Acoustical and Bearing Housing Resonant Vibration on a Centrifugal Pump

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Power Optimization VFD Installation

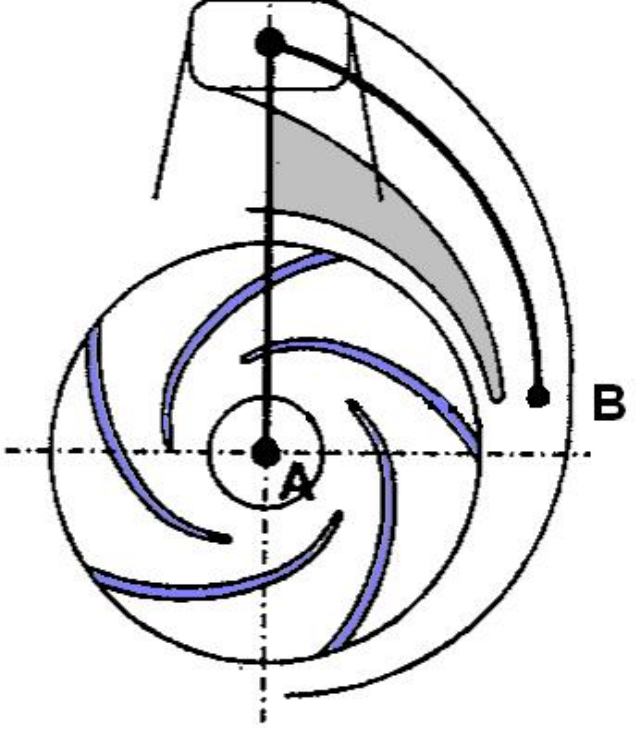
- Pine Bend, Minnesota, 2000 hp, 3600 rpm
- 6x8x13, 5/4 stage centrifugal pump, 4th stage is removed and 7 vanes on all impellers
  - Power optimization study shows a VFD will pay for itself in a short period of time the way this pump is operated

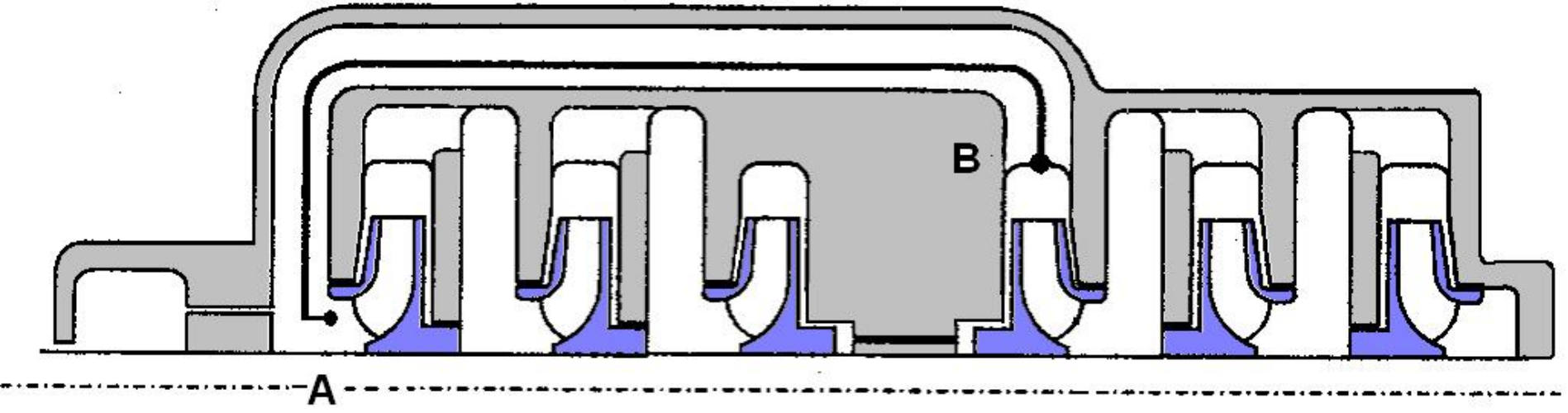
6x8x13 5/4 stage Pump, 2000 hp
Pine Bend, MN

