SAMPLING OF SLURRIES

Contents

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1. INTRODUCTION

1.1 Goals of sampling system design

Reliability is the most important characteristic expected from the system. It should operate without blockages at all process conditions regardless of changes in the process flow rates.

Operating costs should be small. Maintenance should be minimal. Wear parts should last well and be cheap and easy to replace. Flushing water, compressed air and electricity consumption should be small.

Investment price should be small.

The sample representativity should be good.

The Outotec sampling systems feature durable stationary samplers and include engineering of samplers and sample transport to get a reliable, cost effective system giving a representative sample to the on-line analyzer system.

Also linear moving cutter samplers are available.

It is essential to locate the analyzer correctly, find the right sampling points and if necessary, make the correct compromises. The engineering, installation and commissioning of the sampling system is about 80 % of the customer specific work needed for a delivery project.

STOP

Nearly all commissioning problems in analyzer projects come from incorrect engineering of sample transport or incorrect location of samplers. The engineering is more difficult than common sense would assume. Follow this manual and use the expertise of Outotec.

2. THE SAMPLING PROJECT

Selecting samplers and their locations

When the layout and the flows of the process have been designed one can start selecting samplers and sampler locations. See section 3.SELECTION OF PRIMARY SAMPLERS. More information about the samplers is in section 4.PRIMARY SAMPLERS. For more exact information of available sizes and installation dimensions see respective data-sheet.

Selecting location of analyzer

The **location of the analyzer** has a decisive effect on the investment and maintenance costs of the sample transport system. Therefore, selecting a place for the analyzer is a most important aspect in the design of the system. (See also Analyzer Installation Instruction Manual)

Samples are preferentially transported to the analyzer using process pump pressure (PSA, SPSA, ASA or SPA -samplers) or gravity (LSA, NLA, SKA,-samplers). If needed, pumps should be specified.

Selection return flow options

The primary samples not used by the analyzer must be returned somehow to the process. Some can be joined and returned to a common point, some must be kept separate.

The samples used by the analyzer are much smaller only 40- 25 l/min for a fraction of the time. These can be separated and returned separately to the process if needed using a demultiplexer. However, all the measured streams from one multiplexer is automatically separated from the streams of another multiplexer so often the analyzed streams of each multiplexer are returned jointly to one process point.

Optimizing the selections

The selections above influence each other and how many pumps are needed. Sometimes an improved selection of sampling points, height and location of the analyzer as well as reselecting the return flow options reduces the number of pumps and improves the reliability of sampling.

Selecting sample pipe and pump if necessary

The sampler shall firstly give a sample flow rate suitable for the analyzer (See section 7.SAMPLE FLOW RATE). The samplers can be divided into two groups.

1. The first group uses the process pressure at the sampling point. For these samplers and the two stage samplers **the sample pipe diameter and length to the multiplexer should be calculated to give the right friction to give the right flow.** Usually pipes are between 32 and 50 mm inner diameter.
2. The second sampler group, the gravity flow samplers, has no pressure at the sampling point. The sample pipe should be a gravity pipe to the multiplexer or the pump sump from which the sample is pumped to the multiplexer. **The cutter opening is selected to give the right flow.** Pipes are generally 52-64 mm inner diameter.

The sampler shall secondly provide a representative sample of the process flow. For good representativity flow velocity into cutter or nozzle is about the same as the velocity of the bulk flow around the cutter or nozzle.

Installation of primary samplers

General installation instructions can be found in section 4.PRIMARY SAMPLERS. Proper installation instructions are available separately for each sampler type

All samplers (except MSA) are equipped with shut off valves for the sample flows and a flushing valve for the sample pipe, (VSA). The valves can be manual or automatic. The automatic valves are connected to a valve box set (VBS) which changes the electrical signals from the analyzer into pneumatic signals to the actuators.

Installation of sample pipe

The sample pipes are small in diameter, which means higher friction and higher risk of clogging than for process pipes. **Thus sample pipe routing and installation are more demanding than for process pipes. Most sampling problems are caused by sample pipes not engineered or installed properly.** Seldom proper detailed engineering is done. The installation crew must get very strict orders of how to do the installation.

1. First of all the sample pipe must be routed correctly. See 5.TO ROUTE THE SAMPLE TRANSPORT PIPE. Note that the rules are different for pressure pipes 5.1 and 5.2 than for gravity flow pipes 5.3.
2. Secondly the installation must be done well. The pipe must be well supported, have large radius bends and a smooth inner surface. See section 6.INSTALLATION OF PIPE.
3. In addition to the principles explained in the manual example drawings are available for the routing and connections of sample pipes.

Commissioning of sampling system

In the commissioning the first thing is to check that the engineering and installation rules have been followed. When the system starts up the sample flows should be checked, and if they are not as required the system must be improved. Advice on this is found in section 7.SAMPLE FLOW RATE.

Problems with sample pipes plugging up.

Most often this is caused by trash caught by steps in the inner surface of the sample tube, or by some other fault in the installation. However sometimes it is difficult to follow all the necessary rule. Then one can as an alternative use controlled sampling.

Sample flow can be continuous or controlled. Controlled sampling requires of course automatic valves. In its simplest form the sample pipe and the cutter or nozzle are regularly flushed. This control feature is standard for the PSI:s. The Courier analyzers have the additional capability to do many kinds of sampling control by selecting the right parameters. One possibility “On demand sampling” means automatic stopping of the sample flow and flushing of cutters and sample pipes, when the sample flow is not needed by the analyzer.

3. SELECTION OF PRIMARY SAMPLERS

When selecting the sampler for a certain stream there are many things to think about. Should one take the sample from a pressure pipe or volume under pressure or from a gravity flow? Sometimes the choice is obvious sometimes both are possible. Many things influence the selection of the size and the type of the sampler. The size of the process pipe, the flow rate and the required quality of sample are the most important factors to consider. The type of the process stream is also important, is it a tail, feed or concentrate. In the following are two simple tables one for pressure samplers and one for gravity samplers for your guidance. They cover just standard situations.

In the tables na. means not applicable. The sample quality has been classified in three groups.

+	SAMPLE IS USEFUL FOR ON-LINE ANALYSIS IF SAMPLER IS CORRECTLY INSTALLED AND SLURRY IS MAINLY FINE<100 MICRON. NOT RECOMMENDED FOR PSI
++	SAMPLE IS USEFUL FOR ONLINE ANALYSIS AND CAN BE USED FOR METALLURGICAL SAMPLING IF SAMPLER IS CORRECTLY INSTALLED AND SLURRY IS MAINLY FINE<100 MICRON.
+++	CAN BE USED FOR METALLURGICAL SAMPLING

Table 1. Selection of pressure sampler for on-line analyzer

Process location	**Stream**	**Flow-rate**	**Pipe size**	**Sample quality**	**Sampler**	**Note**
After pump or long vertical pipe	all	> 600 l/min	> 100 mm	++	PSA (or SPSA)	SPSA nozzle wear high
After pump or long vertical pipe	all	< 600 l/min	≤ 100 mm	++	Sector sampler ASA	Can take 25, 50 or 75 % of flow
Horizontal pipe	Not frothy stream	> 500 l/min	> 100 mm	+ Fine	SPSA	
Flotation cell	Tail	all	na.	+ correctly installed	SPA	

Table 2. Selection of gravity sampler for on-line analyzer

Process location	Stream	Flow-rate	Pipe size	Sample quality	Samp-ler	Note
Nearly horizontal gravity pipe	all	25 -1000 - (1600) m3/h	≤ 600 mm	++	LSA or NLA	Flow >1000 m3/h requires partly plugged cutter or secondary sampler ASD
Gravity flow in flat bottom launder	all	< 1000 - 2000 m3/h	na.	++	SKA	
Nearly horizontal gravity flow	all	> 500 m3/h	na.	++	TSC	Two Stage Cutter give larger openings than LSA
Nearly horizontal gravity pipe (large launder)	no froth Feed	> 350 m3/h	≥ 250	++	CPS	Recommended mixing step in front
Small gravity flows		<400 l/min	50 mm	++	ASD	Often secondary sampling for PSI 500
Gravity flow	all	36 - 200 m3/h		+++	LMC	For metallurgical sampling of small streams
Gravity flow	all	60 - 18000 m3/h	na.	+++	MSA	For (metallurgical) sampling of medium to large streams

A well-engineered sampling system using static samplers gives good enough samples for runtime material balances. For really accurate material balance calculations static samplers and on-line analyzer data may not be sufficient. The material balance includes besides the metal content in the solids also process flow rate and % solids in the flow. Shift composite samples collected by MSA samplers give samples correctly mirroring variable process flows and solids contents for material balance calculations.

4. PRIMARY SAMPLERS

All samplers (except MSA) are equipped with shut off valves for the sample flow and a flushing valve for the sample pipe (VSA). The valves can be manual or automatic.

Sample flow can be continuous or controlled. Controlled sampling requires of course automatic valves. In its simplest form the sample pipe and the cutter or nozzle are regularly flushed. This control feature is standard for the PSI: s. The Courier analyzers have the additional capability to do many kinds of sampling control by selecting the right parameters. One possibility “On demand sampling” means automatic stopping of the sample flow and flushing of cutters and sample pipes, when the sample flow is not needed by the analyzer.

4.1 Accessibility for service

All samplers occasionally need to be inspected and serviced. It is advantageous to locate the samplers, so that they are easily accessed from an existing service platform. This is especially true for the gravity flow samplers, their cutters get much more easily clogged than the round nozzles of pressure pipe samplers. Sometimes additional service platforms need to be built for the samplers.

4.2 Gravity flow samplers

ASD 50 small gravity flow sampler

Figure 1. ASD DN50

This sampler has an adjustable cutter which cuts a sample to an analyzer. It has been primarily designed to be bolted on top of a PSI500 to reduce the sample flow of a slurry with low transparency. It can also be used as a secondary sampler or as a primary sampler for very small flows. It can also split the sample in two parts one going to a PSI and the other to a Courier.

LSA and NLA

The LSA Launder Sampler and the NLA Non-Plug Launder Sampler are suitable for sampling from near horizontal, non-pressurised pipes of DN 100 to DN 600. A cutter installed in the middle of the box shaped body of the sampler cuts a representative sample from the process flow through the box.

