A TABLE TOP HELIODON WITH A MOVING LIGHT SOURCE FOR USE IN AN ARCHITECT'S OFFICE

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ABSTRACT

Heliodons have been developed to simulate sunlight direction in relation to a building model. In the pursuit of a heliodon capable of producing quasi-parallel light impinging on physical building models for simulating sunlight impingement for various hours of the day 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 horizontal model stand. The light source assembly is adjustable for giving simulated sunlight (only simulating for the directional and parallelity aspects of sunlight) onto the building model, for the desirable day, time, and latitude of the location of the modelled building. This directional adjustment of light is effected by moving the simulated light generator about the simulated earth axis, thus also allowing strong demonstration of physical solar movement around the building model. In order to receive the simulated sunlight which comes out in a limited face area of the lens, the building model and/or its stand have to be moved to ensure that the simulated quasi-parallel light will fall onto the desirable parts of the building model. This model movement is a simple movement just for keeping the correct north-south orientation of the building model, and for catching the simulated sunlight, without tilting the building model.

1. INTRODUCTION

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

The variables to be adjusted are [2,3]:

- 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].

While each heliodon is designed on different emphasis of its purpose of measuring certain variables, and for certain operation convenience, the category 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 category 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 size of building model to be tested, the accuracy of the results offered by the heliodon and its applicability in testing building models of different latitudes.

In the pursuit of a tool capable of producing quasi-parallel light (i.e. the parallelity aspects of sunlight) impinging on physical building models for simulating various hours of the day and various days of the year, and for varying latitudes, yet occupying a space generally affordable in an architect's design office, a table top heliodon has been developed. The simulated quasi-parallel light is adjusted to move about the simulated earth axis, thus also allowing strong demonstration of physical solar movement around the building model.

In operation, this heliodon is placed on a normal office table, with the building model placed on a horizontal model platform, 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 heliodon, i.e. the office/studio table which acts as the horizontal platform for placing the heliodon, while the simulated sunlight is falling onto the parts of the model to be examined. The building model is not to be tilted.

Furthermore, the simulated light is set at close distance to the building model, yet with sufficient clearance maintained between the Fresnel lens of the light source and the model, for observing the testing effect of the model. This makes the heliodon compact, and suitable for operation on top of an office table.

2. THE SOLAR POSITIONS AND THE TABLE TOP HELIDON

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 d = -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 between 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 [10]. 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 at the same day, solar azimuth and altitude angles at the same moment. 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 base frame, a latitude selector scale (Fig. 6) and its related fixing mechanism, time selection scales mounted on time rings (Fig. 7) and the related positioning and fixing mechanism for the simulated sunlight generator (Fig. 8). This generator contains a solar declination selector (Fig. 9) for selecting the various days of the year and four rollers for moving the generator around the time rings (Figs. 2, 8). All these components are connected/fixed by various means such as bolts and nuts at desirable positions. The building model is placed on the flat movable model stand (Fig. 9), 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 parallel to the orientations of the heliodon (Figs. 2 to 5).

3. SIMULATING THE QUASI-PARALLEL LIGHT (I.E. PARALLELITY OF SUNLIGHT) AT VARIOUS SOLAR POSITIONS – FOR VARIOUS LATITUDES

The latitude selector (Fig. 6) is marked with a circular graduation of latitude degrees from 0 to 90 degrees, suitable for operating the heliodon in either hemisphere. The latitude selector is also provided with a slot for setting the desirable latitude degree and for primary fixing of the time ring assembly at this degree by a bolt and a nut. Further fixing of the time ring assembly to the base frame can also be effected by bolts and nuts (Figs. 2 to 6).

The setting will make the axis of the circular time rings parallel to the simulated earth axis (Figs. 1 to 5).

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

Because the outer time ring is strong and physically provides (Figs. 2 to 5, Fig. 7) a circular path for the rollers of the simulated sunlight generator to move about it and stay at varying positions on it, various moments of apparent solar time can be simulated. The desirable apparent solar time on the outer time ring is read off at the location of the time scale as marked by the time pointer. The outer time ring scale is fixed and is set for apparent solar time, (Figs. 2 and 7). The inner time ring, which is concentric with, and rotatable about, the outer time ring, can be set for local standard time relative to the apparent solar time shown on the outer time ring by established methods [12]. The time pointer simultaneously reads the apparent solar time and local standard time.

