May 3, 1966 A. F. SPILHAUS 3,248,866

ASTRONOMICAL CLOCK

Filed Dec. 10, 1963 7 Sheets-Sheet 1

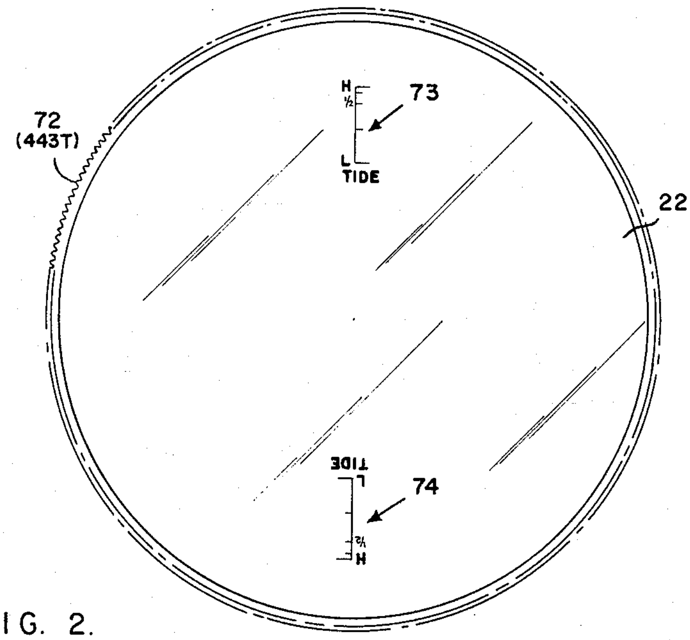

FIG. 2.

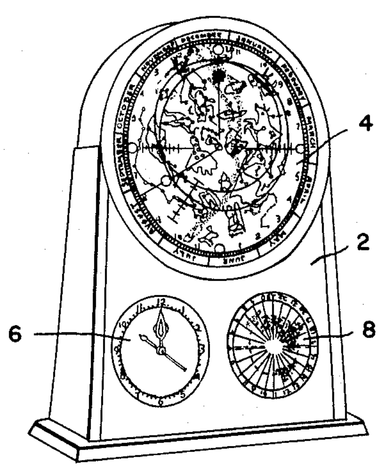

FIG. 1.

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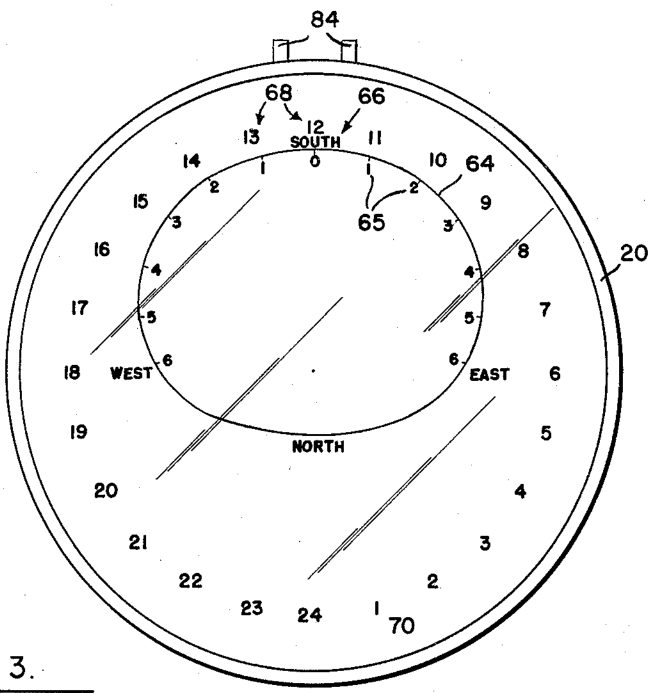

FIG. 3.

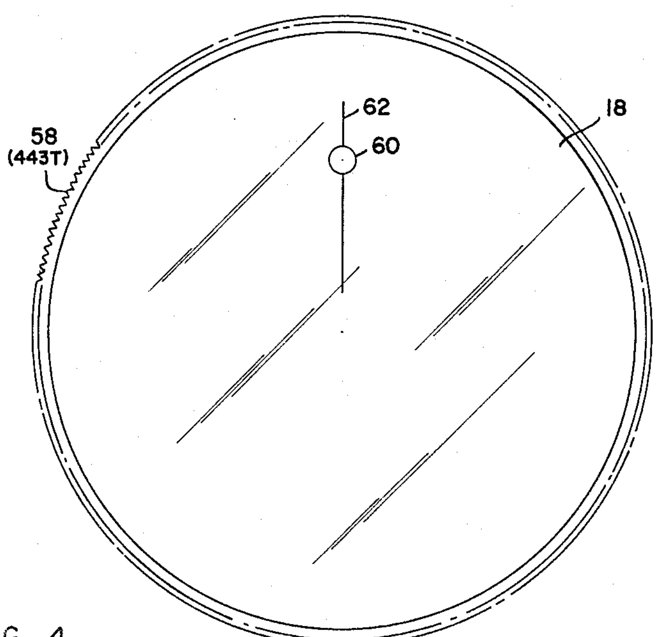

FIG. 4.

