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PROCEEDINGS AT THE FOUR HUNDRED AND FIFTIETH GENERAL MEETING

Held at Kelvin House, corner Marshall and Hollard Streets, Johannesburg

Thursday, 25th November 1954

J. P. ANDERSON (President) was in the Chair and declared the meeting opened at 8 p.m.

There were present 50 members and visitors and the Secretary.

OBITUARY

THE PRESIDENT said his first duty was a sad one and that was to announce to members the death of J. K. Gillett, a Member of the Institute and a member of Council. He joined the Institute on the 26th January 1933 and passed away on the 17th November 1954. He had served on the Council from 1939 until he went on active service in 1942, and then again from 1951 to the time of his death.

As a mark of respect to the deceased and in sympathy with the bereaved, the meeting rose and stood in silence for a few moments.

MINUTES

The minutes of the monthly general meeting held on the 28th October 1954 were taken as read and confirmed.

MEMBERSHIP

The Secretary announced that in terms of By-Law 5.2.4, the Council had elected the undermentioned candidates to membership of the Institute in the following grades :—

Associate Member : ALBERT STEPHEN BRIDGER.

Associate : DOUGLAS MAYNARD CASTLE.

Students : DENNIS JAMES DICKS, JULIAN ALWYN BOUTTELL, JACOBUS PETRUS HENDRIK BAAREND KIRSTEIN, HAROLD MICHAEL LEVITON, WYNAND JAKOBUS LOUW, JOSEFUS DANIEL MATTHEE, GERARD JOHN MOOLMAN, PETRUS JACOBUS BADENHORST OTTO, JOHN HENRY VAN DER WALT.

Transfer from Associate Member to Member : RUPERT GETTLIFFE.

Transfer from Graduate to Associate Member : PETER JOHN FENTON.

DECLARATION OF ELECTION OF OFFICE BEARERS FOR 1955

THE PRESIDENT announced that in terms of the Constitution, the Council had elected the following office bearers for 1955 :—

President : Professor G. R. Bozzoli.

Vice-Presidents : R. W. Kane, I. de Villiers and M. Hewitson.

Honorary Treasurer : A. W. Lineker.

ELECTION OF HONORARY MEMBER

The President informed members that at the Institute's last Council meeting the Council, in terms of Clause 2.3 of the Constitution, had unanimously elected Mr S. F. Harvey as an Honorary Member of the Institute in recognition of his valued association with the Institute since 1912.

PAPER AND DISCUSSION

The paper entitled 'A review of recent additions and improvements to South African marine navigational aids' was presented by E. C. Lodge (Associate Member) who also demonstrated some of the equipment described.

The President proposed a vote of thanks to the author for his paper, and G. A. Dalton (Past President), V. A. Wilmslow (*communicated*), G. Williams (Member), H. G. Jones (Associate Member), K. H. O'Donovan (Associate) and B. L. D. Porritt (Associate) contributed to the discussion.

DECEMBER MEETING

The President drew the attention of members to the fact that the next monthly general meeting of the Institute would be held on Wednesday, 15th December 1954, at which some films would be shown, some items of practical interest brought forward, and an important report made by Professor Bozzoli on the Conference of Commonwealth Engineering Institutions.

The President declared the meeting closed at 10.12 p.m.

Institute Notes

Cape Western Local Centre

Members of the Institute visiting Cape Town are cordially invited to attend general meetings of the Cape Western Local Centre which are held in the Demonstration Theatre, Electricity House, Strand Street, Cape Town, on the second Thursday of each month.

A general meeting of the Cape Western Local Centre was held in the Demonstration Theatre, Electricity House, Strand Street, Cape Town, on Thursday, 11th November, 1954.

Mr C. N. Larkin (Vice-Chairman of the Centre) was in the Chair and declared the meeting open at 8.15 p.m. Sixty-two members and visitors were present.

The Chairman extended a cordial welcome to all members and visitors, among whom were several members of the South African Institute of Refrigeration.

Colonel G. H. Webster (Associate Member) presented a paper entitled 'The heat pump and its possibilities' which was illustrated by a number of graphs and diagrams projected on the screen.

The author dealt with the thermodynamics of the subject, described various systems and concluded with descriptions of oversea installations and possible future applications.

The Chairman, Bruce Morison (Member), Dr H. D. Einhorn (Member), A. G. Newton, R. Bowie, C. E. B. Cooper, Professor R. Guelke, C. W. Everett, E. G. Reynolds and J. D. MacHutchon contributed to the discussion on the paper.

Colonel Webster replied to a number of the questions raised by the contributors.

There being no further business, the Chairman declared the meeting closed at 10.25 p.m.

A REVIEW OF RECENT ADDITIONS AND IMPROVEMENTS TO SOUTH AFRICAN MARINE NAVIGATIONAL AIDS

By E. C. LODGE* (Associate Member)

This paper was received on the 6th June, 1954

SUMMARY

In common with most lighthouse administrations the South African Railways found the post-war period devoted to the introduction of technical improvements and to overcoming a backlog of maintenance and installation work.

This paper touches on some of the problems encountered and deals briefly with the technical details of some of the aids to mariners installed and about to be installed on the coast of South and South-West Africa.

The recent widespread installation of radar equipment on merchant ships has had its impact on lighthouse engineering. A brief outline of the design theory of radar reflectors is given together with a discussion on the future applications of this new aid.

The manner in which most South African harbours are built out from the mainland poses a problem in the design of breakwater navigation lights, the solution of which is rendered more difficult by the glare of city illuminations. An original solution based on recent experiment and experience is described in detail.

A new illuminant in the field of lighthouse engineering is mentioned and the possible reasons for its unexpected conspicuity are discussed.

CONTENTS

1. INTRODUCTION

An examination of the activities of any lighthouse service reveals the extent of its interests and the manner in which it uses the fruits of development work in almost every branch of the art and science of engineering. Into the building of a modern lighthouse go the efforts of all manner of specialists and the result is a combination of many skills. In this respect lighthouse engineering, while claiming the right to remain conservative in the interests of reliability, is at the same time doing its best to keep up to date.

One result of this progressive trend is that electricity is playing an ever-increasing role in the application of new aids to mariners. It was not very long ago that the field of lighthouse engineering was almost exclusively the province of the civil engineer. Those were the days when the criterion of perfection was the graceful tapered tower constructed very often under difficult and hazardous conditions in a position exposed to the fury of the elements. Inevitably one's mind goes back to the romantic struggle in the building of the Eddystone Lighthouse and others like it, to the Colossus of Rhodes, to the Pharos at Alexandria and to the fantastic edifice of the Tour de Cordouan. While these structures were remarkable, the service they provided the mariner, although the best under the circumstances, would be very poor compared with to-day's standards.

Generally speaking, the structure of a modern lighthouse is less important than the nature of its equipment, the greater part of which is electrical. The illuminant is an electric lamp which requires a comparatively small lens to produce a beam of high intensity. Power at isolated stations is derived from diesel- or petrol-electric generators which supply the radio beacon, the radio telephone and the nautophone fog signal. Shore-to-

* Mr Lodge is the Lighthouse Engineer of the South African Railways Administration.

ship signalling is conducted by means of a mains- or battery-operated Aldis lamp. Other aids to mariners like radar and the hyperbolic position-fixing systems, although not at present installed in South Africa, are becoming common overseas. The radar reflector, although not actively energized, is designed to respond to high-frequency shipborne radar equipment. While the storm-lashed rock lighthouse will continue to play its valuable part in the protection of shipping, the present-day trend towards the fully equipped electrified station of functional design demands space on the mainland and easy access for fuel supplies.

The civil engineer, however, still retains an interest in lighthouses in the construction of towers, quarters, roads and water supplies. In positions exposed to the elements, maintenance of these assets alone becomes at times a serious problem. The approach roads to many outlying stations are little more than tracks through bush and sand dunes and they require constant attention to keep them open. The horticulturist is called in to assist with the work of preventing sand dunes from engulfing roads and buildings by the judicious planting of indigenous bush and grass. At Cape St. Francis, however, the difficulties are insuperable and the only effective means of transport is the horse-drawn vehicle or the ox-wagon with pneumatic tyres.

The South African lighthouse service finds itself at present in the transition stage between the old and the new concepts of what is considered to be adequate service to mariners. During the last decade, a number of stations which were provided with a main light only, have been electrified and expanded to include the ancillary services of radio beacons, radio telephones, and fog signals. Automatic, unattended lights are operating at isolated points and active consideration is being given to further installations of a similar nature. Storm-warning signals and radar reflectors are on the list of impending improvements. Rocket lifesaving

TABLE I

ATTENDED LIGHTHOUSES AND THEIR SERVICES

Lighthouse	Main light[1]	Radio beacon	Fog signal	Radio telephone	Rocket apparatus
Port Nolloth	A	X	X	X	X
Cape Columbine	E	X	X	X	X
Robben Island	E	X	X	X	X[2]
Cape St. Blaize	E	X[2]	X	X	
Hood Point	E	X	X		
Swakopmund	A	X		X	
Pelican Point	A		X	X	
Diaz Point	P		X	X	
Cape Point	E	X			X
Cape L'Agulhas	E	X			X
Cape Hermes	A	X			X
Dassen Island	E			X	X[2]
Green Point (Cape)	E		X		
Cape St. Francis	E		X		X[2]
Cape Recife	E	X	X		
Bird Island	P			X	X[2]
Cape St. Lucia	A	X			
Slangkop	E				X
Port Shepstone	A				X
Danger Point	E				X[2]
The Hill, Port Elizabeth	E				
Great Fish Point	E				X[2]
Bashee	A				X[2]
Green Point (Natal)	P				
Durban South	E	X			

NOTE.—(1) A indicates acetylene gas-operated light
P indicates paraffin-operated light
E indicates electrically-operated light

(2) To be installed in the near future.

apparatus is maintained at those stations where access may be gained to the adjacent shore line in the event of an emergency and in this respect also, improvements are contemplated. From time to time new quarters are built for the lightkeeping staff and the Non-European labourers on the principle of each family being housed in a separate cottage with facilities for gardening in preference to the old system of providing semi-detached quarters adjacent to the lighthouse tower.

The services available at attended lighthouses are indicated briefly in Table I. Details of beam intensities, geographical ranges and characters of the flashing lights are omitted for the purpose of brevity. For the same reason the details of the other services are not given.

The list is not complete without mention of the 32 automatic lights installed within the precincts of major and minor harbours and the 16 automatic lights situated at isolated points. Thirteen light and bell-buoy installations mark dangerous reefs or define harbour channels.

It is in the field of automatic installations that development and expansion are concentrated on account of the high capital and working costs of attended lighthouses. With the widespread application of modern shipborne navigational aids like radio telephony and telegraphy, direction finders, depth indicators and radar, the necessity is diminishing for new lighthouse installations set up especially for the purpose of keeping a watch on the sea. The existing complement of attended stations may be considered to be adequate. The need has been expressed for more automatic lights and radio beacons. Only where powerful new fog signals are installed will operating staff be required for the essential task of detecting the fog and setting the plant in operation. Small fog signals have been designed to sound continuously, no attempt being made to conserve power during periods of fine weather, but the application of plant of this nature is obviously limited to isolated localities in order to avoid giving offence to local residents.

It is not possible in a paper of this nature to describe all the additions and improvements which have been effected recently, nor is it proposed to repeat technical information which is readily available in standard works of reference. In papers presented to this and kindred institutes, the basic principles of many items of equipment peculiar to lighthouse engineering including radio beacons and fog signals have been described in detail. It is proposed, therefore, to discuss in this instance only those aids which are of comparatively recent origin and projects and achievements with which the author has been concerned particularly those of a predominantly electrical nature. The paper will be of general rather than specialized interest, and it is hoped that in describing some of the problems that have arisen in recent years and the manner in which they have been solved, some idea of the task of the South African lighthouse service will be made apparent.

2. MAJOR ATTENDED LIGHTHOUSES

One of the interesting facts about the major attended lighthouses spread along the shores of South and South-West Africa is that no two are alike in all respects. It could be expected that since Van Riebeeck first caused a beacon fire to be lit on Vuurberg on Robben Island in 1657, some standard policy would by now have been evolved outlining the requirements of buildings, plant and equipment. Experience has shown, however, that as new lighthouses come to be designed new ideas and techniques are inevitably applied both in the technological field as well as in the interests of the comfort of the lightkeeping staff.

Of the 24 attended lighthouses, 14 are electrically operated, the power consumption of the lamps varying from 1 to 4 kilowatts, three stations use paraffin-vapour incandescent mantles for the main illuminant and seven operate with acetylene mantles or open-flame burners. The intensities of the lights vary with the size and type of illuminant and the type and focal distance of the lens employed in each case. Pelican Point has the lowest intensity (1 500 candelas) with its open-flame acetylene burner and a 500-mm drum lens, while Cape Point produces a beam of 19 500 000 candelas by means of a 4-kW electric lamp and a first-order rotating lens. The range of each light depends solely on the elevation above sea level and the atmospheric visibility conditions between the observer and the light. Of the electric stations, five derive their power from municipal mains, the remainder having their own diesel-generating sets. Wherever it is possible to do so and when reticulated electric power becomes available it is more economical to change over to a mains supply so long as the prime movers are retained for emergency use.

From time to time it is found necessary to replace worn-out power plant and the opportunity is taken to install modern equipment. Cape L'Agulhas, for example, has been equipped with horizontal single-cylinder diesel generators for many years, until the demand increased by the provision of lighting in the quarters and the installation of a radio beacon, when a two-cylinder vertical diesel generator was added. Maintenance of the old engines became difficult and costly due to the shortage of spares and the necessity for more frequent skilled attention. A total breakdown of the electrical plant was feared which would have resulted in the re-introduction of the paraffin vapour standby burners and a consequent drop in the intensity of the light from 12 000 000 to 520 000 candelas.

It was decided to construct a new building containing a watchroom with an unrestricted view of the sea, a radio beacon room, and a larger engine room equipped with three diesel-generators of 9-kVA capacity and three of 2½-kVA. With this arrangement maximum flexibility is achieved for varying day and night loads and a spare set of each type will be constantly available. The 240-A.h., 90-volt battery of secondary cells will be eliminated in favour of the operation of the radio beacon during the day from one of the 2½-kVA sets. Economy in maintenance expenditure and, what is more important, maximum reliability are expected to result from this modernization project. A start with the work is being made during the current financial year.

