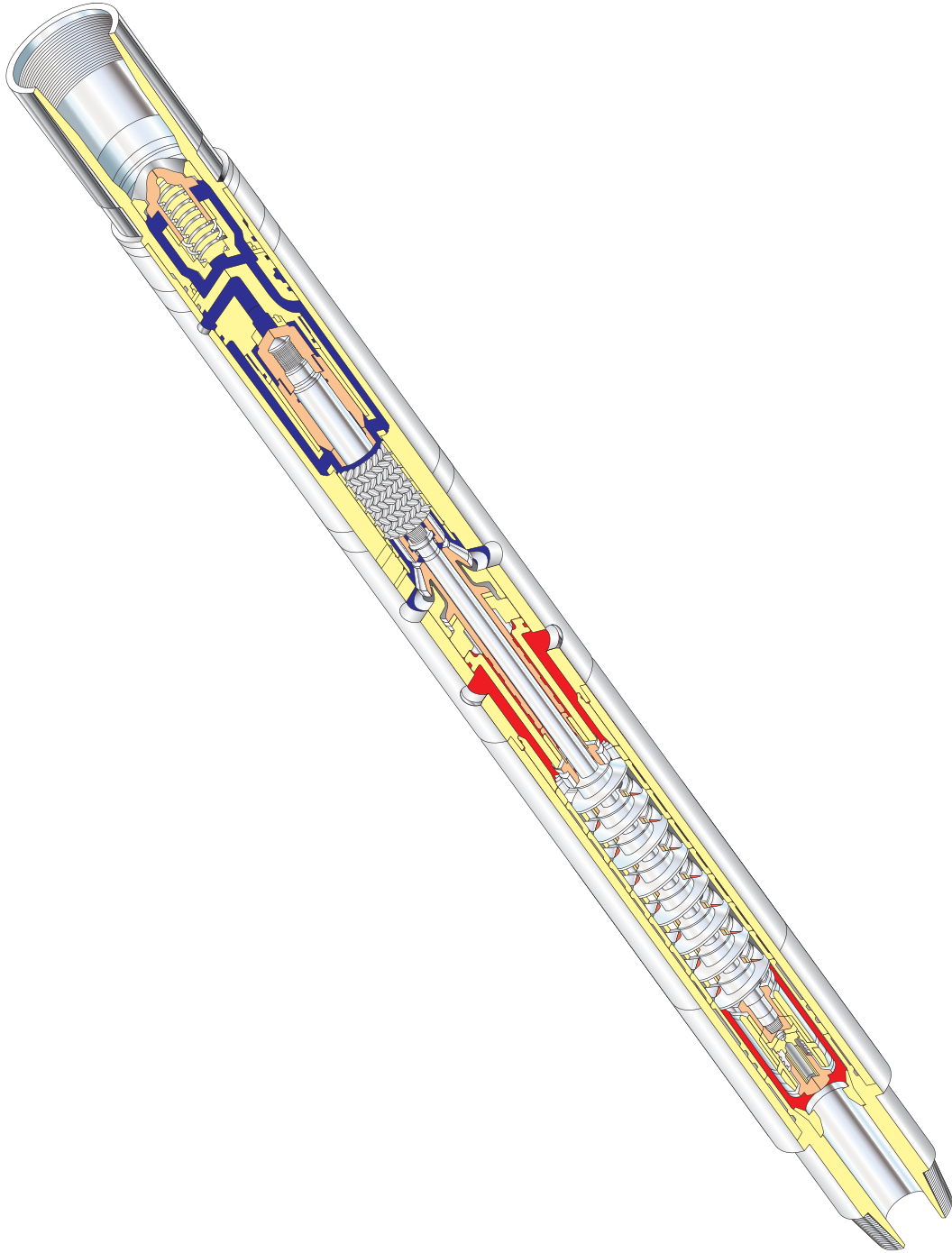




**HYDRAULIC SUBMERSIBLE PUMP (HSP) SYSTEM**



# Introduction

Hydraulic Turbine Driven Submersible Pumps (HSPs) offer a simple and robust solution for well or seabed boosting. The HSP was specifically designed to provide maximum reliability and flexibility under varying operating duty conditions in challenging well environments.

**HSP technology has a proven track record in:**

- » Variable duty conditions
- » High GOR wells
- » High viscosity, heavy oils

**The HSP can be utilised in a variety of applications including:**

- » Oil well production, both offshore and onshore
- » Multiphase downhole and subsea boosting
- » Aquifer lift
- » Combined production and injection duties in a single well bore
- » Pressurised flooding from aquifer to injection zone

## Duty Range

**Produced Flow Rate**

- » Up to 85,000bpd

**Turbine Power**

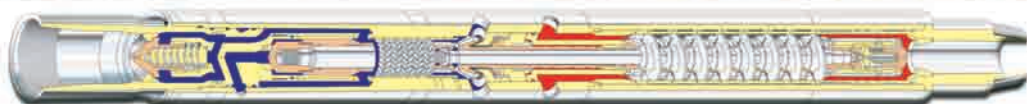
- » Up to 1,340HP (1MW)

