THE SELECTION OF A NOVEL CRYSTALLISER DRIVE

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Abstract

The decision criteria of cost, power and performance are considered in the selection of a new crystalliser drive, together with the requirements of energy, efficiency, massecuite cooling, ease of maintenance, plant availability, and aesthetics. A description is given of the novel drive chosen, together with several illustrations of the assembly.

Introduction

The decision was taken to double the 'B' Crystalliser capacity at the Tongaat-Hulett Sugar Mill at Maidstone. To accomplish this it was agreed that two vertical crystallisers of 135 m^3 each would be installed together with the required water circuitry for cooling and drives for the rotors, with the former 112 m^3 of horizontal B-crystallisers being re-allocated to A-massecuites.

The broad specification given for tender was for two drives to operate between 0,5 - 1,3 r.p.m., with a maximum torque of 175 000 Nm. This torque was finally modified to a maximum design limit of 275 000 Nm in order that the units could, if necessary, be converted in future to C-duty.

Decision Criteria

The selection decision was based on the following criteria, some of which were considered to be essential:

- Variable speed and constant torque requirements should be met (essential).
- Massecuite cooling should be possible, using water cooling through the rotating element (essential).
- Availability should be 100% for the duration of at least a full 10 month season between major services.
- Maintenance should be as simple as possible, and a good local back-up would be necessary if the repair work proved to be beyond the capabilities of mill personnel.
- Primary input power should be as low as possible. Although electricity is generated on site, it still has a real value and must be considered in the total operating cost. Thus overall drive efficiency should be maximised.
- The total installed cost of the drives should fall within the budgeted figure which had been based on other similar units in the Industry (essential).
- The drive should comply with the required levels of housekeeping in terms of cleanliness and aesthetics.

Available Options

The main options available in terms of conventional equipment were:

(1) Twin motors, hydraulic or D.C., with a chain and sprocket final drive.

(2) Twin motors, hydraulic or D.C., with a worm and wheel final drive.

(3) Single, shaft-mounted hydraulic motor, with or without reduction gearing.

The use of frequency speed-controlled A.C. motors was not considered, due to the lack of local experience.

Options (1) and (2) are in use at various mills in the S.A. sugar industry and all are reported to operate well. Option (3), however, posed the major problem of the introduction of cooling water into the rotating element of the crystallisers, which was a primary requirement. Therefore all shaft-mounted drives were specifically excluded, except the HM 275 which offered the possibility of a cored centre.

Details of the various drives considered are listed in Table 1.

TABLE 1

Cost and Performance Details

	Motor & power pack	Primary reducer	Final reduction	Total cost/unit	Gross estimated efficiency	power installed
Type '1'	Hydraulic	Epicyclic gears	Transmission chain and sprocket			
	R32 000		R10 500	R42 000	75%	22 kW
Type '2'	Hydraulic	Nil	Worm & Wheel			
	R17 500		R29 000	R46 500	37%	44 kW
Type '2'	D.C.	Nil	Worm & Wheel			
	R24 000		R29 000	R53 500	50%	50 kW
Type '3'*	Hydraulic (shaft-mounted)	Epicyclic	Nil	R30 500	75%	30 kW
	R30 500					
Type '3'	Hydraulic (shaft-mounted)	Nil	Nil			
	R42 000			R42 000	90%	22 kW

* No facility for entry of cooling water to rotor and thus the drive was excluded.

It can be seen from the table above that there is little to choose between the various options in terms of total price. There is, however, a variance in overall efficiency of the different drives, mainly in terms of the choice between chain reduction or worm and wheel reduction for the final drive.

Choice of the Drive

The drive selected was the Type '3' option of the Oilpower HM 275. This unit met all the primary criteria for the choice of drive except perhaps for aesthetics of the unit itself, and it was felt that, because of the geometry, it would not be difficult to shroud it in an acceptable manner. The decision was made rather subjectively, as price was not a major consideration since all drives fell into a relatively narrow cost band. Although the novel locally developed (and patented) HM 275 drive was as yet virtually unproven, the principle of its design was sound and mill management's confidence in the unit had been reinforced by participation with the suppliers in the successful development of the (smaller) prototype crystallizer drive at Maidstone during 1983. The concept of the drive was attractive as it would fit inside the diameter of the crystalliser itself, the efficiency of the drive was better than others considered and it effectively removed the need for both a primary reducer and for a worm wheel or transmission chain final reduction.

