A TABLE TOP HELIODON DEVELOPED FOR USE IN AN ARCHITECT'S DESIGN STUDIO

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ABSTRACT

Heliodons have been developed to simulate sunlight direction in relation to a building model. For placing the building model, heliodons can be divided into two categories. In one category, the model is to be tilted, and normally also rotated [1-3]. In the other category, the model is to be placed horizontally, and normally also stationary [4-6].

The later category of heliodons, with a horizontally placed building model, and with the simulated sunlight moving around it, will certainly help architectural professionals, students and laymen visualise the change of sunlight direction around a building and the related effect on insolation and shading.

In the pursuit of a heliodon capable of simulating quasi-parallel light impinging on physical building models for simulating sunlight impingement for various hours of the days and various days of the year, and for varying latitudes, yet occupying a space generally affordable in an architect's design studio, a new table top heliodon has been developed.

This paper reports on this heliodon which simulates the directional and parallelity aspects of sunlight. It employs a movable artificial directional light source assembly giving light onto a building model which is placed on a flat table, with the flat table acts as the horizontal plane for the building model. The light source assembly is adjustable for giving simulated sunlight (only simulating for the directional and parallelity aspects of sunlight) onto the flat table, which is the simulated horizontal plane, for the desirable day, time, and latitude of the location of the modelled building. In order to receive the simulated sunlight which comes out in a limited face area of the lens, the building model has to be moved about the flat table which is the simulated horizontal plane. This model movement is a simple movement just for keeping the north-south orientation of the building model in line with that of the table, and for catching the simulated sunlight, without tilting the building model.

1. INTRODUCTION

Heliodons are developed for testing of sunlight effect on physical building models, aiming at reproducing the actual direction of sunlight in relation to a building.

The variables to be adjusted are [3]:

- the latitude variable, which defines the sun-paths in relation to the geographical location,
- the seasonal variation, which relates to the declination of the sun on a given day, and
- hourly change of the sun from East to West.

The heliodons developed so far could be broadly categorised into two categories:

- a fixed light source (single lamp or multiple lamps) [2,7-9], or a moving light source [1,2], with the building model rotated and/or tilted
- the building model is placed horizontally, and the light source moves [4-6,10]

While each category or type is designed on different emphasis of its purpose of measuring certain variables, and for certain operation convenience, the type with horizontally placed models appear most easily understood to most people including students, professionals, building developers and purchasers and building users. A heliodon of this type should be a basic equipment in an architectural office.

In designing a heliodon with horizontally placed building models, there exists a compromise among space available, convenience and speed of operation, the accuracy of the results offered by the heliodon and its applicability in testing building models of different latitudes.

This paper reports on an innovative table top heliodon which is in fact a sunlight simulation system capable of simulating quasi-parallel light (i.e. the parallelity aspects of sunlight) impinging on physical building models for simulating various hours of the days and various days of the year, and for varying latitudes, yet occupying a space generally affordable in an architect's design office.

In operation this heliodon is placed on a normal office table, with the building model placed horizontally on the same table, but moved to receive the simulating sunlight falling onto it. Such movement is simple, because the purpose is to keep the north pointer of the physical model always parallel with the north pointer of the innovative tool, i.e. the office/studio table which acts as the horizontal platform for placing the building model, while the simulated sunlight is falling onto the parts of the model to be examined. The building model is not to be tilted.

2. THE SOLAR POSITIONS AND THE TABLE TOP HELIODON

The sun is considered to travel with respect to an observer on the surface of the earth (i.e. topocentric observation) from d = +23.44 deg to –23.44 deg from Summer Solstice to Winter Solstice and vice versa, year by year (Fig. 1, Table 1), on the assumption that there is practically no difference of topocentric observation and geocentric observation (i.e. observing the sun fictionally at the centre of the earth) in relation to simulating the variables of concern of the heliodon. This assumption is acceptable for architectural modelling, and is used in the design of the heliodon, because the distance between the sun and the earth far outweighs the diameter of the earth.

While it is common that this annual sun path is presented as part of an imaginary spherical surface, it can also be presented as part of an imaginary cylindrical surface [11]. For the convenience of illustrating the principles of design and operation of this table top heliodon, the cylindrical presentation is used (Fig. 1). To an observer located at a certain latitude, the sun appears to travel from East to West about the axis of this cylinder which is in fact practically coincides with the axis of the earth. This apparent movement of the sun will be similarly observed by the observer located at other latitudes, with different observation of sunlight duration, solar azimuth and altitude angles of course, even at the same day. For different latitudes, the angle L is different (Fig. 1).

The above movements of the sun relative to the observer/building are simulated in this table top heliodon (Figs. 2 to 5). In this heliodon, simulated directional and parallelity aspects of sunlight (for the various possible combinations of latitude, time and day) will impinge onto physical models which are commonly physical building models to be located on a simulated horizontal plane.

This heliodon (Figs. 2 to 5) comprises a latitude selector scale 16, a time selection scale 9, a solar declination selector 7, a simulated sunlight generator 3, all connected/fixed by various means (as described later), supported by a frame 22, which stands on a flat table 1. The building model is placed on the flat table 1, allowing the model to be located and moved upon it, but without tilting the building model. The true north-south orientation of the building model, and hence, east-west orientation, are always maintained identical to the orientations of the simulated horizontal platform 1 (Fig. 2), when the heliodon is in operation.

