A novel mill scale effluent treatment system includes the pumping of scale directly from the original location (without settling basins), screw-type dewaterers, continuous filters or high-gradient magnetic filters. Capital and operating costs are considered to be appreciably less than for conventional systems.

Techniques for reclamation of water and scale

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WATER flow rates used for direct cooling in continuous casting and hot rolling may range from 250 to over 10,000 cu metres/hr (1000 to 40,000 gpm). The traditional methods of handling these streams involve collection of coarse material in pits, which are emptied by cranes or chain-scrapers, followed by separation of fines and oil in large settling basins and, finally, removal of micron-size material and residual oil in batteries of back-washed sand filters.

The mill scale treatment system is a service arrangement for steel production. It should not interfere with the main process and preferably meet the following criteria:

- Continuous and unmanned operation.
- Compact, especially when retrofitted in an old plant.
- Location remote from the mill operation.
- Low installation and operating costs.

Traditional handling methods are not unfeasible, but hardly satisfy these criteria. However, area restrictions, economy, environmental concern and labor protection have promoted alternative methods of treatment. Equipment has been adapted for the various requirements of scale and water handling in Scandinavian mills. These developments started in the late 1970's. They included the slurry transportation of scale, coarse scale removal, and filtration. The methods have been gradually modified and developed. Although they cannot be considered as innovative, they combine and achieve in one system these various requirements and criteria.

The design characteristics and plant descriptions utilizing these methods are reviewed.

Processing units

Slurry transport — Coarse mill scale is a heavy abrasive product. Initially, pumping does not appear to be an appropriate method for transporting this type of material. The density of the material is in the range of 4.9 to 5.2 g/cu cm with particle sizes ranging from a few microns to fist-size.

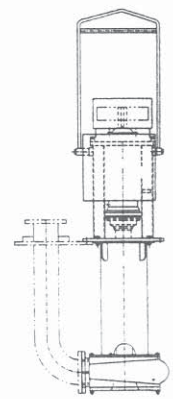

Fig. 1 — Semi-submersible pump (type VASA G).

The first pump installation for this duty was made in a plant where, because of building restrictions, there was no alternative but to pump the material. The final choice was a semi-submersible vertical centrifugal pump similar to that illustrated in Fig. 1. It had the following desirable characteristics:

- Rigid shaft and bearings to withstand the impact from heavy objects.
- Open impeller to allow the passage of any object entering the pump housing.
- Insensitive to variations in flow rate.
- Insensitive to air blockage.
- Capable of running dry.
- Deposits in the pump can be released by a bottom impeller or by return spray-holes.

The pump does not require sealing water and the entire pump can be raised for inspection or service.

Although pump availability is high, it is, nevertheless, unacceptable to shut down a mill operation for servicing a pump. Consequently, a stand-by pump is needed. A typical sump for two pumps is shown in Fig. 2. A scrap basket

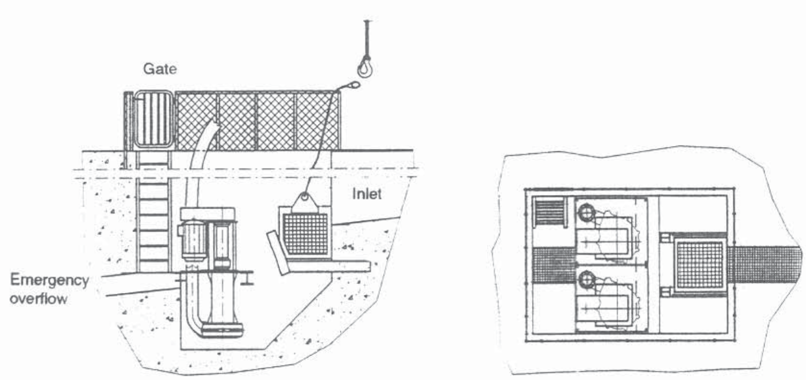

Fig. 2 — Pump sump arrangement.

traps oversize scale and foreign objects 1 to 2 in. The sump is designed to avoid build-up on the walls. It should be small, with steep sloping walls ending in a bottom area approximately twice the width of the pump housing.

