GLOBAL PUMP SOLUTIONS

GREEN PAPER
FROTH PUMP DISCUSSION

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Mineral processing plants

Most mineral processing operations are designed to efficiently extract the valuable mineral with minimal loss. The mined ore is usually crushed and ground in the mill to very fine particles and resulting slurry is further processed for mineral separation.

What is froth?

Sometimes froth is encountered during the mineral separation process. Froth is an aerated slurry that can occur naturally, or in some processes is created deliberately to assist separation of the minerals. Additional considerations need to be taken to assist their transfer through the plant and these are discussed below.

How does froth effect pump performance?

Pumps run less efficiently when pumping air entrained liquids. The higher the quantity of entrained air, the greater the potential drop in flow, head and efficiency. Air entrained in slurry can bind at the impeller eye – heavier liquid is centrifuged out of the impeller eye, leaving the potential for air to block the eye of the impeller. Additionally, the froth volume takes up the usual liquid volume.

It is virtually impossible to predict how much air will be pulled from froths when they are being pumped therefore a special approach is required to the pump and system design.

Standard horizontal pumps, gravity fed with frothy slurry from a conventional hopper, will often perform in a cyclical, unstable manner evidenced by swings between full and nearly no flowrate, with associated power surges.

This cycling is caused by the intermittent air locking. The centrifugal action of the impeller selectively drives slurry from the eye of the impeller, leaving a growing bubble of air trapped in the eye. This accumulation of air impedes flow of slurry from the hopper to the impeller, effectively inducing partial flow in the suction line. This can cause the flow rate to drop to nearly zero.

Due to the temporary blockage the head in the suction tank will rise until it is able to compress the bubble, allowing full flow to occur once again. This cycle is repeated. Effectively the pumps are acting as 'bubble compressors'.

The deterioration of performance for a given percentage of air or gas varies from pump to pump depending on rotating speed, specific speed, pump size, suction pressure, discharge pressure, number of stages and various special design features.

At the pump, frothy slurries are treated as an equivalent fluid, with increased volume and decreased density. The coefficient of proportionality is called the pump froth factor. Depending on the design of the suction arrangement this froth factor can vary from 1 to as much as 8.

Unintentional frothy slurries

Where froth is not an intentional part of the refining process, it is best to use methods that remove froth from the system so they can be pumped with conventional severe duty slurry pumps.

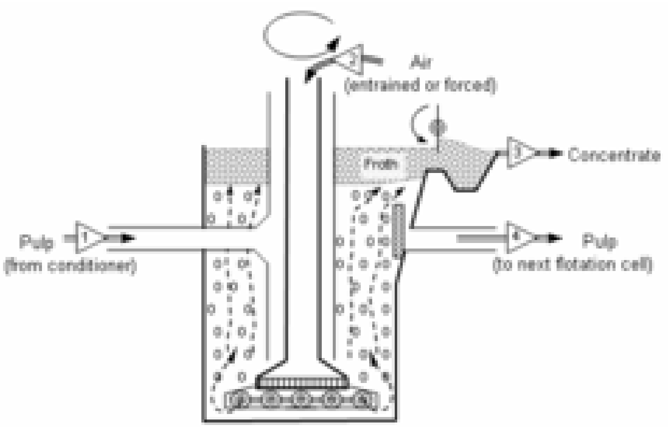
Intentionally frothy slurries

Froth is intentionally formed in both coal washing and base metal concentrators (copper, nickel, molybdenum, lead, zinc etc.).

The floatation process

The floatation process is often utilised to separate the concentrate from the gangue (waste) material. Here, reagents are added to cause the finely ground ore particles to be hydrophobic (water repellent). Air is injected into the flotation cells to assist the fine particles to attach to the air bubbles and rise to the surface where they can be collected and piped away. The hydrophilic (attracted to water) particles sink to the bottom of the cell from where they are also removed. In some processes the desired material rises to the surface, and the waste to the bottom, and visa versa in other processes.