Isolated lighthouses depend on rain for their water supplies, the roofs of buildings generally acting as catchment areas. Occasionally in the dry seasons, water has to be transported by road vehicles. Pelican Point and Diaz Point in South-West Africa depend entirely on supplies transported by tug and road tanker respectively. Constant treatment and chemical analysis of diesel-engine cooling water is necessary to obviate the effects of salinity and other impurities. For this reason preference will be given wherever possible to air-cooled engines for future installations.

The maintenance of steel structures in the aggressive atmosphere at the coast presents a problem throughout the world. Lighthouse towers and radio masts receive the constant attention of the lightkeeping staff during their periods of routine, over and above their watchkeeping, duties. Before they can develop into patches, rust spots are removed by wire brushing followed by surface treatment and painting. Towers are repainted frequently to preserve the value of the colour schemes as daymarks for shipping. For the removal of rust and old paint the oxy-acetylene descaling method has been found to give excellent results.

For the latest radio-beacon installations wooden aerial masts will replace steel structures in an effort to reduce maintenance costs. The practice of the Departments of Defence and of Posts and Telegraphs of installing hardwood lattice self-supporting masts and stayed wooden poles has been copied. Another innovation will be the use of nylon-covered flexible steel wire ropes for halyards and stays. Port Nolloth radio beacon, installed during September, 1954, is the first to have stayed wooden masts. Pelican Point and Cape St. Blaize beacons will be similarly equipped next year.

Remotely situated unattended lights have hitherto all been gas operated, the many inventions of the Swedish engineer Gustav Dalén early in the century having made it possible for acetylene to be used reliably and safely for this purpose. Cape Seal light is quoted as an example of this type of installation.

Mains-operated electric lights are situated, for obvious reasons, close to towns or at harbour entrances. The Durban north and south breakwater lights are simply constructed of 250-watt bunched-filament lamps contained within drum lenses, while the Bluff temporary light has a petrol-engine generator, manually started, available in case of a failure of the mains supply. These installations are due for replacement in the near future. The Cooper light, details of which are quoted, is the latest addition to the list of semi-unattended automatic mains-operated installations. Its construction stems from the demolition of that graceful structure, the old Bluff lighthouse, when it was found to be in the way of the guns of the Bluff battery during the war.

3. UNATTENDED AUTOMATIC LIGHTS

3·1 *The Cape Seal light*

During 1950, the Cape Seal automatic light was brought into service. Cape Seal, or Robberg as the fishing enthusiasts of Plettenberg Bay know it, is a wild promontory almost separated from the mainland by a gap or fault in the geological system. It was a major task transporting the components of the lantern, the steel tower, the building materials for the cylinder housing and rest room, and the cylinders themselves, first across the gap, suspended from a steel cable, and then up the cliffs, through the bush and across the sand dunes. Once a year the task is repeated on a smaller scale when the cylinders are changed.

The lantern contains a 500-mm diameter, ground and polished, 360° drum lens, a pressure regulator, a flasher and six open-flame burners each of 20-litres per hour capacity. The 'character' by which the light is recognized by mariners consists of three flashes of 0·5 seconds duration every 20 seconds. The flash whose intensity is 2 070 candelas is designed to be visible in clear weather up to a distance of 16½ nautical miles. The elevation of the light above H.W.O.S.T. is 474 feet.

Except for periodic inspection visits the light is unattended and operates on a bank of ten acetylene cylinders, each containing more than 5 000 litres, for a service period of twelve months. A 40 per cent economy in the consumption of gas is obtained by the use of a sunvalve which opens and closes the gas supply to the flasher within half an hour of sunset and sunrise respectively. Should the sun be overcast by cloud the light will continue to burn throughout the day.

3·2 *The Cooper and the Umhlanga Rocks lights*

Fully-automatic electric flashing lights have made their appearance in this country since the war only. Lighthouse engineers must of necessity be conservative in their efforts to provide a reliable grade of service to mariners and they have only recently been convinced that electricity can be a reliable source of power, even where its generation is under their control. Where, however, power is obtained from an outside source, from a local power station or from a cross-country grid system, the usual practice is to provide some means of standby power. This takes the form of batteries, of an acetylene-gas installation, or of a petrol or diesel engine and generator. Durban's newest lights at Cooper Lighthouse and at Umhlanga Rocks are examples of the last method, while the Beach Anchorage light at Durban is typical of the mains-operated light with a gas standby.

The Cooper and the Umhlanga Rocks lights are fully automatic in operation. A time switch set for sunset and sunrise connects, via a supervisory relay system, the municipal mains supply to the 1-kW lamp and the ¼-h.p. motor which turns the lens at the correct speed for the character of the light. Should one lamp burn out another comes automatically into focus and a visual alarm is operated. An interruption to the mains supply causes a single-cylinder, 3-b.h.p., petrol engine-driven generator to start under the action of a 24-volt, 150-A.h. lead-acid battery and a special starter motor.

The generator delivers 1½ kW at 220 volts d.c. and the starting motor, when running at the rated speed of 1 250 r.p.m., charges the battery at 20 amperes in preparation for the next failure of the mains supply. A bi-metal strip contact mounted on the engine exhaust guards against the choke on the carburettor being operated should the mains supply fail again shortly after it has been restored and before the engine has cooled down sufficiently to warrant the use of the choke.

The optical system consists of rotating bulls-eye lenses and prisms of 187·5-mm focal distance giving a beam intensity of 950 000 candelas at Cooper Light and 475 000 at Umhlanga Rocks.

The towers for both lights are almost identical and of novel construction so far as lighthouses in this country are concerned. They are of reinforced concrete, 70-feet high, circular, with a wall thickness of only 9 inches and a constant external diameter of 15½ feet throughout the length. This shape, departing as it does from the conventional graceful tapered design, has the advantage that the moving shuttering method may be employed in the construction. By this method preparatory work may be extensive, but the actual construction proceeds quickly. The shell of the Cooper Light tower took less than five days and nights to complete by three gangs working in 8-hour shifts.

3·3 *The Durban Beach Anchorage light*

The Beach Anchorage light at Durban consists of a lantern containing a drum lens of 500-mm diameter mounted on a lattice steel tower 70 feet high. The principal illuminant is a 250-watt searchlight lamp deriving its power from the municipal mains via an electric flasher which provides a character of 3-seconds light and 2-seconds dark. An astronomical time switch causes the light to operate at sundown and to discontinue at sunrise. The intensity of the light under these conditions is 7 000 candelas which is reduced by a red filter to 2 800 candelas.

Should the mains supply fail, or should the lamp filament burn out, the holding coil of an electrically-operated gas valve becomes de-energized, and acetylene is allowed to pass from a bank of cylinders to a gas flasher and a lamp-exchanger mechanism via a pressure-reducing regulator. The pilot flame is constantly alight so that the three 30-litre per hour burners operate as soon as acetylene is supplied to them from the flasher. The character remains at 3-seconds light and 2-seconds dark but the intensity is now only 650 candelas with the red filter in position.

Upon restoration of the mains supply the gas burners are extinguished and are replaced at the focal point of the lens by the 250-watt lamp.

3·4 *Standby power for mains-operated lights*

Of the two methods described of achieving a standby for a mains-operated electric light, the acetylene burner is by far the simpler, involving as it does no prime movers and rotating machinery, and the space taken up for the equipment is small and inexpensive. But it suffers from the disadvantage that large intensities are impossible with acetylene gas without recourse to mantle-type burners which are not so reliable as the open-flame burners. For small intensities, up to a maximum of 2 000 candelas, gas installations are simple and clean, and the shelf life of the gas accumulators or cylinders is infinite ; but the replenishment of the gas supply is laborious, the cylinders requiring to be despatched when empty to a distant gas station for recharging. Cylinders are easily damaged by rough handling and must be condemned in the interests of safety when there is the possibility of a dent forming even a small pocket or cavity in the porous mass within the cylinder. A high degree of gas purity is essential to safeguard the regulator and flasher mechanisms from the effects of chemical corrosion. The efficiency of the ventilation system in a gas lantern operating from day to day in various climatic and weather conditions is a most important factor. Insufficient ventilation causes incomplete combustion of the acetylene and a thick deposit of soot obscures the light. Minute kelp flies and other flying insects must be prevented from entering the lantern because of the ease with which the pilot flame may be extinguished. With these disadvantages overcome, however, the acetylene-gas light is a most reliable instrument, and it has served the South African Lighthouse Service well over the last forty years.

The question may well be asked—why not arrange for a mains-operated light to have a battery-operated standby ? There are many advantages in the use of batteries over gas cylinders and electric lanterns may be totally enclosed so that there is no ventilation problem. Mechanisms are available that replace as many as 23 defective lamps in succession. Electric flashers or character devices are of simple construction.

The answer has been, in the past, the distrust with which secondary cells have been viewed. Inspection by means of voltmeter and hydrometer does not always give a reliable indication of the available capacity. Considerable and undetectable damage may be caused by unskilled charging. The quality of the initial filling and forming of a secondary cell is an important factor in its life and service efficiency. A saline atmosphere can have an adverse effect on the electrolyte. Low ambient temperatures can cause freezing and high temperatures lead to excessive evaporation.

When these disadvantages are overcome it is expected that the battery-operated electric lantern will become common in the field of marine navigational aids. Both dry and secondary cells are popular for this purpose in other countries. In South Africa lead-acid cells are used as the source of power for radio beacons, and for starting the standby petrol-electric plant of the Cooper and the Umhlanga Rocks lights. The automatic fog bell to be installed in the near future at the Berg River mouth will rely entirely on secondary cells. A small electric portlight, operating on cells of the air-depolarized type has been tested and found suitable for installation.

Primary cells of the air-depolarized type are gaining favour overseas especially in installations where the load on the battery is intermittent. They are particularly applicable to the operation of a small automatic portlight using for example a 12-volt, 12-watt lamp. With a lens of 250-mm diameter such a lantern would provide an intensity of 250 candelas and would be visible for eleven miles in clear weather.

With a normal one-tenth character (the duration of the flash being one-ninth of the duration of the dark period) the dry cells could be expected to last 15 months with the lantern operating day and night, and approximately 27 months in conjunction with a sunvalve or a light switch. The battery would consist of ten cells, each being of the size 8½ in by 8½ in by 11 in, the capacity being 2 000 ampere-hours at the 1 000-hour rate of discharge.

In the event of primary or secondary cells acting as the power reserve for mains-operated lights, the low voltage employed makes it necessary to use a lamp changer mechanism to bring the low-voltage lamp automatically into focus when the mains supply fails. Another simple arrangement, not hitherto used in this country, consists of a battery-operated low-voltage light, the battery being continuously trickle-charged by the mains supply. An interruption in the latter then requires no lamp changer mechanism nor the operation of any moving parts.

4. LIGHT AND BELL BUOYS

It has been an ancient practice to mark the position of an underwater obstruction by means of a floating object or buoy secured to the sea bottom by a rope or a chain. Identification was made easy by the shape or colour of the buoy. Later, special superstructures with daymarks were added. Lights were fitted operating at first with crude oil and later with acetylene, propane, and butane gas. Electric buoy lanterns operating from dry or secondary cells are popular in some countries but these have not yet been adopted in South Africa although tests of this form of illumination are at present being conducted. Sound signals in the form of bells and whistles were ingeniously contrived to take advantage of wind and waves. The modern buoy is not complete without one or more of these aids together with the latest floating aid to mariners, the radar reflector.

In recent years two buoy installations have been completed, each marking the site of an underwater obstruction which was found too difficult to remove by blasting.

4·1 *The Whittle Rock buoy*

The False Bay site, known as Whittle Rock, is 7½ nautical miles south-east of Simon's Town and some 4½ miles off the main land near Miller Point. The buoy, anchored in 22 fathoms, carries an acetylene-gas lantern, a clapper-type bell and an octohedral radar reflector. Acetylene gas is contained in six gas accumulators each of more than 5 000-litres capacity and is sufficient to operate the light, flashing continuously day and night with a character of 0·5-second flash and 4·5-seconds eclipse for over twelve months.

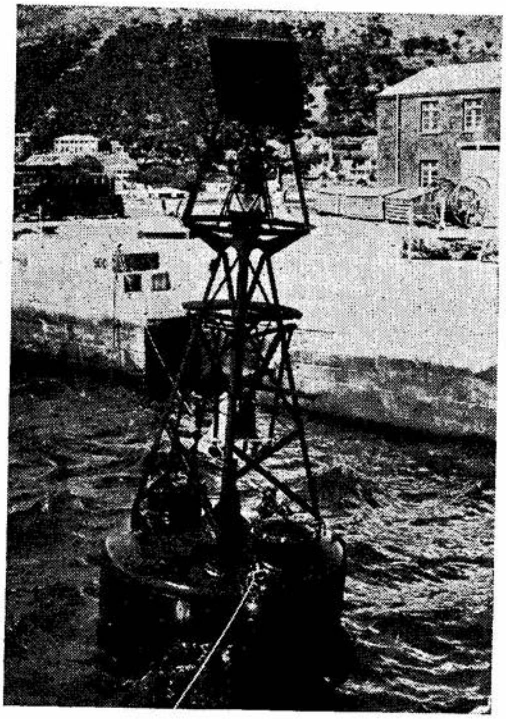

Fig. 1.—The Whittle rock light and bell buoy in Simonstown harbour prior to installation. The octahedral radar reflector is mounted above the lantern

In conformity with general practice this installation consists of two identical buoys as shown in Fig. 1, one in service and the other ashore receiving maintenance attention. It says much for the reliability of the gas supply and the quality of the lantern and the flasher that they can be left with confidence for twelve months on a deep-sea buoy in a position which is inaccessible in all but the calmest weather.

The only trouble so far encountered with this buoy has been an interesting case of corrosion of the mooring chain in the section near the sea bed. While investigations are proceeding into the cause of the corrosion it is hoped that the application of cathodic protection, in the form of magnesium anodes on the sea bed will overcome the trouble.

4·2 *The Table Bay Harbour buoy*

A different problem required solution in the case of the buoy obtained to mark the rocky outcrop in Table Bay. In view of the incidence of fog in this area, which is only a mile off the end of the breakwater and directly in the shipping lane to the Duncan Dock, and the fact that fog in this position is generally accompanied by a dead calm sea which would not operate a clapper-type bell, it was decided that the bell should be power actuated.

