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Lubrication of Sendzimir mills

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LUBRICATION OF SENDZIMIR MILLS

By L. R. Seeling*

Sendzimir cold mills require a well-engineered lubricating system. 'Z' mills are extremely rigid and compact and are intended to operate totally enclosed. The backing bearings are mounted on shafts that are eccentrically actuated, and these bearings are normally flood-lubricated with the same oil that lubricates the roll bite. This necessitates careful design and operation of the lubricating system.

By employing very small diameter work rolls, suitably backed up by intermediate rolls and bearings, very high specific pressures exist between the work rolls and the strips; thus quite large reductions are made on the hardest of materials. The roll bite lubricant is sprayed in large quantities from spray boards located very close to the bite. Materials having a tensile strength up to 350 000 lb/in^2 are commonly reduced, and where the effect of roll flattening can be bothersome it is readily overcome by the use of carbide work rolls.

This paper outlines the general principles relating to lubrication of these mills, and a few typical lubricating systems are illustrated.

MILL LUBRICATION OF 'Z' MILLS presents very different considerations than have to be met on conventional rolling mills.

COLD MILLS

The Sendzimir cold mill is of the design commonly known as a 'Cluster Mill' and can be of the 1-2-3-4, 1-2-3 or 1-2 design, but by far the greatest number in use are of the 1-2-3-4 type. There are now well over 200 cold mills in operation throughout the world: 108 of these in the U.S.A. and 103 throughout the rest of the world. Generally speaking these mills are designed for reversing operation, although some strip mills are for a one-way operation, as are the sheet mills.

The design of mills ranges all the way from 4½ in wide to 120 in wide and having speeds up to 3500 ft/min.

These mills employ very small diameter work rolls, from ¼ in to 3½ in diameter, which are made from tool steel or carbide, and which are in direct contact with first intermediate rolls, successively backed by second intermediate rolls, four of which are driven (Fig. 22.1); these in turn are backed by a plurality of anti-friction bearings on each of the backing shafts. Thus all the rolls are solidly backed up along their full length by the very rigid one-piece housing. A pair of work rolls can be changed in less than 1 min, even part way through a coil with the strip in the mill.

Precise shape control is obtained by an unusual system of eccentric adjustment of the backing bearings mounted on shafts A and D, and each shaft is carried by a plurality of adjacent saddles (see Figs 22.1, 22.2, and 22.3), which permits the shape of the mill to be adjusted during rolling by a method termed 'As-U-Roll crown adjustment'.

Each saddle contains an individual adjustment by secondary eccentrics contained within the saddle and provides a very wide control of shape. A hydraulically operated adjustment for the screw-down control is provided on shafts B and C, this being a parallel adjustment of these two shafts by a primary eccentric contained within each saddle, and the operation is by a toothed segment on each end of these shafts. The control of the two screw-down shafts is by a hydraulic-mechanical servo system, which provides precise control of very close rolling tolerances. Strip edge pressure relief is built into the mill by the first intermediate rolls being tapered at one end, the taper on the top rolls being at the opposite side of the mill to that on the bottom rolls. These first intermediate rolls are laterally adjustable and will permit a range of strip widths to be rolled on one set of rolls. The use of this adjustment eliminates over-rolled or under-rolled edges.

The very rigid design of 'Z' mills and the use of very small work rolls means that the specific pressure on the

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work rolls is very high; this is well illustrated by the fact that stainless, nimonics, and other hard alloys can be reduced by as much as 96 per cent without an intermediate annealing operation. The specific pressures in the bite can be 300 000 lb/in^2 or higher. The work rolls are usually made from hardened tool steel, but when the specific pressures are of the order that roll flattening is a problem, then this can be overcome by the use of carbide work rolls.

Because of the extremely close tolerances possible with this mill, for instance 50 in wide stainless and carbon steels are commercially rolled within a tolerance of 0·0002 in, together with the very fine finishes that are obtained, all the way from commercial low carbon finishes to mirror finishes in the range of tenths of a micro-inch at the production rates up to 50 ton/h, the lubrication and filtration requirements are of great importance.

The wide range of materials rolled necessitates that the lubrication system for each mill be designed for the particular service requirements. Some of the metals rolled are as follows:

Low, medium, and high carbon steels, tinplate and silicon steels.

Stainless steels—all grades.

Copper, brasses, and all alloys such as beryllium.

Aluminium and its alloys.

Titanium, tantalum, zirconium, cobalt, stellite, high speed steels, magnetic alloys.

Exotic and precious metals.

Atomic energy materials.

