Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

The Lifetime Reliability Solutions
Certificate Course in Maintenance and Reliability
Module 3 – Other Condition Monitoring Techniques for Machinery

Session 12
Other Condition Monitoring Methods

1. Definition:

Condition Monitoring has historically focussed on the acquisition and analysis of measurable parameters that would give useful information as to the condition of machine components and, hence, a forecast of the likely serviceability of the machine.

The wider view of Condition Management must take into account the performance of the machine, or the system of which it is a part, and report on excursions away from previously defined acceptable tolerances.

The definition of Condition Monitoring suggested earlier embraces the concept of Performance Monitoring also.

The process of systematic data collection and evaluation to identify changes in the performance or condition of a system or its components, such that remedial action may be planned in a cost effective manner to maintain reliability.

2. What is the Purpose of Performance Monitoring?

There is the classic story of the condition monitoring technician who completed a vibration survey on a pump after it was reported as running erratically. He reported that the pump had the lowest vibration levels ever measured and it was therefore in perfect condition.

Shortly after receiving this advice the plant operator noted that the pressure gauge was much lower than usual and further investigation showed that the pump wasn't pumping at all!

The pump was isolated and opened up and it was found that the impeller had sheared off! Of course it had a beautiful vibration signature – but it wasn't doing anything!!

This illustrates one dimension of why performance monitoring is needed to make sense of some situations.

The technology of Process Control has developed rapidly in recent years as part of the information revolution and many system performance parameters are monitored and alarms set for out of tolerance conditions. This is particularly true for systems more so than individual machines – unless they are process critical.

There are still many situations in industry where it is not immediately apparent that performance of a particular machine has dropped off. Sometimes systems are self-compensating without identifying the reason why, for example, three pumps are now needed to be running to do the work formerly handled by two.

There are other situations where, in the normal course of events, there is quite insufficient data to enable any accurate judgement on performance to be made. An example would be the fuel efficiency of a heavy-haul locomotive. The only way to determine the specific fuel consumption of one locomotive compared to another doing similar work would be to install instruments and data logging to record fuel flow, throttle position, brake usage, track speed and the like.

With the continuing advances in digital data acquisition and information processing it is likely that the data gathered from manual condition and performance monitoring surveys will increasingly appear alongside plant performance data on Distributed Control Systems and be used to assign maintenance priorities.

3. Applications for Performance Monitoring.

Machines and Systems for which Performance Monitoring surveys may be required on a routine basis include the following items:

- Pumps – due to impeller wear, seal ring wear (re-cycling) or blockage.
- Fan Systems – due to filter blockage, blade fouling or re-cycling.
- Boilers – due to loss of thermal efficiency for many different reasons
- Heat Exchangers – due to fouling or blockage.
- Steam Turbines – due to blade fouling and numerous other reasons.
- Air Compressors – due to wear, filter blockage, valve leakage (reciprocating), etc.
- Diesel or Gas Engines – due to loss of compression (rings or valve leakage) etc.
- Electrostatic or bag dust filters – due to fouling, shorting or leakage.

Note that electric motors are not included on the list because fall-off in performance is usually measurable by standard condition monitoring processes such as vibration and thermography. Perhaps the most useful parameter for performance measurement of an induction motor is speed in relation to load. This should always be a constant and variations are measurable with vibration analysis. Therefore, generally speaking, special purpose performance monitoring surveys for electric motors are not required.

For the purposes of this Module we will look only at some proposals for performance monitoring of pumps and fans – two of the most common machines in industry and with much potential for savings in power costs through routine efficiency studies.

4. Performance Monitoring of Pumps.

A typical set of centrifugal pump curves is shown opposite. Pump manufacturers extensively test every pump type on a calibrated test tank and produce accurate performance curves. A typical diagram giving the correct names for the parts of a centrifugal pump is also given.

For any given liquid the variables shown on these performance curves are as follows:

- Total Head (discharge minus suction) expressed as a vertical dimension (eg metres) or as pressure differential.
- Power Consumed (shaft power).
- Efficiency
- Flow
- Impeller Type.
- Shaft Speed.