**Operating Speeds**

- » 3,000 to 10,000rpm

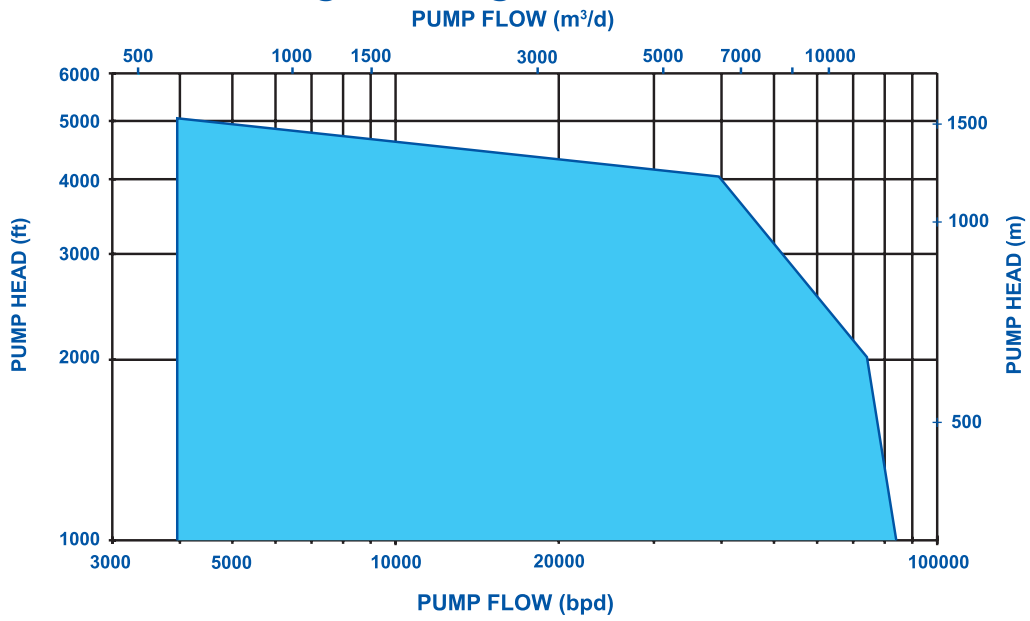
**Fluid Temperatures**

- » Up to 425°F (218°C) in standard configuration



# HYDRAULIC SUBMERSIBLE PUMP (HSP) SYSTEM

## HSP Range Coverage - Standard frames



# Features

## Maximum Reliability

The simplicity and robustness of the HSP and its system facilitates its performance to design specification and under upset conditions for the maximum operational life

- » Multistage hydraulic turbine drive - robust, flexible drive end requiring only high pressure fluid delivered from a surface pump
- » Hydrostatic radial and axial bearing system fed from clean turbine drive fluid - maximises bearing life when pumping fluids containing solids or when product lubrication is marginal due to high gas content
- » No downhole power electrics - eliminates all potential problems associated with cabling, sealing, penetrators and electrical insulation
- » Single shaft machine - no couplings between pump and turbine, enabling shop testing and deployment of an integrated unit, avoiding hook-up problems at the well site
- » No mechanical seals or pressurised barrier between pump and drive - eliminates potential for seal failures
- » Advanced materials technology employed throughout - manufactured in high grade abrasion, erosion and corrosion resistant materials for maximum longevity in aggressive fluid environment
- » Insensitive to setting angle - can be installed and operated in wells at any orientation from vertical to horizontal

## Maximum Flexibility

The unrivalled dynamic range of the HSP enables it to cover the widest possible range of duty points to contend with reservoir uncertainty and through-life well productivity changes

- » Pumps can operate from zero flow to run out conditions - provides the widest possible duty range of any centrifugal well pump
- » Operating speed controlled through regulation of power fluid - using conventional choke technology and / or variable speed power fluid supply pumps
- » High gas handling capability - innovative gas handling pump stage design, combined with automatic speed variation, to prevent gas locking and need for shut-ins for re-prime
- » Nominally constant drive power, low inertia pumpset - capable of continually ranging in speed for better load following

- » Inherent, self-adjusting, thrust balance system - maximises the operating envelope and obviates failures through poor operator practices
- » Insensitive to pump setting depth - no closed volumes sensitive to variation in hydrostatic pressures



## Maximum Operability

The HSP has demonstrated its capability for maintaining functionality and uptime to maximise revenues