Industrial rubber hoses are recommended in the pipe line from the pump. The stand-by pump should have an individual pipe line. Steel pipe can be used on long straight sections.

The pump housing and impeller are fabricated from high-chromium alloy metal. Even on severe mill duties the wear parts normally last more than a year: on finer scale, the parts may last for over 10 years.

The largest pump is able to handle a flow of 1000 cu metres/hr (4400 gpm) at pressures up to 3 bar (45 psi). It is also made in a fully submersed version, type VASA GD (Fig. 3), and is used when the shaft length of the VASA G is insufficient for the depth of the sump.

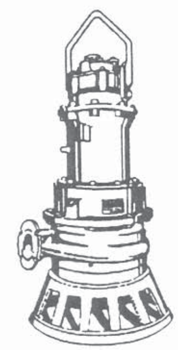

Fig. 3 — Fully-submersible pump (type VASA GD).

The possibility of actually pumping scale away from the location where it is formed and accumulates means that the traditional scale pit can be eliminated in the rolling mill area and replaced with alternative equipment at floor level.

Thus, the necessity of having to use pumping as the only solution, provided a practical alternative method for removing and transporting scale.

Coarse scale removal — Cyclones, magnetic separators and screw classifiers were considered for separating coarse scale.

It was decided to design a screw-type dewaterer capable of handling the voluminous flows in steel mills. The screw classifier/dewaterer is basically a tank where the material settles, with a screw-type conveyor to remove the settled material. Classifiers used in mineral applications operate on a high solid/liquid ratio whereas, for steel mills, the design must be capable of handling a high liquid/solid ratio. For steel mills, a large pool area is essential. However, the transport of scale is relatively easy compared with minerals.

The cyclone, although used for scale separation, suffers from wear, which also affects its operating characteristics. A cyclone is not tolerant of foreign objects and does complete the dewatering of material: the cyclone underflow requires further treatment. The use of a magnetic separator was abandoned because the short contact distance between the magnet and scale would either require large separators, or accelerate the always present danger of wear.

The principal dimensions and a cut-away illustration of the currently, largest screw-type dewaterer is shown in Fig. 4. The pool area has been increased by the addition of a cross-current lamella pack to give a total settling area (pit area) of 200 sq metres (2200 sq ft) allowing for a feed flow of 2000 cu metres/hr (8800 gpm) in one unit.

The screw is fitted with replaceable wear segments, fabricated from high chromium metal, and normally lasts for two years. It has a submersed lower end bearing and the screw may be lifted for service and inspection for several hours while maintaining the feed flow.

The screw will remove approximately 100% of the scale material larger than 100 microns. It will also separate the majority of particles in the size range 50 to 100 microns. The screw has a minimum transport capacity of 10 tonnes/hr making it oversize in comparison with most scale applications.

The dewatered scale is a drip-dry material with less than 2 to 8% moisture depending on the particle size distribution. It is normally collected in a container for recycling or disposal.

A mud guard traps oil and other floating material, which is removed with a skimmer; oil will still be present in the overflow. The water quality is adequate as a transport media, but, for recycling in direct cooling, further treatment is needed.

Continuous sand filter — The screw-type dewaterer may have an overflow suspended solids concentration in the range 100 to 300 ppm. This level is too high to feed static filters in traditional scale effluent systems with acceptable back-wash frequency. However, the level is acceptable for the Dynasand type continuous filter which was introduced contemporaniously with the development of the screw-type dewaterer.