It should be stressed at this point however, that during the past 5 seasons the alternative drives, both hydraulic and D.C., operating in many of the other mills have not required excessive maintenance.

A Detailed Description of the HM Motor

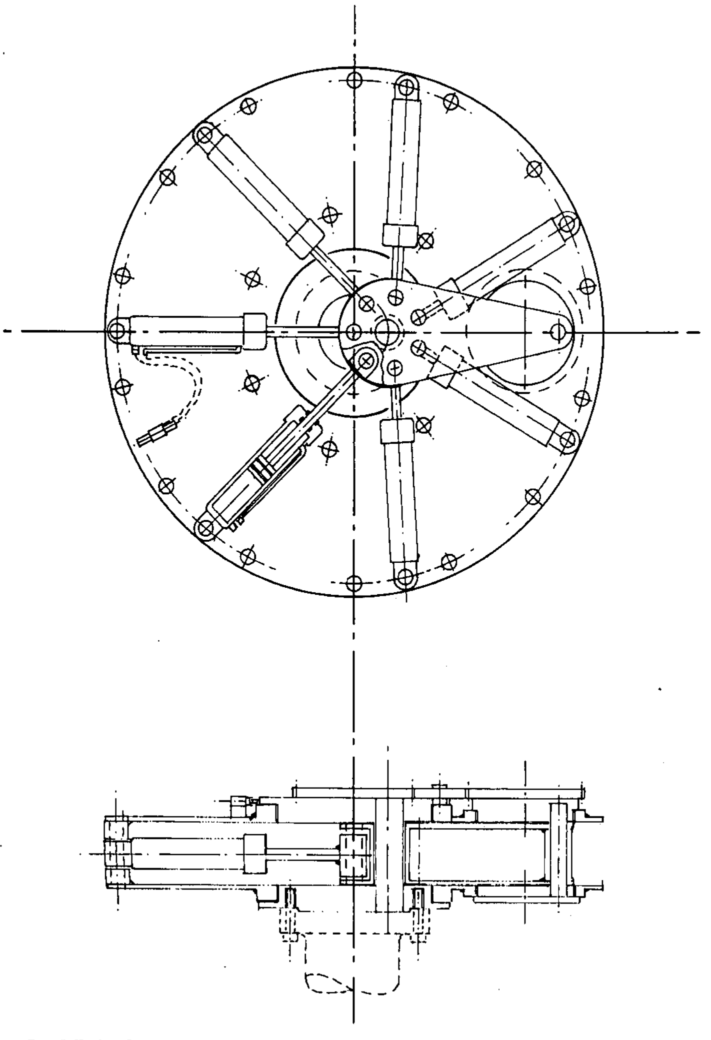

FIGURE 1 Conceptual Design of HM 275

Figure 1 depicts the conceptual design of the HM 275 hydraulic motor which employs hydraulic rams positively attached to the central eccentric.

The concept of this particular motor derives its origins from the radial aircraft enigne, the main difference being that the aircraft engine has a single master conrod which oscillates about the gudgeon pin of the master piston, whereas the HM relies upon 7 cylinders with unique ram connections to the main crank, and positively ensures direction of rotation with 1:1 gearing between the main crank and the slave eccentric.

The motor consists of seven hydraulic double acting cylinders, equally spaced about a pair of discs, acting onto a big-end which has the cylinder end-pins equally spaced. This big-end is attached eccentrically to a boss which rotates about the main shaft centreline. The big-end has a lever arm extending down to a similar eccentric, situated between a pair of cylinders. This eccentric assembly is driven by gears so as to keep the big-end arm moving in a parallel motion, thus preventing the big-end turing around the pin.

This parallel motion or orbit of the master conrod is the heart of the entire motor in that it ensures that the application of force of all cylinders is exerted through one point at all times as opposed to the radial aircraft engine in which the application point continually changes, forming a locus about the crankshaft.

The cylinders are supplied with pressure oil from cam-operated valves which are switched on and off just as the cylinder approaches top and bottom dead centre, in such a way that the cylinder may float past top and bottom dead centres.

In the position shown in Figure 2, with No. 1 cylinder at top dead centre No. 1 cylinder is switched off, Nos. 2 to 4 are switched to pull, and Nos. 5 to 7 are switched to push. This generates a resultant force F applied to the big-end as shown. This force F, multiplied by the effective distance D, produces the required torque.

