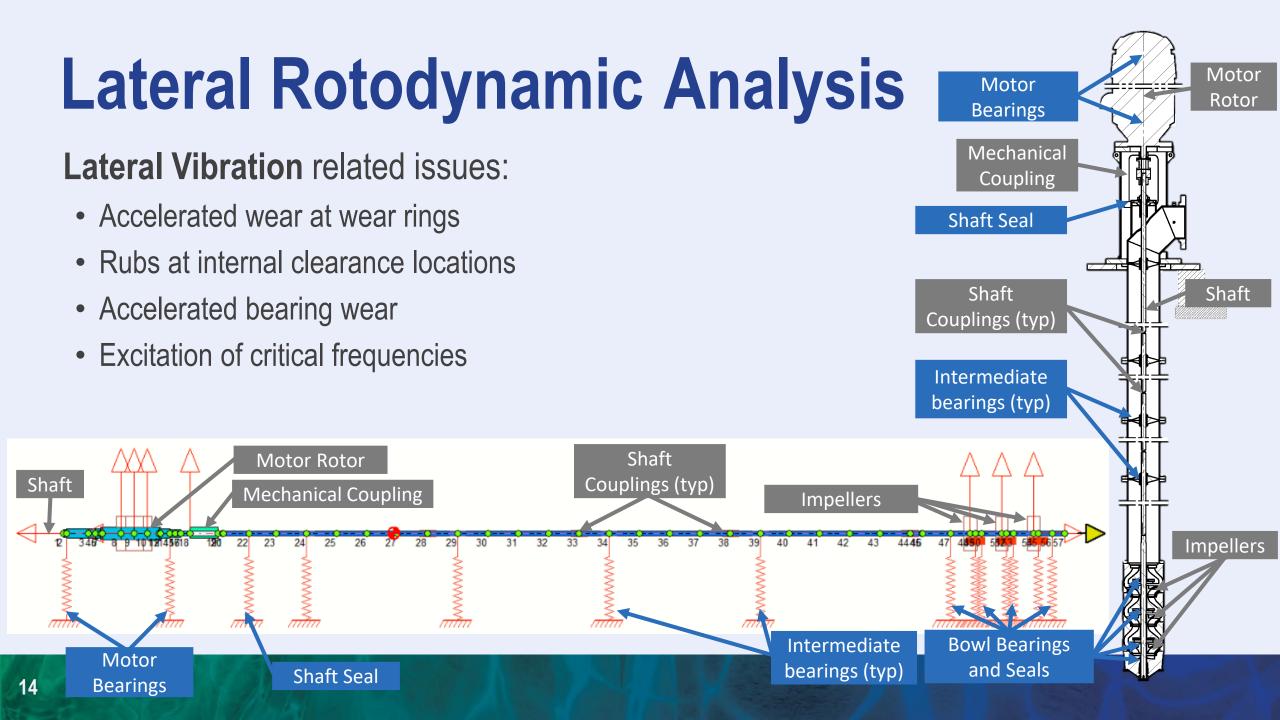
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Vibration Analysis

ANSI/HI 9.6.8: Lateral Rotodynamic, Torsional Rotordynamic and Structural Analyses

• Performing these analyses reduce the risk of vibration and reliability problems

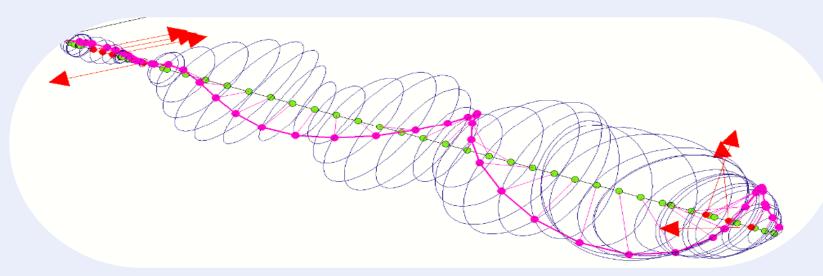




Lateral Rotodynamic Analysis

Lateral Vibration related issues:

