# VIBRATION REDUCTION OF VERTICAL PUMPS
# A CASE HISTORY

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ABSTRACT

Vertical pumps are susceptible to vibration problems partly due to their "one-point" attachment to the foundation. A case history of high vibrations of a vertical pump and a design modification to remedy it are presented here. Vibration measurements were carried out to identify the causes for the high, unacceptable vibration levels and to assess the effectiveness of the proposed design modification.

## Introduction

Vertical pumps of the turbine type have wide applications in the industry. They offer good economics: efficient space utilization - especially for large fluid handling capacities, simplified piping and adaptation to meet underground (low suction heads) or submerged pumping requirements.

However, vibrational behaviour of such pumps is sometimes objectionable or totally unacceptable for certain applications [1]. The fact that vertical pumps exhibit usually higher vibration levels than that of horizontal pumps can be partially attributed to how they are mounted. Vertical pumps are typically attached to the foundation at one point only, normally at ground level. Thus, creating a cantilever effect above and below the attaching point. Moreover, pump base has to support the driving motor weight. It seems that vibrations below pump base are not noted by the user nor do they tend to damage the pumpset, but that of components above foundation level are of concern, specifically motor top which is the uppermost component. Figure 1 shows an example of a vertical pump and its main components.

In power generating stations, especially nuclear ones, a high standard of equipment reliability and performance are required in order to prevent any costly, forced outage. Consequently, pumpsets used in generating stations have to meet some vibration standard. Typical vibration standards adopted are either field specific [2] or general machine oriented [3].

In this case history, preliminary vibration testing of a 4 stage, vertical pump having water lubricated bearings and driven by a 588 kW electric motor through a rigid coupling, operating at 1200 rpm, revealed excessive vibration levels accompanied by premature wear of rotating and stationary pump parts.

## Vibration Measurements

Under typical operating conditions a series of vibration measurements were carried out on the pumpset in two planes: parallel to discharge head and 90° from it. Several measuring points were chosen: (a) motor at top bearing housing, (b) pump at mounting flange, (c) motor at bottom bearing housing, and (d) pump bottom (can). Identification of these points is given in Figure 2. Frequency analysis was performed to detect major amplitude components in the frequency range 0-50 Hz. In addition, impact tests were carried out to determine pumpset natural peak resonance(s) for three cases: (a) motor, (b) pump and (c) pump and motor as one unit.

## Results Interpretation and Design Modification

Displacement measurements at motor top were found to be quite high: 10 and 6 mils peak-to-peak, unfiltered, parallel to pump discharge head and 90° from it, respectively. Typical maximum acceptable levels for such pumpset are 3-4 mils. Frequency spectra indicated that most of the vibration occurred at a frequency corresponding to 1/2 running speed (10 Hz).

Impact tests for the pumpset (pump and motor) at motor top showed a structural resonance around the same frequency range (10-12 Hz) - see Figure 3.

In addition, analytical simulation of pumpset bearing-rotor system using computer programs [4] identified a rotor lateral vibration mode in the range 650-670 rpm, which corresponds to 10.8-11.2 Hz.

Based on the aforementioned measurements and analysis, it was decided to try to shift the pumpset structural resonance away from 10 Hz. To achieve such a shift, a flexible plate, made of steel, was introduced between the pump head and the motor. The flexible plate is shown in Figure 4. It separates motor vibration from pump vibration by allowing each of its halves to vibrate vertically in some independent fashion; thus changing the frequency at which natural resonance of the system occurs.

Vibration levels before and after the use of the flexible plate are given in Table 1; they include displacement amplitudes filtered at frequencies corresponding to 1/2 and full running speeds as well as unfiltered overall levels. The results in the table indicate that the use of the flexible plate resulted in an appreciable reduction in vibration levels at the critical point of motor top. Most of this reduction occurred at 10 Hz. The overall vibration levels at the motor top after the introduction of the flexible plate were 3 and 1.7 mils peak-to-peak, unfiltered, as opposed to the before levels of 10 and 6 mils, parallel to the discharge head and 90° from it, respectively. Frequency spectra of impact tests and vibration measurements, again at motor top, after using the flexible plate are given in Figure 5. Impact tests' frequency spectra indicate that the aforementioned pumpset structural resonance occurring in the frequency range 9-12 Hz, have been successfully shifted to the 7-8 Hz frequency range, after the use of the flexible plate.