Acoustical Resonance Centrifugal Pumps

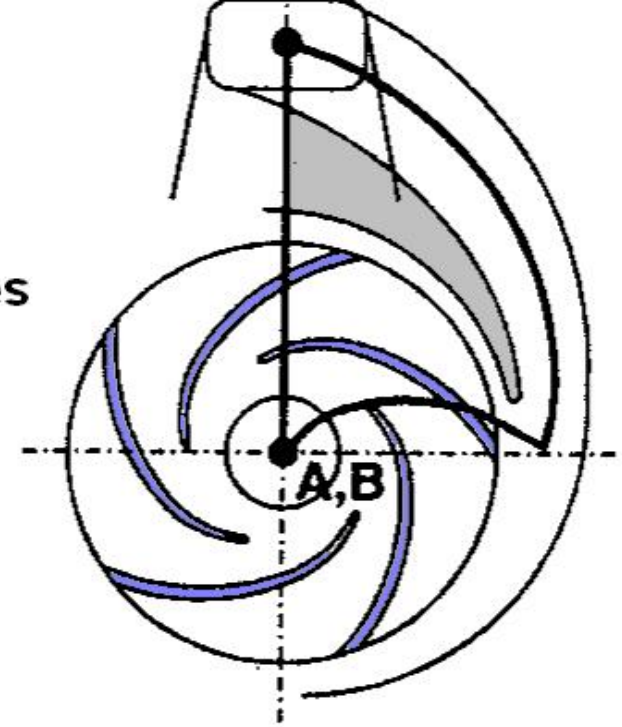
- Acoustical resonance can develop within the hydraulic passageways of the pump, especially in the long cross-overs. It occurs when the affective hydraulic passageway length, is the same length as the sound wave length produced by the vane pass pressure pulsations, thus generating a standing wave.
  - The amplitude of the standing wave is greatly amplified in this condition and creates large pressure pulsations and extremely high vibration levels.
- Acoustic wave length=(60x12)xc / (N x n)
  - C= speed of sound for product pumped, ft/sec
  - N= pump speed, rpm
  - n= number of vanes on impeller

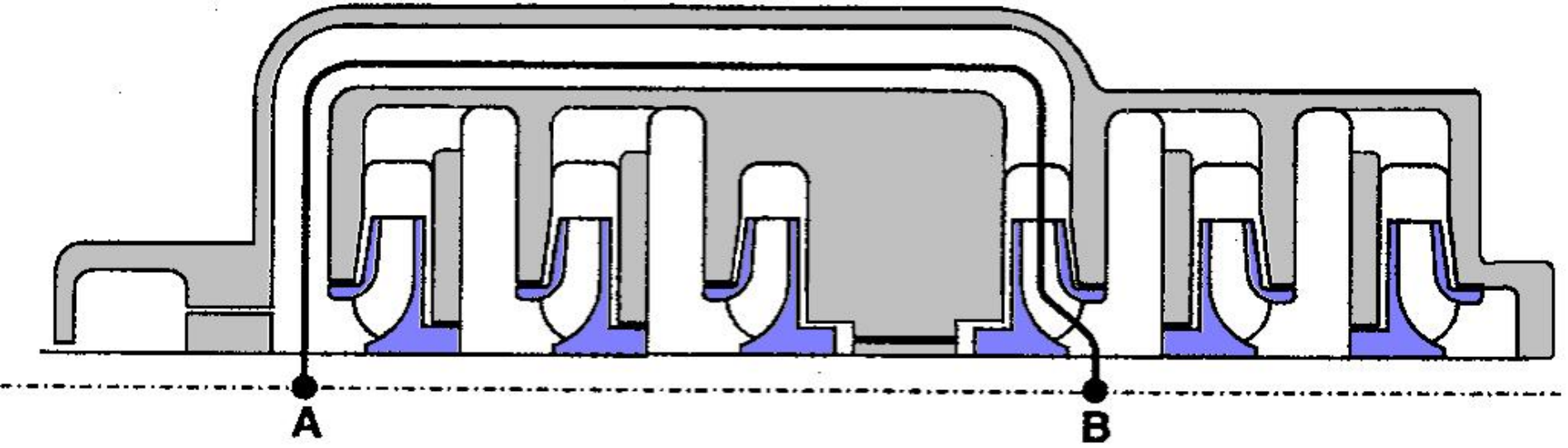
Old Method of Cross Over Length Measurement for Accoustical Resonance Calculations (Volute Lip to Impeller Entrance)



