

Oct. 15, 1940.

F. E. WRIGHT ET AL
GRAVITY TORSION BALANCE

2,218,140

Filed Dec. 15, 1938

6 Sheets-Sheet 1

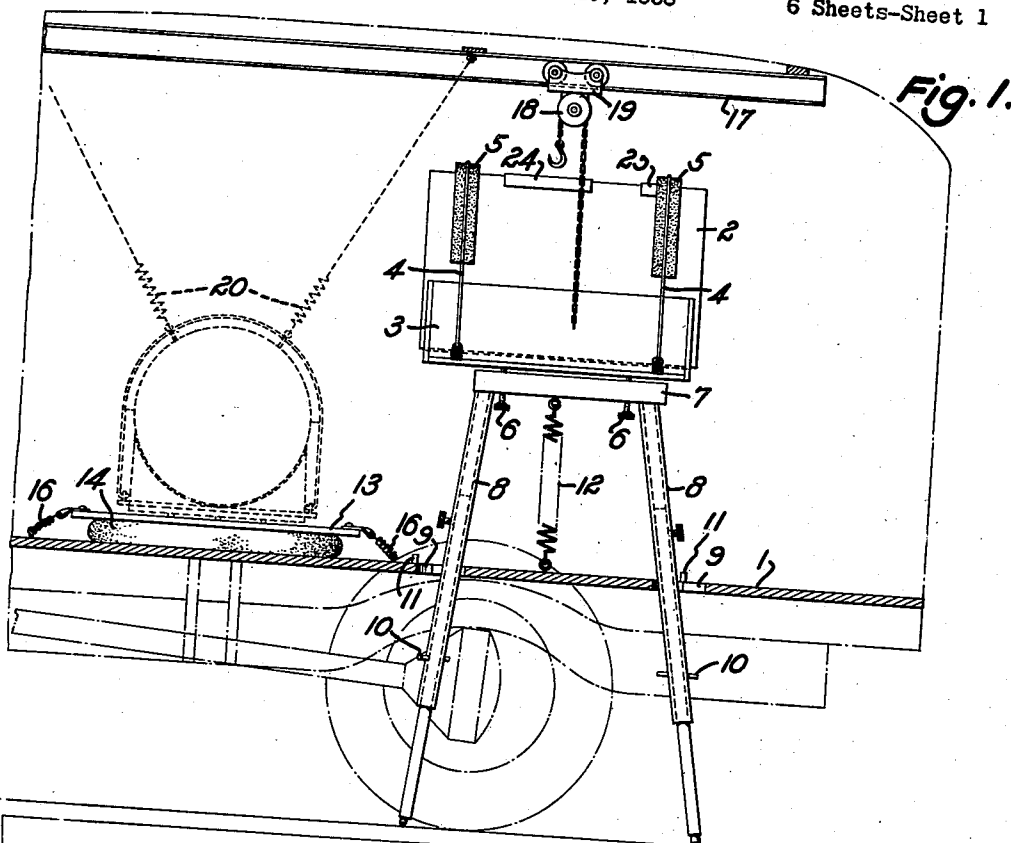


Fig. 1.

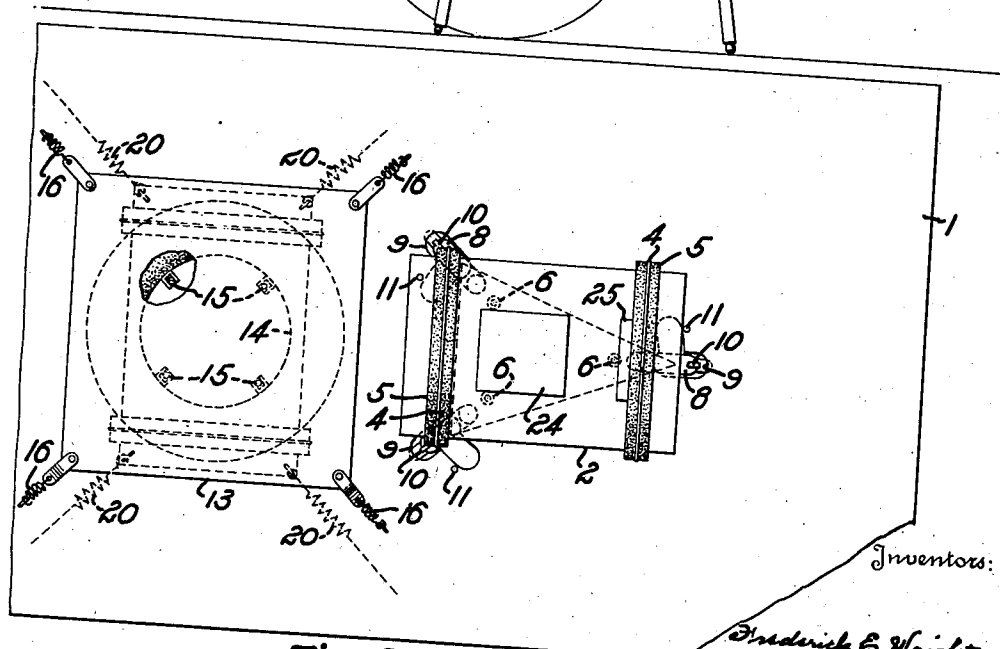


Fig. 2.

