NATAL'S FIRST TURBINE MILL DRIVE

By G. W. HEDGCOCK

It would appear from the requests made by engineers and other technicians in the Sugar Industry that a paper on the turbine mill drive at Umzimkulu would be welcome.

Obviously there is no more favourable occasion for the reading of such a paper than the Annual Congress of this Association.

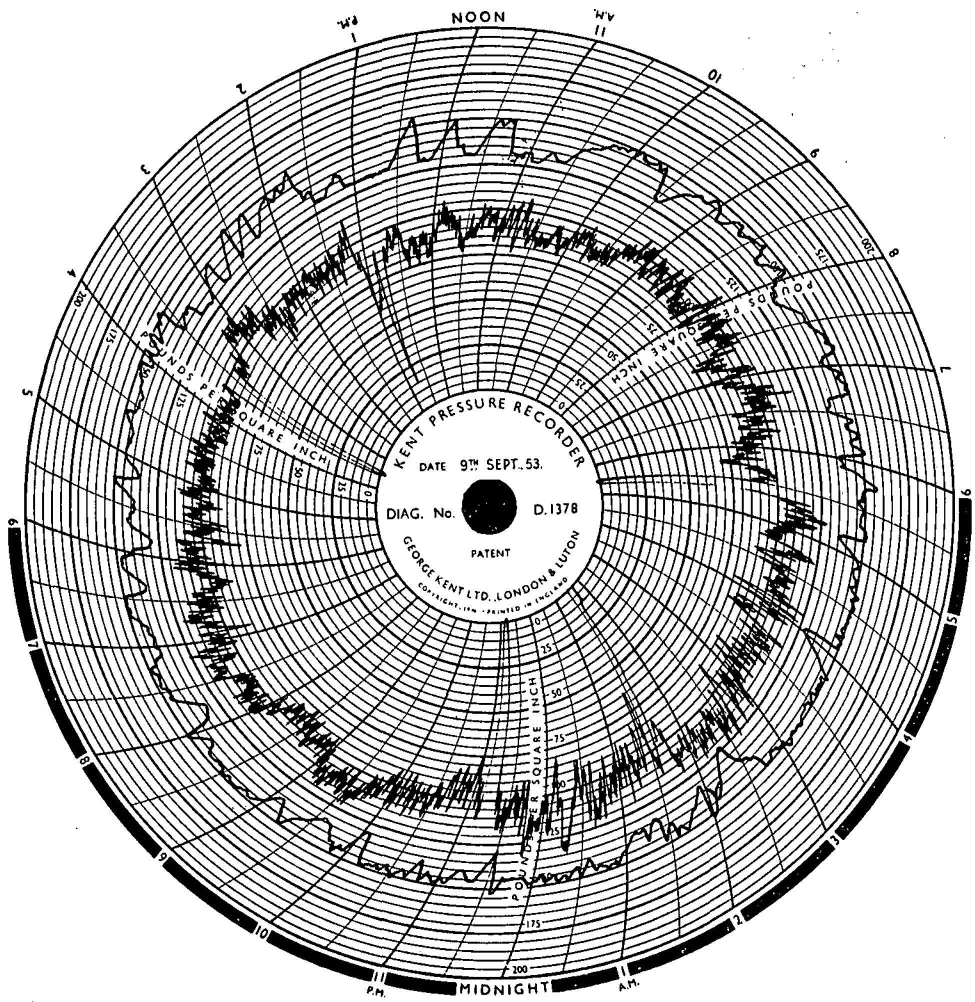
The idea of installing a mill turbine drive at Umzimkulu originated when it was realised that it was no longer economical to maintain the 1900 vintage horizontal reciprocating steam engine in a reasonable state of repair. This engine, a 24″ x 48″ stroke, slide-valve type, had been driving a two-roll crusher and two mills 28″ x 56″ through primary and secondary gearing with an overall ratio of 19.4:1, and a normal crankshaft speed of 45 r.p.m.

There were, of course, alternative arrangements to consider, for example, another horizontal engine to run at 50 r.p.m. or a vertical high-speed engine with reduction gear at 50 r.p.m.

