

THE NEW STEREOPLOT ANALOGUE STEREO PLOTTING
MACHINE

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The major task of aerial photogrammetry is to represent graphically, or acquire digitally, the topographic information of the earth's surface from aerial photographs at different scales according to their purpose of use. The current trend in photogrammetry towards universal analytical restitution systems has not impaired the great importance of analogue stereoplotting machines for map production. Also in the next decade analytical and analogue stereoplotters will be the dominating systems in photogrammetric map production; while analytical machines will be preferred for special tasks, analogue plotters will primarily be used for map production. For such tasks analogue plotting machines will be the most economic solution. Distinguishing features are their simple operation, rugged construction, relatively little maintenance work, high adjustment stability, long life and high accuracy.

Under these aspects the new STEREOPLOTTER analogue stereoplotting machine has been developed. It will gain a strong foothold beside the well-known STEREOMETROGRAPH and TOPOCART analogue stereoplotters, of which far more than 1200 machines are used on all continents. Compared with these two machines the particular merits of the STEREOPLOT are such features as internal plotting table, free-hand guidance, common ϕ , weight compensation of the space rods and photo carriages, one-arm guide rod and connection possibility of digital and analogue peripheral devices. With the STEREOPLOT belonging to the lower-price class of analogue plotters the program of analogue stereoplotting machines is completed.

The basic variant of the STEREOPLOT consists only of the measuring system with internal plotting table and free-hand guidance. Compared with this, there is an extended design variant with hand-wheels, belt drive in the projection plane, electrical outputs for connecting peripheral devices, and the electrical 120 x 120 plotting table. In a third variant this table is replaced by the DZT 90 x 120 Digital Plotting Table. The measuring system is supplemented by digitizers and the electrical height counter is dispensed with. The adapter plate for $c_k = 210$, the weight compensator for the photo carriages, and model corrector have been provided as accessories.

Essential technical features

The STEREO PLOT is an analogue stereoplotting machine. The rugged construction and the mechanical principle with space rods successfully used over decades guarantee great stability of adjustment, high accuracy and a very long life.

The design principle is based on two one-arm space rods which realize the corresponding measuring beams from image point to model point and are mounted in gimbals in spatially movable model carriages. The space rods go through the camera's projection centres designed as cardans and the movable cardans in the image plane connected with the photo carriages. The machine operates on the principle of the scaled-down, strictly spatial reconstruction of the taking disposition using the spatial parallelogram, with the negatives or diapositives being inserted into the photo carriers of the plotting cameras.

The substructure incorporates the drawing plate of the internal plotting table and the electrical system. Two castings support the photo carrier frame with the image planes, the cross-slide system of the projection plane and the viewing attachment.

The photo carriages with the photo carriers move on the cross-slide system with the X-direction being the primary guideway. The image restitution range permits the restitution of photographs with a longitudinal overlap of 50% to 80%. With the model corrector, an additional device, it is possible to correct image errors caused by distortion, earth curvature and refraction. A compensation device for weight balance guarantees also with photo tilts a uniform, smooth and precise movement of the photo carriages.

The photo carriers with the fiducial mark plates are removable. They are designed as turnover photo carriers for unreversed negative or positive observation and can be exchanged. The mark plates have fiducial marks in the axes and diagonals for the image format 23 cm x 23 cm. Negatives and diapositives on film or glass can be restituted.

The standard equipment of the TOPOCART has been designed for the focal lengths 84 mm to 91 mm and 149 mm to 156 mm. On request the system can also be upgraded to the focal length range 209 mm to 216 mm.

Focal length change can be performed simply by exchanging the base plate to which the camera cardan is attached. Fine adjustment is made by milled screws with a setting accuracy of 0.01 mm.

