Y increment, and will be obtained from the projection of one of the diapositives of the stereo pair, with the red filter removed.

After being amplified by a remote video amplifier this signal is reproduced on a small Cathode Ray Tube which is mounted on a second electro coordinatograph. The remote CRT is mounted so as to make an exposure of all of the details in the photograph on to a flat sheet of photographic film. Proper photographic filtering will prevent the second photo of the model from being reproduced, or one light may be turned off since, during this operation, no stereoscopic viewing is required.

The CRT reproducer travels only in the X direction during a single profile (i.e., no Z motion is included in the making of the orthophotograph). Thus, a flat photographic exposure plane is used. True orthographic proportion is obtained by controlling the Z motion of the television camera pick-up tube from the tape recording. This technique, has the advantage of not having to raise and lower a large flat photographic sheet during the profiling operation as would be the case if the exposure slit and film were in the actual model space.

A second advantage is provided in the Integrated Mapping System concept in that the operator is given a chance to change his profile to a completely satisfactory one *before* making an exposure on the orthophotograph.

The third product is the provision for making a permanent recording of the model space. This can be done either concurrently with the line-drop contour chart and/or the orthophoto; or it may be made separately.

Operationally this does not cause any difficulty. It is expected that the three products—contouring, orthophoto and permanent recording—can be accomplished with only two scans of each profile (except the initial one).

Thus: Right to left on the initial scan will provide course data. Left to right will provide a check, or left to right—contouring, exposing and recording.

On subsequent scans, right to left will provide a check with minor corrections. Left to right—contouring, exposing and recording.

*Automation of the Aero Service/Haag-Streit Coordinate Plotter**

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ABSTRACT: *The purpose of this paper is to discuss the value of a directly coupled digital system of automation designed for the Coordinatograph on Static rather than Dynamic principles. Component parts such as the Flexowriter, Drive System, Programmer and Translators comprising the automated system, are explained relative to their applications to Photogrammetric requirements.*

BECAUSE of the rapid rate of technological advance in this country, it is difficult to predict what new developments will take place in manufacturing during the next ten years.

However, the predicted expansion of industry and population growth will surely lead to greater requirements for automation. This will be true in machining, press work and assembly operations of all kinds. It will include our own field, photogrammetry. The building block principle, in which machine tools are assembled from standard, interchangeable heads, bases and other components, will be generally accepted by industry and will make automation economically feasible.

Advances in our own field have demonstrated willingness of members of The American Society of Photgrammetry to meet the challenge of automation and to adapt some of the tooling and machining fields' techniques. With this in mind, more than two years ago, Aero Service Corporation embarked on a research and development project to produce a

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wholly automated coordinate plotter to form an integral part in a completely automated mapping system.

It was felt that the automated coordinate plotter should have a high degree of accuracy. Other prime requirements were versatility and compatibility with in-line functions of other equipment such as stereo-plotters and/or computers.

The basic instrument selected for automation is the Haag-Streit Coordinatograph. Figure 1 shows the manually operated instrument. It is of rack and pinion construction. It has one continous brass rack measuring 60″ in length giving an overall plotting range of $47\frac{1}{4}$″ or 120 cm. The measuring pinions are steel. The "X" and "Y" rails are grey cast iron, stress-relieved to insure continued accuracy. The coefficients of expansion of the instrument and brass racks are essentially the same.

The manual Coordinatograph's ability to repeat coordinate positional information was tested very thoroughly. Approximately 15 coordinate points were located on a stable medium using the manual Coordinatograph. Then the settings of the instrument were disturbed and the drafting medium moved, and the coordinate positions were re-read. This procedure was followed using three operators. Each one read the coordinate information five times after first removing the material, re-orienting and re-reading all the points. The average deviation in the readings made by the three operators did not exceed 0.0013″.

This instrument statisfies the high requirements of accuracy and versatility, as well as simplicity of operation and design, and reliability. All these are necessary to utilize fully the capability of the component parts of the automated system.

The automation system is designed on static rather than dynamic principles. This means that it is directly coupled throughout. If there is a power failure or an erratic contact during the process of plotting coordinate information, the system will not be disturbed in any way.

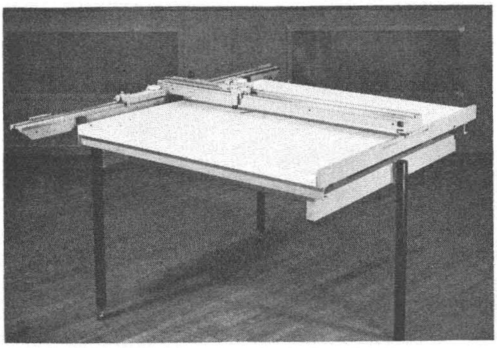

FIG. 1. Manually operated Haag-Streit Coordinatograph.

