There would be a resident Engineer always on the premises, and he would be one of those allround men who have, preferably, had experience in running small stations and supervising mains' work and wiring, etc.

When necessary there would also be a Demonstrator, whose time would be occupied in looking after the students and making with them any tests on plant and new apparatus, etc.

TIME SPENT IN STATION.—The following is roughly an outline of the time to be spent in the various work of the station. Some men would start in the engine-room and, when their time was finished, would change place with those on the gas producer and boilers or on outside work so as to obtain experience of the various duties. Each of the periods would be about two months, so that changing about could be easily arranged.

Of course, it will be understood that the following is for a regular course of one year for the men who have passed through their fourth year; but as a matter of fact they will already have had some work in the station during vacations, and when making tests, etc., during term time.

BOILER HOUSE.—

Getting run of plant and cleaning. Stoking. Attending feed pumps. Looking after gas producer plant. Checking fuel and water, etc.

NOTE.—The student would take stoking alone for a week or so before he tackled this along with the feed water supply, etc.

ENGINE ROOM (on prime movers)—

Greasing and cleaning the various prime movers, that is to say, quick speed engine, gas engines, etc. Looking after piping, steam traps, etc. Starting and running, driving the engines. Overhauling.

ENGINE ROOM (on Electrical plant)—

Attending to dynamo machines, renewing brushes, etc. On switchboard, keeping voltage steady, paralleling, etc. Attending to accumulator battery. Assisting with testing of coal, steam, or gas consumption, etc. Making any repairs.

OUTSIDE WORK.—

Looking after outside mains. Testing for faults. Assisting to make new connections, wiring. Connecting up motors, etc. Cleaning and recarboning arc lamps, etc.

SHIFT ENGINEER.—

Taking charge of shift. Writing up log and records of tests and other office work. Making tests of coal, oil, incandescent and arc lamps, etc.

COMMERCIAL.—

Each student would be given an opportunity of learning something of the commercial working of such a Station.—Plotting load curves, cost, curves, etc., interviewing consumers, etc., indeed, the idea would be to carry out on a small scale everything that is done in a large station.

ARRANGEMENT OF SHIFTS.

The writer's idea of working the station is to have two daily shifts from 7 a.m. to 2 p.m., and 2 p.m. to 9 p.m., the students changing about so that they take mornings one week and afternoons the next. In the vacations only one shift, from 9 a.m. until 4 p.m. would be necessary, so that the students would have half the vacations free, and probably more if they wished. It should, of course, be understood that a good deal would be done in the station merely from the educational point of view, and not necessarily because of its being necessary for the proper running of the plant. From the above it will be seen that in term time the Battery must give current for 10 hours per day and in vacations for 20 hours. It would also run through the week ends from mid-day, Saturday, until Monday morning.

For any special function in the evening such as a Lecture in the Geological lecture theatre, or a dance at one of the College's arrangements would be made to run the generating plant a few hours longer if necessary.

COMPARISON WITH SIMILAR CONDITIONS.

Regarding the question of whether such a station would pay its way seeing that the University is closed down in the summer months the writer would point out that the Hospital, Wardens' houses and the Servants' quarters of the Colleges, besides the Lodges, etc., are occupied practically all the year round. In any case the difference between the summer and winter load is what every lighting station has to contend with and, as a rule, Station Engineers are glad of the respite in summer, as it gives them a chance to overhaul their plant, make alterations, and get level with any back work that has been accumulating during the busy season.

Below are given the figures for the lighting stations of Oxford and Cambridge, which for twelve years have given a supply to similar districts. Both these stations are owned by Companies which are run on strict business lines, and their financial position is on a very sound basis, proper allowance being made from year to year for interest, depreciation, reserve fund, etc.

FOR YEAR ENDING DECEMBER, 1904.