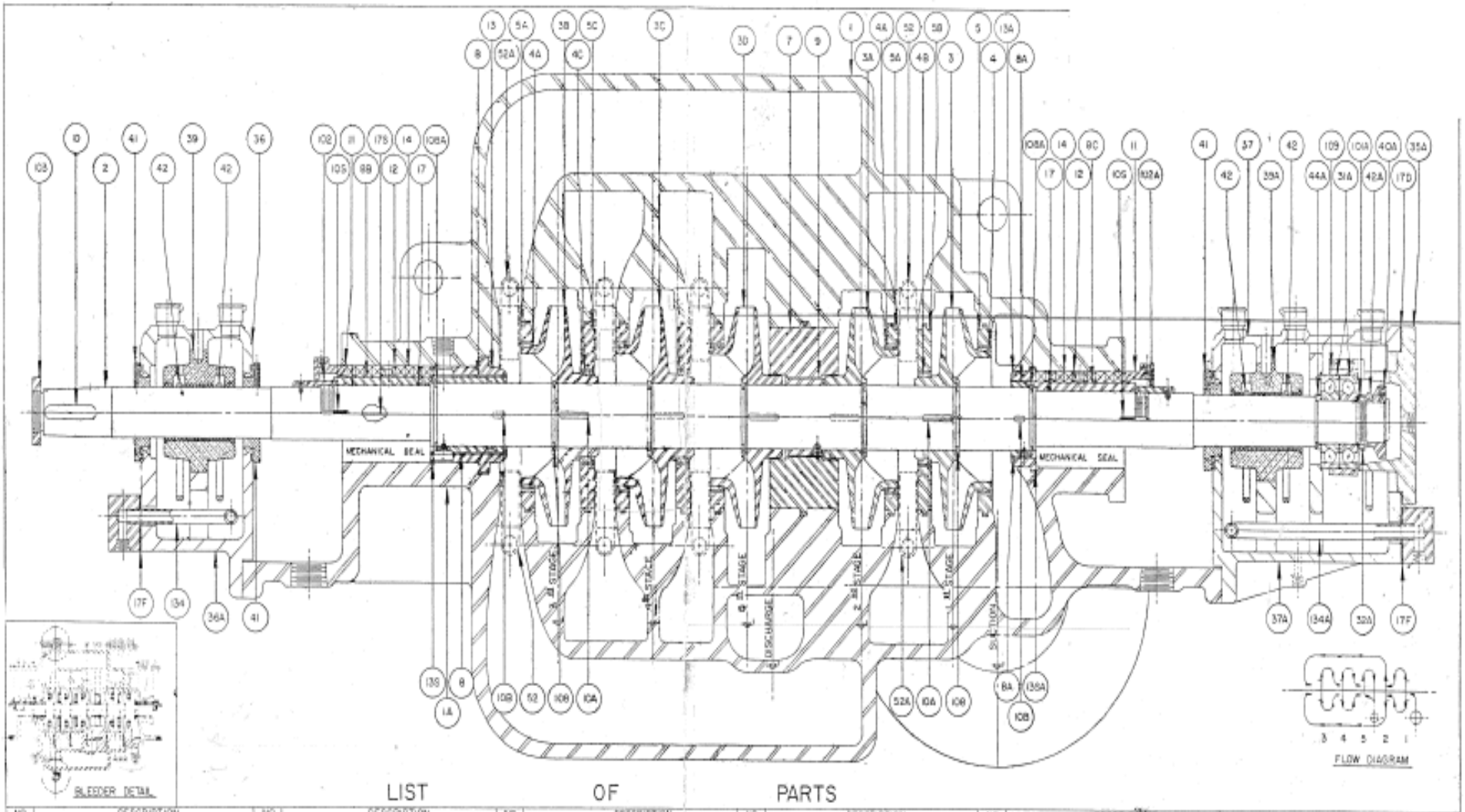


New Method of Cross Over Length Measurement for Accoustical Resonance Calculations (longer than old method since it includes length of impeller vane)





