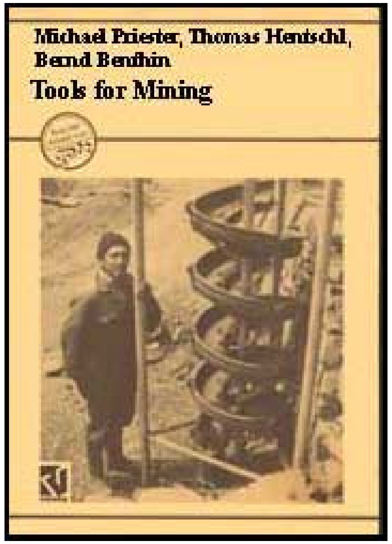


Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

C. Surface mining

C.1. Definition

Like underground mining, surface mining involves the production of mineral raw materials. In the latter, production takes place at surface. Surface mining processes solid rock, loose rock and alluvial deposits. Production takes place on the land surface as well as in rivers and seas, free of deep sea mining. The production activities in surface mining particularly alluvial deposits with heavy and precious metals, entails mainly the processing of products although here an attempt is made to contribute to an improved system through a strict separation

of areas of activities. In the areas of production and hauling, and in draining, various techniques are applied which are used as well in underground mining. A renewed discussion of these devices will not be undertaken in this section.

C.2. Initial conditions and problem areas

A number of different types of deposits are found even in the limited field of alluvial precious metal deposits. This brings about various problems in mining production, particularly in processing.

The following are the most important of those alluvial deposits which have exploitable deposits of gold, as well as tin and tungsten, zircon and sand and gravel minerals and which are appropriate for small-scale mining:

- **recent fluviatile sediments in riverbed areas. This type of deposits is common in the Andes. The high morphodynamic in this mountainous region with its erosion and sedimentation, accounts for a recent genesis of rich precious metal deposits. These unconsolidated loose sediments either are exploited under water using dredges or suction dredges operating directly from the river. During the dry season, or when the riverbed is generally dry as a result of the diversion of the river, these are mined manually or mechanically with shovels, wheel loaders etc. Examples are the riverbed alluvial deposits of eastern scarp of Bolivia's Andes such as the Rio Tipuani, Rio Mapiri, and Rio Kaka. Analogous to the above mentioned gold deposits, recent fluviatile alluvial tin deposits are exploited, e.g. on the Rio Huanuni, Dept. Oruro, Bolivia. After 500 years of mining history, these deposits additionally exhibit anthropogenetic characteristics 1(natural erosions**

from anthropogenous forms such as waste deposits, tailing ponds).

- fluviatile fossil placers and terrace deposits. Being older geological formations, these Palo- frenches (sediment filled old V valleys) and graded terraces are often already solidified. Due to the high mobility of cementing minerals as a result of the climatic conditions of the tropics, even recent accumulations are already solidified. This causes difficulty in mining, and particularly in processing when only liberated feed may be worked upon. Fossil placers of this kind are frequently overlapped with more recent sediments which marks the transition to underground mining. Provided that sufficient quantities of water are available, these alluvial deposits are exploited either hydromechanically by monitors, manually or mechanically. Examples are the gold deposits in the Cangalli series, e.g. Molleterio, Dept. La Paz, Bolivia.

- glacial und fluvioglacial alluvial deposits, moraines and sediments in the pleistocene, that is, recent glaciation of the Andes. Being sediments which have been exposed only to a short and purely mechanical transport devoid of a natural concentration through separation or chemical re- grouping, these alluvial deposits usually contain relatively marginal tin and tungsten deposit. As a result of the negligible natural size reduction to which the material has been exposed, the ores are extensively unliberated. Accordingly, the processing of ores of this kind must also involve crushing and grinding. Otherwise the sediment is usually unconsolidated and is mined using manual or mechanized methods of open-pit mining Example: El Rodeo, Cord. Quimsa Cruz, Dept. La Paz, Bolivia.

- mineral bearing rock slides, llamperas. Inferior forms of heavy mineral alluvial deposits exhibit mineral bearing fell rocks which, analogous to glacial alluvial deposits, are unliberated and partly in huge blocks. After it is produced using a mining method (drilling and blasting), the material is processed in a manner similar to an ore exploited underground. The tungsten bearing fell rocks of the Cerro Chicote Grande, Dept. Oruro, Bolivia, which is mined by the Cooperative Minera Taminani, provide an example.

- anthropogenous deposits such as waste stockpiles, heaps, tailing ponds originating from old production and processing plants. This group of deposits offer a huge potential not only for large scale but also for small scale mining operations.

The following are the reasons behind the wide range of valuable contents of waste deposits:

- the negligible recovery of the processing plants not only of large-scale operations e.g. the COMIBOL in Bolivia with its current output at 40% of the metals but also of small-scale operations,

- the mining of previously rich deposits for centuries for which have left behind comparatively rich waste deposits,

- the mining economy of colonial Latin America which concentrated on precious metals such as gold and silver dumped by-products such as tin, tungsten, among other base metals.

- the sophisticated improved processing techniques which today is capable of, for instance, producing precious metals out of pyrites, led to the conversion of previous waste deposits into new minable deposits.

Today the above-mentioned alluvial deposits constitute an important field of activity in small-scale mining. The significance of these reserves for the national mining industry, and with it small-scale mining, will definitely increase.

Low costs of production, previously crushed material and a reserve situation which, comparatively, can be estimated with certainty, combined with a negligible investment risk, are factors which make these deposits appear predestined for small-scale mining.

Regardless of location, water usually creates crucial problems. In the case of production from a riverbed, besides the high costs of pumping and drying, excess water creates extremely difficult and dangerous working conditions.

To dry it out, the flow of the river is redirected by constructing of flanking dams on one side of the riverbed so that the other side is left to dry and is thus made available for mining.

The yearly turnus of precipitation in the alternating dry and humid tropics characterised by a marked dry and wet season, causes huge fluctuations in the water level: special characteristics of the mesoclimatic specifications in high mountain regions and local precipitations in the catchment area may cause an extreme rise of the river's water level within a short time. The planning of mining is thus influenced significantly by this unpredictable factor.

In the case of production in a dry location, the supply of industrial water requirements of mine and processing plants is particularly a problem. This is especially so when huge quantities of water are necessitated by hydraulic mining methods using monitoring. Such hydraulic mining is often necessary in places where partly a consolidation of materials of alluvial deposits has occurred. These places are usually located high above the draining level and hence difficult to supply with industrial water.

Otherwise, the technical deficiencies of small-scale mining in open-pit mining are significantly lesser compared to those in underground mining. The bigger space requirements of modern technology is not a problem at surface. Production and loading techniques are also available in the countries along the Andes and maybe utilized for the production of raw materials at surface.

As in underground mining, the degree of mechanization of operations dictates production capacity in open-pit mining. The ratio of production of manual-primitive mining to fully mechanized loading and haulage lies at present over 1: 100. In open-pit mining, huge amounts of materials may have to be produced and hauled for negligible raw ore grades. Only through a consequential, step by step partial mechanization is it possible to progress from the subsistence mining of the individual gold digger, from the margins of the subsistence level to a secure existence.

In partial mechanization, the bottlenecks are found in the provision of an energy supply which is reasonably priced and is appropriate rather than in the availability of mining methods (the technology of mining and transport in mining of alluvial deposits is definitely simpler compared to that of the underground mining).

Although it is difficult to draw a distinction between mining and processing in the field of open-pit production, it must be emphasized that critical problems in mining of alluvial deposits in the small and in the smallest scales may be found in the processing. Hence the present work puts emphasis on processing techniques.

C.3. Factors related to environment and health

In many ways, production activities of surface mining have placed a strain on the ecosystem. Apart from the dangers to the environment posed by equipment and vehicles run by internal combustion which produces

- **exhaust fumes**
- **waste oil, and**
- **noise**

open-pit mining disturbs the ecological balance by destroying vegetations and pollution of rivers.

- **Pollution of rivers. Huge quantities of water are contaminated with mud as a result particularly of the open-pit production of alluvial deposit materials from recent riverbeds and the hydraulic mining of alluvial deposits. Usually no purification of the water follows. The effects of the suspended sediment burden endures. In some places, this may extend up to a distance of over 300 km down the river. In irrigated agriculture, the sediment burden renders cultivation difficult. In the dry season, the sludge concentration is especially high and therefore, has serious consequences for people living in areas down the river. On one hand, the quality of**

drinking water, which particularly in lowlands is taken directly from rivers, suffers. Filtration procedures are generally not known. On the other hand, the river fauna is altered or is exterminated as a result of changes in the aquatic environment of the rivers. The consequences are felt not only by fishermen. It is also felt in the supply of food containing animal protein. The river system Rio Tipuani, Rio Mapiri and Rio Kaka in Bolivia presents an example. It can be seen at first glance in which river gold production is being undertaken.

- Dissappearance of vegetation. The huge space requirements of open-pit mining can mean the extensive destruction of vegetation. In the humid tropics that is the climatic region of the eastern scarp of Andes, this has led to the well-known phenomenon of soil erosion (slope sliding, soil flushing, further sediment burden of rivers).

C.4. Pit and quarry industry

Among the raw materials of pit and quarry industry are various minerals and rocks, which are found in the most varied forms of deposits, used in the most varied ways, and which among other things, have extremely differing price values. The nature of mining production, depends on these and other parameters - whether this takes place on the surface or underground - the processing method, the manner of trading, the market and particularly, whether the raw material can be transported. For instance, while highly valued refractory raw materials can pay for their transport worldwide, the construction raw materials can only be marketed within a closeby region due to their low value.

The following overview according to Schneiderhhn lists the main applications of non-metallic raw materials and indicates which raw material can be exploited mainly in open-pit mining (bold and italic):

Light metal ores

Metal ores: Aluminum, Magnesium, Cesium, Rubidium, Potassium, Sodium, Lithium, Strontium, Beryllium, Calcium, Silicon.

Precious stones, gem stones

Salts and fertilizing minerals
Mineral Salt, Potassium Salt, Leucite, Alunite, Saltpeter, Limestone, Gypsum, Anhydrite, Apatite, Phosphate.

Minerals for chemical industry
Sulphur, Halite, Potassium Salt, Limestone, Fluorite, Manganese minerals serving besides of combustibles for producing the basic materials for the large scale chemical industry (Sulphuric Acid, Nitric Acid, Hydrochloric Acid, Fluohydric Acid, Hydroxydes, Ammonia, etc.).

Mineral colors, pen minerals and textile minerals
Iron oxide and hydroxide, Manganese, Cinnabar, Gypsum, Rutile, Baryte, Mica, Graphite, Chalk, Scapstone, Greenstone, Brown Coal.

Lubrication and polished minerals
Graphite, Talc, Pyrophyllit.

Refractory minerals

Quartz, Quartz sands, Graphite, Chromite, Bauxite, Dolomite, Magnesite, Asbestos, Andalusite, Olivine, Cyanite, Dumortierite, Soapstone, Zircon.

Flux minerals

Quartz, Fluorite, Greenland Spar, Apatite, Limestone, Dolomite.

Minerals for electric and thermal insolation

Asbestos minerals, Talc, Serpentine, Sea Foam, Soapstone, Mica, Amber.

Grinding and polishinq minerals

Diamond, Corundum, Emery, Garnet, Quartz, Honestonequartzite, Grindstone-Rock, Red Iron Ore, Diatomaceous earth, Triplit.

Optical minerals

Halite or Mineral Salt, Fluorite, Double Spar, Quartz Cristalls.

Bleaching and absorbent minerals

Allophan, Bolus, Bentonite, Fullers Earth, Diatomaceous Earth.

Minerals for ceramics, cement and glass industry

Kaolin, Clay, Quartz, Feldspar, Talc, Soapstone, Boron Minerals, Rare Earth Minerals, Chalk, Marl, Gypsum, Sand, Gravel Stone, Volcanic Sinter, Chips of Rock.

Building material

Eruptive Rock, Tuffs, Sandstone and other, Building Stone Slates, Clay Slate, Chalk, Marble, Serpentine, Alabaster, Stones for Road Construction, Auxiliary Material for Road Construction, Building Sands and Additives to Artificial Stones.

Basic minerals for building materials and their application are listed below due to their importance for regional development.

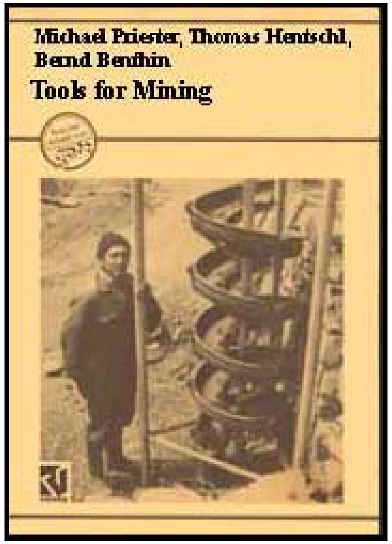
Application:	Therefore suitable stones:
Split Gravel (Ballast	Quartzporphyry, Basalt, Diabase
for roads and rail	Gabbro, Granite, Syenite, Gneiss,
tracks):	Phonolite, Quartzite, Graywacke
Pavement:	Granite, Syenite, Gabbro, Basalt, Diabase, Quartzporphyry, Graywacke
Kerb, stairs,	Granite, Syenite, Gabbro, Sand
sidewalks	stone, Graywacke, Limestone, Quartzite
Interior decoration:	Granite, Syenit, Marble, Serpentine
Monuments:	Granite, Syenit, Marble, Dolomite, Sandstone
Building	Granite, Syenit, Gabbro, Sand-
foundations:	stone, Limestone, Dolomite, Gneiss
Residence rooms:	Tuffite, Sandstone, Limestone
Roofing slate:	Slate, Platy Limestone

Basically, the technique of mining of non-metallic raw materials does not differ from that of the mining techniques described earlier. Solid rock are obtained by drilling and blasting. Only special decorative stones, e.g. marble are produced by sawing using diamond saws. The bigger the blocks to be obtained, the more protective should be the blasting during mining. This can be done by selecting the

correct drilling scheme and particularly through the choice of the appropriate explosive. Through the expansion or dilution of granulated and gelatinous explosives with non explosive components or through the selection of explosive medium which are less powerful, the miner can obtain a huge heap of broken material. Thus the mining of shale for roof tiles for example, uses black powder for the production of large slate blocks. The special techniques of producing blocks of stones and their processing however should not be the concern of the present work especially because these techniques are described accurately in the following recently published work.

STONE. An Introduction. Asher Shadmon. Intermediate Technology Publications. LONDON 1989 [ISBN 0946688 08 7 (UK); ISBN 0942850 15 7 (USA)]

Relative to the mining techniques for metallic raw materials and fuel minerals (coal, lignite, peat, asphalt, bituminous shale), the specific quantities of exploited raw materials are usually greater. Surface mining of construction materials, particularly, is a mass production due to the minimal value of the product already mentioned above. The problem lies mainly in the haulage and the transport to the market. Usually, cost intensive transport systems as truck/wheel loader, etc. are required by means of which operations located on the deposits of these raw materials already land in the range of medium-scale mining. On the other hand, mining activities aiming at highly-valued products, e.g. graphite, diatomite, or other industrial minerals, or mining work which has a big share of manual work or activity which can not be mechanized easily, can definitely be undertaken by the usual small-scale operations using partially mechanized or improvised method.



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 10: Surface Mining Equipment

SPECIFIC SURFACE MINING TECHNIQUES

10.1 Aerial cable-way by gravity

Pit Banks for Deep Mines and Open-Pit Mines
Surface Mining Equipment

germ.: Einfache Schwerkraftseilbahn
span.: teleferico simple por gravedad, cablevia por contrapeso, andarivel por contrapeso
quechua: hualaycho

TECHNICAL DATA:	
Dimensions:	depends on vertical deviation as transport distance
Form of Driving Energy:	technique without external drive
Operating Materials:	
Which:	lubricants
Quantity:	small quantity
ECONOMICAL DATA:	
Investment Cost:	somewhat low, pulleys, cable, container
Operating Cost:	very low

CONDITIONS OF APPLICATION:

Operating Expenditures: low |————|————| high

Maintenance Experience: low |————|————| high

Location extensive difference in topographic level is needed to overpower the

Location Requirements:	extensive difference in topographic level is needed to overpower the friction only by weight of material
Mining Requirements:	the mine or production is above topographic level of beneficiation or further processing
Replaceable Equipment:	roads with transport of mined ore by truck to beneficiation or reloading place
Regional Distribution:	worldwide applied, not only for mining
Experience of Operators:	very good |————|————| bad
Environmental Impacts:	low |————|————| very high
	eventually avoids roads and their consequences (erosion, etc.)
Suitability for Local Production:	very good |————|————| bad
Under what Conditions:	construction of foundations for pulley piles, probably installation of stretching device
Lifespan:	very long |————|————| very short

Bibliography, Source: Priester, Hentschel

<u>OPERATING PRINCIPLE:</u>

Aerial cable-way by gravity is comprised of a circulating cable guided by two pulleys, one at the upper loading level, and the other at the lower unloading level. The buckets which are hitched on the cable are driven by the difference in weights

of loaded or non loaded material.

Thus, the loaded bucket is driven along the cable downward by gravity and pulls the empty one upwards for the next hauling procedure. To control speed, one pulley (preferably the upper one) has a brake, e.g. band brake or shoe brake. An automatic unloading device can contribute to make haulage easier. One pulley should allow cable tension or stretch to vary.

REMARKS:

As an alternative, the simple gravity aerial cable-way can be equipped with separate rail ropes and pull ropes or brake ropes. Two parallel stretched cables serve as rail ropes. They are usually made of mashed wire steel. Along the cables, rollers run which carry suspended buckets. The pull or brake rope that leads over a pulley and put on the brake, connects the two buckets. These are equipped with bottom gates which open automatically while passing a ripper.

Aerial cable-ways driven by gravity are used where ore is to be transported from a mine at the mountain side toe a processing plant located in the valley. Often, processing is bound at the river side to avail of huge quantities of water for Industrial purposes including for hydromechanic driven machines.

SUITABILITY FOR SMALL-SCALE MINING:

Following the chutes, gravity driven aerial cable ways are the simplest and cheapest systems for transporting in vertical distances.

10.2 Cable tool drill

Open-Pit Mining, Well Drilling probably Deep Mining
Surface Mining Equipment

germ.: Seilbohren

span.: perforacion a cable

TECHNICAL DATA:		
Dimensions:	pennsylvanian drilling	drilling in China
	lift 500 - 1000 mm	striking height of bit
	frequency approx. 30 min-1	up to about 12 cm
Driving Capacity:	12 - 15 strikes per minute	
Mode of operation:	continuous	
Throughput/Capacity:	2 - 5 years for 1000 m deep drillings in China	
Technical Efficiency:	at 250 mm (above) - 125 mm (below) 0 0.5 - 1.2 m/d	
ECONOMICAL DATA:		
Operating Cost:	very low drilling cost, partly high rope wear	

CONDITIONS OF APPLICATION:

Operating Expenditures: low |————|————| high

Maintenance Experience: low |————————| high

Deposit brine and natural gas were already found (before Christ) while drilling with

Requirements:	a cable tool drill, where sandstone rocks, soft sandstones, limestones, claystones, generally non sturdy, cohesive loose rocks were drilled out but are not supposed to break back andshould not show much Joining or big cavities, such as karst.
Replaceable Equipment:	bench drilling machines, probably in quarries
Environmental Impacts:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under what Conditions:	cable tool drilling, for example with wooden drilling rigs and wooden or metallic drilling beam can be produced locally
Lifespan:	very long |—————|—————| very short
	a problem is the short lifespan of rope

Bibliography, Source: Feldhaus, Arnold, Treptow, Schmiedchen

OPERATING PRINCIPLE:

In China, cable tool drilling was used with a four-leg rig made of bamboo bundles, above which a drilling tool bit hanging on a rope was being moved. The movement was caused either by a seesaw, e.g. a one side tipping wooden beam on which one or two persons bounced Up and down' or directly by pulling the rope. This then lifted the drill bit a little above the drill bottom and fell down consequently due to its own weight. By twisting the rope, the drilling bit could be moved or turned.

Once the drill bottom was filled with drill cuttings, these loose materials were taken out or excavated into the surface by a simple bailer pulled by the rope. In the mounting and dismantling of the bit and the bailer, a hoist is being used. Bamboo rods served as casings which are partly sealed off with bitumen, resin and linen rags. Water bearing strata could be filled up with mud or clay and resin and could be penetrated again. The Pennsylvanian cable tool drilling method follows the principle of this chinese cable free falling drilling.

<u>AREAS OF APPLICATION:</u>

for drilling of vertical deep blasting holes in open-pit mining
for sampilag
for putting down ventilation holes with 100 - 150 mm diameter

<u>REMARKS:</u>

Cable tool drilling is known in China since more then 2000 years in boring for salt brine sources.

Disadvantages of cable tool drilling are:

- difficult assessment of rope lift due to rope twisting
- aperiodic rotation due to twisting of rope
- no possibility to apply water circulation or flushing
- difficulties in fishing out lost bit if rope breaks, usually a system of rods has to be available

Advantages of cable tool drilling are:

- low weight of needed drilling equipment
- fast installation of drill device
- very straight, exact vertical holes

Rope elasticity is being used in drilling, which means the rope is still stretched as it reaches the drill bottom. Otherwise it will be compressed which leads to breaking of the rope near the bit joint. The Pennsylvanian cable drilling method avoids this rope compression by using drilling jars in the drilling tool.

SUITABILITY FOR SMALL=SCALE MINING:

Cable tool drilling is a suitable technique of putting down deep vertical drill holes without the use of external energy. However, drilling efficiency is comparably low.

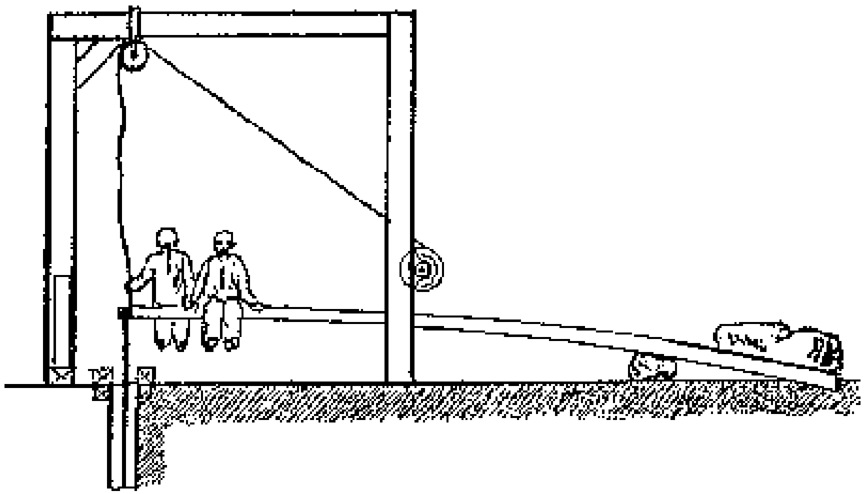


Fig.: The chinese method of putting down a deep well. Source: Feldhaus.

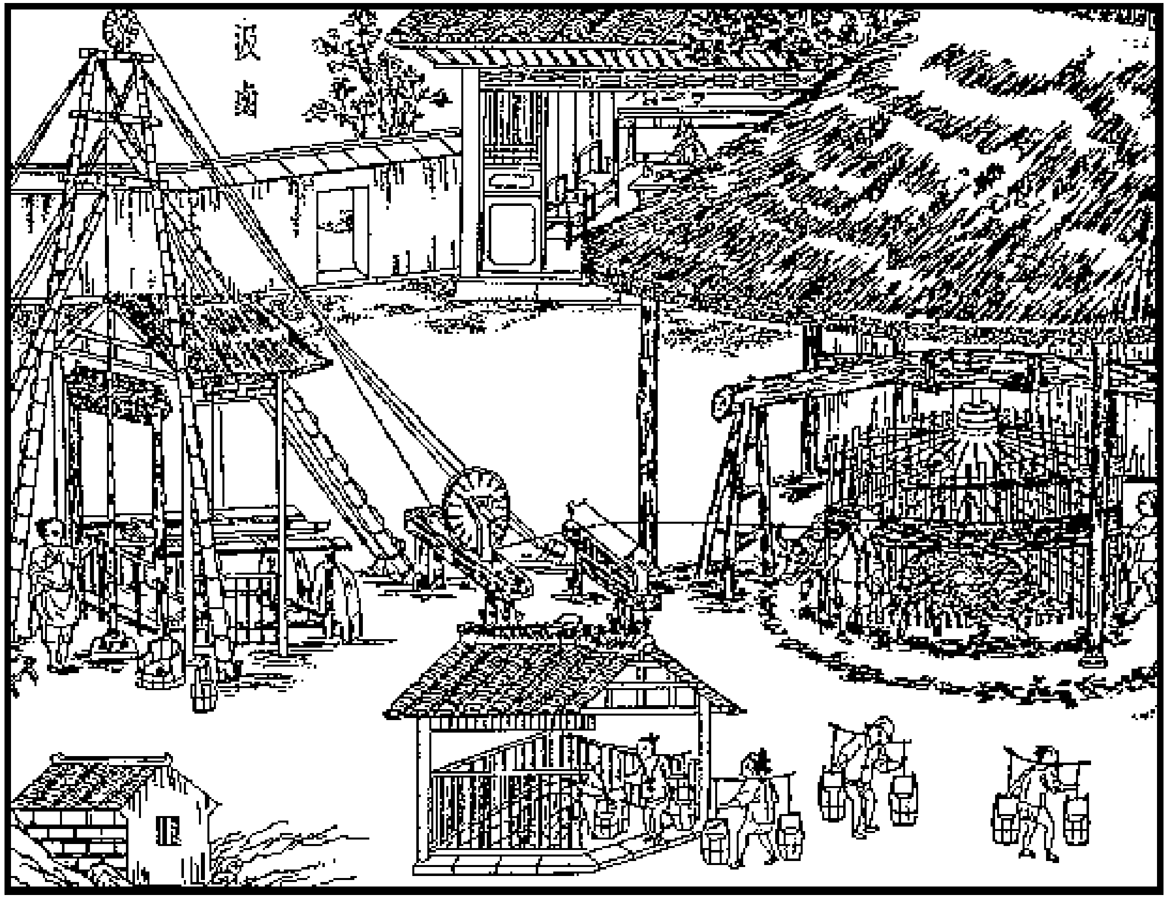


Fig.: Deep drilling installation in China. Source: Arnold.

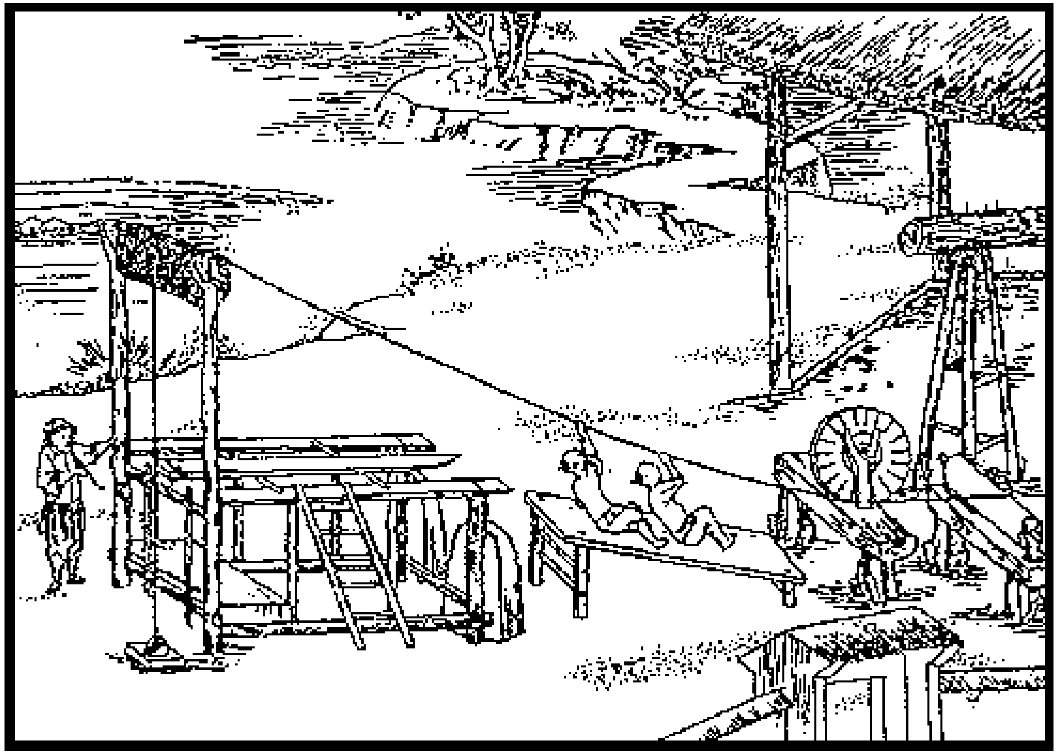


Fig.: Drilling instalation in China with percussion device in ca. 600 before Chr. Source: Arnold.

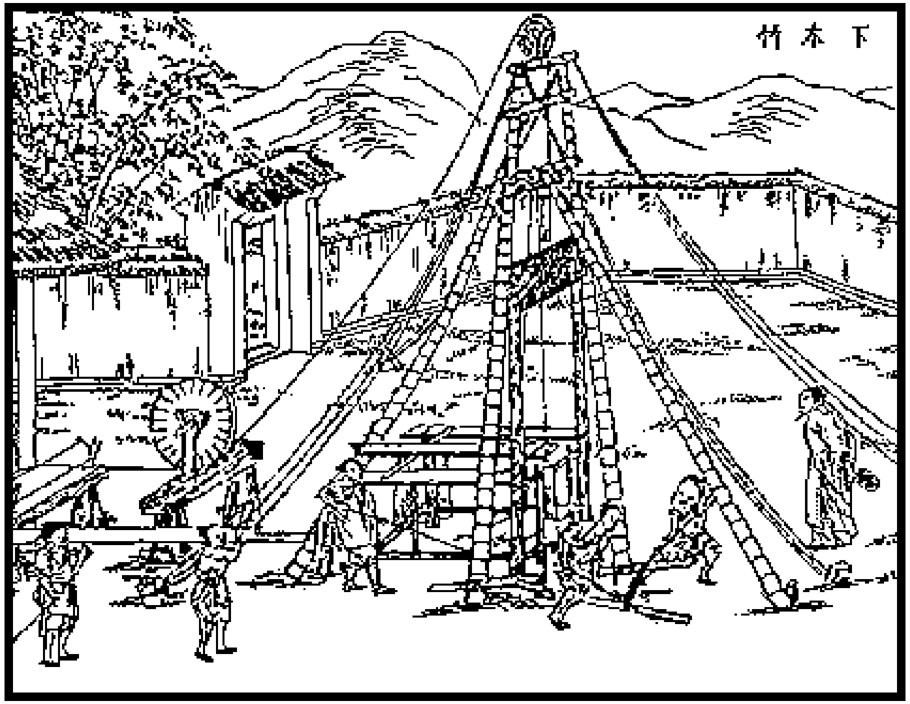


Fig.: Piping or pipe installation in a Chinese deep drilling in ca. 600 before Chr. Source: Arnold.

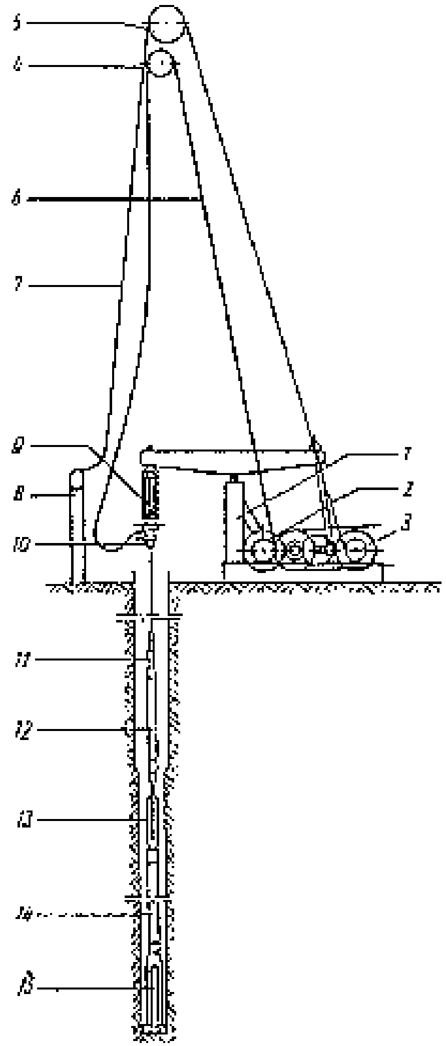


Fig.: Schematic diagram of the Pennsylvanian cable drilling method. Source: Schmiedchen.

10.3 Suction dredge

Aluvial Mining in Open-Pit on River
Surface Mining Level Equipment

germ.: Saugbaggerfloe

span.: dragalina de succion, draga aspirante, draga de succion

Producer: Keene, HG (Colombia), Humphreys Mineral Ind., Mining Equipment Inc., Dopke, COMESA, IAA

TECHNICAL DATA:	
Dimensions:	approx. 2 × 3 m area
Weight:	from 20 - 350 kg weight of machines (engine, pump, chutes)
Extent of Mechanization:	fully mechanized
Form of Driving Energy:	approx. up to 10 PS internal combustion engine
Technical Efficiency:	Other Opportunities: probably drive type "Schiffsmuhle" (see 10.8)
Mode of Operation:	semi-continuous/continuous
Throughput/Capacity:	from 7.5 m^3/d to approx. 220 m^3/d
Operating Materials:	
Which:	gasoline
Quantity:	0.3 - 1.0 l/m^3 sediment
ECONOMICAL DATA:	
Investment Cost:	approx. 7500 to 20.000 DM
Operating Cost:	fuel cost
Consequential Cost through	eventually outboard motor

Coupling Effects:

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————————| high
two man crew, one diver	
Maintenance Experience:	low |————|————| high
Location Requirements:	river with depth of < 10 m
Ore Requirements:	relatively high amount of large sized material
Deposit Requirements:	alluvial, not cemented, loose sandy sediment
Adjoining Rock Requirements:	low clay content
Mining Requirements:	significant locations for mining are places where natural strips or barriers at the river bed traps for gold particles have been formed
Regional Distribution:	Bolivia, Brazil, Ecuador, Colombia, Venezuela, etc.
Experience of Operators:	very good |————|————| bad
Environmental Impacts:	low |————|————| very high

exhaust, fumes, used oil, river contamination by muddy waste which flow back into the river

Suitability for Local Production: very good |————|————| bad

if components are imported such as motor and pump

Lifespan: very long |————|————| very short

Bibliography, Source: Dahlberg

OPERATING PRINCIPLE:

The whole machinery unit (e.g. suction pump, engine, beneficiation) is installed on a floating boat anchored at river banks or controlled by an outboard motor. The motor drives a centrifugal pump. Water is injected by a pressure hose near the suction nozzle into the suction hose and carries water and sediments through this suction hose. This mud flow reaches the float and on a mostly simple gravimetric separation with screening off of large sized fractions and various types of through washers. The remaining pre-concentrate will then be sorted out later by batea, and finally, will either be sorted by hand or amalgamated.

AREAS OF APPLICATION:

Suction dredges are applied or used for mining of alluvial gold in riverbeds. Between 0.75 and 22.5 m³/h sediment is being pumped from a depth of 2 - 10 m with a suction nozzle diameter of between 15" and 8", and is then processed.

REMARKS:

Due to the mostly simple processing with through washers, only large sized gold particles are won. Thus, fine gold is lost. It is to be investigated if fine gold extractions can be recovered by spiral separator or centrifuge. It would be advantageous if the material would have been completely suspended already.

The smallest suction dredges are transportable and are weighing only about 25 kg including the float. In this case, floats are made of truck tyres. Bigger floats have an uplift mechanism, for instance, by the use of barrels.

Bigger floats are equipped with compressed air supply for the divers who will then guide the suction nozzle directly along the river bed or ground.

SUITABILITY FOR SMALL-SCALE MINING:

Not considering the somewhat high amount of investment and operation cost, suction dredges are quite suitable for small-scale recent fluviatile alluvial gold mining with relatively large size particles. Thus, deposits can be mined which otherwise cannot be extracted with manual rustic mining methods.

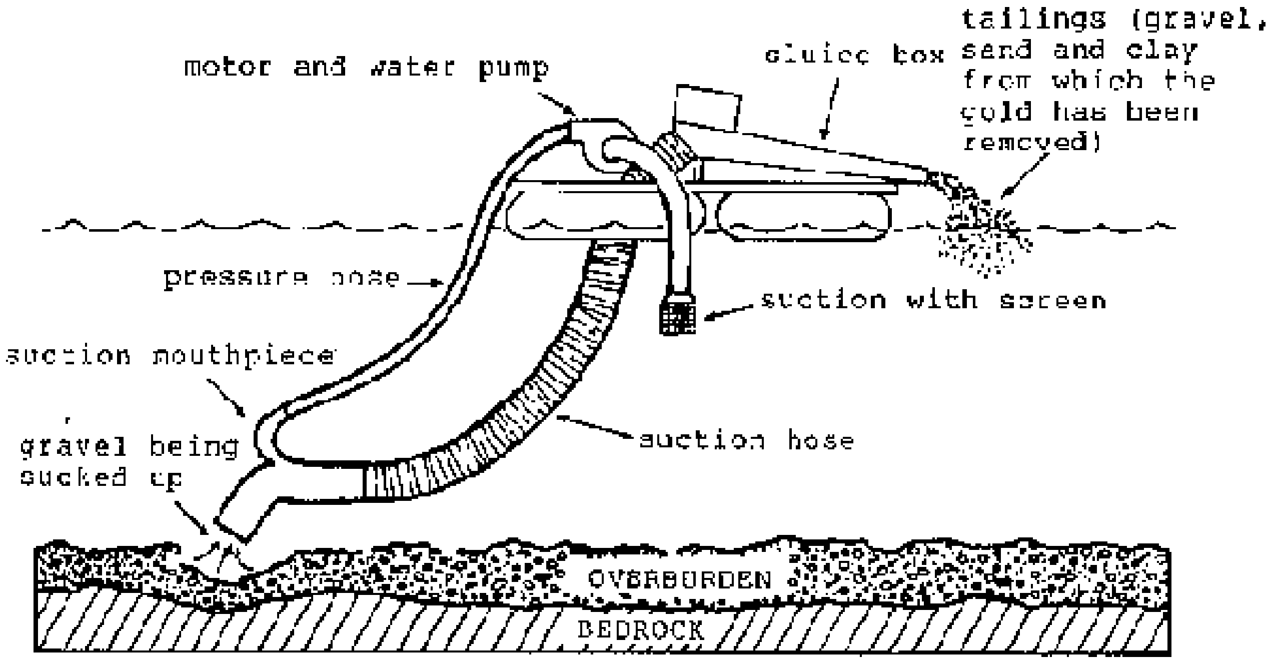


Fig.: Schematic diagram of a suction dredge. Source: Dahlberg.

10.4 Hydram, hydraulic ram pump, rife ram

Pit Banks for Deep/Open-Pit Mining General Surface Mining Equipment

germ.:	Wasserschlagpumpe, hydraulischer Widder, Stoheber, Druckstopumpe, Wasserstoer
span.:	bomba a golpe de ariete, ariete hidraulico, bomba de impulso a presion, impulsor de ague
Producer:	WAMA, Campo Nuevo, Pfister & Langhans, Gebr. Abt, Schlumpf AG, Ch, J. Blake, Las Gaviotas, Rife Hydraulic Engine Man., Cyphelly & Cie, Inteco

TECHNICAL DATA:

TECHNICAL DATA:	
Dimensions:	from 3 - 12 1/min (3/4") drive water, 320 mm height to 280 - 600 1/min (6") 1400 mm
Weight:	18 - 427 kg
Extent of Mechanization:	partly mechanized
Form of Driving Energy:	energy of drive water
Mode of Operation:	semi-continuous
Throughput/Capacity:	quantity of pump water depends on conveying distance: head of drive water 40 % (2 : 1) - 1.25 % (20 : 1) up to 250 m conveying distance
Technical Efficiency:	30 - 60 %
Operating Materials:	
Which:	drive water
Quantity:	depends on conveyance discharge and head of water (minimum 0.5 m)
ECONOMICAL DATA:	
Investment Cost:	brand new, fob Grafing 1400 to 2.000 DM; Campo Nuevo approx. 250 to 550 US$
Operating Cost:	very low, low maintenance, very low wearing
Consequential Cost through Coupling	delivery pipe, hydraulic engineering works

Effects:	

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance Experience:	low |—————|—————| high
Personnel Requirements:	very few, only a periodic control of air content in the air chamber is important
Location Requirements:	water and relief necessary
Mining Requirements:	typical application is in alluvial mining in flood-plain terraces which lie above the drainage level
Replaceable Equipment:	all kinds of pneumatic, mechanical and electrical pumps
Regional Distribution:	earlier worldwide, replaced by electrical systems
Experience of Operators:	very good |—————|—————| bad
Environmental Impacts:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad

Under what	metal manufacture, construction material: standardized pipes

Conditions:
Lifespan: very long |————|————| very short

Bibliography, Source: Fracokel, Meyer, Monninghoff, companies inforation

<u>OPERATING PRINCIPLE:</u>

Drive water flows through the lower part of widder and is released through the open waste valve with accelerating speed. If the speed exceeds a certain limit, the waste valve is automatically closed by the streaming water. A pressure peak occurs caused by this inertia which opens the delivery valve to the air chamber. The backwater is being pressed into the air chamber until the accumulated pressure falls below the internal pressure of the air chamber. Here, the delivery valve then closes while the waste valve opens again.

The procedure as described above reiterates itself periodically. Water that is inside the air chamber is then conveyed through internal pressure to the end user by a delivery pipe.

<u>AREAS OF APPLICATION:</u>

Hydraulic ram pump can always be applied where huge quantities of water with low falling gradient are available and where simultaneously, water is needed above water level for mining, beneficiation, water supply or for other purposes.

<u>REMARKS:</u>

This pump was invented by the Montgolfier Brothers who were awarded with a related patent in France In 1797, and called It hydraulic ram pump or hydram.

Hydraulic ram pumps are suitable for local production if qualified metal manufacture shops are available. As a result, the pumps components can be manufactured with simple pipes, etc. and allows savings in the cost of material and complicated welding works.

A very important source of failure in the operation of the hydram lies with the fact that air cushion in the air chamber can dissolve in (drive) water. If this happens, huge pressure peaks occur in all parts of the hydram thus stopping delivery. As a counteraction, a hole can be drilled into the drive water pipe near the hydram entrance to let fresh air enter into the air chamber, using the principle of the jet pump.

Of further importance is the length of drive water pipe which influences pressure distribution by the closing and opening of valves. Length of the pipe should be preferably between 5 - 12 times of the water gradient or inclination.

Drive water should be free of suspended materials and sediments as much as possible.

It is necessary that the water drive pipe is made of metal since flexible materials, such as PE or PVC usually yield to pressure peaks which then leads to falling pressure and decreased efficiency in the conveyance. The delivery pipe can be made of plastic and can be connected with adhesives, welding seams, or clamping devices.

SUITABILITY FOR SMALL-SCALE MINING:

Hydrams are very suitable for mining purposes if infrastructure for energy supply

is lacking, but sufficient water and water level differences are available. The pumps are very reasonably priced, they are stable and are suitable for local production.

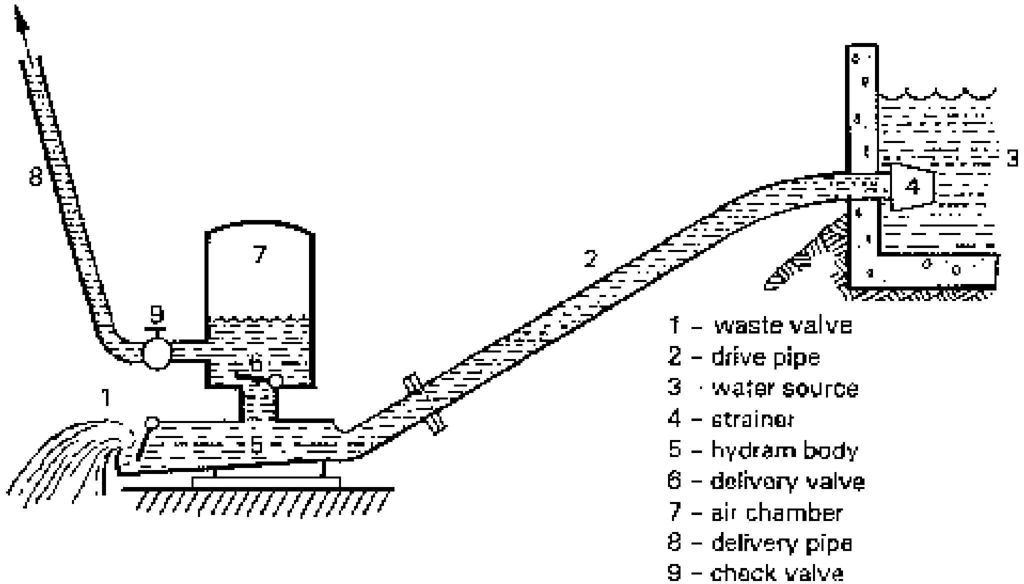


Fig.: Function of a hydraulic ram pump. Source: Fraenkel.

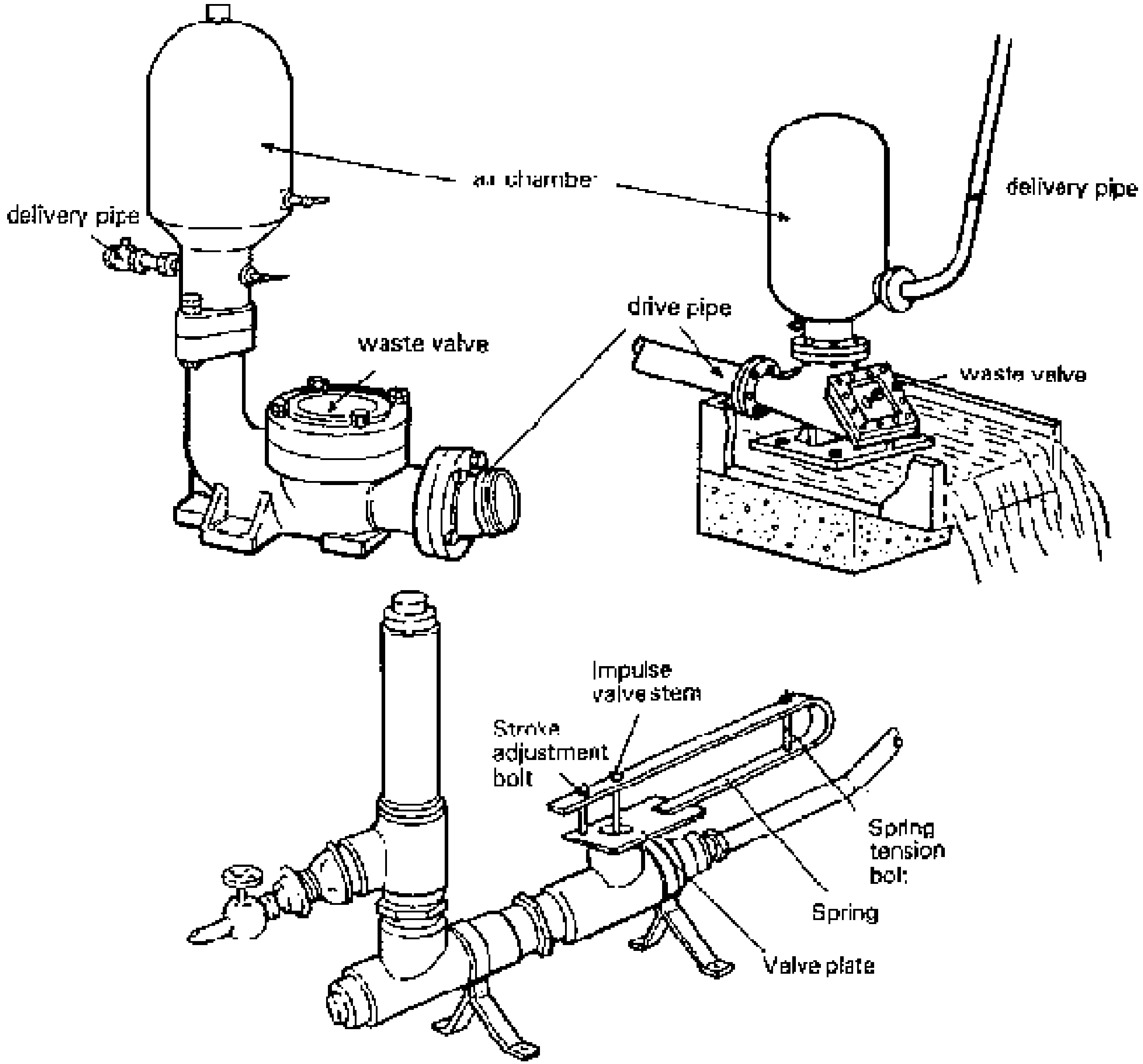
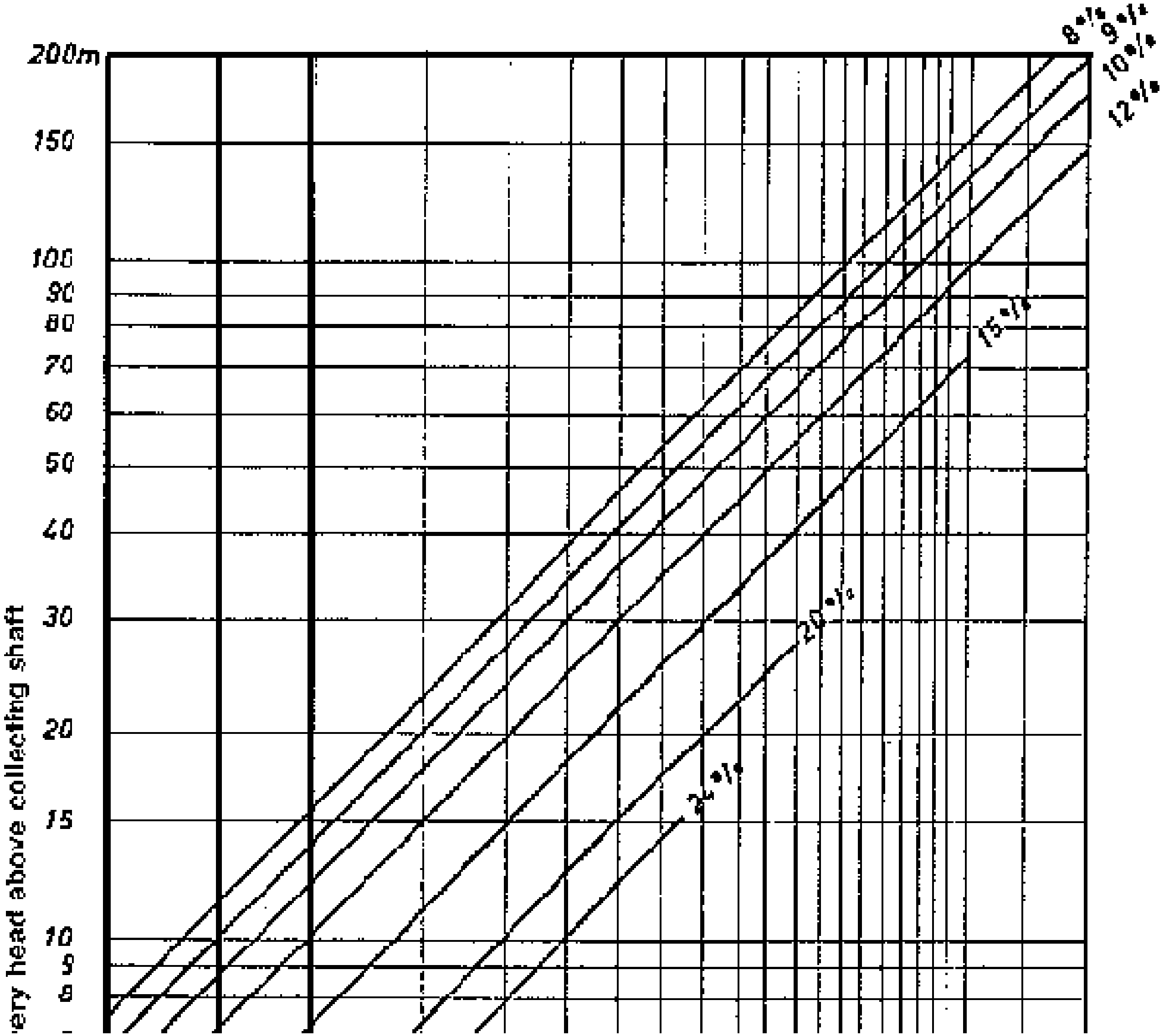
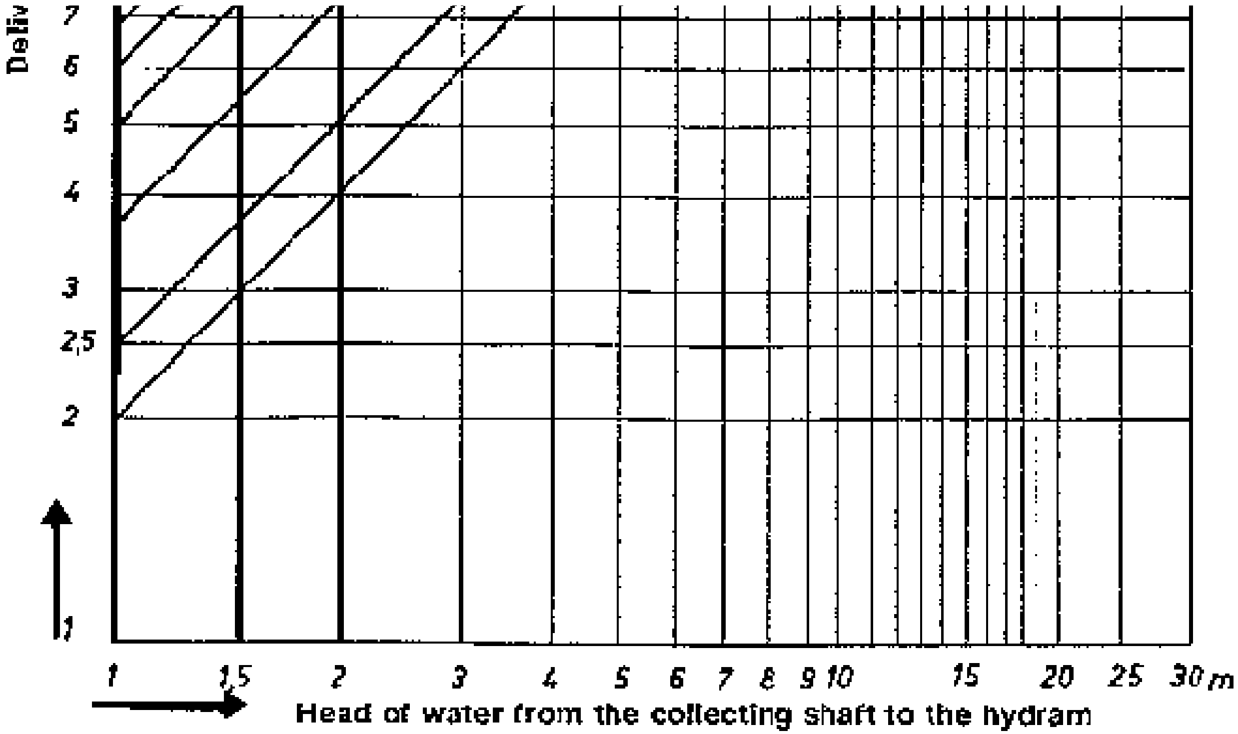


Fig.: Different types of hydrams. Source: Fraenkel. Above left: Traditional European type (Blakes); Above right: South-East-Asian type; Below: Hydram made of pipes.