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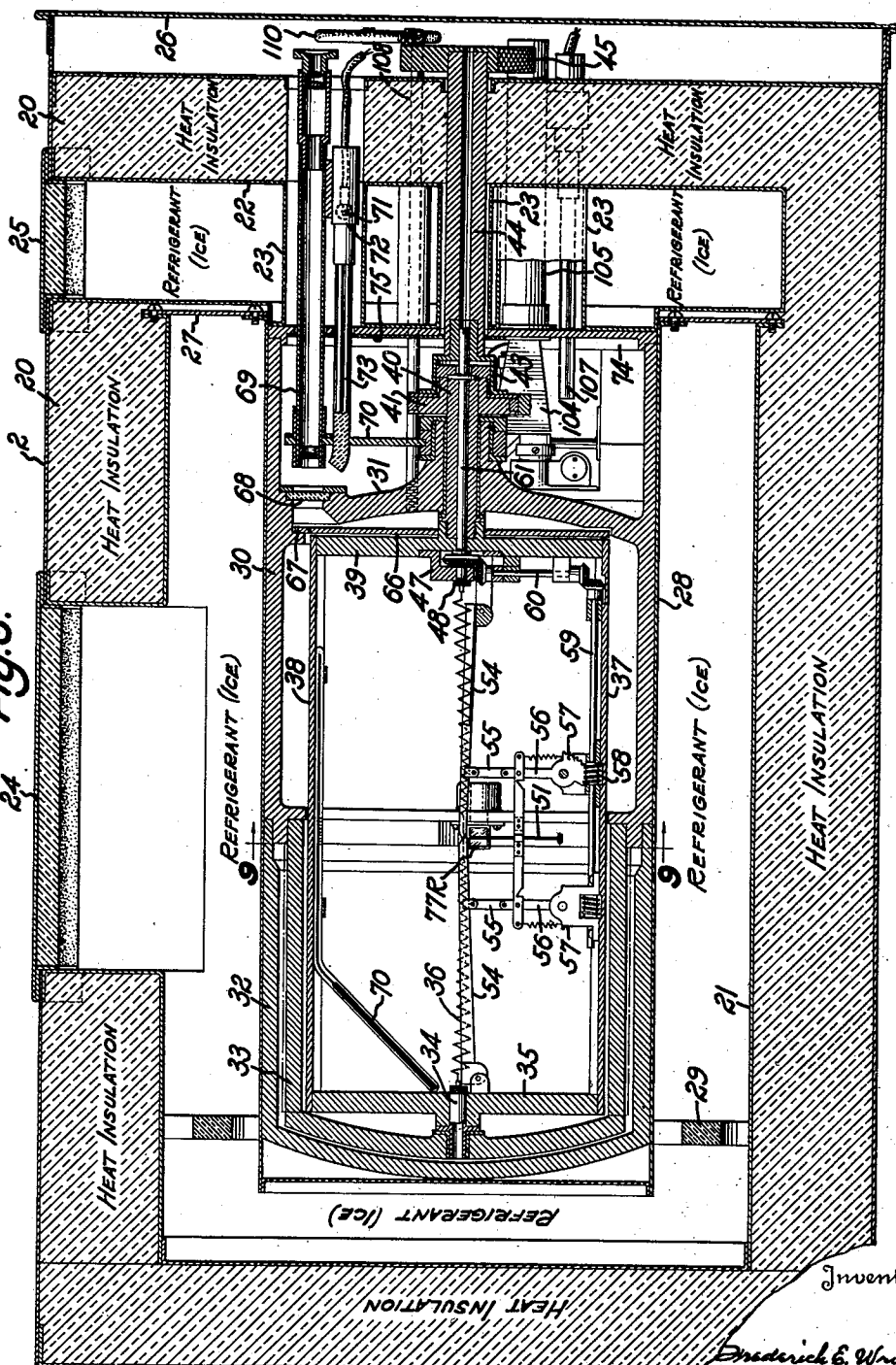
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Fig. 3.



