AN INTRODUCTION TO PIPELINE PIGGING

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INTRODUCTION

In the world we live in today, pipelines are used to transport all manner of powders and fluids from one point to another. From the food industry to oil and gas transportation, millions of lives are affected by the ability to maintain flow through pipelines that cross over land and under sea to deliver a product. Coupled with the economic drive to maintain product flow, the importance of this task has spawned a whole industry to ensure pipeline integrity.

THE BEGINNING

Although shrouded in time and poeticism, the beginnings of pipeline pigging are generally accepted to be in the US in the 1870's as pipelines for oil transportation grew to eclipse the horse drawn tanks that were then used to transport the oil from the well site to the refinery. Crude construction methods and a lack of maintenance meant that over time flow became restricted through the lines resulting in higher pumping pressures and decreased overall efficiency. In order to clear the build up of sludges and waxes in the line, it is rumoured that rags were bundled and tied together and run through the line providing immediate improvement of flow at reduced pumping pressures. Over time the rags were replaced with bundles of leather, which gave even better results due to leather's ability to swell in moisture and provide more positive results. Other materials used to clean lines over the years include straw bales wrapped in barbed wire for oil lines, foam ear plugs for hydraulic control lines, and even, so it's said, loafs of bread for delivery lines in a jam factory.

DEFINITIONS

Before we can further discuss the topic of pipeline pigging we must make some definitions;

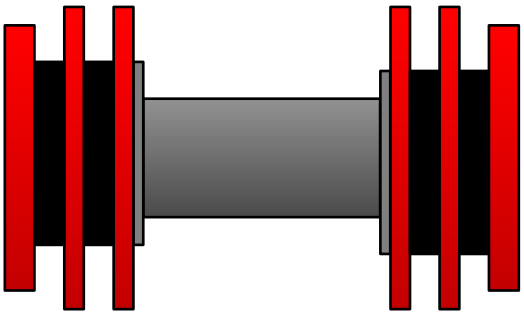
PIG:	A tool propelled through a pipeline to perform a function.
PIG TRAIN:	Several pigs launched in a set order to perform a specific task.
PIG TRAP:	Pressure vessel used for launching and receiving pigs.
UTILITY PIG:	Non-autonomous pig used to carry out simple tasks, e.g. batching, cleaning etc.
INTELLIGENT PIG:	A generic name given to a pig that utilises power to perform a specific task or log specific information. Intelligent Pigs are also referred to as inline inspection tools.
GEL PIG:	Pig created by gelling a given medium.

Note: Intelligent pigs are a specialised area in their own right and will only be mentioned briefly in this paper.

HOW PIGS WORK

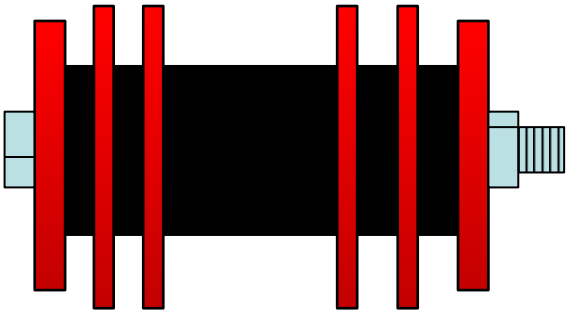
Pigs come in various varieties, the most common being mandrel, single bolt, solid cast, foam, articulated, and spheres.

Mandrel Pigs



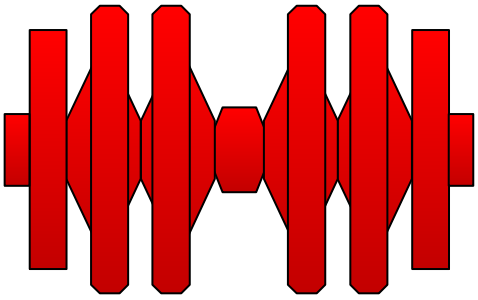
The various elements of the pig are attached, using multiple bolts, to a solid body or mandrel.

