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ISO and Industrial Photogrammetry

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Abstract

Since 1969, when we had an application for complex of LNG which was first imported to Japan from Alaska, NKKK have been enjoying high reputation as fair and independent single surveying organization in Japan who is surveying LNG.

NKKK, as a competent impartial organization has been endeavoring positively for study and development of new technology in various, on the basis of our abundant experience to meet the present requirements, which continues a remarkable progress. Among them, NKKK has been qualified as a member of the survey firms in Japan to participate in the Japan Committee of ISO (International Organization for Standardization) and has been contributing especially in the fieled of tank calibration, introducing our calibration methods. NKKK is to undertake the secretariat of the ISO/TC28/SC5 (mesurement of light hydrocarbon fluids) and Dr. OSHIMA has also been nominated as the convener of WG1 and in charge of calibration of LNG tanks in carriers of the above subcommittee.

PACS is a practical application of the technology of close-range precise photogrametry, however, with the fact that it uses the Planicomp C-100, which is the most advanced analytical stereoplotting system, it is a most accurate calibration method with approval by Japan Customs Authorities.

1. General Description of PACS

PACS is a practical system of application in photogrammetry more specifically, close-range photogrammetry. A brief sketch of its technical process is that first, several sets of stereoscopic photographs of the subject tank interior are taken, next, these photographs are dealt with in a highly precies analytical stereoplotter linked with an electronic computer to form the stereoscopic model of the tank interior in its visual range for mechanical observation and after the operation, the observed data are processed for compiling the tank table.

In the calibration of the spherical tank, photo-shooting operation shall take place repeatedly to get a chain of stereoscopic photographs to be numbered from the first to the last model, which cover the whole space of the tank interior. Target coordinates will be determined on the first model with the reference scales. Second and successive modeles will be connected by means of some common targets in each adjacent model, then a model of the whole tank is formed.

Furthermore, numerous points on the model of tank interior observed and whole shape

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of the tank on which volumetric computation is made, is formed from those coordinates.

Since the object of these photo-shootings is a sphericul tank interior, the same targets are observed on the first and the last models thereby the connection to bc checked.

2. Process of PACS

The process steps of PACS are as follows;

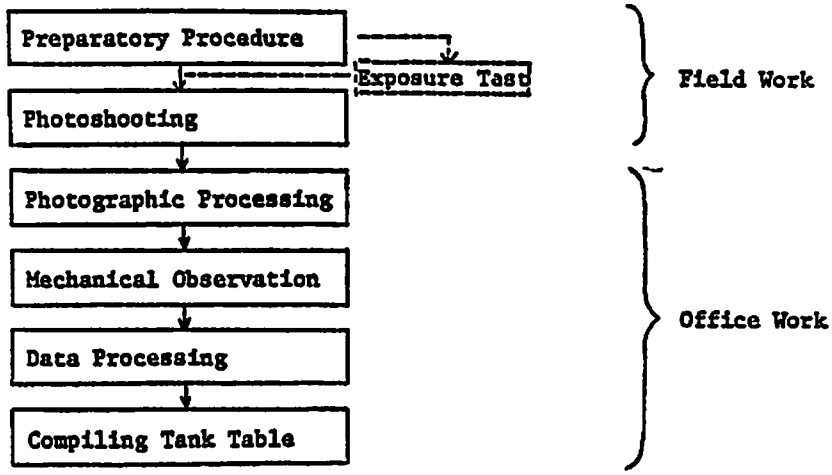


Fig. 1 Flow chart

The workers and time required at each step are as follows;

1. Worker required (per tank)
   - (a) Photoshooting approx. 7 persons
   - (b) Photographic processing 1 persons
   - (c) Mechanical observation 1 persons
   - (d) Data processing 1 persons
     (including compilation of tank table)
2. Time required (per tank)
   - (a) Photoshooting approx. 6-7 hrs.
     (including preparatory work and clearance work)
   - (b) Photographic processing approx. 2 days
     (including development, reproduction of copies, drying of films and photographic papers)
   - (c) Mechanical observation approx. 5 days
   - (d) Data processing approx. 5 days
     (including compilation of tank table)

2.1 Preparatory Procedure

1. Marking as targets
   Targets will be marked at predecided positions on the tank interior by shipyard during fabrication process.