Sectional Drawing 6x8x13, 5/4 stage pump



LIST OF PARTS

NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	CASE-UPPER	5A	CASE WEAR RING	11	GLAND	36A	BEARING COVER	51A	SPLITTER
1A	CASE-LOWER	5B	CASE WEAR RING	12	LANTERN RING	36	BEARING CAP-RADIAL	101A	LOCKWASHER
2	SHAFT	5C	CASE WEAR RING	13	THROTTLE BUSHING-PACKING	36A	BEARING BRACKET-RADIAL	102	SHAFT SLEEVE NUT-PACKING
3	IMPELLER-1st STAGE	7	CASE SEPARATING RING	13A	THROAT BUSHING-PACKING	37	BEARING CAP-THRUST	102A	SHAFT SLEEVE NUT-PACKING
3A	IMPELLER-2nd STAGE	8	SHAFT SLEEVE	13S	THROTTLE OR THROAT BUSHING-SEAL	37A	BEARING BRACKET-THRUST	103	COUPLING NUT
3B	IMPELLER-3rd STAGE	8A	SHAFT SLEEVE	13SA	THROAT OR THROTTLE BUSHING-SEAL	39	BEARING SLEEVE-SPLIT	108	LOCATING RING-IMPELLER
3C	IMPELLER-4th STAGE	8B	SHAFT SLEEVE-PACKING	14	PACKING	39A	BEARING SLEEVE-SPLIT	108A	LOCATING RING-SLEEVE
3D	IMPELLER-5th STAGE	8C	SHAFT SLEEVE-PACKING	17	GASKET-SHAFT SLEEVE-PACKING	40A	OIL RING CARRIER	109	OUTER RACE HOLDER
4	IMPELLER WEAR RING	9	INTERMEDIATE SHAFT SLEEVE	17G	GASKET-BEARING COVER	41	BEARING SHIELD	134	HEAT EXCHANGER ASSEMBLY-RADIAL
4A	IMPELLER WEAR RING	10	KEY-COUPLING	17F	GASKET-HEAT EXCH COIL COVER	42	OIL RING	134A	HEAT EXCHANGER ASSEMBLY-THRUST
4B	IMPELLER WEAR RING	10S	KEY-IMPELLER	17S	GASKET-CASE SPLIT	42A	OIL RING		
4C	IMPELLER WEAR RING	10R	KEY-SHAFT SLEEVE	31A	BALL BEARING	44A	BEARING SHOULDER RING		
5	CASE WEAR RING	10S	KEY-SLEEVE	32A	LOCKNUT	52	SPLITTER		