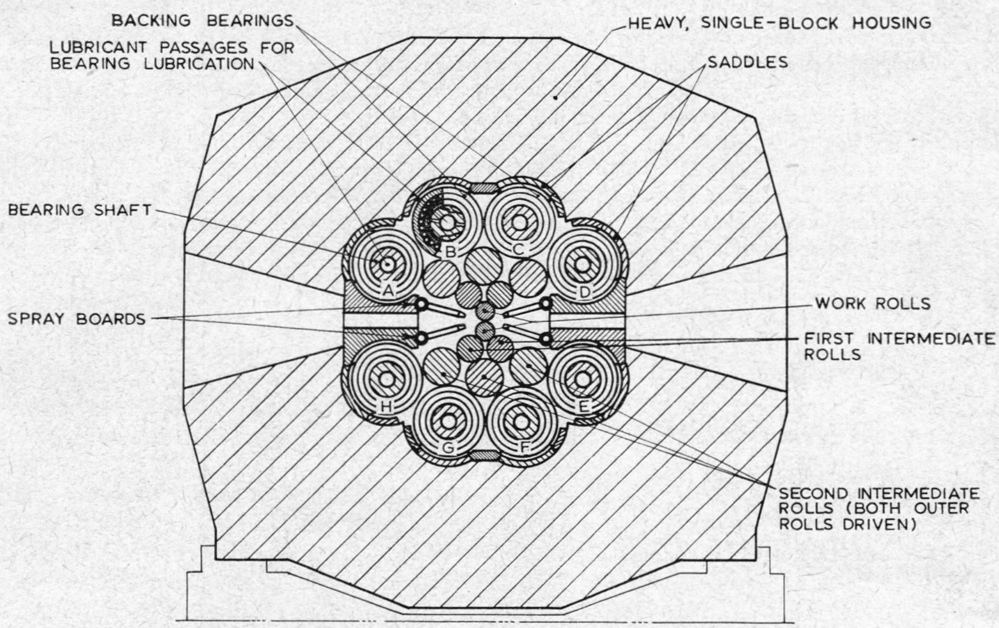

Fig. 22.1. Roll arrangement and lubrication of a Sendzimir 1-2-3-4 cold mill

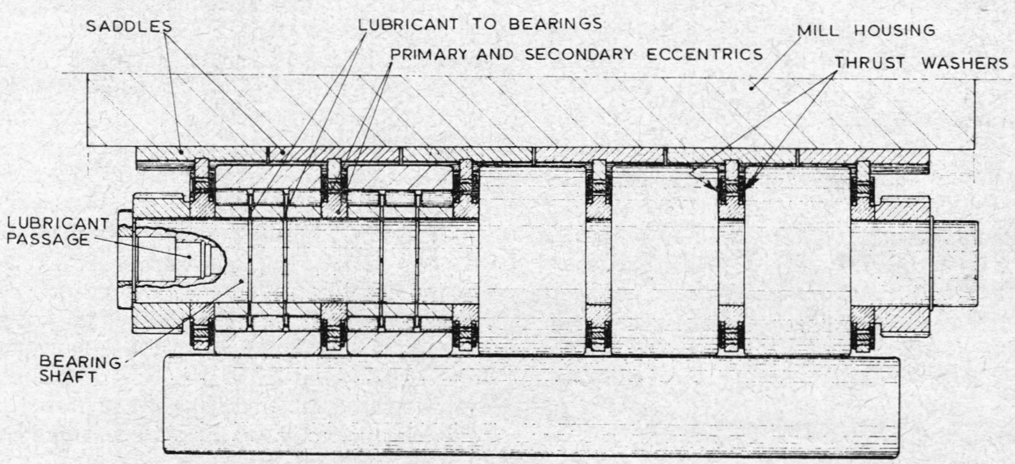

Fig. 22.2. Section through a typical backing assembly of a Sendzimir cold rolling mill

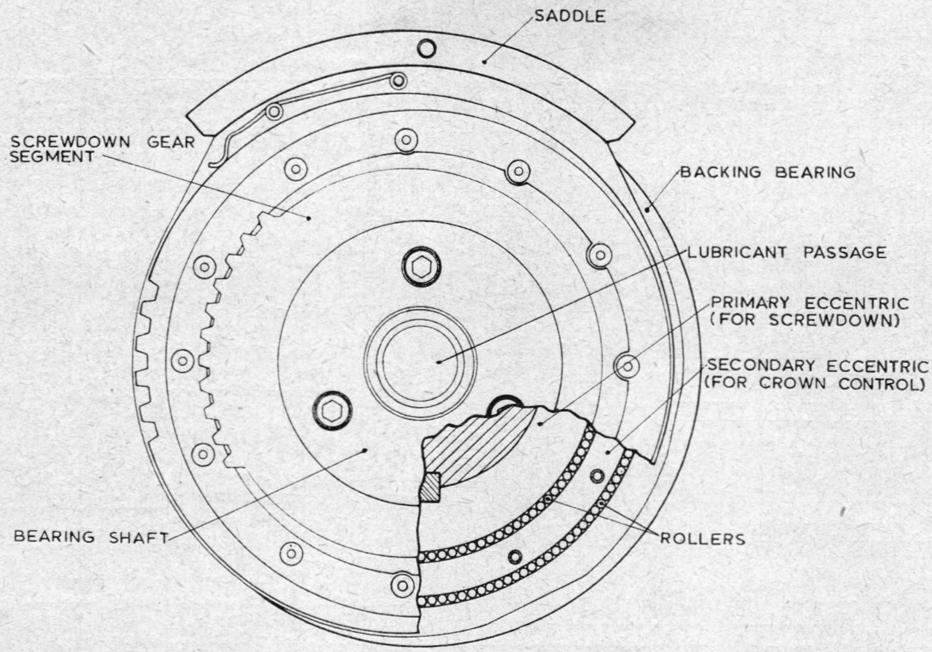

Fig. 22.3. End view of a typical backing assembly of a Sendzimir cold rolling mill