3. SIMULATING THE QUASI-PARALLEL LIGHT [I.E. PARALLELITY OF SUNLIGHT] AT VARIOUS SOLAR POSITIONS – FOR VARIOUS SOLAR DECLINATION ANGLES, I.E. FOR DIFFERENT DAYS

In this heliodon (Figs. 2 to 5) the light source is a simulated sunlight generator 3 which comprises a 12V quartz-halogen lamp (typical 50 W) 5, with the light-emitting element of the quartz lamp 5 positioned at the focal point of a Fresnel lens 4, aiming at producing quasi-parallel light, i.e. simulated sunlight 2. The simulated sunlight 2, is, by the physical design and construction of the simulated sunlight generator 3, set at 90 degree to the centre line 23, (Fig. 3) of the solar declination selector pointer 6.

Quasi-parallel light is given off from the Fresnel lens to simulate the parallelity of sunlight, with about 700 lux obtainable at a few hundred mm to a few meters from and at a direction normal to the lens surface. The area of light delivered does not change practically in this distance range from the lens. This provides sufficient illuminance for testing the building models. At low sun angles, the model could be at 1 m to 3 m from the lens, depending on the size of the table(s) used; and at high sun angles, the model is within 1 m from the lens, depending on the dimensions of the model and the frame 22 and straight rack gear 18 of the heliodon. The simulated quasi-parallel light is set and fixed for various desirable days by adjusting the solar angle declination pointer 6 (Figs. 2 and 6). For use in either hemispheres, different scales corresponding to solar declination angles and days have to be used.

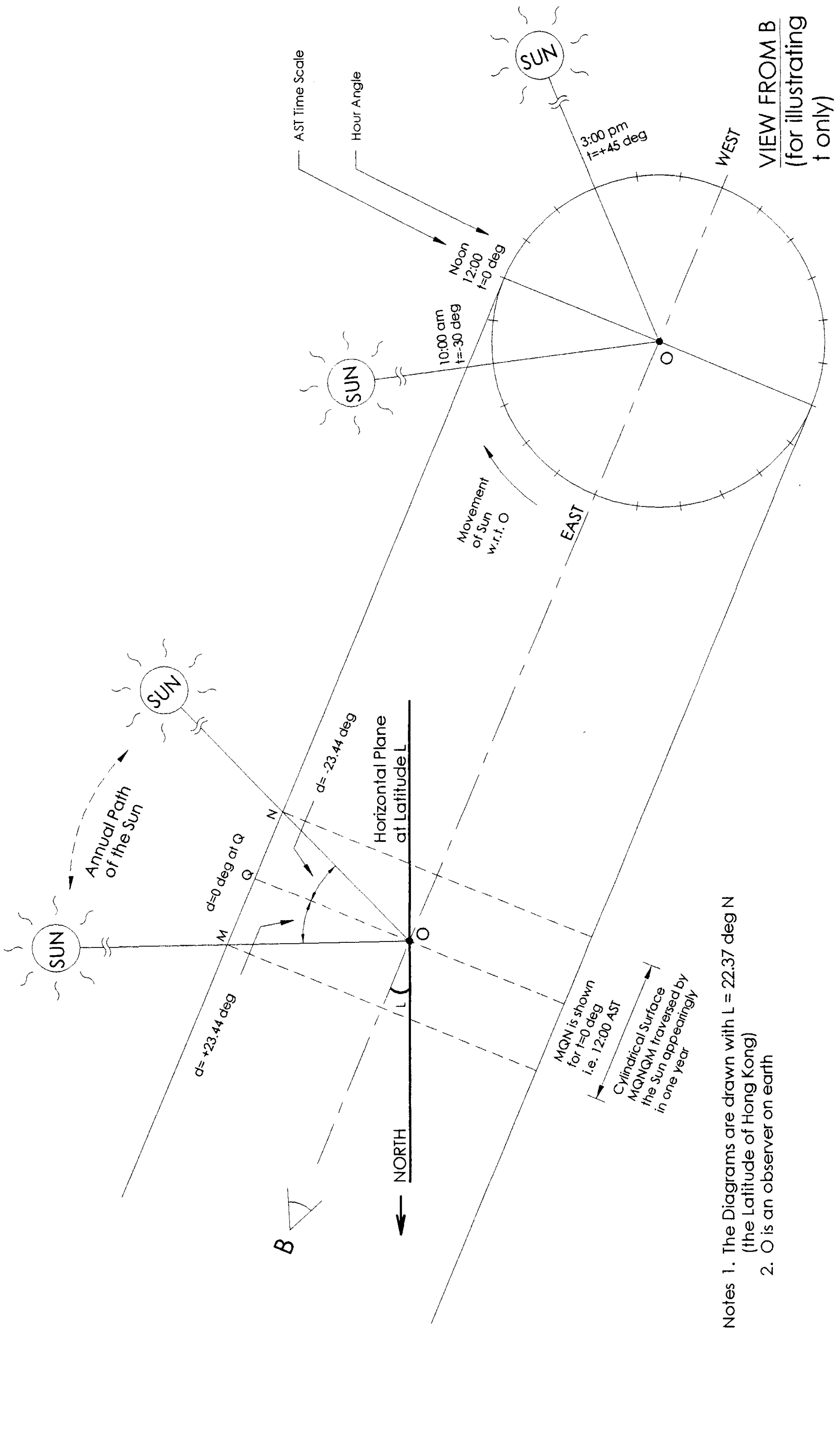

Fig. 1: The principle of designing the heliodon for solar declination, latitude, and hours of the day (for Northern Hemisphere) [Adapted from 11]

Table 1: Mean value of the solar declination (for l99l, noon UT (GMT), abstracted from The Nautical Almanac l99l, HMSO, UK [from Ref. 11])

