CONFIDENTIAL BULLETIN FOR THE USE OF MEMBERS

THE HOSPITAL ENGINEER

NEWS LETTER

No. 3 Issued MARCH 1946

Contents

Hon Editor :
R. G. ROGERS,
" Elmfield,"
Stone,
Aylesbury,
Bucks.

EDITORIAL.

THE Institution commenced another year of its activities on 1st January, 1946. We have, together, come a long way in a comparatively short time since our inaugural meeting at Nottingham on the 28th August, 1943. The progress of the Institution has been made known to you all through the medium of the " Newsletter " as far as it has been possible to reveal details of our negotiations without detrimental effect to matters which are still *sub judice*. I know many of you will be a little impatient to know results of matters, the outcome of which are of the utmost importance to you, but I ask you to exercise the utmost patience and reserve regarding these matters. It is often far from easy to convince other people of the difficulties with which the Hospital Engineer is faced, the wide range of knowledge he has to possess, and the skill and initiative he has to display in order to administer his department economically and efficiently. Of these, and all the other relevant points, I assure you, the members of your J.C.C. are fully aware, and you may rest assured that they are doing everything possible in your interest. There is, however, one way in which you can help the members of your J.C.C. You, the Member, or associate Member as the case may be. How ? By increasing the membership. Get hold of your colleague, and if he is not a member, ask him 'why?' He should be; it is his Institution. Your Council in its deliberations, must know that in voicing its opinion it is speaking for every Hospital Engineer; so will you please see to it that every Hospital Engineer fills up one of our application forms? **Now!** Don't leave it to your fellow member, do it yourself. We are often asked in the course of our negotiations, how many Hospital Engineers we represent. It rests with **you** when we can say 100 per cent.

The newly elected Council for 1946 held its first meeting at The National Hospital, Queen's Square, London, on Saturday, 2nd February, 1946, when all members of the Council attended.

Before the business of the Council commenced the members were addressed by Mr. Hewitt-Mitchell, Secretary of The National Hospital, who said how very pleased he was to let us have the use of the Board Room for our meeting. He said he had taken a great interest in the activities of the Institution of Hospital Engineers, which he was sure was pursuing the proper course by advocating and endeavouring to establish a standard for Hospital Engineers. The result would be all-round efficiency of the Hospital services; to the mutual benefit of the patient (whose well being, comfort and treatment is the primary consideration of us all), the employing Authority, and the Hospital Engineer. He wished the Institution every success for the future and hoped he would have an opportunity of meeting us again on a future occasion.

The Chairman of the Institution, Mr. J. Hargreaves, in reply, thanked Mr. Hewitt-Mitchell on behalf of the Council for his kindness in allowing us the use of the room for our meeting, and thanked him also for the excellent refreshment which he knew had been arranged for the members. It is very gratifying he said, to find that a gentleman such as Mr. Hewitt-Mitchell, holding a high administrative post in the Hospital world, took such a keen interest in the activities of our Institution, and felt sure that such co-operation as this, freely given, must be to the benefit of the Hospital world generally.

Mr. J. Hargreaves was re-elected Chairman of the Council for 1946, and Mr. J. Tomlinson was re-elected Vice-Chairman.

Five associate members were transferred to Full membership on application.

The Council resolved that all branch secretaries should notify members of the existence of the Benevolent Fund, and that they should be asked to contribute 5s. per annum to this Fund. All contributions should be forwarded to the Honorary General Secretary.

Thirty-three applications were received and considered by Council, and all were duly elected.

The date of the next Annual General Meeting was fixed for 3 p.m. on 7th September, 1946, the venue to be somewhere in London. It is hoped to make arrangements for a Ladies' night on this occasion and a sub-committee from the London Branch has been set up to work out details.

At the London Branch meeting on 22nd September, 1945, we were extremely fortunate in having a paper on "The Trend in the Development of X-Ray and some of its applications," by G. S. Innes, Esq., B.Sc., A.M., I.E.E., A. Inst. Phy., of St. Bartholomew's Hospital. Mr. Innes has a vast knowledge of this subject, and the members listened with intense interest to his paper which was well illustrated by means of the Epidiascope. Mr. Innes has certainly whetted our appetites, and we hope he will pay us another visit in the not too distant future. He very kindly gave permission for the paper to be printed in the "Newsletter," and it is contained in this issue.