It has been the general practice on Sendzimir mills to use the same lubricant for the backing bearings that is used for the roll bite. Until recently it was not possible to employ separate lubricating systems for the bearings and roll bite, for one system would be contaminated by lubricant from the other, because of the impracticality of sealing off the backing bearings, which extend across the full width of the mill (see Fig. 22.2). However, the use of a common lubricant for all the lubricating requirements has not posed any great problem but has made it mandatory that a properly engineered filtration system be used. In this way, even with a soluble oil system, excellent bearing life is obtained.

For Sendzimir mills rolling stainless steels with high finishes, other hard to roll materials and carbon steels where mills have a speed that is not classed as high, the mineral oil lubricating systems were employed. With mills being designed for still higher speeds it was essential that the lubricating systems be specified to utilize the higher specific heat of water-soluble oils, in order to cool effectively the strip and work rolls. If soluble oils were not used on these fast mills, the heat would not be carried away effectively from the very small work rolls, and it would result in it being more difficult to maintain thermal stability in the mill. This is well exemplified in one of the faster mills where a total of 4000 hp drives two work rolls of $3\frac{1}{8}$ in diameter, resulting in approximately 7 500 000 Btu/h having to be extracted from the rolls and strip.

This paper, therefore, is confined to the main classes of recirculating lubrication systems in use of Sendzimir mills, which are mineral oil systems, soluble oil systems and dual systems.

MINERAL OIL SYSTEMS

Mineral oil is generally used on mills rolling up to 1500 ft/min on stainless steels and other hard to roll alloys, aluminium, silicon, and occasionally carbon steels. The oil viscosity depends on the material being rolled: for instance, stainless steel uses 100/150 SSU at 100°F, and it is delivered to the mill at a temperature of 90° to 95°F. The pressure of the sprays at the roll bite is 100–125 lb/in^2, while the oil to the bearings is controlled by a suitable pressure regulator and delivered at 40–60 lb/in^2. Approximately 25 per cent of the delivery to the mill lubricates the bearings with the balance going to the roll bite. Because of the high specific pressures involved e.p. additives are used.

The spray boards used to lubricate the roll bite are illustrated in Fig. 22.1; it will be seen that they are located very close to the bite, thus ensuring deriving maximum cooling effect from the impingement velocity, which also effectively blasts off the metal fines generated in the bite.

The filtration systems use one or more of the following means of filtering:

- continuous filtering bands,
- cartridge—paper or cellulose,
- cloth bag,
- diatomaceous and fuller's earth, both of the cartridge, bulk pack, and pre-coat type, which can be automatic, centrifuge,
- decantation,
- magnetic separators.

A combination of these systems can be used as full-flow or on a by-pass basis. Typical systems for Sendzimir mill

