ELECTRICAL ACTIVITIES OF NATAL ESTATES.

By J. B. M. GODFREY.

Mr. Chairman and Gentlemen,

Before commencing this paper, I have to thank Dr. Hedley and his Committee for the privilege they have conferred on me in asking me to prepare and read this paper. This is the second Electrical paper read since the inception of the Technologists Association, the first being read in March, 1926. I have endeavoured to make this paper as interesting as possible, by covering the whole of the Natal Estates Electrical activities, to relate of troubles, their causes, and how they have been remedied, and I have divided these into six sections as follows:

- Power Plant
- Distribution
- Milling Plant Equipment (Electrical)
- Outside Estates
- Umgeni Irrigation Scheme
- Maintenance and Operating Experiences
- General

POWER PLANT.

The original power station erected early in 1921, contained 2 - 300 K.W. Belliss and Morcom S.A.G.E. high speed engine generating sets, to which a further 2 sets were added by 1927. This gave a total output of 1,200 K.W.

In 1928 it was decided to embark on the Umgeni Irrigation scheme for which the initial power requirement was 1,400 K.W. so, after protracted negotiations with the Durban Corporation, and very careful investigation on our own, it was finally decided to erect a new power station, capable of considerable future enlargement to supply the whole irrigation scheme with power from our own generators.

The chief reasons for this decision were, that we could generate power at a very much cheaper rate, we should have no restrictions placed upon us, and would therefore be able to pump for 24 hours. Finally, when the milling plant would be completely electrified it would be possible to operate the Power Station at more or less full load without the expense of a stand-by unit. In the case of one unit being shut down for adjustment or repair during the crushing season it would be necessary to stop pumping, but so far this has not occurred. The results have in every respect more than justified the expenditure, as you will see from the costs given later.

In 1928 we issued specifications calling for tenders for one 2,000 K.W. Turbo-generator set, complete with condenser, one main switch board, 7,600 K.V.A. single phase transformers 2,200/22,000 and 7 miles of transmission line material.

The first unit, commissioned in 1930, was a 2,000 K.W. Belliss and Morcom Turbine of the condensing and pass out type, running at 3,000 R.P.M. Steam pressure 160 lbs. sq. in. at 150°F. superheat. The turbine has 14 stages, and with full load on the alternator, passes out 49,000 lbs. of steam per hour at 10 lbs. sq. in. pressure to the factory.

The main governor is of the vertical centrifugal spring loaded type, operating, through an oil relay, system of 40 lbs. sq. in.

The emergency governor is both distinct and remote from the main governor being fitted at the end of the main shaft, and of the concentric unbalanced ring type, and easily adjustable.

The governing of the unit has proved to be very good and fully automatic over a wide range, which, when considering the varying demands made on the turbine, the varying loads on the alternator and the demand for exhaust steam from the factory is certainly most satisfactory.

Of the surface type, the condenser has a cooling area 3,050 sq. ft. the body is of cast iron, while the tubes, and supporting plates are of Muntz metal (in which no signs whatever of corrosion are apparent). The air pump is a two stage steam ejector type and an advantage is found in that the condenser end doors are swung on ball bearing hinges.

The condensate and circulating water pumps are both two stage electrically driven centrifugal pumps of 38 H.P. and 32 H.P. respectively.

168,000 gallons of cooling water are required per hour at a temperature of 80°F, but in the warmer months this temperature rises on occasions to as much as 100°F. The condenser cooling water is drawn from the original main pond from which also the factory evaporators and vacuum pans draw 320,000 gallons per hour. A new concrete lined cooling pond is under construction and will be used solely for the power station requirements.

The bulk of the steam is supplied from a battery of bagasse fired B. & W. water tube boilers, while two marine type B. & W. mechanically stoked coal fired boilers supply the necessary make up steam. Pressure at the turbine stop valve averages 140 lbs. per sq. in. at a temperature of 480°F.

The turbine is coupled direct through a flexible coupling to an A.S.E.A. electric 3 phase 50 cycle alternator, the pressure being 2,200 volts, the exciter of 18 K.W. capacity is direct coupled to the rotor shaft. Output is 2,700 K.V.A. at 0.75% power factor.
Air for cooling the alternator enters the foundation block at the end remote from the turbine, being cleaned by passing through a Ventex air filter, built into the foundation block, before passing through the windings. We have found this air cleaning system excellent. During the summer months, with full load on the alternator the temperature of the discharged air never exceeds 150°F.

A five point Cambridge temperature detector is connected in circuit as follows, 2 points stator copper, 2 points stator iron, and 1 point exciter field. A selector switch is fitted on the front of the instrument. I should like to make special mention regarding the construction of the generator rotor which is of the parallel slot type. Unlike many other makes this rotor has no end bells, the coils being embedded in the ends of the rotor body and it is therefore impossible in case of overspeed for displacement of the windings to take place. Insulation between turns and core is of oxidised aluminium strip which has that desirable property of increasing in resistance with increase in temperature.

The steam consumption, condensing with steam at 150 lbs. pressure, temperature 480°F, vacuum 27.5, bar 30 H.G. with full load on the alternator, is 15 lbs. of steam per K.W.H. and when passing out 49,000 lbs. of steam per hour is 30.5 lbs. of steam per K.W.H.

During 1930, this unit was operating in parallel with the old power station, and it was found to be more economical to load up the turbine and let the engine high speed generating set supply the balance of the load.

This machine working in conjunction with the old power station, supplied the requirements of the factory and outside plants until 1932, when a second unit was installed. This unit was also a 2,000 K.W. similar in all respects to No. 1 machine excepting only that the turbine has no condenser, being of the straight back pressure type and the voltage is 550 instead of 2,200. In the same season there was installed the first section of the new electrically driven milling plant, consisting of a crusher motor 420 H.P., 1st and 2nd mill motors each 420 H.P., Searby Shredder motor 350 H.P., and cane knives motor 300 H.P.

This second unit was operated in parallel with No. 1 through two English Electric 1,500 K.V.A. coupling transformers, ratio 550/2,200 wound star/star. As the factory load was creeping up with the increased tonnage crushed per hour, in 1933 it was decided to complete the milling installation by installing the 3rd and 4th mills, each being driven by 420 H.P. motors and a 180 H.P. CO2 compressor. This led to the decision to install a third Turbo generator set. This unit is similar in detail to the No. 1 set but is 550 v. and will cover any increase of load in the immediate future.

With this power available it was next decided to order the 4th pumping unit of 600 H.P. for the Umgeni scheme also one of 115 H.P. for the Saccharine Estate followed by a 300 H.P. plant for the Sir Marshall dam, all of which are now installed.

The current sent out from the power station in 1921 was 1,800,000 units and for the year ending October 31st, 1933, it was 16,493,080 units, while we anticipate reaching the 18,000,000 mark or more during the current year, thereby bringing our costs still lower.

The main switch for the No. 1 set is Messrs. Reyrolle's iron clad, compound filled design, 800 amp 2,200 v, remote controlled, and solenoid operated. The voltage pressure is automatically regulated by a B.T.H. regulator. On this panel is the governor servo motor switch for controlling the speed of the turbine, but it is very seldom used as the speed scarcely varies between no load and full load. The exciter field has an automatic switch, protection is provided by a polyphase overload relay with current and definite time limit settings, and is so interlocked that it is impossible to close the alternator switch with the exciter field switch in the "off" position.

In connection with this unit are 2 Reyrolle panels each of 600 amp capacity protecting the 2,200 v. side of the 1,500 K.V.A. coupling transformers through which this machine is paralleled with the other two machines, all of which feed a main bus. The bus-bars are hard drawn copper, three bars in parallel per phase each of a cross section of 90mm. x 10mm. Nos. 2 and 3 machines (350v.) supply the main bars direct through 3,000 amp switches by A.S.E.A. Electric, London. These switches are also remote controlled and motor operated. A novel feature of these two panels is the new high speed A.S.E.A. voltage regulator from which perfect voltage regulation is obtained. It is very small, foolproof and simple with only one pair of contacts, the life of which seems to be indefinite.

We decided to house the main generator switches in the condenser basement at the end of the alternator foundation block. This has been found to be an excellent arrangement, giving ample access for maintenance and overhauls.