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ASTRONOMICAL CLOCK

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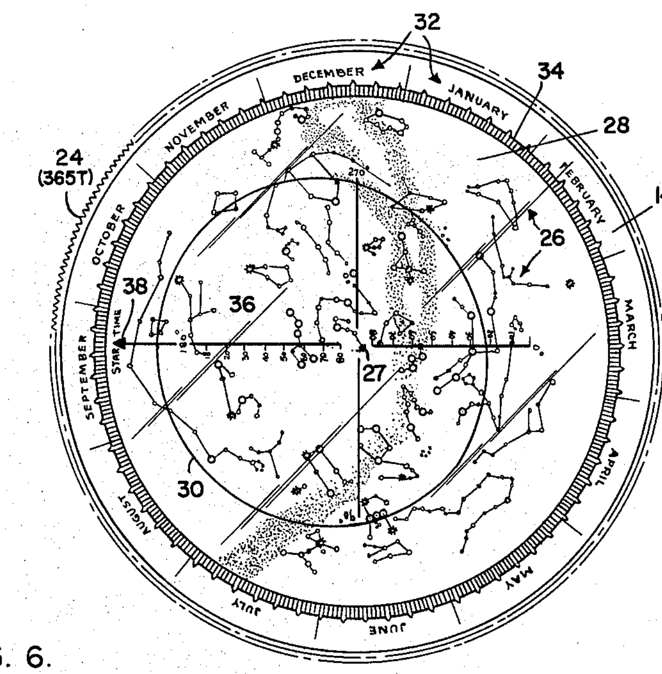

FIG. 6.

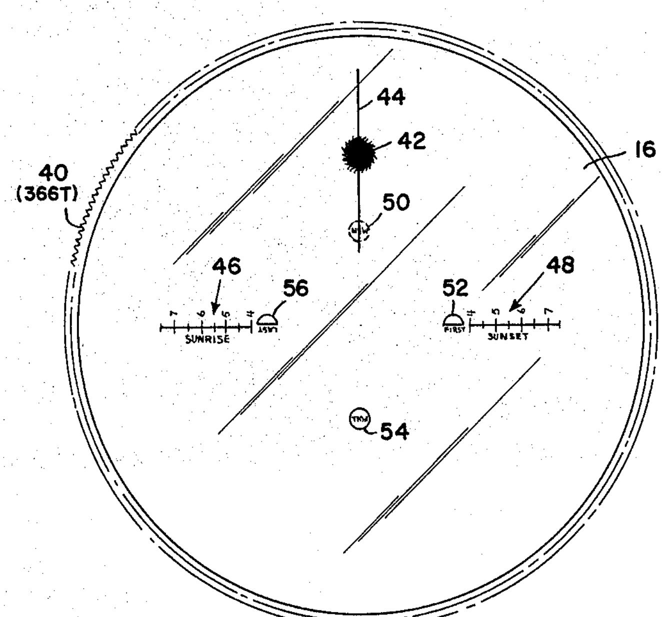

FIG. 5.