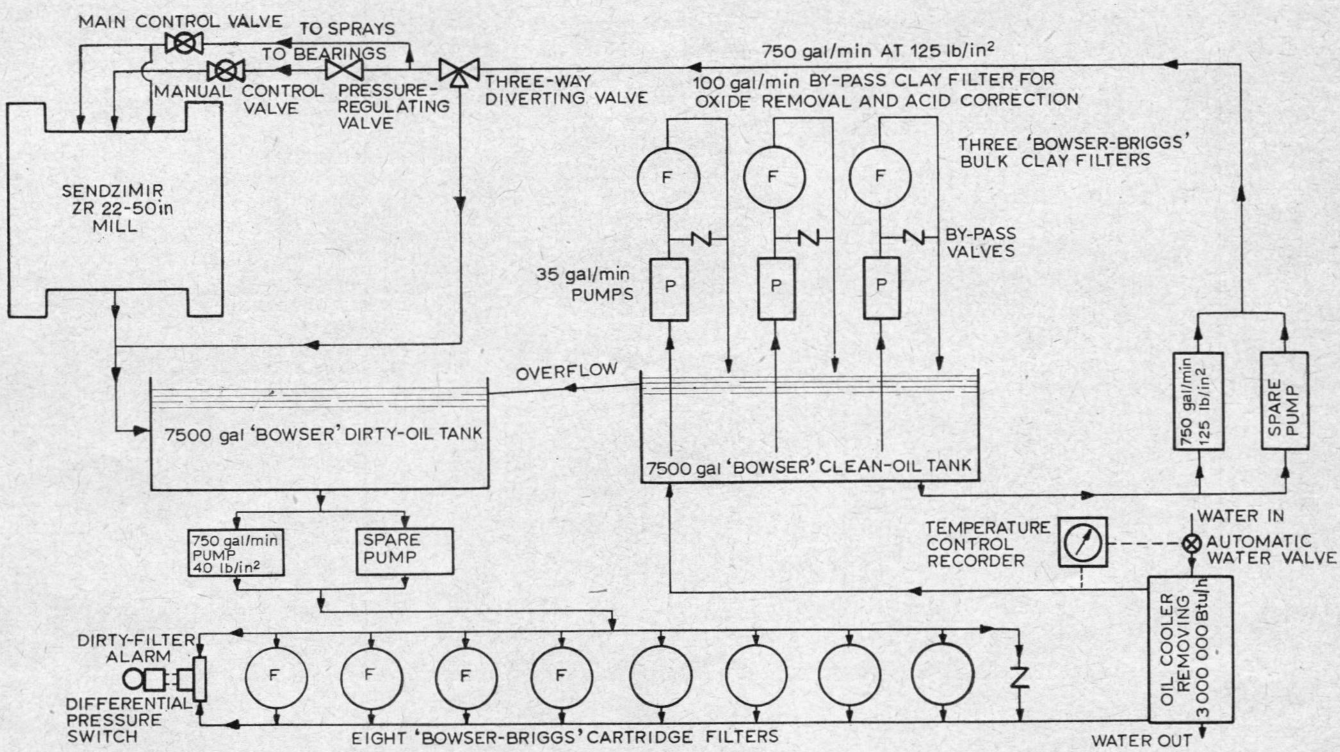

Fig. 22.4. Lubricant flow on a Sendzimir ZR 22–50 cold rolling mill using mineral oil (750 gal/min capacity)

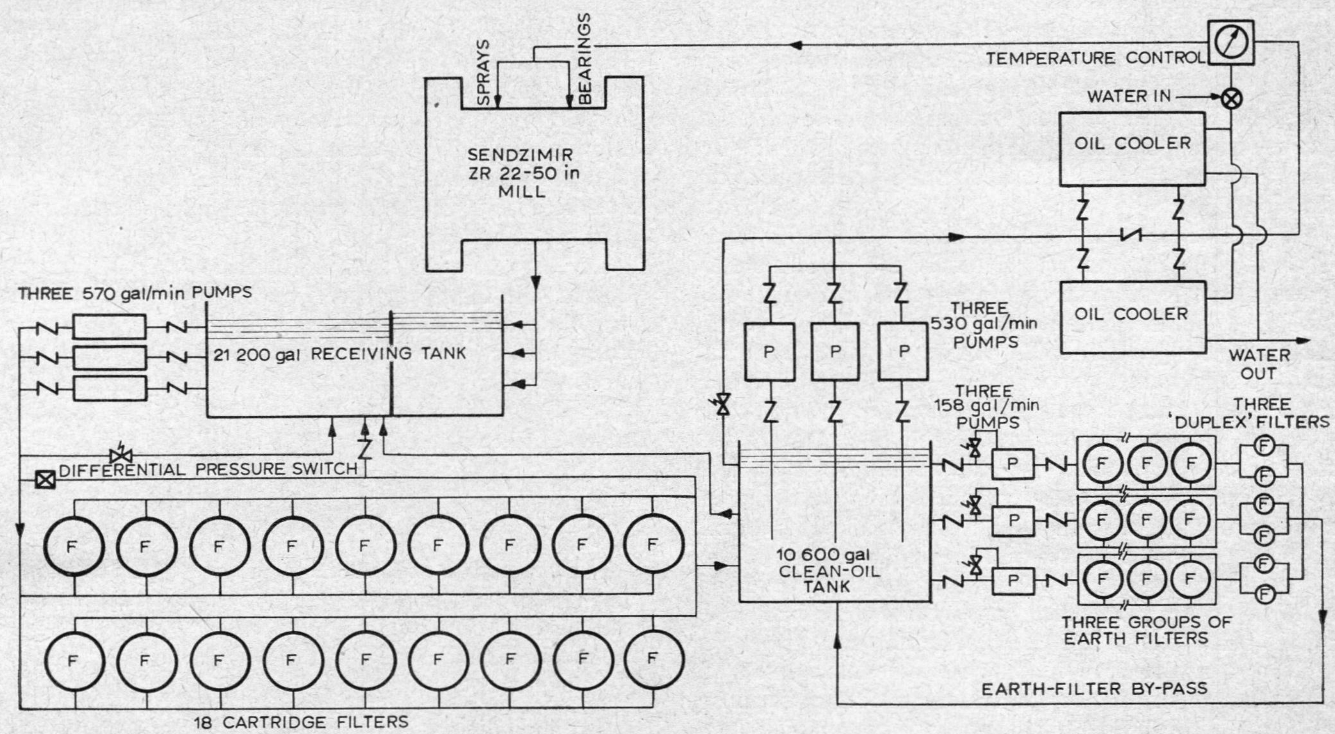

Fig. 22.5. Lubricant flow on a Sendzimir ZR 22–50 cold rolling mill using mineral oil (1060 gal/min capacity)