SECTIONAL DRAWING

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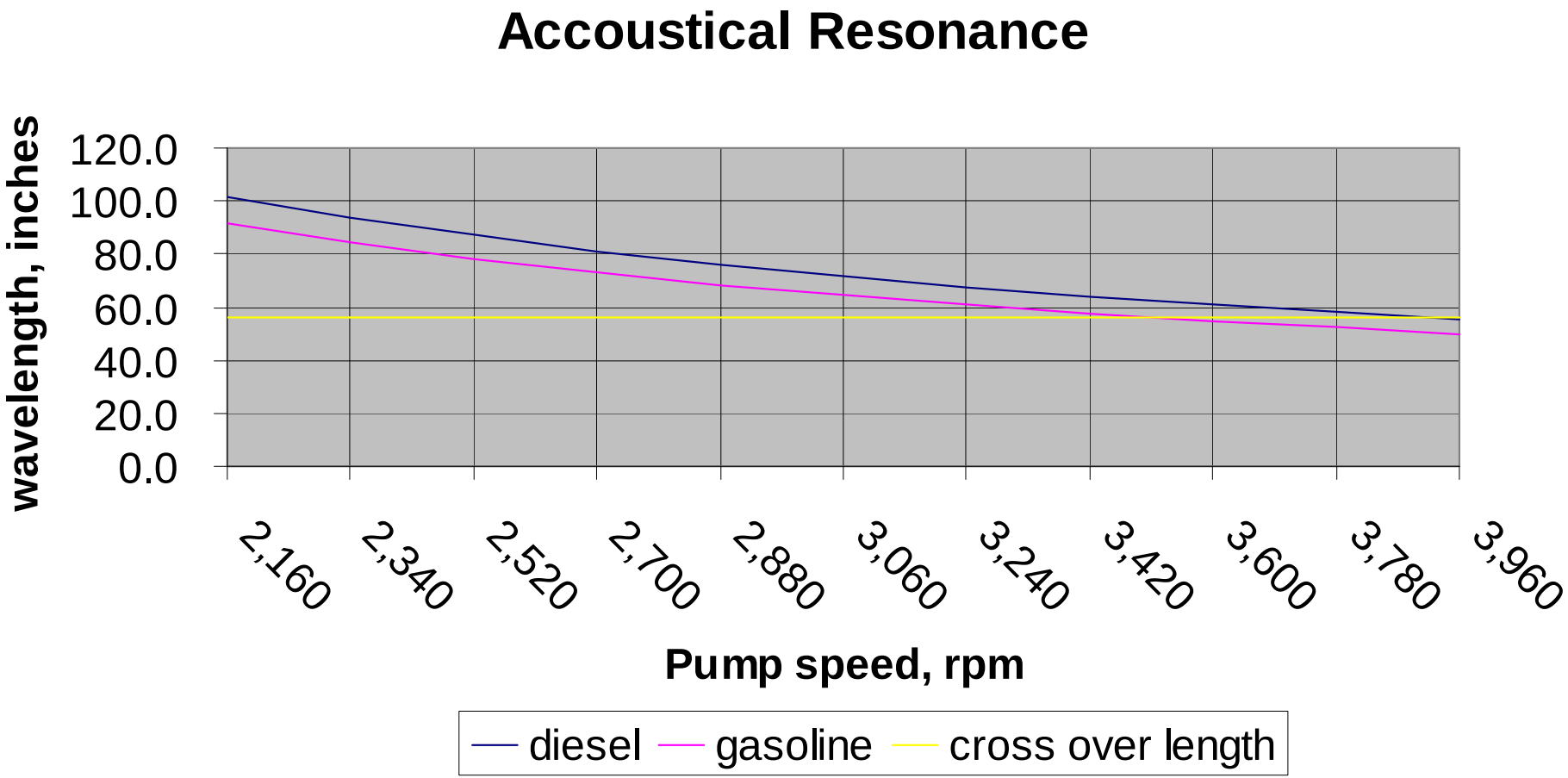
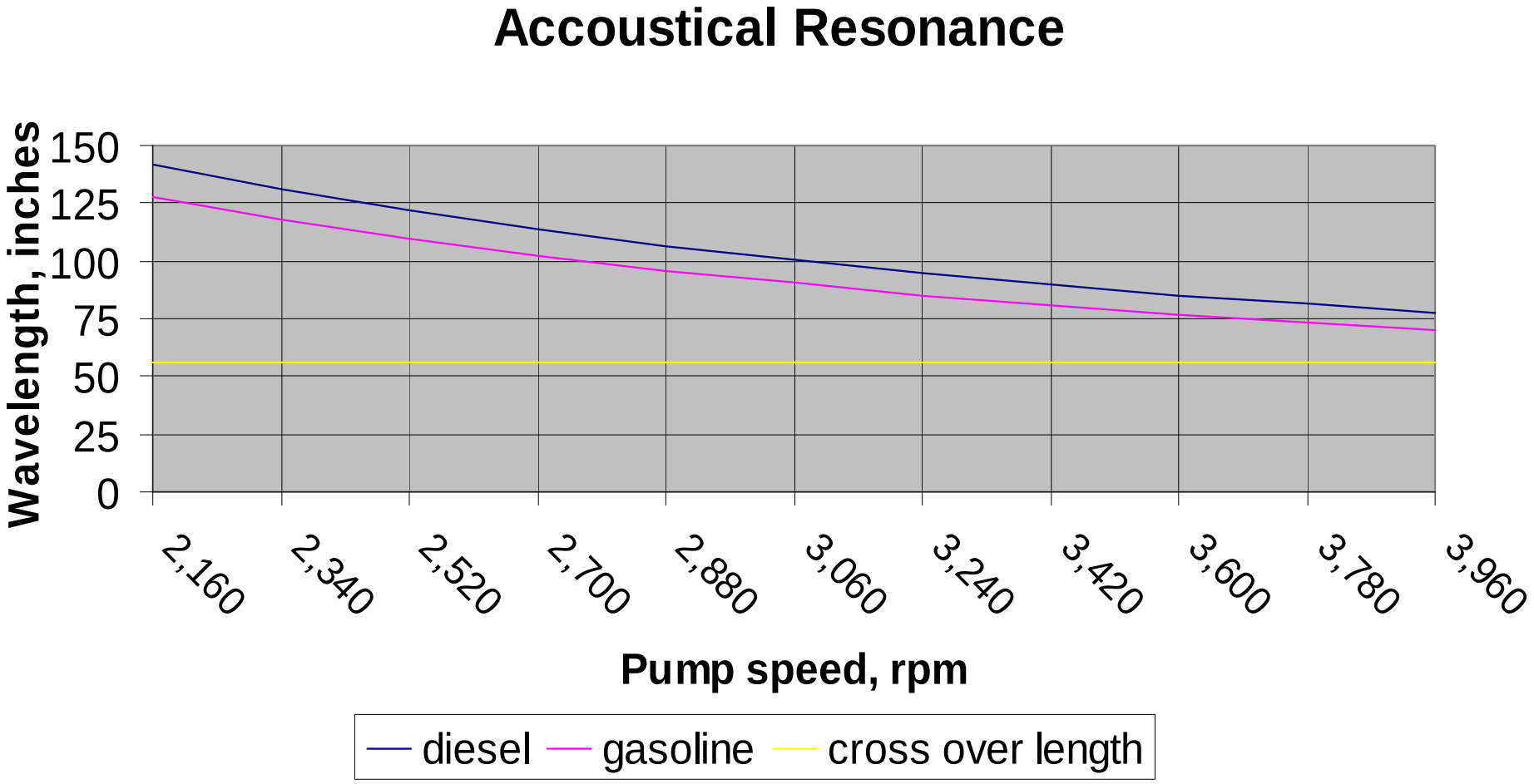
Acoustical Resonance