Table: Falling and efficiency gradients for a hydraulic ramp pump. Source: Schlumpf Company Information.

Pumped quality as a percent of the water volume pumped throught the hydraulic ram:





Table

10.5 Noria

Pit Banks for Deep/Open-Pit Mining General, Open-Pit Mining General Surface Mining Equipment Hauling

germ.:	Schopfrad, Hesselrad
span.:	noria, rueda elevadora
Producer:	M. Impler

TECHNICAL DATA:	
Dimensions:	diameter 2.5 m and bigger, 0.7 m wide

Weight:	700 - 800 kg
Form of Driving Energy:	hydromechanic
Mode of Operation:	continuous
Throughput/Capacity:	1 I/sec, head of water approx. 1.5 m
Technical Efficiency:	up to 60 %
Operating Materials:	
Which:	water
Quantity:	very low vertical interval, but high flowing speeds
ECONOMICAL DATA:	
Investment Cost:	14.000 DM, substantially lower if locally produced
Operating Cost:	very low
Consequential Cost through Coupling Effects:	few water engineering works, flood protection

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |————|————| high
Maintenance Experience:	low |————|————| high

Personnel low

Requirements:	
Location Requirements:	water with streaming speed needed
Mining Requirements:	water demand should be relatively near above the river level since water head ranges only between ca 50 to 60 % of wheel diameter such as for beneficiation of raw ore mined from gravel terraces at river banks.
Replaceable Equipment:	smaller pumps, hydraulic ram pump
Regional Distribution:	historically, widely known; until today, still used in the agricultural industry in Asia and Africa
Experience of Operators:	very good |—————|—————| bad
Environmental Impacts:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under what Conditions:	wood manufacture
Lifespan:	very long |—————|—————| very short

Bibliography, Source: M. Impler, Eckholdt, Meyer, Cancrinus, Fraenkel

<u>OPERATING PRINCIPLE:</u>

Noria is an undershot (Zuppinger-) water wheel with lateral attached buckets. It draws water from the river level and empties out automatically at the upper dead point into a draining chute. Needed is a relatively high streaming or flowing speed but a low falling gradient.

AREAS OF APPLICATION:

Water wheels are used for water haulage from large rivers to a level which is a little higher, such as for operating through washers, wet screening, etc. near a river.

REMARKS:

Wooden water wheels can also be designed so that components can be disassembled and allow its transporting even in remote areas.

Local manufacture with local materials can be implemented easily per instructions and leads to substantial cost savings.

A problem for the operation of water wheels are fluctuating levels of the water surface. If the water level rises to the height of axis, the water wheel could be damaged. Here, flood protection is indispensable. Besides, efficiency declines by a rising water surface level.

Water wheels were built with a diameter of 10 m (Syria) but were less efficient and needed more construction efforts than the other systems.

SUITABILITY FOR SMALL-SCALE MINING:

Only suitable in rivers with less daily or yearly fluctuating water levels and short conveying distance or low head of water.

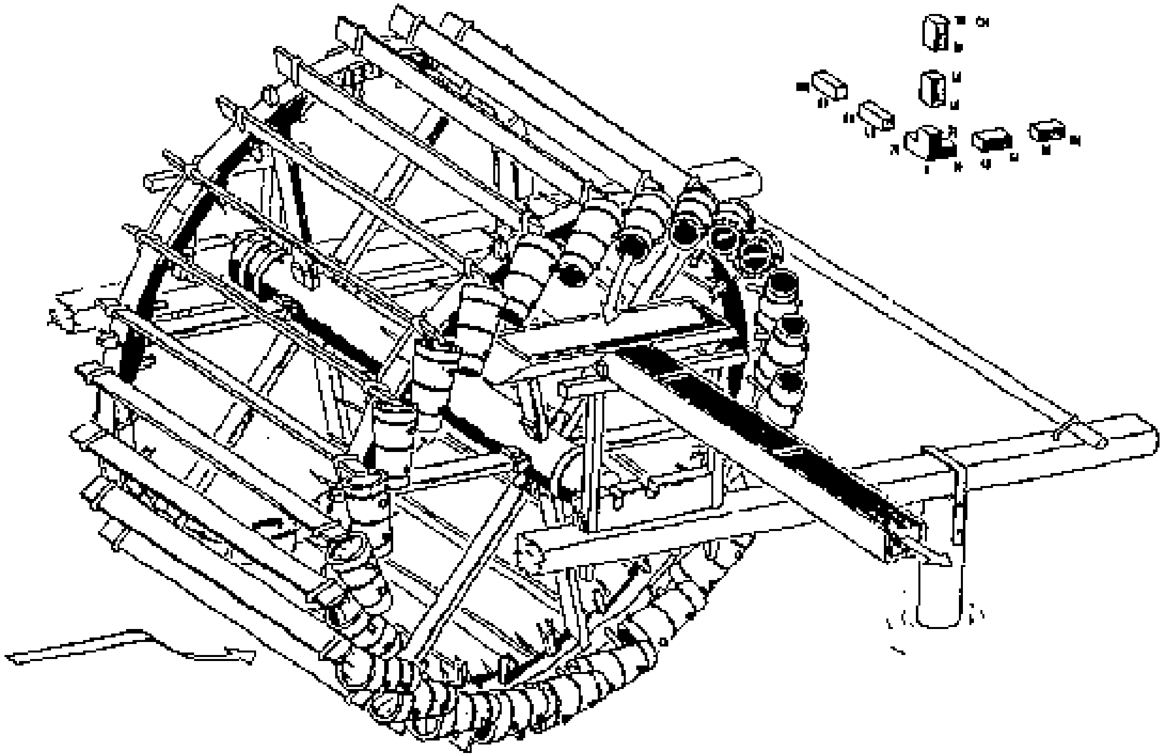


Fig.: A water wheel in North Bavaria. Source: Eckhold.

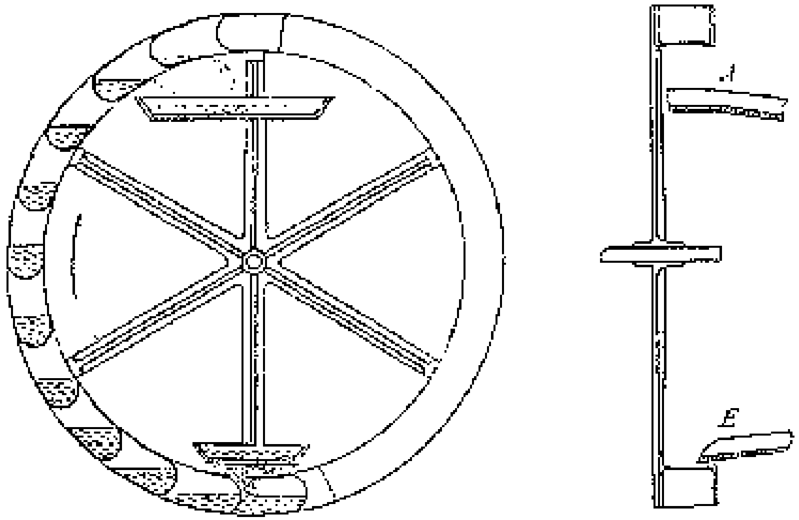


Fig.: Lifting wheel. Source: Treptow.

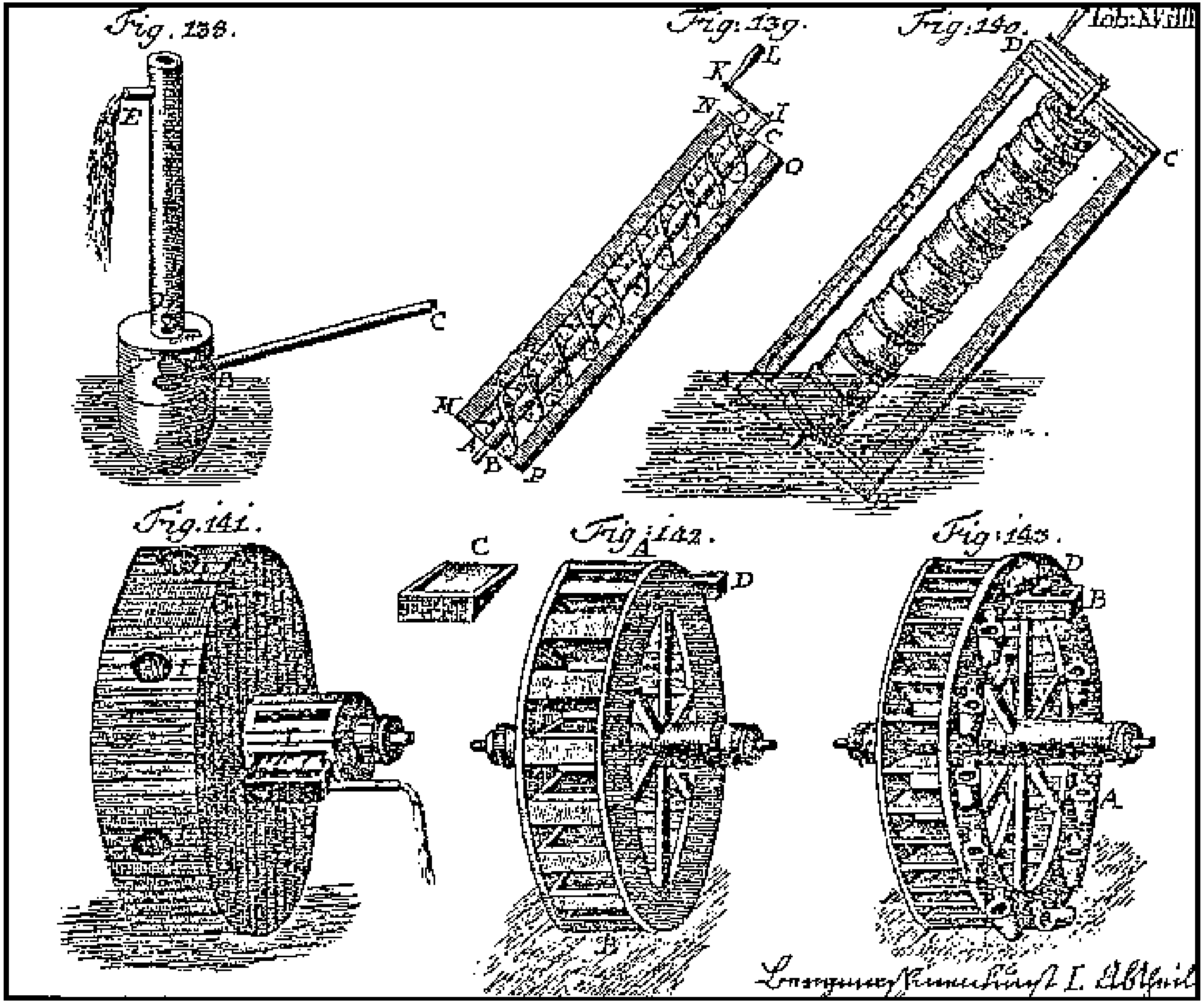


Fig.: Early types of water conveying machines. Source: Cancrinus.

10.6 Tyre pump

Pit Banks for Deep/Open-Pit Mining General Surface Mining Equipment

germ.: Reifenpumpe

span.: bomba con llanta como membrane

TECHNICAL DATA:	
Dimensions:	approx. 1 m × 1 m × 0.5 m + rods
Weight:	approx. 30 kg
Extent of Mechanization:	not mechanized/partly mechanized
Form of Driving Energy:	mechanical, for example, energy from wind and water
Other Opportunities:	manual drive, pedal drive
Mode of Operation:	intermittent
Operating Materials:	none
ECONOMICAL DATA:	
Investment Cost:	approx. 250 DM if locally produced
Operating Cost:	only labor cost
Consequential Cost through Coupling Effects:	driving system, leverage system

CONDITIONS OF APPLICATION:

Operating Expenditures: low I————I————I high

Operating Expenditures:	low |————|————| high
	depends on form of drive
Maintenance Experience:	low |————|————| high
Location Requirements:	low suction and pressure heights
Replaceable Equipment:	other types of diaphragm or piston pump
Experience of Operators:	very good |————|————| bad
Environmental Impacts:	low |————|————| very high
Suitability for Local Production:	very good |————|————| bad
Under what Conditions:	simple metal manufacture
Lifespan:	very long |————|————| very short

Bibliography, Source: Landtechnik Weihenstephan, Fraenkel

OPERATING PRINCIPLE:

A tyre pump is a simple diaphragm pump. The pump room inside the tyres enlarges and becomes smaller alternatively, as the space between the casings of the tyre increases and decreases pulsatingly. The check valves in the feed and discharge line control the inflow and outflow of water.

AREAS OF APPLICATION:

To convey huge quantities of water with small head of water.

REMARKS:

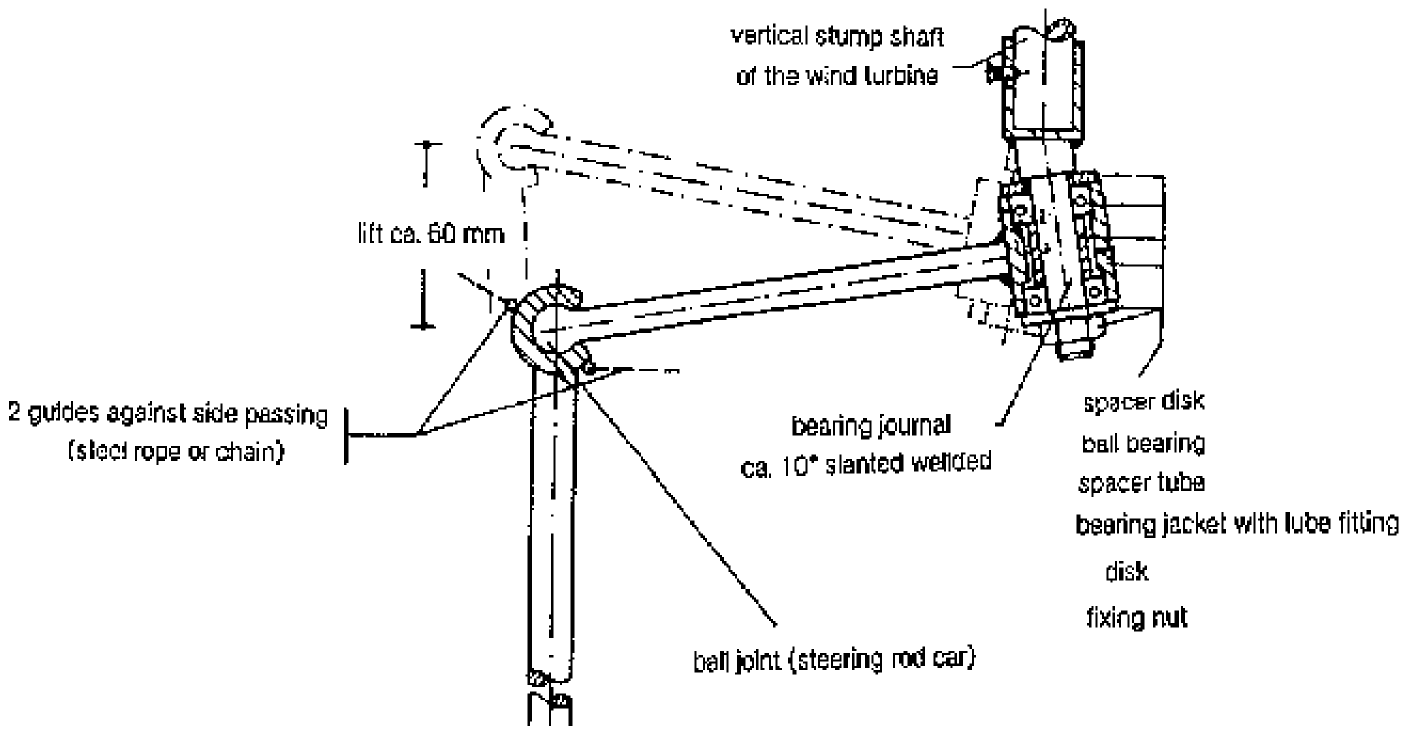
Tyre pump is one of the most simple forms of pumps driven by a pulsating

connecting rod and works simultaneously with low pulse code (even < 100 min-1).

High forces appear to be a problem. A car tyre with 400 mm diameter has a working area of 0.126 m². Such area needs 1.230 N/m pressure height, which means for a 3 m diameter, this is approximately 3,7 N or 376 kg force of connecting rod. All in all, tremendous forces occur at the rods.

SUITABILITY FOR SMALL-SCALE MINING:

Tyre pump is the simplest design to pump water with slow R.P.M. of drive and high torque. It conveys large quantities of water with small head of water which is often used in alluvial gold mining.



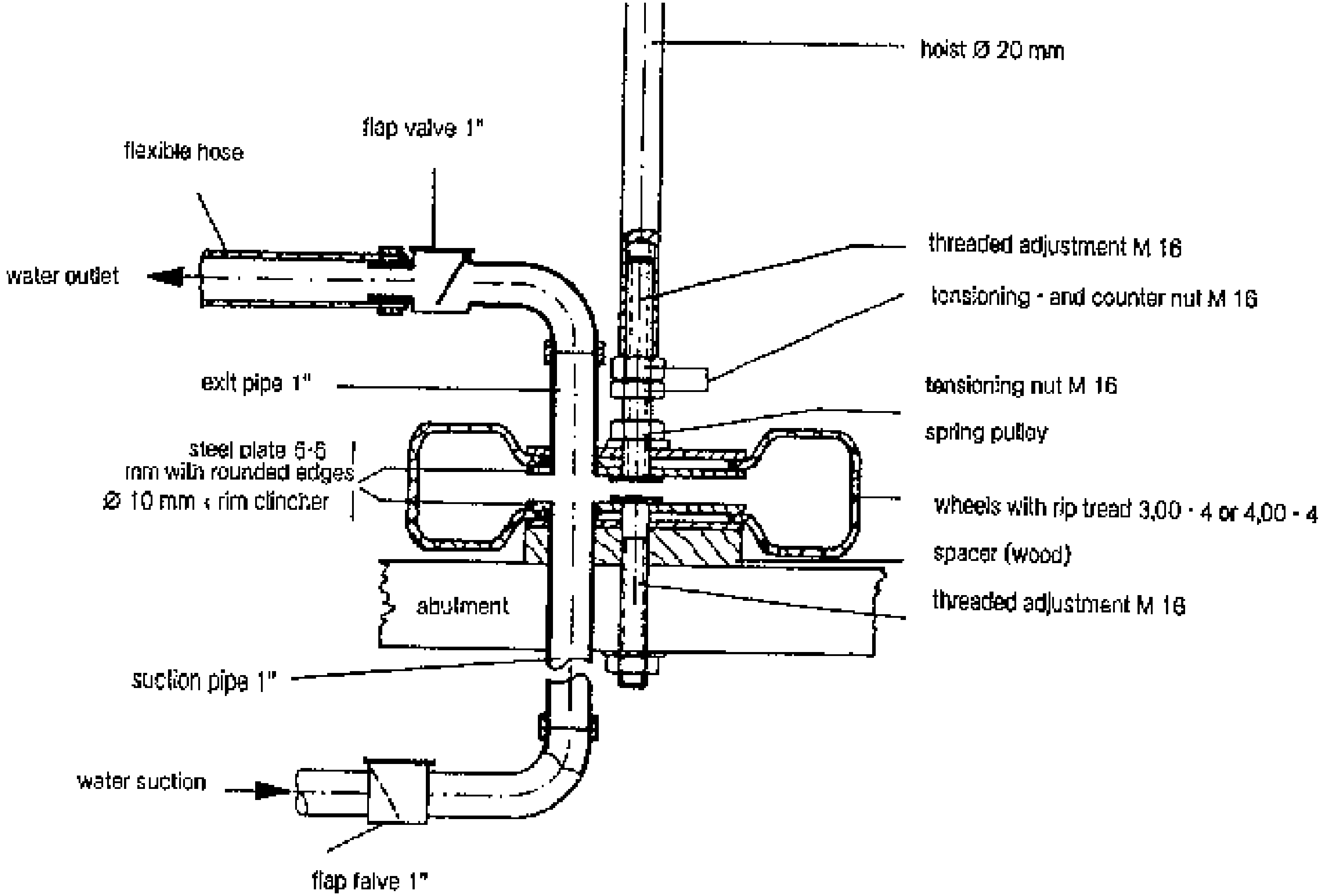


Fig.: Schematic diagram of a tyre pump with eccentric tumbling rod. Source: Landtechnik Weihenstephan.

10.7 Archimedian screw

Alluvial Mining Open-Pit and Quarry Industry Underground Mining Open-Pit Mining/Drainage

germ.: Archimedische Spirale, Wasserschnecke, Tonnenmuhle, Wasserschraube

span.: Espiral de arquimides, espiral pare desague

TECHNICAL DATA:	
R.P.M.:	40 min-1 (min.) - 70 - 80 min-1 (max.); 20 min-1 (min.) - 40 - 50 min-1 (max.)
Angle of Inclination:	open: max. 30°, closed: max. 45°
Dimensions:	covered conveying screw 300 - 700 mm up to max. 12 m length, open screws: 500 - 900 mm
Extent of Mechanization:	not mechanized
Driving Capacity:	depends on head of water: 0.25 - 0.3 kW/m³/min × m h; open screws 0.2 - 0.3 kW/m³/min × m h
Form of Driving Energy:	manual or pedal driven (- 0.6 m h)
Other Opportunities:	in combination with wind wheel, animal power gear
Throughput/Capacity:	- 10 m³/min up to max. 6 m h
Technical Efficiency:	approx. 30 % (wooden traditional closed conveying screws) 60 - 70 % (steel screws in open concrete coverage)
Operating Materials:	none
ECONOMICAL DATA:	
Operating Cost:	energy cost
Consequential Cost through Coupling Effects:	eventually a driving system

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|—| high depends on form of drive
Maintenance Experience:		low |————|————| high
Replaceable Equipment:	pumps with comparably high conveying rate for low head of water, e.g.,water wheel	
Regional Distribution:	peat mining in Germany	
Experience of Operators:		very good |————|————| bad
Environmental Impacts:		low |————|————| very high
Suitability for Local Production:		very good |————|————| bad
Under what Conditions:	wood manufacture	
Lifespan:		very long |————|————| very short

Bibliography, Source: Fraenkel, Hausding, Rittinger

OPERATING PRINCIPLE:

The archimedian screw is comprised of a strong shaft which is twined by a spiral shaped surface thread. To be distinguished are open and closed conveying screws. The open screws rotate with tow tolerance within a fixed half cylindrical channel. The closed screws are completely covered by a cylinder which rotates with the screw. Water is being enclosed by plunging in of screw threads at the lower end of

the archimedian screw. The slight inclined screw displaces water along the cylindrical cover upwards until it flows out at the upper end of the screw.

AREAS OF APPLICATION:

Draining of peat digging, water utilization with very low vertical interval, e.g. in open-pit mining within ground water.

SPECIAL AREAS OF APPLICATION:

Water conveyance with low head of water, recirculation of water in arid regions

REMARKS:

The archimedian screw is one of the oldest water lifting systems. It has been in use since about 200 B.C. in the silver mines In Spain.

Water screws are very stable against suspended solids and other impurisation of water to be conveyed.

Failure in operation of water screws are very seldom and can be easily repaired by an experienced technician locally.

Water screw is most efficient if the filling end is dipped by 50 - 65 % of its diameter into the water and decreases rapidly as the filling end is under water. For fluctuating water levels, a lifting device is recommended.

Only drives of low specific rpm are adequate in order to mechanize archimedian

screws otherwise high losses in efficiency caused by shifting have to be put up with. "animal power gear" or wind wheels would be appropriate as drives.

The pitch of a water screw is mostly identical or a little smaller as the external diameter. The screw is often designed as double or tripple screw.

SUITABILITY FOR SMALL-SCALE MINING:

As manual pumps, archimedian screws are to be used for large conveyance quantities and low lifting height. Due to their simple design and high efficiency, archimedian screws are suitable for use as draining equipment in open-pit mines and for lifting industrial water.

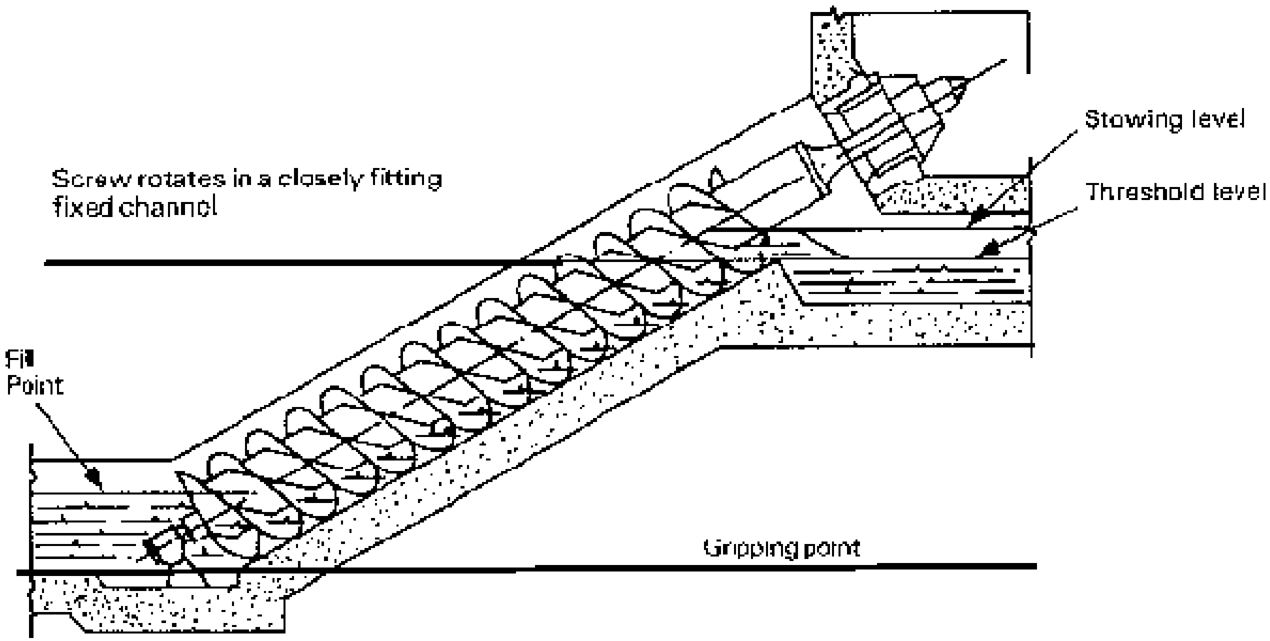


Fig.: A cross-section of an open archimedian screw. Source: Fraenkel.

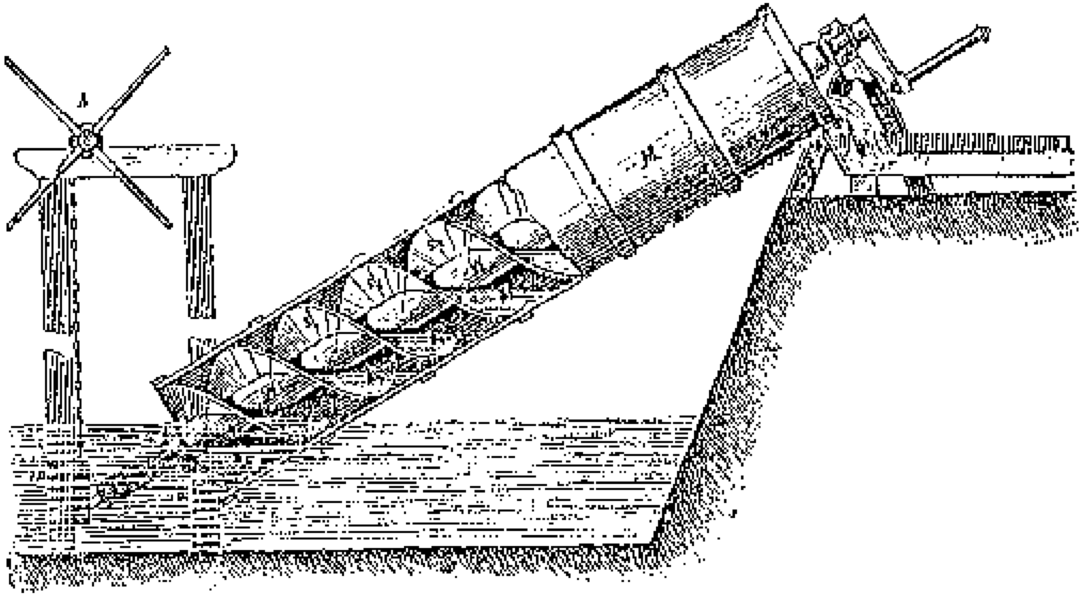


Fig.: A waterscrew. Source: Hausding.

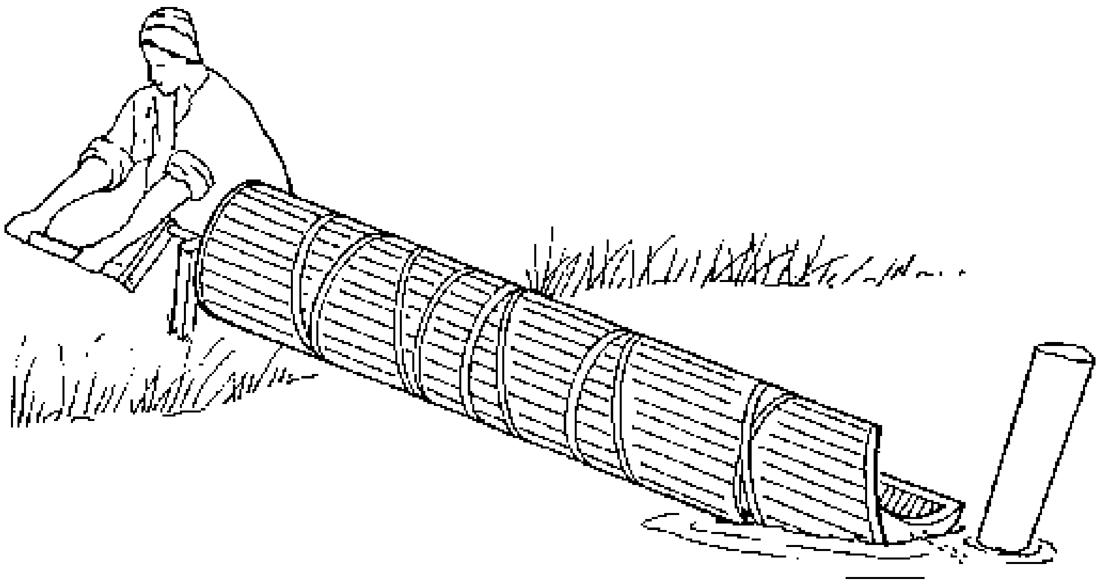


Fig.: A manual driven archimedian screw. Source: Fraenkel.

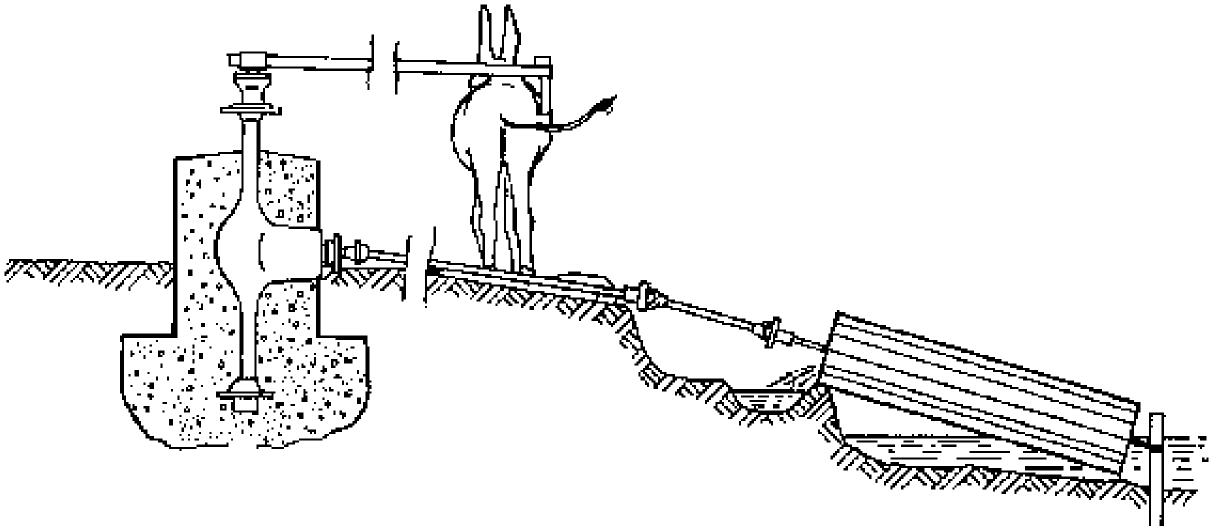


Fig.: A archimedian screw, animal-driven by car axis. Source: Fraenkel.

10.8 Boat mill

Open-Pit Mining at River Level
Surface Mining Machinery

germ.: Schiffsmuble

span.: barco con ruedas hidraulicas pare generar energia, barco o ponton con ruedas de ague pare generar enegia

TECHNICAL DATA:	
Dimensions:	approx. 15 × 5 m
Extent of Mechanization:	partly mechanized
Form of Driving Energy:	hydromechanical, hydraulic energy
Mode of Operation:	continuous

Throughput/Capacity:	up to approx. 10 kW
Technical Efficiency:	equal to a"Zuppinger" wheel: 65 - 70 % (see 19.6)
Operating Materials:	
Which:	water
Quantity:	bigger river with strong rapids
ECONOMICAL DATA:	
Investment Cost:	30.000 to 50.000 DM including water wheels
Operating Cost:	extremely low
Consequential Cost through Coupling Effects:	anchorage

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
Maintenance Experience:		low |————|————| high
Location Requirements:	river with strong rapids	
Regional Distribution:	today almost unknown	
Experience of Operators:		very good |————|————| bad
Environmental Impacts:		low |————|————| very high
Suitability for Local Production:		very good |————|————| bad
Under what Conditions:	but requires too much time and very expensive experienced wood manufacture, metal manufacture	

Under what Conditions: experienced wood manufacture, metal manufacture

Lifespan: very long |————|————| very short

Bibliography, Source: Kur, Mager, Meyer, Muller 1939, v. Konig 1985

OPERATING PRINCIPLE:

Boat mills are stationarily anchored pontoons, floats or boats in river streams equipped with one, two or several undershot water wheels. They are similar to paddle steamers. However, the water wheels are not used as the driving unit, but used exclusively for the production of energy.

The mechanical energy can either be used directly for pumping, beneficiation or for other purposes, or can be converted into electrical energy by a generator (see below).

REMARKS:

A big advantage of the boat mill is its simple control and there's no need for water engineering works. The water wheels are always equally submerged deep into the streaming water, so that during both high and low tides equal forces are applied at the wheels at the same rate of rapid or streaming speed.

Thus, energy can be easily produced from large rivers with heavily fluctuating water levels, such as rivers in tropical climatic zones.

The conversion of energy into electrical power is difficult due to very low rpm of the driving axis of the boat mill. Beforehand, generators should be converted into

slow moving generators by rewinding with long and fine wires. Only in this way can the necessary voltage be attained.

Likewise, a gear has to be placed between the driving axis and the generator.

Boat mills are very old forms in utilizing water energy or hydro power. Their invention could be traced back to 536 A D. and were found to have been used already in mining.

Boat mills were designed in two different models:

- with one water wheel between the main boat and the outrigger boat; and

- with two laterally attached, directly coupled or unattached undershot water wheels and only one boat or ship.

The second model is the one that is more suitable for production of energy and for mining purposes.

SUITABILITY FOR SMALL-SCALE MINING:

A good investment if utilized and financed collectively, such as by cooperatives under appropriate environmental conditions (isolated locations in large rivers). Main advantages are the multi-purpose utilization and there is no need for supply of operating materials and equipment.

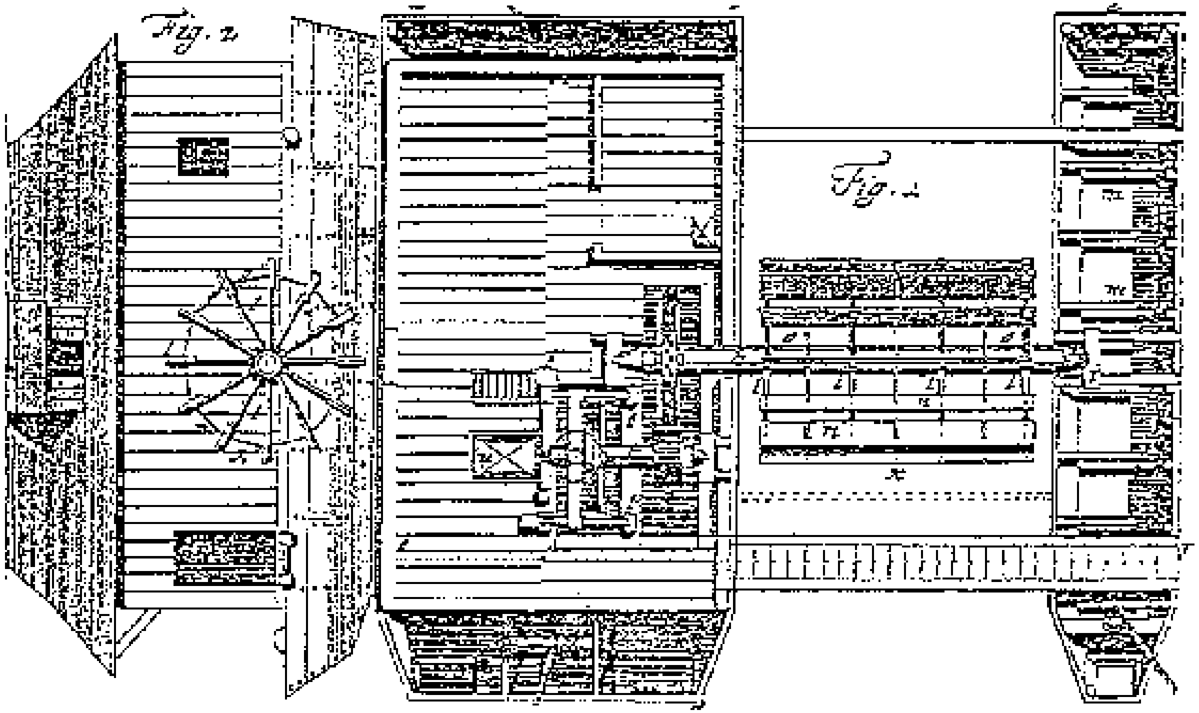


Fig.: A boat mill with an outrigger boat and a main boat; left, side view; right, top view. Source: Kur.

10.9 Hydraulic mining gravel pump mining

Open-Pit Mining of Heavy Mineral and Precious Surface Mining Extraction Metal Alluvial Deposits

germ.:	Kiespumpenabbau
span.:	explotacion con bomba de grave
Manufacturer:	Brauer (Mammutpumpe), Warman Dopke, Met. Lacha, Volcan Buena Fortuna

TECHNICAL DATA:

TECHNICAL DATA:

Dimensions:	10 - 50 m head of water, 6 - 12" delivery pipe, 50 - 600 m length (conveying distance)
Power required:	100 - 600 kW drive for gravel pump, less for water pumps for monitors
Form of Driving Energy:	diesel or electric motors
Alternative Forms:	none
Throughput/Capacity:	20 - 100 m^3/h
Technical Efficiency:	about 0.45 for gravel pump, manufacturer's figures for new pump approx. 60 % by optimal operation
Operating Materials:	
Type:	water
Quantity:	about 20 times the volume of conveyed material with additional auxiliary equipment about 10 times the material volume, up to approx. 65 % (by weight) solids (limestone) and 30 - 40 % (by weight) sand can be pumped
ECONOMIC DATA:	
Investment Costs:	comparably low especially if locally produced. Gravel pump locally manufactured (Malaysia), 8 × 10", approx. 2000 DM without motor; for pumps (5 m^3/h output) manufactured in industrialized countries approx. 5000 DM.
Operating Costs:	approx. 50 % for energy, 18 % for spare parts and material, 25 % for personnel
Related Costs:	high cost of energy supply installation

Related Costs:	high cost of energy-supply installation

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
2 persons minimum		
Maintenance Expenditures:		low |————|————| high
Location Requirements:	large quantities of water must be available	
Deposit Requirements:	Gravel pump mining of alluvial deposits of heavy minerals (tin) and precious metal (gold) which exhibit non-consolidated or only slightly consolidated host rock and limited coarseness of granulation suitable for pumping. The strata underlying the deposit should be water-impermeable and preferably slightly inclined. There are no requirements regarding the thickness of the deposit. Steeply inclined overlying strata is unfavorable,and when present must be of minimal thickness.	
Host Rock Requirements:	none; however, the abrasive strength of the host rock has a major effect on the lifespan of the pump in hydraulic mining	
Replaces other Equipment:	dry mining with wheel loader, trucks, bulldozer, excavators	
Regional Distribution:	in tin mining in Thailand and Malaysia, in gold mining worldwide	
Operating		very good | | | bad

Operating Experience:		very good |————|————| bad
Environmental Impact:		low |———————| very high
	The major cause of environmental pollution is the occaisional high sediment (sludge) load in the high quantities of waste produced; an additional source is the pump's drive-unit.	
Suitability for Local Production:		very good |————|————| bad
Under What Conditions:	very good metal foundries are necessary for repeated casting of new sand-pump impellers. Gravel pumps are locally produced in Malaysia and Thailand.	
Lifespan:		very long |————|————| very short

The working lifespan of gravel pump impellers ranges between 80 and 1200 hours of operation; for locally-manufactured Impellers this figure can lie substantially lower. It has been reported that in Thailand impellers can already wear out after only two days in operation, and are then melted down and recast in a local foundry. The lifespan of the pump housing is about three times longer than that of the impellers.

Bibliography, Source: Hageluken, Gartner

OPERATING PRINCIPLE:

In sand-pump mining of heavy-mineral and precious-metal alluvial deposits,

mining is performed hydraulically, and the mined slurry is transported hydraulically to the beneficiation facility where it undergoes wet mechanical and gravity separation. Hydraulic mining can be differentiated according to two different methods.

Thin sediment deposits of medium-sized granulation with a thickness of less than 3 meters are mined from above by water jets. All other thicker deposits are mined from underneath with a so-called monitor. A monitor is a water-powered water Jet stream which is fed by a fresh-water pump (pressure up to 10 bars, discharge velocity 15 · 50 m/s). The jet stream is directed toward the part of the deposit to be mined, whereby the rock bonds are loosened from the impact, releasing the valuable minerals which then Join the slurry being drawn into the gravel pump. The hydraulic gravel pump is placed at the deepest point of excavation and hydraullically conveys the slurry, with a maximum solids content of 5 - 10 % (by volume), through the delivery pipe to the beneficiation facility. Gravel pumps are usually manufactured with wear-resistant housings and impellers. The beneficiation of the slurry occurs in a parallel-operated system of sluices, possibly with subsequent processing in Jig washers, spiral separators (see 14.18), conical separators or similar apparatuses.

SPECIAL AREAS OF APPLICATION:

Reverse-polarity gravel pumps are also used as turbines when turbid slurries or waters with high solids contents make up the propelling fluid flow.

REMARKS:

Gravel pump impellers are subject to extremely high wear due to the abrasive effects of coarse-grained suspended solids, the extent of which depends on the soil conditions. In general, impeller wear increases with increasing grain size. In order to limit this abrasive wear, it is advisable to screen the slurry prior to its being drawn into the pump, choosing a cut-off fraction Just above the largest grain-size with valuable-mineral content.

To avoid Individual particles from settling out during slurry transport, the specified minimum flow velocity must be maintained.

For positioning the gravel pump, the most successful solution has been to suspend the complete apparatus (directly-coupled pump and drive-unit) from a tripod. This avoids the necessity for an expensive foundation construction. Additionally, suspending the system from a tripod makes the frequent repositioning of the gravel pump easier as mining work progresses.

The smallest incline of the underlying strata between the monitor and the gravel pump should be at least 1:40 In order to avoid losses in valuable minerals through sedimentation. An auxiliary monitor, or booster, can possibly be used to maintain the slurry as a stable suspension and to transport materials which have already settled out.

To increase the density of slurry to be conveyed, auxiliary equipment such as bulldozers, hydraulic shovels, bucket wheel loaders, etc. are employed.

The drive-unit of the gravel pump should be about 30 - 50 % oversized to account, in advance, for excessive loading or increased output demands resulting from

fluctuations in slurry density, extension of the delivery pipe, etc.

SUITABILITY FOR SMALL-SCALE MINING:

Gravel pump mining is characterized by its low investment cost but high cost of energy. It can be the most profitable method of mining heavy mineral sands if deposit conditions are suitable.