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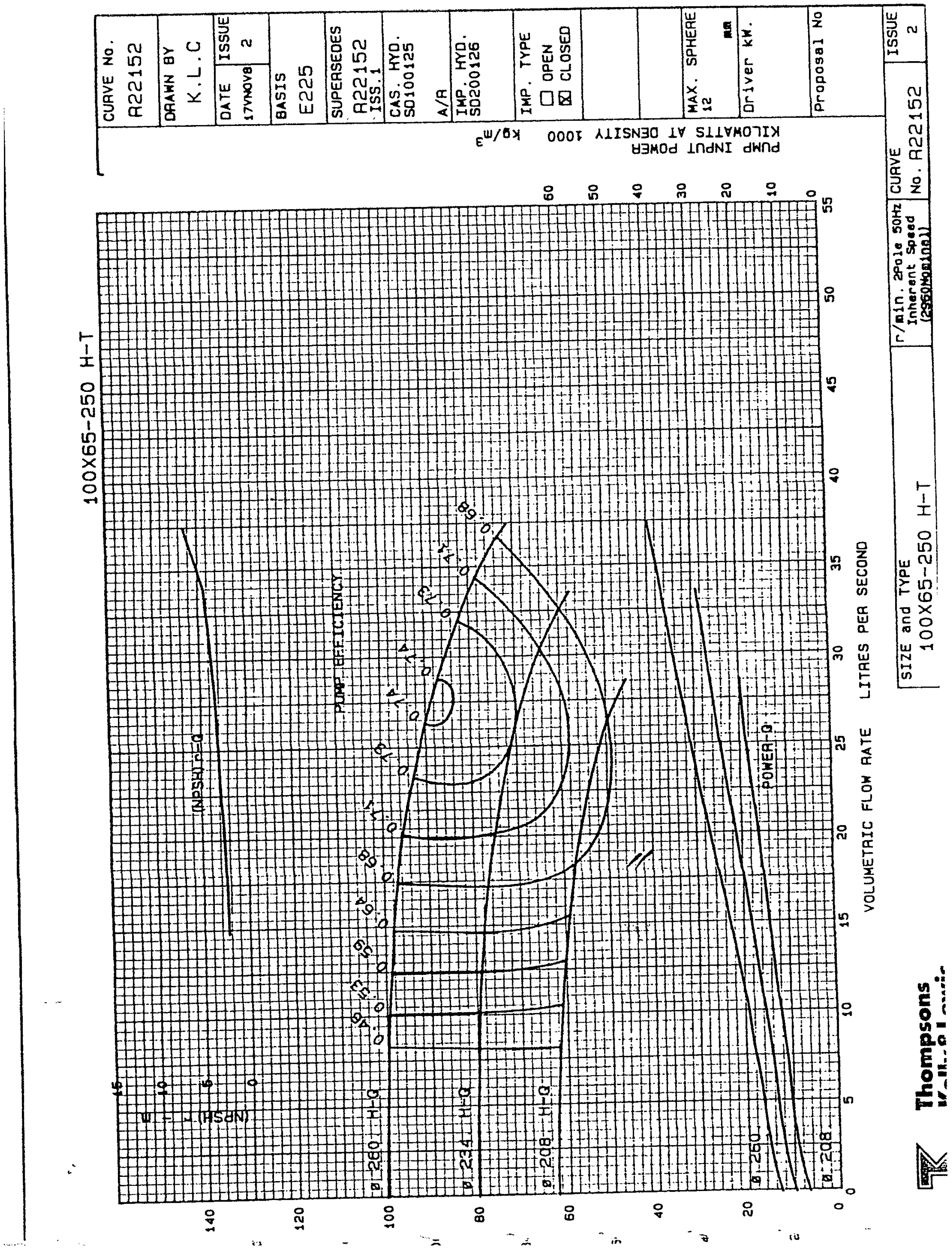
Apart from the last two variables – which are usually specified or known – any three of the first four can be used to identify with reasonable accuracy the 'duty point' for an operating pump. Better still if all four can be measured to minimise errors of measurement. In particular 'power' is not easily measured without taking into account motor and coupling efficiency. This is often an estimate rather than a measurement. Likewise 'efficiency' can vary due to wear and recirculation and therefore this is also not a directly measurable parameter.