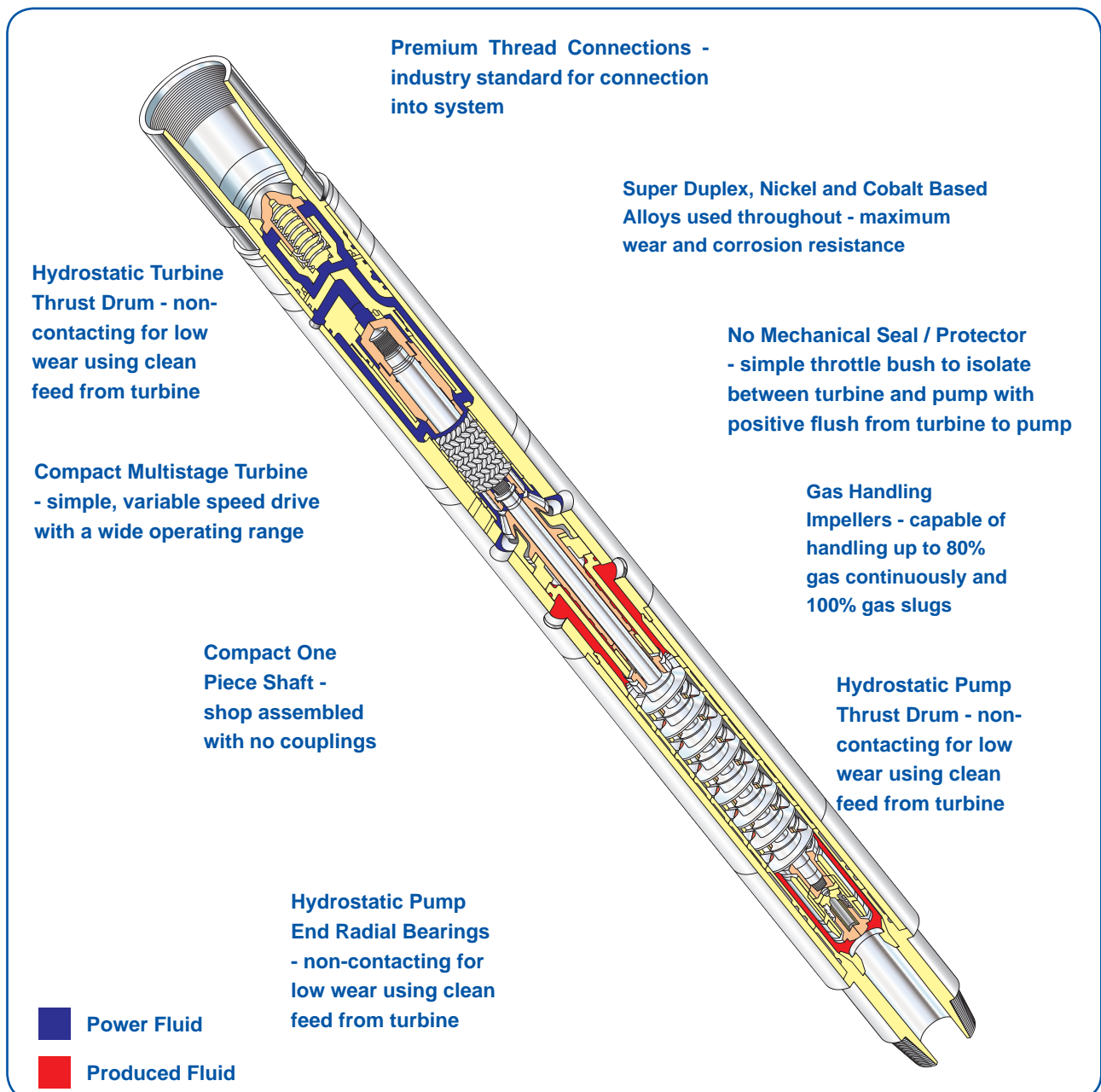
- » Widest possible flow band - each HSP is capable of being operated from 0% to 130% of design flow
- » True “gas handling” multiphase stage designs utilised throughout on all pumps - prevents gas locking and maintains forward pumping to free gas void fractions in excess of 80% at pump inlet
- » Simple speed control to meet target well delivery rates - easily achieved through control of power fluid supply at surface
- » Robust HSP stable to turbine runaway speeds - insensitive to poor operating practices
- » No limitations on start / stop frequency - HSP is insensitive to cyclic operations caused by plant or operator failings
- » System facilitates chemical treatment of the well and flow path - chemical dosing for fluid and flow path conditioning via power fluid system
- » System flushing - well tubing and flow lines downstream of the HSP can be flushed through with power water to purge hydrocarbons or warm through
- » Flow assurance - ability to manage produced fluids to be in a water continuous, (low viscosity), condition downstream of the HSP

# HYDRAULIC SUBMERSIBLE PUMP (HSP) SYSTEM

## Minimum Installation Time

The HSP is quickly and reliably deployed, even on subsea well systems where it has a proven 100% right first time record, minimising time and costs over the hole

- » A “plug and play” machine - the HSP integrated pump and turbine unit requires no shaft make up at rig site as it is supplied fully shop tested as an assembly
- » Simple power supply - using conventional tubing / pipeline technology
- » Short pumpset assembly - typically less than 25% of the length of an ESP system, significantly reduces potential for damage during handling and installation
- » Several deployment options - HSPs can be deployed on tubing or for smaller frame sizes on wireline or coil tubing
- » Verification test at deployment - system can be started and tested to prove pump and completion for both dry and wet tree systems



# Principle of Operation

The basic lift system is shown diagrammatically. Several variations on this are available to optimise the set-up for well and facilities constraints.