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	-23 01	-17 10	-07 40	+04 27	+15 01	+22 02	+23 08	+18 04	+08 22	-03 06	-14 22	-21 46
2	-22 56	-16 53	-07 17	+04 50	+15 19	+22 10	+23 03	+17 49	+08 00	-03 29	-14 41	-21 55
3	-22 51	-16 35	-06 54	+05 14	+15 37	+22 17	+22 59	+17 34	+07 38	-03 53	-15 00	-22 04
4	-22 45	-16 17	-06 31	+05 36	+15 54	+22 24	+22 54	+17 18	+07 16	-04 16	-15 18	-22 13
5	-22 38	-15 59	-06 08	+05 59	+16 11	+22 31	+22 49	+17 02	+06 54	-04 39	-15 37	-22 20
6	-22 31	-15 41	-05 45	+06 22	+16 28	+22 38	+22 43	+16 46	+06 32	-05 02	-15 55	-22 28
7	-22 24	-15 23	-05 22	+06 45	+16 45	+22 44	+22 37	+16 29	+06 09	-05 25	-16 13	-22 35
8	-22 16	-15 04	-04 59	+07 07	+17 02	+22 50	+22 30	+16 12	+05 47	-05 48	-16 30	-22 42
9	-22 08	-14 45	-04 35	+07 30	+17 18	+22 55	+22 23	+15 55	+05 24	-06 11	-16 48	-22 48
10	-21 59	-14 25	-04 12	+07 52	+17 34	+23 00	+22 16	+15 38	+05 01	-06 34	-17 05	-22 54
11	-21 50	-14 06	-03 48	+08 14	+17 49	+23 04	+22 08	+15 20	+04 39	-06 56	-17 22	-22 59
12	-21 41	-13 46	-03 25	+08 36	+18 05	+23 08	+22 00	+15 02	+04 16	-07 19	-17 38	-23 04
13	-21 31	-13 26	-03 01	+08 58	+18 20	+23 12	+21 52	+14 44	+03 53	-07 41	-17 54	-23 08
14	-21 21	-13 06	-02 37	+09 20	+18 35	+23 15	+21 43	+14 26	+03 30	-08 04	-18 10	-23 12
15	-21 10	-12 45	-02 14	+09 41	+18 49	+23 18	+21 34	+14 07	+03 07	-08 26	-18 26	-23 15
16	-20 59	-12 25	-01 50	+10 03	+19 03	+23 21	+21 24	+13 48	+02 44	-08 48	-18 41	-23 18
17	-20 47	-12 04	-01 26	+10 24	+19 17	+23 23	+21 14	+13 29	+02 21	-09 10	-18 56	-23 21
18	-20 35	-11 43	-01 02	+10 45	+19 30	+23 24	+21 04	+13 10	+01 57	-09 32	-19 10	-23 23
19	-20 23	-11 21	-00 39	+11 06	+19 43	+23 25	+20 53	+12 51	+01 34	-09 54	-19 25	-23 25
20	-20 10	-11 00	-00 15	+11 27	+19 56	+23 26	+20 42	+12 31	+01 11	-10 16	-19 38	-23 26
21	-19 57	-10 38	+00 09	+11 47	+20 08	+23 26.4	+20 31	+12 11	+00 47	-10 37	-19 52	-23 26.3
22	-19 44	-10 17	+00 33	+12 07	+20 21	+23 26	+20 19	+11 51	+00 24	-10 58	-20 05	-23 26.4
23	-19 30	-09 55	+00 56	+12 28	+20 32	+23 26	+20 07	+11 31	+00 01	-11 20	-20 18	-23 26.1
24	-19 16	-09 33	+01 20	+12 47	+20 44	+23 25	+19 55	+11 11	-00 23	-11 41	-20 30	-23 25
25	-19 01	-09 10	+01 44	+13 07	+20 55	+23 24	+19 42	+10 50	-00 46	-11 01	-20 42	-23 24
26	-18 46	-08 48	+02 07	+13 27	+21 05	+23 22	+19 29	+10 29	-01 09	-12 22	-20 54	-23 22
27	-18 31	-08 26	+02 31	+13 46	+21 16	+23 20	+19 16	+10 09	-01 33	-12 42	-21 05	-23 20
28	-18 15	-08 03	+02 54	+14 05	+21 26	+23 18	+19 02	+09 47	-01 56	-13 03	-21 16	-23 18
29	-17 59		+03 18	+14 24	+21 35	+23 15	+18 48	+09 26	-02 19	-13 23	-21 26	-23 15
30	-17 43		+03 41	+14 42	+21 44	+23 11	+18 34	+09 05	-02 43	-13 43	-21 36	-23 11
31	-17 27		+04 04		+21 53		+18 19	+08 43		-14 02		-23 07

Note: Declination to north of the Equator is positive, to south is negative; thus for 11 Jan l99l, solar declination angle was 21 deg 50 min south of the Equator.