The Dynasand filter is illustrated in Fig. 5. Water is distributed in the filter bed through the inlet pipe (1) by distributors (2). The water rises through the sand bed (3). Filtered water exits over an overflow weir to the outlet (4). Fouled sand is lifted by an air lift pump (5) to the collection vessel in the upper part of the filter (6). The sand descends into the sand washer (7) where it is rinsed in counter-current flow with a small amount of filtrate. The cleaned sand returns to the filter bed (8) and the wash water is discharged through the wash water outlet (9).

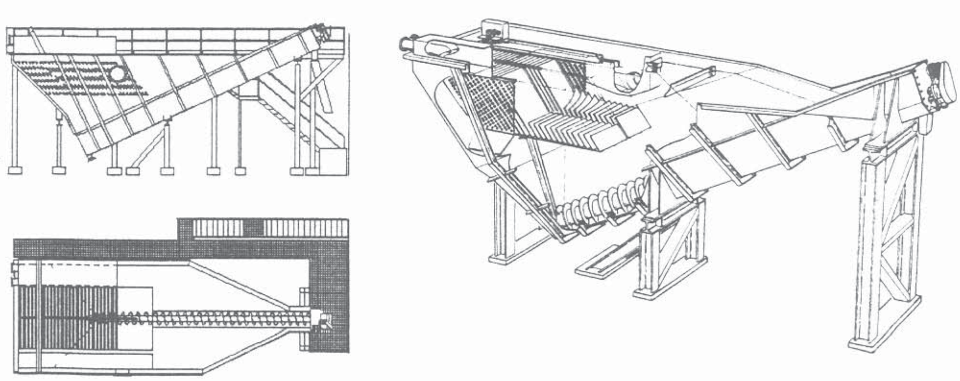

Fig. 4 — Screw-type dewaterer with 2200 sq ft settling area.

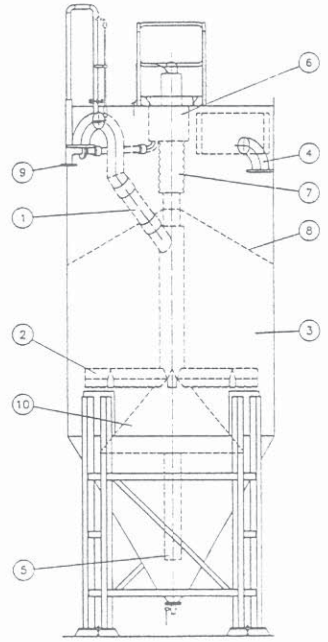

Fig. 5 — Dynasand filter.

Thus, the filter operates with no moving parts or control valves and with a low pressure drop, less than 0.1 bar (1.5 psi). Air consumption for the air lift pump is negligible. Rinse water flow is approximately 5 to 7% of the feed flow.

The quality of the filtered water will be less than 5 to 10 ppm for residual solids and oil, and satisfies most demands for recycling or bleed. For polishing purposes, the filter may be operated with coagulants, a lower feed load or with activated carbon as the filter bed, which will produce filtrates of essentially any desired purity. Operating costs are low.

The filtration rate for a mill scale operation is 25 cu metres/(sq metres/hr) (10 gpm/sq ft). Thus, the largest filter unit, DST 50, with 5 sq metres (54 sq ft) filter area will have a capacity of 125 cu metres/hr (550 gpm). A battery layout for 16 filters is shown in Fig. 6. It has a capacity of 2000 cu metres/hr (8800 gpm) and matches the capacity of the screw dewaterer SD 60-200.

Rinse water from the Dynasand filter would be concentrated in a conventional thickener operating with a surface load of approximately 2 cu metres/(sq metres/hr) (0.8 gpm/sq ft). Thickener overflow is returned to the filter feed pumps. Underflow is discharged through a sluice valve system to allow for a high solids concentration of 45 to 65%. Polymers are required in this thickener but not in other parts of the system of pumps, screw-type dewaterer, sand filters, etc.

Fifteen installations of Dynasand batteries have been installed in Scandinavian steel plants, most of them in combination with the screw-type dewaterers and pumps.