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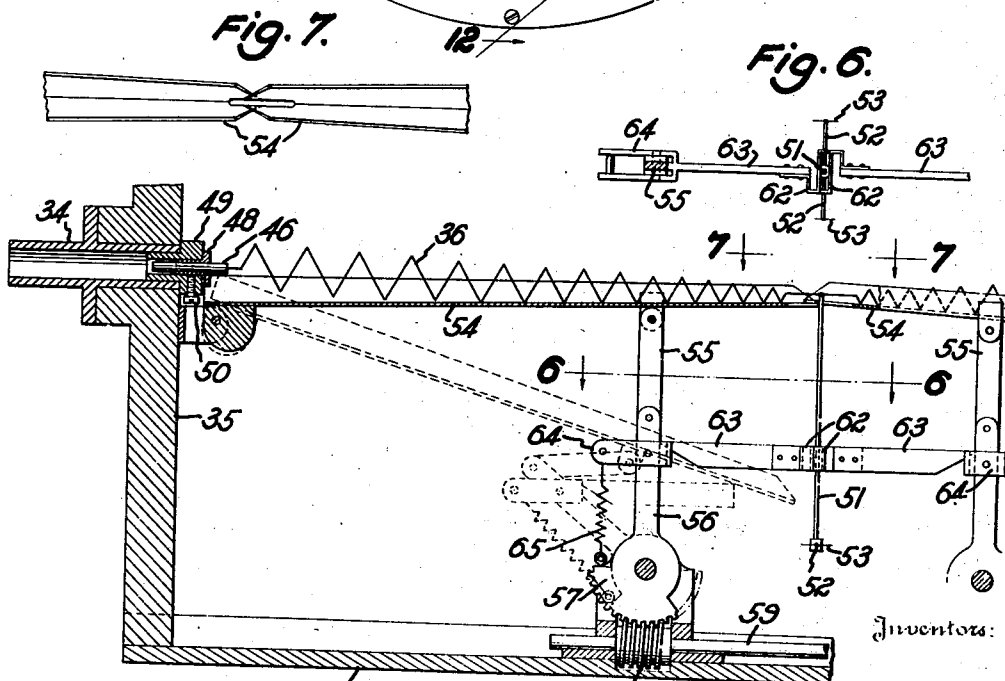
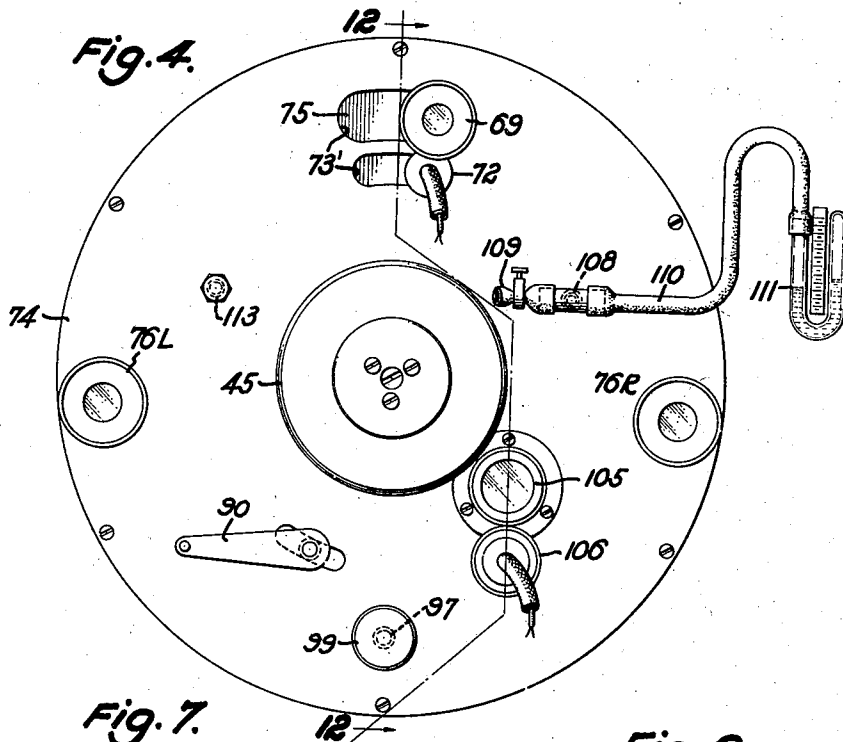


Fig. 5.

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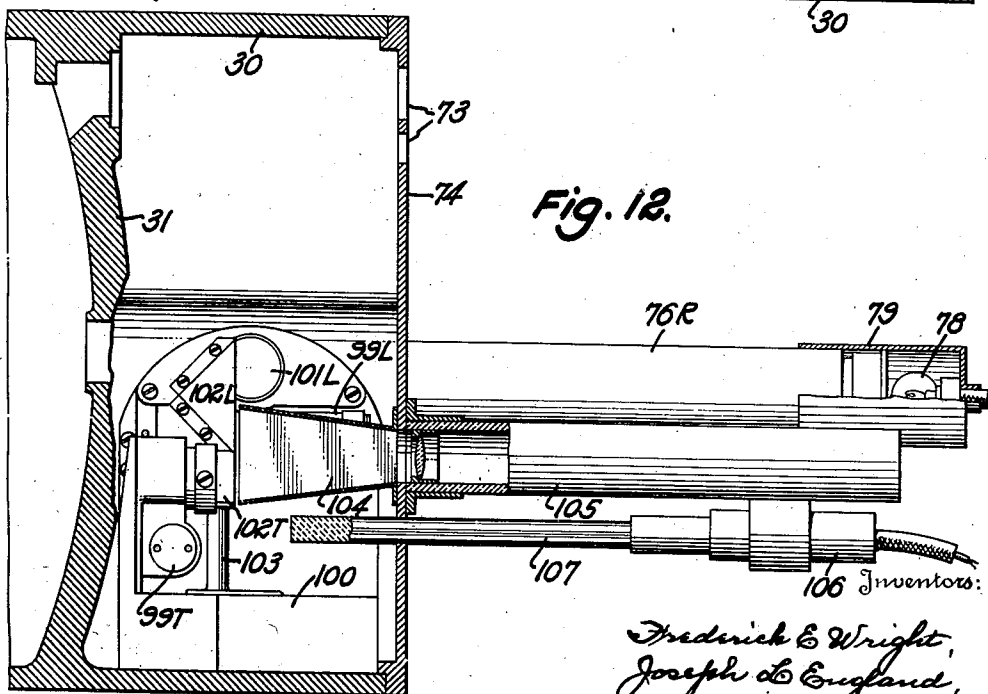
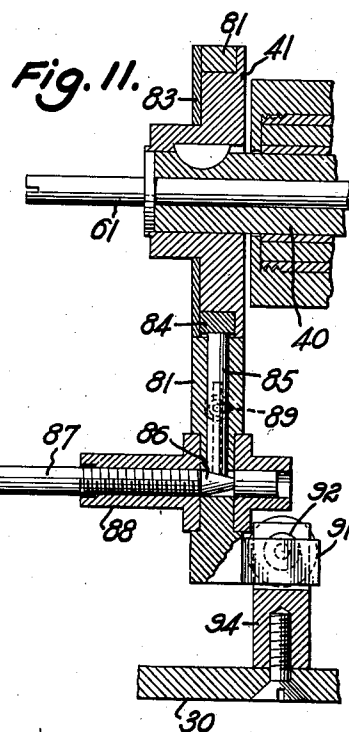
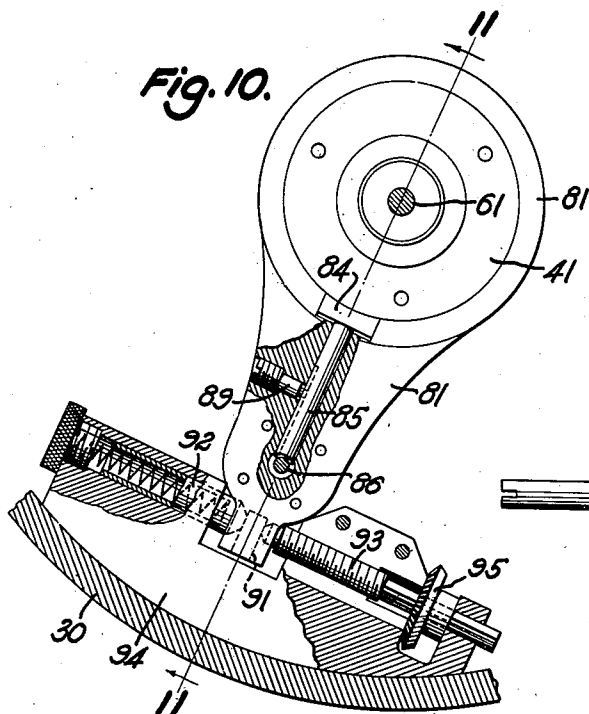
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Fig. 14.

