One of the chief objections to modern electric light sources is their high brilliancy. By brilliancy is meant the foot candles' intensity at the surface of the light source. With such lights it is very important that the eye does not receive the direct rays of the lamp, except at a safe distance. If this precaution is disregarded, what is known as the "glare" effect is produced; that is, by looking at such a lamp for even a short time within 10 feet say, an image of the light is formed in the eye, and does not disappear for some minutes later. This image is very annoying, as it is not possible to read while it lasts, and to work for any length of time with such an unprotected light will seriously impair the eyesight. Such lamps are well illustrated in the inverted Welsbach mantle and the Tungsten lamp, and it is unfortunately only too common to see the neglect of the above precaution with these lamps. The authors venture the opinion that this is largely the cause of weak eyesight, and need for using spectacles in a great majority of cases.

The attached table gives, according to two recent authorities, the brilliancy of some of our more modern illuminants:

TABLE III.

SOURCE.	BARROWS. Candle Power per square inch.	IVES & LUCKIESH Candle Power per sq. in.	Candle Power per sq. Mm.
Sun at Zenith	600,000	...	...
Crater Carbon Arc	200,000	84,000	130
Open Carbon Arc...	10,000-50,000	...	...
Flaming Arc	5,000	...	...
Magnetite Arc	...	4,000	6.2
Nernst Glower	800-1,000	...	...
Nernst Glower (115 volt, 6 amp. d.c.) ...	...	3,010	4.7
INCANDESCENT LAMPS.			
Tungsten, 1.25 w.p.c.	1,000	1,060	1.64
Graphitised Carbon Filament 2.5 w.p.c.	625	750	1.2
Tantalum 2·0 w.p.c.	750	580	0.9
Carbon 3.1 w.p.c.	480	485	0.75
Carbon 3.5 w.p.c.	375	400	0.63
Carbon 4.0 w.p.c.	300	325	0.50
Inclosed Carbon Arc (d.c.)	100-500	...	...
Acetylene Flame..	75-100	...	...
Acetylene Flame (1 ft burner)	...	53.0	0.082
Acetylene Flame (½ ft. burner	...	33.0	0.057
Welsbach Mantle	20-25	31.0	0.048
Welsbach (mesh)	...	56.0	0.067
Cooper Hewitt Mercury-Vapour Lamp ...	16.7	14.9	0.023
Kerosene Flame	4-8	9	0.014
Candle Flame	3-4	..	...
Gas Flame (fishtail)	3-8	2.7	0.004
Frosted Incandescent Lamp	4-8	...	...
25-watt Frosted Tungsten Lamp :			
Tip	...	1.67	0.0026
Side	...	6.00	0.0093
Moore Carbon-Dioxide Tube Lamp	0.6	..	...

One of the first points then to be considered in adopting modern light sources in rooms (especially if in offices, reading-rooms, etc.), is to see that the lamps are either mounted sufficiently high to render ineffective their high intrinsic brilliancy, or if this is not possible (generally the case), to protect them with suitable shades.

We have then to determine the number of lamps to be used, the position and size of each lamp, and the nature of the protecting shade.

For this, it is essential to know to what use the room is to be put, and the nature of the lighting of other adjoining rooms. Information should also be obtained if possible as to what intensity of light is required; but information such as this is, as a rule, unreliable, and it is generally best to rely on one's judgment and previous experience.

The following facts should be kept in view in determining the intensity of light required:

1. That the power required to produce the illumination is (for any one type of lamp) directly proportional to the intensity required. That is if twice the number of lamps are put in or the candlepower of each lamp doubled we get double the intensity on the plane of illumination.

2. That it is generally desirable to keep approximately the same intensity throughout any one building, except for any special reasons.

If one room is brightly lighted, a person going thence to a dull room, cannot discern objects clearly in the latter for some time, although the light may, under ordinary circumstances, be sufficient for him to do so. For this reason, in a well-lighted city, rooms should be lighted better than in houses situated in outlying districts.

3. That the minimum intensity with which a person can read ordinary print in comfort is one foot candle.

The following table (from the "Illuminating Engineer," October, 1911) gives the intensities of illumination recommended by several authorities for various localities, while the actual intensities obtaining in several of the New South Wales Government buildings, and also in some German schools, are given in the tables at the end of this paper.

TABLE IV.

GENERAL TABLE OF ILLUMINATION REQUIREMENTS.