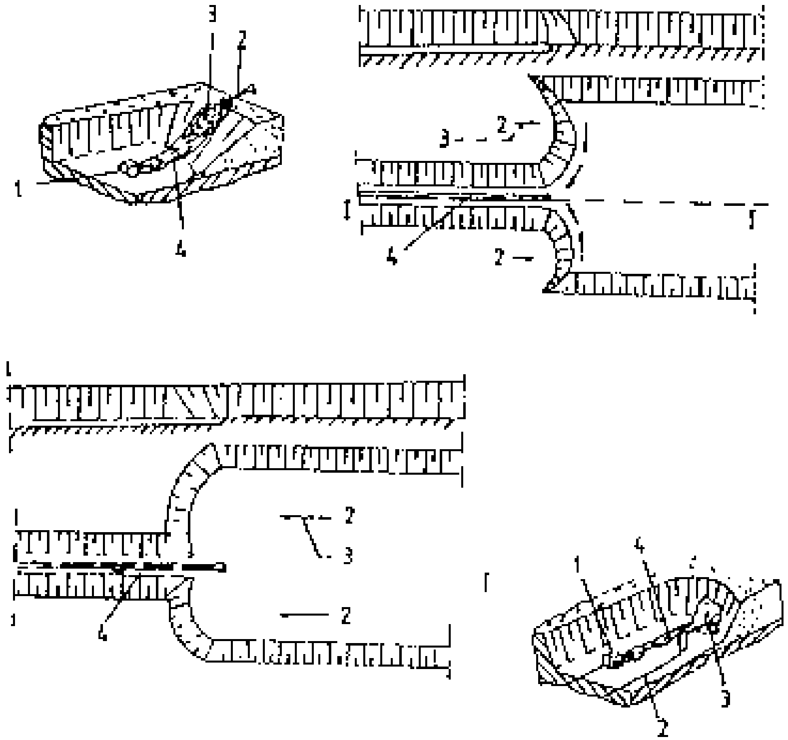


Fig.: Forms of hydraulic mining with with gravel pumps. Source: Gartner.longitudinal section I·I

1. gravel pump. 2. hydromonitor 3. water jet-stream flow direction 4. discharge direction of the slurry (sediment/water mixture)

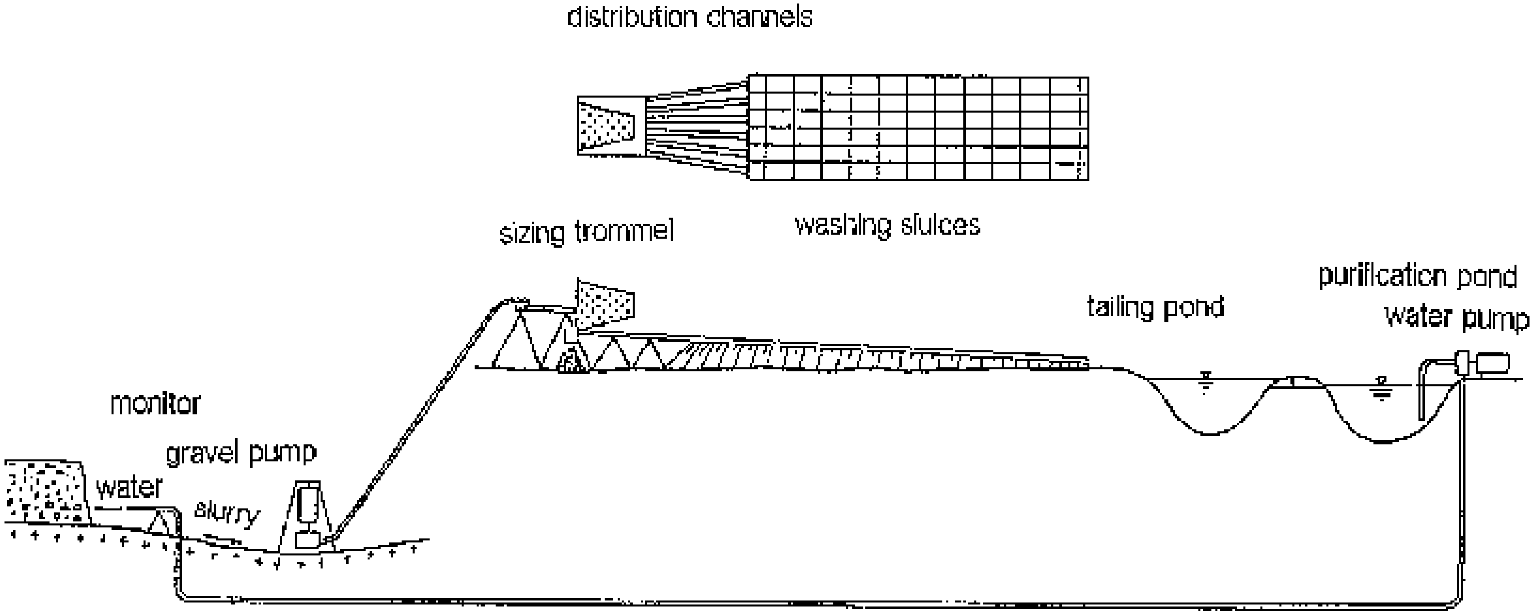


Fig.: Sand-pump hydraulic mining operation with sluice separation. Source: Gast.

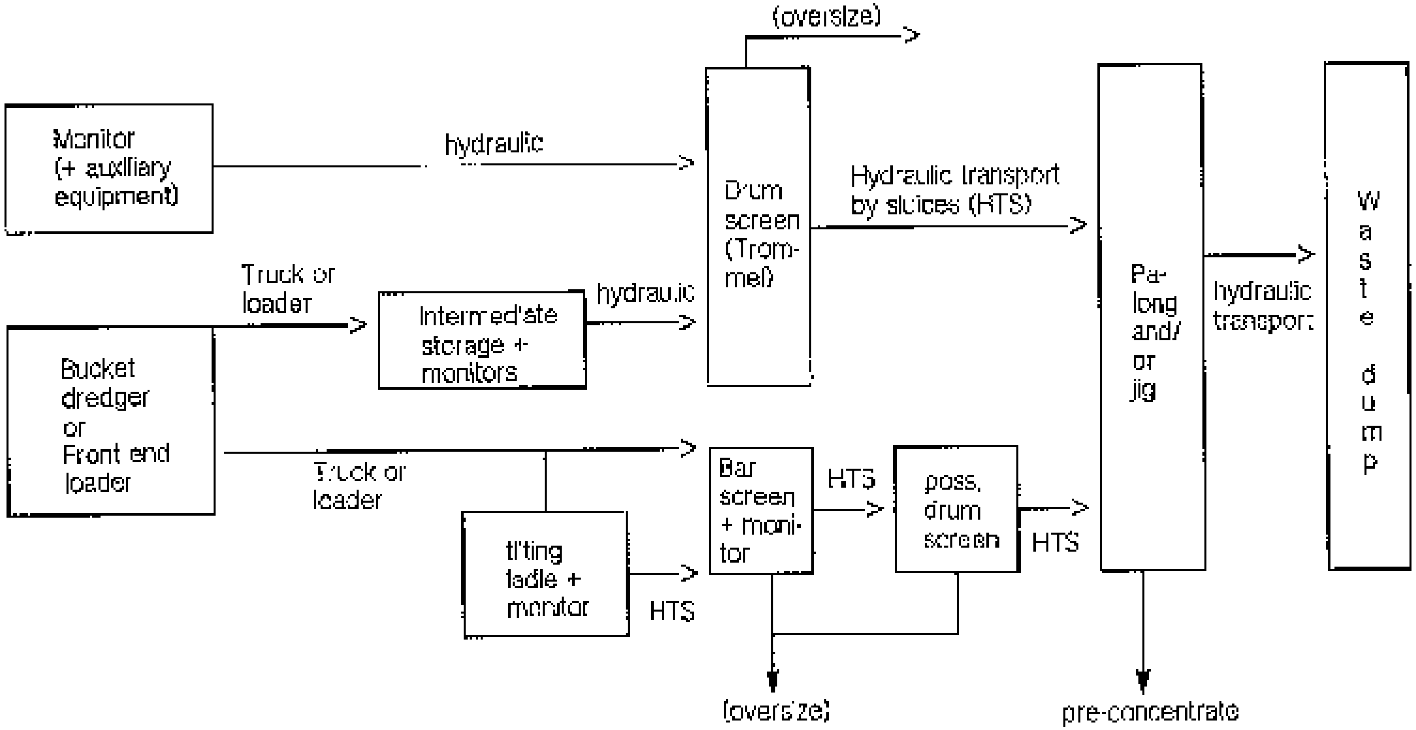


Fig.: Flow chart of alternative mining methods in Southeast Asian open-pit tin mines (not considering floating dredge operation or solid-rock quarries). Source: Hageluken.

Table: Summary of comparison of mining and transporting methods applied in Southeast Asian tin mining.

Source:Hageluken

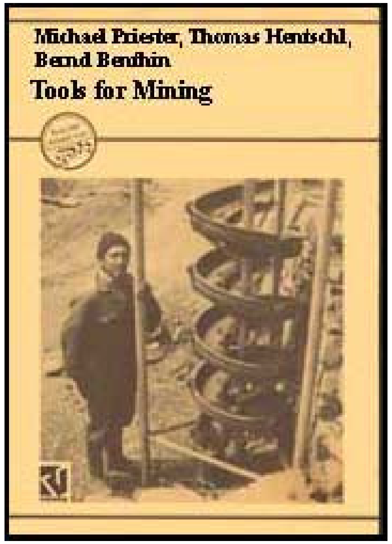
	A	B	C	D
	Hidraulic transport			
	with monitor mining	with monitor mining and	Truck transport with dry mining	Combined truck and

		auxiliary equipment		hydraulic transport
Water requirements	depending on type of earth generally very high since ore is loosened only by water impact	lower than A, since loosening of ore also by auxiliary equipment	low, water only needed for classifying and beneficiation	medium, for interim dump only small loosening forces required
Utilization of energy	bad, mainly transport of water	a little better than A, since higher contents of solids possible	depending mainly on loading capacity/total weight relation of trucks as well as on work organization and conditions of roads	
Abrasive wear	depending on type of earth, generally high wear on pump and pipes		EME: depending on on type of soil, load and EME conditions of roads	
				HT: as A
Coordination of equipment capacity	difficult; necessary power varies after re-location of pump and changed pipe length; mostly oversizing of motors		EBG: simple, since appropriate equipment can be chosen	
			greater transport	HT:

				simple, since
			distances require	length of pipes
			high investments	remain constant
Downtime of the entire operation	by failure of water supply, by moving of the pump position and by failure of a part of the system (pump, pipes, beneficiation or dumping of tailings); direct connection from extraction to waste dump		Total downtime only there is no intermediate deposit and simultaneous failure of all extraction equipment or of all trucks resp. by failure of beneficiation of dumping or tailings if intermediate deposit is impossible	-
Intermediate buffer deposit	not possible	only limited (with auxiliary equipment at the face)	possible	already existing because of method used
Variations in content of solids	high because monitor operations in untouched material		depending on layout of dump, high when dumped directly on grate	lower with controlled monitor operation
Variations in content of	high because heterogene deposits and sedimentation of		reduction of influence by deposit possible by means of blending stockpile	

valuable material	heavy minerals in delivery channel and pump	sump		HT: as A
Desintegration of the ore	through monitor (auxiliary equipment), pump and pipe transport; long reaction time of water		by excavator and addition of water at dump point/screen short reaction time	as A, but shorter reaction time of water
Dependence on climatic conditions	in some areas the mining operation must possibly be ceased because of water shortage during dry season		generally, truck open ation is impossible during the rainy season	
Operation in difficult terrain:				
- swamp	possible	limited	not possible	
- lime slone pockets	possible	limited	limited	
Widespread very small deposits	only possible for very small mines since for larger operations continuous moving of haulage system and beneficiation would be required		possible, high flexibility through truck transport to centrally positioned beneficiation	
Abbreviations: EME = earth moving equipment / HT = hydraulic transportation system				

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 11: Other special techniques

11.1 Welding additives

Mine Workshop
Surface Mining Special Techniques

engl.:	protection against wear, wear-resistant materials
germ.:	Schweizusatzwerkstoffe, Verscheischutz, Panzerungswerkstoffe

span.: materiales pare soldadura, proteccion contra desgaste, material de blindaje

Manufacturer: Vautid

TECHNICAL DATA:	
Dimensions:	for electric manual welding, cast or pressed round electrode rods, 2.5 - 8 mm, 350 - 450 mm in length
Power required:	90 - 320 A ave. current strength, whereby amperage increases with the diameter of the electrodes
Form of Driving Energy:	electric
ECONOMIC DATA:	
Investment Costs:	electrode rods: approx. 20 - 60 DM/kg

CONDITIONS OF APPLICATION:

Operating Expenditures: low |—————|—————| high

Maintenance Expenditures: low |—————|—————| high

Personnel Requirements: good welding skills required

Location Requirements: power supply must be available

Regional Distribution: worldwide in industrialized countries

Operating Experience: very good |—————|—————| bad

Environmental Impact: low |—————|—————| very high

Suitability for Local Production: very good |—————|—————| bad

Lifespan of wear-resistant tools:	very long |————|————| very short this technique is applied to extend lifespan

Bibliography, Source: Vautid-Company information

<u>OPERATING PRINCIPLE:</u>

Available forms of welding materials are standard electrodes, filling wires, continuous cast rods and injecting powder. Various demands upon materials, such as abrasion by hard minerals or cavitation, impact or compressive stresses, temperature extremes caused by high ambient heat or friction, or corrosion by aggressive media can be counteracted by means of coating with the electrode material. Depending upon the requirements, alloys of Fe, Cr, Mn, Ni, W, V, Mo, Nb with Si, B, and C are applied.

<u>AREAS OF APPLICATION:</u>

Electrodes, for example against abrasion, contain in addition to other alloy elements, high proportions of chromium and carbon which form extremely hard chromium carbide during welding. They are used to increase resistance to abrasion of machine parts subject to wear in mining, beneficiation and energy production.

For mining equipment:	shovel bucket teeth, rail parts, pump blades, sand pump impellers, drilling and cutting tools
For beneficiation	crusher jaws, crusher rollers, crusher cones, grinder linings, linings in Chilean (edge) mills, chutes, cyclone linings, pump blades, agitators (stirrers)

equipment:	in flotation cells
For motors and engines:	turbine blades

REMARKS:

The coating of machinery parts with wear-resistant welding materials is, of course, work intensive, but extremely effective and especially important in developing countries, where it can substantially improve the quality of locally-produced machinery components for use in the mining industry. Low labor costs in developing countries enable this work-intensive solution to remain economical. A further significant advantage of this hand coating method lies In the fact that even complicated structures such as pump blades, etc., can be treated.

Depending on the electrode material, the goal is to achieve Vickers hardness values HV 10 from 230 - 2000, corresponding to Rockwell HRC values from 19 to about 70.

Welding materials can be used to coat the following materials:

- non-alloyed steel and cast-steel (magnetic, soft: test with magnet and file)

- alloy steel and steel with up to over 0.5 % C (magnetic, hard) after preheating at approx. 300 - 500° C

- manganese steel (non magnetic, hard), welded cold in water bath

- cast iron (magnetic, soft) possibly when thoroughly preheated (approx. 500°C)

- hard cast iron (magnetic, hard) should not be coated due to danger of cracking.

The electric current should not be too strong and welding should not be too slow in order to prevent too much mixing between the welding material and the melted base material which results in a reduction in hardness.

The maximum thickness of the coating depends upon the welding materials and ranges from 5 to 20 mm; greater thickness is achieved through multiple layers of thinner coatings.

Larger surface areas are sometimes reinforced only with individually welded beads or buttons.

During the hardening process, cracks develop in the coating materials which lower the stress and, as a rule, do not extend to the basic material underneath.

A reworking of wear-resistant parts is usually only possible with SiC or corundum grinding wheels.

For large planar surfaces, pre-fabricated hardened compound plates, special threaded fittings, etc., are available on the market.

Armored and wear-resistant elements made of rubber can be recommended for various purposes, particularly when slow moving parts are exposed to abrasive

materials (slurry) such as in spiral separation.

SUITABILITY FOR SMALL-SCALE MINING:

Wear-resistant materials are highly suitable and effective in greatly increasing the lifespan of locally-manufactured equipment and machine parts, and in reducing the frequency of maintenance and repairs.

11.2 Rubber tanks, flexible tanks

Surface Facilities General
Surface Mining Special Techniques

germ.:	Gummitanks, flexible Tanks
span.:	tanques de goma, cistern as flexopleglables, tanques flexibles
Manufacturer:	Arcotex, Continental

TECHNICAL DATA:			
Dimensions:			
from 700 1	over 10.000 1	up to 40.000 1	up to 100.000 1
2.00 × 1.25 m	4.80 × 3.20 m	8.5 × 5.30 m	10.1 × 10.5 × 1.3m
Weight:			
12 kg	54 kg	130 kg	338 kg
Extent of Mechanization:	not mechanized		
Form of Driving Energy:	not powered		

Form of Driving Energy:	not powered		
ECONOMIC DATA:			
Investment Costs:	5,000 I tank approx. 2000 US$ FOB Santiago de Chile		

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance Expenditures:	low |—————|—————| high
Location Requirements:	due to their flexibility and collapsibility, empty tanks can also be transported through small doors in buildings or into the mine.
Replaces other Equipment:	brick tanks, tank-cars
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very |—————|—————| goodbad
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Arcotex Company information, Continental Company information

OPERATING PRINCIPLE:

The flexible tanks have an interior lining which inhibits splashing of the fluid

content, enabling transport by truck to meet supply requirements for mine water, gasoline, diesel, chemical fluids, etc. The collapsed empty tanks require very little space (less than 5% that of full tanks), allowing the trucks to be used for product and material transport on the return trip.

AREAS OF APPLICATION:

Transporting of fluids for mining, agriculture and industry.

SPECIAL AREAS OF APPLICATION:

Permanent stationary tanks.

REMARKS:

The tanks are filled without pressure, eliminating any need for filling pumps or similar equipment.

The tanks are made of a very strong nylon material which is coated on both sides with black synthetic rubber. The individual sections are joined by heat-cured (vulcanized) seams. To improve safety, additional nylon tarps are placed underneath the tank.

Flexible tanks are available on the market for the following fluids:

- **drinking water**
- **gasoline, diesel and other common fuels**
- **vegetable and mineral oils**

hydraulic fluids and lubricants
waste water, salt water
alcohols
ethylene and various derivatives
leaches and acids up to medium concentration
formaldehyde, formamide, glucose, glycol, glycerin
carbon dioxide, corrosion-preventives, glue, soap buck, various inorganic salts and their leachates, etc.

The tanks are resistant to ageing and to reactions with the fluid content within a temperature range of -30° to + 70° C.

SUITABILITY FOR SMALL-SCALE MINING:

Flexible tanks are especially attractive as mobile tanks for the combined truck transport of fuels (to the mine) and of raw materials (from the mine). They are also suitable for short term application as stationary tanks.

11.3 BY-Pass oil filters, by-pass micro-filters

Open-Pit Mining General Surface and Under ground Vehicles
Surface Mining Special Techniques

germ.:	Bypass-Olfiiter, Nebenstrom-Feinstfilter
span.:	filtro de aceite-bypass, microfiltro secundario
Manufacturer:	Kleenoil

TECHNICAL DATA:

TECHNICAL DATA:	
Dimensions:	0.15 m H, 0.15 - 0.25 m 0
Weight:	approx. 2.5 kg
Form of Driving Energy:	driven by oil pump pressure
Alternative forms:	for stationary systems, additional external manual pump
Throughput/Capacity:	approx. 100 I/h
ECONOMIC DATA:	
Investment Costs:	approx. 640 DM without delivery and installation
Operating Costs:	approx. 40 DM per filter element

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
Maintenance Expenditures:		low |————|————| high
Personnel Requirements:	periodic changing of filter	
Replaces other Equipment:	recycling of lubricating oil can drastically reduce mining equipment oil consumption, and especially minimizes of used-oil disposal problems	
Regional Distribution:	in industrialized countries	
Operating Experience:		very |————|————| good bad

Environmental Impact:		low |————|————| very high
	technique is environmentally advantageous	
Suitability for Local Production:		very good |————|————| bad
Under What Conditions:	good metal workshop, filter candles can be made from suitable types of toilet-paper rolls	
Lifespan:		very long |————|————| very short

Bibliography, Source: Kleenoil information

OPERATING PRINCIPLE:

A microfilter functions by pressing oil through a filter cartridge which removes:

- particles > 1 ym (common oil filters separate above 5 ym), and
- water (for example, condensed water from combustion) down to < 0.05 %.

This results in greatly reducing the abrasiveness of the oil, and substantially inhibits the development of acids from contact between the condensed water and combustion gases. The filter cartridges are made of tightly wound, long fibrous conifer-wood cellulose, held togother by a cotton sleeve.

AREAS OF APPLICATION:

Applicable either as by-pass filters in secondary oil circuits or as stationary microfilter systems.

In secondary oil circuits in engines, they can be installed, for example, on the pressure (delivery) side at the oil-pressure sensor using a tee-piece, or on the return side at the oil pan. The advantage of this installation is that the oil-change Interval no longer needs to be observed, with only an occasional change of filter cartridge being required.

Employed as stationary microfilters, the oil is pumped from the engine's oil pan during periods of non-operation (engine off) through a microfilter unit.

REMARKS:

Following longer periods of operation between oil changes, the oil normally contains up to 4-5 % impurities. With the use of filter cartridges, these impurities are already partially removed during engine operation, so that the time interval between oil changes (i.e. oil lifespan) can be increased ten to fifteen-fold.

90 % of machine wear is caused by acids which develop when acidic by-products combine with water in the oil.

The crucial problems of waste-oil disposal can be largely minimized through application of such filters, which reduce the volume of used oil to around 10 %.

Stationary filter types can also be used for cleaning of hydraulic oil.

Used filter cartridges can be burned, during which the production of smoke is

minimal due to the high proportion of vegetable fibers contained in the filters.

SUITABILITY FOR SMALL-SCALE MINING:

Fine oil filters, either as stationary or by-pass filters, can help solve the disposal problems associated with used oil by substantially extending the lifespan of lubricants.

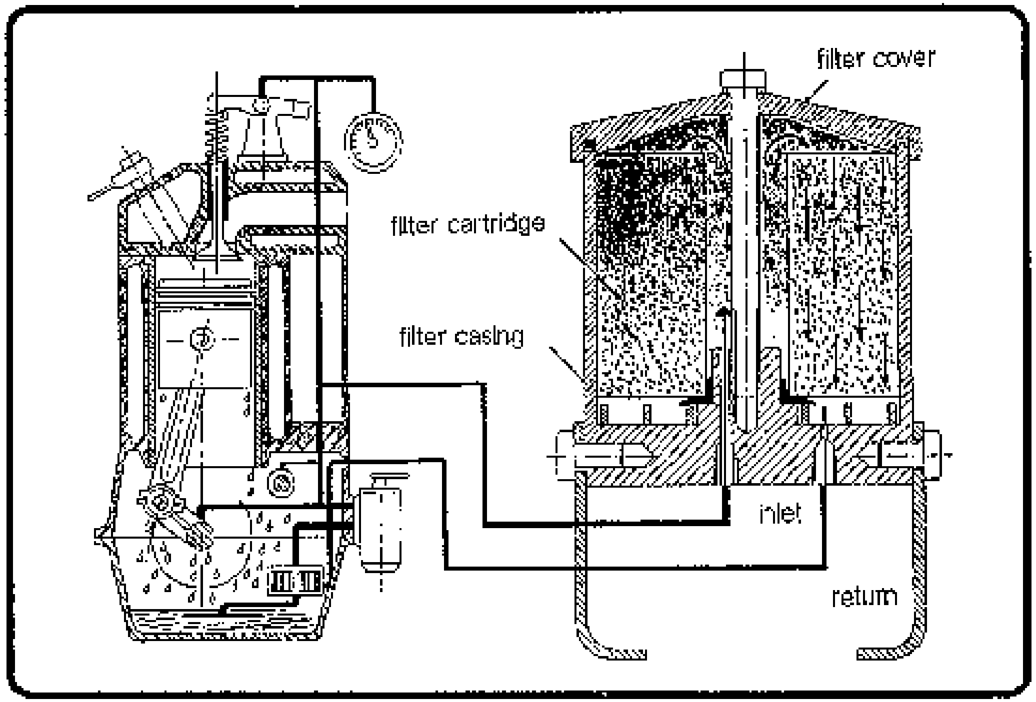


Fig.: Operating principle of a by-pass oil filter in secondary oil circuit. Source: Kleenoil Company information.

11.4 Eccentric motor, vibrator, shaker

Open-Pit Mining Mine Workshop

Surface Mining Special Techniques

germ.: Unwuchtmotoren, Ruttler

span.: motores con contrapeso, vibrador

Manufacturer: Bosch, Italvibras, Netter, Schenck, AEG, Jost

TECHNICAL DATA:			
Dimensions:	depends on type and capacity, from 5 × 5 × 5 cm to 8 × 8 × 65 cm		
Weight:	approx. 100 g to more than 100 kg		
Extent of Mechanization:	fully mechanized		
Power required:	electric alternating-current vibrator: 0.03 - 11 kW; electric direct-current vibrator 0.2 kW (12V)		
Form of Driving Energy:	electric with direct and alternating current		
Alternative forms:	pneumatic		
Technical Efficiency:	vibration frequencies:		depending on form of drive electric
	low frequency,	900 - 3000 min^{-1}	
	high frequency	6000 - 12.000 min^{-1}	
	mechanical	600 - 35.000 min^{-1}	
	centrifugal	pneumatic vibrator	10 N - 70 kW

	centrifugal force:	pneumatic vibrator	10 N - 70 kW
		electric vibrator	40 N - 120 kW
ECONOMIC DATA:			
Investment Costs:	350 to 400 DM for 12 V - external vibrator		

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
Maintenance Expenditures:		low |————|————| high
Equipment which can be driven:	conveying chutes, delivery (feed) chutes, discharging chutes, proportioning chutes, vibrating screens, vibrating sorting units, drainage systems	
Regional Distribution:	vibrating devices are being increasingly employed in conveying, sorting, feed-proportioning and drainage equipment.	
Operating Experience:		very good |————|————| bad
Environmental Impact:		low |————|————| very high
	low noise pollution and possible resonance vibrations	
Suitability for Local Production:		very good |————|————| bad

Lifespan: very long |————|————| very short

Bibliography. Source: Company Information

OPERATING PRINCIPLE:

For use as vibrators or shakers, motors are equipped with unbalanced rotating weights which can be adjusted In order to vary the centrifugal force. An alternative system is the pneumatic piston vibrator, which is characterized by its high adjustability of vibrational frequency and amplitude. Shakers and vibrators can be used as external vibrators mounted to the machine exterior, or as internal vibrators shaking the material directly inside the machine.

AREAS OF APPLICATION:

For loosening or jarring, the vibratory motion reduces the friction forces or breaks down the adhesive attraction, causing the material to loosen and attain flow-like properties. For conveyance, the flow of material can be maintained with the help of vibrations inducing minute forward-advancing movements.

For compressing or compacting, an artificial "flow" of the material, similar to that produced for loosening or jarring, is induced by vibrating whereby the material particles are deposited as densely as possible and the volume of air or water pores is minimized.

REMARKS:

Through the use of an eccentric motor, the machine is shaken by rotational

vibration forces. The use of two counter-rotating eccentric motors of identical frequencies produces a resonance due to linear vibration (see diagram below).

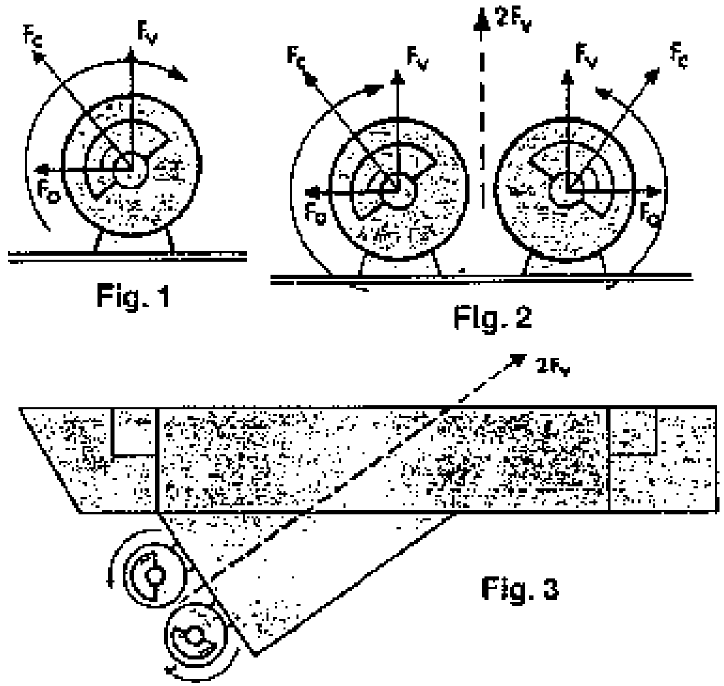


Fig.: Operating principle of a single centrifugal vibrator (Fig.1); two counter-roatating eccentric motors (Fig.2); and a linear vibration system with foundation determining the direction of vibration (Fig.3).

Vibrators should always be fixed at the most rigid (reinforced) part of a machine to allow optimal transmission of imposed vibration. In the event that no reinforcements exist, they must be added to the construction in the area where the shaker is to be attached.

When the entire machine is subject to a low-frequency vibrating, it should be mounted, depending on the weight, on rubber. metal fixtures, screws or leaf

springs.

The following approximation formula can be used to obtain a rough advance estimate of the dimensions for vibrators based on their centrifugal force:

Centrifugal force = (3 to 5) × (weight of the machine to be vibrated + 0.2 × weight of material to be vibrated)

Additionally, the following rough calculation can also be used (by Italvibras):

centrifugal force = amplitude of vibration × total weight of system to be shaken × (rpm)² / 900.000

$$\text{amplitude} = \frac{\text{work} \cdot \text{moment}}{\text{total} \cdot \text{weight}} \times 2$$

with centrifugal force:	kg	weight: kg
work moment:	kg mm	amplitude: mm
rpm:	min^{-1}	

Low-voltage direct-current shakers permit operation with energy supplied from solar cells.

SUITABILITY FOR SMALL-SCALE MINING:

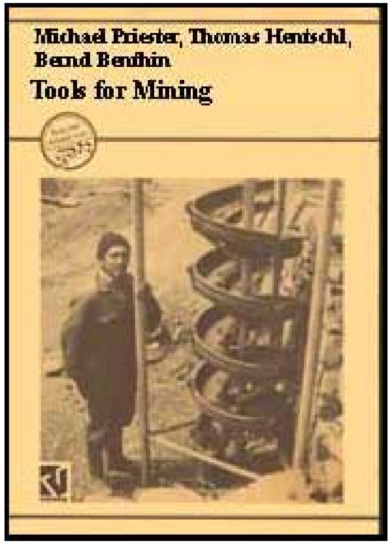
Imported vibrators and shakers, incorporated into locally-manufactured mining and beneficiation machines with high "local content", can increase both the

efficiency and technical quality of such equipment. In beneficiation machines, for example, vibrators increase the selectivity of the sorting processes.

Selection of the required frequency range is facilitated by the following table according to Bosch company information					
	Areas of Application and Vibration Frequency/min.				
PROCESSES AND MATERIALS:	**normal frequency**			**high frequency (HF) + compressed air**	
	1000	**1500**	**30000**	**6000**	**12.000**
COMPRESSING/ COMPACTING of light, normal, and heavy concrete			forms + casings for pre-poured concrete parts, vibrating tables, vibrating frames, battery casings, in-situ-concrete casings, slip form paver, stone forming machines		
of bulk materials of all kinds, molding sand, graphite, powdered quarzite, food stuffs		foundry machinery, packing machinery furnace lining, production of electrodes,			
LOOSING of bulk materials, e.g. sand, lime, cement, coal, grain, etc.		emptying of silos, bunkers, containers, casting boxes, forms, settling grids			
CLEANING		filter equipment, amongst			

	others		
CONVEYING of bulk materials, such as sand, gravel, crushed stone, granulates, concrete; of piece goods, such as castings, packages, chips/cuttings	conveyor chutes, discharge chutes, conveying pipes, ducts, vibrating chutes, spiral conveyors		
SCREENING dewatering	vibrating (jigging) screen, classifying (sizer) screens, dewatering screening through ceramic sieve		

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Acknowledgements

Deutsches Zentrum fr Entwicklungstechnologien- GATE

Deutsches Zentrum fr Entwicklungstechnologien - GATE - stands for German Appropriate Technology Exchange. It was founded in 1978 as a special division of the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH. GATE is a centre for the dissemination and promotion of appropriate technologies for developing countries. GATE defines "Appropriate technologies" as those which are suitable and acceptable in the light of economic, social and cultural criteria. They should contribute to socio-economic development whilst ensuring optimal utilization of resources and minimal detriment to the environment. Depending on the case at hand a traditional, intermediate or highly-developed can be the "appropriate" one. GATE focusses its work on the key areas:

- Dissemination of Appropriate Technologies: Collecting, processing and disseminating information on technologies appropriate to the needs of the developing countries: ascertaining the technological requirements of Third World countries: support in the form of personnel, material and equipment to promote the development and adaptation of technologies for developing countries.

- Environmental Protection. The growing importance of ecology and environmental protection require better coordination and harmonization of projects. In order to tackle these tasks more effectively, a coordination center was set up within GATE

in 1985.

GATE has entered into cooperation agreements with a number of technology centres in Third World countries.

GATE offers a free information service on appropriate technologies for all public and private development institutions in developing countries, dealing with the development, adaptation, introduction and application of technologies.

Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

The government-owned GTZ operates in the field of Technical Cooperation. 2200 German experts are working together with partners from about 100 countries of Africa, Asia and Latin America in projects covering practically every sector of agriculture, forestry, economic development, social services and institutional and material infrastructure. - The GTZ is commissioned to do this work both by the Government of the Federal Republic of Germany and by other government or semi-government authorities.

The GTZ activities encompass:

- appraisal, technical planning, control and supervision of technical cooperation projects commissioned by the Government of the Federal Republic or by other authorities

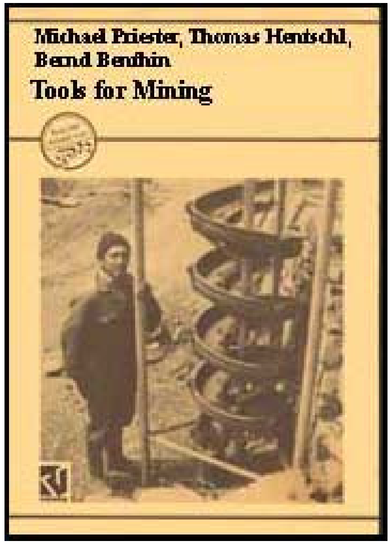
- providing an advisory service to other agencies also working on development projects

- the recruitment, selection, briefing, assignment, administration of expert personnel and their welfare and technical backstopping during their period of assignment

- provision of materials and equipment for projects, planning work, selection, purchasing and shipment to the developing countries

- management of all financial obligations to the partner-country.

Deutsches Zentrum fur Entwicklungstechnologien - GATE
in: Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH
P. O. Box 5180
D-65726 Eschborn
Federal Republic of Germany
Tel.: (06196) 79-0
Telex: 41523-0 gtz d
Fax: (06196) 797352



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

D. Beneficiation

D.1. Definition

The term beneficiation includes all procedures related to the enrichment of raw ores to produce marketable concentrates. These include not only mechanical procedures (e.g. wet mechanical processing) which leaves the material composition of the mineral unchanged, but also chemical procedures (e.g. leaching), which transforms the valuable mineral into other chemical compounds. In addition to the separation of valuable minerals from the non-desired material for purposes of concentration, or the so-called sorting process, the pre- and post-preparatory activities such as crushing, classification, drying, etc. are also included under beneficiation.

Significant values which define the success of beneficiation operations are the concentration factor, total weight recovery and valuable mineral recovery as well as the contents of the concentrate.

D.2. Initial conditions and problem areas

The processing of raw ores into marketable products is a problem of major concern for small-scale mining operations. At present, small-scale mining in developing countries is characterized by a distinct dualism. On the one hand, small operations exist which process their products using modern techniques. Problems with energy supply, the acquisition of spare parts, the availability of operating funds, or simply an inadequate knowledge of the equipment frequently drive these operations to the brink of economical efficiency. On the other hand, there are a number of small-scale mining operations which use more primitive labor-intensive methods and simple machine technology to process the raw ore. These operations are also confronted with substantial technical, organizational and economic difficulties. The major problems associated with these traditional processing methods are:

- minimal throughput, or low specific recovery

Traditional beneficiation facilities produce a throughput value for raw ore which is, in some cases, clearly below 1 t/MS. As a result, small-scale mining processing operations in developing countries are labor-intensive. The problem is intensified by the fact that, as a rule, the beneficiation is performed as a noncontinuous operation with frequent breaks and repetition of feeding, drawing, and deposition activites, resulting in high

proportions of idle time. In some cases, the idle periods can total up to 50 % of the total work time in small-scale mining beneficiation plants.

- low recovery

Desired-mineral recovery of only 50 % or even less occurs frequently . Half of the valuable minerals, which are expensive to extract underground, end up in the tailings piles. As a result, the recovered concentrate represents high production costs. The reasons for this minimal recovery are predominantly attributable to poor organization and planning of the work steps: too coarse or too fine grinding, insufficient classifying, inappropriate equipment selection, interrupted noncontinuous work operation, careless processing of fine-grained material, etc.

The causes for the low concentrate contents which sometimes occur are:

too wide a range of classification of the feed material for the wet mechanical sorting,

too coarse comminution (liberation not yet attained) or

very finely intergrown ores, for which the separation cut-off size in the fine-grain beneficiation is insufficient.

A modification of the entire beneficiation method is not possible for small-scale mining operations; however, there are a number of technical processes available which, when combined, can significantly increase the recovery in modern facilities to values typically in the range of 70 % and even up to 80 - 90 %, depending upon

the degree of intergrowth in the minerals. These processes are:

Physical processes
* wet and dry mechanical
* optical
** magnetic electrostatic processing
Surface-physical processes
* flotation
Chemical processes
* amalgamation and leaching, and finally
Biochemical processes
microbial leaching

Of these, only those marked with a * are of relevance for small-scale mining. Those marked with ** are generally only applied for secondary cleaning of the concentrate (re-concentration) and are farmed out to subcontractors (commission beneficiation). All remaining processes are not suitable alternatives for use in small-scale mining beneficiation due to high investment costs, high degree of complexity, local-market restrictions, or the absence of tradition surrounding the particular process in small-scale mining.

A mechanization and modernization of existing processing plants in small-scale mining operations is hindered by a chronic lack of capital or available funds. Credits for financing mechanization are also not available due to insufficient knowledge of the mineral reserves and the lack of feasibility studies necessary to

allow the deposit to serve as collateral.

It should also be emphasized that mechanization and modernization cannot always be regarded as positive entities. This is clearly indicated through numerous examples where partially malfunctioning or already abandoned modern beneficiation facilities have been rejected in favor of the simple, traditional small-scale mining techniques. The dependence on energy, spare parts and operating materials, combined with the loss of flexibility as a result of high investment costs, often led to more severe problems than those associated with traditional techniques.

Therefore, the possibilities of technical improvements are limited to the most economic inexpensive investments through the purchase and step-by-step introduction of locally-manufactured equipment. Furthermore, organizational improvements in the processing procedure can provide substantial economic advantages.

As an example, the cooperatively-run lead-silver mine in Pulacayo, Bolivia illustrates the necessity for changes in the work organization of the processing procedures. The miners, organized into cuadrillas (four-man mining team) operate about 30 parallel, traditional beneficiation plants, some of which are only able to process coarse-grained feed exceeding 1 mm in size. Fine-grained material with very high silver contents are discharged as tailings without being separated. The follow a rotating schedule between production and processing in which about one third of a monthly work phase is spent on processing. The ore quantity being mined by the cuadrillas for processing is, however, too small to support a beneficiation which includes fine-grain separation. Only the combined raw-ore output of several cuadrillas would provide a volume sufficient to justify fine-grain separation steps.

Beneficiation facilities exhibiting fewer, less critical problems, can also benefit from the incorporation of organizational or procedural improvements. Even minor optimization can achieve lasting improvements in operating efficiency. The critical role played by beneficiation in small-scale mining has long been overlooked.

Other concepts presented as solutions to small-scale mining beneficiation problems have often failed, as illustrated below:

Mobile processing plants which periodically concentrate the raw ore from an entire small-scale mining area, have failed due to problems with infrastructure and technology. According to a study done by the KfW on the possibility of introducing a mobile processing plant for lead-silver ores in the deposit-rich highlands of Bolivia, no appropriate location or mining region could be found. The lack of homogeneity of raw ores and deposits, poor road connections, and the subsistence existence of small-scale mining operations which demand a rapid return on capital, prevent the successful introduction of mobile processing plants.

Equally problematic is introduction of central raw-ore processing plants. High transportation costs and low ore values limit the profitability of central processing. Furthermore, the experience in small-scale mining in Bolivia has shown that central processing plants can only be successful when operated as non-profit enterprises, possibly sponsored by mining-related governmental agencies, and must be run at high capacity. Such an endeavor requires realistic analysis and weighing of facts prior to implementation. Concepts which deliver ore in the form of preconcentrates, whether as hand-sorted products or as pre-concentrates from simple, traditional separation facilities, expand the area of economic influence (marketing base) and offer more efficient solutions than those

involving the sale of raw ores or poorly-processed final concentrates.

Almost without exception, mines located in isolated remote areas have to process their ore in their own beneficiation plants due to the high cost of transportation. The following chapter offers suggestions regarding planning, construction and operation of processing plants appropriate for the needs of small-scale mining.

D.3. Proposals for procedural and organizational solutions

D.3.1 VARIOUS BENEFICIATION PROCEDURES

A number of different processing methods are available for separating raw ores into marketable mineral-ore concentrates, by-products and waste. The composition of the raw ore, the chemical and physical characteristics of the minerals contained in the raw ore, the grain-size distribution, etc. determine which of these methods are most appropriate for separating the desired mineral from the non-desired host material.

The primary processing methods available are:

THE GRAVIMETRIC BENEFICIATION PROCESS:

For the sorting of raw ore feed in which heavy minerals are the valuable mineral source, either dry or wet mechanical methods are employed, depending on the location, which utilize the difference in density between minerals to achieve the separation. In gravimetric processes, variations in density-specific phenomena (e.g. falling speed, radial acceleration), which appear in a sorting medium of air (dry sorting) or water (wet mechanical sorting), to produce a separation of the feed into two or more components (streams), one chiefly containing ore minerals and the other host-rock particles. Equipment used in gravimetric sorting includes sluices jigs, sink-float (heavy-medium) separators, buddies, spiral separators, cyclones, pneumatic classifiers (sifters), etc.

The gravimetric separation is the processing method typically used in small-scale mining.

THE FLOTATION PROCESS:

In flotation, the different electro-chemical surface characteristics of minerals are utilized in the separation process, in that some minerals in a fine-grained slurry are made hydrophobic through the addition of reagents (collectors, activators). Air injected into a tank (flotation cell) containing the slurry carries the hydrophobic particles to the surface where they collect as foam which is then subsequently scooped off. This form of separation, where the mineral concentrate is removed in the foam is known as direct flotation; when the mineral remains in the heavy liquid component, the process is known as indirect flotation. By varying the pH-values of the slurry and the reagent additives, different minerals can be selectively recovered.

In mechanized ore mining, flotation is the most widely used processing method.

THE AMALGAMATION PROCESS:

This process is applied on precious-metal ores. Gold, silver and some of their

compounds have the characteristic that they can alloy with mercury. These alloys are referred to as amalgams. To separate the precious metal, the raw ore is processed together with mercury, the amalgam removed, and the compound then dissociated into the precious metal and mercury by distillation. The amalgamation is performed in washing pans (bateas), sluices, vessels, barrels, amalgamating drums, Chilean (edge) mills, stamp mills, amalgamating bottles or tables.

THE MAGNETIC SEPARATION PROCESS:

Magnetic separation makes use of the varying magnetic susceptability of the minerals contained in the ore being processed. This physical characteristic (magnetism) enables individual, magnetic minerals to be separated from non-magnetic, or less magnetic ones through the use of a magnet.

THE LEACHING PROCESS:

Separation by leaching utilizes chemical solutions, transport and precipitating phenomena Here, under specific Eh-pH conditions, minerals are dissolved by certain acids, leaches or solutions. The presence of bacteria can have a catalytic effect on the reactions. In a separate facility, the metals are dissociated from the solution and concentrated. Leaching is performed in tanks, on ore stockpiles, or in-situ.

Cyanide leaching is gaining in importance in gold mining.

THE ELECTROSTATIC SEPARATION PROCESS:

Electrostatic separation is based on the varying ionization characteristics between minerals subjected to an electric field. This procedure is, however, seldom used.

In addition, there are methods of optical sorting which, however, are only of marginal importance.

Fundamentally, the design of a beneficiation facility should limit, as much as possible, the number of different sorting procedures employed; the greater the number of processes, the more expensive the machinery, and the more complicated, sensitive and unmanageable the beneficiation operation becomes in general.

D.3.2 PREVENTING IDLE PERIODS AND ACHIEVING A CONTINUOUS MODE OF OPERATION

Ore beneficiation in the traditional small-scale mining industry in Bolivia is usually performed as a discontinuous process. Substantial time is lost through intermediary storage of products, restocking the supply of feed or in preparing the equipment. Observations by the authors in the processing facilities indicate that this idle, wasted time accounts for up to 50% of the total time worked. Consequently, attempts to improve processing-plant throughput should be directed toward achieving a continuous mode of operation in which the entire raw-ore feed quantity undergoes comminution, sorting and classifying steps.

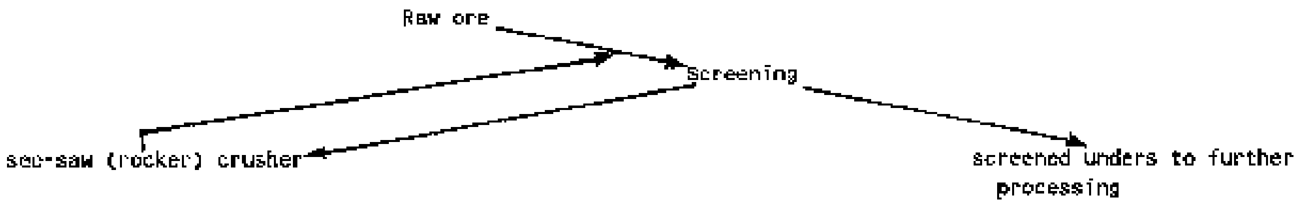
D.3.3 CAREFULLY-PERFORMED COMMINUTION

The output in processing plants drops with decreasing grain-size of the feed. Even in modern mechanized plants, the finest grains present difficulties for the operation. Hence, it is absolutely necessary to ensure that comminution is

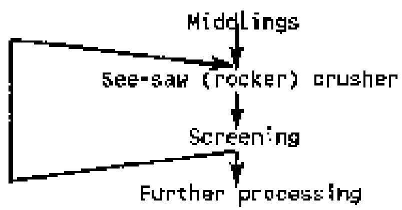
performed so as to produce the smallest possible quantity of fines. This is especially important for those valuable minerals which exhibit a brittle to very brittle tenacity, such as cassiterite, sphalerite and the tungsten minerals scheelite and wolframite. The tenacity describes the fracturing behavior (as opposed to cleavage or scratch (abrasive) hardness) of the mineral, and decisively governs the behavior of a mineral during comminution. Brittle minerals tend to be comminuted quicker, frequently resulting in over-milling (and associated higher proportion of fine material). To prevent the valuable mineral from being reduced to such fine fractions that they can be separated only with great effort, a carefully-controlled crushing is required. When grinding is necessary, it should be limited to a short period, after which a classification can be performed with subsequent regrinding of the over-sized grains.

It is often possible to omit grinding to a large extent.

A flow sheet of a traditional beneficiation facility including a carfully-performed comminution would appear as follows:



A regrinding of the middlings would require the following processing steps::



Figure

D.3.4 PREVENTION OF OVER-GRINDING

Grinding until liberation, or the dissociation of valuable minerals from host rock or waste material, is of fundamental importance to beneficiation technology. In so doing, the occurrence of intermediate products (middlings), i.e. intergrowths of host material with the mineral ores within individual grains, is prevented. On the other hand, however, such a technically-appropriate grinding (from the beneficiation point of view) creates other problems.

High concentrations of fines resulting from excessive grinding not only adversely affect the separation by reducing recovery but also raise energy consumption during grinding, which comprises up to 50 % of the processing costs in modern plants in some cases. In traditional manually-operated processing plants, this energy is produced by hand, for example through the use of simple "see-saw" (or rocker) crushers.

To eliminate the above-mentioned problems, grinding should be entirely omitted when possible and replaced by the processing of coarser-grained material to produce pre-concentrates. A regrinding of the middlings from the coarse-material sorting considerably reduces the feed quantity for the grinding process. This results in lower energy costs (also of importance in terms of energy-supply investment costs), relatively high recovery values, but non-optimal concentrate contents, however.

When the optimal grain size is exceeded, increased losses of the valuable mineral

occur during the pre-concentrate separation process as a result of intergrowths which inhibit the complete liberation of the mineral contained in the large grain sizes.

Raw ore characteristics such as degree of intergrowth, grain-size distribution of the valuable minerals, etc. determine whether a grinding of the feed material is absolutely necessary. Whenever possible, the separation steps should receive only a crushed or broken feed material, such as can be produced by a roll crusher, which yields a final grain size of up to 1 mm. The roll-crusher produces a product which is homogeneous in granulation and therefore exhibits a relatively low proportion of fine fractions.

D.3.5 PROCESSING OF NARROW GRAINSIZE RANGES

In all of the sorting processes, and particularly the gravimentric processes, a classifying effect occurs in addition to a separating effect. Many of the gravity-separation processes are based on sedimentation within a water media, whereby the settling velocity plays a major role. Particle behavior of large, light grains (of low specific density) and small, heavy grains (of high specific density) is similar, which is indicated by their almost identical speed of falling. In order to minimize the classifying effects during classification separation, it is necessary to achieve a sufficiently thorough pare-classifying of the feed material to permit further separation to occur only on narrow grain-size ranges. Many of the traditional small-scale mining plants in Bolivia classify their feed, with grain-sizes between less than 30 mm and the finest fraction, into only five or even fewer grain-size fractions. This results in a relatively low total recovery, and low valuable-mineral content in the concentrate, since the concentrate contains impurities of waste-

material particles which exhibited the same hydraulic behavior as the valuable-mineral particles during gravity separation.