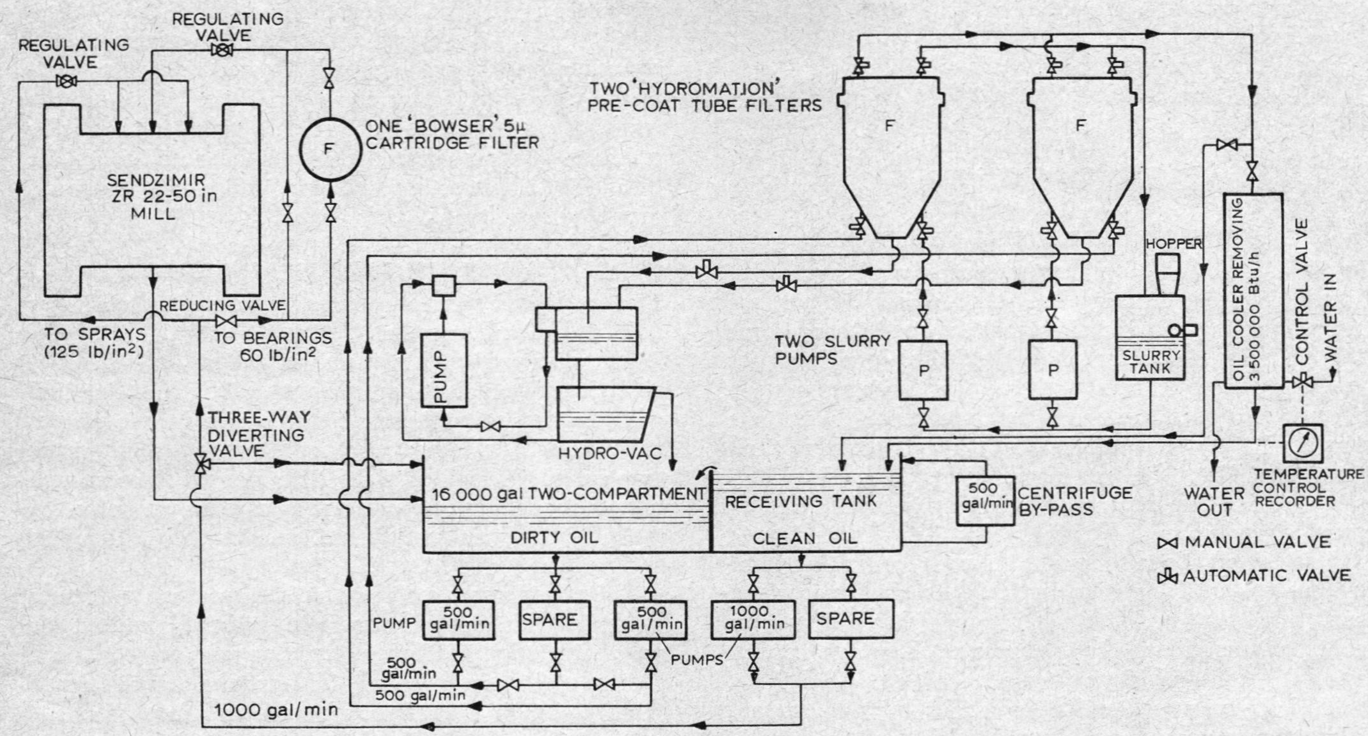

Fig. 22.6. Lubricant flow on a Sendzimir ZR 22–50 cold rolling mill using mineral oil (1000 gal/min capacity)

lubrication using mineral oil are illustrated in Figs 22.4, 22.5, and 22.6. System capacities range from 10 to 20 times the delivery to the mill.

In the systems shown in Figs 22.4 and 22.5 the return flow from the mill is piped into a dirty oil tank from where it is pumped through cartridge filters of approximately 15 μ size and then into the clean oil tank. Oil is taken from the clean oil tank and filtered on a continuous by-pass basis through diatomaceous or diatomaceous and fuller's earth filters to remove the oxides and the finer contamination down to 5 μ size or less.

The system in Fig. 22.6 has full-flow filtration through pre-coat filters employing diatomaceous and fuller's earth filtering media. The oil from the clean tank is passed through a centrifuge on a by-pass basis and the oil for bearing lubrication is passed through a 5 μ cartridge filter. A system of this type is capable of removing contamination down to 1 μ in size, as well as removing oxides from the oil.

A lubricating system is susceptible to a gradual increase in concentration of contamination having a particle size that will pass through the filtering media being used. This build-up usually takes a considerable time before it has detrimental effects on the product being rolled but eventually makes it necessary to replace the batch of oil. However, should the increase in fine contamination necessitate too frequent dumping of the batch of oil, it has proved very effective to install a decantation system. This permits one tank of oil to be kept out of use for a sufficient period to permit the contamination to sediment out and be removed: thus the mill's operation will be continuous by alternating the batch of oil in use.