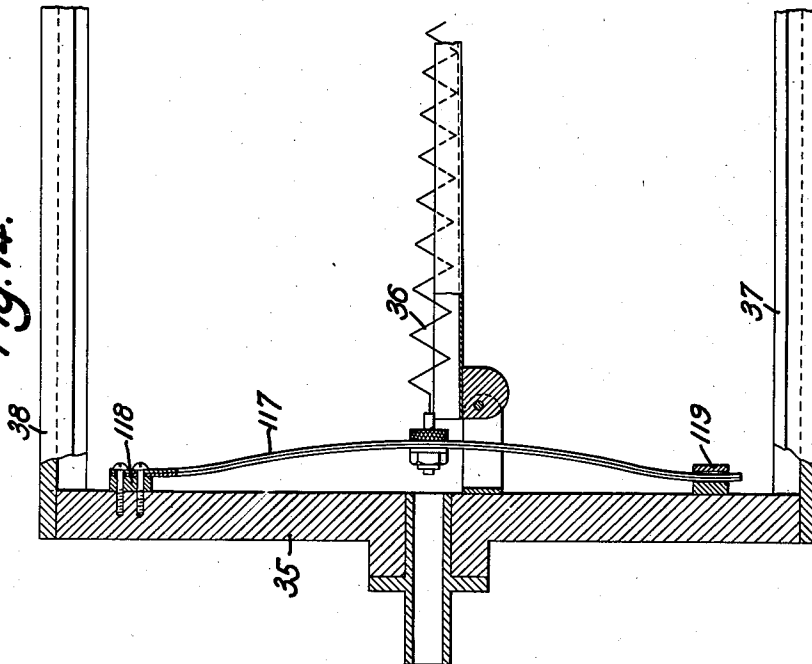
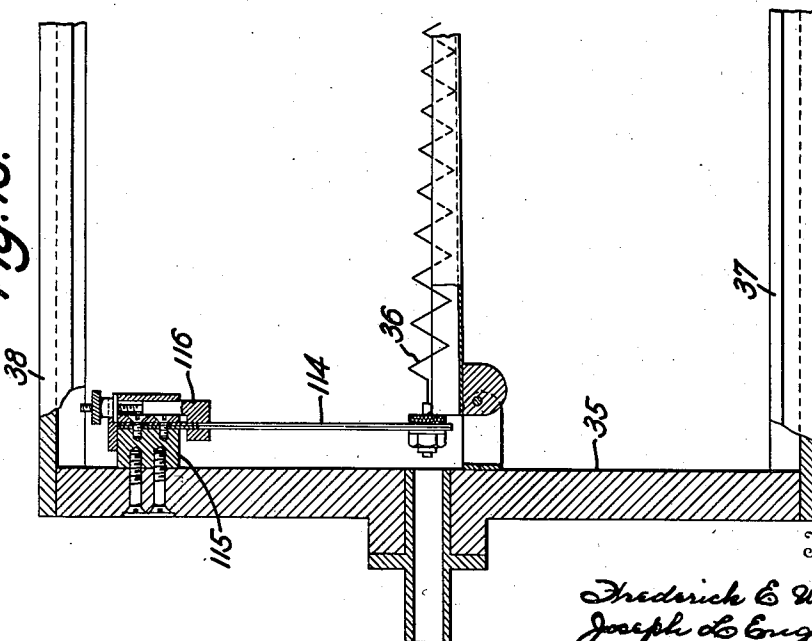


Fig. 13.