As the shaft rotates the cylinders are progressively switched thus producing a relatively smooth turning force. Assuming that the cylinders are switched on and off 2,5° before and after top and bottom dead centre, then each cylinder is in operation for 350° per revolution. Thus all cylinders are in operation over 290° and a minimum of 6 for the remaining 70°.

The cam for operating the hydraulic spool valves controlling the pressure oil to the cylinders and drain from the cylinders

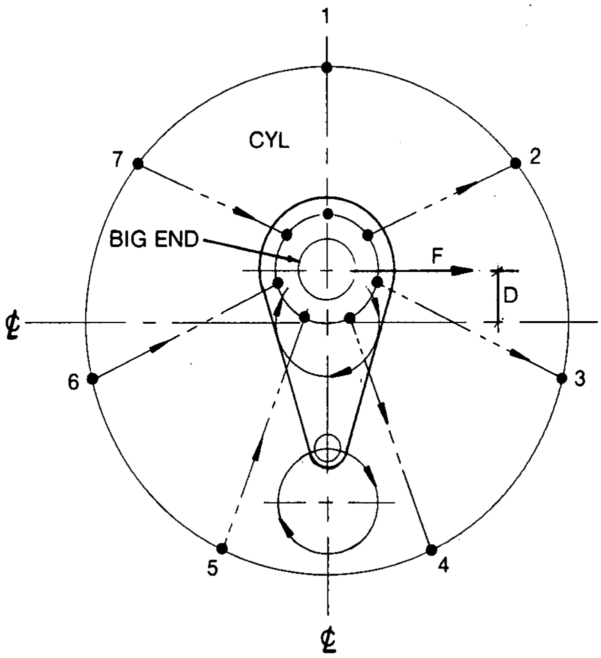

FIGURE 2 Application of Forces in the motor

are very simple parallel cams with only the lead in and out being critical. This is where the timing and introduction of the force is controlled.

All the internal bearings throughout the motor are 'acetal resin polymer' coated onto thin steel backings and in this particular case supplied by Glacier Bearings in the form of their DX material. These bearings have long life with initial lubrication but should be relubricated by hand from time to time. The bearings are easy to replace and relatively inexpensive.

The coefficient of friction of the bearings is low, in the region of 0,10 at the design pressures, and 'stick slip motion' does not occur. This makes them particularly suitable for the very slow speeds.

Specific Features of the Drive at Maidstone

HM 275 Motor Specification

(1) Specific torque 13,83 kNm/MPa
(2) Maximum working pressure 20 MPa
(3) Maximum design torque 275 kNm
(4) Motor displacement 86,9 litres per revolution
(5) Speed range 0 — 1,2 r.p.m.
(6) Overall outside diameter 3 600 mm
(7) Depth (face-to-face) 600 mm.

The motors have 7 double acting cylinders, 125 mm diameter × 70 mm diameter rod × 600 mm stroke. The cylinders act onto a main pin (200 mm diameter) with a 135 mm hole through the centre for cooling water access. This main pin is made from EN 24 heat treated to condition U.

The pistons of the cylinders are fitted with cast iron rings and the rod seals are the only seals which will require replacement. If a rod seal should leak, the motor is stopped, the hydraulic valve actuating that particular cylinder is isolated, the cylinder removed and the motor restarted.

The entire unit as can be seen from figure 3 is a seven pointed star-shaped frame with the points of the star connected with tension bars. It is of mainly bolted construction using fitted bolts throughout and the plates are 20 mm thick. The mode of operation and how the parallel orbit of the master conrod allows the hydraulic cylinders to continually exert force on one point is clearly shown in Figure 3.

The overall mass of the motor excluding the power pack is just short of 5 tons and the reason for the high mass is the heavy construction required to take the forces created by each hydraulic operating in turn.

The rod end pins of the rams are 100 mm diameter and 200 mm long, the restraining bolts holding the tension arms are 50 mm in diameter by 200 mm long, the master conrod has an overall length 1 650 mm and is fabricated in 12 mm plate filling the space between the side plates and the main crankshaft cheekplates are cast in SP600 Meehanite and are 1 000 mm diameter ranging between 140 and 200 mm thick. These dimensions explain the approximately 5 ton mass of the motor.