The biggest plant is projected for Voest-Alpine Stahl, Linz, Austria, where effluent from the roughing mill, with total flow rate of 4800 cu metres/hr (21,000 gpm), will be served by four screw dewaterers and 48 Dynasand filters. The finishing mill of the same plant will operate with one screw-type dewaterer and 16 Dynasand filters. A total of 12 VASA G pumps are used for slurry transport.

High gradient magnetic filtration — Mill scale normally has a high magnetic susceptibility; oil does not. Consequently, the application of magnetic filters to scale has been limited to system where oil is absent. A cut away view of the Svedala filter, HGMF, is shown in Fig. 7. A high strength combined magnetic field is obtained from a coil that induces a field in the surrounding steel which adds to the direct electromagnetic field of the coil. A matrix of filament material, normally expanded metal, is magnetized in the field volume.

The high gradients of the filaments are able to attract small ferromagnetic particles, such as mill scale fines, even in competition with high viscous drag forces. Thus, the filter is able to operate at flow rates up to 500 cu metres/(sq metres/hr) (200 gpm/sq ft).

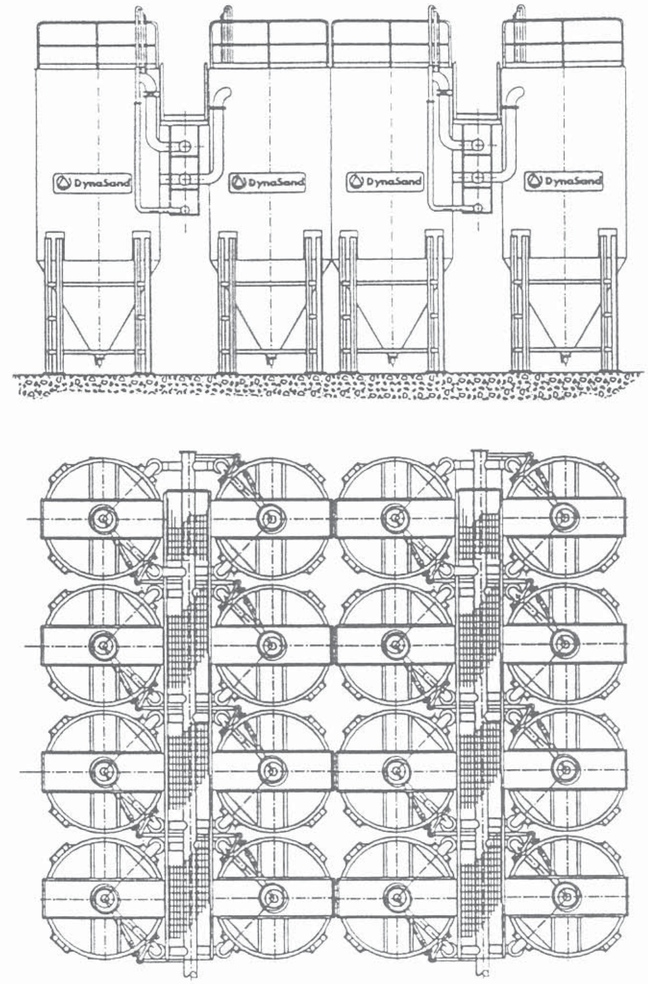

Fig. 6 — Dynasand filter system, flow rate 8800 gpm.