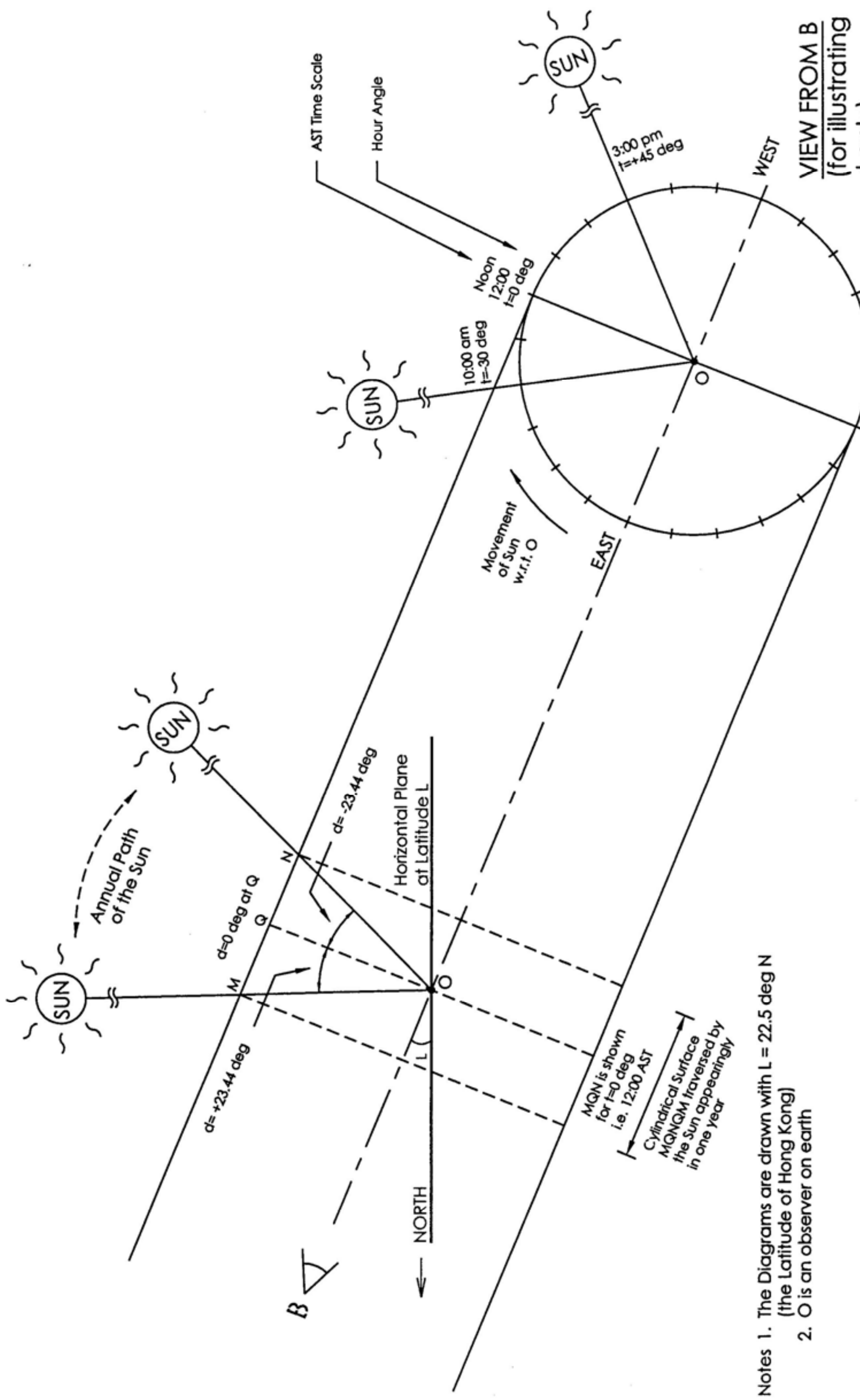

Fig. 1: The principle of designing the heliodon for solar declination, latitude, and hours of the day (for Northern Hemisphere) [adapted from 10]