An interesting feature is that the neutral points of the 2,200 and 550 v. machines are earthed through a single phase 10 K.V.A. transformer, the secondary winding of which is short circuit through fuses with a voltmeter connected across the secondary. In the event of an earth fault occurring, out of balance current flowing in the neutral, the fuse blows, an alarm bell rings and the pressure to earth is recorded on the voltmeter. This has been found very helpful, and more reliable than the more ordinary lamp earth detector, acting as protection to the generators and the plant generally. As an earth fault occurs each outgoing feeder panel
UNITS SENT OUT FROM POWER STATION

ANNUAL COST PER UNIT

FACTORY LOAD

IRRIGATION LOAD

Fig. 2.
is tripped singly until the faulty one is located (needless to say its usually the last), then it is easy to locate the unit at fault. We had four partial earths on the system last crop where the faults proved to be inside starters. By immediately attending to an earth or other fault, what might have been a serious flash over of switch, or starter, or even a complete cable breakdown can be averted as well as the loss of time, which would result from having to shut down the crushing plant while more serious repairs were affected.

In locating an earth fault we have never had to stop the mills for a minute, and as the whole outfit is not costly I would venture to suggest that all factories might be similarly equipped.

On the 22,000 v. system the neutral is also earthed so that immediately a fault occurs the 22,000 v. switch is automatically tripped by a small relay in circuit with the earthing transformer secondary.

The power station switch board consists of:

1 Reyrolle alternator and Exciter panels 800 amps, 2,200 v.
4 Reyrolle feeder 600 amps, 2,200 v.
1 Reyrolle feeder and Exciter panels 100 amps, 22,000 v.
2 A.S.E.A. Electric Alternator and Exciter panels 3,000 amps, 550 v.
8 A.S.E.A. Electric Feeder and Exciter panels 500 amps, 550 v.
9 S.A.G.E. Co panels 500 amps, 550 v.
1 S.A.G.E. Co panels 200 amps, 2,200 v.

When the old power station was discarded at the end of the 1931 crop, the feeder panels were transferred into the new power station in order to have all the main outgoing feeders housed in the one building and under constant supervision.

Half hourly readings of all switchboard instruments are taken and logged throughout the crop as also are the temperatures of the alternator windings, bearings, main turbine bearings, steam at stop valves, steam range temperature and pressure, temperatures of incoming and outgoing cooling water, oil cooler temperatures and vacuum.

All the Ammeters for the mill motors are of the chart recording type, and all charts are charged daily, planimetered, averaged and recorded.

Recording and integrating steam and water flow meters record the flow of steam to the power station, the exhaust returned to the factory, water evaporated in each boiler and the condensate from the condensers. All power consumed by power station auxiliaries is debited to the Power Station in assessing costs.

All alternator and feeder panels are provided with three overload relays with definite time and current settings. The tripping circuit for the Board is 110v. D.C. and is supplied from an Exide battery which also supplies the pilot lights on the switch board.

The alternator terminals are connected to the bus-bars by bare copper connections enclosed in iron ducts. All machines are kept warm by means of enclosed heaters near the air intake to the alternator inside the foundation blocks and are so arranged that whenever a machine is tripped, the drying out gear is automatically switched on. This we have found to be very important and to which I will refer later under the heading of maintenance.

The power generated supplies over 200 motors in the factory and outside estates ranging in size from 2 to 600 H.P. The voltage of all factory motors is 550 while the larger Irigion motors are wound for 2,200 volts.

Statistics showing total annual output of the power station for 1921, 1930, 1931, 1932 and 1933 and the cost per unit, are as follows:

(See Fig. 2.)

<table>
<thead>
<tr>
<th>Year</th>
<th>K.W.H.</th>
<th>Cost per K.W.H.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921</td>
<td>1,800,000</td>
<td>.39d.</td>
</tr>
<tr>
<td>1930</td>
<td>5,287,097</td>
<td>.209d.</td>
</tr>
<tr>
<td>1931</td>
<td>7,287,068</td>
<td>.236d.</td>
</tr>
<tr>
<td>1932</td>
<td>9,397,893</td>
<td>.165d.</td>
</tr>
<tr>
<td>1933</td>
<td>16,493,080</td>
<td>.196d.</td>
</tr>
</tbody>
</table>
DETAILED COST SHEET FOR 12 MONTHS ENDING OCTOBER 31st, 1933.

OUTPUT 16,493,080 units.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Salaries</td>
<td>£836 8 6</td>
</tr>
<tr>
<td>Indian and Native Wages</td>
<td>£205 19 0</td>
</tr>
<tr>
<td>Running Repairs and Annual Labour (European)</td>
<td>£395 3 4</td>
</tr>
<tr>
<td>&quot; &quot; &quot; &quot; (Native)</td>
<td>£67 13 9</td>
</tr>
<tr>
<td>Lubrication</td>
<td>£52 2 11</td>
</tr>
<tr>
<td>Water Service</td>
<td>£51 5 0</td>
</tr>
<tr>
<td>General Stores (includes new oil filtration system)</td>
<td>£473 19 9</td>
</tr>
<tr>
<td>Power and Lighting</td>
<td>£87 4 10</td>
</tr>
<tr>
<td>Head Quarter charges</td>
<td>£261 0 0</td>
</tr>
<tr>
<td>Steam</td>
<td>£8,597 15 3</td>
</tr>
<tr>
<td>Interest on Capital</td>
<td>£2,411 12 6</td>
</tr>
</tbody>
</table>

Cost per unit this period: £13,471 4 10
Cost per unit for off-crop condensing and consuming coal only: .196d.
Cost per unit during the crop: .242d.
Cost per unit no charge for steam: .150d.
Cost per unit for steam: .072d.

Total units sent out at .196: 16,493,080
Factory: 9,125,654
All irrigation plants: 7,367,426

Saving by not purchasing current externally, viz.: £7,367,426

<table>
<thead>
<tr>
<th></th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>£13,471 4 10</td>
<td>£6,016 14 7</td>
</tr>
<tr>
<td>£7,454 10 3</td>
<td>£9,332 1 4</td>
</tr>
</tbody>
</table>
Fig. 1. Power generated in power station and power supplied to navigation pumps.

Power generated 1930-1931

KwH

800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000

May June July August September October November December January

Power supplied to navigation pumps
U.S. Department of Agriculture, Division of Irrigation, Anaheim, Calif., October 25, 1933.


[Graph showing weekly readings for irrigation pumps from 1932 to 1933, with months listed on the x-axis and kilowatt hours on the y-axis.]
FACTORY DISTRIBUTION.

The distribution of power to the factory is by means of 7 outgoing feeders and is sectionalised as follows:

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>K.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Estate power lines, mealie mill</td>
<td>1,075</td>
</tr>
<tr>
<td>2</td>
<td>Boiler House No. 1</td>
<td>1,935</td>
</tr>
<tr>
<td>3</td>
<td>Curing House No. 1</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Clarification</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>Curing House No. 2</td>
<td>120</td>
</tr>
<tr>
<td>6</td>
<td>Boiler House No. 2</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>Injection water and Vacuum Pans</td>
<td>160</td>
</tr>
</tbody>
</table>

Total K.W. 1,075

Milling Plant Load 550 v.

Each unit has its own power station feeder switch as follows:

- Crane for off loading cane: 45 K.W.
- Cane Knives: 120 K.W.
- Crusher: 120 K.W.
- Shredder: 200 K.W.
- 1st Mill: 160 K.W.
- 2nd Mill: 140 K.W.
- 3rd Mill: 150 K.W.
- 4th Mill: 140 K.W.

Total K.W. 1,075

Irrigation Load 2,200 v.

- Umgeni Irrigation: 1,800 K.W.
- Saccharine Irrigation: 80 K.W.
- Mt. Edgecombe Irrigation: 95 K.W.
- Ottawa Estate: 110 K.W.
- Sir Marshall Dam: 200 K.W.

- Total: 2,285 K.W.

Total K.W. 2,285

Umhlanga Rocks Lighting, etc.: 70 K.W.

Total K.W. 2,355

Capacity of Power Plant installed: 6,000 K.W.

Load taken by factory and all outside plants: 5,295 K.W.

Possible surplus load as at May 1st, 1934: 705 K.W.

Behind our station 550v. bus-bars and running parallel with them are the bus-bars which supply the Corporation current. Between the two sets of bus-bars are connected double throw links on each of the 7 factory distribution panels so that any one panel may be linked on to the Corporation supply. This layout is found very useful as we take a supply from this source for our bagasse conveyors in starting up on Sundays and after the boiling off is completed in the factory on Saturday evenings, instead of keeping one 2,000 K.W. machine running for a load of say 200 K.W. It is also useful for trying out units on Sunday morning which have been under repair and during the off season when not irrigating. We have also a bus-bar coupling switch.

