

Presented Paper

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Photogrammetric measurement of Piping systems.

Abstract

A special technological line for Surveying of large pipe Structures has been worked out by the restitution and mapping center of Geocart and the photogrammetric application section of Jenoptic.

Basis theoretical considerations are followed by the description of pilot Surveying Missions in chemical plants. Reference is made to available instrumentation and different possibilities for the representation and the documentation of the final results are discussed. The application of photogrammetric measurement procedures is particularly recommended under hostile environment conditions (high temperatures poison gases, nuclear power stations etc.). The comparison with conventional Surveying techniques shows remarkable gains in working time, cost and over-all-effectiveness.

Parallel to the main application of photogrammetry in topographic national mapping its use also in the non-geodetic field now becomes more and more important. Especially in close-range work measurements are successfully made on machine parts, construction elements and steel constructions. The determination of the measuring points in a uniform three-dimensional coordinate system and the favourable automation capabilities of photogrammetric instrumentation turn out to be extremely advantageous components of subsequent electronic data processing.

In addition, for industrial measurements further features are often decisive for the use of photogrammetric mensuration techniques.

- Since measurements are made indirectly by using photographically produced pictures, the direct physical contact with the object is not necessary. Especially in the case of constructions with difficult access the erection of auxiliary scaffolds for facilitating and taking measurements is made superfluous. By this fact alone enormous costs may already be saved and a considerable amount of working time be gained.
- The indirect measurement of the object protects also the operators from accidents and in frequent cases a special preparation or even the shut-down of the plant during the surveying work is made unnecessary.
- The photogrammetric photographs taken can be preserved in archives, so that over a long period subsequent measurements and surveys can be made, even if the measuring object itself is no longer extant.

Measurement of piping systems

All these facts clearly suggested the use of photogrammetry for the measurement of piping systems in large plants of the chemical industry and in nuclear power stations. First experiments with Jena equipments started about 10 years ago with the objective of graphically representing empirically developed models of pipe arrangements. Valuable experiences were gained at that time. For the simplified recording of the pipe axes and for example, replaced by axial wires and diameter disks and informative graphical representation methods were developed.

For the present work on real piping systems of large industrial enterprises use can be made of a flexible system of camera equipments, whereas for restitution especially the image mensuration with the stereocomparator and the subsequent handling of these primary measuring data in the computer is recommended.

By definition a close range in photography is involved when the calibrated principal distance of the camera (this is to a first approximation the distance of the image plane from the rear nodal point of the lens) is greater than its focal length. The Jena cameras are either adjusted to a fixed focussing distance (SMK series) or the lens is focusable (UMK series). Despite this focussing the calibration parameters must be kept stable. In the cameras of the UMK series this is ensured by a highly precise ball guidance for the lens extension, which keeps the point of symmetry of the optical imaging system in the image plane stable to a few micrometers.

Decisive for a high measuring accuracy in the three coordinate axes is the product of image scale and base ratio. Through a maximum image format, on the one hand, and a field angle of the lens of 100 gon, on the other, this product assumes an optimum value and, thus, with a given accuracy for the image coordinate measurement has the minor error effects.