Single Bolt Pigs



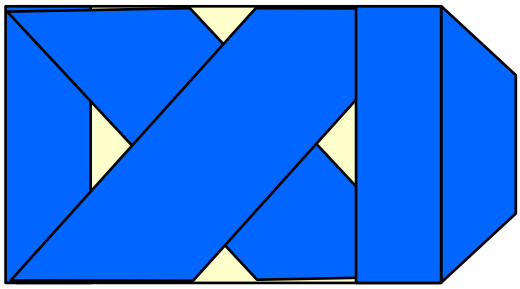
Similar to the mandrel pig, the elements are fitted to a single bolt, rather than a solid body.

Solid Cast Pig



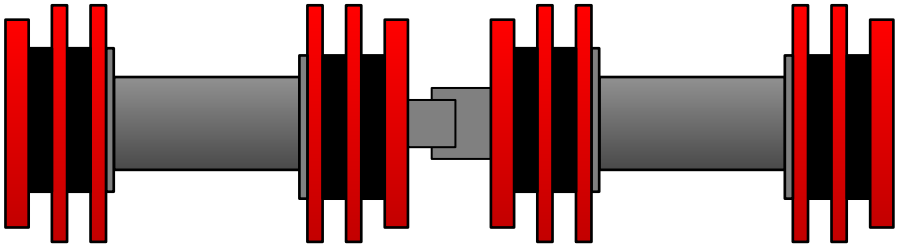
Both sealing and guide elements are cast as a single component in polyurethane.

Foam



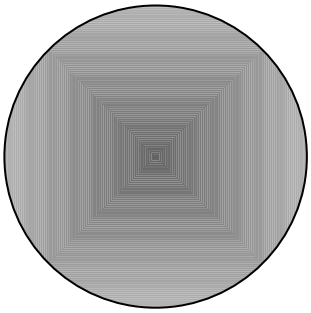
Open cell polyurethane foam is available in light, medium, and heavy density, dependant on the application. Foam pigs can be polyurethane coated to improve wear resistance and stability.

Articulated

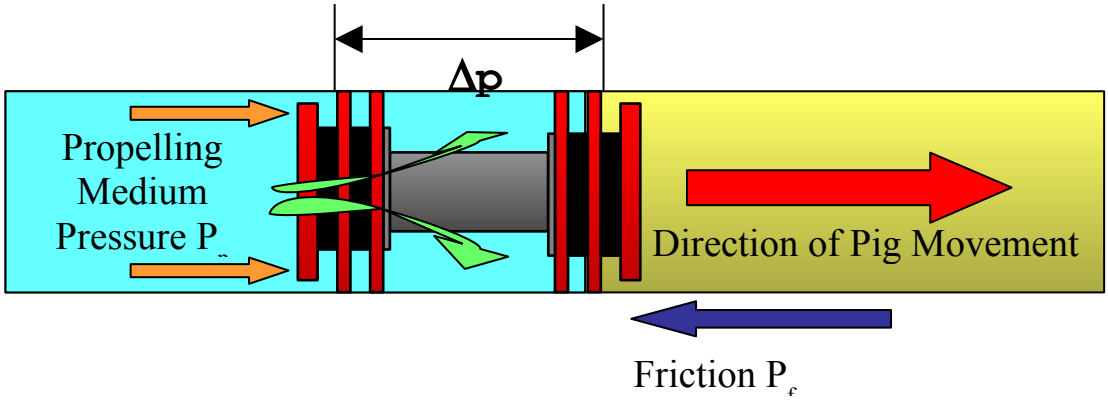


Made up of two or more pigs joined with a universal coupling, articulated pigs form the basis for many intelligent pigs.

Spheres



Spheres can be solid or inflatable with air, water, or glycol and are used for product separation, liquid removal, and in meter proving.



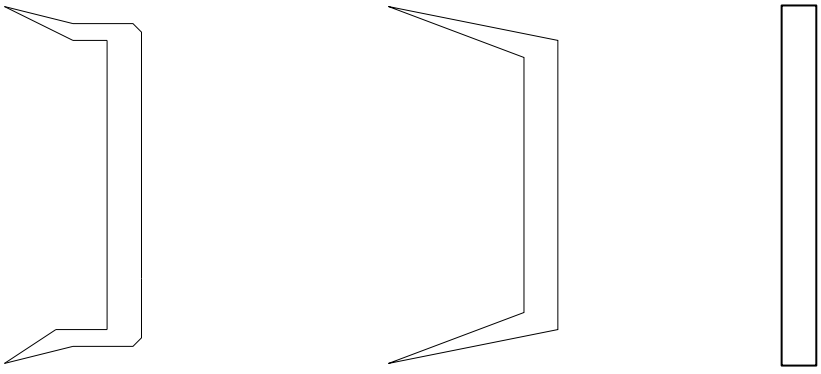
Pigs are designed so that sealing elements provide a positive interference with the pipewall. Once inserted into a line, pigs are driven through the line by applying pressure in the direction of required movement. A pressure differential is created across the pig, resulting in movement in the direction of the pressure drop. In operational lines, this pressure is applied by the line product, whereas, in un-commissioned lines, the propelling medium can be chosen to suit the task being carried out, e.g. water for flooding or dry air or nitrogen gas for dewatering.