From the distribution panels in the power station current is supplied to distribution and sub-distribution switchboards which are placed at central distribution points in the factory. These are supplied by means of 3 core paper cable. They are of the unit type comprising 3 pole switches, cast iron bus-bar chambers and pedestals. Twelve years ago we started casting the bus-bar chambers and pedestals in our foundry and have continued it ever since. Our moulder always keeps some in stock for any extensions found necessary. I find it makes a clean straight forward distribution system. Foolproof and almost dustproof. It is worth the extra expense in place of any other system involving wall mounted switches, V.I.R. bus-bars supported on bobbins, etc. Again, they are there for all time. Every motor has its own switch so that the interruption of one motor does not affect any other. The cost of casting and machining these chambers and pedestals is very low as they are usually done during a slack period.

All connections from distribution boards to the starters and motors is by means of paper cable. Cable work is naturally a little more expensive but this extra expense is justified. Screwed tubing is not satisfactory as I found out years ago that condensation first takes place and trouble follows.

Most cable ends are made off in means of trifurcating boxes some of which we have also cast here.

The unit type boards are usually erected so that extensions can be made at either end to provide for any future extension.

Sometimes the motors and starters are remote from the Board, to obviate danger to life and plant and so far we have never had an accident in this respect. Precaution is taken in case of a repair to motor or starter to draw the switch, take off the operating handle and fasten on a “Danger” label.

The factory lighting distribution system is similar to that of the power side. The main transformers are located in the condenser basement but as the system has developed to large proportions we have 4/10 K.V.A. single transformers located in different parts of the factory. The total lighting load of the factory, workshops and yards is 100 K.W. The pressure is 110v. This voltage I decided would meet all requirements in 1921, and is much safer than the more usual 220 v. as we have no less than 60 portable extension lamps in use for the boilers, quadruples and vacuum pans, and no matter how careful one is, an accident might occur.
ELECTRIC DRIVE MILLING PLANT.

After thoroughly investigating the different types of motor and systems for the mill roll drive it was finally decided to employ the A.C. variable speed commutator motor out of the three systems available, viz:— 
1. A.C. Variable speed commutator motors; 
2. A.C. Variable Frequency system and rheostatically controlled slip ring motors; 
3. Direct Current motors.

It is not the purpose of this paper to thoroughly go into the pros and cons of each system.

The commutator motor makes a very straightforward job, current is supplied direct from the main 550 v. bus-bars through feeder switches, feeding through 3 core paper cable to the primary starting equipment alongside the motors, no special turbo alternators are required as are necessary with the variable frequency system or motor-generator sets as would be required if direct current was employed, current being supplied from standard turbo-alternators sets.

We are in the unique position of being the first factory in the world to employ this type of motor for driving the cane mills, although for many years past they have been used in steel works, a very much more severe duty for any motor. The arrangement in the factory has been greatly simplified by using 3 phase commutator motors, the speed of these motors is regulated by means of shifting the brush position. These motors offer the distinct advantage, in relation to rheostatically controlled motors in that no power is wasted in the secondary resistances, which for motors of this size, would amount to very considerable power loss. The complete milling plant consists of an ordinary slip ring motor with an output of 300 h.p. direct coupled to the revolving cane knives the speed being 500 r.p.m. synchronous, a similar motor is directly coupled to the Shredder, the H.P. being 350 and the speed 1,000 synchronous.

Both motors are controlled by fully automatic contactor equipment, and push button stations for stop and start located alongside their respective motors. The crusher and four mills are each independently driven by a 3 phase variable speed commutator motor, the H.P. being 420/272 at 495/320 r.p.m., 550 v. 50 cycles. These motors are designed for a starting torque amounting to 200% and are totally enclosed, air being supplied from a small fan external to the main motor, directly coupled to a 3 h.p. motor. To protect the motors from impurities in the air, the air passes through an air filter before entering the fan, and the discharged air dust is located in the main motor foundation. The motors are of very robust design.

The starting equipment for these motors is designed for operation by means of push buttons. Remote control push button stations are provided on the main gangway alongside the mills, as well as on the main control board. The individual speed regulations of the crusher and mill motors can be made from their respective push button stations, whereas the common speed regulation of all these motors is carried out from the main control platform by means of a small two-way switch, by turning the switch one way the speed of all the motors is lowered at the same time, and the speed of them all is raised by turning the switch in the opposite direction.

The motors can be started, stopped, speed raised or lowered and inched from all the push button stations as well as at the main control board, there are also four additional emergency stop buttons located in the mill house, which have been found very useful at times. By depressing one of these buttons the whole milling plant stops. Interlocks are provided between the various mills, permitting starting in the right sequence only. When stopping a motor the preceding motors also stop, e.g., when stopping the motor for No. 4 mill, the motors for Nos. 3, 2, and 1, and the crusher stop automatically when the mill motors have to be adjusted or any other repair work on the mills has to be carried out. The interlocking circuit can be opened by means of a small double throw switch in order to permit of any of the motors being started up and controlled independently. An interlock also prevents the main motor from starting before the small fan motor has started. Hence, everything being fully automatic, very little is left to the human element.

The main motor will not start on depressing the start button unless the Brush gear has been returned to its low speed position. Immediately on pushing the stop button to stop main motor the little servo motor starts up and stops automatically when the brush gear has reached its low speed position. Provision is also made that by raising the speed of all the mill motors each individual motor stops automatically, on reaching its predetermined speed.

The starting resistances are designed on the current limiting principle, the overcurrent protection relays being of the thermal bi-metal type the starting equipment, and all the resistances are mounted in a sheet metal cubicle. Cable boxes are built into the motors and also provided for the incoming and outgoing cables.

Each mill motor has an electric speed indicator mounted on the main control board. Connected to the rotor shaft at the commutator is a small generator which is connected to a voltmeter calibrated in R.P.M., then there is also the speed recorder which chart records the speed of the five mill units right through the crop, each at one minute intervals. Ammeters are provided at each push button station on the mill gangway also at the push buttons on the main control board.
It may be of interest to you to have a few notes on the development of the 3 phase commutator motor from the time it appeared on the market. The motor was introduced in 1912, and was an invention by A.S.E.A. The design and the construction has been considerably altered and improved upon. The first motors built were of moderate size but to-day there are no technical or constructional difficulties in building this type of motor up to as high as 1,000 h.p. Some of the largest electrical manufacturers in England and America long ago, bought manufacturing licences from A.S.E.A.

The most striking feature of the commutator motor is that the speed can be regulated without any loss of power whatsoever over a very wide range.

The rotor has two distinct windings embedded in the same slots, the bottom one being the primary winding to which is connected the supply voltage through slip rings. The top winding is the secondary or regulating winding, which is connected in series with the secondary winding which is in this case, located in the stator frame.

Both the latter windings are connected together to the commutator and by shifting the brushes along the commutator, a major or minor part of the regulating winding is connected in. Brush shifting is carried out by means of a 1/2 h.p. servo motor located at the top of the main motor and is operated from push button stations.

In as much as the cost of the generating plant must be considered, electrically driven mills cost a little more than steam driven mills, but the extra expenditure is more than justified as the electric drive is superior in every respect to the steam engine drive.

The advantages of the electric drive are:—

1. The electric drive, with the aid of switchboard instruments, has made it possible in a simple and exact manner to ascertain the amount of power taken by each set of rollers for a given speed and condition of milling. Power readings are a close index to the efficiency of grooving, mill settings, relative speed adjustments and other mechanical adjustments.

2. Centralized control is ideal. All speed changes are made by the Shift Engineer or the Mill hand, the whole plant is so simple and foolproof that a mistake cannot be made, the operator at times stops and also starts the complete milling plant. The crushing rate per hour can be adjusted to the cane supply, or to the factory requirements by the small master switch which decreases or increases the speed of the whole plant. Centralized control not only reduces the number of operators as compared with those on a steam engine plant but more important is the better control resulting. It is possible when the cane is very rich in sucrose content to increase the crushing rate and so crush as much of the crop as possible while the cane is at its best, without altering the settings of the crusher or mills.