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Therefore the only two reliable parameters which can be directly measured and applied to the charts are head (pressure) and flow.

Head is easily measured using pressure gauges. These are often installed and should be calibrated if any serious measurements are required. Calibration facilities are usually readily available.

Flow is less easily measured if no flow meters are installed. The only practical option in this case may be to use ultrasonic flow measurement. In most cases this can be applied and give results of between +/- 1% to 5% depending on the method used. Ultrasonic flow meters can be hired and are relatively easy to use. They come in two kinds, Doppler and Transit-time, to cover dirty and clear liquids respectively. Refer to the notes given at the end of this Session.

Some ultrasonic transit-time flowmeters also offer the capability to measure temperature rise across the pump (or heat exchanger) and calculate thermal power. This termed 'Absorbed Power'. For liquids other than water a 'calorific coefficient' constant needs to be applied but, for relatively inexpensive equipment, an accuracy of within +/-5% can be expected. A much more sophisticated instrument called the Yates Meter is now available with claims of overall accuracy better than 1%.

When all the data has been measured and applied to the appropriate pump curves it will be obvious as to whether there is good correlation or significant apparent errors. If all the data, both measured and estimated, fits together comfortably then there can be good confidence in determining the duty point and efficiency of the pump in the system.

If the data does not fit well then it is likely that there is a problem that could be one or more of these:

- Impeller wear has reduced the effective diameter.
- Leakage around the seal ring is causing significant recirculation. Flow drops.
- The 'system head' is different to expectations due to blockage or leakage.

Further investigations must be made until there is confidence that the fault is identified and then appropriate maintenance actions should be planned.

Potentially the most valuable outcome of pump performance testing is optimisation of efficiency and hence power usage. Often a change in impeller size will allow optimisation of the duty point and very significant power savings can result.

5. Performance Monitoring of Fans.

Centrifugal fans are very simple machines but they can be extraordinarily troublesome in typical industrial applications.

Firstly, they are sometimes poorly built or built to a price with inadequate structural stiffness, cheap bearings, design short-cuts and little consideration for the operational and maintenance demands of a long service life.

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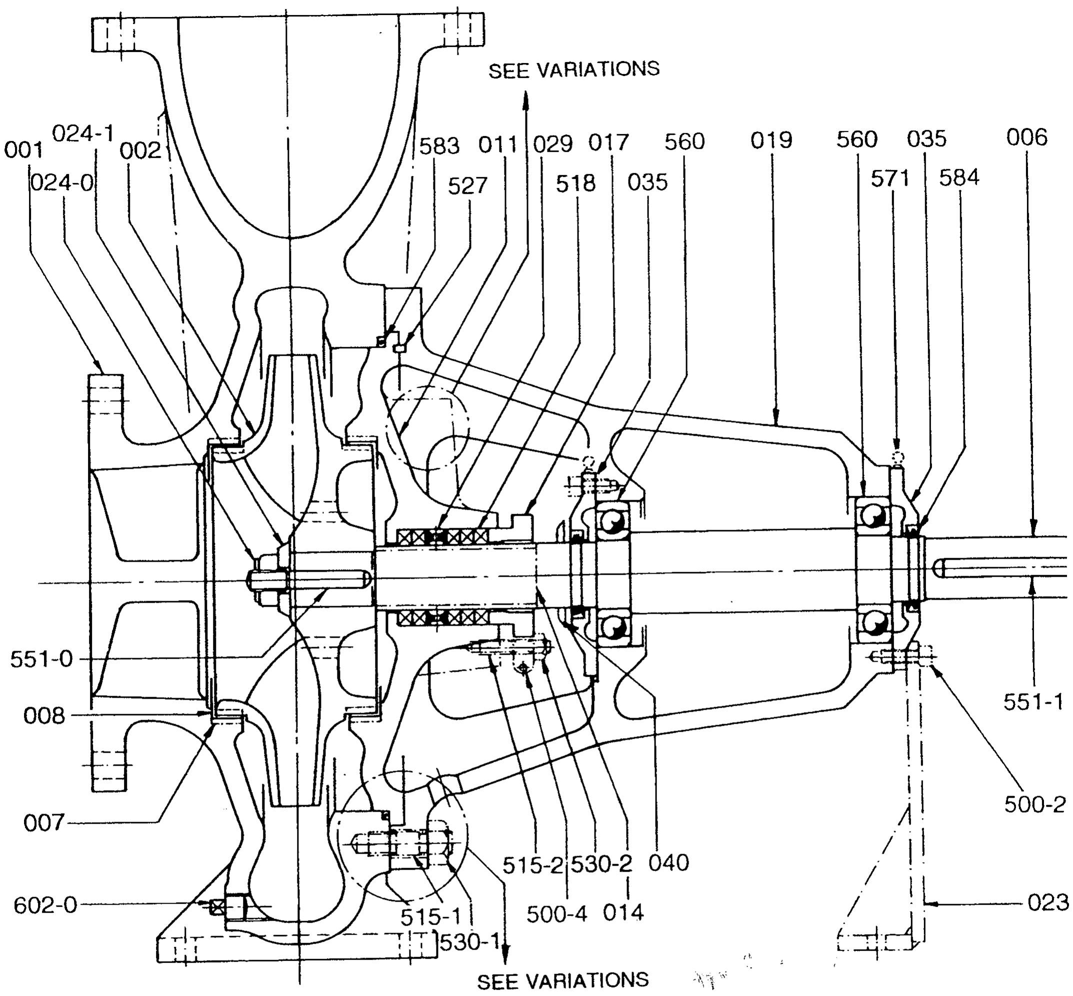
FIGURE 4