Carbon-dioxide gas contained in three cylinders in a pocket within the buoy body is the source of power. The striking mechanism consists of a piston-operated hammer controlled by a flasher or timing device which causes the 200-kilogram bell to be sounded four times every minute, day and night, for the service period of three months. The lantern is operated by acetylene in the normal way. Radar reflectors of an unusual design will be installed shortly whereby it is expected that the radar range of this buoy will be increased from 3 to 10 miles or more—see Fig. 3.

5. RADAR REFLECTORS

Radar reflectors on buoys and other structures have made their appearance since the war. The need for them has arisen from the fact that imperfect echoes and sometimes no echoes at all are obtained from low-lying hazards like sand banks and also from prominent landmarks like circular lighthouse towers.

While ships' radar installations operating on the shorter wavelengths provide better definition, even these have difficulty in recording the many sand spits, small islands, and rocky promontories along the coast line. Where hills some distance inland from an invisible obstruction show up well on the radar screen, the temptation for an inexperienced navigator to cut the corner may well lead to disaster.

Notwithstanding the justifiable acclaim with which radar has been received as a new aid to mariners, the anomalous situation

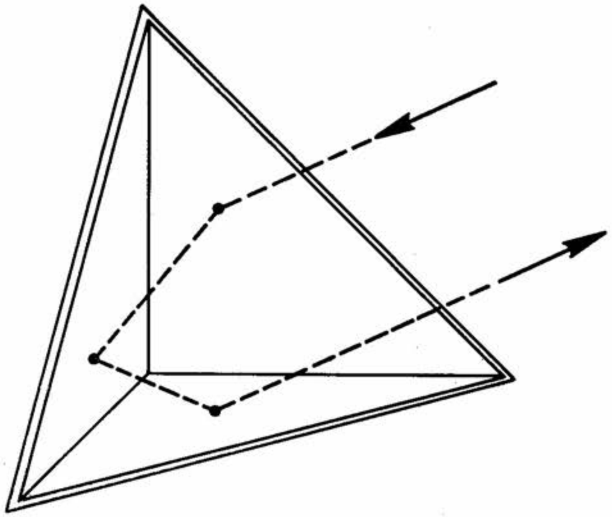

Fig. 2a—Radar pulses from any direction are returned by the corner type radar reflector in the same direction as the incident ray

arises that in the hands of a navigator in strange waters it may prove a source of danger. This argument pertains particularly to localities like Pelican Point near Walvis Bay, Britannia Reef and Cape Columbine, Danger Point, Quoin Point, Cape L'Agulhas, Cape St. Francis and Cape Recife.

Reflectors have been used to good advantage on naval practice targets and on small craft employed in air-sea rescue operations. A light folding type of reflector is used at times in the whaling industry to mark newly-killed whales. This enables the catcher to concentrate on other activities while the whales are collected by a radar-equipped vessel and towed to the factory ship.

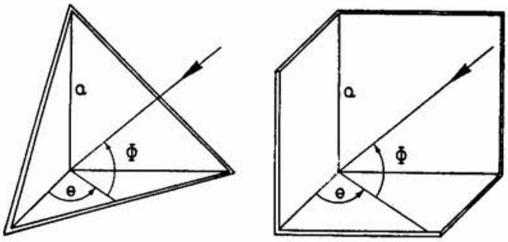

Fig. 2b—Triangular and square type corner reflectors

Several reflectors have been developed, the commonest being the corner type with either triangular or square sides as shown in Fig. 2b. The values for the angles θ and ϕ for optimum energy return are 45° and 35° respectively. These reflectors are generally placed in such a way that the centre line of the opening is horizontal.

It can be appreciated that where omni-directional performance is required, such as on a buoy, a number of reflectors must be mounted in a circle facing outward. The octahedral cluster mounted on the Whittle Rock light and bell buoy has an energy response characteristic consisting of six lobes equally spaced through 360°. The reflector is made of copper sheet cut into squares and isosceles triangles and assembled with great accuracy to form eight corner reflectors. The sheets are riveted together, welding being avoided owing to the danger of distorting the plates. The whole assembly is mounted above the lantern of the buoy as shown in Fig. 1 so that care must be taken in the design of the supporting members

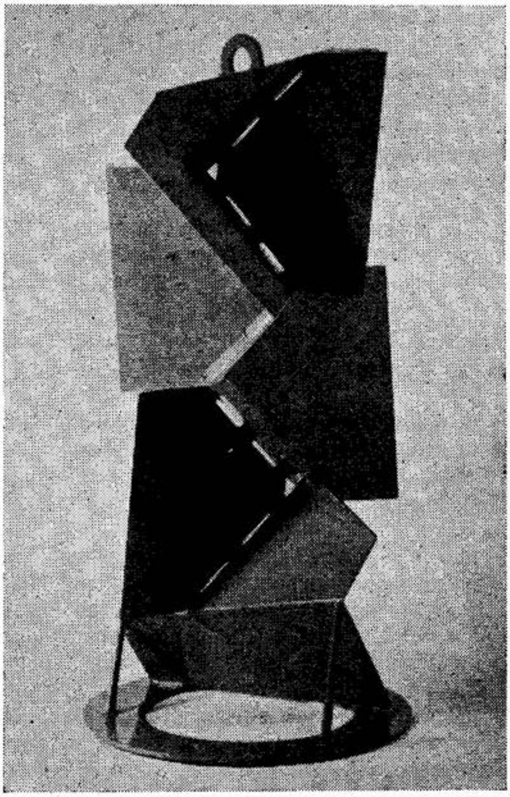

Fig. 3—Spiral type radar reflector

Photograph: A.G.A., Sweden

so that they do not obscure the light in any direction.

A recent Swedish design which gives a relatively uniform reflection all around the horizon is shown in Fig. 3, from which it can be seen that this novel shape can be resolved into a large number of corner reflectors.

The strength of the echo returned by a corner reflector depends on a number of factors, the most important of which are the power and frequency of the incident pulse, the size of the reflector, the presence of nearby objects from which secondary reflections may be obtained and the relative heights above sea level of the radar aerial and the reflector.

It has been found that the maximum range on a calm sea from a triangular corner reflector on an average U.K. marine radar of aerial height 50 feet is :—

$R_{max} = 1\,270\ ah_2$ yards

where a = length of the right-angle side of the corner reflector in inches

h_2 = height of the vertex of the reflector above the sea, in feet.

The maximum range of the same reflector in free space or over a very rough sea is :—

$R_{max} = 770\ a$ yards

where a, as in the previous expression, is in inches.

In the case of the reflector in the Whittle Rock buoy, where a is $23\frac{1}{2}$ inches, h_2 is $13\frac{1}{2}$ feet, the maximum range in a calm sea is 11·2 nautical miles and 8·94 miles in rough weather.

That the range is greater in calm weather is fortunate because it generally happens that a smooth sea and fog occur at the same time, and it is in fog that the radar reflector is most useful.

The application of radar reflectors to fixed structures and research on the subject of the design of structures to give maximum radar returns is engaging attention. Experiments are being conducted overseas and it is too early to predict whether an efficient form of passive aid will be developed, or whether accent will be placed on the development of the active aids like the racons and ramarks. These are high-powered land-based radar beacon transmitters which cause a characteristic signal to be displayed on a ship's indicator from which the distance and bearing of the beacon may be obtained. The ramark operates continuously, while the racon is triggered into action by the ship's radar pulses.

The installation of radar navigational aids of both the passive and the active types along the coast line of South Africa is considered to be a distinct possibility for the future which will be quite apart from, although complementary to, the existing radio-beacon service and any hyperbolic position-fixing system that may be introduced. It is thought that, at the outset, cluster-type corner reflectors will form a constituent part of the equipment at lighthouses and at the more important automatic lights in the near future, and that the experience gained in this direction will influence the design of common structures like lighthouse towers and pedestals for automatic lights.

6. APPROACH LIGHTS FOR SOUTH AFRICAN HARBOURS

South Africa is unfortunate in not being blessed with a serrated coast line with innumerable bays and wide river mouths which, in other countries, form natural havens for shipping. Durban Harbour has been developed from one of the few natural navigable lagoons, and were it not for the lack of fresh water in the vicinity, Saldanha Bay would surely have been the obvious site for the first settlement at the Cape. Apart from these, the major ports are protected by breakwaters built out into the ocean. Port Elizabeth is a typical example and East London is not very different in this respect notwithstanding that the harbour lies at the mouth of the Buffalo River.

Table Bay is a very exposed indentation in the coast line, the harbour requiring extensive artificial protection. Luderitz is more fortunate in being in the lee of Shark Island, and Walvis Bay has the sand spit Pelican Point for partial protection, but, in varying degrees, each harbour has two peculiarities in common, viz —

i the breakwaters jut out into the sea. This has the effect that the mariner comes upon the harbour, as it were, without warning, particularly in heavy weather when rough seas extend right up to the very entrance

ii the town or city is situated about the harbour in such a way that the city illuminations at night appear to the approaching mariner to be in the background of the harbour navigation lights.

Because of the first peculiarity the necessity exists for powerful navigation lights to be installed on breakwaters and other obstructions in the fairway, and on account of the second the effectiveness of these lights is largely negatived by the overwhelming glare of the city lights in the background.

Since World War II the street lighting of coastal cities has improved not only in extent but in the widespread application of high-pressure mercury-vapour and sodium-vapour lamps, advertising signs, robots and beach illuminations. Incorrectly adjusted street-lighting and dock-lighting fittings allow a vast amount of light to spill out seawards, the effect of which has to be seen to be believed.

The Railway Administration has a certain amount of control over the situation in that it has the power to prohibit or cause to be removed any light visible to seaward which may be mistaken for a navigation light by mariners. This, however, in practice places limitations on advertising signs and robots only—the glare remains. Dock and street lighting in harbour areas are under control and periodic inspections are carried out to ensure that fittings are correctly adjusted. It has been a matter for concern, however, that in the design of municipal street lighting very little attention appears to be paid to the spillage of light in horizontal and sometimes vertical directions. It is appreciated that a reason may be found in the desire of civic authorities to install ornamental rather than functional fittings and that beach illuminations are considered essential for every seaport city. The lighthouse engineer and the mariner whose interests he has at heart must take, literally, a different view of the situation. At some coastal ports the improvements in street lighting are proceeding so rapidly that difficulty is found in keeping pace with them. Particularly is this the case with Cape Town's new foreshore where the construction of buildings has started on the reclaimed ground behind the Duncan Dock and the problems associated with background glare are increasing rapidly.

At this stage it is felt that the solution to the problem is not to be found in any restrictive measures, but rather an attempt should be made to improve the conspicuity of the navigation lights above the glare of city illumination.

Hitherto any improvement in the conspicuity of a light has been brought about by an increase of intensity or candlepower. Usually this may be effected in the case of a drum- or a rotating-lens type light by increasing the intensity of the light source. An electric lamp may be replaced quite simply so long as the limitations imposed by the physical dimensions of the filament and its focal height are complied with. Open-flame type acetylene-gas lanterns of suitable size and gas consumption, on the other hand, have their upper limit in the region of only 2 000 candelas, a figure which has been proved inadequate at certain localities.

At the present stage of lighthouse engineering practice the determination of the intensity of a light to be conspicuous at a given range under conditions of comparatively high background brightness must of necessity be empirical. Until the difficulties associated with photometry at very low levels of illumination are overcome, the solution will continue to be the result of trial and error and personal experience.

7. THE FLUORESCENT LANTERN

7·1 *Experiments at Table Bay Harbour*

The general improvements effected in Cape Town's city lighting since the war and particularly the foreshore illuminations introduced for the Van Riebeeck Tercentenary made it imperative for the conspicuity of the Duncan Dock entrance lights to be increased if ships were to be brought into harbour safely at night time—see Fig. 4. In the outward direction the problem of background glare does not arise and, therefore, the sailing of ships *from* the harbour was not affected.

At this time the 500-mm acetylene-gas entrance lights were, on the port side, 800 candelas and on the starboard side, 2 000 candelas, the colours being red and white respectively. Their character was 0·5-second flash and 1·5-seconds dark.

From seaward the lights of Cape Town form a long thin horizontal line from Milnerton to Camps Bay, with a slight bulge in the centre caused by the lights in those parts of the city rising to the foot of Table Mountain. Green Point Lighthouse, with its flash of 850 000 candelas showed up well, but all the other navigation lights tended to get lost in the background glare of the city.

In view of the difficulties attendant upon increasing the intensities of the harbour entrance lights, it was decided to experiment with an entirely new medium in the field of marine navigational lighting, namely, the cold-cathode fluorescent lamp.

