A “stable” curve is very important for a pump operation, especially for pumps operating in parallel. The higher the energy level, and the more critical an installation is – the more this could become an issue. API 610 even states that “…pumps that have stable head/capacity curves (continuous rise to shutoff) are preferred for all applications and are required when parallel operation is specified. When parallel operation is specified, the head rise shall be at least 10 percent of the head at rated capacity…”

![Fig. 1 Stable (left) and Unstable (right) H-Q curves](image1)

A centrifugal pump operates at the intersection point of a pump curve and a system curve. A system curve is a parabola starting from zero in case of mainly friction losses (long pipe with restrictions, such as valves, fittings, etc.), or a parallel line in case of mainly static head (pumping up to a vessel). Or, it can also be a combination of both:

![Fig. 2 A pump operates at the intersection of a pump H-Q curve and a system curve...](image2)

If the pump curve is stable, there is always a unique point (“A”) – an intersection of a pump curve and a system curve. If the pump curve is unstable, the region between
“B” and “F” has two possibilities – at either flow Qb, or Qf:

![Diagram showing stable and unstable curves]

Fig. 3 Stable curve (left) has a single definition of an intersection between a pump curve and a system curve. Unstable curve (right) has two flows where a pump can operate, at the same head.

Imagine a parallel operation, with two pumps piped to a common header. Suppose Pump-1 is running and Pump-2 is idle, ready to be brought on-line. Starting of a pump is usually done near the shut-off (valve just slightly cranked open), in order to minimize motor load. If Pump-1 is running in a “funny” region, say at point “C” (where curve is unstable), the system head is Hc, - i.e. higher then the shutoff head Hf, which is what Pump-2 will generate at first, when it starts. Therefore Pump-2 can not open the check valve, which is held closed by the higher pressure Hc – imposed by the already-running Pump-2.

![Diagram showing parallel pumps and unstable region]

Fig. 4 Two pumps in parallel – pump P2 is having trouble starting...

Imagine next that several pumps are already running in parallel. Since they discharge to a common header, their discharge head must be the same. However, each pump may have different flows – either Qc, or Qe. If a plant operator wants to increase the total flow and opens the discharge valve more, Pump-1 will increase its flow, and its head will decrease (Qcc, Hcc). The new system head Hcc will now “push” the Pump-2 to lower flow (Qee). Eventually, a “stronger” pump may completely “take out” the weaker pump to near, or at the shut-off head. Operator, only noticing a total increase in flow, would not even know of this happening, - while the Pump-2 “unexplainably” begins to vibrate, shake, and possibly fail:
Fig. 5 Pump P1 is forcing pump P2 out... Not a nice thing...

An excellent source of reference on this, with a more detailed explanation of unstable curves, is in a book (a "classic"!) by A.F. Stepanoff, "Centrifugal and axial Flow Pumps", John Wiley publication, 2nd Edition, page 293. There, the author also addresses the system conditions that would contribute to, or further aggravate, the situation:

- The mass of water must be free to oscillate, - a typical scenario in boiler feed applications
- There must be a member in the system which can store and give back the pressure energy or act as a spring in a water system. In a boiler feed pump cycle, the elastic steam cushion in the boiler also serves same purpose. Long piping can also do the same.

Stepanoff also provides recommendations:

- By-passing part of the capacity to the suction supply tank.
- Automatic capacity governor near the boiler, with very slight throttling at the pump to stop H-Q swings.
- Braced piping, except for the provision for heat expansion.
- Avoid operation near critical point.

For higher Specific Speed pumps (see separate article on Ns and Nss definitions), such as axial flow pumps, the instability happens at flows substantially closer to BEP, as compared to lower specific speed pumps (such as boiler feed). However, this instability is local, and the curve continues to rise again, after the local region of instability:
As the reader has pointed out, and it is true - that the “best” designs, with regard to efficiency, often end up with unstable curves. Such is the nature of hydraulics! - of the pumping machinery. A better and more practical compromise is not to “push” the efficiency overly high at a single BEP (best efficiency) point, but to have a more “balanced” design, where efficiency may still be good overall, but the curve is stable. This is because, in practice, it is almost impossible to limit a pump operation to a very near region of flow.

All pumps, regardless of their energy level, may experience these difficulties with curve instability. As a practical matter, small pump, however, such as inexpensive commercial units, or even small pumps for chemicals, such as ANSI, usually either do not operate in parallel too often, or, if they do, they can be started at more open valve. Since the energy level is small enough, and the duration is short, as compared to a much more powerful units (such as boiler feed pump, circulating vertical pumps, etc.), there is seldom (but could happen!) a problem with these pumps.

By note to the readers – we welcome any additional comments on the subject. If anyone would like to expand or add on a personal experience regarding curves instability and practical ways of how it was handled – please let us know, so that we can add your contribution in the next edition.

To learn more about this topic, e-mail your comments to DrPump@pump-magazine.com

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