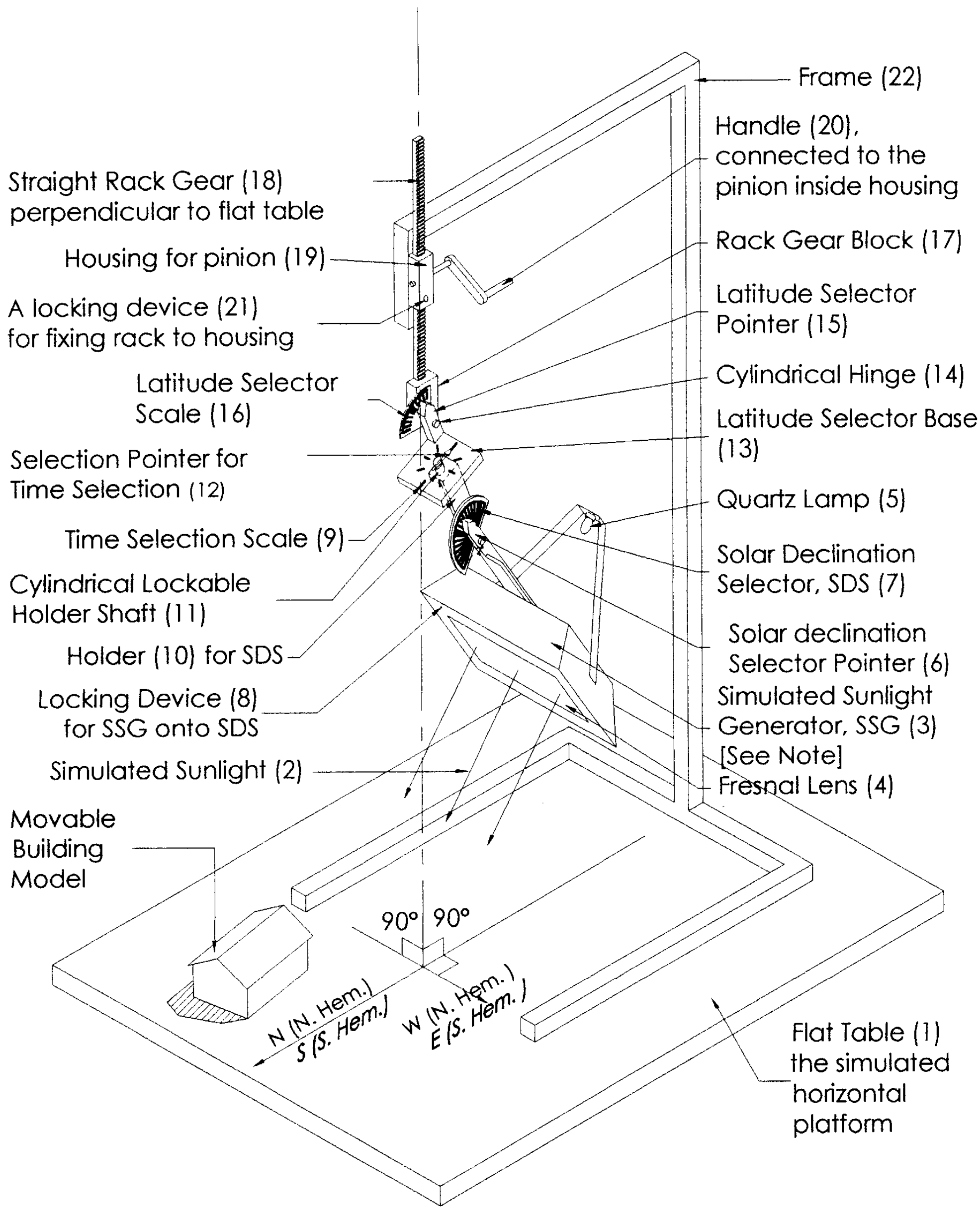

Fig. 2: Isonometric view of the sunlight simulation system

(Note: Electrics for the simulated sunlight generator, i.e. (3), are conventional techniques, and therefore not shown)

In the component/heliodon assembly (Figs. 2 and 6), the simulated quasi-parallel light 2 (Figs. 2 and 3) at Summer Solstice (i.e. June 21, corresponding to solar declination angle of + 23.44 degree, Table 1) in Northern Hemisphere will be in the direction of line MO at noon of apparent solar time (Fig. 1), and in the direction of line NO at Winter Solstice (i.e. Dec 22, corresponding to solar declination angle of – 23.44 degree, Table 1). The simulated quasi-parallel light 2 (Figs. 2 and 3) will be in the direction of line QO at Equinox days. (i.e. Mar 21, Sept 23, corresponding to solar declination angle of 0 degree, Table 1) (Note: the settings of angles of the heliodon are rounded up to 0.5 degree, due to the practical limitations of the dimensions of the related angle components). At Equinox days, the centre line of the solar declination pointer 23 (Figs. 2 and 3), which is at right angle to the simulated quasi-parallel light (Fig. 6), is parallel to the axis 24 of the cylindrical lockable holder shaft 11, (Fig. 7), which is parallel to the earth axis (Fig. 1). Because the topocentric and geocentric observation assumptions stated earlier are used, these mentioned centre lines 23, 24 could be considered as coaxial.

