Presented Paper

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The photogrammetric measurement of spherical tanks.

Abstract

Special tanks in the oil industry suggested the
development of photogrammetric measuring techniques
for non-topographic objects. A particular point was
the determination of irregular surfaces, which could
not economically be measured by traditional methods.
The whole technique is a combination of geodetic
distance and angle measurement and photogrammetric
coordinate measurement in a stereoscopic model. A
special variant of this general technology is the
measurement of spherical tanks as used for the
transport of natural gas on special tanker ships.
The camera used with succes was the UMK 10/1318
Universal Measuring Camera from Jena.

Bloms Oppmäling A/S in Oslo is an engineering bureau concerned with land surveying and photogrammetry since 1954. Recently it has extended its activities to data processing and cartography. Through its close relation with the oil industries of Norway and Libya it has become well experienced in underwater surveying of continental shelves which has won this firm numerous contracts abroad including a recent commission in the Republic of Cuba.

The idea to develop photogrammetric techniques of measuring non-topographic objects was prompted by special problems that had to be solved in the oil industry. One of the engineering teams had turned to industrial photogrammetry with growing success. Experiments were followed by pilot work, and these grew in several cases into working technologies which are now routinely applied at Bloms Oppmäling.

Over the last five years attention had been focussed on extremely accurate coordinate measurements. These activities were born out of the need for digital descriptions as the basis for the application of electronic data processing methods. This concerned mainly coverage of irregular surfaces which, from an economic point of view, could not be covered by conventional methods. Bloms Oppmäling applied photogrammetry and solved the problem successively. The method is a combination of geodetic distance and angular measurements and photogrammetric coordinate measurements carried out in a stereoscopic model.

Measuring of spherical tanks as they are used for transporting natural gas on specially designed tankers is a special version of this general technolgy. The problem is to determine departures from the spherical form caused during assembly and the volume at different filling levels.

In developing a suitable procedure the engineers of Bloms Oppmäling were able to draw on fifteen years general experience in the calibration of oil storage tanks available with Norwegian refineries. Against this background a contract was signed with Rosenberg Verft A/S in Stavanger, Norway, which were building a series of gas tank vessels equipped with spherical tanks made by Kvaerner Burg A/S. These tanks have a diameter of roughly 37 m. The technique developed by Bloms Oppmaling in association with the Norwegian data processing firm of Datacom A/S guarantees an accuracy of volumetric determination of 0,1‰ under field conditions which fully meets the requirements made. The instruments used for recording the photograms included apart from a one-second theodolite and a precision stereoplotter, which are part of the standard equipment for land surveys carried out by Bloms Oppmaling, the UMK 10/1318 Universal

Measuring Camera made in JENA. This camera has proved
highly efficient in pilot works and routine tank
calibrations in Norway, the Federal Republic of Germany
and Japan. The factors which mainly contributed to the
great accuracy of the volumetric measurements were the
large image scale and the favourable base-to-height
ratio afforded by the wide aperture angle. Another extre-
mely practical feature is the possibility of using films.

Bloms Oppmäling's method of measuring spherical tanks
has been widely covered by a process patent.

The tank surface is described numerically by triaxial
rectangular coordinate triples of about 1200 object
points which were measured in photogrammetric stereo-
models, with the exception of 85 geodetically deter-
mined control points. A closed ring polygon of 5 station
points in a horizontal plane in the lower third of the
tank, which are marked inside the sphere on an assembly
scaffold (Figs. 1 and 2), forms the basic reference
system for the subsequent determination of the coordinates
of the surface points. These measurements are made with
a onesecond theodolite and a calibrated invar subtense
bar. Closing error tolerance is 1 mm. Control measure-
ments of the diagonals are also considered in adjusting
this pentagon.

From these polygon points 17 control points each (of a
total of 85) are determined in 5 horizontal planes (cf.
Figs. 1 and 2) by intersection over the sides of the
polygon and the diagonals of the pentagon. By redundancy
in determination and subsequent adjustment the average
coordinate error (as vector) is kept at + 7 mm. Based
on the coordinates of the 85 object points the first de-
termination to ascertain the bearing of the centre of the
sphere is made. From this the operator can tell where
to take diameter measurements. Finally photographs are
taken from the polygon points with a UMK 10/1318 universal
measuring camera (Fig. 3).

The camera is stationed in such a way that the photographs
obtained from the polygon points in different directions
can be combined into stereopairs. This too is done with
redundancy in determination so that the object points
are contained in several stereograms. Maximum
permissible tolerance of photogrammetric coordinate
determination at the control points which have been
intersected by theodolite is $\pm$ 10 mm.

