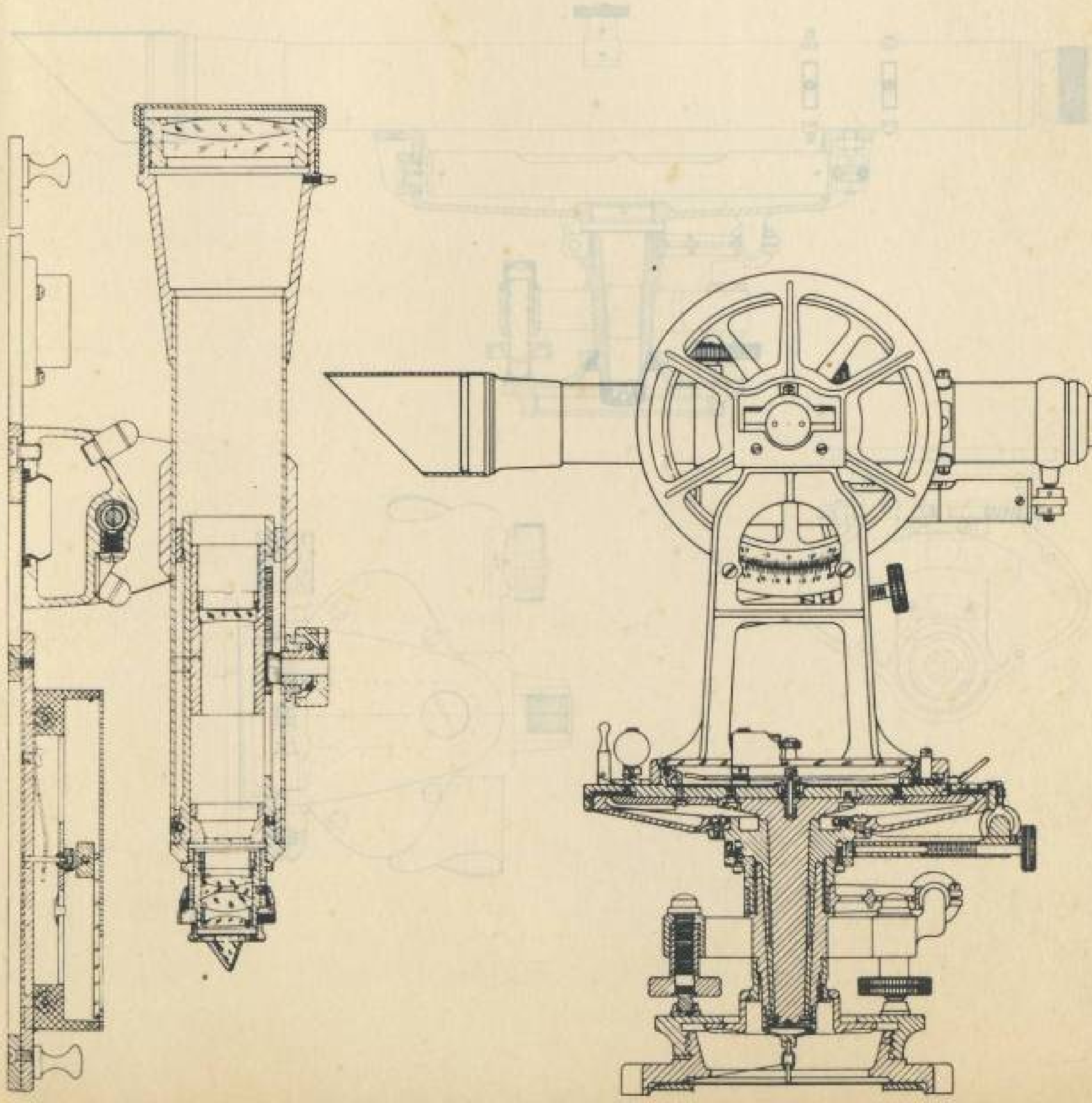
care and adjustment of K&E SURVEYING INSTRUMENTS



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K&E's Solar Ephemeris is published in a separate booklet.

INTRODUCTION

We've been part of the American surveying scene for over a century. Supplying all sorts of engineering equipment from leveling rods to theodolites. High quality instruments that are precise. Sturdy. And dependable.

We keep developing new products, and making improvements in design so we can give you even more accurate instruments that will give you long years of dependable service.

Under normal working conditions K&E instruments need little attention. For instance, our instruments are virtually moistureproof. And dustproof too. And you know how important that is when you have to work in rain. Or on a dusty site. But we wanted to give you some basic information to help you get the most accurate results and efficient operation from all of our products. And you'll find this type of information in our manual.

So that's why we call it a "Care & Adjustment" manual. It's not meant to replace factory repairs. But it'll help you get the best possible performance from all of our instruments.

And if you need any repairs for any reason there are qualified people in our repair shops all over the U. S. who will be glad to assist you. Just contact your nearest K&E branch or dealer for the location of the nearest repair shop. Or write: Keuffel & Esser Company, 20 Whippany Road, Morristown, N. J. 07960.

GENERAL INFORMATION

CARE

Rain, snow or dust. During rainfall, protect the instrument with a surveyor's field umbrella. If the instrument gets wet, let it dry in a dust-free place; it is not necessary to wipe it. Excess dust penetrating an instrument will cause damage. If working in dust or rain, keep the waterproof hood over the instrument as much as possible.

Clean the lenses. Considerable dirt can accumulate on the objective lens (front lens) without affecting the operation of the instrument. If the light through the telescope appears to be dim, it is probably caused by dirt on the exterior surface of the rear eyepiece lens rather than on the objective lens. To reach the exterior surface remove the eyepiece end cap. To clean dust from the lenses, use the camel hair brush provided. The objective lens on a K&E telescope should be removed only by a competent instrument repairman. Even loosening and reseating the lens will disturb adjustments and, unless the lens is removed in dry, dust-free air, the telescope may be damaged.

Avoid damage. If the instrument receives a blow or falls, a factory repair will probably be required. To avoid damage: (1) Do not leave the instrument unattended; and, (2) Find good footing and spread the tripod legs wide before setting up the instrument.

CARE IN OPERATION

Dusty or sandy areas. Special precautions must be observed when the instrument is used in a dusty or sandy environment since dust and sand are highly abrasive. If foreign matter adheres to mating surfaces, the mechanisms may bind. The instrument should be frequently brushed and wiped clean. Avoid scratching any of the optic surfaces while cleaning. Protect the instrument from blowing dust and sand. Always place a protective cover over the instrument when not in use.

Rainy or humid conditions. In spite of its enclosed construction, the instrument is not waterproof. In humid areas, a drop in temperature may cause condensation to fog the lenses and prisms. Internal fogging can usually be removed by placing the instrument in a warm, dry environment. External condensation may be removed using the chamois. During rainfall, protect the instrument with a surveyor's field umbrella. When not in use, cover it with the waterproof hood. If the instrument is wet, do not keep it in the carrying case. As soon as possible, remove the instrument and dry it before returning it to the case.

Salt-water areas. Salt is highly corrosive to metal. When using the instrument in salt-water areas, wipe it frequently with the chamois. If salt-water contacts the instrument, the exterior should be thoroughly cleaned. As soon as possible, take the instrument to a repair facility for cleaning.

ADJUSTMENTS AND INSTRUMENT TESTING

Surveying instruments should be frequently tested and rarely adjusted. Modern instruments seldom need adjustments. Adjustments are sometimes necessary after repairs. The chief need for adjustment is caused by improper adjustments that were not required.

Before making adjustments, test to see that any apparent lack of adjustment is actually caused by the condition of the instrument and is not deficiencies in the test. To properly test an instrument, observe the following precautions:

1. Choose a cloudy day, if possible.
2. Make sure the tripod shoes are tight and the instrument is firmly screwed to the tripod.
3. Set on firm ground, out of the sun but in good light, where clear sights of approximately 200 ft. can be made in opposite directions.

4. Spread the tripod feet well apart and position them so that the tripod plate is nearly level. Press the shoes firmly into the ground or place them in chipped depressions in masonry.
5. If a conventional tripod is used, after setting up, free and then tighten all three tripod hinge screws to relieve residual friction. (With a K&E Wide Frame Tripod, this operation is unnecessary.)
6. Attach the sunshade and carefully focus the eyepiece. After leveling the instrument, loosen all leveling screws slightly and relevel to relieve any residual strain. Have all screws equally firm but not tight. Too much force will deform the centers and cause friction and play.
7. Perform all of the tests in the order given for the type of instrument being tested*. Do not adjust the instrument unless a particular test indicates the same amount of error at least three times.
   Caution: Be on the lookout for creep when adjusting the levels. Creep is caused by tripod settlement or by temperature change of the instrument. This may happen if the instrument is brought outside or is exposed to body or other radiant heat. After setting a bubble or the line of sight, let the instrument stand for a few seconds to see that no movement occurs.
8. Before making the adjustment, consider whether the error will have a material effect on field results. In making this decision, remember that most tests make the error appear double in amount.

   Adjustments should be made in the order given, so that no previous adjustments will be disturbed. At the completion of the adjustment the parts should be firmly set without strain. After an adjustment is made, the instrument should be tested immediately. After the adjustments are completed, all of the tests should be made again in case another adjustment may have been disturbed.

LUBRICATION

Disassembling the instrument. Generally the instrument should not be disassembled. If it is necessary to lubricate the instrument, it should be done indoors and in a dust-free area. Care should be exercised since there is more chance for damage and for the accumulation of dust when the instrument is disassembled than in years of field use.

Lubricating the instrument. Instruments should be lubricated occasionally with special instrument lubricant. A small amount should be applied, since excess lubricant collects dust. Each surface to be lubricated should be wiped dry with a clean, lint-free cloth. If the surface is gummy, a little naphtha may be used to clean it. Interior surfaces can be

*These tests are found for various instruments in other sections of this manual.

reached by using a cloth covered wooden stick. An amount equivalent to not more than one drop of fine watch oil (74 0640) should be applied at each of the points to be lubricated. Lubricant should be applied to each part just before re-assembly. It should be well spread and worked in. All excess lubricant should be carefully wiped dry. To work the lubricant into the center bearings, put the two mating parts together, then raise and turn and lower to four or five positions.

Preparation for arctic temperatures. All K&E surveying instruments will operate perfectly at arctic temperatures if lubricated with special cold temperature lubricant. (This can be purchased through any K&E branch or dealer.) The instrument should be disassembled and old lubricant removed with a solvent such as naphtha before applying the special lubricant.

TRANSPORTING

Short distances. For short distances in cleared, level areas, the operator may carry the instrument mounted on the tripod. If carried on the tripod, it must be carried upright; be sure locks and leveling screws are snug.

Caution: Handle the instrument carefully when moving the instrument mounted on tripod. Do not subject it to bumps, jars or shocks and do not leave the instrument unattended.

Long distances.

1. When the instrument must be carried for more than a short distance or over rough terrain, the instrument should be trahsported in a carrying case.
2. Handle the carrying case carefully to avoid sudden jolts, continued vibration, or other shocks that might damage delicate parts of instrument.
3. If the instrument is to be carried long distances by manpower, use its carrying case.
4. If the instrument is to be transported by vehicle for long distances, it should be carried in the transportation case.

Shipping. Place the carrying case in a strong box about 2 inches larger than the instrument case. Pack closely wadded newspaper or other shock absorbing material in the space. It is sometimes difficult to identify the instrument's owner, unless the instrument is carefully described in the correspondence and the serial number given. A suggestion is to tie a tag to the instrument with the serial number and the owner's name on it.

SECTION I — TRANSITS

INTRODUCTION

The repeating transit is a versatile instrument. It will peform any ordinary surveying operation, and if operated properly, will give desired accuracy.

It can be used for setting out angles, straight lines, curves and grades. The relatively long telescope and erecting eyepiece make it easier for the transitman to bring the stakeman into the field of view and to give him the proper directions when his movements are observed through the telescope.

The double center makes it possible to set the vernier at zero (or any required setting) before taking a backsight. This is an important element in any layout work. Short lines of levels can be run and grades can be established well within the accuracies usually required. High accuracy in leveling can be attained when desired by keeping the sights short. The superior optics in the K&E instrument make it especially useful for stadia work, Polaris observations, and whenever the target is poorly illuminated.

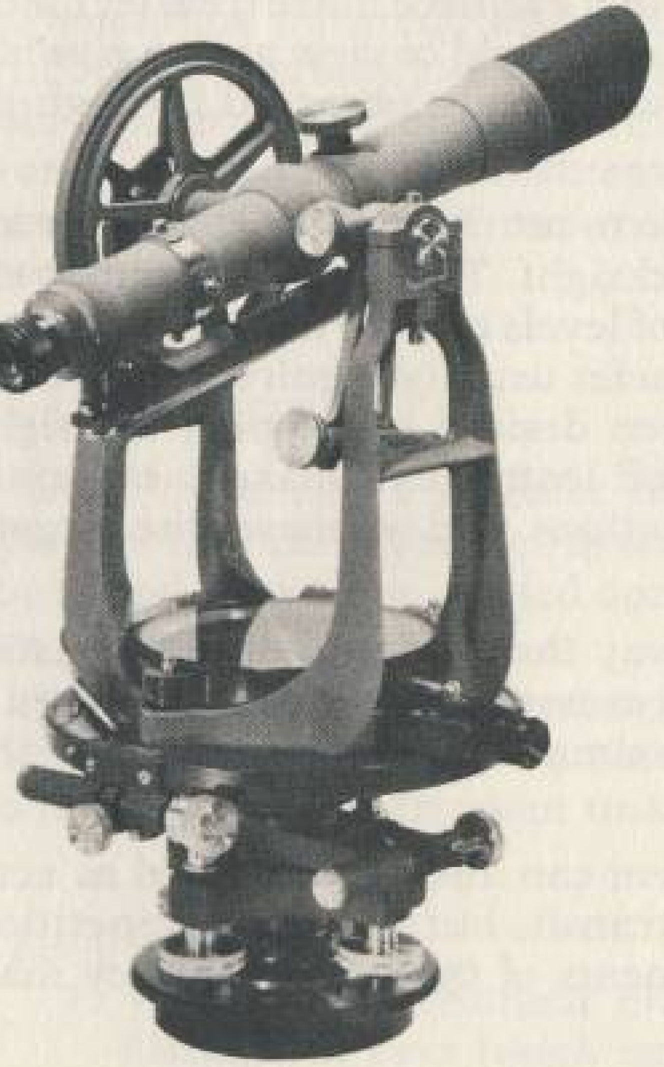
By "repeating" angles in such a way that the sum of the measurements is accumulated on the circle, traverse angles can be measured as accurately as desired and will approximate the same speed as with a directional theodolite.

The angles of a triangulation system can also be measured as accurately as desired with a repeating transit, but the many repetitions required take longer than measurements of the same accuracy made with a directional theodolite.

A repeating transit consists of three major assemblies: 1) the alidade; 2) the circle assembly; and, 3) the leveling head. Because of its double center, the alidade turns within the circle and the circle within the leveling head.

FEATURES

Clamps. On the circle assembly, immediately below the circle, are two collars which serve as brake drums for the upper and lower clamps. When the upper clamp is tightened, the circle is clamped to the alidade; when the lower clamp is tightened the circle is clamped to the leveling head; hence, to the ground. After either clamp has been tightened, a precise setting between the two parts clamped together can be made with the appropriate tangent screw.



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74 0150

To measure an angle, both clamps should be loosened. Then the zero of the vernier on the alidade is brought to the zero of the circle. The upper clamp is tightened and a precise setting is made with the upper tangent screw. The telescope is then directed toward the first point, the lower clamp is tightened and the cross lines are brought exactly on the point with the lower tangent screw. The line of sight will now be exactly on the first point and the vernier will be exactly zero.

The upper clamp is loosened and the telescope is directed toward the second point, thus moving the vernier around the circle. The upper clamp is then tightened and the cross lines are brought exactly on the second point with the upper tangent screw. The vernier will give the exact value of the horizontal angle.

Two speed tangent screw. When this screw is turned continuously in one direction, it operates at normal speed. When its direction is reversed, the alidade is turned at one-eighth normal speed for a short distance. Then normal speed is picked up again. In this way high accuracy is attained in aiming at a point or in setting the vernier. Simply turn past the desired position then use low speed in both directions to make the precise setting.

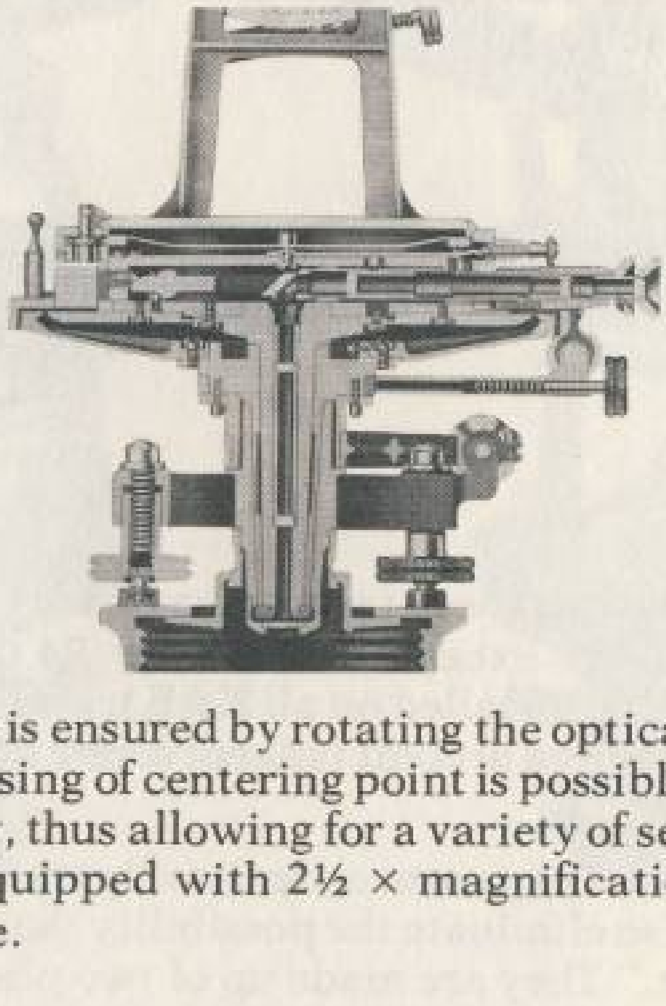
K&E supplies the two speed tangent screw for the upper motion on all PARAGON® Transits except 74 0070 to 74 0150. The two speed tangent screw can be installed on all K&E transits manufactured since 1954, by unscrewing the present tangent screw and screwing in the two speed device.

Spanned verniers. They ensure precise alignment when assembled on the transit, and also eliminate the possibility that the verniers might be too "long or short." They are made up of two plate verniers as a single unit. Instruments with spanned verniers are more accurate than similar instruments not so equipped.

Optical plummet. Most K&E transits are available with built-in optical plummets. The optical plummet enables the instrument to be centered over a given point quickly and precisely by means of an optical system built into the vertical center of the instrument.

The line of sight to centering point is turned 90° by a prism so that viewing is actually horizontal, facilitating ease of observation.

Instruments equipped with the optical plummet can eliminate one third of the set-up time required when the conventional plumb bob is used. The optical plummet provides even greater time saving and centering precision on windy days.



Centering accuracy is ensured by rotating the optical plummet about its axis. Eyepiece focusing of centering point is possible through a range of 24 inches to infinity, thus allowing for a variety of set-up heights. The optical plummet is equipped with 2½ × magnification and a circular reticle in the eyepiece.

OPERATION

Mount the transit. Set up the tripod with the legs spread, feet set firmly into the ground, and with the head nearly level. Unscrew the tripod cap.

Remove the instrument from its case and grasp it with both hands at the leveling head. Screw it firmly on the tripod head. Remove the objective cap and replace it with the sunshade (this gives the telescope nearly even balance). Open the eyepiece shutter by moving the small pin into its slot.

Focus the telescope. Point the telescope at a bright, unmarked surface or the sky, and focus the eyepiece on the cross lines. Sight the target and focus by means of the objective focusing pinion. Move the eye left and right relative to the eyepiece and determine if the cross lines remain on the point sighted. If they do not remain superimposed, adjust the focus until the apparent motion or parallax is eliminated.

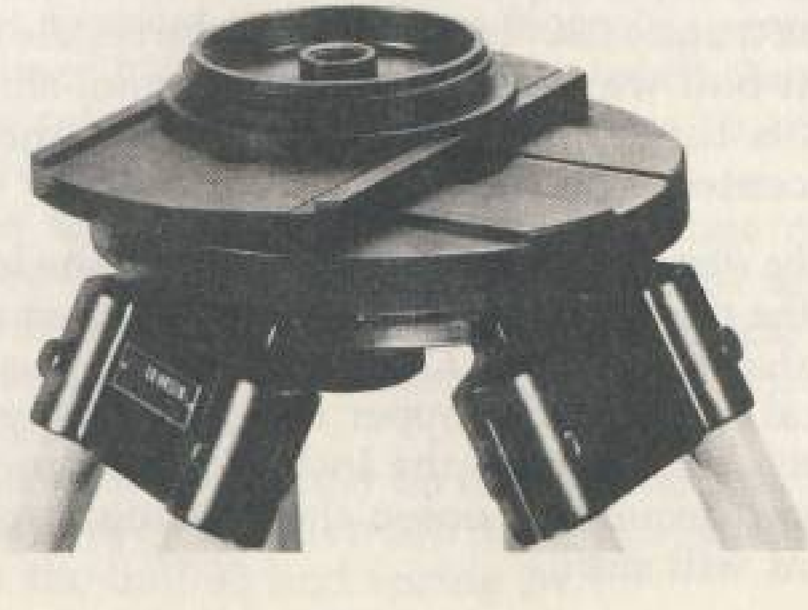
Level the instrument. Always begin leveling by loosening two adjacent leveling screws. Level the instrument by adjusting two pairs of opposite leveling screws alternately, keeping the pressure on the tripod plate very light until the instrument is practically level. Finish by slightly increasing the pressure until the screws are firm but not tight. If one pair of screws should bind, loosen one screw of the opposite pair.

NOTE: While operating the instrument never allow the clothing to come in contact with the tripod or the instrument. Never touch the instrument itself, except at the points necessary for operation, and when completing a sight be sure to touch only the tangent screw involved.

Level the telescope. Level the instrument in the usual manner. Turn the vertical circle vernier to zero, set the upper clamp and turn the instrument until the telescope is aligned with a pair of opposite leveling screws. Set the lower clamp. Center the telescope bubble with the vertical tangent screw. Free the upper clamp and turn the instrument 180°. If the telescope bubble does not center, bring it half way toward the center with the vertical tangent screw. Level again with the leveling screws and repeat until the telescope bubble will center in both positions. Turn the instrument 90° and level with the leveling screws. The telescope bubble should now remain centered when the telescope is pointed in any direction.

Reading the vernier. To read the vernier hold the reading glass at least 1½ inches above the window. Steady the hand by touching the upper plate, with the little finger. Keep both the center of the glass and the eye exactly in line with the lines on the part of the vernier being observed.

Raise the compass needle. Never pick up the instrument without raising the compass needle from its pivot. A slight jar will cause the hard jewel to break off the fine pivot point, thus making the needle sluggish. The needle will never again be accurate until the pivot has been resharpened.



Parallel shift tripod. For use with transits having optical plummets it enables the instrument to be moved in any direction during the centering operation. Since proper functioning of the optical plummet requires that the instrument be level, the tripod is constructed so that the instrument remains level throughout the centering operation. In this way any sight obtained with the optical plummet is perpendicular to the level of the instrument. Movement on the parallel shift tripod is 2 in. in all directions. The all-Teflon coating on the tripod plate ensures smooth sliding action.

Optical plummet. The instrument may be set up over a point either with or without a plumb bob as a preliminary aid.

Procedure.:

1. Position the tripod over the point. When using a plumb bob suspend it from the hook located inside the tripod clamp screw. (This hook is locked out of the way when not in use.) Adjust the tripod legs to bring the plumb bob to about an inch of the point, keeping the tripod head nearly level. Remove plumb bob and lock hook to side of tripod clamp screw.
2. Level the instrument with the leveling screws.
3. Turn the eyepiece cap in or out until the reticle is in sharp focus. Slide the eyepiece and tube assembly in or out until the ground or mark is in focus.
4. Loosen the tripod clamp screw. While looking through the optical plummet, shift the instrument until the reticle is precisely centered on the mark. Tighten the tripod clamp screw, and check to see that mark is still centered. If necessary, relevel the instrument. (Minor releveling will not affect the optical plummet.)

NOTE: When looking through the optical plummet, the reticle appears to move to the right when the instrument is shifted to the right. It appears to move up when the instrument is shifted toward the observer.

5. When the mark is at a distance greater than tripod height and high accuracy is required, center with the parallel-shift and then turn the transit 180° in azimuth. If the reticle moves off the point, move it half-way back with the parallel-shift. Then, when the transit is turned in azimuth, the reticle should follow a small circle centered on the mark.

Returning the instrument to the case. Be sure the leveling head is near the center of the tripod plate. Level the instrument so the leveling head is parallel to the tripod plate. Clamp the telescope so that it is approximately vertical. Tighten the upper clamp securely and free the lower clamp. Unscrew and remove the instrument from the tripod. Tighten the lower clamp securely. Loosen the leveling screws slightly, so that the instrument will shift.

Then, slide the instrument into the case with the tripod plate under the guides in the bottom of the case. Center the instrument, if no checking block holds it center. Ensure the telescope will not come in contact with the case. Do not force the door closed; rearrange instrument if necessary.

Transporting the instrument. Keep it from vibration and away from contact with any hard surface. On the floor of a car, stand the case on its rubber feet. Place some soft material around it to prevent it from falling. For shipping instruments, see page 6.

MAINTENANCE, LUBRICATION AND DISASSEMBLY

Read the general information for care and lubrication of instruments, pages 3 and 5.

Parts to be lubricated.

1. Bearing surfaces and shoulder of inner center.
2. Outer bearing surface and shoulder of outer center.
3. Telescope axle bearings.
4. Spring plunger for each tangent screw.
5. Threads of clamp screws, tangent screws and leveling screws.
6. Collars and surfaces of the three clamps.
7. Surface of half ball and both surfaces and thread of tripod plate.

NOTE: To reach some of these points the transit must be partly disassembled. The steps for disassembly and reassembly are given.

Disassembly:

1. Turn the telescope horizontal, tighten all three clamps, and unscrew and remove the three tangent screws 21, 131. Note where each belongs.
2. Unscrew and remove the three tangent screw spring box caps 20, 135 together with their springs and plungers. Note where each belongs.
3. Remove the vertical circle guard fastening screws 216 and remove the guard 215, taking care not to touch the vertical circle.
4. Remove the telescope trunnion cap screws 16 and lift the trunnion caps 144 off.
5. Lift out the telescope. Unscrew the telescope clamp lock nut 205. Unscrew the telescope clamp screw 204 and take off the clamp 201, being careful not to touch the vertical circle. Lay the telescope assembly down without allowing the vertical circle to touch anything.
6. Lay the instrument carefully on its side and unscrew the plumb bob chain and eye or center cap 35, if provided. Be careful not to drop out the ball 33 and spring 34.

7. Loosen the center nut lock screw, if one is provided. Remove the center nut 32 with the special wrench provided.
8. While pushing the leveling head and the standards together, carefully set the instrument upright. Lift out the alidade carefully, rotating it back and forth slightly to start it. Avoid touching the center bearing surfaces with the end of the center. Lay the alidade carefully on its side with the center horizontal, but not touching anything. Lift out the circle assembly with the same care; avoid touching the circle graduations with the fingers. Lay it face down on a clean, soft cloth.
9. Loosen the leveling screws 3. Turn the leveling head on its side and remove the half ball lock screw 8 and unscrew the half ball 7. The shifting plate 6 and the tripod plate 1 will come with it.
10. If the instrument has fully enclosed leveling screws, unscrew the leveling screw caps 4. (Left hand threads.) Unscrew the four leveling screws. Note where each belongs. Unscrew the leveling screw stems 3. Thread and unscrew the leveling screw shoes 5. If the instrument has exposed leveling screws, remove the leveling screw dust caps, if any. Unscrew the leveling screws. Note where each belongs. Thread and unscrew the leveling screw shoes if the instrument has them.
11. Loosen the lower clamp screw 17 and remove the assembly. Note which side is uppermost.
12. Unscrew the upper clamp collar screws 16. These are the slotted screws, and they are nearest the center. (On some instruments these are on the lower side of the collar.) Mark the position of the collar with a scribe. Be very careful not to touch the circle centering screws or vernier disc centering screws. If these are disturbed, the centering of the circle and vernier disc will be lost. Re-centering is impossible except by a trained instrument repairman. Remove the collar 15. Loosen the upper clamp 10 and remove it. The gib 11 and the connecting shaft 13 can be dropped out.
13. Remove both upper and lower clamp screws 12, 17.

All surfaces that need to be cleaned and oiled are now exposed.

Reassembly:

1. Replace the upper clamp screw, the connecting shaft and the gib. Replace the assembly on the drum with the lug up. Replace the upper clamp collar and screws and screw them home, with equal pressure on each. Tighten the clamp.
2. Replace the lower clamp screw, replace the assembly, and tighten the clamp.
3. Replace the leveling screw assembly. Make sure the stems are tight and the leveling screws are screwed in (on instruments with fully enclosed leveling screws).