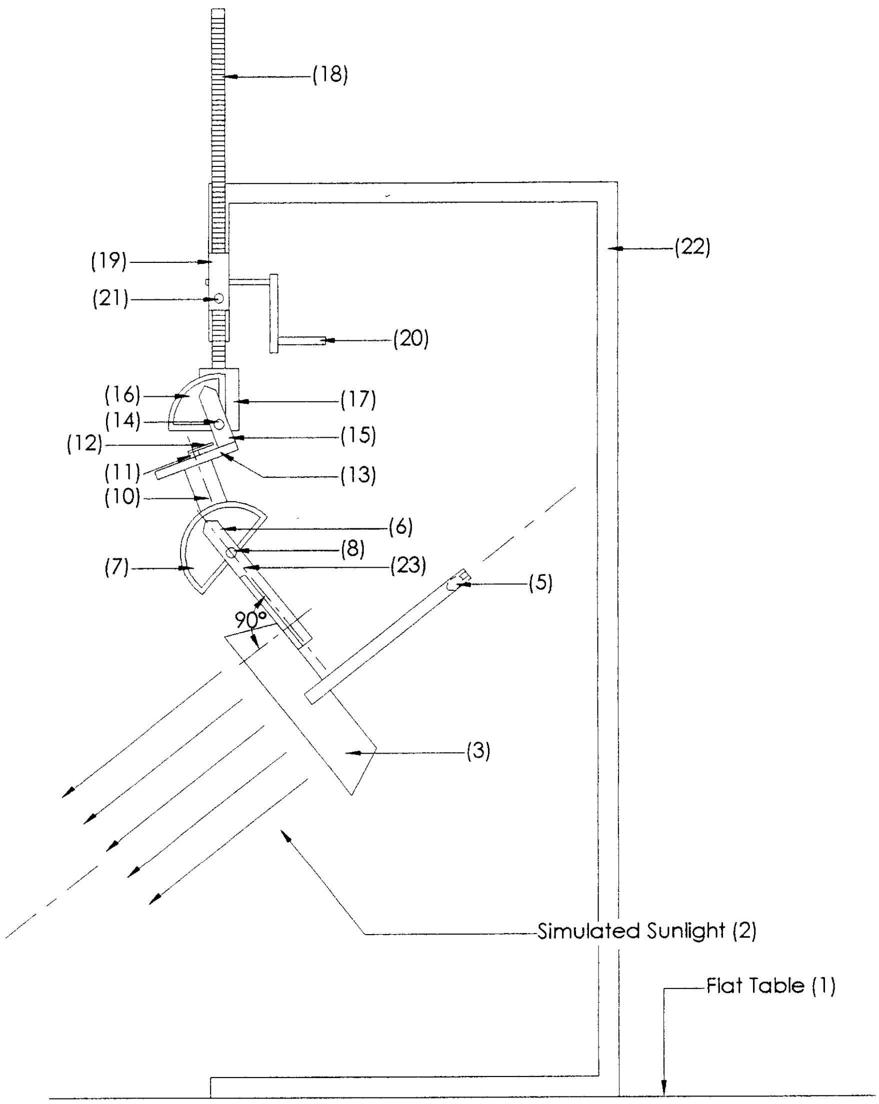

Fig. 3: Side view of the sunlight simulation system

(see Fig. 2 and the text for the legend of the components)

4. SIMULATING THE QUASI-PARALLEL LIGHT [I.E. PARALLELITY OF SUNLIGHT] AT VARIOUS SOLAR POSITIONS – FOR VARIOUS HOURS/MINUTES OF VARIOUS DAYS

When the solar declination angle is selected at zero degree, i.e. Equinox days, (Figs. 2, 3, 6), the centre line 23 of the solar declination selector pointer is parallel to the axis 24 of the cylindrical lockable holder shaft 11 (Figs. 2, 3, 7). Hence, the plane in space traversed by the centre line 23, is also parallel to the axis 24.

Since the simulated sunlight generator 3 is fixed to the solar declination selector pointer 6 (Fig. 2), the simulated sunlight generator 3 can be locked onto the solar declination selector 7, via locking the solar declination selector pointer 6 onto the solar declination selector 7 by means such as a locking device 8 (Figs. 2, 3), for various solar declination angles selected.

Time selection is effected by rotating the cylindrical lockable holder shaft 11, so that the selection pointer for time selection 12 points to the desired time marked on the time selection scale 9 (Figs. 2 to 4, 7, 8). The time scale 9 is marked on a latitude selector base 13 which is fixed to a latitude selector pointer 15. By design and construction of the related parts, the centre line 25 (Fig. 7) of the latitude selector pointer 15 is parallel to the axis 24 of the cylindrical lockable holder shaft 11 (Fig. 7). Therefore, for whatever time selected and whatever latitude selected (Figs. 2, 3, 6, 7), the axis 24 of the cylindrical lockable holder shaft 11 is parallel to the plane in space traversed by the centre line 25 of the latitude selector pointer 15. When the latitude is selected at 90 degree, i.e. simulated for the north/south pole, the said centre line 25, and the said axis 24 of the cylindrical lockable holder shaft 11, by design and construction of the related parts, are perpendicular to the simulated horizontal platform 1 (Figs. 2, 3, 7). When the latitude is selected at zero degree, i.e. simulated for the equator, the said centre line 25, and the axis 24, will be parallel to the simulated horizontal platform 1. The holder 10 for solar declination selector is fixed to the cylindrical lockable holder shaft 11, such that the holder 10 can be locked onto the latitude selector base 13 by a suitable device such as a G-Clamp (not shown), when a desirable time is selected in the way as described earlier. Although apparent solar time is shown (Fig. 8), additional movable time scales (not shown) can also be fitted onto the latitude selector base 13, to obtain other time scales such as the local standard time.