001	Casing	024-0	Impeller Nut	530-1	Nut Casing
002	Impeller	024-1	Impeller Washer	530-2	Nut Gland
006	Shaft	029	Lantern Ring	* 518	Packing
007	Seal Ring	035	Bearing Cover	551-0	Key Impeller
008	Wear Ring	040	Water Thrower	551-1	Key Coupling
011	Back Cover	500-2	Cap Screw	* 560	Ball Bearing
014	Shaft Sleeve	500-4	Bolt & Nut	571	Grease Nipple
017	Gland	515-1	Stud Casing	* 583	O-Ring
019	Bearing Housing	515-2	Stud Gland	* 584	V-Ring
023	Mounting Foot	527	Peg	602-0	Drain Plug

* Recommended Spares

Secondly, many fans have to handle gases that may be corrosive, dirt-laden, abrasive and wet. This means very harsh duty conditions that may demand significant maintenance. Often that maintenance is neglected resulting in significant efficiency reductions.

Like pumps, fans are usually supplied with duty curves which, depending on the quality of the fan, may be actual test results or just estimates from design.

The three sets of curves below are generic for a variety of fan types and take into account the three common methods of flow control, namely downstream damper control, inlet-vane control and variable speed. The curves are for common backward curved centrifugal fans.

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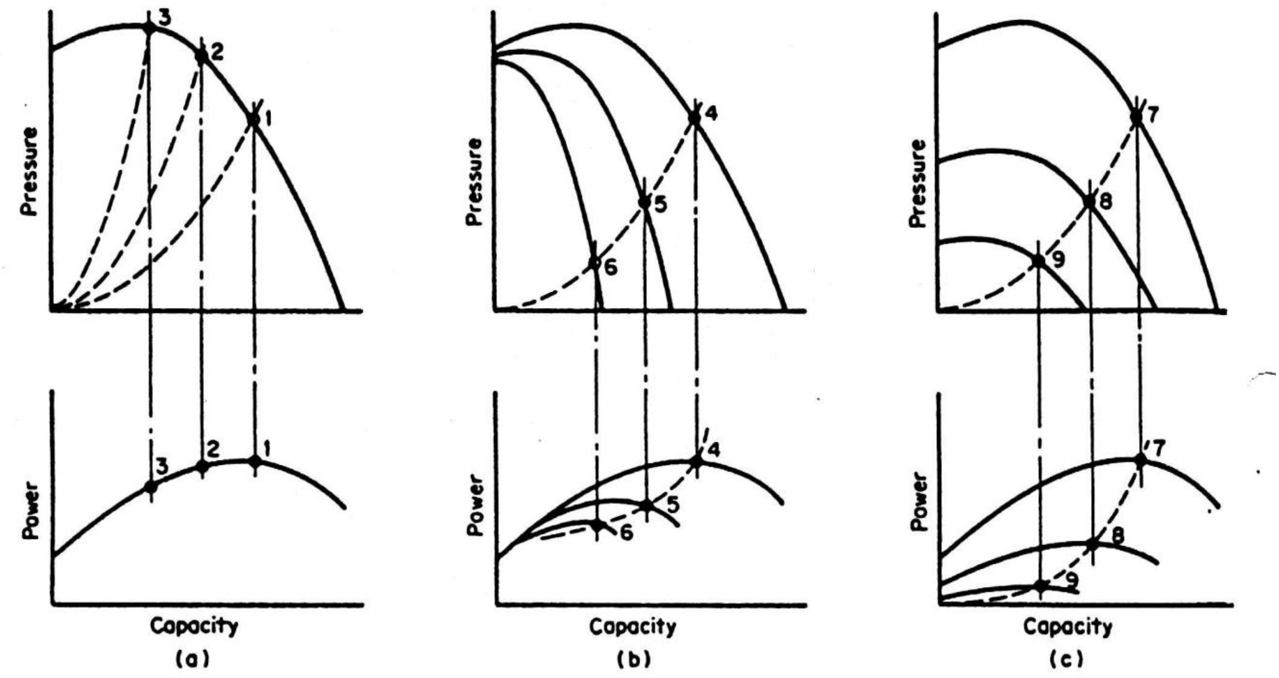