The density and solids content of the slurry feed are essential parameters for achieving good separation results from classifying, sorting, and clarifying steps. The maximum allowable solids-contents of the feed for the various separation equipment are presented in the following table (from Trawinski, Priester):

Table: Standard Values for Solid Contents of Slurry Feed for Classifying, Sorting and Clarifying Processes

	Solids Content of Feed
Conical hydrocyclone	max. 20 % by vol
	in extreme cases up to
	40 % by vol
CBC cyclone	max. 15 % by vol
	in extreme cases up to
	25 % by vol
Countercurrent hydro-classifier	25 - 40 % by vol
Rake classifier	30 - 50 % by vol
Spiral classifier	30 - 50 % by vol
Tables	max. 15 - 20 % by vol
Spiral cleaner	max. 15 - 20 % by vol
Conical separator	max. 20 % by vol

Jigs	max. 10 % by vol
Dense medium cyclone	max. 10 % by vol
Countercurrent separator	max. 25 % by vol
Buddles	max. 10 - 15 % by vol
Circular buddies	max. 10 % by vol
Sedimentation barrel	approx. 30 - 50 % by vol
Filter press	15 - 40 % by vol
Disk-type vacuum filter	10 - 20 % by vol
Rotary drum vacuum filter	10 - 30 % by vol
Rotary-drum belt-type	
vacuum filter	20 - 40 % by vol
Thickener	max. 5 - 10 % by vol

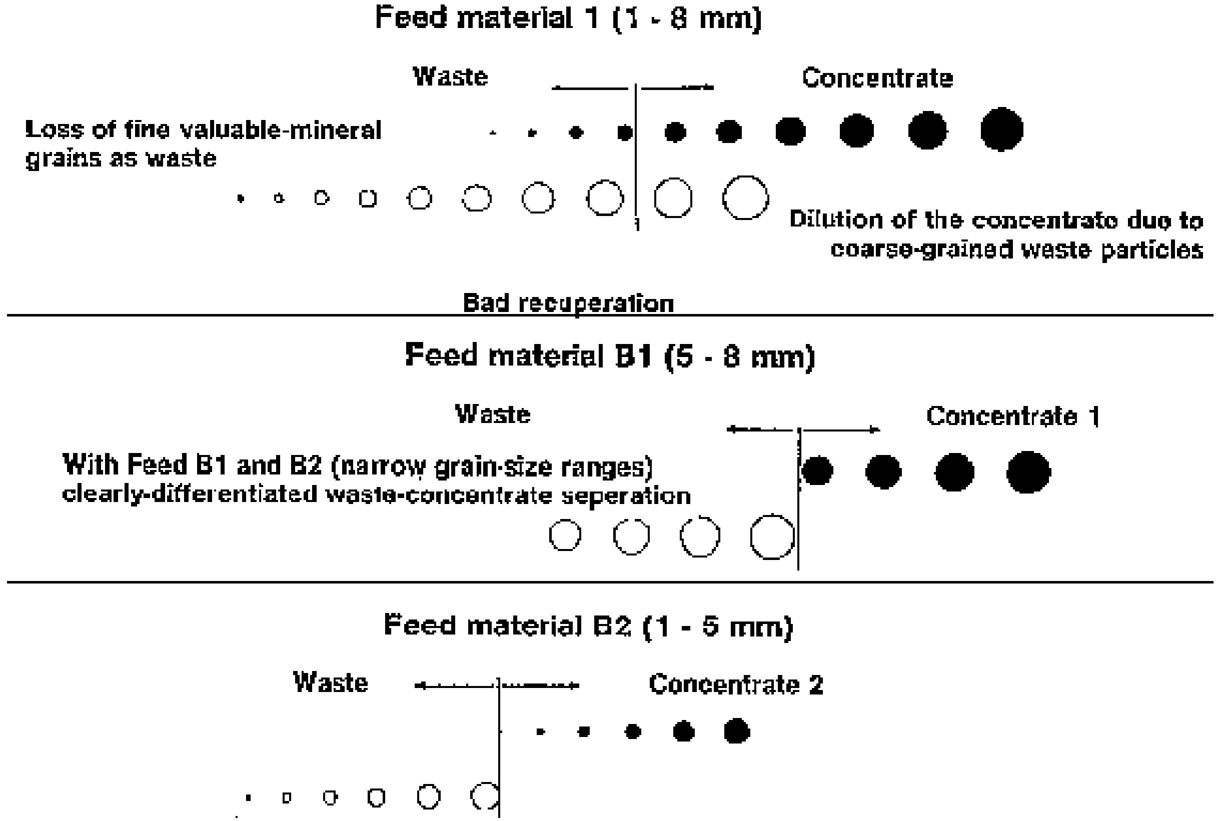


Fig.: Schematic diagram of a classifying separation with wide-range (1) and two narrow-range (B1 and B2) classified feed fraction; black circles; valuable mineral (heavy component), white circles: vaste mineral (light component).

Table: Gran-size ranges (in ym) of feed material for various beneficiation equipment and techniques: upper and lower limit, respectively; extreme values in parentheses.

Conical hydrocyclone	(5) 10 - 200
Rake classifier	200 - 5000
Hydraulic classifier	(20) 50 - 1000 (2000)

Wet screen classifier	(50) 75 - 5000
Dry screen classifier	(40) 100 - 10000
Pneumatic cyclone	(10) 50 - 150
Sizing drum	250 - 50000
Hand sorting	5000 - (500 mm)
CBC cyclone	20 - 500
Shaking table	(20) 50 - 1000 (3000)
Spiral separator	(30) 50 - 1000 (3000)
Cone separator/ fanned sluice	(30) 50 - 1000 (3000)
Sink-float separator	(400) 500 - 5000
Dense-medium cyclone	200 - 5000
Jig	(80) 100 - 5000 (10000)
Sluices	(60) 100 - 1500 (3000)
Bartle's-Mozley table	(2) 5 - 100 (200)
Low-intensity wet magnetic separator	(40) 50 - 2000 (5000)
High-intensity wet magnetic separator	(10) 20 - 500 (2000)
Flotation	(5) 15 - 500
Foam Flotation	(100) 150 - 1500 (2000)
Selective agglomeration	2 - 50
Thickener	0 - 50
Bartle's belt table	(5) 10 - 100

Amalgamation	(20) 50 - 2000
Gold leaching	0 - 750
Fluidized bed concentrators or centrifuge	20 - 2000
Flotation in sluices	200 - 3000
Flotation in buddies	20 - 250
Washing gulley	100 - 2000
Sludge pond, buddle	(20) 50 - 1500
Mechanized buddle	10 - 500
Dolly tub (Schanz process)	20 - 2000
Air Jigs	30 (200) 500 - 2000
Air tables	50 - 600 (50 mm)
Dry magnetic separation	
- low intensity	100 - 5000
- high intensity	80 - 1000
Electrostatic sorting	(75) 100 - 1000 (1500)
Electrodynamic sorting	(40) 70 - 2000 (5000)
Magnetic induction	500 - 10000
Dry Sluice	75 - 1500
Dry vibrating Sluice	200 - 1500

D.3.6 INCREASING SPECIFIC THROUGHPUTS

The use of certain equipment or processes in a traditional beneficiation procedure limits the throughput of the entire operation. An example of this is the employment of sludge ponds to recover the fine-grained solids in a slurry, which perform with such a low throughput so that some processing plants have entirely eliminated any separation of fines. Considering that the finest grains contain significant amounts of the valuable mineral, this decision is detrimental in terms of total plant recovery values. As an alternative, solutions such as those applied, for example, in San Cristobal, Porco, Bolivia should be emphasised. In this region, the parallel operation of multiple sludge ponds has been implemented in order to increase the specific throughput in the fine-grain separation steps. The simultaneous, parallel running of other processing steps in a continuous or semi" continuous operation is likewise possible, such as pinched sluices, spiral separators, funnel furnaces, etc.

D.3.7 HYDROCLASSIFYING VS. SCREENING

Especially in wet mechanical beneficiation processing, the type of classifying employed determines the precision of separation in the sorting process. Hydroclassifying is clearly more appropriate than screening for feed-preparation of sorting equipment such as furnaces, buddies and sluices. The reason for this is that a hydroclassified material is separated according to equal settling rates, which means that larger, lighter particles and smaller, heavier particles end up in the same fraction. When one of the above-named pieces of equipment is charged with this feed, a better spatial separation between heavy and light materials is achieved than with screened feed due to the drifting resulting from the flow forces applied on the grain surfaces. A further advantage for small-scale mining is the continuous operating mode which hydroclassifying provides in non-mechanized

plants.

At present, screening is the primary feed separation method used in traditional small-scale mining in developing countries. It has, however, the following disadvantages:

- **low throughputs**
- **low separation precision**
- **higher operating costs, and**
- **discontinuous mode of operation,**

which are eliminated with hydroclassifying.

D.3.8 PRODUCTION OF PRE-CONCENTRATES

In order to avoid handling large quantities of material in the beneficiation facility, one of the initial steps should be the production of pre-concentrates, particularly where feeds of low valuable-mineral content are involved, such as tin ore with around 2 % Sn, but also for higher-content feeds as well. These pre-concentrates can be produced by one of two methods, or a combination of both. The simplest method involves manual hand sorting, whose importance and application to "selective semi-mechanized mining" in solving beneficiation problems specific to small-scale mining has already been described in Horvay (1983). Through manual sorting or hand picking, a marketable hand-sorted concentrate, as well as a pre-concentrate for further beneficiation, is obtained. The alternative method for achieving pre-concentrates employs sorting equipment with high specific throughput.

Whereas hand sorting of pre-concentrates is realistically limited to material of grain-sizes larger than 10 mm, a wide assortment of pre-concentrating sorting equipment is available for feed material of grain-sizes ranging from 30 to 100 mm. These are:

for coarse grain sizes: (approx. 1 - 2 mm)	piston jig
for medium grain sizes: (approx. 300 ym - 2 mm)	Sluices, sludge ponds, spiral separators,
for fines: (approx. 50 - 500, ym)	pinched sluices

The employment of any of the above-named sorting equipment requires a presizing of the feed material in order to achieve a sufficiently high recovery from the pre-concentrating process.

- The primary advantage of pre-concentrating the raw ore is that the quantity of feed entering successive sorting steps is reduced. Pre-concentration of feed material, for example tin ore, from 2 to 4 % Sn (in this case), eliminates 50% of the waste material (assuming 100% recovery), and the throughput quantity in the succeeding steps is reduced to one half.

- For all of the marketable hand-sorted pre-concentrates, further beneficiation efforts (comminution, classifying, sorting) are not necessary. Losses in recovery can also be avoided for this portion of the ore.

D.3.9 HOMOGENIZATION OF FEED MATERIAL

In small-scale mining in Bolivia, the authors could repeatedly observe that totally inhomogeneous feed material served as charge for the various separation equipment. A sludge pond for fine-grain separation serves as an example in which first the middlings from a previous separation step and then raw ore comprised the feed, whereby the second feed input (raw ore) was deposited directly onto the sedimentation cone of the first (middlings). This procedure can lead to spatial variations in concentrations within the subsequent sedimentation cone due to extreme periodic variations in the granulation and heavy-metal content of the feed. This problem can be solved by mixing the separate feed constituents in order to attain a homogenous feed prior to further processing. Homogeneity of the feed is essential for semi-continuous or continuous processes whose operating parameters such as feed quantity and rate, inclination of separating tables, reagent additives, etc. are determined by the slurry-feed characteristics.

Sufficient homogenisation can frequently be achieved through very simple methods, such as the dumping of different feeds, one on top of the other, onto the cone-shaped discharge pile. While the cone as a whole is inhomogeneous, removing the material from the side near the bottom of the cone induces a certain degree of homogeneity through the resulting sliding and resettling of material.

D.3.10 SECONDARY PROCESSING OF THE MIDDLINGS

In all traditional beneficiation procedures, middlings are produced as a by-product

of the processes. These products occur as two different forms, namely:

> **- middlings produced as a result of low separation accuracy in the sorting facility. Although the components are liberated, i.e., the valuable mineral occurs as free grains and is no longer intergrown with host rock, waste material, or secondary minerals; however, the grains are not separated according to whether they do or do not contain the valuable mineral. This type of middlings frequently occurs in mechanized gravity-separation processing, especially when the specific characteristics, such as density, do not vary greatly between the valuable mineral and the host rock particles.**

> **- middlings which emerge from prior comminution steps but still exist in an unliberated form where individual grains still contain intergrowths of the valuable mineral with host rock material. This type of middling product occurs even in the most precise separation processes, and valuable mineral so contained cannot be separated by further processing without additional comminution.**

The two forms of middlings can also occur as a combination. In any event, the nature of the middlings must be determined prior to any successive processing to prevent any unnecessary expensive regrinding of already-liberated material and resulting reduced recovery due to the increased proportion of fines. The washing pan (common for panning for gold) offers a simple, fast and reasonably priced apparatus for quickly determining the characteristics of the middlings and the further processing steps required:

- liberated middlings require secondary separation
- non-liberated middlings require recrushing or regrinding prior to secondary separation.

In small-scale mining in developing countries, middlings frequently receive only very incomplete further processing, or are simply discarded as waste. This practice, however, cannot be economically justified; no additional mining costs, and only minimal grinding and separating costs, are incurred by secondary processing of the middlings, costs which generally can be recovered through marketing of the resulting products. Only in cases of very fine-grained material should the sale of middlings to an operation with mechanised beneficiation be considered.

D.3.11 CLASSIFYING OF FEED PRIOR TO SEPARATION PROCESSING

Technical journals of the last century record the debate among engineers over the English versus German classifying methods used in beneficiation processes.

The "Harzer" or German method involves first sizing the feed material and then separating the narrow grain-size fractions, while **the English method** makes use of the sizing effect of the wet mechanized separation operation and then classifies only the products. For example, in the case of sludge-pond separation, the feed material, which includes a wide range of grain-sizes, is sorted and the concentrate extracted and then classified. The coarse-sized material thus obtained comprises the end concentrate, and the undersized material constitutes the pre-concentrate which is then further separated.

Mining of base metals (non-ferrous metals) in Latin America, particularly tin

mining, was primarily influenced by Anglo-Saxon engineering during the 19th century. As a result, the English method of wet-mechanized beneficiation has been dominated even in small-scale mining. The advantage of this method is that only the concentrates and the middlings are classified, with waste material remaining unclassified. In so doing, the cost of sizing is minimised. I However, the several disadvantages associated with this method justify a reconsideration of the use of the English method in small-scale mining. On one hand, the sorting of feed material which exhibits a wide-range granulation occurs at such high slurry flow velocities that the coarse grain fractions are also separated out. These high slurry velocities also frequently cause the fine and very fine-grained particles to be carried off due to their large specific surface area and be removed as part of the tailings. A sizing of the material before sorting would have the advantage that the fine and finest grain fractions could be separated and sorted at low slurry flow velocity. On the other hand, the disadvantages of subsequent classifying via settling are substantial. Materials exhibiting a wide range of grain sizes are more difficult to sort by settling processes than materials of narrow-range granulation. This is explained by the fact that the bonds in narrow-range grain-size fractions are loosened more easily during the pulsating settling process, therefore requiring less energy. This is of significance particularly in the manually-run jig separation process in small-scale mining in developing countries.

D.3.12 BENEFICIATION OF FINE-GRAINED MATERIAL

A significant shortcoming of beneficiation facilities, both in large-scale operations as well as in small-scale mining processes in developing countries, is the insufficient attention devoted to fine grain sorting. Beneficiation plants with low valuable-mineral recovery (for example, less than 50 % recovery from modern

mechanized beneficiation of tin ores at the Bolivian state-owned COMIBOL mines), lose, as a rule, a large quantity of the valuable-mineral source in the fines. Additionally, plants are encountered where fine-grain sorting is non-existent. The rich silver ores of Pulacayo (Bolivia) are beneficiated using traditional small-scale mining methods whereby, in some cases, all material smaller than 1 mm lands on the waste pile. In view of this problem, the significance of fine-grain beneficiation cannot be emphasized enough. Especially for two raw-ore types, the concentration of valuable mineral in the fine and finest fractions is of great importance:

- raw ores which exhibit a fine intergrowth and therefore require fine grinding to liberate the valuable mineral. Deposits of non-iron metallic ores, for example those of sub-Volcanic or submarine emanative genesis, or sulfide veins with oxidized valuable-mineral sources, or stratified tin deposits, such as frequently occur in the Latin American Andes, exhibit this fine intergrowth and must be handled during beneficiation with special attention regarding the fine grain distribution. Similarly, alluvial gold deposits where the gold occurs as fine grains also belong to this category of raw ores. In traditional mining operations without any separate fine-grain separation processes, the recovery can lie well below 10% in some instances.

- raw ores where the valuable-mineral sources are brittle minerals which are quite easily subject to overgrinding during comminution. Sphalerite, cassiterite (tin ore) and scheelite are only a few examples of this type of brittle mineral ore (see Table). A pre-concentrate can already be achieved by performing selective classifying, since the fine" grain fraction already represents a pre-concentrate following the initial comminution step. In any

event, beneficiation of these raw materials requires that particular consideration be given to the fine-grain fractions.

One solution is demonstrated by the unfortunately already historic example of a wet mechanized silver-ore beneficiation performed in Pulacayo, Boliva up until 1952, where even separating table wastes were resorted using mechanized sludge ponds to achieve very fine concentrates. In mining of gold alluvial deposits, gold centrifuges and cyclones, for example, could be employed; for extracting non-iron metallic-ore concentrates, the above-mentioned mechanized sludge pond, Bartles-Mozley-separating table, or blanket sluice (corduroy table), etc. could be used.

Difficulties are encountered in the wet mechanical separation of fine and very fine-grained material due to the fact the final falling velocities of minerals of varying density approach similar values with decreasing grain size. Thus, beneficiation of the finest grains involves greater expense and achieves lower recovery at a lower degree of concentration compared to those separation facilities for coarsergrained material. Nevertheless, in the majority of cases, a fine or finest-grain sorting stage is of advantage.

D.3.13 MANUAL SORTING BY HAND

Hand sorting of raw ores, feed materials and concentrates during beneficiation is of special significance in small-scale mining operations, as mentioned by Horvay (1983) amongst others. Examples from fluorite mining in the Upper Pfalz region of Germany (until 1988) show that even under conditions of extremely high labor costs, as found in German mechanized mining, hand picking plays an important role. Pre-concentrates or concentrates can be won by manual sorting, performed

either as negative selection (sorting out of waste-rock material) or as positive selection (selection of chunks of pure ore). In both cases, the material load on the beneficiation plant is obviously reduced. Moreover, for positively-selected material, losses due to low valuable-mineral recovery are minimised. One difficulty is the relatively low efficiency, or performance rate, which characterizes the hand-sorting operation in Andean small-scale mining, as a result of very poor working and sorting conditions. Improving the hand-sorting operation by providing cleaner material (through wet classifying of coarse material, for example), better lighting, etc. at the separation tables or sorting belts could increase efficiency.

D.4. Environmental and health aspects

Beneficiation operations exert substantial impact on the natural environment.

Noise pollution from comminution (crushing or grinding) processes and the operation of power equipment.

Air pollution from multiple sources:

- Dust pollution, especially as a result of dry sorting of feed material, for example from air classifiers and dry classifying.

- Air pollution resulting from mercury vapors produced during open-circuit distillation of amalgam occurs frequently in gold mining and leads to a variety of health risks due to mercury contamination: loss of hair, decay of fingernails and bones, and can also result in death (see also Section D.6.5.1).

One solution to this problem is the implementation of closed-circuit amalgamation through the use of distillation retorts.

Water pollution. Contamination of the drainage system from beneficiation processes is an especially serious and dangerous problem, particularly considering the multiple utilization of surface water. In semi-arid regions with defined dry periods, rivers represent the ultimate source of water. The use of water can basically be categorized according to three primary purposes:

1. as drinking water for the population, which usually uses untreated water directly from rivers.

2. for irrigation purposes in agriculture, and

3. as process water for small industries, whereby mining with its widespread geographical distribution and large water requirements for raw-ore beneficiation is the primary industrial consumer of water.

Legal restrictions regarding water rights, environmental regulations, etc. in the Andes region are generally either non-existent, or their compliance not controlled, so that competitive surface water consumption needs pose serious problems.

The situation is worsened by the fact that the natural biochemical decomposition of toxic pollutants in the water occurs at a substantially slower rate in the Andes region due to the high elevation with its low oxygen partial pressure and very low water temperatures.

Specifically, the following pollutants may be released by beneficiation processing:

- Sludge/Silt: occurs in all wet-mechanized and flotation beneficiation processes.

- Toxic flotation reagents: those reagents most commonly used in small-scale mining in Latin America are sulfuric acid, diesel oil and long-chained carbon-hydroxides (frothers and collectors) such as xanthate. In small-scale mining, the manner in which these substances reach the drainage system is not known. Especially problematic is the regulation of dosages of reagent additives used for the noncontinuous, low-recovery flotation processes. Compared to large industrial-scale flotation operations, the concentrations of reagents used in small-scale mining are extremely high.

- Highly toxic cyanides: used as activator substances in selective sulfide flotation and in leaching. The decomposition of cyanide normally takes two years; however, in the Andes region the process is accelerated as a result of more intensive ultra-violet (UV) radiation at higher elevations. Demarcated sludge ponds (sedimentation basins) for receiving waste products are urgently necessary in small-scale mining as well.

- Amalgam and mercury: These two substances are released in water during amalgamation of gold in stamp mills, sluices, tables, and Chilean (edge) mills. More detailed information on this subject is presented in Section D.6.5.

The mining industry's most serious environmental problems stem from the beneficiation operations. In this area, changes and remedial measures designed specifically for small-scale mining are particularly important, a fact which justifies

the large amount of attention given to beneficiation in this handbook.

D.5. Processing of diamonds

Diamonds constitute an important branch of precious-stone extraction. Small-scale mining accounts for about 10 - 15 % of the entire global diamond production. The methods employed for mining and processing diamonds differ according to the geology of the deposit:

1. **Primary deposits, diamond-containing volvcanic breccia (tuff) of basic and ultra-basic rocks such as Volcanic chimney vents, the socalled Kimberlite or blue ground; additionally, Precambrian olivine rock.**

2. **Secondary deposits which consist of weathered, decomposed products of diamond-containing rocks. These may develop either as hardened sediments, for example in the form of conglomerates, as loose sediments in river beds, or above blue-ground deposits as yellow ground.**

In the beneficiation of diamonds originating from primary deposits or hardened sediments, care must be taken to prevent the precious raw stones from being crushed or ground along with the waste rock. The high cleavability (splitting tendency) of diamonds requires a very careful grinding of the parent rock. In the South African small- and medium-scale diamond mining operations, a special form of grinding has been developed. Following extraction, the feed material is thinly distributed over the ground surface where it is exposed to natural weathering. On the so-called 'floors' the weathering process is enhanced by adding water. The sorting of the comminuted material can proceed in different ways:

OPTIC-MECHANICAL :

Performed by hand sorting, whereby the feed material is spread out in a thin layer on a sorting table and the diamonds, being highly visible due to their light refracting characteristic, are manually sorted. The lower profitable grain-size limit lies at a weight of about 5 mg (1/40 karat).

Modern optic-mechanical separation procedures involve photometric or radiometric sorting which utilizes artificially-induced luminiscence of the diamond. A thin stream of material flows through an optical detector which responds to the special optical characteristics of the diamonds and steers a pneumatic nozzle which blows the diamond grain out of the material stream.

GRAVIMETRIC :

Gravimetric utilizing the density of the diamond (3.52 g/cm^3)

In the processing of diamonds, small-scale mining in developing countries frequently uses jigs, mostly in the form of manual separators. In this procedure, the lower profitable grain size is about 150 ym due to the minimal density variations between the quartz, the main sediment component, and the diamonds, the valuable mineral (q = 1.48 for separation in water). To increase the precision of separation, jigs with beds are used; for diamond processing, glass balls serve as the bed material (glass bed).

Grease tables utilize the strong hydrophobia exhibited by diamonds; the feed material is suspended in a slurry which flows over the greased surface of a stationary sorting table. The diamonds are drawn to the grease, from which they

are later individually recovered.

Additional methods of gravimetric separation include the sink-float separation processes with FeSi-slurries in normal sink-float separators or in heavy-media cyclones. The FeSi, a weighting material for increasing the slurry density which appears 65 to 90 % in the <0.05 mm fraction, is recovered after sorting by means of magnetic separation.

ELECTROMECHANICAL:

Electrostatic-separators can successfully separate diamond-containing feed up to maximum grain size of 6 mm, whereby the semi-conducting characteristic of diamonds are utilized as the basis of separation.

D.6. Gold beneficiation processing

D.6.1 GENERAL INFORMATION

The processing of precious-metal-containing raw minerals places special demands on the separation method employed due to the physical and geochemical characteristics of the gold and the economic geology of the deposits. Gold generally occurs in deposits where the content of raw ore, in primary deposits, lies at 100 - 200 g/t (maximum) and 1 - 2 g/t (minimum). The lower limit serves as the grade cut-off for marginally economically mineable deposits. Sedimentary deposits generally contain between 0.2 and approx. 20 · 50 g/t raw precious-metal ore. The beneficiation of these ores must, correspondingly, concentrate to a

factor of up to 100,000. At the same time, comparatively larger amounts of raw ores must be mined and processed in order to cover the production and processing costs. Due to the low wages in most developing countries, coupled with the predominance of manual labor, a gold recovery of about 0.3 9 gold per man-shift is still considered an acceptable production level.

A further problem confronting gold processing, specific to precious-metal alluvial (placer) deposits, is that many operations can only mine seasonally. During the rainy season, the rivers often carry such large quantities of water that mining activities in the riverbed or along the banks are hindered. Correspondingly, the beneficiation facilities must either be located above the high-water level or be semi-mobile to allow its transfer to higher ground at the start of the rainy season.

Additionally, the grain shape of gold, both from sedimentary deposits as well as after grinding, is in many ways unfavourable for hydromechanic gravity processing. Flat, flour-type gold grains of the smaller particle range can only be gravimetrically separated with major difficulty, despite the high specific density of gold.

D.6.2 ALTERNATIVE PROCEDURES

Among the various techniques for general mineral processing, many can be applied specifically for the processing of gold ores. The methods can be differentiated according to those methods which produce pre-concentrates that are not marketable as final concentrates, and those methods which lead to marketable final concentrates containing between 90 and > 99 % Au. These processing alternatives are presented in the following tables, in which those

techniques appropriate to small-scale mining appear in bold face.

Table: Methods for the processing of gold ores into pre-concentrates.

Type of separation	Process	Steps	Equipment	Reeagents
mechanical	GRAVIMETRIC BENEFICIATION	sorting	gold pan, jigs, sluices (wet + aero), tables (wet + aero), animal skins centrifugal classifiers, spiral classifiers, CBC cyclone separators, heavy material traps	
	DENSE MEDIUM SEPARATION	sink-float separation	sink-float separator, glass flask	dihydrogendodecawolfra. mate =3.1g/cm³
electrical	ELECTRO-STATIC BENEFICIATION		esta-separator	
surface mechanical	FLOTATION			
	- indirect	conditioning, sorting, washing	conditioning tank flotation cell	frothing agents, collectors, depressants, activators
	- direct	conditioning,		pH-reagents

		sorting, washing		
magnetic	MAGNETIC SEPARATION	sorting	magnetic separator	

*** analytical method only**

Table: Methods for Beneficiation of Gold Pre-concentrates into high-quality marketable Gold Concentrates

Clase of separation	Process	Steps	Equipment	Reagents
mechanical	HAND PICKING (SORTING)			
	COAL-GOLD AGGLOMERATION	agglomeration, separation, stripping	reaction vessel/tank	oil, activated carbon
thermal	ROASTING, AIR CLASSIFYING	roasting, air classifying	roasting furnace	
	GOLD VOLATILIZATION	chloridized roasting, voiatilization		sodium chloride, chlorine gas
	SEPARATION by SMELTING	smelting, separation of gold	furnace, caucible	borax, soda, potash
	FIRE ASSAY*	smelting with	muffle or retort	taste (assay) lead,

		gold collector, separation, cupellation	furnace, crucible, cupel	borax, soda, potash
chemical	AMALGAMATION with open or closed Hg cycle	alloying, separation, distillation	in stamp mill, chilean mill, amalgamating barrel, gold trap, sluice, amalgamating table, gold pan, centrifuge, amalgam press distillation retort	mercury, possibly caustic soda, sodium amalgam ammonium chloride, cyanide or nitric acid for joining finest Hg beads surface act. agts., tensides.
	CYANIDE LEACHING as heap leaching, vat leaching, agitation leaching with Merill-Crowe, CIP, CIC-, CIL process or zinc precipitation	chemical solution as complex, adsorption, stripping	leaching tanks, adsorbers	Na cyanide CaO for adjusting pH, Zn (possibly + $PbNO_3$) or activated carbon
	THIOUREA LEACHING	chemical solution as complex, adsorption,	leaching tanks, adsorbers	thiourea, pH-reagents, Al or Fe powder SO_2

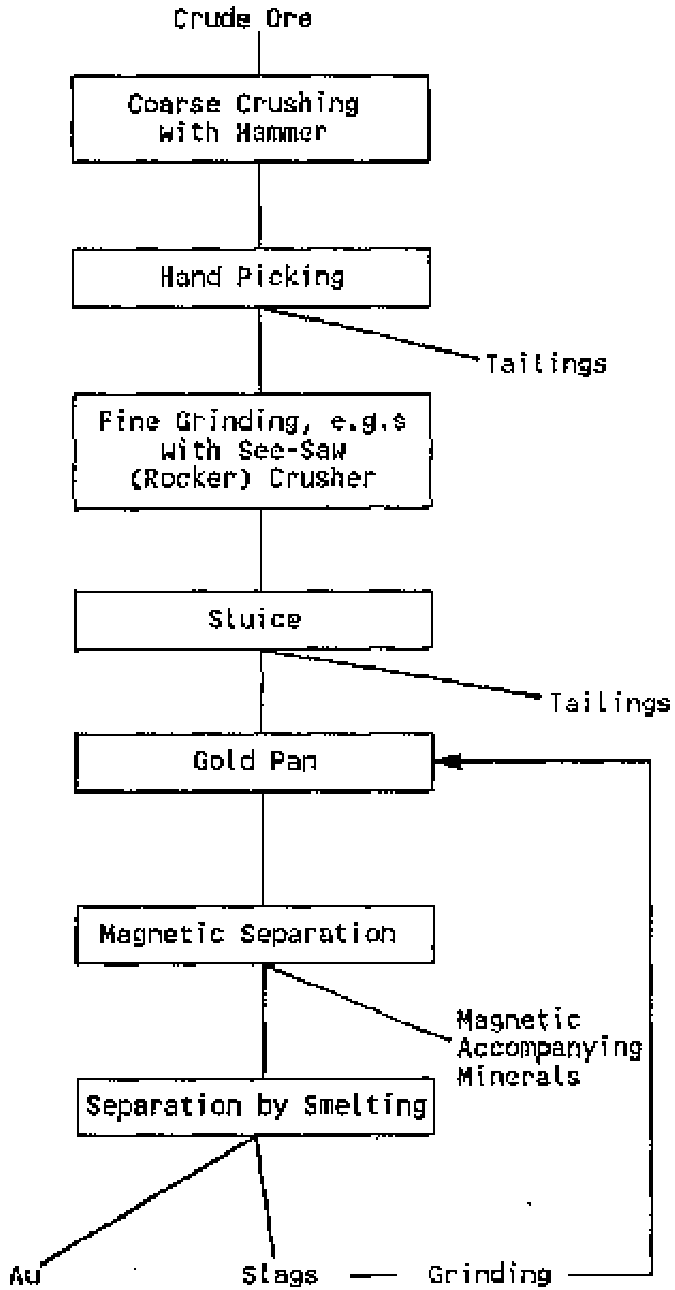
		stripping		
	CHLORINATION BIO-D- LEACHANT PROCESS	formation of halogen-complexes (e.g. tetra-chlorine-bromine com plex)	reaction tanks, leaching tanks	chlorine gas, organic bromodimethylhydrates
	BRINE LEACHING			salt solutions, manganese dioxide, sulfuric acid
	LEACHING with solutions, containing thiosulfate, rhodonate, polysulfides or nitrite			
biological	BACTERIAL LEACHING			bacteria, air as oxidizing agent

*** as an analytical method only. Techniques printed in bold type are wholly or partly applicable to small-scale mining.**

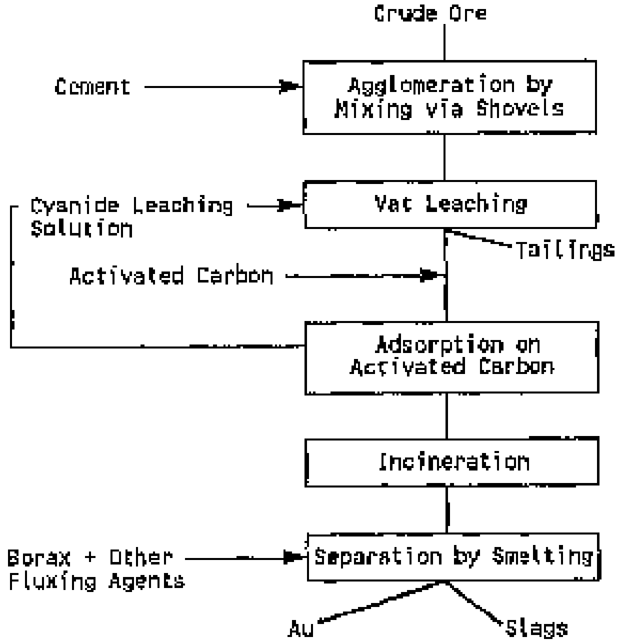
D.6.3 PROCESSING PROCEDURES

Depending upon the nature of the raw ore, and the investment possibilities for the

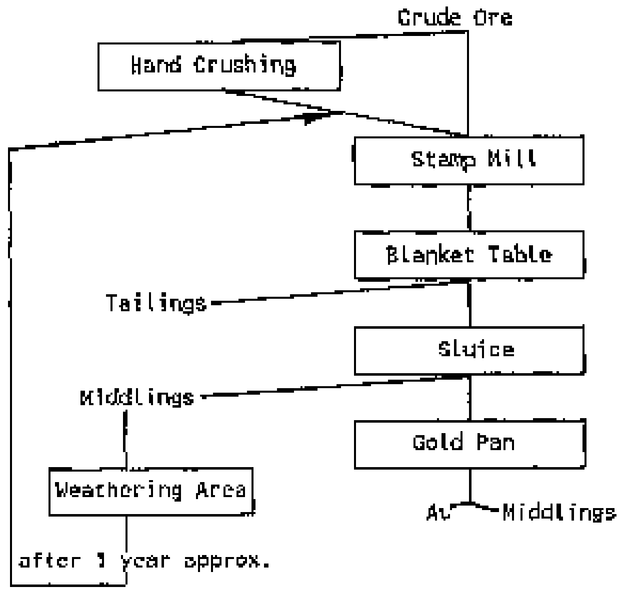
beneficiation plant to acquire equipment, processes emerge which include production of final concentrates. A few selected procedures for gold-ore beneficiation of various raw ores and grain size magnitudes are presented as flow sheets on the following pages.



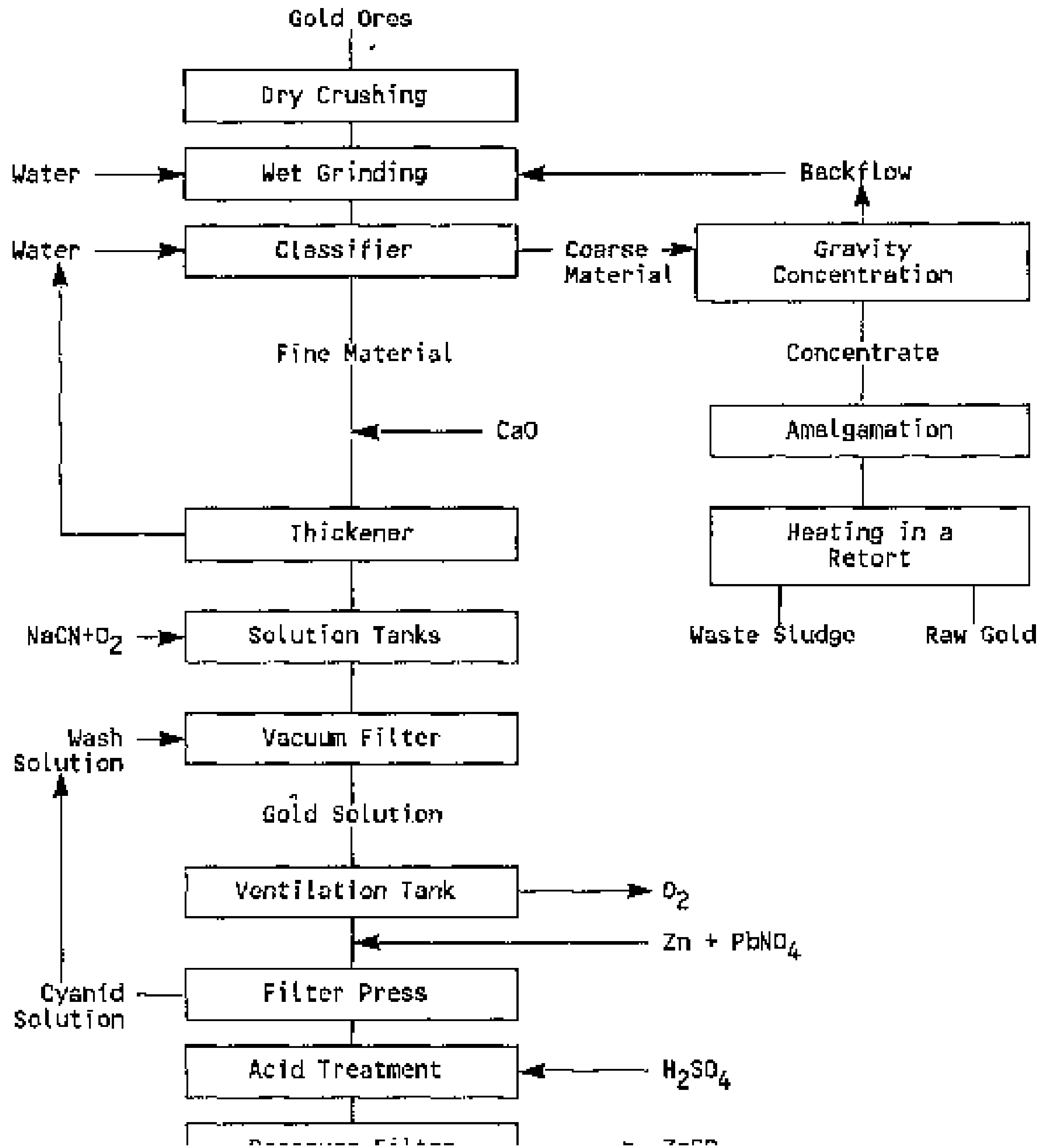
Flow sheet of a small-scale manually-run gold-ore beneficiation plant in the Philippines.

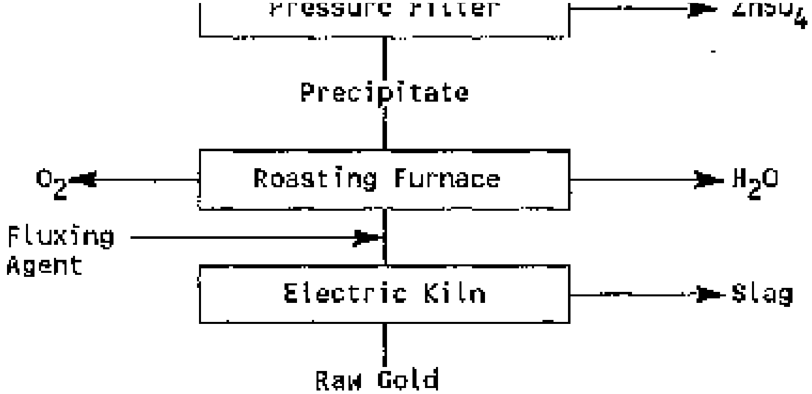


Flow sheet of a small-scale tank leaching of tailing containing free (liberated) gold and adsorption using locally produced activated carbons, Brazil.

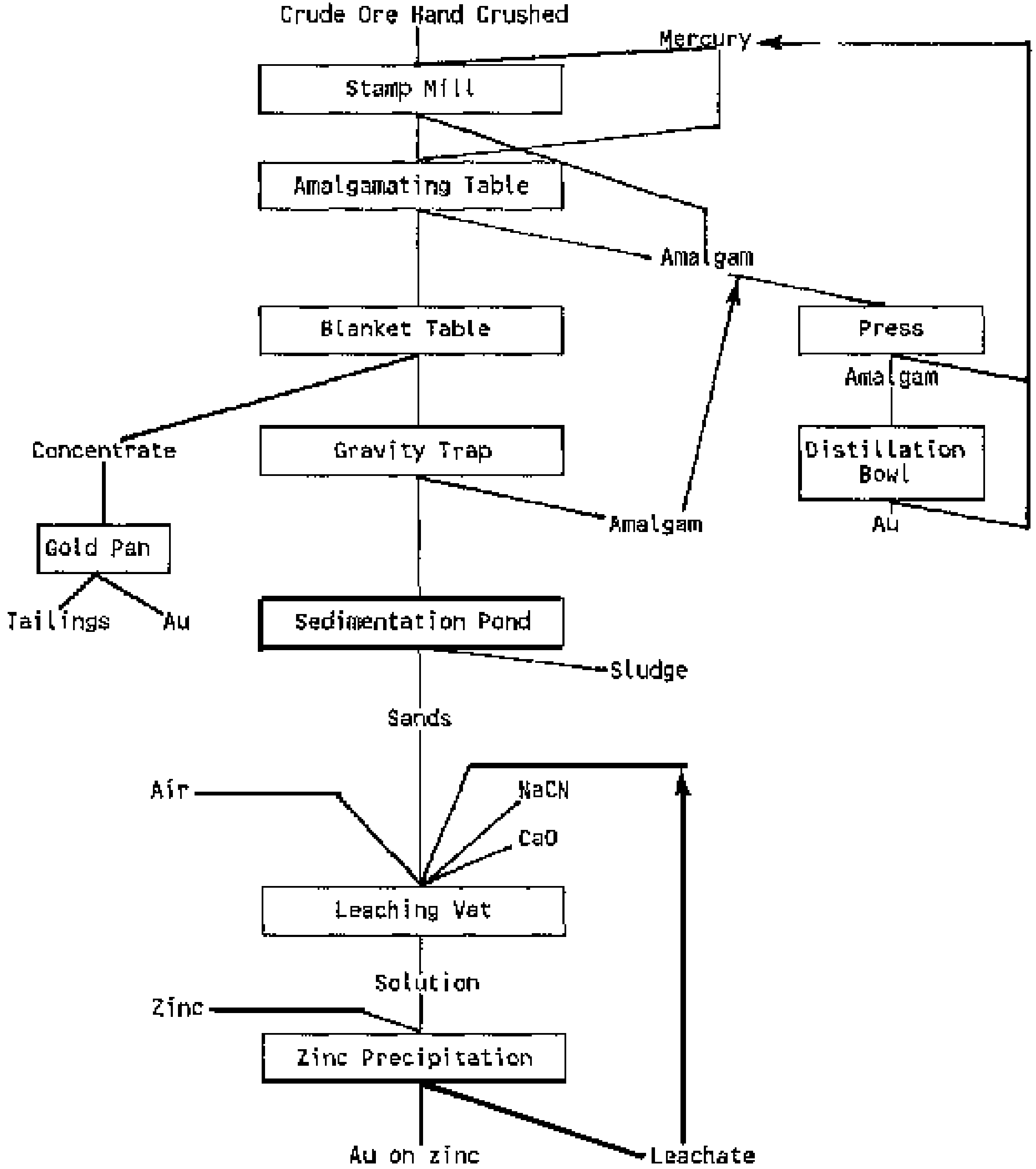


Flow sheet of a small gravimetric beneficiation plant for primary gold-ores in the Andean region of Narino, Colombia.

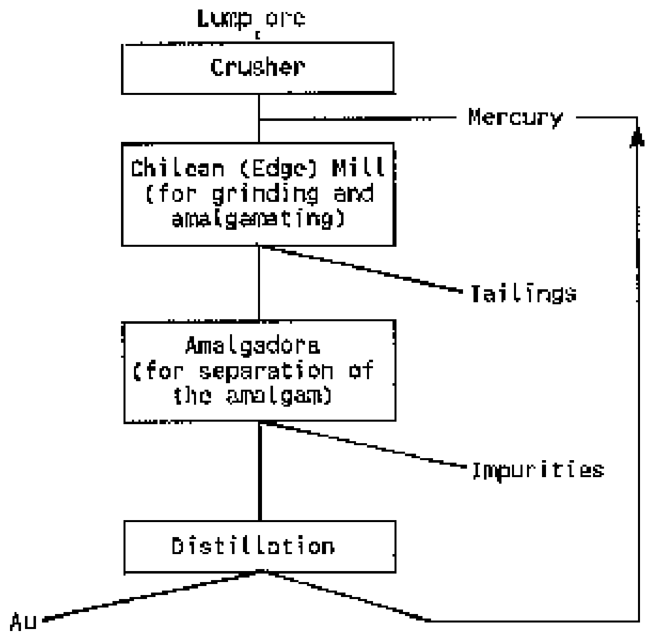




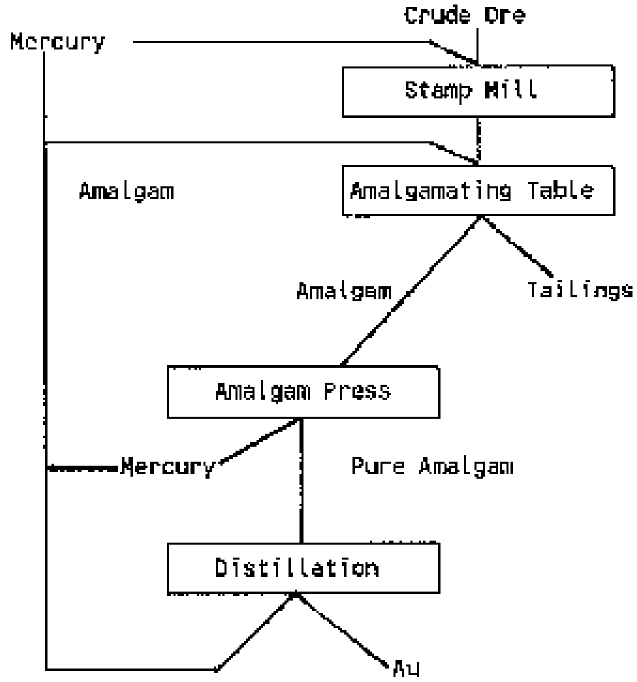
Flow sheet of a large mechanized beneficiation plant for primary gold-ores with a combined gravitational and leaching process. The hydromechanically-extracted pre-concentrates are amalgamated, the fine material processed by a tank leaching and the Merrill-Crowe process and then refined by a smelting separation.


Crude Ore Hand Crushed
Mercury
Stamp Mill
Amalgamating Table
Amalgam
Blanket Table
Press
Amalgam
Concentrate
Gravity Trap
Distillation Bowl
Amalgam
Au
Gold Pan
Tailings
Au
Sedimentation Pond
Sludge
Sands
Air
NaCN
CaO
Leaching Vat
Solution
Zinc
Zinc Precipitation
Au on zinc
Leachate

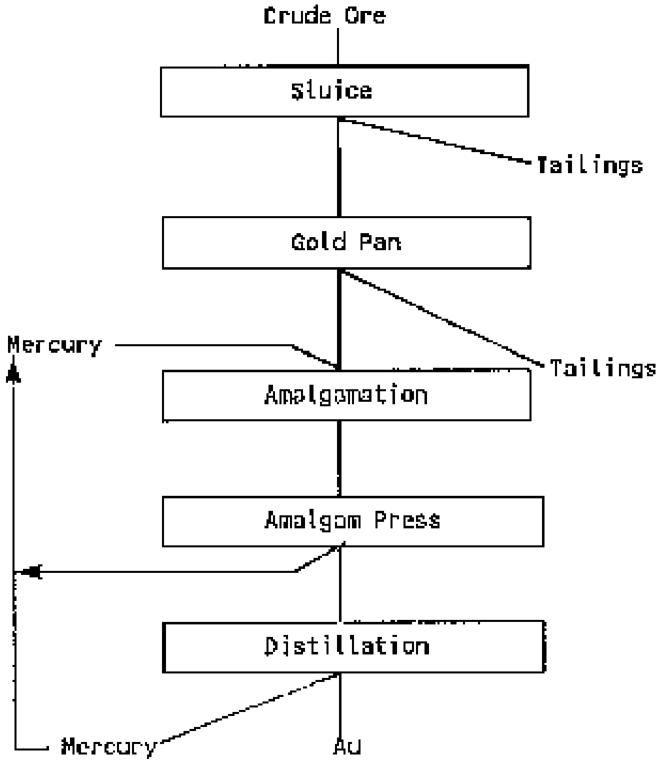
Flow sheet of a beneficiation plant for primary gold ores with amalgamation and leaching, Mina Los Guavos, Narino, Colombia.



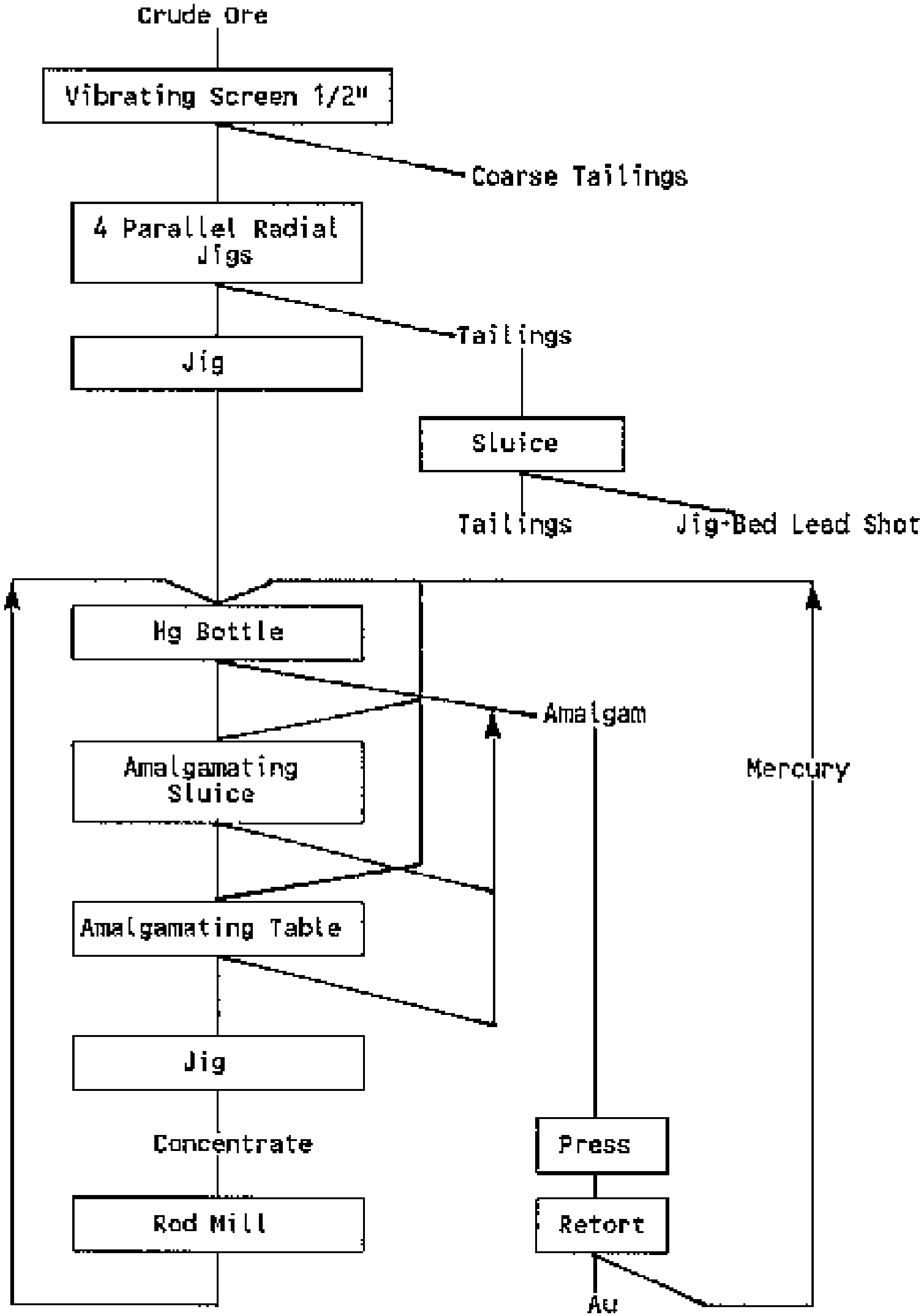
Flow sheet of a mechanized beneficiation plant for primary gold-ores from Bolivia (Mina Luchusa/Dept. La Paz), wich is however also typical for small and medium-scale operations in Chilean gold mining.