TYPICAL APPLICATIONS

cyclone overflow pipes
distributor pipes
concentrate pipes

COMMON FEATURES

designed for near horizontal pipes with gravity flow
cutter and sampler body design ensures representative sampling
cutter replaceable without removing the sampler
large inspection lid
Adjustable stainless steel cutter used up to DN 350 size, fixed cutter for larger sizes
Rubber lined cutter blades standard
Hard metal Cr/Ni cladding of cutter blades optional

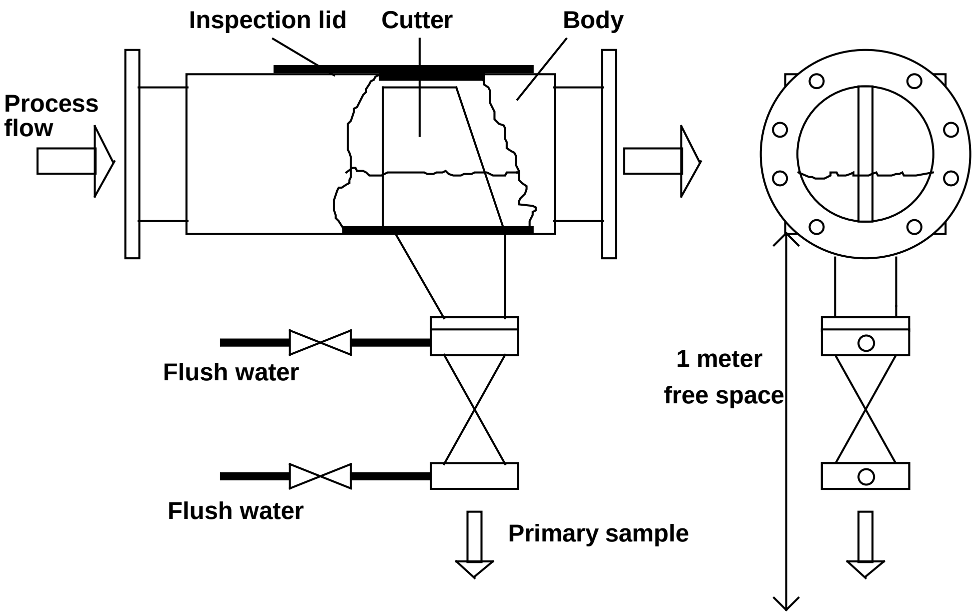


Figure 2. Sketch of LSA

NLA FEATURES

automatic periodic mechanical cleaning of cutter

Reserve space for valves and pipe curve about 1 meter below LSA and NLA.

Best sampling results are achieved in pipes with a turbulent flow and a reasonably constant flow rate. The vertical cutter extracts a representative sample of the slurry flow, even if the slurry is segregated in the vertical direction.

Sample flow out of the box sampler by gravity. A valve set (VSA) is required for shutting off the sample flow and for flushing of the sample line and the cutter.

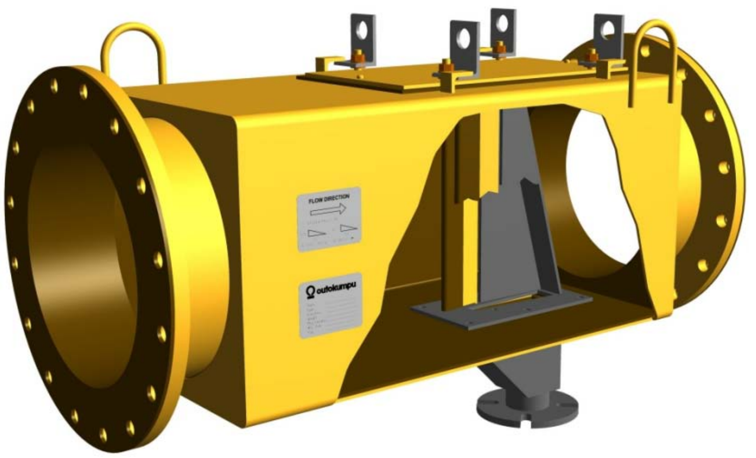


Figure 3. LSA. Adjustable rubber lined cutter vanes are brown and yellow in the figure.

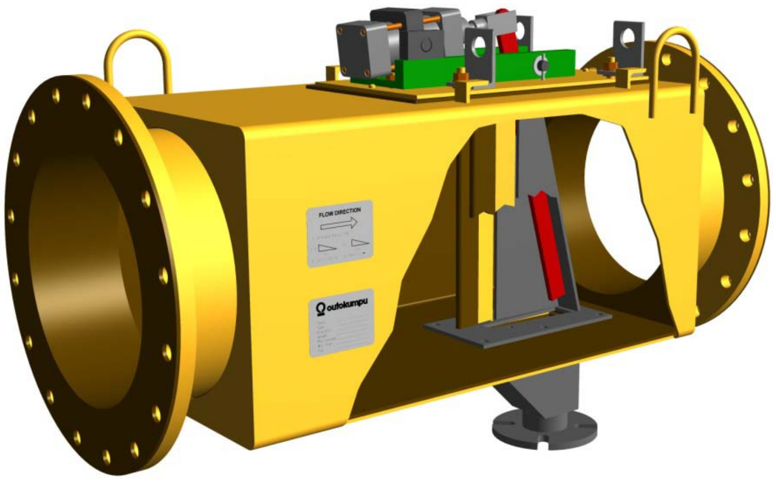


Figure 4. NLA. The normal lid of the LSA has been replaced with a lid with the cleaning mechanism.

SKA stationary knife sampler

TYPICAL APPLICATIONS

Flat bottom launders

FEATURES

Adjustable cutter can be easily pulled up from above for maintenance. No nuts or bolts to open.

Manual or pneumatically operated shut-off and flushing valves

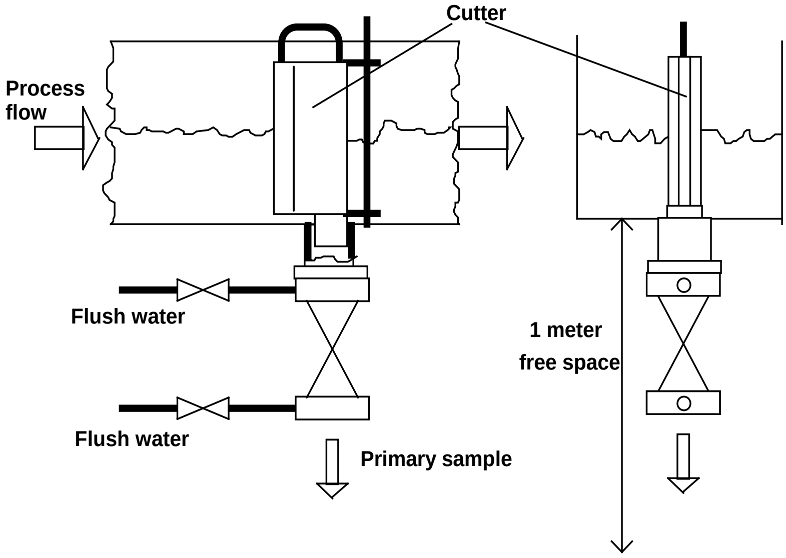


Figure 5. SKA

Reserve space for valves and pipe curve about 1 meter below SKA

CPS two stage “boot” sampler for high flows

TYPICAL APPLICATIONS

Cyclone overflow
Distributor pipes
Tail launders also curved bottom launders

FEATURES

Easily installed on top of a launder or on a box built on top of process pipe.

The sampler is hinged so that the whole sampler can be turned out of the process stream for inspection around the axis attaching it to the outer frame

The sample outlet is compatible with sizes DN50

CPS HYDRAULIC INSTALLATION

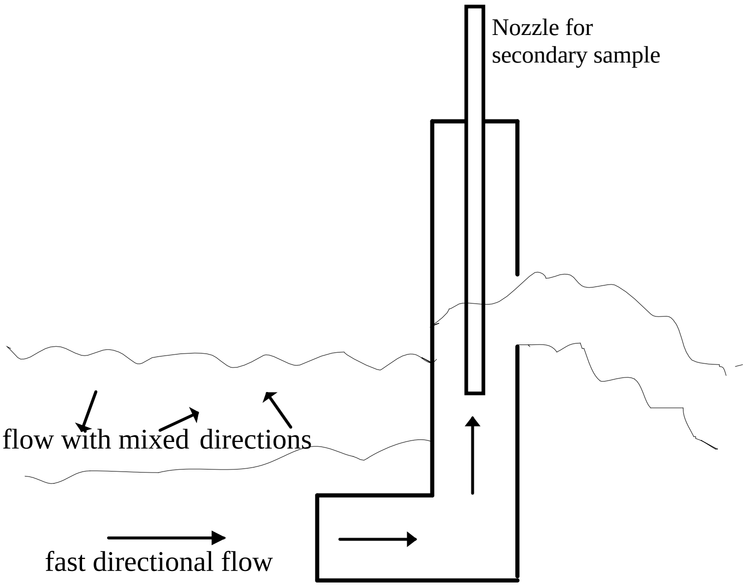


Figure 6. Sketch of the boot

The toe of the boot should be well submerged in the incoming fast process flow to give a representative sample. This is a critical issue.

This limits for small flows the size of the boot, which is close to the bottom, leaving a gap for stones between the boot and the bottom of the launder.

It means also that generally the launder for the boot is not made wider than the incoming launder or tube (unlike for LSA).The launder for a process tube has a round bottom the same size as the tube. For small tubes the bottom diameter and the box is slightly larger than the process tube.

The boot and the frame holding it, if they are big compared with the launder, can dam the whole flow creating a layer with disorganized flow on top of the fast process flow. This layer should not be sampled by the boot.

Mixing in front of the sampler is advantageous. For instance a step in the bottom of the tube puts solids moving along the bottom in suspension.

PRIMARY SAMPLE

The sample is a full pipe flow. To suck out the sample a negative pressure must be created by for instance a siphon. For reliable operation the siphon requires a regular automatic flush and filling of the sample line.

