Split Flow™ Technology – Taking Occam's Razor to Refining

a report by

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1. Split Flow™ Pumps; 2. Web Sage

The 14th century philosopher William of Ockham (1285–1349) opined that "Multiplicity ought not to be posited without necessity", which in contemporary lexicon translates as 'everything should be as simple as possible, but not simpler'. Occam's Razor is the inspiration for a unique pump innovation used for petrochemical refining. Split Flow™ simplifies the current practice of selecting multiple or oversize pumps for dual service applications. The Split Flow design incorporates an auxiliary booster impeller with a separate discharge into an American Petroleum Institute (API) Standard overhung centrifugal pump (see *Figure 1*). This allows the pump to split the discharge into two separate streams. The advantages of this design are: use of smaller motors – energy (kW) savings and thus carbon dioxide (CO_2) reduction; use of fewer pumps – capital savings; and better pump-to-system hydraulic fit – longer mean time between repairs (MTBR) for seals and bearings (see *Figure 2*).[1]

A common design issue encountered in the refining process involves pumping a liquid to two dispositions where a smaller secondary stream requires a considerably higher discharge pressure than the primary stream. An example is the overhead liquid on a naphtha splitter where liquid from the overhead receiver is used as reflux and is also pumped to a stabiliser that operates at a higher pressure than the naphtha splitter. Current practice is to either install two pumps, e.g. a high-flow, low-head pump for the reflux service and a separate low-flow, high-head pump for the product/export service, or to install a single pump oversized to pump all of the liquid at the higher discharge pressure and throttle the discharge flow (by control valve) to produce the required lower head for the primary reflux stream. The two-pump system requires that one pump be sized for low-flow, high-head; this frequently poses selection and reliability issues. The single oversized pump system requires a larger pump and motor driver and involves throttling of the primary flow; this wastes energy. Another option employs a low-head primary pump sized for both streams with a separate low-flow booster pump to increase the head of the product stream.

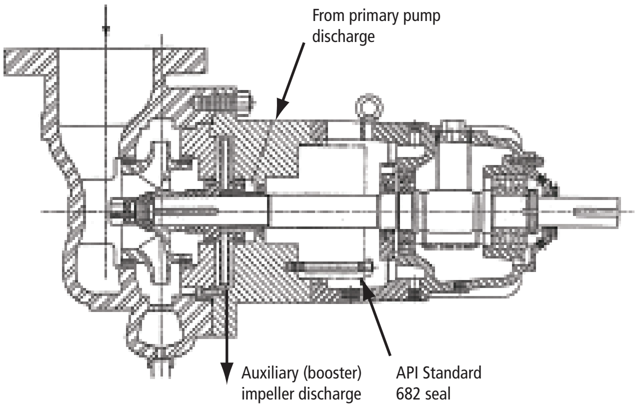
Considering Occam's Razor, it is logical to incorporate the booster pump performance into the primary pump (see *Figure 3*). The single-pump system using Split Flow simply incorporates the booster pump hydraulics into the primary pump, with obvious benefits, including no multiplicity, no throttling with attendant energy waste and optimisation of the pump hydraulic performance for both streams.[2]

Figure 1 illustrates the prototype pump with a top suction orientation option (the primary top discharge is not shown). The pump case, primary impeller and bearing bracket are standard. The shaft and case cover are modified to incorporate the booster impeller. The prototype pumps were designed with external conduits to feed the auxiliary impeller from the primary impeller discharge. In keeping with Ockham's simplicity premise, subsequent designs provide for internal feed from the primary to the booster impeller.[1] To simplify the adaptation of a custom-designed, low-flow booster impeller to API Standard pumps, a drilled-hole disc type design (similar to the 'kicker stage' used with boiler feed pumps) was selected for ease of manufacture, lowest axial space requirements and robust characteristics. The modified pump design has proved its reliability, with minimal maintenance of seals and bearings. Where process conditions require secondary flows exceeding practical limits for drilled-hole disc type impellers, suitable impellers are available from various other API Standard pump types.

The prototype application of Split Flow, manufactured by Flowserve, is currently in use at the Shell refinery in Martinez, California (see *Figure 4*). This application for fractionator reflux service uses a pair of 4x6x10, 60 horsepower pumps that have operated successfully since June 1996. The alternative common-practice oversized design would have used two 4x6x13 pumps with 125 horsepower motors and throttled the excess head at the primary reflux flow outlet. The Split Flow design facilitates conformance with impeller diameter criteria for overhung type pumps; for example, Shell specifies a 13 inch maximum diameter for overhung pumps at 3,600rpm.[1] The use of Split Flow with smaller motors reduced energy consumption at the Martinez refinery prototype installation by 36kW, or 315,360kWh per year. This results in a saving (based on US$0.10/kWh) of approximately US$31,500 per year. Reduction in electricity consumption also reduces CO_2 emissions. The 36kW/315,360kWh annual savings calculates to a reduction of 233–433 tones of CO_2 per year, depending on the type of power generation, e.g. coal, natural gas, etc.[3]