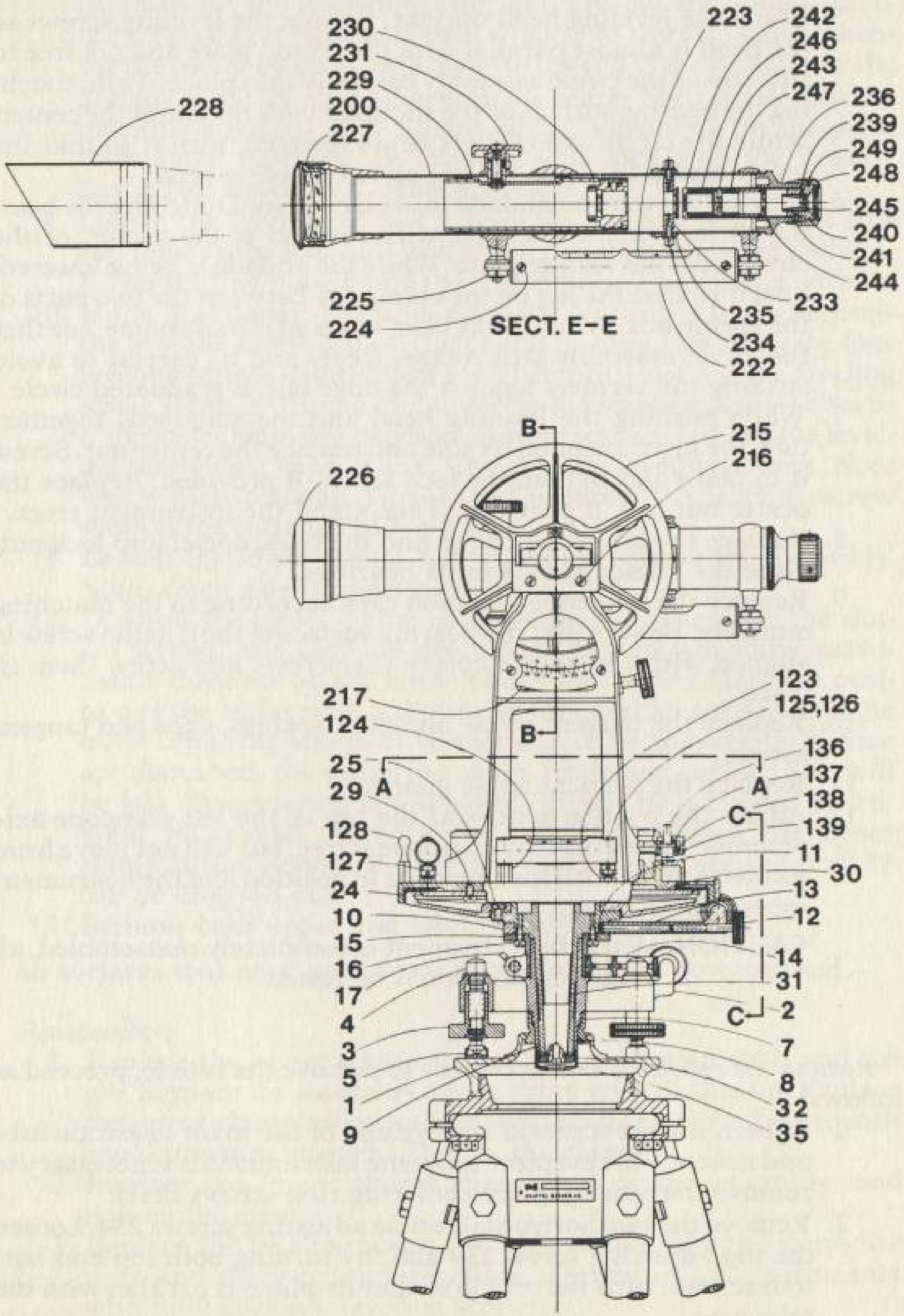
4. Place the tripod plate and the shifting plate in position and screw on the half ball. Turn the half ball home so that the lock screw can be replaced, and screw in the lock screw.
5. Stand the leveling head upright, tighten the leveling screws so the head is almost parallel with the tripod plate and not free to tilt. Lower the circle assembly carefully into place. Avoid touching the bearing surface or the shoulder with the end of the center. While the circle assembly is being lowered, turn it so that the lower clamp fits over the lug on the leveling head.
6. Carefully lower the alidade into place. Avoid touching the bearing surface or the shoulder with the end of the center, or the circle with the vernier plate. While the alidade is being lowered, turn it so that the lug on the clamp fits between the two parts of the spring box. When it has been lowered almost home, see that the circle assembly still rotates freely and be careful to avoid striking the verniers against the edge of the graduated circle.
7. While pushing the leveling head and the standards together, turn the instrument on its side and replace the center nut. Screw it in place and tighten the lock screw, if provided. Replace the center nut cap, if provided. Then stand the instrument erect.
8. Replace the telescope clamp and the telescope clamp lock nut. Place the telescope axle in its bearings.
9. Replace the telescope trunnion caps according to the matching numbers. Be sure that the bearing surface of the friction screw is aligned with the axle. Replace the screws and screw them in place.
10. Replace the tangent screw plungers, springs, caps and tangent screws.
11. Replace the vertical circle guard.
12. Adjust the friction screws at the top of the left telescope axle trunnion cap so that the telescope is free, but will not move from its own weight with the sunshade in position and the instrument focused at a distant point.

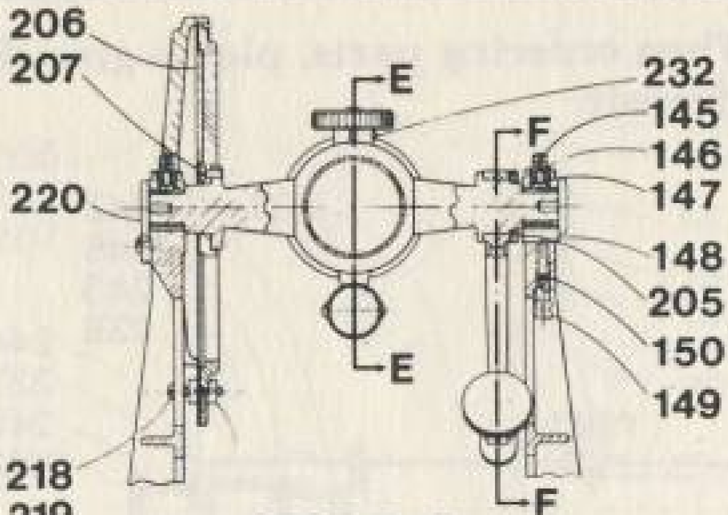
    CAUTION: After the instrument is completely reassembled, all adjustments should be tested.

Remove the reticle. If it is necessary to remove the reticle, proceed as follows:

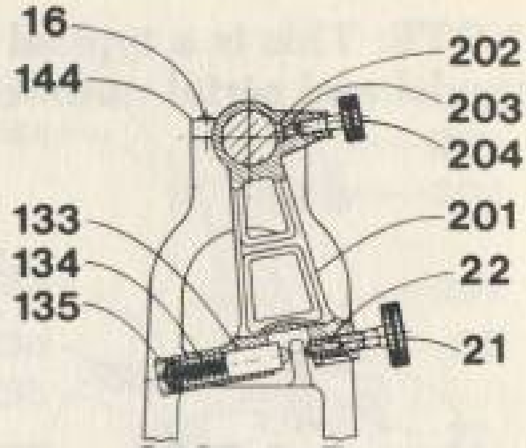
1. Loosen the set screw at the eye end of the main telescope tube and unscrew the eyepiece (on some instruments it is necessary to remove the four eyepiece centering ring screws first).
2. Remove the two horizontal reticle adjusting screws 234. Loosen the top adjusting screw 234 and, by turning both top and bottom screws, turn the reticle so that its plane is parallel with the telescope.

NOTE: This is a typical transit. When ordering parts, please give the model and serial number of your transit.

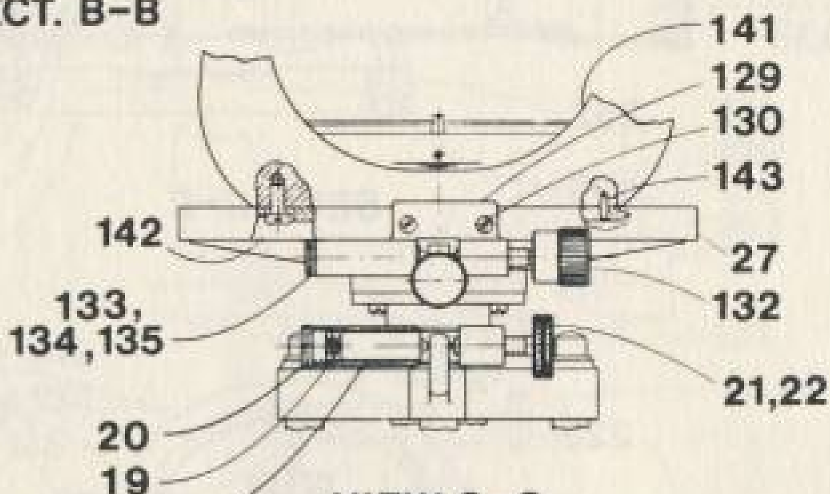




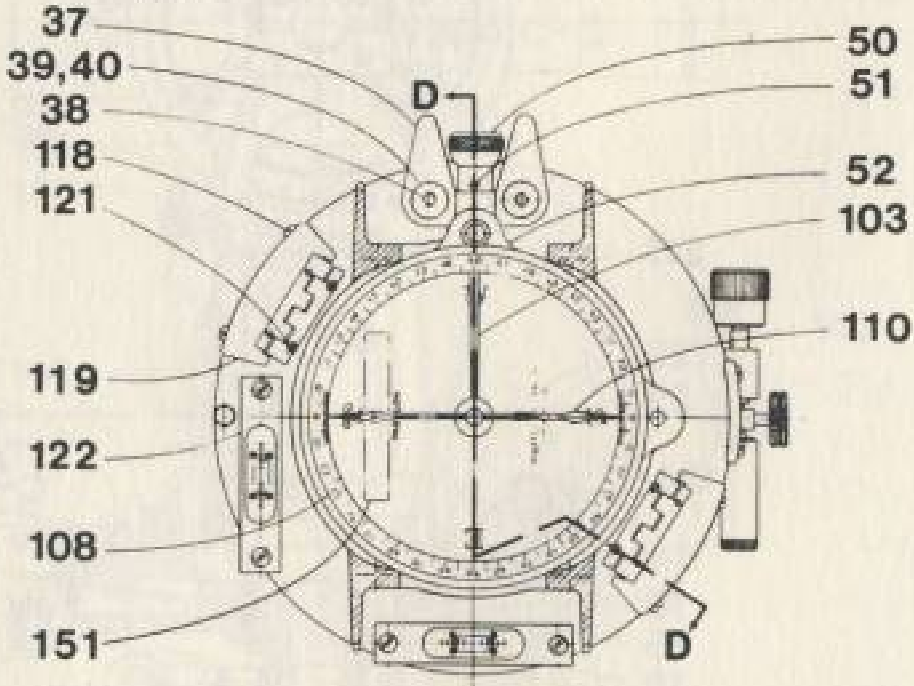
SECT. B-B



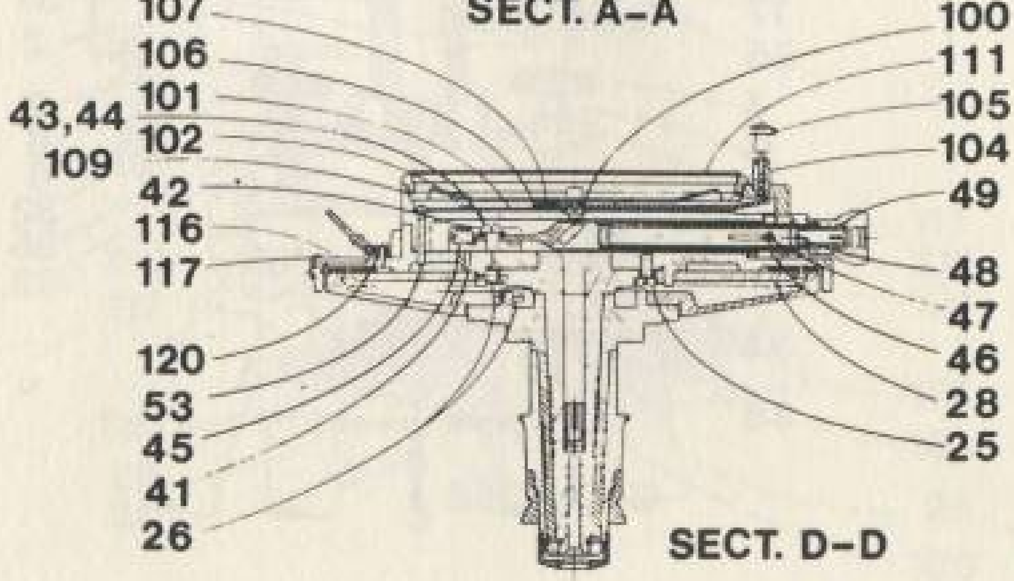
SECT. F-F



VIEW C-C



SECT. A-A



SECT. D-D

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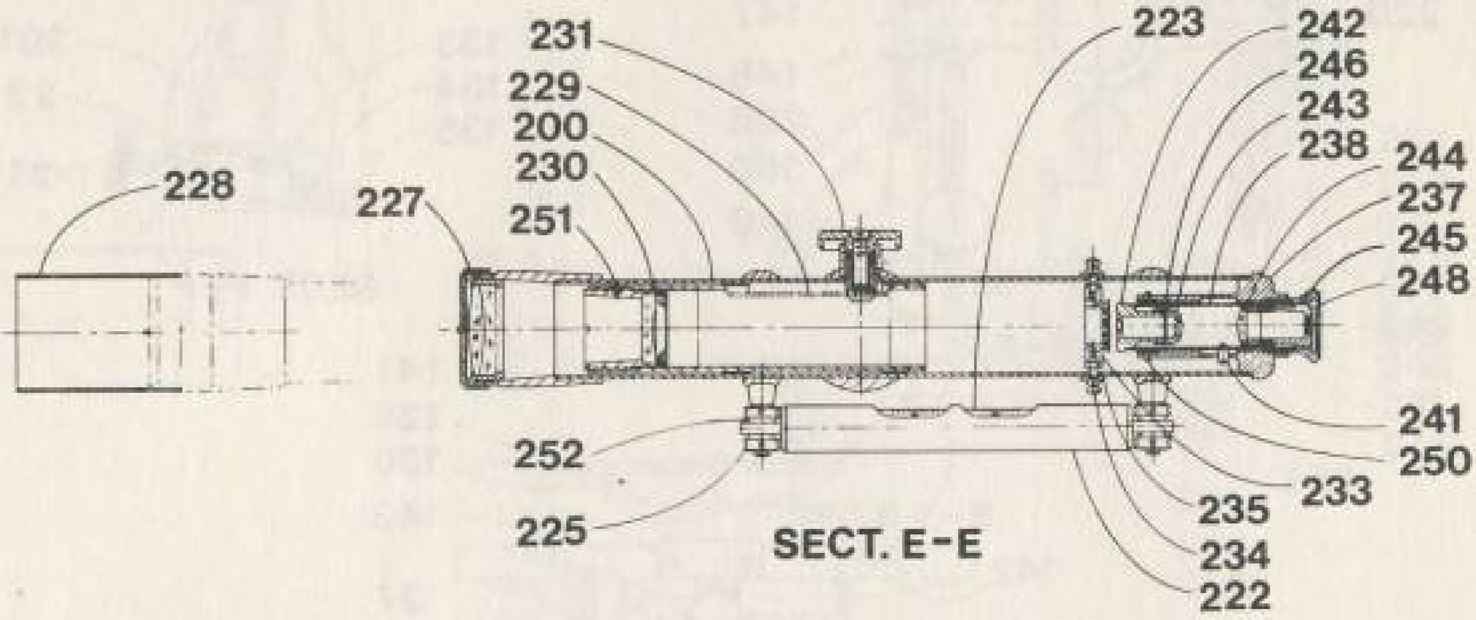
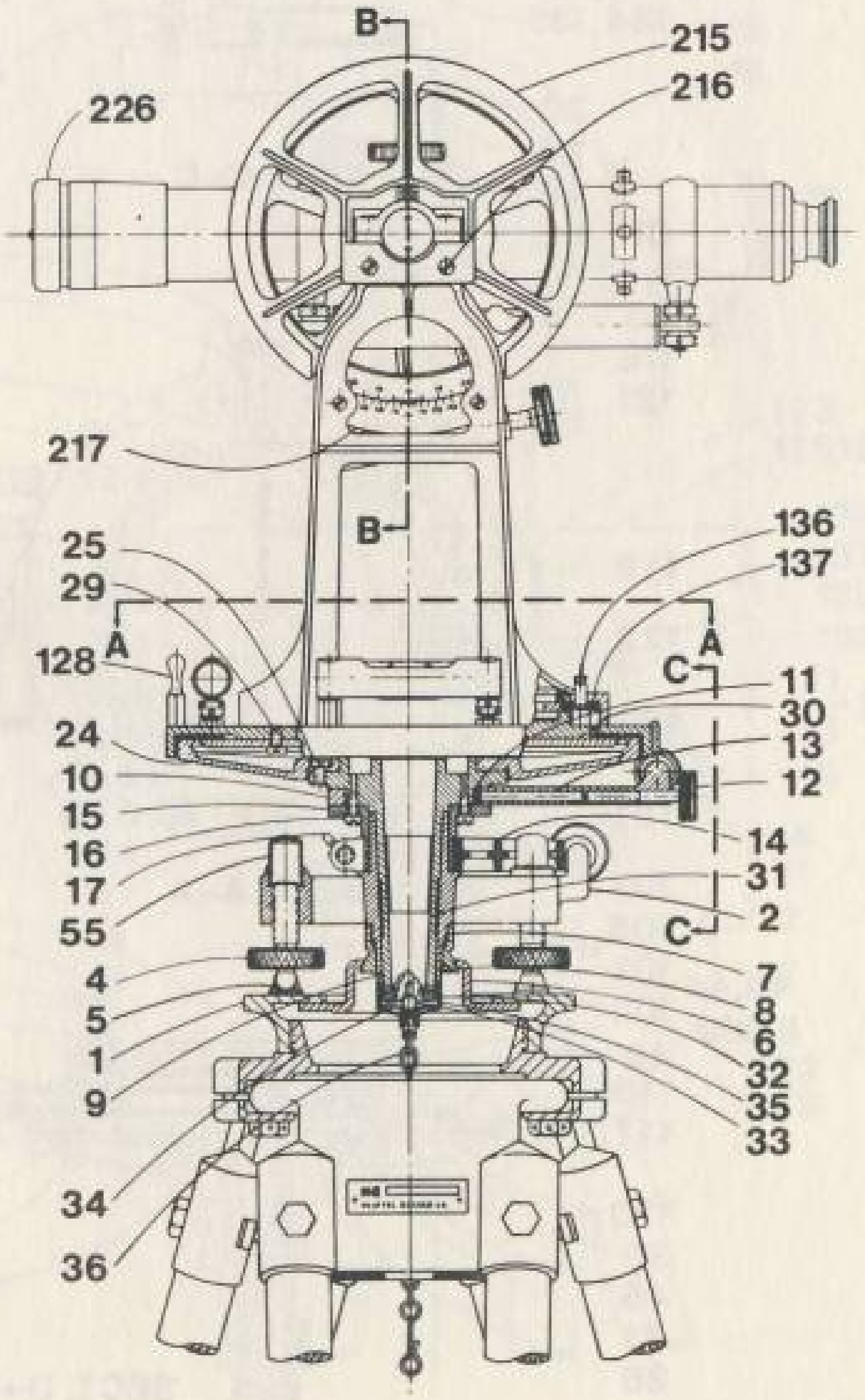
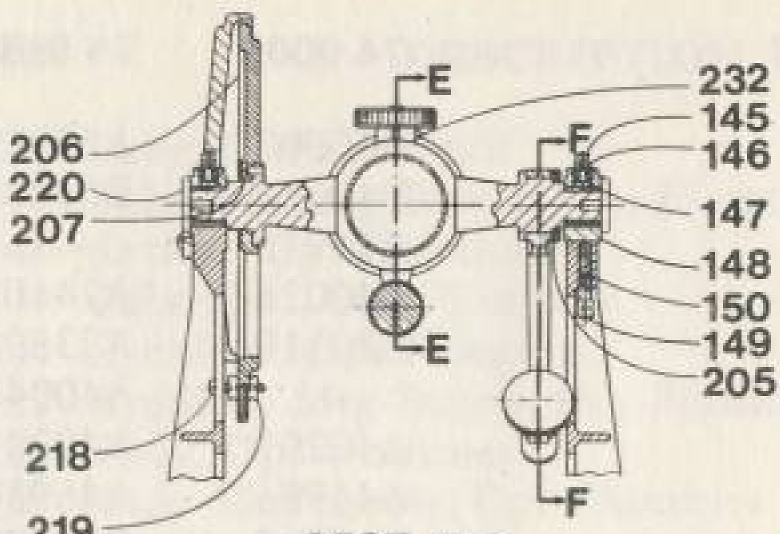
NOTE: This is a typical transit. When ordering parts, please give the model and serial number of your transit.







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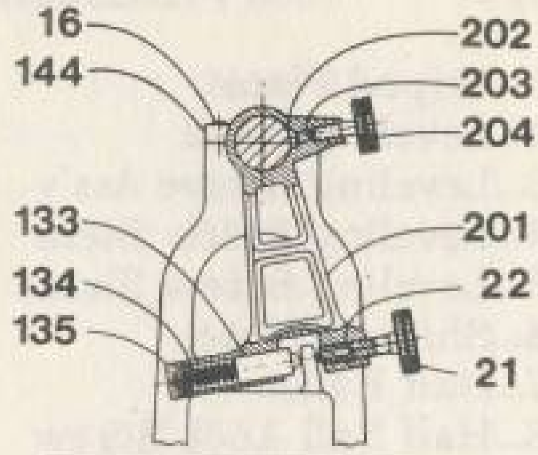

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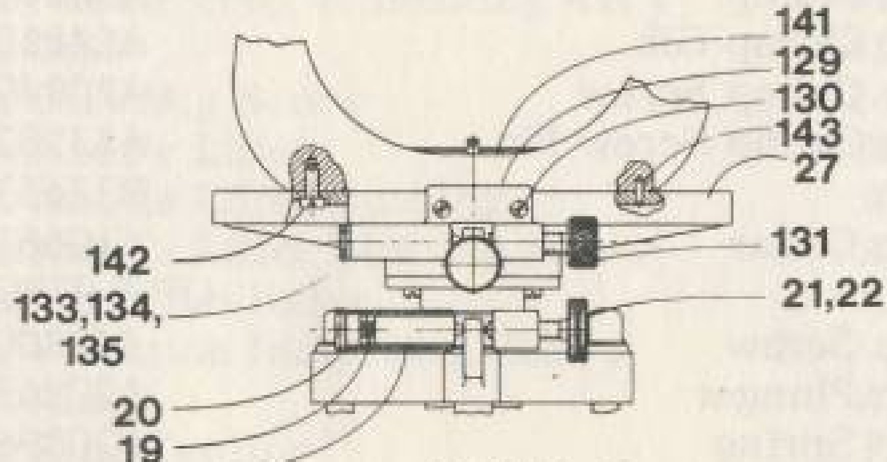
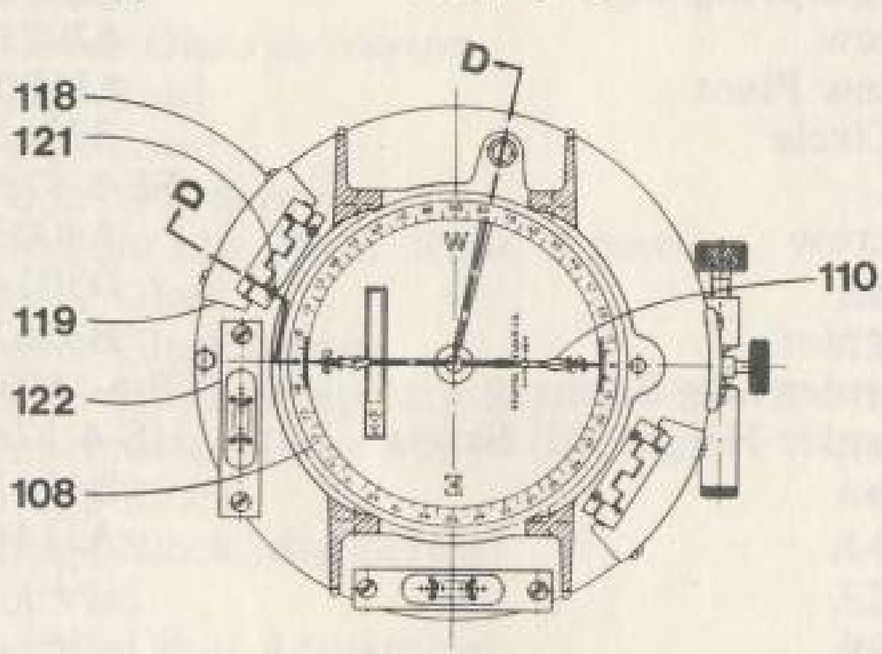
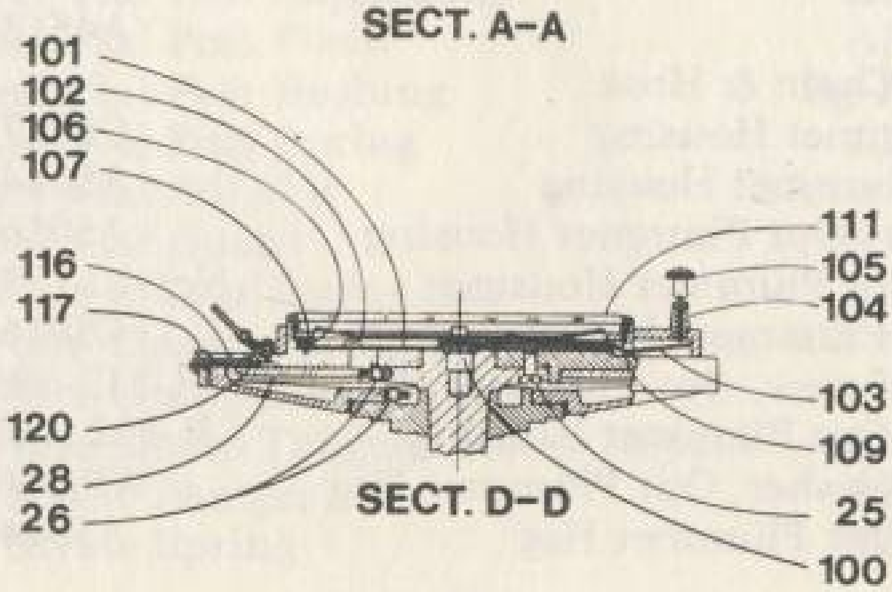


VIEW C–C



SECT. A–A



SECT. D–D

74 0150

NO.	DESCRIPTION	74 0005	74 0150
1	Tripod Plate	B46007	A23919
2	Leveling Head	B40014	B51091
3	Leveling Sleeve Ass'y	A44916	—
4	Leveling Screw Stem	A40026	A24108
5	Leveling Screw Shoe	A20119	A23895
6	Shifting Plate	—	A40043
7	Half Ball	A40201	A40201
8	Half Ball Lock Screw	A46986	A46986
9	Outer Center	B20725	B20725
10	Vernier Plate Clamp	A10660	A10660
11	Vernier Plate Clamp Gib	A24810	A24810
12	Vernier Plate Clamp Screw	A20849	A20849
13	Vernier Plate Clamp Screw Pin	A33782	A33782
14	Lower Clamp	B33633	B33633
15	Lower Clamp Collar	F10661	F10661
16	Mtg Screw	OF-6-979C	OF-6-979C
17	Lower Clamp Screw	A48800	A48800
18	Lower Clamp Plunger	A20865	A20865
19	Lower Clamp Spring	F20896	F20896
20	Lower Clamp Spring Cap	F20866	F20866
21	Tangent Screw	A20814	A20814
22	Tangent Screw Pivot	A31000	A31000
24	Horizontal Circle	B33616	C51092
25	Mtg Screw	FF-8-978A	FF-8-978A
26	Adjusting Screw	A40037	A40037
27	Vernier Plate	D50145	C33614
28	Spanned Vernier	B33624	C51093
29	Spanned Vernier Mtg Screw	FF-6-1893A	FF-6-1893A
30	Spanned Vernier Height Adj Screw	HS-4-1766	HS-4-1766
31	Inner Center	B45131	B33626
32	Center Nut	A31446	A31446
33	Center Ball	—	A46145
34	Center Spring	—	A23164
35	Center Cap	A45136	A10680
36	Plumb Bob Chain & Hook	—	A24134
37	Optical Plummet Housing	C50171	—
38	Stud, Opt Plummet Housing	A50148	—
39	Stud Washer, Opt Plummet Housing	A50162	—
40	Stud Nut, Opt Plummet Housing	Nct-10-1734	—
41	Mount, Opt Plummet Housing	C50165	—
42	Mount Mtg Screw, Opt Plummet Housing	R-832-6BR	—
43	Mtg Screw, Opt Plummet Housing	R-832 .4BR	—
44	Mtg Screw Washer, Opt Plummet Hsg	WP-8BR	—
45	Adj Screw, Opt Plummet Hsg	A50146	—