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ASTRONOMICAL CLOCK

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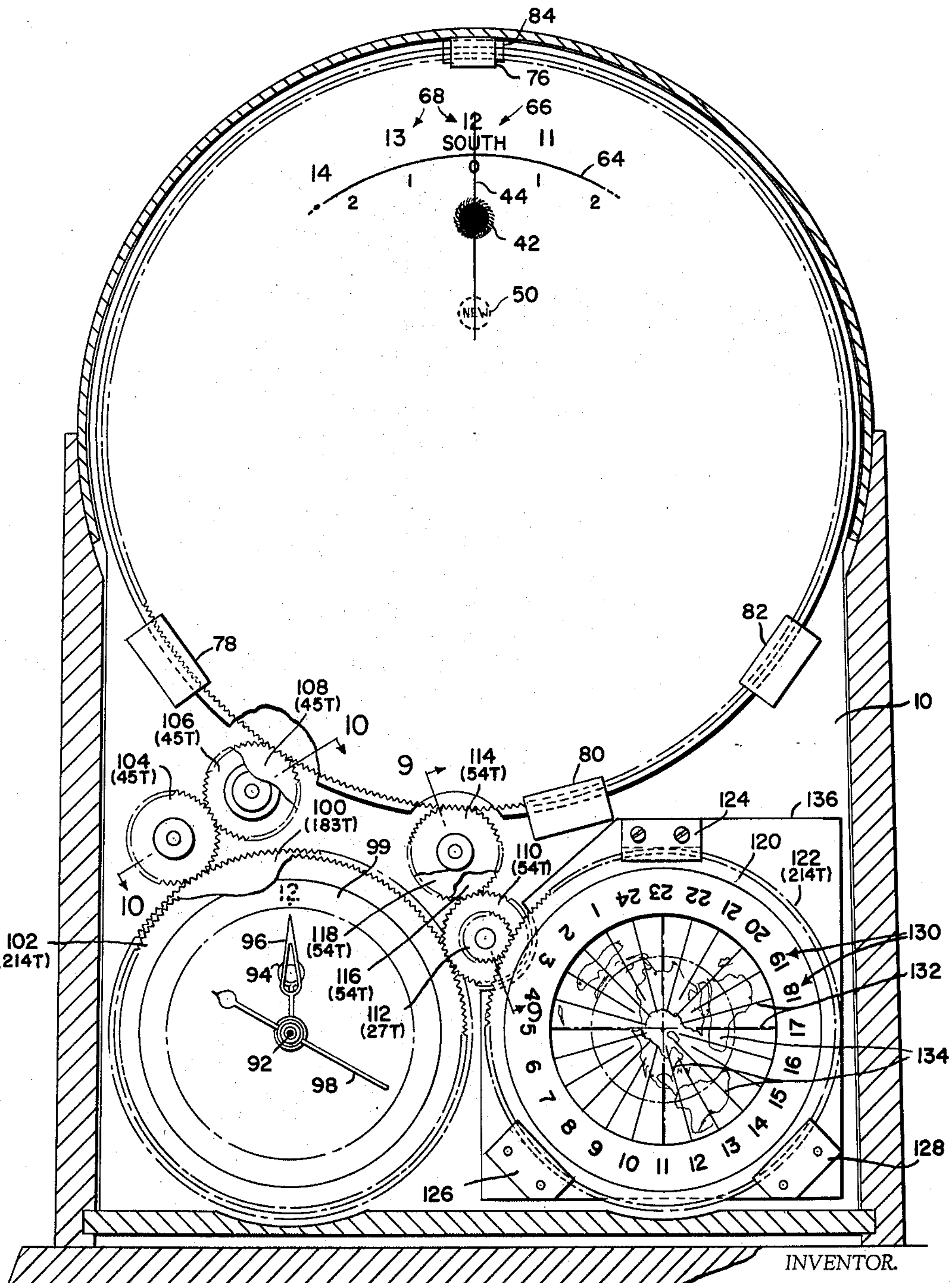

FIG. 7.

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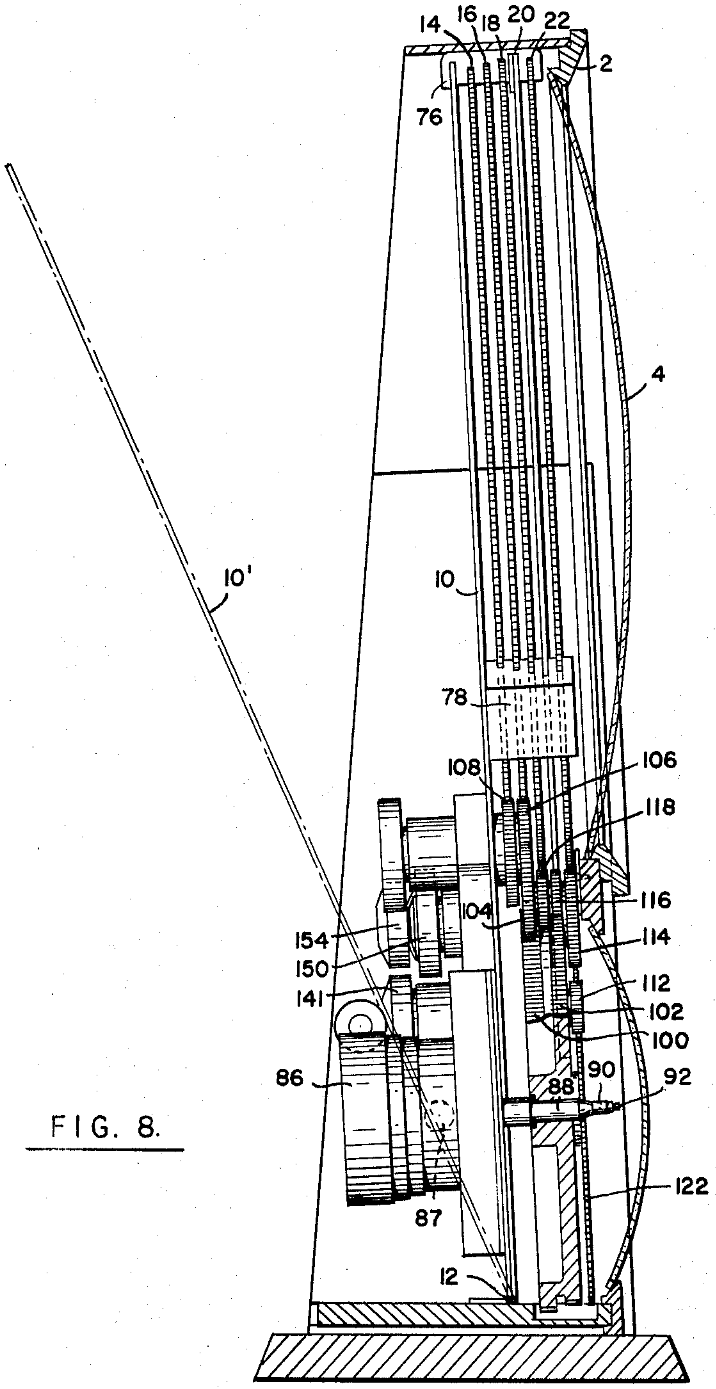

FIG. 8.