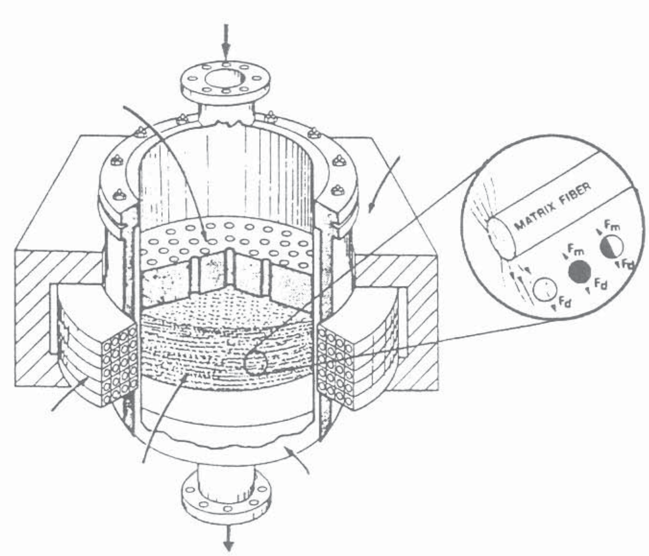

Fig. 7 — High-gradient magnetic filter (type HGMF).

The pressure drop over the filter gradually increases during the discontinuous filter cycle and, eventually, requires rinsing. The feed flow is then stopped, the magnet is turned off and flushing is made with air, which gives small flush volumes. The filter tolerates a feed concentration of 500 ppm with acceptable filter cycles of 30 min. The flushing procedure takes approximately 60 seconds.

The inability to capture oil limits the use of the HGMF filter for scale removal, but effluent standards are excellent for annealing facilities and in effluents in the production of iron powder. The small volume of flush water is an advantage and concentration of the solids is facilitated by magnetic flocculation.

The noncontinuous operation is a disadvantage. The feed flow requires buffering during the back-flush but, except for the automatic valves, it operates without moving parts.

Power consumption for the coil is similar to that for the feed pumps to the filters.

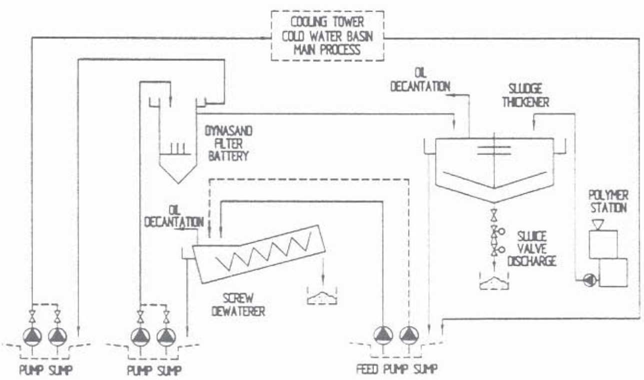

Fig. 8 — Mill scale effluent treatment system.

A novel system

General arrangement — A simplified flowsheet for a novel mill scale effluent treatment system, is shown in Fig. 8. Instrumentation includes level controls for stand-by pumps, guards on rotating shafts, turbidity indicators on filtrate and timer or torque signals for the operation of the sluice valve discharge.

The layout for a plant based on this flowsheet with a feed flow rate of 1000 cu metres/hr (4400 gpm) is shown in Fig. 9.

The pump sumps, as described previously, are relatively small in size. The remaining equipment is erected on a flat concrete foundation. A slightly sloped floor with a central canal for collection of general clean-up water is recommended. This water could, preferably, terminate in the scrap basket and then used as make-up water to the process flow.

An alternative system using a high-gradient magnetic filter unit is shown in Fig.10. Total flow in this system is 360 cu metres/hr (1600 gpm).

Manpower — The plant illustrated in Fig. 8 will not require permanent staffing. It should, however, be visited once per shift to verify that everything is operating normally. Removal of scale and sludge containers will be a daily operation.

Consumption — The total installed power in the plant is 460 kw (625 hp): pump requirements are 450 kw. The total power will not be utilized and, since the stand-by pumps are not in operation, the power consumption in the plant will be less than 200 kw (270 hp).

Polymer consumption in the thickener is approximately 100 g/hr. Total air consumption for the filters is 8.4 N cu metres/hr which translates into less than 2 kw for the compressor.