SOLUBLE OIL SYSTEMS

No attempt will be made to discuss the comparative merits of the many soluble oils available and in use.

Many Sendzimir mills use the same soluble oil for lubricating the backing bearings and the roll bite, with excellent bearing life when using soluble oils in concentrations of 12 to 25 per cent.

Soluble oils have undergone considerable development in recent years. The filtration of soluble oils presents different problems than are encountered with mineral oils, with which, apart from it being necessary to maintain the rust inhibitors, e.p. additives, defoaming and detergent additives at the desired levels, there are some types of filtering media, e.g. earth filters, that should not be employed because they not only remove the contamination but also the minute oil droplets that have great affinity for forming around the fine particles of contamination.

Below are noted some of the filtering principles employed for soluble oils, and while some are used as a sole method of filtering, it is more usual to find in use in one system a combination of a number of the filtering principles:

Full-flow continuous paper bands.

Magnetic separators on full-flow or by-pass, employing magnetic drums and scrapers, or stack-type magnetic rods with scrapers.

Cartridges.
Centrifuge.
Flotation and skimming.
Decantation.

Typical systems are illustrated in Figs 22.7 and 22.8, and these will be found self-explanatory.

DUAL LUBRICATING SYSTEMS

In the U.S.A. and elsewhere there are a small number of installations that have two entirely separate systems, the prime purpose of which is to enable quick change-over for the rolling of different metals, where one lubricant will not be suitable for all of them; thus the best advantage of each type of lubricant can be employed. This permits a mineral oil to be used in one system and a soluble oil in the other. With these dual installations it is usually necessary to have two separate filtering systems in order to provide the optimum filtration.

Dual systems are also installed to use the same lubricant in each system; this is particularly advantageous where such as silicon steels, which are notoriously dirty, are rolled on the same mill as stainless steels, which, as well as other metals, require a clean oil.

The pinion stands and reducers for the winders are lubricated by conventional systems. Due to many Sendzimir mills employing winding tensions as high as 136 000 lb tension on stainless mills, the winder mandrel segments are subjected to massive collapsing pressures generated by the tension and coil collapsing forces. Particular attention has to be paid to the correct design of lubricant application between the sliding surfaces of the segments and pyramids, which, even though manufactured from heat-treated alloy steels, are subject to being deformed by extrusion. All surfaces subjected to these high specific pressures are pre-coated with molybdenum disulphide during initial assembly and are lubricated with MoS_2 grease during service.

SENDZIMIR PLANETARY MILLS

Finally, a brief mention of the Sendzimir hot planetary mills and their lubrication.

The planetary mill is a unique rolling mill that is a radical departure from any other hot rolling mill. This mill will effect up to a 98 per cent reduction in one pass to produce close tolerance strip. In fact it is the only really true continuous mill, for the slabs are fed into the mill butted one to another, and as long as slabs are being fed the mill is delivering strip for 100 per cent of the time it is in operation.

There are a number of these mills in operation and under construction in widths up to 57 in, while still wider mills are under design and have production rates up to 300 and 400 ton/h. Slabbing planetary mills are also being designed as integral mills in tandem and semi-continuous lines.

The principle of the planetary mill is illustrated in Figs 22.9 and 22.10, from which it will be seen that slabs are fed by feed rolls into the reduction zone. The slab is reduced to strip in one pass by a rapid succession of small reductions performed by each pair of co-acting work rolls.