	Cambridge.		Oxford.
Population	40,000	...	53,000
Total Expenditure...	£101,561	...	£145,401
Revenue from Supply	12,380	...	18,223
Revenue from Meters, etc. ...	755	...	1,347
Total Costs...	5,443	...	8,597
Surplus after providing for Interest, Depreciation, Reserve Fund, etc.	6,239	...	5,843
Dividends paid on Ordiuary Shares, 1901	7%	...	5%
,, ,, ,, ,, 1902	7%	...	$5\frac{1}{2}$%
,, ,, ,, ,, 1903	7%	...	$6\frac{1}{2}$%
,, ,, ,, ,, 1904	7%	...	7%
Present price of £5 shares ...	$5\frac{7}{8}$–$6\frac{1}{8}$	...	$6\frac{1}{4}$–$6\frac{3}{4}$
No. of B.O.T. Units Sold... ...	523,298	...	847,136
Works Costs per B.O.T. Unit ...	1·62d.	...	1·67d.
Total ,, ,, ,, ...	2·5d.	...	2·44d.
Average price obtained for Private Supply	5·68d.	...	5·34d.
Average price obtained for Public Lighting...	3·6d.	..	2·21d.
Equivalent of 8 c.p. lamps connected	47,112	...	65,276
Plant Capacity, in Kilowatts ...	1,500	...	1,200
Load Factor, that is to say— $\frac{\text{Units} \times 100}{\text{Max. Load} \times \text{Hours of Year}}$	9·67%	...	9·21%

The two Stations are entirely different—Parsons' turbines driving alternators at Cambridge, and slow running steam engines driving direct current dynamos at Oxford—yet the costs and prices charged are very similar, which shows that there is nothing either in the one or other system to account for its success.

The load factor figure is interesting, and it will be noted that it is under 10 per cent. in each case, whereas statistics of most towns of the same size usually show over 15 per cent. The reason is, of course, due to Cambridge and Oxford being University centres yet, with this handicap, both Companies pay 7 per cent. dividends, which is high as dividends go in England.

It may be said, that, these two instances are not quite analogous to the proposed University Station, but the writer contends that the difficulty, if such it is, is accentuated for both Oxford and Cambridge depend entirely on the Universities.

One point the writer would like to bring out clearly is that the University Station will start under more favorable circumstances than either Cambridge or Oxford, for it must be remembered that most of the plant in these stations has been running ten years, which is a very long time in Electrical Engineering history. Plant for a given output is now not only much cheaper, but also much more efficient.

PRESENT COST OF GAS.

Below is a Summary of the Gas Bills paid by the Various Buildings:—

UNIVERSITY—			£ Per Annum.
Main Building	...	£84	
Chemistry & Metallurgy	...	79	
Physics	...	35	
Engineering	...	36	
Geology	...	23	
Medical School	...	89	
Entrance Lamps	...	4	
Lodges	...	20	
Macleay Museum	...	4	
Common Room	...	6	
Biology	...	6	
Outside Lamps, by contract	...	160	
		——	£150
LAMPS ON UNIVERSITY GROUNDS—			
36–60 c.p. lights at £4 each	...	£144	
2–180 ,, ,, £8 10s. each	...	17	
		——	161
LAMPS IN VICTORIA PARK—			
10–60 c.p. lights at £4 each	...		40

		Average Daily. cubic feet.	
PRINCE ALFRED HOSPITAL—			
C Pavalion	55 burners, 4 gas rings	750	
D ,,	55 ,, ,, ,,	750	
Operating Block,	60 ,, ,, ,,	1,100	
Front Administrative Block,	60 burners	600	
Back ,, ,,	75 ,,	700	
Cottage Wards and Mortuary	20 ,,	600	
Nurses Home	120 ,,	350	
Laundry, 3 Ironers and	12 ,,	250	
		5,100	
365 × 5,100 cub. ft. at 4s. a 1,000 cub. ft.		...	375

PRINCE ALFRED HOSPITAL EXTENSION—

Albert Pavilion, 200 lights, probably.	
Victoria ,, 200 ,, ,,	
Say 365 × 4,000 cub. ft., at 4s. a 1,000 cub. ft....	337

ST. ANDREWS' COLLEGE—

Gas Jets, 189 (42 not in use).	
Gas Stoves, 9.	
147 Gas Jets in constant use ...	109
Warden's House, 40 Gas Jets, 3 Stoves ...	25