Flow sheet of a small gold beneficiation facility in vein-ore gold mining in Ecuador.



Flow sheet of a small manual alluvial-gold beneficiation operation in Brazil.


Crude Ore
Vibrating Screen 1/2"
Coarse Tailings
4 Parallel Radial Jigs
Tailings
Jig
Sluice
Tailings
Jig-Bed Lead Shot
Hg Bottle
Amalgam
Amalgamating Sluice
Mercury
Amalgamating Table
Jig
Concentrate
Press
Rod Mill
Retort
Au

Flow sheet of a mechanized alluvial-gold beneficiation facility near Barbacoas, Narino, Colombia.

In small-scale gold mining in developing countries, gravity separation for pre-concentrating as well as amalgamation for production of marketable final concentrates are of major importance. The technical optimization of these processes in order to increase recovery and pre-concentrate contents are critical aspects in improving beneficiation operations. Suggestions for attaining these goals are offered in the respective technical sections of the handbook.

D.6.4 PRODUCTION OF BY-PRODUCTS

A further strategy for improving the economic success of gold processing plants includes the marketing of by-products. In primary gold deposits, the deposit genesis of the associated (paragenetic) mineral composition determine the economic feasibility of mining or processing by-products, which, amongst others, include:

- Antimonite	- Scheelite
- Copper pyrite	- Bismuth minerals
- Uranium minerals	- Silver and silver minerals
- Galena (PbS)	- Sphalerite

ALLUVIAL GOLD DEPOSITS

Fluvial heavy-mineral deposits, which include important gold deposits, represent

the physical deposition of heavy, weather-resistant minerals, meaning that the sought-after gold can be associated with numerous other minerals. Some of these by-product minerals are easy to extract and market separately (the names of which appear marked with a * in the following table).

Table: Potential Composition of Alluvial Gold Deposits and their Primary Characteristics

Mineral	Chemical Formula	Color	Density (g/cm^3)	Hardness according to Mohs	Remarks
Free gold*	Au(+Ag)	golden-yellow	15.6 - 19.3	2.5	
Magnetite	Fe_3O_4	black	5.2	5.5 - 6.5	shiny, strongly magnetic
Ilemenite	$(Mg,Fe)TiO_3$	black	4.5 - 5.0	5.6	weakly magnetic
Garnet	$M^{2+}3M^{3+}{}_2(SiO_4)3^2$	red, brown	3.8	6.5 - 7.5	vitreous luster
Zirkon *	$ZrSiO_4$	brown, light yellow, colourless	4.7	7.5	diamond luster
Hematite	Fe_2O_3	dark steel grey, black	4.9 - 5.3	5.5 - 6.5	rounded grains
Chromite	$FeCr_2O_4$	iron black to brown black	4.1- 4.9	5.5	possibly weakly magnetic
Olivine	$(Mg,Fe)_2SiO_4$	olive green	3.3 - 3.4	6.5 - 7.0	vitreous luster

Olivine	$(Mg,Fe)_2SiO_4$	olive green	3.3 - 3.4	6.5 - 7.0	vitreous luster, transparent to translucent, good cleavability
Epidote	$HCa_2(Al,Fe)_3SiSO_1V_3$	pistachio green	3.2 - 3.5	6.7	
Pyrite	FeS_2	bronze yellow	4.9 - 5.1	6.0 - 6.5	angular grains, metallic luster
Monazite *	$(Ce,La,Di)PO_4+ThO_2$	yellow	4.9 - 5.3	5.0 - 5.5	resinous or greasy luster, rounded grains
Limonite	$2Fe_2O_33HO$	dark brown	3.6 - 4.0	5.0 - 5.5	
Rutile	TiO_2	red brown, red	4.2	6.0 - 6.5	metallic diamond luster
Platinum *	Pt (possibly also Ir)	steel white	16.5 - 18.0	4.0 - 4.5	malleable, flakes and grains
Iridium *	Ir (also Pt, etc.)	silver white greyish	22.6 - 22.8	6.7	angular grains
Iridosmium*	Ir Os	tin white to light steel-gray	19.3 - 21.1	6.7	flat grains, tenacious, good cleaveability
Cinnabar	HgS	red	8.0 - 8.2	2.0 - 2.5	
Wolframite*	$(Fe,Mn)WO_4$	black, dark grey	7.2 - 7.5	5.0 - 5.5	semi-metallic luster, good cleavability

					(axotomous)
Scheelite *	$CaWO_4$	white, light yellow, brown or grey	5.9 - 6.1	4.5 - 5.0	diamond to greasy luster, translucent
Cassiterite *	SnO_2	brown or black	6.8 - 7.1	6.0 - 7.0	friable, rounded grains
Corundum *	Al_2O_3	brown, yellow	3.9 - 4.1	9.0	diamond to vitreous luster
Saphire	Al_2O_3	blue	3.9 - 4.1	9.0	diamond to vitreous luster
Ruby	Al_2O_3	red	3.9 - 4.1	9.0	diamond to vitreous luster
Diamond *	C	white, colourless, pale	3.5	10.0	diamond to greasy luster
Native Mercury	Hg	tin white	13.6		small opaque, fluid beads
Amalgam	Hg, Ag, Au	silver white	13.0 - 14.0		friable to tenacious
Galena	PbS	lead grey	7.4 - 7.6	2.5 - 2.7	metallic luster,very good cubic cleavage, brittle
Silver *	Ag	silver white	10.1 - 11.1	2.5 - 3.0	tenacious,malleable, black tarnished

Copper	Cu	red brown	8.8 - 8.9	2.5 - 3.0	tenacious, flexible
Bismuth	Bi	tin white	9.8	2.5	friable, metallic luster
Cerussite	$PbCO_3$	colourless, white	6.5	3.0 - 3.5	diamond luster
Columbite * Tantalite	$(Fe,Mn)(Nb,Ta)_2O_6$	iron-black, grey, brown-black	5.3 - 7.3	6.0	iridescent, semi-metallic luster, good cleavability
Quartz	SiO_2	colourless	2.6	7.0	vitreous or greasy luster, no cleavage
Felspar	Silicates with K, Na, Ca, Al, etc.	colourless, white, light yellow, cream, pink	2.5 - 2.7	6.0 - 6.5	good cleavage vitreous luster,

D.6.5 TECHNICAL AND ECOLOGICAL PROBLEMS IN AMALGAMATION

Amalgamation is one of the most important processes in gold production in small-scale mining in developing countries. Gold in ore slime is alloyed with mercury into an amalgam and then this is separated by heating into mercury steam and gold.

The simplicity of the technique and its gold yield has favoured amalgamation in the eyes of small-scale miners. Health risks and ecological dangers are however

not considered. As a result of the faulty application of the procedure, reports of massive mercury poisoning in developing coutries are encountered now and again, Unfortunately, such incidents are not to be viewed as isolated accidents. The same is true for Latin America where, according to estimates, a million people work directly in gold mining. In Brazil alone 650.000 people are active in this branch. Other important gold producing problematic countries of South America are Bolivia, Chile, Ecuador, Colombia, Venezuela and Surinam. But also in countries of other continents, for instance, the Philippines, New Guinea and Ghana, environmental problems as a result of the application of mercury are increasing.

The sensibilization of people to ecological issues in Brazil in connection with the destruction of tropical rain forests has lead to intensified investigations into the mercury problems.

Exact figures about the extent of Hg-emssion in the tropical ecosystem are hardly available especially since figures about mercury purchase do not exist and the real gold production - which eventually allow inferences - lies very evidently above the official output. According to Brazilian reports, mercury consumption lies between 35 and 200 t Hg/y. The most recently promulgated mercury prohibition in Brazil has largely remained ineffective.

D.6.5.1 TOXICOLOGY OF THE HG AND ITS COMPOUNDS

The toxicity of mercury depends greatly upon the nature of the compound and the state of oxidation of the mercury.

Some 75 - 80 % of steam-forming mercury, such as that released in amalgam

distillation in an open cycle or circulation, is reabsorbed pulmonarily by humans. It reaches the kidneys through the bloodstream and with a half-life period of about two months, it is excreted again from the body as Hg-protein compound. The toxic effect results from the Hg2+-Ions. The manifestation of an acute Hg poisoning through inhaling of mercury steam proceeds in stages as follows:

1. **Colic, vomitting and intestinal inflammation**

2. **Kidney and urinary tract complaints**

3. **Acute intestinal inflammation, and eventually**

4. **Formation of cysts on the gums (stomatitis mercurialis) accompanied by a heightened light sensibility (Photophobia).**

If the mercury steam is inhaled for a longer period, chronic poisoning develops (Merkurialismus). The symptoms are:

- **formation of cysts**
- **HgS-deposits in the body**
- **nervousness, and trembling**
- **speech impairments, concentration difficulties, among others**

Many "garimpeiros" ("gold diggers" in Brazilian Portuguese) suffer from acute and chronic mercury poisoning.

Inorganic Hg^{2+}-compounds exhibit analogous toxicity consequences.

Organic mercury compounds, particularly methyl mercury (CH_3Hg^+) are highly toxic for men. When taken in through contaminated food, this is assimilated in the blood due to its stability and solubility in fat, and leads to damages to nerve ends.

Metallic mercury cannot be absorbed by the human body and is not toxic in this form.

D.6.5.2 MERCURY CYCLE

Mercury that is released in the atmosphere by evaporation is oxidized in the course of time under the influence of ozone, air humidity and ultra-violet radiation. Precipitation transport these ions to earth. Further details of the Hg-cycle in the biosphere and the incorporation of metallic mercury through mining. Microbial anaerobic conversions especially in aquatic ecosystems and on land can lead to a methylizing of the mercury.

The above mentioned inorganic and organic Hg-compounds reach the human body through drinking water, food and through respiration. An especially critical point is the Hg-concentration through the food chain of fishes which can accumulate this element at a multiple rate compared to the concentration in the environment. This effect is even increased by the fact that the Hg-transformation in methyl mercury and its intake in warm, tropical bodies of water (depending upon the temperature and Eh-pH conditions) is especially high.

New researches in Brazilian ecosystems show clear violations of the effective "Maximale Arbeitsplatz Konzentration" (MAK) and "World Health Organization" (WHO) threshold value for Hg and its compounds (see box).

WHO- and MAK-limits for mercury

drinking water	maximum 4 yg/1	
fish	maximum 0.5 yg/g weight;	
	or	maximum 0.2 mg methyl-Hg
	per person and week	
	or	maximum 0.3 mg inorganic Hg
fruits	maximum 0.03 mg/kg weight	
air one breathes	for Hg°	maximum 0.1 mg/m³ (MAK)
	for organic	
	Hg-compounds	maximum. 0.01 mg/m³ (MAK)

The following mercury contents were found in:

drinking water, up to	11/µ/ltr
in fishes, up to	2.7 µg/g peso fresco
in spawns, up to	3.8 µg/g
in the air, up to	0.3 mg/m³

The last figure was obtained in the surroundings of an amalgam distillation plant The extreme values measured exceed the corresponding reference measurement in drinking water by a factor of 250, in fishes by about 300 times and in the air by a factor of 14,000. Unfortunately, it was found that the mercury concentrations were not restricted to the particular area. Rather, significant mercury levels were

found within a radius of about 200 km around the mining area.

This manifests itself in the mercury levels in human blood, in the urine and in the hair particularly in comparison to the normal values contained in parentheses below:

in the blood	in urine	in the hair	
ppb Hg	ppb Hg	yg/g dry weight	
up to 175	up to 225	up to 40.0	
(10-13)		(0.5-8)	(0.7-3)

The indian natives are affected in a particular way by the mercury contamination of the environment since they nourish themselves almost exclusively from their immediate surroundings. River fishes are, for example the most important source of animal protein for this ethnic group. To worsen their situation, migrating gold diggers are competing in their living space.

D.6.5.3 AMALGAMATION IN SMALL-SCALE MINING FOR GOLD

The first use of amalgamation for gold production presumably dates back to mining in Bosnia in the reign of Emperor Nero (54- 68 A.D.). Until now, small-scale mining uses this technique very intensively.

For amalgamation, liberated, basic, not incrusted Au- for instance through fine iron oxides - in grain sizes of between 2 mm and 20 - 50 m is appropriate. The lower grain size is essentially determined by the interfacial tension of the mercury and that of the water as well as the shape of the grain.

Amalgamation may be applied in sedimentary ores as well as the primary intergrown gold ores. In alluvial deposit mining, the already liberated gold is made to combine with Hg. Riffle troughs whose riffle spaces are filled with mercury mainly serves this purpose. The entire suspended feed is made to flow through the trough. During this process, the slurry extracts about 5 - 30 % of the mercury from the troughs for which generally there is no available catchment mechanism. The addition of bigger amounts of soap or similar tensides should increase the beneficiation output while Hg losses decreases.

Primary ores require the exploration of valuable minerals. The miner amalgamates either directly during the grinding or crushing or in a separate procedural stage after grinding. In simultaneous amalgamation and crushing, small-scale mining utilizes pan grinders, stamping mills, ball mills or manual weight crusher. For post-activated amalgamation, amalgamating barrels, amalgamating furnaces (see respective technical discussions) and manual amalgamation in washing pans are used.

On the average, losses on metallic mercury from the sorting and amalgamation installations account for about 40 - 50 % of total losses.

The resulting amalgam-Hg mixture is separated into the highly viscous amalgam (Au2Hg and Au3Hg) and liquid mercury by squeezing-through a piece of leather or a towel (usually through the shirt of the miner).

The production of gold takes place through heating of the amalgam lumps with about 50 - 60 wt. % Hg, 40 - 50 % Au which are wrapped in paper. The procedure is done in an open ceramic bowl using a blow lamp and in temperatures of 350-

600%. The steamed mercury goes directly uinto the atmosphere; it accounts for about 50 - 60 % of the entire Hg emissions.

Researches of the author in Ecuador and Colombia have shown that retorts (see technical discussion 15.7) for Hg distillation in closed cycles are known and usually available but are rarely applied. The main reason behind this is the discoloration of the gold after distillation in the retorts- presumably as a result of Fe-compounds-, and consequently a lesser valuation of the product by small-scale miners. It is to be determined to what extent technical improvements could encourage acceptance of distillation retorts.

In some cases, especially when mercury supply is short, a fresh banana leaf placed on top of a vaporising dish or basin can serve to the partial recovery of mercury. Mercury condenses on the surface of the leaf.

D.6.5.4 WAYS OF MINIMIZING RELEASE OF MERCURY DURING AMALGAMATION

As described above, the emission of mercury takes place in metallic form during amalgamation as well as in the form of steam through the separation of the amalgam in mercury and gold. This section discusses ways of avoiding both of these sources of contamination.

Metallic mercury is produced in the amalgamation devices almost exclusively as crushed mercury in the form of tiny pearls, referred to as "floured mercury". The surface of these tiny globules are usually inactive due to impurities (among others, very fine mineral particles, fat and oil sediments from the water), other chemical transformations (for example, incrustations from antimony amalgam and

the globules' inherent surface tension. This means that the globules can neither serve amalgamation nor fusion of gold and are discharged during high slurry speeds.

In vein ore mining, it is possible to avoid such loss of mercury. This is done through the separation of the simultaneous processes of amalgamation and grinding or comminution in pan grinders (as in Chile) or stamping mills (as in Ecuador and Colombia) using two procedural steps. The effect of high slurry speeds during amalgamation is avoided.

In alluvial gold deposit mining the use of mercury in trough washing, during which huge amounts of mercury is released in the environment, should be avoided. Instead, it is recommended in the two branches of mining to first produce the highest possible quality of pre-concentrate. Among the devices appropriate to wet mechanized gravity sorting using specifically high throughput are: fluid bed centrifugals, spiral separator, cone separator and fine grain separator with bedding, tables or improved sluices. Through post-concentration by means of precipitation of mineral by-products, for instance through magnetic separation, the pre-concentrates can be further improved.

Afterwards, the relatively small amounts of concentrate can be amalgamated in appropriate amalgamation installations such as in closed amalgamation barrels (referred to in Ecuador as "chancho") or in quick grinding mill (for example, Berdan pan). These devices also allow the addition of reagents for the improvement of the surface activity of mercury, for example (NaOH, nitrate amalgam, ammonium chloride, cyanide and nitric acid or tenside.

The least that can be done in plants in which a change in the course of the process is not possible would be planning post-activated sink angles to catch the "floured mercury".

To prevent the release of mercury steam, the "queimador" (the one which distills the amalgam) must distill only in close mercury cycle. Amalgam pressing and distillation retorts sink the mercury loss up to below 0.1% per distillation. Distillation retort must be user-friendly and hence, in their construction, care must be taken especially in the choice of materials and the cooling systems.

Alternatively, the amalgam can be chemically separated. In the process, the hot thinned or diluted nitric acid dissolves the mercury and gold slime comes off. From the resulting mercury nitrate solution mercury is again deposited with base metals. Ores containing silver, lead to a successive Ag-concentration in mercury which then necessitates distillation to purify.

Generally, it appears that the centralisation of amalgamation and/or distillation is to be advised. Miners can then further process pre-concentrates or amalgam in these central plants.

D.6.5.5 TECHNICAL ALTERNATIVES TO THE SUBSTITUTION OF AMALGAMATION

As alternative to amalgamation, there are available a number of methods of gold production or extraction. Most of these however have not gained currency in mining until today. Among these is the "gold-coal agglomeration" which was developed about 70 years ago but has not found application in beneficiation. Others such as cyanide leaching has extensively dispensed with amalgamation in

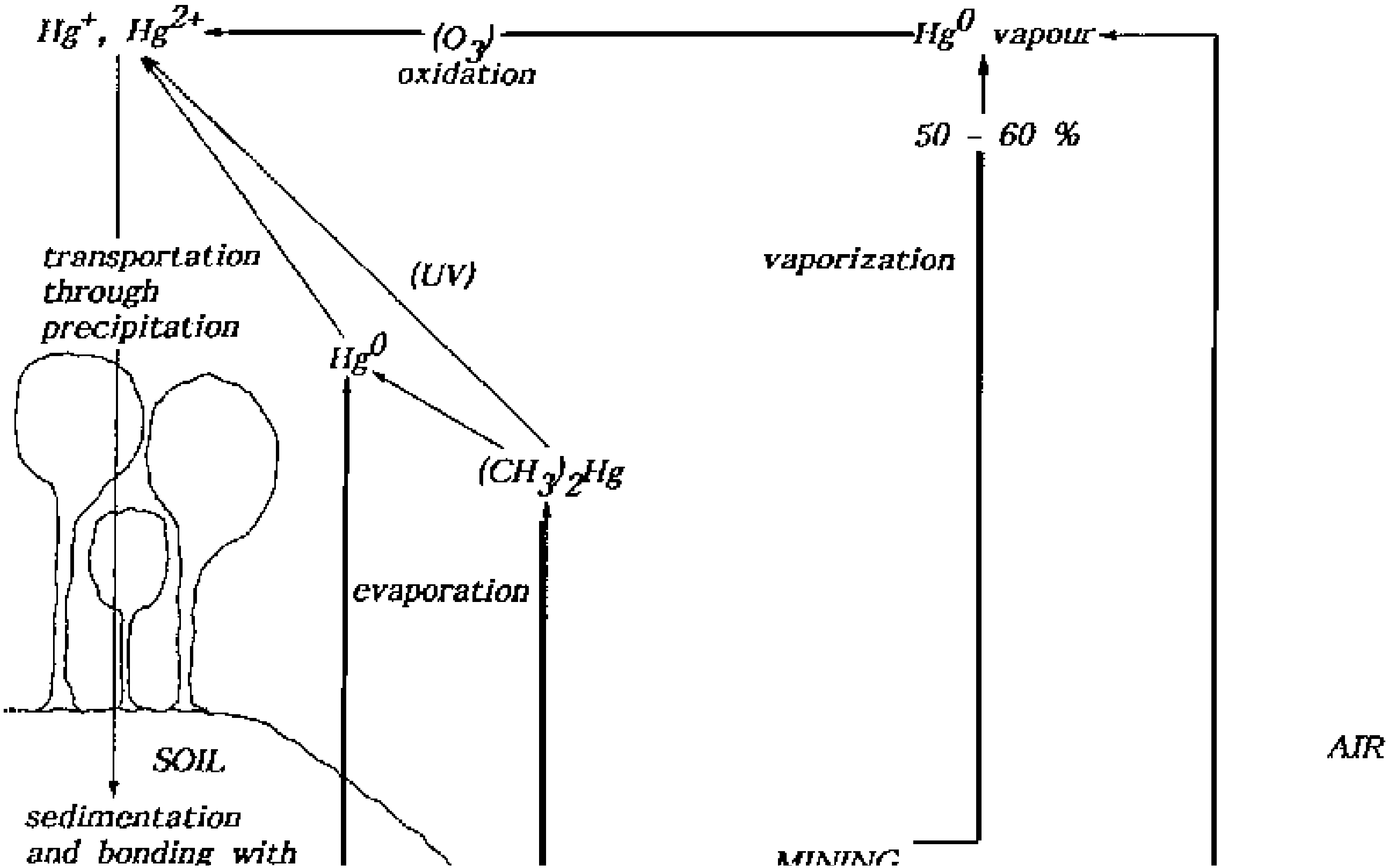
large-scale mining. Due to complicated procedures, difficult control and the dependence on huge amounts of reagents etc., these alternatives are not rendered less appropriate for small-scale mining. Further development, technically, of the gravimetric beneficiation such as the sorting in centrifugal area, the increased utilization of vibration devices or equipment or the combination of gravity beneficiation with other physical processes correspond more to the requirement of small-scale mining. Such devices, for example, the Knelson centrifugal, allow the production of pre-concentrates with very high quality and whose final conversion into marketable products takes place in one last procedural step. This is the melting separation of gold pre-concentrates in gold and clinker using borax as fluxing agent, a process which the "mineros" usually do themselves.

D.7 The processing of phosphate-containing raw-minerals into p-fertilizers

Around 85% of phosphate fertilizers produced today come from phosphorites and sedimentary phosphate mineralizations which are comprised of fine mineral crystallises. For application in developing countries, the simplest fertilizer processing methods are most appropriate for meeting the needs of small-scale mining. A direct feed of raw mineral is frequently not practical due to the relatively low solubility of untreated phosphorites. This can be alleviated by performing a short activation grinding, which dissociates the mineral bonds and consequently increases the specific surface area, and also fractures the crystallite structure which significantly increases the weatherability and therefore the solubility of these minerals.

The other important raw material from which phosphate fertilizers are produced is apatite. This mineral is even less soluble than phosphorite, so that a direct

application of apatite onto cultivated fields exhibits a fertilizing effect only after a period of 10- 15 years. In small-scale mining in Zambia, the apatite raw-ore with about 10 - 20 % POx content, is currently being processed by having it react with sulfuric acid which produces a readily soluble mineral fertilizer. Small processing plants, with capacities of up to 2t/d, employ cement mixers as reaction tanks for the treatment with sulfuric acid.



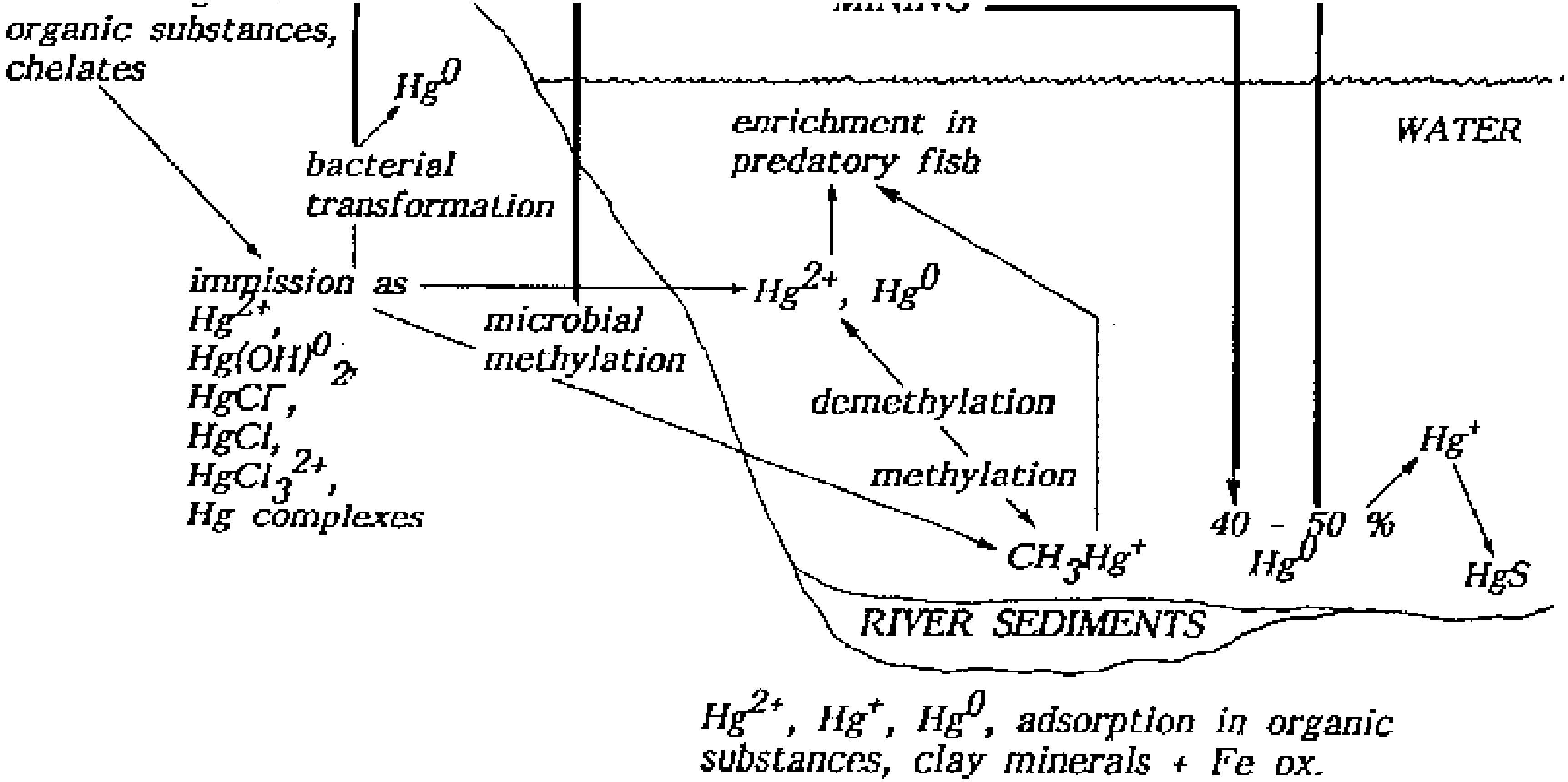


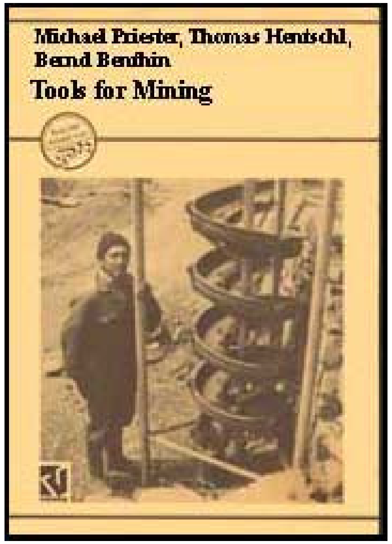
Fig.: Impact and circulation of mercury into the ecosystem by small-scale mining.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 12: Crushing

(introduction...)



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 12: Crushing

BENEFICATION TECHNIQUES

12.1 Jaw crusher, jaw breaker

Mining General (Ore, Coal, Sand and Gravel)
Beneficiation, Crushing

germ.:	Backenbrecher, Knackwerk
span.:	chancadora de mandibulas, trituradora de mandibulas
Manufacturer:	Millan, Volcan, Denver Peru, Denver USA, FUNSA, MAFUQUI, Alquexco, Eq. Ind. Astecnia, IAA, INCOMAQ, COMESA, FAHENA, FIMA, Fund. Callao, H.M.,

MAGENSA, MAEPSA, Met. Callao E.P.S., Met. Mec. Soriano, Talleres Mejia, ASEA, FAMESA, MEPSA

TECHNICAL DATA:	
Dimensions:	approx. 0.7 × 0.7 × 1.5 m minimum
Weight:	approx. 350 kg minimum
Extent of Mechanization:	fully mechanized
Power Required:	3 - 10 kW for <=2 t/h
Form of Driving Energy:	electric, diesel or gasoline driven internal combustion engine
Alternative forms:	very successful with turbine drive and transmission
Mode of Operation:	continuous
Throughput/Capacity:	from 350 kg/h
ECONOMIC DATA:	
Investment Costs:	between 1000 US$ (350 kg/h) and 4000 US$ (1.5 t/h) for Bolivian production; etween 4000 US$ (1 t/h) and 18.000 US$ (2 t/h) for imported crusher cif La Paz
Operating Costs:	personnel wages, energy costs and minimal repair costs; cost of replacing jaws when worm

CONDITIONS OF APPLICATION:

Operating low I—————I—————I high

Operating Expenditures:		low |————|————| high
Maintenance Expenditures:		low |————|————| high
Personnel Requirements:	low	
Grain Size Material:	depends on type of crusher: here < 20 cm 0	
Output:	crushing ratio of 5: 1 to 10: 1; smallest final grain size approx. 5 - 10 mm; only compressive loading: maximum grain size of feed up to 1,000 mm; crushed product approx. 100 mm (main area of application)	
Replace other Equipment:	stamp mill	
Regional Distribution:	worldwide	
Operating Experience:		very good |————|————| bad
Environmental Impact:		low |————|————| very high
	noise and dust pollution	
Suitability for Local Production:		very good |————|————| bad
Under What Conditions:	local machine manufacturing	
Lifespan:		very long |————|————| very short

Bibliography, Source: Taggert, Schubert, v. Bernewitz, Priester, Gerth, DBM, Callon, Althaus

OPERATING PRINCIPLE:

The Jaw crusher crushes the raw-ore feed by pressing it between two jaws, one fixed and one moveable, in a wedge-shaped crushing chamber. The moving Jaw pivots around its upper (feed side) axis. At its lower end, the Jaw is moved via an eccentrically-driven toggle system, which in turn increases or decreases the volume of the crushing chamber. During the decreasing stroke, the ore becomes broken, and subsequently slides deeper into the chamber as the Jaws open again, expanding the crushing chamber; this process repeats itself until the final grain size is reached, whereby the crushed ore falls out of the chamber through a slit at the bottom.

AREAS OF APPLICATION:

Pre-crushing and crushing of raw ore.

REMARKS:

Can successfully be mechanizing with turbines, whereby the starting torque of turbines has an advantageous effect, for example if the crusher is clogged; in this case, the power can be adjusted significantly lower than with electric power units.

Raw ore should first be screened $\propto\rightarrow$ reduced feed quantities, lower energy costs.

The wear on the crushing Jaws depends greatly on the tenacity (toughness) of the feed material; sufidic ores rich in quartz, for example, can wear out a set of crushing jaws after only 30.000 t, galena-sphalerite ores in graywacke after approx. 60.000 t and carbonate iron-ores first after around 300.000 t (Gerth, et. al.).

Fine Jaw crushers have wider jaws and operate at higher rpms, with one jaw frequently being of concave construction so that the crushing chamber tapers down in almost parallel flanks, thereby minimizing the occurrence of fines.

Wear-resistant coating of crushing jaws with welding material (see 11.1) leads to an extended lifespan.

SUITABILITY FOR SMALL-SCALE MINING:

Jaw crushers are the most simply-constructed apparatuses for coarse preliminary crushing, and can also be locally produced in developing countries. The application of jaw crushers can significantly improve the efficiency of beneficiation operations.

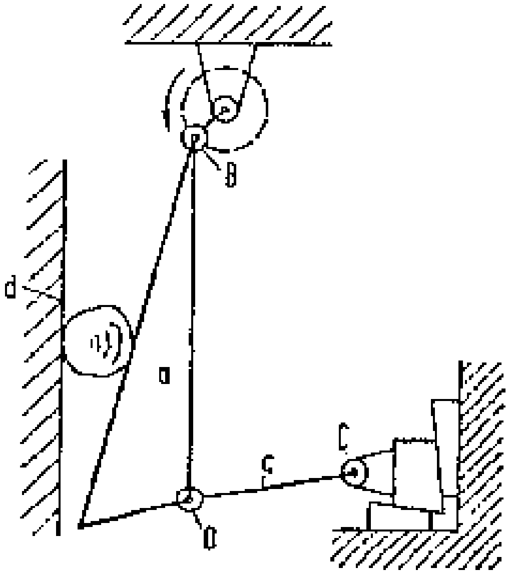


Fig.: Operating principle of the single-jaw crusher. Source: Ullmann. a) crushing jaw c) supporting plate d) fixed plate B: eccentric pivot C: supporting-plate bearing.

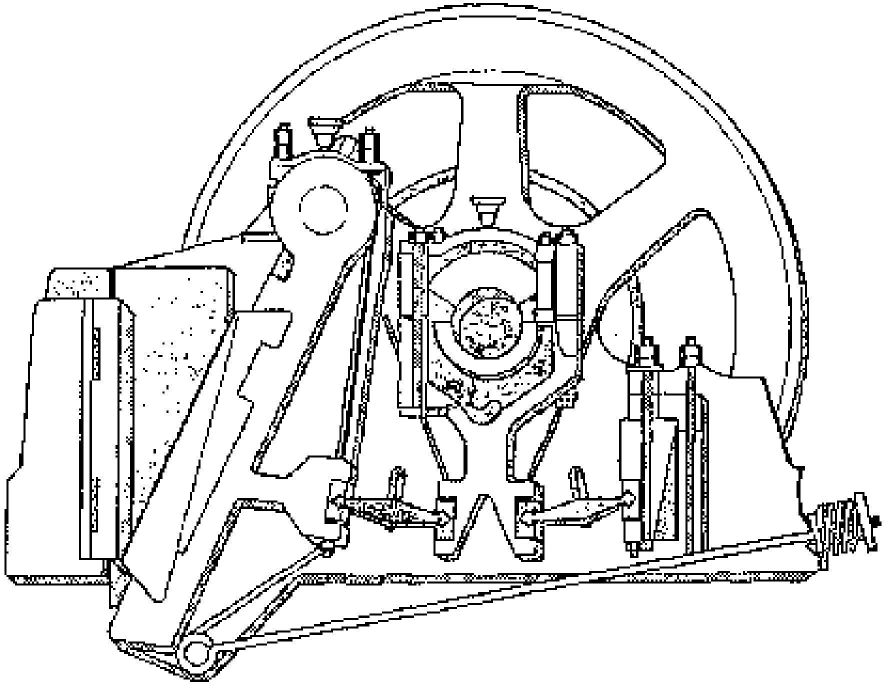


Fig.: Jaw crusher. Source: Armstrong.

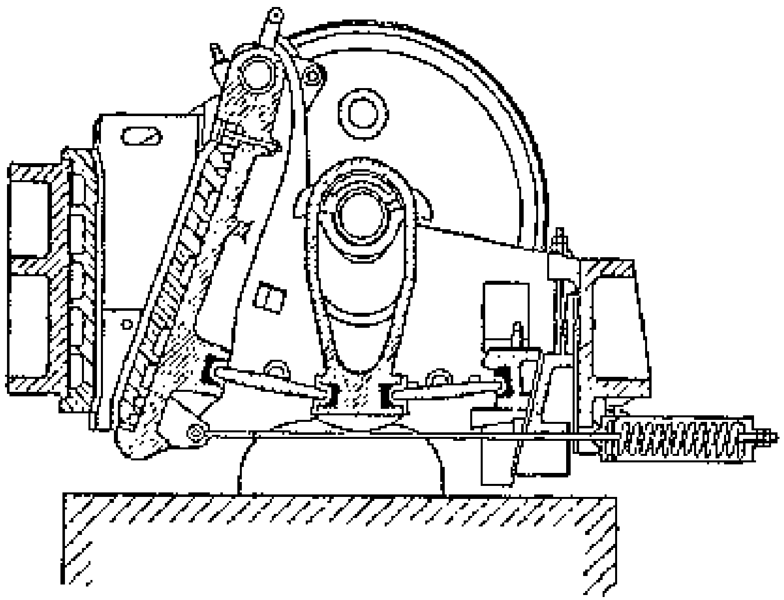


Fig.: Jaw crusher. Source: Gerth.

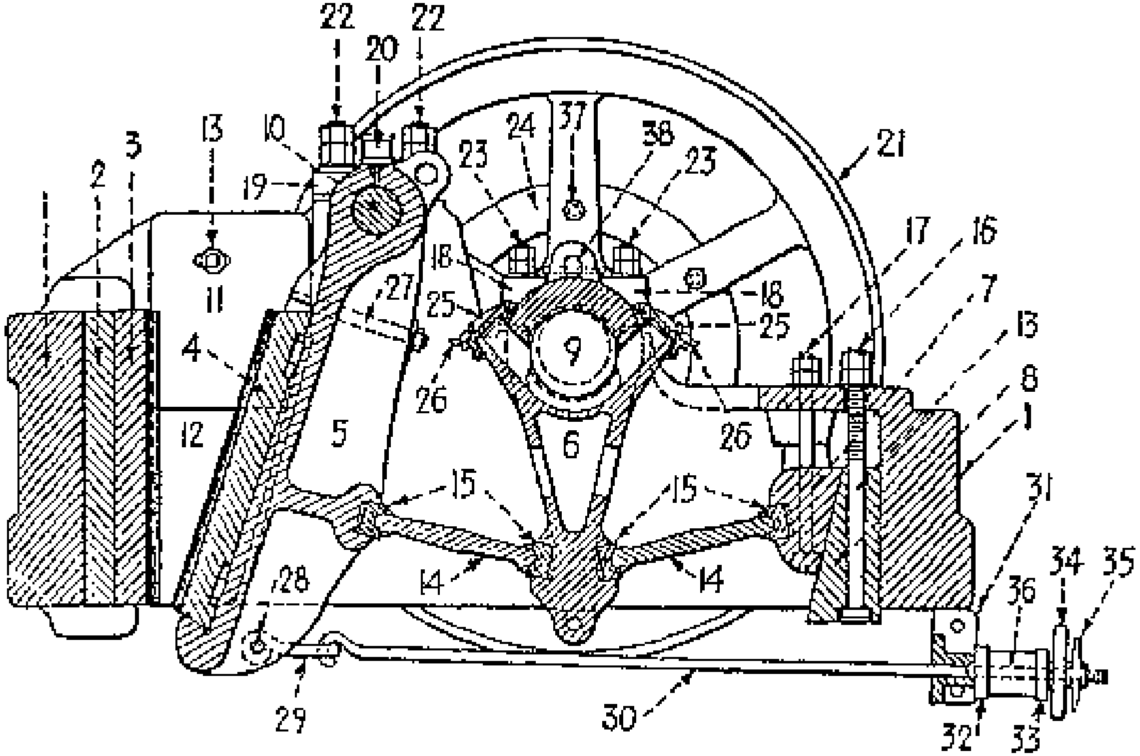


Fig.: Detailed diagram of a jaw crusher. Source: Bernewitz.

12.2 Roll crusher, roll grinder

Mining General (Ore, Sand and Gravel)
Beneficiation, Crushing

germ.:	Walzenbrecher, Walzwerk, Walzenmuhlen
span.:	trituradora de rodillos, chancadora de rodillos, molino de discos, laminador, molino de rodillos
Manufacturer:	Millan, Volcan, Denver

TECHNICAL DATA:	
Dimensions:	approx. 0.7 × 0.7 × 1.5 m, roller die 25 cm or more
Weight:	approx. 350 kg
Extent of Mechanization:	fully mechanized
Power Required:	starting at approx: 5 kW
Form of Driving Energy:	electric motor, internal combustion engine
Alternative Forms:	possibly hydromechanic
Mode of Operation:	continuous
Throughput/Capacity:	approx. 700 kg/in
Technical Efficiency:	degree of comminution between 3:1 and 4:1
ECONOMIC DATA:	
Investment Costs:	Denver mill, 2 t/h: 18.900 US $, Volcan mill, 500 kg/h: 5000 US $, Millan mill approx. 6500 DM including motor fob La Paz
Operating Costs:	labor costs, energy costs, minimal wear

CONDITIONS OF APPLICATION:

Operating Expenditures: low |————|————| high
Maintenance Expenditures: low |————|————| high

Personnel Requirements: low

Personnel Requirements:	low
Grain Size:	> 20 - 25 mm (max. 100 mm)
Output:	100 % < 1.5 mm with especially homogeneous grain-size distribution
Replaces other Equipment:	other mills
Regional Distribution:	rare
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
	especially dust and noise pollution
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	metal manufacturer for steel
Lifespan:	very long |——————————| very short

Bibliography, Source: Priester, Schennen, Treptow, Gerth, Callon, Schubert

OPERATING PRINCIPLE:

The feed material is crushed between two counter-clockwise rotating rollers to a degree of fineness allowing it to fall through a slit at the bottom. In the event that the pressure becomes too great, the rollers deflect outwardly, increasing the gap between them and consequently also the final grain size.

AREAS OF APPLICATION:

Crushing of brittle ore in preparation of hydromechanic gravimetric sorting of

medium-sized grain fractions.

REMARKS:

Roll crushers are known for producing a ground product with a very low proportion of fines.

30 - 200 g of hard-steel wear per ton throughput depending on hardness and tenacity of the feed material.

The roll crushing of hard minerals (igneous rocks, hard ores, gravel sediments) uses smooth Jaws, whereas the rollers for crushing medium hard or soft material (e.g. Iimestone, anhydrite, sedimentary Iron ores, etc. or salts, clays, soft brown coal, etc.) are fluted or serrated.

The roller diameters should equal approx. 20 times that of that largest grain-size contained in the feed.

SUITABILITY FOR SMALL-SCALE MINING:

Roller mills are suitable machines for fine crushing, which leads to extreme exposure of the feed in case of somewhat coarse intergrown ore avoiding further fine milling.

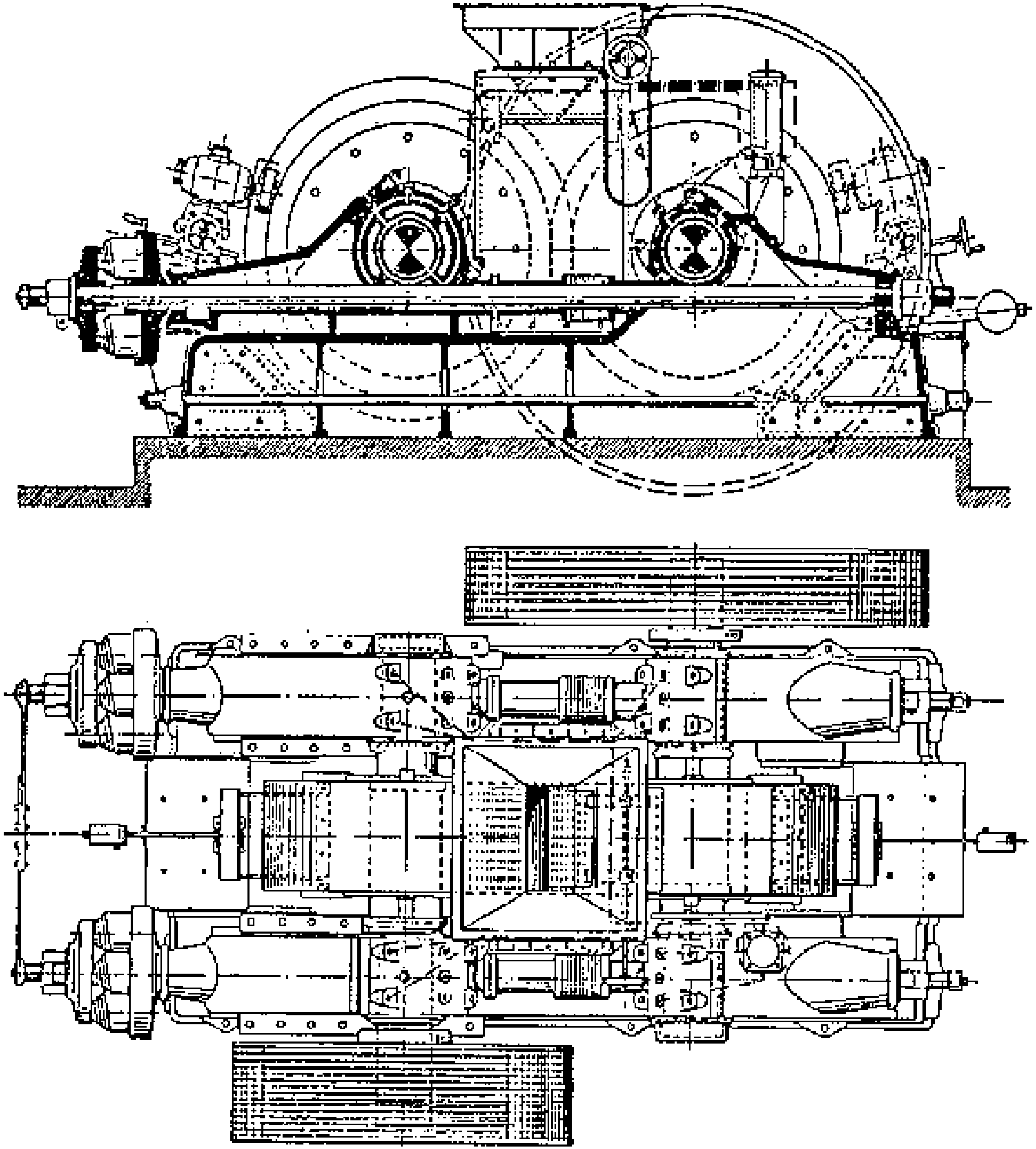


Fig.: Roll crusher. Source: Gerth. Above: side view; Below: plan view.

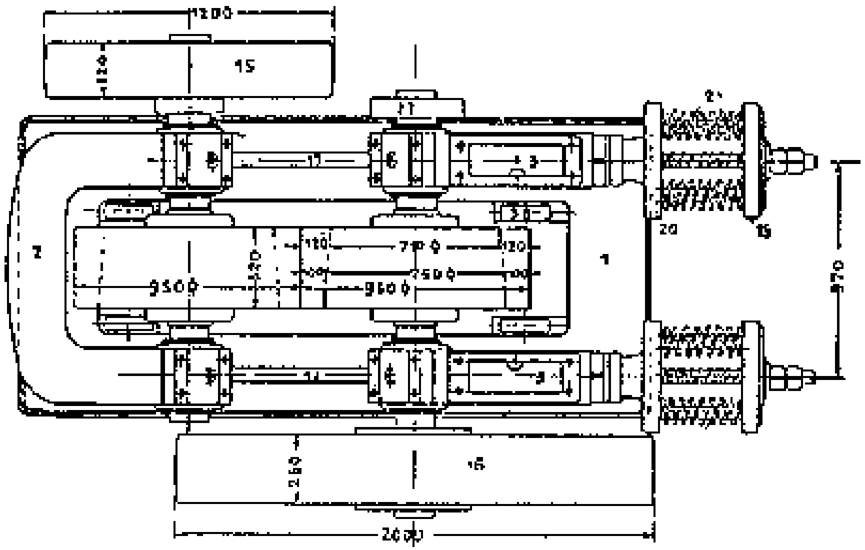


Fig.: Plan diagram of a roll crusher with swinging rollers. Source: Schennen.