(a) Number and position

Total 162 points of targets will be marked at intersection of latitudes (include the equator) and longitude at respective intervals of 20°.

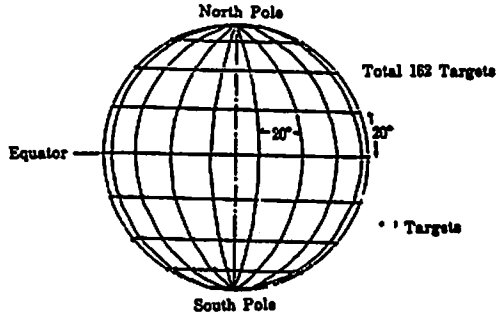


Fig. 2 Position and number of targets

(b) Shape of targets and way of marking

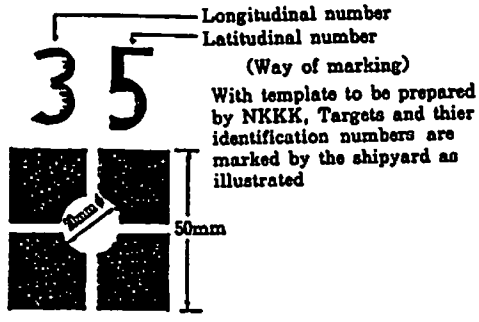


Fig. 3 Target and identification number

2. Setting of reference scales

Reference scales are hung along periphery of the pipe tower.

3. Setting of camera pedestal

The pedestal made from aluminum ladder is set at predecided locations.

4. Exposure test

An exposure test is to be carried out on the spot. To insure the correctness of the exposure, a photograph is taken, developed and checked on the spot immediately. From the exposure test, the best exposure can be determined then formal photographing will take place.

2.2 Photoshooting

Stereoscopic photogrnphs which cover all the tank interior are shot one after one fiom predecided stations.

Because of limited photographing coverage, two photographs are taken from a camera station by moving the camera angle up and down.

Meanwhile for a contingency due to difficulty with the camera, a spare one the same kind as used is arranged.

Camera station is determined according to the tank structure, for example, 10 station on approx . 9 meters of altitude.

We can enumerate the following cameras as suitable for our use:

Table 1

Name	Carl Zeiss(jena) UMK 10/1318	Sokkisha KSK-100	Carl Zeiss TMK-10	Wild P31
Focal Length	99 mm	90 mm	60 mm	45 mm
Picture Size	120×166 mm	102×145 mm	90×120 mm	92×118 mm
Distortion	5 μ and less	7 μ and less	4 μ and less	4 μ and less

At present, PACS uses Carl Zeiss (jena) UMK 10/1318.

2.3 Additional Field Work

1. Measuring work
   In-tank and wall temperatures are observed, in addition, height of gauge pedestal and of the others required are measured.
2. Confirmation and verification of accuracy
   As a measure to confirm calibration accuracy by the PACS, some object of which length has been known is photographed at the time of official photographing. Then, its length measured by the PACS is compared with the known length of the object.

2.4 Mechanical Observation

Stereoscopic photographs obtained from the previous paragraphing are set onto the analytical stereoplotter, then, the data necessay for compilation of the tank tables are observed on the stereoscopic model, formed therein by means of the procedure undermentioned.

Our PACS is now using PLANICOMP C-100 as the stereoplotting instrument, the performance of which is described below:

Size of measuring mark (mess mark) 20μ
Orientation capability 1μ

Besides, this instrument decides nominated positions mechanically, and records observed data on magnetic tape automatically so that there is no risk of erroneous recording.

Utilizing this function, 36 points (10 interval at a level) at each of the 35 levels (about 1-meter interval in height) are determined automatically. (Fig. 4)

Then, coordinates (x, y, z) of observation points exist nearly a nominated position are noted by manual operation of the Planicomp C-100.