Note: Sufficient flow is also required to ensure pig movement at a suitable velocity.

Once the force behind the pig becomes greater than the opposing frictional force, the pig will move in the direction of the applied force (pressure).

The pressure at which the pig begins to move is known as the "break-out" or "stiction" pressure. This tends to be greater than the pressure required to maintain movement and is characterised by a pressure rise followed by a pressure drop to a plateau for the pig launching operation.

Depending on the design of the sealing element, pigs can either be run in a single direction, or run backwards or forwards through a line. Pigs that can only be run in one direction are known as unidirectional pigs, and have polyurethane sealing elements of the cone or cup design. These types of pigs are generally used in established lines known to be piggable.



Cup-Type Seal Cone-Type Seal Bi-Directional Seal

Sealing elements in the bidirectional pigs are flat, providing an identical seal in either direction, and therefore, giving more adaptability in previously unpigged lines.

Additional sealing elements can be added to pigs, leading to better sealing properties along with a higher pressure differential required to drive the pig.

Support for the pig to ensure it remains central in the line can be provided by either support discs, or, for large diameter pigs, centralising wheels.

As a general guide, the following table summarises pig characteristics:

Component	Size
Sealing Disc Diameter	102% to 105% Pipeline ID
Support Disc Diameter	99% Pipeline ID
Pig Assembly Length	1.5 × Pipeline ID

TYPES OF PIGS

Batching Pig: Also known as a swabbing pig, the batching pig is designed to act as a simple barrier between dissimilar fluids or to provide a sweep of a line.

Gauging Pig: The inclusion of a simple gauge plate, made of a soft metal (generally aluminium), on batching pigs provides the function of confirming the integrity of the flow area of the pipe. Any major intrusions into the line will cause damage to the gauge plate, highlighting there is a problem, though not highlighting where.

Cleaning Pig: Pigs can be configured with various tools to aid cleaning. Circular brushes, spring-mounted brushes, scrapers, or plough blades for waxes and sludges, or more aggressive tools such as carbide "pins" for removal of scales.

Magnetic Pig: Inclusion of powerful rare earth magnets on the circumference of the pig mandrel allows the pig not only to lift ferrous debris from the line, but can also provide the secondary function of activating pig signallers.

Note: Foam pigs also allow the addition of gauge plates, brushes, abrasives etc., although these are either fitted into the pig using bolts, or by direct casting into the polyurethane coating.

Intelligent Pigs: Research and development into inline inspection tools began in the late 1960's. Advances in technology have lead to pigs that can carry out complex tasks and data logging as they traverse the line. Mapping, geometry measurement, crack detection, measurement of metal loss, and many other tasks can be carried out. Intelligent pigging is now an industry within an industry.

Gel Pigs: For certain tasks and in certain conditions, a viable alternative to running mechanical pigs is the use of gel pigs. Rather than use a solid barrier between fluids, a gelled substance can perform the same task. Various mediums can be gelled, including water (fresh and salt), glycol, methanol, solvents, diesel, and crude. The gels can be designed specifically to a required viscosity or cast as solid with chemical components designed to break down the gel after a given time or when a set temperature or pH has been reached.

Gels have their limitations and are not generally suitable for long runs, in dry pipelines, or where the propelling medium is gas because they tend to suffer from "gas cutting" or excess bypass.

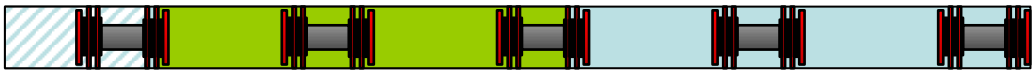
PIG SELECTION

Selection of the correct pig depends on several factors such as line type, length, material, condition, propelling medium, and the function to be performed. Advice should be sought from pig manufacturers and those experienced in the science and art of pigging.