NO.	DESCRIPTION	74 0005	74 0150
46	Tube, Opt Plummet	Note 1	—
47	Tube Guiding Screw, Opt Plummet	A50147	—
48	Reticle, Opt Plummet	A45261	—
49	Tube End, Opt Plummet	B50158	—
50	Eyepiece, Opt Plummet	Note 2	—
51	Eyepiece Mtg Screw, Opt Plummet	A48401	—
52	Body, Opt Plummet	Note 3	—
53	Body Mtg Screw, Opt Plummet	OF-2031-17	—
55	Leveling Screw Cap	—	A23284
100	Compass Needle Pivot & Bushing Ass'y	A45174	A50368
101	Compass Dial	B40306-2	A51113
102	Compass Dial Mtg Screw	R-2-1762A	R-2-1762A
103	Compass Needle Lifter	A50669	A40060
104	Compass Needle Lifter Bushing	A24865	A24865
105	Compass Needle Lifter Bushing Screw	A24866	A24866
106	Compass Variation Index	A33642	A33642
107	Compass Variation Index Mtg. Screw	FF-2-1914A	FF-2-1914A
108	Compass Ring	A33640	A33640
109	Compass Ring Tension	F11349	F11349
110	Compass Needle	A51094	A51094
111	Compass Cover Glass & Mount	—	A51096
112	Compass Box Stud	—	—
113	Compass Box Cover	—	—
114	Compass Box Mtg Screw	—	—
115	Compass Needle Lift. Bush. Repl. Screw	—	—
116	Vernier Cover Glass	A33798	A33798
117	Vernier Cover Glass Strap	A23462	A23462
118	Vernier Cover Glass Strap Mtg Screw	R-2-1522C	R-2-1522C
119	Vernier Reflector & Hinge Ass'y	A48250	A48250
120	Vernier Hinge Block	A40107	A40107
121	Vernier Hinge Block Mtg Screw	A40111	A40111
122	Plate Level Vial	A24525	A24525
123	Plate Level Vial Post Adjustable	A10664	—
124	Plate Level Vial Post Fixed	A10665	—
125	Plate Level Vial Post Bushing	Bg-1547A	—
126	Plate Level Vial Post Spring	A24522	—
127	Plate Level Vial Adj Nut	Nct-6-915A	—
128	Plate Level Vial Guard	A40092	A40092
129	Vernier Plate Clamp Spring Box	A23299	A23299
130	Vernier Plate Clamp Spring Box Mtg Screw	R-4-1610A	R-4-1610A
131	Vernier Plate Clamp Tangent Screw	—	A20816
132	Vernier Plate Clamp Tangent Screw 2 Speed	A34391	—
133	Tangent Screw Plunger	A20781	A20781
134	Tangent Screw Spring	F20895	F20895

NO.	DESCRIPTION	74 0005	74 0150
135	Tangent Screw Spring Cap	F20867	F20867
136	Declination Adjustment Pinion	A33644	A33644
137	Declination Adjustment Pinion Washer	F20569	F20569
138	Declination Adjustment Pinion Spacer	A45187	—
139	Declination Adjustment Pinion Set Screw	HS-2-459A	—
140	Plug	—	—
141	Standard	D50151	D33612
142	Standard Mtg Screw	FF-10-542	FF-10-542
143	Standard Mtg Pin	PS1651	PS 1651
144	Bearing Cap	D50151-1	D33612-1
145	Bearing Cap Bushing	Bg-1830A	Bg-1830A
146	Tension Plug	A31575	A31575
147	Tension Plug Washer	W-1906	W-1906
148	Bearing Block	D50151-2	D33612-2
149	Bearing Block Adj Screw	A40039	A40039
150	Bearing Block Adj Screw Pin	A40148	A40148
151	Name Plate	A24583	—
200	Telescope Barrel & Axle	C33652	C51099
201	Telescope Clamp	A33645	A33645
202	Telescope Clamp Gib	A24779	A24779
203	Telescope Clamp Pin	A33784	A33784
204	Telescope Clamp Screw	A24777	A24777
205	Telescope Clamp Nut	A21649-1	A21649-1
206	Vertical Circle	A21428	A21432
207	Vertical Circle Mtg Screw	A40145	A40145
208	Stadia Circle	—	—
209	Stadia Circle Holder	—	—
210	Stadia Circle Holder Mtg Screw	—	—
211	Index Ring Horizontal	—	—
212	Index Ring Vertical	—	—
213	Index Ring Bushing	—	—
214	Index Ring Bushing Screw	—	—
215	Vertical Circle Guard	M-8216-4	M-8216-4
216	Vertical Circle Guard Mtg Screw	R-4-886C	R-4-886C
217	Vertical Vernier	A21191	A21441
218	Vertical Vernier Screw	R-4-2206	R-4-2206
219	Vertical Vernier Nut	Nct-4-875	Nct-4-875
220	Telescope Axle End Cap	A24697	A24697
221	Telescope Axle Cover	—	—
222	Telescope Level Vial Ass'y	A20707	A51111
223	Telescope Level Vial Only	A20742	A33656
224	Telescope Level Vial End Lock Screw	R-2-1522A	—
225	Telescope Level Adj Nut	Nct-10-1734A	Nct-10-1734A
226	Objective Cap	F20967	B50123-1

NO.	DESCRIPTION	74 0005	74 0150
227	Objective Lens & Mount	—	A51102
228	Sunshade	A40183	A21180
229	Telescope Draw Tube	A33769	A40015
230	Telescope Focusing Lens Ass'y	A47184	A51103
231	Telescope Focusing Pinion Ass'y	A33777	A33777
232	Telescope Focusing Pinion Lock Screw	OF-2-474	OF-2-474
233	Reticle	A46614	A51112
234	Reticle Adj Screw	CO-4-2190A	CO-4-99
235	Reticle Shutter	A23897	A44438
236	Eyepiece Body & Tube	A33727	—
237	Eyepiece End Ring	—	A33651
238	Eyepiece Tube	—	A23983
239	Eyepiece Tube Screw	SS-2024-38	—
240	Eyepiece Focusing Sleeve	A47154	—
241	Eyepiece Focusing Sleeve Screw	SP-6-996A	FF-4-2209A
242	Eyepiece Lens I & Mount	A47162	A51107
243	Eyepiece Lens II & Mount	A47160	A51108
244	Eyepiece Lens III & Mount	A47158	A51109
245	Eyepiece Lens IV & Mount	A47156	A51110
246	Diaphragm Erector	A47164	A24206
247	Eyepiece Threaded Bushing	A47163	—
248	Eyepiece Cap	A21641	A20137
249	Eyepiece Cap Screw	HS-4-1910A	—
250	Eyepiece End Ring Tension Spring	—	A40097
251	Telescope Focusing Lens Mount Screw	—	FC-2-652A
252	Telescope Level Vial Spacer	—	A51084

Note 1 — Consists of B50157 & A45259
Note 2 — Consists of C50149 & A45262
Note 3 — Consists of C50150 & A50163

3. Thread a pointed stick of soft wood into the side screw hole of the reticle now facing the eyepiece end of the telescope.
4. Remove the two remaining reticle adjusting screws 234 and carefully withdraw the stick with the reticle on it.

If the reticle has spider web cross lines, the spider web can be removed with alcohol. New spider web should be replaced under tension and placed exactly on the scribed marks on the reticle. This should be done under plenty of light and using the eyepiece as a microscope. The new spider web can be held in place with a drop of shellac.

To replace the reticle in the telescope reverse the order of steps.

After replacement, the stadia ratio should be re-determined.

ADJUSTMENTS

Before performing any adjustments read General Care — Adjustments, page 4.

Plate Levels

1. *Object:* To adjust the plate levels so that the bubble will center when the azimuth axis of the instrument is placed in the direction of gravity (made truly vertical).

Test: Set the horizontal circle vernier at zero. Clamp the upper clamp. With the lower clamp free, turn the instrument in azimuth until each plate level is aligned with a pair of opposite leveling screws. Set the lower clamp. Center the bubble precisely. Free the upper clamp and turn the instrument 180° in azimuth. The bubble should center.

Adjustment: If either bubble fails to center, bring it halfway back with the leveling screws. Then, by turning the capstan nut at the adjustable end, raise or lower that end of the level tube until the bubble centers.

Cross Line Reticle

2. *Object:* To center the cross lines on the optical axis. Should not be made if it can be avoided; it needs to be approximately correct and it disturbs three other adjustments.

Test: Determine if the cross lines appear to be in the center of the field of view and if they are near enough to the optical axis to give good results.

Adjustment: The cross line reticle is held in position by the four capstan head reticle adjusting screws in tension. Loosen two adjacent screws. By adjusting the four screws with the fingers, center the cross lines. Tighten the screws by alternately turning a vertical screw and a horizontal screw by small increments.

3. *Object:* To make reticle perpendicular to the elevation axis.

Test: Aim at a sharply defined point. Move the line of sight up and down with the telescope tangent screw. The vertical cross line should remain on the point.

Adjustment: Loosen two adjacent reticle adjusting screws. Gently tap the sides of the screws so that they move around the telescope until the vertical cross line is rotated to its correct position. Tighten the same screws. As the cross lines are placed on the reticle at right angles at the factory, when the vertical line is correct, the horizontal line is also in its correct position.

4. *Object:* To make the line of sight perpendicular to the elevation axis.

Test: Sight a well defined point 200 feet or more distant. Reverse the telescope on its elevation axis and note or mark a point appearing on the vertical cross line at about the same elevation and distance from the instrument as the first point, but in the opposite direction. By turning the instrument approximately 180° in azimuth, again sight the original point. Again, reverse the telescope on its elevation axis. The vertical cross line should fall on the second point.

Adjustment: Loosen the top reticle adjusting screw. Then by loosening one side screw and tightening the other alternately by small increments, move the cross line one-quarter the distance toward the second point. Tighten the top screw. Recheck adjustments for reticle, numbers 2 and 3.

Elevation Axis

5. *Object:* To make the elevation axis perpendicular to the azimuth axis.

Test: Aim at a high target (about 45°). Then, aim down at a horizontal scale (about 45°) and read the scale. Reverse the telescope and turn 180° in azimuth. Sight the lower point. Raise the telescope. The vertical line should fall on the upper point.

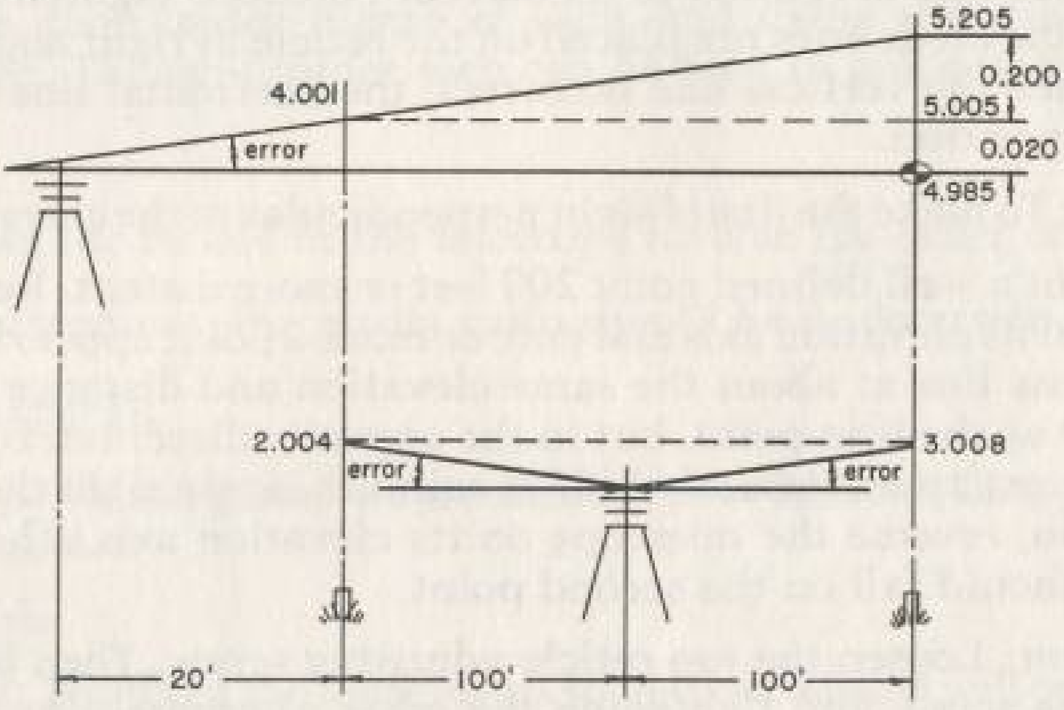
Adjustment: Move the cross line between one-quarter and one-half the distance toward the upper point by raising or lowering the movable bearing block in one of the standards.

Telescope Level

6. *Object:* To make the telescope level center when the line of sight is horizontal.

Test: The test is made by the peg method. On fairly level ground, set up the instrument where it is protected from direct sun rays, and drive two stakes in opposite directions at exactly equal distances from the instrument. Preferably, the stakes should be about 100 feet from the instrument.

Take a rod reading on each stake. Level the telescope carefully for each reading, using the telescope level. The difference between the two readings will be the true difference in elevation between the stakes. Then set up in line with the two stakes, but at a known distance beyond one of them equal to some convenient decimal fraction of the distance between the stakes. Level the telescope carefully, and take a reading on the near stake.



If the reading of the near stake is 4.001, the reading on the far stake should be 4.001 plus the difference between the values obtained at the center set up, i.e. 3.008 – 2.004 = 1.004. 4.001 + 1.004 = 5.005. Assume that the horizontal cross line strikes at 5.205. The line of sight must slope upward at a rate of 0.200 ft. in 200 ft. In the 20 ft. between the instrument and the near stake, the error introduced by this slope is, by similar triangles, 1/10 of 0.200 ft. or 0.020 ft. Applying the two errors to the reading of the far stake, 5.205 – 0.200 – 0.020 = 4.985. A target set at 4.985 will be level with the instrument.

If the line of sight, instead of striking above the computed reading, strikes below it, the two errors must be added to the rod reading instead of being subtracted from it.

Set the target accordingly. Using the vertical tangent screw, bring the horizontal cross line to the target.

Adjustment: Center the telescope level by raising or lowering the adjustable end by means of the adjusting nuts.

Vertical Circle Vernier and Stadia Indices

7. *Object*: To make the vertical circle vernier read zero, the horizontal stadia index read 100, and the vertical stadia index read 50* when the line of sight is perpendicular to the azimuth axis.

*Omit references to stadia indices if the instrument is not so equipped.

Test: Level the instrument with the telescope level as described on page 11. The vernier and the two stadia indices should give the proper readings.

Adjustment: Loosen the screws slightly, and tap them lightly until the correct reading is obtained. Tighten the screws. Make sure that the vernier or the indices have not been set too close to the circle that they bind.

Optical Plummet

The K&E optical plummet is factory adjusted and, with ordinary handling, field adjustment is rarely required. Before assuming adjustment is necessary, the test described below should be made at least three times. If all three results show the same error, adjustment is required.

Object: To adjust the line of sight of the optical plummet so that it coincides with the azimuth axis of the instrument.

Test: Draw a cross on a small card, fasten the card to a stake or other object so that it will not move. Level the instrument over the cross.

1. Aim the optical plummet exactly at the cross.
2. Rotate the transit 180° in azimuth. If the reticle moves off the cross, adjustment is required.
3. With the reticle remaining in the same position as (2) above, follow the adjustment procedure.

NOTE: Test should be done at instrument height.

Adjustment.

1. With the leveling screws, bring the optical plummet bull's eye half-way toward the mark. Then bring the circles precisely on the mark with the capstan adjusting nuts (see instructions below).
2. Repeat test and make further adjustments if necessary.

Adjustment of the optical plummet is accomplished with the four capstan nuts on the top and bottom of the eyepiece guard. To raise the reticle, loosen the two bottom nuts slightly and an equal amount. Tighten the two top nuts. To lower the reticle, reverse the procedure.

To move the reticle to the right, loosen the lower right nut and the top left nut. Tighten the upper right and the lower left nut. To move the reticle to the left, reverse the procedure.

To achieve the desired result, it is better to watch the reticle while the adjustment is being made and to only loosen and tighten the nuts on one side at a time.

SECTION II — LEVELS

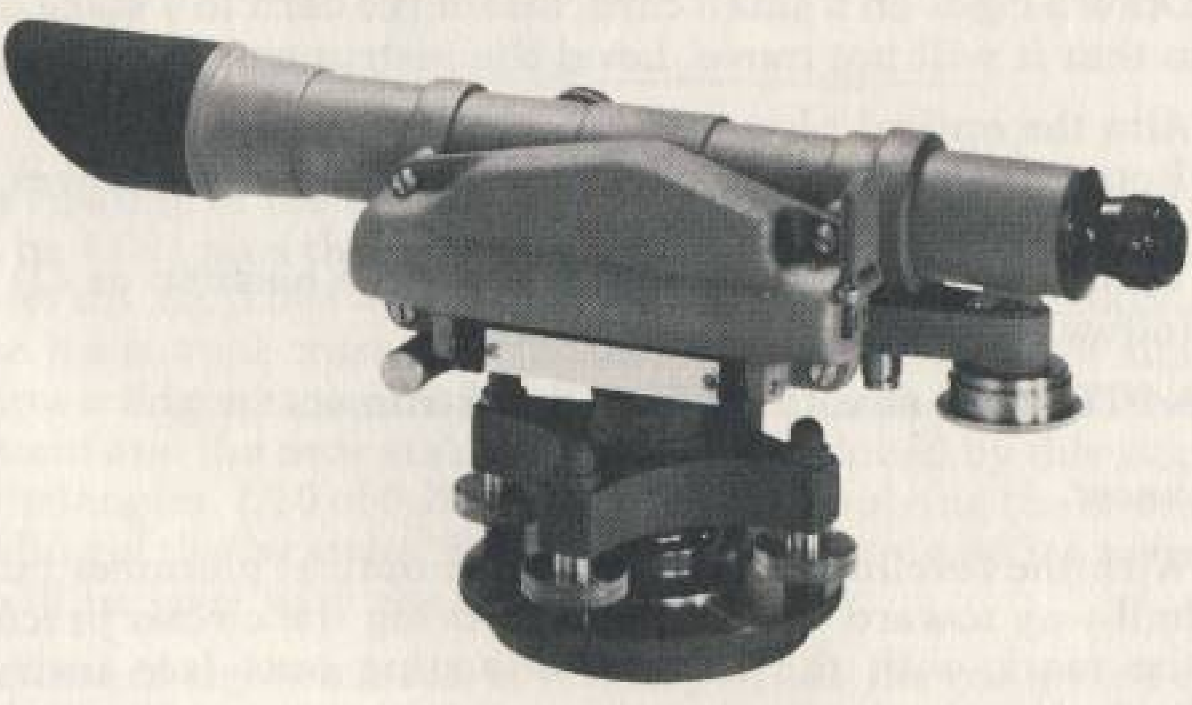
INTRODUCTION

The engineers' level provides a quick means of determining vertical distances or difference in elevation when used with a leveling rod. Two engineers' levels will be discussed in this section: Tilting Level; and the Dumpy Level.

THE TILTING LEVEL

This instrument is designed for precision and speed. It has an erecting telescope of about 30 power. The bubble is observed through a coincidence device from a position about one inch to the left of the eyepiece.

When the instrument is first set up, the leveling head is leveled roughly with the small circular bubble, which may be observed in a mirror from a point about one inch to the right of the eyepiece. No time is wasted in walking around the instrument or in turning it in azimuth, or by unnecessary precision in leveling it.



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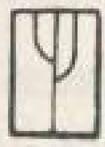
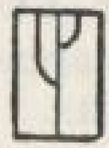
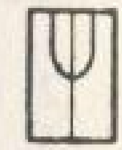
OPERATION

NOTE: If the optimum performance of the Tilting Level is desired, the proper procedure for first order leveling and the "least squares" method of adjusting the results should be followed. For these the reader is referred to Special Publications Nos. 239 and 240 of the U.S. Department of Commerce, Coast and Geodetic Survey, Manual of Geodetic Leveling and Manual of Leveling Computation and Adjustment by Howard S. Rappleye.

Taking a rod reading. Center the circular bubble with the leveling screws. This is for rough leveling; precise leveling is unnecessary at this time. Focus the telescope on the rod.

In the mirror or oblong window to the left of the telescope the bubble ends may be seen to look like:  or 

Turn the screw until the bubble ends are in coincidence like: 

The line of sight is now horizontal. Take the rod reading. Check the bubble for coincidence immediately. If still in coincidence, the reading is good.

NOTE: If the bubble ends are not bright, turn the reflector under the bubble so that more light is reflected up through the bubble tube. If the bubble ends do not appear, turn the micrometer screw until they come into view.

In extremes of temperature, the point of coincidence will appear near the top or the bottom of the window, according to the actual length of the bubble. This, of course, does not affect the accuracy of the instrument.

Faster rough leveling. Profile leveling, cross sectioning and other rough leveling can be speeded up by use of the reversing point. The reversing point is the position of the tilting screw operating wheel that causes the bubble to center when the vertical axis is vertical. When the wheel is in this position, the instrument can be precisely leveled with the leveling screws, (see leveling, page 11). Once it is leveled in this manner, cross-section shots can be safely taken to hundredths of a foot without releveling.

Set up the instrument, center the circular bubble, turn the telescope until it is in line with a pair of opposite leveling screws, and center the main bubble with the tilting wheel by observing the coincidence of its ends. Turn the telescope 180° in azimuth and center the bubble by moving it half the distance with the leveling screws and half the distance with the wheel. Turn the telescope 90° in azimuth and center the bubble with the leveling screws. Repeat this procedure until the bubble ends remain in an ⅛ inch of coincidence in all positions. The tilting wheel will now be at its reversing point. Mark this position with a pencil or note the reading of the graduated circle if the instrument is so equipped.

The reversing point should be checked from time to time as it will change as wear occurs in the instrument.

When the circular level is in good adjustment, cross-section shots up to 200 feet long can be safely taken to tenths of a foot when the instrument is leveled with the circular level alone. Set the tilting wheel at its reversing point and center the circular bubble. Less than 10% of the shots will be in error by more than 0.05 foot.

MAINTENANCE, LUBRICATION AND DISSASSEMBLY

In the maintenance of levels the following are accomplished as described for transits.

1. Precautions — page 3, 5.
2. Removal of the reticle — page 15.
3. Preparation for arctic temperatures — page 6.

A level is lubricated in the same manner as a transit, (see page 5). Only the following points need to be lubricated:

1. Bearing surfaces and shoulder of center.
2. Spring and plunger of clamp.
3. Threads of clamp screw, tangent screw, and leveling screw.
4. Collar and surface of clamp.
5. Surface of half ball and upper surface and thread of tripod plate.
6. Micrometer screw.
7. Telescope trunnion bearings.
8. Tilting screw compression spring.

Disassembly. Unscrew tension stud lock nut (188) and tension spring housing (190). The tension spring should fall out. Unscrew telescope trunnion bearing cap screws (131) and remove caps (130). Lift out telescope.

Remove level bar 146 and center 145 in the same way the circle assembly is removed on a transit, page 13, No. 6, 7. Remove clamp mechanism as described for the transit, page 14, No. 11. Remove half ball and leveling screws as described for the transit on page 14, No 9.

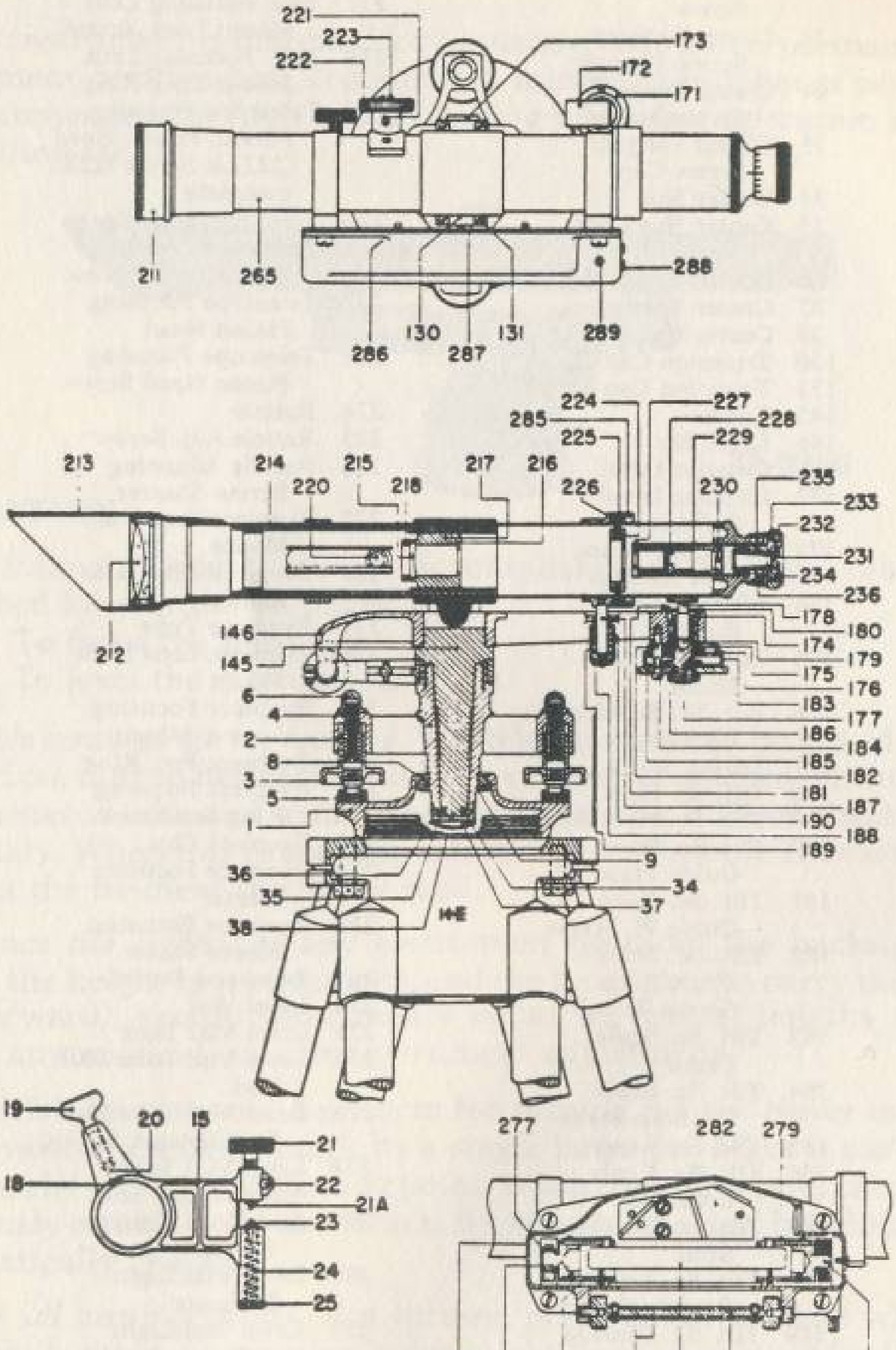
All surfaces that need to be cleaned and lubricated are now exposed. Reassemble the instrument in reverse order.

ADJUSTMENTS

Make the coincidence of the ends of the bubble occur when the line of sight is horizontal. Perform the test for the peg adjustment as described for the telescope level of the transit, page 25-26.

After the target has been set, bring the line of sight on it by turning the micrometer screw. There are three capstan head screws at the back of the bubble housing. Loosen the two outside screws. Turn the middle screw until the ends of the bubble are in coincidence. Re-tighten the two outside screws.

No other adjustments are necessary.



5210-1 Tripod Plate
2 Leveling Head
3 Leveling Screw Head
4 Leveling Screw Stem
5 Leveling Screw Shoe
6 Leveling Screw Cap
8 Half Ball
9 Half Ball Lock Screw

15 Clamp
18 Clamp Gib
19 Clamp Screw
20 Clamp Screw Pin
21 Clamp Tangent Screw
21A Clamp Tangent Screw Pivot Pin

5210-22	Clamp Tangent Screw Tension Screw	216	Telescope Focusing Lens Mount
23	Clamp Tangent Screw Plunger	217	Tele. Focusing Lens Mount Lock Screw
24	Clamp Tangent Screw Spring	218	Tele. Focusing Lens Mount Lock Ring
25	Clamp Tangent Screw Cap	219	Telescope Focusing Pinion, Pinion Head (222) & Screw (223), complete
34	Center Nut	220	Tele. Focusing Pinion
35	Center Nut Lock Screw	221	Telescope Focusing Pinion Lock Screw
36	Center Cap	222	Telescope Focusing Pinion Head
37	Center Spring	223	Telescope Focusing Pinion Head Screw
38	Center Ball	224	Reticle
130	Trunnion Cap	225	Reticle Adj. Screw
131	Trunnion Cap Screw	226	Reticle Adjusting Screw Shutter
145	Center	227	Eyepiece Lens I & Mount
146	Level Bar	228	Eyepiece Lens II & Mount
171	Circular Level	229	Eyepiece Tube
172	Circular Level Reflector	230	Eyepiece Lens III & Mount
173	Telescope Trunnion Rosette	231	Eyepiece Focusing Lens & Mount
174	Tilting Screw Bushing	232	Eyepiece Foc. Ring
175	Tilt. Sc. Index Drum	233	Eyepiece Focusing Ring Set Screw
176	Tilt. Sc. Bushing Lock Nut	234	Eyepiece Cap
177	Tilting Screw	235	Eyepiece Focusing Sleeve
178	Tilt. Sc. Pivot	236	Eyepiece Focusing Sleeve Screw
179	Tilt. Sc. Pivot Ball	265	Telescope Barrel
180	Tilt. Sc. Pivot Guide Plate	274	Level Vial
181	Tilt. Sc. Pivot Guide Pl. Screw	275	Level Vial Tube
182	Tilt. Sc. Scale Drum Stop Screw (Fixed)	276	Level Vial Tube Ball End
183	Tilt. Sc. Scale Drum	277	Level Vial Tube Ball End Tension Spring
184	Tilt. Sc. Scale Dr. Stop Screw	278	Level Vial Tube Adjustable End
185	Tilt. Sc. Knob	279	Level Vial Tension Spring
186	Tilt. Sc. Knob Lock Nut	280	Level Vial Light Reflector
187	Tilt. Sc. Tension Stud	281	Level Vial Light Reflector Holder
188	Tilt. Sc. Tension Stud Lock Nut	282	Level Viewing Unit
189	Tilt. Sc. Tension Spring	283	Level Vial Housing
190	Tilt. Sc. Tension Spring Housing	284	Level Vial Housing Screw
211	Objective Cap	285	Reticle Adj. Sc. Cover
212	Objective Lens & Mount	286	Bubble Adj. Lock Scr.
213	Sunshade	287	Bubble Adj. Screw
214	Tele. Draw Tube	288	Mirror Attach. Screw
215	Telescope Focusing Lens	289	Screw for Bubble Adjusting Hole

When ordering parts, state Serial No. of instrument.

