Run Times
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There are many reasons why a centrifugal pump may suffer premature failure, but the vast majority of issues are related to just a handful of fundamental problems. This issue is the first of a series that will address what I'll call the seven deadly sins of centrifugal pump ownership. In no particular order of importance they are as follows:

1. **Off-design operation**
2. **Misapplied design (i.e. wrong type of pump)**
3. **Cavitation**
4. **Excess nozzle loads**
5. **Poor lubrication**
6. **Misalignment**
7. **Neglect**

Each of these items, either alone or in combination, costs users billions of dollars a year in lost profits. All of them are identifiable and avoidable. Often the product of poor planning or execution (and thus unanticipated), these problems usually surface after construction is complete, making them far more costly to correct than if they had been discovered earlier.

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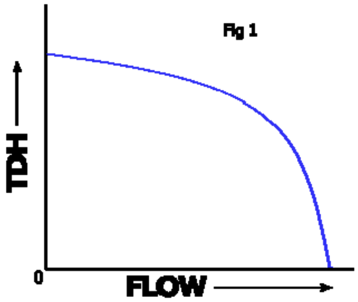
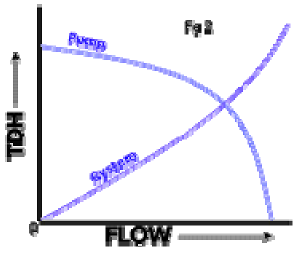
Deadly Sin No. 1: Off-design operation.

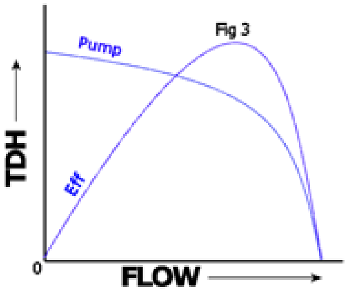
Every centrifugal pump has a performance characteristic that derives from both geometry and operating speed. With speed held constant, any centrifugal pump will produce a range of performance from some amount of total dynamic head (TDH) at zero flow to a point of zero total dynamic head at some maximum flow (Fig 1). Between the zero and maximum flow extents lies a narrower flow range within which a pump will give good reliable performance. Operation outside of this acceptable range may severely shorten pump life.



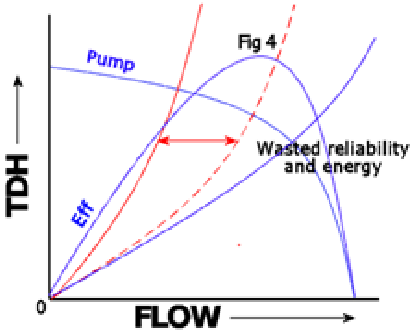


Just as a pump performance can be plotted to show TDH at various flows, a system curve can be plotted to depict the system's resistance to those flows. The resultant curve is called a system curve. A centrifugal pump will *always* operate on its performance curve at the point of system curve intersection. The intersection point is the flow rate where system resistance equals the TDH developed by the pump (Fig 2).

Every centrifugal pump has a point of most efficient operation referred to as the pump's best efficiency point (BEP). When a centrifugal pump operates away from its BEP there is a mismatch between the angle at which flow approaches the impeller inlet vane and the inlet vane angle[1]. The further away from the BEP that a pump operates the more substantial the mismatch becomes between the vane and fluid approach angles. At some point of off-design flow, cavitation may occur, not only at the inlet, but also internal to the fluid passages of the impeller. On diffuser style pumps turbulence can temporarily shutdown flow passages creating what is known as a hydraulic stall. Cavitation and stalling in a pump are severe events that create random side loads on impellers. Additionally, off-design operation can initiate both suction and discharge impeller recirculation that blocks flow, accelerates wear, and can cause additional unbalanced loading. Resultant side forces can be severe enough to cause rubbing of the impeller on the casing, premature seal and bearing failure, and even broken shafts.



Problems often are initiated in the system design and selection process. During system design, engineers calculate the system resistance to flow for all the piping, valves, heat exchangers and other inline components and use that information to specify the pump performance requirements to the pump manufacturer. System design engineers are also likely to add safety factors to their calculations such as consideration for fouling of piping and heat exchangers over time. It is also common to specify a pump that delivers more than is generally required in order to have extra pump capacity available for any upset event. Pump manufacturer's, in turn, tend to select pumps conservatively. Performance test standards apply greater penalty to pumps that deliver insufficient head than those that deliver a little too much TDH, so manufacturers tend to round their TDH calculations upwards. The compendium of these events is a pump and system that may operate further away from BEP than anyone intended.



Not only does off BEP operation result in higher maintenance costs it results in greater electrical cost. A 200 kW pump with a BEP of 80% that is operated at 60% efficiency wastes 50 kW. At 5¢/Kw.hr, that's $20,000 per year in unnecessary power consumption.

As a final note it should be mentioned that the degree to which off-design operation affects reliability is also greatly influenced by the power density levels of the pump. High energy pumps are much more prone to component failure resulting from off-design operation than low energy pumps. As power and speed increase so does the sensitivity to off-design operation. For this reason manufacturers of high energy pumps often severely restrict certain large pumps to very narrow bands of allowable operating range. The manufacturer should always be consulted if there is a question of allowable operating limits. Regardless of the pump's size or power, pumps operating at BEP will last longer and cost less than similarly situated pumps that don't.

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[1] This is true for the vast majority of rotary kinetic pumps; however, there are some specialized exceptions, such as partial emission and pitot tube pumps, where the pump capacities are not driven by blade angles.