LOCALITY.	ILLUMINATION.				
	*Monasch (Lux).	† Bloch (Lux).	‡ Toone (Ft. candles).	Various Sources (Ft. candles).	Average in Ft. candles (very approx).
Spinning Mills	15	15-20	1½-2	—	1.5
Weaving (light colours)	25-30	25-35	1½-2	—	2.5
Weaving (dark colours)	30-40		2½-4	—	3.5
Machine Shops	30	25-35	3 -4½	1	3.0
Foundry	30	—	—	3	3.0
Fine Work (Mechanical)	40	35-50	5 -10	—	5.5
LIVING ROOMS—					
Drawing Room	—	20-30	1-2	1½-2	2.0
Dining Room	—	—		1½	1.5
Bedroom	—	—		1½	1.5
Commercial Office	30-40	35-50	2-5	4	4.0
Drawing Office	50-60	60-80	5-6	8	6.0
Concert and Entertainment Halls ..	40-50	35-50	2-4	2	3.5
Theatres	—	—	1-3	2	2.0
Churches	—	—	2-4	—	3.0
Printing Works	40-50	—	4-5	—	4.5
Compositors	40-50	60-80	—	8	6.0
Shops	30-50	35-50	4-4½	2½-5	4.0
Shop Windows	—	—	—	8 -20	14
Restaurants	—	35-50	—	2½	4.0
HOTELS—					
Small Rooms	—	10-15	—	1½	1.5
Large Rooms	—	15-20	—	2	2.0
Corridors	—	—	½-1½	0.6	1.0
Railway Cars	—	—	1-2	2	2.0
Post Office (Sorting Department) ..	—	—	2-4	7	4.5
Schoolrooms	—	35-50	—	2-2½	3.0
Lecture Theatres	30-40	35-50	2-4	—	3.5
Ball Rooms	—	—	2-3	2	2.5
LIBRARIES—					
General	—	—	1-2	—	1.5
Local	—	—	3-4	—	3.5
Reading Tables	—	—	2½-10	3½	5.0
Bookshelves	—	—	4	1½	2.5
Reading (ordinary print)	—	—	3-4	2	3.0
STREETS—					
Main..	—	3 -6	0.1	½	0.5
Side	—	1½-3		0.1	0.15

* Elektrische Beleuchtung, p. 221. † Grundzuge Beleuchtung stechnik, p. 132.
‡ Electrical Review, London, vol. 68, 1911, p. 981.

Having decided the intensity required, and knowing the area of the room, we can find the power required in watts to illuminate the room as follows:

The area in square feet multiplied by the required intensity in foot candles gives the actual useful light in lumens. Dividing this figure by 4 π gives the total equivalent mean spherical candlepower. As then we know the watts per mean spherical candlepower of the particular kind of lamp to be used, the useful watts are known.

To find the total watts input, it is necessary to assume a figure for the efficiency of the illumination. To determine this we must know the character of the room and the system of lighting proposed. With white walls and ceilings efficiencies up to 70 per cent. may be obtained; but this is extremely rare. Common efficiencies range from 50 to 60 per cent., while for coloured walls and ceilings the efficiency falls off very rapidly, sometimes as low as 10 per cent. The effect of the walls and ceilings on the lighting of a room can be strikingly shown by the following table—the result of some researches carried out by the Holoplane Company.

Let N/1 equal increase due to light ceiling alone.
Let N/2 equal increase due to light walls alone.
Let N/3 equal increase due to light floor alone.
Let N/4 equal additional increase due to interaction of light ceiling and light walls.
Let N/5 equal additional increase due to interaction of light ceiling and light floor.
Let N/6 equal additional increase due to interaction of light walls and light floor.
Let N/7 equal additional increase due to interaction of light walls and light floor and light ceiling.

TABLE V.

LIGHT SOURCE.

	One bare Lamp.	One Lamp with Reflector.	Three bare Lamps.	Three Lamps with Reflectors.
	Per cent.	Per cent.	Per cent.	Per cent.
N/1	79	33	96	29
N/2	63	19	77	26
N/3	11	5	4	0
N/4	53	23	54	37
N/5	5	0	6	4
N/6	5	12	11	10
N/7	42	58	60	45
Total ...	258	150	308	151

From the total watts input the size and number of the lamps is obtained. No very definite rules can be given as a guide to determine whether a smaller number of lamps, each of large intensity, should be used in preference to a large number of lamps of low candlepower. Other questions, such as the limitations of the metallic filament lamp, the degree of shadows required, the architectural features of the room, and the cost, have all to be considered.

It may be mentioned that, with the greater number of lamps employed, the shadows of any one object in the room are less distinct and troublesome; but, on the other hand, the cost of the installation is increased.

In offices, schoolrooms, etc., where much reading is carried out at night, it is very important to see that the positions of the lamps are so arranged that the person, the object and the lamp are never in a straight line; if such is the case, the light from the lamp is reflected directly from the paper into the eye of the person reading.

