A new pipeline cleaning technology:

Hydraulically Activated Power Pigging (HAPP™)

By Björn Stoltze, HAPP Technology Ltd.

- Content -

1 Abstract

The need to overcome certain disadvantages of current pigging methods led to the development of the patented **H**ydraulically **A**ctivated **P**ower **P**ig (HAPP™) technology.

A HAPP consists of a brake unit, a seal unit and a cleaning head. The brake unit ensures that a pressure difference develops over the seal unit and the fluid transported in the pipeline is transformed into high-pressure jets cleaning the pipeline inner wall.

This highly efficient technology has great potential to be employed for numerous non-standard pigging jobs. As a consequence it enables pipeline operators to save capex and opex today required for complicated pigging programs.

2 Introduction

Pipelines transporting crude oil or gas condensates frequently suffer from deposition of wax, hydrates or other substances. As a consequence pipeline operators see their operation costs going over-budget as pump capacities need to be increased to compensate negative effects such as

- restricted flow due to reduced inner diameters of pipelines
- increased wall roughness
- increased viscosity of the oil

The phenomena of pipelines becoming less economic subsequent to deposit formation are well known. The oil and gas industry developed strategies to limit deposit formation as well as methods to clean affected pipelines. Most often, a deposit control strategy simply consists of scraping the deposits away from the pipe wall by regular pigging.

In a large number of cases deposit formation is not so severe and regular pigging manages to keep the deposit formation within the pre-set limits. At locations where the oil composition or the surrounding circumstances are unfavourable, substantial amounts of deposits build up at the pipeline inner walls. In extreme cases pipelines may become totally blocked. Cases where tons of removed deposits have been collected in pig traps are reported from all over the world.

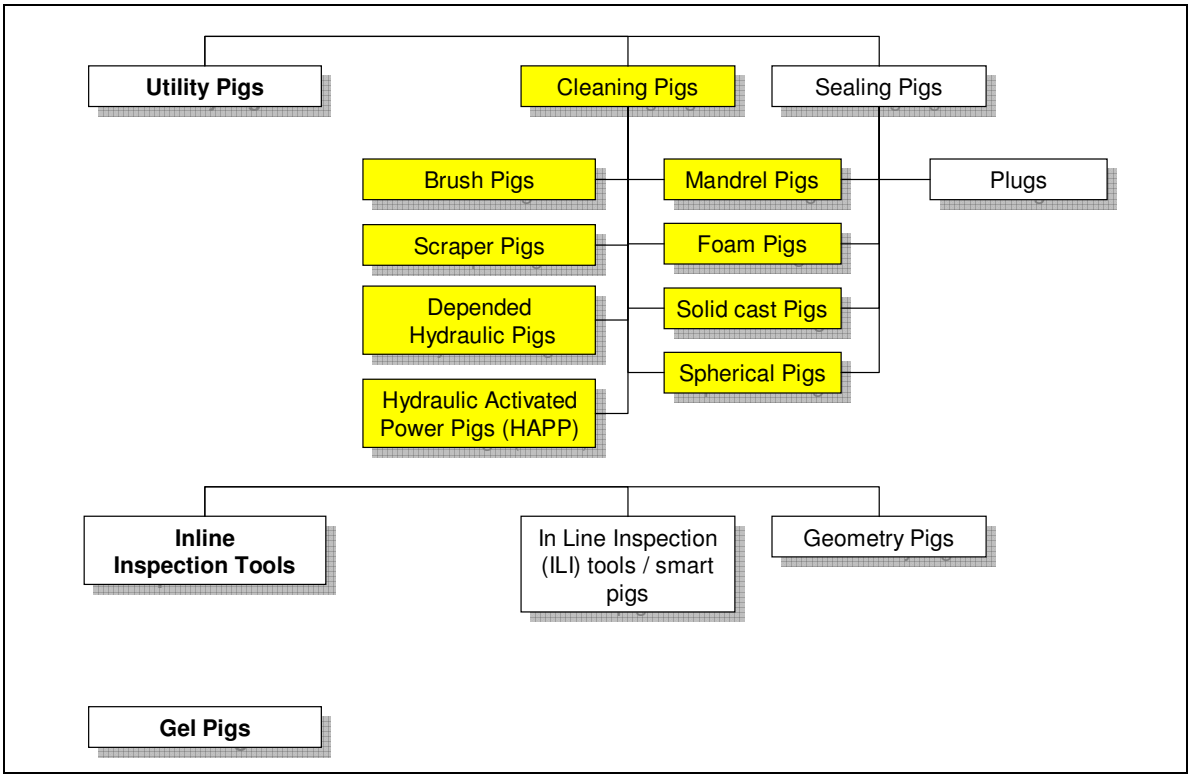
The situation becomes even worse if regular cleaning of an unfavoured pipeline has been neglected. Once deposits accumulate to a larger thickness, the wax contained in it forms high viscose networks with solid-like mechanical properties. Particularly at production shutdowns the oil is allowed to cool down, which favours deposit precipitation. More details about conditions for deposit / wax formation in pipelines are given in the presentation "Pigging of pipelines with high wax content" by Alf Tordal, Statoil at the 2006 PPSA Seminar.