Fan characteristics with (a) damper control, (b) variable-inlet vane control, (c) variable-speed control.

The measurable parameters for a fan are as follows:

- Motor current and hence, an estimate of shaft power.
- Shaft speed.
- Pressure differential – using a manometer or electronic differential pressure device.
- Flow – if flow transducers are fitted.

Note that fans fitted with dampers allow a variety of test conditions and this can help to provide a variety of conditions from which a characteristic curve can be estimated.

There are a variety of ways by which flow may be measured but pitot-tube installations are probably the most common. Note that transit-time ultrasonics can also be used very effectively but the transducers must be installed in the duct looking directly at each other from one side to the other. It is not possible to make reliable measurements *through* the duct wall as for liquids.

Again, it is desirable that that the manufacturers test curves be available for any such test. However, reasonable estimates can be made from on-site tests and using text-book formulas for efficiency.

6. Non-Destructive Testing

1. Non destructive testing can be used for some on-line condition monitoring applications but is more often used in a condition checking role. Many of the techniques are invasive or require a shut down of plant.

There are 5 main groups

- Radiography
- Magnetic Particle Inspections
- Dye Pentrant
- Ultrasonics
- Visual (borescopes etc)

2. Radiography
Used mainly for the examination of welds, castings, forgings etc for manufacturing defects.

- Portable equipment
- Permanent record (film)
- Potential health risk
- Relatively expensive procedure
- Must have two licensed operators

3. Magnetic Particle Inspection
Used mainly to detect surface cracking in ferrous (iron, steel) materials.

- Gear teeth, bolts, shafts, structural steel
- Fast, cheap portable
- Permanent record by photograph
- May need to demagnetise some items

4. Dye Penetrant Procedures
Similar to magnetic particle, but detects cracks in any material.

- Can be used for aluminium, plastic, glass etc
- Very cheap and simple to apply
- Temperatures in the range 15 to 50^{o}C
- Good precleaning required
- Some expertise needed for good results

5. Ultrasonics
a) Used in the detection of sub-surface cracks and defects.

- Requires skill and experience to produce good results
- Accurately defines size and location of defects
- Requires a flat surface above area to be examined
- Difficult to hard copy results

b) Measurement of wall thickness

- Relatively simple and accurate technique

It is in ultrasonics that some major advances have been made in more recent times, many of them arising from the nuclear power industry where there is a need for non-invasive techniques. These have now become available to wider industry, particularly in the field of pressure vessel and pipeline testing.

7. Visual Inspection

To examine parts of machinery or plant that are not accessible for normal visual inspection.

- Fibrescope/borescope; from short rigid borescopes to long flexible fibrescopes
- Closed circuit television; useful for pipeline inspections
- Stroboscope; to “freeze” rotating parts for examination