- Crossover length, old method = 56 inches as determined by pump manufacturer's engineer by reviewing pump hydraulic drawings passage lengths (volute lip to impeller entrance)
- Cross over length, new method = 79.5 inches (closed loop method includes distance around impeller periphery and across next impeller eye)
- Speed of sound in product used for this analysis
- Diesel fuel – 4264 ft/sec
- Gasoline – 3837 ft/sec
- Butane – 3184 ft/sec
- Different sources provide different speeds so results can be different

Acoustical Analysis of existing 7 vane impellers, shows problem at higher speeds



Acoustical Analysis of proposed 5 vane impeller, shows separation margin



HIGH VIBRATION with 5 vane impeller 2.8 in/sec (over all, unfiltered, peak) on gasoline but not on diesel

- The modified pump and VFD were installed and everyone said it ran great for about a year. Then the seal flush tubing failed and a more thorough analysis was conducted and determined the pump had high vibration levels when pumping gasoline at higher speeds.
- The pump ran smooth on diesel fuel but rough on gasoline indicating an acoustical resonance problem. The bump test indicated that the inboard bearing housing in the vertical direction had a natural frequency which was also excited by the 5 vane impeller.

VFD installation with pump modification

The original pump had 7 vane on all impellers and the impeller feeding the cross over was changed to 5 vane to avoid an acoustical resonance condition