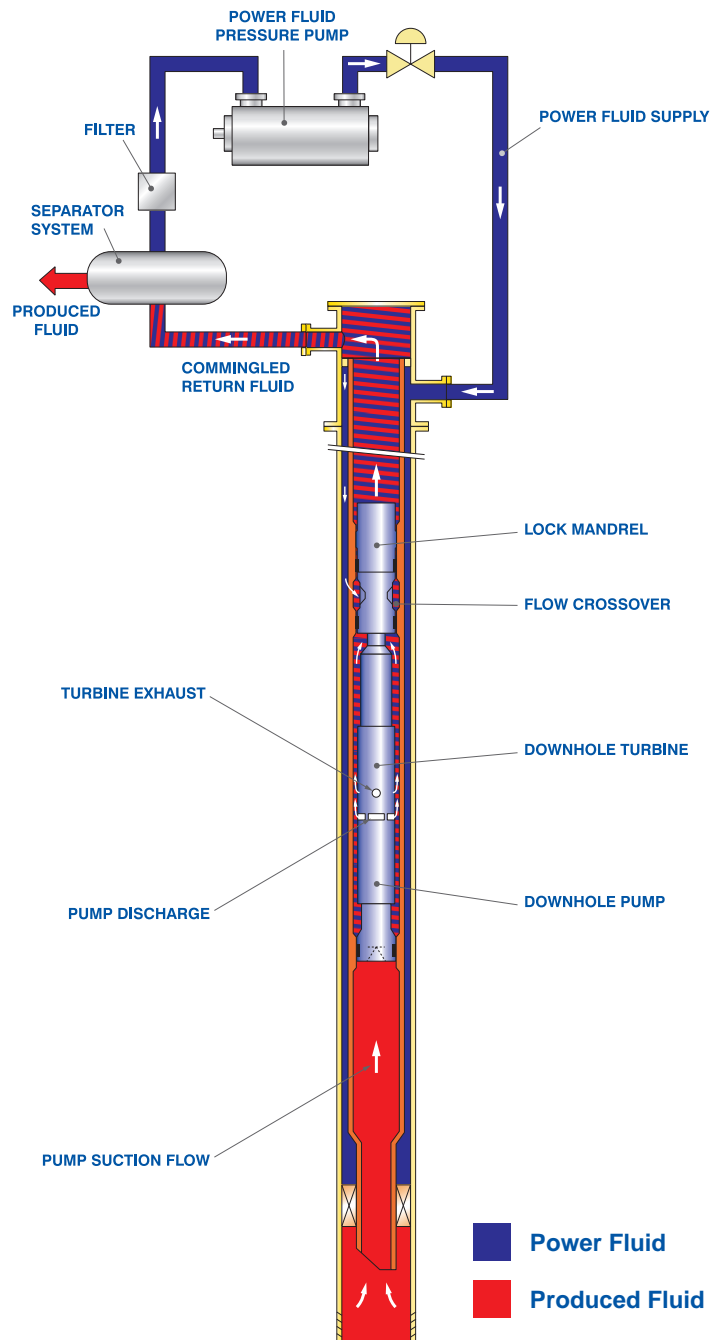
In the application shown power fluid, (water or oil) is boosted in pressure by a suitable power fluid charging pump and passes through a regulating control valve, (providing primary means of regulating the HSP output). The power fluid enters the well tubing - casing annulus at the tree and flows down to the pump setting depth where it enters the turbine through a flow crossover. The energy in the power fluid is converted in the turbine stages to provide the shaft power required to drive the pump end.

The pump end is connected to the pay zone through a suction tail pipe and reservoir fluids pass up through the tail pipe and into the pump stages where they are boosted in pressure before commingling with exhausted turbine power fluid. The commingled fluids flow through the crossover and up into the production tubing to the tree where they exit into the flow lines / riser system.

At surface the commingled fluids enter the production facility separation system where the power fluid is separated from the produced reservoir fluids, cleaned of any significant solids and then supplied to the charge pump to begin the cycle again.

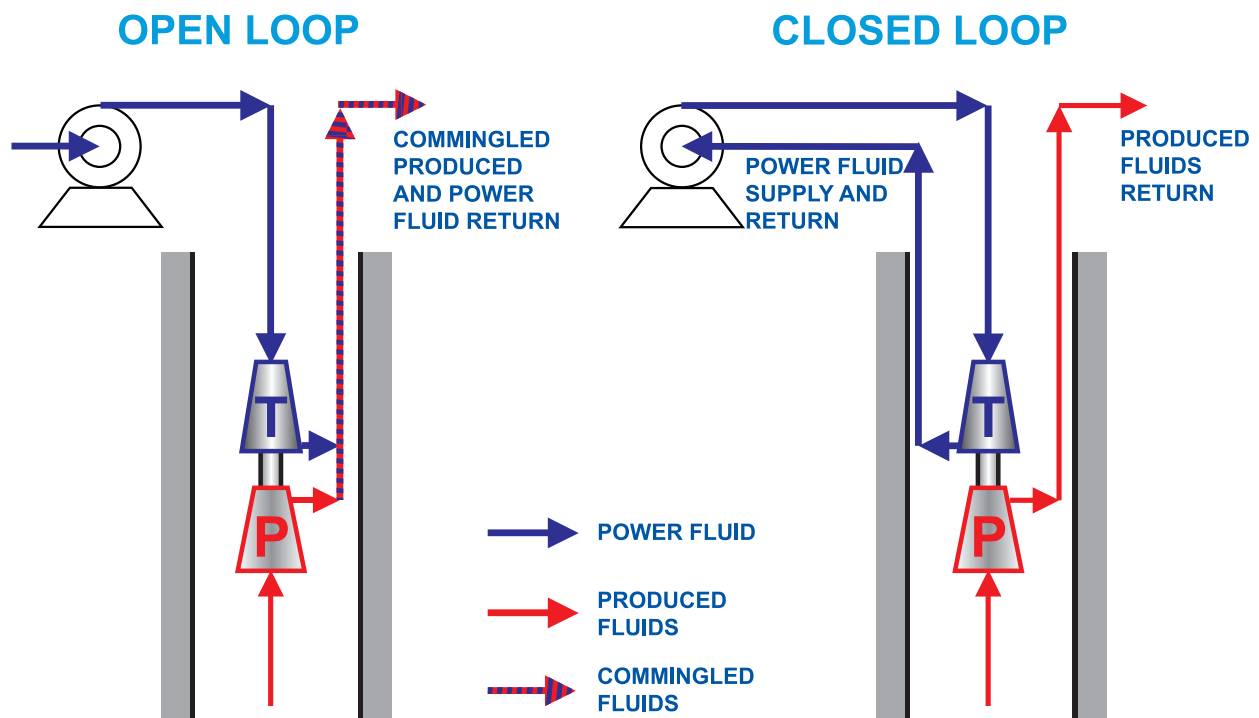


20,000bpd HSP



DOWNHOLE COMPLETION FOR WIRELINE CONVEYED HYDRAULIC DRIVE DOWNHOLE PUMP

## HSP Open and Closed Loop Power Fluid Systems



## Turbine Drive System

The dynamic range of the turbines is complemented by a broad efficiency curve that provides maximum efficiency over a wide duty range. This feature is a major contributor to the flexibility of the HSP in terms of both speed and duty flow rate.