3 Today's typical pigging methods

3.1 General classification of pigs

In order to prevent deposit formation or, if already formed, remove deposits from pipeline inner walls, regular cleaning / pigging programs are performed.
Typically the pipeline operators themselves or service providers run cleaning pigs through the pipelines. To date, a large range of different cleaning pigs for this purpose has been designed. A good overview of the state of the art of pig design is given in the PPSA's book "An introduction to pipeline pigging".

The following picture shows a general classification of pipeline pigs highlighting the cleaning pigs used today for pipeline pigging.



3.2 Characteristics of cleaning pigs

All cleaning pigs are used to remove solid or semi-solid deposits or debris from pipelines. Some of them can also be used for sealing purposes demonstrating that their design has not been optimized for cleaning.

3.2.1 Cleaning force / effectiveness

The common feature of most cleaning pigs is the cleaning force applied. By pushing the pig through the pipeline a mechanical force between the pipe inner wall and the pig itself is established. This force simply scrapes the deposit off the pipeline inner wall.
The pig velocity and the hardness and shape of the cleaning edge determine the cleaning force. The faster the pig, the higher the cleaning impact on the deposits but at the same time only a thin deposit layer is removed.
As a consequence, several pigs using different pig diameters need to be run in order to safely clean away the entire deposit layer. In no case is an active cleaning action applied to remove the deposits.

A very effective method of pipeline cleaning uses high-pressure water jets for removal of extremely hard incrustations in chemical pipelines. This technology uses high-pressure water pumps which feed pressurized water through hoses to a cleaning head. The cleaning head directs the jets onto the pipeline inner wall removing even hardest deposits.

Although very effective, this technology cannot be used for longer pipelines as the length of the supplying hoses with the attached cleaning head is limited. This method is referred to as dependent hydraulic pigging and applies an active cleaning force.

3.2.2 Deposit removal

Typically removed deposits accumulate in front of the pig and become pushed out of the line with the pig moving forward. The longer the pipeline or the thicker the deposit layer on the inner wall the more deposit accumulates. This may form a plug in front of the pig at times resulting in several tons of collected material. In case the pig diameter is not correctly chosen or the pipeline contained a thicker deposit layer than expected, the pig is at risk of becoming blocked by the heavy plug in front of it. As a consequence several pig runs might be required in order to avoid pig blockage.

To reduce the risk of pigs getting stuck, they are more often equipped with by-pass openings. Thus, a certain amount of the liquid transported in the pipeline is allowed to pass through these holes, flushing down-stream the removed deposits.
Before pigging a pipeline with unknown or significant (wax) deposits, appropriate sized cleaning pigs and their number of runs have to be thoroughly determined. The set-up of such a pigging program could take extended time, effort and experience. Additionally several types of pigs may need to be procured.
The choice of a wrong diameter or unsuitable pig can, in the worst case, result in full pipeline blockage.

3.2.3 Pipeline operations

Another very important criterion for a pipeline operator is the potential of maintaining pipeline operation during a pigging job. Any interruption of operations or a decrease of product flow rate needs to be limited to a minimum to avoid economic losses.
Traditional cleaning / pigging jobs do not always allow this. Heavily contaminated pipelines in particular need to adapt operations to the chosen pigging program. There may even be situations that require these pipelines to entirely stop operation in order to conduct the appropriate cleaning procedure. A stuck pig is the worst scenario. Rescue operations and flow remediation in this case are extremely costly.

Summarized it can be said that today's pigging methods still show the following disadvantages:

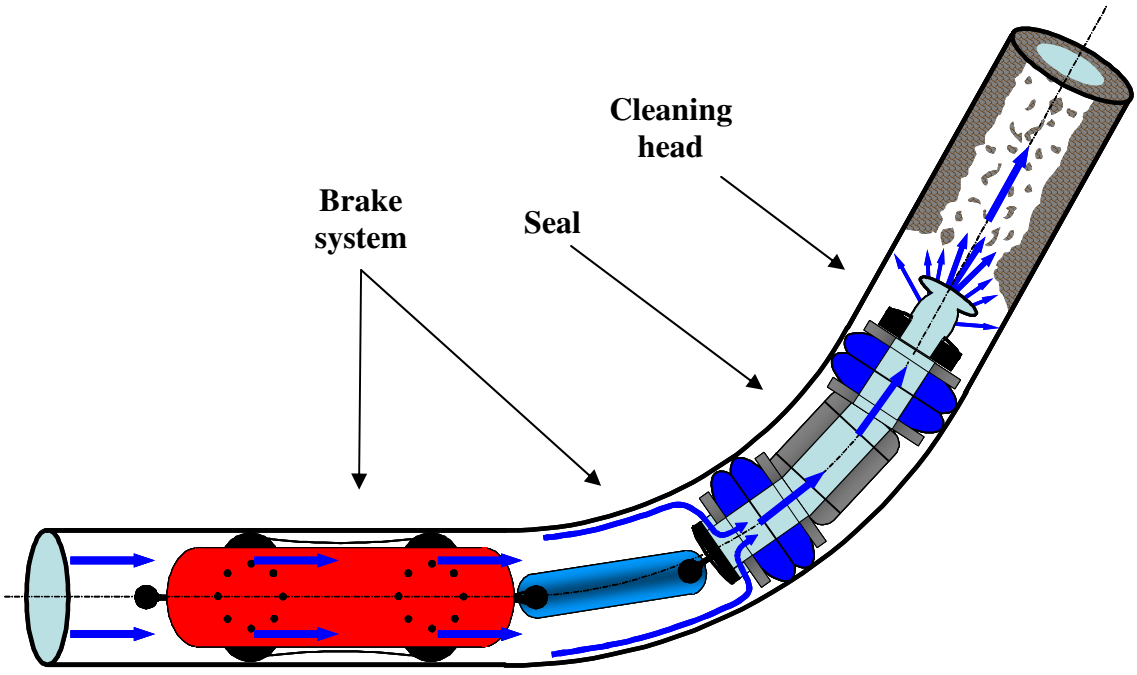
1. The cleaning force applied is not actively created but a result of the scraping effect between the pipeline inner wall and the pig's outer diameter. Neither of these variables is calculable or controllable.
2. The only cleaning technology using an active cleaning force (high pressure water jets) is limited by reach.
3. Deposit removal with common cleaning pigs is done by accumulating the removed deposits in front of the pig and pushing the plug out of the line with the pig itself. Pigs with integrated bypasses allow less plug formation thus reducing the risk of completely blocking the line.
4. In the case of heavily contaminated pipelines operation often needs to be interrupted or at least adapted to the pigging program thus creating additional operational expenditure.

4 The HAPP™ Technology

Considering the weaknesses of current cleaning pigs mentioned above, a new cleaning approach has led to the development of the patented **H**ydraulically **A**ctivated **P**ower **P**ig (HAPP™) technology.

4.1 Construction

A Hydraulic Activated Power Pig consists of three units: a brake unit, a seal unit and the cleaning head as shown below:



All units have openings that allow the entire fluid flow through the pipeline to bypass. The brake unit ensures that the HAPP is held back against the fluid flow in the pipeline. The fluid pushes against the following seal unit, which channels it into the openings of the cleaning head. Seal unit and cleaning head pose a flow restriction resulting in a pressure difference across HAPP. The fluid is accelerated in the cleaning head's nozzles creating extremely

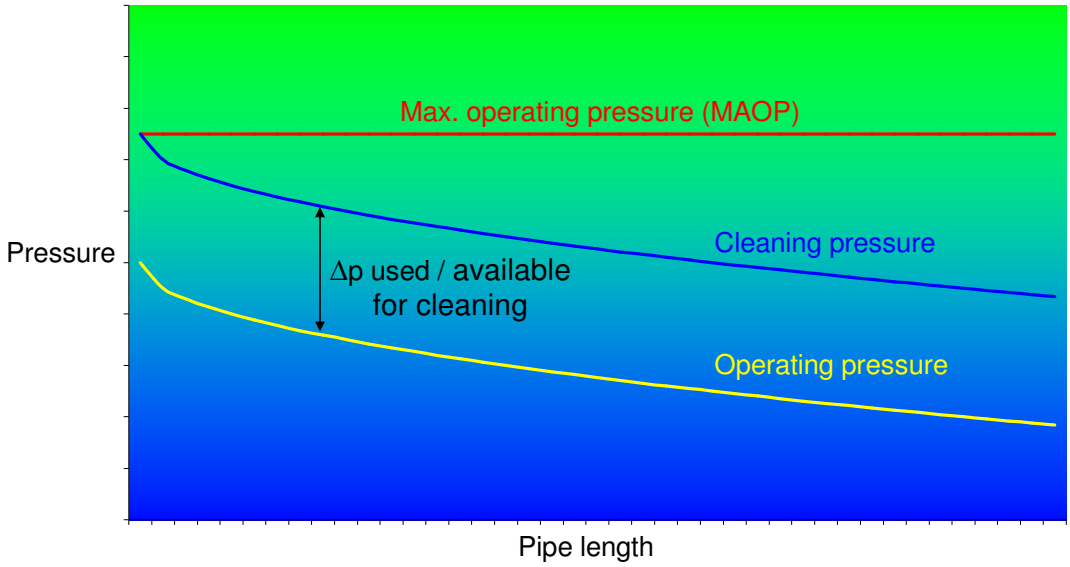
powerful liquid jets. These jets are directed onto the pipe inner wall and remove any kind of deposit.