EDITOR.

THE TREND IN THE DEVELOPMENT OF X-RAY EQUIPMENT AND SOME OF ITS APPLICATIONS.

IN 1895 Roentgen discovered a new type of invisible, penetrating radiation which he called X-rays. The rays cause some types of crystals to fluoresce, emitting visible light, so indicating the presence of the rays, not only positionally but quantitatively by the intensity of the fluoresence. The rays also affect photographic films and plates just as ordinary light does, while they are absorbed by materials approximately according to the material density and logarithmically as the thickness of the material traversed. These properties lead to the first practical application of X-rays, namely in the radiography of the human body. For this purpose relatively low voltage X-rays only are required—up to 80,000 volts. Since these early days, Radiography has become a precise science requiring skilled operators and Diagnosticians.

In the early 1900's it was observed that these rays appeared to have some effect on surface malignant lesions. In some cases the cancerous lesions completely disappeared after prolonged irradiation but the surrounding normal tissue survived, showing that some malignant cells are more radiosensitive to X-rays than is normal tissue. Only a very small proportion of cancerous growths are to be found on the surface of the patient and with the low voltage equipments then available, it was impossible to get a therapeutic dose to lesions buried in the patient. The demand therefore went out for higher and higher voltage equipments.

Before enlarging on the development of X-ray equipment since the early days, let us first pause and consider the modern conception of matter and how X-rays are generated. All substances are made up of one or more of the 92 elements singly or in chemical composition with one another. The smallest part of any element found taking part in a reaction is the **atom** of that element, each atom of any one element being identical chemically but not necessarily physically. (There are isotopes which have slightly different masses).

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                    COMPOUNDS
                        |
      Combinations of Atoms of Elements


                       ATOM
                         |
         ---------------------------------
         |                               |
      Nucleus                        Electrons

(Positive Charge =n              (1 Negative charge
  and Mass =m    )                 each, n off  )
         |
     -----------------
     |               |
  Protons         Neutrons
   (n off)        (m-n off)
  Each            Each
   Mass 1          Mass 1
 Charge 1        Charge 0
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Fig.1

The atom is envisaged as comprising two parts—(1) the nucleus which is positively charged and contains the mass of the atom and (2) an orientated cloud of electrons each of negligible mass and each with one negative charge.

The atom itself has normally no charge, the number of electrons being equal to the positive charge on the nucleus. These various particles must not be visualised as being all bunched together but more like the following illustration. If we imagine the inside of St. Paul's Dome to be an atom, then the nucleus will be a pin head at the centre, while the electrons will be grains of sand uniformly deposited over the space and of number never greater than 92! There is a further division whereby the nucleus is made up of protons of mass one and charge one and neutrons of mass one and no charge. This gives us the final picture of matter made up of three particles, the proton, the neutron and the electron in proportions necessary to produce the mass and internal charge of the atom considered. Fig. 1 gives the family tree of matter, while Fig. 2 illustrates the Helium atom.

HELIUM

Mass 4.
Charge 2.