It was hoped that greater conspicuity could be obtained by increasing the size of the light source, particularly the vertical dimension, thereby achieving a contrast with the horizontal line of city lights. The fluorescent lamps, which were 8-feet long

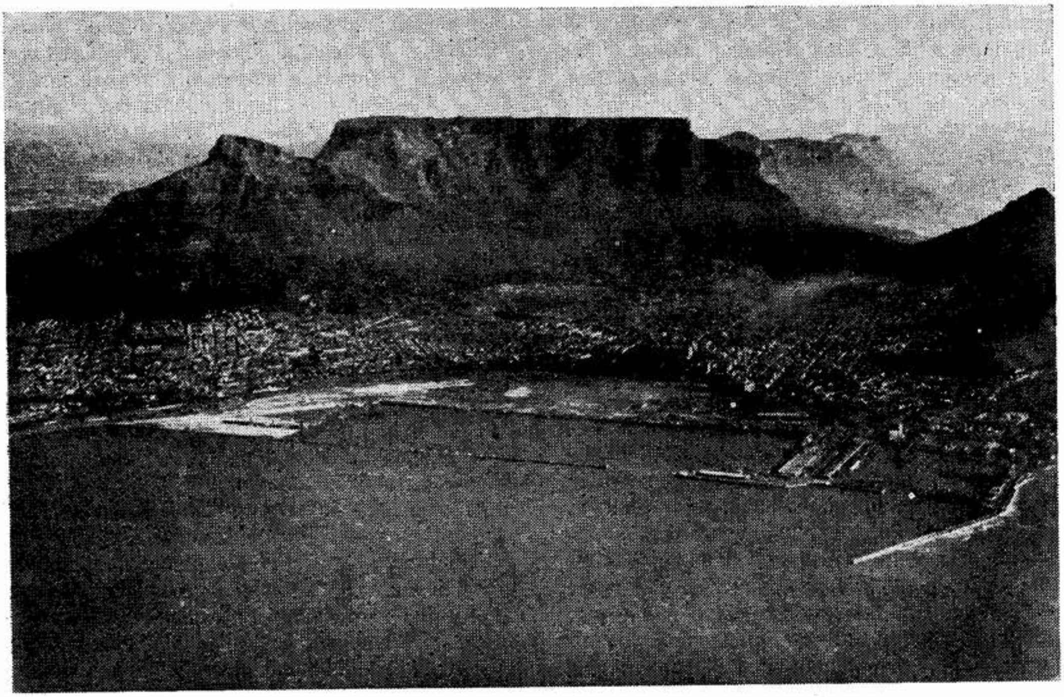

Fig. 4—Table Bay Harbour, showing from left to right, the Duncan Dock the Alfred Basin and the breakwater. From seaward the city is directly behind the navigation lights
Photograph: South African Railways

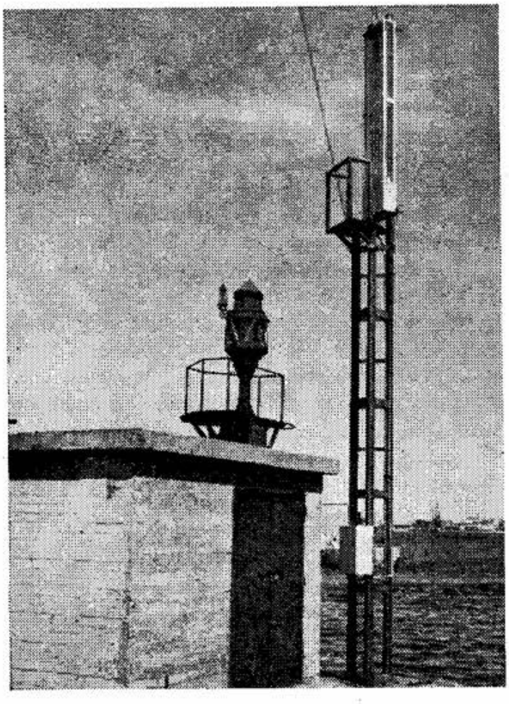

Fig. 5—The fluorescent lantern at the Duncan Dock with the acetylene gas lantern on the left
Photograph: South African Railways

and 25-mm diameter, were mounted side by side and an inch apart with their axes vertical on a backboard facing seaward as seen in Fig. 5.

A flexible switching arrangement controlled by an operator in radio contact with the observers' craft enabled variations of lamp colour, of the number of lamps and of the character of the flash to be set up without delay. It was thus possible for comparisons to be made continuously from the craft in a number of positions in Table Bay having the known values of the existing acetylene-gas entrance lights as a control.

7·2 *The lantern design*

From the data obtained, a lantern was designed and installed adjacent to the starboard entrance light consisting of eight white lamps of colour temperature 3 500°K. Behind six of the lamps a white-painted panel was set up to act as a reflector with the object of achieving a polar distribution shown

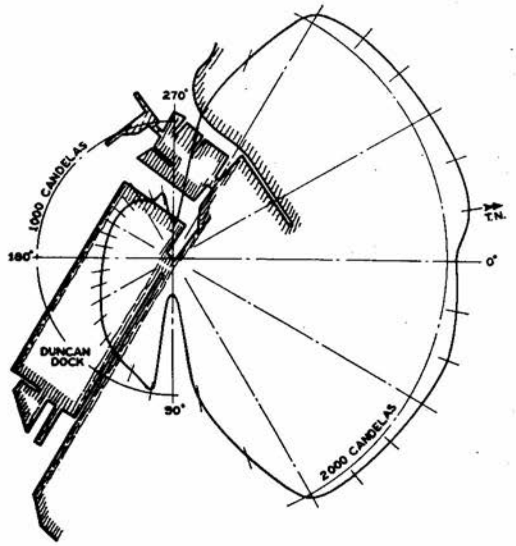

Fig. 6—The theoretical horizontal light distribution from the Duncan Dock fluorescent lantern which is arranged to provide minimum intensity in the direction of a ship about to enter the dock

in Fig. 6. With the aid of an electrically-operated gas valve, the existing acetylene lantern was retained as a standby in case of an interruption to the mains supply, and for this reason, the character of the gas light, i.e. 0·5-seconds light and 1·5-seconds dark, was applied to the electric flasher. The lantern was mounted so that its centre was 36 feet above H.W.O.S.T.

7·3 *The visible range*

The conspicuity of this fluorescent lantern was immediately acclaimed by pilots and visiting mariners who suggested the installation of similar lights at other harbours. Where most lights are obscured by heavy rain and fog, the fluorescent light has the peculiar property of lighting up the water vapour particles for a considerable distance around the lantern. The theoretical intensity in the direction in which the lantern is facing is not more than 2 000 candelas, but the range at which it has been recognized, *notwithstanding the glare of the city lights in the background*, would suggest a light of greater intensity or one having the property of influencing the eye to a greater extent than a normal point source of light.

The actual maximum luminous range has not been ascertained, but it has been recognized in clear weather (*i*) from a ship's bridge 75 feet above the water line at a range of 17 nautical miles, (*ii*) from a point on the Malmesbury–Hopefield road which is 38 statute miles from the Duncan Dock, and (*iii*) from an aircraft flying at 1 500 feet above Dassen Island, which is 33 nautical miles from the light.

7·4 *Criteria for conspicuity*

Accepted lighthouse illumination theory gives a figure of 20 nautical miles for the maximum range of a light of 2 000 candelas. This assumes an atmospheric transmission factor per sea mile of 0·9, illumination at the eye for threshold vision of 0·67 sea-mile candela and that the conspicuity of the light is not impaired by background glare. That the existing gas light of 2 000-candelas intensity loses its conspicuity in clear weather only six miles from the Duncan Dock is an indication that the fluorescent medium has some strange advantage over the point-source type light of comparable intensity.

In attempting to find a reason for this, a number of possibilities must be taken into consideration.

The ability of the eye to see an object depends on the four primary factors: brightness, size, contrast and time of exposure. For threshold-limiting conditions these are mutually interactive, that is to say, a reduction in one of them requires a corresponding increase in one or more of the other three. The threshold condition pertains in the process of observing a navigation light at the extreme limit of its luminous (as distinct from its geographical) range. At shorter range or for supra-threshold visibility, the effect of interaction is not so marked. One other factor in the case of a navigation light is its ability to penetrate the moisture-laden atmosphere immediately above the sea.

7·4·1 The brightness factor

Although the brightness of the lamps in the Duncan Dock lantern is of the order of 0·5 candela per square centimetre, the fact that they are spaced at approximately 2-inch centres in front of a white enamel-painted plane reflector reduces the overall brightness to 0·2 candela per square centi-

TABLE II

BRIGHTNESS OF LIGHT SOURCES

Source	Candelas per square cm	Colour temperature, °K
Moon	0·25	4 125
Candle flame	0·54	1 930
Acetylene flame	6·7	2 400
Tungsten-filament lighthouse lamps :—		
100 watts	120	2 360
1 000 watts	725	2 360
4 000 watts	1 200	2 360
Paraffin-vapour incandescent mantle	40	2 720
Fluorescent lamps, cold-cathode, 25-mm dia :—		
white	0·486	3 500
daylight	0·442	6 500
warm white	0·514	4 500
Fluorescent lamp, hot-cathode, 1½-in diameter	0·72	3 500

metre, which is approximately that of the moon. Table II shows how very low this figure is in comparison with other common light sources and it is obvious that a reason for the conspicuity of this lantern is not to be found in the brightness value of the lamps employed.

An unexpected advantage of this low brightness is that mariners are not blinded on close approach as they would be by, say, a conventional electric light of the same range.

7·4·2 The size of the optic

It is possible that on account of the comparatively large area of light presented to the observer a greater number of receptors on the retina of the eye are activated, thus producing a greater effect on the optic nerve than a near-point source. An alternative theory concerns the distribution and density of the rods and cones about the fovea on the retina of the eye. The rods, of which there are well over 100 000 000, are absent from the centre of the fovea but are distributed some 5 to 6 millimetres from it at a density of 160 000 per square millimetre and it is the rods which are associated with vision at low levels of illumination. The cones, less in number, are concentrated mainly at the centre of the fovea and function when illumination values are much higher.

It would appear that a large light source, even of low average brightness, is able to activate a greater number of rods than a smaller and brighter source and that under these conditions retinal sensitivity is of a higher order.

Weight is lent to this theory by experience gained during the war when black-out illumination became a subject of serious study. It was found that the magnitude of the area of an illuminated surface had a greater effect on its visibility from an aircraft than the intensity of the light energy emitted. This effect can be seen from seaward in the vicinity of the major South African sea ports, when the funnels of floodlit ships stand out clearly above the background of city lighting.

7·4·3 The contrast of the optic with its background

Contrast in illumination engineering means the ratio of the brightness-difference between the object and its background to the brightness of the background. As previously stated the brightness of the fluorescent lantern is low compared with that of other light sources, particularly the tungsten-filament lamp which is the most common medium for city illumination.

An important phenomenon relating to city lighting when viewed from a distance, however, is that individual lights tend to lose their conspicuity and merge into a dull haze covering the extent of the city visible to the observer. The brightness of this haze is thus of a low order, and the fluorescent lantern, interposed between the observer and the haze is enabled to be conspicuous on this account.

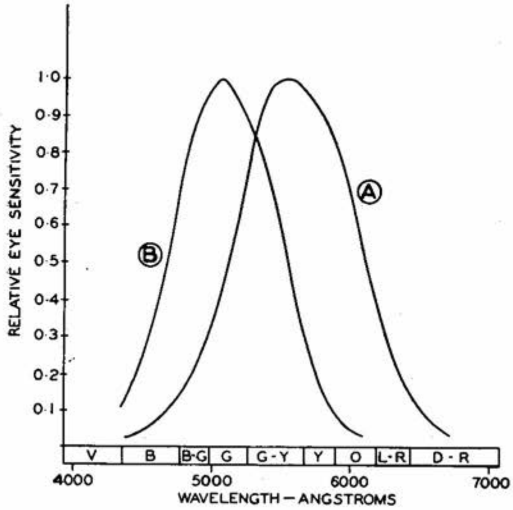

Fig. 7—The relative eye sensitivity in relation to the visible spectrum under the conditions of (A) normal levels of illumination (0·1 candela per square foot or higher), and (B) low levels of illumination (10^{-4} candela per square foot or less)

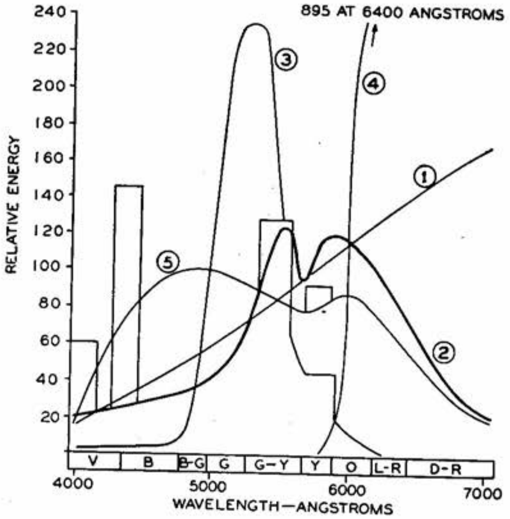

Fig. 8—Spectral energy curves for light sources :—

(1) incandescent filament
(2) fluorescent lamp, 3,500°K white
(3) fluorescent lamp, green
(4) fluorescent lamp, red
(5) fluorescent lamp, 4,500°K white

The colour contrast is appreciable in that the fluorescent lantern is a clear white, while the background, at a range of 5 miles or more, becomes a dirty yellow-white. Red navigation lights and advertising signs stand out clearly at close range, but they, too, merge with the background when viewed from a distance. When green fluorescent lamps were substituted for the white lamps in the lantern, they were even more conspicuous. This is understandable when reference is made to the eye-sensitivity characteristic in Fig. 7 and the spectral energy curves in Fig. 8.

The Purkinje effect on the eye-sensitivity curve applies in the process of observing a navigation light. While the human eye is most sensitive in the green-yellow portion of the visible spectrum under conditions of normal illumination at the eye of 0·1 candela per square foot or higher, as the field brightness is reduced the axis of the sensitivity curve moves over to the blue-green end of the spectrum. It may be inferred that light sources emitting large amounts of energy in the region of 5 000 Angstrom units will be more conspicuous at long range than those sources of similar intensity emitting energy of a greater wavelength. Fig. 8 illustrates the distribution of light energy over the visible spectrum for different light sources,

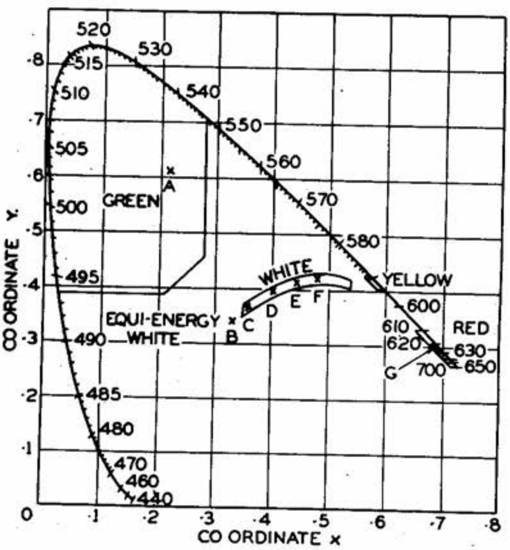

Fig. 9—The colours of light sources described on the I.C.I. chromaticity diagram. The enclosed areas indicate the allowable limits for navigation lights

A —fluorescent lamp, green
B —fluorescent lamp, 6,500°K white
C —fluorescent lamp, 4,500°K white
D —fluorescent lamp, 3,500°K white
E —tungsten-filament lamp
F —acetylene flame
G —fluorescent lamp, red

from which it can be seen that the green and the white fluorescent lamps are superior to the incandescent filament lamp in this respect.