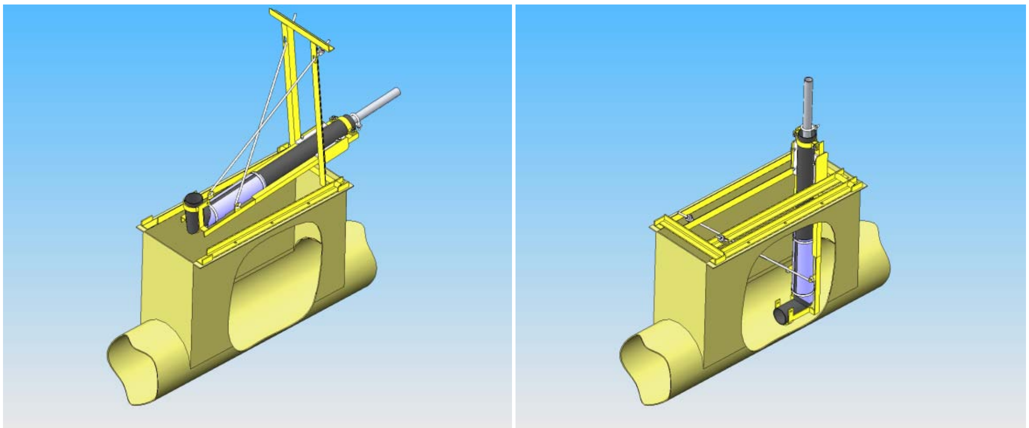


Figure 7. CPS 90 in maintenance and sampling positions

Two stage cutter TSC sampler for high flows

FEATURES

Two stage sampling for large streams in single inexpensive unit. Larger cutter openings than for single stage cutter.
Heavy-duty stainless steel construction
Easily installed in launder or LSA-type box
Removable two stage cutter. No bolts to open
Adjustable stainless steel primary cutter
Exchangeable stainless steel secondary cutter

TYPICAL APPLICATIONS

Cyclone overflow
Distributor pipes

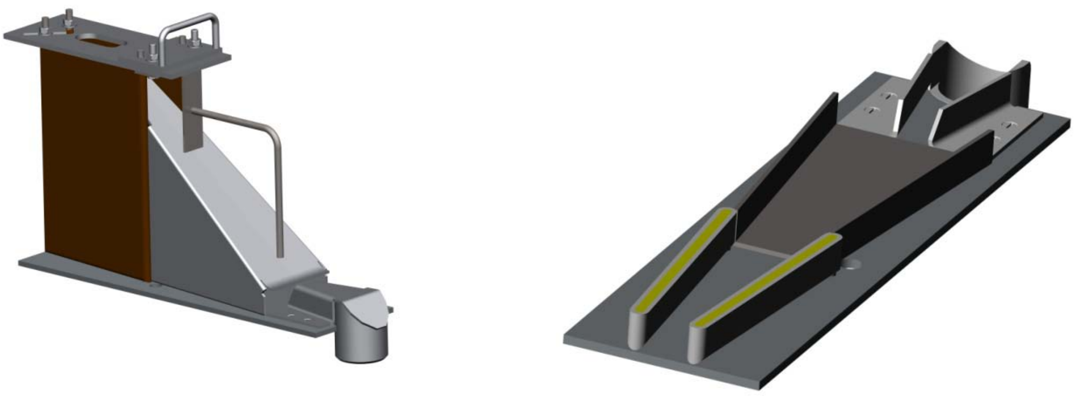


Figure 8. Two stage cutter sampler. The process flow comes from the left. On the right-hand side is a horizontal cut through the sampler

THEORY OF OPERATION

The sampler is generally suitable for sampling near horizontal non-pressurized pipes or Launders with flows higher than 420 m3/h. The primary adjustable cutter in the center of the stream cuts a representative sample from the process flow. The sample is reshaped in the cutter to a broad low cross-section larger than the high narrow inlet cross-section. This makes it possible to use a second cutter to reduce the sample flow to the required size. Best sampling result are obtained for turbulent flows with a reasonably constant flow rate.

Sample flow out is by gravity. The pipe is full so the pipe flow is pressure flow fed by gravity. A valve set is required for shutting off the sample flow and for flushing of the sample line and secondary cutter.

Suitable sampling points for gravity samplers LSA, NLA, SKA, CPS or TSC

There are 4 basic requirements for the sampling point:

1. There is no pressure in the process pipe at the selected point

The LSA acts as a flow resistance, which can cause a local pressure in the sampler if the process tube is too full in front of the sampler.

2. The flow velocity in the pipe or launder is not so high that it causes excessive wear. A long slope before the sampler must have a shallow angle.

3. The process pipe or launder is near horizontal at the sampling spot, slope to be less than 20 %.

4. If two different flows are joined a straight length of pipe or launder of at least 10 times the diameter of the pipe or width of the launder is recommended.

4.3 Samplers for pressure flows

TYPICAL APPLICATIONS

pumped lines

pumped final tailing lines

flotation cell tailing

PSA pressure pipe sampler

The pressure pipe sampler is always installed in a vertical orientation, generally immediately above a process pump. A good alternative is after a long (>10 x diameter of pipe), straight vertical stretch of the pipe.

The sample is taken with a nozzle from the middle of the turbulent flow region in the sampler. Standard nozzle size is DN50. The nozzle has been selected to give approximately isokinetic flow, which is to have a similar average flow velocity inside the nozzle as outside in the sampler body. The sample pipe diameter is usually smaller than the nozzle diameter.

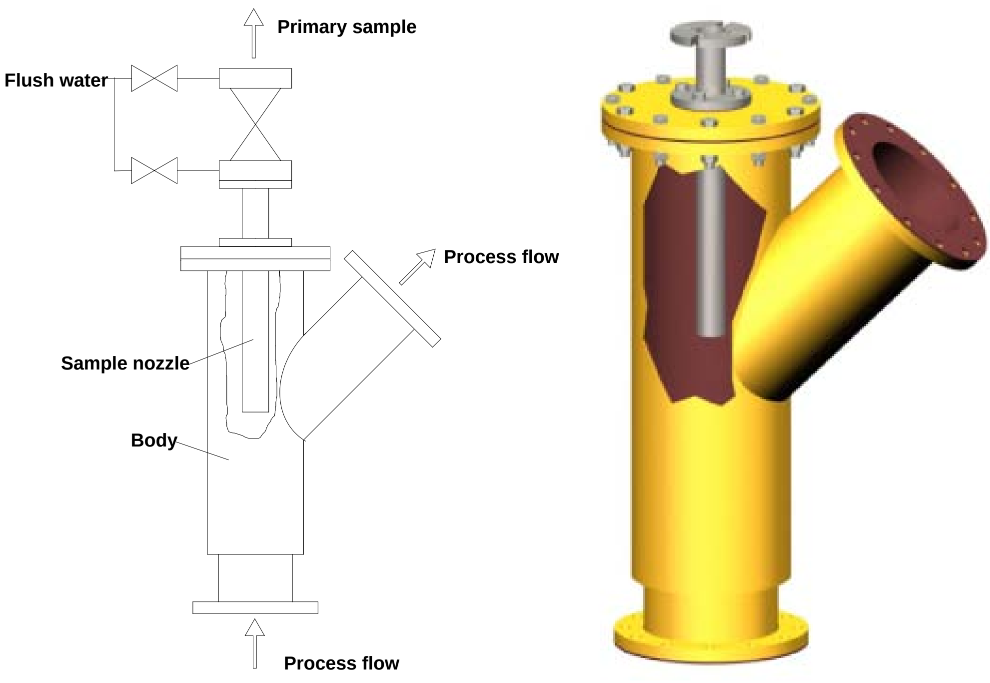


Figure 9. Sketch and three-dimensional picture of PSA (DNA 250)

SPSA straight pressure pipe sampler

The straight pressure pipe sampler (formerly called HPSA horizontal pressure pipe sampler) is similar to the PSA except that the sampler can replace a straight section of the process pipe. It can also be installed horizontally.

The sampler gives, when installed in the horizontal position, a less representative sample than a normal PSA. In the horizontal position mixing is important in the process pipe before the sampler. If the majority of particles are smaller than 100 microns (150 mesh) mixing of the process stream is generally good and the sample quality is thus also good.

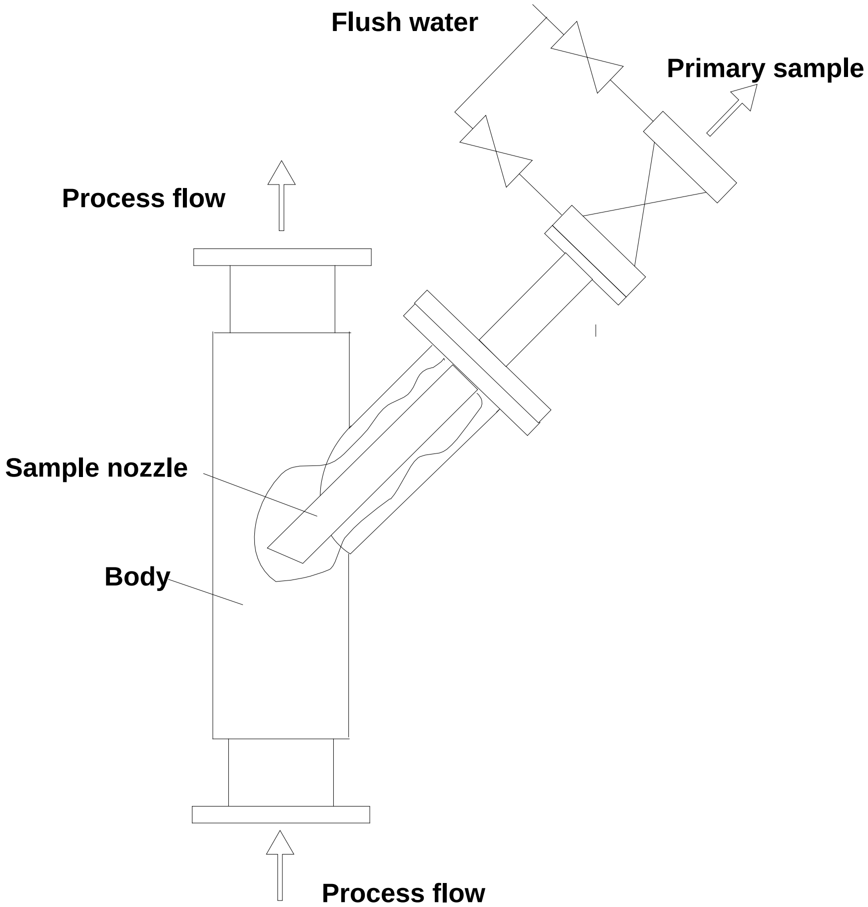


Figure 10. Sketch of straight pressure sampler

ASA Sector sampler

In the case of a very small process flow a major part of the process flow must be taken as a primary sample. In this case a suitable nozzle would be too large to be practical. Instead an internal wall to give a sample cuts a sector of the flow in the vertical sampler. One fourth or more of the original process flow can be taken in this way.