			£ per Annum.
St. Paul's College—			
Hall...	60	Gas Jets.	
College Room ...	48	,,	
Fellows' Room and Library	6	,,	
Billiard Room ...	10	,,	
Servant's Quarters ...	10	,,	
Warden's House ...	40	,, ...	80
St. John's College—			
Gas Jets Installed 75, of which 55 in use at one time			42
Women's College—			
100 Gas Jets (20 stopped); 1 Cooking Stove; 3 Water Heaters; 3 Gas Rings; 27 Gas Heating Stoves			100
Moore College—			
56 Gas Jets (42 in constant use)			
House 26 Jets (10 in constant use)			30
			£1,865

The new Engineering School will require much more lighting than shown above, whilst the Fisher Library will, of course, be considerable addition when it is finished. Some day there will be in the Union Building and there is the natural growth of the University and the Colleges, etc., to allow for. It may fairly be assumed, therefore, that if the present gas system is perpetuated about £2000 will be paid annually.

ESTIMATED COST OF ELECTRICITY WORKS.

BUILDINGS to house boiler, engines, dynamos, accumulators, etc., and other apparatus, also water tank, foundations, flue for boiler, coal store, office and accommodation for Resident Engineer £1900

STEAM-ENGINE PLANT, consisting of one water-tube boiler, with all fittings complete; one 150 B.H.P. quick-speed engine, say 500 revs. direct coupled to two 45 KW. 240 volt dynamos, arranged one on each side of the three-wire system £1600

PIPING for steam exhaust and feed, also valves, feed water heater, steam pump, water meter, water storage tank, and cooling tower, etc £1000

GAS PRODUCER PLANT, consisting of one 150 H.P. producer, charging platform, washer, sawdust purifier, piping, water tanks, two 75 B.H.P. engines, each connected by belt to a 45 KW. 240 volt dynamo, similar to those coupled to the steam-engine, so that a spare armature will fit any of them £2400

STORAGE BATTERY, consisting of 125 cells on each side of middle wire, with stands, acid and connections; also boosters	£1500
MAIN SWITCHBOARD, and station board, with meters, resistances, connecting cables, and testing instruments, etc.	£500
OVERHEAD TRAVELLER, and rails, weighbridge, barrows, oil filter and tank, tools, etc.	£200
MISCELLANEOUS, station and office lighting; also spares for engines and armature field coils for dynamo and for booster	£200
FEEDER LINES, including $2\frac{1}{2}$ miles overhead and $\frac{5}{8}$-mile underground; also distributing cable, consumers' connections, arresters, and telephones	£1500
OUTSIDE ARC LIGHTING, engineering expenses and contingencies	£1200
	£12,000

It will be seen that all the dynamos are identical in size and both the steam and the gas plant will have two dynamos, one on each side of the middle wire. This arrangement, combined with the fact that it will be fairly easy to balance the load on each side, makes it possible to dispense with a Balancer. The latter uses up a good deal of power, and is a nuisance in many ways, being a small finicky machine, without the backbone of a large dynamo having power behind it. As the dynamos are all one size the spare parts are reduced and a Hopkinson test for electrical efficiency can be made very easily by simply taking out a few coupling bolts.

ALLOCATION OF COST OF PLANT.

In the above estimate for plant the writer gives fair market prices, but it should be remembered that makers are likely to quote very reasonably in order to get their plant installed in a station where every student handling it, is a likely future customer. Regarding duty, there is just a possibility that, as the plant is to be used for educational purposes, it will be allowed to come in duty free. It will be noticed that nothing is allowed for workshop tools because, of course, the workshops of the Engineering School would be available. In small, country stations, this item for tools is relatively a high one, and the University Station is, therefore, very favorably situated in this respect.

A Condenser is not included in the above plant for the reason that there will have to be a very good surface condenser in the Engineering School for the steam turbine and other purposes, and this can be connected up to the engine in the Power Station when required.

As it is intended to use the plant in the Power Station for testing purposes, this will materially reduce the amount of plant in the Engineering School. Instead of a small gas-producer plant, there will now be a comparatively large one in the Power Station, and the same may be said of the steam-engine. Regarding the storage-battery, £600 of the money for the new Engineering School has been allocated to this, and the writer now proposes that the battery should be double the size and housed in a separate room, forming part of the Power Station building.

In this way the two objectionable items of plant on account of the fumes they give off, namely, the gas-producer and the storage-battery will be removed from the Engineering School. Noise and vibration of the gas engines will also be got rid of.