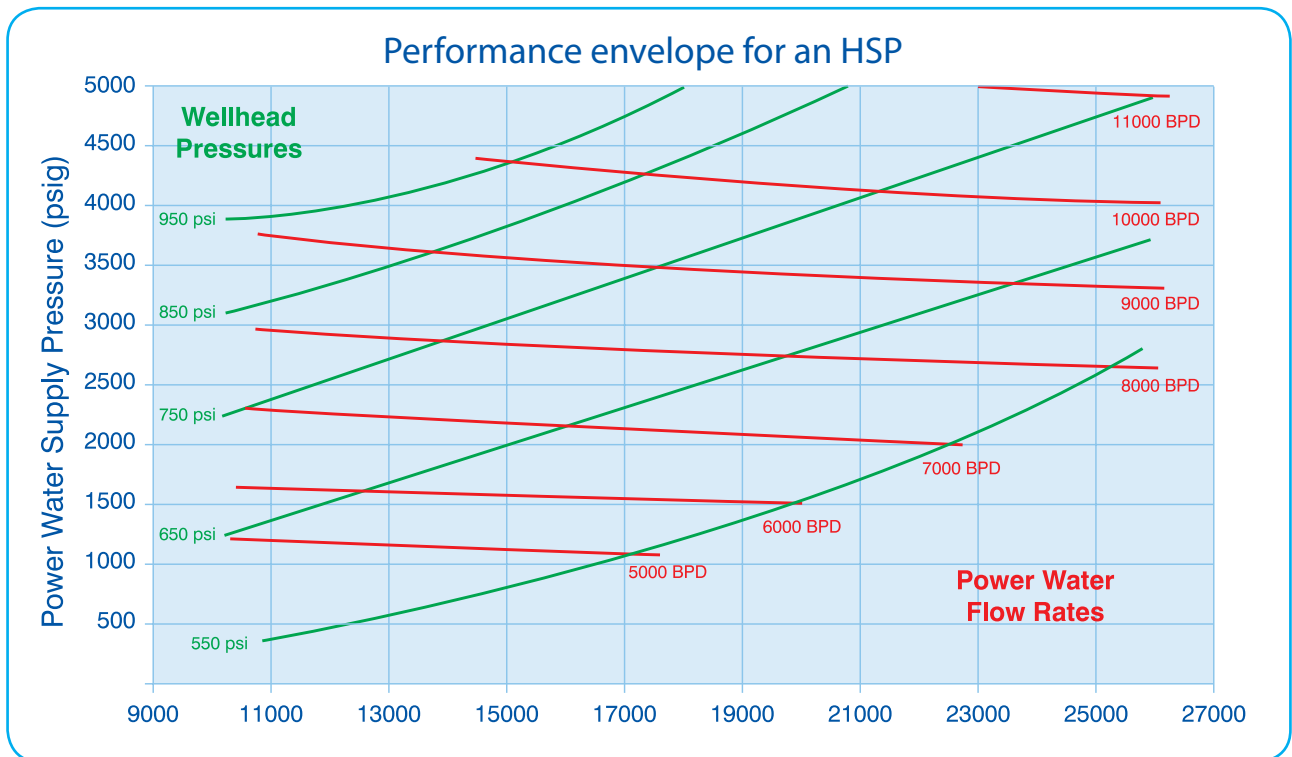
Several standard turbine frame sizes are available to provide optimal matching to the pump end configuration. For any given turbine frame design, the turbine power fluid flow and pressure requirements can be tuned to meet system design requirements through variation of the stage blade height and the number of stages used. The technology is scalable and provides for bespoke designs where required.

By selection of the appropriate turbine design, it is possible to configure the system to have a specific power fluid to produced (reservoir pumped) fluid ratio. Systems can be designed to operate with power fluid to produced fluid ratios of a specified value in a range between 0.5 to 3.0 barrels of power fluid per reservoir barrel produced. In the case of the open loop, commingled systems design, this affords the ability to maintain the produced fluids in a water continuous phase from first production to improve flow assurance of heavy oils and mitigate against emulsions.

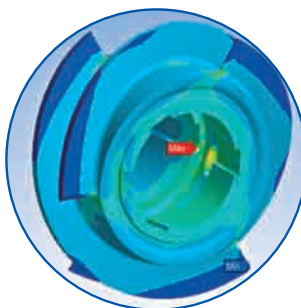


# Pumping Flexibility

Artificial lift systems often require a high degree of flexibility to account for uncertainties in duty definition and changing duty conditions over the life of the well. The HSP has been specifically designed to cover the widest possible range of operating points, utilising the combination of a nominally constant power and yet variable speed turbine drive to provide unrivalled flexibility in operation.



The HSP ranges across its operational envelope through the modulation of power water being supplied to the turbine and through use of the production choke at the tree where fitted. The performance plot above shows how a typical HSP can be made to cover the required operating window (delivered produced reservoir flow for a range of flowing wellhead pressures), through modulation of the power water flow and pressure being supplied to the turbine drive.