Photogrammetric coordinate measurement is carried out
in relatively and absolutely oriented models using a
precision stereoplotter. Then the redundancy in deter-
mination is adjusted to a mean error of $\pm$ 6 mm. Taking
into account the remaining parameters of the measuring
setup an absolute mean error of $\pm$ 10 mm is obtained for
the object points determined by photogrammetry.

Further processing of the data yields for each elevel of object points arranged at vertical intervals of 1 m a mean radius and the degree of departure of the surface from the intended spherical form with respect to the mean radius (Fig. 4). The volume is then calculated on the basis of this surface description, taking into account the installations inside the tank.

At a radius of 15.5 m the volume can be determined to an accuracy of $\pm$ 0.3 mm which by the laws of error propagation gives a theoretical error of the volume of the sphere of $\pm$ 0.05 °/oo.

The measuring technique developed by Bloms Oppmäling is both very precise and highly economical to use.

Photogrammetric measuring of spherical tanks is an example illustrating that industrial metrology may well benefit from the application of photogrammetric techniques.
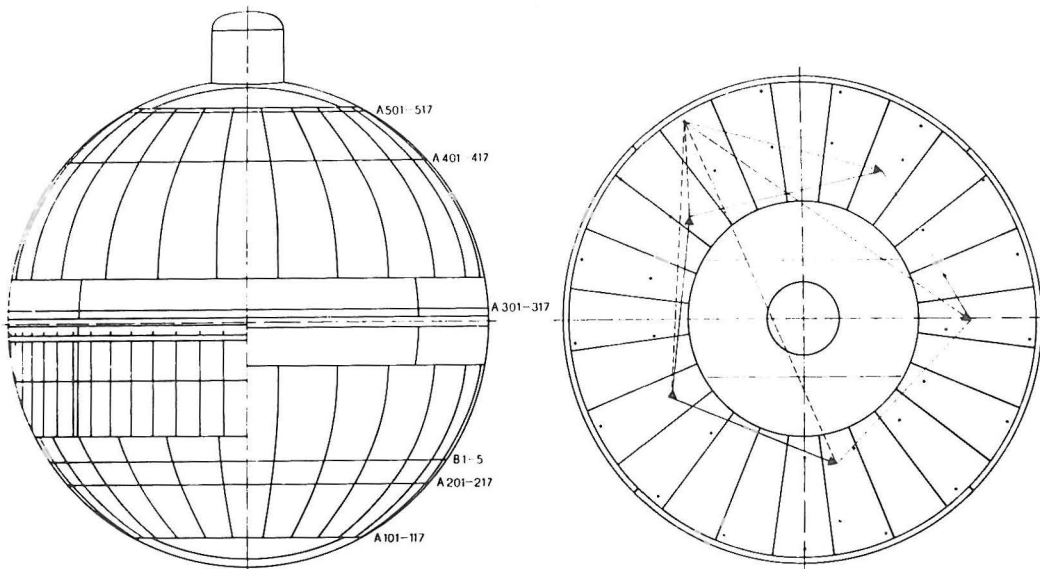
Fig. 1:

Measuring setup, elevation.
A = control points,
B = geodetically measured
    points.

Fig. 2:

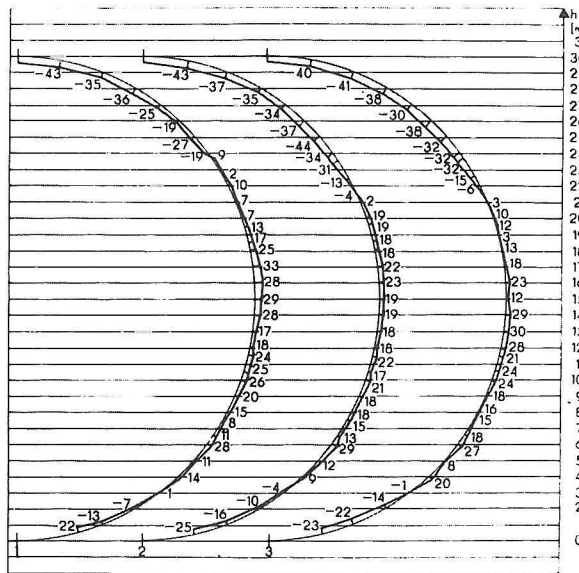Measuring setup,
plan view.

Fig. 3: Photogram taken with the UMK 10/1318.

Fig. 4: Departures of tank internal surface from the spherical form.