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A SURVEY OF OPTICAL ANGULAR
TRANSFER DEVICES FOR
LABORATORY AND MISSILE
APPLICATIONS


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DECEMBER 1961



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A subsidiary of Thompson Ramo Wooldridge Inc

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I. INTRODUCTION

This report has been generated to satisfy a need for a survey of optical angle transfer devices for laboratory and missile applications. The instruments catalogued and described here are frequently used in many laboratory applications where it is necessary to determine angular deviations to a high degree of accuracy such as angle gage block calibration, parallelism of optical flats or wedge surfaces and surface table flatness. Applications are also encountered in the inertial component testing where optical alignment procedures are necessary in the evaluation of precision gyros and accelerometers. In addition, optical alignment equipment listed is required for aligning and automatically monitoring the inertial guidance system of a missile prior to launch. Proper selection and use of these instruments makes it possible to align the guidance system employed in missile and space vehicle development to within seconds of arc with respect to a geographical reference and automatically maintain this precise alignment over long periods of time.

II. TABULAR INFORMATION

Data are tabulated in the following tables: on single axis and two axes visual and photo-electric autocollimators, two photo-electric autoreflectors and several first order theodolites adapted to employ visual and photo-electric autocollimating eyepieces; mention is made of seven known vertical azimuth transfer devices. Information presented includes Manufacturer and Model Numbers, description, primary use, working aperture, focal length, field of view or angular range, sensitivity, calibration technique and type of readout. A list of manufacturers' addresses and representatives is included as an appendix.

III. SUGGESTIONS FOR EQUIPMENT SELECTION

In selecting an autocollimator or autoreflector for a specific laboratory or missile azimuth alignment application, the following brief suggestions or guides may prove useful:

- (1) The construction of the instrument should be such that it is inherently stable and fundamentally simple and reliable, thereby minimizing the need for frequent adjustments, and simplifying repair if the need arises.
- (2) The instrument should be light weight, portable, convenient to operate after a short warmup time, and versatile in the sense that it could be used for various applications.
- (3) Design features should be incorporated to permit ease of mirror acquisition, to minimize human errors associated with sightings and readout and to provide continuous angle readout information which can be recorded, and/or displayed for visual observation.

AUTOCOLLIMATORS, VISUAL, SINGLE AXIS
TABLE I

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
A. VISUAL								
1. <u>Single Axis</u>								
Davidson Optronics - Comparison Type Model D-600	Lab	2.5 in.	20 in.	25 min. of arc	0.1 sec	Micro- meter Dial and Sliding Scale	Visual	
Davidson Optronics - Coordinate Type Model D-638	Lab	2.5 in.	Folded 20 in. System	20 min. of arc	0.25 sec	External Seconds Drum With a Recticle Pattern	Visual	
Hensoldt (Wetzlar) Germany Model 300	Lab		300 mm	±15 min. of arc	30 sec	Fixed Recticular	Visual	
Hensoldt (Wetzlar) Model 500	Lab		500 mm	±15 min. of arc	1 sec	Measuring Eyepiece	Visual	
Hilger Watts - Microptic (Great Britain)	Lab	1.37 in.	10.8 in.	10 min. of arc	0.1 sec	Micro- meter Drum	Visual	
Taylor, Taylor and Hobson, General Purpose, Type "E" (Great Britain)	Lab			±16 min. of arc	1 sec	Micro- meter Drum	Visual	

AUTOCOLLIMATORS, VISUAL, SINGLE AXIS
TABLE I (Continued)

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
Wild (Switzerland)	Lab					Micro- meter Drum	Visual	Instrument for Testing Plane Surfaces
Keuffel and Esser, BAC P1	Lab	1.5 in.		±5 m.n. of arc	0.1 sec	Micro- meter Drum	Visual	Direct Reading to 1 sec
Keuffel and Esser AC P1	Lab	1.5 in.		±5 min. of arc	0.1 sec	Micro- meter Drum	Visual	Barrel Type Autocollimator. Direct Reading to 1 sec.