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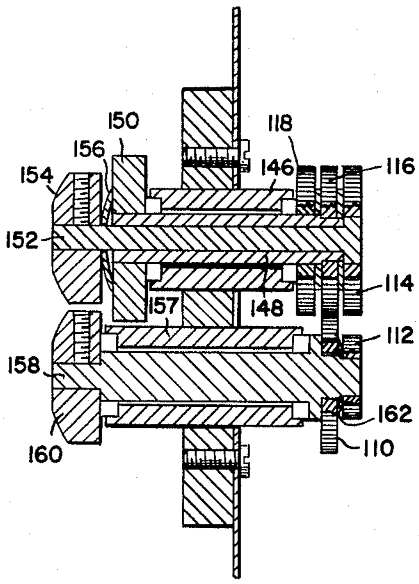

FIG. 9.

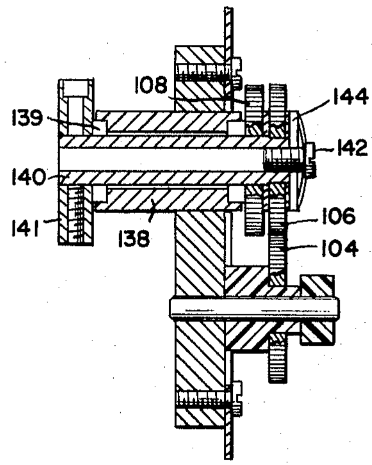

FIG. 10.

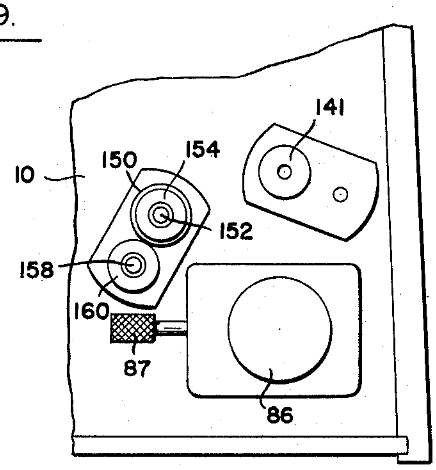

FIG. 11.

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ASTRONOMICAL CLOCK

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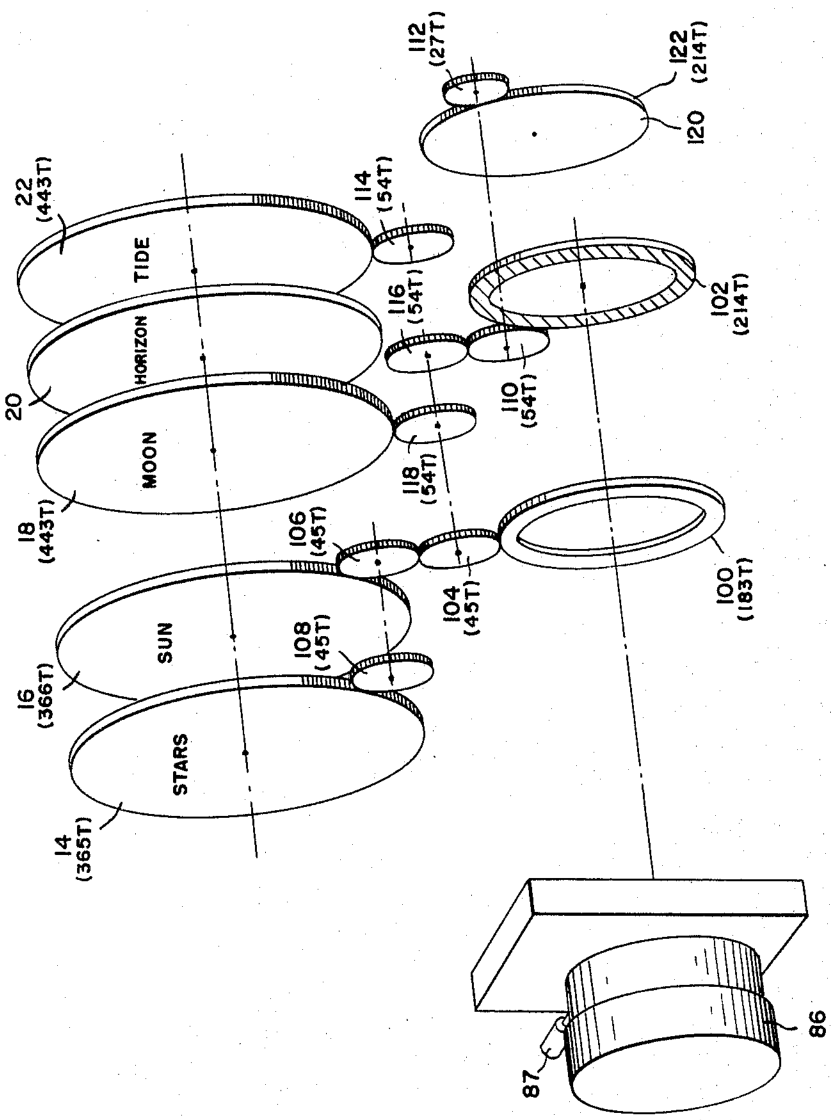

FIG. 12.