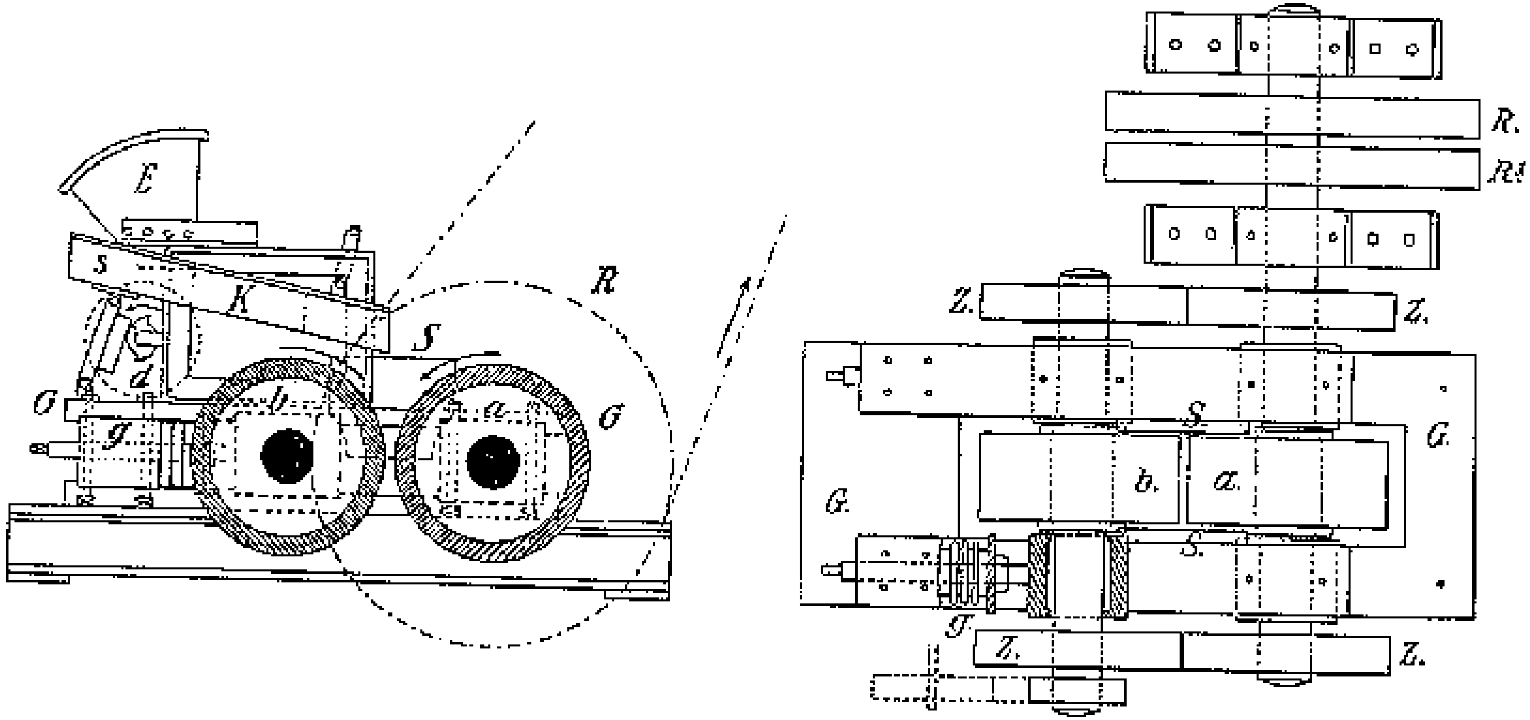


Fig.: Roll crusher. Source: Treptow. Above: side view, Below: plan view.

12.3 Ball mill

Mining General (Ore, Sand and Gravel)
Beneficiation, Crushing

engl.:	ball crusher, manual ball mill
germ.:	Kugelmuhle, Handkugelmuhle
span.:	molino de boles, molino de boles a mano
Manufacturer:	Millan, KHD, Volcan, Denver, Alquexco, Eq. Ind. Astecnia, IAA, Talleres Mejia, Buena Fortuna, COMESA, Met. Mec. Soriano, FAMESA, FAHENA, FIMA, FUnd. Callao, H.M., MAGENSA, MAEPSA, Met. Callao E.P.S.

TECHNICAL DATA:	
Dimensions:	approx. 1.5 × 1 × 1 m
Weight:	approx. 150 kg
Extent of Mechanization:	manual to fully mechanized, depending on drive system
Power Required:	from 100 W up to several kW, e.g. approx. 7.5 kWh/t energy input to crush Volcanic sulfide ores, up to 50 kWh/t energy consumption for milling of hard quartzite and similar ores
Form of Driving Energy:	electric
Alternative forms:	manual, pedal drive, hydromechanic with water wheel
Mode of Operation:	semi-continuous/continuous
Throughput/Capacity:	1 t/h: 11 - 12 kW
Operating Materials:	
Type:	Water grinding bodies (Zylpebs or balls)
Quantity:	bulk-volume approx. 25 - 45 % of mill capacity
ECONOMIC DATA:	
Investment Costs:	manual ball mill: approx. 1000 DM when locally produced; Millan mill 500 US$,
Volcan mill:	10.000 US$, Denver mill: 22.000 US$ for mills with approx. 1 t/h throughput
Operating Costs:	replacement of worn milling balls, energy costs
Related Costs:	possibly thickener, since ground product is a slurry

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance Expenditures:	low |—————|—————| high
Personnel Requirements:	low
Location Requirements:	water availability is the only requirement
Grain Size:	approx. < 30 mm
Replaces other Equipment:	see-saw (rocker) crusher for fine crushing
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	small ball mills can be produced locally in good metal-manufacturing workshops, for example in the Philippines, where ball mills are being produced entirely locally.
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Museum case de la Moneda, Potosi, Ullman, Schubert, Taggert, Stewart

OPERATING PRINCIPLE:

Manual hand-cranked ball mills with spiral feed chute are used for fine grinding. The ball mill is a rotating cylindrical crushing device which contains steel balls which comminute the material through percussive, shearing and compressive (squeezing) forces. Rotating the drum results in a continuous cascading of the balls and material contained inside. The duration of milling is determined by the final grain-size desired for the ground product. Water flowing through the mill removes the fine material.

AREAS OF APPLICATION:

Fine grinding of middlings, raw ores or pre-concentrates.

SPECIAL AREAS OF APPLICATION:

For special grinding steps where it is important that the products remain free of iron, such as in grinding of graphite, hard stones of flint, granite, etc. are used instead of the balls.

REMARKS:

In autogenous grinding, only the feed material itself, in the absence of balls or other grinding bodies, is subjected to the rotation of the mill drum. The grinding is achieved as a result of the larger material grains functioning as the balls, crushing

the smaller or softer feed components. An example where autogenous grinding is applied is in the liberation of loosely-consolidated gold-containing conglomerates.

All types of ball mills produce high proportions of fine-grained product. In the case of particularly brittle minerals such as scheelite, wolframite, cassiterite, sphalerite, etc., this readily leads to overgrinding, resulting in poor recovery of the valuable mineral. Under these conditions, grinding needs to be performed with care, including prescreening and intermediate screening of the fines, and recycling of the screened overs back into the mill.

When the ground product is discharged from the mill as a slurry, the heavy material components remain in the mill longer due to their increased resistance to the flow forces. Consequently, grinding must be conducted correspondingly carefully, or an alternative method of removing the ground product from the mill must be employed, such as screening.

CONSTRUCTION INFORMATION:

Wheel bearings from cars are suitable as bearings for hand-cranked ball mills.

With belt or chain-driven systems, the entire mill housing is rotated.

The optimal rotational speed (rpm) is 75 % that of the critical rotational speed, or that where the centrifugal force causes the mill balls to remain on the drum perimeter:

$$n_{opt} = \frac{32}{\nu \cdot D}$$

n in min^{-1}
D = mill diameter in m

For this rotational speed, at 30 % degree of filling, the power can be determined by the following formula

P (kW) ~ 10 GK (t) × V D (m), where GK is weight of balls in 1000 kg

For 20 % degree of filling the power is about 10 % higher, and for 40 % degree of filling about 15 % lower.

The rotational speeds for coarse grinding lie somewhat higher than for fine grinding, to a maximum of

D diameter of ball mill <= D/20

Old rail sections, cemented Into place, provide an inexpensive ball-mill lining.

The ends of the mill housing can be placed on roller or ball bearings, or on other forms of rollers or tires, the latter form can also be used to drive the mill, allowing good access to the front and back ends of the mill for easier handling at the feed and discharge points.

SUITABILITY FOR SMALL-SCALE MINING:

Hand-cranked ball mills have a rather limited application due to their low throughput. Useful primarily for regrinding of middlings. Small mechanized ball mills are appropriate in small-scale mining operations where finely-intergrown ore

requires a fine liberation grinding, in which case a good supply of replacement parts must be available.

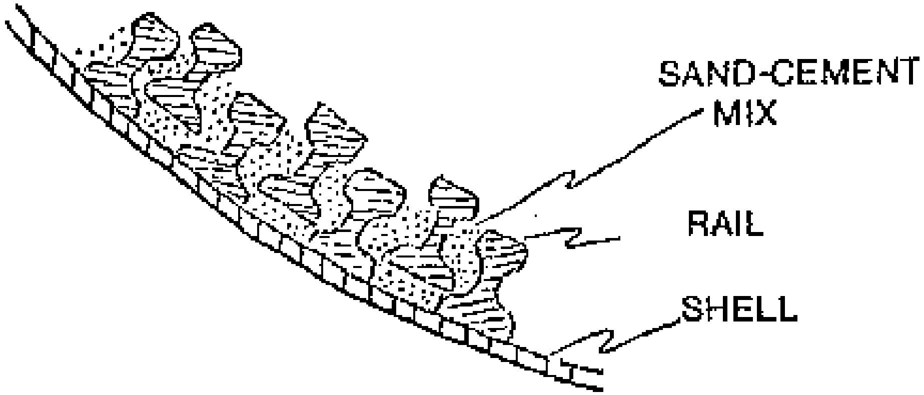


Fig.: Mill lining of old rails cemented to the drum. Source: Stewart.

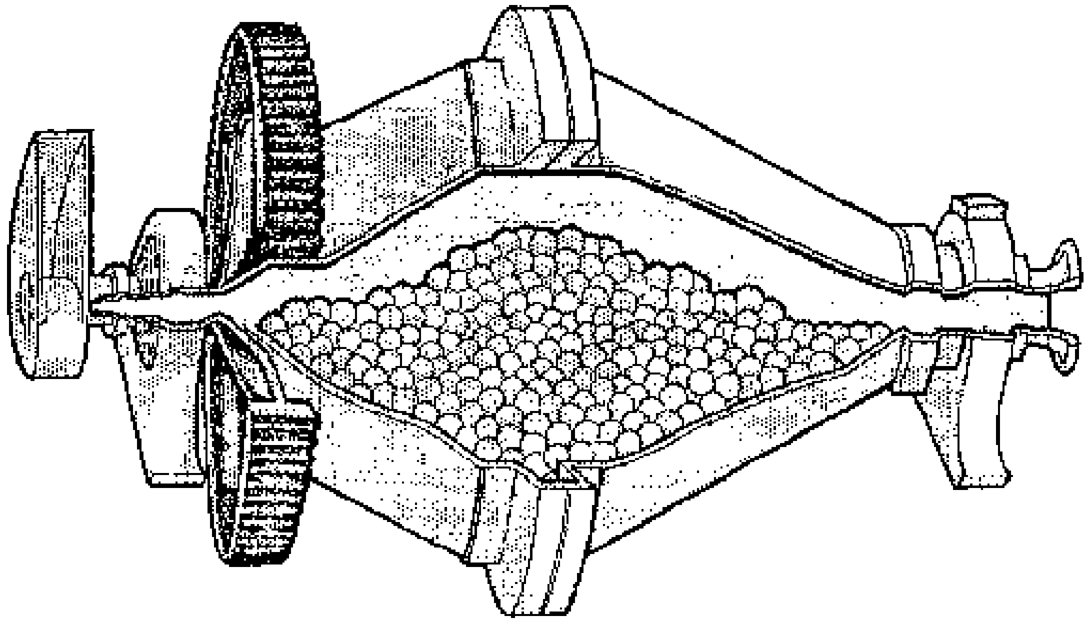


Fig.: Schematic diagram of a ball mill. Source: Armstrong.

12.4 Stamp mill, hammer mill

Metal Mining (gold ores, tenacious ores)
Beneficiation, Comminution

germ.: Pochwerk, Hammerwerk

span.: bocarte, bateria de pisones, molino antioqueno, molino caiforniano, mortero (K.)

TECHNICAL DATA:	
Dimensions:	approx. 4 × 2 × 1 m; 400 - 700 mm-deep die (box) in wet stamp mill, depending on final grain size (approx. 1 mm)
Weight:	several tons; stamp piston about 150 kg
Extent of Mechanization:	fully mechanized
Power Required:	depending on size, up to 10 kW
Form of Driving Energy:	mechanical, driven by hydropower or internal combustion engine; approx. 300 mm lift; approx. 60 stamps/mini approx. 0.6 PS/ stamp
Mode of Operation:	intermittent/semi-continuous/continuous
Throughput/Capacity:	approx. 0.8 - 2.5 t / 24 hrs / stamp
Operating Materials:	
Type:	water for wet stamping
Quantity:	0.4 - 0.8 ft^3/min. stamp
ECONOMIC DATA:	
Investment Costs:	steel stamp mills approx. 10.000 DM including motor (in Colombia); wooden stamp mills approx. 1000 DM for a three-piston stamp mill

	of wooden-construction, and an additional 100 DM per stamp shoe. Wooden stamp mills are much cheaper, since the raw materials are generally less expensive and the mill easier to construct.
Operating Costs:	depends on mechanization
Related Costs:	drive system; e.g. approx. 1300 DM for wooden water wheel in Columbia

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |—————|—————| high
Maintenance Expenditures:		low |—————|—————| high
Location Requirements:	water availability	
Grain Size:	< 100 mm	
Output:	high degree of crushing; final grain sizes < 2 mm	
Replaces other Equipment:	crushers, other mills, Chilean (edge) mill	
Regional Distribution:	historically widely distributed, today rather rare; used in Asia for Au and rice!, in Brazil, Ecuador and Colombia for processing gold ores; pedal-driven lever stamp mill used on harvested crops (e.g. in Nepal for threshing rice), historically used in Japanese gold mining (tail hammers).	
Operating Experience:		very good |—————|—————| bad
Environmental		low |—————|—————| very high

Environmental Impact:		low |————|————| very high
	with wooden stamp mills dust pollution, otherwise primarily noise pollution; for the construction of wooden stamp mills, wood consumption, which, however, is relatively negligible, since the wood is cut and formed on-site without much excess waste, and the life span of wooden stamp mills is quite long. The energy consumed during casting of steel stamp mills is much more environmentally deterimental.	
Suitability for Local Production:		very good |————|————| bad
Under What Conditions:	for steel stamp mills: good metal manufacturers, possible production of stamps from old rails; for wooden stamp mills: carpenters, frequently working directly on-site; stamp shoes produced in metal foundries.	
Lifespan:		very long |————|————| very short
	wear almost exclusively limited to stamp shoe	

Bibliography, Source: Treptow, Priester, Agricola, Calvor, Wagenbreth, Schennen, Reitmeier, Villefosse, Gaetzschmann, Rittinger, Cancrinus, de Hennezel, Diderot, Callon, Treptow/Sado, Clennell, DBM, Uslar, Kirschner.

OPERATING PRINCIPLE:

The stamp is raised by means of a camshaft and falls down, under its own weight, onto the stamp dle. The mill is constructed with a higher wall at the intake side to accommodate the feed input. The discharge side is equipped with slots, screens or weirs. The stamp die, where the crushing occurs underneath the stamp, is

constructed of very hard material or of a sufficiently-thick layer of coarse material. In the recommended wet stamp milling, stamping is performed under water and the final ground product is flushed out by a supplementary stream of water. Multiple-stamp mills usually consist of four to six stamps.

AREAS OF APPLICATION:

For wet or dry crushing of coarse metalliferous ores.

SPECIAL AREAS OF APPLICATION:

For crushing and amalgamation of Au-ores (tray amalgamation).

REMARKS:

Sn, W, and other brittle ores are subject to overgrinding due to the high peak impact forces. For this reason, the use of the stamp mill in metal mining, except for gold ores, has been replaced by crushers.

Invented as a single-stamp dry stamp mill by Heinrich dem Jungerer (Henry the Younger, 1489 - 1568) in the Harz mining region of Germany.

Designed also as a tail hammer, front stamp, helve hammer etc.; this design with horizontally moving stamps is suitable for water-powered drive systems such as water levers or "Gnepfe", which are water see-saws equipped with a slowly-filling container at one end to raise the counterweight at the other end, whereby the water container abruptly empties Itself again.

Stamp mill drive-systems have traditionally almost always been hydromechanic, employing water wheels; exceptions were steam-operated mills.

The stamp shoe and stamp stem should always be independently constructed to permit easy replacement of worn shoes. However, the joint between the stem and the shoe must be rigid to prevent slippage and a resulting drop in efficiency.

Wooden stamp dies should be protected against wear by leaving a layer of already-crushed material in the die to buffer it from newly-added coarse feed; mills operated under these conditions then exhibit wear-resistant characteristics similar to steel stamps.

Of importance in the crushing process is the stamping frequency too low a frequency leads to sedimentation of the fine material and consequently a very fine milling with low throughput. Optimal stamp frequencies are in the range of approx. 30 min-1 for fine milling up to approx. 90 min-1 for coarse milling.

For stamp-mill processing in gold mine operations, it is important that the slurry does not contain any oil or grease, and therefore it is absolutely necessary to prevent lubricants from dripping into the stamp die. The presence of lubricants in the slurry causes immediate flotation of the fine gold in the successive separation processes.

In gold mining in Ghana and Ecuador, locally-produced mortars are used for manually-operated impact or stamp crushers. As stampers, car axles or axle stumps constructed of high-tensile steel can be used. The local name In Ecuador for these is "porron".

Fundamentally, the throughput of stamp mills is relatively low. Therefore, mechanized gold mines have chosen to replace them with crushers for coarse-crushing steps, and with Chilean (edge) mills for finer grinding requirements.

For use in gold mining, the stamp mill is equipped with a screen (e.g. in Colombia with perforated rubber, zarandas) on the discharge side, and with mercury, or even better silver-amalgamated replaceable copper plates, on the feed-intake side.

Coarse heavy material is often concentrated in the stamp die.

OPERATING EXPERIENCE:

In the Andean gold mining region of Colombia, locally-manufactured stamp mills are the most widely used crushers. These wooden stamp mills, made of chachajo-wood, are generally driven by primitive, overshot water wheels. The three to four catchers per stamp are located directly on the axis of the water wheel. Mills with between three and five stamps are in use. The time required to construct such a mill totals about three weeks for the complete installation. The stamp shoes are made of iron and are replaced approximately every 6 months; the bearings are predominantly slide bearings. Iron stamp mills can be purchased from local machine manufacturers, and are usually powered by diesel engines and a system of belts or chains. The catcher-equipped axle rests on rollers or ball bearings.

To avoid flotation caused by dissolved lubricants, the Colombian miner grinds pieces of sisal leaves (cabuya, fique, lat.: Fourcraea macrophylla Baker) in with the feed material (see Technique 15.2).

SUITABILITY FOR SMALL-SCALE MINING:

When stamp mills can be manufactured at low cost, and a hydromechanical, slow-moving direct drive system is available, they are advantageous compared to other, turbo-driven crushers (jaw crusher, roll crusher). Stamp mills are especially suitable for the grinding of tenacious gold ores.

Wooden stamp mill with three stamps and open stamp die, easily visible are the Inset iron stamp shoes, and above them the water wheel axle with catchers for driving the stamps. In the foreground, a blanket sluice with blanket-cover removed; La Llanada' Narino, Colombia

Iron stamp mill with drive-belt gear transmission from a diesel engine. At stamp mill discharge side, the perforated rubber strips serving as screens. In foreground, blanket sluice for gold sorting. La Llanada, Narino, Colombia.

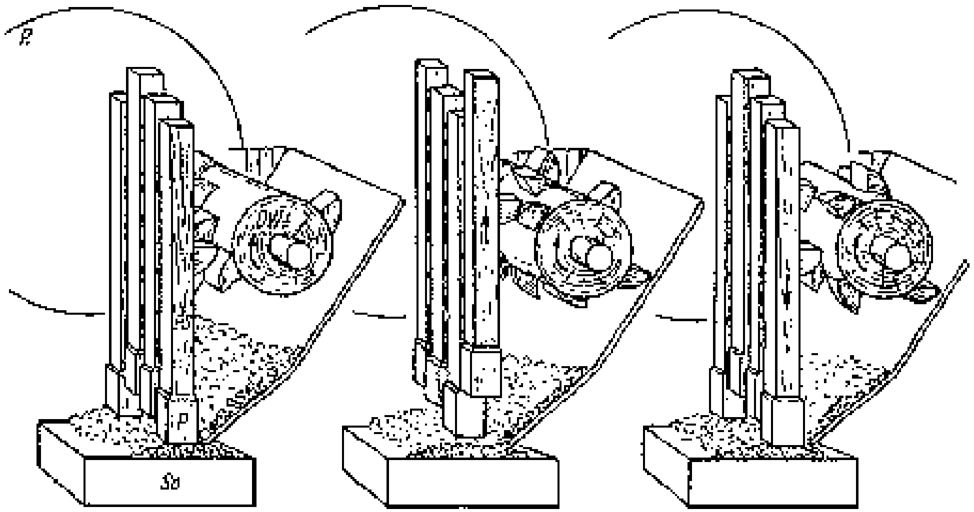


Fig.: Functional diagram of a stamp mill. Source: Wagenbreth.

Wooden stamp mill with three stamps and open stamp die; easily visible are the

insert iron stamp shoes, and above them the water-wheel axle with catchers for driving the stamps. In the foreground, a blanket sluice with blanket-cover removed; La Llanada, Narino, Colombia.

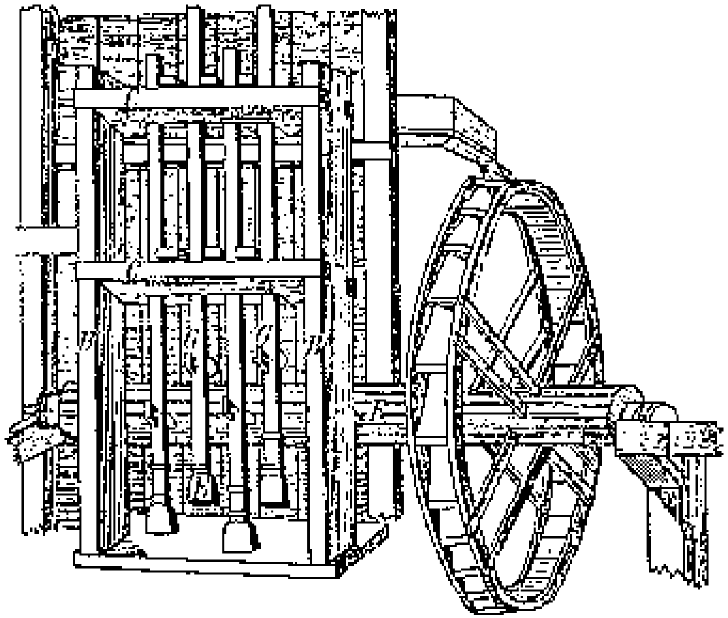


Fig.: Water-wheel-driven dry stamp mill. Source: Schennen.

Iron stamp mill with drive-belt gear transmission from a diesel engine. At stamp mill discharge side, the perforated rubber strips serving as screens. In foregound, blanket sluice for gold sorting. la Llanada, Narino, Colombia.

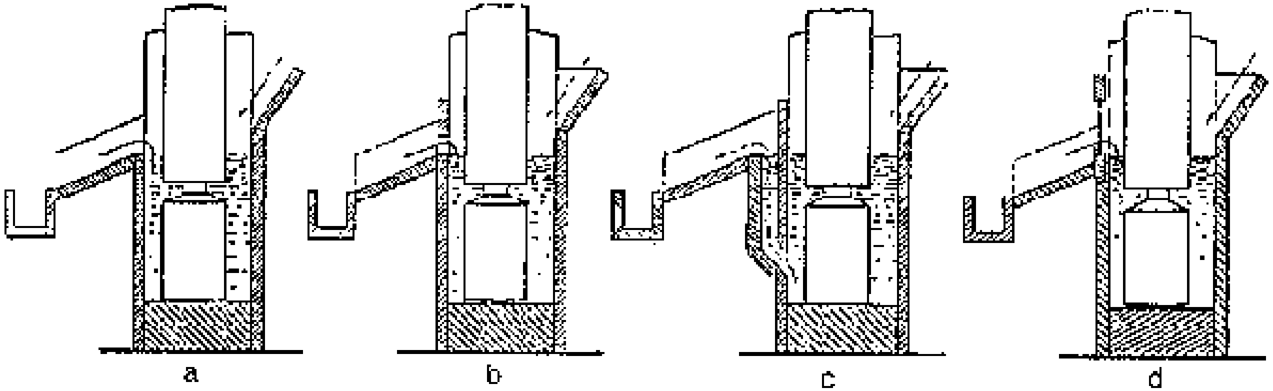


Fig.: Discharge installations in wet stamp mill. Source: Treptow.

Manual stamping mortar (porron) for crushing of rich gold ores in Guaysimi, Ecuador.
Left: discharge over the wall, middle: discharge throught a slit, right: discharge throught piston (stamp) displacement.

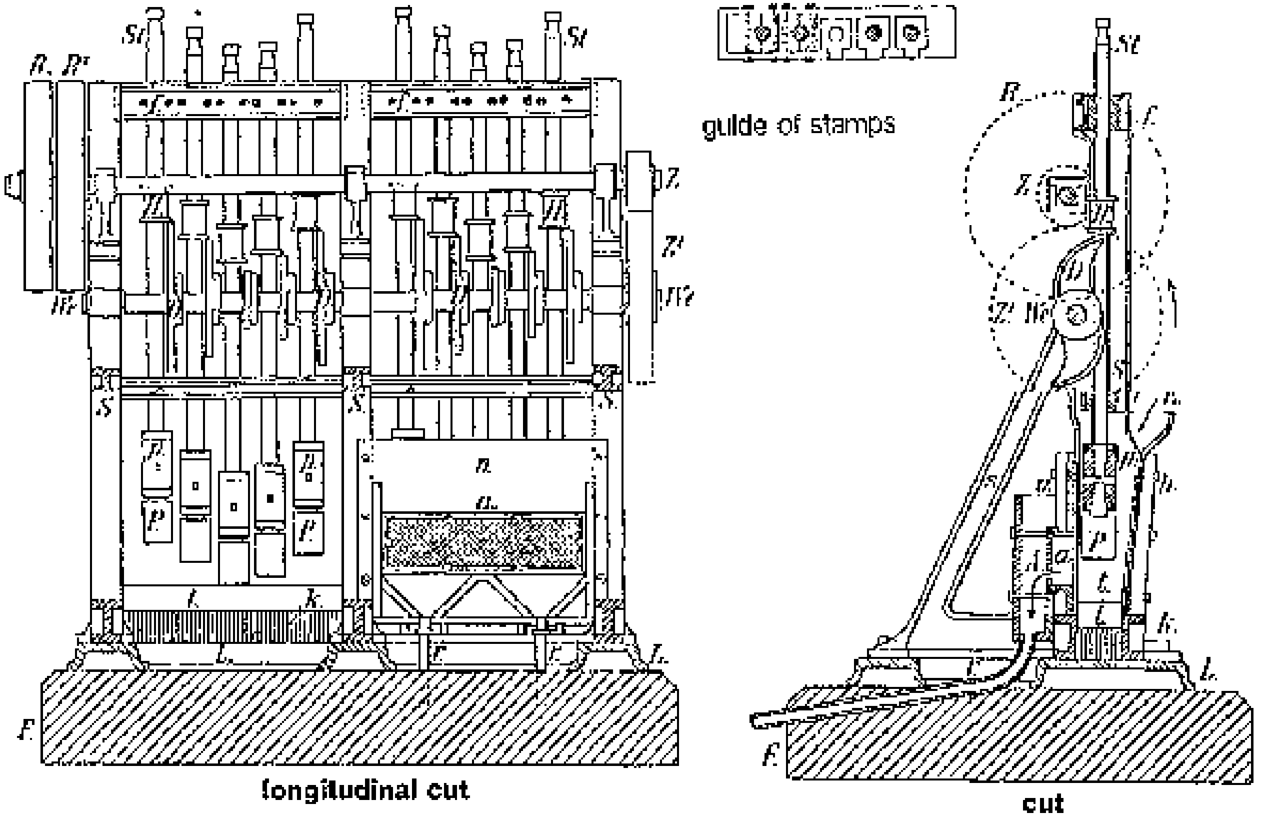


Fig.: Californian stamp mill with trimmed set of screens. Source: Treptow.

Fig.: Wet stamp mill. Source: Agricola.

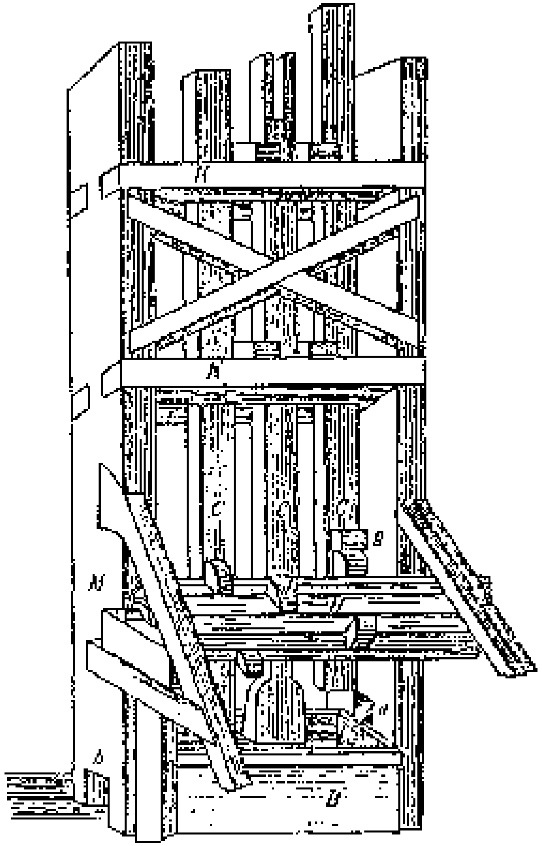


Fig.: Wet stamp mill. Source: Schennen.

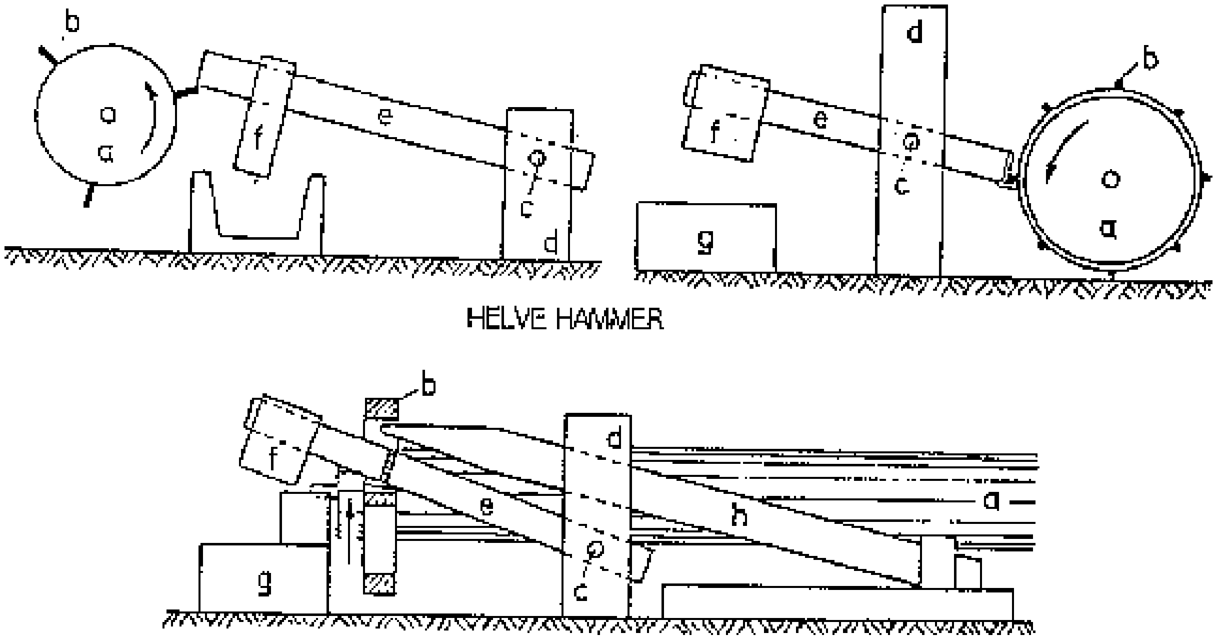


Fig.: Hammer mills. Source: Eckholdt.

a=AXLE, b=CATCHERS, c=STAMP LEVER JOINT, d=STAMP LEVEL JOINT HOLDER, e=STAMP LEVER, f=STAMP, g=ANVIL, h=OVERHEAD STABILIZER

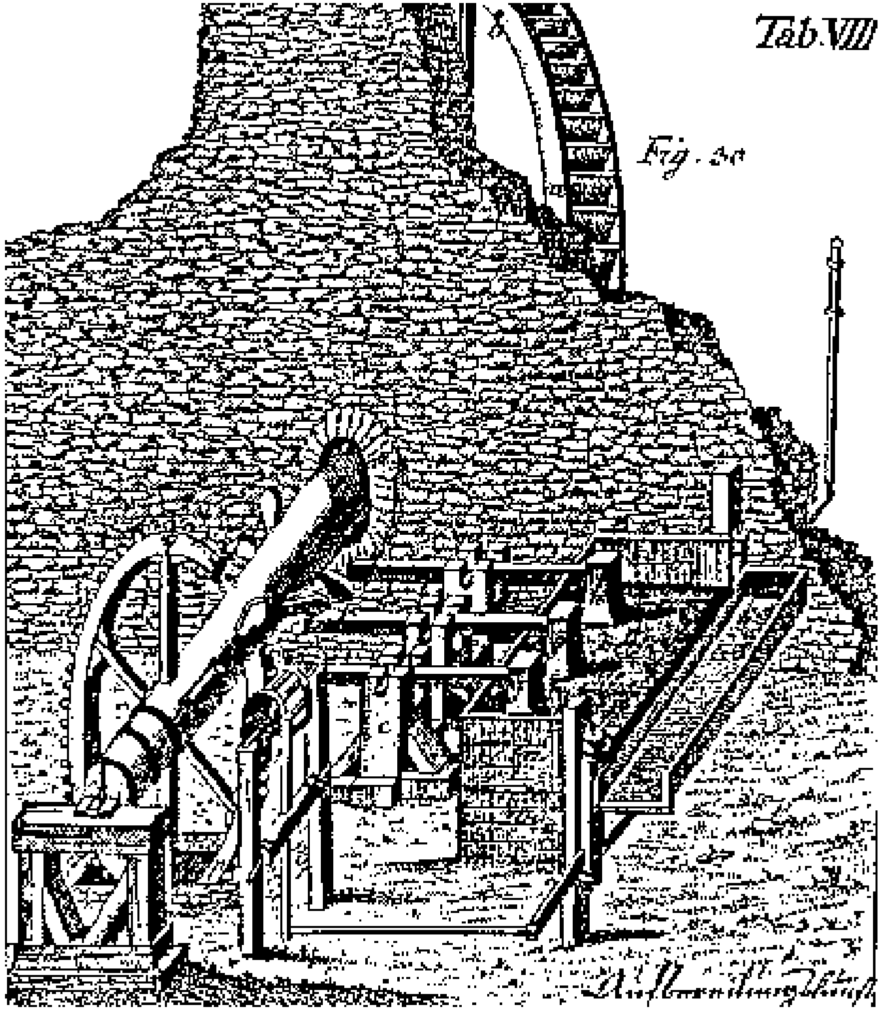


Fig.: Tail hammer. Source: Cangrinus.

12.5 Chilean mill edge mill, roller mill

Ore Mining (Gold Ore, Sand and Gravel (colored clays)) Beneficiation Crushing

germ.: Kollergang, Rollquetsche

span.: trapiche, molino de muelas, molino chileno, milling track: solera, wheel casing: Llanta

Manufacturer: Millan, Volcan/both in La Paz, Bolivia, Talleres J.G.

TECHNICAL DATA:	
Dimensions:	approx. 2 × 2 × 2 m HWD + drive
Weight:	> 1000 kg
Extent of Mechanization:	fully mechanized
Power required:	5 - 7 kW + 15 kW starting motor
Form of Driving Energy:	electric
Alternative forms:	hydromechanic, animal-powered whim
Mode of Operation:	continuous
Throughput/Capacity:	approx. 1000 kg/in
Operating Materials:	
Type:	water
ECONOMIC DATA	
Investnment Costs:	approx. 5000 to 6000 DM (locally produced in Bolivia)
Operating Costs:	depends on type of drive system

CONDITIONS OF APPLICATION:

Operating Expenditures: low |————|————| high

Maintenance Expenditures:	low |—————|—————| high
Personnel Requirements:	low
Gain Size:	up to 20 mm
Special Feed Requirements:	even hard abrasive feed materials can be crushed
Output:	very high degree of crushing; very fine ultimate grain size
Replaces other Equipment:	ball mills, amalgamating mills, stamp mills
Regional Distribution:	Chile, Ecuador, Bolivia; earlier worldwide, today mainly in agriculture for milling of oil producing fruits (oil mill)
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
	high when combined with amalgamation, otherwise low
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	metal manufacturers, foundry
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Priester, v. Bernewitz, Gerth, Schennen, Schabel, Diderot,Gaetzschmann, Treptow

ECONOMIC DATA:

Investment Costs:	approx. 5000 to 6000 DM (locally produced in Bolivia)
Operating Costs:	depends on type of drive system

OPERATING PRINCIPLE:

The Chilean (edge) mill is a typical crusher used in gold beneficiation of primary gold-quartz veins. Two steel-rimmed concrete wheels, frequently weighing more than half a ton, roll around a circular milling track and grind the ore underneath them, yielding fine to very fine grain-sized products due to the high degree of crushing forces exerted. The final grain size is determined by the length of time the mineral is crushed or by the velocity of the water flowing through the mill.

AREAS OF APPLICATION:

For fine grinding and pulverizing. For grinding and amalgamation of Au-ore.

REMARKS:

The real advantage of the edge (Chilean) mill in ore beneficiation lies in its ability to simultaneously grind and amalgamate gold ore, whereby fine gold is kneaded into the mercury so that the amalgam is reached by fine gold particles, which would not otherwise be amalgamated without the kneading due to the mercury's high surface tension. At the same time, the surfaces of liberated gold particles are cleanest during milling, not yet becoming corroded again.

The extremely heavy weight of the wheels poses difficulties in overcoming intertia

during the start-up phase, possibly requiring a stronger starting motor. The outer axle stump is sometimes supported by a chain in order to minimize the high lifting forces that occur.

In northern Chilean gold mining, when the grinding operation includes a simultaneous amalgamation, the cone-shaped rim of the grinding track is sometimes covered with copper plates to serve as an amalgamation table. This aids in the binding of finely-distributed "floured mercury".

In general, the Hg-losses during amalgamation in Chilean mills are somewhat high. The finely crushed, flushed-out mercury and amalgam require subsequent removal by gravimetric secondary separation, for example in a hydraulic trap.

In gold mining in Ecuador, copper plates for amalgamation directly suceed the Chilean mill in the beneficiation procedure.

SUITABILITY FOR SMALL-SCALE MINING:

Especially for small-scale gold mining, edge (Chilean) milling with simultaneous amalgamation is very suitable, provided that environmental damage is avoided. For other forms of ore mining, this system is suitable only in limited situations, such as for very finely intergrown ores. For all other types of feed material, the occurence of larger proportions of fines poses difficulties.

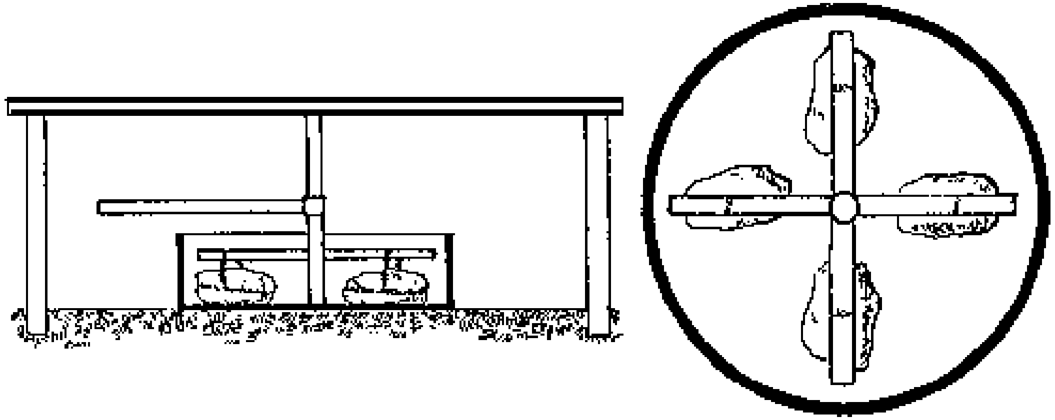


Fig.: Molino de arrastre, an early form of the edge (Chilean) mill. Source: Ulsar. Left: side view, Right: top view.

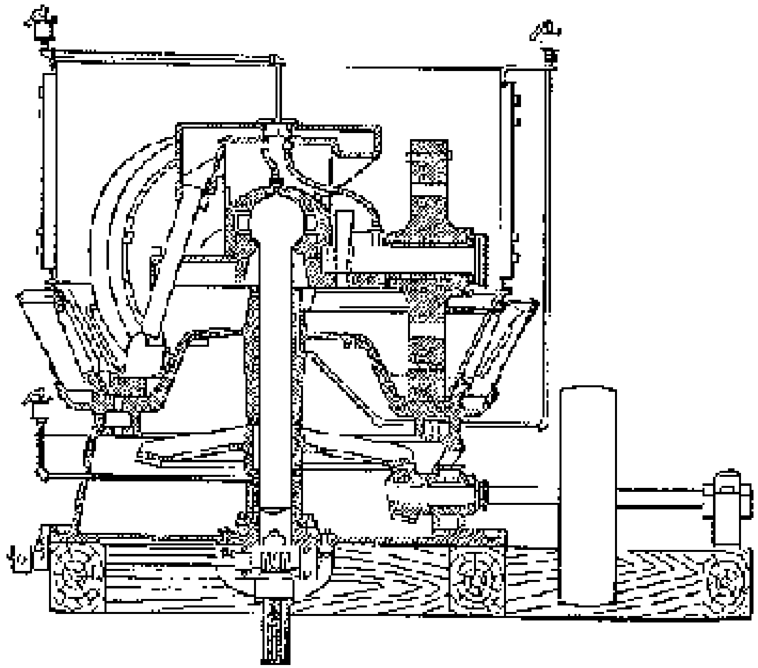


Fig.: Diagram of an edge (Chilean) mill. Source: Bernewitz.

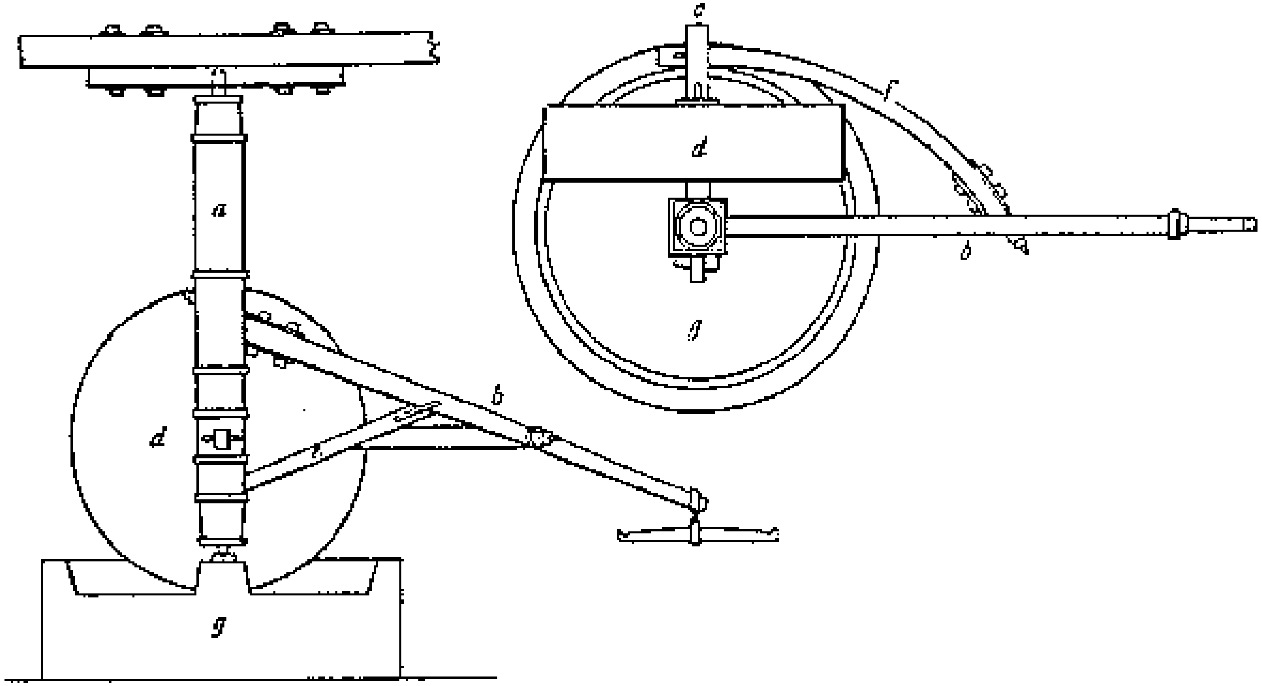


Fig.: Early type of Chilean mill as roller mill with animal-powered whim. Source: Schennen. Left: side view, Right: top view.

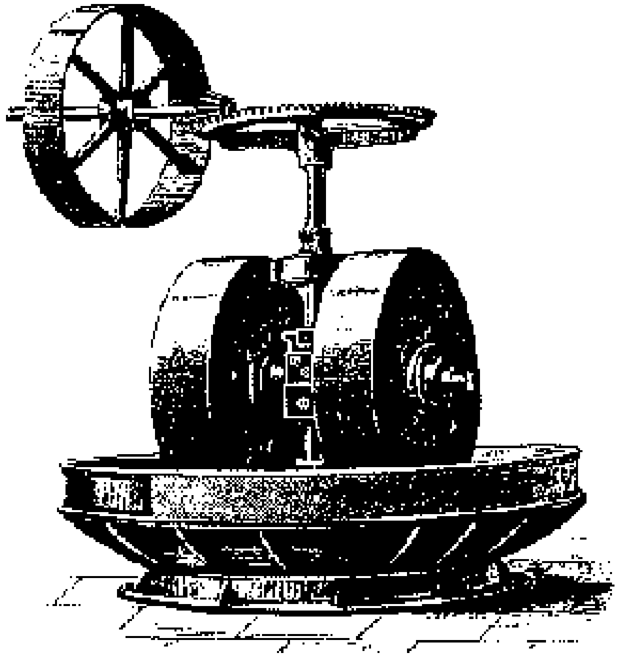


Fig.: Edge (Chilean mill. Source: Schanabel.

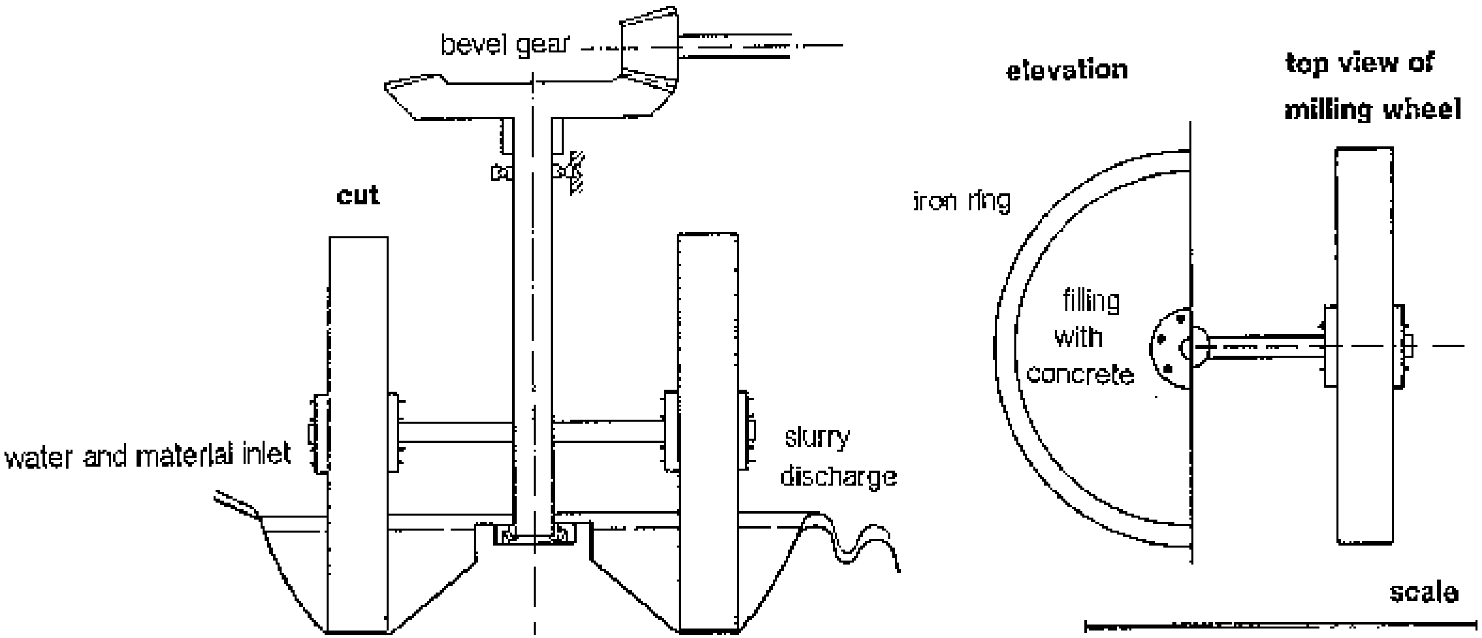


Fig.: Construnction diagrams of an edge (Chilean) mill produced in Bolivia. Source: Priester.

12.6 ''See-saw'' crusher, ''rocker'' crusher

re Mining (Gold Ore, Sand and Gravel (colored clays))
Beneficiation, Crushing

germ.: Wiegezerkleinerer
span.: quimbalete, maray

TECHNICAL DATA:

Dimensions:	approx. 1.5 × 1 × 2 m HWD
Weight:	up to >= 2 t
Extent of Mechanization:	not mechanized
Form of Driving Energy:	manual
Alternative forms:	in Peru partly hydromechanic with water wheel
Mode of Operation:	semi-continuous
Throughput/Capacity:	0.7 - 1.5 kg/M × min

ECONOMIC DATA:

Investment Costs:	nominal since usually self-constructed
Operating Cost:	Iabor costs only

CONDITIONS OF APPLICATION:

Operating low I————I————I high

Operating Expenditures:	low |————|————| high
Maintenance Expenditures:	low |————|————| high
Grain Size:	up to approx. 5 - 10 cm
Output:	degree of crushing very high, depending on duration of milling: normally 1: 5 to 1:20; final grain-size depending on mill design, of up to 100 % < 100 ym, homogeneous grain distribution in ground product
Replaces other Equipment:	mills, Chilean mills, stamp mills
Regional Distribution:	Bolivia, Peru, Chile, Honduras, Philippines
Operating Experience:	very good |————|————| bad
	disregarding the work-intensity involved with the technique, very good
Environmental Impact:	low |————|————| very high
Suitability for Local Production:	very good |————|————| bad
Under What Conditions:	see-saw crusher made of hard rock material (granite, gneiss, etc.) or welded together from scrap Iron, possibly filled with stones or concrete, on a steel or stone plate, are primarily locally produced
Lifespan:	very long |————|————| very short
	practically no wear

practically no wear

Bibliography, Source: Priester, Latin America Seminar Hannover, Ahlfeld, Hentschel, Rittinger

OPERATING PRINCIPLE:

Very heavy stone or steel see-saw or rocker crushers are rolled, with the help of a lever arm, over the material to be ground, which is placed on a stone or steel surface. This method of crushing is comparable to that of roll crushers. Through a slight rotation at the dead-canter lever-arm position, the wheels can be repositioned on the grinding surface.