THE DUMPY LEVEL

This instrument is designed for accuracy, reliability, permanence of adjustment, and low cost. It contains a minimum number of parts, and is recommended for high grade leveling when fast operation is not a controlling factor.

75 0300

OPERATION

The following operations are accomplished in the same manner as described for transits on pages 10, 11.

1. To focus the telescope.
2. To level the instrument.

Bubble centered during reading. The telescope should be aimed at, and focused on, the rod before the bubble is precisely centered. The moment it is centered, the rod should be read and the bubble checked immediately. When this procedure is followed the bubble is exactly centered at the moment the rod is read.

Balance the sights. At any instrument position, the backsight, (to obtain the height of instrument), and the foresight, (to carry the elevation forward), should have nearly equal horizontal lengths to neutralize any residual error in instrument adjustment.

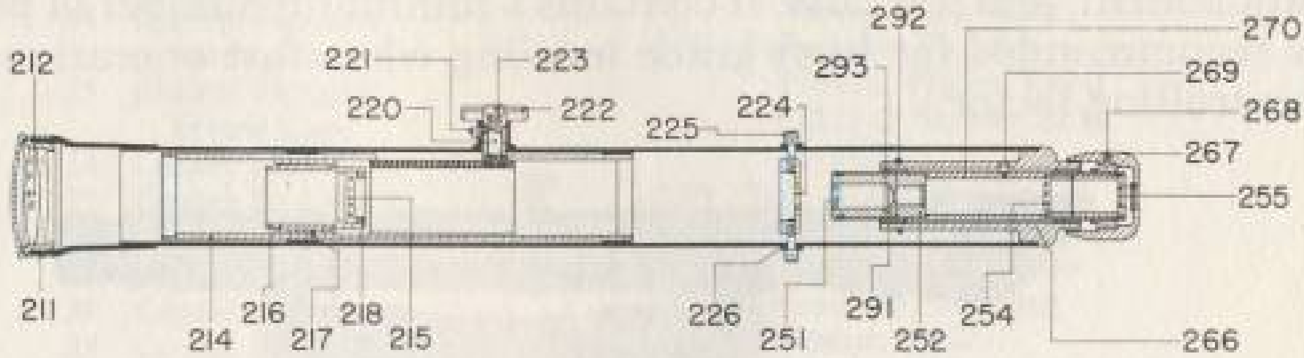
Establish benchmarks. Use them for turning points. Never establish the elevation of a benchmark by a single foresight. Make it part of the level line by using it as a turning point. When the line of level checks on a previously established benchmark, the shots to the new benchmark are automatically checked.

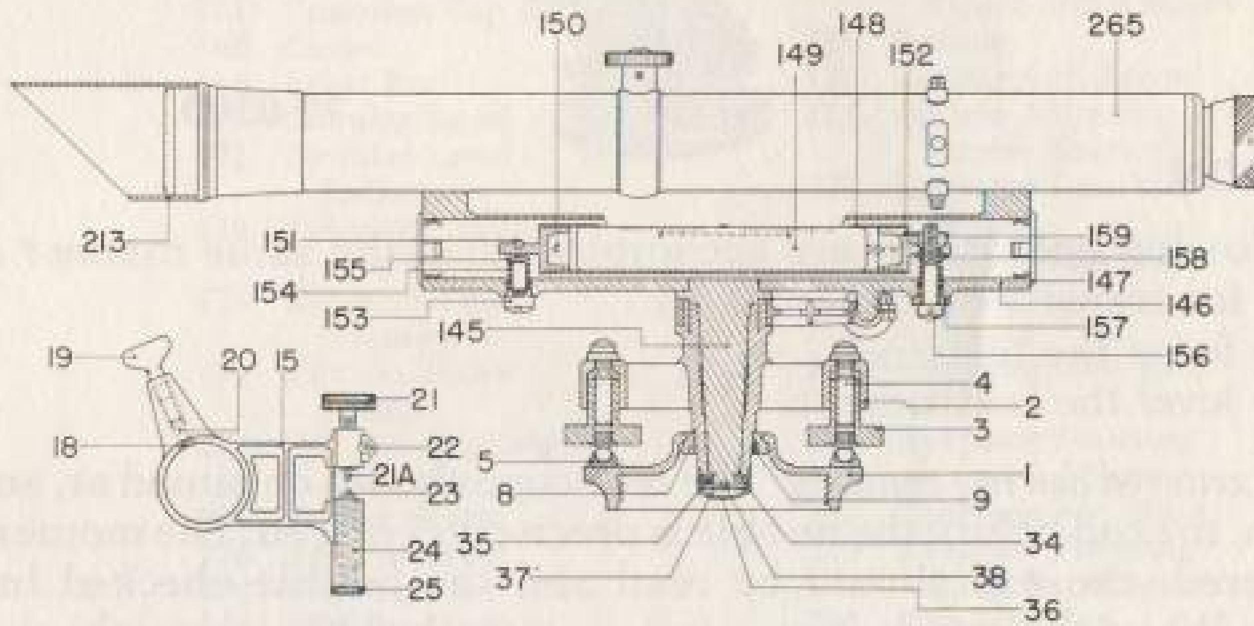
Mark all turning points. If a turning point is not marked when the foresight is taken, some other point might be used in error for the next backsight.

MAINTENANCE, LUBRICATION AND DISASSEMBLY

In the maintenance of levels, the following are accomplished as described for transits.

1. Precautions — page 3, 5.
2. Removal of the reticle — page 15.
3. Preparation for arctic temperatures — page 6.





5216-1 Tripod Plate
2 Leveling Head
3 Leveling Screw Head
4 Leveling Screw Stem
5 Leveling Screw Shoe
8 Half Ball
9 Half Ball Lock Screw
15 Clamp
18 Clamp Gib
19 Clamp Screw
20 Clamp Screw Pin
21 Clamp Tangent Screw
21A Clamp Tangent Screw Pivot Pin
22 Clamp Tangent Screw Tension Screw
23 Clamp Tangent Screw Plunger
24 Clamp Tangent Screw Spring
25 Clamp Tangent Screw Cap
34 Center Nut
35 Center Nut Lock Screw
36 Center Cap
37 Center Spring
38 Center Ball
145 Center
146 Level Bar
147 Level Bar End Cap
148 Telescope Level Vial Tube & Ends Complete
149 Telescope Level Vial Only
150 Telescope Level Vial Tube End Lock Screw
151 Telescope Level Pivot
152 Telescope Level Tube End Position Pin
153 Telescope Level Tension Screw
154 Telescope Level Tension Screw Spring
155 Telescope Level Tension Screw Stud
156 Telescope Level Adjusting Screw
157 Telescope Level Adjusting Screw Bushing
158 Telescope Level Adj. Sc. Washer
159 Telescope Level Adjusting Screw Nut
211 Objective Cap

DUMPY LEVEL — COMPONENT PARTS

5216-212 Objective Lens & Mount
213 Sunshade
214 Telescope Draw Tube
215 Telescope Focusing Lens
216 Telescope Focusing Lens Mount
217 Telescope Focusing Lens Mount Lock Screw
218 Tele. Focusing Lens Mount Lock Ring
219 Telescope Focusing Pinion, Pinion Head (222) and Screw (223) complete
220 Telescope Focusing Pinion
221 Telescope Focusing Pinion Lock Screw
222 Telescope Focusing Pinion Head
223 Telescope Focusing Pinion Head Screw
224 Reticle (See 74 0300)
225 Reticle Adjusting Screw
226 Reticle Adjusting Screw Shutter
251 Reticle Lens I & Mount
252 Reticle Lens II & Mount
254 Reticle Lens III & Mount
255 Reticle Lens IV & Mount
265 Telescope Barrel
266 Eyepiece Body
267 Eyepiece Focusing Ring
268 Eyepiece Focusing Ring Lock Screw
269 Eyepiece Cam Screw
270 Eyepiece Draw Tube
291 Front Aperture
292 Tension Spring
293 Ring, Eyepiece Guide

When ordering parts, state Serial No. of instrument.

A level is lubricated in the same manner as a transit, (see page 5). Only the following parts need to be lubricated:

1. Bearing surfaces and shoulder of center.
2. Spring and plunger of clamp.
3. Threads of clamp screw, tangent screw and leveling screws.
4. Collar and surface of clamp.
5. Surface of half ball, and upper surface and thread of tripod plate.

Disassembly. Remove level bar 146 and center 145 in the same way the circle assembly is removed on a transit, page 13, No. 6, 7. Remove clamp mechanism as described for the transit, page 14, No. 11. Remove half ball and leveling screws as described for the transit, page 14, No. 9.

All surfaces that need to be cleaned and lubricated are now exposed. Reassemble the instrument in reverse order.

ADJUSTMENTS

The bubble should center when the azimuth axis is placed in the direction of gravity. This relationship makes it unnecessary to relevel the instrument more than a slight touch for any observation. If the adjustment necessary to obtain this relationship is made, then the complete peg adjustment must be carried out immediately, as the bubble will no longer center when the line of sight is horizontal.

To make the bubble center when the azimuth axis is placed in the direction of gravity: (1) Roughly level over each of the two pairs of opposite leveling screws; center the bubble over the pairs. (2) Turn the instrument 180° in azimuth. The bubble should center. If it does not, bring the bubble half way toward the center with the leveling screws. Center the bubble with the capstan adjusting screw or nut or, on some Dumpy Levels, with the opposing nuts at one end of the tube.

To make the horizontal cross line lie in a plane perpendicular to the azimuth axis aim at some well defined point and turn the telescope slightly left and right with the tangent screw. The horizontal cross line should remain on the point throughout the sweep. If it does not, loosen slightly two adjacent reticle adjusting screws. Tap the side of the screws until the cross line is rotated to its correct position. Tighten the screws.

To make the line of sight level when the bubble is centered make the test for the peg adjustment as described for the telescope level of the transit, pages 25-26.

After the target has been set, focus on the rod and center the bubble. Bring the horizontal crossline on the target with the reticle adjusting screws. Loosen a side screw. Move the upper and lower screws by small increments. Finally, tighten the sidescrew previously loosened.

SECTION III — PLANE TABLE ALIDADES

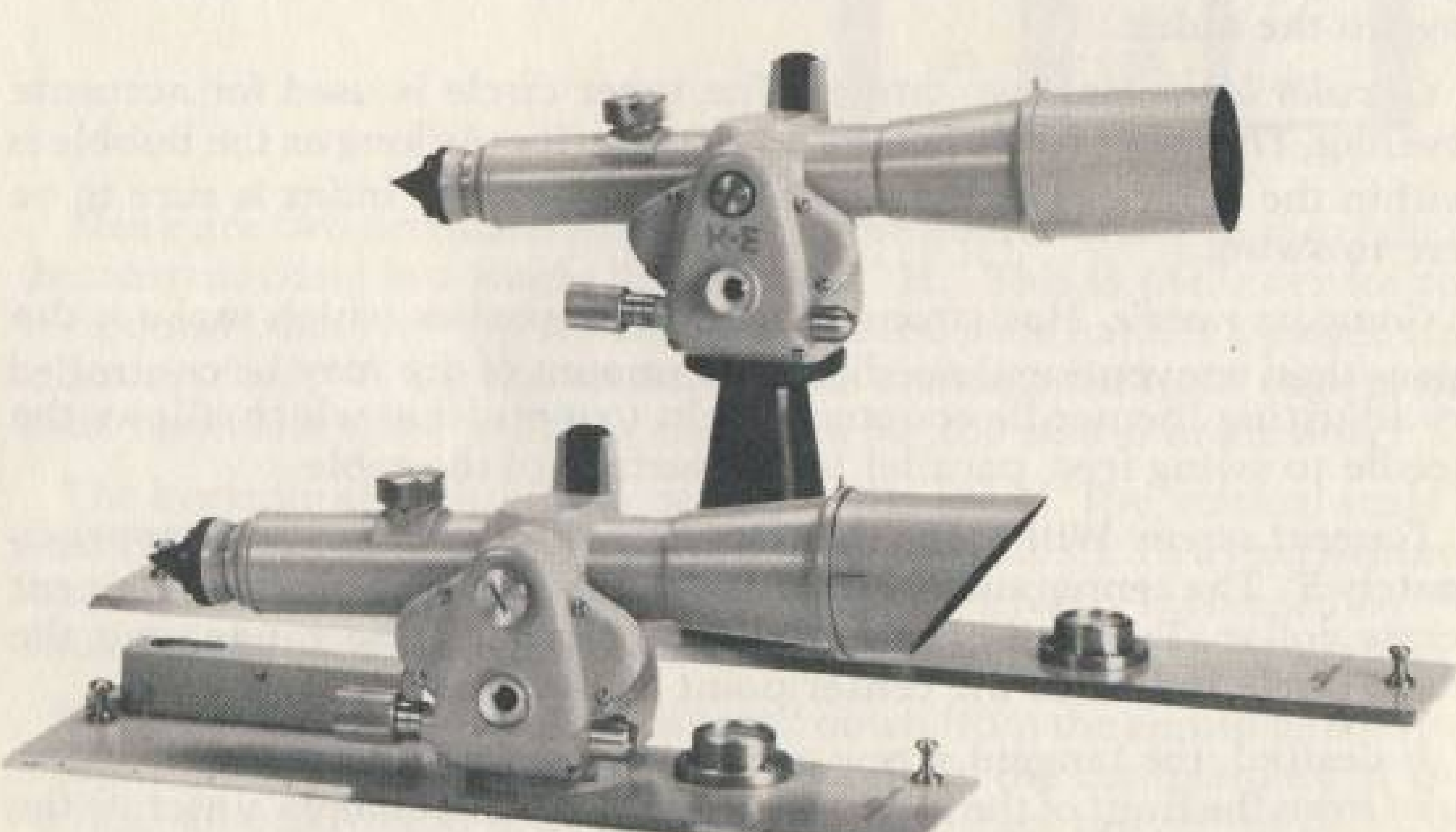
INTRODUCTION

Plane Table Alidades provide the best means of mapping small areas and of completing details between survey control points. They are also important in areas that aerial photographs will not detect objects because of size or forest cover.

Plane table mapping has three important advantages over other types of ground mapping:

1. All direction measurements are instantly recorded on the map. The intervening processes of recording field notes and plotting them are eliminated.
2. The map is constructed at once, in the field, so that no permanent records are necessary other than the map itself.
3. The topographer sees the ground that he is mapping. He can draw a more perfect representation of the ground and yet use fewer field observations.

In cooperation with the U.S. Geological Survey, K&E has developed the K&E Paragon® Self-Indexing Alidades.



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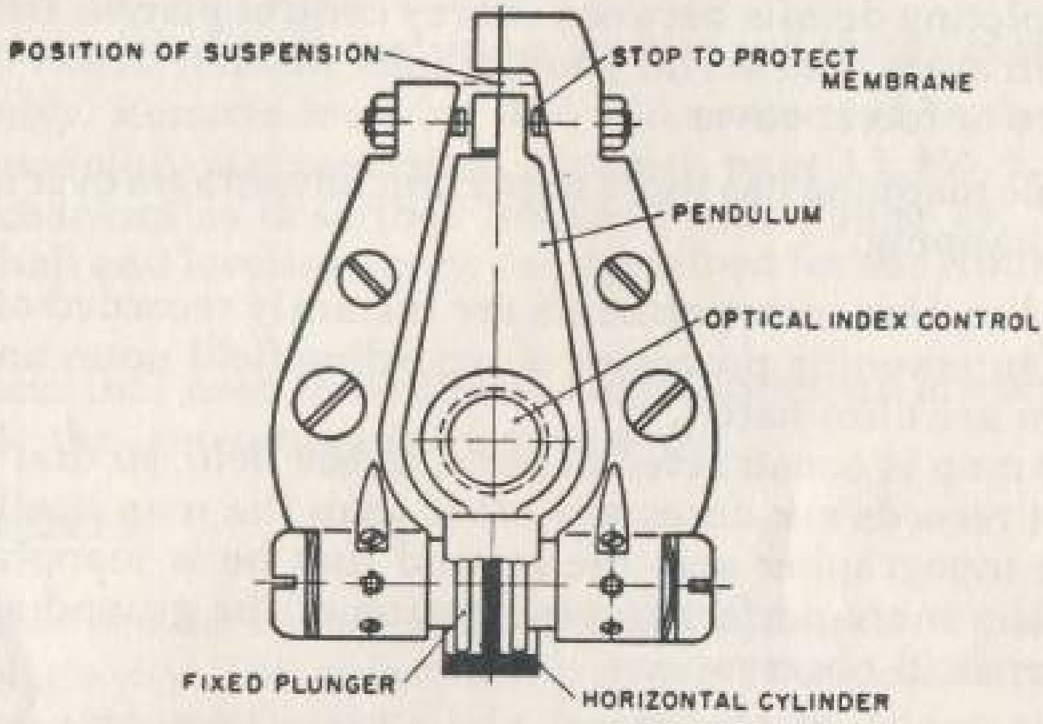
The self-indexing alidade has a pendulum device which automatically corrects for slight residual tilts of the plane table. The scales are read optically and the instrument gives results that are approximately four times as accurate as those attained with conventional alidades.



Pendulum Damping Mechanism

FEATURES

Pendulum. Suspended by a membrane; its swing is air damped. An optical part mounted in the pendulum brings the correct scale readings to the index.

Circular level. Has two circles. The inner circle is used for accurate leveling. The outer circle acts as a safety device. As long as the bubble is within the outer circle, the pendulum that sets the index is sure to be free to swing.

Compass needle. Has strong magnetic properties which make it dip more than conventional needles. The amount of dip may be controlled by adjusting the needle counter weight to a position which allows the needle to swing free, parallel to the surface of the table.

Tangent screw. Will move the telescope through a range of approximately 5°. The center and limits of the range are marked on the tangent screw collar. Two red circles indicate limits of the range, and the black circle indicates the center point of the range.

If desired, the tangent screw can be reversed so that it may be operated from the front of the instrument. To make this change, unscrew the cap mounted on the standard in line with the tangent screw. Remove spring and plunger, if they did not come out with cap. Unscrew the tangent screw assembly. Replace the collar and the tangent screw before replacing the spring, plunger and cap.

OPERATION

Aim the telescope vertically. There is no clamp to hold the telescope in position. The slope of the telescope is retained by a special spring-friction device. Aim the telescope by hand and make the final adjustment with the tangent screw. The open sights on the top of the telescope facilitate aiming.

The degree of friction can be regulated by turning the large screw at the right-hand end of the elevation axis. A coin will fit in the slot on the screw.

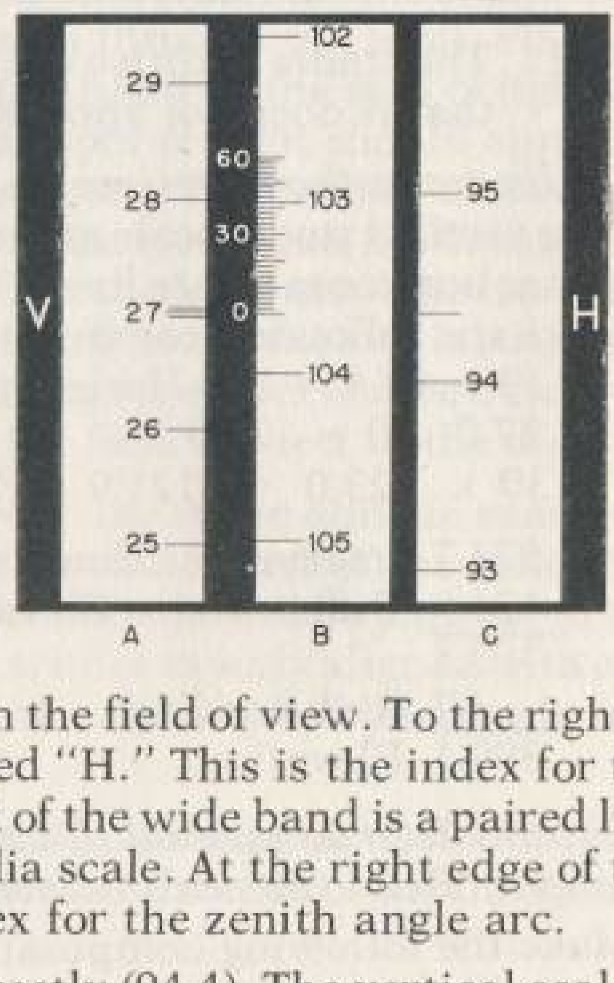
Reading the scale. As soon as the instrument is aimed, the arcs can be read. No index level need be set, as the automatic indexing feature takes over. The arcs are read at the eyepiece located at the top of the left-hand standard.

View through Scale-Reading Eyepiece

A. Vertical Scale reads 27.0

B. Elevation Angle Scale reads 103° 42′

C. Horizontal Multiplier reads 94.4



There are two vertical black bands in the field of view. To the right of the narrow band is a single line marked "H." This is the index for the horizontal stadia multiplier. At the left of the wide band is a paired line index marked "V" for the vertical stadia scale. At the right edge of the wide band is a scale which is the index for the zenith angle arc.

The horizontal multiplier is read directly (94.4). The vertical scale is read (27.0) and 50 is subtracted from it giving (–23.0). To avoid a minus reading the vertical multiplier values are arbitrarily increased by 50. Thus, 50 must be subtracted from each reading to obtain the true value.

Zenith distance. The angle measured down from the zenith to the line of sight is the zenith distance. It is, therefore, the complement of the vertical angle. To find the vertical angle, subtract the zenith distance from 90°. When a minus sign results, the vertical angle is negative.

Reading the zenith distance. First read the number which is adjacent to the small scale (103). This gives the number of degrees. The small scale reads in minutes at intervals of two minutes. Read this scale at the point where the degree mark coincides. In this example the reading is 42. The complete reading is 103°42′. The vertical angle is then computed:

$$\begin{array}{rr} & 90°00' \\ \text{zenith distance} & \underline{-103°42'} \\ \text{vertical angle} & -13°42' \end{array}$$

NOTE: While reading the arcs, be careful not to disturb the plane table. If it is deflected, the slope of the line of sight will be changed and thus move above or below the point of aim. The automatic index will then give the reading for this new slope and not the slope desired.

Making an Observation

Two methods are recommended for making observations, the Stadia Arc Method and the Zenith Angle Method. In both examples assume that the elevation of the instrument is 525.7 feet above sea level.

NOTE: The stadia additive constant is negligible in this instrument so that it does not appear in the computations.

Stadia arc method. Determine the stadia intercept (5.30 for example). Set the vertical stadia scale at the nearest exact value 27.0. Read the rod at center horizontal cross line 4.7. Read the horizontal multiplier 94.4.

Make the following computations:

5.30 × 94.4 = 500 Horizontal Distance
27.0 – 50 = –23.0
5.30 × –23.0 = –121.9 Difference in Elevation

525.7	Instrument Elevation
–121.9	Difference in Elevation
403.8	
–4.7	Rod Reading
399.1	Elevation

Zenith distance method. Determine the stadia intercept (5.30 for example). Read the zenith distance 103°42′ and the rod 4.7.

Make the following computations on the stadia slide rule:

$$\begin{array}{r} 90°00' \\ \underline{-103°42'} \\ -13°42' \end{array}$$

Set the slide index at 530
Set the indicator at 13°42′ for H and read 500
Set the indicator at 13°42′ for V and read 121.9
Compute the elevation as before

It may be convenient to make up a table of vertical angles equivalent to zenith distances from 80° to 90°. Most plus vertical angles fall within this range. Values of minus vertical angles are merely the zenith distance minus 90°.

FIELD ADJUSTMENTS

1. *Object.* To make the zenith distance read 90° when the line of sight is horizontal.

Two methods are recommended, the collimator method and the peg method. The collimator method is the better of the two but it requires a level in good adjustment.

The collimator method. Set up the alidade on a plane table and set up a level instrument in good adjustment as close to it as possible. Choose a location so a well illuminated background is behind the level. Regulate the height of the level so that the two instruments are at very nearly the same elevation. Focus the level on some point 800 feet or more distant. Without changing the focus, aim it approximately at the center of the plane table and carefully center the spirit level.

Stand on the opposite side of the plane table from the level and move the eye until a round spot of light is seen through the level. Place the alidade telescope barrel on the line established by the spot of light and pointed toward the level telescope. The spot of light should appear in the alidade telescope. It will look like a very hazy white circle if the alidade is not in focus or, if the alidade is nearly in focus, the background *seen through the level* may appear. Regulate the focus until the cross lines of the level are seen, and carefully focus on them. If the two instruments are properly in line, the field of view through the level will be a clear-cut circle approximately in the center of the field of view of the alidade.

Test. Bring the central horizontal cross line of the alidade exactly on the central horizontal cross line of the level. Because of the collimator action of the level, the line of sight of the alidade will be parallel to that of the level even if the two instruments are not exactly aligned with each other. Accordingly, the line of sight of the alidade will be exactly level and the reading should be exactly 90°.

Adjustment. To adjust the reading, loosen the capstan lock nut just to the right of the tangent screw mechanism at the rear of the instrument and regulate the capstan screw.

Peg method. Select two supports for the alidade about 200 feet apart and at nearly the same elevation. Two plane tables are excellent. Construct a small target that will stand on the plane table at exactly the same height as the center of the friction adjusting screw on the left end of the telescope axle.

Test. Level the instrument on one support and place the target on the other. Aim at the target and record the zenith distance reading. Mark the horizontal position of the center of the instrument and the position of the target and interchange them. Aim at the target with this arrangement and record the second zenith distance. The average of the two zenith distances should be exactly 90°.

Adjustment. To adjust the reading, loosen the capstan lock nut just to the right of the tangent screw mechanism at the rear of the instrument and regulate the capstan screw. If the average of the readings is not 90°, change the reading at the second position in a direction toward 90° by an amount equal to the error of the average.

	Example 1	Example 2
First reading	88°20′	92°32′
Second reading	91°48′	87°26′
Sum	180°08′	179°58′
Average	90°04′	89°59′
Error 04′		*Error 01′*
2nd Reading 91°48′		*2nd Reading 87°26′*
Set at	91°44′	87°27′

SHOP ADJUSTMENTS

Disassembly

Object. To align the line of sight with the edge of the blade. This adjustment is not necessary unless the blade has been removed or when two or more alidades are to be used on the same manuscript or map.

Test. Place the instrument on a plane table and carefully level the plane table. Make up a target with two short vertical lines 1½ inch apart, designed so that the right-hand line can be seen by the naked eye and the other through the telescope. Mount the target so that it is nearly in line with the surface of the plane table and at least 25 feet distant. Aim the line of sight at the left-hand target. Eye along the right-hand edge of the blade. The right-hand target should be on line.

If this test is to be made several times, it is best to set up a permanent jig that will hold the blade in a definite position. A permanent mark can then be established on which the line of sight should fall.

Adjustment. Loosen the four screws 3 underneath the blade that screw up into the pedestal. The holes in the blade are oversize so that the pedestal can be rotated through a small angle. Adjust as required and tighten the screws.

Remove the blade. Unscrew the four screws 3 underneath the blade that are threaded upward into the pedestal.

Remove the standards from the pedestal. At the top of the pedestal is cemented a large rubber washer 6. Work this loose and move it down the pedestal. Four Allen-head screws 5 will be exposed which thread upward into the base of the standards. Remove these screws.

Remove the telescope eyepiece for cleaning. Unscrew and remove the knurled screw ring 529 at the eyepiece end next to the telescope barrel. Rotate the eyepiece counter-clockwise until a set screw can be seen in the side of the eyepiece sleeve. Remove this screw 528. This screw serves as a pawl which engages the spiral focusing groove. Slide out the assembly. In reassembly, this pawl must be engaged in the groove.

Remove the focusing knob and pinion. This is mounted on the top of the telescope. Loosen the set screw 519 on the right side of the focusing-knob-pinion housing. Pull out the knob 516. To replace the pinion, carefully push it into the housing, rotating the knob back and forth slightly so that the teeth of the pinion will engage in the rack. Hold the knob so that the set screw will engage in the hole. Tighten the set screw.