When (perhaps the most difficult matter to settle) the position, number, and size of each lamp is determined, the last remaining point is the selection of the shade. This depends on two functions. Firstly, the average distance apart of the lamps, and, secondly, the most convenient mounting height; the former of which has been already fixed, and the latter is controlled as a rule by the height of the ceiling.

These functions being determined, it is quite easy, from the photometric curve of the various shades on the market, to select one which will give approximately uniform illumination under the conditions.

The above gives a rational method for determining the efficient uniform lighting of any large room where light shadows are not undesirable. The method may seem at first rather tedious and involved; but after a little practice, it is possible to shorten the process and to determine the results with fair certainty, and it is largely adopted by the authors for the various problems that occur from time to time.

The method can be expressed as follows:—

Watts Input =

$$\frac{\text{Area of Room} \times \text{Intensity} \times \text{watts per mean spherical candle power} \times 100}{4\pi \times \text{efficiency per cent.}}$$

$$= \frac{A \times I \times w \times 100}{4\pi \times e}$$

$$= 12.3\,\frac{AI}{e}\text{; for metallic filament lamps where } w = 1.55$$

Thus the expression can be reduced to the form—W = k AI—where k is a constant depending on the efficiency of the lighting and the watts per candlepower of the lamp, and represents the watts per foot candle per square foot. For an efficiency of 50 per cent., and with metal lamps k=.246. It is in this form that the formula is perhaps most useful.

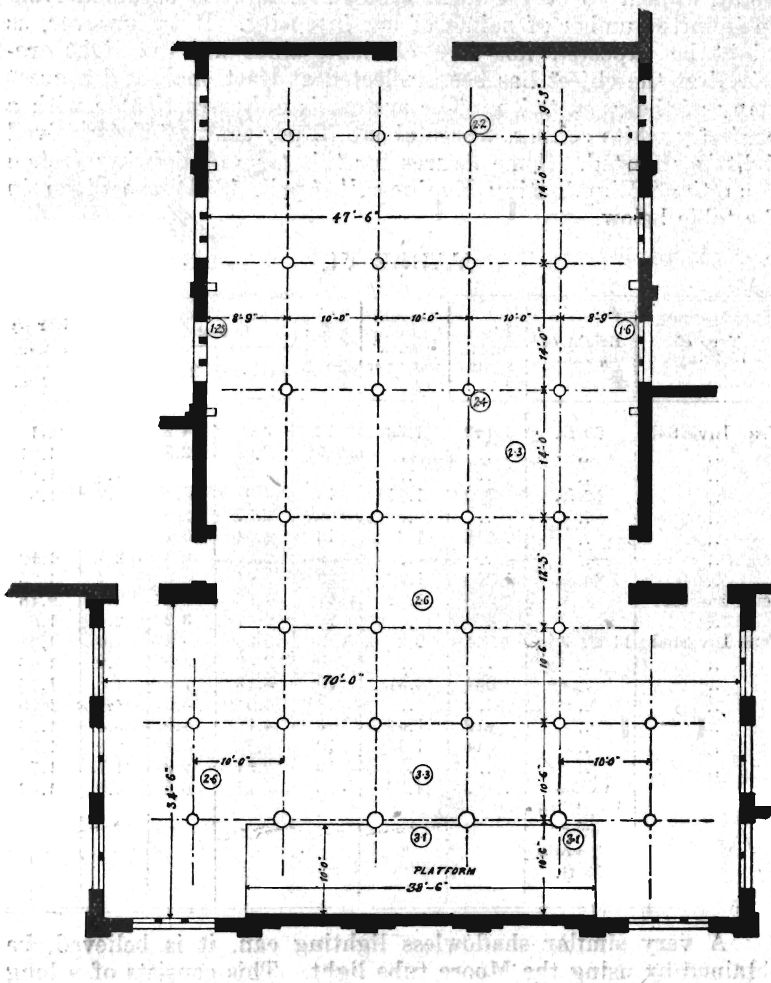
If, however, as in drawing-offices, absolutely shadowless light is required, we must adopt what is known as the "inverted" system of lighting, i.e., where all the light is reflected from a large area, and none received direct from the light source. This would appear to be the ideal system, as light is obtained from an infinite number of points of low intensity. It is, however, as might be expected not very efficient, since all the light received at the object has been reflected at least once, and a great many of the rays, twice. The system is only practicable with a perfectly white ceiling, where about 75 per cent. of the received light is reflected. Some figures for this type of lighting (taken from the "Illuminating Engineer," April, 1911) are given in the table below.

TABLE VI.