That the colours of the red, white and green fluorescent lamps are consistent with the internationally recognized requirements for navigation lights is shown in Fig. 9 where their co-ordinates are plotted on the I.C.I. chromaticity diagram.

7·4·4 The penetration factor

The yellow-white light emitted by the old wick-type lighthouse lamps has had a reputation for good penetration power in mist and heavy weather which would appear to be unfounded. This theory is supported by the conclusions reached by several investigators between 1920 and 1930, but experience with the Duncan Dock fluorescent lantern, however, suggests that a blue-white light has better penetration. The possibility exists that with new illuminating media the old concepts may have to be amended.

In more recent years, no less an authority than Luckiesh and Moss have decried the illuminating properties of yellow light and have stated that: 'the so called yellow fog lamps actually reduce the brightness of objects, and therefore their visibility, without adequate compensation in some other manner.' An important contribution to this argument is found in the conclusions of Ferguson, Reeves and Stevens that the mercury-vapour lamp is more glaring than the tungsten-filament and the sodium-vapour lamps of the same intensity over a range of brightness from 1·5 to 55 candelas per square inch. While the visual conditions in the above example are different from those pertaining under very low ambient illumination, nevertheless, the eye is shown to respond better to the shorter wavelengths.

The water vapour in the air above the sea can be assumed to be of the same form as, but of much lower density than the sea itself. In this medium the French Navy's Undersea Research Group established beyond doubt that water acts as a selective filter for the warm colours of white sunlight allowing only the blues and greens to penetrate.

While it is admitted that no visible light, not even the most powerful searchlight, can penetrate a heavy fog far enough to be suitable for navigation purposes at long range, if it is possible to aid the mariner feeling his way cautiously through dock entrances and past obstructions in the fairway in thick weather, then some progress has been achieved. It is submitted that the white and the green fluorescent lights, emitting large amounts of energy of the shorter wavelengths fulfil this role to a certain extent at close range. The problem is one which invites further study and experiment.

7·5 *General*

Apart from its visual characteristics, the advantages of a fluorescent lantern are its low cost compared with that of other types of navigation light, the versatility with which almost any horizontal light distribution characteristic may be arranged, and the fact that there is no focal plane of light, the result of which is that the lantern is equally visible over a wide range of vertical divergence. This is of particular advantage to aircraft and, in the case of a light installed at a considerable height above sea level, to surface craft approaching close in.

The fluorescent lantern in the field of marine navigational aids is still in its infancy. Until recently the use of cold-cathode lamps has been imperative where flashing lights are required, but it is understood that a new type of hot-cathode lamp has been produced that may be flashed without appreciably reducing its life.

The Duncan Dock lantern has now been in service for over two years without a failure. The original lamps are still in use after flashing some 16 000 000 times and, by visual comparison with a new lamp, show no sign of reduced efficiency. The initial capital cost of the installation, including the power distribution, was only 20 per cent of the cost of a conventional drum-lens type of acetylene lantern and cylinders. The operating costs have also been very low.

In view of the success of this installation the principle of using fluorescent lamps in lanterns shaped to suit local conditions is being extended to other harbours where background glare causes the navigation lights to be ineffective.

The arrangement and number of lamps in the lantern depends on the intensity required throughout the arc of visibility for each particular locality. For breakwater extremities the arc of visibility is generally 360° and the required intensity is obviously less to landward than in the seaward direction because of the dark background brightness in the former case. For lights designed for installation on the coast an arc of visibility of only 180° may suffice. For each installation a different configuration of lamps within the lantern may have to be applied for maximum effect. In the case of the Duncan Dock the lamps were arranged side by side in a straight line, but a lantern is now being designed for the Port Elizabeth breakwater which will consist of three perspex tubes 8 feet long of 6 inches diameter each containing six lamp positions equally spaced about a central column, the surface of which will be treated to form a specular reflector. This unit principle allows of the mounting of the tubes in positions relative to one another and the employment of the number of lamps in each tube to be arranged to suit any requirement, as shown in Fig. 10.

The details of the lamps at present in use are as follows :—

Length	93 inches
Diameter	25 mm
Lamp watts	43 watts
Operating voltage	450 volts

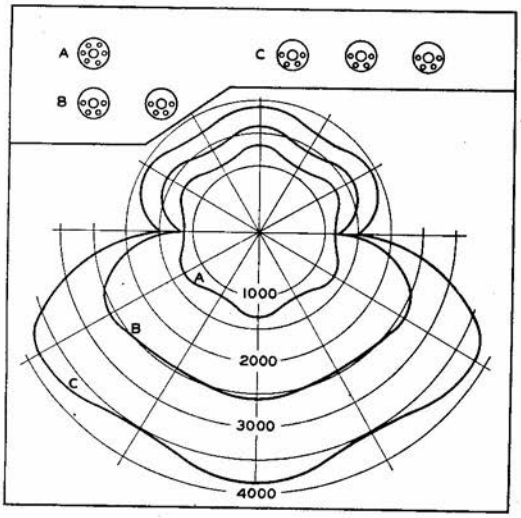

Fig. 10—The theoretical horizontal light distribution from three arrangements of tubular fluorescent lanterns. The scale is indicated in candelas. Fluorescent lamps, 8 feet long and 1 inch diameter are grouped about central specular reflecting rods and contained in 6 inch diameter perspex tubes

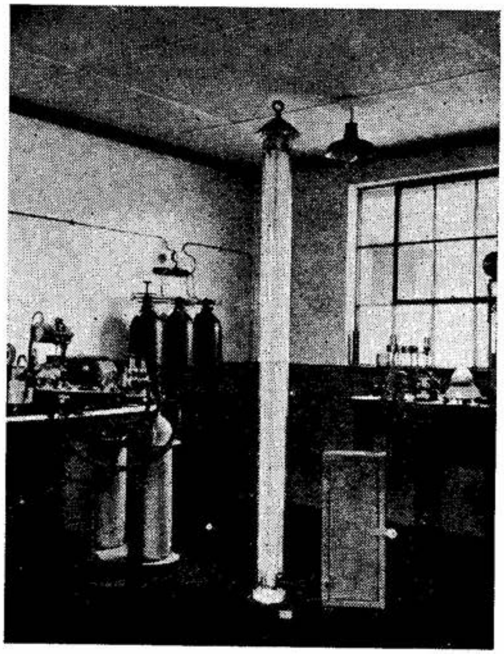

Fig. 11—The tubular type fluorescent lantern. Six lamps, 8 feet long and 1 inch diameter are contained within a 6 inch diameter perspex tube. The control equipment is housed in the cabinet on the right of the lantern

Lamp current	120 mA
Efficiency	60 L/watt
Lamp life	15 000 hours
Light output (100 hours) ...	2 500 lumens
Intensity (max)	254 candelas
Colour (white)	3 500 A°
Brightness	0·486 Cd/cm²

8. Acknowledgments

The writer is indebted to the South African Railways Administration for the facilities of studying the Lighthouse Service, and for the assistance rendered in the compilation of drawings and the supply of photographs. It is desired to acknowledge the permission given by the Press Photo Service to reproduce a photograph. Messrs A.G.A., Sweden, assisted with photographs and drawings, and the author's thanks are due to those who have contributed advice and criticism.

9. REFERENCES

1. HOGBEN, MILWRIGHT and STEMP. Admiralty Signal and Radar Establishment Monograph No. 833.

2. CAPT. F. J. WYLIE. A survey of five years progress in marine radar. *Journal of the Institute of Navigation*, Vol. XII, No. 1 (Jan. 1954).

3. *International Lighting Review*, Vol. 5 (1952/3).

4. MATTHEWS and VAN LIEMPT. *Philips Technical Review*, Vol. 5, No. 4 (April 1940).

5. P. J. BOUMAN. *Philips Technical Review*, Vol. 5, No. 10 (Oct. 1940).

6. W. J. WELLWOOD FERGUSON. *Trans. Ill. Eng. Soc.*, Vol. XVII, No. 3 (1952).

7. W. R. STEVENS. Principles of Lighting.

8. M. LUCKIESH and F. K. MOSS. Reading as a Visual Task.

9. C. L. AMICK. Fluorescent Lighting Manual.

10. F. C. BECKENRIDGE. Proc. of the International Ill. Congress, 1931.

11. *British Standard* 942 : 1949. Formulae for Calculating Lighthouse Beams.

12. J. Y. COUSTEAU. The Silent World.

13. *G.E.C. Journal*, Vol. XX, No. 3 (July 1953).

14. W. E. BARROWS. Light, Photometry and Illuminating Engineering.

15. H. G. JONES. Lighthouses and other aids to navigation. *Trans. S.A. Institute of Electrical Engineers* (May 1946).

16. K. C. SUTTON-JONES. Lighthouse engineering. *The Engineer* (July and August 1947).

17. W. M. HAMPTON. The control of light by a lighthouse lens. *Trans. Ill. Eng. Soc.*, Vol. XVII, No. 3 (1952).

DISCUSSION

G. A. Dalton (Past President): To most people, from adolescence to old age, lighthouses, lightships and visible aids to navigation hold a peculiar fascination. To all of these the paper has a very definite appeal. To the engineer, and particularly those who are, or who have been actively associated with navigational aids, the paper is not only replete with interest, but is of considerable value technically, high-lighted throughout by the standard of its prose.

In the introduction to his paper the author has set out to gladden our hearts by drawing our attention to the very imposing part which electricity is now playing in modernizing aids to help the mariner on his way. This being so, and with continuous research, it would be safe to prophesy that within measurable distance the 'storm-lashed rock lighthouse,' with all the glamour surrounding it, will disappear, to be replaced possibly by unattended automatic lights with radar reflectors as adjuncts, or some ingenious robot system still to be developed. The author's statement that storm-warning signals and radar reflectors are on the list of impending improvements lends colour to such conjectures.

It is indeed good to note that the trend of thought is to eliminate the attended stations, with all the inordinate costs involved, and to concentrate on their replacement by the non-attended automatic station which has now proved its reliability. By eliminating the costly attended station, it should then be economically possible to double up the number of lighthouses on the South African coastline, and by doing so secure the advantages, so very much desired by mariners, of establishing the succeeding, before relinquishing the rear, light.

The author, in the initial stages of his paper, made mention that not many moons ago the civil engineer was the final arbiter of lighthouse engineering, and from this aspect that old stalwart L'Agulhas, well over a hundred years of age, bears testimony to the work of those stouthearted engineers who brought it into being. It is indeed heartening, however, to hear of its modernization in the modern concept, and there is little doubt about the improved efficiency and handsome economies which will result.

With regard to the non-attended automatic light at Cape Seal, the author makes mention of the extreme difficulties attendant upon the annual exchange of gas cylinders. It would be interesting to learn whether consideration has been given to the possibility of placing the gas-cylinder magazine on the sea shore contiguous to the lighthouse, and replenishing it from the sea. Of necessity, this would probably mean the laying of a rather long pipe line to the lantern but, with the small pressures and velocities dealt with, the losses would be negligible.

In connection with the author's reference to the light continuing to function on overcast days, would this not indicate that some attention is necessary to the setting of the sun valve? Surely during daylight hours only intense gathering darkness, such as the prelude to a storm of major proportions, should cause the valve to operate.

Proceeding from the fully automatic gas-operated light the author has claimed our interest in his description of the fully automatic electric flashing lights installed in the Cooper and Umhlanga Rocks Lighthouses at Port Natal.

Is it possible for the author to provide the first cost and running costs of these installations, shown separately, and what in his opinion the costs would have been for gas installations designed to provide similar services to mariners? Have the all-electric systems been functioning long enough to determine their reliability and continuity of service in comparison with the gas system of operation; in other words, have there been any failures to record, and their nature?

The author in his coverage of standby power for mains-operated lights makes mention that gas installations are simple and clean, and the shelf life of the gas accumulators or cylinders is infinite, yet in the same sentence he states that the replenishment of the gas supply is laborious. A measure of ambiguity exists in this and some clarification appears to be necessary. Assuming that the shelf life is twelve or fifteen months, can the exchange of cylinders and perforce the inspection of the light once in this period be considered laborious?

Mr Lodge states that cylinders are easily damaged by rough handling necessitating their condemnation. Surely something is wanting in their distribution to preclude the inordinate severity of handling to which they are apparently subjected. What is the percentage per annum of cylinders damaged by rough handling and condemned in consequence? Can the author state whether damage to cylinders of this nature is experienced overseas in such countries as the United States, Canada and Scandinavia?

With regard to the necessity for ensuring a high degree of gas purity to safeguard the regulator and flasher mechanisms, is it not possible that the damage to these parts, experienced from the use of impure gas, is a secondary effect? Can the author lend substance to the theory that the impurities in the gas are consumed in the burner, and form—together with other combustible products—acids, which in turn attack the brass in the regulator? The resulting by-product is then the agent causing the damage by corrosion to which he refers.

The author foretells that when the disadvantages — which he has itemized as inherent in the use of secondary cells, including the adverse effect of saline-laden atmosphere—have been overcome, there will be an almost universal use of the battery-operated electric lantern. No doubt the author is quite satisfied that the proved infallibility and reliability of the gas system will be matched by the battery-operated system. Is it then his contention that the latter system will in the end definitely prove its advantage in point of costs, both capital and running?

It is most interesting to note that primary cells of the air-depolarized type are gaining favour overseas, more especially where intermittent loading prevails. The author instances their application for small automatic harbour lights and electric-buoy lanterns. In view of the tendency, evidenced by the author, to limit major attended stations on our coastline, and concentrate on the automatic unattended station, the question may be asked as to whether consideration has been extended to the use of air-depolarized cells for operating radio beacons automatically at such locations. Is the author aware of the installation at Fuglehuken in Spitsbergen which consists of 55 air-depolarized cells arranged in five parallel groups of eleven each? This battery energizes radio apparatus which operates continuously, sending out the signal *FG* in morse for one minute followed by an eclipse of three minutes. The drain on the battery varies between the normal minimum of 100 milliamperes, and a maximum of 1 ampere at the instant of despatch. The station is completely unattended, and is visited once a year for attention to cells and apparatus. There are ten similar stations functioning satisfactorily well within the Arctic Circle.