Clearly, there will have to be some give and take regarding the allocation of expenditure, and the writer thinks it would be a fair thing to charge £2000 of the £12,000 to the Engineering School. The Senate would then only have to find the balance. In the statement of expenditure given below, the Interest and Depreciation item is therefore taken on £10,000 instead of on £12,000, for it is clear that the above £2000 will have to be spent in any case.

POWER STATION BUILDING.

As the Power Station building would principally consist of a brick shell to contain the Generating plant, a neat-looking structure could be erected by contract at quite moderate cost.

No chimney would be required, for there has to be one in the new Engineering School, and it only means extending the flue from the Power House boiler. In any case there is very little for a chimney to do as the gas plant will generally be running and this does not require either chimney or flues.

By having the Engineering School and the Power Station near together, the one can help the other very materially. For example, the boilers can be connected together so that in case of emergency the boiler in the Engineering School could give steam to the engine in the Power Station or vice versa. The dynamos in the Electrical Laboratory may also be looked upon as spare plant because the voltages are suitable. In the matter of spare plant the station is, therefore, most favourably situated when compared with any ordinary station.

The building itself would be a one-storey structure, built in the style of the Biological Department. Ample light would be obtained from side windows. At one end of the building there would be the office, Testing-room, and Engineers' rooms, and at the other end a large doorway giving access to the Engine-room, so that a dray could be backed right in, under the overhead traveller.

REASONS FOR ECONOMICAL RUNNING.

In addition to points above referred to, which tend to reduce the actual cost of the Station, the following are some of the reasons why electric energy should be produced cheaply:—

COST OF SITE, *Nil*.—The site costs nothing, whereas with most stations which are in any way favorably situated regarding their load, the cost of land is very high.

WAGES, *Nil*.—As the actual work about the Station is to be done by the Students, the wages item almost disappears. It should be noted that when tabulating Board of Trade returns the Management expenses are placed separately from the wages and the writer has followed this course. In reply to the query, why not pay the students, the writer would point out that they are going to obtain experience which hundreds of young men in England pay 50 and 100 guineas a year to gain. Again, the Medical students are not paid for attending at the Hospital during their fourth or fifth year, although many of them do valuable professional work whilst there.

As an incentive to running the Station economically and to keep the students at their work a certain amount of the balance each year might be distributed amongst those who have helped to make it.

RENT, RATES, AND TAXES, *Nil*.—The writer understands the University is relieved from Rent, Rates, and Taxes, and the writer assumes that this would apply to the Power Station also. It has been suggested that there might be taxes; but it is not to be run with the idea of making profits. The object is to provide the University, Colleges, and Hospital with cheap electric power whilst, at the same time, providing a valuable adjunct to the Engineering School.

COST OF WATER.—The charge for water would be practically *Nil*, because the gas plant would be mostly used for running the lighting, and in such a plant water is merely used for cooling, so that the quantity of make-up is small. Waste from the hydraulic testing, etc., in the Engineering School, would probably provide all that is required.

LOW COST FOR REPAIRS.—As practically all those about the Station would be men having some engineering training, it may be fairly assumed that there would be little in the way of repairs and breakdowns. In any case, such repairs, etc., would mostly be effected on the premises by the students, as it would be valuable experience for them.

HIGH EFFICIENCY OF DISTRIBUTION.—Owing to the favorable position of the Station as regards the various points of supply the general efficiency of distribution will be high. Usually 70 to 80 per cent. is considered a good figure; but as the loss on the longest feeder is under 5 per cent. the writer anticipates an over all efficiency of distribution of over 90 per cent.

PROBABLE REVENUE.

We have seen that the Load Factor at both Cambridge and Oxford is just under 10 per cent., but still lower Load factors are given by holiday places, such as Weston-Super-Mare, 8.06; Bangor, 7.70; Colwyn Bay, 7.38; Llandudno, 8.41; Morecombe, 7.62; Rhyl, 8.17, etc.

From a revenue producing point these places are more awkward to deal with than the University area because the season only lasts two or three months. It may fairly be assumed, therefore, that 8 per cent would be a safe figure to take for the University.