AUTOCOLLIMATORS, VISUAL, DOUBLE AXIS
TABLE II

Manufacturer - Description	Use	Aperture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
<u>2. Double Axis</u>								
Davidson Optronics - Bull's Eye Type 30 Min. Field D-602	Lab	2.5 in.	Folded 20 in. system	20 min. of arc	5 - 10 sec	Reticle pattern	Visual	Dark field circular pattern reticle
Davidson Optronics - Alignment Telescope - Autocollimating Type D-275	Lab			30 min. of arc	5 sec	Reticle pattern	Visual	15 - 1 minute rings
Davidson Optronics D-647 Infrared Autocollimator	Lab	12 in.	Folded 48 in. system		5 milliradians in any direction	Graduated reticle	Visual in the visible range	Used primarily to check optical alignment, range and sensitivity of infrared systems.
Remasco, Inc.	Lab	1.87 in.	15 in.	See note		Graduated reticle	Visual	Reticles with 20 minute field in 15-second graduations, and with 10 minute field in 5-second graduations are standard equipment.
Grufl and Esser - BAC	Lab	1.5 in.	-	30 min. of arc	-	Graduated Reticle	Visual	
" " " BAC P2	Lab	1.5 in.	-	±5 min. of arc	0.1 sec	Micrometer Drum	Visual	Direct reading to 1 sec.
" " " AC P2	Lab	1.5 in.	-	±5 min. of arc	0.1 sec	Micrometer Drum	Visual	Barrel Type Autocollimator Direct Reading to 1 sec.
Nikon Autocollimator Model 1	Lab	1.6 in.	8 in.	±30 min. of arc	1 min	Reticle Scale	Visual	
" " " Model 2	Lab	1.65 in.	20 in.	±15 min. of arc	10 sec	Reticle Scale	Visual	
" " " Model 3	Lab	1.6 in.	16 in.	0 - 40 min. of arc	5 sec	Micrometer Drum	Visual	Range of Micrometer Scale 60 sec.
" " " Model 5	Lab	2.75 in.	25 in.	0 - 30 min. of arc	1 sec	Micrometer Drum	Visual	Range of Micrometer Scale 60 sec.
Leitz (Wetzlar) Model ABCAA	Lab	2.25 in.	20 in.	16 min. of arc	1/10 sec	Micrometer Ocular	Visual	} Notable Micrometer ocular for measurements in both horizontal and vertical planes.
" " " Model AADHM	Lab	2.25 in.	20 in.	30 min. of arc	1/10 sec	Micrometer Ocular	Visual	

AUTOCOLLIMATORS, VISUAL, DOUBLE AXIS
TABLE II (Continued)

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensidvity Calibration	Type of Readout	Notes
Scherr-Opto Tooling Model C140B	Lab	-	15 in.	30 min.of arc	15 sec	Reticle	Visual
Scherr-Opto Tooling Model C150B	Lab	-	15 in.	10 min.of arc	5 sec	Reticle	Visual
Scherr-Opto Tooling Model C200B	Lab	-	15 in.	See Note	1 sec	Reticle	Visual Total Field is 12 minutes along one axis only.
Hilger and Watts TA50	Lab	1.9 in.	34 in.	10 min.of arc	0.1 sec of arc	Micrometer Drum	Visual To change from horizontal to vertical measurement, the micro- meter eyepiece is rotated through 90 degrees.
Hilger and Watts TA51	Lab	1.9 in.	34 in.	10 min.of arc	0.1 sec of arc	Micrometer Drum	Visual Angular Displacements in the hori- zontal and vertical planes can be measured simultaneously.

AUTOCOLLIMATORS, PHOTO-ELECTRIC, SINGLE AXIS
TABLE III

Manufacturer - Description	Use	Aperature	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
B. PHOTO-ELECTRIC								
I. Single Axis								
H and I Controls - Refractosyn Electronic Autocollimator - Model R29A	Lab				< 1 μ st		Analog	
Autonetics	Field	5 in.	Folded 25 in system	± 75 sec	0.1 sec		Analog	Developed by Autonetics for the H and D Mouteman Program
Barnes Engineering Co. Photo-electric Auto-Collimator "PEAC"	Lab or Field	2.5 in.		± 40 mins. at close range	< 1 sec		Analog	Range 160 feet (Greater range available with a modified objective)
Chance Vought - Optical Platform Alignment Linkage (OPAL)	Lab or Field	4 in.					Analog	Overall alignment accuracy: ± 7 seconds with the detector in a fixed installation
Davidson Optronics D-604, Signal Autocollimator	Lab	2.5 in.	Folded 20 in system					Used to monitor angular velocities of external reflecting surfaces
Davidson Optronics D-665-105 Automatic Autocollimator, 20' Range, Analog Readout								See description of D665-107 below
Davidson Optronics D-665-107 Automatic Autocollimator, 2' Range, Analog Readout	Lab and Field	2.5 in.		± 1 min arc	0.1 sec		Micro-meter Dial and Sliding Scale	Accuracy 0.5%
Davidson Optronics D-665-110 Automatic Autocollimator, 40' Range, Analog Readout								
Davidson Optronics D-604 Signal Autocollimator	Lab	2.5 in.	Folded 20 in system					Designed to monitor angular velocities of mirrors turning about either a horizontal or vertical axis