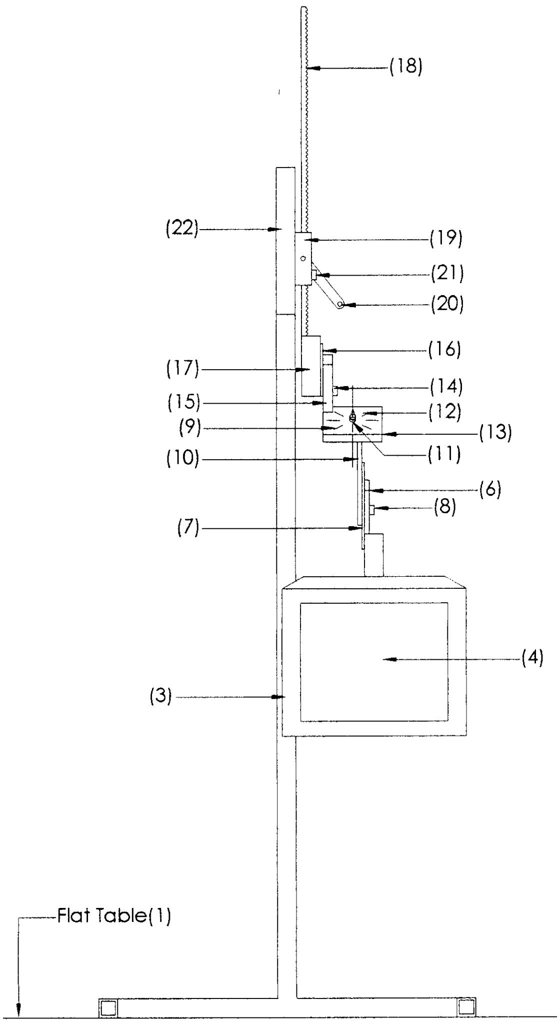

Fig. 4: Front view of the sunlight simulation system (Shown at apparent solar noon)

(see Fig. 2 and the text for the legend of the components)

When noon of apparent solar time is selected, the plane traversed in space by the centre line 25 of the latitude selector pointer 15 for selecting various latitudes, is, in fact, parallel to the plane in space traversed by the centre line 23 of the solar declination selector pointer 6 (Figs. 2, 3, 6, 7), because the said centre line 24 is parallel to these two said planes.

5. SIMULATING THE QUASI-PARALLEL LIGHT [I.E. PARALLELITY OF SUNLIGHT] AT VARIOUS SOLAR POSITIONS – FOR VARIOUS LATITUDES

At noon of apparent solar time (or true solar time), for various possible selection of solar declination angles (i.e. days which correspond to the said solar declination angles) (Table 1, Figs. 2, 3, 6), the centre line 23 of solar declination selector pointer 6 will traverse a plane in space, with this plane parallel to the vertical plane containing the identified true north-south line of the simulated horizontal platform 1. This true north-south line can be arbitrarily selected on the platform/table 1, considering the convenience of locating the said device of invention, and the said model to be tested.

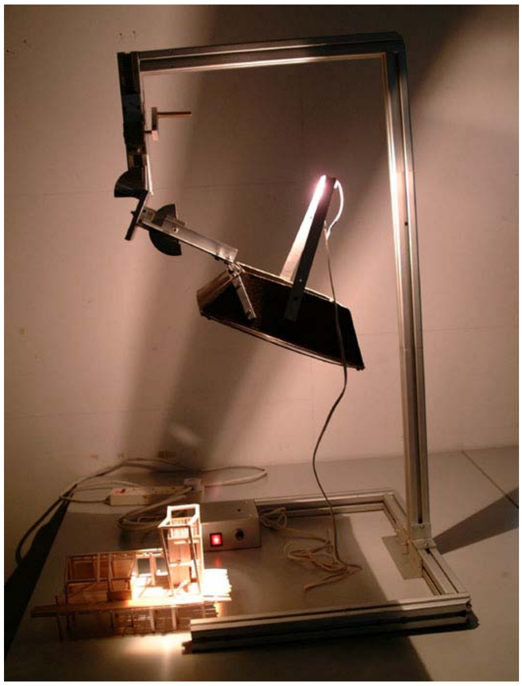

Fig. 5: The table top heliodon

(The heliodon is shown operating for the latitude of Hong Kong at 22.37 degree N, at noon of apparent solar time and at Equinox days, i.e. 21 Mar, 23 Sept)

That is, at noon of apparent solar time, the plane traversed by the centre line 23 of solar declination selector pointer 6, will be at 90 degree, to the simulated horizontal platform 1.

The solar declination selector 7 is fixed onto the holder 10, which is also fixed to the cylindrical lockable holder shaft 11 (Figs. 2, 3, 6, 7). When the solar declination angle is selected to be zero degree by the solar declination selector pointer 6, the centre line of the solar declination selector pointer 23, is parallel to the axis 24 of the cylindrical lockable holder shaft 11. The cylindrical lockable holder shaft 11 is allowed to rotate about the latitude selector base 13, at which there is a cylindrical opening for housing the lockable holder shaft 11. The selection pointer for time selection 12 is fixed to the lockable holder shaft 11.

The latitude selector pointer 15, (Figs. 2, 3, 7) is free to rotate about the cylindrical hinge 14 for selection of latitude angles ranging from zero degree to 90 degree marked on latitude selector scale 16, with the axis of said cylindrical hinge 14 always lying on and perpendicular to the centre line 25 of the latitude selector pointer 15 (Fig. 7).

Once the desirable latitude is selected, the latitude selector pointer 15 can be fixed to the latitude selector scale 16 and rack gear block 17, by means such as a G-Clamp (not shown) (Figs. 2, 3, 7). The latitude selector scale 16 is fixed to a rack gear block 17, which is fixed to the straight rack gear 18. The said rack gear 18 can be moved in a straight path up and down about the housing for pinion 19, by turning the handle 20 (Figs. 2 to 5, 7), with the said straight path at 90 degree to the simulated horizontal platform 1. This vertical adjustment of the light source, together with the horizontal movement of the model described earlier, will enable portions by portions of a large building model to receive the same simulated light.