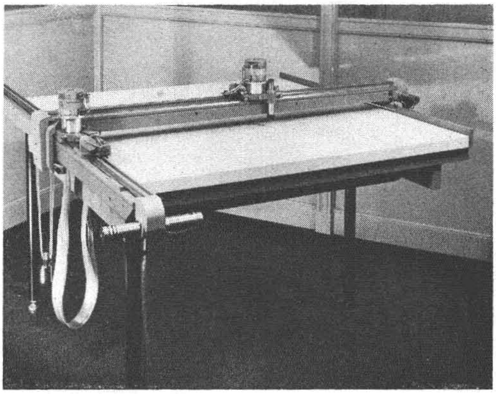

FIG. 2. Drive motors for the automated Coordinatograph.

Figure 2 shows how the configuration of the basic manual Haag-Streit Coordinatograph has been changed. It illustrates the drive motors located at the extremities of the "X" and "Y" rails. The encoders occupy the areas originally utilized by the counter dials.

Dynamic systems operate through the use of pulses rather than static voltages. The pulses are generated by the encoder as it rotates, and are stored in electronic counting circuits rather than in relays. These circuits count pulses, add, subtract and perform with them the required logic operations. A slight electrical interference can disturb the dynamic system, and it has no means of re-establishing its frame of reference once lost. A static system has been chosen over a dynamic system because the latter is less dependable in this vital respect.

The static system, by referring to its encoder, has at all times an absolute indication of its position. Regardless of how stable and reliable a pulse counting system might be made, it could never be as surely defended as the absolute directly coupled system.

A rather significant advancement in the method of conducting power to the component parts of the automated Coordinatograph is illustrated in Figure 3 which shows the ribbon tape Mylar conductors. This tape contains 30 conductors laminated between strips of Mylar. Two tapes for a total of 60 conductors are employed. The tape permits the carriage to move freely from position to position; there is no drag in the movement of the carriages from heavy, cumbersome electrical

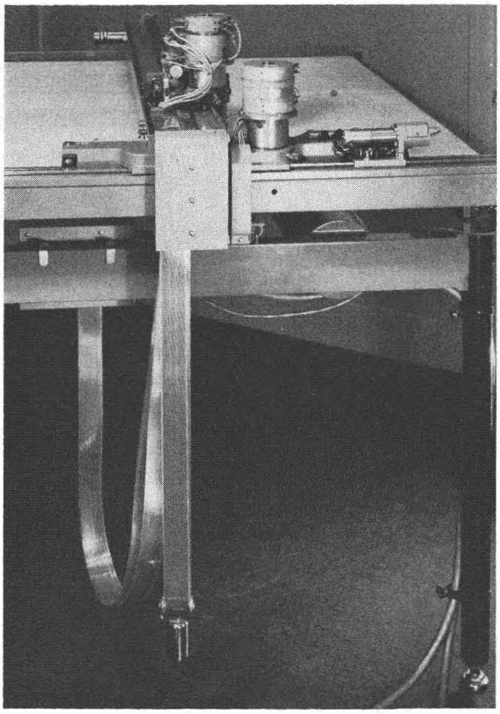

FIG. 3. Thirty conductors are laminated in the Mylar strips to supply power to automated Coordinatograph.

connecting cables.

Many positioning systems are not wholly digital throughout. Although the input data may be in digital terms, this information is quickly converted to analog form within the machine. One method is to arrange a relay tree which the command signals set so that it will pick off calibrated voltages from a divider network. The voltages become the analogs of position, and are used in appropriate servo circuits, such as self-balancing bridges.

Systems of this type usually incorporate amplifiers and vacuum tube circuits. They are more complex in theory and more difficult for service personnel to adjust or repair. The varying voltage amplitudes and phases which must be understood and measured with intricate instrumentation may be the reason for this difficulty. By comparison, digital circuits using relays and contact devices are simpler, having only ON-OFF signals or polarity changes. The fact that the signals' magnitudes are less quantitative implies freedom from many circuit aging effects, and provides greater reliability. For these reasons there was selected the completely digital system designed on static rather than dynamic principles.

One of the most widely-used methods of input for data processing is punched paper tape. Figure 4 shows the Friden Flexowriter which performs this input function in the automated Coordinatograph. The Flexowriter provides four necessary components: 1) a *keyboard* for entering data and instructions on paper tape; 2) a *punch* to prepare the tape for automatic plotting and recording of coordinate locations; 3) a *tape reader* to enter the information for automatic plotting; 4) an *electric typewriter* to give a printed record of located points when performing a readout function.

Taking advantage of the accurately ground racks and pinions of the basic Coordinatograph was sought. There was selected a shaft-position encoder where size, weight, low torque, and inertia were of paramount importance. After examination of the available commercial encoders, it was concluded that the series CG-700 encoder assemblies manufactured by the Datex Corporation would satisfy these stringent requirements.