- Accelerated wear at wear rings
- Rubs at internal clearance locations
- Accelerated bearing wear
- Excitation of critical frequencies



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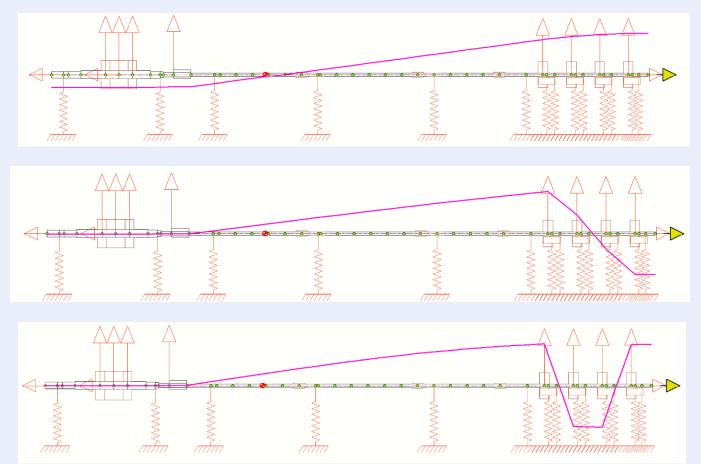
Torsional Rotordynamic Analysis

Torsional Vibration related issues:

- Damaged couplings
- Gear wear, noise
- Shaft fatigue or failure

Torsional Analysis

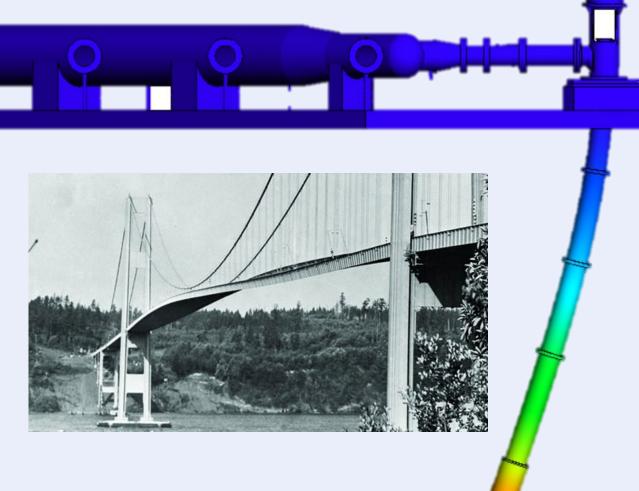
• Performed on the *complete train* (pump, driver, couplings, and gears)



Structural Analysis

Structural Analysis

- Performed to non-rotating portions of the pump and system to provide reasonable assurance that structural natural frequencies will not be close enough to typical excitations (resonant).
 - Determine reed frequency
 - Identify and ideally shift any frequencies within the pump operating range
 - Keep structure stiffness in mind



Requirements for Vibration Analysis

ANSI/HI 9.6.8: Lateral Rotodynamic, torsional rotordynamic and structural analysis

Rotodynamic Pumps – Guideline for Dynamics of Pumping Machinery:

- Damaged couplings
- Gear wear, noise
- Shaft fatigue or failure

	document be acq prior to using this Note 2: The vendo	Note 1: It is recommended that the user of this document be acquainted with the document's contents prior to using this matrix. Note 2: The vendor and user should agree on the suggested level of analysis as determined in step 4.				
		the contract specifi ns of Appendices E determined.				
	Table 9.6.8.3. to Enter sum from Table 9.6.8.3.1, Lateral rotor dynamic analysis	e and enter uncerta 1 for each type of a prisional, and structu Enter sum from Table 9.6.8.3.1, Torsional rotor dynamic analysis ine and enter risk vi	nalysis, latera iral. Enter sum Table 9.6. Structural dy analysi	nl, from 8.3.1, rnamic s		
	RISK	Unknown, new desig Significant modifica similar design - no e	an with no field	experience.	20 10	
	9.6.8.3.1 fe	nd enter ur or each typ onal, and s	e of an	alysis, la		
Enter sum from Table 9.6.8.3.1, Lateral rotor dynamic analysis		Enter sum Table 9.6.8	100 C 100		um from 9.6.8.3.1.	