AREAS OF APPLICATION:

Grinding of coarse to medium-grained ores as part of the beneficiation process. Many mining operations crush exclusively with see-saw or rocker crushers.

SPECIAL AREAS OF APPLICATION:

Concave circular stampers are used for fine-crushing/recrushing of fine-grained middlings (see photo opposite).

REMARKS:

Even hard abrasive material can be processed; the wear on the see-saw or rocker crusher remains very low, however the great physical effort required for the hand-crushing of this material poses difficulties. In gold mining in North-Peru, these crushers are sometimes driven by water wheels.

A well-formed grinding surface makes the crushing process significantly easier. The geometric center should be above the mass center.

See-saw or rocker crushing can be performed either as a wet or a dry process, whereby wet crushing produces a more homogeneous product with fewer fines and also minimizes the occurrence of airborne silicate dusts.

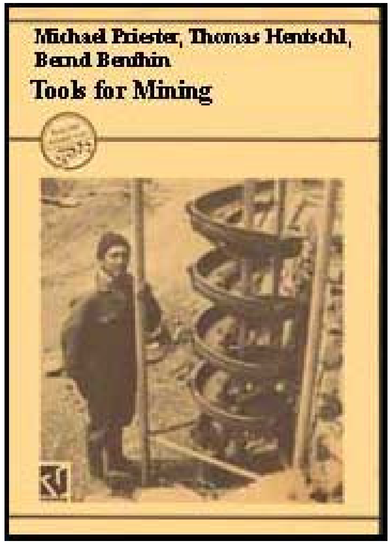
Wet crushing could possibly be performed in troughs or sluices, with the fine grains being carried out in the water flow.

According to Rittinger, very hard quartz-ores are sometimes burned prior to crushing in order to shatter the crystals. This in turn reduces the required output in the crushing step by approx. 15%.

In northern Chilean gold mines, poured-concrete milling wheels called "marajes", which run in concrete or stone troughs and are moved by the use of branches or two simple wooden levers, are employed for wet crushing and amalgamation.

SUITABILITY FOR SMALL-SCALE MINING:

As a traditional and widely-used crushing apparatus in Latin American small-scale mining, the see-saw or rocker crusher can still be employed today whenever the quantity of feed material is low, such as for secondary grinding of middlings. Despite its being a highly work-intensive technique, the see-saw crusher is the most effective of the non-mechanized crushing processes.



Tools for Mining: Techniques and Processes for Small Scale Mining (GTZ, 1993, 538 p.)

Technical Chapter 13: Classification

13.1 Set of rigid screens

Mining General
Beneficiation, Classification

engl.: screening gate, grizzly

germ.: Siebklassierung in starren Sieben, Durchwurf, Reibgatter

span.: clasificacion en tamices fijos, clasificacion por tamano en tamiz

TECHNICAL DATA:	
Dimensions:	starting at 30 × 40 cm screen area for single screen, up to 2 × 2 m for coarse screens (grizzly)
Weight:	starting at 5 kg per screen
Extent of Mechanization:	not mechanized
Form of Driving Energy:	manual feeding, possible manual drawing as well
Mode of Operation:	semi-continuous
Throughput/Capacity:	very dependent on grain-size of feed
Operating Materials:	
Type:	water for wet screening
ECONOMIC DATA:	
Investment Costs:	example: for three screens 300 DM
Operating Costs:	labor costs only

CONDITIONS OF APPLICATION:

Operating low I————I————I high

Expenditures:	
Maintenance Expenditures:	low |—————|—————| high
Location Requirements:	water availability
Grain Size:	100 ym up to several decimeters separation cut-off size (screen openings)
Special Feed Characteristics:	no clay-containing' sticky material
Replaces other Equipment:	other classifiers
Regional Distribution:	worldwide
Operating Experience:	very good |—————|—————|bad
Environmental Impact:	low |—————|—————|very high
Suitability for Local Production:	very good |———|—————|bad
Under What Conditions:	frames are very suitable for local production by carpentry or metal workshops; screens are generally imported since they are subject to extreme abrasive forces and must therefore be constructed of high-quality material.
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Stout, Schennen, Stewart, Priester, Reitemeier, Villefosse, Gaetzschmann, Cancrinus

OPERATING PRINCIPLE:

Screen classification with rigid (stationary) screens can be performed either wet or dry. Dry screening is applied for dry coarse-grained material and occurs in an inclined screen. Wet classification is conducted in "screening gates", or a series of successive stationary screens built into a sluice or trough, sequentially going from coarser to finer screen openings from the top (feed end) to the bottom (discharge end) of the trough. The screened unders are transferred to the next (one degree finer) screen via the processing water.

AREAS OF APPLICATION:

For classifying material of coarse and medium granulation prior to its entering the main separation facility.

SPECIAL AREAS OF APPLICATION:

Selective classification of products from sorting and comminution processes.

REMARKS:

The dry screening process with the inclined screen is disadvantageous in that it has a low separation precision as a result of undesired separation of adhesive grains.

Wet screening in rigid screens and distributing the material over the screen by means of a spatula leads to inhomogeneity in the slurry comprised of the screened unders. When the classification processes, which are sensitive to changes in the feed slurry, directly succeed the wet screening, then special equipment (such as pinched sluices) for homogenizing the slurry flow must be placed between these two steps. Screens were already being applied in antiquity in Greek mining. For acidic process water, it is absolutely necessary that the bottom of the screens be constructed of stainless steel or plastic. During wet screening, care should be taken to either catch the fines in sedimentation basins, or immediately separate them in sludge ponds, to avoid high losses of valuable minerals.

Grizzlys, used for coarse-material separation, should be installed with a minimum inclination of 25° - 30°, allowing the coarseest fractions to roll down the grid and be collected for subsequent crushing.

SUITABILITY FOR SMALL-SCALE MINING:

Wet screening is a low cost, simple, quick and precise alternative for sorting feed material of medium to coarse grain-size. Especially when only smaller quantities of feed require processing, a mechanized classification is not necessary.

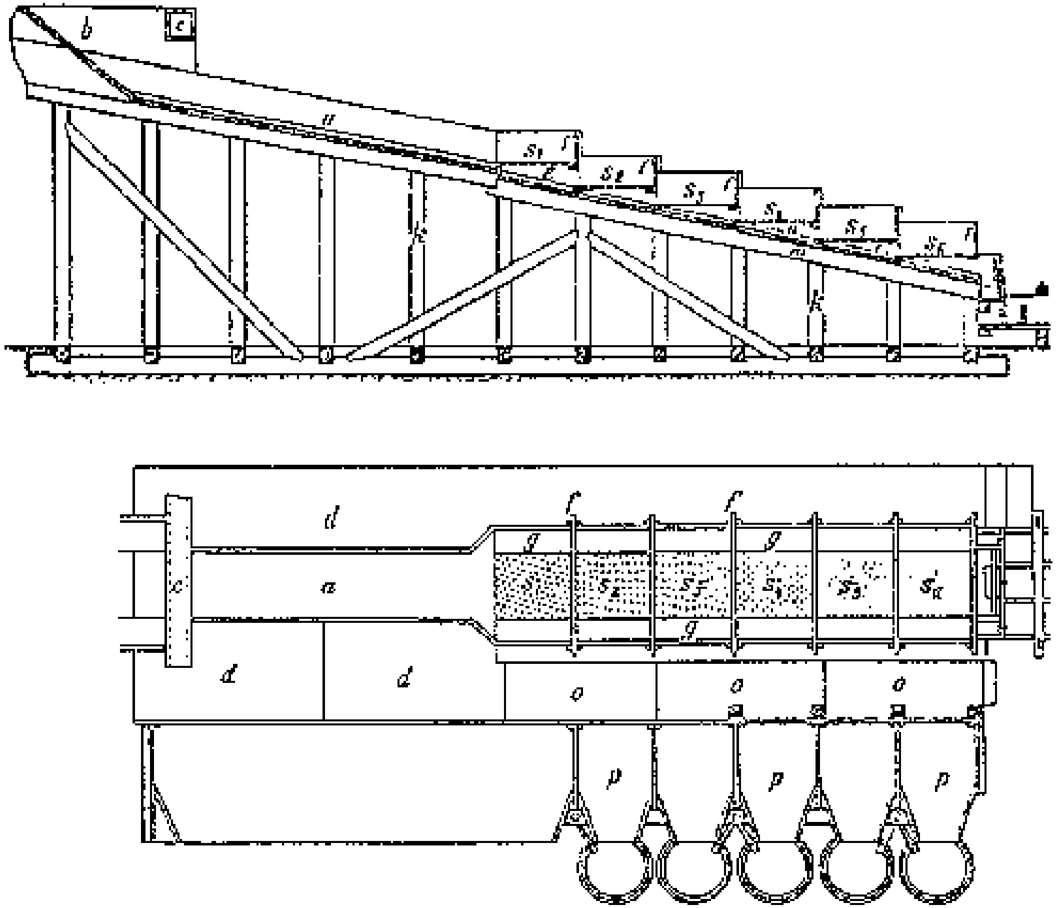


Fig.: Screening gate or screened grid-washer for wet classification with rigid screens. Source: Schennen.

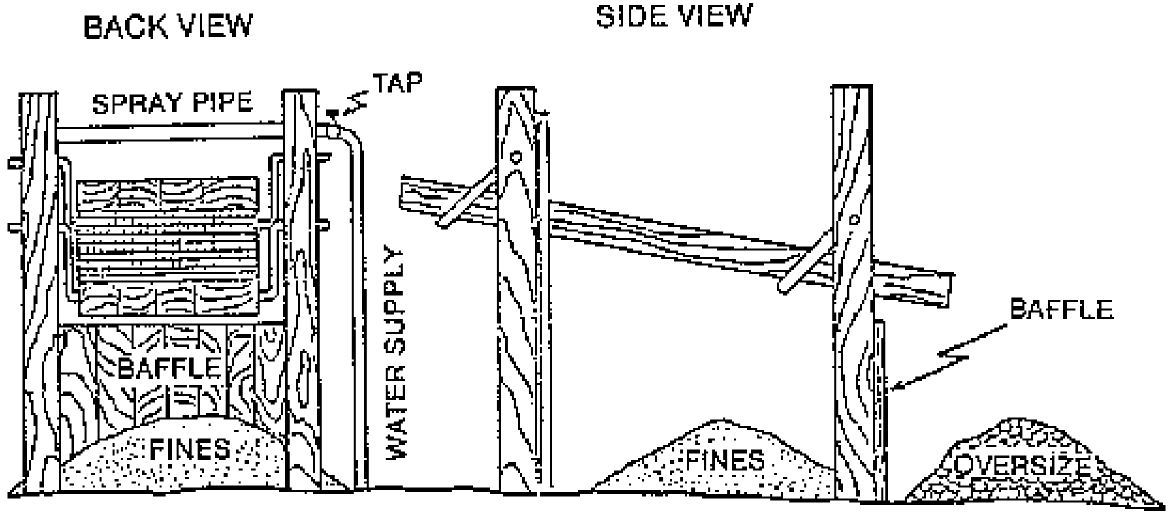


Fig.: Simple hand screen with sprinkling device. Source: Stewart.

Screening gate for wet classification of course-grained material. Clearly visible are the outles for the screened unders , wich then directly enter the next (finer) subsequent sorting step; Mina Candelaria, Sud lipez, Bolivia.

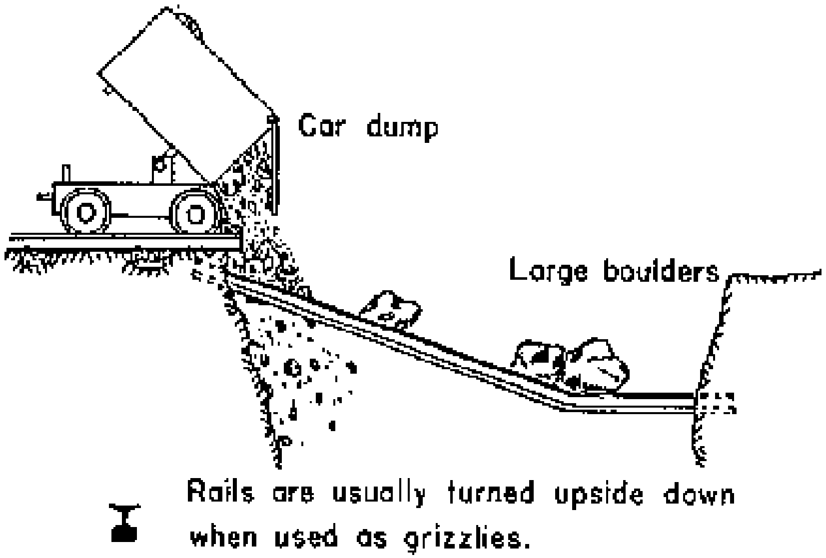


Fig.: rigid, fixed grate for separating out large boudles, made of rails. Source: Stout.

Wooden grizzly for separating coarse coal underneath an unloading ramp for end-loading mine cars; Colliery in Region Rio Checua, Cundinamarca, Columbia.

13.2 Screen riddle, vibrating screen

Mining General
Beneficiation, Classification

germ.:	Ruttelsiebe, Schwingsiebe, Ratter
span.:	criba vibradora, instalacion de tamices con movimiento circular
Manufacturer:	Schenk, Jost, Mogensen, Eduardo, INCOMEC, Milag, Met. Cancha, Volcan, Alquexco, Eq. Ind. Astecnia, IAA, INCOMAQ, COMESA, FAHENA, Telsmith, FIMA, FAMINCO, Famia, fund. Callao, H.M., MAGENSA, MAENSA, MAEPSA, Met. Callao E.P.S.

TECHNICAL DATA:	
Dimensions:	from 30 × 40 cm upwards, 10° - 20° inclination, 80 - 100 min-1 vibrating or shaking frequency
Weight:	from approx. 50 kg up to several thousand kg
Extent of Mechanization:	fully mechanized
Power:	low, maximal 1 PS/m² screen area
Form of Driving	hydromechanic impact mechanisms, manual impact mechanisms

Energy:	
Alternative forms:	pedal drive
Mode of Operation:	continuous
Technical Efficiency:	comparably higher than that of rigid screens
Operating Materials:	
Type:	water
Quantity:	60 - 80 % by volume of feed quantity
ECONOMIC DATA:	
Investment Costs:	manual, starting at 100 DM per screen when locally produced
Operating Costs:	usually labor costs only, possibly energy costs
Related Costs:	drive system

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————————| high
	depending upon degree of mechanization
Maintenance Expenditures:	low |————|————| high
	the removal of adhesive (sticky) grains in the feed is necessary
Location	water availability

Location Requirements:	water availability;
Grain Size:	> 50,um up to < 50 mm
Replaces other Equipment:	rigid screens
Regional Distribution:	not known in semi-mechanized processes in small-scale mining in Latin America; only used for wet classification in Jig operations
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	wood and metal manufacturing shops
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Calvor, Agricola, Fischer, Schennen-Jungst, Liwehr, Villefosse, Delius, Gaetzschmann, Rittinger, Cancrinus, de Hennezel, Gerth

OPERATING PRINCIPLE:

In contrast to rigid, fixed screens, the bottom of vibrating screens (screen riddles) oscillates either longitudinally or laterally, shaking the material on the bottom of the screen and enhancing the flow through the screen openings. This results in a separation between the oversized (screen overs) and undersized (screen unders)

grain fractions.

AREAS OF APPLICATION:

Dry or wet classification of coarse, medium or fine-grained feed fractions.

REMARKS:

Deflection with vibrating screen 55 - 80 mm
Deflection with impact screen 25 - 55 mm

The space requirement for vibrating screens is much less than that for rigid screens. Colotten placed underneath the screens for catching the individual fractions allow the screens to be staggered vertically on top of each other.

Car springs can be used as shaking devices and buffers.

Optimal ratio of screen length to width is approx. 2.7: 1

SUITABILITY FOR SMALL-SCALE MINING:

Even slightly-mechanized forms of vibrating screens are preferable to rigid screens due to their higher efficiency, lower space and water requirements, and finer degree of separation.

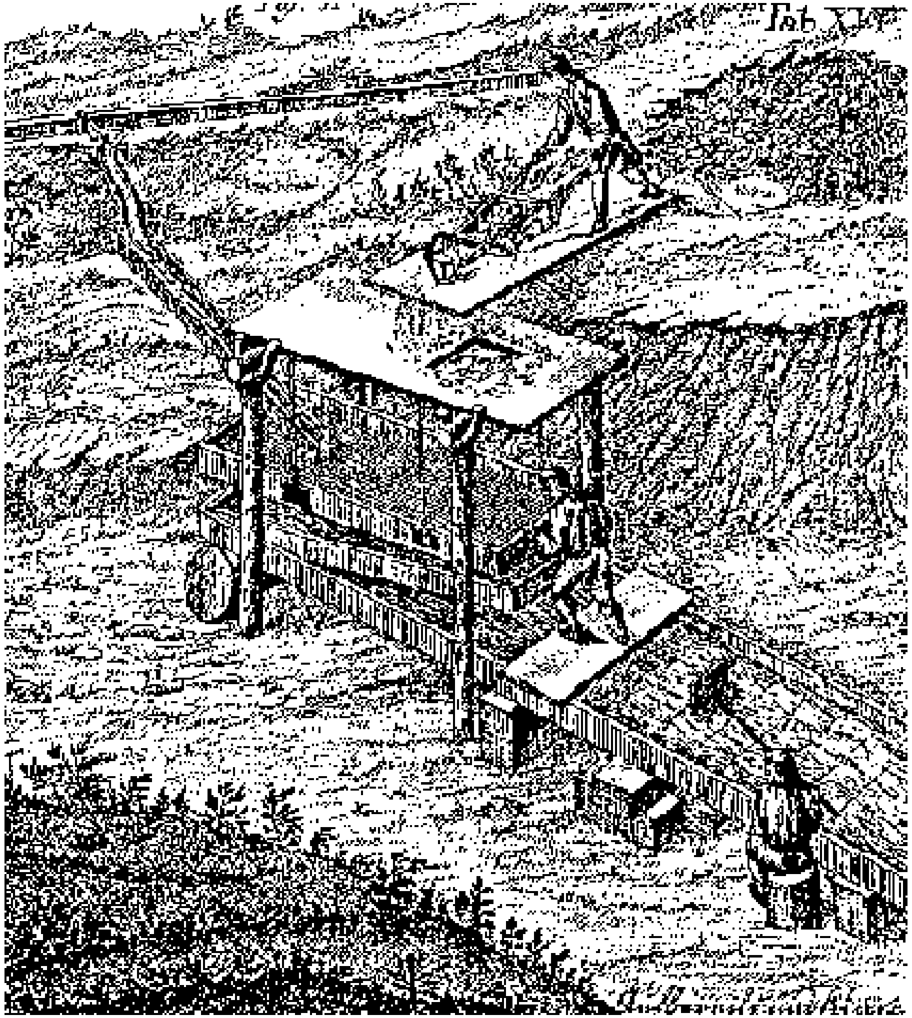


Fig.: Manual shaking screen. Source: Cancrinus.

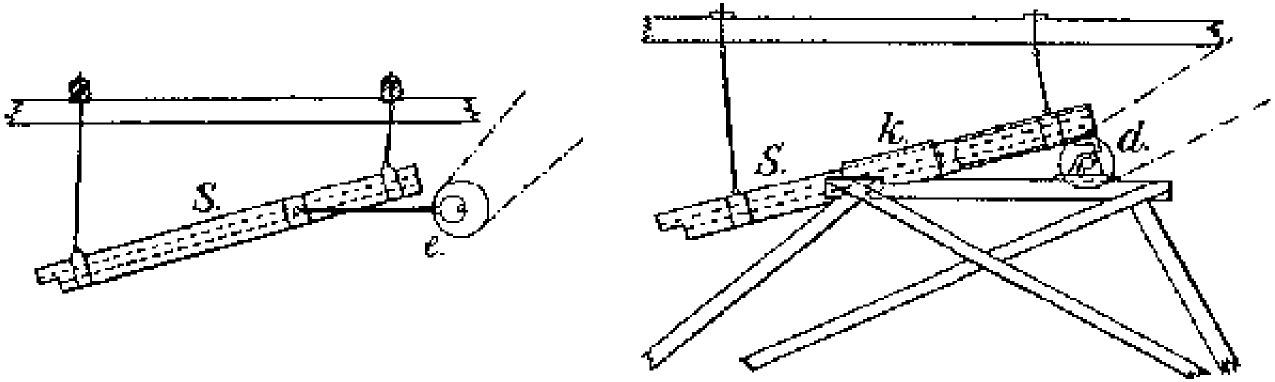


Fig.: Operating principle of a vibrating screen (left) and impact screen (right). Source: Treptow.

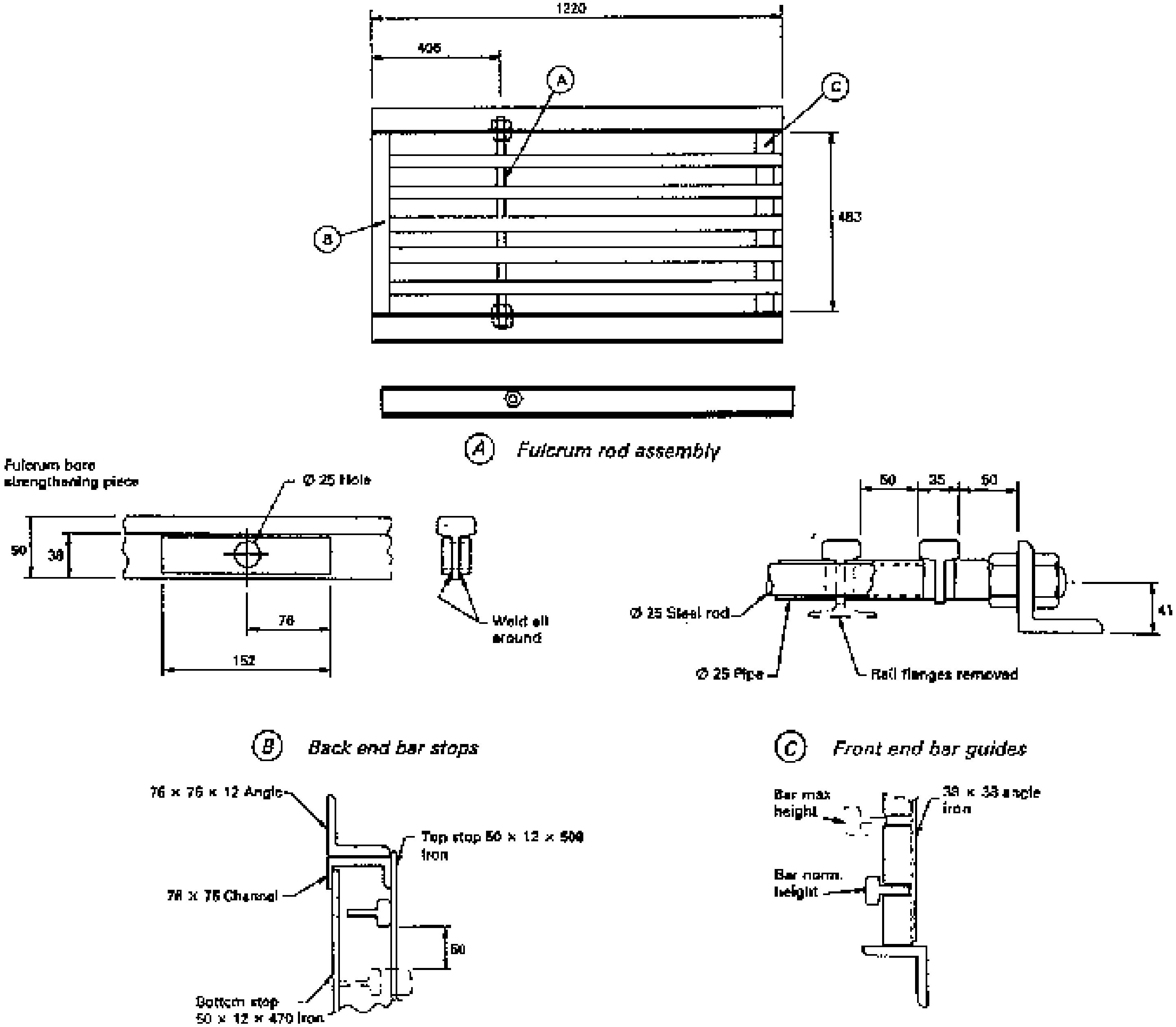


Fig.: Self-vibrating screens made of railroad rails which start swinging upon impact of the feed material. Source: ITDG.

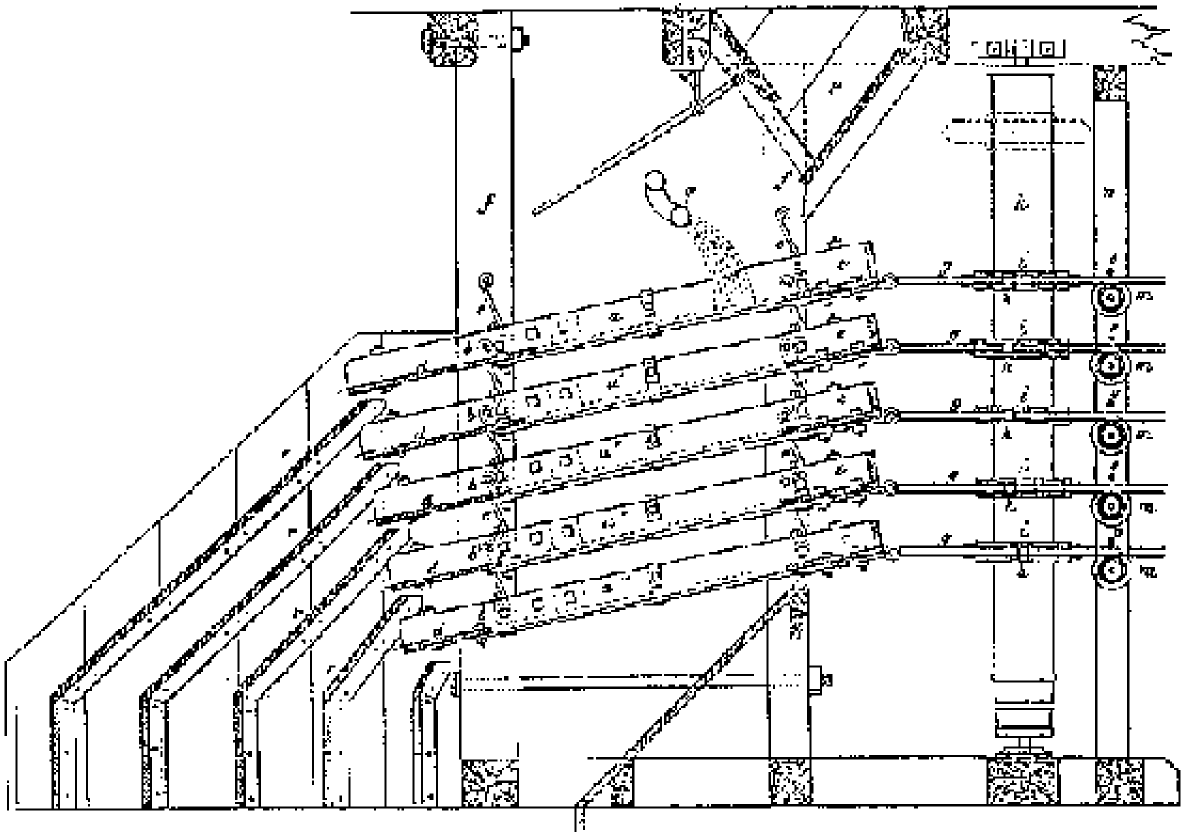


Fig.: Multiple-step screen riddle. Source: Liwehr.

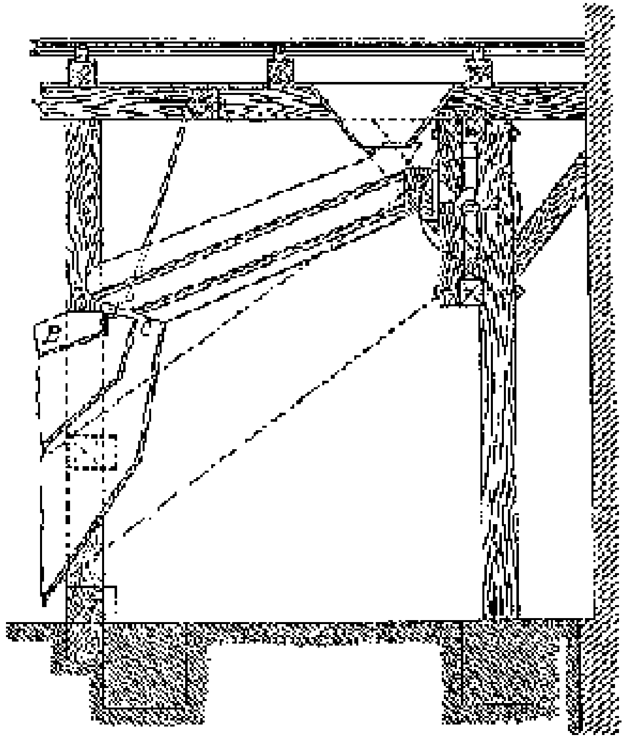


Fig.: Two-step impact screen. Source: Schennen.

13.3 Cantilever grizzly

Mining General (pit and quarry)
Beneficiation, Classification

germ.:	Antriebslose Schwingsiebe
span.:	criba vibradora sin fuerza motriz (parrilla)
Manufacturer:	Mogensen

TECHNICAL DATA:

Dimensions: separable grain-size cut-off: 25 - 40 mm minimum, approx. 300 mm

	maximum
Weight:	from approx. 200 kg
Extent of Mechanization:	not mechanized
Form of Driving Energy:	uses impact of falling feed material to induce shaking
Alternative forms:	as vibro-sizer for material that is very difficult to screen, but then mechanized
Mode of Operation:	continuous
Throughput/Capacity:	> 100 t/h

ECONOMIC DATA:

Investment Costs:	minimum of 20.000 DM fob location of manufacture in Germany
Operating Costs:	very low

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance Expenditures:	low |—————|—————| high
Location Requirements:	none
Grain Size:	< 1000 mm
Output:	precise screening

Replaces other Equipment:	vibro-screens
Operating Experience:	very good |————|————| bad
Environmental Impact:	low |————|————| very high
Suitability for Local Production:	very |————|————| good bad
Under What Conditions:	Mogensen holds a patent for its product "rod-sizer". Other forms of powerless self swinging screens can be locally constructed from old rails or by using old drilling rods.
Lifespan:	very long |————|————| very short

Bibliography, Source: Company's Information, Mogensen

OPERATING PRINCIPLE:

Screening occurs through the use of one-sided and divergently attached rods, inclined so as to allow the feed material to flow over the "grate". The impact of the material flowing over the grate causes the rods to swing, which in turn prevents the grate from becoming clogged.

AREAS OF APPLICATION:

Coarse screening prior to coarse crushing Screening of gold-containing

conglomerates Screening of coarse coal Classification of construction material in industrial minerals (pit and quarry) operations

REMARKS:

For local production, old drilling rods are very suitable; they are inexpensive, very resistant to wear, highly elastic and available on the local market.

The lower separable grain-size limit lies around 50 - 100 mm.

SUITABILITY FOR SMALL-SCALE MINING:

For non-mechanized coarse-grain classification, the "rod-sizer" is very suitable for application in vein ore mining, In alluvial mining and in pit and quarry mining due to its high throughput and simple construction.

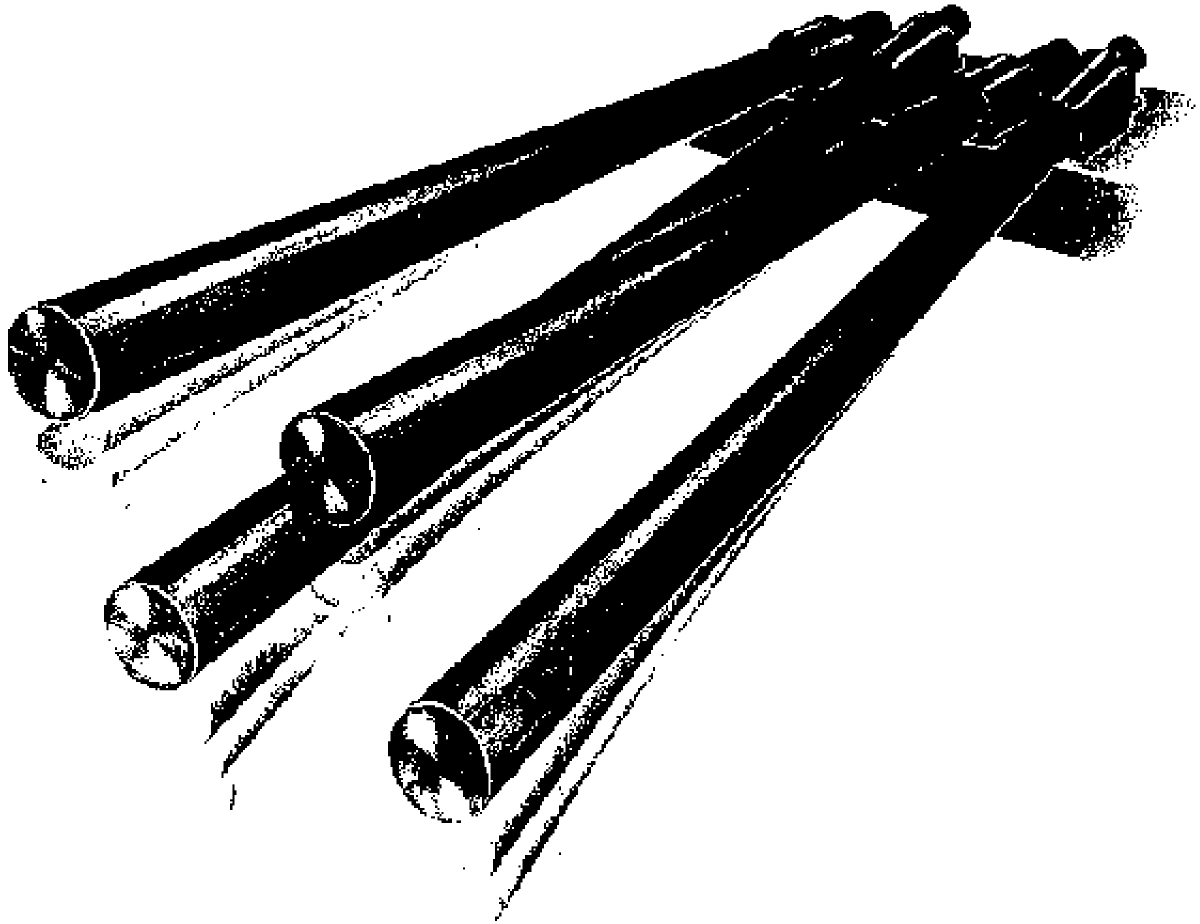


Fig.: Non-powered "rod-sizer" for coarse screening. Source: Mogensen company information.

13.4 Sizing drum, classifying drum

Mining of partly consolidated loose material Beneficiation, Classification

germ.:	Klassiertrommel
span.:	tromel clasificador, criba rotativa

Spain: tromel clasificador, criba rotativa

Manufacturer: Milag, Met. Lacha, Alquexco, IAA, Buena Fortuna, FAHENA, FIMA, MAGENSA, MAEPSA, Met. Callao E.P.S.

TECHNICAL DATA:		
Dimensions:	18 - 25 min-1 rpm, circumferential speed < 1 m/s, diameter 2 0.5 m, length 2 m for single drum with three sizing grades	
Weight:	starting at approx. 100 kg for smaller types	
Extent of Mechanization:	semi-mechanized	
Driving Capacity:	starting at 0.5 kW	
Form of Driving Energy:	hydromechanic	
Alternative Forms:	internal combustion engine, electric drive, manual operation for small models	
Mode of Operation:	continuous	
Throughput/Capacity:	minimum 1 t/h;	
	for dry screening:	0.27 t/m^2h per mm screen opening
	for wet screening:	0.45 t/m^2h per mm screen opening
Operating Materials:		
Type:	water	

Type:	water	

ECONOMIC DATA:	
Investment Costs:	starting at approx. 1500 DM
Operating Costs:	mainly energy costs

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |—————|—————| high
Maintenance Expenditures:		low |—————|—————| high
Location Requirements:	water availability	
Grain Size:	< 50 mm	
Replaces other Equipment:	screens and vibrating screens	
Regional Distribution:	locally applied in small-scale mining in Latin America	
Operating Experience:		very good |—————|—————| bad
Environmental Impact:		low |—————|—————| very high
Suitability for Local Production:		very good |—————|—————| bad
Under What Conditions:	good-quality perforated plates or screens must be available on the national market	
Lifespan:		very long |—————|—————| very short

Bibliography, Source: Gerth, Priester, Treptow, Fischer, Callon, Stifft, Schubert,

Rittinger

OPERATING PRINCIPLE:

The sizing or classifying drum is a mechanized form of wet screening in which several screens or perforated plates (arranged finer to coarser from intake to discharge) are aligned so as to form a drum. The drum is rotated by an external belt-drive transmission. The material moves from finer to coarser screens, during which the undersized grains are discharged via cones and distributed to the various sorting devices, such as hand jigs or sludge ponds.

Water is sprayed after 100 to 120 degrees rotation (from deepest point) to clean the screens and improve material transport.

REMARKS:

The sizing drum is characterized by its highly synchronous operation. The throughput quantity greatly depends upon size of the screen openings, with coarser screens delivering a higher throughput. Double-shell or triple-shell screens require less electrical energy and water consumption, have higher throughput, and are subject to less wear. Reference has also been made to manually-driven classifying drums (Stifft).

Two different types are in operation:

- **drums with cylindrical screens and inclined axis and**
- **drums with conical screen housings and horizontal axis**

Angle of Inclination: 4° - 5°

Lifespan: with wet screening up to 20.000 t throughput; with dry screening up to 100.000 t.

The disadvantages of sizing drums are the comparably high energy consumption and low self-cleaning effect

To process tenacious, sticky or clay-containing materials, a preliminary sorting with a screenless drum-unit, equipped only with catchers, should be performed. In this unit, the material is precrushed autogenously.

Drums constructed without an axis also exist. Such drums must have a load-bearing housing which also enables the load to be carried on rollers (such as, for example, four car wheels), a construction which then permits a simpler drive-system design,

SUITABILITY FOR SMALL-SCALE MINING:

Sizing drums are most suited in small-scale mining for classification of coarse and medium-grained feed material. Advantages lie in the high throughput quantities, continuous mode of operation and low space requirements.

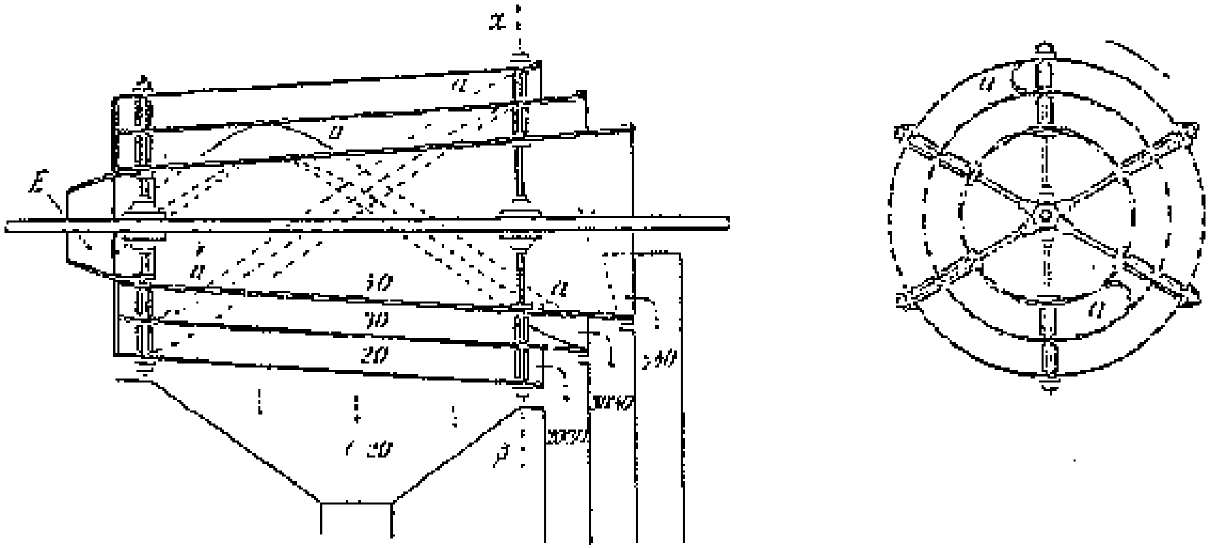
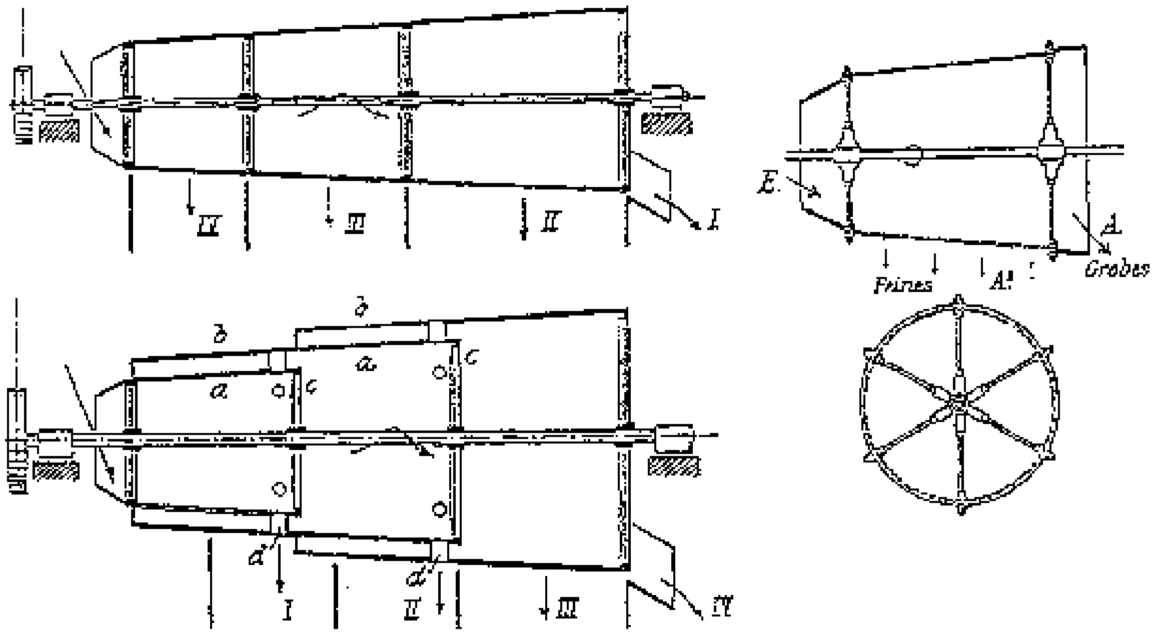


Fig.: Concentric multi-step drum with conical screens for easy screen replacement. Source: Treptow.



Figures

Fig.:Conical sizing drums, above with screen housing, below with concentric screens. Source: Fischer.

Fig.: Conical drum: longitudinal and cross-section views. Source: Treptow

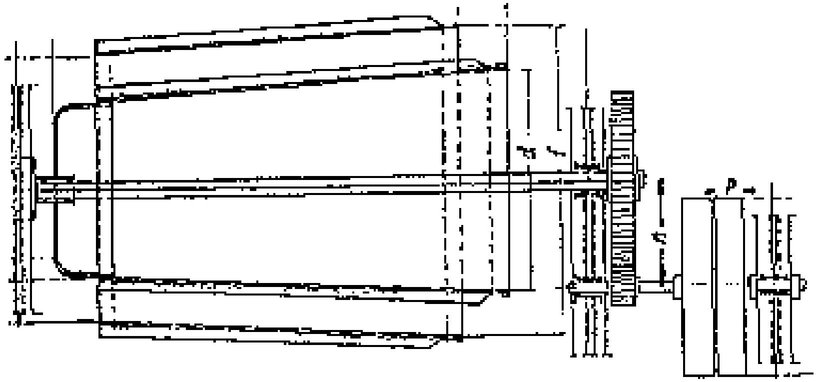


Fig.: Double-shelled drum. Source: Gerth.

Fig.: Construction for inserting screen plates into a concentric drum. Source: Treptow.

13.5 Cone classifier

Mining General
Beneficiation, Classification

engl.:	box classifier, settling box
germ.:	Spitzkasten

span.: clasificador de caja en punta, caja en punta

Manufacturer: FIMA

TECHNICAL DATA:

Dimensions:	from about 1 × 0.8 × 2 m up to several m in width and over 10 m in length
Weight:	from approx. 40 kg
Extent of Mechanization:	not mechanized
Form of Driving Energy:	only processing-water current
Mode of Operation:	continuous
Operating Materials:	
Type:	water
Quantity:	slurry with < 40 % by vol. solids

ECONOMIC DATA:

Investment Costs:	approx. 200 DM when locally produced
Operating Costs:	labor costs only

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance	low |—————|—————| high

Expenditures:		
Location Requirements:	water necessary	
Grain Size:	fines up to 1 mm	
Output:	Separates into several different grain-size fractions, for example a 3-chamber settling box into 3 distinct fractions plus fines. Settling-box classification leads to more precise separation results in later processes (concentrating tables, sludge ponds, chutes, etc.) than does screen classification.	
Replaces other Equipment:	screen classification	
Regional Distribution:	rare	
Operating Experience:		very good |—————|—————| bad
Environmental Impact:		low |—————|—————| very high
Suitability for Local Production:		very good |—————|—————| bad
Under What Conditions:	simple carpentry workshop	
Lifespan:		very long |—————|—————| very short

Bibliography, Source: Treptow, Quittkat, Priester, Callon

OPERATING PRINCIPLE:

A cone classifier or settling box is comprised of several settling chambers, in the form of inverse pyramids, with outlets at the bottom. The slurry-feed flows through this series of chambers, and depending upon the retention period, intake and discharge flow velocity, volume of the settling chamber, etc., specific grain fractions settle out onto the bottom of the chamber (according to the principle of equal settling velocites) and are removed. The remaining slurry flows into the succeeding basin, where the next finer fraction is separated via sedimentation.

AREAS OF APPLICATION:

Classification of medium and fine-grain feed material for subsequent processing in hydromechanic gravimetric separating facilities.

REMARKS:

- lost fines can be avoided by the use of a back (underscreen) water flow (settling boxes with clean water countercurrent)
- the walls have > 50° inclination
- Rittinger provides the following dimensioning and calculation guidelines:

Per m³ slurry input per minute, the following dimension relationships for single chambers are applicable:

Slurry flow should be approx. 45 l per minute and m water surface.

No. width length discharged material

1	1 m	2 m	40 % of the weight
2	2 m	3 m	20 % of the weight
3	3 m	4 m	18 % of the weight
4	4 m	5 m	10 % of the weight

in sludge overflow 4 %

<u>SUITABILITY FOR SMALL-SCALE MINING:</u>

As non-powered fine-grain classifiers, settling boxes (cone classifiers) are very suitable for small-scale mining beneficiation of fine material due to their sturdy construction, continuous mode of operation and low investment costs.

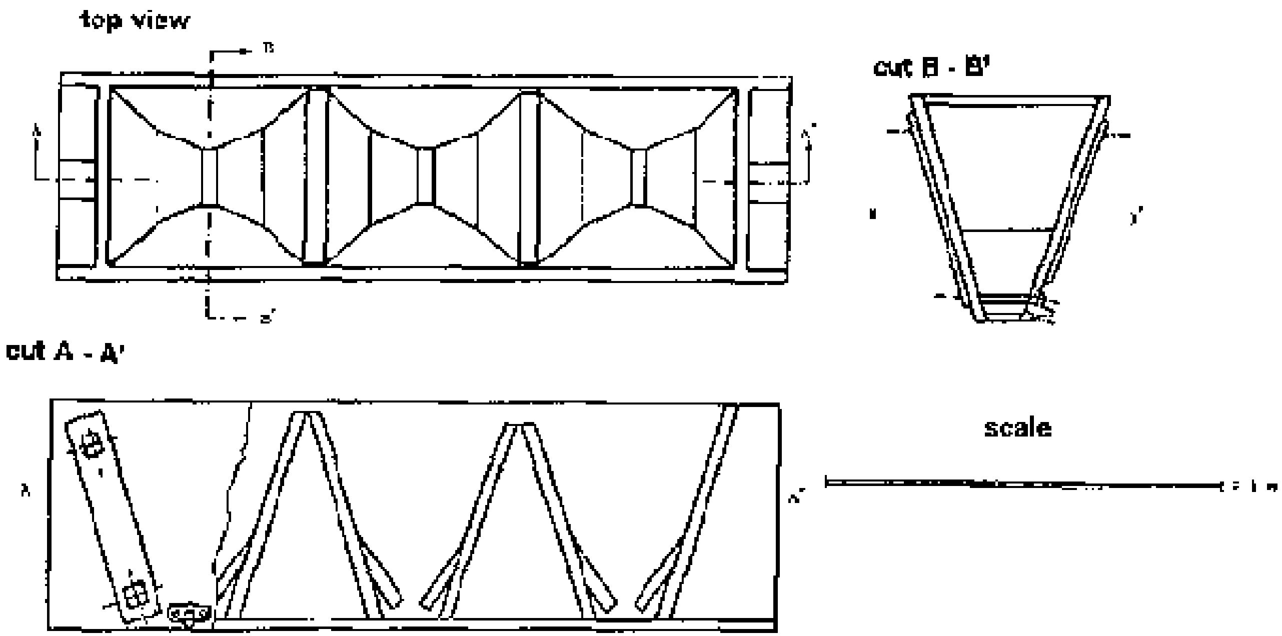


Fig.: Wooden cone classifier (settling box). Source: Priester.