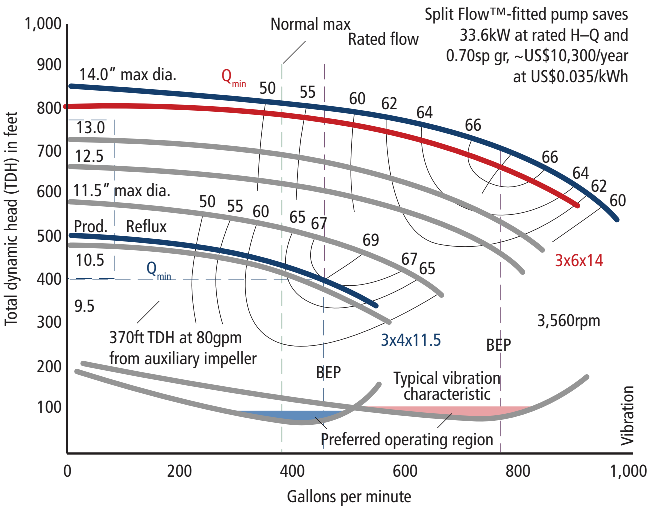
The use of a booster impeller incorporated into a larger primary pump to produce a higher-head, low-flow stream is not new. Its application with high-energy, multistage boiler feed pumps as a 'kicker stage' has been common practice for many years. This design precludes the requirement for a separate low-flow pump with a very high suction pressure, assuredly not conforming with Ockham's axiom. A Split Flow pump (with primary impeller) is sized for the total flow of both the primary and secondary streams at the head required for the primary stream. The auxiliary impeller, which takes suction from the primary impeller discharge, is sized for the secondary flow at the additional head required by the process. Secondary flows will typically range from 0 to 30% of the total flow with heads from 170 to 250% of the primary flow head. The Split Flow feature provides for the auxiliary impeller maximum diameter to equal the primary impeller maximum diameter. The final impeller diameters are selected based on the individual stream requirements. While any low-flow impeller is inherently inefficient, note that approximately

Figure 1: API Standard OH2 Pump with Auxiliary Impeller (Split Flow™)



Source: Centrifugal Process Pump with Booster Impeller, United States Patent No. 5,599,164, 4 February 1997. Available at: www.uspto.gov/web/offices/com/sol/og/index.html

Figure 2: Debutaniser Reflux/Product Pumps

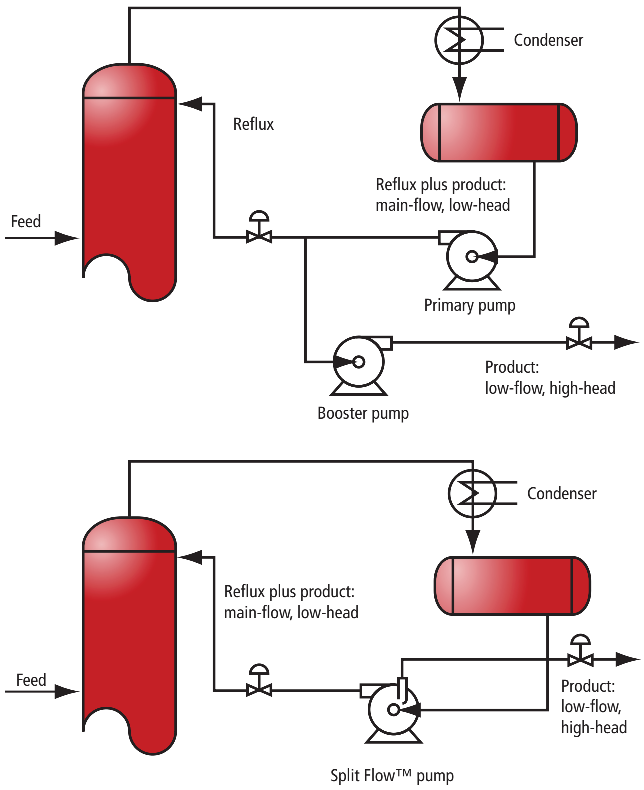


Source: Smith FL, Split Flow™ Process Pumps Save Energy, Application for DOE NICE3 Program, January 2002. Available at: splitflowpumps.com/about/nice3.htm

half of the total dynamic head (TDH) required by the secondary stream is produced by the more efficient primary impeller. The Split Flow feature uses less horsepower than a separate small, low-efficiency pump. The Split Flow feature is applicable for both API Standard horizontal (OH2) or vertical in-line (OH3) overhung pumps.