AUTOCOLLIMATORS, PHOTO-ELECTRIC, SINGLE AXIS
TABLE III (Continued)

Manufacturer - Description	Use	Aperture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
Davidson Optronics D-650 Point Source Autocollimator (5 Second Point)								
Levidson Optronics D-975 Automatic Short Range Electro Theodolite	Field							For ARMA Inertial Guidance System.
Randow Laboratories - Midarm II (Precision Automatic Angle and Rate Monitor)	Lab			2 1/2 degrees (See Note)	0.02 sec		Analog or Digital	Range can be extended to 360 degrees using a pair of optical units plus an optically flat polygon.
Fecker (American Optical) Medium Range - Model 100	Field	Approx. 4 in.		15 min. of arc	<1 sec		Analog	
Keuffel and Esser - EAC P1 Electronic Autocollimator	Lab	-	-	±25 sec of arc	1/50 sec	Indicator	Analog	Sensitivity selection ±1, ±25, ±100 sec.
Keuffel and Esser - EAG TPI Electronic Autocollimator	Lab	-	-	±100 sec of arc	1/50 sec	Indicator	Analog	Sensitivity selection ±1, ±25, ±100 sec.
Perkin - Elmer - Short Range Azimuth Alignment Theodolite Model No. 169-0170, Range 50 feet	Field			±7 min. of arc at 50 feet			Null Device	Used with the Jupiter Weapons System
Perkin - Elmer - Short Range Azimuth Alignment Theodolite Model No. 169-0300, Range 50 feet	Field			±7 min. of arc at 50 feet			Null Device	Used with the Male Weapons System
Perkin - Elmer - Intermediate Range Azimuth Alignment Theodolite Model No. 533, Range 100 feet	Field			±8 min. of arc at 100 feet			Null Device	

AUTOCOLLIMATORS, PHOTO-ELECTRIC, SINGLE AXIS
TABLE III (continued)

Manufacturer - Description	Use	Aperture	Focal Length	Field of View (Range)	Sensitivity	Collimation	Type of Readout	Notes
Perkin - Elmer - Automatic Autocollimator	Field	7 in.	36 in.	±5 min.	0.2 to 0.5 sec	-	Analog	For AC Spark Plug Co. to be employed in the Azimuth Alignment set for the Titan Missile Inertial Guidance System
Perkin - Elmer - Long Range Azimuth Alignment Theodolite Model No. 523-0005, Range 400 feet	Field			±3.5 min. at 150 feet	< 2 sec	-	-	Jupiter Medium Range Theodolite
Perkin - Elmer - Electro-Collimator	Field	7 in.	36 in.	±10 min. at 100 feet	< 1 sec	Pratt and Whitney Table	Digitized Angle Readout	Developed by the Perkin - Elmer Corp. for American Bosch ARMA Corp. to be used for Alignment of the Atlas Inertial Guidance System
General Mills - Electro - Collimator	Field	7 in.	36 in.	±10 min. at 100 feet	< 1 sec	Pratt and Whitney Table	Digitized Angle Readout	Same as above
Hüger and Watts (TA3)	Lab	1.4 in.	-	10 min. of arc	0.5 sec of arc	Micro-meter Drum	Visual (Micro-meter Drum)	The system is of the Null-setting type: exact setting is obtained by bringing the needle of the meter to the central zero.

AUTOCOLLIMATORS, PHOTO-ELECTRIC, DOUBLE AXIS

TABLE IV

Manufacturer - Description	Use	Aperture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
<u>2. Double Axis</u>								
Autonetics (North American Aviation) WS133A Minuteman and GAM77 (Hound Dog)	Lab or Field	2.36 in	372mm	± 12 mins Elevation and Azimuth	0.1 sec of arc	Theodolite Scales	Analog and Visual	Wild T3 theodolite modified to incorporate photo-electric readout
Barnes Engineering Co. (Under Development) D-704				2 1/2 in				
Davidson Optronics, D-705 Two Axis Signal Autocollimator,	Lab or Field	5 in		30 min of arc				
Davidson Optronics, D-706 Two Axis Signal Autocollimator	Lab or Field	7 in						
Davidson Optronics, D-707 Two Axis Automatic Autocollimator	Lab or Field	2.5 in		± 1 min of arc	± 0.1 sec of arc	Micrometer Dial and Sliding Scale	Analog and Visual	
Davidson Optronics D-925 Two Axis Autocollimating Theodolite, D-925	Lab or Field	2.5 in		± 1 min of arc	less than ± 0.2 sec	Micrometer Dial and Sliding Scale	Visual, Analog and Digital	Quaternary output ± 1 second and ± 58 seconds (other outputs on special order)
Chrysler Missile Division WS133A, Mobile Minuteman (Under Development)	Field	5 in		± 1.5 Deg.	less than 1 sec		Analog	Used in conjunction with ou. Chrysler twist autocollimator.