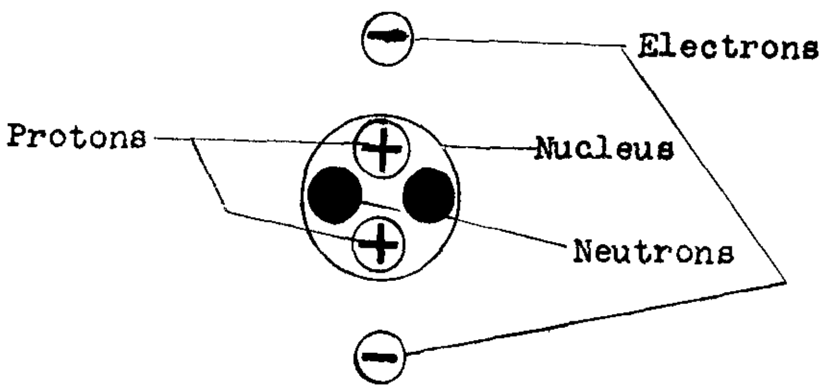

Fig. 2

In the generation of X-rays we are primarily interested in the electron which is the smallest of these three particles. To get some idea of its size :—if twelve million million of them could be induced to line up side by side, which is impossible, they would stretch one inch. Roentgen discovered that if he bombarded a target with a stream of electrons moving at a high speed, not all of their energy appeared as heat, but some appeared as a new invisible radiation which he called X-rays. The usual way of producing a stream of electrons is to heat in a vacuum a metallic filament, usually tungsten, to a white heat, when it is found that a continuous copious supply of electrons is emitted. If in the same vacuum envelope there is another electrode to which is applied a positive potential, relative to the filament, the electrons are attracted to this electrode and arrive there with a velocity depending on the voltage through which they have fallen. For instance if the potential applied across the electrodes is 200,000 volts the electron speed is some 130,000 miles per second. When the electron beam hits the target it is just like a hammer hitting a gong, most of the energy is used in moving the gong, some goes in heat, while only a little appears in sound—in the case of the electrons the majority of the energy disappears as heat and at the most a per cent. appears as X-rays. This is understandable when we return to our illustration of an atom as the space inside the dome of St. Paul's, the nucleus a pin head, the electrons grains of sand and we shoot in a single electron, a sand grain. The probability of this electron being arrested by a head-one collision with one of the particles is remotely small and this is the process which would represent the generation of an X-ray quantum, while, when the electron passes through an atom, it repels the atom electrons causing them to vibrate as if they were supported by elastic fibres to the nucleus and this process is the process of generating heat. So it is obvious that most of the electron beam energy will disappear as heat and only a very small part of it will produce X-rays.

As the potential across the X-ray tube is increased so is the output wavelength of the emergent X-ray beam reduced and with this reduction in wavelength comes increased penetration and a decrease in the relative absoprtions of substances of different densities. Diagnostically, the greater the difference between the absoprtions of different tissue the better ; but for therapeutic treatment the less the difference the better, for lesions have a nasty habit of hiding behind high absoprtion tissue, *e.g.*, behind bone.

Up to about 1930 many attempts were made to increase the voltage applied to therapy equipments above 200,000 volts, not only to attain the benefits of higher penetration but to investigate whether there was any increase in the relative destructive power of these shorter wavelength rays on malignant tissue as compared with that on normal tissue.

All therapy departments up to the year 1932 were operating with equipments fitted with sealed off X-ray tubes, that is X-ray tubes which had been evacuated and conditioned on the vacuum pump and then sealed off from it and removed. They were of the two electrode variety, (Fig. 3) with a cathode (filament) and anode (target). Above 200,000 volts it was found that the electrical stresses

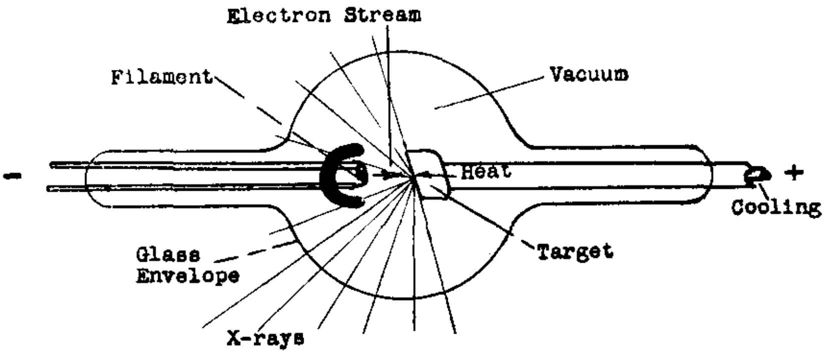

Fig.3

on the envelopes and electrodes was so great that gas was extracted from them, resulting in gas discharges, progressing to direct electrical break-down between the electrodes, irreparably damaging them and often causing external flashing over of the tube and puncturing of the envelope. This became a costly process since each tube cost at least £100.

In this country and the U.S.A. there then appeared Continuously Evacuated X-ray tubes, where the tube functioned while being evacuated all the time. This meant that as gas was dragged out of the electrodes, it was automatically removed and the pressure in the and never allowed to rise. In this country the development was carried out by Messrs. Metropolitan Vickers Electrical Co., Ltd., initially with the view to provide a 250,000 volt equipment with low replacements costs. Since the tube was pumped all the time, materials which tended to gas for a long period and which therefore could not be contemplated for sealed off tubes, but which had many admirable electrical properties, were incorporated in these tubes.