Requir	ements for	Pump Type	Table S	0.6.8.3.1 — Uncertainty values Torsional Rotordynamic Analysis	Structural Dynamic Analysis
Vibration Analysis		Types OH & BB Pumps with Rigid Rotor Designs	Maximum speed > 3800 rpm, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Variable speed driven, U = 2 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 \cdot bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No. of vanes = 3 or fewer, U = 3	Tesins with three or more elements, U = 1 Synchronous motor driven, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Internal combustion engine driven, U = 2 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 1000 bhp, U = 3	Flexible foundations, U = 1 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No. of vanes = 3 or fewer, U = 3 NOTE: For vertically oriented OH & BB pump types, use type VS pump values.
	Maximum speed > 3800 rpm, U = 2 Specific gravity < 0.7, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Variable speed driven, U = 2 Rever > 30 kW (40 kbm) and < 375 kW	(E00 blue	guilation Total U	$ System Configuration Total U \(Sum) \\ Trains with three or more elements, U = 1 \\ Synchronous motor driven, U = 2 \\ Fly wheel driven, U = 2 \\ Drive shaft driven, U = 2 \\ Internal combustion engine driven, U = 2 \\ Variable speed driven, U = 3 \\ Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 \\ Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 \\ Power > 750 kW (1000 bhp), U = 3 \\ Power > 750 kW (1000 bhp), U = 3 \\ } $	$ System Configuration Total U \ (Sum) \\ Flexible foundations, U = 1 \\ Variable speed driven, U = 3 \\ Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 \\ Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 \\ Power > 750 kW (1000 bhp), U = 3 \\ No. of vanes = 3 or fewer, U = 3 \\ NOTE: For vertical structures for OH & BB pump types, use type VS pump values. $
Type VS Pumps	Power > 30 kW (40 bhp) and < 375 kW U = 1 Power > 375 kW (500 bhp) and < 750 k bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No. of varies = 3 or fewer, U = 3		guration Total U(8um) red > 3800 rpm, U = 2 ly < 0.7, U = 2 lon, U = 2 lond driven, U = 2 W (40 bhp) and < 375 kW (500 bhp), lond < 750 kW (1000 lond driven, U = 3 = 3 or fewer, U = 3	System Configuration Total U(Sum) Trains with three or more elements, U = 1 Synchronous motor driven, U = 2 Fily wheal driven, U = 2 Drive shaft driven, U = 2 Internal combustion engine driven, U = 2 Variable spead driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3	System Configuration Total U(Sum) Drivers supported separately, U = 1 Drivers supported by pumps, U = 2 Finishle foundations, U = 2 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No. of vanes = 3 or fewer, U = 3
	System Configuration Total U (Sum}	uncertainty can be reduced sub- l low, e.g., less than 1.0%.	System Configuration Total U (Sum) antially by obtaining assurance from the VFD ma	System Configuration Total U (Sum) anufacturer that the contribution of higher har-
NOTE: In the case	of VFDs, the uncertainty can be rec	duced su	bstan		

monic frequencies to distortion is low, e.g., less than 1.0%.