Remove the scale-reading eyepiece. This is the black knurled cylinder 49 at the top of the left hand standard. Loosen the set screws 55 at the side of the eyepiece. Pull out the eyepiece.

Optical System

The adjustment of the optical system is a delicate and painstaking operation. Since it requires the removal of certain cover plates which expose sensitive parts, it must be performed in a dust-free room. Under no circumstances should the main left-hand cover plate be removed. This exposes the pendulum mechanism. The pendulum mechanism cannot be disassembled or repaired except by a specially trained instrument repairman. Keuffel & Esser Company has instrument repairmen trained for this work.

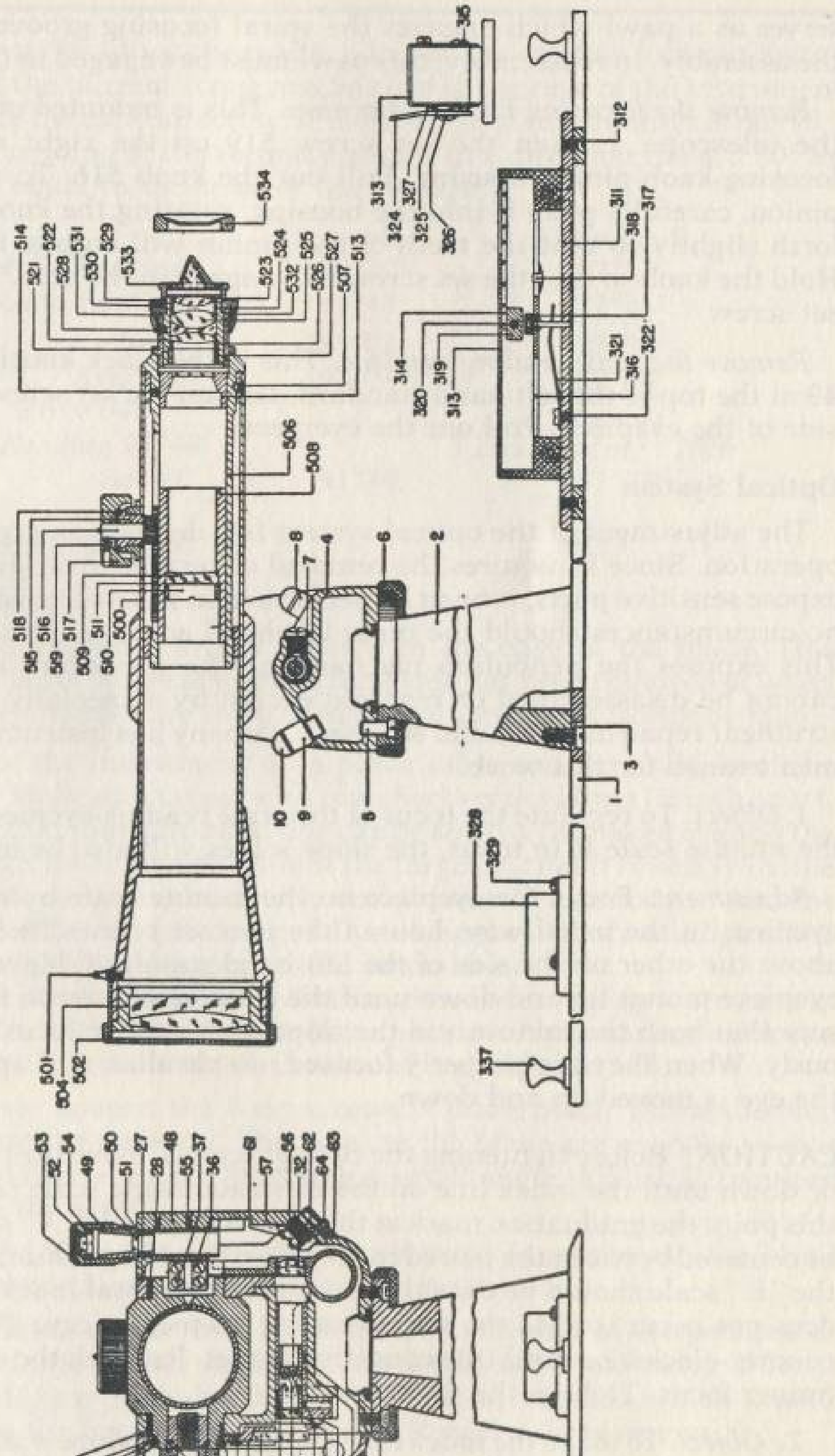
1. *Object.* To regulate the focus of the scale reading eyepiece so, when the minute scale is in focus, the slope scales will also be in focus.

Adjustment. Focus the eyepiece on the minute scale by rotating the eyepiece in the usual way. Loosen the two set screws 55 located one above the other on the side of the left-hand standard. Move the whole eyepiece mount up and down until the slope scales are in focus. Make sure that both the minute and the slope scales are in focus simultaneously. When they are properly focused, no parallax will appear when the eye is moved up and down.

CAUTION: Before tightening the two set screws, move the telescope up or down until the index line on the elevation angle scale reads 90°. At this point the graduation mark at the 50 reading on the "V" scale should be centered between the paired index lines. The 100 graduation mark on the "H" scale should be directly under the horizontal index line. If this does not occur, rotate the scale reading eyepiece sleeve clockwise or counter-clockwise until this condition is met. Recheck the eyepiece for proper focus. Tighten the set screws.

2. *Object.* To make the index lines parallel to the slope-scale markings and to center them so that they extend across the markings.

Adjustment. Follow the same procedure as noted in the "Caution" portion above.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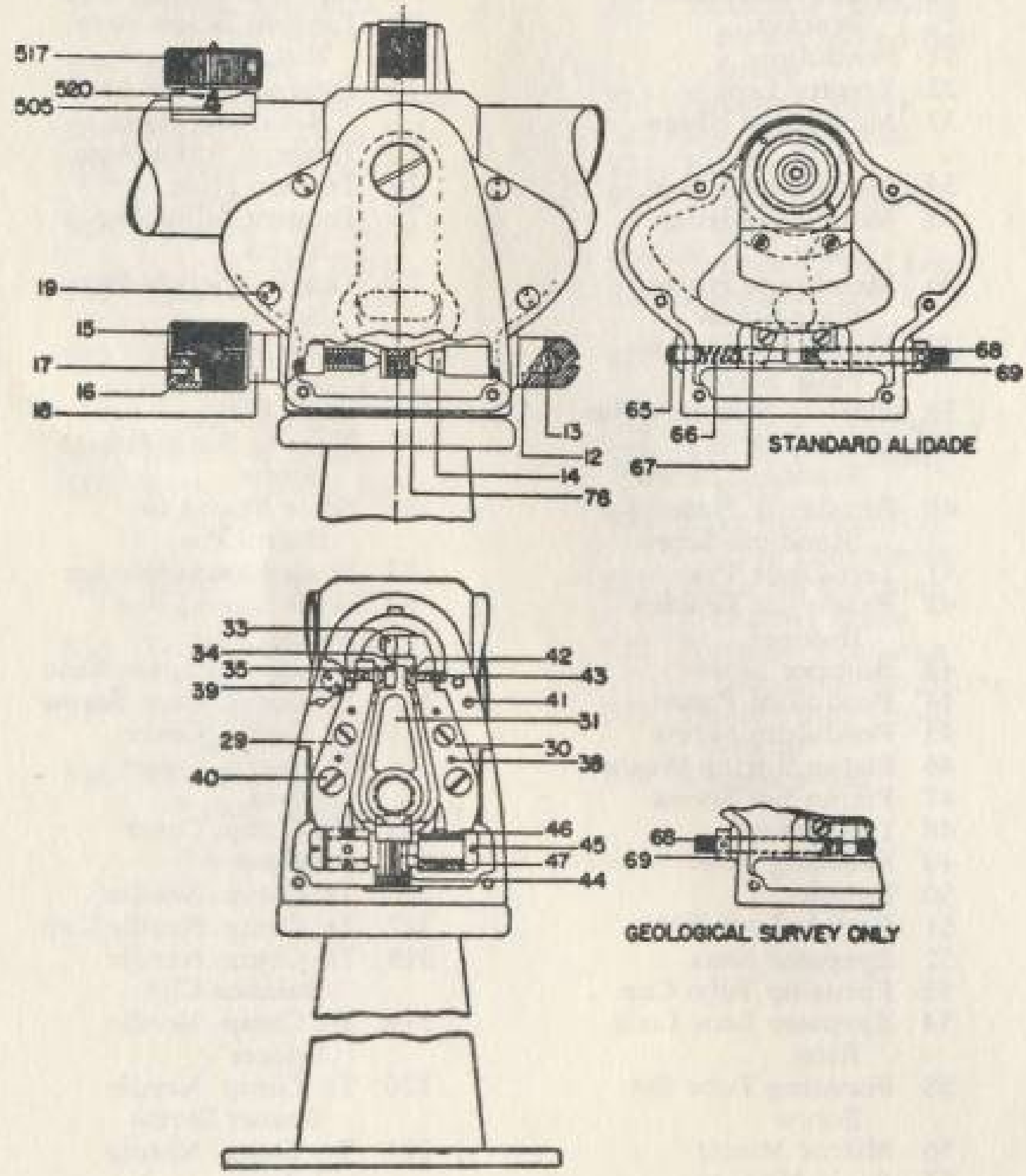


5226-1 Base Plate
2 Pedestal
3 Base to Pedestal Screw
4 Standard
5 Standard Mounting Screw
6 Protective Housing
7 Opening Adjustment Screw
8 Right Bumper Mount
9 Left Bumper Mount
10 Telescope Bumper
11 Right Cover
12 Tangent Screw Plunger Bushing
13 Tangent Screw Spring
14 Tangent Screw Spring Plunger
15 Tangent Screw Cap
16 Tangent Screw
17 Tangent Screw Cap Screw
18 Tangent Screw Bushing
19 Right & Left Cover to Standard Screw
20 Regulator Lens Mount Tube
21 Regulator Lens
22 Regulator Lens Mount
23 Regulator Lens Mount
24 Regulator Tube Plate
25 Regulator Tube Plate Screw
26 Regulator Lens Mount Screw
27 Standard Plate

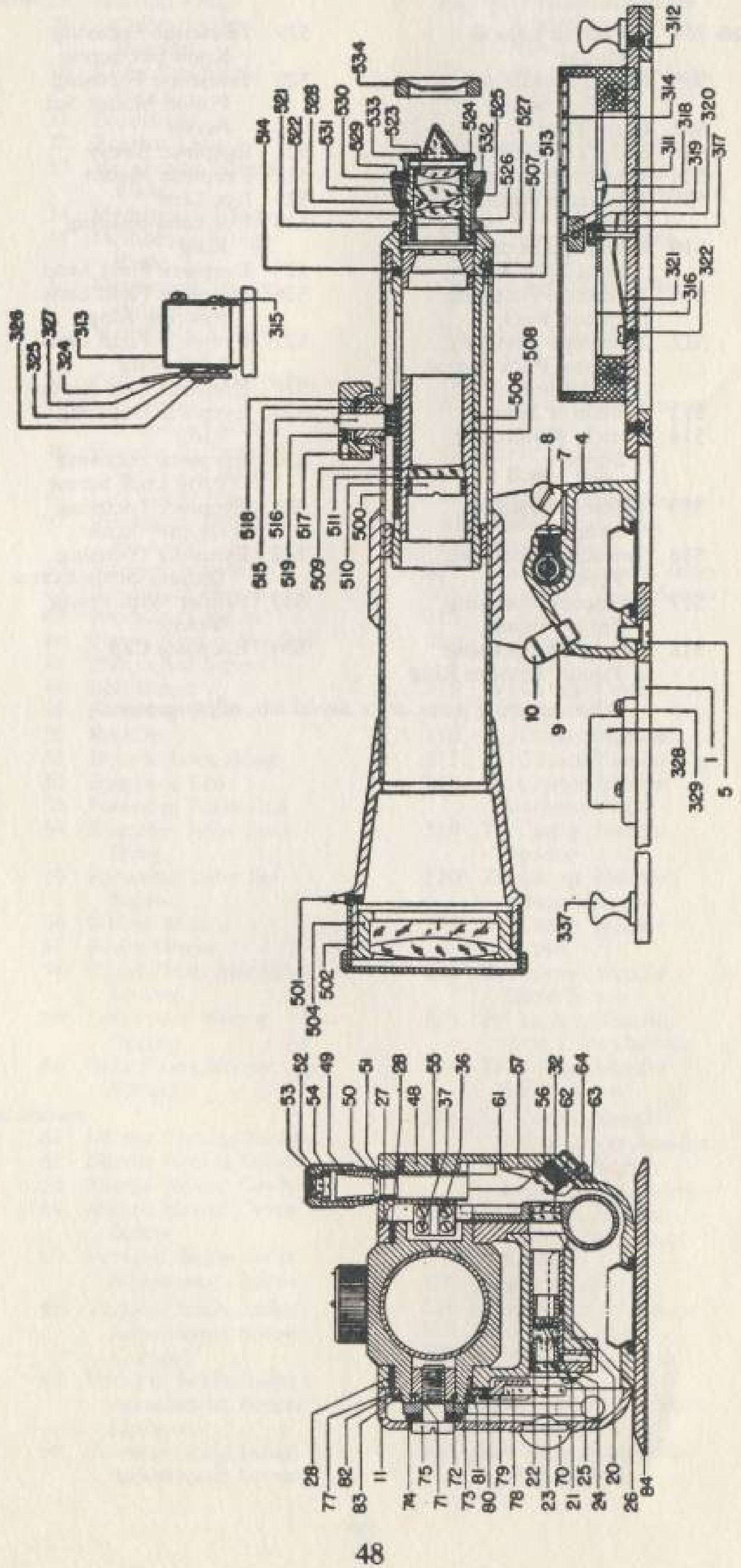
5226- 28 Friction Plug
29 Left Pendulum Bracket
30 Right Pendulum Bracket
31 Pendulum
32 Erector Lens
33 Membrane Hinge Plate
34 Membrane Hinge
35 Membrane Hinge Plate
36 Membrane Hinge Plate Screw
37 Membrane Hinge Plate Screw
38 Plate to Standard Pin
39 Left Cover to Standard Screw
40 Bracket & Plate to Standard Screw
41 Left Cover Pin
42 Pendulum Bracket Bumper
43 Bumper Screw
44 Pendulum Piston
45 Pendulum Screw
46 Piston Spring Washer
47 Piston Set Screw
48 Left Cover
49 Focusing Tube
50 Reticle
51 Reticle Lock Ring
52 Eyepiece Lens
53 Focusing Tube Cap
54 Eyepiece Lens Lock Ring
55 Focusing Tube Set Screw
56 Mirror Mount
57 Scale Mirror
58 Right Front Mirror Spring †
59 Left Front Mirror Spring †
60 Side Front Mirror Spring †

† Not shown

61 Mirror Spring Screw
62 Mirror Mount Screw
63 Mirror Mount Cover
64 Mirror Mount Cover Screw
65 Vertical Scale Index Adjustment Screw
66 Vertical Scale Index Adjustment Screw Spring
67 Vertical Scale Index Adjustment Screw Plunger
68 Vertical Scale Index Adjustment Screw
69 Vertical Scale Index Adjustment Screw Nut
70 Light Gathering Lens
71 Tangent Screw Arm Nut
72 Tangent Screw Arm Retaining Ring
73 Tangent Screw Arm
74 Tension Plate
75 Tangent Adjusting Screw
76 Tangent Screw Arm Screw
77 Scale Mount
78 Scale
79 Scale Plate
80 Plate to Scale Mount Screw
81 Scale Mount to Barrel Pin
82 Scale Mount Washer
83 Scale Mount Nut
84 Button Plug
311 Trough Compass Base
312 Tr. Comp. Base Screw
313 Tr. Comp. Cover
314 Tr. Comp. Cover Glass
315 Tr. Comp. Cover Screw
316 Tr. Comp. Needle
317 Tr. Comp. Needle Cap
318 Tr. Comp. Needle Balance Clip
319 Tr. Comp. Needle Spacer
320 Tr. Comp. Needle Spacer Screw
321 Tr. Comp. Needle Lifter
322 Tr. Comp. Needle Lifter Screw
323 Tr. Comp. Needle Cam (Not shown)
324 Tr. Comp. Needle Lifter Lever
325 Tr. Comp. Needle Lifter Lever Washer
326 Tr. Comp. Needle Lifter Lever Screw
327 Tr. Comp. Needle Lifter Lever Stop Screw
328 Circular Level
329 Circular Level Screw
337 Base Plate Knob
500 Telescope Barrel & Axle
501 Telescope Front Sight
502 Telescope Cap
503 Telescope Sunshade (Not Shown)

5226- 504 Objective Lens & Mount
505 Pinion Saddle to Barrel Screw
506 Body Tube
507 Body Tube Set Screw
508 Telescope Draw Tube
509 Telescope Focusing Lens
510 Telescope Focusing Lens Lock Ring
511 Telescope Focusing Pinion Rack
512 Telescope Focusing Pinion Rack Screw (Not Shown)
513 Reticle & Mount
514 Reticle Mount Set Screw
515 Telescope Pinion Mount
516 Telescope Focusing Pinion
517 Telescope Focusing Pinion Head
518 Telescope Focusing Pinion Tension Ring
519 Telescope Focusing Knob Set Screw
520 Telescope Focusing Pinion Mount Set Screw
521 Eyepiece Sleeve
522 Eyepiece Mount
523 Eye Lens
524 Eye Lens Spacing Ring
525 Eyepiece Field Lens
526 Eyepiece Field Lens Spacing Ring
527 Eyepiece Field Lens Lock Ring
528 Eyepiece Cam Screw
529 Eyepiece Focusing Ring
530 Eyepiece Focusing Ring Lock Screw
531 Eyepiece Focusing Diopter Scale
532 Eyepiece Focusing Diopter Scale Screw
533 Holder With Prism Mount
534 Eyepiece Cap

When ordering parts, state Serial No. of instrument.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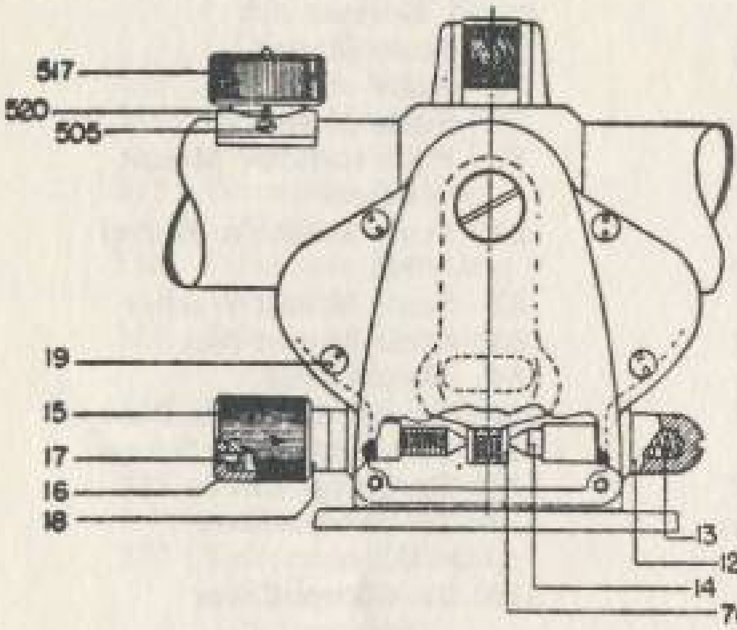
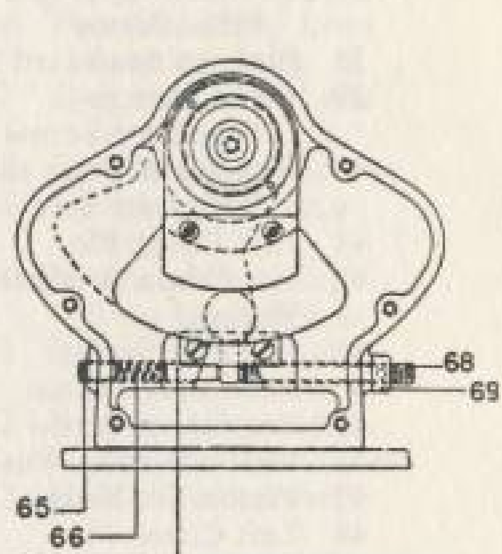
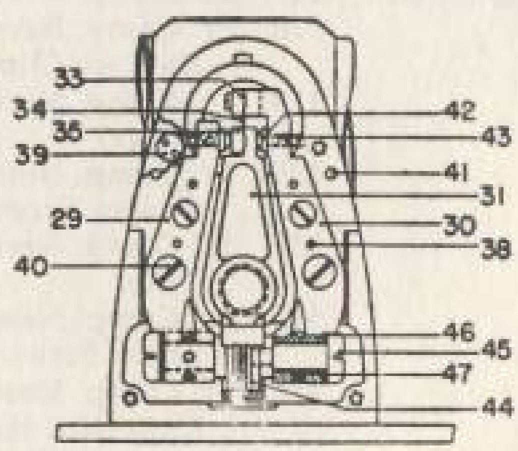
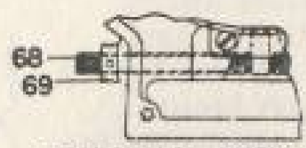




STANDARD ALIDADE





GEOLOGICAL SURVEY ONLY

5231-1 Base Plate
4 Standard
5 Standard Mounting Screw
7 Opening Adjustment Screw
8 Right Bumper Mount
9 Left Bumper Mount
10 Telescope Bumper
11 Right Cover
12 Tangent Screw Plunger Bushing
13 Tangent Screw Spring
14 Tangent Screw Spring Plunger
15 Tangent Screw Cap
16 Tangent Screw
17 Tangent Screw Cap Screw
18 Tangent Screw Bushing
19 Right & Left Cover to Standard Screw
20 Regulator Lens Mount Tube
21 Regulator Lens
22 Regulator Lens Mount
23 Regulator Lens Mount
24 Regulator Tube Plate
25 Regulator Tube Plate Screw
26 Regulator Lens Mount Screw
27 Standard Plate
28 Friction Plug
29 Left Pendulum Bracket
30 Right Pendulum Bracket
31 Pendulum
32 Erector Lens
33 Membrane Hinge Plate
34 Membrane Hinge

5231-35 Membrane Hinge Plate
36 Membrane Hinge Plate Screw
37 Membrane Hinge Plate Screw
38 Plate to Standard Pin
39 Left Cover to Standard Screw
40 Bracket & Plate to Standard Screw
41 Left Cover Pin
42 Pendulum Bracket Bumper
43 Bumper Screw
44 Pendulum Piston
45 Pendulum Screw
46 Piston Spring Washer
47 Piston Set Screw
48 Left Cover
49 Focusing Tube
50 Reticle
51 Reticle Lock Ring
52 Eyepiece Lens
53 Focusing Tube Cap
54 Eyepiece Lens Lock Ring
55 Focusing Tube Set Screw
56 Mirror Mount
57 Scale Mirror
58 Right Front Mirror Spring †
59 Left Front Mirror Spring †
60 Side Front Mirror Spring †

† Not shown

61 Mirror Spring Screw
62 Mirror Mount Screw
63 Mirror Mount Cover
64 Mirror Mount Cover Screw
65 Vertical Scale Index Adjustment Screw
66 Vertical Scale Index Adjustment Screw Spring
67 Vertical Scale Index Adjustment Screw Plunger
68 Vertical Scale Index Adjustment Screw
69 Vertical Scale Index Adjustment Screw Nut
70 Light Gathering Lens
71 Tangent Screw Arm Nut
72 Tangent Screw Arm Retaining Ring
73 Tangent Screw Arm
74 Tension Plate
75 Tangent Adjusting Screw
76 Tangent Screw Arm Screw
77 Scale Mount
78 Scale
79 Scale Plate
80 Plate to Scale Mount Screw
81 Scale Mount to Barrel Pin
82 Scale Mount Washer
83 Scale Mount Nut
84 Button Plug
311 Trough Compass Base
312 Tr. Comp. Base Screw
313 Tr. Comp. Cover
314 Tr. Comp. Cover Glass
315 Tr. Comp. Cover Screw
316 Tr. Comp. Needle
317 Tr. Comp. Needle Cap
318 Tr. Comp. Needle Balance Clip
319 Tr. Comp. Needle Spacer
320 Tr. Comp. Needle Spacer Screw
321 Tr. Comp. Needle Lifter
322 Tr. Comp. Needle Lifter Screw
323 Tr. Comp. Needle Cam (Not shown)
324 Tr. Comp. Needle Lifter Lever
325 Tr. Comp. Needle Lifter Lever Washer
326 Tr. Comp. Needle Lifter Lever Screw
327 Tr. Comp. Needle Lifter Lever Stop Screw
328 Circular Level
329 Circular Level Screw
337 Base Plate Knob
500 Telescope Barrel & Axle
501 Telescope Front Sight
502 Telescope Cap
503 Telescope Sunshade (Not shown)
504 Objective Lens & Mount
505 Pinion Saddle to Barrel Screw
506 Body Tube
507 Body Tube Set Screw
508 Telescope Draw Tube
509 Telescope Focusing Lens

510 Telescope Focusing Lens Lock Ring
511 Telescope Pinion Rack
512 Telescope Focusing Pinion Rack Screw (Not Shown)
513 Reticle & Mount
514 Reticle Mount Set Screw
515 Telescope Pinion Mount
516 Telescope Focusing Pinion
517 Telescope Focusing Pinion Head
518 Telescope Focusing Pinion Tension Ring
519 Telescope Focusing Knob Set Screw
520 Telescope Focusing Pinion Mount Set Screw
521 Eyepiece Sleeve
522 Eyepiece Mount
523 Eye Lens
524 Eye Lens Spacing Ring
525 Eyepiece Field Lens
526 Eyepiece Field Lens Spacing Ring
527 Eyepiece Field Lens Lock Ring
528 Eyepiece Cam Screw
529 Eyepiece Focusing Ring
530 Eyepiece Focusing Ring Lock Screw
531 Eyepiece Focusing Diopter Scale
532 Eyepiece Focusing Diopter Scale Screw
533 Holder With Prism Mount
534 Eyepiece Cap

When ordering parts, state Serial No. of instrument.

3. *Object.* To adjust the elevation angle scale so that it reads 90° when the telescope is level.

Adjustment. Place the alidade on an approximately horizontal surface. Aim the line of sight at a level collimator (a surveying level will serve).

Fine adjustment. Some instruments are equipped with an opposed screw and lock nut located at the lower right end of the standard. In this case, loosen both capstan head lock nuts and regulate both screws simultaneously. If the instrument is not equipped as above, the adjusting screw will be at the objective end of the lower part of the standard. Loosen the lock nut and rotate the screw until the proper adjustment is made.

Coarse adjustment. If the fine adjustment is not sufficient to eliminate the error, proceed as follows:

> On the left-hand main cover plate is a small cover plate about ½ inch long which is held in place by a screw. Remove this plate. Five screws are underneath it. The three small screws push and the two large screws pull on the support of a small mirror. By tightening and loosening these screws, the required adjustment is made.
>
> The two small screws on the right-hand side, when turned in opposite directions to each other, move the index line to the left or right, depending upon the sequence used in turning. The small left-hand screws, operated in conjunction with the larger left-hand center screw, move it up or down.
>
> When the adjustment is completed, all screws should be firm.

4. *Object.* A. To regulate the apparent swing of the pendulum so that it gives the correct reading when the blade is tilted to any angle within the pendulum's range of correction.

B. To regulate the apparent length of the slope scale.

Preparation. Remove the spring and plunger that oppose the main tangent screw. To do this, unscrew the cap mounted on the standard in line with the tangent screw. A coin or screw driver may be used. A spring and plunger should come out with the cap. If they do not, turn the instrument objective end down and tip it until they come out.

Grind out the center of the blade of a small screw driver so that a V-shaped notch is formed which will fit the screws. Remove the six screws located around the perimeter of the cover plate on the right-hand standard. Lift off the plate.

Unscrew the large slope-friction adjusting screw at the right-hand end of the elevation axis. Remove this screw and with it both the rubber and brass washers. Lift off the tangent screw arm.

With a spanner wrench, unscrew and remove the lock ring and the washer which hold the scale mount.

Lift off the scale mount carefully. Note the pin which holds the mount in the proper position. The pin may come out with the scale mount, if it does not, let it remain. If it does come out, in assembly the pin must be replaced in the same hole.

A small lever will be exposed. This lever is actuated either by two opposed screws or by a single screw and an opposed spring and plunger. Remove the spring and plunger or the opposing screw. This is done by loosening the capstan head lock nut and unscrewing the Allen-head screw located at the base of the standard on the eyepiece side.

In the same manner, back off the other screw located at the base of the standards on the objective side. Remove the two screws that hold a small plate which retains the lever.

The lever is part of and at the end of a horizontal cylinder which is a mount for two small lenses. Carefully extract the lens mount. Loosen two set screws in the lens mount. One is threaded into the side of the cylinder and the other is parallel to it and threaded into the lower end of the lever. Tighten the set screws until they provide a slight friction which will tend to hold in position the two lens cells within the cylinder.

Push the lens cell nearest the arc about 1/32 inch towards the arc.

Completely re-assemble all parts including the cover plate, tangent-screw and opposing-spring assembly.