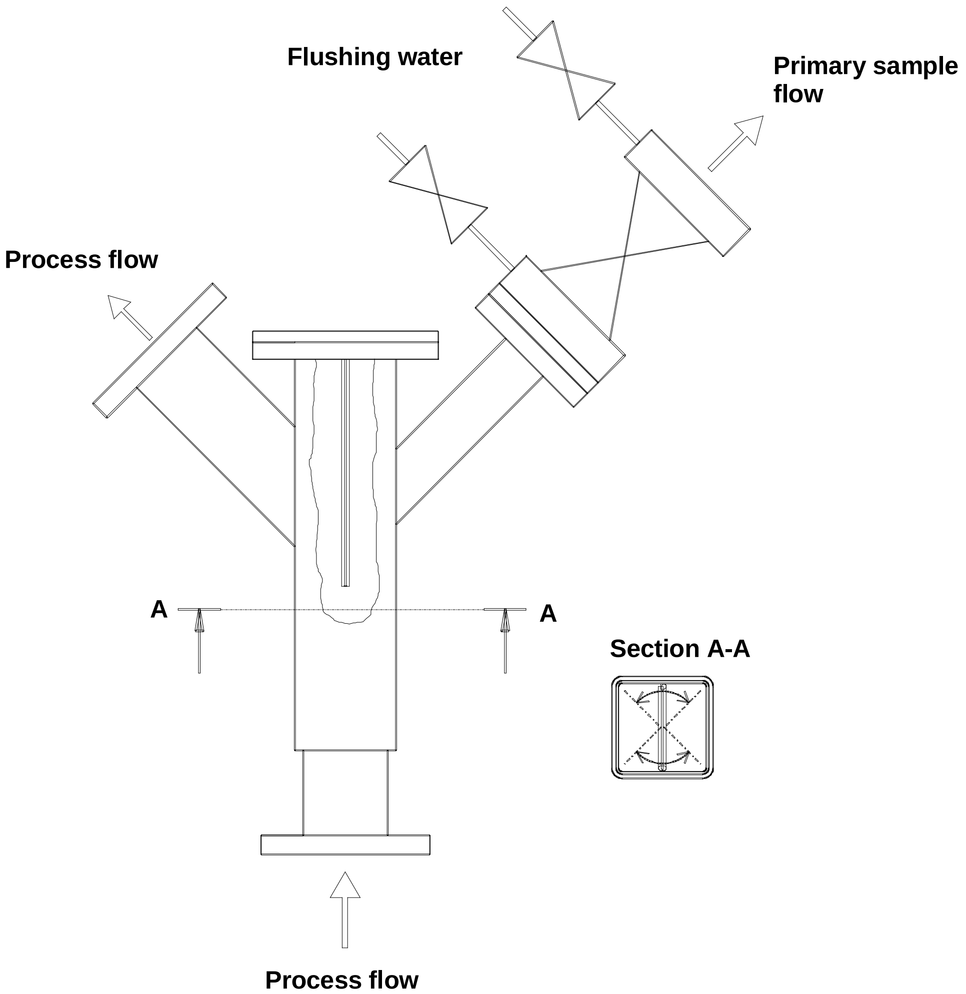


Figure 11. In the ASA sampler a vertical plate halves the flow or a vertical V-shaped plate quarters the flow.

SPA Suction pipe sampler

TYPICAL APPLICATIONS

- feed boxes with several inlets
- tank cell discharge or intermediate box

The suction pipe sampler is used when other standard samplers cannot be used. A pipe is inserted into a well-mixed vessel and a sample extracted with the pipe. If there is a direction of flow in the vessel, isokinetic sampling is approximated by directing the opening of the pipe so that the direction of the flow in the vessel is into the pipe opening. The pipe or nozzle is preferable directed downwards so that the nozzle is not filled with solids if the sample flow is cut off. A valve set (VSA) should always be installed.

If the majority of the particles are smaller than 100 microns (150 mesh) segregation of the sample, when it is sucked into the nozzle, mixing of the process stream is generally good and the sample quality is thus also good. How well the sample is mixed in the vessel is however always a concern.

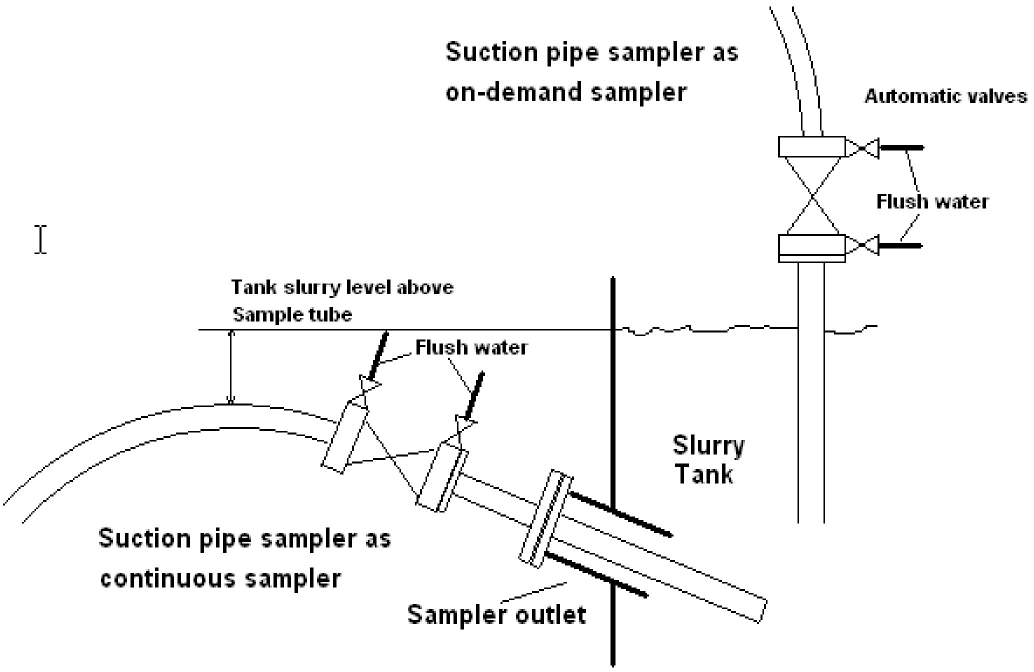


Figure 12. Two installation examples of the SPA

If the sampler is used to take a continuous sample, the sampler and the sample pipe should over its whole length be under the slurry level of the vessel from which the sample is taken. Otherwise the sample flow will not start and if it is manually started, by filling the sample pipe with water, it will normally slowly stop.

With controlled sampling suction can be used and the sample taken over the edge of the tank. The tank needs no sampler outlet. The sampler can be taken out and serviced at any time.

4.4 Composite sampling

Vacuum Filtering Unit VFU

The multiplexer of the Courier can take composite samples of all streams. A very convenient unit for collecting and filtering the composite samples is the vacuum filtering unit VFU. Each unit can filter all six samples from one multiplexer and the optional vacuum pump unit can serve two vacuum filtering units.

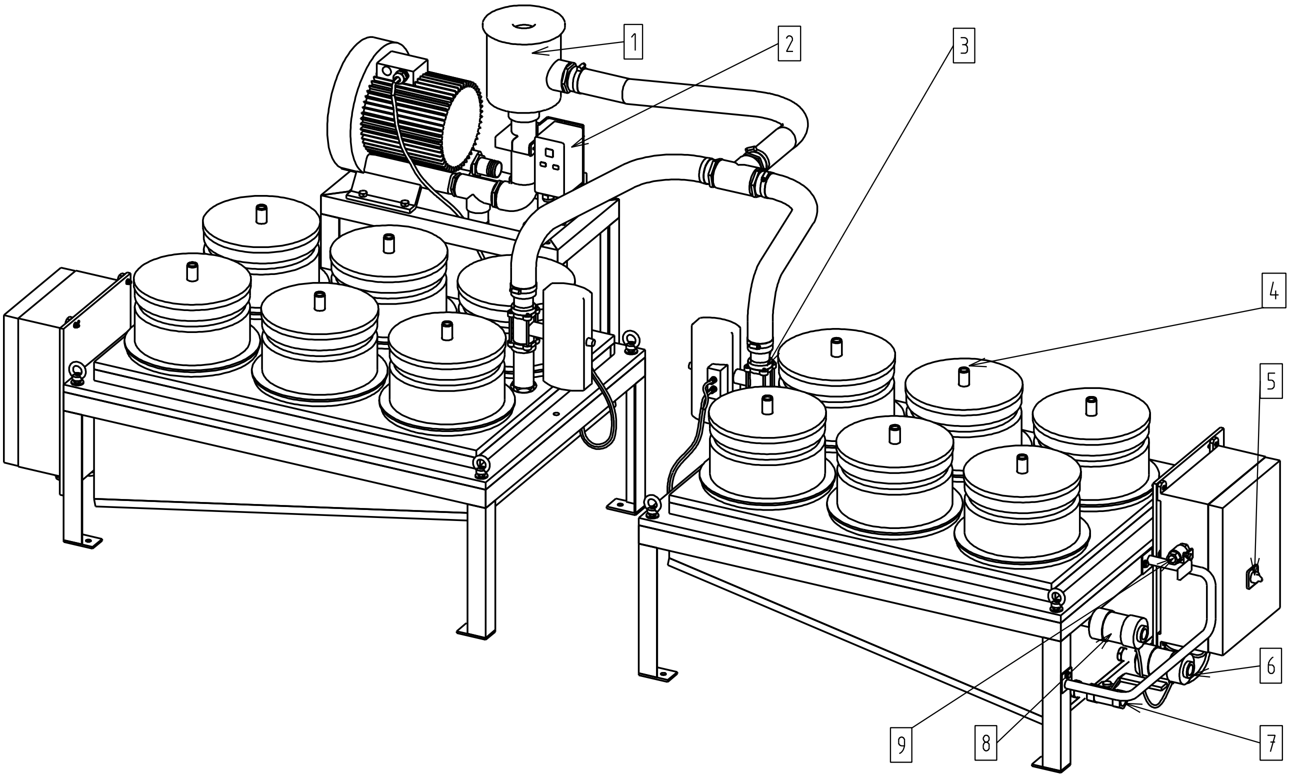


Figure 13. A configuration of two Vacuum Filter Units for drying twelve composite samples. Vacuum Pump Unit behind the Vacuum Filter Units. 1:Suction air filter element (inside); 2: Motor starter; 3:Suction valve; 4:Sample inlet; 5:Maintenance switch; 6:Drain valve: 7: Manual drain valve; 8:Relief valve; 9:Instrument air inlet

Flexible hose sampler SSA 50

For composite sampling systems with no multiplexer in use a flexible hose sampler with similar characteristics as the multiplexer composite sampler has been developed.

Figure 14. The flexible hose sampler followed by a one pot vacuum drying unit.

LMC moving cutter sampler

This sampler is an alternative to the previous one the SSA 50 when a final composite sample is taken without a multiplexer. Depending on its size the primary flow can be larger than for the SSA50. It has a linearly moving cutter across the stream. It requires less head than the SSA50

The LMC 80Is used to take composite sample from 9 - 30 m^3/h (150 to 500l/min) flows with moving cutter

The big LMC 150 includes two-stage sampling and can take a composite sample from streams up to 120

m^3/h

Inlet can be rotated in all horizontal directions. A vertical inlet is also possible

They can also be used to take continuous samples for an analyzer from streams 36 - 200 m^3/h

Figure 15. LMC 80

Figure 16. LMC150

4.5 Multi-stage Metallurgical Slurry Sampler MSA

Outotec's Multi-stage Metallurgical Sampler provides a truly representative slurry sample for metallurgical accounting and on-stream analysis. The sampler operates automatically and offers high availability with low maintenance.

Operation of the sampler is based on a combination of static cutters followed by moving sample cutters. Volumetric flow is reduced by static multi-cutters and moving multi-cutters to a suitable size for final metallurgical sampling. Additional sampling stages are added, as necessary, to meet the requirements of higher process flow rates.

The sample from the crosscut sampler is a continuous flow of about 150 l/min suitable for a Courier® analyzer. (Single cuts at intervals also possible.) The final composite sample is taken by a flexible hose sampler from this flow in the Courier® on-stream analyzer multiplexer or in a separate standalone composite sampler unit.