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United States Patent Office

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3,248,866
ASTRONOMICAL CLOCK

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Filed Dec. 10, 1963, Ser. No. 329,433
2 Claims. (Cl. 58—3)

This invention relates to astronomical clocks and particularly to a clock which provides for the display of a great variety of astronomical data.

Clocks are known which display astronomical data in a more or less qualitative form and clocks are also known which display limited amounts of data quantitatively. The present invention relates particularly to a clock displaying a great variety of astronomical data to a sufficiently accurate quantitative extent as to fit the desires of many persons interested in such data, among whom might be listed persons directly interested in astronomy, navigation, boating or fishing, seashore resident, etc. The clock provided in accordance with the invention may also be used for instruction purposes in many fields having to do with astronomy or its offshoots. While, usually, the clock would be set to follow accurately astronomical phenomena existing at a present time, for instruction purposes it may be adjusted arbitrarily to illustrate special occurrences and then reset to normal. The general object of the present invention is to provide such a clock which despite the great variety of data presented by it and quantitative accuracy is relatively simple in its construction, adjustment and operation.

Briefly stated, the clock comprises one set of five dials of which four are concentrically rotatable and closely superimposed so that relatively moving indicia thereon may be used for indications, the four face dials, at least, being transparent so that observation of the rearmost dial may be made, this rearmost dial being imprinted preferably with a dark background on which are indicated the major constellations and other data as will shortly appear. The fixed dial outlines the horizon and carries other markings of significance.

Among the matters exhibited by the set of dials just mentioned are the following:

The constellations and their component stars in their positions with respect to the horizon marked with compass points so that an observer may determine at the time given by the clock what stars will be visible and their positions with respect to compass points and their approximate declinations.

The position of the sun is also ascertainable with respect to the horizon and also the approximate times of sunrise and sunset.

Demonstrated also is the apparent progress of the sun through the constellations, and of course its relationship to the vernal equinox. Concurrent with this is the indication of the day of the year, so that the clock is also a calendar. Solar time is indicated by this set of dials.

The position of the moon is also indicated in its relation to the stars and sun, as are also indicated its phases. Indications are also given from which approximate times of moon rise and moon set may be determined.

Tides are indicated and settings are provided to enable the clock user to set the indications for local tide conditions. Times before and after high tides may be determined.

Various other data are exhibited as will become more apparent from consideration of matters set forth hereafter.

The clock further embodies a conventional clock driven in the case of electrical alternating current powering by a conventional synchronous clock motor which drives the other moving elements of the clock through proper gearing. The synchronous motor may be replaced by a spring or a battery powered clock mechanism if the clock is to be used under conditions, as on boats, in which the usual sixty cycle supply or other control frequency supply is not available. Additionally there is provided a clock indicating time in various locations throughout the world, with Greenwich mean time of special interest.

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The moving dials of the astronomical clock have a particularly advantageous construction and mounting. They are in the form of gears made of transparent plastic and by reason of their size they may have large numbers of teeth giving rise to simplification of gearing and high accuracy of relative motions. In particular, moon positions and times of tides are indicated with high accuracy over very long time periods. Further, shafts are eliminated by mounting the toothed dials in guides of Teflon or similar antifriction material providing for free movement without the necessity for any liquid lubrication. The absence of shafts avoids interference with display of indicia located at or near the center of the dials.

Adjustments are provided for initial settings of the displayed elements to take care of time settings, geographical locations, and initial date for moon positions and tides. These adjustments also provide for special settings for purposes of instruction.

The general objects of the invention indicated above and others relating to details of construction and operation will become more apparent from the following description, read in conjunction with the accompanying drawings in which:

FIGURE 1 is a perspective view showing the general appearance of the clock;

FIGURE 2 is an elevation of the toothed dial which will be referred to as the tide dial;

FIGURE 3 is an elevation showing the fixed dial which may be conveniently referred to as the horizon dial;

FIGURE 4 is an elevation of a toothed dial which will be referred to as the moon dial;

FIGURE 5 is an elevation of the toothed dial which will be referred to as the sun dial;

FIGURE 6 is an elevation of the toothed dial which will be referred to as the star dial;

FIGURE 7 is a vertical sectional view taken inside the front of the clock case illustrating both the visible elements and the elements of the drive gearing, the displayed data of the upper dials in this figure being only fragmentarily indicated;

FIGURE 8 is a sectional view through the case showing the mechanism partly in side elevation and partly in section;

FIGURE 9 is a fragmentary section taken on the plane indicated at **9—9** in FIGURE 7;

FIGURE 10 is a fragmentary section taken on the plane indicated at **10—10** in FIGURE 7;

FIGURE 11 is a fragmentary rear elevation showing primarily the controls for effecting adjustments; and

FIGURE 12 is an exploded perspective view illustrative of the drive and adjustment arrangements.