General Arrangement Drawing 1.0: A Typical Cylindrical Froth Flotation Cell



Schematic Flow Diagram 1.0: Typical Flotation Cell Internal Workings

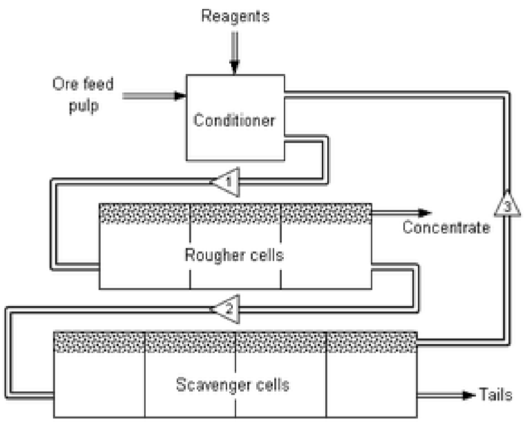
The numbered triangles in Schematic Flow Diagram 1.0 show direction of the flow stream. A mixture of ore and water called Pulp (or slurry) enters the cell from a conditioner, and flows to the bottom of the cell. Air is passed down a vertical column containing an impeller where shearing forces break the air stream into small bubbles.

The flow rate and tank size are designed to give the minerals enough time to be activated. In this example the mineral concentrate froth is collected from the top of the cell, while the remaining slurry flows to another cell.

Flotation can be performed in rectangular or cylindrical mechanically agitated cells or tanks, flotation columns, Jameson cells or deinking flotation machines.

Flotation circuit stages

Flotation circuits often employ up to three pre-concentration stages usually referred to as “*Roughers*” and “*Scavengers*” followed by additional stages known as "*Cleaners*" to maximize mineral recovery. The froth overflow is typically pumped from one cell to the next and then downstream for further processing.



Process Flow Diagram 2.0: Typical Flotation Circuit

In Process Flow Diagram 2.0, the ore slurry (ore feed pulp) is mixed with reagents to create a Conditioner Pulp. The Conditioner Pulp [1] is fed to a bank of rougher cells which remove most of the desired minerals as a concentrate. The Rougher Pulp [2] passes to a bank of Scavenger Cells where additional reagents may be added. The Scavenger Cell froth [3] is usually returned to the Rougher Cells for additional treatment, but in some cases may be sent to special cleaner cells. The Scavenger Pulp is treated until it is barren enough to be discarded as tails. More complex flotation circuits have several sets of cleaner and re-cleaner cells, and intermediate re-grinding of pulp or concentrate.

Centrifugal slurry pumps are often used in the launders of floatation services, transferring from one part of the process onto another.

What are typical froth factors?

The froth factors are determined by site analysis of the slurry.

Froth factors, which must be verified by site personnel, are typically in the following ranges:

Application	Pump Froth Factor
Copper rougher concentrates	1.5
Copper cleaner concentrates	3
Molybdenum rougher concentrates	2
Molybdenum concentrates	3
Potash	2
Iron concentrates	4 to 6
Coal	6

The froth factor should allow for deaeration in launders and hoppers etc. It is essential to try and reduce the froth factor as much as possible before it enters the pump as only then will the most efficient and reliable pumping system be encountered.

How to select the correct pump size

Although there is no reported scientific evidence to support the case, empirical data reports that standard but oversized centrifugal pumps can be used to pump froths (likely to be due to the impeller eye being larger and being able to dispel more air). The special KETO froth pump impeller, discussed below, assists pumping frothy liquids without having to oversize the pumps.