In Figure 3 two hydraulic transducers attached tangentially at either side of the motor are also shown. The rationale for these units is that experiments are to be undertaken to measure

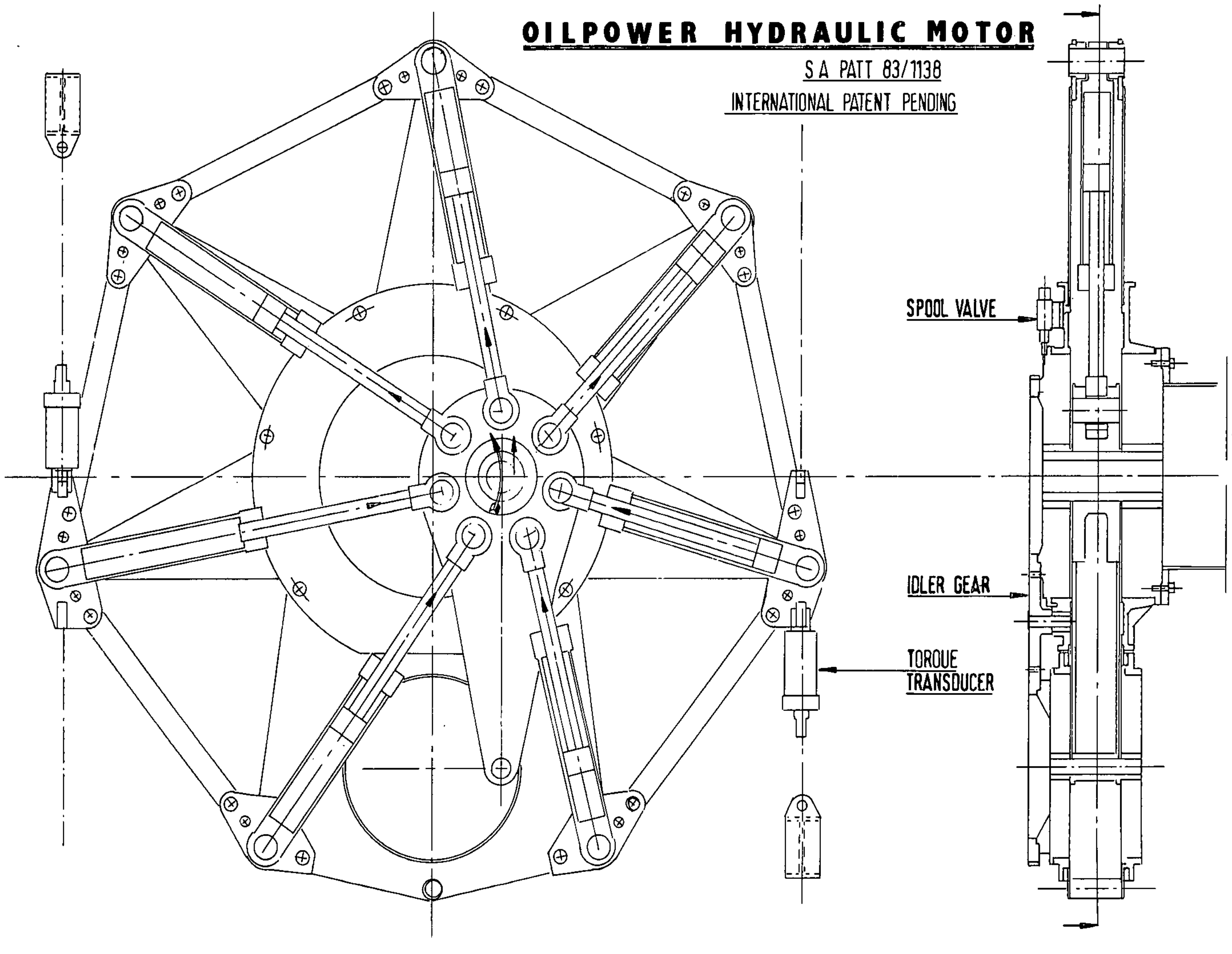

FIGURE 3 General arrangement of the motor

accurately the actual power input to the cyrstallisers at various brixes and temperatures of massecuite.

The motors are flange mounted directly on top of each rotor element and restrained by two opposing chains.