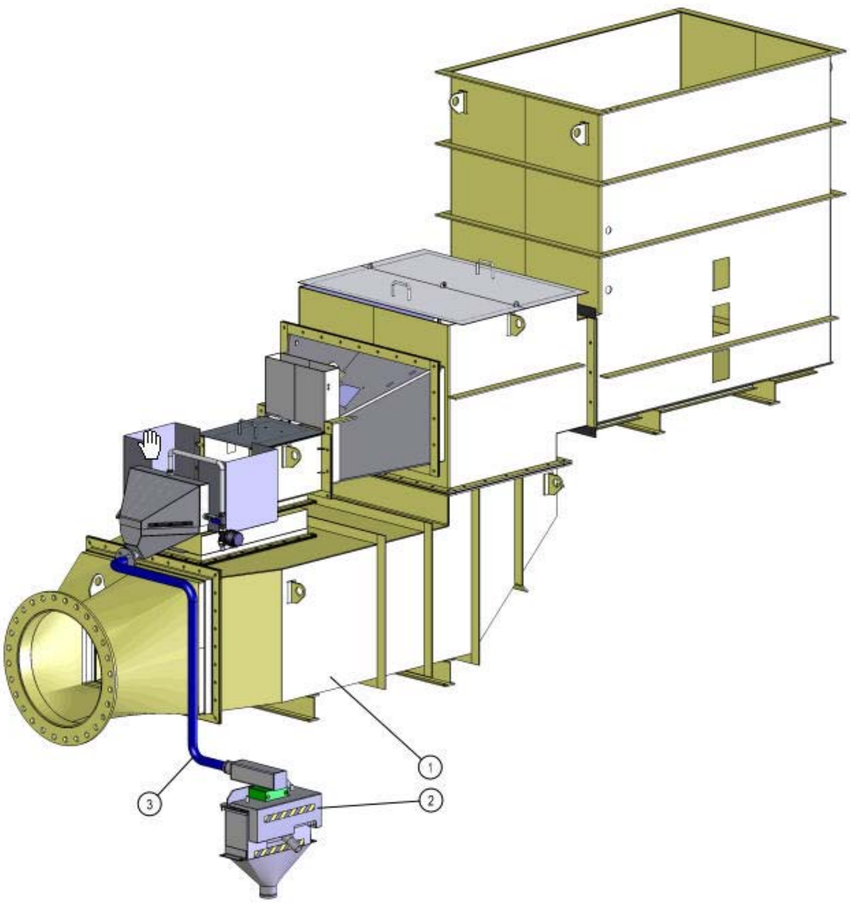


Figure 17. MSA2/80 followed by a LMC80

The incoming flow to the sampler should preferable have a speed of 2.5m/s or more. If two streams are to be joined before the sampler the preferred way is to use a Y-piece in front of the sampler or a separate box in front of the sampler. The two arms of the Y-piece should be on top of each other to enhance their mixing.

The process flow drops into a launder under the sampler if the flow continues into a pipe as in fig.17. This pipe must be big enough and be inclined enough so too much head is not developed in the launder under the sampler causing overflow and splashing.

The preferred way is to eliminate the launder under the sampler and drop the process stream straight into a sump for further pumping.

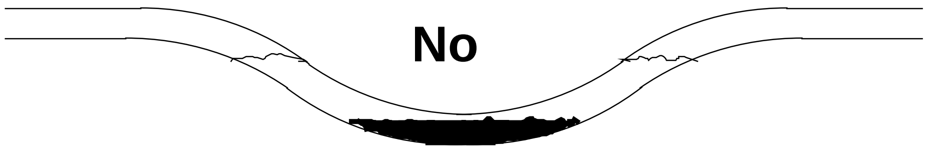
5. TO ROUTE THE SAMPLE TRANSPORT PIPE

The route of the sample transport pipe has a decisive influence on the wear of the pipe and its tendency to get blocked. Blockages may be due to three causes: impurities, settling of the slurry when the sample flows and settling of the slurry when the flow stops.

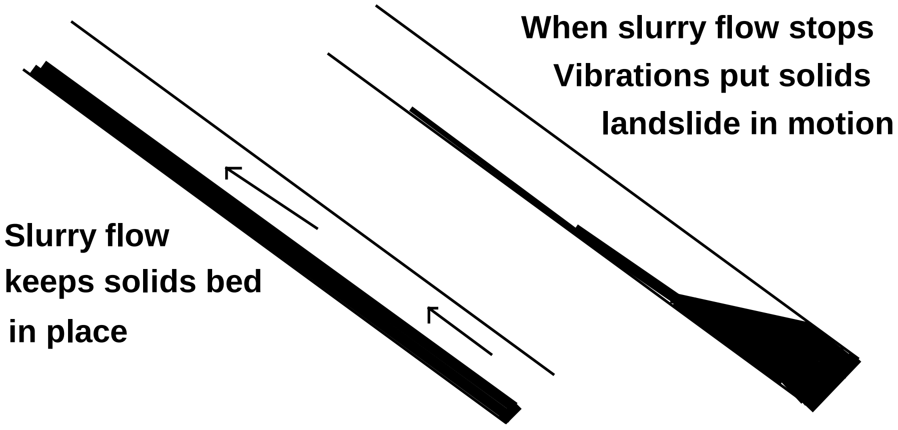
Sample pipes can be of two kinds; pressure pipes and gravity pipes. Pressure pipes run full and the pressure within the pipe can be negative or positive. In gravity pipes the slurry runs at the bottom of the pipe downwards by gravity and the top is filled with air at ambient pressure.

5.1 Principles of selecting the slopes and route of pressure pipes

If the pump stops, maybe the supply of electricity is lost; the pipe should drain as well as possible. The slurry should flow out to empty the pipe. No sagging of the pipe is allowed. Any slurry, left in the pipe, will settle, causing an obvious risk of blockage. As the pipe is seldom ideally supported, the practical **minimum design slope is about 2** %. However often horizontal cable trays are in practice used for sample pipes. Often they work in practice.



Care must be taken to ensure that the slurry, which has settled on the bottom of the pipe, will never shift in a "landslide", because this would result in a blockage. The most dangerous moment is when the uphill flow stops and the friction of the slurry against the solid bed is lost.

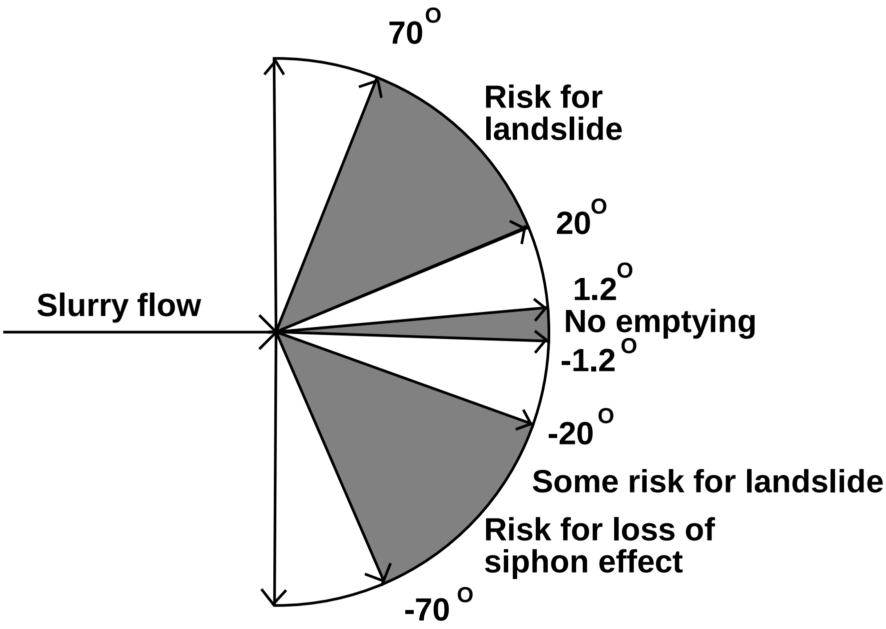


The pipe must be either **nearly vertical** (so slurry cannot settle during flow) or **nearly horizontal**, having a slope of less than 20° (35%) (So solids on the bottom will remain immovable). A downstream pipe may have a steeper slope because the solids will not settle so easily on the bottom of the pipe. However, the downstream slope should be the same throughout the length of the pipe or it should get steeper towards the end.

Air in the slurry causes a different problem. If a negative pressure condition occurs at any point in the pipe, the air will expand and the effective specific weight of the slurry is reduced. The upper part of a pipe followed by a steep downward slope is often such a point. In such cases, the siphon pressure created by the slope is easily lost. It may prove difficult for the air to move downwards, and it gathers in the upper part of the pipe. In the end there will be gravity flow in the steep downstream slope.

Steep downstream slopes must be avoided if the siphon effect of the pipe is to be utilized.

If the siphon effect is not to be used a breather at the beginning of the down slope and a change to a bigger sized tube will make sure that the last down slope end of the tube has gravity flow. This is a better solution than not knowing what kind of flow there will be.



The grey areas are the ranges of pipe slope to avoid when the slurry flows out of the centre of the circle. Slope is in degrees.

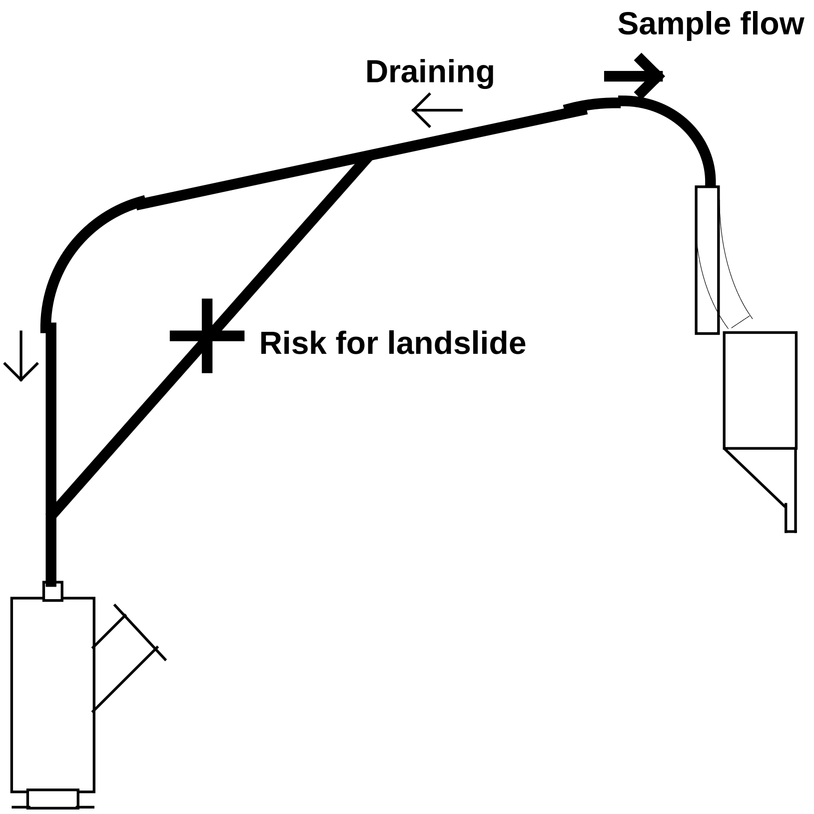
It is sometimes difficult to follow the above rules, for example, a suitable route just cannot be found. **In this case it is advisable to use controlled sample transport**. The controlled sample transport pipe is for the most time empty or filled with water. Thus if the pump stops for any reason during this time there is no solids, which can settle and cause blocking. On the other hand, regular flushing of the pipes prevents the formation of layers of solid material on the bottom of the pipes, thus reducing the risk of "landslides". Controlled sampling does help some in the loss of the siphon effect caused by air in the pipe. The siphon effect is regularly re-established, when the pipe is flushed and filled with water.