The projection plane consists of the cross-slide system in which contrary to the image plane the y guideways are the primary guideways. This enables a smooth and uniform x, y movement. On the x carriage the guide rods are mounted in gimbals one behind the other in y direction and the weight of the guide rods is balanced by counterweights. The arrangement of the guide rods enables the longitudinal tilt to be carried out without so that the orientation process is considerably facilitated.

Besides, the z spindle is mounted on the x carriage and the model carriage simultaneously serves as stylus carriage for the internal plotting table.

The internal plotting table consists of a luminous surface of 400 mm x 480 mm and permits a ratio of 1:2 between photo and model scale. In the basic design variant the drawing head is manually operated while in a second variant operation of the electromagnetic lifting magnet is by a foot switch. Lead holders, ball-point refills, ink pens and scribes can be used as drawing sheets.

The x-, y-movement is made by freehand guidance on the x-model carriage in the basic design variant. It can be extended by handwheels. Via synchros, which with regard to long life and accuracy proved to be of excellent value in the STEREOMETROGRAPH precision plotting machine transmission is made to belt drives attached to rollers in order to prevent slippage. Incremental shaft encoders can additionally be attached to the rollers for digital output. The direction of rotation of the handwheels is reversible.

Motion of the z-coordinate is performed by a foot disk. Transmission to z-spindle and height counter is likewise effected via synchros. An incremental shaft encoder can be attached to the z-spindle for digital output.

The height counter is an independent module connected via cable to the distribution box. With a variable gear 10 different scales can be selected readable in meters or feet. The least count on the digital counter is 0.01 m or 0.1 foot. When the Digital Plotting Table is connected the heights are displayed on the counter of the control desk of DZT 90 x 120. According to the transmission ratio between 0.01 to 9.99 from the plotter to DZT 90 x 120 model scales can be selected in steps of 100 units between 1:100 to 1:100000.

For the output of the coordinates x, y and z, electrically via synchros and digitally by incremental encoders, receptacles are available permitting 4 peripheral devices to be connected electrically and two digitally. The coordinate ranges in the plotter are safeguarded by microswitches delivering acoustic signals when the end stop of the range is reached.

The following elements are available for orientation: b_x , b_{y_I} , φ_I , φ_{II} , ω_I , ω_{II} and $\bar{\varphi}$. Through the common $\bar{\varphi}$ absolute orientation is essentially simplified and relative orientation not disturbed. By means of the b_y by setting it is possible to measure vertical parallaxes in numerical orientation techniques and to ascertain more conveniently residual errors in relative orientation. The same elements of orientation are available as in precision plotters and the same methods of orientation can be applied.

Image rotation is performed with the knurled knobs on the photo carriers. The convenient setting and the high reading accuracy of 0.02 gon or 0.02 mm resp., are of particular advantage in numeric orientation methods with transfer of the calculated orientation data from aerial triangulation or in computer-aided plotting.

With the viewing system the photographs are observed frontally from below with a constant 7-fold magnification. Longitudinal and lateral tilt as well as the bx-setting require optical units which compensate displacement. The measuring beam has been kept very short, for it is already in the camera where photograph and fiducial mark are united, so that no measuring errors are produced by the optical system. The fiducial mark is a green luminous mark with a size of 0.04 mm. Image illumination and fiducial marks are separately adjustable in brightness. The Schmidt prisms installed on either side of the path of rays permit the compensation of an image rotation, if any. The large visual field of 32 mm in connection with the natural stereoscopic viewing of the terrain in frontal image observation has a favourable effect on the sure guiding of the measuring mark in the plotting of contour lines. The high resolution capability of the coated optics guarantee the recognition of smallest details in the photograph.