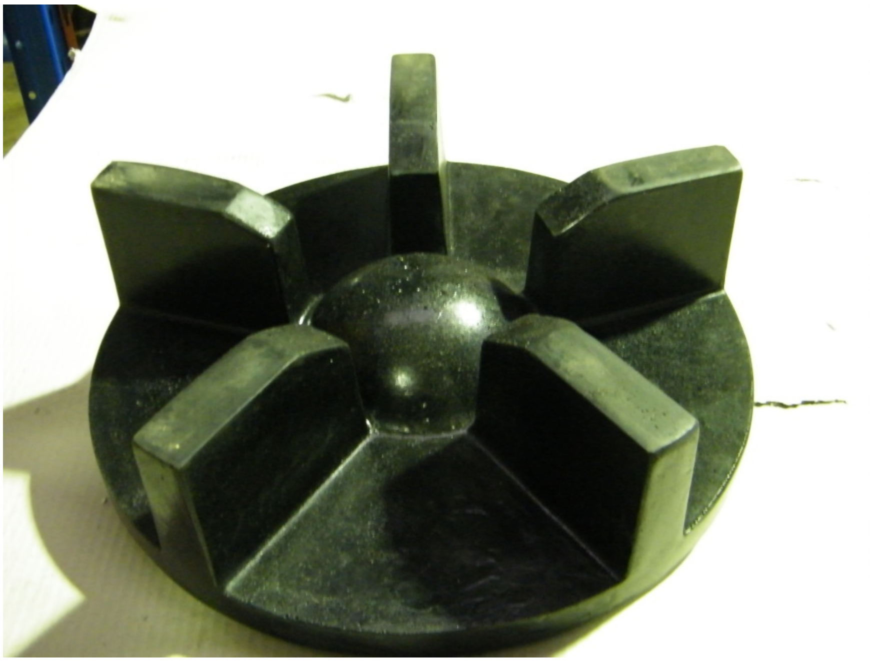


Photo 1.0: KETO HS-F Froth Pump Impeller

The majority of field applications have froth factors less than 3 in which case the KETO horizontal HS-F pumps can be used. Froth factors above 3 and up to 6 can be handled by the KETO vertical VS-F pumps which contain specialised build in hopper tanks and open impellers configured in a way to automatically minimise the amount of air entering the eye of the impeller.

Slurries with higher froth factors (6 and above) create problems in pump performance and centrifugal slurry pumps are not recommended in this situation.

Usually froth pumps range in size from 2” to 8” discharge – sizes accommodated by KETO H-SF pumps.

How are KETO HS-F pumps configured?

Some slurry pump brands use complex impeller designs with dramatically increased inlet diameters. This results in non standard, long lead time and expensive spares: special throat bushes; special cover plates; special liners; special impellers.

The KETO HS-F impellers are designed to work in STANDARD KETO HS series severe duty slurry pumps. The result is that ANY KETO pump up to the L200 (10x8) can easily be converted to use on froth duties by simply changing the impeller. Froth pump impellers are maintained ex stock KETO Australia and at most stocking distributors.

What materials to use

Most froth duties, in order for the product to float, have finely ground solids which makes KETO PU01 Urethane is often ideal for froth. In most services it is extremely erosion resistant, and is seldom chemically attacked by the reagents used in the floatation process. KETO Australia keep high stock levels of urethane to assist clients requiring these parts. On request Chrome White Iron (WI05), Natural Rubber, Neoprene, Hypalon, and more are available to order.

Using KETO HS-F impellers for froth

The HS-F impeller developed by KETO for froth applications is a radial vane open impeller, usually comprising 5 or 6 vanes, depending on the pump size. The impeller can be retrofitted to all KETO HS pump sizes without any modification. The resulting HS-F pump requires no oversizing for applications with froth factors up to 3. We do however recommend some additional flow allowance for froth factors of 2.0 and higher. This allowance should be 50% of the flow over the Desired Froth Factor minus the 2.0 Froth Factor.

For Example: A 100l/sec slurry flow and 3.0 Froth Factor, the HS-F pump should be sized for 150l/sec.

With the HS-F impeller, select pump for 150l/sec [100l/sec+ 50% of 100l/sec x (3.0-2.0) = 150l/sec] at the stated total dynamic head.

Using a conventional KETO HS impeller for froth

The above case is dramatically different to using a standard closed severe duty slurry pump impeller. With a Froth Factor of 3.0, a standard pump needs to produce 3 times the curve flow at the stated operated against the nominated total dynamic head must be used. Using the duty in the example above:

For Example: A 100l/sec slurry flow and 3.0 Froth Factor, the HS pump should be sized for 300l/sec.

With the conventional HS impeller, select pump for 300l/sec [100l/sec x 3.0 = 300l/sec] at the stated total dynamic head.

How is the motor sized?

Pump power requirements should be calculated for the increased flow point, under conditions that froth is not present as during power outages, and plant start up, the slurry may contain no froth and hence actually produce the higher flow. During normal froth service operation the pump will absorb less power.

How do the KETO HS-F froth pump impellers work?

The HS-F impeller accomplishes this task in three different ways:

The design consists of a rear shroud with five or six equally spaced flat radial vanes, large inlet eye and wide open water passages. This allows the froth-laden slurry to pass through the impeller very easily.