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UNITED STATES PATENT OFFICE

2,218,140

GRAVITY TORSION BALANCE

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Application December 15, 1938, Serial No. 245,994

9 Claims. (Cl. 265-1.4)

This invention relates to gravity torsion bal-
ances or apparatus for the measurement of the
variations in the force of gravity.

The invention relates to a torsion balance of
the type described and claimed in Patent No.
1,579,273, granted April 6, 1926 to Frederick
Eugene Wright, one of the present inventors.
The essential elements of such a torsion balance
comprise a helix of wire mounted in a frame or
cradle that is rotatable about a horizontal axis
passing through the ends of the helix, a radial
boom or weight arm secured to the center of the
helix, and devices for measuring the angular dis-
placements of the frame which result in a rota-
tion of the radial boom into horizontal positions
at opposite sides of the helix. The elastic de-
formation of the helix, by rotation of the frame
to raise the boom from its normal position de-
pending below the helix, establishes a stress in
the helix which counterbalances the force of
gravity. Reference is made to the prior patent
for the method of operation of apparatus of this
type.

An object of the present invention is to pro-
vide a gravity torsion balance of the type stated
in which the various parts associated with the
helical spring and its rotatable frame are of new
physical design and contribute to the stability
of the apparatus. An object is to provide a tor-
sion balance of the horizontally arranged helix
and radial boom type, the balance including mov-
able members for supporting the helix and lock-
ing the boom against movement when the ap-
paratus is not in use. A further object is to
provide a torsion balance of the type stated in
which all moving parts are in a hermetically
sealed cylinder from which the air is exhausted.
Other objects relate to the provision of improved
forms of auxiliary devices such as illuminating
systems, levels, temperature indicating systems,
and mechanisms for rotating the frame that
carries the helix. Still another object is to pro-
vide a gravity torsion balance including a ther-
mally-responsive connection between the helical
spring and its supporting frame, the arrange-
ment being such that temperature changes in
the connection compensate partially for changes
in the rigidity modulus of the helical spring with
changes in temperature.

These and other objects and advantages of the
invention will be apparent from the following
specification when taken with the accompanying
drawings in which:

parts in section, of an embodiment of the inven-
tion as set up in operative position within a
truck;

Fig. 2 is a fragmentary plan view of the appa-
ratus shown in Fig. 1;

Fig. 3 is a central vertical section, on a larger
scale, through the torsion balance and its heat
insulated housing;

Fig. 4 is an end elevation of the same;

Fig. 5 is a fragmentary central vertical section,
on a larger scale than Fig. 3, of the spring helix
and the supporting pans in which it rests when
the apparatus is not in use;

Fig. 6 is a fragmentary horizontal section as
seen on line 6-6 of Fig. 5;

Fig. 7 is an enlarged plan view of the meeting
ends of the supporting pans;

Fig. 8 is an enlarged end elevation of the tor-
sion balance casing as seen when removed from
the outer housing;

Fig. 9 is a transverse section of the instrument
case, as seen from the left of Fig. 3, after re-
moval of the casing cap;

Fig. 10 is a fragmentary end elevation, with
parts in section, of the fine adjusting mechanism
for rotating the frame;

Fig. 11 is a transverse section substantially on
line 11-11 of Fig. 10;

Fig. 12 is a fragmentary transverse section
substantially on line 12-12 of Fig. 4; and

Figs. 13 and 14 are fragmentary transverse
sections of the helix, its supporting frame and
temperature compensating devices for connect-
ing the helix to the frame.

In Figs. 1 and 2, the reference numeral 1
identifies the floor of a truck in which the ap-
paratus may be transported or set up, from the
ground below the truck, for the taking of meas-
urements. The outer cylindrical shell 2 of the
protective housing of the apparatus rests in and
is secured to a cradle 3 by clamp rods 4 that are
drawn down on shock absorbing strips 5 of sponge
rubber or the like that rest on the upper half of
the housing.

When set up for use, as shown in solid lines,
the cradle 3 rests on leveling screws 6 that ex-
tend through a table 7 that has telescoping tri-
pod legs 8 that are extended to rest on the ground
beneath the truck. The legs extend through T-
shaped openings 9 in the floor 1 and have cross
pins 10 that may be engaged behind pins 11 on
the floor, by a partial rotation of the table, when
raised, to support the table from the truck floor.
A spring 12 is connected between the bottom of

Fig. 1 is a fragmentary side elevation, with

the table and the floor of the truck to hold the table in stable raised position during transportation. The cradle 3 and instrument housing 2 are transferred to a platform 13 when the apparatus is not in use. Platform 13 rests on a resilient support, specifically an automobile inner tube 14 that is held in place on the floor by angle brackets 15, and the platform is resiliently held against movement by a plurality of springs 16.

The instrument and its housing 2 are quite heavy and an I-beam 17 is secured to the top of the truck to facilitate movement of the apparatus by a hoist 18 on the trolley 19 which rolls along the lower flanges of the beam 17. When moved to inoperative position, as shown in dotted lines, the casing may be restrained from vibration by a plurality of springs 20 that are connected between the housing and the truck.