4.2 How it cleans

Unlike common pipeline cleaning pigs, a HAPP does not touch the pipeline inner wall for cleaning purposes. Cleaning is done with the transported fluid. In addition to completely cleaning the inner wall, the liquid jets also remove deposits out of pits, thus creating ideal conditions for any inline inspection of a pipeline.
Complete removal of any deposit also frees water captured in pits between the deposit and the inner wall. Water trapped by deposits and in contact with the pipeline's inner wall is the main reason for metal loss due to pitting corrosion. A thorough cleaning with a HAPP can stop pitting corrosion.

The pressure difference available for cleaning is adjusted by selecting the appropriate cleaning head. In order to maintain the original operating flow rate of the pipeline only the pumping pressure needs to be increased by the chosen pressure difference required for cleaning. In case the pump is already working at its limit, not allowing for a pressure increase, the chosen pressure difference required for cleaning will reduce the pumping pressure available for fluid transport. In this case and only for the time the pig travels through the pipeline, the product flow rate will be reduced by the equivalent for the pressure difference used for cleaning. The energy balance for HAPP cleaning is illustrated in the following figure.

Energy balance during HAPP™ cleaning



Usually the differential pressure required for cleaning depends on the deposit characteristics. In order to minimize additional power requirements a cleaning head will be chosen that only generates the power necessary to remove a particular deposit. The cleaning power applied is the product of the flow rate through the pig and the pressure difference over the pig.

4.3 The brake unit

The brake unit ensures that the travel speed of a HAPP can be up to 60 times slower than the fluid velocity thus allowing the HAPP to entirely remove deposits from the pipe wall before it travels across the cleaned surface. The travelling speed is always controlled and remains

constant over the entire cleaning run ensuring that the cleaning efficiency remains the same from the beginning to the end of the run.

The slower a HAPP travels the stronger the fluid jets become for cleaning.

4.4 Deposit removal

Once the cleaning head is correctly chosen and the travel speed well adjusted, a HAPP needs only one single cleaning run to completely remove all deposits.

Deposits removed are immediately flushed downstream the pipeline with the permanent fluid flow through the line and the HAPP. The benefit of the immediate evacuation of the loosened material is no risk of a HAPP getting stuck by a plug that has accumulated in front of it.

4.5 Geometrical features

The construction of a HAPP fulfils all requirements necessary to negotiate T-fittings, steps, pipe diameter changes within a certain range, deformed pipe inner diameters, welding lines, elbows etc. A future development will enable a HAPP to adapt to various pipe sizes.

5 Field tests & References

The development of the HAPP technology has been carried out and tested as follows:

Cleaning efficiency:	Tested and verified in paraffin contaminated spool pieces at test loop facilities of SHELL E&P Technology Company, Houston, USA.
Mechanical reliability:	Tested and verified at the test loop facility of Aqua Drill International, Dickinson, Texas, USA.
First pigging job:	Completed successfully a cleaning job at a 7,3 miles onshore crude oil line in Denver City, Texas, USA. [Braheney Line, ID: 6,25", operated by Equilon Pipeline Company]

6 Range of Application

The HAPP technology is notably appropriate for:

- Non-standard and difficult industrial pipeline cleaning / pigging jobs.
- Industrial pipeline cleaning / pigging jobs which need to be carried out while the pipeline is kept in operation.
- Industrial pipeline cleaning / pigging jobs desiring an exceptionally clean pipeline (i.e. a prerequisite for intelligent or smart pigging).
- Cleaning jobs that need to be completed in one single run or a very short time.
- Pipelines already subject to a regular cleaning / pigging program but still requiring a more powerful cleaning run from time to time in order to prevent build-up of hard scale.

7 Conclusion

A HAPP has the unique ability to actively transfer pipeline pumping power into highly concentrated cleaning energy locally available all along the pipeline. The HAPP technology avoids many problems frequently occurring with classic cleaning pigs commonly used today.

In relation to other pipeline cleaning technologies, the HAPP technology can be considered as one of the most effective and elegant technologies available on the market today.