Teething Troubles

Hydraulic Actuation

The model used for demonstration, together with the first commercially sized unit, driving a Blanchard-type horizontal crystalliser, suffered from a problem of too rapid switching of the pressure oil supply to the cylinders. The reason for this was that the switching on and off of the pressure or drain to the cylinders was controlled by micro switches, running with rollers on the directional cam.

It was found in the final unit that it was preferable to have these valves switched using a cam operated hydraulic spool valve, and thus softening the 'knock' on the cylinders. As a result of this, the entire unit became hydraulic and had no electrical control whatsoever.

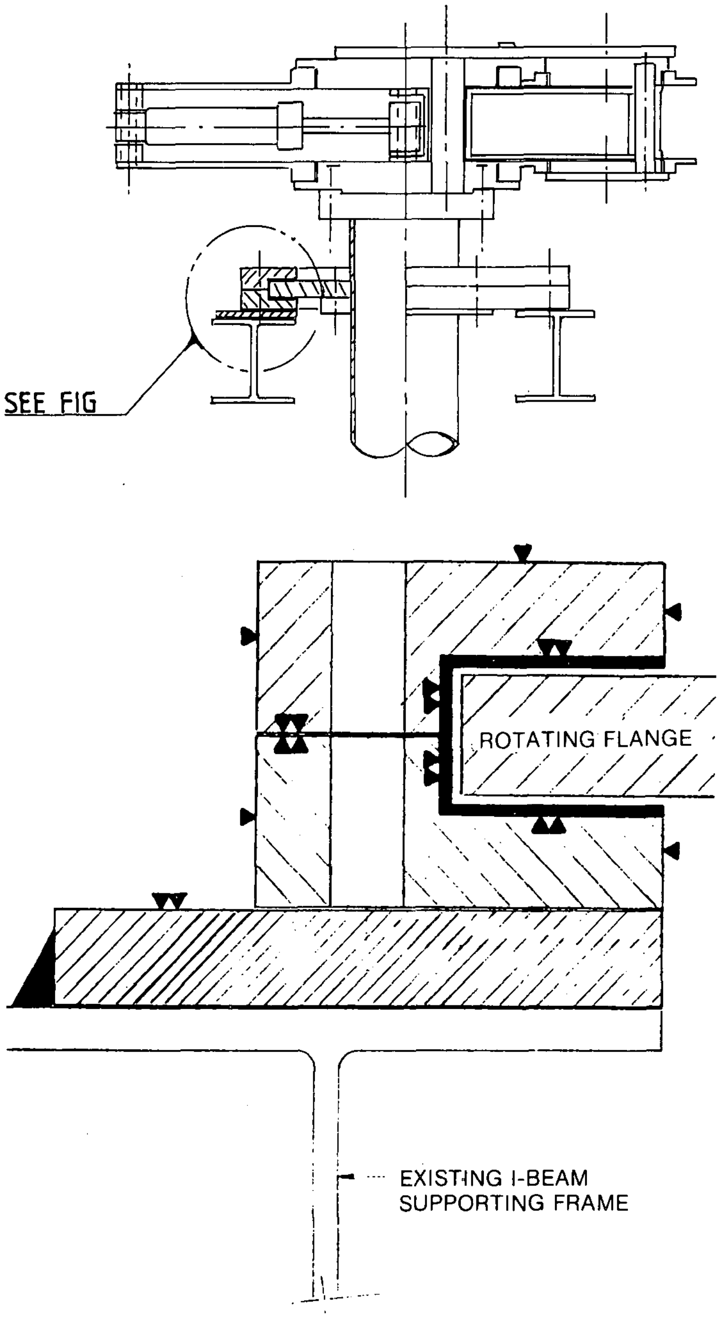

FIGURE 4 Axial bearing arrangement

Axial Bearing Support

Because these motors were to be used in the vertical position, and have no inherent internal axial thrust bearings, it was necessary to design the thrust bearing to accept the deadweight of the rotor element as well as the approximately 5 tons of the motor itself, although in operation under normal circumstances the rotor element very nearly floats in the massecuite.

In Figure 4 a simple axial bearing arrangement with an additional radial facility using SKF material which requires grease lubrication approximately once every six months is shown. It is interesting to note that in this particular installation the cost of fabrication and machining of the bearing housing and bearing materials was no more expensive than installing a spherical roller or taper axial thrust bearing.