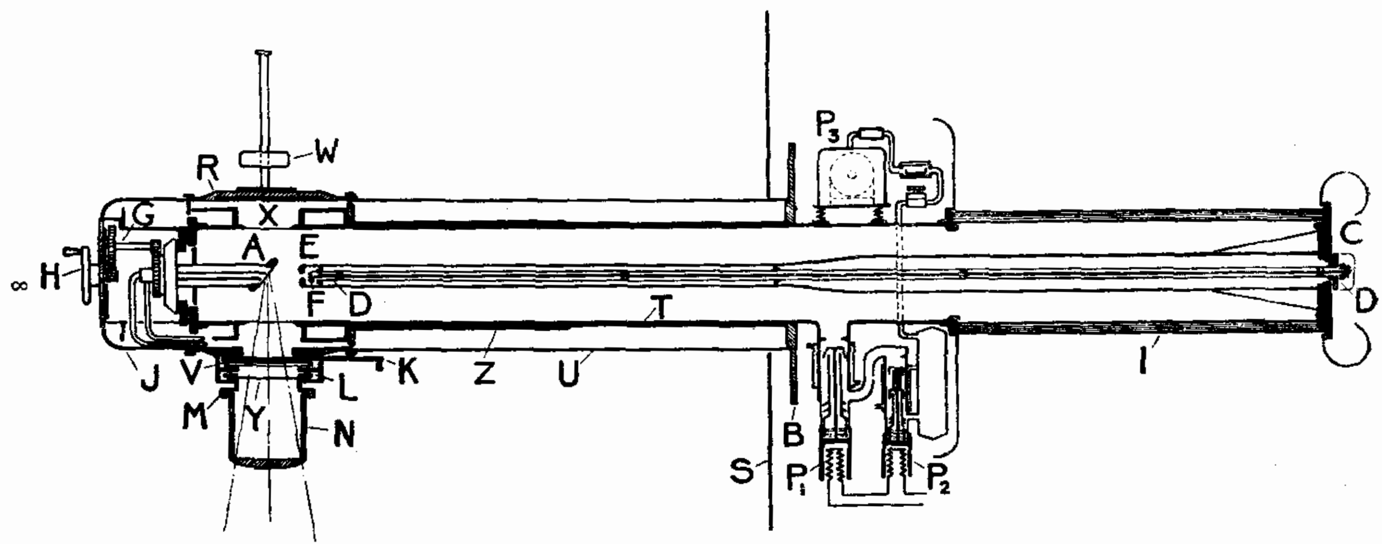

Fig. 4.—Section of X-Ray Tube (250,000 volt.) continuously evacuated.

The vacuum cylinder of the tube (Fig. 4) comprised an 8inch solid draw steel tube (T) fitted with steel end flanges (C) flatted to 1/100,000 of an inch. On one end was bolted by insulated bolts an 8inch diameter ¾inch thick wall cylindrical porcelain insulator (I), also with its end faces ground flat. Supported on the remote end of the insulator was the 7ft. long steel cathode tube (C,E) inside which slipped the filament assembly (F, D, D), the filament (F) comprising a three turn flat helix of tungsten costing about 6d. On the front end of the steel tube which projected into the treatment room, to the left of (S), was fitted the copper gold target (A) rotatable through a rotating vacuum steel to steel joint, fitted with oil sealing rings. The static joints between the steel tube and porcelain, between the porcelain and cathode flange, are made vacuum tight by sealing off with a special low vapour pressure bitumen, while the joints between the steel tube and the target head and the filament assembly and the cathode flange are made off with a quickly demountable seal in the guise of a low vapour pressure plasticine. A tube so sealed will remain at 1/10,000 of an atmosphere for weeks on end without the vacuum pumps being on.

The tube is continuously evacuated by a completely automatic pumping plant (P123) which attains a vacuum of 1 millionth of an atmosphere. The main pumps are oil condensation pumps (P1, P2) operating in principle similar to the water jet pump. Fig. 5 shows the operating principle of these pumps. Oil is boiled in the boiler (B). The vapour rises up the funnel (F) and emerges through the jet (J) as a high speed stream of heavy particles in the direction shown. If any air molecules are encountered they are bumped downwards, so reducing the pressure in the top of the pump and the air molecules ultimately jostle one another out through the exit pipe to the next stage, while the oil vapour is condensed on the cooled side of the pump and trickles back to the boiler. These condensation pumps have to be backed by a mechanical rotary vacuum pump, scavenging to air. The whole pumping plant is simple and except for the mechanical pump motor needs little attention, 1.25 kilowatts power giving a plant of 250 litres per second (55 gallons per sec.) at a millionth of an atmosphere.