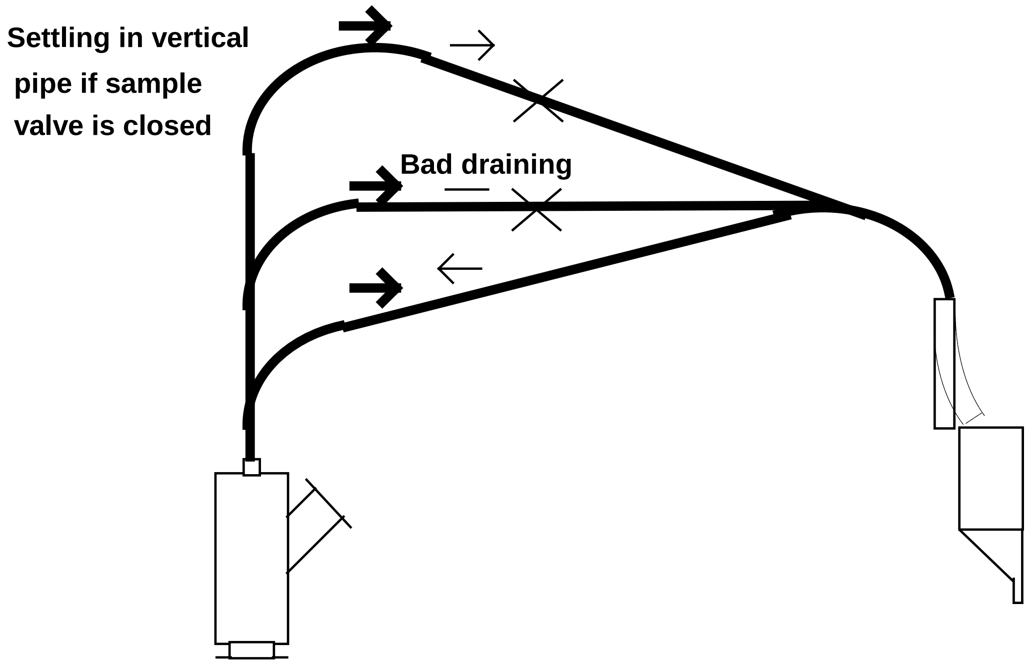
If the pump stops when sample flow is on, even with controlled sampling, the risk of blockage is still present. For this reason, it is always preferable to follow the above rules as far as possible.

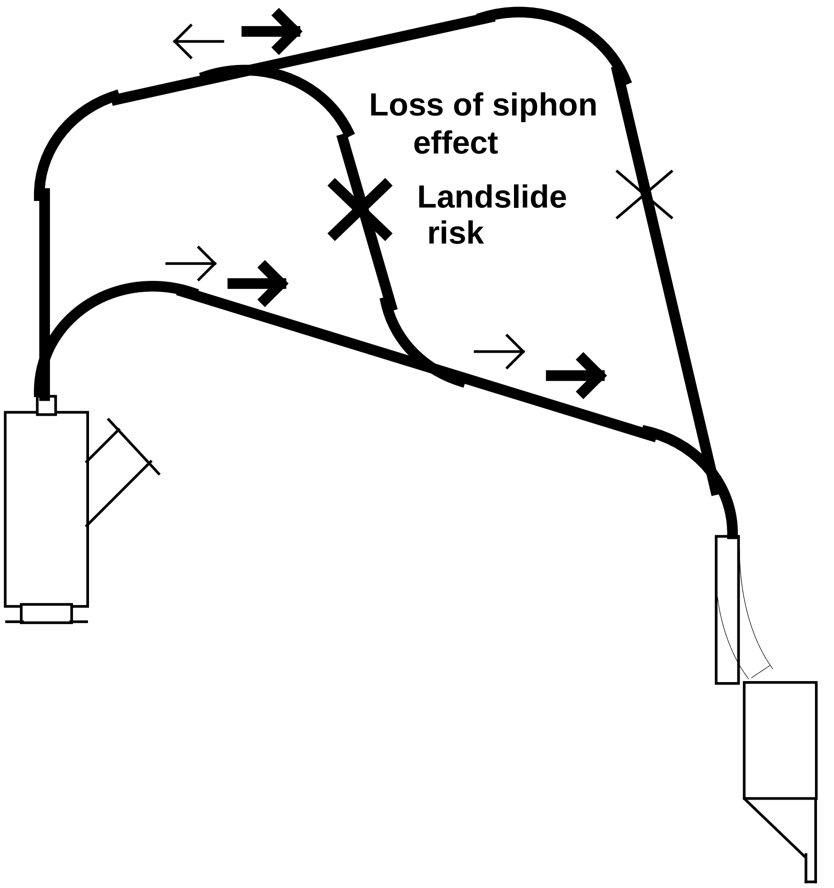
Examples of pressure pipe routes

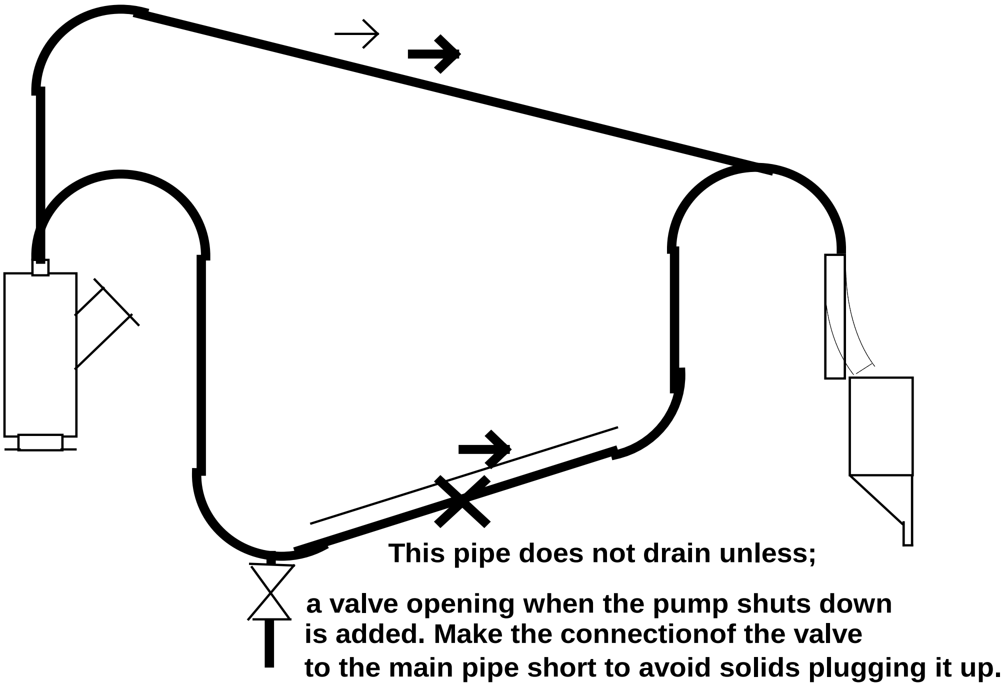
Each of the diagrams on the following pages shows at least two route alternatives, a good one and a less good one. The following symbols are used in the figures:

- Direction of slurry flow
- Direction of emptying of pipe
- Emptying of pipe not guaranteed
- Forbidden Routing
- Undesirable routing to be avoided

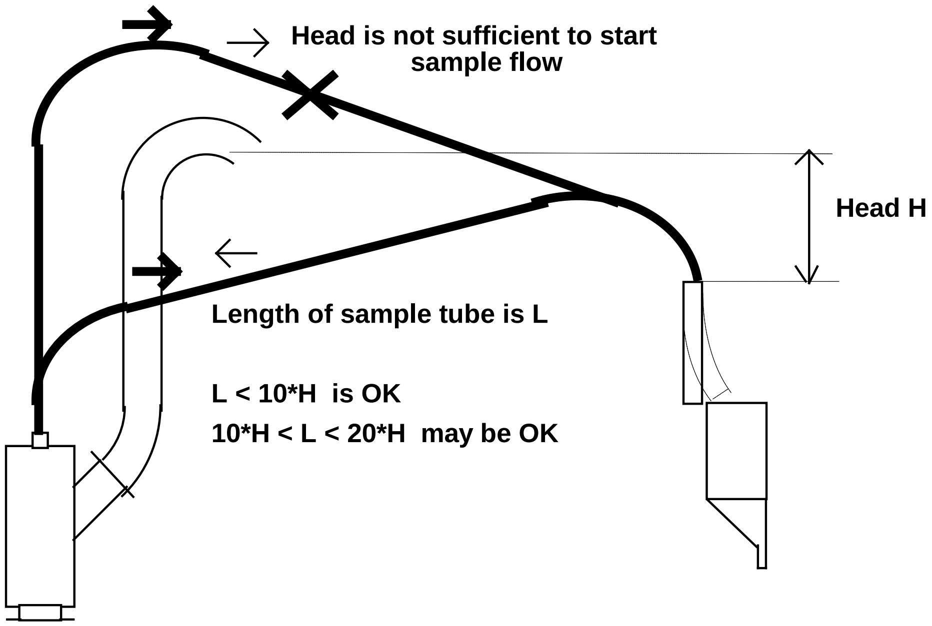



Settling in vertical
pipe if sample
valve is closed
Bad draining


Loss of siphon
effect
Landslide
risk



5.2 Pressure pipe pressure requirements and route



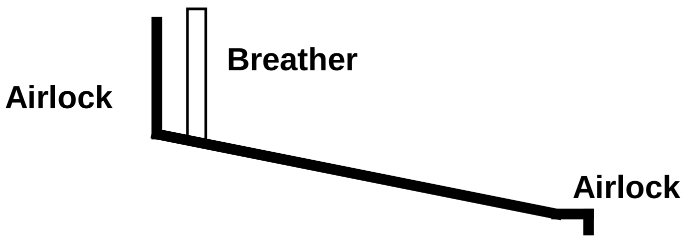
The sample pipe should at no point go too close or higher than the zero pressure point of the process pipe; otherwise the sample flow will not start. Because the sample pipe is smaller, it has a very much higher friction than a process pipe. Thus the head should be at least 10 % of the sample pipe length to assure a reliable flow. A 5 % head can sometimes be enough under favorable circumstances. A sampling engineer can decide if the head is sufficient.