Test. A. Aim the line of sight into a level collimator. A surveying level will serve. Note the reading. Adjust the support of the blade until the zenith distance reads approximately 25 minutes. Re-aim the line of sight at the collimator. The zenith distance reading should be the same as before. If it is not, remove the cover plate and follow the adjustment procedure below.

Adjustment. Remove the cover plate, move the lens mount nearest the arc to the left if the angle reading is too large and vice-versa. Replace the cover plate. Check by tilting the blade about 25 minutes in the opposite direction.

Test. B. With the tangent screw, aim the telescope so that the zero end of the scale coincides with a degree mark. The 60 minute mark should coincide with the next smaller degree mark.

Adjustment. Remove the cover screw at the right of the center in the base of the standards on the eyepiece side.

One small lens cell will be exposed which contains the lens to be adjusted. Around the cell is a groove. The cell can be moved left or right by engaging a small screw driver in the groove.

Move the cell to the left or right until the vernier is the correct length.

Note whether or not the focus of the scale is still clear when observed through the eyepiece. If any parallax exists, adjust the scale reading eyepiece sleeve up or down until parallax is eliminated.

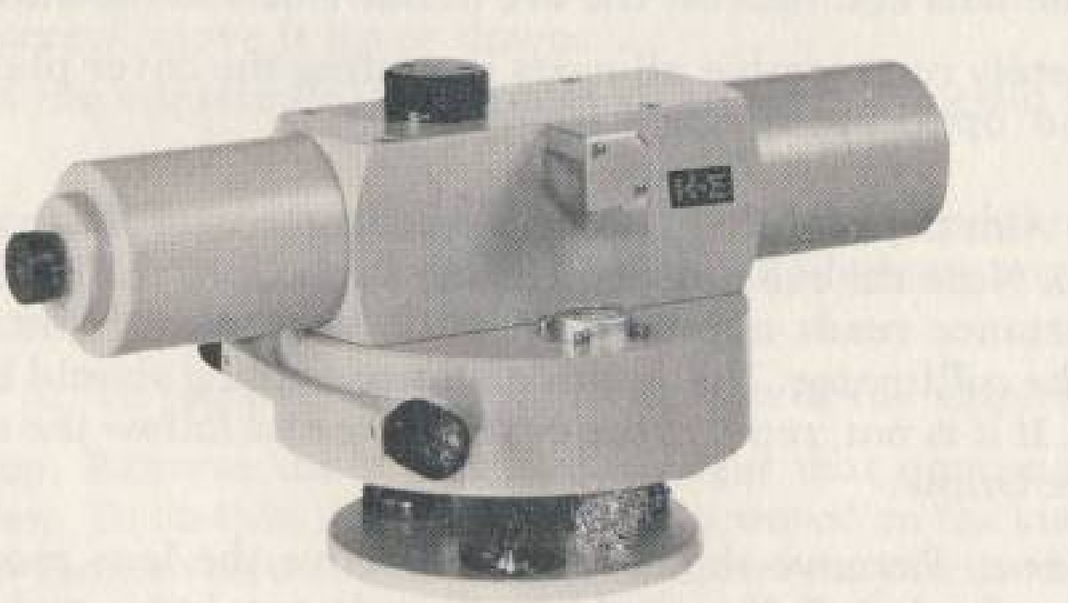
When these adjustments are complete, disassemble, remove the mount that contains the lens cells and tighten the set screws.

Reassemble all parts and recheck all adjustments. Particularly, check the adjustment of the scale reading eyepiece.

SECTION IV — ZEISS SELF LEVELING LEVEL Ni 2

INTRODUCTION

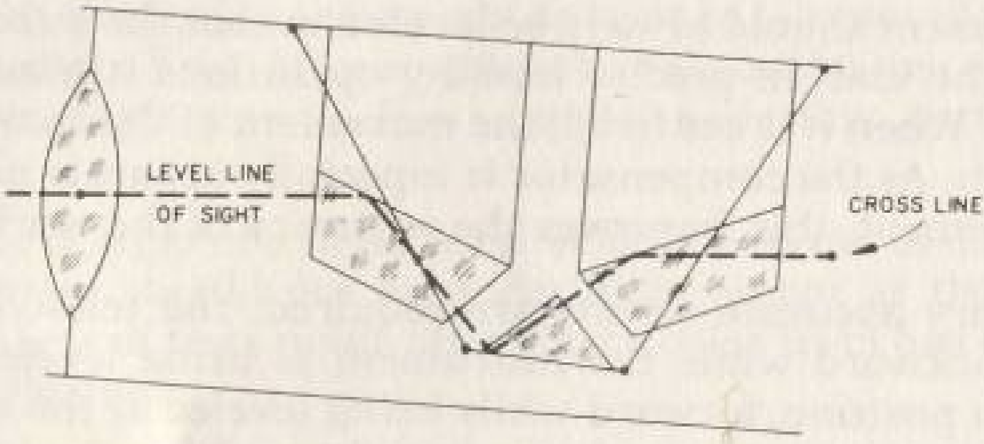
This level is an unparalleled instrument. When it has been leveled by centering the circular level, it holds the line of sight precisely level *automatically*. It gives first-order accuracy and is fast and simple to use. These qualities make it an all-purpose level, which can be used with great advantage for any type of work from cross-sectioning to benchmark leveling. It is faster and more accurate than any of the instruments usually employed.



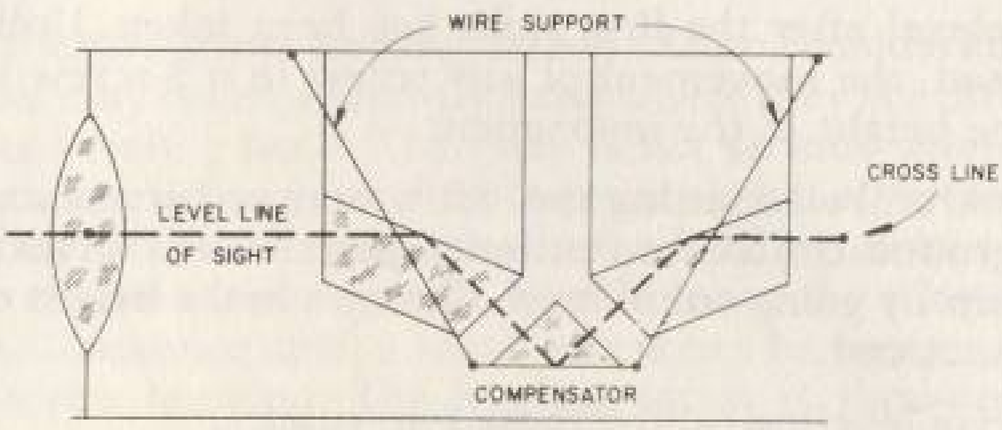
Zeiss Self-Leveling Level (K&E 75 0020)

The schematic line drawing (page 55) shows its operation. When the telescope is tilted, a prism called the *compensator* swings to a position that levels the line of sight. The movement of the prism is air-damped by a disk-like cylinder which moves over a stationary pistion (not shown).

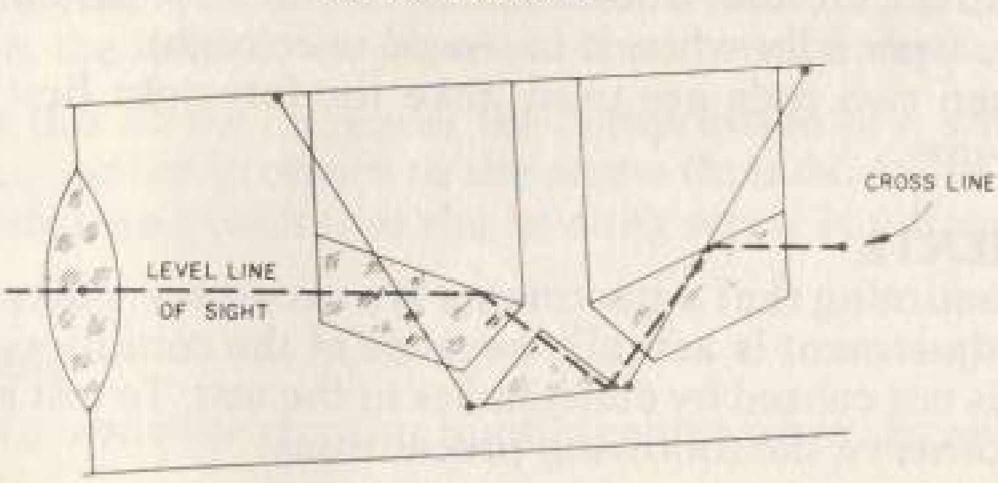
The three leveling screws have a fast pitch for rapid, approximate leveling. There is no azimuth clamp. The azimuth movement of the upper part of the instrument is controlled by an adjustable brake. The exact azimuth desired is set with an endless tangent screw, with two thumb screws, for either hand. The stiffness of the screw can be regulated by turning one thumb screw against the other. The focusing device has a high and low gear. A continuous motion in one direction utilizes the high gear. When the motion is reversed, the low gear operates for a short distance for precise focusing.



WHEN TELESCOPE TILTS UP
COMPENSATOR SWINGS BACKWARD



TELESCOPE HORIZONTAL



WHEN TELESCOPE TILTS DOWN
COMPENSATOR SWINGS FORWARD

The reticle has stub stadia lines placed to give a stadia ratio of 0.3 : 100 for three-wire leveling. Other ratios* are available to order. The minimum focus is 11 feet. A focus reducing lens (75 0210) is available which, when attached, reduces the minimum focus to 5.9 feet.

*Other ratios, 0.6:100 and 1:100.

OPERATION

Open the case, remove the instrument and place it on the tripod. The hold-down screw, attached to the tripod, is threaded into the hole at the base of the instrument. Tighten the screw firmly.

There is a very important rule that must be followed. *Always keep the circular level in perfect adjustment* as described below. Neglect of this rule may cause the compensator to stick or to give inaccurate readings. The instrument should always be leveled so that the bubble is near the center of the vial. In precise leveling operations it must be centered *accurately*. When it is centered, the movement of the compensator is at a minimum. As the compensator is especially accurate near the center of its movement, this improves the accuracy of the work.

When very accurate results are required, the telescope should be pointed backward while the instrument is being leveled at the first instrument position, forward while being leveled at the second instrument position, and so on alternately throughout the level run. This eliminates the accumulation of certain, very small systematic errors.

Never relevel after the first sight has been taken. Unlike a 4-screw leveling head, the movement of any screw in a 3-screw leveling head changes the height of the instrument.

Be very careful when using the instrument on bituminous surfaces or on frozen ground. Unlike conventional spirit levels, it gives no indication of settlement by going out of level. Changes in the height of instrument may go unnoticed.

For precise leveling follow these two rules:

1. Keep the circular bubble centered when the instrument is not in use, especially when it is stored over night.
2. When two rods are used, take the foresight first at alternate set-ups.

ADJUSTMENTS

Before assuming that adjustments are necessary, make sure that any need for adjustment is actually because of the condition of the instrument and is not caused by deficiencies in the test. To test an instrument properly, observe the following precautions:

1. Choose a firm support for the instrument. Usually this can only be found outdoors. The floor of a building, even if concrete, will deflect when the observer moves around the instrument.
2. Choose a cloudy day. If the sun is shining, the work must be carried out in the shade, but in good light.
3. The circular bubble should be centered at once, and then the instrument must accommodate itself to temperature and to

eliminate hysteresis in the pendulum support. This requires 30 minutes to an hour, depending on how great a temperature difference exists between the place of storage and the outdoor temperature.

4. Be on the lookout for *creep* when adjusting the circular level. Creep is caused by tripod settlement, or by the temperature of the instrument changing. This change may happen if the instrument has just been brought outside or is exposed to body or other radiant heat. After setting a bubble or the line of sight, let the instrument stand a few seconds to see that no movement occurs.

5. The line of sight of a Zeiss level seldom gets out of adjustment. Adjustment should not be undertaken except as the result of several sets of tests made after the circular level has been carefully adjusted.

Leveling Screws

Adjust the friction of the leveling screws. After considerable use the leveling screws may become slightly loose where they are threaded into the tribrach or leveling head. This play is not serious when using the instrument as a level. However, if the instrument has a horizontal circle and it is used to measure angles, play in the leveling screws will affect the accuracy of this measurement. To eliminate the play, turn each leveling screw clockwise until a small screw can be seen on the side of the leveling screw bushing. The leveling screw is threaded into the bushing. The screw is located in that portion of the bushing which is toward the vertical center line of the instrument. It can be seen by looking across the hold down plate outward toward the bushing.

Tightening this screw increases the compression of a small spring, which in turn, applies pressure to the screw threads. Avoid tightening the screw to such an extent that the leveling screw is difficult to turn.

Circular Bubble

1. *Object.* To make the circular bubble center when the azimuth axis is vertical.

The accuracy of the instrument is considerably increased when the azimuth axis is as nearly vertical as it is possible to set it with the circular bubble. The compensator mechanism is designed so that the compensator is at the center of its movement when the azimuth axis is vertical. The accuracy with which the compensator corrects for the residual tilt of the telescope is greatest when the compensator is at its center of movement.

Test. Turn the telescope in azimuth until it is parallel with a pair of leveling screws. Center the bubble precisely in the ring with the leveling screws. Turn the telescope 180° in azimuth until it is parallel with the same pair of leveling screws. The bubble should return to center. If it does not, adjustment is required.

Adjustment. In the circular level mount, on the lastest models, there are four slotted-capstan head adjusting screws. The outer edge of the circular level mount is a spherical surface, and is precisely fitted in a recess in the box housing. With a screwdriver or adjusting pin loosen or moderately tighten all four screws until they are seated. Repeat the test as the bubble may be moved further out of adjustment.

If the bubble fails to center, bring it halfway toward the center with the leveling screws. To bring it the rest of the way, loosen the slotted-capstan head screw that lies in the direction of desired bubble movement. Tighten the opposite screw until the bubble is in line with the other two adjusting screws. A final adjustment of these two adjusting screws should then bring the bubble to the center. Turn the telescope 180° in azimuth until it is parallel to the same pair of leveling screws. If the bubble fails to center, repeat the adjustment.

When the adjustment is complete all of the screws must be firm but not tight. The bubble should remain exactly centered in the ring as the telescope is turned in every direction. If it does not, repeat this adjustment.

On earlier models, it is first necessary to unscrew the lock ring at the base of the observation prism and remove the prism unit. If the instrument is not equipped with an observation prism, unscrew the adjusting-screw-guard ring which surrounds the circular level. This will expose three slotted head adjusting screws. The circular vial is supported by a resilient washer which forces it upward against the screws. With a screw driver loosen or moderately tighten all three screws until they are seated. Repeat the test as the bubble may be moved further out of adjustment.

If the bubble fails to center bring it halfway toward the center with the leveling screws and the balance of the way by tightening the most logical adjusting screws until the bubble is precisely centered. Do not loosen any of them. Turn the telescope 180° in azimuth until it is parallel to the same pair of leveling screws. If the bubble fails to center, repeat the adjustment.

When the adjustment is complete all of the screws must be firm but not tight. The bubble should remain exactly centered in the ring as the telescope is turned in every direction. If it does not, repeat this adjustment.

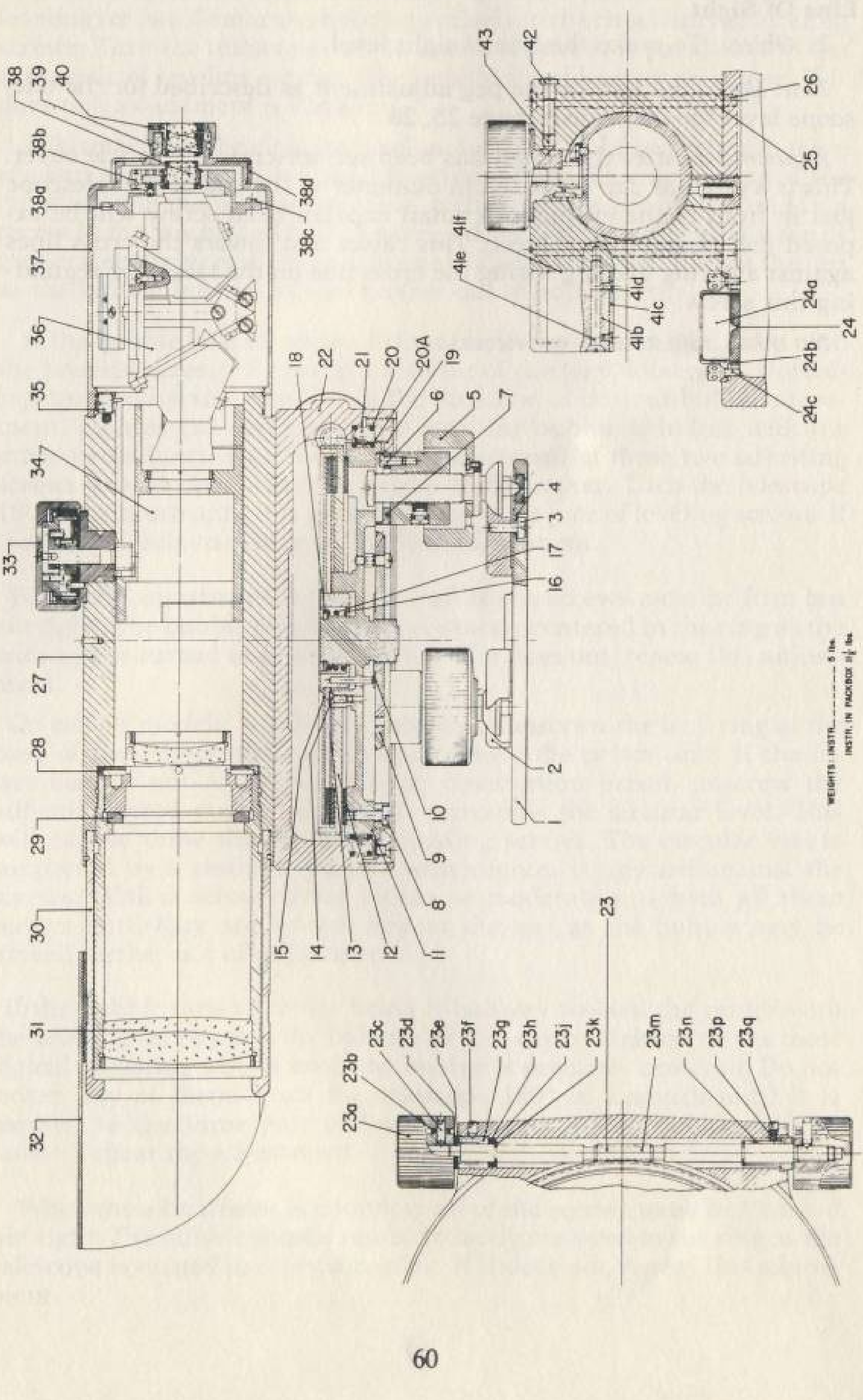
Line Of Sight

2. *Object.* To make the line of sight level.

Test. Make the test for the peg adjustment as described for the telescope level for the transit, page 25, 26.

Adjustment. After the target has been set, unscrew the reticle cover. This is a circular cap 1 5/16 inch in diameter at the end of the telescope just in front of the eyepiece. A small capstan head screw will be exposed just above the eyepiece. This raises and lowers the cross lines against a spring loading. Bring the cross line on the target by regulating this screw.

No other adjustments are necessary.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38a
38b
38c
38d
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41b
41c
41d
41e
41f
42
43

ZEISS NI 2 — COMPONENT PARTS

5223-1 Lower Foot Plate
2 Foot Clamp
3 Foot Clamp Screw
4 Washer
5 Leveling Screw, Complete Assembly
6 Leveling Screw Assembly Fastening Screw
7 Leveling Screw Mounting Ring
8 Mounting Ring Screw
9 Friction Adjusting Disk with Stop Screw
10 Membrane
11 Lower Friction Plate with Cork
12 Worm Gear Plate
13 Membrane
14 Membrane Mounting Screw
15 Membrane with Cork Surface
16 Set Spring Housing
17 Set Spring
18 Set Spring Lock Ring
19 Ball Cage with Shoe & Lock Screw
20 Ball Race, Outer Ring
20a Ball Race, Inner Ring
21 Ball (Mention Quantity Required When Ordering)
22 Box Housing for Telescope
23 Lateral Drive, Complete Assembly
23a Knob
23b Gib Nut
23c Gib Screw
23d Spring Washer
23e Plastic Washer
23f Right Bearing Set Screw
23g Right Bearing
23h Plastic Washer
23j Metal Washer
23k Spring Washer
23m Worm
23n Left Bearing
23p Coil Spring
23q Coil Spring Screw
23s Left Knob Set Screw
24 Circular Vial & Housing Complete Assembly
24a Circular Vial
24b Mount
24c Adjusting Screw
25 Telescope Supporting Disc
26 Telescope Housing Mounting Screw
27 Telescope Housing (furnished only as a Unit with Draw 34)
28 Stadia Ratio Adjusting Ring
29 Stadia Ratio Adjusting Ring
30 Objective Protection Sleeve
31 Objective Unit, Complete Assembly
32 Sunshade
33 Telescope Focusing Pinion Complete Assembly
34 Telescope Draw Complete with Lens (furnished only as a Unit with Telescope Housing 27)
35 Excentric Stop for Draw, Complete
36 Compensator Unit, Complete Assembly
37 Ocular, Complete Assembly
38 Reticle, Complete Assembly
38a Reticle Centering Mount
38b Reticle Adjusting Screw
38c Reticle Centering Mount Screw
38d Reticle Screw Cover
39 Eyepiece Cap with Diopter Scale
40 Eyepiece Cap Lock Screw
41a Prism (not shown)
41b Mount
41c Lock Plate
41d Prism Plate Screw
41e Observation Prism Assembly Mounting Screw
41f Intermediate Disk
42 Cover Screw
43 Focusing Pinion Lock Screw

When ordering parts, state Serial No. of instrument.

SECTION V — SURVEYING DATA

THREE-WIRE LEVELING

For fast, accurate, self-checking benchmark leveling, the three-wire method is outstanding. Both U. S. Geological Survey and the U. S. Coast and Geodetic Survey have found it to be the most economical and the most accurate method developed. In spite of this, the three-wire method is unfamiliar to many engineers.

K&E leveling equipment is designed so this method can be applied to the best advantage whenever desired.

Method. The three-wire method can be applied whenever the reticle of the level has stadia lines. The rod is read at each of the three lines and the average is used for the final result. The bubble is centered before each reading. The half-stadia intervals are compared to check for blunders. Example:

	Reading	
Upper Wire	8.798	
Middle Wire	6.563	2.235 Upper Intercept
Lower Wire	4.332	2.231 Lower Intercept
Sum	19.693	
Average	6.564	

The final rod reading is 6.564 feet. The upper and lower intercepts differ by only 0.004 foot, a normal accidental error, so it is evident that no blunder has been made.

Theory.

1. Tests have shown the levelman can read the rod more accurately than he can set a target.
2. The three readings can be made quickly as the adjustment of the bubble between readings never requires more than a slight movement.
3. The note-keeper can check the intercepts more quickly than the reading can be checked by the rodman.
4. The accuracy is as great as if three lines of levels had been run and the results averaged.
5. Since the stadia intercept is available, the length of each sight is known and the total length of run between benchmarks can be computed. This can be used to compute the accuracy of the work and to adjust a level net.
6. The unbalance between the horizontal lengths of the foresight and the backsight at each instrument position is known at once.

7. When the instrumental error per unit distance is determined by the peg method, the effect of the error can be eliminated, since the residual unbalance between the foresights and the back-sights can be computed.

K&E equipment. To facilitate the three-wire method, K&E furnishes reticles that have stub-stadia lines that are spaced so that the stadia intercept is 0.3 foot at 100 feet, instead of 1.0 foot at 100 feet. The stub-stadia lines are short cross lines that cannot be mistaken for the long central line used for ordinary leveling. Reducing the size of the stadia intercept has two advantages. The lines are brought nearer to the best part of the optics, and there is less chance for the lines of sight to fall above or below the rod when there is considerable difference in height between the instrument and the rod.

The Zeiss Ni2 Self-Leveling Level (75 0020) is exceptionally well adapted to three-wire leveling. It is extremely accurate; no releveling is required between the readings of the three wires. It is regularly equipped with a glass reticle with cross and stub-stadia lines having a stadia intercept of 0.3 per 100.

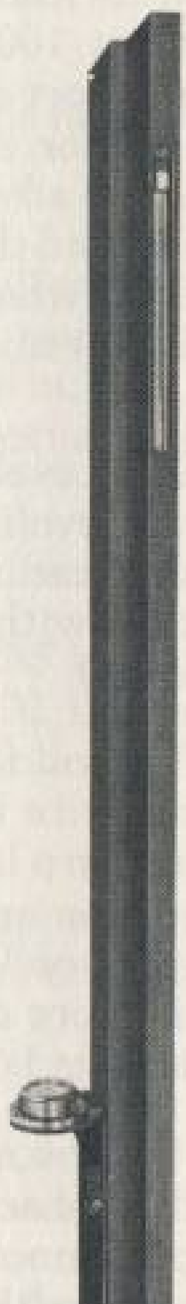
K&E yard rod. This rod (81 0537) is designed for precise benchmark leveling by the three-wire method. It combines all of the features required in a precise rod in a light, easily handled piece of equipment. It is shown in the illustration and described on page 64. Its chief feature is that it is engine divided on LO-VAR® steel to hundredths of a yard. This makes the divisions more clearly visible at greater distances and the accuracy of the readings is increased.

Theory. It is well known that readings on a Philadelphia rod can seldom be repeated more accurately than to 2 or 3 thousandths of a foot. It follows that a rod cannot be read at usual sight distances to better than the nearest thousandth of a yard. On the yard rod, thousandths of a yard are easily read by estimation.

The size of a hundredth of a yard division corresponds closely to the size of the divisions used on the rods of the U. S. Geological Survey and the U. S. Coast and Geodetic Survey. For first order leveling, these agencies use rods divided in centimeters. A hundredth of a yard is very nearly a centimeter.

Advantage. The obvious advantage of the yard rod for three-wire leveling is that the *sum of the three readings gives the rod reading in feet.* Also, when the 0.3 per 100 stadia intercept is used, the length of a sight in feet is found by multiplying the total stadia intercept by 1000. Example:

Front



Back showing
circular level
and thermometer

LOVAR® Precise Rod No. 81 0537

	Reading	
Upper Wire	2.879	
Middle Wire	2.802	
Lower Wire	2.724	
Sum	8.405	Rod reading in feet
Difference Upper & Lower Wire	0.155	
Length of Sight	155 feet	

Description of yard rod. The Yard Rod (81 0537) consists of a T-section mahogany staff 10 feet long with a face 1½ in. wide. It supports, in recessed guides, the LO-VAR® steel engine divided ribbon, graduated to yards, 10ths and 100ths of yards. The lower end of the ribbon is securely attached to the hardened steel shoe and the upper end is held at an established tension by a strong spring. The pattern of the markings is shown in the illustration.

The rod may be supplied with a Circular Rod Level (81 0550) and also a Precise Rod Thermometer (81 0545) which can be mounted in a hole through the rod so that its bulb is in contact with the back of the ribbon.

Two-rod method. To obtain the best speed in precise leveling, two rods should be used. When the observations are completed at any instrument set-up, the rods and the instrument are moved forward simultaneously. Half way between benchmarks, the rods should be interchanged to eliminate the effect of any possible index error. This method should always be used with the self-leveling level in order to take full advantage of the great speed possible with this instrument.

K&E furnishes these rods in pairs in a wooden carrying case, which has space provided for the storage of two rod levels and two thermometers.

Suggested form for field notes. K&E has received many requests for a suggested form for field notes for three-wire leveling. Three forms follow. The first form can be used with an ordinary rod graduated in feet. It shows all of the arithmetic checks that are available when three-wire leveling is used. The second form is similar but applies to the yard rod. The third is a short form for use with the yard rod. Explanations are given with each form. (K&E Field Book 82 0012 or Loose Leaves 82 0267 are easily adapted for recording these notes.)

Suggested Form of Notes for Philadelphia Rod

+ Rod	Stad.	Check	− Rod	Stad.	Check	Elev.	Sta.	Stad
8.266[1]			3.491			98.461	BM 29	
	161[4]			171				
8.105[2]		−.0013[6]	3.320		+.0010	+8.104		+326
	165[5]			168				
7.940[3]		8.1037[7]	3.152		3.3210	106.565	HI	+326
24.311[8]		8.1037[10]	9.963		3.3210	−3.321		−339
0.326[9]	326[11]		0.339	339		103.244	TP 1	− 13[12]
6.574			4.623					
	216			204				
6.358		−.0003	4.419		+.0013	+6.358		+433
	217			200				
6.141		6.3577	4.219		4.4203	109.602	HI	+420
19.073		6.3577	13.261		4.4203	−4.420		−404
.433	433		.404	404		105.182	TP 2	+ 16
6.203			2.819					
	182			188				
6.021		+.0013	2.631		+.0010	+6.022		+300
	178			185				
5.843		6.0223	2.446		2.6320	111.204	HI	+376
18.067		6.0223	7.896		2.6320	−2.632		−373
.360	360		.373	373		108.572	BM 30	+ 3
Sums	1.119	20.4837		1.116	10.3733			

Explanation. This form of notes is arranged to fit a standard field note book. There are six columns for the left-hand page and three columns for the right-hand page. The standard twenty-five lines are used, five lines for each instrument position.