The tube is surrounded by the necessary lead protection (Z) which weighs some five hundredweight, while an adjustable angle portal (Y) in the form of the rotatable cylinder (R) covers the tube window (X). The tube is mounted on lifting gear giving a 4ft. 6in. traverse vertically so that the beam can be brought into position on any part of the patient.

The High Voltage for the tube is supplied from a two-valve rectifying circuit, employing two continuously evacuated rectifiers.

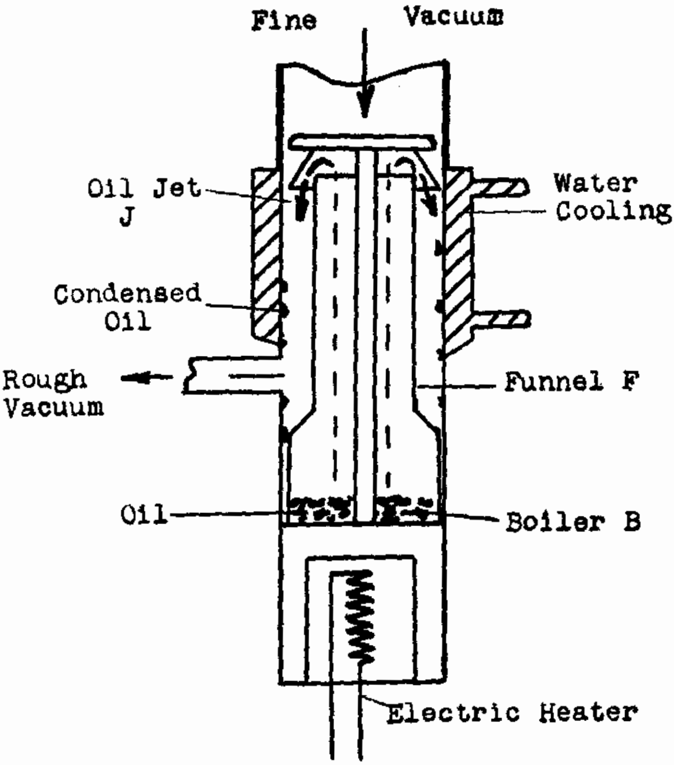

Fig. 5. Oil Condensation Vacuum Pump.
(Schematic Section)

The price of such an equipment is high when compared with that of its "sealed-off" colleague, but maintenance costs are low provided that the hospital has on its staff someone conversant with the plant. For instance the replacement of a rectifier filament during operation entails the following procedure. Shut off the rectifier pumping plant and allow the oil diffusion pumps to cool down, or, in the case of an emergency, hasten the cooling process by cold water application—break the filament seal—remove the filament assembly—fit a new filament which one has made oneself and the cost of which would be about 6d.—replace the filament assembly—start up the pumping plant—seal off the filament vacuum joint—and wait for the pumps to bring the vacuum back to 1/millionth of an atmosphere—the total proceedings can just be accomplished in 1½ hours. The replacement of a sealed-off valve to take the above C.E. valve's place would cost at least £50.

In the U.S.A. the hospitals work in much more close collaboration with the engineering and physical departments of universities in fact, all departments usually being in the same buildings, more like our provincial universities in this country. This close collaboration resulted in the production of many experimental types of high voltage tubes and generators, unfortunately most of them so experimental that they were quite unsuitable for clinical investigation, since continuity of operation was rarely attained. A few based on the principle of the old Wimhurst machine, the Disc being replaced by a wide fabric belt rotating at some hundred miles per hour, conveying a charge up to the high voltage end of the tube, have however given good and consistent service, but this type unless enclosed is dependent on atmospheric conditions which are notoriously bad here.