The protective housing has a thick layer of heat insulating material 20, see Fig. 3, between the outer shell 2 and the compartments formed, respectively, by a rear shell 21 in which the instrument is located and a forward drum 22 through which a plurality of tubular passages are formed by walls 23. Both compartments open through the top wall of the shell 2 for receiving a medium, indicated by the legend "Refrigerant (ice)," for maintaining a constant temperature within the housing. The constant temperature may be maintained above normal atmospheric temperatures, when the apparatus is used in remote regions, by placing heating resistances in the compartments and filling them with water.

Insulated covers 24, 25 are provided for the openings into the respective compartments, and the outer end of the housing is closed by a tight fitting cover 26 when the apparatus is not in use.

An annular plate 27 is secured to the forward end of the shell 21 and to the correspondingly arranged end flange or the tubular container 28 which receives the case of the torsion spring mechanism with a close sliding fit. The rear end of the container 28 is supported axially of the shell 21 by a plate 29 of insulating material that is perforated or notched, as shown, to permit ice and/or water to pass to the rear of the inner chamber.

The various shells and walls of the housing are preferably formed of stainless steel. Material of this type is desirable throughout the housing and particularly so for the chamber 28 to preclude electrolytic action between it and the instrument case which is of cast aluminum alloy.

The case comprises a forward tubular section 30 having an outwardly domed transverse wall 31, and an end cap 32 that is hermetically fitted upon the rear end of the tubular section. A yoke 33 secured to the rear end of case section 30 is axially bored to receive the tubular hub 34, see Fig. 5, that is fixed to the rear bar 35 of the frame by which the helix 36 is supported.

Side members 37, 38 of the frame are rigidly secured between the rear bar 35 and the front bar 39. A tubular shaft 40 is secured to the front bar and journaled in the axial bore of the transverse wall 31 of the case section 30. The flanged collar 41 of a slow motion drive, to be described later with reference to Figs. 10 and 11, is keyed to the shaft 40. The cupped end of a coupling member 43 is secured between the collar 41 and the outer tubular shaft 44 which extends through the front end of the housing and carries a knob 45 that may be turned manually to rotate the frame.

The ends of the helix 36 of tungsten wire are

secured in axial bores in small rods 46 that are mounted in a bracket 47 on the forward frame bar 39 and in the tubular hub 34 of the rear bar 35. The mountings of the rods 46 are similar but only the rear mounting is shown in detail in Fig. 5. The rod 46 extends into a split gland 48 within the bushing 49 that is fixed to the hub 34. A set screw 50 is threaded into the bushing to clamp the gland 48 upon the rod 46 and to the bushing.

A boom or radial arm 51 is secured to the center of the helix 36 and carries a transverse wire 52 that has a signal 53 at each end. These signals are fine glass filaments that extend parallel to the axis of rotation of the helix and its frame. The advantage of the glass filament type of signal is that, when viewed by transmitted light, it has the appearance of a narrow bright band between two black bars. The diameter of the filament is such that the light band is but 20 slightly wider than the crosswire of the telescope with which it is to be viewed, and the light band may therefore be accurately superposed on the crossbar.

As shown in Fig. 3, and in greater detail in Figs. 5 to 7, mechanism is provided for supporting the helix in unstressed condition when the apparatus is not in use. This mechanism comprises a pair of shallow troughs or pans 54 that are pivoted to the end bars 35, 39 of the rotatable frame. The inner ends of the pans overlap and are slotted, see Fig. 7, to clear the boom 51. Links 55 are pivoted to the pans and to links 56 which terminate in gear segments 57 in mesh with worms 58 on a shaft 59 that extends along the side frame 37 of the frame. A cross shaft 60 and bevel gears connect the shaft 59 to the adjusting shaft 61 that lies within the hollow shaft 40 of the frame. The outer end of shaft 61 has a kerf for receiving a screw driver that may be inserted through the outer hollow shaft 44.

The boom 51 is resiliently held against movement by S-shaped springs 62 of flat phosphor bronze on the ends of arms 63 that terminate in yokes 64 which are pivoted to the links 56. The lower outer edges of the arms 63 are cut away to allow the arms to fold down, as shown in dotted line, when engaged by the pans as they move to lowered position. The upper edge of each bar 63 engages its link 56 to limit upward movement of the arms by springs 65 that are connected between the yokes 64 and the associated gear segments 57. The worms 58 are threaded in opposite sense and the links 56 therefore rock in opposite directions when the shafts are rotated. The manner in which the pans 54 and clamp arms 63 move into inoperative position will be apparent from inspection of Fig. 5.

A scale plate or graduated circle 66 is secured to the hub of the frame bar 39, see Figs. 3 and 8, to cooperate with a vernier plate 67 that is secured to the case section 30 in line with a hermetically sealed window 68 in the transverse wall. A telescope 69 for viewing the vernier plate and adjacent section of the scale plate is mounted on an arm 70 that is journaled on the hub or wall 31 for limited angular movement along the vernier plate 67. The scales are illuminated by light transmitted from a small electric bulb 71, in a casing 72 secured to the telescope, through a clear glass rod 73 of "Pyrex" glass or quartz that has its inner end bent towards the window 68.