The absence of the front shroud extends the width of the HS-F vanes thereby extend the pumping capacity by as much as 50%. In addition, the large eye area, open waterway and orientation of the discharge nozzle minimizes the possibility of air binding in the pump.

The HS-F impeller is designed to produce a relatively flat flow-head curve. This allows the pump to operate at different points on the rpm curve, with small changes in system head. As the system head decreases due to the increased in-flow and higher sump level, the pump duty point moves out on the curve and pumping capacity increases rapidly to accommodate the additional slurry and froth. Since the HS-F pump operates over a wider flow range, adequate motor power is recommended to cover the pump run-out condition.

System design tips for pumping froth

The design of froth pumping systems should facilitate an effective breakdown of froth in the pump hopper. Effectiveness of methods employed will depend on the tenacity of the froth.

The effect can be greatly reduced, if not completely eliminated, by effective design of the tank/suction pipe system. The key to stable pumping is to decant the froth, allowing only liquid and solids to be presented to the pump. Use of fine water spray, and larger/deeper pump hoppers can assist in reducing the froth in the slurry. This increases pump efficiency, and reduces the size of pump required, as well as significantly reducing operating costs.

Heads in froth applications should be kept to a minimum. Heads over 20m are not recommended and if mandatory additional caution should be taken.

Sump and Hopper Design

Size:
Sump size should be adequate for at least 2 minutes of retention time. Depending on froth factor, it is sometimes necessary to extend the retention time.

Shape:
Sump should have large surface area to allow air to escape. Bottom of sump should be conical or sloped at a steep angle enough to prevent build-up of solids. Agitators may be used to break down the froth and prevent solids settling.

Feed:
Pipes and launders feeding the sump should be located far from the pump suction pipe and preferably submerged below the liquid level to avoid entraining air. Baffles may be used to minimize air entrainment and break down some of the froth.

Height:
Sump height should be adequate to maintain the minimum liquid level required to eliminate vortex formation and keep air from entering the suction pipe to the pump.

Suction pipe selection

Length:
Pump should be located close to the sump with a short straight suction pipe. The suction tank should be slightly sloping down to the pump. NEVER use suction lifts. Avoid negative suction pressures (e.g. from excessive line losses)

Diameter:
Pipe should be sized for adequate carrying velocity necessary to keep solids from settling and minimize friction loss. Pipe velocity of 5 to 6 ft/sec is usually sufficient.

Fittings:
Keep fittings to a minimum. If a shut-off valve is used, select one with same opening as the suction pipe without any obstructions or air pockets. Preferably use a slight downwards sloping angle towards the pump suction nozzle.

Inlet:
Design for maximum submergence to avoid vortex formation and entrain air.

Air Bleed:
For froth factors 2 and above, use an eccentric reducer, flat side down, incorporating a standpipe 50% the diameter of the main suction pipe. The standpipe is located directly before the reduction angle to enable air to be dispelled.

What pump layout is best?

All KETO HS-F pumps are supplied with the discharge nozzle rotated to 'Position 1' as shown in Photo 2.0.

This enables entrained air to be easily dispelled from the pump during operation.