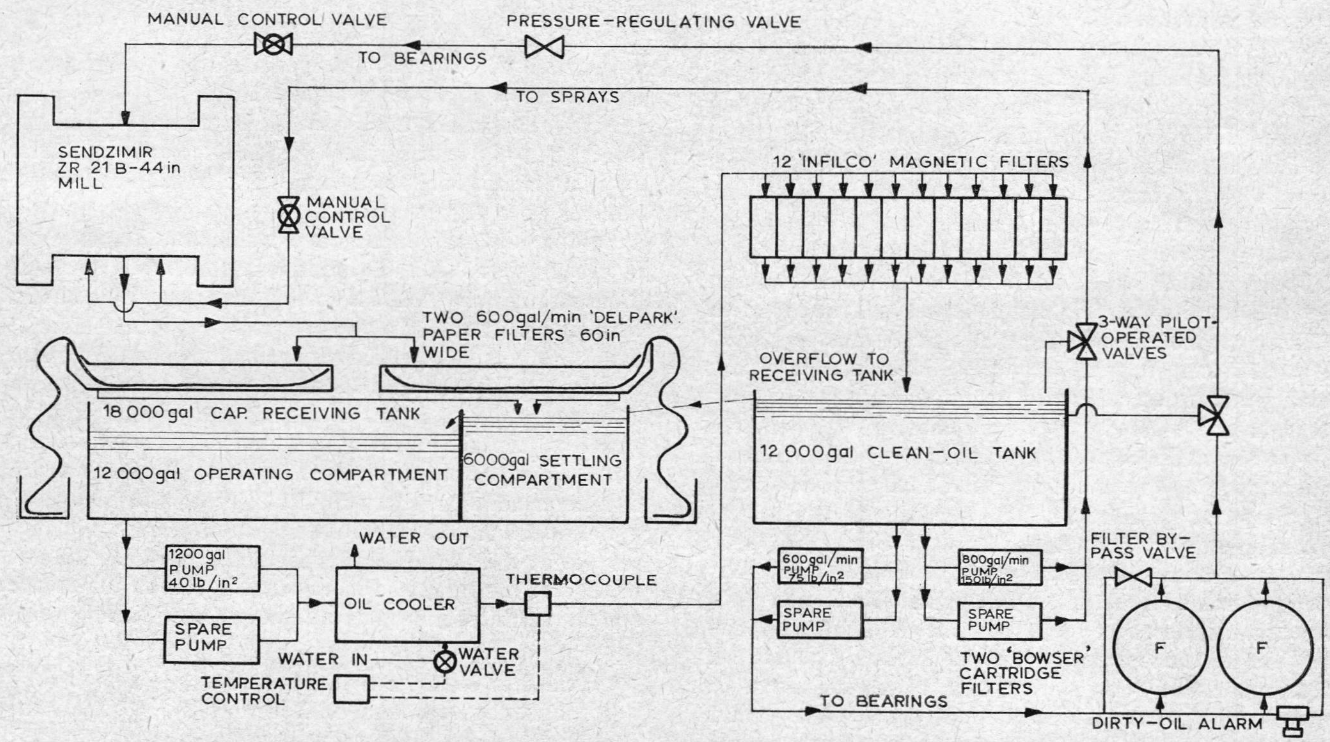

Fig. 22.7. Lubricant flow on a Sendzimir ZR 21B–44 cold rolling mill using water-soluble oil (1400 gal/min capacity)

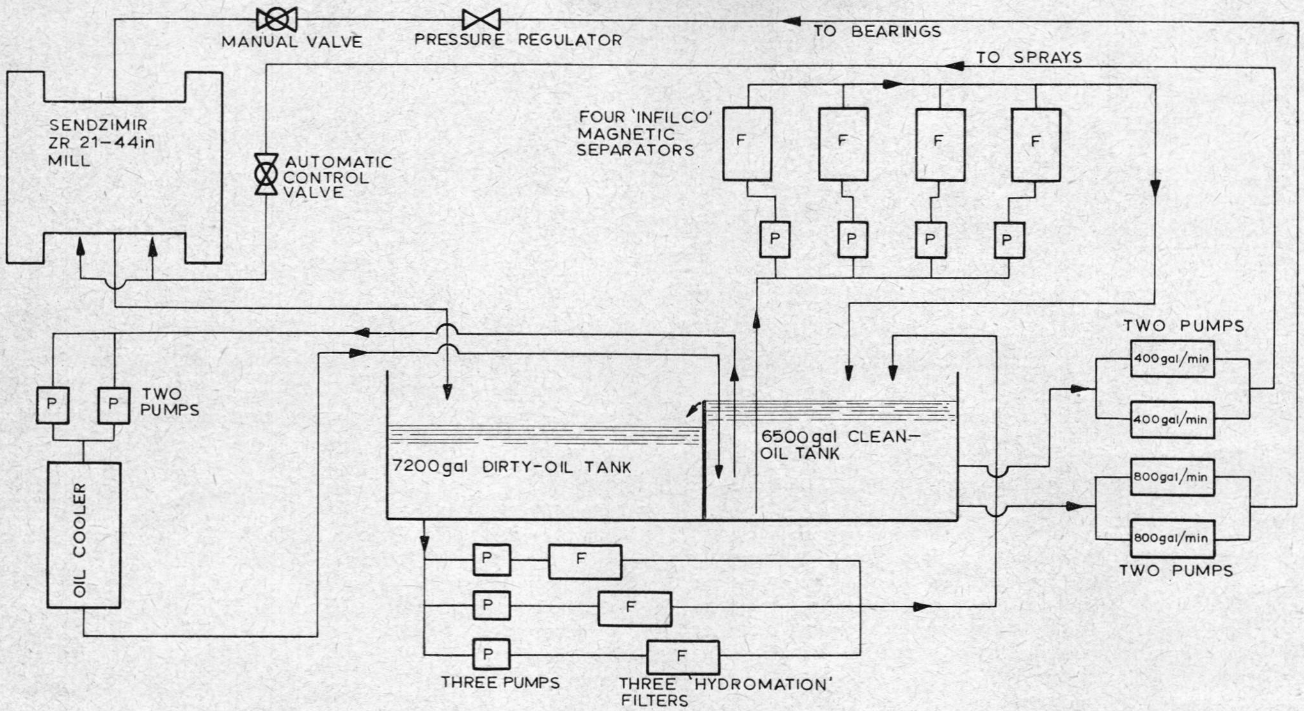

Fig. 22.8. Lubricant flow on a Sendzimir ZR 21–44 cold rolling mill using water-soluble oil (1200 gal/min capacity)