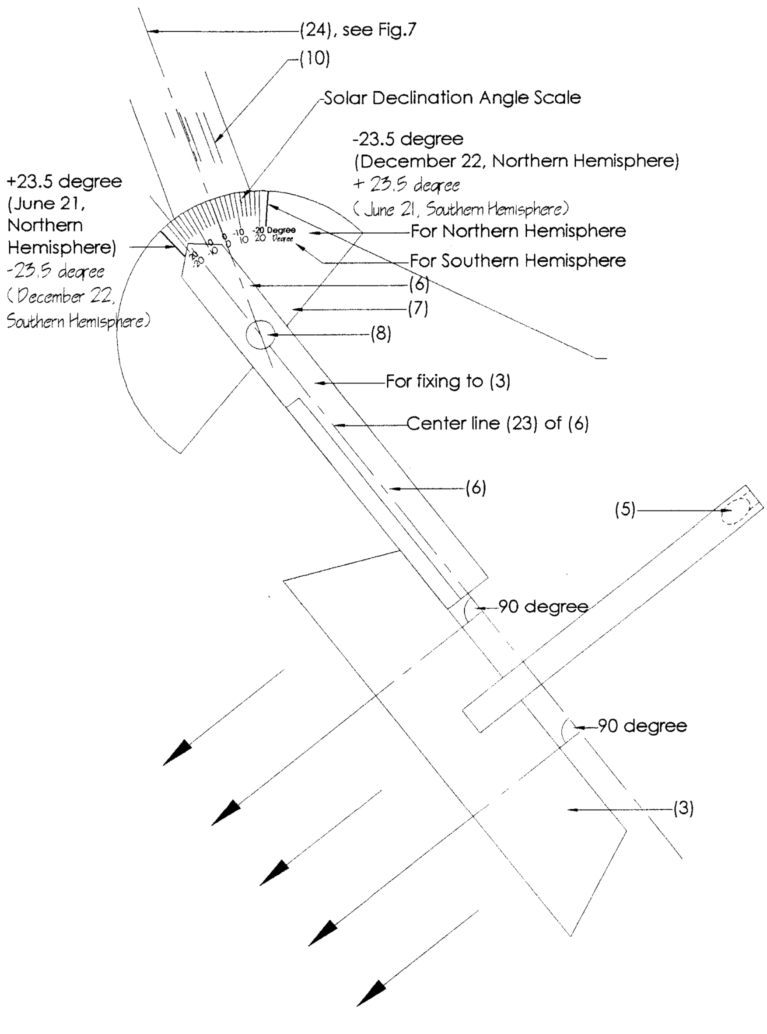

Fig. 6: Side view of solar declination selector and simulated sunlight generator

(see Fig. 2 and the text for the legend of the components)

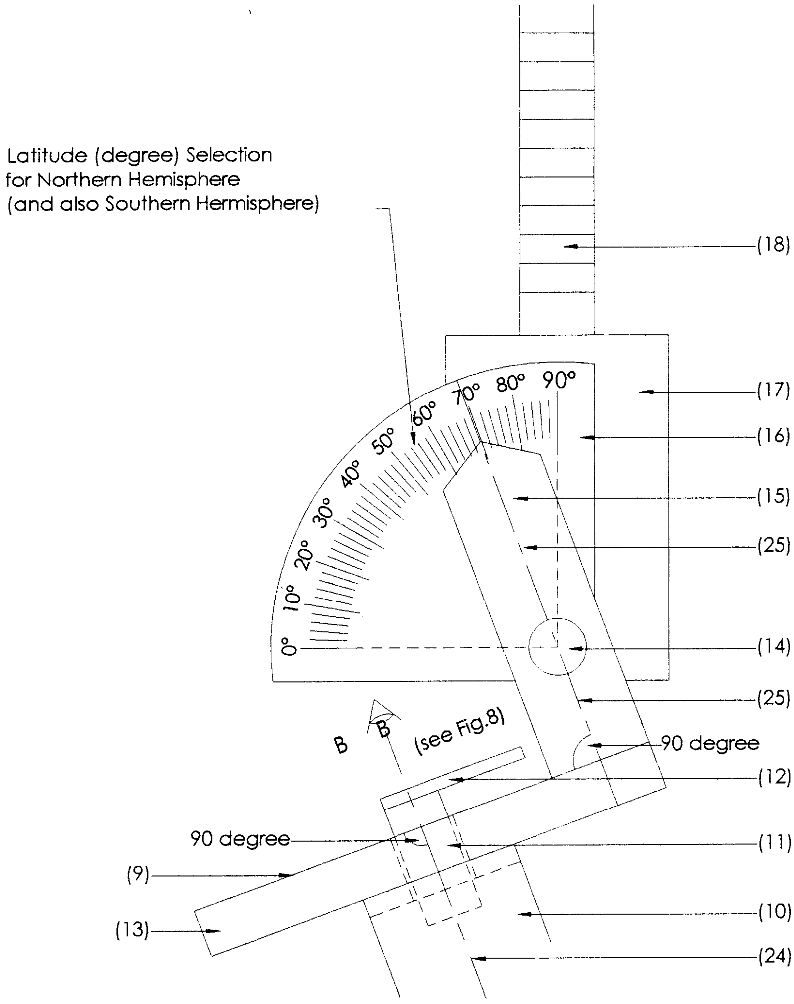

Fig. 7: Side view of latitude selector base and latitude selector scale

(see Fig. 2 and the text for the legend of the components)