Type of Lighting.	Height of Room.	Floor Area sq. ft.	Current Consumption in watts per sq. ft.	Number of Readings Taken.	Actual Illumination in foot candles.			Diversity = Max. / Min.
					Average.	Max.	Min.	
True Inverted	20 ft.	1,440	1.38	16	3.06	4.2	2.0	2.1
,,	,,	,,	,,	9	2.07	2.3	1.9	1.21
,,	,,	,,	,,	5	1.68	1.8	1.6	1.12
,,	12 ft.	760	1.31	13	4.0	5.4	3.0	1.8
,,	,,	,,	,,	9	2.37	2.6	2.2	1.18
,,	,,	1,248	1.6	16	4.84	6.1	3.0	2.03
,,	,,	,,	,,	9	2.6	2.8	2.5	1.12
,,	20 ft.	1,950	1.02	9	2.64	3.0	2.4	1.25
Semi-Indirect	18 ft.	2,500	1.32	17	4.12	4.8	2.2	2.18
,,	,,	,,	,,	12	2.64	3.2	2.0	1.6
True Inverted	14 ft. 9 in.	554	2.2	8	5.25	5.8	4.9	1.2
,,	,,	,,	,,	9	2.58	3.1	1.9	1.63
,,	,,	864	2.31	10	6.18	7.0	4.8	1.46
,,	,,	,,	,,	8	4.3	5.0	4.0	1.25
,,	,,	479	1.01	5	4.1	4.9	3.5	1.76
,,	,,	544	1.83	10	3.8	5.2	2.9	1.78
,,	,,	,,	,,	10	2.51	2.9	1.7	1.7
,,	varies height to over reflectors 13 ft.	1,452	1,36	6	5.21	6.5	4.0	1.62

A very similar shadowless lighting can, it is believed, be obtained by using the Moore tube light. This consists of a long tube containing nitrogen at very low pressure. The light given from this is a rich golden yellow, and as the tube is taken round three or four walls of the room, light is received from a large number of points. No installations of this tube, so far as the authors are aware, have been carried out in New South Wales, and no figures are obtainable for comparison.

When the "inverted" system was first brought out, it was very largely adopted, as it was thought that the uniform light obtained was the aim of all lighting problems. It has, however, not proved entirely satisfactory. No artistic effects can be produced, due mainly to the absence of shadows. If of high intensity it has an irritating effect, as there are no dark spots for the eye to rest, as much as possible being kept white to produce



Lighting of The
TECHNICAL COLLEGE AUDITORIUM
Fig. 2.

Fig. 3.

a good efficiency, everything has a flat appearance, and nothing stands out. For these reasons and for its low efficiency, the system should not be adopted except where the circumstances demand an absolutely shadowless light.

It will therefore be seen that the problem of providing uniform illumination in a room may be conveniently considered as a physical problem, up to the point of determining the total watts required to light the room; beyond this it is mainly physiological, in other words, the total watts depend on concrete facts, the efficiency of the system adopted, the type of lamp used, the colour of the walls, etc., the position and size of the lamps depend on the position of the persons occupying the room, the purposes for which the room is required, etc., also that there are two general methods available, the "direct" system and the "indirect" system.

To make the method clearer, an actual example is taken, i.e., the new Auditorium at the Sydney Technical College. A plan of this room is given below and the leading dimensions shown. The purposes for which this room would be required are obvious. The light should be good enough for people to read ordinary print with ease; but no prolonged reading would be required. The intensity adopted was in this case two foot candles in main hall, increasing to three over the stage, where a better light would naturally be necessary. The total area of this room was 5285 square feet. Multiplying this by two (the required intensity) gives 10,570 lumens, which represents a mean spherical candlepower of 842.

With the metal filament lamp we can expect 1.55 watts per mean spherical candlepower, and this represents 1302 watts usefully employed. Allowing an efficiency of 50 per cent., 2604 watts are required for lighting the room. Actually, 2204 watts were used, consisting of 28/63 watt lamps and 4/110 watt lamps, the four latter being placed over the stage, to obtain the additional intensity. The lamps were spaced as shown in the sketch, and Holophane I7 shades were used.

The actual intensities obtained in various portions of the building are also shown on Figure 2, and the photograph **Fig. 3** shows the general effect of the lighting.

The mean illumination intensity over the whole room, from actual measurements, is approximately 2.4 foot candles, which gives an illumination efficiency of 70 per cent. This high efficiency may at first be doubted; but when it is considered that only a small proportion of the lighting is reflected off the walls or ceilings, the lamps being kept at a distance from the walls for this purpose, the majority being "directed" by the shade, and that the efficiency of the shade (i.e., the ratio of mean spherical candlepower to lamp with shade, to lamp without shade) is about 82 per cent., the efficiency does not seem unreasonably high.

The authors have frequently noticed that there is a strong prejudice against mounting lamps higher than about 8 or 9