3. The operating and maintenance cost of the electric drive is negligible when compared with the steam drive. As mentioned previously the number of operators is reduced. The motors and apparatus are serviced by the same electrician, who looks after the other motors in the factory. The labour required for oiling the train of mills, is practically eliminated.

The maintenance cost so far, has been limited to cleaning the motor windings and spraying same with insulating varnish and attending to contacts on the control equipment and fitting commutator brushes.

4. Other advantages of the electric drive are a cleaner and quieter mill house, elimination of live and exhaust steam ranges, clean exhaust steam, free from cylinder lubricating oil, quicker evaporation of water from the juices and so on.

5. A spare rotor and stator is always on hand in case of an accident, where generally this practice is not possible with steam engine drive.

6. Starting, stopping, reversal and adjustments can be quickly made. Prompt starting and quick stopping save time.

Finally, the great flexibility of the whole milling plant results in increased mill extraction.

Certainly, we had our initial troubles, as shortly after starting up the first section of the new milling plant for the 1932 crop, the ends of the rotor bars at the high voltage point short circuited, this being caused through flakes of carbon (partially burnt bagasse) and fine particles of carbon dust being blown into the motor.

The design of the motor is identical with that of an ordinary slip ring induction motor with the exception that the rotor has two windings. It was the ordinary slip ring winding that gave the trouble and not the commutator or regulating winding. It was found that most of the carbon entered the motor between the fan shaft and the casing but other crevices were found and closed up. The suppliers of the plant had the ends of the bars capped with presspahn and then laced, this was done to the rotor bars at each end, it took three weekends to complete the three machines. After this everything went well, no stoppages at all until approaching the end of the crop, when two rotor bars flashed over at the commutator end of the rotor, hitherto the trouble had on every occasion taken place at the slip ring end. After a thorough investigation it was found that the presspahn caps that had been fitted had collected quantities of fine carbon dust. The manufacturers were advised by cable and they demanded that the five rotors should
be returned to them on the completion of the crop. This was done and they dismantled the whole rotor and rewound it with a continuous taping to the ends of the bars. We went through this crop without a single stoppage on account of motor troubles.

The machines were supplied under a twelve months guarantee which was extended for a further twelve months. The firm who supplied the plant, acted very promptly and left no stone unturned to put the job right. After these two years' experience, I would say that having once operated an electrically driven plant, one would not willingly go back to one which is steam driven.

**ELECTRICITY SUPPLY TO OUTSIDE ESTATES.**

The area of the Company's estate is 30,000 acres of which about 20,000 acres, divided into thirteen section, are under cane. Of these sections, each under the supervision of a sub-manager and overseers, nine are supplied with power from the power station for lighting, driving agricultural appliances and secondary irrigation plants apart from the main irrigation system situated on the banks of the Umgeni river. Regarding the general lay out of the Estates all, with the exception of two outlying estates, are situated within a radius of about four miles, centering from the mill.

Cornubia, the first section to be electrified, necessitated the building of one mile of power line, the pressure being 550 volts.

A 2 h.p. motor was installed to drive a chaff cutter which had hitherto been turned by hand, and then a 7.5 h.p. motor to drive a pump supplying water to the stables and Indian barracks. As this pump had previously been driven by a steam engine and boiler, figures were at once available which showed a remarkable reduction in running costs and repairs, while the saving in labour was no less than five natives per day. Based on this experience, eight more sections have been electrified and all machinery previously driven by petrol, paraffin and heavy oil engines, have been replaced by the cleaner, quieter and more suitable electric motor. In every case a reduction in fuel and maintenance costs was noted and the ever present "leakage" of petrol, paraffin and coal ceased.

In every section the sub-managers' and overseers' houses and the stables are electrically lighted. Not only is there a considerable saving (after allowing 10% on the capital cost of the plant), but electricity has proved not only to be much safer and cheaper with maintenance charges practically nil but much more reliable than any other previously used form of prime mover.

The major item in the construction of a power transmission line is the cost of poles. In 1921 we experimented with gum poles set in concrete with the concrete set 12 inches above ground level. This measure of protection, however, proved to be hopelessly inadequate, for after 18 months of service every pole was found to have been badly attacked both by white ants and rot, and had to be replaced by standards made from discarded tram rails.

With these new poles, also set in concrete bases, two lines about five miles in length were built and it was found that while being more permanent they were inclined to whip which necessitated the use of more stays than the tubular type would have required.

After many experiments it was decided that the best type of pole would be constructed from a 16 foot length of discarded 4 inch boiler tube, lengthened by means of a 3 inch pipe acetylene welded on to the boiler tube. As a base plate a discarded truck wheel was clamped on to the bottom by means of three "J" bolts and the whole set in a concrete base. The cost of this type of built up pole fitted with a channel iron cross arm is 18/-.

At present we have about 50 miles of line built with these poles and it has been proved that they make a very substantial job. Never at any time has the welding given way despite the fact that we have two lines of this type of pole supporting in one case 3 x .06 sq. in. copper conductor and the other No. 6 guage.

Now, however, as regards corrosion, one exception must be mentioned and that is the line running along the Admiralty Reserve at Umhlanga Rocks which was originally built with this type of pole. It was noticed that while the boiler tube section showed no signs whatsoever of any deterioration the 3in. black iron pipes welded on and the cross arms showed considerable corrosion and these poles had to be replaced.

It was at this time that the chief of the Government Forestry Research Department had read a paper on "Seasoned and Chemically" treated poles, so it was decided to replace our own built up poles with wooden ones of this type obtained from Pretoria, also to use galvanised cross arms and clamps. Now, after three years of service during which time they have been carefully examined both above and below ground, they show no signs whatsoever of rot or any other deterioration. This type of pole is only necessary where very adverse conditions are met with. In this case the poles are within a few yards of the sea.

The cost of a heavy 24 foot wooden pole ex Siding 421 Zululand, is 12/9d. The one disadvantage is that owing to its greater weight and bulk, erection costs are naturally much higher than with a steel pole.

The only steel poles we have ever purchased have been those used for E.H.T. lines. Our lines exceeding a pressure of 550 volts have a continuous earth wire, each cross arm is bonded to same, and
connected to a suitable main earth. Pole mounting, lightning arrestors are used to protect transformers and other apparatus. We have experienced no trouble from lightning on our 550 volt lines, but quite a little on our 2,200 volt lines and so far, none whatsoever on the 22,000 volt line.

The cost of material per mile of power line to transmit 12 h.p. at 550 v. should not exceed £60.

UMGENI PUMPING SCHEME (ELECTRICAL)

Generally, this scheme consists of a main pumping station situated on the north bank of the Umgeni River and supplied with power from the Power Station at Mount Edgecombe. The water is pumped from the Umgeni River through the rising main and delivered into a main concrete lined canal (graded to a fall of 1 in 3,000), through M’Kraal, Phoenix. Mount Edgecombe on to Ottawa, a distance of nearly 16 miles.

At intervals along this main canal outlet valves and measuring chambers are fitted enabling secondary irrigation canals to be fed and an accurate record of water supplied to be kept. This scheme was commenced four years ago, and now some 9,000 acres are under irrigation which area is constantly being increased by constantly extending secondary furrows and by erecting secondary pumping plants and dams.

This irrigation scheme, involving the expenditure of thousands of pounds is the result of years of patient experiment. In the year 1922 a small plant of 50 h.p. was erected on the Mount Edgecombe estate to pump the waste water from the mill, this amounted to 20,000 gallons per hour. The water was pumped from a collecting pond below the factory through 3,500 ft. of 6in. piping against a total head of 195 ft. and delivered to a sump on the Phoenix Road. From this point furrows were arranged to lead the water onto dry lands whose annual yield per acre had been noticed. After these fields had been under irrigation a considerable increase was recorded. This increase justified the first experiment and led to further plants being installed wherever water was available. In 1924 a 150 h.p. plant was installed on the Blackburn Estate delivering 42,000 gallons per hour against a total head of 485 feet, again in 1926 a further plant was installed in Westbrook Estate also of 150 h.p. and delivering a similar quantity of water.

By this time several estates had been electrified and power was available for pumps—this obviated the necessity of buying expensive prime movers, the power was there and the experimental pumps were merely coupled up to the system. Results justified further extensions.

The main plant now consists of five 600 h.p. motors, driving centrifugal pumps each delivering 3,000 gallons per minute through a 34in. diameter steel pipe 1,080 ft. long against a total head, from all causes, of 487 feet.