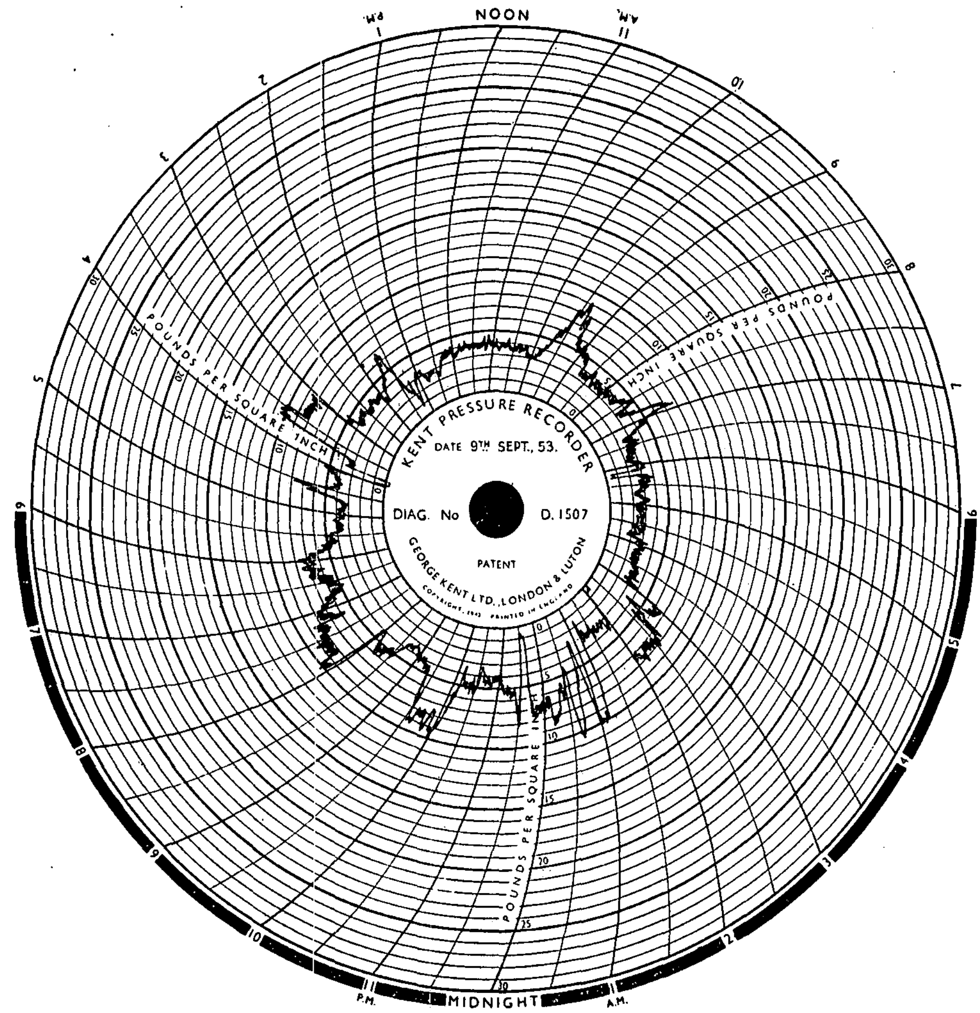
The turbine and reduction gear drive were selected on account of the low cost and reasonable time of delivery; other factors such as steam consumption, available floor space, etc., were not controlling.

Ultimately, Messrs. Mirrlees Watson delivered a 300 h.p. single-stage axial-flow machine, to operate at 160-lb. per square inch with 100°F. superheat and exhausting at 10-lb. per square inch. The steam consumption at full load was estimated at 37.8 lbs. per h.p. hour and the maximum speed arranged for was 4,000 r.p.m. A fabricated steel-cased gear box contained the double reduction gears to reduce the speed at the output shaft to 50 r.p.m.

It may be of interest to note that the shipping weight of the complete unit was just over nine tons.