The first three columns apply to the backsights, the next three apply to the foresights and the right-hand page is used to carry the elevations and the cumulative unbalance of the stadia intercepts.

(1), (2), (3) are wire readings.

(4) = (1) − (2), (5) = (2) − (3), (6) = (4 − 5) ÷ 3, (7) = (2) + (6)

(8) = (1) + (2) + (3), (9) = (1) − (3), (10) = (8) ÷ 3, (11) = (4) + (5)

(12) is the cumulative unbalance of the stadia intercepts.

Checks. (7) must equal (10) and (9) must equal (11).

Sums. The sums at the bottom of the page are respectively the sum of the lengths of the foresights (in stadia intercepts), the sum of the foresights, and corresponding values for the backsights. When properly combined, they are used to check the values for the final benchmark, viz:

	Elev.	Stad.
	20.4837	1.119
	− 10.3733	−1.116
	+ 10.1104	+ .003
BM 29	98.4610	0
BM 30	108.5714	+ .003

Suggested Form of Notes for Yard Rod

+ Rod	Stad.	Check	− Rod	Stad.	Check	Elev.	Sta.	Stad.
3.897(1)			0.734			206.481	BM 61	0
	72(4)			76				
3.825(2)		11.475(6)	0.658		1.974	+11.473		+146
	74(5)			77				
3.751(3)		−2(7)	0.581		−1	217.954	HI	+146
11.473(8)		11.473(9)	1.973		1.973	−1.973		−153
.146(10)	146(11)		.153	153		215.981	TP 1	− 7(12)
2.694			1.248					
	63			62				
2.631		7.893	1.186		3.558	+7.894		+125
	62			61				
2.569		+1	1.125		+1	223.875	HI	+118
7.894		7.894	3.559		3.559	−3.559		−123
.125	125		.123	123		220.316	TP 2	− 5
3.174			2.648					
	55			60				
3.119		9.357	2.588		7.764	+9.360		+107
	52			60				
3.067		+3	2.528		+0	229.676	HI	+102
9.360		9.360	7.764		7.764	−7.764		−120
.107	107		.120	120		221.912	BM 62	− 18
28.727	378		13.296	396				

Explanation. This form of notes is also arranged to fit a standard field notebook, with six columns for the left-hand page and three columns for the right. Again the standard twenty-five lines are used, five lines for each instrument position.

(1), (2), (3) are wire readings.

(4) = (1) − (2), (5) = (2) − (3), (6) = three times (2), (7) = (4) − (5)

(8) = (1) + (2) + (3), (9) = (6) + (7), (10) = (1) − (3), (11) = (4) + (5)

(12) is the cumulative unbalance of the stadia intercepts.

Checks. (8) must equal (9) and (10) must equal (11).

Sums. The sum 28.727 should be computed by adding all the plus rod readings and the sum 378 by adding all the half stadia intercepts. Similarly for 13.296 and 396. When properly combined, they are used to check the values for the final benchmark, viz:

	Elev.	Stad.
	28.727	378
	−13.296	−396
	15.431	− 18
BM 61	206.481	0
BM 62	221.912	− 18

Short Form of Field Notes for Yard Rod

+ Rod	Stad.	− Rod	Stad.	Stad.	Elev.	Sta.
3.897 (1)		0.734			206.481	BM 61
	72 (4)		76			
3.825 (2)		0.658				
	74 (5)		77			
3.751 (3)	146 (7)	0.581	153 (8)			
11.473 (6)		1.973 (9)		− 7 (10)	+9.500 (11)	
2.694		1.248			215.981	TP 1
	63		62			
2.631		1.186				
	62		61			
2.569	125	1.125	123			
7.894		3.559		+ 2	+4.335	
3.174		2.648		− 5	220.316	TP 2
	55		60			
3.119		2.588				
	52		60			
3.067	107	2.528	120			
9.360		7.764		− 13	+1.596	
				− 18	221.912	BM 62
28.727	378	13.296	396			

Explanation. In this short form of field notes only five columns are used on the left-hand page of the field notebook, and two on the right.

(1), (2), (3) are wire readings.

(4) = (1) − (2), (5) = (2) − (3), (6) = (1) + (2) + (3), (7) = (4) + (5), (10) = (7) − (8), (11) = (6) − (9)

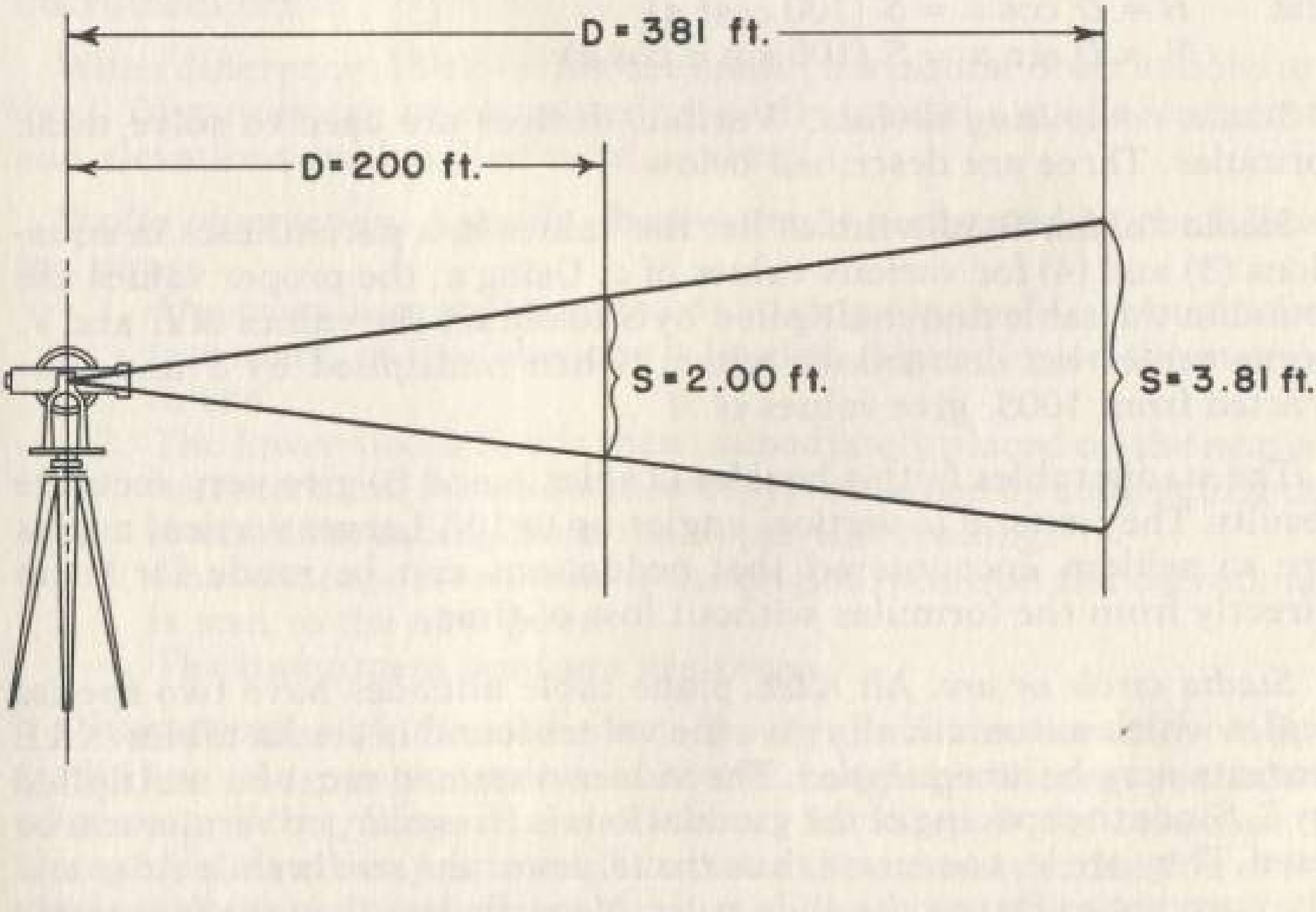
Sums. The sum 28.727 should be computed by adding all the rod readings and the sum 378 by adding all the half stadia intercepts. Similarly for 13.296 and 396. When properly combined, they are used to check the values for the final benchmark, viz:

	Elev.	Stad.
	28.727	378
	− 13.296	− 396
	+15.431	− 18
BM 61	206.481	0
BM 62	221.912	− 18

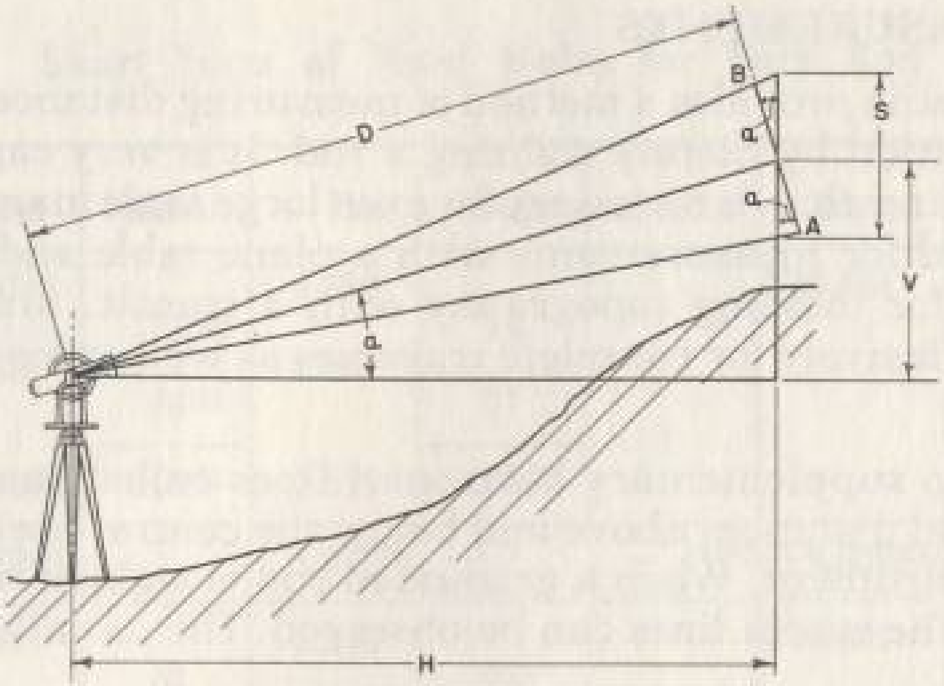
STADIA MEASUREMENTS

Purpose. Stadia provides a method of measuring distances and differences in elevation by merely sighting a rod. It is very rapid, and the accuracy is better than is necessary for even large scale mapping. Stadia is always used for measurements with a plane table and it is nearly always used for locating topography with a transit. Stadia is often employed exclusively for complete traverses as well as for ties to other control.

Theory. Two supplementary horizontal lines called stadia lines are placed at equal distances above and below the central horizontal cross line of the instrument. When a graduated rod is sighted, the length of rod between the stadia lines can be observed. This is called the stadia intercept, *S*.



In modern K&E internal focusing instruments the distance between the stadia lines is such that, when the telescope is horizontal and the rod is vertical, the distance *D* from the center of the instrument to the rod is equal to *100 times the stadia intercept.* (Fig. 1), i.e., $D = 100\ S$ (1) (In level 75 0020, *D* is equal to 333 times the stadia intercept. 75 0000 is furnished with this intercept when so ordered.)



Inclined sights. When the sight is inclined as in Fig. 2, the stadia intercept S must be multiplied by the cosine of the vertical angle a to obtain AB perpendicular to D.

From Fig. 1 $D = 100\,AB$

Therefore $D = 100\,S \cos a$ (2)

and $H = D \cos a = S\,(100 \cos^2 a)$ (3)

$V = D \sin a = S\,(100 \sin a \cos a)$ (4)

Stadia computing devices. Various devices are used to solve these formulas. Three are described below.

Stadia tables. Stadia tables list the values in a parentheses in equations (3) and (4) for various values of a. Using a, the proper values are found in the table and multiplied by S to obtain the values of H and V. Some tables list corrections which, when multiplied by S and subtracted from $100S$, give values of H.

The stadia tables in this booklet (Tables A and B) give very accurate results. They extend to vertical angles up to 10°. Larger vertical angles are so seldom encountered that reductions can be made for them directly from the formulas without loss of time.

Stadia circle or arc. All K&E plane table alidades have two special scales which automatically give the values found in stadia tables. K&E transits may be so equipped. The values obtained must be multiplied by S. Since the spacing of the graduations is irregular, no vernier can be used. They are less accurate than the tables or the stadia slide rules and they are not as fast as the slide rules. Nevertheless they are frequently used because of their convenience. To avoid minus readings, the readings for vertical heights have been arbitrarily increased by 50 on all K&E instruments. Thus, 50 must be subtracted from each reading to obtain the true value. On K&E conventional alidades, 30° has been added to vertical angle readings. Thus, 30° must be subtracted to obtain the vertical angle. On K&E self-indexing alidades, the vertical angle readings have been replaced by zenith distance readings. The zenith distance readings must be subtracted from 90° to obtain vertical angles.

Example	Zenith Distance	Corresponding Vertical Angle
	68	22
	108	−18

Rods used. Ordinary self-reading leveling rods with targets can be used up to 800 feet. Special stadia rods with graduations that are more easily read are used for longer distances.

Point sighted on rod. The difference in elevation *V* that is obtained by stadia, extends from the center of the instrument and the point sighted on the rod. To simplify the corrections necessary to obtain ground elevations, it is best to sight at a target set at the *h. i.* which is the height of the instrument center above the station over which the instrument is set up. *V* then equals the difference between the two ground elevations. Often a certain mark (usually the 5 ft. mark) is always sighted throughout the survey. *V* is then the vertical height from a point 5 ft. below the instrument center.

When differences in elevation are small, horizontal observations are used. Distances can be computed mentally from the stadia intercepts and elevations are handled as in leveling.

Stadia observation. A stadia observation is performed by the following steps:

1. The cross lines are brought on the target at the *h. i.* or on the five foot mark, or the telescope is leveled, depending on the method in use.
2. The lower stadia line is then immediately placed on the nearest foot mark and the stadia intercept is obtained by subtracting the lower line reading from the upper line reading.
3. The telescope is returned to the original position and the rodman is sent to the next point.
4. The instrument readings are taken.

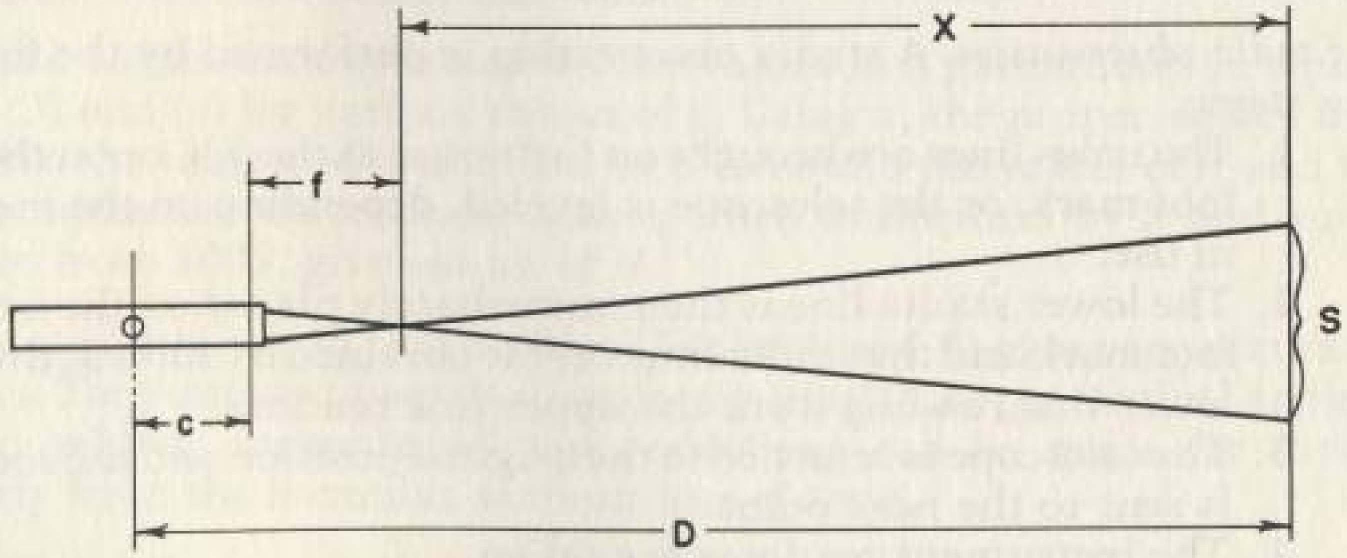
Observations with the stadia arc. To obtain better accuracy with a stadia arc, many engineers prefer to use a slightly different procedure after completing Steps 1 and 2 above. For Step 3 the telescope is changed in elevation just enough to cause the nearest graduation of the vertical stadia arc to coincide exactly with the index. The position of the central cross line on the rod is then recorded. The difference in elevation, from the ground at the instrument to the ground at the rod, is then computed thus:

$$\text{h. i.} + V - \text{rod reading}$$

Accuracy of stadia measurements. A single stadia observation has an accuracy of about 1/300 in distance and about 0.06 feet in elevation per hundred feet of length. A stadia traverse in which the intercepts and the vertical angles are observed in both directions along each course has an accuracy of about 1/500 and an elevation closure of about 0.8 feet × $\sqrt{\text{miles}}$. Under unusual conditions it may be necessary to use special procedures to obtain high accuracy. The instruments must be calibrated very carefully, no approximation can be used in computation, each observation must be repeated many times, and refraction must be carefully avoided. With similar care, accuracies as high as 1/2000 have been recorded.

Calibration of a stadia telescope. The formula for internal focusing instruments, $D = 100S$, changes slightly with changing focus and varies slightly from instrument to instrument. These variations are negligible except for very accurate measurements. For such determinations a correction curve should be constructed for the instrument to be used by measuring exact stadia intercepts at various known distances. The following distances are recommended: 25, 50, 100, 200, 400, 800, 1600 feet. Plot the curve on semi-logarithmic graph paper.

Formulas for external focusing instruments. On external focusing instruments, the distance X (Fig. 3), which is proportional to the stadia intercepts, is measured from the exterior principal focus of the lens. To obtain a value for D the distances f and c must be added. Their sum (and the total correction) is about one foot.



The resulting formulas are therefore:

$$D = 100\,S + 1 \tag{5}$$
$$H = 100\,S \cos^2 a + \cos a \tag{6}$$
$$V = 100\,S \cos a \sin a + \sin a \tag{7}$$

Since a is usually less than 10 degrees, multiplying the last term in equation (6) and in equation (7) by $\cos a$ will not appreciably change the values of H and V. These equations can therefore be written:

$$H = (S + .01)\,100 \cos^2 a \tag{8}$$
$$V = (S + .01)\,100 \sin a \cos a \tag{9}$$

All stadia computing devices can be used with external focusing instruments by substituting for S the value $S + .01$.

FORMULAS TO USE WITH VERTICAL ANGLES GREATER THAN 10°

	Internal Focusing	External Focusing
Hor. Dist.	$100\ S \cos^2 a$	$100\ (S + 0.01) \cos^2 a$
Vert. Ht.	$100\ S \sin a \cos a$	$100\ (S + 0.01) \sin a \cos a$

Where: S = stadia intercept; a = vertical angle

TABLE A
HORIZONTAL CORRECTIONS FOR STADIA INTERCEPT 1.00 FT.

Vert. Angle	Hor. Cor. for 1.00 ft.	Vert. Angle	Hor. Cor. for 1.00 ft.	Vert. Angle	Hor. Cor. for 1.00 ft.
0°00′		5°36′		8°02′	
	0.0 ft		1.0 ft.		2.0 ft.
1°17′		5°53′		8°14′	
	0.1 ft.		1.1 ft.		2.1 ft.
2°13′		6°09′		8°26′	
	0.2 ft.		1.2 ft.		2.2 ft.
2°52′		6°25′		8°38′	
	0.3 ft.		1.3 ft.		2.3 ft.
3°23′		6°40′		8°49′	
	0.4 ft.		1.4 ft.		2.4 ft.
3°51′		6°55′		9°00′	
	0.5 ft.		1.5 ft.		2.5 ft.
4°15′		7°09′		9°11′	
	0.6 ft.		1.6 ft.		2.6 ft.
4°37′		7°23′		9°22′	
	0.7 ft.		1.7 ft.		2.7 ft.
4°58′		7°36′		9°33′	
	0.8 ft.		1.8 ft.		2.8 ft.
5°17′		7°49′		9°43′	
	0.9 ft.		1.9 ft.		2.9 ft.
5°36′		8°02′		9°53′	
					3.0 ft.
				10°03′	

Results from Table A are correct to the nearest foot at 1000 feet and to the nearest 1/10 foot at 100 feet, etc.

Multiply the stadia intercept by the tabular value and subtract the product from the horizontal distance.

Example. Vertical angle, 4°22′; stadia intercept, 3.58 ft.
Corrected Hor. Dist. =

$$358 - (3.58 \times 0.6) = 356 \text{ ft.}$$

Table B gives the vertical heights for a stadia intercept of 1.00 ft. Multiply the stadia intercept by the tabular value.

Example. Vertical angle, 4°22′; stadia intercept, 3.58 ft.

$$\text{Vertical Height} = 3.58 \times 7.59 = 27.2 \text{ ft.}$$

TABLE B

VERTICAL HEIGHTS FOR STADIA INTERCEPT 1.00′

Min.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0	0.00	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45
2	0.06	1.80	3.55	5.28	7.02	8.74	10.45	12.15	13.84	15.51
4	0.12	1.86	3.60	5.34	7.07	8.80	10.51	12.21	13.89	15.56
6	0.17	1.92	3.66	5.40	7.13	8.85	10.57	12.27	13.95	15.62
8	0.23	1.98	3.72	5.46	7.19	8.91	10.62	12.32	14.01	15.67
10	0.29	2.04	3.78	5.52	7.25	8.97	10.68	12.38	14.06	15.73
12	0.35	2.09	3.84	5.57	7.30	9.03	10.74	12.43	14.12	15.78
14	0.41	2.15	3.89	5.63	7.36	9.08	10.79	12.49	14.17	15.84
16	0.47	2.21	3.95	5.69	7.42	9.14	10.85	12.55	14.23	15.89
18	0.52	2.27	4.01	5.75	7.48	9.20	10.91	12.60	14.28	15.95
20	0.58	2.33	4.07	5.80	7.53	9.25	10.96	12.66	14.34	16.00
22	0.64	2.38	4.13	5.86	7.59	9.31	11.02	12.72	14.40	16.06
24	0.70	2.44	4.18	5.92	7.65	9.37	11.08	12.77	14.45	16.11
26	0.76	2.50	4.24	5.98	7.71	9.43	11.13	12.83	14.51	16.17
28	0.81	2.56	4.30	6.04	7.76	9.48	11.19	12.88	14.56	16.22
30	0.87	2.62	4.36	6.09	7.82	9.54	11.25	12.94	14.62	16.28
32	0.93	2.67	4.42	6.15	7.88	9.60	11.30	13.00	14.67	16.33
34	0.99	2.73	4.47	6.21	7.94	9.65	11.36	13.05	14.73	16.39
36	1.05	2.79	4.53	6.27	7.99	9.71	11.42	13.11	14.79	16.44
38	1.11	2.85	4.59	6.32	8.05	9.77	11.47	13.17	14.84	16.50
40	1.16	2.91	4.65	6.38	8.11	9.83	11.53	13.22	14.90	16.55
42	1.22	2.97	4.71	6.44	8.17	9.88	11.59	13.28	14.95	16.61
44	1.28	3.02	4.76	6.50	8.22	9.94	11.64	13.33	15.01	16.66
46	1.34	3.08	4.82	6.56	8.28	10.00	11.70	13.39	15.06	16.72
48	1.40	3.14	4.88	6.61	8.34	10.05	11.76	13.45	15.12	16.77
50	1.45	3.20	4.94	6.67	8.40	10.11	11.81	13.50	15.17	16.83
52	1.51	3.26	4.99	6.73	8.45	10.17	11.87	13.56	15.23	16.88
54	1.57	3.31	5.05	6.79	8.51	10.22	11.93	13.61	15.28	16.94
56	1.63	3.37	5.11	6.84	8.57	10.28	11.98	13.67	15.34	16.99
58	1.69	3.43	5.17	6.90	8.63	10.34	12.04	13.73	15.40	17.05
60	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45	17.10

HOW TO SET OFF THE MAGNETIC DECLINATION

The magnetic declination is the angle measured from the true north to the direction of the compass needle. A 12° west declination is present when the needle points 12° west of true north. The declination is different in different localities, and in any locality it is continually changing. The U.S. Coast and Geodetic Survey publishes charts from which the declination can be estimated for any time or place in the United States.

When the compass circle is set in its normal position, the needle gives the magnetic bearing of the line of sight. This is shown in Fig. 1 with the instrument pointed to the true north. The compass circle can be rotated by turning the capstan head pinion (near the south or west mark) so that the needle will give the true bearing of the line of sight.

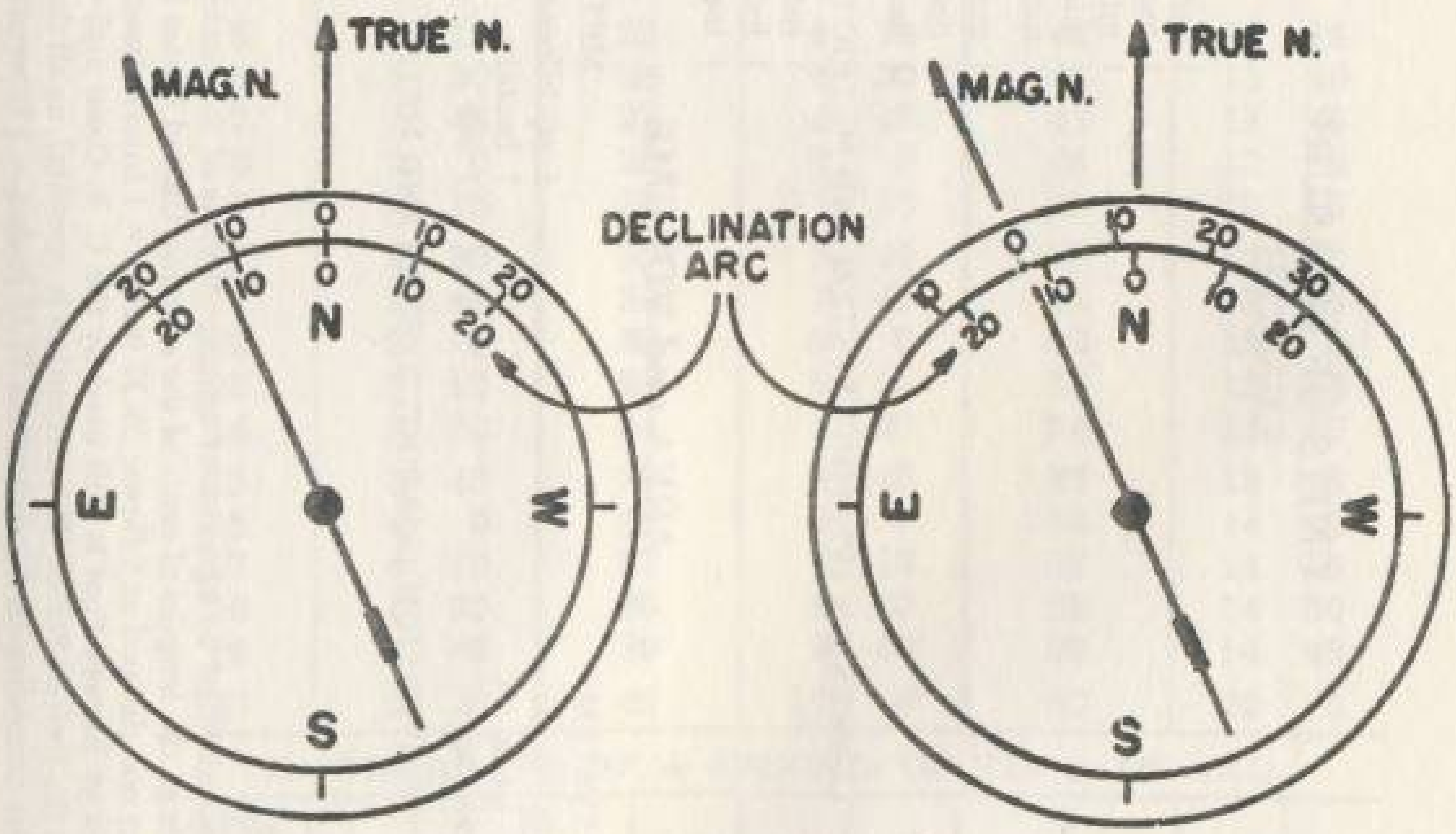


Fig. 1. Fig. 2.

The extent of rotation of the circle is measured *by the declination arc* in the base of the compass box next to the north part of the circle.

To set the circle for a declination of 12° west, turn the pinion clockwise and hence the circle counter-clockwise until the zero of the circle coincides with 12° to the left of N on the declination arc. The result is shown in Fig. 2. The instrument will now read true bearings for all points of the compass. The procedure is the same in the southern hemisphere.