Requir	ements for	Pump Type	L	Table 9.	6.8.3.1 — Uncertainty values Torsional Rotordynamic Analysis	Structural Dynamic Analysis
Vibration Analysis		Types OH & BB Pumps with Rigid Rator Designs	Fly wheel of Drive shaft Variable sp Power > 30 U = 1 Power > 37 bhp), U Power > 75	peed > 3800 rpm, U = 2 triven, U = 2 driven, U = 2 eed driven, U = 2 kW (40 bhp) and < 375 kW (500 bhp), 5 kW (500 bhp) and < 750 kW (1000 = 2 0 kW (1000 bhp), U = 3 s = 3 or fewer, U = 3	Titains with three or more elements, U = 1 Synchronous motor driven, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Internal combustion engine driven, U = 2 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 1000 bhp, U = 3	Flexible foundations, U = 1 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No. of vanes = 3 or fewer, U = 3 NOTE: For vertically oriented OH & BB pump types, use type VS pump values.
	Maximum speed > 3800 rpm, U = 2 Specific gravity < 0.7, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Variable speed driven, U = 2 Revers > 30 kW (40 kbc) and < 375 kW	(E00 bbs)		guration Total U(Sum) hed > 3800 npm, U = 2 ly < 0.7, U = 2 hen, U = 2 ken, U = 2 ken, U = 2 W (40 bhp) and < 375 kW (500 bhp), W (500 bhp) and < 750 kW (1000 W (1000 bhp), U = 3 = 3 or fewer, U = 3	System Configuration Total U (Sum) Trains with three or more elements, U = 1 Synchronous motor driven, U = 2 Fly wheel driven, U = 2 Drive shaft driven, U = 2 Internal combustion engine driven, U = 2 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3	System Configuration Total U(Sum) Flexible foundations, U = 1 Variable speed driven, U = 3 Power > 30 kW (40 bhp) and < 375 kW (500 bhp), U = 1 Power > 375 kW (500 bhp) and < 750 kW (1000 bhp), U = 2 Power > 750 kW (1000 bhp), U = 3 No, of vanes = 3 or fewer, U = 3 NOTE: For vertical structures for CH & BB pump types, use type VS pump values.
Type VS Pumps	Power > 30 kW (40 bhp) and < 375 kW U = 1 Power > 375 kW (500 bhp) and < 750 k bhp), U = 2 Power > 750 kW (1000 bhp), U = 3			Table 9.6.8.3	System Configuration Total U (Sum) Trains with three or more elements, U = 1 ne and enter uncertain .1 for each type of an orsional, and structu	alysis, lateral,
	No. of vanes = 3 or fewer, U = 3 System Configuration Total U (3) e of VFDs, the uncertainty can be red to distortion is low, e.g., less than 1.0		bstar	Enter sum from Table 9.6.8.3.1, Lateral rotor dynamic analysis	Enter sum from Table 9.6.8.3.1, Torsional rotor	Enter sum from Table 9.6.8.3.1, Structural dynamic analysis

Requirements for Vibration Analysis

Note 1: It is recommended that the user of this document be acquainted with the document's contents prior to using this matrix.

lote 2: The vendor and user should agree on the uggested level of analysis as determined in step 4.

lote 3: Compose the contract specifications using pplicable portions of Appendices E and F using the evel of analysis determined.

Step 1 - Determine and enter uncertainty value "U" from

ed

					tor	for each type of ar sional, and structu Enter sum from			
Step 2 - Determin	ne and enter risk va	lue "R" from suggested val	ues below.	Enter selected R value	e 9.6.8.3.1, Bral rotor Dic analysis	Table 9.6.8.3.1, Torsional rotor dynamic analysis	Table 9.6.8.3.1, Structural dynamic analysis		
	Unknown, new desig	n with no field experience.	20						
RISK Significant modifications to standard product or similar design - no experience in field.		10		2 - Determin	ne and enter risk va	alue "R" from sugges	sted values below.	Enter selected R value	
R Minor modifications to standard product or similar design proven in field.		4		RISK	Significant modificat	sign with no field experience. 20 cations to standard product or experience in field. 10		-	
	Identical or standard	product, proven field history.	2		VIBER		to standard product or	-	
						Identical or standard	I product, proven field I	history. 2	
risk value "U"	the "R" values from selected in step 1 for These are the "RUI	or each type of		s	risk value "U"	the "R" values from selected in step 1 f These are the "RU Torsional	or each type of		
Lateral	Torsional	Structural							
					Products	of R x U, or RU	N numbers		
Durationste	(D 11 D11			a	nalysis type (later	al, torsional, or struct nalysis for each type guidelines below.			
Products	of R x U, or RUI	N numbers			RUN value	from step 3	Suggested level of analysis		
					51		None Required		
					> 15,		Level 1		
				and the second second	> 20,		Level 2 Level 3		
21 West Yost • Pa	arametrix					160	Level 3 +Validation*		
				And the second s			A CONTRACTOR OF THE OWNER		