Power is supplied from a bank of three single phase transformers of 1,800 K.V.A. capacity situated in the basement of the Power Station. The current is supplied from the 2,200 v. bus-bars through a 600 amp. Reyrolle iron clad compound filled switch to the primary of the transformers, the pressure is stepped up to 22,000 v. and is supplied to the seven miles of overhead transmission line through a 22,000 v. Reyrolle feeder switch. A 1,000 ft. type H callenders 22,00 v., 3 core paper cable to the first tower on the Durban side of the factory.

This type of construction lends itself admirably to the undulating country which this line traverses. There are 76 towers, the normal span of which is 500 feet. While crossing valleys the longer spans reach 1,300 feet without this type of tower the construction would have been much more difficult. With the tubular type of pole, 238 poles would have been necessary and nearly four times the number of insulators would have been used. The conductors are hand drawn copper wire of .06 sq. in. section and the continuous earth wire is No. 6 gauge cadmium copper wire. The insulation consists of three disc insulators in series per phase and four in series for the straining towers, a special clamp supports the wires so that it is impossible for the wire to run through should a conductor break.

The great advantage of the Kay tower is its flexibility, during a gale the vertical member will deflect slightly and immediately right itself with the cessation of strain, consequently the towers are always plumb, whereas the tubular or lattice pole would, under similar circumstances, bend and retain a permanent set just above ground level. This tower has been found to stand up to any abnormal conditions so far encountered.

The cost of a Kay tower line erected is also much cheaper than those of other construction and while the maintenance is considerably lower having only a quarter of the usual poles and insulators to maintain.

At the Umgeni the current is transformed down from 22,000 v. to 2,200 v. in a sub-station identical with the one at the factory end, situated on the north bank of the river, 400 ft. above the pump house. The power is transmitted down the bank to the pump house through a double circuit line supported on heavy masts designed and manufactured by Messrs. Gilbert, Hamer & Co. of Durban.

The two incoming feeders are each coupled to a 500 amp. feeder switch of the cubicle type and each cubicle controls three pumping units. The motors are of the wound rotor type with continuous rated slip rings.
The control equipment is fully automatic throughout. The motors start by pressing a push button which closes the primary contactors and the motors are accelerated up to speed by the automatic closing of the secondary contactors cutting out the rotor resistance in five stages. Overload protection is provided on the primary side, also time and current relays on the secondary side, it being arranged that it is not possible to run the units up to speed too quickly.

When it was decided to install the fourth unit, we had insufficient transformer capacity and that owing to the droughty conditions prevailing it was very badly needed. To rectify this it was found that the cost of six new transformers with the necessary Reyrolle switchgear, buildings, cables and accessories would be approximately £8,000, it was decided instead to install power factor correction apparatus of 250 k.v.a. capacity which raised the power factor from 0.81 to 0.87 giving us the necessary load to supply the new fourth unit from the existing transformers without any undue heating. The fifth unit is at present merely a standby, but when the sixth is installed to complete the scheme, the additional transformers will be necessary to run the whole six units and then the static condensers will continue to serve their purpose. Apart from the main Umgani plant there are several secondary pumping plants totalling 780 h.p. on the various estates.

**MAINTENANCE AND OPERATING EXPERIENCES.**

Regarding maintenance, the conditions obtaining in the sugar industry is possibly worse, from an electrical point of view, than that found in any other industry.

The invariably moist atmosphere is laden with carbon dust and very fine particles of bagasse which is very harmful to all types of electrical plant.

We have found it necessary to blow out all motors with compressed air at 60 lbs. per sq. in. pressure every week during the crushing season, taking Saturday evening and most of the Sunday for the purpose but even with this care, when the motors are completely dismantled during the off season, an accumulation of fine sticky bagasse is found adhering to the motor windings, while in the curing house, the windings are found to be thickly coated with fine sugar dust necessitating washing down with water, drying out and varnishing before being put back into service. For every motor a history card is compiled and kept on record showing rotor clearances, details of overhaul, repair and clearance tests. Should the bearings have worn down say three or four thousandths of an inch, not sufficient to call for fitting new ones, the clearances of this motor are tested more often than those motors showing uniform clearance—these details are also noted for record. Great care is of course taken in case the clearance becomes such that there is danger of the rotor fouling the stator.

Belt driven units have in the past been a cause of trouble as the Indians, taking as usual the easiest way, would, in the event of a belt breaking, merely join up the broken ends without putting the motor forward, thus causing excessive wear in the bearings and possibly a rewind through the rotor fouling the stator.

Again, we experienced a lot of trouble due to the incomplete combustion of the bagasse in the furnaces. Flakes of partially burnt bagasse in the atmosphere were drawn into the motors, especially the slip ring motors, and generally on the larger motors from 50 h.p. upwards, bar wound motors and stators at the high voltage points would flash over, usually at the back end of the clip joining the end of the coils or just under the binder.

To overcome this trouble we enclosed the ends of the rotor and stator bars with a G.E.C. compound specially manufactured for this purpose. This sealed the windings but in the case of a repair being necessary it was a difficult job and great care had to be exercised in taking off the compound as it sets very hard. We also tried fitting thin presspahn boxes of a special design over the ends of the coils but the fan effect of the rotor drew dust into the pockets.

Another method which proved to be satisfactory, is the insertion of mica between the bars and allowing it to project 1 in. over the ends, then giving it a good coating of insulating varnish.

The specification for all motors now purchased by us, calls for the ends of all coils to have a continuous taping and the machine to be finished with an acid and moisture resisting insulating varnish, for the ordinary standard type of motor is not satisfactory in some section of a sugar factory. We also specify that the starting equipment should be arranged so that a slip ring motor should start turning on closing the stator switch with the controller in the off position. A rotor should never be open circuited. Dirt has also been the cause of switch and starter breakdowns, but this was overcome by sealing with Ellison's compound all crevices especially where cables or conduit enters the switch or starter.

Regarding the care of totally enclosed alternators and motors operating at or near sea level where the humidity at times is very high, I have found that it is most essential that if a machine is shut down, even if only for a period of 48 hours to have lamps or resistances in circuit to keep the unit warm otherwise it becomes damp and if an insulation resistance test is not taken before putting the motor into service the results might be disastrous. The cause being that there is little or no circulation of air and the temperature of the windings is down to that of the atmosphere. First of all we tried an exhaust fan inserted in the discharge air duct
to create a circulation of air when the machine was shut down, but after tests we found that a more satisfactory method was to keep the unit above atmosphere temperature as was mentioned before. This also applies to the mill commutator motors, immediately one of these units is shut down, the drying out gear is automatically switched on. All units are given an insulation resistance test immediately on closing down for the week-end and a second test before starting up on Sunday evening, all these tests and operations are logged.

All the factory main feeders, the connections from the main distribution boards to the starters, and from the starters to the motors are by means of paper cables, lead covered, armoured and served, this is rather expensive in first cost, but the extra expenditure is more than justified.

With steel conduit and V.I.R. wire condensation is apt to take place whereas paper cable is there for many years, and makes a stable job. All cable ducts are filled with dry sand and further protected by a covering of cement 3/4 in. thick, this prevents rats and other vermin getting through, probably to the main bus-bars.

Before closing this section I should like to relate my experience briefly on overhead transmission lines. I will take the Umgeni 22,000 v. line. A specification was issued for the pin type of insulator for a working pressure 22,000 v. Soon afterwards (this was in 1929), I heard of serious breakdowns on the commission's 33,000 v. lines at Salt River where they had discarded the pin type of insulator in favour of the disc type of suspension insulator in order to increase the creepage path to earth as it had been proved that with pressures above 11,000 v. and within 12 miles of the sea, salt precipitation takes place, so we altered our specification accordingly.

We have since experienced this ourselves on the 2,200 v. here supplying Umhlanga Rocks during the last few years of drought—it occurs after a long period of drought, that on the section of the line near the coast, static discharges take place and can be clearly seen at night and on occasions I have had every insulator washed down. The same applies to our automatic phone service and to our Government phone extensions to the beach, all lines will be in perfect order during the day, yet complaints are received at night time.

It is from these difficulties, experienced by all of us in our separate mills, no matter how worrying at the time, that experienced is gained, valuable lessons are learned and future troubles avoided. As this is merely a recital of my own personal troubles, I would venture to suggest that if the electrical heads of the mills could meet together, say every two months to discuss the problems of the day, much good advice could be exchanged, and much benefit to all ensue.