PIGGING FUNCTIONS

Fluid Separation

Pigs form a solid barrier between dissimilar fluids, e.g. liquid and gas. As such, pigs can be utilised in a train to "batch" chemicals or other fluids to perform a function. A good example of this would be the following pig train.



Nitrogen Gas | Slug Glycol | Slug Glycol | Slug Fresh Water | Slug Fresh Water

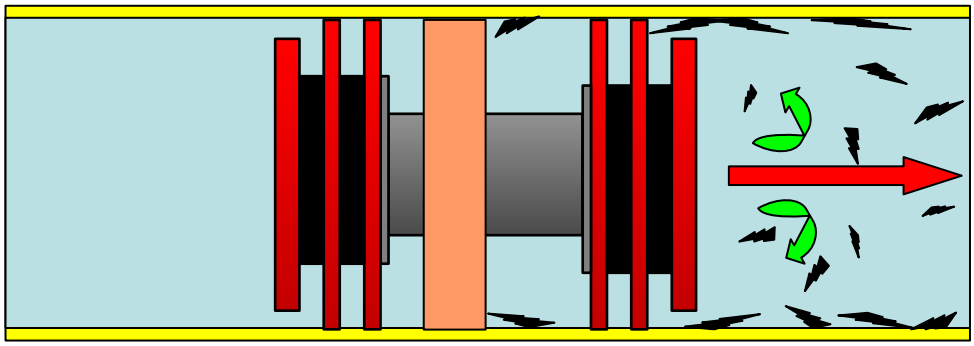
The first two slugs of fresh water provide desalination for a line previously flooded with seawater, while the glycol slugs aid in dehydration and hydrate inhibition upon the introduction of product. The whole train is driven by nitrogen gas.

Displacement

As there is a solid interface formed between the pipe wall and the pig sealing element, any fluid in the line (liquid or gas) is displaced from the line as in the pig train above. Inevitably there is some bypass due to surface roughness, weld penetration, and seal bypass.

Cleaning

Like the process for displacement, the positive interface between the pig and the pipe wall imparts a cleaning action on the pipewall. This can be further enhanced by the addition of brushes, scrapers, or even more aggressive tools to the pig. For lines where ferrous debris is expected, magnets attached to the pigs can add a pick-up action for removal of magnetic debris.



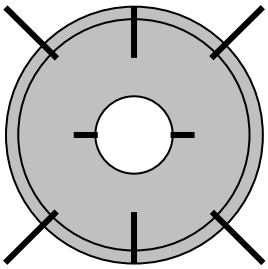
Discs and Brushes Clean Pipe Wall

Debris Removed Due to Turbulence

The turbulence within the fluid flow will hold any small, solid debris in suspension, effectively sweeping it out of the line. The use of bypass ports through the pig can aid this sweeping effect.

Waxes and sludges tend to adhere to the pig brushes and scrapers and are generally "ploughed" through the line.

Gauging



Gauge Plate

In order to identify any major restriction in flow area through a line a simple metal plate is attached to the pig to provide an internal line gauge. Generally sized to 95% of the pipeline internal diameter (95% nominal or 95% minimum, dependant on specification being used), the gauge plate tends to be made of a soft metal such as aluminium and is chamfered on the leading edge. It is common to "petal" the gauge plate with short, radial cuts to minimise the risk of the pig becoming stuck. These radial cuts through the gauge plate allow the plate to bend more easily if an obstruction is encountered.

REASONS FOR PIGGING

Pigging of a pipeline is required at various stages of a pipeline's life for a variety of reasons. These are summarised below in an example of an oil production pipeline.

Precommissioning

When new pipelines are built, they generally need to be cleaned of construction debris and prepared for hydrostatic testing. This is generally done by utilising a pig train consisting of cleaning, gauging, and batching pigs to flood the line.

Depending on the medium to be transported in the line, further pigging may be required for dewatering and drying operations.

Commissioning

As the product is introduced into the line, a batching pig or pigs can be used to separate the product from the medium currently in the line.