# Bearing System

A major factor in the longevity of the HSP is the hydrostatic bearing system, used for both radial and axial shaft support.

## Shaft Radial Support

The HSP utilises a series of hydrostatic bearings to support the shaft radially. A small quantity of clean turbine power fluid is bled off through a centrifuging device incorporated at the turbine - pump interface and is fed to the pump end main bearings.

The benefits of this are -

- » When pumping aggressive fluids containing solids, the bearings are kept clean at all times
- » When the pump is handling high free gas content, the bearings are always supplied with clean liquid and cannot run dry
- » The use of non-contacting fluid film bearings means that their life expectancy is greatly increased over conventional rubbing bearings

## Shaft Thrust Balance

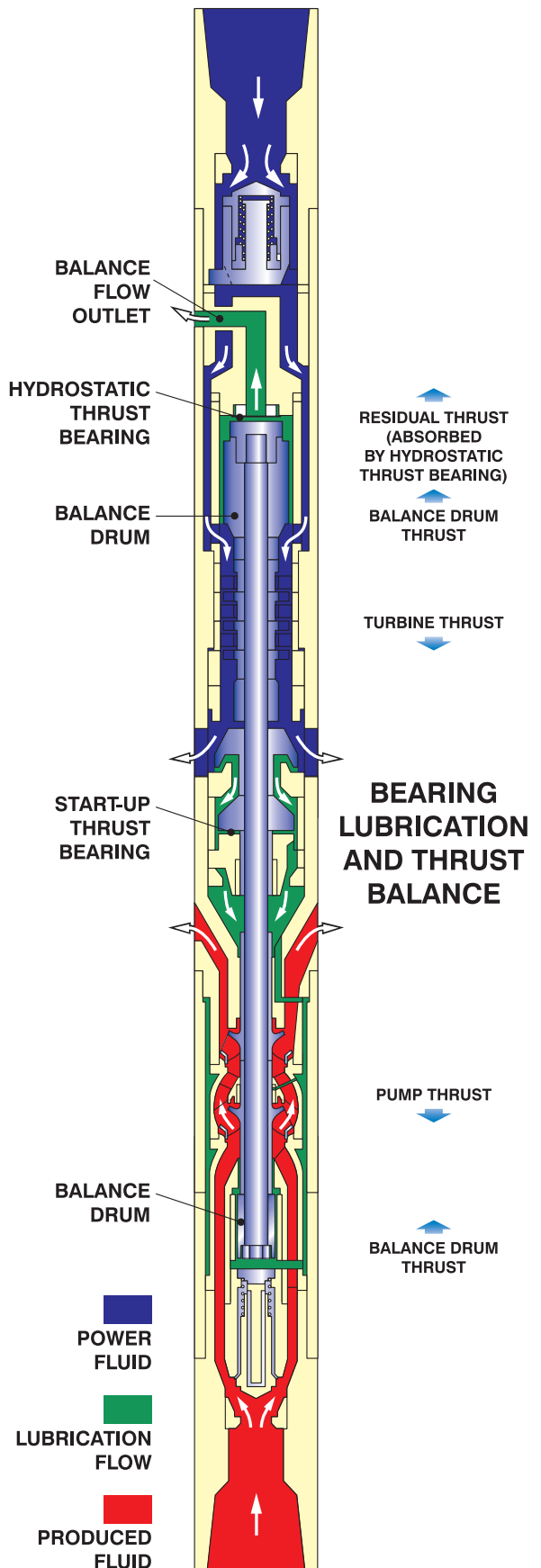
Conventional centrifugal pumps often have a limited thrust window, due to the difficulty of incorporating bearings capable of carrying the high loads at off-design conditions

However, in recognition of the constraints that a limited thrust window imposes on operability and potentially pump working life, the HSP was designed with a hydrostatic thrust balancing system, which is inherently self-regulating. This ensures that, as hydraulic loads vary in relation to one another across the pump and turbine operating window, the shaft is maintained in a stable tensile mode at all times. The advantage of this arrangement is that the HSP can be operated at flows from 0% to 130% of design flow rate. From an operational perspective this ensures the HSP can provide for true soft-starting of wells and that it is unaffected if operated for prolonged periods of time at no or low flows.

## Materials of Construction

All lift systems are exposed to erosion, abrasion and corrosion from the pumped fluids and to counter any threat to long-term performance, the HSP employs advanced materials technology throughout. The suite of materials used has been selected following extensive research and development work on pumps, both in the laboratory and in the field. Materials used include super duplex steels, nickel and cobalt alloys, engineering ceramics and cermet.