## Conclusion

The use of a flexible plate, introduced between a vertical pump head and the driving motor, has produced an appreciable reduction in motor top vibration levels. This reduction is attributed to a shift in the pumpset natural structural resonance away from the critical frequency of 1/2 running speed.

## References

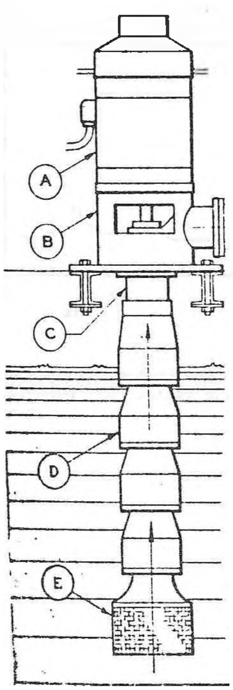

1. A. Kovats, "Vibration of vertical pumps," Journal of Engineering for Power, April 1962, pp 195-203.

2. API Standard 610, "Centrifugal pumps for general refinery services," Fifth Edition, March 1971, American Petroleum Institute, Division of Refining, 1801 K Street, N.W., Washington DC 20006.

3. ISO 3945, "Mechanical vibration of large rotating machines with speed range from 10 to 200 rev/s - Measurement and evaluation of vibration in situ", Ref No ISO 3945-1977 (E).

4. D.F. Li and E.J. Gunter, "Linear stability analysis of dual-rotor systems - A manual for use with computer program STAB2V2", Report No UVA/528140/MAE78/113, Research Laboratories for the Engineering Sciences, School of Engineering and Applied Science, University of Virginia, 1978.

5. R.J. Fritz, "The effects of an annular fluid on the vibrations of a long rotor, Part 1 - Theory and Part 2 - Test", Journal of Engineering for Industry, December 1971.


A ELECTRIC MOTORS
B DISCHARGE HEAD
C DISCHARGE COLUMN
D TURBINE PUMP BOWL ASSEMBLY
E SUCTION STRAINER

Figure 1. Typical Vertical Pump Components

Table 1. Vibration levels with and without flexible plate. For measurement point identification, see Figure 2.

| Measurement Point | Vibration Level, p-p mils | | | | | |
|---|---|---|---|---|---|---|
| | 10 Hz (1/2 running speed) | | 20 Hz (running speed) | | Overall level unfiltered | |
| | Without plate | With plate | Without plate | With plate | Without plate | With plate |
| Motor top: | | | | | | |
| A | 7 | 0.5 | 0.6 | 0.4 | 10 | 3 |
| B | 4.6 | -- | 0.4 | 0.4 | 6 | 1.7 |
| Motor bottom: | | | | | | |
| C | 1.3 | -- | 0.6 | 1.5 | 3 | 4.8 |
| D | 1.7 | -- | 0.4 | 1.8 | 5 | 4 |
| Pump head: | | | | | | |
| E | 1.8 | -- | 0.6 | 1.8 | 5 | 5 |
| F | 0.6 | -- | 0.3 | 0.6 | 1.5 | 2.5 |
| Pump bottom: | | | | | | |
| G | 1.2 | -- | 4.4 | 3.0 | 7 | 4 |
| H | -- | -- | 5.2 | 3.4 | 7.5 | 5 |

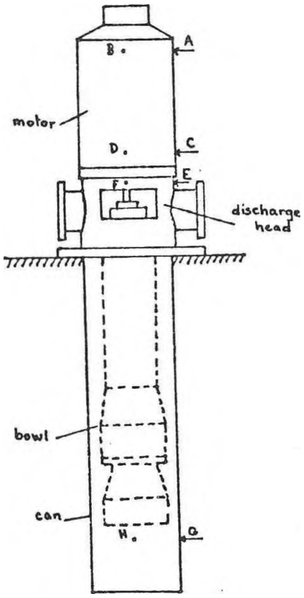



Figure 2. Vibration Measurement Points.
Given points identification is used in Table 1.

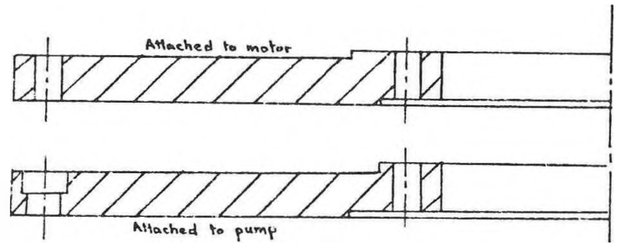



Figure 4. Details of flexible plate.