Measuring technology

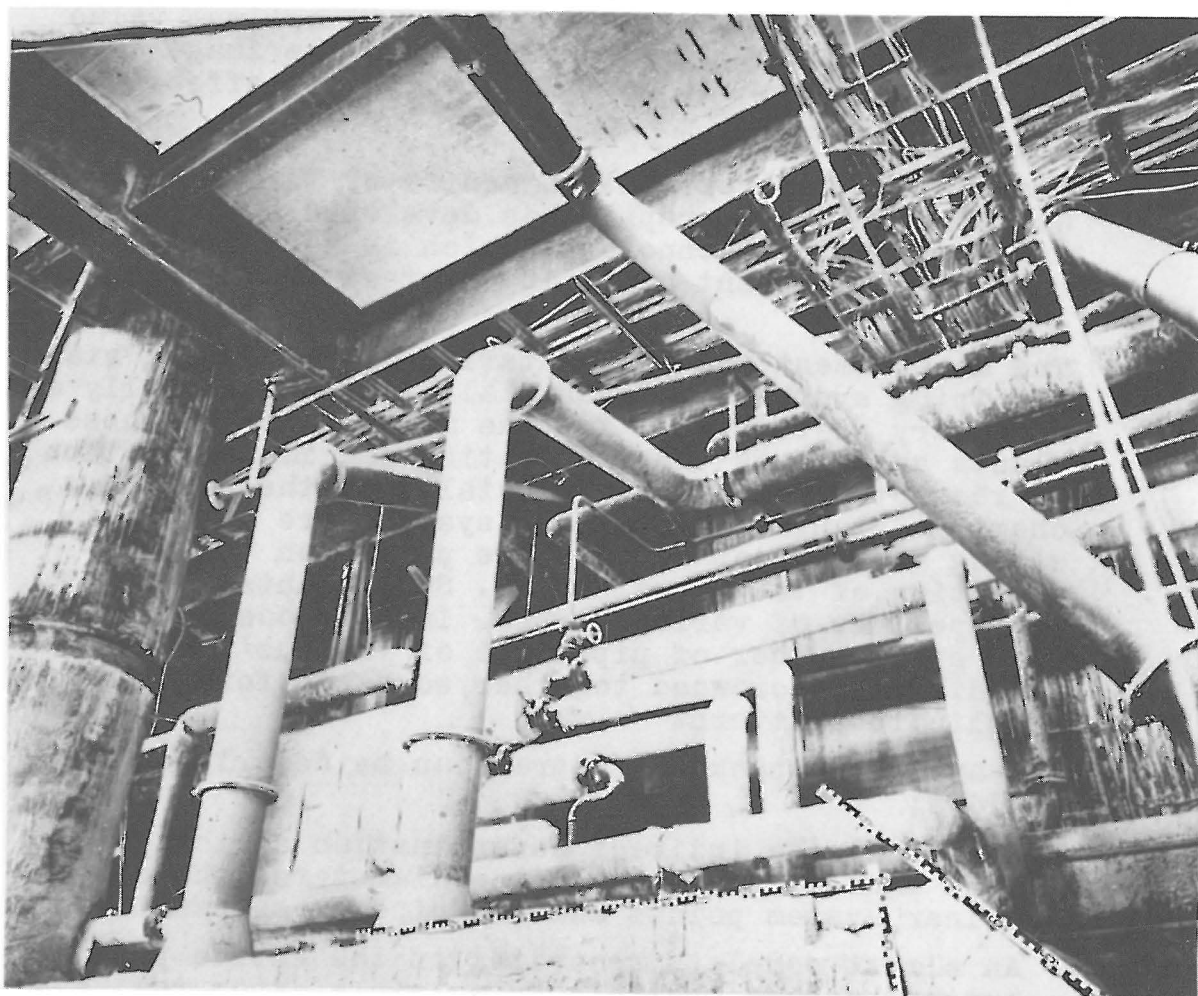
The mapping and restitution centre of VEB Kombinat Geodäsie und Kartographie has developed a photographic and restitution technology, which is used for the routine measurement of piping systems in the chemical industry.