In the STEREO PLOT the ratios of image scale to model scale are as follows:

c_k	=	90	min.	1.44	max.	2.2
c_k	=	150	min.	1.25	max.	2.2
c_k	=	210	min.	1.2	max.	1.6

With the transmission possibilities on the plotting tables, viz. electrical plotting tables 0.16 to 6.25 and digital plotting tables 0.01 to 9.99, we are capable of achieving transmission ratios of 1:12 for electrical plotting tables and 1:20 for digital plotting tables between image and map scales. The electrical plotting tables 120 x 120 EZ-A and 90 x 120 EZ-F are electrically coupled with the plotter via synchros. The electric connection allows the place of erection to be freely chosen. The plotting tables are provided with transmitted illumination. The plotting ranges are 120 cm x 120 cm or 90 cm x 120 cm, resp. A variable gear enables plottings to be made at 21 different scales between 0.16 to 6.25-fold. The stylus carriage is fitted with a lifting magnet which is actuated by a foot switch. The mount of the lifting magnet takes holders for leads, steel scribes, sapphires, ball-point refills and ink-pens. A warning system signals the limits of the ranges. The plotting table can be correlated to the plotter by cable exchange and the sense of rotation freely selected.

The DZT 90 x 120 Digital Plotting Table or the computer-aided plotting system are linked via connectors to the three encoders in the STEREO PLOT. The drive of the two plotting table coordinates is effected by racks and pinion which are connected

with d.c. servomotors through a gear. A separate measuring system ascertains the actual coordinates. The entire electronic system is housed in a separate electric cabinet. The equipment is under the control of microcomputers. Operation is effected by pushbuttons which are clearly arranged on the control desk. The DZT is distinguished by the following features: double lifting magnet, optional correlation to the plotter, scale selection between 0.01 and 9.99, alternative display of plotting table coordinates, drawing of 5 symbols in 6 sizes, straight-line joining of measuring points, synchronous following, 4 different types of lines with three selectable line lengths, change-over to manual control without loss of correlation to the measuring system, precise setting of points, print-out of height numbers, electrostatic fixation, and additional off-line control of the plotting table by magnetic tape.

The computer-aided plotting system is an extension of the digital plotting table by a computer. Thus the plotting table software could be extended and possibilities of application were essentially increased. Operation of the system is via the keyboard of the display.

An additional functional keyboard simplifies operation, so that it involves no problems. Compared with the DZT 90 x 120 the computer-aided plotting system has further particular advantages such as calculation of absolute orientation, calculation of plotting table orientation, calculation of rectangularity for drawing buildings, closing of polygons, hatching of areas, calculation and plotting of parallel lines, alphanumeric lettering at any angle, free generation of symbols, signatures and line types.

Technical data

Image size	23 cm x 23 cm
Viewing magnification	7x
Field of view referred to image plane	32 mm
Fiducial mark diameter	0.04 mm
Eyepiece distance	55 mm to 75 mm
Eyepiece focussing	-5 D to +5 D
x-, y-movement	freehand guidance with handwheels coarse motion 55 mm/rev. fine motion 1.8 mm/rev.
z-movement	with foot disk 5 mm/rev.
Calibrated focal length c_k	84 mm to 91 mm 149 mm to 156 mm 209 mm to 216 mm
Longitudinal tilt φ_I, φ_{II}	± 5.5 gon
Lateral tilt ω_I, ω_{II}	± 5.5 gon
Common longitudinal tilt $\tilde{\varphi}$	± 5.5 gon
Image rotation κ	± 15 gon
Base component by	60 mm to 220 mm

Base component by I	± 10 mm			
Image coordinates				
x' left photo	-115 mm to +60 mm			
right photo	- 60 mm to +115 mm			
y'	± 115 mm			
Spatial coordinates				
x coordinate	380 mm			
y coordinate	480 mm			
z coordinate	$c_k + 40$ mm to 350 mm			
Max. field angle	139 gon			
Height counter scales	1:1000	1:1250	1:1600	1:2000
in metric plotting scales	1:2500	1:3200	1:4000	1:5000
	1:6250	1:8000		
Accuracy				
Medium coordinate error referred to image plane	$m'_{x,y} \leq \pm 0.010$ mm			
Medium height error in % of flight height	$m_h : h_g \leq \pm 0.07$ %			

Summary

The new analogue stereoplotting machine employs the mechanical principle of space rods, which realize the corresponding measuring beams for image point to model point.