In this country at the request of St. Bartholomew's Hospital, London, Messrs. Metropolitan Vickers, Manchester, installed the first million volt X-ray plant put into commission in this country, if not in Europe. In princple, it is similar to the 200 Kilovolt tube already described, except of course enormously bigger. The tube spans the treatment room projecting into generator rooms at each end. Each generator room houses a 500,000 volt generator, one positive, one negative. The problem of providing complete X-ray protection was a mechanical one and was finally overcome by using a hollow steel tapered cylinder filled with eight tons of lead shot surrounding the tube. This cylinder has one aperture and the whole cylinder can be made to rotate by remote control to any required angle so that any beam angle is available from 0 degrees to 110 degrees. The size of the beam is controlled by a two hundredweight, adjustable lead diaphragm, also angulable about the tube, and opposite which the lead cylinder aperture locks itself when actuated. The treatment and high voltage generator rooms are completely isolated from the rest of the building by ray proof walls of interlocking barium blocks, and the protection is so good that films can be stored in close vicinity to the treatment room for years without harm.

The equipment has now completed some 12,500 hours use, while some of the pumps have done over 100,000 hours without overhaul. The maintenance costs have been amazingly low, under £50 per annum. During the war the hospital suffered many direct hits, and although the nearest was only some 20 yards away, the plant was never out of action.

Clinically, the results on patients with the million volt X-rays have justified the experiment, results never before attained having been accomplished. X-rays unfortunately cannot be focussed and the method of obtaining a greater dose at the lesion buried deep in the patient relative to that at the patient's surface, is to crossfire many beams into the patient, aimed at the lesion. The arrangement of these beams or fields and the calculation of the resultant dosage distribution in the patient is the responsibility of the physicist attached to the therapy department. More and more the therapeutic treatment of patients is becoming a combined operation between the medical radiotherapist, the diagnostician, the physicist and the engineer—the treatment becoming a mathematical process clincically controlled. The physical and clinical results obtained at a million volts lead one to hope that at higher voltages further advances will be accomplished in the eradication of cancer, but it will be many years before proof is available.

Unfortunately the war put an end to the continued development of X-ray equipment in this country, this being carried out in the U.S.A. There, in fact, the development of high voltage gear was given quite a fillip by the introduction of X-ray examination of nearly all castings and welds as routine practice. This is a most convenient method in that it is non-destructive but, in the author's opinion, not too much weight must be put on its results for it has very serious limitations. For instance unless the presence of a crack and its general plane is known, it is practically impossible to show it by X-rays and the interpretation on Skiagrams is exceedingly difficult, requiring great experience.

In the U.S.A. this demand for metallography brought forth a beautifully compact million volt set by the G.E. Co., of America. (4ft. diameter by 6ft. long complete), the secret being in the design of the high voltage transformer. In transformers we are accustomed to see heavy iron cores, but in the G.E. one the transformer is like the tuning coils in our wireless sets without iron and they function by resonating. Inside the transformer coils is placed the multi-acceleration tube, the electrons being accelerated over a path some five feet long on to the water cooled target. The whole is mounted inside a steel tank and instead of oil insulation an insulating gas called Freon is used. We understand that 2 and 5 million volt models of this type are now available, but it is doubtful if hospitals in this country will be able to face the possibility of having to pay £1,500 for a replacement tube if the tube should fail. There is no reason why this type of plant should not be supplied with a continuously evacuated tube, with its beneficial maintenance cost reduction.

Recently information has been released of a new type of equipment, called a betatron, which is capable of producing X-rays up to voltages of 100 million volts. This is accomplished by injecting electrons into a vacuum dough-nut located between the polefaces of a special high power A.C. magnet. The effect is that the electrons rotate in a circular path, just as if they were flowing round the coils in a transformer ; the number of turns being equivalent to the number of revs the electrons make and in fact the whole tends to an infinite ratio transformer. At a predetermined voltage or time the electrons hit a target and produce X-rays. The controlling and positioning of such equipment and beams will be an immense mechanical problem which has not yet been approached, but it is hoped that with these new weapons in the hands of the combined hospital staffs, mortality from cancer may become a thing of the past.

G. S. INNES, B.Sc., A.M.I.E.E., A.Inst.P.

Physicist and Engineer to Moselle Sasoon High Voltage X-ray Department, St. Bartholomew's Hospital, London, E.C.1.

NORTHERN BRANCH.

We wish to congratulate Mr. H. Armstrong, of this branch, on his appointment as Chief Engineer and Clerk of Works at Stafford Mental Hospital. Mr. Armstrong was formerly deputy to Mr. Clark at Gateshead Mental Hospital.