As regards the question of price the City Council charge 4½d. per Board of Trade unit as a flat rate and 5d. and 2d. on the maximum demand system. An average charge of 3d. per B.O.T. unit will, therefore, be a low average price.

Statement of Revenue on the Assumption that 126,000 B.O.T. Units are Sold Per Annum.

An 8 per cent. Load Factor reckoned on a 180 Kilowatt maximum load gives—

$$\frac{8\% \times 8{,}760 \text{ hrs.} \times 180 \text{ k.w.}}{100} = 126{,}000 \text{ B.O.T. Units.}$$

and 126,000 B.O.T. Units at 3d. per unit — £1,575.

It will be noted that this is lower than the total sum at present paid for gas. It usually happens that when electricity becomes available the standard of lighting is raised and the tendency in this direction, together with increased outside lighting in Victoria Park, etc., and the natural growth of the University, Colleges, etc., would increase the above Revenue.

PROBABLE EXPENDITURE.

The gas plant would generally be employed for giving a supply for and it is now admitted that for small plants, if not for large ones, a gas producer plant is the cheapest way of generating energy. In this respect the Station would start under extremely favorable conditions.

In order to see what can be done in a small modern Electric Station driven by producer gas plant, it is convenient to consider figures given in Mr. Campbell's authoritative and much quoted paper on *Gas Engines for Central Stations*, read at the Leeds University in November of last year.

Figures Obtained in Recent Gas Driven Station.

Name of Town.	Units Sold Per Annum.	Load Factor.	Cost per Unit Sold. Fuel.	Oil, Waste and Water	Wages.	Repairs.	Works Costs.	Fuel Used.	Cost of Fuel in Bunkers.
Walthamston	814,187	15·45	·46d.	·19d.	·36d.	·06d.	1·07d.	Anthracite Coal	26/- per ton
Redditch ..	265,717	14·11	·88d.	·19d.	·53d.	·24d.	1·84d.	....	....
Northwich ..	157,198	9·2	·51d.	·15d.	·50d.	·35d.	1·51d.	Mond Gas	2d. per 1,000 cub. ft.
Guernsey .. (May to Oct.)	180,866	..	·30d.	·09d.	·22d.	.16d.	·77d.	Anthracite Peas	18/8 per ton.
Average			.537	·155	·402	·202	1·29		

The latest example of an up-to-date gas producer plant at Guernsey gives the remarkably low Works Costs of just over $\frac{3}{4}$d. per B.O.T. unit sold. And it will be noticed that this is obtained when using coal at 18/8 a ton.

Now, allowing for the various items which are *Nil* in the case of the University Station, a Works Costs of one penny per B.O.T. unit sold should be on the safe side.

As regards Depreciation the rates vary for the different parts of plant. Thus it is about 1 per cent. on buildings, $1\frac{1}{2}$ per cent. on feeder wires and cables, $2\frac{1}{2}$ per cent. on engines and dynamos, 4 per cent. on boilers and producer plant, 6 per cent. on electrical instruments, and as much as 10 per cent. on storage batteries. It is usual, however, to lump all these items together and to allow a single percentage on the total outlay. Thus, if the interest rate is 5 per cent. and it is assumed that the entire plant has to be renewed at the end of 20 years, then 3 per cent. of the original outlay reserved annually will provide for renewal of such plant.

The writer assumes that the money would be lent at four per cent. and certainly much of the plant will last longer than 20 years, therefore 6 per cent. seems a fair figure to take for Interest and Depreciation.