Then, coordinates of the observation points are recorded on the magnetic-tape of the mini-computer.

Major erroneous factor at the time of observation by the Planicomp C-100 arises from human error at the time of the conforming operation of the mess mark, and this is deemed to be less than 5μ which corresponds to 1/4 of 20μ, the diameter of the mess mark.

3. Data Processing

The best-fit circle and its radius is calculated on the basis of 36 coordinates (x, y, z) at each level in accordance with the following procedure.

Procedure to calculate the best-fit circle from the least square method.

$$(x_i-x_0)^2+(y_i-y_0)^2-r_0^2=\varepsilon_i \quad (1)$$

Where:

x_i, y_i: Observed coordinate

x_0, y_0: Coordinate of the center of the best-fit circle

r_0: Radius of the best-fit circle

ε_i: Residual

$$\left.\begin{aligned} x_0&=x_0'+\Delta x \\ y_0&=y_0'+\Delta y \\ r_0&=r_0'+\Delta r \end{aligned}\right\} \quad (2)$$

where: x_0', y_0', r'_0: Initial values

Substitute (2) for (1), then develope by Tailor's Law and linearize it omitting the terms higher than second order;

$$[(x_i-x_0')^2+(y_i-y_0')^2-r_0'^2]-2[(x_i-x_0')\Delta x+(y_i-y_i')\Delta y+r_0'\Delta r]=\varepsilon_i' \quad (3)$$

Then, Δx, Δy, Δr are calculated when the normal equation is solved,

$$\left(\frac{\partial(\Sigma\varepsilon_i'^2)}{\partial(\Delta x)}=0 \quad \frac{\partial(\Sigma\varepsilon_i'^2)}{\partial(\Delta y)}=0 \quad \frac{\partial(\Sigma\varepsilon_i'^2)}{\partial(\Delta r)}=0\right) \quad (4)$$

and x_0, y_0, r_0 are calculated from (2).

Since x_0, y_0 and r_0 have been led from an approximation, x_0 shall be replaced by x_0, y_0 shall be replaced by y_0' and r_0 shall be replaced by r_0' then normal equation shall be solved again to calculate new x_0, y_0, r_0.

This calculation is repeated until Δx, Δy and Δr converge satisfactorily to infinitesimal value, then the best-fit circle is obtained.

It is regarded that Δx, Δy and Δr have converged as they reached $\Delta x^2+\Delta y^2+\Delta r^2<(0.5\,\text{mm})^2$ and at that time the radius r_0 of the best-fit circle is obtained to an accuracy of 1 mm.

4. Compiling Tank Table

Theory of compilation of the tank table is as follows:

1. Obtain the best-fit circle for 35 levels in full heigth of tank.
2. As illustrated below, apply shape of spherical zone between adjacent two levels. (Fig. 5)
3. Obtain total 36 spherical zones, including top and bottom caps, of which centers and radiuses are different from each other.
4. Calculate the fomula of these spherical zones, which make up the sphere then compile the tank tables.

Spherical zone to be applied between level H_i and H_{i+1} has radius R_i of which center originates at O_i. (Fig. 6)

And the point O_i is intersection of vertical axis of the sphere and a perpendicular from the mid-point M of the $\overline{P_iP_{i+1}}$

Note: Tank table is compiled on the reference temperature −160°C.

Effect of liquid head and in-tank displacemente for tank volume is calculated in particular.

5. Calibration Accuracy by PACS

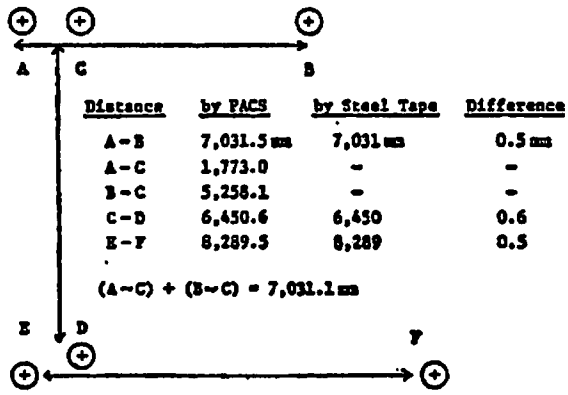
Comparison with the other Conventional Method When we filed the application for approval on PACS with the Yokohama customs authorities, we measured and calibrated the following two objects by way of demonstration examples using both PACS and Strapping Method under the witness of the customs officers in charge so as to prove the accuracy of PACS by means of comparing their test results with each other.