The Branch held its first annual dinner at the Gosforth Assembly rooms on the evening of Saturday, 29th December, 1945. There was a good attendance of members as well as several guests who are interested in the Institution and Hospital services generally. The dinner was followed by musical items, which were contributed by members and guests alike, and resulted in a very enjoyable evening being had by all.

J. R. Carr,
Hon. Branch Secretary.

WEST OF ENGLAND BRANCH.

At a recent Branch meeting, Mr. S. Coppin presented a very interesting paper on "Steam costs—Past and Present."

An interesting and well-attended Branch meeting was held on 26th January, 1946, at the Bristol Royal Infirmary, when the Hon. General Secretary, Mr. R. E. Rogers, addressed the meeting.

H. A. Adams,
Hon. Branch Secretary.

LANCASHIRE BRANCH.

The Lancashire Branch was inaugurated at Preston on 25th November, 1944, when 19 members attended. Since this time we have met quarterly in various parts of Lancashire and have had excellent meetings. The membership has now increased to 34. Our colleagues in North Wales, feeling they were not numerically strong enough to establish a Branch of their own, were invited to join our Branch for the time being. This they have done to our mutual advantage and pleasure.

At the last branch meeting, a very interesting and instructive paper entitled " Utilisation of Steam " was read by R. R. Jennings, Esq., A.M.I.M.E. This was greatly appreciated by all present, as was the lively and interesting discussion which followed.

The next meeting is convened for 25th May, 1946, when the venue is Southport. We wish to extend a very hearty invitation to any of our colleagues who happen to be in the locality to join us on this occasion, when we trust they will enjoy the meeting as well as the amenities of this excellent resort.

C. W. OLIVER,
Hon. Branch Secretary.

YORKSHIRE BRANCH.

The Hospital Engineers of Yorkshire have been conscious for a long time of the need for this Institution and gladly came forward to the Leeds General Infirmary on the 16th December, 1944, to form the Yorkshire Branch. Since then, meetings have been held bi-monthly, and the membership has increased from 12 to 29.

At each meeting a guest speaker is invited to give a talk on a subject of interest to the members. The following list gives an idea of the subjects we have covered.

10th February, 1945	:	Material Construction and Maintenance of Valves by Mr. Sewell, Chief Engineer of Messrs. Hopkinsons, Ltd., Huddersfield.
7th April, 1945	:	Asbestos Clothing as applied to Calenders and Steam Presses by Mr. H. Taylor, of Messrs. Turner Bros., of Rochdale.
2nd June, 1945	:	Hydro Extractors by Mr. N. Thorp, of Messrs. Broadbent, Ltd., Huddersfield.

21st July, 1945	:	Open discussion on the important problem of Mechanical Stokers.
6th October, 1945	:	Automatic Telephone Systems, by Mr. E. G. Smith, of the Automatic Telephone and Engineering Co., Leeds.
1st December, 1945	:	Treatment of Boiler Feed Water by Mr. A. E. Rukwood, of the I.C.I., Bradford.
9th February, 1946	:	An informal Talk on Calorifiers by Mr. Allen Royle, of Messrs. Royles, Manchester.

H. L. EGLIN,
Hon. Branch Secretary.

ANNOUNCEMENTS.

In Newsletter No. 2, I published a suggestion from the Southern Branch that the names and addresses of Branch Chairmen and Secretaries be published in the next issue. Here then, are those which have been sent to me to date.

Lancashire Branch :

Branch Chairman : E. HEALD, ESQ., Engineer's House, Wood Villas, Clifton Road, Prestwich, Manchester.

Hon. Branch Sec. : C. W. OLIVER, ESQ., 52 Cavendish Road, West Disbury, Manchester 20.

Yorkshire Branch :

Hon. Branch Sec. : H. L. EGLIN, ESQ., 9 Omberley Gardens, Leeds, 8. (Phone : Leeds 59233).

West of England Branch :

Branch Chairman : R. D. HEATH, ESQ., Engineer's House, Cotford, near Taunton.

Hon. Branch Sec. : H. A. ADAMS, ESQ., 2 Glenside Villas, Blackberry Hill, Fishponds, Bristol.

REMINDER.

Subscriptions for 1946 are now due.

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