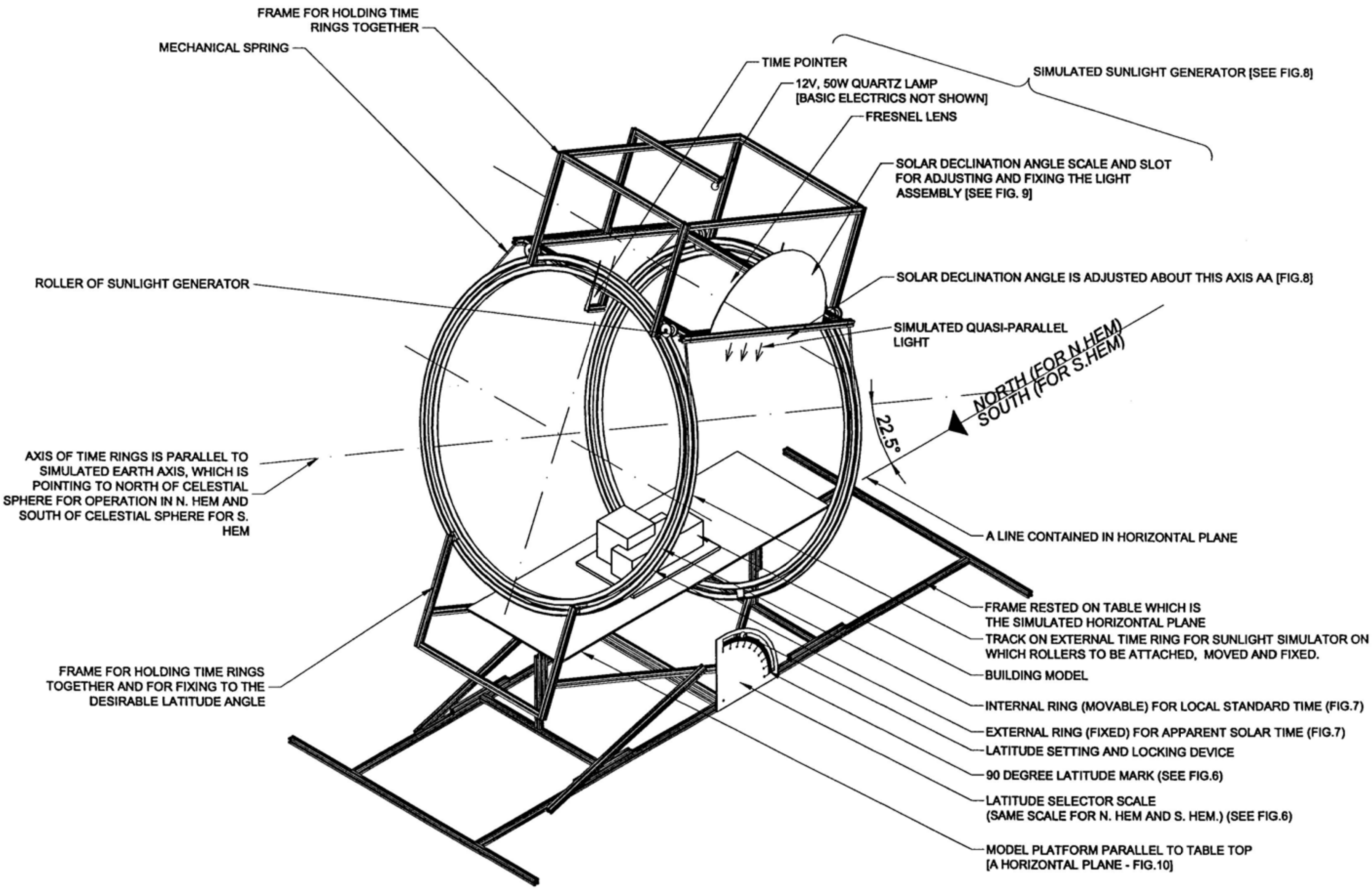

Fig. 2: The heliodon (set at 22.5 deg Latitude North – e.g. Hong Kong, noon apparent solar time on Equinox days) (Note: basic electrics not shown)

Table 1: Mean value of the solar declination (for 1991, noon UT (GMT), abstracted from The Nautical Almanac 1991, 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 1991, solar declination angle was 21 deg 50 min south of the Equator.