Requirements for Vibration Analysis

Step 4 - Using the calculated "RUN" value from step 3 for each analysis type (lateral, torsional, or structural), determine the suggested level of analysis for each type of analysis from the guidelines below.

RUN value from step 3	Suggested level of analysis
≤ 15	None Required
> 15, ≤ 20	Level 1
> 20, ≤ 50	Level 2
> 50, ≤ 160	Level 3
> 160	Level 3 +Validation*

ote 1: It is recommended that the user of this ocument be acquainted with the document's contents rior to using this matrix.

lote 2: The vendor and user should agree on the uggested level of analysis as determined in step 4.

Note 3: Compose the contract specifications using applicable portions of Appendices E and F using the evel of analysis determined.

tor	sional, and structu	iral.
Enter sum from	Enter sum from	Enter sum from
Table 9.6.8.3.1,	Table 9.6.8.3.1,	Table 9.6.8.3.1,
Lateral rotor	Torsional rotor	Structural dynamic
dynamic analysis	dynamic analysis	analysis

Step 2 - Determi	Enter selected R value		
RISK NUMBER,	Unknown, new design with no field experience.	20	
	Significant modifications to standard product or similar design - no experience in field.	10	
DIVIDER,	Minor modifications to standard product or similar design proven in field.	4	
	Identical or standard product, proven field history.	2	

Level 3

+Validation'

 Step 3 - Multiply the "2" values from step 2 times the risk value "U" selected in step 1 for each type of analysis. These are the "RUN" values.

 Lateral
 Torsional

 Structural

 Products of R x U, or RUN numbers

 Step 4 - Using the calculated "RUN" value from step 3 for each analysis type (lateral, torsional, or structural), determine the suggested level of analysis for each type of analysis from the guidelines below.

 RUN value from step 3
 Suggested level of analysis

 \$15
 None Required

 > 15, \$20
 Level 1

 > 20, \$50
 Level 2

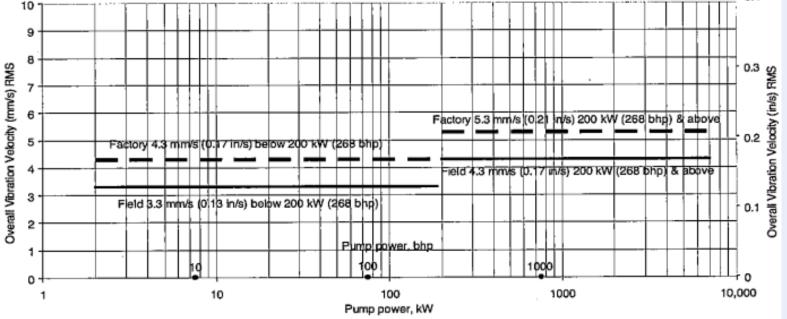
 > 50, \$160
 Level 3

> 160

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Vibration Testing and Measurement

ANSI/HI 9.6.4



Application notes:

- The factory criteria are applicable for new pumps with either a factory or new motor. The field criteria are intended for use when both the pump and motor are in new condition.
- 2) For operation outside the POR but within the allowable operating region (AOR), increase the values shown by 30%.
- For solids-handling versions of VS pump types, increase the values for AOR and POR, respectively, by 50% (tested free of clogging conditions).
- Pump types refer to Figure 9.6.4.2.3.1.
- Allowable pump values are based on historic data and, as more test data become available, limits will be subject to change.