Alignment of the Bearing Faces

As no facility was available for machining the bearing faces on the top end of the rotor element prior to installation, and it was considered essential that these faces be absolutely true to the centre-line of the shaft, it was necessary to find a means whereby the face could be positioned exactly normal to the axis of the rotor element.

In order to do this, the services of a surveyor were called upon and, with the use of a theodolite, it was possible to weld a stub-shaft with a pre-machined bearing surface on it, to an accuracy of ± 0,01 millimetres.

This was considered to be sufficiently accurate to prevent any excessive wear through cork-screwing of the bearing surfaces.

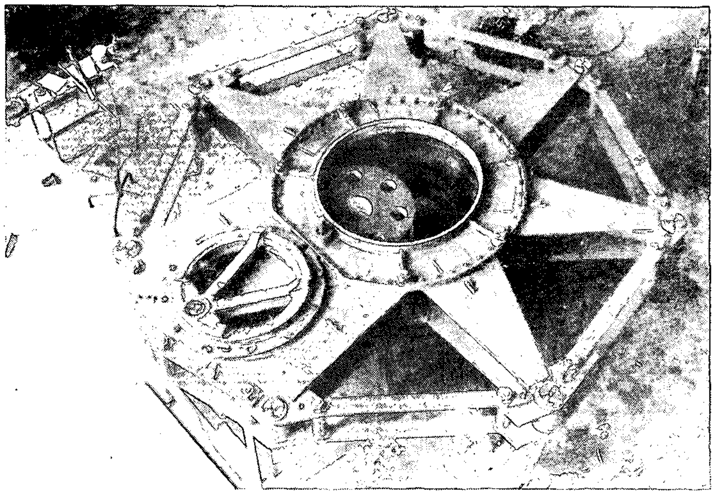

FIGURE 5 The basic frame

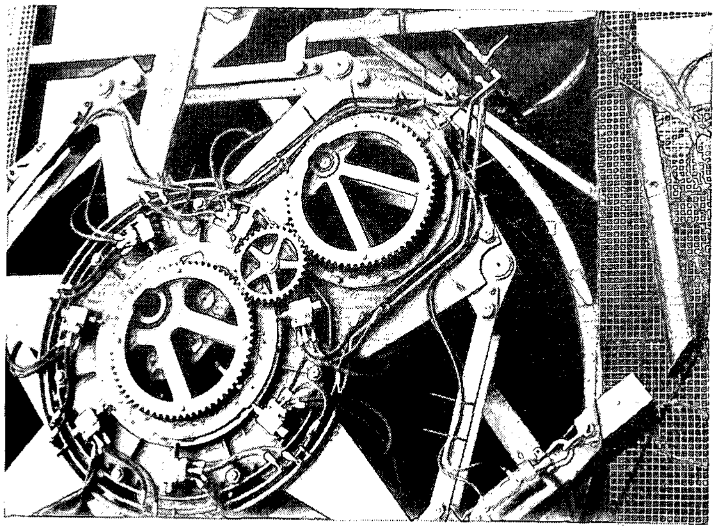

FIGURE 6 The assembled motor

Maintenance

The basic need of all hydraulic systems is that they must operate with 'clean' oil — this is something which is foreign to much sugar mill engineering and therefore all precautions must be taken to ensure that the oil is as clean as possible.

Three filters are employed for this purpose:

(a) filling the power pack;

(b) return oil from the circuit; and

(c) pressure oil en route to the power cylinders.

If there should be a problem on this particular motor, in the form of a ram failure, it is possible to stop the crystalliser, isolate the offending unit, and re-activate the drive; losing only (1/7th of 290/360) or 11,5% of the performance.

There are, however, some trade tricks to stripping and repairing hydraulic cylinders such as these, and it is advisable to refer to the suppliers before undertaking the dis-assembly of a cylinder.

Conclusion

At the time of submission of this paper the motors had just been installed and commissioned and therefore no power pressure or speed analyses have been possible. The commissioning was totally trouble free and there is no doubt that the motors will prove successful in this particular duty. It is quite possible that they would prove suitable for high torque slow speed installations such as pressure feeder drives or diffuser drives. The estimated overall dimensions for a drive for a diffuser of say 200 ton per hour at 16½ fibre would be two motors 6 m diameter by 1 m wide.