AUTOCOLLIMATORS, PHOTO-ELECTRIC, DOUBLE AXIS
TABLE IV (Continued)

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
Keuffel and Esser EAG P2	Lab	-	-	± 25 sec of arc	1/50 sec	Indicator	Analog	Sensitivity selection ± 1 , ± 25 , ± 100 sec
Keuffel and Esser EAG TP2	Lab	-	-	± 100 sec of arc	1/50 sec	Indicator	Analog	Sensitivity selection ± 1 , ± 25 , ± 100 sec
Perkin Elmer - Optag 1 (Optical Pickoff Two Axis Gyro)	Lab or Field	0.30 in.	0.60 in.	2.5 degrees	0.05 sec		Analog	
Perkin Elmer - Optag 1 (Optical Pickoff Two Axis Gyro)	Lab or Field	1/6 lens		< 1 degree	0.05 sec		Analog	1 inch dia., 1 3/4 inch length, weight 9 ounces

AUTOCOLLIMATION THEODOLITES, VISUAL
TABLE V

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensitivity Calibration	Type of Readout	Notes
A. VISUAL	}						
Askania - Werke (Germany)							
Kern DKM-2, DKM-3 (Switzerland)							
Wild T2, T3 (Switzerland)							

SEE GENERAL LITERATURE PROVIDED BY SUPPLIER.

AUTOCOLLIMATION THEODOLITES, PHOTO-ELECTRIC
TABLE VI

Manufacturer - Description	Use	Aper- ture	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
B. PHOTO-ELECTRIC Autonetics(North American Aviation) C22	Lab and Field	2.36 in.	372 mm	±12 mins Az. and El.	0.1 sec	Theodolite Scale	Analog and Visual	(Wild T3 modified to accept an Autonetics Photo-electric eyepiece)
Davidson D-925	Lab or Field	2 1/2 in.	20 in.	2 min at 135 feet	0.2 sec	Azimuth and Elevation Scale	Analog and Visual	Azimuth Setting can be read to 0.5 sec and is accurate to 1.0 ser Elevation scale readability and accuracy ± 1/2 min.
BARNES MODEL 23-210	Lab or Field	-	-	-	-	-	Analog and Visual	Employs a Rotary Table for setting Azimuth Angles to an accuracy of one second and an Elevation Mech- anism for directing the Autocol- limation Axis along slant paths from 20 degrees above to 10 degrees below the horizontal.

AUTOREFLECTORS, PHOTO-ELECTRIC
TABLE VII

Manufacturer-Description	Use	Aperature	Focal Length	Field of View (Range)	Sensitivity	Calibration	Type of Readout	Notes
Davidson Optronics D-965 Automatic Long Range Alignment Electrotheodolite (See General Characteristics Below)	Field	2.6 in.	20 in.	± 10 min. at 500 feet	1 sec of arc	Spectrometer Base	Analog and Visual	Various Modifications Used for Thor Alignment and Development Phases of Atlas, Jupiter, Minuteman, and Titan programs.
Davidson Optronics D-678 Modification 1, for General Electric (Polaris R and D)	Field	2.6 in.	20 in.	± 10 min. at 500 feet	1 sec of arc		Analog	Polaris (R and D Program) Essentially the same as the D-985 mentioned above.
Perkin-Elmer LRLA Long Range Theodolite (See General Characteristics Below)	Field	-	-	± 6 min. at 800 feet ± 24 min. at 200 feet			Analog	