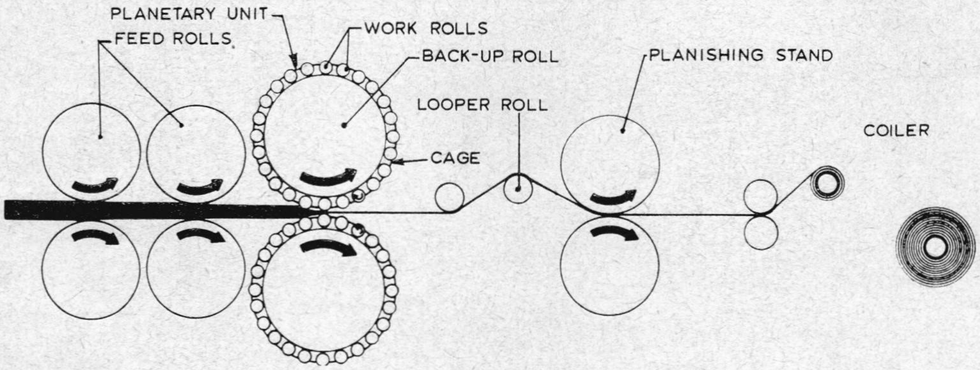

Fig. 22.9. Principle of a Sendzimir planetary hot strip mill with two pairs of feed rolls

The slab temperature only needs to be 200° to 300°F, lower than temperatures necessary for other hot rolling mills, for advantage can be taken of the substantial temperature rise in the reduction zone. The work rolls are in contact with the hot metal for a very short time and have to travel all around the back-up rolls, where they are effectively cooled before again touching the slab. This results in the work roll temperature not exceeding 180°F during operation.

On this mill the lubrication of the pinion stands, roll neck bearings and screw-downs follows the systems well known and used on conventional mills. These systems for oil lubrication are of the recirculating type, and for the grease applications the cyclic impulse systems are employed.

Lubrication of the work roll necks is somewhat special, and on a mill having a back-up roll speed of 500 rev/min the work rolls rotate at approximately 2500 rev/min. The work roll bearings nowadays are plain bearings of a proprietary bronze and are oil lubricated. This oil is supplied to these bearings in cyclic measured amounts and it is not possible to recover this oil for recirculation; it is therefore allowed to be carried away with the mill cooling water. The quantity of oil consumed is too small to warrant any attempt to effect recovery.

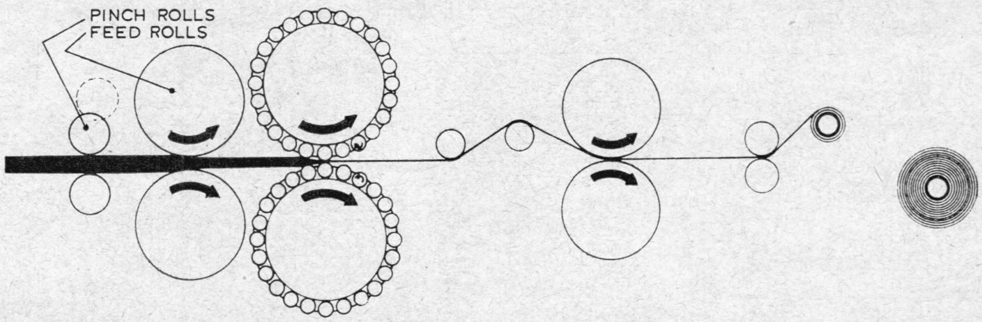

Fig. 22.10. Principle of a Sendzimir planetary hot strip mill with one pair of feed rolls and pinch rolls

APPENDIX 22.I

SENDZIMIR MILL ROLLING OIL LUBRICANT PERFORMANCE REQUIREMENTS

United States Steel Corporation Requirement No. 151

General requirements	A well-refined oil specifically designed for use in Sendzimir Mills, which will serve the dual function of roll oil and lubricant for mill components. It must leave no harmful residue on the metal during annealing.
Compounding	Must contain an oiliness-type additive to improve rolling characteristics and surface finish on the strip. Rust inhibitor to protect mill components is essential. Suitable anti-foam and oxidation resistance may be obtained by quality base oil selection or use of additives.
Base oil type	May range from naphthenic to paraffinic in type.
Viscosity D-88	Viscosity code classes 13 or 14.
Flash, C.O.C.	Not less than 300°F.
Colour, A.S.T.M.	4 max.
Rust prevention	Pass A.S.T.M. D-665 (synthetic sea water).
Sulphur, percentage	0·3 max.
Oil oxidation by static oxygen	Not less than 20 h for 60 mm pressure drop.
Corrosion	
Copper strip, 3 h at 212°F	A.S.T.M. D-130 classification 2 max.
Steel strip, 3 h at 212°F	No discoloration.
Field test	Satisfactory for the application intended.

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