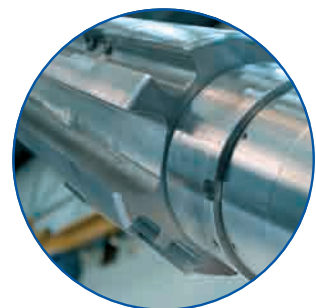
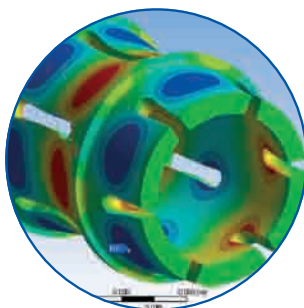
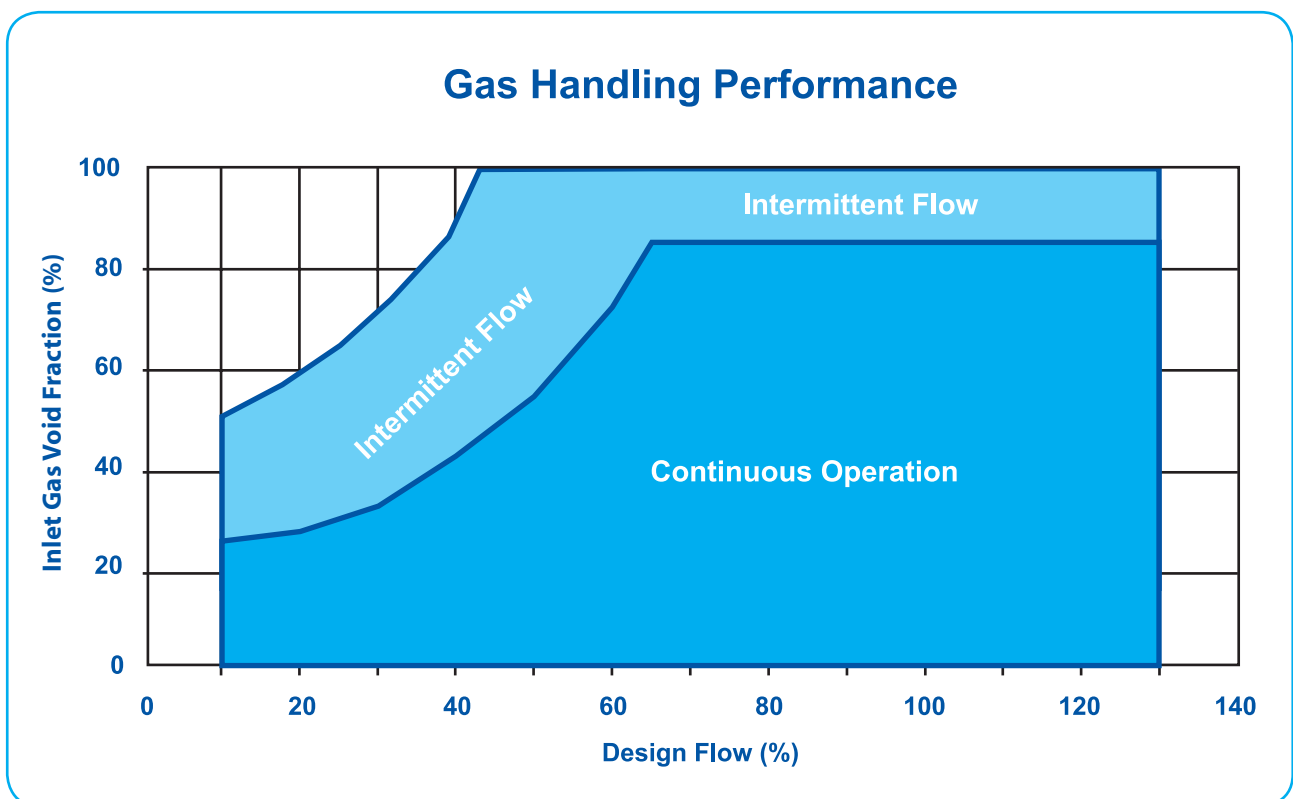
The result is a pumpset that is capable of running for many years in aggressive fluid environments without premature performance degradation.



# Multiphase Pumping Capability

To meet the challenge of sustained downhole pumping when handling reservoir fluids with high free gas content, the HSP was the first downhole pump to utilise special axial flow “gas handling” stages. This innovation eliminates the traditional problem of gas - liquid separation and stage choking caused by formation of gas cores at impeller inlet.

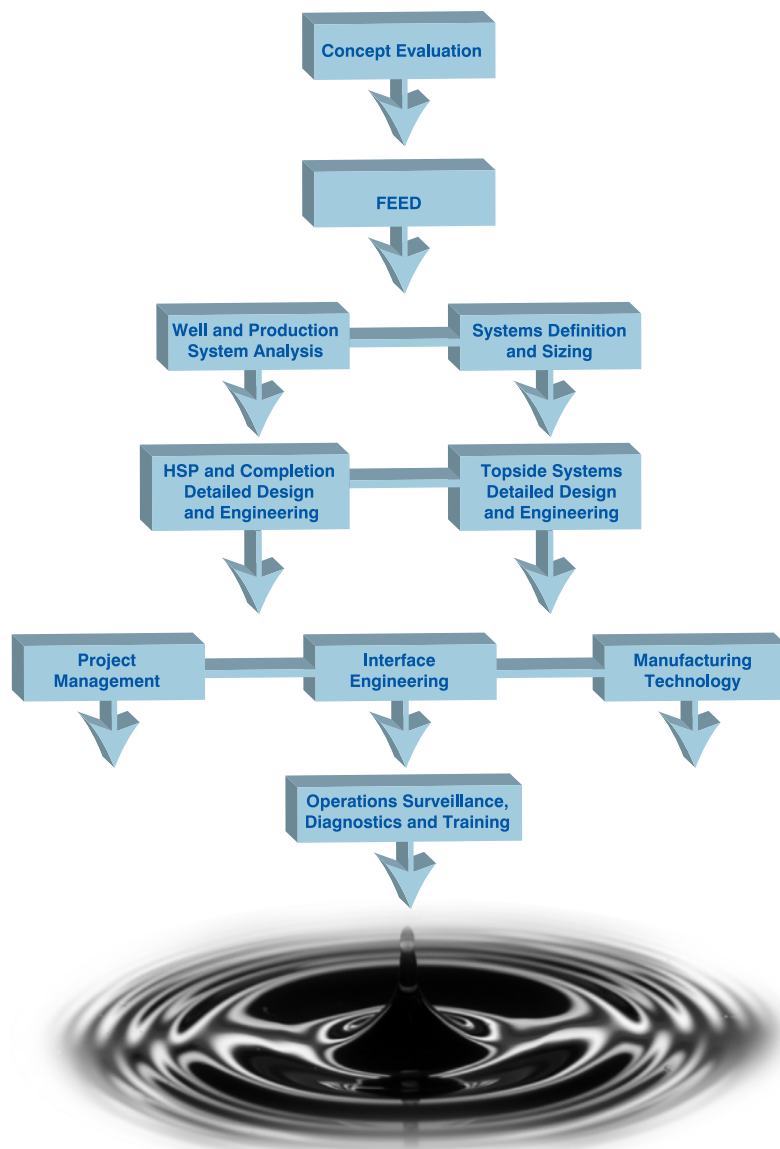
The use of this patented technology in conjunction with the HSPs inherent variable speed turbine drive system, provides for unrivalled gas handling capability. The design has proved so successful that it has been adopted as the standard stage design for current HSPs. This ensures that the pumpset is always ready to handle high gas content, which covers for any uncertainty in reservoir conditions and provides maximum operability.



