About inspection frequencies.

We were discussing condition based maintenance programs with our maintenance first line supervisor. We wanted him to start using predictive tools such as portable vibration data terminals to be deployed on a regular basis – as an enhancement to inspection visits his mechanics were making based on their five senses around the plant's pumps and compressors. The response was "no, we do not need any sophisticated tools – we know when a pump is about to fail. Just let us do what we have been doing all along."

Rather than continuing the discussion we decided to invite the representative of a company engaged in vibration monitoring on a contractual basis. When we started to discuss the frequency of potential rounds and data taking we were surprised that the contractor seemed to have no scientific or non-intuitive approach to determining this frequency. He indicated that his survey frequency was going to be around four weeks – this was how everybody else was performing periodic monitoring; this would suffice to catch equipment problems in time. We found this puzzling as it was quite obvious that some problem equipment, sometimes referred to as *bad actors*, would naturally require more frequent visits. The question arose, how do we set inspection frequencies?

It is not uncommon to see plants determine their equipment inspection frequency based on a criticality analysis. At first view, it may seem reasonable to use criticality of the equipment, but the foregoing discussion already indicated that there might be some other criteria that should govern inspection frequencies.

Let us suppose we are setting the inspection frequency for a simple component such as a V-belt. We assume the belt is part of a drive train for a fan associated with a large pipe ventilated induction motor. The inspection method would probably involve the on-line use of a stroboscope which would reveal any wear progress. The motor and the fan are very critical according to the criticality study. Inspection frequency for the highest criticality score is often recommended to be one inspection every shift.

Intuitively, we recognize that it does not make any sense to inspect a belt every shift. Why? Because the inspection frequency must be based on how long, on average, it takes to develop a failure in a component. The belt in our example will not fail from one shift to another unless there is a completely random event. The most likely failure is that the belt will wear over a period of 6 to 8 months. We should therefore, determine the inspection frequency according to the component's time to defect limit or Failure Developing Period (FDP)[1]. After estimating the FDP we will set the inspection frequency to $\frac{FDP}{2}$.

In our example, we estimate an FDP of 8 months and set the inspection interval to 4 months.

Hopefully, the reader will have understood that our example pertained to a fairly time dependent, non-random failure pattern. There are however, many pieces of equipment in our plants that fail in a random mode – just like the pumps and compressors at the beginning of our column. Here we must optimize our predictive maintenance program, and we return to the question of how to determine inspection or checking frequencies in face of randomly occurring defects.

The answer could lie in using the Mean-Time-Between-Failure or MTBF value

[1] See T. Idhammar, *Maintenance management legends, PLANT ENGINEERING,* September 2004, page 31-34.

pertaining to the equipment population in question. MTBF is calculated by dividing the equipment population by the number of failures experienced during a month[2]. In many operating units this number has become a rough yardstick for equipment reliability or sometimes even a key performance indicator (KPI). MTBF is a variable in the reliability function:

$$R = e^{-\frac{t}{MTBF}} \times 100 \qquad (1)$$

where: R = Reliability (%)
e = Base of the natural logarithm
t = Mission time

By calling R the capture rate (CR), i.e. the probability of coming across faults around our equipment covered by periodic inspection programs and knowing our MTBF we are now able to determine the inspection interval, t, when solving equation (1) for t. Thus:

$$t = MTBF \times \ln CR \qquad (2)$$

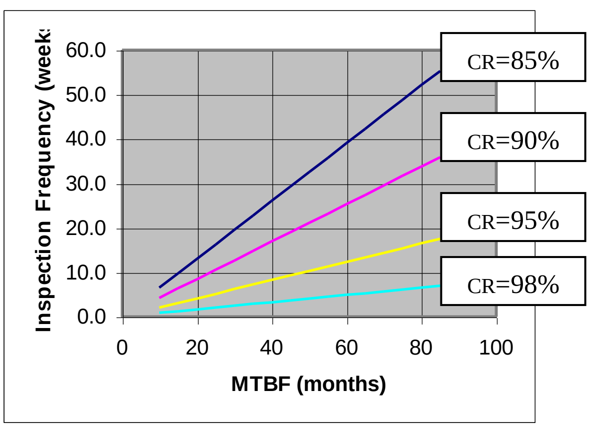

Figure 1. Inspection frequency vs. MTBF

Figure 1 shows inspection intervals as a function of equipment MTBF and various capture rates (CR). It reminds us of the fact that as our equipment's MTBF increases we could also prolong inspection intervals. Here is an example: If our machinery population covered by predictive monitoring techniques had an MTBF of 36 months and we wished to have a capture rate of 95%, our inspection frequency should be 7 weeks. As we might improve the reliability of our machinery to say, an MTBF of 45 months we are prompted to increase our inspection interval to 9 weeks. This also means however that all along there is a probability that we will not be able to capture 5% of the occurring problems; we are going to miss them because we are not there to inspect. This is borne out by the fact that we experience unexpected machinery break-downs in spite of periodic monitoring programs - much to our management's disappointment. Only continuous monitoring will reduce if not eliminate that risk.

[2] **Example:** Population of same size pipeline pumps (P) = 13
Monthly failures (F) = 2

$$MTBF = \frac{P}{F} = \frac{13}{2} = 6.5 \text{ months}$$

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