APPENDIX I



APPENDIX II

The body of the turbine is of cast iron, split horizontally, with two white metal lined water cooled bearings, the whole carried on supports cast as part of the bottom portion of the casing. This portion also holds the nozzle box, containing six fixed and three variable nozzles and also one row of fixed blades opposite the nozzle outlets. A nickel steel shaft 2½″ in diameter carries the forged steel rotor, barely 30″ in diameter, which carries two rows of stainless steel blades. An efficient seal on the shaft is maintained by three carbon rings on each side of the rotor. The oil pump is mounted on the free end of the shaft and a bibby type coupling between turbine and gear case on the other.

All gearing shaft bearings are white metal lined, and, like the rotor shaft bearings, are lubricated under pressure, while the gears are spray lubricated from the same supply.

The high-speed spindle is extended with a square end through the gear case away from the turbine. This square is used for turning the machine in reverse or as required.

The setting up of this plant was comparatively straightforward. The old engine foundation was cut away only where necessary to clear the exhaust line, oil return pipes and oil supply tank, and the new concrete was cast over the old block and into the flywheel pit to a depth of six feet. The engine crankshaft was cut approximately through the flywheel seat and a solid coupling fitted to match the output shaft coupling of the gearbox. Lining up was worked back from this crankshaft coupling face.

A new pinion was used to replace the old crankshaft pinion. It was felt that the wear which had taken place on the old pinion would not be uniform, but concentrated on two groups of a few teeth each situated at 180° from one another, due, of course, to the pulsating power output of the replaced reciprocating engine.

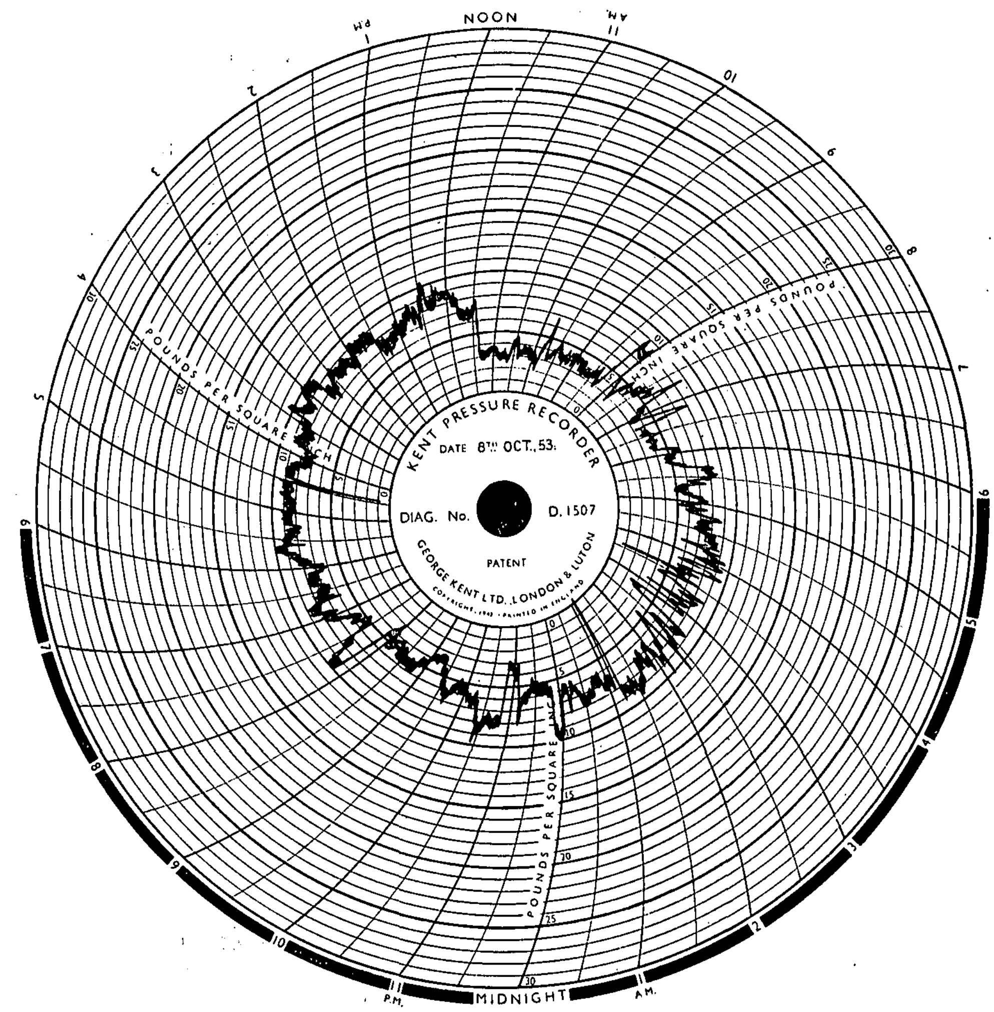
Precautions taken with the steam lines were, in the case of the 7″ exhaust, a spring-loaded support at the second bend away from the machine, and in the case of the 4″ live main, a copper bend against the stop valve. The 4″ line was connected to a steam separator in the main range.