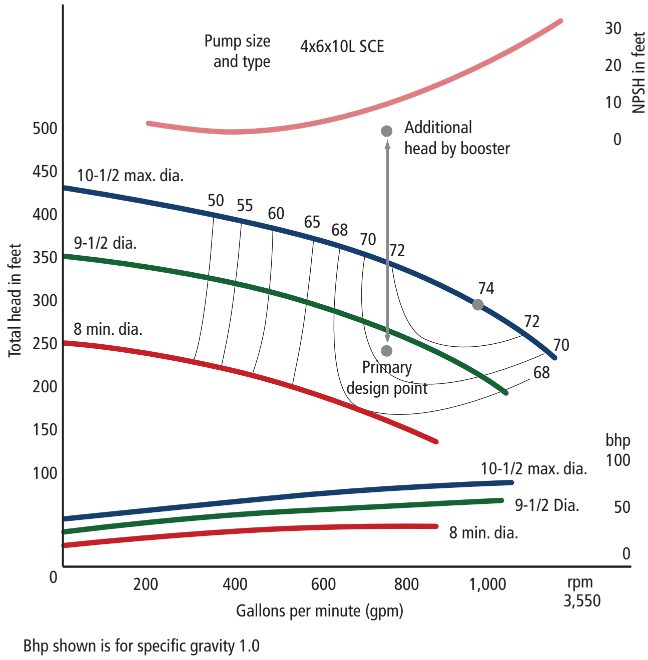
It is important to recognise the API does not categorise pumps modified with the Split Flow feature as two-stage overhung types. The API proscribes use of two-stage overhung designs based upon their marginal MTBR histories. *Figure 4* notes a 13-year satisfactory operating history for the Split Flow prototype pumps. The API Standard 610 Foreword, for many editions, notes the following: "Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy-conserving approaches should be aggressively pursued by the manufacturer and the user. Alternative approaches that may result in improved energy utilization should be thoroughly investigated and brought forth."[4]

Figure 3: Conventional versus Split Flow™ Pump Systems



Source: splitflowpumps.com

Figure 4: Prototype Pump Performance Curves



Source: Murray WE, API Process Pump Innovation Results in Significant Cost Savings, Pumps and Systems, July 1998. Available at: splitflowpumps.com/pdf/psm_7-98.pdf

Alternative approaches to pump selection illustrating some miscellaneous applications and energy-saving benefits from the use of Split Flow are detailed on performance curves that illustrate how one Split Flow pump replaces two conventional pumps (see *Figure 5*),

Figure 5: Caustic Solution Feed Pumps

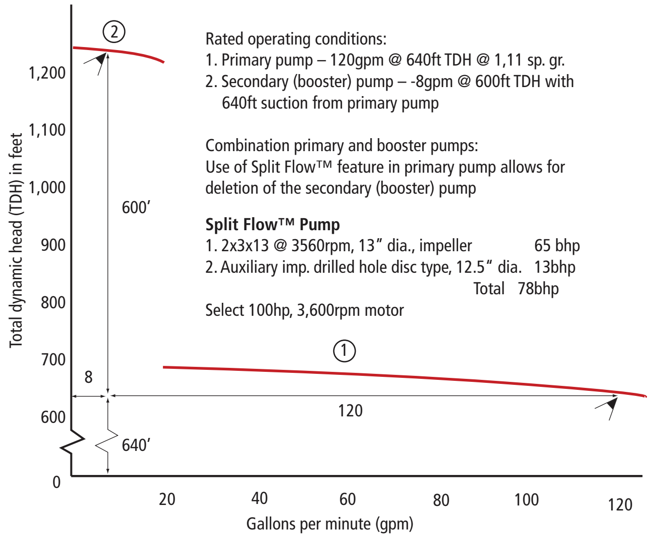
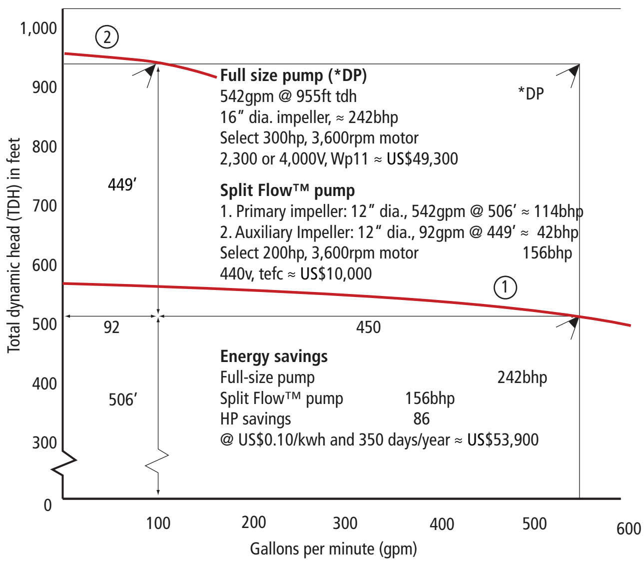