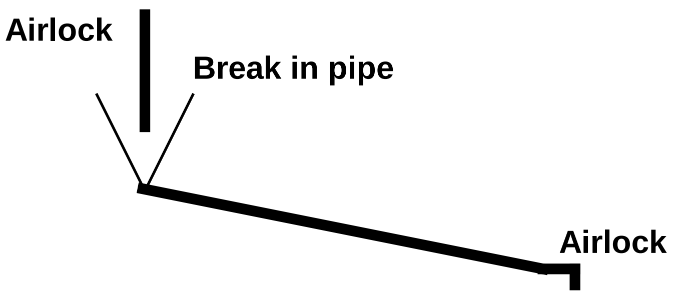
5.3 The route of gravity lines

A gravity line is by definition "a pipe in which the slurry at all points is at ambient pressure". The pipe is continuously sloping down so that gravity gives the energy to overcome the friction of flow. Changes in flow velocity caused by changes in slope cause a varying thickness of slurry flowing on the bottom of the pipe. This assumes that air can freely move about in the upper part of the pipe to accommodate the varying thickness of slurry.

However, airlocks that stop the flow of air are easily created in small diameter sample pipes. If the pipe is open at both ends to air, one airlock is generally not serious but if there are two such airlocks, the section between the two airlocks can become an unwanted pressure pipe.

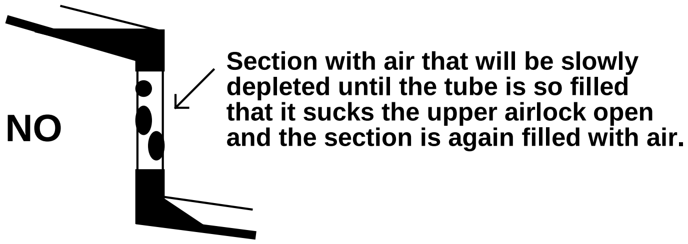
A breather pipe can of course be installed between the two airlocks preferable close to the upper one. These breather pipes have however a tendency to clog up unless they are regularly cleaned and flushed. A clear break of the pipe might be a better solution.





Reasons for airlocks

Sharp bends

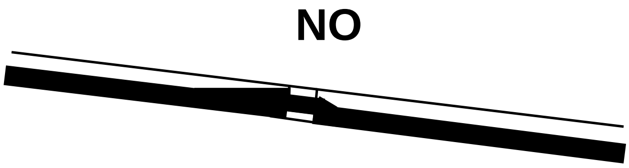


Vertical section between two airlocks can lead to surging, producing oscillating flow. The sharp bend forms an airlock because additional energy is required to quickly change the direction of flow.

Horizontal section

To get the slurry to flow through a pipe sloping upward or a horizontal or nearly horizontal section of the pipe, some head is required. This means that the pipe fills up. A down-slope of 5 % is generally the minimum requirement to avoid this type of airlock.

Internal pipe joining piece



If pipes are joined by using a short piece of smaller diameter pipe, the cross-section of the pipe is easily halved at that point. A half or more full pipe will then be completely filled at that point

LSA sampler full with slurry

This situation is to be avoided otherwise no air flows into the cutter. This easily leads to the whole sample pipe becoming a pressure pipe. This makes the slurry flow rate too high if a normal gravity flow pipe size has been used. To correct the situation the sample pipe has to be selected smaller in diameter than otherwise. It is engineered as a pressure pipe. An alternative solution is to add a breather pipe close to the cutter.

Flow de-accelerator on top of multiplexer

This is a unit used to fill the multiplexer hose to reduce the speed of the slurry hitting the screen in the multiplexer. It acts, then, by definition as an airlock and to maintain proper gravity flow, no other airlocks are allowed.

6. INSTALLATION OF PIPE

6.1 Recommended sample pipe

The sample pipe must be made of a wear resistant material. The pipe must be smooth on the inside. It is recommended that a **high-density polyethylene (HDPE) pipe** be used.

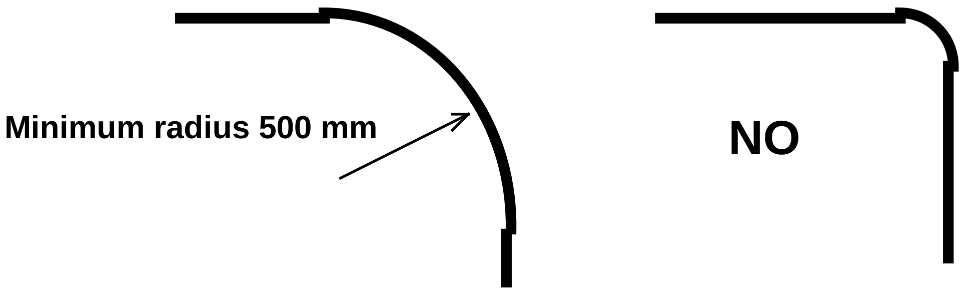
For smaller pipe sizes coiled pipe can be used. It is however difficult to get the pipe completely straight without heating. The number of joints along the line should be minimized, and the pipe must not be bent beyond its flexible range.

The inside diameters of the pipes vary between 26 and 50 mm for pressure pipes. The most common standard sizes (inside diameter) are 32 and 41 mm. Gravity pipes are generally 55 mm but larger pipes can be used.

6.2 Pipe curvature

To minimize wear, the radius of the bends in the pipes should be at least 500 mm, preferably more.

THE STANDARD READY MADE BENDS FOR WATER AND SEWAGE PIPES MUST NOT BE USED.



6.3 Contractions in pipe diameter

Normally, no contractions in the diameter of the transfer pipe are allowed.

REDUCING THE SLURRY FLOW BY THROTTLING IS FORBIDDEN.

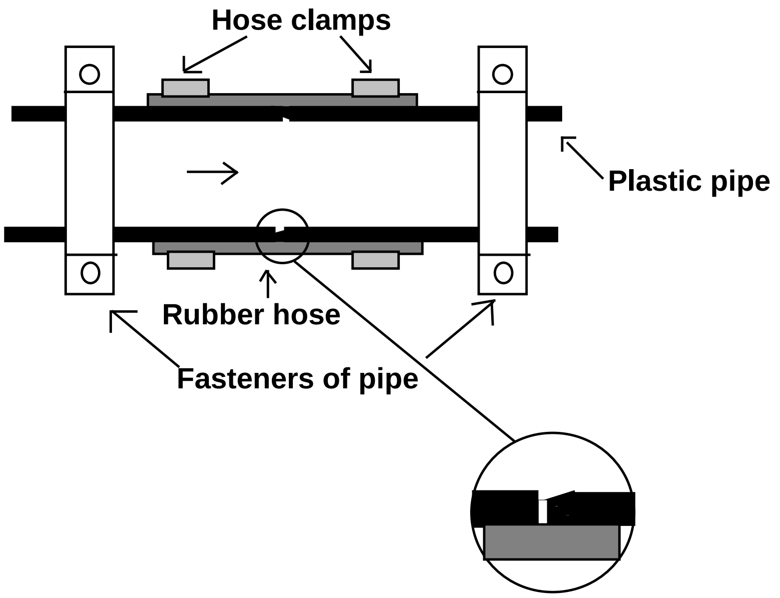
At the throttling point, the wear increases dramatically as does the risk of blockage. Diameters exceeding the normal diameter of the transfer pipe are allowed, but even then the wear increases at the point, where the diameter is reduced to its normal value.

6.4 Installing the pipe

The way in which the pipe is installed is also important for a trouble free operation of the sample line.

It is important that the **pipe is properly installed and supported**. Because of the centrifugal forces, pipe bends should be well fastened on both sides of the bend. Special attention should be paid to the multiplexer connection. A pipe with a small angle of inclination must be adequately supported to prevent sagging. It may even be necessary to provide the pipe with a continuous angle iron support or with supporting brackets placed at distances of some 60 cm from each other.

Pipe joints can be simply made by using a length of flexible hose of a suitable size to accommodate the plastic pipe inside it. Insert the plastic pipes end to end inside the flexible hose and fasten them with hose clamps on both sides of the joint. Commercial couplings essentially making similar joints are also available Anchor the pipes on a support on both sides of the joint. In the event of pipe blockages, this kind of joints can be dismantled and reassembled to allow the pipe to be cleared. Welding have been used to make joints of a more permanent nature, but are not recommended due to the risk of blockages caused by this method. (See two pages down)



6.5 Avoiding pipe blockages

Blocking of pipes can be caused by solids settling in the pipes or by foreign objects. Settling can be avoided by using sufficient flow speed and by a good pipe route as explained in previous sections. Foreign objects are another matter.

Foreign objects can be of several kinds:

1. **Volume objects**. Seldom stones cause blockages in pipes (Cutters are a different matter) more often lighter substances like rubber and plastic can be the culprit.
2. **Long stiff objects like wooden sticks or pieces of metal wire**. These pass through the pipe well if they are parallel with the flow-lines, but if they are longer than the pipe diameter and turn across the stream they easily get stuck.
3. **Soft objects like plastic sheet or threads.** These seldom are the primary cause of blocking but often wrap around objects in their path, like long stiff objects and cause the final blockage.

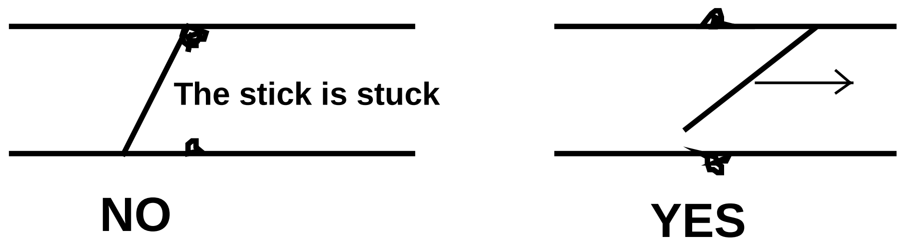
Volume objects

Volume objects are removed by screening. Large objects can get stuck at points where the flow channel is reduced, like going from a PSA nozzle into the sample pipe. The rule is to make that reduction easily accessible. So, in the PSA, the valve should have an opening at least equal to the nozzle size and the reduction in size occurs after the valve. Thus the valve can be closed and the blockage found after the valve, where it is easy to remove.

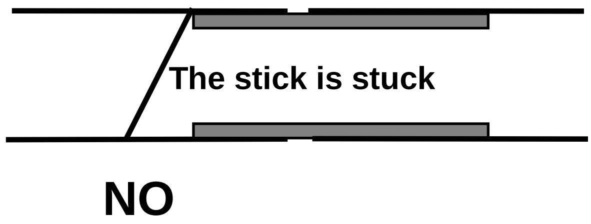
Long stiff objects like sticks

Long stiff objects generally follow the flow quite well. The end of the object can scrape against the wall, but will continue its path unless the scraping end finds a step that stops its movement. The object then turns across the stream and easily gets lodged. These blockages typically occur at pipe joints and constrictions.