An instrument panel mounted near the machine contains three pressure gauges, indicating nozzle steam pressure, exhaust pressure and lubricating oil pressure; and two meters, one recording both stop valve and nozzle steam pressure, and the other recording exhaust pressure.

A tachometer, indicating turbine speed and roll speed in feet per minute, and control buttons, are also fitted to this panel. These are duplicated on a panel on the mill platform for remote control.

The governor, which has not been referred to so far, is of American design and manufactured by the Woodward Governor Company and is an entirely independent unit. It is mounted on the side of the gear casing and driven through bevel gears by the intermediate gear shaft. It is of the hydraulic type with a self-contained oil pump. The work capacity is approximately 8 ft. lbs.

The remote control servo motor adjusts the spring tension on the fly ball. Under working conditions



APPENDIX III

the governor proved extremely sensitive, controlling speeds from 1,000 to 4,000 r.p.m. irrespective of the load demand.

During the crushing season an experiment was carried out as follows:—

The turbine was run up to 2,500 r.p.m. with the mills empty. This was found to be the maximum comfortable speed at no load, so far as the open gears were concerned. The feed was then brought into the mills until the second mill top roll had lifted to ¼″ to the normal working position, and without any adjustment to the speed control or nozzle settings, the turbine speed had remained constant at 2,500 r.p.m. Observations under the two conditions were:—

	Mills Empty	Mills Full
Speed of turbine	2,500	2,500
Nozzle pressure	23	120
Exhaust pressure	1	5
Calculated h.p.	20	150

This indicates excellent governing.

Another feature of the governor is the inclusion of a load limit control and load indicator. The load limit can be set to limit the maximum output of a machine to any power within its capacity. This is most valuable where a machine has been installed of greater power than is immediately required, and where there may be fear of damage to the driven machinery to which it is coupled, should the full power be transmitted.

Some doubt was felt about the ability of the turbine to start up with the mills full, as would be the case after an emergency stop. This fear, however, was found to be completely groundless as on opening the turbine stop valve, full speed was attained within a matter of seconds.

This starting under load was accomplished with apparently so little effort that subsequent stops of short duration—such as are necessary to adjust a carrier slat or clear a chokeless pump—were made without emptying the mills or reducing the feed.

Appendix I shows the nozzle pressure chart chosen as an illustration with its frequent stops to indicate that the nozzle pressure does not rise above normal when starting under these conditions. Appendix II shows the exhaust card for the same period.

While the mills were crushing at a reasonable rate the factory heat balance seemed to be fairly good, but later in the season when, due to a falling off in cane deliveries, it was necessary to reduce the grinding rate by 15 per cent., exhaust pressure rose as indicated in Appendix III. This shows that the steam prime movers were passing more steam than the boiling house required when handling the reduced quantity of juice. This coming season a higher crushing rate is anticipated with the hope that steam consumption, and thus fuel consumption, will be reduced.

The steam consumption of the turbine (37.8 lbs. per h.p. hour when developing 300 h.p.) increases, according to a curve supplied by the makers, by 10 per cent. when developing 200 h.p. and by 37.5 per cent. when developing 100 h.p.