Figure 6: Desalter Water Feed Pumps



Source: Kane L, Pump innovation reduces motor size, H P Innovations, Hydrocarbon Processing, January 1998. Available at: plitflowpumps.com/articles/hcp.htm

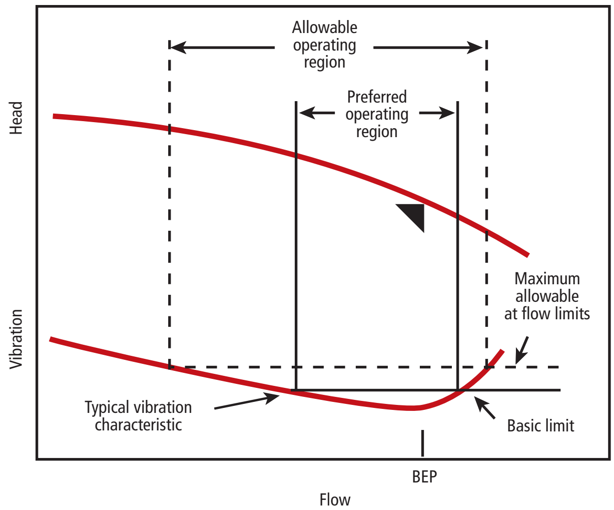
show that Split Flow can provide a viable option to using high-speed, integral-gear-type pumps for low-flow, high-head applications and illustrate how the Split Flow feature is used (see *Figure 6*): it lowers brake horsepower for the process by avoiding an oversized (full size) pump requiring discharge throttling – significant annual kWh savings; reduces motor size and also provides cost savings from medium to low voltage, i.e. typical process plant motor specs require medium voltage rating for motor sizes above 200 horsepower; allows overhung design – uses 12-inch-diameter impellers; and the full-size pump uses a 16-inch diameter impeller – larger impellers may require selection of a higher-cost, between-bearings design pump.

Juxtaposing pump performance curves (see *Figure 2*) for a representative example application (debutaniser reflux/product service) illustrates advantages of using Split Flow pumps, i.e. a conventional (oversized) selection uses a 3x6x14 pump rated for 450gpm at 770ft TDH and requires a 150 horsepower motor and a Split Flow selection uses a 3x4x11.5 pump rated for 370gpm at 400ft TDH Reflux, plus 80gpm at 770ft TDH Product, and thus requires a 75 horsepower motor.[5]

This example (see *Figure 2*) shows that use of the Split Flow pump, with smaller-diameter impellers, facilitates pump selection closer to best-efficiency point (BEP). Use of the smaller pump effectively extends the MTBR for shaft seals and bearings. The MTBR is a function of rotor vibration, which in turn is a function of operating flow with respect to BEP flow. The relationship between flow and vibration is juxtaposed as 'typical vibration characteristic', based on API standard 610, Par. 2.8.3, Figure 2-7 (see *Figure 7*). The use of smaller-diameter impellers also allows for a lower safe minimum flow (Q_{min}). This is an important benefit since normal operating and maximum flows are always less than rated flows.[5]

In summary, the use of Split Flow for applications requiring pumping the same liquid to different pressures offers the following benefits: lower energy consumption due to optimised system efficiency results in kW savings and lower carbon emissions; lower CAPEX from either number or size of installed pumps and motors; use of smaller-diameter impellers facilitates the selection of conservative overhung-type pumps; and longer MTBR resulting from developing the higher pressures in the Split Flow pump, with both impellers operating closer to their BEP.

Figure 7: Relationship Between Flow and Vibration



API Standard 610, Eighth Edition, Aug, 1996.

New developments frequently occur in areas important to process plant design. Engineers in every discipline need to be alert for opportunities to save capital and reduce operating costs. We must prevent our habits from blinding us to new ways of improving our plants. The Split Flow option is a new way of reducing operating and capital costs. n

1. Murray WE, Wilkinson V, Available at: splitflowpumps.com/pdf/caseStudy1.pdf
2. Sloley AW, Murray WE, Available at: splitflowpumps.com/about/option.htm
3. Murray BT, Sweeney J, Available at: splitflowpumps.com/about/co2.htm
4. API Standard 610, American Petroleum Institute, Washington, DC.
5. Bloch HP, Available at: splitflowpumps.com/pdf/hcp-0202.pdf and addendum: splitflowpumps.com/pdf/hcp-add.jpg