Operational Pigging

During the life of a line, operational pigging is a cheap effective way of maintaining flow and minimising back pressure. Pigs can be used to mechanically clean waxes and other hydrocarbon build-ups, or chemicals can be batched between pigs to provide chemically enhanced cleaning. Inline inspection is generally carried out as part of a routine maintenance plan.

Decommissioning

Whether pipelines reach the end of their useful life, or have their use changed (e.g. changing a production line to a produced water disposal line), they generally require some form of cleaning. Again, mechanical and chemical means can be used to allow subsea disconnection/reconnection, and in some cases pipelines can be dewatered for recovery and reuse.

PIGGING MEDIUMS

Liquid

The preferred medium for propelling pigs is an incompressible liquid. Incompressible liquids provide maximum control over pig speed as well as lubrication for the pig seals, minimising wear, and maximising seal effectiveness and life.

Liquids such as water, crude oils, or process products and chemicals can be used as propelling mediums. Care should be taken to ensure sealing element materials are compatible with fluid medium and prevailing pressure and flow conditions.

Gas

As gasses are compressible, the amount of stored energy behind a pig propelled with gas is far greater than that of a similar pig propelled with liquid. Appropriate consideration should be given to safety implications resulting from this stored energy. Pig movement can also be affected by improper use of a compressible gas as a propulsion fluid. Failure to deliver adequate quantities of gas required to maintain sufficient pressure behind the pig can result in a stop-start motion of the pig. This effect can be minimised to some extent by sizing equipment properly and maintaining a constant back pressure on the pig to minimise velocity changes.

When pigging with gas as a propelling medium, wear may be increased on the sealing discs. This should be considered during pig selection.

Multiphase Fluid

When the pig propelling medium is multiphase, the same safety consideration should be given to the pigging operation as if the propelling medium were gas. Extra care should be taken to consider the effect of slugging and the associated forces at the receiving end. Any temporary pipework should be secured and permanent facilities and equipment should be rated for multiphase flow.

PIG LAUNCHING AND RECEIVING

Pigs can be inserted into lines directly or via spool insertion, however, the most common method of getting pigs in and out of lines is through the use of pig traps. The selection of pig traps and the method of launch and receipt of pigs depend on several factors.

Subsea Pig Trap Topside Pig Trap

Subsea, topside, and land-based traps differ in design, as can be seen from the photographs above. Additional protection for associated launch/receive pipework and valves is required, as are the proper type and operation method of the valves used.

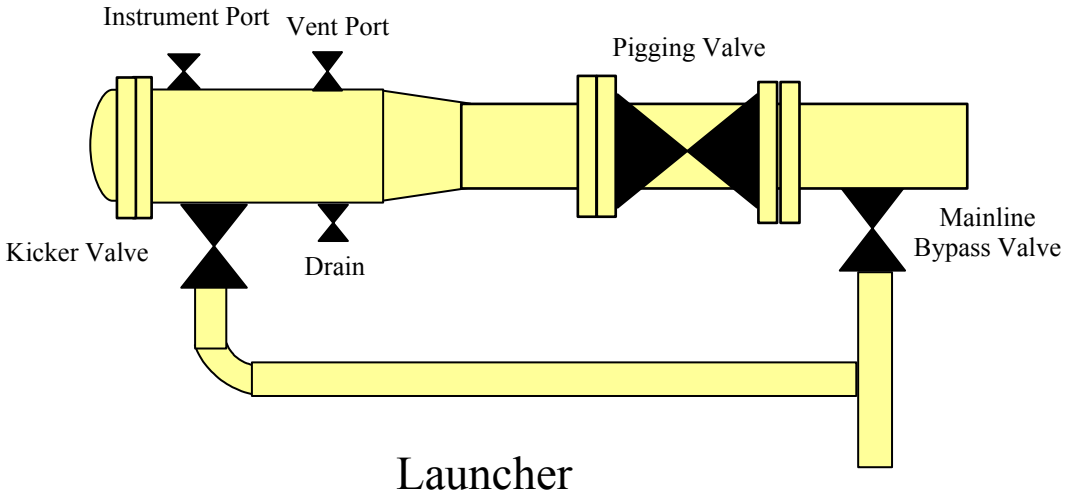
The type and size of pig will have a bearing on pig launcher or pig receiver design. An example would be spheres being launched rather than pigs. In that case, the pig trap design could be shorter. Similarly, if articulated pigs or an inline inspection tool were to be launched, the pig trap design would reflect this.