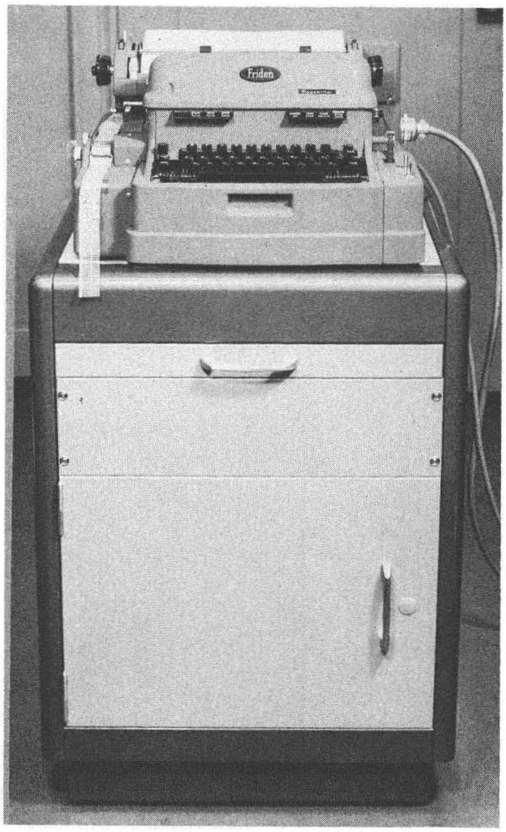

FIG. 4. Friden Flexowriter supplies input data for automated Coordinatograph.

Figure 5 depicts the positions occupied by the Datex encoders on the Coordinatograph. They fit the openings which house the counter dials on the manual instrument. The torque load for this encoder is a 0.70 oz. per in. with an accuracy of one part in a thousand.

These encoders in series may be coupled directly to the input shaft, providing 1,000 positions of the least significant digits per 360° rotation. This input unit may then be geared in a step-down ratio to another series encoder, which essentially counts the number of revolutions of the high-speed unit and thus determines the higher significant digits. The low-speed encoder utilizes double brush, lead-lag logic to eliminate ambiguities due to gearing inaccuracies and backlash. Hence, the accuracy of the CG-700 series is limited only by the accuracy of the encoder attached to the input shaft. Because the gearing to the low-speed encoder is in a step-down ratio, the inertia reflected back to the driving system by the low-speed encoder is a fraction of the inertia of this disc and has negligible effect on the drive requirements.

The modular rack containing the input programmer is shown in Figure 6. This programmer has several functions:

1) *to set the X-Y switching*, ensuring that the correct encoder is connected and appropriate drive motors operating.
2) *to actuate the Translator* which converts the IBM 8-digit binary code used in the Flexowriter to decimal equivalents and enter this in the Comparator.
3) *to actuate the Comparator* which indicates coincidence reached by the decimal digits.
4) *to actuate the Translator II* which receives the binary-coded cyclic decimal data and converts it to decimal contact closures by means of relays.

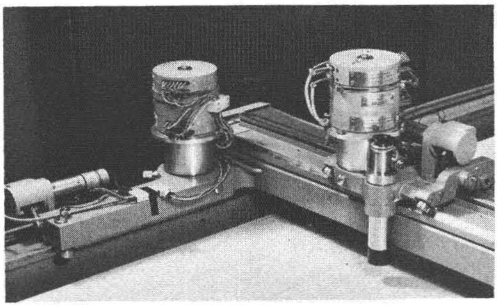

FIG. 5. Datex encoders have an accuracy of 1 part in 1,000.

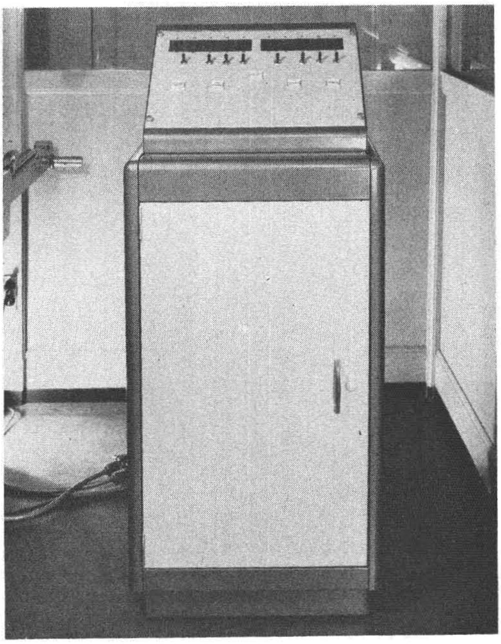

FIG. 6. Input programmer unit for the automated Coordinatograph.

This translator II provides three outputs: one for the comparator, one for the light bank, and one for the parallel-serial programmer.

This console also contains the visual display which projects the digits indicating the *X-Y* location of the encoders. Immediately below the visual display are located the toggle switches controlling the speed of the carriages.

The maximum speed of the instrument is 3″ per second, and in the lowest range is 0.003″ per second. The toggle switches may be actuated individually to control the approach speed of the carriages to a location which is to be plotted or read back.

It is felt that the features of the new automated Coordinatograph have usefulness in many of the diversified applications of industry, as well as in the requirements peculiar to mapping. This instrument's high degree of accuracy, stability and reliability may well present new economies as a basic unit in a completely automated, integrated mapping system.