Coming to the subject of light and bell buoys the author makes mention of buoy lanterns, operating from primary or secondary cells, finding favour in some countries, and that tests with this form of illumination are now being conducted in South Africa. Will the author intimate whether the tests are covering the use of both primary and secondary cells? In the case of secondary cells, how is charging undertaken? If the cells are removed for charging what is the average period between changing the discharged cells for fully charged ones, and the costs involved?

The author's reference to the results achieved at the Whittle Rock Buoy are of great interest, more especially the investigations which are proceeding into the corrosion of the mooring chain. It is noted that this corrosion is localized in that part of the chain adjacent to the sea bed, and it is hoped that the cure will result from placing magnesium anodes on the bed of the sea. Has the author considered the feasibility of attaching the magnesium anode to that part of the mooring chain which, depending on the tides, alternates between resting on the sea bottom and being lifted from it? The underlying reason for the more intensive corrosion of this part of the chain would appear to be that the protective layer formed as a by-product of the reaction itself is mechanically ground away by this alternating motion of the chain. It goes without saying that this preventive measure will be watched with a great deal of interest, for the system employed, if successful, has manifold applications in all harbours and coastline installations.

It is most interesting to note that the buoy in Table Bay is completely gas operated. Could the author provide comparative cost and operational statistics on the assumption that such an important amenity as this were converted to all-electric operation?

background of city lights. I feel that its efficiency is due more to biological than physical reasons, for the sheet of light subtends a relatively large angle at the eye, and the intensity of illumination is low, so that the eye does not desensitize itself as it does with a powerful revolving light of high luminous intensity. In other words, it would appear that for navigational lights the integral of the light falling over an area in the eye is the major factor, and that the eye itself functions to a certain degree as a limiting device.

Mr Lodge has failed to mention two very important advantages of the fluorescent light, its low weight and the possibility of installing the code-senders some distance from the light. This means that the light can be installed on a breakwater on top of a 40-foot lattice tower, with the control equipment at the shore end. The light will thus be above green water and need only be protected against spray, while the lattice tower will offer little resistance to the seas.

E. C. Lodge (*in reply*) : Mr Jones' reference to the fact that the code senders of the fluorescent light may be installed some distance from the light is pertinent. This practice is followed with the Durban North and South breakwater lights and the breakwater fog signals at Cape Town, Port Elizabeth and East London, and it is of very real advantage when heavy seas make access to the end of the breakwaters impossible for maintenance staff.

B. L. D. Porritt (Associate) : Mr Lodge has mentioned the use of radar reflectors to assist in the identification by ships buoys, etc., and I should like to make a small contribution to his most interesting and informative paper in the form of a few brief notes on marine radar which I think are relevant to this subject.

Marine radar

Modern marine radar navigational equipment operates mostly on a wavelength of about 3 cm (9 300–9 500 megacycles/second) known as the *X*-band. This band has proved to have propagation characteristics resulting in high discrimination of objects, and it also possesses the advantage from the mechanical point of view that the aerial scanner unit for this band is of reasonable size and weight and can therefore readily be fitted to small vessels such as coasting craft who find a navigational aid of this description particularly valuable when they are navigating in the very often treacherous waters close to the shore.

Marine radar is a compact device. One well known make of set, which is designed for installation in small craft, comprises four units :—

a Scanner and r.f. unit usually mounted forward of the bridge or sometimes on a mast crosstrees

b Display unit, usually mounted in the wheel or charthouse

c receiver unit

d Power unit.

The power unit converts the ship's d.c. supply to 80-volts 1 000-c/s supply and draws less than 1 kilowatt from the ship's power source.

The display provides a plan position shown on a cathode-ray tube with a long-afterglow screen. The picture on the screen is that seen from the scanner unit with the ship in the centre. A radial time base is rotated at a speed of 24 r.p.m. in exact synchronism with the scanner. Objects reflecting the transmitted pulses cause a brightening of the trace and their range can be read off as a function of the time-base length and range rings on the tube enable this to be done with accuracy. Bearings can be read off against the cursor surrounding the tube. The display can be switched to suitable ranges selected in steps, typical ranges being 0·5, 1, 3, 10, 25 and 45 nautical miles. Discrimination of objects such as buoys is obtained to within 25 yards with an accuracy of 5 per cent or less. Bearing discrimination of objects plotted on the tube is about 1½ degrees.

The transmitted pulse length is short, say, 0·1 microseconds for the half- and one-mile ranges, but the pulse is automatically lengthened on switching to the longer ranges where discrimination is not so important and where solid painting of distant coast lines and long-range targets is wanted. Special circuits are incorporated in the equipment to assist in the suppression of echoes from rain and snow when this interference becomes objectionable.

That marine radar is of great value as a navigational aid is evidenced by the large numbers of ships that have been fitted. I am unable to quote accurate figures for all the manufactured types of marine radars, but 3 500 ships have been fitted with one make since 1946. The South African Navy has followed the lead of the British Navy and is being fitted with the naval version of this make throughout. The South African Railways have several tugs fitted with various types of marine radar for small vessels.

Harbour radar

The complementary land application of radar to its marine application as a navigational aid, is to plant it at a harbour control point to enable the shore authority to have a detailed view of the movements and positions of every vessel in the harbour area.

The equipments used for this purpose can be simple or elaborate according to the size of the harbour. One or more 12-inch or 15-inch cathode-ray tubes are used and the display gives accuracies of the order of 1-per cent range linearity and 0·5 degrees bearing.

Some of the more obvious uses of the harbour radar are :—

a It will reveal any vessel which has anchored in an unauthorized position, perhaps in a difficult channel or near a dock entrance, and can assist in her movement if necessary

b If a vessel has stranded or is in distress for any reason her position can be rapidly determined and aid sent to her immediately

c The position of buoys and other floating sea-marks can be checked and any mark which has drifted can be detected and a warning issued. The radar can also aid the recovery of the mark and its replacement

d The operation of dredgers can be supervised and their attendant hoppers watched to ensure that they are dumping in the approved areas.

Many other applications will suggest themselves. On a much publicized application reported at length in the Press was the observation by radar of ferry movements in the Liverpool Docks enabling this service to continue in dense fog.

V. A. Wilmslow (*communicated*): Mr Lodge has given a good insight into the fine work done by his department in safeguarding shipping along our treacherous rocky coast and the manner in which various forms of lighthouse illumination are brought out.

In early times, shipping was warned of dangerous places along the coasts by faggot fires on top of towers. Later, these were replaced by oil lamps or flares and then by gas or electricity, as described by Mr Lodge.

While gas-operated installations proved reliable after a fashion, the many disadvantages associated with gas lights prompted American lighthouse engineers to develop electrically-operated lanterns to their present stage of efficiency. The present-day standard of workmanship and design of the modern electric lantern, besides advanced battery design, has improved to such an extent in recent years, that this type is gradually replacing the gas type in many countries throughout the world.

As South Africa is a battery-producing country, whereas gas cylinders and associated apparatus must be imported, I am surprised at Mr Lodge's statement that electric battery-operated unattended lights have not been installed at remote points in South Africa.

Furthermore, since 1930 the American lighthouse authorities have replaced virtually all acetylene lights on fixed structures with electricity in the United States and, as of a year ago, the number of electric buoys exceeded the number of acetylene buoys in their Coast Guard Service. There are nearly 13 000 electrically lighted aids to navigation under the U.S. Coast Guards' jurisdiction, and less than 2 000 acetylene lights, of which approximately 1 400 are buoys. On the lower Mississippi River there are close to 800 paraffin lights, but there they use the cheapest type of light possible because the sites on which they are located often drop into the river overnight and all equipment is lost. Of special interest are the buoy installations at the mouth of the Columbia River in Oregon. These buoys mark the river bar and, even in calm weather, are pulled under and out of sight every few waves because of the surf action rolling across the shallow bar. The electrically-operated light is the only one which has proven reliable there.

Buoy installations, of course, are much more demanding on equipment than fixed-structure installations, and battery-operated electrical lanterns mounted on buoys have proved most successful at Wellington in New Zealand. This site is said to be one of the most exposed locations in the world. On the question of withstanding extreme temperatures, there are more than thirty lights in the Persian Gulf under the control of the Arabian American Oil Company, where temperatures are known to go above 120°F. There are over 500 lights in Venezuela, where temperature and humidity are extremely high. The Demarara River in British Guinana is entirely lighted with electrically-operated equipment. Cuba, the Panama Canal, the Phillipines and Hawaii have several hundred electrically-operated lights, and Bermuda and Nassau in the Bahamas are extensive users.

Electrically-operated beacons have proved most reliable in cold climates, such as in Canada where many hundred are installed and added to at the rate of a hundred each year. Many of these lanterns, as well as those operated by the U.S. Coast Guard Service on the Great Lakes, are allowed to remain 'on station' where temperatures drop below 20 degrees below zero. Although navigation ceases because the lakes are frozen, equipment is found to be operating the following spring.

There is no problem in furnishing a lantern with a battery supply which will operate continuously for one year without service. A beam candlepower of 2 000 can be obtained from a 300-mm lantern with a 32-volt, 60-watt lamp.

Comparing automatic electric lights with oil or gas lights, we find they are not only more economical in operation, but resist flooding when submerged in water. They also resist high winds and hurricanes which often extinguish gas lights. Insects cannot extinguish electric beacons, nor can internal condensation nor external ice formation extinguish the light.

When dry cells or caustic-soda primary cells are used, the handling and shipment of heavy gas accumulators is eliminated. With storage batteries field-handling methods are similar to those used for gas accumulators, but as the batteries may be charged locally, or at the nearest lighthouse depot, freight charges of heavy gas cylinders is avoided.

Another advantage of electric beacons is the complete elimination of fire and explosion hazards, especially in inaccessible locations.

Batteries of South African manufacture can be obtained anywhere to replace those in service or to operate a light until regular servicing and recharging is convenient.

With electric beacons any characteristic or coded flash is easily accomplished on site by simply changing the characteristic disc, and actual measurement of the lighted period of each flash to one hundredth of a second can be made.

Automatic lampchangers in electric beacons provide for continuous service should a lamp burn out, thereby eliminating troubles common to gas lanterns, such as clogged or broken burners.

K. H. O'Donovan (Associate): In spite of the acknowledged conservatism of lighthouse engineering, Mr Lodge has shown in his paper what great strides the science has made, particularly in the last two decades—probably due to the increased impetus of the second world war. Lighthouse engineers, and more particularly lighthouse keepers, have, in the past, made themselves notorious for their scepticism of 'new-fangled' ideas like electricity, as evidenced by the long struggle to convince them of their reliability. Now that it has been realized that new methods can be as reliable as, if not more so than, the old, while at the same time being far more efficient, scepticism has given way to a desire to render the utmost service by adopting such new methods as may render the service more valuable.

Mr Lodge's paper impresses upon us the fact that not only is he one of the more progressive lighthouse engineers, but he is also well in the vanguard with his revolutionary research into the use of fluorescent gas-discharge lamps for marine lighting.

There is very little doubt that the new fluorescent harbour entrance lights at Cape Town are a marked improvement visually. Mariners would be the first to condemn them if they were not. They have yet to prove themselves reliable over a long period and the factor of economy is to be considered. In this regard, I am disappointed that Mr Lodge did not give some figures regarding the relative running costs of the fluorescent lantern and the existing gas light or a comparable-beamed incandescent electric lamp.

Generally speaking, the luminous efficiency of a mercury-vapour discharge lamp is of the order of 36 to 50 lumens per watt, and used as a harbour light without reflector this would be reduced to about 30 per cent of this value. With an ordinary white reflector the luminous efficiency would have a value in the region of 20 to 30 lumens per watt. This efficiency is low in comparison with a beamed electric incandescent lamp. However, Mr Lodge has proved that the discharge lamp has a greater photometric effect and therefore it appears that the overall performance of the fluorescent lantern may compare favourably with an incandescent lamp for the same power consumption.

Although it would not affect the practical issue, it would be interesting if Mr Lodge could provide some photographic data in connection with his new lantern. A known exposure on a film of known spectral sensitivity would provide a basis on which the photometric effect could be investigated and the emission measured. The reason for this suggestion is that although of course the spectral sensitivity of the film is not the same as that of the eye, the uncertainty of visual judgment is eliminated so that an exact explanation of the difference in effect between the new and the old lantern could be ascertained.

In a new type of buoy light submitted to the Administration for consideration a gas-discharge lamp is used in place of an incandescent lamp. This lamp is beamed by a cylindrical lens in the same way as the old type and is powered by batteries. An interesting feature of this type of light is that different colours are provided by different types of gas discharge—for example a red light is produced by a neon-discharge lamp. The luminous efficiency is not much further reduced for coloured lights than it is for white lights. The obvious advantage is the elimination of filters.

The harbour entrance light at Cape Town has a similar inherent advantage and there can therefore be no doubt at all that for coloured harbour lights a fluorescent light of suitable colour is far more efficient than a filtered incandescent lamp. This principle may possibly be extended in the future to such installations as the Beach Anchorage light at Durban mentioned in Mr Lodge's paper where, as he states, a loss of 4 200 candelas in 7 000 is suffered due to filtering.

In conclusion, I would like to express the opinion that Mr Lodge's investigation of fluorescent harbour lighting must sooner or later receive the attention of lighthouse engineers throughout the world and its advantages recognized. He is to be congratulated for his courageous departure from tradition in the interests of safer and more efficient marine aids to navigation.

E. C. Lodge (*in reply*): It is difficult to quote accurately the total operating costs of the fluorescent lantern and the gas lantern which it replaces at the Duncan Dock, because maintenance costs (labour and material) have been negligible in both cases. The relative costs of fuel per year, however, are as follows :—

Fluorescent lantern (municipal supply) : £3 10s. 2d.
Gas lantern (acetylene) : £51 17s. 6d.

A mains-operated incandescent light with a drum lens and with a range comparable with the fluorescent lantern would consume electricity to the value of approximately £1 15s. 0d. per year, but it would have the disadvantage that mariners would be blinded on close approach by the brightness of the light.