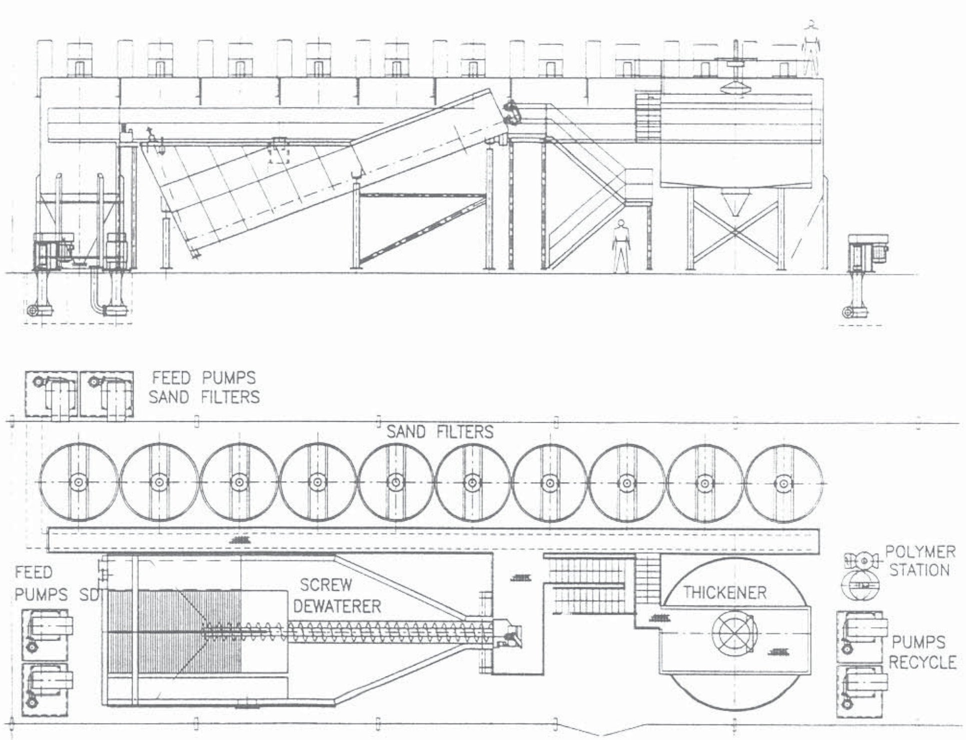

Fig. 9 — Mill scale effluent treatment system, flow rate 4400 gpm.