UNITS OF MEASURE
LENGTH

U. S. SYSTEM

1 mile (mi)	= 5280	feet
1 chain (ch)	= 66	feet
1 rod (rd)	= 16.5	feet
1 yard (yd)	= 3	feet
1 foot (ft)	= 12	inches (in)
1 nautical mile	= 6076.1155—	feet
1 fathom (fm)	= 6	feet

METRIC SYSTEM

1 kilometer (km)	= 1000 meters
1 meter (m)	= 1000 millimeters
1 millimeter (mm)	= 1000 micrometers
1 micrometers (μm)	= 1000 nanometers
1 nanometer (nm)	= 1000 picometers (pm)
1 meter	= 10 decimeters
1 decimeter (dm)	= 10 centimeters (cm)
1 nanometer	= 10 angstroms (Å)

COVERSION 1959-FOOT SYSTEM AND METRIC SYSTEM

1 kilometer	= 0.62137119 +	miles
1 meter	= 3.2808399 —	feet
1 meter	= 39.370079 —	inches
1 mile	= 1.609344	kilometers
1 foot	= 0.3048	meters
1 inch	= 25.4	millimeters

AREA and VOLUME

1959-FOOT SYSTEM

1 sq. mile	= 640 acres
1 acre (A)	= 10 sq. ch.
1 acre	= 43560 sq. ft.

METRIC SYSTEM

1 sq. kilometer	= 100 hectares (ha)
1 hectare	= 100 ares
1 are	= 100 sq. meters

CONVERSION 1959-FOOT SYSTEM AND METRIC SYSTEM

1 hectare	= 2.4710538 +	acres
1 cu. meter	= 1.30795 +	cu. yards
1 cu. cm.	= 0.0610237 +	cu. in.
1 acre	= 0.40468564 +	hectares
1 cu. yard	= 0.764555 –	cu. meters
1 cu. inch	= 16.3870 +	cu. cm.

Note. In 1959, the Foot System was redefined by agreement among officials of the nations where it is used, as follows: 1 yard = 0.9144 International Meter exactly. This reduced the lengths of units of the existing United States Foot System approximately 2 parts in 1,000,000. The then existing United States system was defined as follows: 39.37 inches = 1 International Meter and the foot in that system is now called the American Survey Foot. The American Survey Foot is still used by the U. S. Coast and Geodetic Survey and therefore applies to all the horizontal and vertical control nets in the United States. This exception is essential, as all data in feet published by that Bureau are the result of conversion from International Meters according to the definition 39.37 inches = 1 International Meter.

TABLE C

CONVERSION OF TIME TO ARC

HOURS OF TIME INTO ARC

T.	A.	T.	A.	T.	A.	T.	A.	T.	A.	T.	A.
hrs.	°	hrs.	°	hrs.	°	hrs.	°	hrs.	°	hrs.	°
1	15	5	75	9	135	13	195	17	255	21	315
2	30	6	90	10	150	14	210	18	270	22	330
3	45	7	105	11	165	15	225	19	285	23	345
4	60	8	120	12	180	16	240	20	300	24	360

MINUTES OF TIME TO ARC

SECONDS OF TIME TO ARC

Min. *Sec.*	° '	' "	Min. *Sec.*	° '	' "	Min. *Sec.*	° '	' "
1	0	15	21	5	15	41	10	15
2	0	30	22	5	30	42	10	30
3	0	45	23	5	45	43	10	45
4	1	0	24	6	0	44	11	0
5	1	15	25	6	15	45	11	15
6	1	30	26	6	30	46	11	30
7	1	45	27	6	45	47	11	45
8	2	0	28	7	0	48	12	0
9	2	15	29	7	15	49	12	15
10	2	30	30	7	30	50	12	30
11	2	45	31	7	45	51	12	45
12	3	0	32	8	0	52	13	0
13	3	15	33	8	15	53	13	15
14	3	30	34	8	30	54	13	30
15	3	45	35	8	45	55	13	45
16	4	0	36	9	0	56	14	0
17	4	15	37	9	15	57	14	15
18	4	30	38	9	30	58	14	30
19	4	45	39	9	45	59	14	45
20	5	0	40	10	0	60	15	0

HUNDREDTHS OF A SECOND OF TIME TO ARC

100ths of sec. of time s.	.00 "	.01 "	.02 "	.03 "	.04 "	.05 "	.06 "	.07 "	.08 "	.09 "
0.00	0.00	0.15	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35
.10	1.50	1.65	1.80	1.95	2.10	2.25	2.40	2.55	2.70	2.85
.20	3.00	3.15	3.30	3.45	3.60	3.75	3.90	4.05	4.20	4.35
.30	4.50	4.65	4.80	4.95	5.10	5.25	5.40	5.55	5.70	5.85
.40	6.00	6.15	6.30	6.45	6.60	6.75	6.90	7.05	7.20	7.35
0.50	7.50	7.65	7.80	7.95	8.10	8.25	8.40	8.55	8.70	8.85
.60	9.00	9.15	9.30	9.45	9.60	9.75	9.90	10.05	10.20	10.35
.70	10.50	10.65	10.80	10.59	11.10	11.25	11.40	11.55	11.70	11.85
.80	12.00	12.15	12.30	12.45	12.60	12.75	12.90	13.05	13.20	13.35
.90	13.50	13.65	13.80	13.95	14.10	14.25	14.40	14.55	14.70	14.85

TABLE D

TEMPERATURE CORRECTIONS FOR STEEL TAPES BASED ON COEF. OF EXP. OF 0.00000645 PER DEGREE

For these temperatures subtract correction	Correction per 1000 ft.	For these temperatures add correction	For these temperatures subtract correction	Correction per 1000 ft.	For these temperatures add correction
6[illegible]°F.	.00000	68°F.	28°F	.25800	108°F.
6[illegible]	.00645	69	27	.26445	109
66	.01290	70	26	.27090	110
65	.01935	71	25	.27735	111
64	.02580	72	24	.28380	112
63	.03225	73	23	.29025	113
62	.03870	74	22	.29670	114
61	.04515	75	21	.30315	115
60	.05160	76	20	.30960	116
59	.05805	77	19	.31605	117
58	.06450	78	18	.32250	118
57	.07095	79	17	.32895	119
56	.07740	80	16	.33540	120
55	.08385	81	15	.34185	121
54	.09030	82	14	.34830	122
53	.09675	83	13	.35475	123
52	.10320	84	12	.36120	124
51	.10965	85	11	.36765	125
50	.11610	86	10	.37410	126
49	.12255	87	9	.38055	127
48	.12900	88	8	.38700	128
47	.13545	89	7	.39345	129
46	.14190	90	6	.39990	130
45	.14835	91	5	.40635	
44	.15480	92	4	.41280	
43	.16125	93	3	.41925	
42	.16770	94	2	.42570	
41	.17415	95	1	.43215	
40	.18060	96	0	.43860	
39	.18705	97	−1	.44505	
38	.19350	98	−2	.45150	
37	.19995	99	−3	.45795	
36	.20640	100	−4	.46440	
35	.21285	101	−5	.47085	
34	.21930	102	−6	.47730	
33	.22575	103	−7	.48375	
32	.23220	104	−8	.49020	
31	.23865	105	−9	.49665	
30	.24510	106	−10	.50310	
29	.25155	107	−11	.50955	

Example: Measured distance at 29°F. = 782.36
Correction −.25155 x .782 = −.20
Corrected Length = 782.16

CORRECTION FOR MERIDIAN COVERGENCE

Apply when traverse angles are checked by celestial observation.

$C = \Delta\lambda \sin \phi$ $\qquad$ $C'' = 52.13 \text{ m} \tan \phi$

where: C is angular convergence, $\Delta\lambda$ is long. diff., o is mean lat., m is distance east or west in miles.

CORRECTION FOR SLOPE

Square the difference in height of the two ends and divide by twice the slope measurement. Subtract the result from the slope measurement.

Slope meas. 100 ft. Diff. in ht. 12 ft.

$100 - \frac{144}{200} = 99.28$ ft. (error 0.003 ft.)

CORRECTION FOR CURVATURE and REFRACTION IN LEVELING

The correction equals $-.000209\ S^2$ where S is the number of hundreds of feet in the sight.

Length of sight 220 ft.

Rod reading = 8.276
Correction: $-.000209\ (2.2)^2 = -.001$
Corrected reading = 8.275

PROBABLE ERROR

If d_1, d_2, d_3, etc. are the discrepancies of various results from the mean, and if Σd^2 = the sum of the squares of these differences, and n = the number of observations, then the Probable Error is computed thus:

$$\text{P.E. Mean} = \pm\ 0.6745 \sqrt{\frac{\Sigma d^2}{n(n-1)}}$$

$$\text{P.E. One Obser.} = \pm\ 0.6745 \sqrt{\frac{\Sigma d^2}{n-1}}$$

MEASUREMENT EQUIVALENTS

π = 3.1415927 –	log	= 0.49714987
1 radian = 57.295780 – deg.	log	= 1.75812263
1 radian = 3437.7468 – min.	log	= 3.53627388
1 radian = 206264.81 – sec.	log	= 5.31442513
1 degree = 0.017453293 – rad.	log	= 8.24187737 – 10
1 minute = 0.000290888 + rad.	log	= 6.46372612 – 10
1 second = 0.000004848 + rad.	log	= 4.68557487 – 10

TRIGONOMETRIC FORMULAS

$\frac{\sin A}{\cos A} = \tan A$ $\quad \sin^2 A + \cos^2 A = 1$ $\quad \tan^2 A + 1 = \sec^2 A$

$$\sin A = \frac{1}{\csc A} = \cos(90° - A) = \frac{\tan A}{\pm\sqrt{\tan^2 A + 1}}$$

$$\cos A = \frac{1}{\sec A} = \sin(90° - A) = \frac{1}{\pm\sqrt{\tan^2 A + 1}}$$

$$\tan A = \frac{1}{\cot A} = \cot(90° - A) = \frac{\sin A}{\pm\sqrt{1 - \sin^2 A}} = \frac{\pm\sqrt{1 - \cos^2 A}}{\cos A}$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$ $\quad \cot(A \pm B) = \frac{\cot A \cot B \mp 1}{\cot B \pm \cot A}$

$\sin(A \pm 90°) = \pm \cos A$ $\quad \cos(A \pm 90°) = \mp \sin A$

$\sin(180° \pm A) = \mp \sin A$ $\quad \cos(180° \pm A) = -\cos A$

$$\sin A + \sin B = 2 \sin \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$$

$$\sin A - \sin B = 2 \cos \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$$

$$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$$

$$\cos A - \cos B = -2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$$

$$\sin 2A = 2 \sin A \cos A$$

$$\cos 2A = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A = 2\cos^2 A - 1$$

$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$ $\quad \cot 2A = \frac{\cot^2 A - 1}{2 \cot A}$

$\sin \tfrac{1}{2}A = \pm\sqrt{\tfrac{1}{2}(1 - \cos A)}$ $\quad \cos \tfrac{1}{2}A = \pm\sqrt{\tfrac{1}{2}(1 + \cos A)}$

$$\tan \tfrac{1}{2}A = \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A} = \frac{1}{\cot \tfrac{1}{2} A}$$

SOLUTION OF OBLIQUE TRIANGLES

Angles are A, B, C. Slides opposite are a, b, c respectively.

Case I given a, B, C.

$$A = 180° - (B + C) \qquad b = \frac{a}{\sin A} \sin B$$

$$c = \frac{a}{\sin A} \sin C$$

Case II given a, b, A.

$$\sin B = \frac{\sin A}{a} b \qquad C = 180° - (A + B)$$

$$c = \frac{a}{\sin A} \sin C$$

Case III given a, b, C. $\quad A + B = 180° - C$

$$\tan ½ (A - B) = \frac{a - b}{a + b} \tan ½ (A + B)$$

$$A = ½ (A + B) + ½ (A - B)$$
$$B = ½ (A + B) - ½ (A - B)$$

$$c = \frac{a}{\sin A} \sin C$$

Case III given a, b, C: *alternate method.*

$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} \text{ or } \sin A = \frac{\sin C}{c} a$$

$$\cos B = \frac{a^2 + c^2 - b^2}{2ac} \text{ or } \sin B = \frac{\sin C}{c} b$$

$$\text{or } B = 180 - (A + C)$$

Case IV given a, b, c.

let $s = ½ (a + b + c)$

$$\text{and } r = \sqrt{\frac{(s - a)(s - b)(s - c)}{s}}$$

$$\tan ½ A = \frac{r}{s - a} \qquad \tan ½ B = \frac{r}{s - b} \qquad \tan ½ C = \frac{r}{s - c}$$

Case IV given a, b, c: *alternate method.*

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} \qquad \cos B = \frac{a^2 + c^2 - b^2}{2ac}$$

$$\cos C = \frac{a^2 + b^2 - c^2}{2ab} \qquad \text{or } C = 180° - (A + B)$$

$$\text{Area} = ½ bc \sin A = \frac{a^2 \sin B \sin C}{2 \sin A}$$

$$= \sqrt{s(s - a)(s - b)(s - c)}$$

SECTION VI —
ZEISS THEODOLITES & K&E EDM EQUIPMENT

ZEISS THEODOLITES

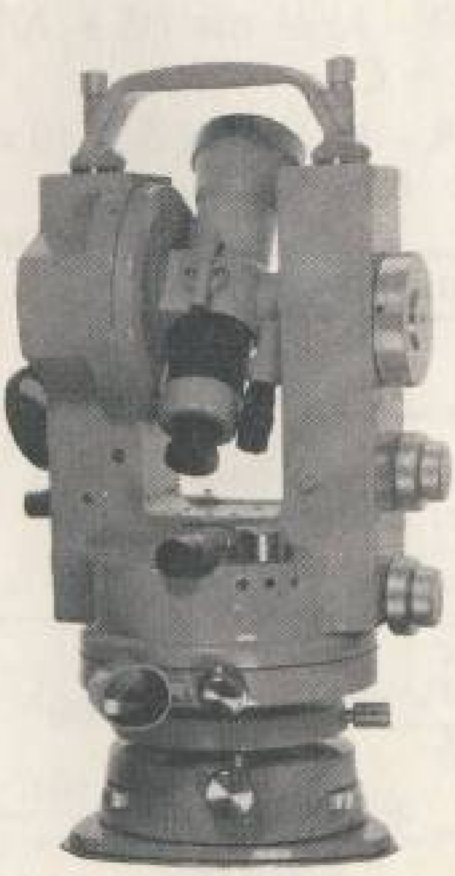
K&E is the official and exclusive United States and Canadian distributor of the world famous Zeiss Theodolite line, made in West Germany.

Only in Zeiss Theodolites are the features and precision that have made Zeiss outstanding in the opto-mechanical field. K&E offers an extensive selection, including the Zeiss Th2 One-Second Reading Theodolite, Th43 Optical-Scale Theodolite, and RTa 4 Reduction Tacheometer Theodolite. All meet the specific requirements of American and Canadian engineers.

Brief descriptive data pertaining to the three models follows. For complete information regarding Zeiss Theodolites and accessories, write to Keuffel & Esser Company, Morristown, N. J. 07960.

Th2 Theodolite (73 0300)

Unique, simplified, "digitized" circle-reading system on Th2 Theodolite increases reading speed, prevents errors.



73 0300

Ball base ensures particularly rapid leveling. A parallel motion device between the ball base and the tripod permits rapid centering without releveling the instrument. Unique design of torsion plate prevents rotation between upper and lower section of base.

Unsurpassed Zeiss optical system includes apochromatic objective.

Automatic vertical-circle indexing simplifies vertical angle measurement. Long compensator overcomes influence of external vibrations.

Two-speed focusing telescope.

Unusually bright, sharp, circle-reading optical system minimizes eye fatigue and error.

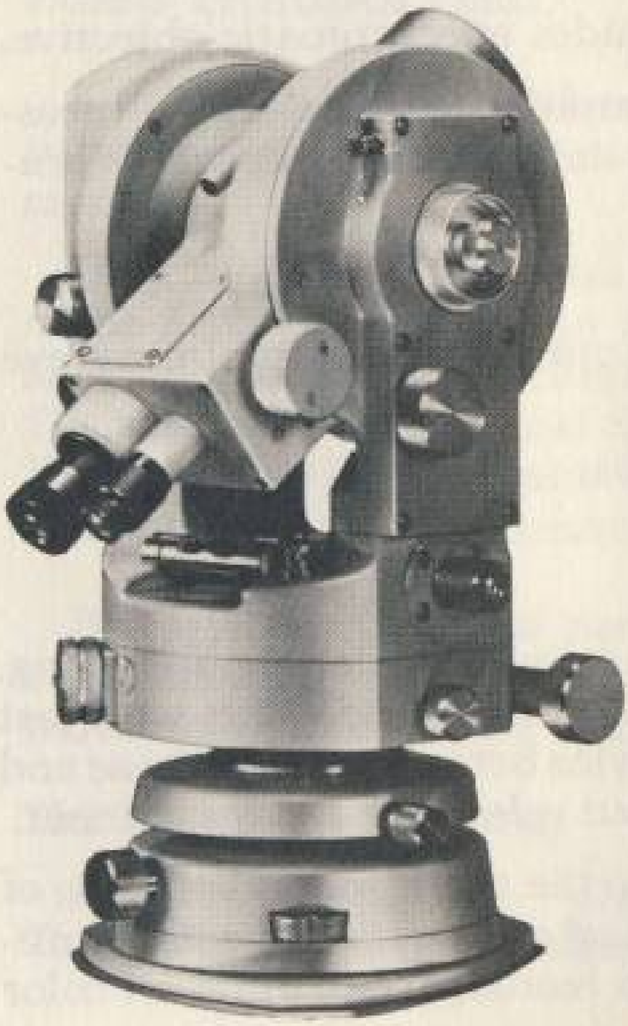
Sighting collimator for rapid and convenient coarse sighting.

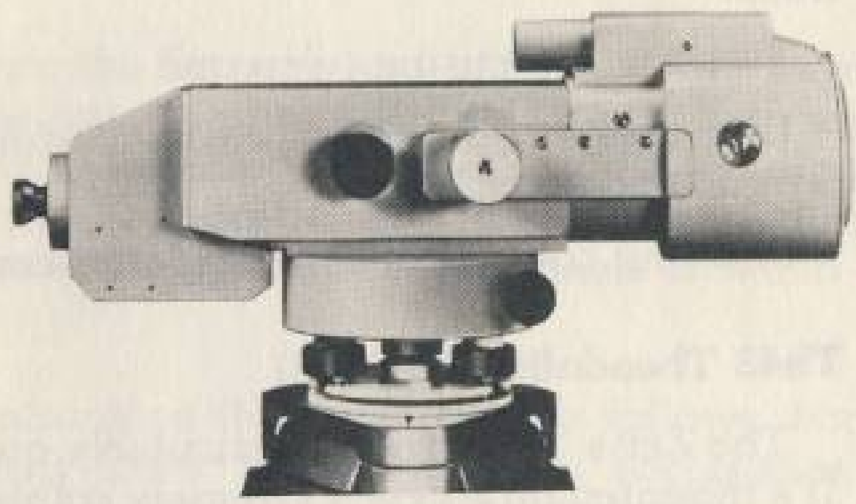
Th43 Theodolite (73 0308)

The Zeiss Th43 gives particularly quick and simple rough leveling. It's mounted on a new, extremely stable ball base that works with just two leveling screws. A parallel motion device between the ball base and the tripod permits rapid centering without releveling the instrument.

World-famous Zeiss optical quality is in the telescope and reading of circles. Simultaneous viewing of horizontal and vertical circles eliminates the need for changing over between readings, and different color images effectively reduce errors.

73 0308





75 0007

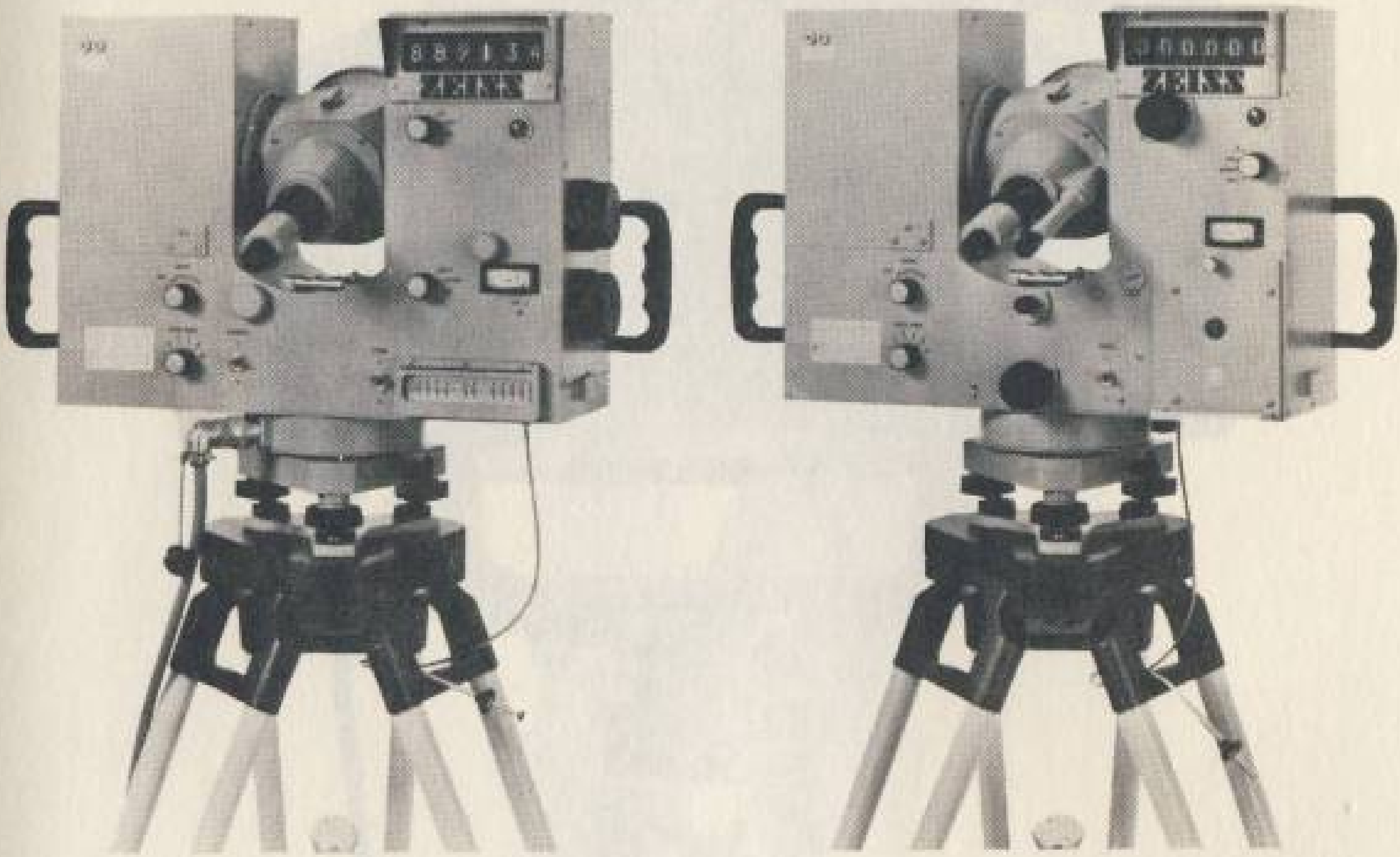
73 0401

Reduction Tacheometer RTa 4 (73 0401). Zero setting, erected image; ideal instrument for stadia measurements. Automatically converts slant range to horizontal distances and gives corrected differences in elevation. Especially suited for highway construction, grading and other large scale applications within a range of 6 ft, to approx. 500 ft. Also used for distances within a range of 6 ft. to approx. 1000 ft. for topographic mapping of large areas.

The RTa 4, is also an optical scale theodolite with the same characteristics and applications as the Th43.

Ni 1 Self-Leveling Level (75 0007). First order level of high optical performance, with parallel plate micrometer. This instrument is particularly suited for first and second order work, geodetic leveling, precise alignment and leveling in optical tooling, precise observations of soil movements, and checks on the settlement and deformation of buildings.

The Ni 1 Self-Leveling Level sets its own line of sight level with great accuracy by means of a device called a compensator which is not affected by usual temperature change.



Reg Elta 14 Electronic Recording Tacheometer-Rangefinder (73 0680). For high accuracy distance measurement with coded angle measuring system.

The fields of application for this highly accurate instrument are traversing, determining control points, staking out bridges, dams, and other major structures, and for producing digital ground models.

One measurement takes only 20 seconds, during which all necessary frequency changes, computations, and recordings are performed. A six-digit system of Nixie tubes displays readout for either the horizontal angle, the vertical angles or the slope distance. These three readouts and 12 variable code numbers are recorded on punched paper tape.

SM 11 Electronic Tacheometer-Rangefinder (73 0700). Combines a ranging unit, optical scale theodolite, and power supply in one compact housing.

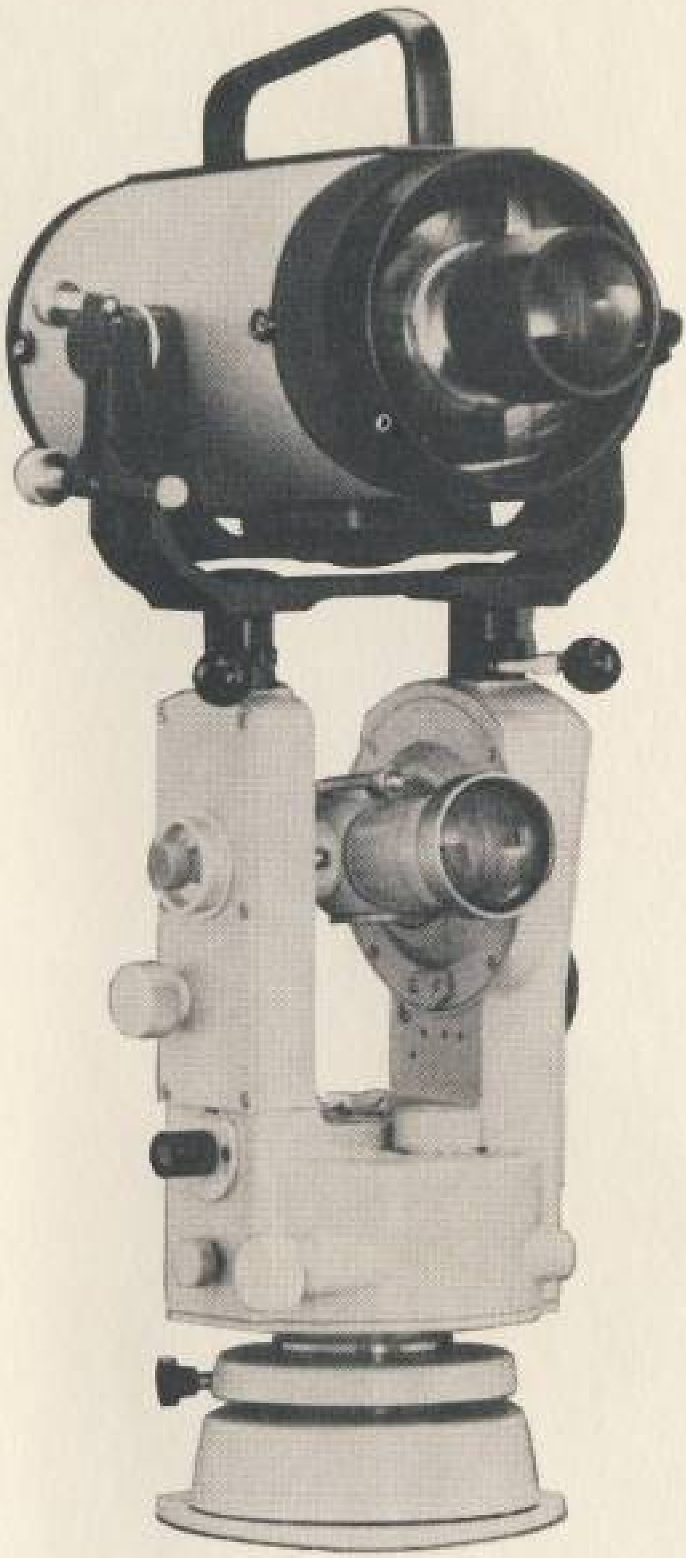
This instrument is similar in function and design to the Reg Elta 14, but does not have coded graduated circles and punched tape recording unit. The slope distance is displayed on Nixie tubes, and the vertical and horizontal circles are viewed simultaneously on a reading microscope.

K&E EDM EQUIPMENT

Ranger IV (76 0330) — Intermediate range instrument using helium-neon laser source for readings from 3 ft. to 8 miles in feet or meters. Accuracy ±(0.02 ft. + 2ppm).

Rangemaster (76 0303) — Long range instrument using helium-neon laser source for reading from 3 ft. to 40 miles in feet or meters. Accuracy ± (0.02 ft. + 1ppm).

The Ranger Series provides a full range of distance capabilities for a multitude of surveying needs.



MicroRanger (76 0298) is an electronic distance measuring system that conveniently mounts on most theodolites, and transits. It permits angular sightings and distance measuring without time-consuming mounting and dismounting procedures.

Within seconds it provides distance measurements of 3 feet to more than 1 mile (or 1m to 1.6km), with an accuracy of ±(0.02 ft. + 2ppm). An auto-ranging feature rapidly updates a 7-digit numerical display as the range to the target varies. There are no calculations to contend with, for correction factors are simply dialed into the control unit.

The MicroRanger comes with a 12-volt rechargeable nickel-cadmium battery, or can be powered with a standard 12-volt storage battery.