GENERAL CHARACTERISTICS

D-985

	<u>Perkin-Elmer (LRLA)</u>
Operating Distance.....	Distance..... 200 to 1000 feet
Theodolite.....	Elevation..... ± 30 degrees Rotation..... 360 degrees Azimuth Monitoring Range..... ± 6 minutes of arc at 800 feet ± 24 minutes of arc at 200 feet
Glass Circle.....	Rotation Sensitivity and Reproducibility (with sway compensation operative)..... Better than 2 seconds of arc
Translation.....	Rotation Output Noise..... Better than 2 seconds of arc
Angular Range of Automatic Operation.....	Sway Compensation Range..... 10 inches
Acc. of El. Scale.....	Sway Sensitivity and Reproducibility..... Less than 1/8 inch at 1000 feet (equivalent to better than 2 seconds of operating distance)
Response Speed.....	Rotation Output Signal..... Provided by VERNISTAT* or potentiometer, with frequency and voltage characteristics as desired.
Sensitivity of System.....	
Linearity of Readout.....	
Power Requirements.....	
	115 ± 10 v; 60 ± 3 cps; 250 watts
	115 ± 5 v; 400 v cps; 3.5 watts

VERTICAL AZIMUTH TRANSFER DEVICES
TABLE VIII

Manufacturer - Description
Chrysler Missile Division ^a
Davidson Optronics
National Physical Laboratories Teddington, Middlesex, England
Perkin - Elmer Corporation a. Twist Autocollimator b. Alignment Polarimeter
Keuffel and Esser Electronic Torsion Angle Indicator - Teal
Norden Division United Aircraft Corporation

BECAUSE OF THE RAPID ADVANCES IN THIS AREA IT IS SUGGESTED THE
READER CONTACT THE INDIVIDUAL COMPANIES AS TO THEIR MOST
RECENT DEVELOPMENTS.

^a Developed for the Mobile Minuteman Weapons System (program canceled December, 1961)

IV. MANUFACTURERS AND LOCAL REPRESENTATIVES

Manufacturer	Local Representative
Askania-Werke AG, Berlin-Friedenau	Los Angeles Scientific Instrument Co. 2451 Riverside Drive Los Angeles 39, California NO 2-2128
Autonetics (A Division of North American Aviation)	9150 East Imperial Highway Downey, California SPruce 3-2233
Barnes Engineering Company Stamford, Connecticut	Costello and Company 2740 South La Cienega Blvd. Los Angeles 34, California UP 0-8537
Chance Vought Electronics Dallas 22, Texas	690 North Sepulveda El Segundo, California OR 8-5785
Chrysler Corporation Missile Division Detroit, Michigan	None
Davidson Optronics	2223 Ramona Blvd. West Covina, California EDgewood 7-7281
J. W. Fecker (American Optical) Pittsburgh, Pennsylvania	1433 Cole Place Los Angeles 28, California HO 3-4161
General Mills, Inc. Mechanical Division Minneapolis, Minnesota	Suite 105, Airport Office Bldg. 8929 South Sepulveda Blvd. Los Angeles 45, California OR 3-4622
H and H Controls 7 Le Roy Drive Burlington, Massachusetts	
M. Hensoldt and Sohne Optische Werke AG Wetzlar, Germany	Max Erb Instrument Co. 3341 West Olympic Blvd. Los Angeles 19, California RE 1-6349
Hilger and Watts, Ltd. London, England	Engis Equipment Co. 431 South Dearborn Street Chicago 5, Illinois HA 7 3223

Manufacturer	Local Representative
Kern and Co. Ltd. Aarau, Switzerland	Los Angeles Scientific Instrument Co. 2451 Riverside Drive Los Angeles 39, California NO 2-2126
Keuffel and Esser, Hoboken, New Jersey	1327 South Olive Street Los Angeles 15, California RI 7-7601
Ernst Leitz Wetzlar, Germany	Opto-Metric Tools, Inc. 137 Varick Street New York 13, New York ORegon 5-9076
Nikon Incorporated Instrument Division 111 Fifth Avenue, New York 3, New York	A. G. Heinze Company 2307 East Foothill Blvd. Pasadena, California MU 1-7474
Norden Division, United Aircraft Corporation Stamford, Connecticut	
Razdow Laboratories Inc. 77 12th Avenue Newark 3, New Jersey Mitchell 3-8116	
Remanco, Inc. 1805 Colorado Avenue Santa Monica, California	
(Opto Tooling) G. Scherr Co. 200 LaFayette Street New York 12, New York	Scherr - Tumico Company 3537 West Olympic Blvd. Los Angeles 19, California RE 1-8777
Perkin Elmer Corporation Norwalk, Connecticut	5670 East Washington Blvd. Los Angeles 22, California PA 2-4900
Taylor, Taylor and Hobson, Ltd. Leicester, England	Engis Equipment Company 431 South Dearborn Street Chicago, Illinois HA 7-3223
Wild-Heerbrugg, Switzerland	Surveyors Service Company 2021 South Grand Avenue Los Angeles 7, California RI 7-0606

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