The number of pigs required to be launched or received in the pig train would have an effect on the physical size of trap and associated pipework required, although space limitations may also have an effect.

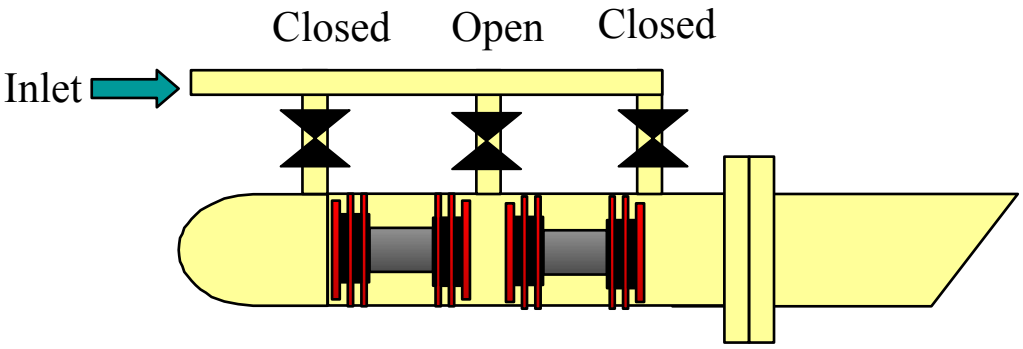
The pressure rating of the pig trap required to meet system design codes/standards and function can also affect physical size and design of the trap.

Whether a trap is temporary or permanent can affect design. Construction material can be affected, as can method of closure. Temporary traps may have simple flange closures, whereas, permanent traps tend to have quick opening door-type closures.

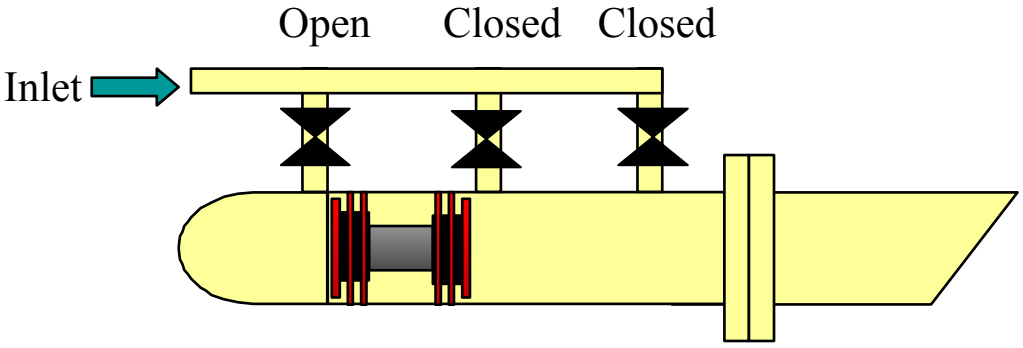
The actual method of operation for launching and receiving pigs also affects how the pig trap is constructed. As an example, a multiple-pig pig train can be launched in several ways. Each pig can be loaded individually and launched at set intervals, stopping flow of propelling medium, and venting line pressure to ambient prior to loading each pig. The same train can be loaded behind a pigging valve and launched without stopping flow, allowing pressure equalisation between the line and pig trap.



Again the same pig train can be launched from a multiple-pig pig trap by redirecting flow through pipework to allow individual pig launching as in the sketch below.



To Launch First Pig



To Launch Second Pig

The pig trap can also feature additional ports for pressure/temperature monitoring, chemical injection, pig signalling, etc.

THE FUTURE

As long as there are pipelines in operation, there will be a need for pipeline pigging. As technology advances, the use of intelligent pigs will increase as real-time communications allow pigs to record more information while being more compact as data storage will no longer be an integral part of the pig. Advances in power technology will lead to stronger, longer-life batteries that will allow more difficult tasks to be performed on longer and longer lines.

Increased pigging awareness, combined with increased production of heavier crude or crude from marginal fields and increased exploration and production in geographic areas with greater temperature fluctuations will all serve to increase the requirement for operational pigging.

ACKNOWLEDGEMENTS

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