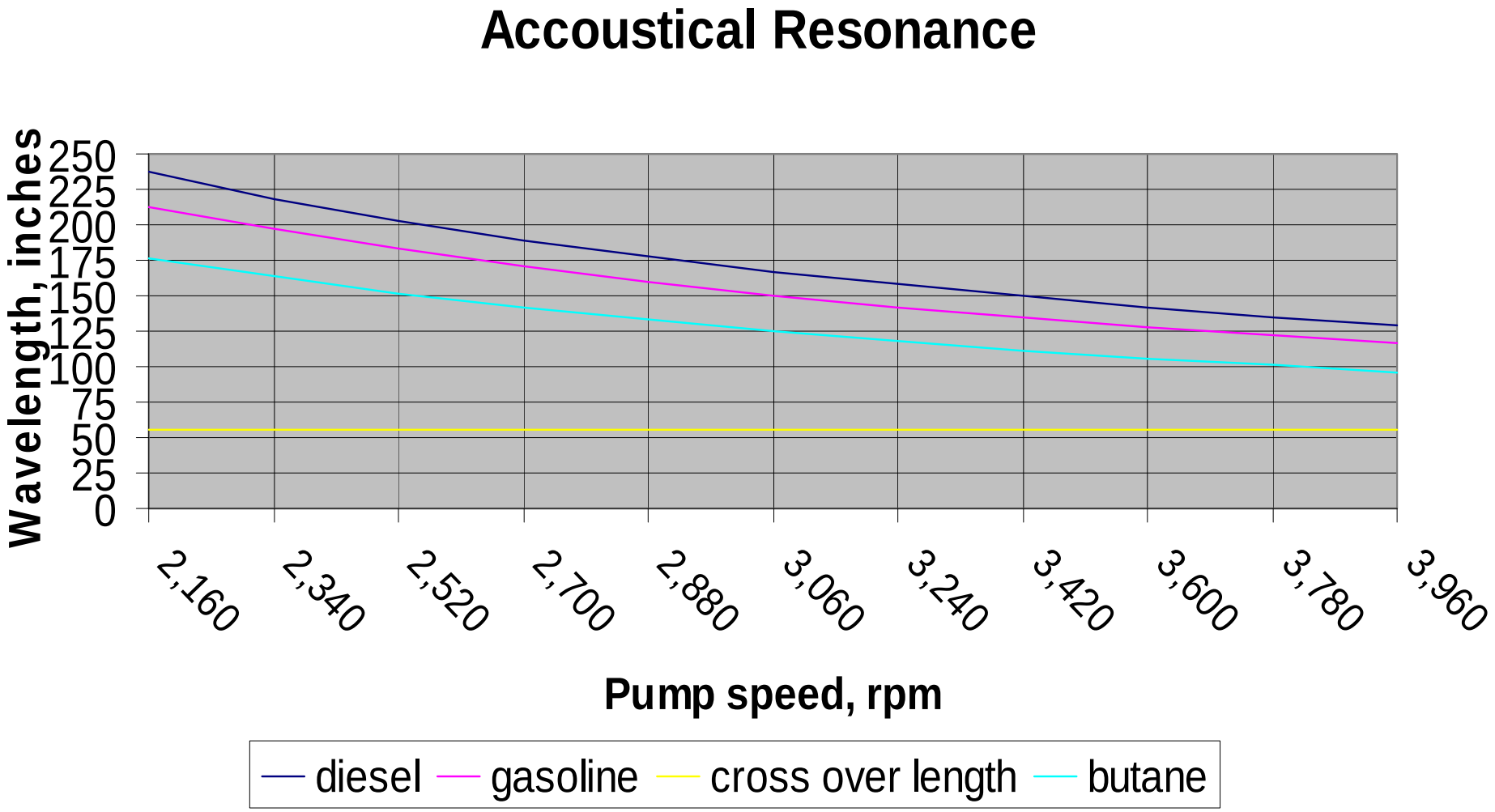
- The pump ran smooth while pumping diesel fuel but ran extremely rough when pumping gasoline at higher speeds.
- **Data while pumping diesel fuel (.86 SG), inboard vertical**

VFD%	Pump Speed Rpm	Vibration, in/sec Over all, unfiltered, peak
80	2890	.02
90	3240	.13
95	3420	.16
100	3590	.16
107	3820	.19 (peak at 5X)