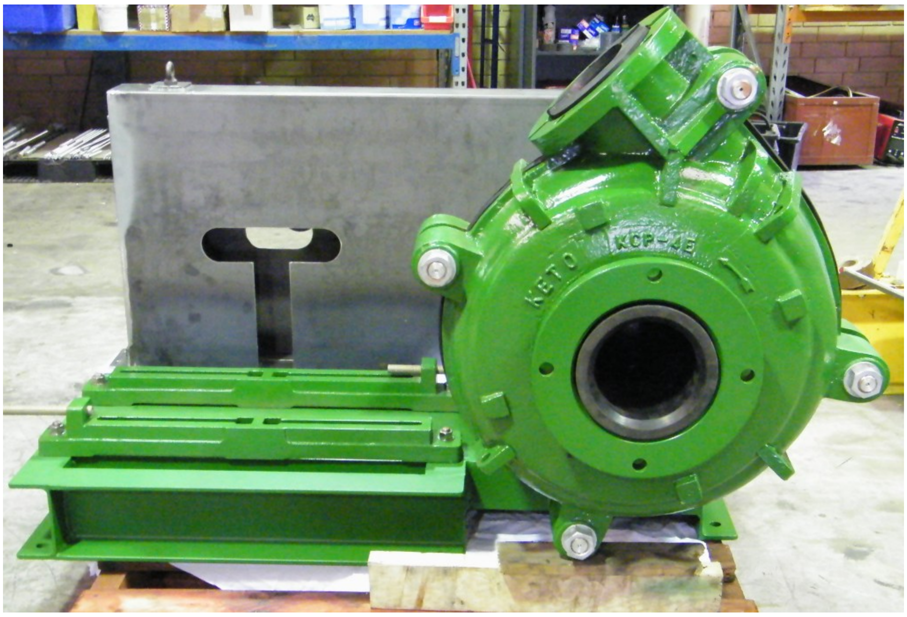
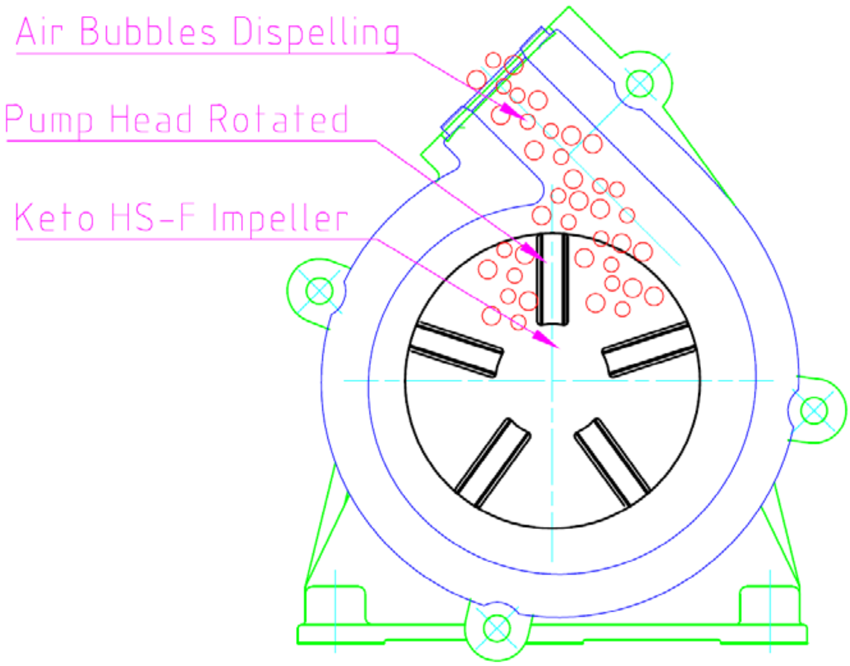


Photo 2: KETO HS-F Froth Pump – Discharge Nozzle Orientation



Sectional Drawing 1: KETO HS-F Froth Pump – Air Dispelling

Other considerations

Too Much Entrained Air:
Add a standpipe from the top of the suction pipe leading back to the top of sump if there is a tendency for the air to accumulate.

High Froth Factor:
Do not overestimate froth factors. Froth factors usually range between 1.2 and 3.0 for most flotation applications.

Excessive Froth:
When too much froth makes pumping difficult, it may be necessary to add chemical-defoaming agents (surfactants) to the slurry.

Appendix: Chemicals of flotation

Collectors:
Collectors either chemically bond (chemisorption) on a hydrophobic mineral surface, or absorb onto the surface in the case of, for example, coal flotation through physisorption. Collectors increase the natural hydrophobicity of the surface, increasing the separability of the hydrophobic and hydrophilic particles.

Xanthates:
- Potassium amyl xanthate (PAX)
- Potassium isobutyl xanthate (PIBX)
- Potassium ethyl xanthate (KEX)
- Sodium isobutyl xanthate (SIBX)
- Sodium isopropyl xanthate (SIPX)
- Sodium ethyl xanthate (SEX)

Dithiophosphates:
- Thiocarbamates
- Xanthogen Formates
- Thionocarbamates
- Thiocarbanilide

Frothers:
- Pine oil
- Alcohols (methyl isobutyl carbinol (MIBC))
- Polyglycols
- Polyoxyparafins
- Cresylic Acid (Xylenol)

Modifiers:
pH modifiers such as:
- Lime CaO
- Soda ash Na_2CO_3
- Caustic soda NaOH
- Acid H_2SO_4, HCl

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