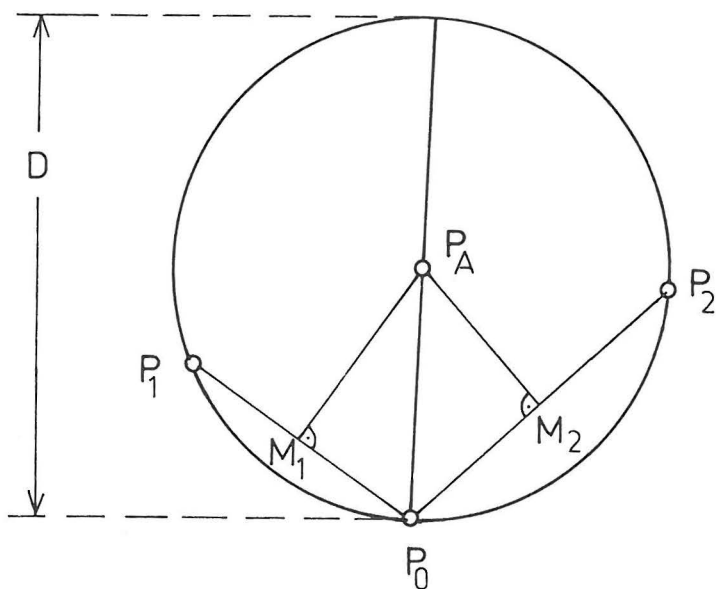
The measurement and documentation of the actual state of piping systems in industrial plants is normally a necessary prerequisite for the maintenance of these plants as well as the preparation and implementation of reconstruction work. Especially in the case of chemical plants whose piping systems are subject to strong wear, great demands are placed on the documentation of the actual state. Such plants consist of pipelines of various types. In most cases there is a great number of pipelines of various lengths and diameters crowded together so as to form a complicated pattern.

The available package program can be described as follows:

- It allows the indirect determination of the pipeline axes, the external pipe diameters, the container system points and the pipe cross sections.
- An almost complete recording of the entire piping system becomes possible by multiple exposures; also geodetic completion measurements and mechanical distance measurements may be included in the whole program.

- With small-format stereometric cameras (with bases of 0.4 and 1.2 m) and an object distance up to 20 m the mean coordinate error with regard to the spatial axes lies within ± 3 cm, which in most practical cases corresponds to the definition accuracy of pipeline elements with insulating casing.
- The results are represented as photographic documentation, in graphical plan views and front elevations, in isometric drawings as well as numerically in the form of coordinate and distance lists.





Geg.:

$$P_0 (x,y,z)$$

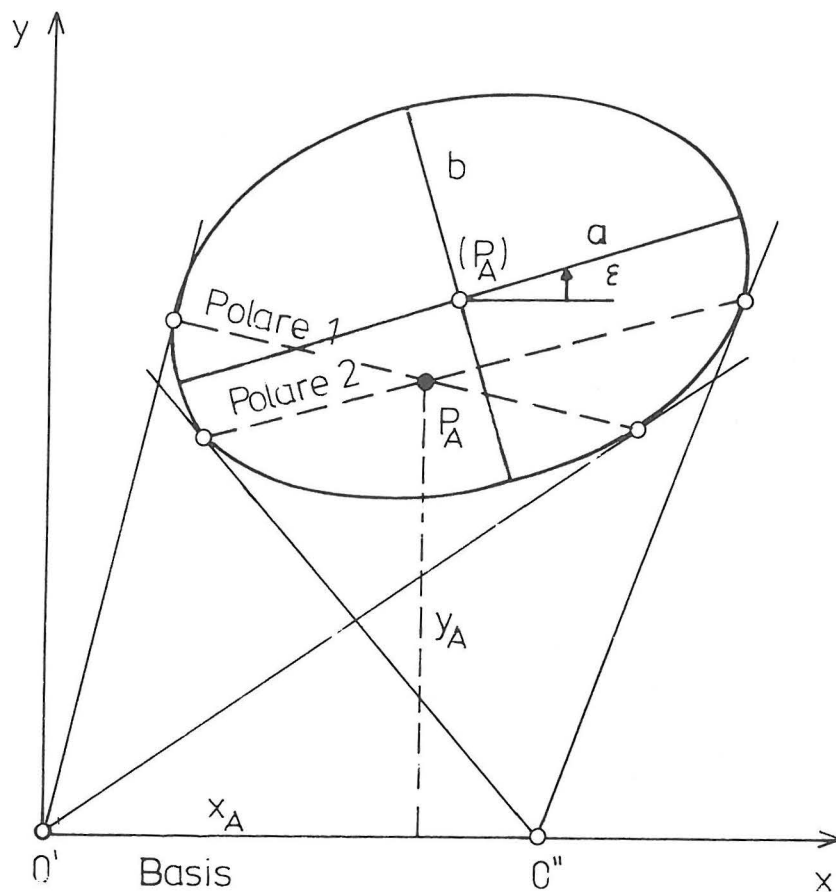
$$P_1 (x,y,z)$$

$$P_2 (x,y,z)$$

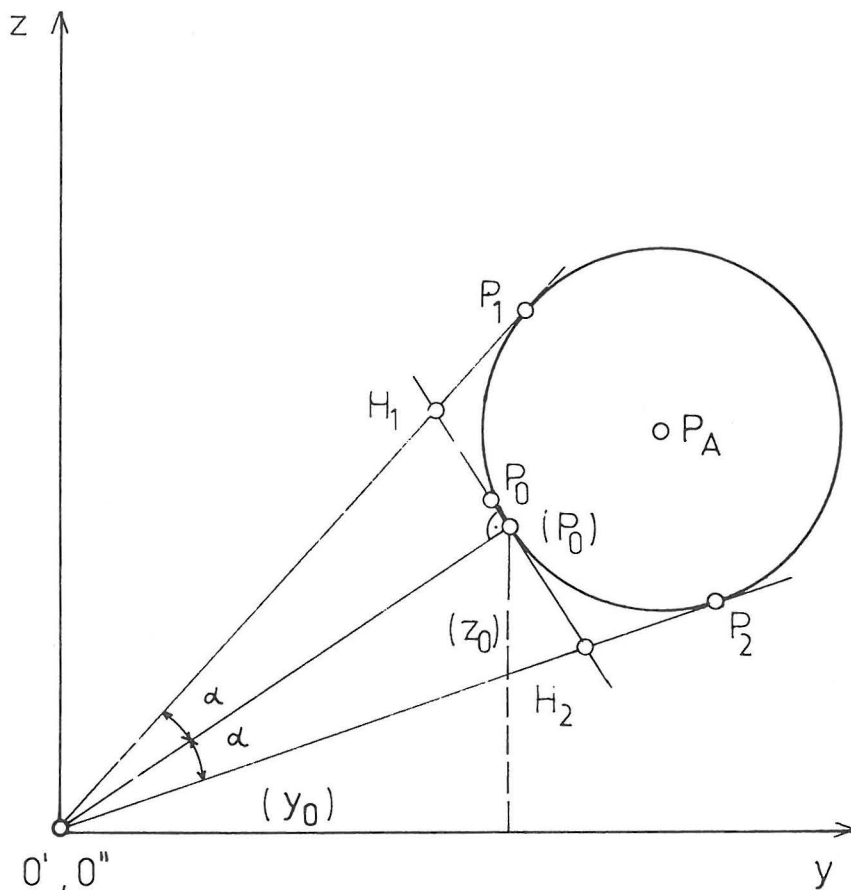
Ges.:

$$P_A (x,y,z)$$

Piping program 1: This is a rigorous method for the determination of the pipeline axis and of the outside diameter of a pipe. The program allows of an arbitrary position of the pipeline axes relative to the camera direction. A prerequisite is, however, that 3 points - lying on a visible circumference in the model and having a distance from each other being as large as possible - can be stereoscopically measured.



Piping program 2: It is applied, either when a visible circumference line in the spatial model cannot be recognized and the pipeline axis is approximately parallel to the base and thus horizontal, or when vertical pipelines are to be measured with a horizontal base. The method is a combination of the stereoscopic measurement of a point on a cylinder surface and the monocular setting of the two sight edges.



Piping program 3: Both measuring marks are monocularly set in x' direction on the two sight edges of the cylindrical measuring object. The calculated axial point is an approximate value. The resulting position error depends on the object distance, the pipe diameter as well as the spatial position of the pipeline axis in the system to be photographed. The determination of diameters is not possible in this case. This program is applied, when the pipeline runs in an arbitrary direction in space but not horizontally and when for any reasons (e.g. glare or when no circumference line is recognizable) a stereoscopic setting cannot be made.