The telescope 69 and lighting system pass through arcuate slots 73' in the cover 74 that closes the forward end of the case section 30.

and through one of the longitudinal passages through the forward compartment 22. The slots 73' are substantially closed against the entrance of air by plate 75 that is journaled on the shaft 44, the telescope 69 and glass rod 73 having a snug fit where they pass through the plate.

Telescopes 76R, 76L for the primary observation of the signals 53 when the boom is raised are secured to right and left walls, respectively, of the case section 30 and extend to the front of the housing through openings in the cover 74 and passages through the drum compartment 22. Prisms 77R, 77L are mounted at the inner end of case section 30 in line with the respective telescopes to direct the line of sight inwardly towards positions into which the signals 53 are raised by rotation of the frame and helix. The signals are illuminated by a lamp bulb 78 in a housing 79, Fig. 12, that is fitted over one of the telescopes 76R, 76L when the observation is to be made with the other.

These telescopes also serve to read the temperature within the instrument case from thermometers 80 that are mounted on the frame members 37, 38 with their bulbs at opposite ends of the frame. Both thermometers are read by the telescope 76R with the arrangement shown in Fig. 9, and both are illuminated when in reading position by light transmitted through the telescope 76L. The telescope 76R is normally focused on the point *a* which the glass filament 53 reaches when the boom is elevated. The thermometers will be at point *b* on the line joining the prisms 77R, 77L when temperature readings are to be made. It is possible to refocus the telescope but this is not necessary with the apparatus shown in Fig. 9. Negative lenses 81 are mounted in each frame member in such positions, as indicated by the broken lines, as to lie in front of the prism 77R when the thermometer on the opposite frame member is in line with the prism 77L. The negative lens increases the focal length of the objective of the telescope 76R to bring it in focus at the point *b*.

The vernier or slow motion mechanism for making the final adjustment of the frame is shown in Figs. 8, 10 and 11. The upper annular end of a rock arm 81 fits loosely about the collar 41 and is held in place by the annular plate 83. Plate 83 has been removed, as the parts are shown in Fig. 10, to show the locking block 84 that is loosely seated in a recess in the arm 81 in line with the push rod 85 that rests on the conical section 86 of the cam rod 87. Rod 87 is threaded into a bushing 88 and, when moved to the right, Fig. 11, forces rod 85 upward to clamp the block 84 to the collar 41. The lower end of rod 85 is cut at an angle and curved to fit the cam 86, the rod being held against rotation by the guide pin 89 that engages a slot in the rod. Cam rod 87 extends to the front of the housing and is fitted with a handle 90, Fig. 8.

The lower end of arm 81 is provided with a lug 91 that extends between the spring pressed plunger 92 and the adjusting screw 93. The plunger and screw are in axial alinement in the block 94 that is secured to the case section 30. The outer end of the adjusting screw slides in the hub of a bevel gear 95, the gear being arranged in a slot in the block 94 and keyed to the adjusting screw. A section 96 of the threaded bore for the screw 93 is removable, see Fig. 8, to facilitate the assembly of the screw and gear 95 on the block 94. The hollow adjusting shaft 97 has a bevel gear 98 in mesh with

gear 95 and is provided with an adjusting knob 99, Fig. 4.

A pair of "Zeiss" levels 99L, 99T are mounted on a bracket 100, at the forward end of case section 30, with their axes parallel to the axis of helix 36 and to a horizontal line transverse to that axis. The levels include prism systems 101L, 101T, respectively, that permit a reading of the level from a point in a plane through the axis of the level. Additional prisms, 102L, 102T, are mounted on a post 103 in line with the Zeiss level prisms and so disposed that images of the two levels are formed in vertical alinement. A flared tube 104 is secured to the cover 74 in line with the prisms 102L, 102T and the telescope 105, and the levels are illuminated by a lamp bulb in the casing 106 and the clear glass rod 107.

A pipe 108 is threaded into the transverse wall 31 of the case section 30 and terminates in a T-coupling at the front end of the housing. A flexible tube 109 on one branch of the T extends to a vacuum pump, not shown, and flexible tube 110 extends from the other branch to a vacuum gauge 111. The pipe 112, shown at the left side of Fig. 8, serves to supply grease to the bearing of the shaft 40. The outer end of the pipe is closed by a cap 113, Fig. 4, that may be removed to fit a grease gun to the pipe. The grease serves both as a lubricant and as a seal for the evacuated chamber in which the helix is located.

Temperature effects upon the rigidity modulus of the tungsten helix 36 may be partially compensated by altering the axial length of the helix with changes in temperature.

As shown in Fig. 13, the inner end of the helix 36 is carried by the end of a bimetallic strip 114 which is secured to a block 115 on the frame bar 35. The effective length of the bimetallic strip may be varied by the slide 116 that closely engages the strip 114 and is adjustable towards and away from the block 115.

A simpler construction, as shown in Fig. 14, includes a bimetallic strip 117 that has one end secured to a block 118 on frame bar 35 and its other end extended through a guide block 119, the helix 36 being secured to the center of the strip.

The apparatus is operated in substantially the same manner as the torsion balance described in the Wright patent. The two angularly spaced signals or glass filaments 53 permit location of the viewing telescopes below the axis of the frame, the angular spacing of each signal from the boom being such that the upper signal reaches line *ab*, Fig. 9, when the boom 51 is horizontal.