R. A. Harvey and V. A. Lord (*contributed*) : Mr Lodge's paper is a very comprehensive one, covering as it does, a wide field in the application of marine navigational aids. It is very interesting to note that batteries have so many advantages over gas for emergency purposes. These advantages are overwhelming if the correct type of battery is used together with trickle charging. Former troubles may possibly have been due to the use of unsuitable battery types or the wrong type of controlgear. We consider that the most suitable form of battery to be used for standby lighthouse duties is of the sealed-in Planté type. It should preferably be kept on continuous trickle charge and brought into action when required by means of an automatic switch. This method of control is very widely used in Great Britain for emergency lighting in cinemas, hospitals, public buildings, etc. It has been fitted in some of the lighthouses in Great Britain where the power is normally taken from the public supply system. Amongst these are Withernsea Lighthouse and Lowestoft Lighthouse. The batteries and controlgear at these installations have been in use for almost twenty years without any major overhaul being necessary. There is no doubt whatever that trickle-charged Planté batteries are far more economical and reliable than portable batteries for this class of duty.

In the two lighthouses mentioned above there is a lamp-changing device to change from a mains-voltage lamp to a battery-voltage lamp when the mains fail. This is, however, not really essential since it is possible to supply the main lamp from the main supply at battery voltage through a step-down transformer and to change over directly to the battery by means of a contactor in the event of a mains failure. It would presumably be necessary, in addition, to have a lamp-changing device so that another lamp can be brought into use immediately in the event of filament failure, but there is no real need to have two different voltages for the main and emergency conditions.

In the paper, various criticisms are made of secondary cells when used for standby purposes. Many of these do not apply to a standby Planté battery used on trickle charge, but they are dealt with in detail below :—

a Voltmeter and hydrometer readings

We consider that a hydrometer gives a very good indication of the capacity available in a battery so long as it is used in accordance with the battery maker's instructions.

Voltmeter readings are not so valuable as hydrometer readings and are almost useless when the battery is on open circuit. If, however, the battery is on discharge, the voltmeter does give some indication of the capacity available.

If stationary batteries are kept on continuous trickle charge for standby purposes, voltage readings and hydrometer readings are merely a routine matter to ensure that the battery is in a fully-charged state.

b Charging

We agree that damage can be done by unskilled charging. The amount of special charging required with a trickle-charge system is, however, very small, as it is necessary to give a charge only after an emergency discharge. The maintenance of standby emergency batteries is frequently undertaken by comparatively unskilled people.

c First charging

We agree that first charging is an important factor in the life and service efficiency of a battery. If the instructions issued by the battery manufacturer are followed, however, there should be no difficulty in this direction. They are quite explicit and readily understood by the average battery attendant.

d Saline atmosphere

The modern type of sealed-in battery is very little affected by a saline atmosphere. This is proved by the effective use of lead-acid batteries on board ship.

e Temperatures

There is very little risk of battery electrolyte freezing in the temperatures which will be experienced in South Africa. In the case of a standby Planté battery the fully-charged specific gravity is 1·210 and this acid will freeze at minus 25°F, i.e. 57° of frost. When the battery is fully discharged at the 10-hour rate, the specific gravity of the electrolyte will be in the region of 1·160 and this acid will freeze at 0°F, i.e. 32° of frost.

High temperatures certainly lead to an increased evaporation, but with sealed-in cells this evaporation is not excessive. Sealed-in batteries are extensively used in India and other tropical climates without trouble from this cause.

Discussion at Cape Western Local Centre on The main line electrification of the Cape Western System of the South African Railways

By G. WILLIAMS (Member)

Transactions, June 1954

G. D. G. Davidson (Member): Thank you Mr Chairman. It is a pleasure to be able to second the vote of thanks which Mr Dalton has proposed and I am sure that I am voicing the sentiments of everyone here this evening when I say that we have listened to Mr Williams' paper with great interest.

The attendance itself bears out that the subject of Mr Williams' paper is a popular one, both to those who were directly concerned with the electrification of the Railways as well as to those who are on-lookers. It is a subject of general public interest.

The electrification of the Railways in the Western Cape is a furtherance of the railway electrification which has taken place elsewhere in the Union, and I gathered this evening in a short conversation with Mr Williams that as much as 60 per cent of the goods traffic in this country is now hauled electrically. Mr Williams added (I speak from memory) that something over 80 per cent of the passenger miles are also electrically hauled and we cannot have failed to observe tonight that the Railways, in the development of the Cape Western electrified system, have brought a great deal of experience to bear upon the layout of their plant and upon their methods of construction.

Insofar as the Electricity Supply Commission is concerned, the decision of the Railways to electrify from Cape Town to Touws River came at a crucial time in our development. The picture, briefly, is that before the war the distribution system did not extend beyond this side of the du Toit's Kloof mountains, and the highest transmission voltage was 33,000 which would not have allowed us to go much farther afield. During the war development was restricted, one of the major projects being the construction of a line through du Toit's Kloof to the Worcester area, enabling that area to be supplied by means of this single feed from the Cape. Immediately after the war, however, it became evident that there was a tremendous potential offering for municipal electrification and for rural development in the hinterland beyond the du Toit's Kloof mountains. This, however, was difficult to undertake economically until we were able to co-ordinate it with the proposal of the Railways to electrify their system. The picture thereupon changed and it became possible to consider amongst other items the construction of a power station at the Worcester end of the system, a development which was not only desirable but which was becoming essential from the point of view of load and continuity of supply.

Mr Dalton touched briefly on the question of the construction of a power station in that area. Worcester, rather than further north, was chosen, because one cannot only select a power station site from the strategic point of view, suitable sites being limited due to lack of water supply. All facts considered, Worcester appeared as the right position for a power station to serve railway, rural and municipal development. Consequently the Hex River Power Station was constructed and was put into operation in mid-1952.

We had at the same time to reconsider the design of our transmission system, where, as I said before, the highest voltage was then 33 000 volts. That was inadequate for the distances and for the loading for which we were about to cater and we had to decide upon the next step, in conjunction with the Railways. A great deal of collaboration took place from 1946 onwards between the

Commission and the Railways in order to plan the most economic and satisfactory development. The choice of system voltage lay between 66 and 88 kV, and eventually a 66-kV system was decided upon. As far as mercury arc rectifier transformers are concerned, a voltage above 88 kV on the primary side leads to difficulties, due, as Mr Williams has mentioned this evening, to the stresses to which such a transformer is subjected under backfire or shortcircuit conditions, and 66 kV has the merit that it permits of a correspondingly more robust construction. That was one consideration. Another factor was that, provided electrification to Beaufort West did not have to be contemplated, the distances and the loadings throughout the system could adequately be catered for at 66 kV and therefore it was unnecessary to go to additional expense to provide an 88-kV system. Thirdly, it had become our policy early in the war that wherever possible lines constructed for 33 kV would actually be designed to operate at 66 kV in order to cater for any subsequent development, which at that time could only be guessed at. Consequently, our system lent itself to conversion to 66 kV with a minimum of expenditure.

Another factor which disposed us in favour of 66 kV was that at the time, immediately after the war, certain items of equipment, such as switchgear, were obtainable within any reasonable period only from America, and as the standard American 69-kV class of switchgear fits in very satisfactorily for 66-kV working, we were able to obtain equipment at short notice and at competitive prices.

One of the major problems which had to be considered, and this became a joint effort not only between the Railways and ourselves but also with the G.P.O., was the question of the avoidance of telephone interference. Trouble of that nature had occurred elsewhere in the Union and all parties were anxious to avoid it here. Fortunately we were able to reap the benefits at that stage of the work which had been done by the Power and Communications Systems Co-ordinating Committee, which consists of representatives from the Railways, Post Office, Escom and certain other bodies and functions for the purpose of studying this question of telephone interference. The Committee has laid down standards, particularly in regard to the separation of transmission lines from communication circuits, and our system was planned and routed in accordance with the recommendations of this Committee.

Mr Williams mentioned that in the Cape the S.A.R. does not regenerate into the a.c. system. That is not done largely to avoid the high harmonics which occur with inversion of mercury arc rectifiers. As a further step to make sure of having a minimum of telephone interference, corona loss on certain lines was kept down by insulating slightly above the minimum standard and by means of these combined measures we have successfully avoided telephone interference on the Cape Western system. The precautions which had to be adopted were often troublesome, and on one occasion, only after we had carefully planned and routed a line of some 20 miles in length did it become apparent that we were running very close to a G.P.O. circuit and we were obliged to re-route the entire line—fortunately before construction had started.

There is, Mr Chairman, one question which I would like to put to Mr Williams. I am sure it is one that the Railways must have considered carefully and that is the economics of a.c. traction on this Cape Western section. A.C. traction has long been in use on the Continent and latterly in England. It seems to be growing more popular and I shall be interested to hear Mr Williams' views on the relative merits, economic and technical, of a.c. versus d.c. traction. In the case of d.c. traction the feed-in points have to be somewhat close on account of the low track voltage and in the design of our system we were constrained to keep our own voltage limits at the traction substations within close tolerances. The figures specified by the Railways were that the voltage must not exceed 102 per cent of normal at its highest on account of the possibility of flashing over of the commutators of the traction motors, particularly during regeneration, and at the other end of the scale, under track fault conditions, the voltage on our system was not to drop below 85 per cent of normal in order that there would be adequate power behind the d.c. track breakers to ensure their tripping under all conditions of track fault. From that point of view, d.c. electrification meant a stiff transmission system, more so perhaps than would be necessary with the higher voltage a.c. traction and it would, as I say, be interesting to hear Mr Williams' views on the relative merits of the two.

Finally Mr Chairman, I would like to second very heartily the vote of thanks to Mr Williams for a most interesting paper and I hope that the subsequent discussions this evening will justify the effort which Mr Williams has made and the trouble to which he has gone in visiting us.

G. WILLIAMS (*in reply*): Mr Davidson made reference to the choice of voltage, 66 kV or 88 kV. We prefer the 66 kV for the rectifier substations for the reason that a much more robust transformer can be built at that voltage than at 88 kV and the cost of the switchgear is very materially reduced.

As regards telephone interference, the rectifiers are of course harmonic generators, particularly if voltage regulation or inversion is used, and Mr Davidson is perfectly correct in his assumption that that was one of the reasons which weighed against the use of invertors or regulators on the rectifiers. As a matter of fact, it gave rise to the possibility of doing without the inversion and led to the investigation of the economics of the problem. It is very gratifying to say that whilst inversion is objectionable from the telephone point of view a very detailed and lengthy investigation indicates not only is it not desirable from this point of view but it is, in fact, not good economics. It is better to put more money into the conductivity and do away with inversion as the resistances are only coming into play really when there is bunched traffic. With the ideally operated train schedule we hope that there will be little or no current destroyed in the resistances, certainly not enough to justify the cost of inversion plant.

Mr Davidson also mentioned the question of a.c. traction. It may be interesting to know that when we worked out this scheme we ran out both schemes, a d.c. and an a.c. scheme, using the $16\frac{2}{3}$ cycle. We did not run out a 50-cycle proposition here for several reasons. Firstly it is very much in its infancy and secondly from all technical aspects (and this has been borne out by experience overseas) the 50-cycle traction is not satisfactory where there are many stops on bad grades with heavy goods trains. The $16\frac{2}{3}$ cycle, however, did appear to be attractive and we worked it out. There seems to be a lot of misunderstanding about this a.c.—d.c. controversy, the general impression being that a.c. is a cheaper proposition. In fact it might be interesting to note that in this particular scheme in which 40 locomotives will be required finally, the two schemes came out almost exactly the same on cost, owing to the higher cost of the locomotives, but any increase in the motive power over 40 locomotives, tips the scale in favour of d.c. traction. As we wanted 40 locomotives, and the probabilities are that this number will be increased, in fact the certainty is that it will, it was obviously not good business to use $16\frac{2}{3}$ on plain economics.

The voltage regulation referred to by Mr Davidson was critical. We asked for a critical regulation on the a.c. side for the very good reason that we had absorbed all margin on the d.c. side. Insofar as keeping our copper down, despite the very large cross section, we had to work to the highest permissible d.c. voltage on the motor that the manufacturer was likely to tolerate and in regeneration we had to allow the voltage to rise to the highest figure that is really tolerable on the d.c. load and there was little or nothing left over for the Electricity Supply Commission.

S. MCCRACKEN (Member): I have very few comments to make about the paper as several of the other speakers have touched on some of the points I was going to mention, but I have noticed that there has been trouble with the chassis on these latest locos and that seems peculiar to this system and I don't think that altogether the manufacturers can be blamed for the trouble that has been experienced. It has been quite common apparently and it must, I think, be associated with the combination of narrow gauge and the short radius curves you have got on this particular system.

Mr Dalton made some reference to the brush boxes and that is a point that I was going to touch on because some 30 years ago I advocated the use of double brush gear and I am pleased to say that the firm with which I am now associated has since adopted those recommendations in a very large measure particularly on the larger machines but it occurs to me that the traction motor is an ideal application for double brush gear. With double brush gear you have got smaller brushes, lower and smaller inertia brushes and provided they are provided with small inertia independent springs the conditions really should be very much better than with one great solid brush with a very much higher inertia factor. It is a fact that two smaller brushes of the same area as one large brush will carry approximately 50 per cent greater current without any signs of distress. I should be interested if the author could tell us something more about his experiences. I know that they have had some teething trouble with these brushses; were these associated with long runs on down grades where perhaps they got glazing on the commutator and maybe one brush took on a higher glaze and the other brush had a matt finish? If so, have they tried the two varieties of brushes, one forward and one rear? I should like a little more information on that subject because it is of great interest to me.

I notice that the high-speed d.c. circuit breakers are now operating on rate of rise of current, presumably that is a coil operating off a turn on the d.c. circuit which will destroy the flux and allow the breaker to open in a very short period. Is back-up protection provided?

I have in mind a very serious occurrence on the Bombay/Baroda and Central Indian Railways some 25 years or so ago where a breaker of this type was arranged for automatic reclosing on an unattended substation where without back-up protection and due to a failure of the lock-out relay it went on reclosing indefinitely until the air in the substation was ionised, arcs were being drawn over a matter of feet, d.c. arcs, and eventually the whole substation was burnt down and the system was out of action for several days. It was a most serious accident which could have been avoided by back-up protection on that high-speed circuit breaker.

G. WILLIAMS (*in reply*): Mr McCracken referred to the bogie frames.

Well, it is agreed of course that on the 3 feet 6 inches gauge and the curvatures experienced on our routes the duty imposed on the frames is very severe indeed but I must point out that these facts were previously made known to the world in published papers and we make no bones about it when we order frames that we intend to subject them to the most violent stress owing to the curvature and torsion loads and we naturally expect design to take care of that.