Fig. 3: The table top heliodon
Set for the latitude of Hong Kong (22.5 degree North), noon apparent solar time, Equinox day (21 March or 23 September), with model placed on model platform – looking from the South-West side

Fig. 4: The table top heliodon
Set for the latitude of Hong Kong (22.5 degree North), noon apparent solar time, Equinox day (21 March or 23 September), with model placed on model platform – looking from the East side

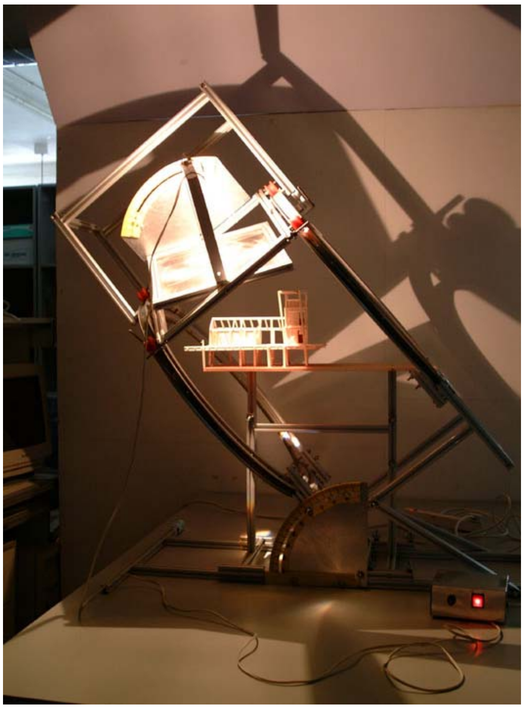

Fig. 5: The table top heliodon
Set for the latitude of Beijing (40 degree North), 10 am apparent solar time, summer solstice day (21 June), with model placed on model platform – looking from the East side