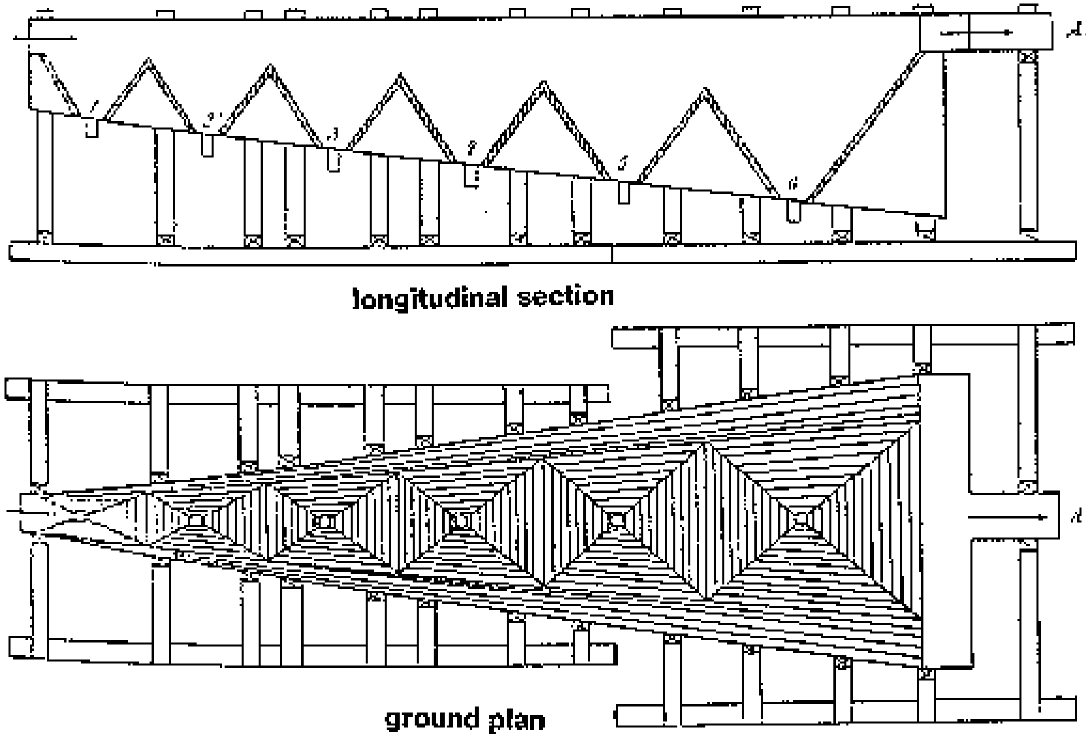


Fig.: Cone classifier (settling box). Source: Treptow.

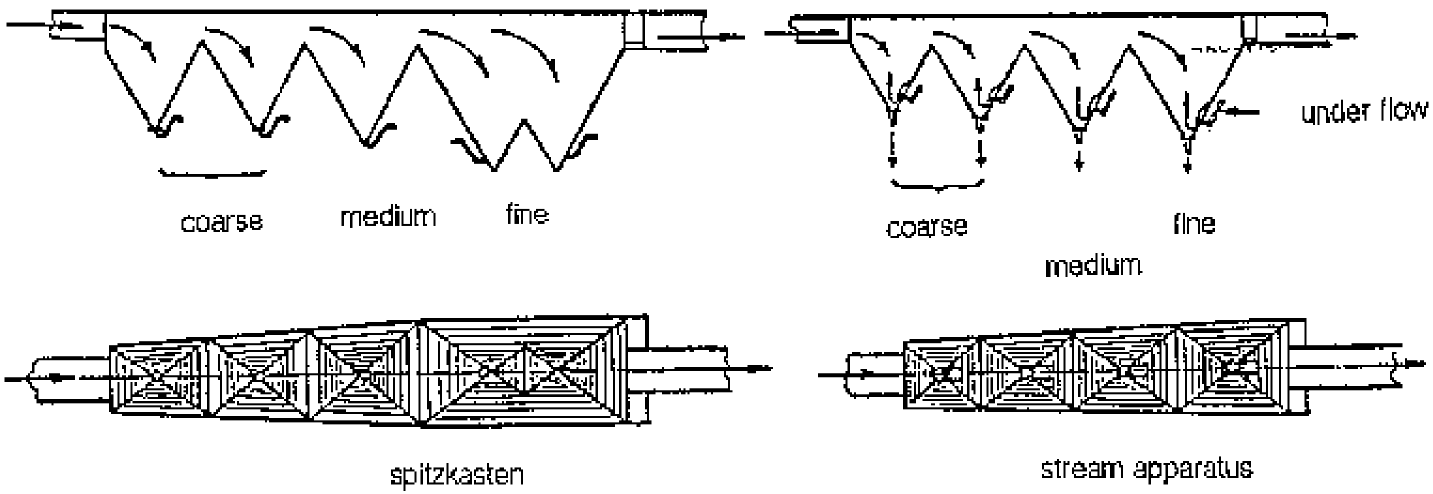


Fig.: Cone classifiers and cone classifier with fresh water countercurrent. Source: Quittkat.

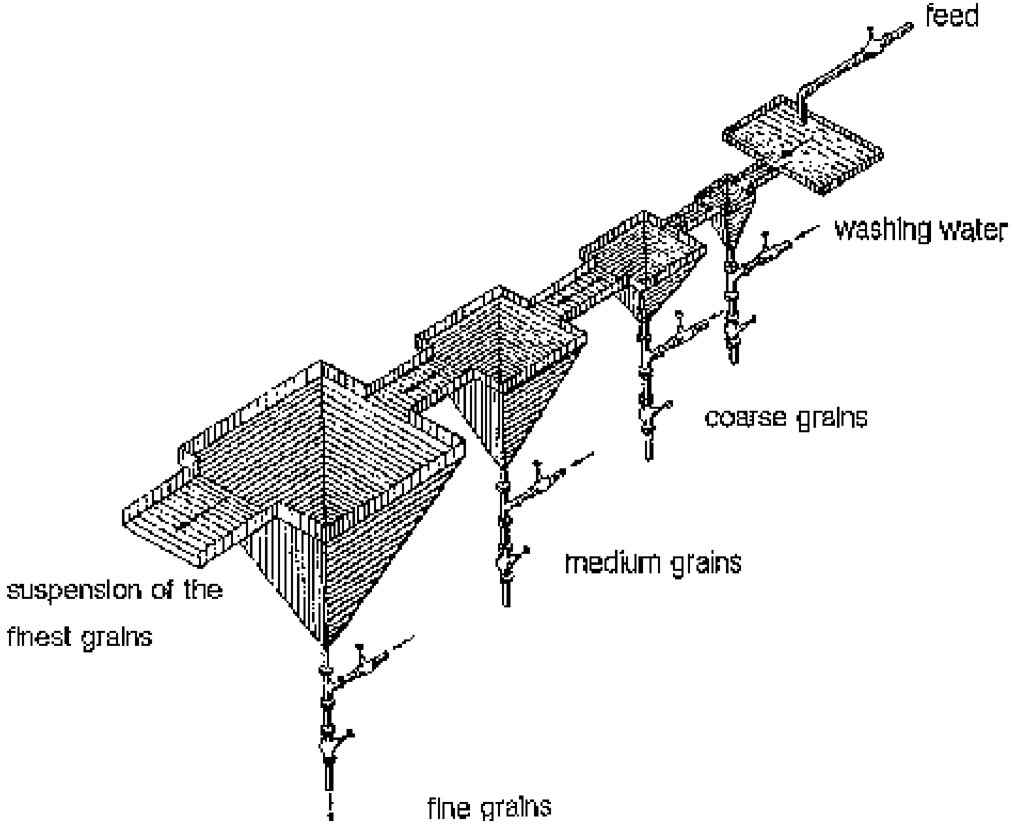


Fig.: Cone classifier with countercurrent. Source: Otero.

13.6 Countercurrent hydraulic classifier

Mining General
Beneficiation, Classification

engl.:	chamber classifier
germ.:	Aufstrom-Hydroklassierer, Kammerklassierer
span.:	hidroclasificador de corriente ascendente, clasificador hidraulico, clasificador de cameras

Manufacturer: Denver Peru, TMM Potosi Bolivia

Manufacturer: Denver Peru, TMM Potosi Bolivia

TECHNICAL DATA:	
Dimensions:	60 × 60 × 100 cm HWD
Weight:	approx. 50 kg
Extent of Mechanization:	not mechanized
Form of Driving Energy:	only processing water and supplementary water
Mode of Operation:	continuous
Throughput/Capacity:	> 0.5 t/h
Technical Efficiency:	high separation precision
Operating Materials:	
Type:	water
ECONOMIC DATA:	
Investment Costs:	3-chamber, cif La Paz: 9000 US$; Taller Metal Mecanico Potosi: 500 DM
Operating Costs:	very low, low labor costs

CONDITIONS OF APPLICATION:

Operating Expenditures: low |————|————| high

Maintenance low |————|————| high

Expenditures:	
Personnel Requirements:	operating experience necessary
Location Requirements:	water and vertical gradient required
Grain Size:	< 1 mm
Output:	separates, according to equal-settling velocities, into 3 fractions plus fines-overflow
Replaces other Equipment:	screen classification, cone classifiers (settling boxes)
Regional Distribution:	worldwide
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	qualified carpentry or metal workshop, high-quality screens must be available on the national market
Lifespan:	very long |—————|—————| very short

Bibliography, Source: Priester, Quittkat, Schubert, EP 0012740

OPERATING PRINCIPLE:

The countercurrent hydraulic classifier separates the feed into three or more fractions plus a fines-overflow by means of a cassifying chamber with partitioning walls of varying height. For each fraction to be separated, a bottom screen is provided through which an added underwater flow builds a fluidized bed or turbulent layer. Classified products are removed from the fluidized bed through pipe drains, located in the center of the bed and regulated by cone-shaped valves. In the direction of slurry flow, continually finer products, or products with increasingly slower settling velocities, are separated out. The process is regulated by both the added underwater current and the adjustable valves.

AREAS OF APPLICATION:

Classification of fine-grained feed into several fractions in a continuous operation.

REMARKS:

The precision of separation is higher than with cone classifiers (settling boxes). Extensive experience is required to optimally regulate the process in correlation with the particular feed material. The processing of sulfide ores requires that the equipment be of high-quality materials, especially the screens, since the processing waters are usually acidic and lead to extremely rapid corrosion.

The latest patent literature refers to a cross-current hydro-classifier serving as the basis for an analytical apparatus for examining the grain-size distribution in cement. This classifier has a very narrow and high cross-section, a small classifying-chamber volume, and comparably low throughput, but can continuously or semi-continuously separate the feed material into as many as

seven fractions. This operating principle could be applied to hydraulic chamber classifiers for use in ore beneficiation as well.

SUITABILITY FOR SMALL-SCALE MINING:

Countercurrent hydraulic classifiers are very suitable for use in small-scale mining beneficiation operations. Low Investment costs, suitability for local production, drive-less operating systems, and high throughput characteristize this apparatus. Sufficient experience in regulating the apparatus is a prerequisite for optimal utilization; when newly Introduced, its proper use can only be achieved through on-thejob-training (educational requirements).

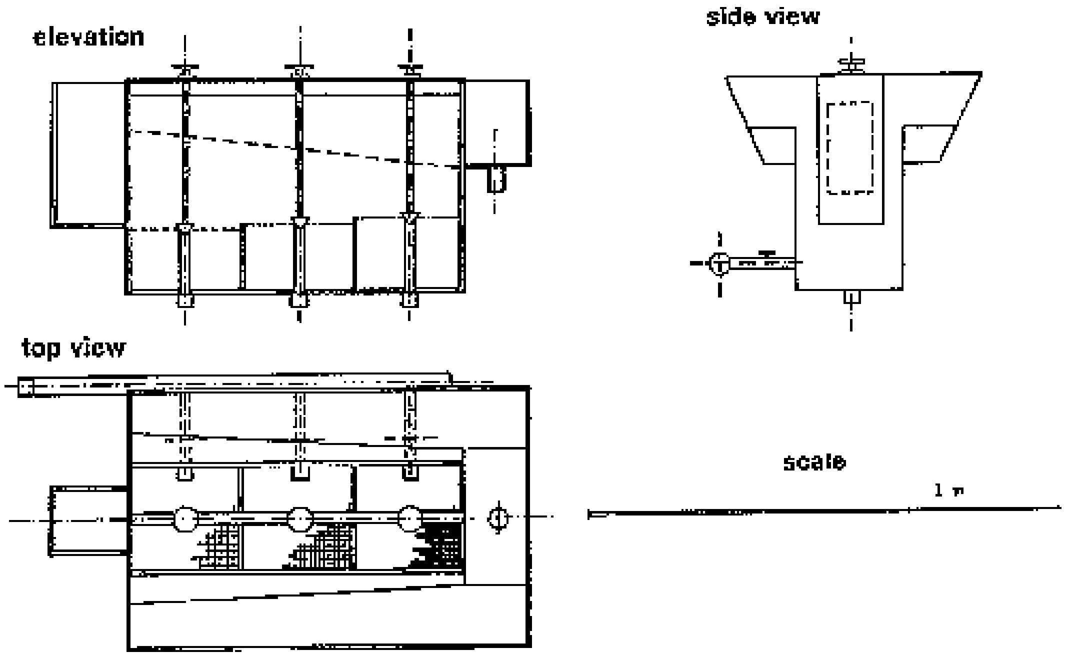


Fig.: Construction design of a hydro-classifier, type Taller Metal Mecanico, potosi. Source: Priester.

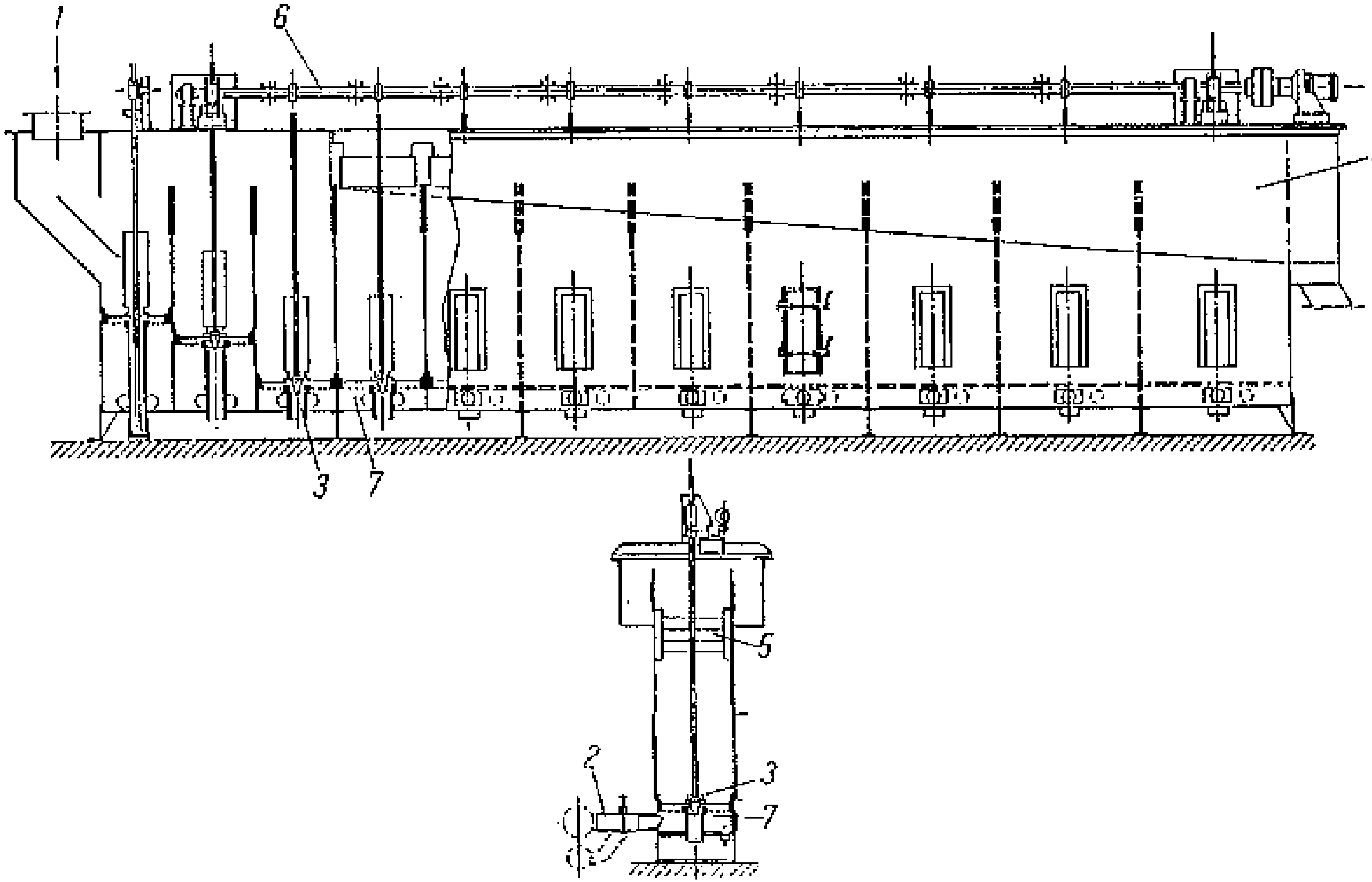
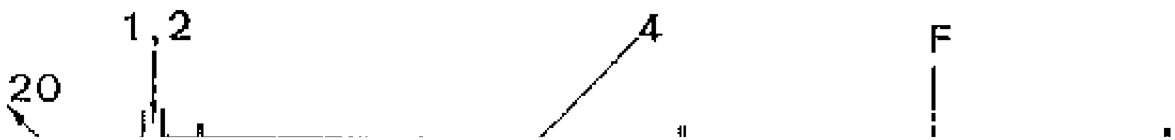


Fig.: Chamber classifier: 1) slurry feed inlet, 2) underwater inlet, 3) sand outlet, 4) sludge overflow, 5) overflow weir, 6) cam shaft, 7) performed bottom. Source: Quittkat.



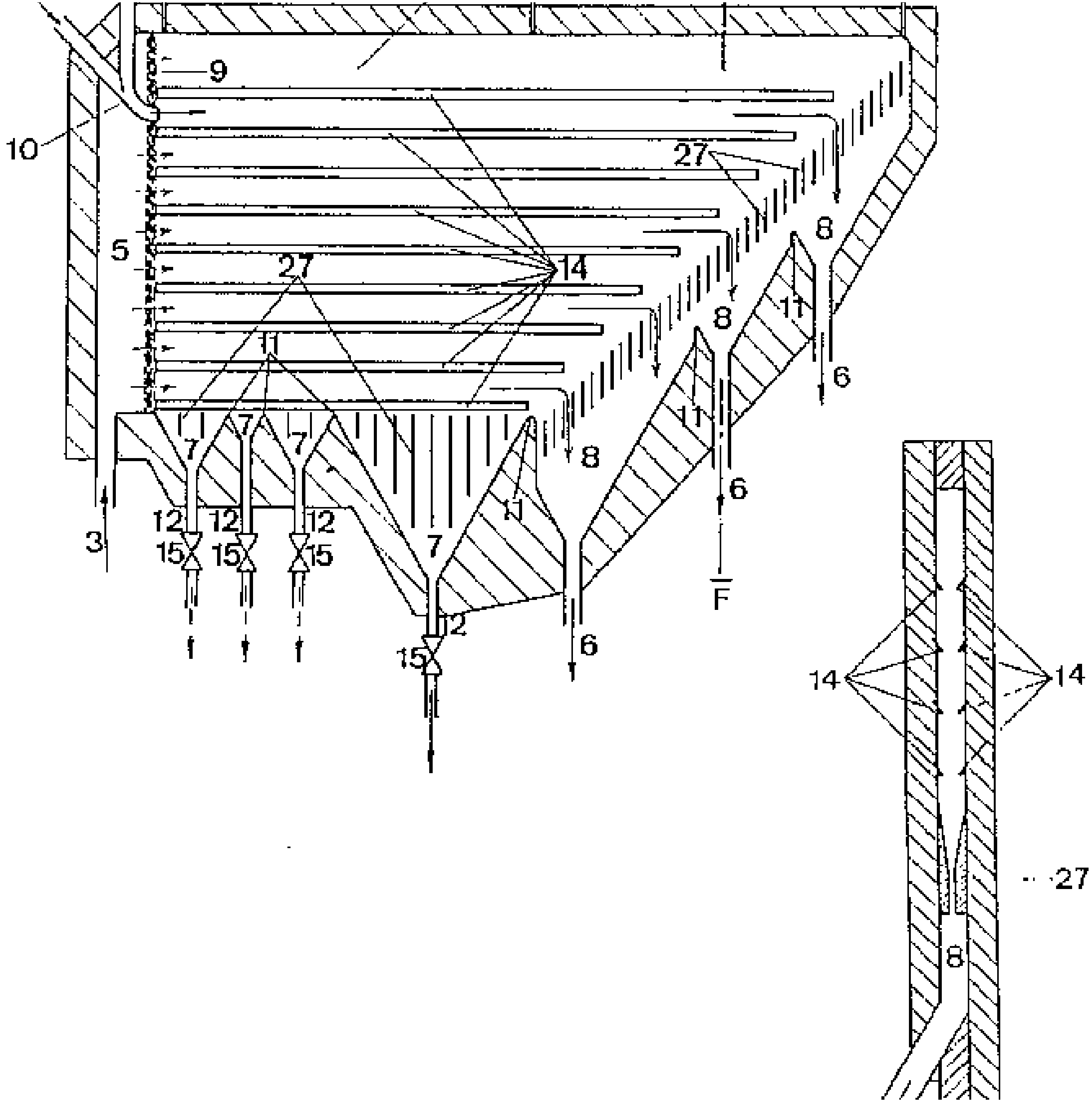

9
10
5
27
14
27
8
11
8
11
6
11
7
7
7
8
6
3
12
12
12
15
15
15
7
11
12
15
F
6
14
14
27
8

Fig.: Patented classifier for cement samples; longitudinal and cross-section (patent no. EP 0012740).

13.7 Hydro-cyclone

Mining General (Gold, Ore)
Beneficiation, Classification

germ.:	Hydrozyklon
span.:	hidrociclon
Manufacturer:	AKW, Schauenburg, Dorr-Oliver, Warman, Mozley, Eduardo, Met. Lacha, Voican, Eq. Ind. Astecnia, IAA, INCOMAQ, Buena Fortuna, COMESA, FAHENA, FIMA, MAGENSA

TECHNICAL DATA:	
Dimensions:	single cyclones with 10 - 1000 mm 0
Weight:	starting at approx. 1 kg
Extent of Mechanization:	not mechanized when operated only by hydrostatic pressure from the slurry
Power:	pressure of slurry
Form of Driving Energy:	hydrostatic, higher pressures only with the use of a pump, 0.3 - 40 bar
Alternative Forms:	pump with electric or hydromechanic drive system

Mode of Operation:	continuous
Throughput/Capacity:	throughput of slurry up to > 100 t/h, 100 - 2000 g acceleration, throughput is f (nozzle diameter for influent and overflow, and influent pressure). Grain-size of separation between 5 and 2150 ym (maximum 500 ym)
Operating Materials:	
Type:	water
ECONOMIC DATA:	
Investment Costs:	< 1000 DM
Operating Costs:	low
Related Costs:	pipelines for pressurized water and possibly slurry pump

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
Maintenance Expenditures:		low |————|————| high
Personnel Requirements:	low	
Location Requirements:	water and elevation difference (Dh) must be available	
Grain Size of Feed:	separation cut-off grain-size up to 500 ym	

Special Feed Requirements:	the higher the grain-size to be separated, the larger the diameter of the cyclone has to be.
Output:	depending on type of hydraulic cyclone, more classifying (acute-angled cyclone) or more sorting (obtuse-angled cyclone) occurs.
Replaces other Equipment:	classifiers and sorters for fine fractions
Regional Distribution:	rare in Latin America, otherwise widely distributed
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad
Under What Conditions:	metal manufacturing workshop, or workshop for special plastics used in low-pressure cyclones
Lifespan:	very long |—————|—————| very short
	depends upon abrasiveness of the feed material

Bibliography, Source: AKW, Shoukry, Schubert

<u>OPERATING PRINCIPLE:</u>

The slurry feed flows into the cyclone under acceleration (due to hydrostatic pressure) through a tangential inlet-nozzle. Inside the cyclone, the whirling

slurry-flow is divided into two currents - an outer sinking portion and an inner ascending portion - as a result of a damping effect from the cyclone's lower conical section. Under these conditions, the heavier or coarser grains comprise the descending slurry-flow and are removed with the underflow, whereas the finer-grained material enters the ascending slurry-flow and is carried out with the overflow (see sketches).

Hydro-cyclones are differentiated according to their areas of application:

- acute-angled hydro-cyclone: solid-fluid-separation (thickening, solids separation), cone angle 10° - 20°,

- intermediate design: classification (cone angle < 20°), - cylindrical hydro-cyclones: sorting, pre-concentration, etc. (CBC-cyclones).

<u>AREAS OF APPLICATION:</u>

- thickening of finest (silty) slurries, suspensions, etc. - desliming

- classification, for example in conjunction with carefully-controlled comminution involving preliminary and intermediary classifying in the milling process

- selective classification, such as for two materials of varying fineness (e.g. quartz sand, kaolin)

- sorting or classifying separation in order to pre-concentrate fine heavy-mineral fractions, e.g. gold, tin or tungsten ores.

SPECIAL AREAS OF APPLICATION:

Sink-and-float method in a heavy-medium cyclone with ferro-silicon.

In this process, separation occurs in a slurry of magnetite or ferrosilicon (FeSi) of a defined density. The dense material can be removed later by magnetic separation. Best results are achieved using atomized dense material due to the rounded grates and also the production process, which lead to:

- **low viscosity of slurry**
- **greater resistance to corrosion**
- **lower mechanical abrasive wear of the powder**
- **lower mechanical abrasive wear of the machine**
- **lower surface adhesion of the beneficiated product**

Slurry densities of between 2.0 and 3.8 kg/1 can be achieved with FeSi, enabling ores of iron, manganese, chromite, lead, tin and zinc, as well as fluorite, barite, diamonds, gravel and scrap-iron to be separated.

REMARKS:

A hydro-cyclone classification performed prior to separation with spiral separators, concentrating tables, settling basins, etc., whereby grains are sorted primarily according to their surface area exposed to flow forces, produces a more precise separation than with screen classification.

DESIGN CONSIDERATIONS:

The hydro-cyclone component most susceptible to wear is the underflow nozzle, which is subjects to coarse grains flowing through at relatively high pressure. Various designs for underflow nozzles exist which can extend the lifespan of a cyclone:

- hard-porcelain lining

- replaceable underflow nozzle made of wear-resistant material (rubber, PU, hard porcelain)

- pneumatically-controlled rubber discharge nozzle - manually-controlled rubber discharge nozzle

For normal acute-angled cylindrical-conical cyclones with intake angles of 10°-20°, the following dimensions can be recommended:

D_i = (0.15 - 0.25) Dc where D_c : diameter of cyclone

D_o = (0 20 - 0-40) Dc where D_i : diameter of intake nozzle

D_a = (0.15 - 0.80) Do where D_o : diameter of overflow nozzle

D_a : diameter of underflow nozzle

The finer the separaion cut-off grain size, the smaller the diameter of the cyclone and the higher the intake pressure must be.

<u>SUITABILITY FOR SMALL-SCALE MINING:</u>

Due to the diverse areas of application for purposes of desliming or desilting, classifying or sorting, the hydro-cyclone is very suitable for small-scale mining. Prerequisite for drive-less operation is the minimal elevation gradient of 3 - 10 m. Even considering that hydro-cyclones can only be locally produced in exceptional cases, they are still appropriate particularly for sorting classification purposes. Hydro-cyclones are comparably simple in design and low in cost.

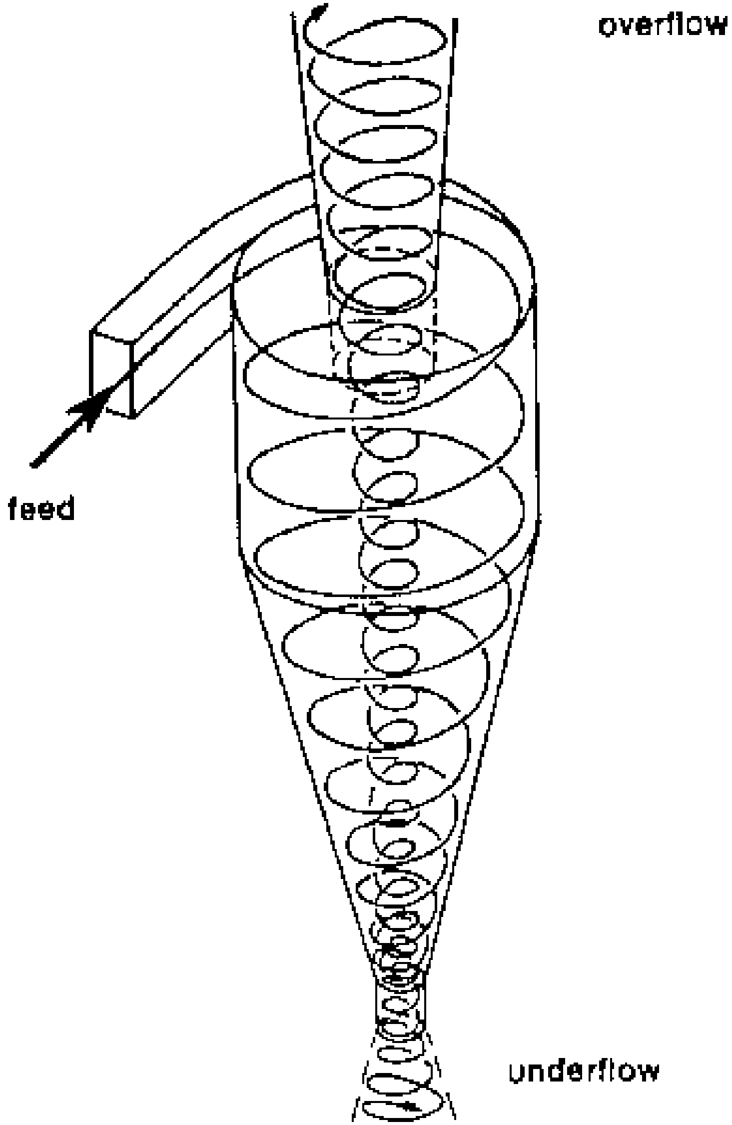


Fig.: Diagram of flow pattern in a hydro-cyclone. Source: AKW.

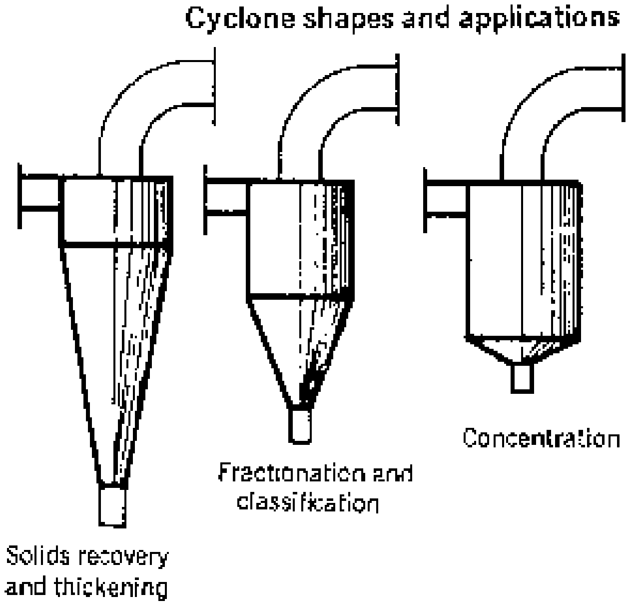
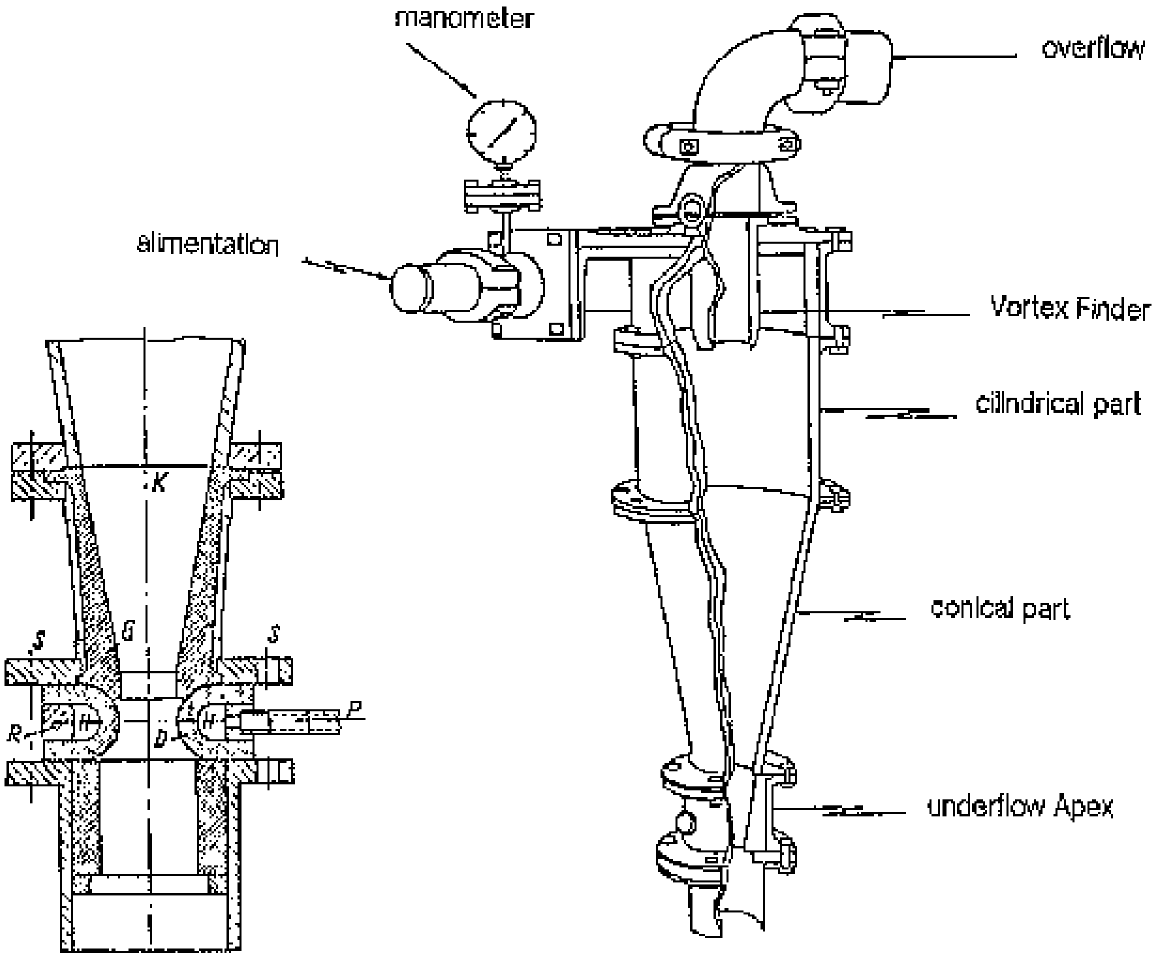


Fig.: Various types of cyclones for desliming (left, classifying (middle) and sorting (right). Source: AKW.



Figures

Fig.: Pneumatically-controlled under-flow nozzle for hydro-cyclones, made of elasomer. Source: Guelt

Fig.: Modular construction of a hydro-cyclone. Source: Shoukry.

13.8 Log washer, spiral classifier

Mining General

Benefication, Classification

germ.:	Logwasher, Spiralklassierer
span.:	atrisionador, clasificador de espiral
Manufacturers of spiral classifiers:	FUNSA, Volcan, IAA, COMESA, FAHENA, FIMA, Famia, Fund. Callao, MAGENSA, MAEPSA, Met. Mec. Soriano, PROPER, FAMESA

TECHNICAL DATA:	
Dimensions:	1 × 1 × 8 m HWD, inclination 1: 20, shaft diameter 18", length of shovel 9", also smaller dimensions possible
Weight:	several tons
Extent of Mechanization:	semi-mechanized
Power:	up to 25 PS, double-classifier up to 30 PS, 15 - 20 min-1
Form of Driving Energy:	belt transmission from internal combustion engine, electric motor
Alternative Forms:	turbine/water wheel
Mode of Operation:	semi-continuous
Throughput/Capacity:	up to 100 t/24 h
Operating Materials:	
Type:	water
Quantity:	up to 200 I/min
ECONOMIC DATA:	

Investment Costs:	when locally produced 1000 to 5000 DM
Operating Costs:	depends on drive system

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |—————|—————| high
Maintenance Expenditures:		low |—————|—————| high
Location Requirements:	water requirements must be met	
Grain Size of Feed:	< 5 - 10 cm	
Output:	cclassified into underflow (silt and fine fraction) and overflow (coarse fraction)	
Replaces other Equipment:	sppiral classifier	
Regional Distribution:	USA, Australia	
Operating Experience:		very good |—————|—————| bad
Environmental Impact:		low |—————|—————| very high
Suitability for Local Production:		very good |—————|—————| bad
	if hard lumber is available	
Under What Conditions:	wood and metal-manufacturing workshops	
Lifespan:		very long |—————|—————| very short

Bibliography, Source: v. Bernewitz, Schennen

OPERATING PRINCIPLE:

Analogous to spiral classifiers. The slurry, fed onto the lower one-third of the shaft, is separated by means of the shovels into an upward-flow containing the coarse, heavy grains and a downward-flow containing the light-weight grains. The classification box of rectangular cross-section fills with material at the start of the process before the actual classification begins.

AREAS OF APPLICATION:

Desliming, classification, drainage, and separating of the ground product in grinding circuits.

REMARKS:

Construction does not require that the housing be adjusted to the cross-section of the shaft since gaps are filled with minerals.

Separation cut-off grade is determined by angle of inclination.

SUITABILITY FOR SMALL SCALE MINING:

In smaller dimensions log washers are also appropriate for small-scale mining classification purposes if a suitable drive-system is available at low energy costs. Log washers are very suitable for local production.

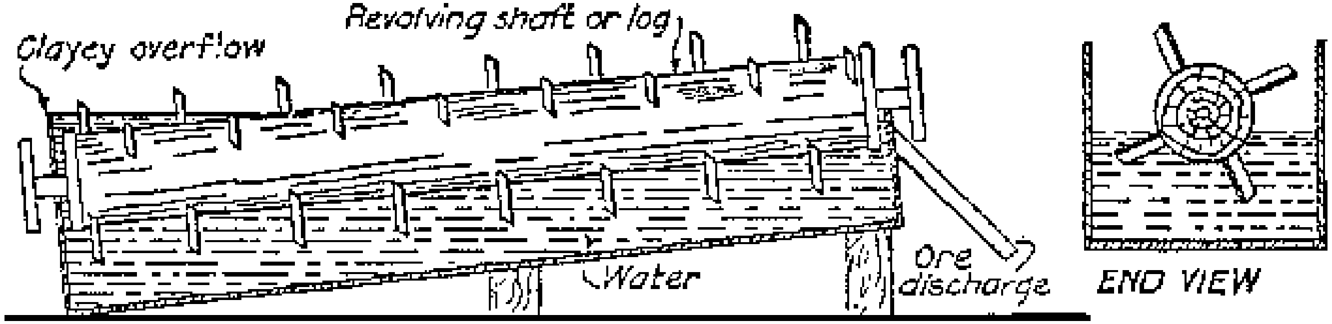


Fig.: Schematic diagram of a log washer. Source: Bernewitz.

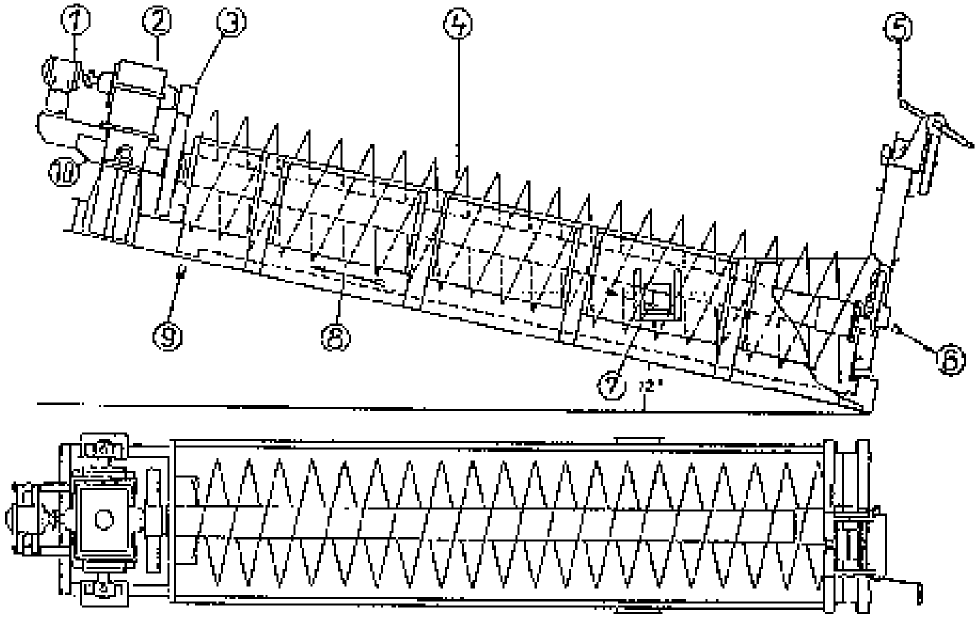


Fig.: Design of a single spiral classifier: 1) motor, 2) drive, 3) gear wheel, 4) spiral, 5) lifting device, 6) outlet, 7) feed intake, 8) flow (transport) direction, 9) discharge, 10) traverse. Source: Schiedchen.

13.9 Rake classifier

Deep Mining General
Beneficiation, Classification

germ.:	Rechenklassierer
span.:	clasificador transportador a rastrillo
Manufacturer:	Volcan, Eq. Ind. Astecnia, IAA, COMESA, FAHENA, MAENSA, FAMESA

TECHNICAL DATA:	
Dimensions:	1.2 × 3.5 × 1.0 m HWD for a small rake classifier, working frequency 10 - 30 min-1, minimum angle of inclination 12 Weight: approx. 600 kg
Extent of Mechanization:	ully mechanized
Power:	1.5 PS
Form of Driving Energy:	mechanical via electric motor, internal combustion engine, turbine
Mode of Operation:	continuous
Throughput/Capacity:	0.5-1 t/h
Operating Materials:	
Type:	water
ECONOMIC DATA:	
Investment Costs:	minimum of 10.000 DM when locally produced
Operating Costs:	low, primarily energy costs

CONDITIONS OF APPLICATION:

Operating Expenditures:	low |—————|—————| high
Maintenance Expenditures:	low |—————|—————|high
Location Requirements:	none, except water
Grain Size of Feed:	high proportion of fine grains (0.1 - 0.5 mm) necessary to guarantee stability of the suspension. Only under these conditions can a rake classifier separate with high precision.
Special Feed Requirements:	30 - 50 % by vol. solids in the slurry
Output:	the classifying is regulated by controlling the slurry density
Replaces other Equipment:	spiral classifier
Regional Distribution:	very rare
Operating Experience:	very good |—————|—————| bad
Environmental Impact:	low |—————|—————| very high
Suitability for Local Production:	very good |—————|—————| bad

Under What Conditions:	national machinery manufacturers
Lifespan:	very long |————|————| very short

Bibliography, Source: Gerth

OPERATING PRINCIPLE:

In a declined trough, the coarse material is scraped upwards by a rake. At the return point, the rake is lifted, moved back down to the initial position and lowered onto the bottom of the trough. The fine material remains suspended and flows out over a weir at the lower end of the trough. The slurry-feed intake is located about a third of the way up from the lower end of the trough.

AREAS OF APPLICATION:

For intermediary classification of milled material in a closed grinding circuit.

REMARKS:

Very low wear, limited to the rake.

The rake has a very long lifespan due to the possibility to adjust its height. For lead-zinc ore, Gerth estimates a rake lifespan of approx. 30.000 t throughput (rake height worn from 60 down to 20 mm).

SUITABILITY FOR SMALL-SCALE MINING:

Rake classifiers are characterized by their simple construction and low wear' and are suitable for small scale mining if they can be nationally manufactured.

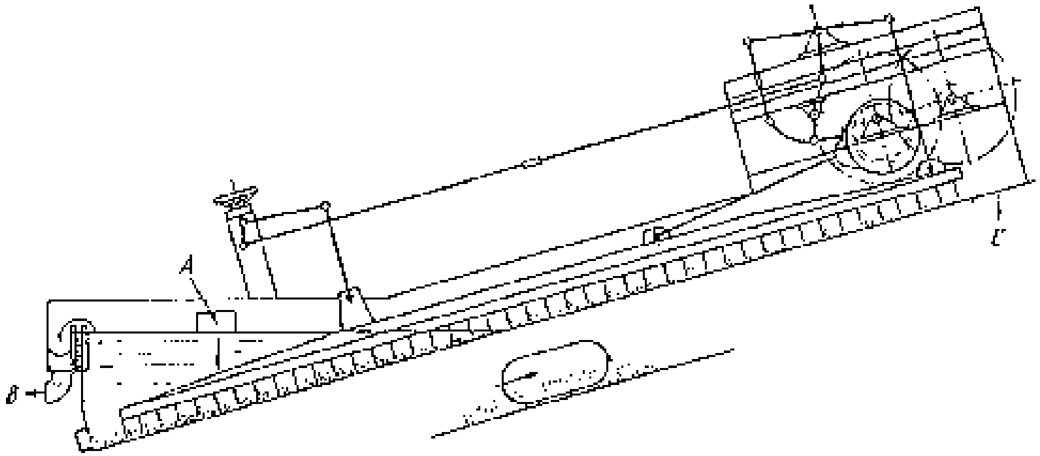


Fig.: Schematic diagram of a rake classifier. Source: Schmiedchen.

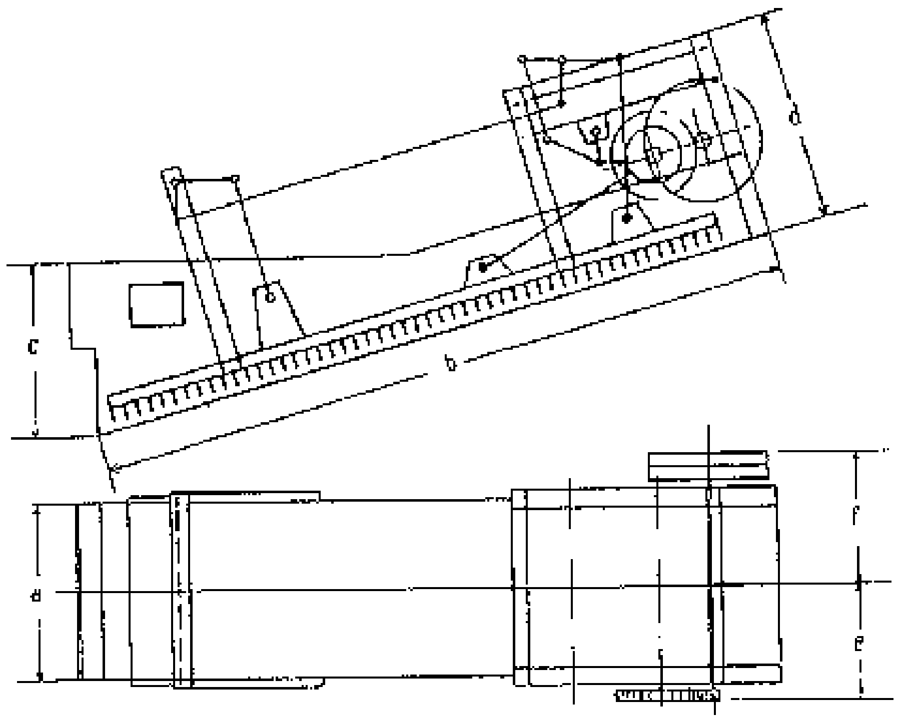


Fig.: Simplified elevation drawing of a rake classifier. Source: Schmiedchen.

13.10 Sluice, sluice box, washing sluice

Mining General
Beneficiation, Classification

germ.: Lauterrinne, Ablauterrinne, Waschrinne

span.: canaleta de lavado, canaleta de relavado, canaleta de limpieza .

TECHNICAL DATA:	
Dimensions:	inclination: approx. 10°, several stepped sections approx. 50 - 60 cm in width and 50 cm in depth, 4 - 5 m total length
Weight:	masonry construction, built into the ground
Extent of Mechanization:	not mechanized
Form of Driving Energy:	uses the energy of flowing water, possibly supported by turning the material with rakes, shovels, etc.
Throughput/Capacity:	several tons of material per hour
Operating Materials:	
Type:	water
Quantity:	at least ten times the feed quantity
ECONOMIC DATA:	
Investment Costs:	very low since the sluice is built into the ground with minimal effort

Operating Costs:	labor costs only
Related Costs:	beneficiation equipment for the fine slurry, e.g. settling basins or buddies

CONDITIONS OF APPLICATION:

Operating Expenditures:		low |————|————| high
Maintenance Expenditures:		low |————|————| high
Location Requirements:	water must be available in large quantities	
Grain Size of Feed:	from silt fraction (fines) to approx. 200 mm	
Special Feed Requirements:	washing (i.e. dissociation of strongly baked, partially solidified grain bonds) must occur during beneficiation of conglomerates and breccia, or during re-processing of old waste deposits or abandoned workings	
Output:	coarse fraction is sufficiently cleaned to allow hand-sorting	
Replaces other Equipment:	washing drum, autogenous mill	
Regional Distribution:	found rarely in small-scale mining, e.g. in Bolivia/Potosi	
Operating Experience:		very good |————|————| bad
Environmental		low |————|————| very high

Environmental Impact:		low | | | very high
	depending on type of feed, sludge (fines) loading can occur, requiring a subsequent fines separation, when necessary with sludge pond or settling basin.	
Suitability for Local Production:		very good |————|————| bad
Under What Conditions:	local production is easily possible since only simple masonry work is involved	
Lifespan:		very long |————|————| very short

Bibliography, Source: Rittinger

OPERATING PRINCIPLE:

The feed material in the washing sluice is separated into its individual components through the energy conveyed by the flowing water and through supplementary agitation (manually-operated shovels, rakes, etc.).

AREAS OF APPLICATION:

For crushing and classifying slightly-solidified conglomerates and breccia as well as cemented crude ore from underground mines, old deposits or abandoned workings.

REMARKS:

To process feed with high clay content, e.g. from abandoned works, the material is mixed with water in a basin or pit and is repeatedly kneaded by means of stamping or worked with scrapers or picks. In this way, the adhesive and cohesive forces of the cemented clay fractions are broken down. This process is called ch'etachado in Quechua. It is very work intensive, but in combination with subsequent washing in a sluice, it is the only possibility for non-mechanized mines to process feeds with high clay contents.

SUITABILITY FOR SMALL-SCALE MINING:

Washing in sluices is the simplest method of crushing and classifying slightly-solidified feed or feed materials of high clay content.