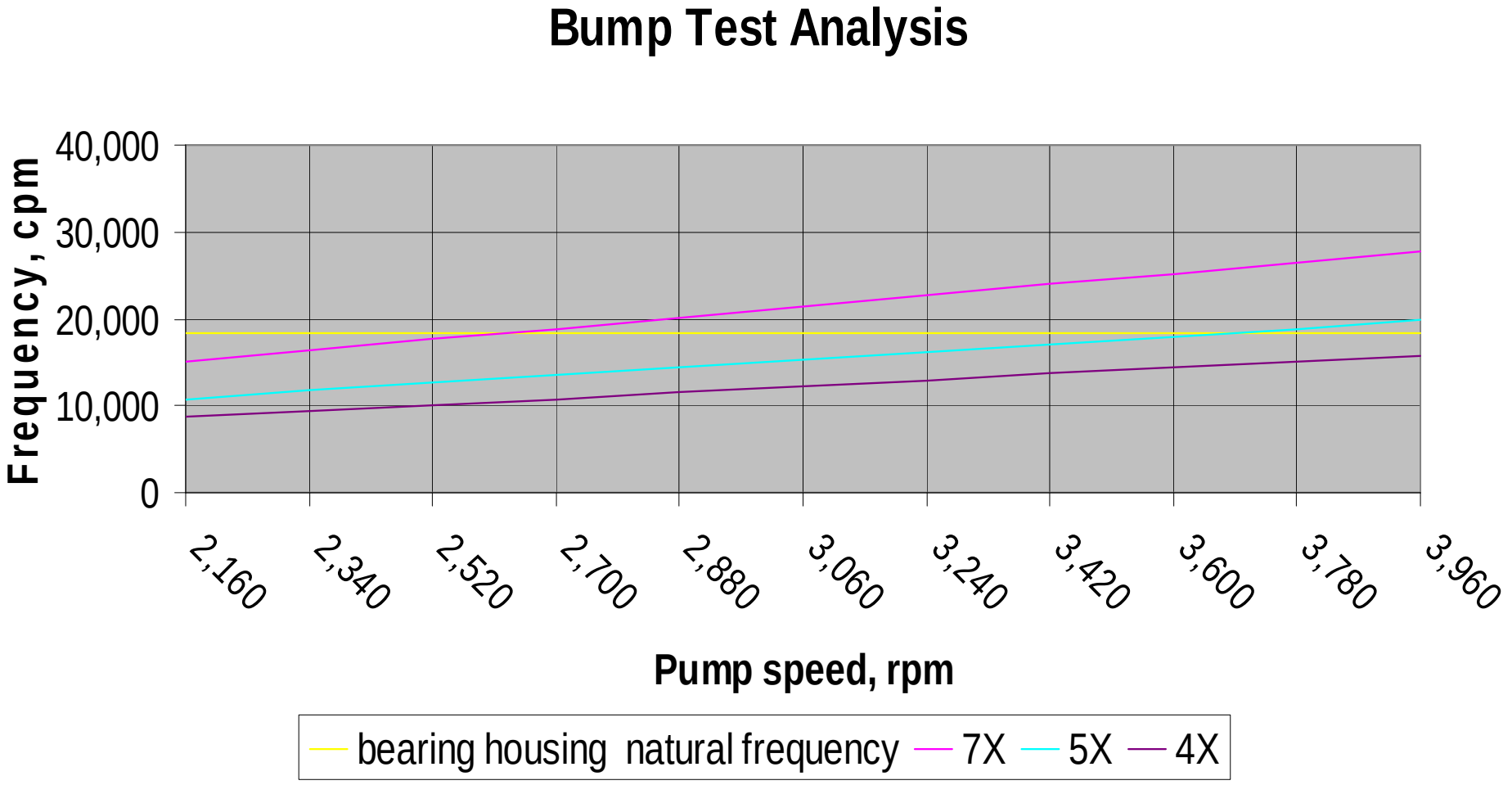
- **Data while pumping gasoline (.73 SG), inboard vertical**

85	3085	.02
100	3590	1.0 (peak at 5X)
105	3800	2.8 (peak at 5X)
110	3980	.48 (peak at 5X)

Acoustical Analysis of proposed 4 vane impeller, shows greater separation margin



Bearing Housing Bump Test Analysis
natural frequency = 305 hz = 18,300 cpm
5 vane shows a problem at 3600 rpm



VFD installation with 2nd pump modification

The impeller feeding the cross over (2nd stage) was changed from a 5 vane to 4. All other impellers are still 7 vane (same as original pump from factory).

- All problems are now resolved and the pump runs with low vibration levels at all speeds while pumping all products.

- **Data while pumping diesel fuel (.86 SG), inboard vertical**
- VFD% Pump Speed Vibration, in/sec
  - Rpm Over all, unfiltered, peak
- 100 3590 .10
- **Data while pumping gasoline (.73 SG), inboard vertical**
- 100 3590 .15

Summary

- Installing VFDs on pumps that were formerly constant speed pumps can cause new vibration problems to be encountered .
- Acoustical resonance conditions can occur in the long cross over. New methods of measuring acoustical cross over lengths is now available that provide better results.
- In some situations, vane pass frequencies can excite bearing housing natural frequencies and create a resonate conditions.
- Variable speed centrifugal pumps have a much higher chance of having vibration problems and a lot of analysis and field testing needs to be performed to avoid problems.