We did have trouble on these frames. They were difficult to put right and it meant a lengthy and costly operation which I am afraid the makers were most unhappy about but it was quite obvious that the frames as supplied did not stand up to the duty.

I have referred also to the split-brush design. Now, we claim little or nothing of the credit in solving that problem save our persistence in going ahead with it. The design was insisted upon by the maker who quite frankly stated he couldn't guarantee his motor if we reverted to solid brushes, which quite obviously was our intention in order to obtain a troublefree job and it was due to this insistence that we persevered with the split-brush although at the outset we were very sceptical about it. We had never used them before and they appeared at first sight to be just an infernal nuisance. However, the designer insisted on them and it is very gratifying to say that he was quite right, we could and did find that a split brush gives excellent service.

The other query was of the type of journey they were on. I must admit to Mr McCracken that that appears to have had a very considerable bearing on the matter. The first loco was put into service in Natal. They were all put on very long passenger train runs; they were all passenger trains (we sent them down there for that purpose) and they were therefore subjected to long stretches of high-speed running without any rest whatsoever. It is quite possible therefore, as Mr McCracken inferred, that a great deal of the trouble we experienced on those brushes was due to the fact that they were on the most severe type of service right from the outset. However, it is gratifying to say again that we have overcome the problem even on the severe long fast passenger runs.

Mr McCracken's remarks about the back-up protection on the high-speed circuit breakers has given me quite seriously to think. We have never had any such an occurrence as he referred to. I can see distinctly the possibility of such a thing happening but conditions on our system are slightly different in that the substations are not entirely unattended. All the substations, whilst they are unattended from the point of view of technical staff, are remotely controlled from the nearest signal cabin and in the cabin there are indications showing circuit breakers open and shut, rectifiers on and off load, and any occurrences such as Mr McCracken envisages will come under the eye of the signalman. If the reclosing or opening does fall down, the signalman can hardly miss it because his lights will keep flashing. If they do not reclose at the third time and stop, he will undoubtedly have some instructions which would enable him to close down the substation manually until someone visits it. We have that additional safety feature but as I say Mr McCracken's illustration of what could happen here will need a little investigation as to the possibility of this set up of ours. I'd hate to experience an occurrence such as he has related.

H. E. Gibbard (Associate Member): Reading through Mr Williams' paper, one cannot help but be amazed at the comprehensive manner in which such a variety of aspects of the electrification scheme has been covered in such a relatively small space. Each one of these aspects is a topic in itself for an interesting paper and I only hope that in due course the Institute will be privileged to hear other papers read which deal in more detail with the individual items of equipment. Judging from remarks in the opening portions of the paper, it would appear that very careful thought had to be given to economy and first costs and one can well imagine that to exercise this economy and yet evolve a first-class job must have called for considerable weighing up of merits of tenders and construction processes and procedures.

Under the heading of 'Overhead Wires and Fittings' mention is made of the employment of springs at the anchoring points to maintain conductor tension under varying temperature conditions. Perhaps the author would be good enough to provide more details of the 'prescribed limits' on which the design was based. In some parts of the world the catenary and contact wires are maintained in tension by means of weighted counterpoises, as opposed to the employment of springs, but it may be that in such regions temperature variations are even greater than in the Cape and, furthermore, icing conditions may have to be encountered.

The spring tensioning arrangement is, I should imagine, considerably simpler than that of using weights to maintain tension on account of the necessity in the latter case of using a rope and pulley system between the conductor pull-off points and the sides of the anchor structure. There is possibly an advantage to be gained by the weighted method of tensioning and that is the tension is theoretically even, no matter the extent of elongation or contraction: a feature which is not afforded by springs. Could Mr Williams please give reasons for the use of spring tensioning as it is my belief that this is an innovation as far as the Railway Administration is concerned?

The development of a form of section insulator which satisfactorily survives the passage of a pantograph between live and faulty line sections is quite an achievement and I think either a picture or a detailed description of the assembly would be beneficial to all who are in any way interested in this aspect of overhead line construction. Is it to be understood that the contact wires are terminated at this section insulator? As Mr Williams states that some difficulty was experienced in constructing the insulator with sufficient mechanical strength to withstand the tension of the contact wire, I should imagine such is the case. It is presumed that the catenary conductors are swung to the side in order to avoid the arc from the horn gaps reaching the catenary and thus transferring the arcing to other portions of the overhead system.

The employment of fabric reinforced material for the main insulation in the section insulator has evidently been found satisfactory. It is my impression that the presence of fabric tends to cause the insulation to deteriorate, the material swelling in the process. Possibly some means have been adopted to seal the surfaces of the insulation to avoid ingress of moisture.

A paper describing the rectifiers installed in the substations appeared in the Journal of another South African Engineering Institution at the reading of which I was invited to comment on behalf of this Institute. My comments under this heading are, therefore, short. There is, however, one aspect mentioned by Mr Williams in connection with the rectifiers upon which I would like to remark and that is the close temperature control which has been found necessary to obtain satisfactory operation. Instability of the arc can occur, however, under conditions of low ambient air temperature or by rapidly varying air temperatures.

In the former case starvation occurs at the cathode and adequate precaution should be taken to ensure that air temperatures lower than that for which the rectifier is designed are not reached. In the latter, it is a matter of ensuring that the temperature distribution in the rectifier itself is right so that with the varying loads inherent with traction duty, together with variation in temperature of the cooling air, do not unduly disturb this distribution. The maintenance of correct heat distribution of a completely air-cooled steel tank rectifier during load swings is apparently more difficult than in the case of the water-cooled rectifier on account of its lower thermal capacity. To avoid arc instability under these conditions, some form of heating other than by the arc itself is evidently necessary. The manner in which this additional heat is applied is dependent to a large extent on the design of the rectifier; in some cases this is accomplished by heaters incorporated in the anode assemblies, as distinct from general internal heating in the upper portions as described by the writer.

Reference is made to the resonant shunts which have been installed, which include for absorption of the sixth harmonic. Later in the paper it is mentioned that in each substation (all of which are double unit) one transformer is provided with a star connected primary winding and the other with a delta connected primary winding to give overall twelve-phase operation. It would appear, therefore, that the provision of the sixth harmonic shunt is superfluous; is it to be assumed that the provision of this shunt is to cater solely for conditions when one of the two units is out of service?

For single track working and loading conditions generally, it would appear that the substation ratings are higher than those normally employed, bearing in mind too the relatively large conductor cross sections employed on the track equipment. It may be that these features are related to the necessity for provision of high track breaker settings and as these settings are related in turn to the minimum fault currents likely to be attained on individual sections, it would be interesting to know what figure is usually allowed by the author for the breaker setting as a percentage of the minimum fault current.

I can find no mention in the paper of the provision of tie-stations or mid-section breaker controlled sectionalising points. Unfortunately, the advance copy of the paper which I received did not include the diagrams and it is probable that Fig. 1 shows the sitings of such switching points. If any sectionalising stations have been installed, it would be of interest to know whether the closing of the breakers is automatically line controlled or controlled from a nearby signal cabin, as in the case of the substation breakers.

K. Lewis (Member): It is regretted that Mr Williams did not give some further information concerning the reasons for the South African Railways & Harbours adopting an electric traction system for the main line in preference to the diesel electric or straight diesel.

Whilst the use of electric traction makes for cleaner running it certainly seems to make the system far more inflexible than it was with steam locomotives.

The electrified system is also extremely vulnerable to damage and the whole system can be put out of operation if, for instance, one of the power stations was damaged—unless, of course, the railways take preference over industrial and private consumers!

Further, if an overhead line conductor is broken or a train is derailed with subsequent damage to mast and overhead gear, the accident immediately becomes a major incident because of the other trains held up and having, possibly, to be towed out of the 'dead' area by a steam locomotive to allow the breakdown train access to the derailment or overhead line fault.

Another point is that it does not seem economical that coal which has to be used for the production of electricity should have to be conveyed over a considerable stretch of the electrified system. The electrification also appears to overload still more the single track from the interior to Cape Town and as, during the past few years Cape Town has always been short of coal during the winter months, this position, it appears, will be aggravated.

Admittedly, in considering the changeover to electric traction the Railways must have been very heavily biased by the fact that coal is the only indigenous fuel available in the Union and full use would naturally have to be made of this fact. But surely this condition has now changed completely in view of Sasol which will produce quite considerable quantities of diesel fuel oil. There is also a refinery in Durban which is producing quantities of diesel oil. Admittedly, in this case, the crude oil comes from a source external to the Union, but the fact remains that in the event of hostilities, every effort would be made to keep this factory running in order to supply other forms of fuel to users in the Union.

To sum up, therefore, when the railways were considering changing the Cape Western system, was due attention paid to diesel electric traction and, if so, it would be very interesting to know the reasons for not adopting this extremely flexible form of traction which appears to be so successfully used overseas, especially in the United States.

W. M. De Boor (Associate Member): It has been my privilege to spend considerable time with Mr Williams and his staff while the electrification of the Cape Western System was under construction. For this reason, I have studied Mr Williams' present paper, which constitutes an excellent summary of the main features of the Cpae Western electrification system, with particular interest.

In the historical introduction to his paper, the author mentions that the proposal to electrify the main line from Bellville to Touwsriver brought about a review of the power supply position in the Cape area as a whole. This appears to me to be a very modest statement. The actual position would probably be more accurately reflected by saying that, as a result of this decision, it became possible to supply a large area, at advantageous rates, with all the electric power required for its industrial and rural development.

The Cape area is, in my opinion, very fortunate indeed to have been presented almost simultaneously with two important facilities for its economic development; namely,

(*a*) a greatly improved train service
(*b*) an ample supply of electric power at low rates.

The reductions in train running times achieved over the electrified section mentioned in the paper, prove the first point beyond any doubt. The second point has been borne out by Mr Davidson's contribution to the discussion. It is to be hoped that these considerations will whet the appetite for more railway electrification schemes in other parts of the country where electric energy is still produced in small power stations at comparatively high cost, and rail transport could be vastly improved by the introduction of electric traction.

Electrification of railway lines is often decided upon in other countries on account of the considerable economical advantages derived from the resulting possibility of distributing electric power at low rates over extended areas, even though the density of the rail traffic in itself would not warrant immediate electrification. The decision to electrify approximately 150 track miles of the railway line between Elisabethville and Kolwazi in the south of the Belgina Congo was, for example, influenced to a certain extent by such considerations.

The electric locomotives in operation on the Cape Western System must be among the most powerful units built for 3 feet 6 inches gauge railways. It is noted that the nose suspended type of driving motors was adopted for these locomotives. It may be of interest to mention, in this connection, that in many overseas countries locomotive designs incorporating bogie-mounted motors are more commonly used. The advantages of materially reducing the unsprung weight of the locomotives are obvious and the resulting reduction in the cost of track maintenance must be considerable, although it is difficult to express it in concise figures. Furthermore, commutating conditions are more favourable, and the average life expectancy is longer for bogie-mounted motors owing to the absence of hard shocks from the track.

It may be argued that a flexible transmission from the motors to the driving axles entails a complication in the design of the locomotives. Operating experience over long years has shown, however, that this point is not of major importance. Locomotives incorporating bogie-mounted motors would appear to be of considerable interest for the conditions prevailing on the electrified sections of the South African Railways, on which the track is generally winding its way through mountainous country.

In the design of, and the construction methods adopted for, the track equipment, steelwork and foundations, overhead wires and fittings, etc., the South African Railways' engineers have displayed a very high degree of ingenuity and engineering skill. I am convinced that railway engineers all over the world will study, with great benefit, the brief references made thereto in the present paper.

In the chapter of the paper devoted to substation equipment, the main advantages of the air-cooled rectifiers, as compared with water-cooled rectifiers, are briefly outlined. It is also mentioned that a very close temperature control is essential for trouble-free operation of air-cooled rectifiers, the greatest instability being experienced at low temperatures. As this remark might cause some misunderstandings among those who are not entirely familiar with the somewhat specialised subject of mercury arc rectifiers, I may be permitted to explain this point in some further detail.

In common with other types of machinery, such as motor car and diesel engines, steam turbines, etc., mercury arc rectifiers have an optimum temperature range within which they will give the best performance. For mercury arc rectifiers, the main factor influencing this range is the pressure of the mercury vapour in the rectifier tank, which fundamentally depends exclusively on the temperature in the rectifier and not on the type of the cooling medium used.

A difference exists, however, between the water-cooled and the air-cooled types of rectifiers, insofar as the thermal inertia inherent to water-cooled rectifiers is comparatively high, owing to the considerable thermal storage capacity of their cooling water system, and is comparatively small for air-cooled rectifiers. Consequently, temperature variations will be slower in water-cooled than in air-cooled rectifiers. On the other hand, a comparatively small amount of heat energy will bring a cold air-cooled rectifier to the required safe minimum temperature, whereas it may even become necessary to introduce a certain amount of hot water in the cooling system of a really cold water-cooled rectifier to achieve the same result.

From the above remarks, it is obvious that air-cooled rectifiers are somewhat more susceptible to temperature fluctuations of the ambient air than is the case for water-cooled rectifiers, and that effective temperature control is, therefore, of greater importance for air-cooled mutators. In cold countries, heating installations of limited capacity are usually provided for the substation buildings in order to ensure favourable operating conditions for air-cooled, and even for water-cooled, rectifiers. Under local climatic conditions, heating devices built into the air-cooled rectifiers as described in the paper would appear to meet the requirements. In a few cases where a substation is located in an exceptionally cold spot, it may be indicated to further improve operating conditions by providing some simple and inexpensive devices which will cause the air volume in the substation building to act as a thermal buffer between the rectifiers and the out-door atmosphere. Operating experience over an extended period will best indicate the actual requirements in this respect.

The fact that the old established water-cooled rectifier is more and more supplanted by its younger air-cooled counterpart may be accepted as a conclusive proof of the superiority of the air-cooled type of rectifier. This applies in particular to rectifiers for traction purposes, and to my knowledge, the large majority of traction substations built in recent years in all parts of the world have been equipped with air-cooled rectifiers for the reasons outlined in the paper.

In conclusion, I should like to express my sincere thanks to Mr Williams for having presented us with this paper, which is not only of great interest to railways engineers, but also to all the many other engineers who, like myself, take a special interest in all matters connected with railways.

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