The clock comprises a case **2** which may be of any suitable decorative type, the case being provided with circular windows indicated at **4**, **6** and **8** through which are displayed, respectively, the astronomical data, local time, and world time, the latter showing the local times at various places on the earth, and specifically Greenwich mean time. The numerals for the local time clock may be displayed on an annular ring at the periphery of the window **6**.

A plate **10** hinged at its lower edge at **12** is arranged to be tilted rearwardly as indicated at **10'** and is normally held in its upright closed position by spring latches (not shown). This plate carries all of the operating parts of the clock, and hinging is provided to make the sun disc accessible for adjustment.

The astronomical display of the clock is effected by the use of relatively movable discs respectively designated **14**, **16**, **18**, **20** and **22** which are shown in FIGURES 2 to 6, inclusive. It will be convenient to describe these discs in the order from back to front of the clock. They are concentrically mounted in slightly spaced relationships and since all of the discs except the rearmost are transparent, the indicia of all are visible to the observer. All are desirably formed from a transparent plastic such as a methyl methacrylate resin (e.g., Plexiglas). The indicia may be printed thereon by silk screening.

Referring to FIGURE 6, the disc **14**, the star disc, is in the form of a gear having teeth **24** which in the modification disclosed are 365 in number. The number of teeth given herein will be described to provide a consistent set to give the gear ratios for proper relative motions. One of the advantages of the present invention is that because of the use of large diameter discs for the astronomical set teeth may be provided on their peripheries in sufficient numbers to give, conveniently, the accurately desired gear ratios, this feature being coupled with the mountings of the discs at their peripheries and avoidance of the necessity for central nested shafts which would impair the display. The disc **14** except at its periphery provides a star chart on which the constellation and the principal visible stars are indicated at **26**. The disc is concentric with the north celestial pole, Polaris being indicated at **27**. For best display the star chart is provided with a dark background indicated at **28** (blue or black) which may have contrasting areas indicative of the extents of the constellations. On these the various indicia are printed in white or other light color. For clarity, of course, the imprinted constellations and stars are shown in the drawings in black. The star field may be quite detailed but is only indicated in part in FIGURE 6. Other indicia superimposed on the star field comprise the curve **30** which cooperates with sunrise and sunset scales on the sundial, declinations markings **36** and a sidereal time indicating arrow **38**. Provided at the periphery of the disc **14** are the month markings **32** and the day markings **34**, which for ease of reading may have fifth days accentuated. The month and day markings show desirably in black on a white opaque field so that the disc **14**, as a whole, presents an opaque background. However, if back illumination is provided this disc may be translucent with transparent markings.

The next disc in front of that just described is the sun disc **16**, FIGURE 5, which is provided with 366 teeth **40** about its periphery. The pitch of the teeth of the disc **14** and **16** is the same and then mesh with identical idler pinions rotating together as will appear hereafter. The sun disc is transparent except for the markings which may be in white or gold. (For consistency here and hereafter it will be assumed that the clock is to be illuminated from its front; variations for back illumination will be obvious.) For easy recognition the sun is indicated by the disc **42** through which passes the radial line **44**. The intersection of this line across the horizon shows the approximate azimuth of the sun, though for casual observation the sun disc **48** may be used. This disc carries the sunrise and sunset scales **46** and **48** (to be read with respect to the curve **30**), and also moon phase indicia **50**, **52**, **54** and **56** which may be used in estimation of the appearance of the moon.

The next disc in sequence from the back to the front is disc **18**, FIGURE 4, which is provided with 443 teeth **58**. Using this number of teeth and a somewhat smaller tooth size than for the teeth of the two discs already described the disc **18** may be of comparable diameter so as to be similarly mounted at its periphery. For example, typically, the star and sun discs may have teeth of 40 pitch while the moon and tide discs may have teeth of 48 pitch. The moon disc carries a representation **60** of the moon and a radial line **62** therethrough, both desirably printed in white.

The line **62** is particularly useful in approximately identifying the azimuthal position of the moon by its intersection with the horizon **64**. This line read against the numerical hour markings **65** along the horizon also gives an approximate time interval from which moon rise or moon set may be estimated relative to its meridian position.

In front of the moon disc there is the fixed disc **20**, FIGURE 3. Its major markings **64**, is of the horizon which is marked with the compass points as shown at **66**. Solar times are indicated at **68** and against these may be read the sun line **44** and for sidereal time the arrow **38**. The horizon marking is for a particular latitude in which the clock is expected to be used, but different horizons may be provided for the various latitudes. Hour markings **65** running from south eastwardly and westwardly along the horizon are of use in estimating times before or after high tide, times of moon rise and moon set, etc. The markings on disc **20** may be in white, the remainder of the disc being transparent.