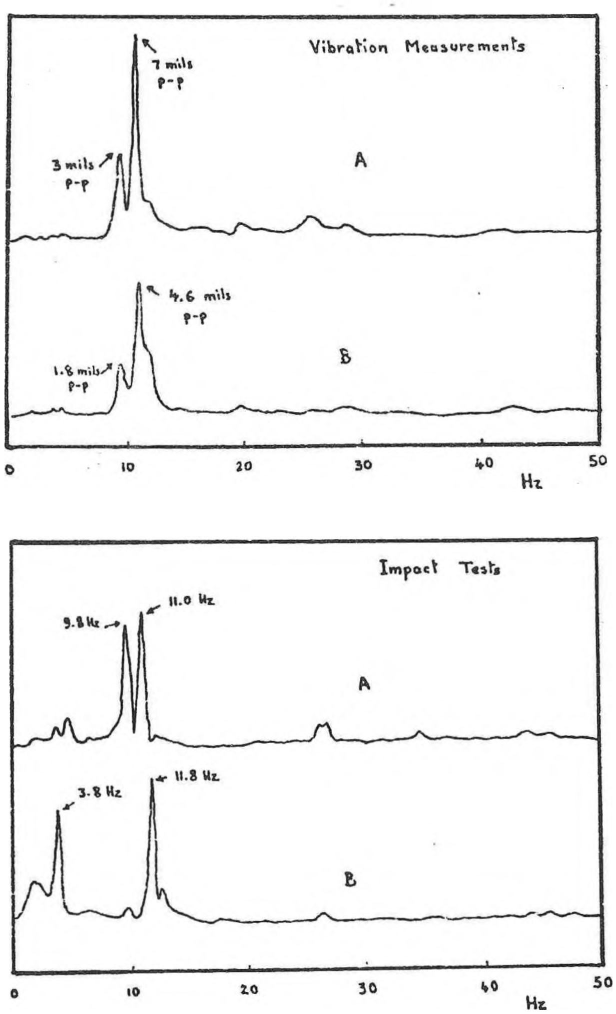



Figure 3. Frequency spectra of vibration measurements and impact tests at motor top. A: parallel to discharge head; B: 90° from discharge head.

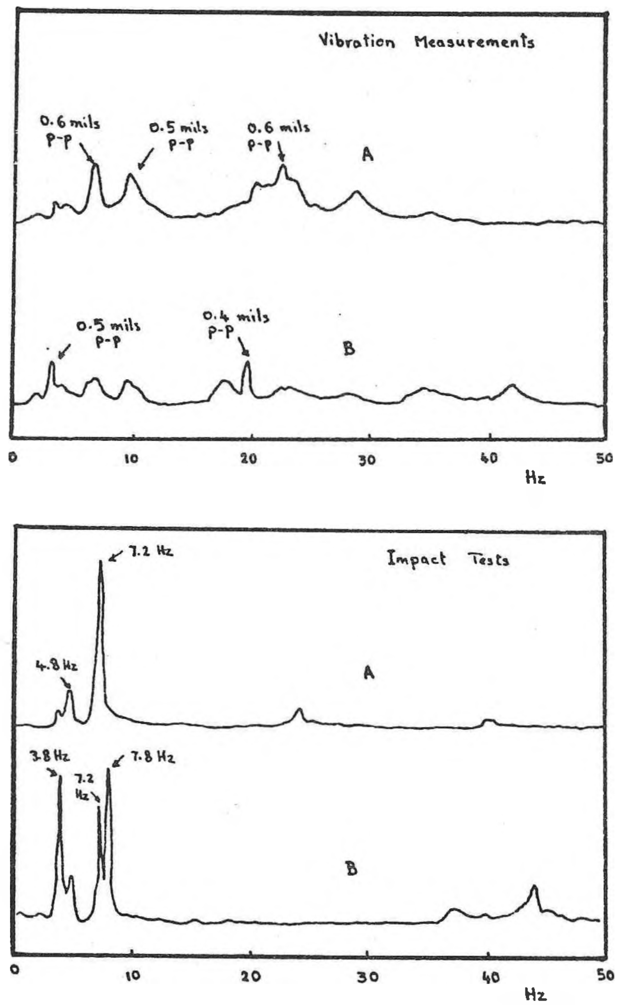



Figure 5. Frequency spectra of vibration measurements and impact tests at motor top after installation of flexible plate. A: parallel to discharge; B: 90° from discharge head.