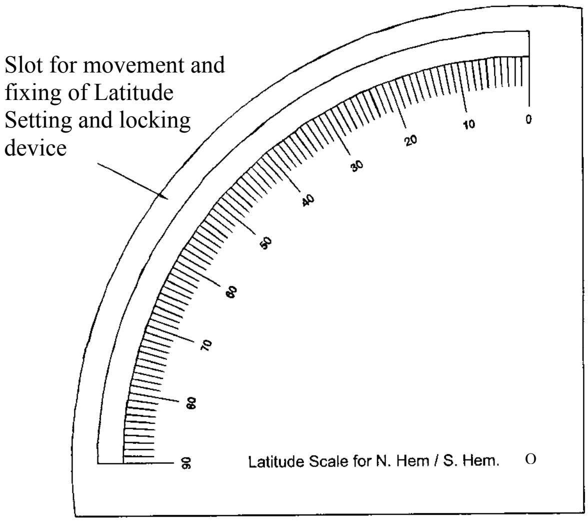

Fig. 6: Latitude selector scale

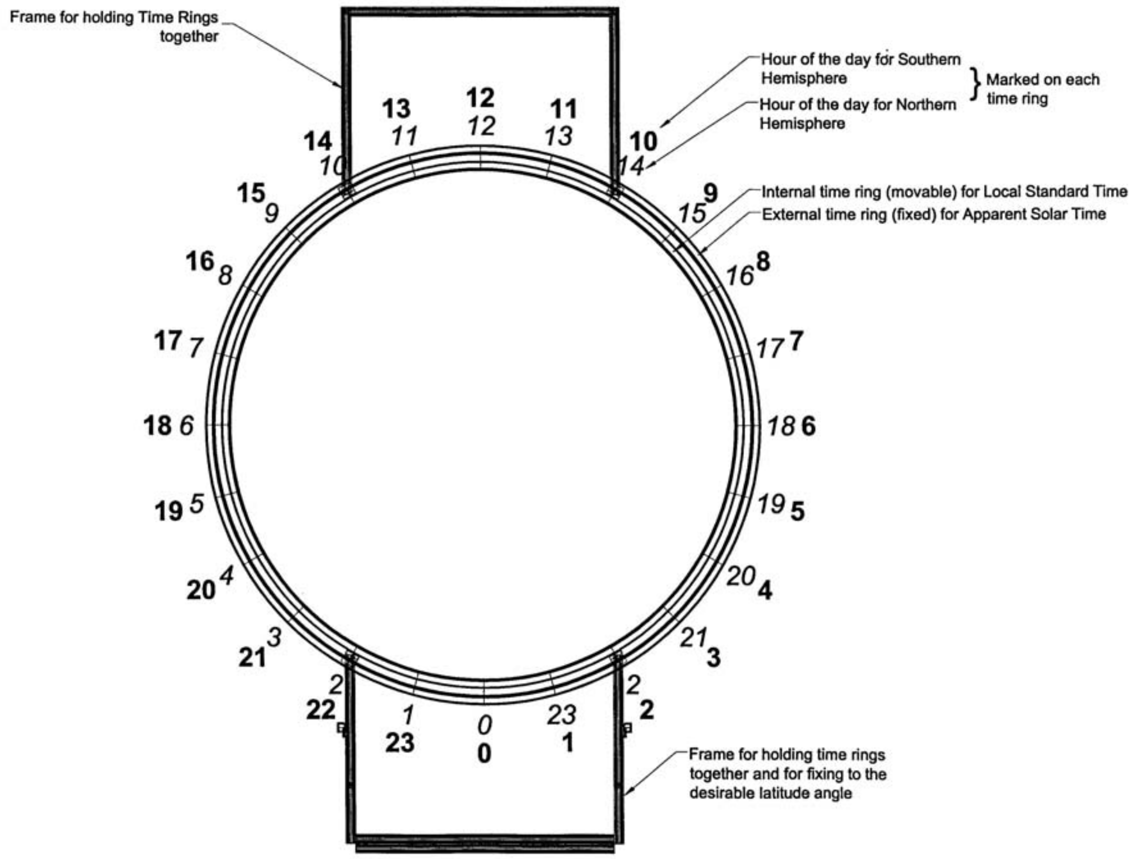

Fig. 7: Elevation of time rings for N. Hem/ S. Hem

When the simulated sunlight generator is turned to the desirable position for time selection, the tension of the mechanical spring keeps the simulated sunlight generator in this desirable position.

Note that different time scales are used for operating the heliodon in the Northern Hemisphere and Southern Hemisphere (Fig. 7).

5. 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 having a 12 V quartz-halogen lamp (typical 50 W) (Fig. 8), with the light-emitting element of the quartz lamp positioned at the focal point of a Fresnel lens, aiming at producing quasi-parallel light, i.e. simulated sunlight. The simulated sunlight, is, by the physical design and construction of the simulated sunlight generator and other components of the heliodon, set at 90 degree to the centre line (Figs. 1and 2) of the simulated earth axis, when the solar declination angle is selected at zero degree, i.e. Equinox days (Figs. 1, 2, 8 and 9).

Quasi-parallel light is given off from the Fresnel lens to simulate the parallelity of sunlight, with about 700 lux obtainable within a few meters from and at a direction normal to the lens surface. This provides sufficient illuminance for testing the building models, without excessive dimming of the operating environment such as an architect's office.

The simulated quasi-parallel light is set and fixed for various desirable days (Table 1) by adjusting and fixing the simulated sunlight generator to the desirable readings of the solar angle declination scale (Figs. 2, 8, 9). Note that for use in either hemispheres, different scales (Fig. 9) corresponding to solar declination angles and days have to be used (Fig. 8).

The simulated quasi-parallel light (Figs. 1, 2, 8) 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 (Figs. 1, 2, 8) 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), at right angle to the simulated earth axis (Figs. 1 and 2).