The front disc **22**, FIGURE 2 is the tide disc and is dimensionally the same as the moon disc **18**, there being 443 teeth at **72**. Tide markings are provided as shown at **73** and **74** indicative of high, low and intermediate tide conditions. These markings may be in white, the remainder of the disc being transparent. The markings read against the horizon indicate the tide conditions: i.e. when one of these markings is at the top of the horizon, high tide exists; and the deviation along the horizon indicates time before or after high tide. The scales **73** and **74** themselves indicate the tide condition when read against the horizon line. A tide disc separate from the moon disc is provided to permit adjustments to be made indicative of local tide conditions.

All of the discs **14**, **16**, **18**, **20** and **22** are mounted concentrically by Teflon guides **76**, **78**, **80** and **82**, secured to the plate **10** and slotted to receive the peripheries of the discs. The rotating discs are thus mounted for free, low-friction movement and the guides serve to maintain the teeth of these discs in mesh with their driving gearing. In the case of the stationary horizon disc **20**, rotation is prevented by ears **84** of this disc embracing the sides of the uppermost Teflon guide **76**. In the case of the sun disc **16** play in the guides is desirably sufficient so that this disc may be moved out of mesh with its driving idler and so initially adjusted to bring its indications of time and the indications of the local time clock in proper relationship. For example, during daylight saving time the time indicated by the sun disc should be standard local time while it will generally be desirable to have daylight saving time indicated by the clock. Because changes in this respect would normally be made only twice a year it is not worth involving independent setting means since the sun disc may be readily lifted, adjusted, and then dropped into mesh, meshing being thereafter maintained merely by the weight of the disc.

The plate **10** mounts the driving clockwork **86**. When the clock is to be used with a controlled frequency alternating current source, the clockwork is desirably of the synchronous motor type incorporating reduction gearing to provide drive for the conventional hour, minute and sweep second shafts **88**, **90** and **92**, respectively. However, the clockwork may be of wound spring type or of the type maintained in operation by direct current. The conventional time-setting adjustment is provided at **87** and, as will become apparent, this serves not only for the adjustment of the hour and minute hands of the clock but also for the other elements which are driven by the hour shaft **88**. The hour, minute and sweep second hands are illustrated in FIGURE 7 at **94**, **96** and **98** and are readable against the twelve hour dial **99** which is in the form of a concentric marked ring carried by the frame.

The hour shaft **88** has secured to it a composite gear comprising two gears **100** and **102**. The former, at the rear, has 183 teeth, while the latter **102** has 214. If, for example, the former are forty pitch, and the latter forty-eight pitch, the two gears are approximately of the same diameter.

The gear **100** drives a 45 tooth idler **104**. A pair of coaxial idlers **106** and **108**, each having 45 teeth, are driven together by the idler **104** which meshes with the idler **106**. Provision, later described, is made for relative adjustment of the idlers **106** and **108**. These idlers respectively drive the sun disc **16** having 366 teeth and the star disc **14** having 365 teeth. Because the pitch diameters of the last mentioned discs are very nearly the same, proper driving conditions are achieved even though these discs are essentially coaxial, very slight backlash taking care of proper driving conditions.

A pair of pinions **110** and **112** are coaxially mounted for simultaneous drive, though provision is made as will appear later for relative adjustment of these pinions. The former is provided with 54 teeth meshing with the 214 teeth of the gear **102**. The latter is provided with 27 teeth.

Three pinions **114**, **116** and **118**, each having 54 teeth, are mounted coaxially but are relatively adjustable as will later appear. The pinion **110** meshes with the pinion **116** and this serves for the drive of the pinions **114** and **118** which mesh, respectively, with the teeth of the discs **22** and **18**, each of which discs is provided with 443 teeth as mentioned previously.

The pinion **112** meshes with the teeth **122** of a disc **120** of transparent plastic of the same type as that used for the discs previously described. There are 214 teeth **122**. The disc **120** is mounted in slotted Teflon guides **124**, **126** and **128** to provide for free, low-friction movement. Imprinted on the discs **120** are twenty-four hour indications **130** with associated radial lines **132** for easy reading against a world map imprinted as indicated at **134** desirably with outlines of the continents, major cities, and other markings indicative of the longitude of Greenwich and the international date line. These latter matters **134** are printed on a plate **136** which is secured to the plate **10** behind the disc **120**, the plate **136** serving for the mounting of the Teflon guides.

The matter of the adjustments will now be described.

The adjustment of the star disc relative to the sun disc is provided by the mounting of pinions **106** and **108** by means of a bearing **138** carrying at its ends Teflon washers **139** providing for low friction mounting of a tubular shaft **140** to which is secured an adjusting knob **141**. A screw **142** is threaded into the forward end of the shaft **140** and bears on a disc-type spring **144** to clamp together the pinion **108** which is secured to the shaft **140** by a press fit, the pinion **106** which has a running fit on the shaft, and interposed washers which may be of nylon to provide frictional driving engagement between the pinions while permitting the pinion **108** to be adjusted, the pinion **106** being driven by the pinion **104** as already described.