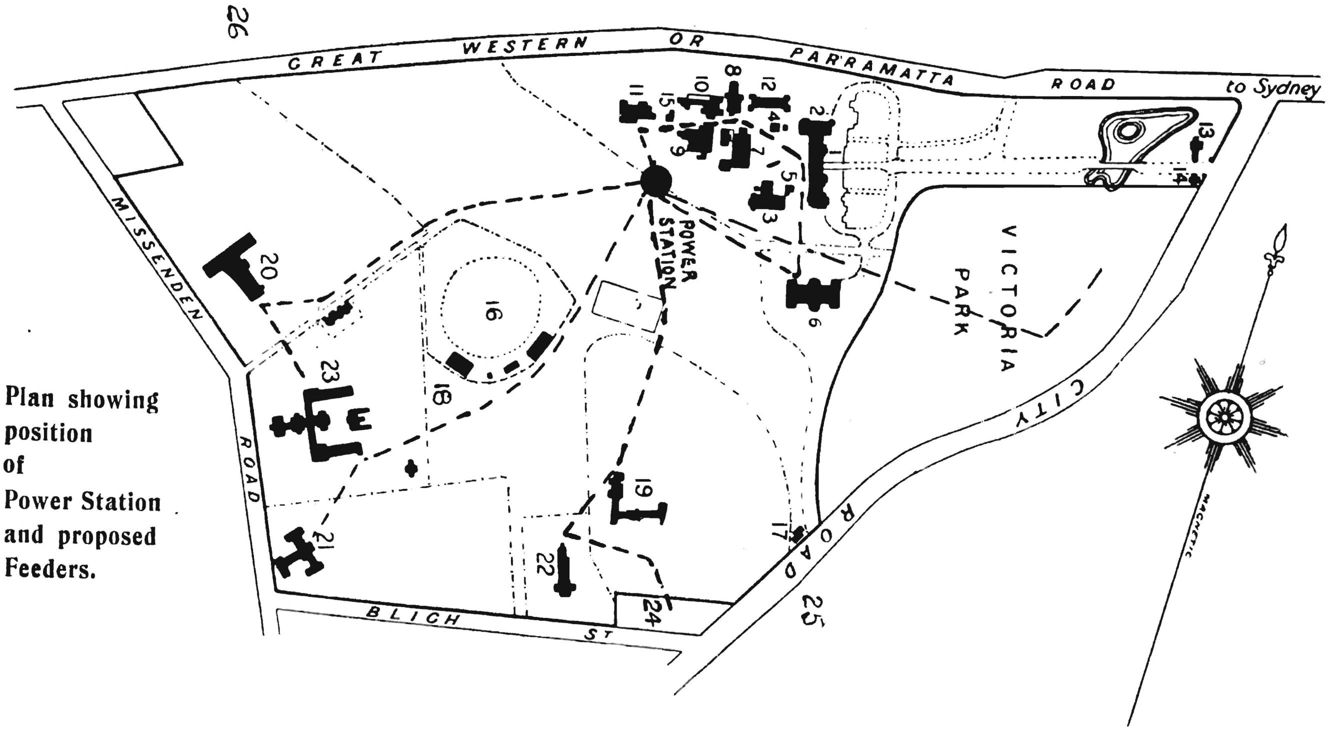
Fuel, Oil, Waste Water and Repairs, 126,000 B.O.T. units at 1d.	£525
Management, Engineer, Allowance for Insurance, &c.	£450
Interest and Depreciation 6 per cent. on £10,000 ...	£600
	£1575

That is to say in the completed station Revenue balances Expenditure, which is all the writer set out to show. As has been pointed out the idea of establishing the Station is not to make profits, and the above estimates are only given to indicate that the investment of the £10,000 is a safe one.

The accounts could be audited in the usual way with other University accounts, and the Senate would thus be able to see exactly what was being done.

For the sake of experience to the students, the costs and accounts would be worked out to the uttermost farthing, not merely once a year, but frequently, so that the books and costs, etc., would be practically available for inspection at any time.

It may be worth pointing out that all ordinary electric supply undertakings are subject to the usual risks of business, bad debts, etc., contingencies hardly likely to occur with the University Station.



Plan showing position of Power Station and proposed Feeders.

1. University Main Building
2. Great Hall
3. Fisher Library
4. Men's Common Room
5. Womens' Common Room
6. Medical School
7. Department of Chemistry, Metallurgy, Assaying and Mining.
8. Department of Geology and School of Mines
9. Department of Physics
10. Department of Engineering
11. Department of Biology
12. Macleay Museum
13. Gardener's Lodge
14. Messenger's Lodge
15. Caretaker's Lodge
16. Cricket Ground
17. Attendant's Lodge
18. Tennis Courts
19. St. Paul's College
20. St. John's College
21. St. Andrew's College
22. Womens' College
23. Royal Prince Alfred Hospital
24. Moore College
25. Deaf and Dumb Asylum
26. Arnott's Biscuit Factory