A very important item for those responsible for any large electrical undertaking, is safety. It might be interesting to know that we are installing a 32 v. circuit for plugging in extension lamps used in the overhaul of boilers, evaporators and other auxiliaries in difficult and inaccessible places. Although the present factory lighting pressure is only 110 v., we have found that even at this low voltage accidents have been known to occur, luckily we have had none ourselves, but have decided that "Safety First" is a policy to be followed and are acting accordingly.

In the case of a motor fault, the motor is immediately isolated and the starter locked out, but on one occasion the oil switch was switched to the "off" position and pad-locked but it was found out later, that the switch was actually "in," the moving contacts were held in by the finger contacts owing to a small blob of copper welding them together. This occurred when the switch operated on short circuit current. This was found out when closing in the feeder at the power station.

**GENERAL.**

The adoption and the since rapid expansion of the use of electricity at Mount Edgecombe is due in no small measure to Mr. W. A. Campbell, the Managing Director, who from the very beginning in 1921, has been fully alive to the benefits which would result and the developments made possible through using electricity, and the possibility of reducing costs in every department.

It was Mr. Campbell who finally decided that the mills were to be driven by variable speed A.C. commutator motors. This decision has been fully justified by results. Although the factory is fully electrified with the exception of three vacuum pumps and half a dozen juice pumps, there is still a lot to be done.

For instance, ploughing by electrically driven ploughs is carried out on a large scale in England and on the Continent. It is the cheapest ploughing possible, not only is the initial cost of the ploughs much lower, but the power costs are almost negligible.

That current is promoting growth is another matter which may be profitably gone into and also as a means of clarification and purification of the juices.

Mr. PULLAR: I think we must congratulate Mr. Godfrey on writing such a very interesting and able paper on a subject which at first sight might be looked upon as commonplace.

It is very interesting to note the great variation in the use or application of electricity at Mount Edgecombe. As most of the coming generation
seem to be mainly interested in becoming electrical engineers it shows that the sugar industry offers possibilities of experience which cannot be gained in many industrial concerns, and as the electrical manufacturing industry does not exist in this country it is very fortunate, and offers a wonderful field for the rising generation. Unfortunately at present this probably only refers to one mill out of twenty odd, but no doubt after further investigation this will extend throughout the mills.

The first thing that strikes me is the size of the undertaking. I took out a few figures which may be of interest.

The units sold by the Pietermaritzburg Corporation for last year were approximately 10,000,000 units. The working expenses were 1.139d. per unit; the total expenses 1.753d. per unit, and the average cost from the Commission 0.493d. per unit, made up of .3d. for the first quantity, .2d. for the second, .15d. for the third, and then plus 6/8d. per K.V.A. per month maximum demand. This represents 60% of the output of Natal Estates.

The Durban Municipality was approximately 100,000,000 units, the working expenses being .727d., the total expenses 1.05d. per unit. In this case Natal Estates represents 17% of the Durban Municipality’s total output.

Cape Town—total units sent out, 78,000,000, working expenditure .884d., total expenses 1.312d. per unit. In this case the Natal Estates is practically 20% of the Cape Town output.

Pretoria Municipality, 38,000,000 per annum: working expense .611d. per unit, total expense 1.096d. per unit. In this case Natal Estates’ output is practically 40% of the total output of Pretoria.

The above figures show that in the sugar industry there is a very good case for an isolated power plant, in spite of the fact that irrigation takes place in the off season.

Unfortunately Mr. Godfrey has not told us how much they use for irrigation in the off season. I believe I am right in saying that during the crushing season if they shut down their coal fired boilers they will be still able to devote their plant to outside the factory; to what extent I am not certain. Against that you have to consider that Natal Estates is a double carbonatation factory with all sorts of contrivances which most other factories do not want. Therefore other factories could develop on the same lines, and have much more power available from bagasse. All other mills must obviously develop on these lines and these matters want a good deal of discussion and thrashing out. While on the question of costs I believe the £8,597 for steam is really based on Natal Estates’ own system of accounting, which is not quite comparable with outside factories. I believe if you substituted your coal cost for that figure you would reduce the figure, and it would be more interesting to other people who are not aware of Natal Estates’ own system of accounting. On the question of variable speed motors, Mr. Godfrey states these can be built up to 1,000 h.p. I should like to correct him there, there is no limit now. It used to be 250 h.p. a few years ago. Then regarding the power line construction I would like to know if there is any sign of corrosion on the steel wire guys on that construction as it was very much criticised by people when put in.

Mr. GODFREY: No, it is not possible to shut down our coal fired boilers altogether during the crop and to supply all irrigation plants from the bagasse fired boilers. Although outside plants have been supplied with 1,303,206 units during the period under discussion from bagasse.

Had our factory not been a double carbonatation factory, i.e., sugar milling and refining combined, then of course a larger quantity of power would be available for irrigation, etc. But you will note that the factory is balanced from a steam point of view and a surplus for other purposes.

Your suggestion regarding the item for steam, viz., £8,597 being substituted for the cost of coal is quite correct it would materially lower the cost per unit below the figure given. As you know if we had no power plant at Natal Estates high pressure steam would be taken direct from the boilers through a reducing valve for evaporating purposes, boilers would still be necessary and also labour to operate them. But with Natal Estates’ system of accounting, all operating, renewing, maintenance and interest charges are debited to the power station. Regarding the steel wire guys on the Kay Towers there is no sign whatsoever of any corrosion, before erection they were treated with a special solution, in fact the construction of the towers have justified their use from every point of view, this line was constructed in 1929.

Mr. J. MONKS: May I be permitted to add my congratulations to Mr. Godfrey on his very excellent paper which deals comprehensively with the Natal Estates Electrification Scheme, and reflects great credit on those responsible for its adoption.

The prosperity of South Africa is dependant to a high degree on electrification, one example alone, the present output of the Rand has only been made possible by its general application. It is equally desirable for the Sugar Industry here to keep in step with the electrification of the country and participate in its benefits.

Referring to the cost sheet on Page 4 of Mr. Godfrey’s paper the largest item on the bill is for steam, and I would like to suggest that the distribution of this item throughout the factory would prove the subject of a further interesting paper for the future, particularly as the logging of all impor-
tant readings is systematically carried out as referred to on Page 3.

Messrs. MacBeth and Mackesy have given some particulars of the latest boiler development at Mount Edgecombe in their paper of December last, read before the Associated Society of Certified Mechanical and Electrical Engineers. I would like to make a few general comments regarding the prime mover which, together with the boiler plant, is responsible for the steam bill. It is, therefore, in this direction where economies are to be looked for, both by type of installation and operation.

Cooling Water.

Referring to Page 1 the supply of an adequate cooling pond is undoubtedly essential, the rise in cooling water temperature from 80° to 100°F. would drop the vacuum say 2 in., and cause an increase in the steam consumption of the H.P. turbine say approximately 8% at full load.

Governing.

Again referring to Page 1, second column, paragraph four. I agree that the governing should be satisfactory over a wide range. The firm I represent have running in a paper mill in England a 3,125 kw. turbine of the double passout condensing type giving process steam absolutely oil free, at constant pressures of 60 and 20 lbs. per sq. inch gauge, under the automatic control of two independent governors, the machine responds perfectly to the varied demands met with in a paper mill.

Nozzle Grouping.

To obtain economic operation where a varied demand has to be met, the grouping of steam admission valves and nozzles is of importance, both at the high and low pressure portions.

Superheat.

Referring to Page 1, top of the second column, a steam pressure of 160 lbs. and superheat of 150°F. are given as the conditions for the first 2,000 kw. turbine.

The penultimate paragraph on Page 1 gives an average pressure at the stop valve of 140 lbs. gauge, temperature 480°F. say, 120°F. of superheat.

The steam consumption on Page 2, paragraph three, is given with conditions of 150 lbs. pressure, 480°F., say 115°F. superheat, i.e., 150-115 = 35°F. difference of superheat and allowing the accepted figure of 1% change in steam consumption for every 12°F. change of superheat, (Baumann I.E. Proc. 1912, Vol. 48). This represents a loss in steam consumption when operating as a H.P. machine of nearly 3% and under the passout conditions of possibly more like 8%. It also has the effect of reducing the temperature of the passout steam by approximately the same amount, viz., 35°F., and I should say that with the lower initial superheat, presuming the turbine to be efficient, the condition of the passout steam would be wet. It is desirable that this steam on leaving the turbine should be slightly superheated say 30 to 50°F., so that condensation is prevented in the mains, and it reaches its destination with little or no loss in weight or heat content.