The machine is designed for the restitution of photographs taken with focal lengths of 90 mm, 150 mm and 210 mm and it incorporates an internal plotting table, a freehand guidance, common ϕ , handwheels and foot disk for coordinate movement, weight compensators of the space rods and the photo carriage, digital and analogue output of coordinates on peripheral devices.

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- 8 ASA PH 2.5-1960 American Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous Tone)
- 9 DIN 4512 Photographic Sensitometry, Determination of photosensitivity of Black-White-Negative Material for photographs
- 10 TGL 143-408/12 Photosensitive Silver Halide Recording Material on Transparent Base, Determination of General Sensitivity

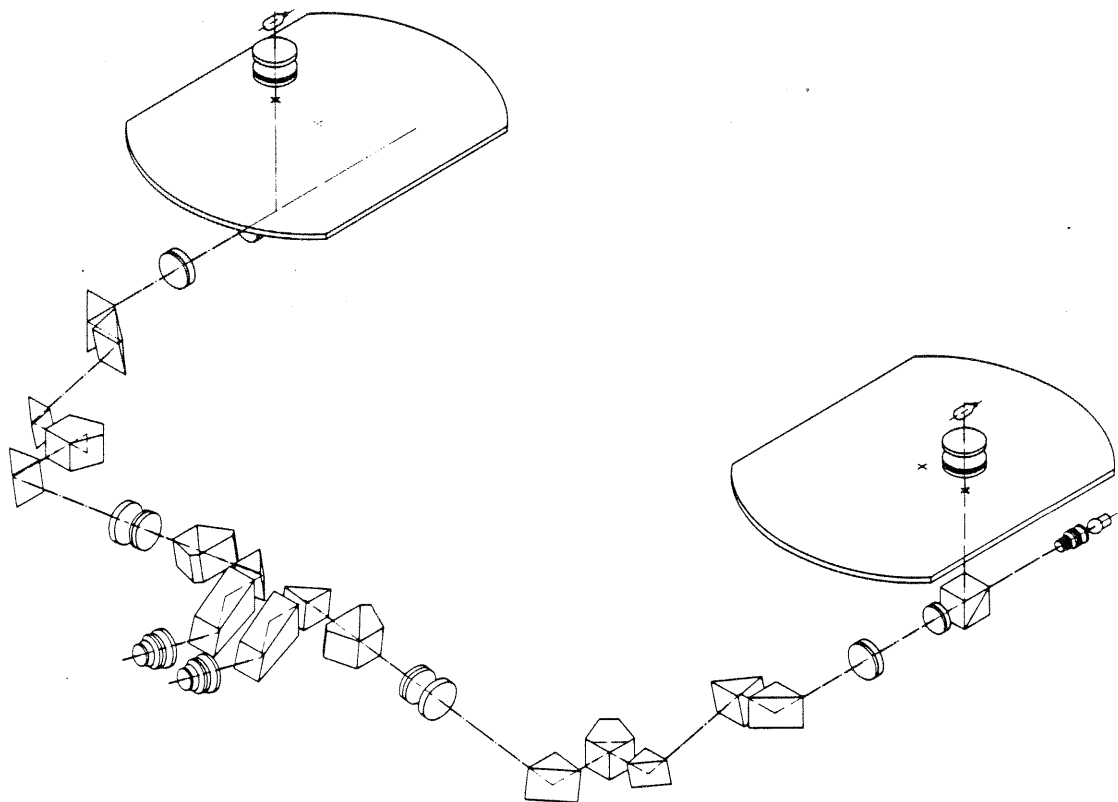


Fig. 1 Optical design of the STEREOPLOT from JENA

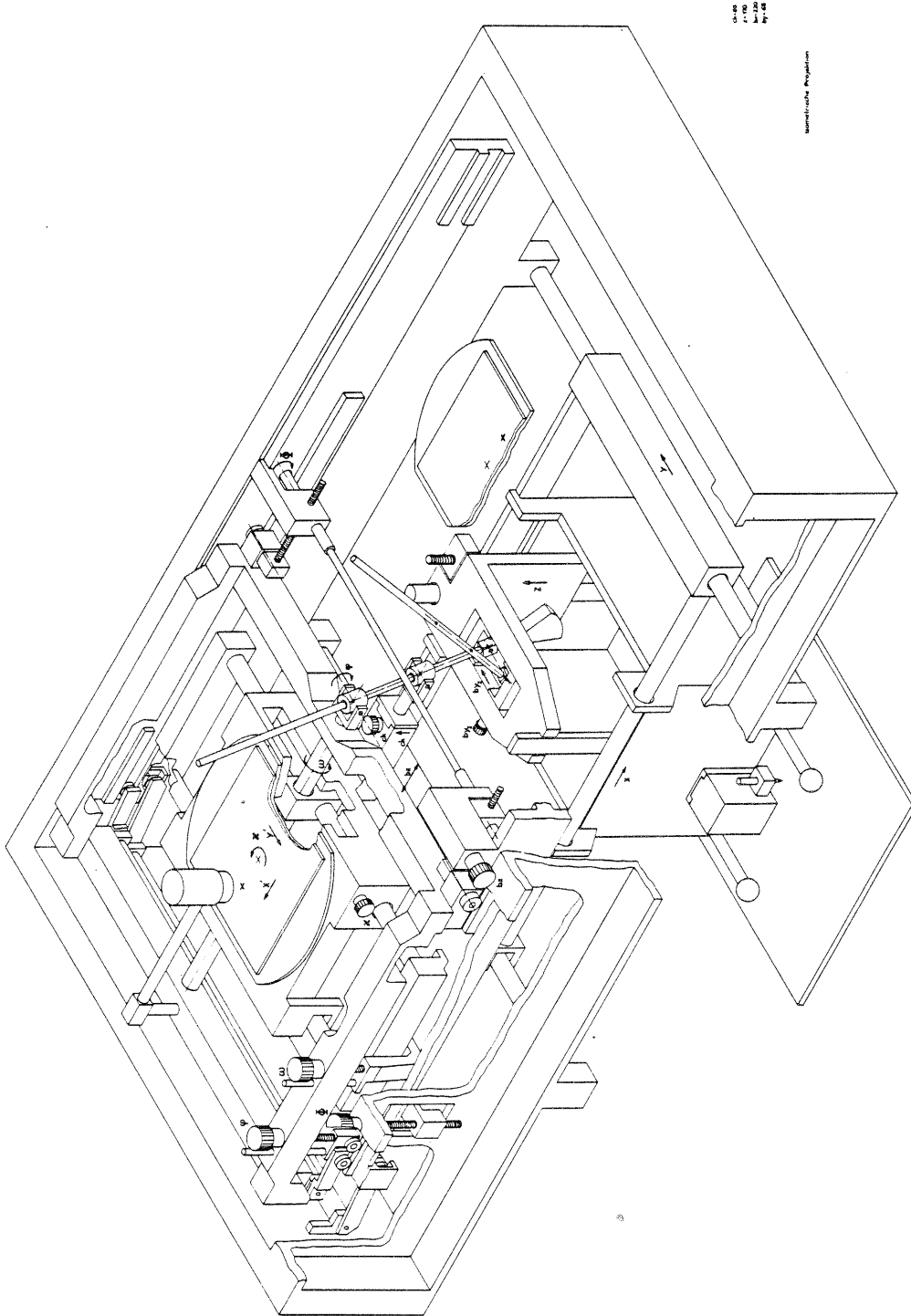


Fig. 2 STEREOPLOT from Jens, schematic representation