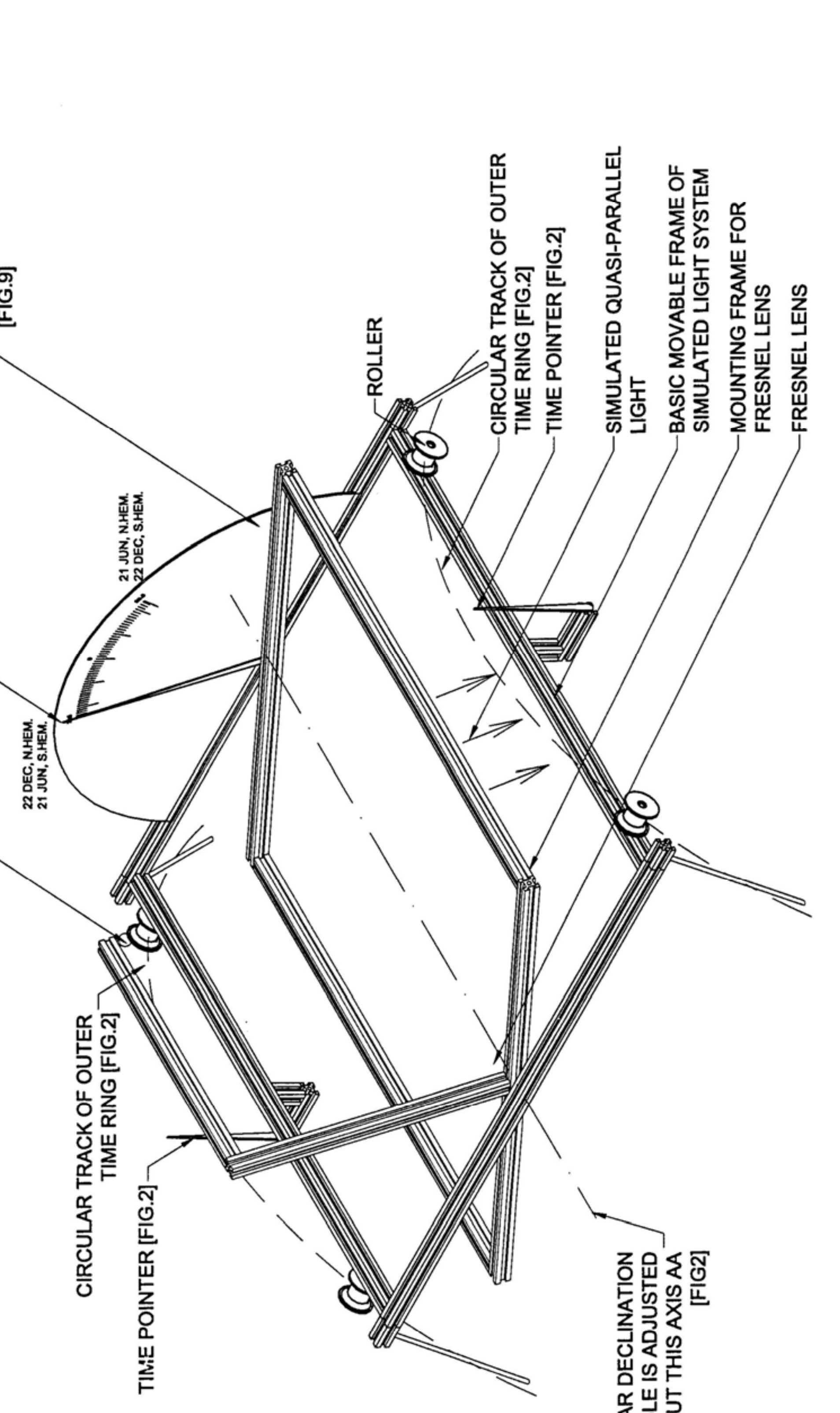

Fig. 8: The movable simulated quasi-parallel light system (basic electrics not shown)