Irrigation.

Referring to Figure No. 2 it would appear that with increased irrigation, the electrical load is going to increase without materially affecting the process steam quantity, and a later development may find you adopting a high pressure primary turbine to operate in conjunction with your existing units, the object of such a unit being to generate steam at a higher pressure and expand it through a back pressure turbine down to the pressure in the existing engine room mains. A scheme of this description gives increased output with reasonable cost and retains the existing plant.

This and many other attractive schemes are available to meet demands for power and steam, and should be carefully considered for individual requirements.

Coal Firing.

In view of the experiments which are being carried out to employ the bagasse for the production of paper, its adoption would necessitate coal firing for steam raising. Coal is going to cost money, and steam conditions must be chosen to give the best overall economy.

Mr. McLEAN: On reviewing this paper one is forcibly struck by the enterprise shown, and the progress made in the application of electricity to sugar production. The whole plant and layout is a tribute to all concerned.

The balance sheet showing generation costs is very interesting, and on the face of it reflects very creditable figures, but, on closer examination, these figures cannot go altogether unchallenged.

Taking European Salaries, including repairs, etc., the cost is given as £1,231 11s. 10d. Making the assumption that the Electrical Engineer receives a salary of £450 per annum, and that two journeymen at standard rates each receive £338 per annum, and one apprentice receives £105 11s. 10d., the European wages bill has been covered, thus:—

<table>
<thead>
<tr>
<th>Category</th>
<th>Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineer</td>
<td>£450 0 0</td>
</tr>
<tr>
<td>Journeymen</td>
<td>338 0 0</td>
</tr>
<tr>
<td>Apprentice</td>
<td>338 0 0</td>
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<tr>
<td></td>
<td>105 11 10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£1,231 11 10</strong></td>
</tr>
</tbody>
</table>

Assuming that three shiftmen are employed, it leaves none but native staff to cope with any other
Assuming that two shiftmen and two apprentices are employed, it seems hardly possible that such a staff could capably cope with all the necessary work incidental to a plant of this type and size. If the figures given are correct, then the staff service is outstandingly meritorious, and a very high rate of efficiency is being maintained.

Coming now to steam charges as shown; we are told that no charge is made for bagasse as it costs nothing, but this does not show a true reflection of the actual average cost per unit, as everything should bear its cost charge. The actual production of bagasse by the mills is just as much a cost as is the sugar juice, it being impossible to produce juice without bagasse, and vice versa. Therefore whether it is a waste product or not, the bagasse should have a definite cost allocation.

This is all the more necessary when the bagasse is used as a production fuel for power, otherwise a false steam generation cost is shown, and an engineer external to the sugar industry would be completely mislead by the low costs as shown.

A further argument in favour of charging up the bagasse is this: should any external industry arise, such as paper or beaver board making, etc., which could profitably absorb the bagasse, coal would have to be purchased for the furnaces; perhaps partly covered in cost by the sale of bagasse, therefore the bagasse should be credited with a definite value assessed on its thermal content.

Now, allowing the former assumptions, and giving wet bagasse an average heat value of 3,600 B.T.U. per lb., for a true cost, the total amount of bagasse passed through the furnaces multiplied by its heat value, should be charged up on the cost of an amount of coal having an equivalent heat value.

Assume a grade of coal having heat value of 12,600 B.T.U. per lb. then 12,600 = 3.5, which

\[ \frac{3,600}{12,600} \]

would be the heat ratio, or, in other words, three and one half tons of bagasse would be equivalent to one ton of coal on a heat basis rating; and should have an equivalent cash value.

Without knowing the tonnage of bagasse passed through the furnaces per annum, it is impossible to show the cost difference in this particular case, but I feel that it would make an appreciable difference per unit generated.

Taking a random case, and suppose a factory to use 33,000 tons of bagasse per annum in its furnaces, then 33,000 = 9,200 tons of coal (equivalent).

\[ \frac{3.5}{3.5} \]

Assume coal purchased at 15/- per ton and then the fuel cost works out at 66,900 per annum, which would mean an appreciable difference to unit cost.

Sufficient has been said to show that I consider the cost as shown on the cost sheet is not quite an accurate reflection of the actual cost, and in my opinion the unit cost would be increased somewhat were this method of allocation adopted. All else apart, it would be interesting to know just how much the cost allocation method outlined here would increase unit cost, and I trust it may be possible for the figures to be given.

Again I must congratulate the author on an exceedingly interesting and informative paper, the remarks re distribution lines and Kay Towers being particularly useful. I trust too, that my remarks may be construed as an endeavour to show the ordinary engineers' points of view, as opposed to that of the sugar engineer.

Mr. GODFREY: I must thank you for the interest you have taken and in connection with the points you have brought forward, I wish to state that:-

Firstly the item for operating and maintenance costs £1,253 11s. 10d. are absolutely correct. As already stated we employ one switchboard attendant per shift, three in all.

In the first instance this item represents the power station only, generating costs of course do not include maintenance of lines, factory motors and the extensive electrical plant external to the factory, there is a small general maintenance staff for the whole plant from which the power station draws when required, and any labour used in this connection is debited to the power station.

Again a proportional percentage of any salary is charged to the power station the balance is charged to other sections of the company's plant.

During the period under discussion the power station was out of commission for short periods during the off crop when irrigation was not required, it must not be assumed that this lowers the cost per unit, on the contrary for the operating staff overhaul the plant, their time of course being debited to the power station and during a very wet season they are employed overhauling the factory plant, after the power plant overhaul is completed. I would also state that for every week the station is out of commission the cost per unit is increased by 0.01d. per unit.

Secondly the item you also criticise is the item for steam, as already stated no charge is included for bagasse.

I would again point out how efficient a power station is when passing out steam for process work in the factory.

In the first instance after extracting the juice from the cane steam at 10 lbs. pressure is required for boiling and converting same into sugar; the power station contributes 90,000 lbs. per hour for this work; the turbines are really reducing valves, reducing the pressure from 160 lbs. to 10 lbs.
Prior to the electrical installation, the factory auxiliaries were driven by a number of small inefficient steam units, also dross coal had to be mixed with the bagasse and purchased power was necessary to keep the steam pressure normal at times. Since electrification all the factory steam requirements are provided from the bagasse without the use of coal and purchased power, and during the period 1,303,206 units were supplied for irrigation purposes over and above the factory requirements from bagasse.

A very important factor is the percentage of fibre in the cane which varies from 14%-17%, at times there is a large surplus at other times there is just sufficient to generate current for the factory requirements only.

By charging the power station for the bagasse used in the generation of steam the average cost per unit is .276d. for the twelve months, whereas for the same period with bagasse free steam the cost is .196d. per unit including all other charges in both cases.

When all irrigation pumps of a total capacity of 2,285 kw. are in commission the fuel requirements are provided from the coal fired boilers, the cost of coal is included in the cost of steam and the power station is charged with the same.

Your remarks regarding the disposal of bagasse to a secondary industry do not apply as the bagasse would probably be sold at a figure higher than its value as a fuel in B.T.U.'s, this would not increase the cost per unit but would rather tend to reduce same.

I can assure you that the costs given have been carefully compiled by our statistical department, and costs are being rendered weekly throughout the year and under the Locking system of control the Head of every department knows each and every week what his costs are. Should this figure vary, reasons for this variation are ascertained immediately and noted.

Finally the operating costs of this station are the lowest for its size in the Union, and I trust that the foregoing will leave no doubt whatever in your mind as to the accuracy of the figures given in the cost sheet.