For directly comparable results, the readings at each station should be made in the same order and all readings should be made at a definite time interval after starting the rotation of the frame to raise the boom 51. Accuracy within one part in a million has been obtained with one embodiment of the invention by rotating the frame and helix, as uniformly as is possible in manual operation, to bring the signal at the proper level at one side of the axis for a reading exactly three minutes after the rotation of the frame is started, then returning the frame at a more rapid rate to bring the boom 51 to vertical position and, exactly one minute after the first reading, starting the three-minute rotation of the frame to obtain the reading with the signal at the opposite side of the axis. The one minute interval permits the recording of the

first reading and the transfer of the lighting system from one telescope to the other.

These methods of operation, together with the pans for supporting the helix in unstressed condition except during the short periods of actual use, substantially eliminate the development of residual strains that would impair the accuracy of the measurements. The load is applied for only a short time in one direction and the same load is then applied in the opposite direction for the same period. This reversal of the stress counteracts the strains set up by the first stressing of the spring. The spring recovers quickly from any residual strain present at the completion of one set of readings and each measurement is therefore made with the spring in an unstrained condition.

We have described what we now believe to be the preferred embodiment of the invention but it is to be understood that there is some latitude in the design and arrangement of the component parts of the apparatus.

We claim:

1. In a torsion gravity balance, the combination with a horizontally arranged helix of elastic material, a frame carrying the helix, means including a hollow shaft supporting said frame for rotation about the axis of the helix, a boom extending radially from the center of the helix, and means for indicating the angular rotation of the frame which displaces the boom into horizontal positions at opposite sides of the helix, of means for supporting the helix when the apparatus is not in use, said supporting means comprising elongated pans pivoted to the ends of the frame and positioned beneath the helix, a linkage system for raising and lowering each pan, and operating means for said linkage systems extending into said hollow shaft.

2. The invention as claimed in claim 1, in combination with means carried by said linkage systems for resiliently holding said boom against displacement when the pans are in raised position to support the helix.

3. In a torsion gravity balance, the combination with an evacuated case, a frame pivotally supported in said case for rotation about a horizontal axis, a helix of elastic material carried by said frame, a boom secured to said helix at the center thereof, an arm transversely secured to said boom in a plane at an angle to the axis of said helix, and signals on said arm and equally spaced from the boom, of optical systems for viewing the lower signal when the frame is rotated to displace the boom to opposite sides of the helix, said optical systems including a telescope at each side of the case below the axis thereof, and a prism at each side of the case for directing the line of sight of each telescope transversely of the case and towards the other prism, whereby light directed through one telescope illuminates the signals as the boom is raised towards the other telescope.

4. The invention as claimed in claim 3 wherein said signals comprise fine glass filaments.

5. A torsion gravity balance comprising an evacuated case, a helix of elastic material and a frame supporting the same in the case for rotation about its axis, a radial boom secured to said helix, and means for indicating the angular displacements of the frame which raise the boom

to horizontal position at opposite sides of the helix; said indication means including a graduated circle and a vernier plate within the case, and a window hermetically sealed to the case for viewing the graduated circle and vernier plate.

6. In a torsion gravity balance of the type including an evacuated case housing a pivotally mounted frame carrying a helix from which a boom depends, and a pair of telescopes and prisms secured to opposite sides of the case and in line with each other below the axis of the frame for observing signals carried by the boom; means for observing the temperature within the case, said means comprising a thermometer carried by the frame and having a stem in the field of view of one telescope, an opening in the frame in line with the thermometer stem, a negative lens in an opening in the opposite side of the frame for aligning with one prism when the frame is rotated to position the thermometer stem in line with the other prism, said negative lens increasing the normal focal length of the associated telescope to focus on the thermometer stem.

7. In a torsion gravity balance, an evacuated case housing a rotatable frame carrying a helix to which a boom is secured, a shaft secured to said frame and extending to the exterior of said case, a rock arm encircling said shaft, a block on said arm and means for clamping the block to the shaft; said means including a push rod engaging said block, a rotatable cam rod extending parallel to said shaft, said cam rod having a threaded section engaging a correspondingly threaded portion carried by the rock arm and a conical section engaging the end of said push rod, and means for displacing said rock arm angularly to impart a slow motion adjustment to said shaft when the block is clamped thereto.

8. In apparatus of the type described, a case housing a frame, means at the ends of said case supporting the frame for rotation about a horizontal axis, a pair of levels mounted in the case at right angles to each other, the axes of said levels being parallel respectively to the axis of said frame and to a horizontal line transverse to the axis of said frame, prisms associated with each level to permit viewing the same from the end of the level, auxiliary prisms adjacent each other for viewing the two prism systems from an end of said case, a cover closing said case, a telescope extending to the exterior of said case for viewing the auxiliary prisms, a clear glass rod extending into said case, and a light bulb at the exterior of said case in line with said rod for illuminating said levels.

9. Apparatus for measuring the force of gravity comprising a torsion balance including a horizontally arranged helix of elastic material, a cylindrical case enclosing said balance, an annular compartment in which said case has a close fit, a drum compartment in front of said annular compartment, optical systems associated with said torsion balance and extending through passages in said drum compartment, a housing enclosing said compartments, and heat insulating material between said housing and said compartments, each compartment having an opening extending to the exterior of said housing at the top thereof.

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