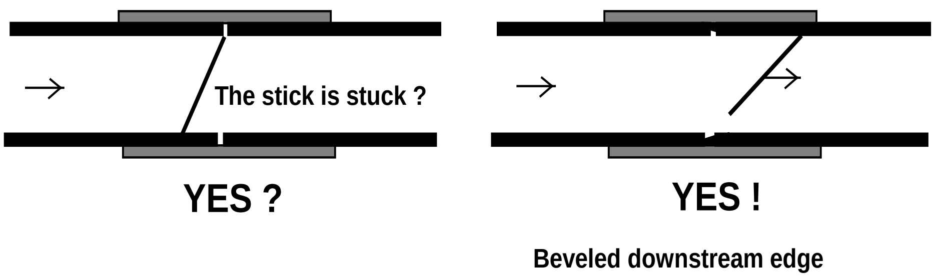
Welded butt joints



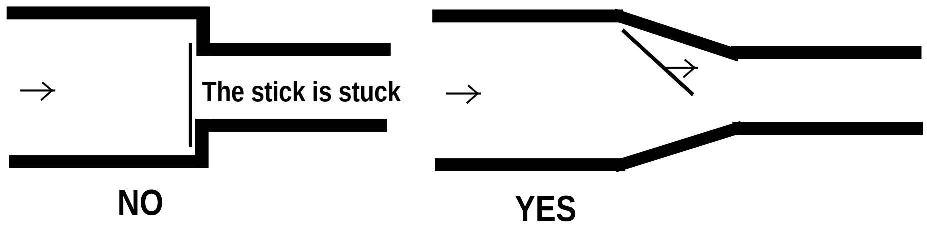
Internal pipe joints



External pipe joints



Pipe diameter contraction



7. SAMPLE FLOW RATE

7.1 Sample flow rate requirements

When the sampling system has been installed and has been started up, the sample flow rates should be checked that they fulfill the requirements below. The flow rates should in all cases be recorded and reported back to the person who has done the sampling engineering. If the requirements are not fulfilled something should be done about it with or without the help of the sampling engineer.

Analyzer

The minimum primary sample flow rate is determined by the slurry flow used by the analyzer. The minimum flow-rate in the table already increases the cycle time of the COURIER.

At maximum flow there will be unwanted splashing in the multiplexer and depending on the abrasiveness also wear in the multiplexer. The multiplexer inlet must be well filled to reduce the velocity of the slurry. To reduce the velocity often a flow de-accelerator must be used to couple the sample pipe to the multiplexer.

Table 3 Primary sample flow in l/min for different analyzers.

Analyzer	Recommended	Minimum	Maximum
Courier 5/6 SL	100-200	45	300
PSI 500 Coarse slurry	50-200	40	300
PSI 500 Fine slurry	50-100	40	170
PSI 300	70-200	30	300

Sample transport

The speed of flow in the pipe should be above roughly 1 m/s to keep the slurry in suspension. It must be smaller than 2-4 m/s to keep the wear down. The value depends on the abrasiveness of the slurry. The wear of the pipe depends strongly on the speed of the slurry. The wear roughly increases as the square of the speed.

The speed is directly proportional to the flow-rate for a fixed pipe diameter. The speed can be calculated after the flow rate has been measured and compared to the values in the table below. If for instance the flow-rate is two times the value in the table also the speed is two times 1 m/s.

Table 4. The flow rate of pipes with different inner diameters, at 1 m/s speed of flow.

Standard inner ∅ mm	Flow-rate l/min	at 1 m/s US Gallons/min
20	19	5
26	32	8.5
32	48	12.5
41	79	21
50	118	31

7.2 Measuring the primary sample flow rate

The primary sample flow rate can be measured by filling a suitable big tank from the multiplexer bypass and by measuring the time it takes to fill the tank. The volume divided by the time gives the flow-rate

A less accurate but more convenient way is to measure the multiplexer filling time of COURIER 5/6/30. When a new stream is going to be measured the multiplexer is first automatically flushed and drained. Then the empty tank is filled with slurry. The filling time, that is the time of the hose in the forward position, can be measured and used as above. The accuracy is not so good for high flow-rates because the tank volume is so small.

For the COURIER 5/6/30AP/XP the multiplexer tank volume is 9 liters with the new vibrator level sensor. The reaction delays of the hose are about 1.25 seconds. The multiplexer tank drains through the bypass hose with a rate of about 40 l/min. The bypass flow should also be measured. See table 5.2.

Table 5. Estimating the flow rate with the filling time.

Filling time T seconds	Bypass flow B l/min	Total sample flow Q l/min
30	40	59
20	40	70
15	40	81
10	40	105
6	40	160
4	40	250
3	40	360

Q = (9*60/(T-1.25) + B) l/min

COURIER 5/6 calculates the primary sample flow rate automatically based on the filling time of the sample tank. The measurement has only to be enabled. The sample flow-rate is displayed on the local display and the Operator Station main display.

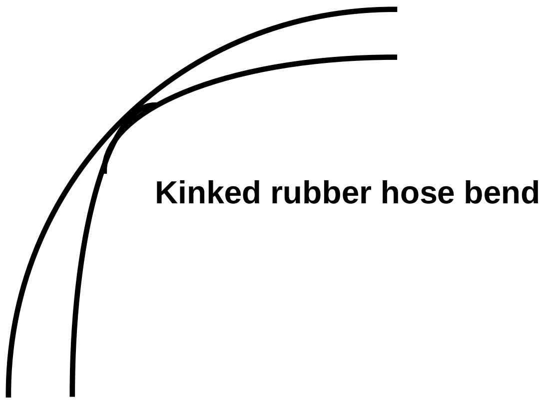
Courier 5/6 produces warnings for the operator for the low and high flow- rates according to the parameter settings.

7.3 What to do if the primary sample flow rate is not as required

Sometimes the sample flow rate is not within the recommended range. There can be many different reasons for that: Temporary problems like blockages, errors in the installation, or errors in the engineering or the data on which the engineering is based. In the following are a few situations and some tips of what to do. If in doubt consult the sampling engineer.

Flow does not start

First check that valves are open and the sampler cutter is not blocked. Rubber hoses can be kinked in curves and/or due to negative pressure. Use always rubber hoses that can withstand vacuum also.



Next check that the sample pipe on its way to the multiplexer does not go above the available head. Compare picture on page 31.

Flow starts well but slowly drops to a low flow and often stops

A typical reason is that solids settle on the bottom of the pipe and constrict the pipe. Flow speed is not high enough compared to the settling rate of the slurry. Head should be increased or the sample pipe shortened. In many cases a pump is needed. Regular flushing with the controlled sampling feature is also one possibility to rectify the situation.

Sample pipe has been designed for pressure flow

The sampler is typically a PSA, HPSA, SCS or SPA. The sample pipe includes a steep slope down in which the flow changes slowly into gravity flow. An air leaks in from the outlet or the air comes from the slurry itself.

If the air comes from the outlet a flow de-accelerator or other airlock can be added. If the air comes from the slurry itself the only way is to decrease the slope, so that no air is collected or controlled sampling is used.

Often the flow finally stops, because the solids settle and block the pipe.

Sample pipe has been designed for gravity flow

The sampler is typically a LSA, NLA or SKA. Settling of the solids is probably the reason. Suspicious places are horizontal or near horizontal parts of the pipe. In these parts the pipe fills up and turns into pressure flow. The flow can be too slow. A more continuous slope is better or controlled sampling can be used.

Pumped pipe

If in the front of a horizontal pump there is no sump the pump can suck the rubber hose sample valve close. In this case the speed of the sample pump must be decreased to reduce flow and negative pressure at sample valve.

Too small sample flow from the start

This indicates that either some mistake has been made in the engineering or the installation has been done in a way not intended by the engineering. Sometimes the sample flow has been designed to be rather small because the process flow is very small. These situations must then often be accepted.

Compare the installation and the engineering design and the data the design is based on. Make any easy corrections to the installation. Consult the sampling engineer.

Look for constrictions in the pipe and eliminate them. Such are partly deflated hose bends and "Internal pipe joints", see pages 38-40.

If no easily corrected mistakes can be found and the pipe is a pressure pipe you can follow the procedure in section 5.4

Too high sample flow

Do not reduce the flow with the sampler valve or by any other short constriction.

The flow velocity will be very high at the constriction and the wear will also be very high.

Sample pipe has been designed for pressure flow

The sampler is typically a PSA, HPSA, SCS or SPA.

Do not constrict the flow by reducing the nozzle.

In addition to higher wear of the nozzle the isokinetic sampling will be destroyed and the sample representativity will go bad for coarse samples.

The right way is to decrease sample pipe diameter or make it longer to increase the friction. See section 5.4

Sample pipe has been designed for gravity flow

The sampler is typically a LSA, NLA or SKA. One very common reason is that the process pipe or launder is so full that the cutter acts as an airlock and turns the sample pipe into a pressure pipe.

Do not reduce the cutter opening.

That destroys the isokinetic sampling. The cutter would have to be made very small to decrease the flow. That increases the wear and the tendency for the cutter to get blocked.

The effect of the airlock can be eliminated in the way described on page 33 in section 3.3. However if there is pressure at the sampling point this might not help, but the tube must be treated as a pressure tube and corrected according to section 5.4

If the process flow is higher than the flow used in the design of the cutter, and the sampler or launder is not too full, then the cutter opening can be adjusted narrower in LSA and NLA types (DN 100 to DN 350) and also in SKA samplers to decrease sample flow.

If the sample flow originally was about right, but the flow has increased with time, then the cutter probably has been worn wider and needs to be replaced.

7.4 Changing primary sample flow rate for pressure pipe

The normal way to change the flow-rate is to change the primary sample pipe to a bigger size for more flow or a smaller size for less flow. The error in the pipe size can be caused by wrong information about the sampling point, its pressure or air-content for example. The speed of the flow will not change much. To change the speed of flow either the length of tube or the head must be changed.

If there is too much flow from an LSA there is usually in practice pressure at the sampling point, but no pressure was assumed in the design. Sometimes the LSA can be moved to a better point but often the easiest solution is to treat the sample pipe as a filled pressure pipe and change the pipe size as explained below.

EXAMPLE

The flow rate in a 26 mm pipe is 100 l/min. This flow is 3 times the flow in the table 5.2.1. Thus the speed is also three times higher, that is 3 m/s, which is pretty high.

Too change the flow rate and speed there are two methods.

1. The next bigger pipe size will roughly double the flow rate and increase flow speed with 10 %.
2. If the ratio H/l, sample pipe head to length, is decreased with a factor of two flow rate and speed will both be reduced by roughly a factor of 1.5.

After both these changes, both the flow speed and flow rate are within target specs.