Taking photogrammetric photographs

The camera stations are chosen so that a vibration-free

erection of the camera is ensured. Generally, several stereo exposures are necessary for completely recording the particular piping system. These stereo photographs must be arranged so that the stereo models overlap by about 30 % so as to ensure a reliable model connection. The exposure stations can be arranged in different heights. A geodetic determination of the stations of the cameras is not necessary.

The establishment of the camera directions relative to a given spatial object coordinate system is not subject to a restriction, the camera axes (of the stereometric camera or of camera pairs with parallel optical axes) may have any orientation in space. In the case of pipelines with complicated spatial arrangement the respective object parts have to be photographed from at least two different directions preferably perpendicular to each other so as to achieve a better optical penetration.

A control point determination for the absolute model orientation is generally not necessary. For scale determination, orientation means such as plumb lines and graduated rods are used which are arranged prior photography. It has proved expedient to use in the model space two up to maximally five graduated rods as well as one marked plumb direction. In the overlap zone of neighbouring models three model tie points have particularly to be signalled in cases where no conspicuous object details may assume this task.

The selected and realized taking disposition is represented in a sketch, which is the basis both for the photographic process and the following plotting.

So as to ensure an independent control of the results in the handling of single models in the accessible part of the object a control distance up to a length of 10 m of any orientation between conspicuous points is measured with an accuracy of 1 cm. If overlapping stereomodels of an object have been taken a surpassing control distance up to 20 m is measured per model complex. In spaces with unfavourable light conditions floodlights have to be set up for a largely shadowless illumination of the measuring object.

Measurement of image coordinates and their transformation into space coordinates

The restitution of the photo negatives is stereoscopically made pairwise with digital recording of the measured image coordinates on a computer-compatible data carrier (preferably magnetic tape or floppy disk); in this procedure photo enlargements are of considerable help for the organisation and control of completeness of the measuring operation.

In measurements with the Stereocomparator (Steko 1818

or Stecometer) the image coordinates for each point, the parallaxes, a point number as well as an operation index are recorded for later electronic data processing with a minicomputer which then calculates the spatial model coordinates. For the absolute model orientation the program of a spatial Helmert transformation (similarity transformation with scaling and rotation about three spatial axes with redundantly determined point quantities) is employed. As determination elements for the transformation parameters use is at least made of 3 space coordinates of a point, the planimetric coordinates of a point, the height of a point or the distance between 2 points, which were directly measured on the object. Besides, for calculation also certain straight lines in space, such as supporting structures and edges as axial directions or certain faces of the room, such as floor, ceiling, walls may be input as layout or elevation planes of the object coordinate system.

Representation of results

First, the photographic documents are obtained as a result of stereophotogrammetric exposures after the processing the photographic material. This photographic documentation is available in the form of original negatives and enlargements of the photogrammetric photographs, copies and sketches of the taking disposition. Although no metric information can directly be taken from this material, it may with advantage be used for acquiring highly informative non-geometric data (especially from enlargements of photogrammetric photographs).

Very often surveyings of the actual state in the case of new pipelines primarily serve for the documentation of the actual piping system to facilitate later partial reconstructions, repairs or the elimination of damages. The photographic documentation also allows at a date in the far future the partial or complete graphical or digital-numerical representation of the state of the piping system as it was at the time of exposure. Several customers make use of this advantage of performing the restitutions at successive stages. This applies especially to piping systems which, after photogrammetric records were made of them, are further reconstructed, insulated or which for other reasons (e.g. in nuclear power stations) remain largely inaccessible. The enlargements of photogrammetric photographs are also immediately or later used to decide in cooperation with the customer on the extent and choice of the details to be plotted.

Within electronic data processing programs can be integrated which output control information on data carriers for the graphical point or line representation on an automatic mapping machine. This is performed at

an agreed scale and in fixed planes of projection. As a result plans of the piping system are obtained in various planes (e.g. plan view or front elevation) with the representation of pipeline axes, machines, fittings, valves and other planes of the pipelines. Furthermore, also an isometric representation with freely chosen isometry parameters can be realized under four different viewing directions.