# HSP Systems Design

The HSP benefits from many years of experience in design of both rotating machinery and the required supporting system equipment for both surface and downhole pump applications. Our policy is to become involved at all stages of the project from initial lift system, concept definition and evaluation, through to surveillance of operations and production optimisation.

Maximum use is made of in-house expertise in the fields of FE Stress and Thermal Analysis and Computational Fluid Dynamics, to fully identify system requirements and provide optimal equipment designs. Modern analytical techniques are utilised by engineers with many years experience in the field of product research and development, equipment design and testing, systems analysis and advanced manufacturing technology. All of these elements are brought together to provide customers with high quality products and services for maximum field productivity.



**Our goal is to provide the client with systems that take care of themselves, with guaranteed levels of performance, allowing operators to focus on production optimisation.**

**Clyde Pumps Ltd**  
incorporating **WEIR PUMPS Glasgow**

149 Newlands Road, Cathcart, Glasgow G44 4EX, Scotland  
Tel: +44 141 637 7141 Fax: +44 141 637 7358  
Email: sales@clydepumps.com Web: www.clydepumps.com



**UK Regional Sales contacts**

**Service and sales coverage:**

Scotland, North East region, North West region, West Midlands, East Midlands, South West, South East.

Tel: + 44 141 637 7141

Fax: + 44 141 637 7358

Email: uk@clydepumps.com

**Clyde Pumps Ltd Worldwide Sales contacts**

**Europe**

Belgium:	Tel: + 32 71 91 94 10	Fax: + 32 71 91 94 30	Email: belgium@clydepump
Estonia:	Tel: + 372 625 9570	Fax: + 372 654 1359	Email: estonia@clydepump
Finland:	Tel: + 358 9 8330 0600	Fax: + 358 9 8330 0609	Email: finland@clydepumps
France:	Tel: + 33 688 0801 31	Fax: + 33 950 6291 02	Email: france@clydepumps
Germany:	Tel: + 49 281 8150	Fax: + 49 281 815 185	Email: germany@clydepum
Norway:	Tel: + 47 67 592 150	Fax: + 47 67 592 169	Email: norway@clydepump
Poland:	Tel: + 48 32 216 84 12	Fax: + 48 32 216 88 18	Email: poland@clydepumps
Russia:	Tel: + 7495 967 3453	Fax: + 7495 785 0636	Email: russia@clydepumps.

**Americas**

Atlanta:	Tel: + 1 770 557 3600	Fax: + 1 770 557 3651	Email: atlanta@clydepumps
Brazil:	Tel: + 55 19 3841 5086	Fax: + 55 19 3841 5086 (ext 224)	Email: brazil@clydepumps.c
Canada:	Tel: + 1 800 267 3068	Fax: + 1 866 599 3765	Email: canada@clydepump
Maryland:	Tel: + 1 410 368 7000	Fax: + 1 410 368 6721	Email: maryland@clydepurr
Oregon:	Tel: + 1 503 641 0545	Fax: + 1 503 643 1303	Email: oregon@clydepumps
Texas:	Tel: + 1 281 446 6765	Fax: + 1 281 446 3952	Email: texas@clydepumps.c

**Asia / Australia**

Australia:	Tel: + 61 2 9757 7400	Fax: + 61 2 9757 7499	Email: australia@clydepumj
Beijing:	Tel: + 86 10 6598 9500	Fax: + 86 10 6598 9595	Email: beijing@clydepumps
India:	Tel: + 91 11 4175 5619	Fax: + 91 11 4175 5622	Email: india@clydepumps.c
Shanghai:	Tel: + 86 21 6160 6969	Fax: + 86 21 6160 6968	Email: shanghai@clydepurr
Singapore:	Tel: + 65 6276 7117	Fax: + 65 6278 7117	Email: singapore@clydepur

**Middle East / Africa**

Abu Dhabi:	Tel: + 97 12 631 1959	Fax: + 97 12 635 1242	Email: abudhabi@clydepurr
South Africa:	Tel: + 27 11 704 0580	Fax: + 27117040597	Email: southafrica@clydepu

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