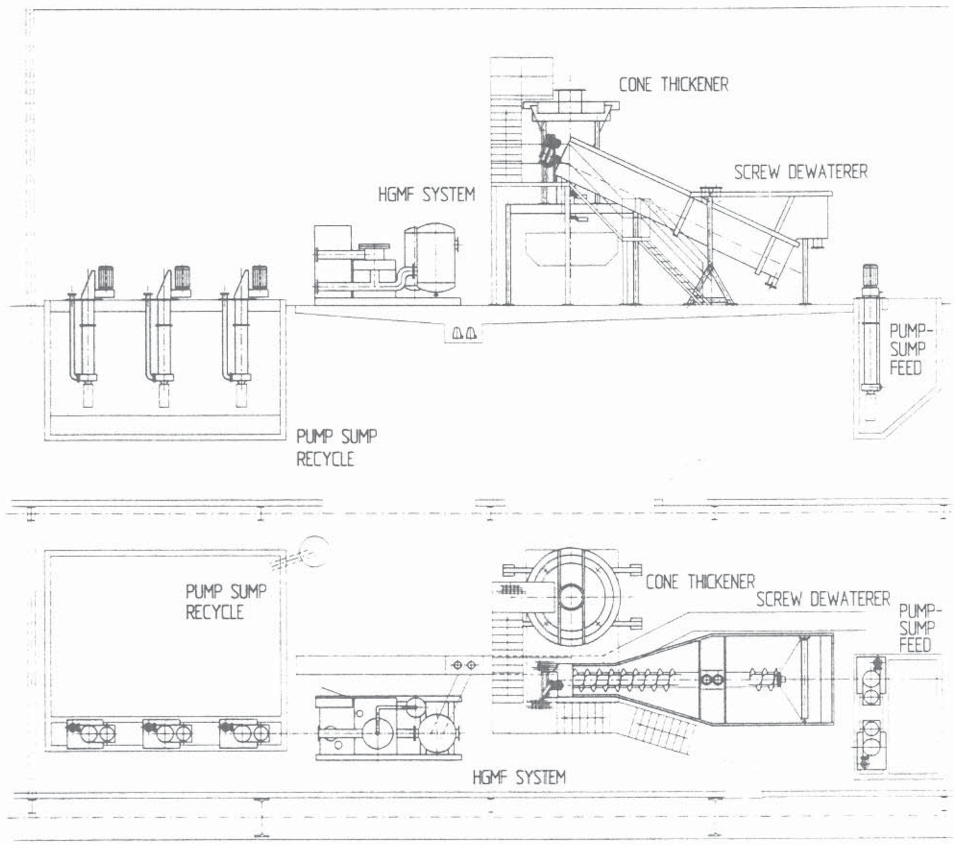

Fig. 10 — Mill scale effluent treatment system with high-gradient magnetic filter (HGMF), flow rate 1600 gpm.

Costs

An independent consultant, VBB VIAK (Sweden), has calculated a 50% higher installation cost for a conventional scale pit system vs a screw-type dewaterer and pumps including both construction and equipment. The absence of settling basins in the system should give further savings.

The total estimated costs for the described 1000-cu metres/hr plant excluding construction costs is estimated as:

- Equipment, $1.2 million.
- Piping, $75,000.
- Support steel, walkways, platforms etc, $75,000.
- Electrical installation, $200,000.
- Engineering, $150,000.
- Commissioning, $200,000.

The total estimated cost is $1.9 million.

An assumed yearly capitalized cost of $300,000 corresponds to a cost of $30/hr. Spares are estimated at $50,000 or $6/hr.

Other costs are:

- Manpower, $20/hr.
- Power at $0.10/kwhr, $20/hr.
- Chemicals $1/hr.

In total, a cost of $81/hr is equivalent to a treatment cost of $0.81/cu metre of water or $0.35/1000 gal of water.

Summary

Water flow rates, used for direct cooling in continuous casting and hot rolling of steel, range from approximately 1000 to over 40,000 gpm. The traditional method for handling these streams involve collection of coarse material in pits that are emptied by cranes or chain-scrapers, followed by separation of fines and oil in large settling basins and, finally, removal of micron size material and residual oil in back-washed sand filters. Area restrictions, economy, environmental concern and labor costs have promoted alternative methods of treatment. These include:

- Pumping the bulk of the material and water directly from the original location of solids. Rigidly designed centrifugal pumps, capable of handling scrap material up to 2 in., allow subsequent treatment to be moved away from the area of steel production to a locality of choice.
- Pumping allows further handling in equipment installed at floor level. Screw-type dewaterers with lamella plates can process 9000 gpm in one unit. They will remove all scale greater than 100 micron, which normally represents over 90% of the total solids present, and will deliver a dewatered material, with less than 5% moisture.
- Overflow from screw-type dewaterers contain approximately 100 to 300 ppm of solids. Continuous filters, operating with no moving parts, will produce a filtrate with less than 5 to 10 ppm of solids and oil. The continuous wash flow, approximately 5% of the feed flow, is concentrated in a conventional thickener to a sludge having 60 to 70% solids.
- High-gradient magnetic filters are an alternative to sand filters that operate with extreme filtration rates up to 2000 gpm/sq ft. Solids removal is as good as a sand filter, but has limited oil separation capability.

Design characteristics for the individual machines have been reviewed. An integrated system has high availability, operates automatically, is less costly, and is safer and more compact than traditional facilities. Representative cost data have been provided. ▲