(1) The horizontal and vertical lengths on a surface wall of an office building.

(2) A cylindrical thnk on shore of 1,000 cubic meters in capacity.

Test Results

(1) Comparing Exhibition of Horizontal and Vertical Lengths measured by Two Methods.



Note: Stereoscopic photographs of the object were shot obliquely at the predecided camera positions in order to prove superiority of the PACS.

(2) Comparing Exhibition of Tank's Dimensions

Averaged Inner Radius

Height of Measured Position (mm)	by PACS (mm)	by Strapping (mm)	Difference (mm)	%
No. 2 Ring (2,075)	5. 296. 3	5. 295. 6	+0. 7	+0. 01
No. 1 〃 (1,875)	5, 295. 2	5, 295. 7	−0. 5	−0. 01
No. 1 〃 (1,505)	5, 299. 2	5. 299. 5	−0. 3	−0. 01
No. 1 〃 (440)	5, 300. 2	5, 297. 9	+2. 3	+0. 04

Full Height

by PACS (mm)	by Steel tape (mm)	Difference (mm)	%
11,956 + 6 * = 11,962	11,962	0	0

Note: * thickness of the top angle

(3) Volumetric Comparison by Two Methods

Depth (mm)	(Empty) by PACS (m^3)	(Full tank) by Strapping (m^3)	Difference (m^3)	%
160	10.072	10.065	0.007	0.07
1,000	84.249	84.189	0.057	0.07
2,000	172.492	172.376	0.116	0.07
3,000	260.756	260.600	0.156	0.06
4,000	349.019	348.824	0.195	0.06
5,000	437.223	437.076	0.147	0.03
6,000	525.431	525.329	0.102	0.02
7,000	613.793	613.613	0.180	0.03
8,000	702.158	701.901	0.257	0.04
9,000	790.600	790.261	0.339	0.04
10,000	879.041	878.624	0.417	0.05
11,000	967.441	967.033	0.408	0.04
11,590	1,019.597	1,019.194	0.403	0.04

Note: Comparison was made taking into conisderation the effect by expansion of the tank shells due to liquid head.

Comparison between NKKK'S and DBA Method

The list shows comparison with the main items between two methods.

Items	NKKK' SPACS	DBA Method
Dimension Measuring Accuracy	±0.4mm (for dia, 36.5m)	±0.4mm (for dia, 36.5m)
Overall Measuring Accuracy	± 3 mm (for dia. 36.5m)	——
Capacity Calibration Accuracy	±0.02%	±0.025%
Camera	ZEISS-made f: 99mm; Wide-angle (60°×80°)	DBA-Originated one f: 65mm; Super wide angle (approx. 110°)
Targets	162 points (for model conection)	401 points (for both model connection and observation)
Number of observation Points	about 1,200 points (35 levels)	401 points (17 levels)
Analytical Plotting Instrument	PLANICOMP C-100 (Stereoscopic models of observation points composed in its visual range make their coordinates (x, y, z) put down straight on a magnetic tape of a linked electronic computer)	A Monocomparator (Merely the positions of observation points pictured on the single photographs are observed)
Data Processing	A simple operation is needed to apply the best-fit circle to each of 35 levels based on the data of coordinates.	Before the operation to obtain the basic data for tank calibration a series of complex procedures should be carried out in order to produce stereoscopic coordinates of the positions of the observation points on the single photographs.
Compiling Tank Table	After the tank is divided at 35 levels, its table is compiled according to its peculiar shape.	After the tank is divided at 17 levels, its table is compiled.

Fig. 4, Fig. 5, Fig. 6 は 249 頁参照。