The step taken at Umzimkulu in installing this modern drive was certainly one in the right direction, and now that sugar factories in South Africa are operating boilers of higher pressures than was the case a few years ago, it should not be long before a fair percentage of the mills are driven by turbine.

Mr. Bentley said that the subject of turbine drives was of growing importance to our Industry. It was interesting to note that this unit with its gear-box was coupled up with a solid coupling to the existing gearing, and, in spite of the fact that a new pinion was fitted, was it not possible that heavy shock loading might be transmitted back to the new gears from the old gears? To avoid this a flexible coupling between the turbine gear-box and the old gearing was surely worthy of consideration.

A further point of particular interest to factory engineers was that the steam passing through a turbine was at no time in contact with lubricating oil, as was the case with reciprocating engines, and it passed out to process and eventually back to the boilers as feed-water completely free of any contamination.

As regards steam consumption of a turbine drive, the fact that this might be high when the turbine was not running at its rated horse-power was not to be considered of primary importance. To quote Mr. Northcroft; an eminent authority on the use of steam, "The best form of reducing valve is the steam engine." In a sugar factory a large proportion of the steam is required for the process at low pressure and to generate it at high pressure, drop the pressure in an engine by doing useful work and then make use of the latent heat for process work, is certainly more efficient than passing high pressure steam to the exhaust range through a reducing valve.

Mr. Hedgecock replied that a turbine drive had been chosen on account of its low cost and it was felt that a flexible coupling on the output side of the gear-box would be a costly item, as it would be fairly large. Every precuation was taken with the fitting up of the old gearing shaft, which was machined and then lined up as a whole with the slow speed shaft in the gear-box.

Mr. Main asked if the figure of 37.5 lbs. of steam per B.H.P./Hr. for the mill turbine was actually recorded as such. It was common practice these days for sugar factory turbo-alternators to operate on 28 to 35 lbs. steam per B.H.P./Hour and the figure of 37.5 lbs. seemed rather high.

Mr. Hedgecock said that the figures given were supplied by the makers, and that it must be remembered that the machine referred to was only a single-stage unit. Such units were not as economical on steam as the multi-stage turbines which were used where steam consumption was important, but of course, the multi-stage machine had a higher initial cost.

Further to Mr. Bentley's remarks he agreed that as he had removed an old engine in a poor mechanical condition, which probably used 50 lbs. of steam per H.P. Hour, the turbine consumption had not been considered as very important when choosing a replacement mill drive.

Mr. Walsh mentioned that Empangeni was installing three turbine-drive units. There were certain problems in connection with turbine drives for mills which might not be apparent at first sight. It must be remembered that a turbine ran at a very much higher speed than the ordinary steam engine, and any small variation required in mill roller speed meant a very large variation in the turbine speed. He thought that the figure for steam consumption mentioned could only apply when the turbine was running at its most economical speed. To illustrate this point he quoted some figures for a steam turbine drive, basing these on an inlet steam pressure of 145 p.s.i.g., 100° superheat and an exhaust pressure of 10 lbs. p.s.i.g.

Speed R.P.M.	B.H.P.	Steam lbs./hour	Consumption lbs./BHP/hr.
5,700	550	18,600	33.8
5,000	550	19,100	34.7
4,500	525	19,100	36.4
4,000	485	19,100	39.4
3,500	440	19,100	43.3
3,000	390	19,100	49.0

The following are the steam consumptions at various powers below full load, at the maximum speed of 5,700 r.p.m.

	Steam Consumption	
B.H.P.	lbs./hour	bsl/BHP/hr.
500	16,500	33.0
450	15,500	34.5
400	14,500	36.2

It will be noted from the above that at 3,000 r.p.m. and at 390 B.H.P. the total steam consumption is actually more than when running at 5,700 r.p.m. developing 550 B.H.P. For the actual load conditions shown in the paper, he considered similar conditions would apply, and that when running a turbine much under capacity, to obtain real economy the machine would have to be run near its most economical speed. This was not the case with the ordinary steam engine.