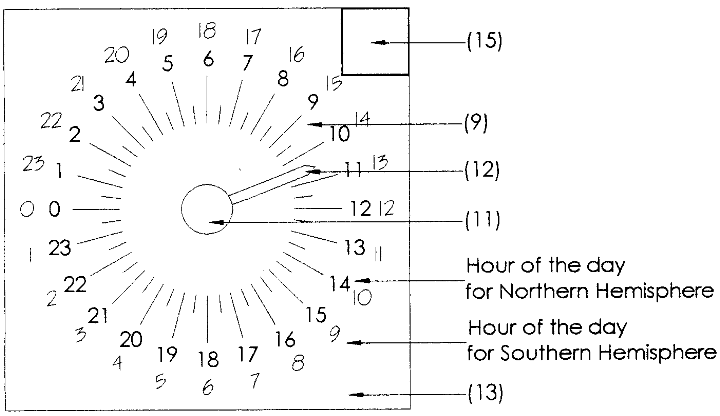

Fig. 8: View BB (see Fig. 7) – Looking at latitude selector base and time scale (shown with apparent solar time scale) in a direction parallel to the axis of lockable holder shaft (11)

(see Fig. 2 and the text for the legend of the components)

Also, by design and construction of the related parts, the plane in space traversed by the centre line 25 of the latitude selector pointer 15 (Fig. 7), for various possible latitude selection on the latitude selector scale 16, is parallel to the straight path in space traversed by the straight rack gear 18 (Figs. 2 to 5, 7), which can be locked, by suitable locking device such as locking device 21, onto the pinion housing 19. The movement of the straight rack gear 18 about the housing for pinion 19, can be effected by means such as turning a handle 20 (Figs. 2 to 5, 7). The housing for pinion 19 is fixed to a frame 22, which stands on the said flat table 1, i.e. the simulated horizontal plan.

6. FURTHER NOTES ON OPERATION OF THE HELIODON

In providing simulated sunlight 2 (Figs. 2, to 4), for the various combinations of latitude, time and day (i.e. the corresponding solar declination angle), as shown in the figures, the simulated sunlight 2 will change its direction relative to the simulated horizontal platform 1. The model (i.e. commonly a physical building model) has to be moved on the simulated horizontal platform 1 (Fig. 2), to receive the simulated sunlight 2, with the true north-south orientation of the said model kept parallel with the identified true north-south orientation of the simulated horizontal platform 1. The adjustment of the straight rack gear 18 up and down about the housing for pinion 19, and the adjustment of the parts below the straight rack gear 18 described earlier, will then enable the simulated sunlight 2 to move up and down, but keeping its parallelity, to impinge onto the various parts of the building model (Fig. 2) for the various combinations of latitude, time and day.

The electrical provisions for supplying power to the quartz-halogen lamp 5 (Figs. 2, 3, 6) are not shown because such electrical provisions are devices of existing technology. They are however shown in the photo (Fig. 5).

Since the quartz-halogen lamp 5 (Figs. 2 and 3) is commonly 50W, the simulated sunlight 2 is not strong, so a reasonably dark or dimmed indoor environment has to be available for operating the said heliodon. Furthermore, the said sunlight simulation is primarily on the directional and parallelity aspects of sunlight. Other aspects of sunlight such as the spectral aspects, the energy intensity aspects are not simulated.

7. CONCLUSION

Since the building model is kept horizontal, options of quickly and loosely fitted working models can be tested. This allows quick comparison of options of building models.

Also this heliodon can be operated on a table of normal dimensions in an architect's office. This will bring about more popular use of heliodons in solar design of buildings.

The description of this heliodon made above is on testing building models in Northern Hemisphere. However the same principles can be applied for testing building models in Southern Hemisphere using the same heliodon, but following the different sets of marking of the time scale 9 and of the solar declination angle scale 7 for corresponding days to be selected; the same latitude selector 16 however can be used for both hemispheres.

NOMENCLATURE

AST Apparent Solar Time, or true solar time.

d the declination angle of the sun with respect to the centre of the earth, d = +23.44 deg at Summer Solstice and d = –23.44 deg at Winter Solstice. Different declination angles correspond to the different days of the year (Table 1).

L geographical latitude of a place at Northern hemisphere

$\underline{OQ}$,$\underline{OM}$ etc. alphabets with a line underneath mean a line joining the points denoted by the alphabets

t hour angle, t = 0 deg for solar noon (i.e. AST l2:00 noon), for one hour, the hour angle elapsed is l5 deg., t is positive for AST p.m. and negative for AST a.m

1,2… component identification numbers of the invented heliodon, shown in the drawings of the heliodon and mentioned in the text

Legend to Components of the Heliodon

1 simulated horizontal plan, simulated horizontal platform, flat table
2 simulated sunlight
3 simulated sunlight generator
4 Fresnel lens
5 quartz-halogen lamp
6 solar declination selector pointer
7 solar declination angle scale
8 locking device for locking simulated sunlight generator 3 onto solar declination selector 7

9 time scale
10 holder
11 cylindrical lockable holder shaft
12 selection pointer for time selection
13 latitude selector base
14 cylindrical hinge
15 latitude selector pointer
16 latitude selector scale
17 rack gear block
18 straight rack gear
19 pinion housing
20 turning handle
21 locking device for fixing straight rack gear 18 to pinion housing 19
22 frame
23 centreline of solar declination selector pointer 6
24 axis of the cylindrical lockable holder shaft 11
25 centreline of the latitude selector pointer 15

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11. K.P. Cheung, "An alternative solar chart and its use in a case study", Architectural Science Review, Vol. 40, No. 1, p. 24, Table 1, March (1997).