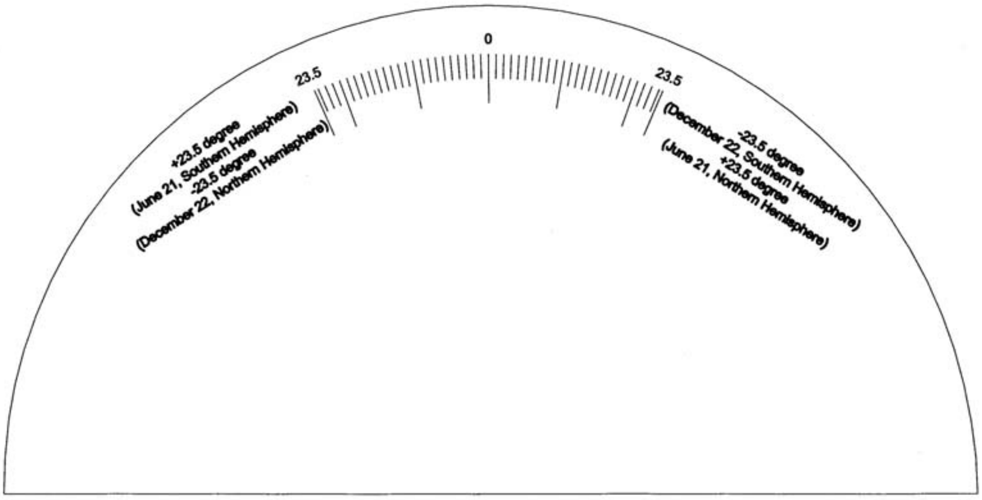

Fig. 9: Solar declination selector

6. FURTHER NOTES ON OPERATION OF THE HELIODON

In providing simulated sunlight (Figs. 1 to 5), for the various combinations of latitude, time and day (i.e. the corresponding solar declination angle), the simulated sunlight will change its direction relative to the simulated horizontal model platform. The model (i.e. commonly a physical building model) and/or the model platform (Fig. 10) have to be moved horizontally (Fig. 2), to receive the simulated sunlight, with the true north-south orientation of the said model kept in line with the identified true north-south orientation of the heliodon.

This prototype heliodon occupies a space of 1.58 m long x 0.6 m wide x 1.3 m high, suitable for placing onto a table of the design office of an architect. Because the internal diameter of the inner time ring of this prototype is 540 mm, allowing for 50 mm minimum clearance between the Fresnel lens and the building model (Figs. 1 to 5), the dimensions of the model are limited to 600 mm long x 400 mm wide x 400 mm high. Depending on their actual sizes, building models falling within these dimensions may have to rely on adjusting the height of the model platform, in order to have the related parts of the building model to be impinged by the simulated quasi-parallel light.

The electrical provisions for supplying power to the quartz-halogen lamp (Figs. 2, 3, 8) are not shown because such electrical provisions are devices of existing technology. They are however shown in the photos (Figs. 3 to 5).

This heliodon simulates the directional and parallelity aspects of sunlight. Other aspects of sunlight such as the spectral aspects, the energy intensity aspects are not simulated.

The use of Fresnel lens in this heliodon has enabled quasi-parallel light to be generated at close proximity to the building model, substantially reducing the distance traditionally allowed between the light source and the building model, when using a bright lamp [1]. This has contributed greatly in reducing the heliodon dimensions, making it suitable for operation in an architect's office.

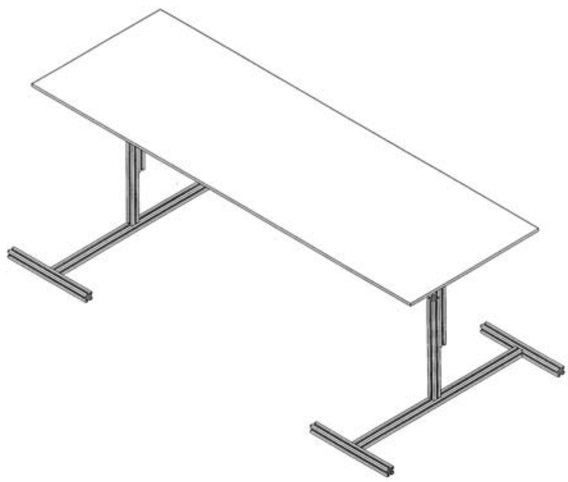

Fig. 10: Movable building model platform

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. However the building model is limited to certain dimensions.

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 simulated quasi-parallel light is adjusted to move about the simulated earth axis, thus also allowing strong demonstration of physical solar movement around the building model.

While an earlier reported table-top heliodon [13] exhibits the potential of becoming a compact and demountable heliodon for storage when it is not in use, it cannot show the solar path easily and clearly to the normal users. This currently described heliodon, however can show the solar path easily and clearly to the normal users, but it cannot be easily demounted, and therefore occupies a definite space also when it is stored. Of course then, the dimensions of the models of buildings that can be tested by both heliodons depend on the dimensions of the components of the heliodons and the testing platforms.

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

<u>OQ,OM</u> 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

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