Figure 9.6.4.2.5.1b — Allowable pump vibration, pump types VS1, VS2, VS3, VS4, VS5, VS6, VS7, and VS8 (For a more complete description of pump types, refer to ANSI/HI 1.1-1.2 and ANSI/HI 2.1-2.2.)

Electrical and I&C Requirements

NEMA MG-1 vs VFD Rated

Safety factors, starting conditions, and limitations

Shaft Grounding Rings

Bearing damage due to induced current

Motor Iubrication

Grease vs oil

Instrumentation and Controls

Temperature, load, and vibration monitoring

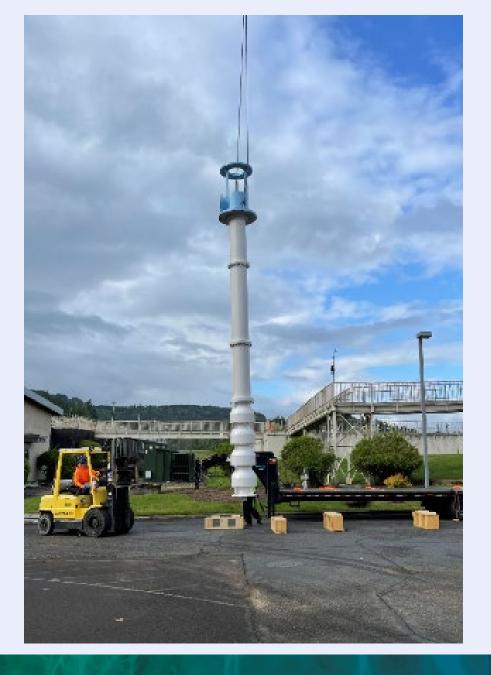
Case Study | JWC Water Treatment Plant

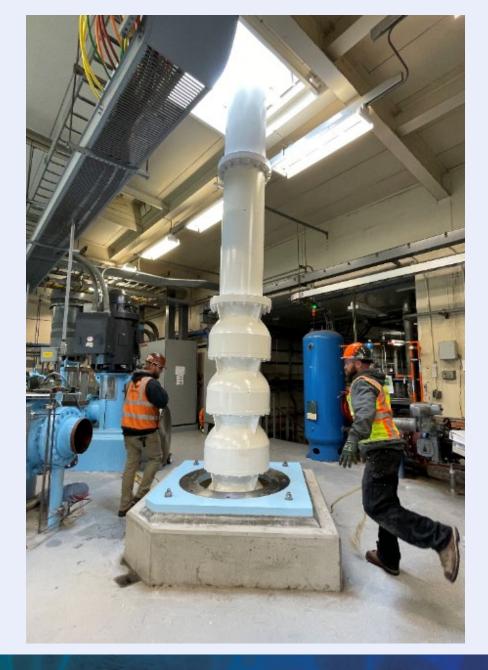
FWPS #2

FWPS #1



Current Pump Stations							
FWPS NAME	FIRM CAPACITY (MGD)	TOTAL CAPACITY (MGD)	NOTES				
FWPS #1	36	46	Firm Capacity assumes largest pump is out of service				
FWPS #2	25.9	38.9	Firm Capacity assumes largest pump is out of service				
Total FWPS #1 and #2	61.9	84.9	Current Capacities				





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Closing Remarks

- Large Pumps (200+ HP) have unique considerations
- Standards such as NSF 61, HI 9.6.8, and NEMA MG-1 provide lot of specific guidance
- Still require detailed conversations with both manufacturers and clients
- Leverage those

THANK YOU



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