In the case of the moon and tide discs, these must both be adjustable independently of their drive. As already described, there are three equal size pinions **114**, **116** and **118**, the first driving the tide disc, the last the moon disc, and the intermediate one being driven from the pinion **110**. A bearing **146** provided, as previously described, with Teflon bearing washers, mounts the sleeve **148** within which there is in turn mounted the shaft **152**. The sleeve **148** carried the knob **150** and the shaft **152** carries the knob **154**. A spring **156** is located between these knobs and provides adjustable clamping action between the pinions which are separated by washers, the pinion **118** being secured by a press fit to the sleeve **148** while the pinion **114** is secured by a press fit to the shaft **152**. The pinion **116**, driven by the pinion **110** will carry frictionally with it during driving the pinions **114** and **118**, but these may be individually adjusted relative to it by manipulation of the knobs **154** and **150**.

Provision for adjusting the drive of the world time clock is afforded through the mounting involving the bearing **157** provided with Teflon washers as previously mentioned which mount a shaft **158** to which there is secured the adjusting knob **160**. The pinion **112** is secured to this shaft and an interposed spring **162** provides clamping to the pinion **110** which is driven by the gear **102**. This arrangement, accordingly, provides normal frictional drive of the world time clock disc, but this may be adjusted by manipulation of the knob **160**.

The descriptions so far given will have made generally clear the operation of the clock. The drive of the local time clock is, of course, straightforward from the clockwork, and the drive of the world time clock disc through one revolution in twenty-four hours is through the gearing **102**, **110**, **112** and **122**, the last being provided by the teeth on the disc **120**.

Adjustment of the clockwork simultaneously adjusts the hands of the local time clock and the disc **120**, but the latter may be independently adjusted by the knob **160**. This last adjustment takes care of the difference between standard and daylight saving time, and also the matter of settings for different localities, so that Greenwich mean time may be read on the world time clock.

The drives of the star and sun discs from the equal size pinions **106** and **108** and the arrangement of the 365 teeth on the star disc and the 366 teeth on the sun disc take care of the proper exhibiting of the sun's apparent motion through the stars. The setting of the stars relative to the sun is taken care of by adjustment of the knob **141**. Proper adjustment of the day indication is also thus afforded to take care of leap year correction. (The quarter-day per year change is so slight in affecting observation as not to warrant special gearing, and a one day shift adequately takes care of the leap year change.)

Adjustments relative to the horizon are simultaneously made. Sunrise and sunset indications are provided by reading the scales **46** and **48** against the curve **30** provided for this purpose.

The motion of the moon is very accurately reproduced (to approximately one part in ten thousand) by the gearing described. The phases of the moon are indicated by reading its position relative to the markings **50**, **52**, **54** and **56** on the sun disc. Estimates of times of moon rise and moon set are made by reference to the hour markings along the horizon.

Tide conditions are readable from the tide discs. The setting of the tide disc is to take care of local or other tides of interest and settings may be made with reference to suitable tide tables. Once set, however, the tides are indicated with good accuracy.

More or less astronomical indications may be provided as desired. For example, the ecliptic and equator may be indicated. Mechanical variations may also be made. For example by incorporating in the driving gearing for the sun disc friction adjustment means of the type already described the sun disc may be adjusted independently of the hands of the local time clock.

It will be evident that various other details may be changed without departing from the invention as defined in the following claims.

What is claimed is:

1. An astronomical display clock comprising a plurality of approximately coextensive rotatable discs each of which is toothed at its periphery to form a gear, a first of said discs displaying indicia representing the celestial sphere, a second of said discs displaying indicia indicative of the position of the sun, and a third of said discs displaying indicia indicative of the position of the moon, means mounting said discs coaxially, a stationary reference member displaying indicia indicative of an observer's horizon, the last mentioned member and said discs being stacked adjacent to each other with all of said discs in front of the rearmost being primarily transparent except for the indicia thereon so that the superimposed indicia may be viewed simultaneously, and a clockwork mechanism driving said respective first and second discs in the

same direction in the speed ratio of 366/365 with the latter at the rate of one revolution per day and driving the third disc in said direction in the speed ratio of 428/443 with respect to said second disc, the number of teeth on said third disc being greater than the number of teeth on either of said first and second discs, and the pitch of said teeth on said third disc being greater than the pitch of the teeth on said first and second discs.

2. An astronomical display clock comprising a plurality of approximately coextensive rotatable discs each of which is toothed at its periphery to form a gear, a first of said discs displaying indicia representing the celestial sphere, a second of said discs displaying indica indicative of the position of the sun, and a third of said discs displaying indicia indicative of the stage of a tide when read against indicia indicative of an observer's horizon, means mounting said discs coaxially, a stationary reference member displaying indicia indicative of an observer's horizon, the last mentioned member and said discs being stacked adjacent to each other with all of said discs in front of the rearmost being primarily transparent except for the indicia thereon so that the superimposed indicia may be viewed simultaneously, and a clockwork mechanism driving said respective first and second discs in the same direction in the speed ratio of 366/365 with the latter at the rate of one revolution per day and driving the

third disc in said direction in the speed ratio of 428/443 with respect to said second disc, the number of teeth on said third disc being greater than the number of teeth on either of said first and second discs, and the pitch of said teeth on said third disc being greater than the pitch of the teeth on said first and second discs.

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