Mr. J. ROBERTS: I should like to add to what others have said in words of congratulation to Mr. Godfrey for this excellent paper, and also to compliment him upon the very fine work which has been carried out at Natal Estates factory in the installation of this very complete electrical plant. I have known Mr. Godfrey many years and there are very few other people outside his Company who know the good work as I know it. It is well known of course, or I hope it is well known, that the Electricity Supply Commission is very greatly interested in the electrification of the Sugar Industry but not to supply current to it. There is no doubt whatever that a process steam plant is more in the nature of being an electric generating station than an electric power consumer, and I am sorry that I have not had more opportunity to enlarge on this point; I am sorry that more opportunity has not been given for the discussion of this very fine paper of Mr. Godfrey's in view of the very great importance of the general principles of electrical generation from process steam (hear, hear). I had taken the liberty of preparing some diagrams which would have brought out the point, and I am very disappointed that you have not been able to decide to meet again tomorrow, because I think that the sugar industry should go into this question. I do not say they require education on the point, they are as highly technical a body of men as you can find, but there are special aspects of this question which I think are deserving of more study than they have had. Process steam plants are essentially most economic producers of electricity. Whatever the development may be in the introduction of soft canes, supposing you arrive at a stage where with the most economical use of your bagasse in boilers considerably more efficient than the average and perhaps even more efficient than the best in the field now, supposing you had arrived at the stage when the bagasse was just sufficient to give you your requirements of power and heat, it would pay, and pay handsomely; to add to that bagasse by coal in order to increase the temperature of the steam and pressure of the steam, because that coal so used would turn out electricity at about a quarter of the expenditure of fuel that is necessary in a modern power station. To what extent that might be commercially profitable depends entirely on the demand for electricity in the neighbourhood. If that sugar factory were right out in the wilds where there is no market for electricity of course it is of no value; if it happens to be within easy reach of a large population consuming electricity then it would undoubtedly turn out to be a most handsome proposition. I would say to those friends of mine who have remarked that the cost of the transmission line and the cost of the plant would put the proposal out of grounds that it is really only a matter of economics, and it can be worked out in advance. If the factory is 300 miles away I would say straight away that it would be impracticable. If it were 25 or even 100 miles then I think probably it would be found to pay. It is all a matter of economics which we engineers have got to sit down and work out for ourselves. I must congratulate you on a very successful conference. I doubt very much whether you have given enough time for it, and I hope that next year you will devote three times as much time to the engineering section.

CHAIRMAN: We have come to the limit of our time and it is a great pity the discussion has had
to be cut so short. Before breaking up I want to accord a very hearty vote of thanks to Mr. Godfrey for his very able and interesting paper. It has been one of considerable interest to the Industry in general. Electrical development in the sugar industry is bound to go ahead. The reason why some factories are hanging back at present is because the time has really not arrived just yet when such developments have been actually made necessary, but that time, I am sure, is not far distant. There is the question of reduced fibre in the cane due to the so-called soft canes, and apart from that the very evident advantage and gain to be derived from further extended use of electrical power. (Applause.)

Gentlemen, that is the last paper of this session. It has been a long week, and I want to thank you all here who have attended these meetings. I now close the congress.

On Mr. Booth's motion, a vote of thanks was passed to the President (Mr. B. E. D. Pearce), Mr. Camden Smith and Dr. Hedley, for their work in the running of the congress.

APPENDIX.

In addition to the above which was contributed by Mr. Roberts to the discussion when the paper was read, he—at the Editor's request, furnished charts for re-production in the Journal which there was not time to exhibit at the Conference, and he has also contributed the following:

The charts attached are intended to illustrate diagrammatically how efficient a process steam plant is, as distinguished from a Power Station plant, for producing electrical energy.

Figures 1 and 2 show what happens with steam generated at a pressure of 650 lbs. per sq. in. abs. superheated to 750°F. in an industrial plant where low pressure steam is used for heating purposes, electricity being derived from the turbine in expanding the steam from 635 lbs. per sq. in. to 10 lbs. per sq. in. gauge. The quantity of steam indicated in each case is one pound and it will be seen that 994 B.T.U.’s are usefully employed in the process plant; 206 B.T.U.’s utilised in the Turbine; and 180 B.T.U.’s returned from the process steam plant to the boilers as condensate, assuming latter is returned at 212°F.

Electrical Energy is therefore obtained at the rate of 1 K.W. hr. with 0.3655 lbs. of coal on the basis of a calorific value of 12,700 B.T.D.'s per lb. and a boiler efficiency of 80%.

From figure 2 alongside, showing what goes on in a Power Station, it will be seen that with steam at the same conditions, 948 B.T.U.’s are usefully thrown away to the Condenser and the number of B.T.U.’s required to generate Electricity is 1,311 of which only 363 B.T.U.'s are usefully employed in the turbine and the total consumption of coal is 1,354 lbs. of coal per Kilowatt hour.

Figures 3 and 4 make the same comparison but with steam at 150 lbs. absolute pressure. In this case the Kilowatt hour can be obtained from 0.367 lbs. of coal in a process steam plant, whereas in a Power Station the expenditure of fuel will be 1.7 lbs.

The second chart is of general interest to Sugar Factories, the various diagrams showing the relationship between cane, bagasse, steam and energy on the basis of one ton of cane.

In the construction of these various diagrams the following data applies:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Pressure</td>
<td>650</td>
</tr>
<tr>
<td>Steam Temperature</td>
<td>750</td>
</tr>
<tr>
<td>Tons of Cane per ton of</td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>9</td>
</tr>
<tr>
<td>Fibre</td>
<td>15.25</td>
</tr>
<tr>
<td>Bagasse Analysis</td>
<td></td>
</tr>
<tr>
<td>Fibre</td>
<td>44.85</td>
</tr>
<tr>
<td>Sucrose</td>
<td>3.65</td>
</tr>
<tr>
<td>Moisture</td>
<td>51.50</td>
</tr>
<tr>
<td>Lbs. of steam per lb. of bagasse</td>
<td>2.165</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>65.0</td>
</tr>
</tbody>
</table>

Figures 5 and 6 make the same comparison again but with steam at 150 lbs. absolute pressure. In this case the Kilowatt hour can be obtained from 0.367 lbs. of coal in a process steam plant, whereas in a Power Station the expenditure of fuel will be 1.7 lbs.

The diagrams are self-explanatory, but if they are examined it will be seen that in diagram "A" 2,000 lbs. of cane are represented vertically to scale, the corresponding diagram "B" showing amount of bagasse obtained from this cane being the same scale.

Based on the conditions as stated above it will be seen that 575 lbs. of cane are necessary for the production of process steam from a boiler with...
RELATIVE HEAT CONSUMPTION PER POUND OF STEAM
In Industrial Back Pressure Turbine (70%) and Power Station Condensing Turbine (75%)
efficiency of 64.0 per cent. and an evaporation ratio of 2.165 lbs. leaving a surplus amount of bagasse of 210 lbs. from the total of 680 lbs.

Diagram "C" represents the total amount of steam obtained from the combustion of 680 lbs. of bagasse, 470 lbs. of the latter producing 1,020 lbs. of process steam, the balance of 210 lbs. producing 466 lbs. of surplus steam.

Finally, diagram "D" clearly indicates the proportion of the total energy obtained from process steam and surplus steam. It will be noted that out of the energy from process steam the factory will take 40 per cent. i.e., 22.2 Kilowatt hours, leaving 76.8 Kilowatt hours of surplus energy which can be transmitted to network or distributed for other industrial enterprises, irrigation, etc. An approximation of these figures gives the following analysis:

Total energy per ton of cane 100 kwhrs. or 100%
Energy used in Factory 23 kwhrs. or 23%
Surplus Energy 77 kwhrs. or 77%

Based on 9 tons of cane per ton of sugar the total surplus energy per hour would be 693 kwhrs., whilst for 50,000 tons of sugar per season there will be a surplus amount of energy — $34 \times 10^6$ kwhrs.

If and when soft canes are introduced, say, to the extent of 50 per cent. of total crop, and assuming a reduction of fibre content equal to 20 per cent. in these soft canes, the net reduction in quantity of bagasse per ton of cane will be 10 per cent. Consequently per ton of sugar there will only be eight tons of bagasse available instead of nine. This directly affects the output of surplus energy and for the case cited above of 50,000 tons of sugar per season the surplus energy for utilisation in the network is $26.55 \times 10^6$ kwhrs.

Mr. GODFREY: I have to thank Mr. Roberts for his kind remarks. During the past 14 years it has always been a matter of interest to him in the electrical undertaking developments here, at Mount Edgecombe, and further, he has on occasions rendered us very valuable assistance when called upon. It is a matter of regret that it is not possible to reply at the moment to his very interesting discussion, including diagrams, which must have entailed quite a large amount of work and taken up a lot of time to compile, but I hope in the near future at our next Committee meeting that data will be available to discuss the merits of super steam pressure power plants with him.