RESULTS OF A LEVELING OPERATION CARRIED OUT ON A FLOATING PLATFORM

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SUMMARY

The writer deals with a leveling operation carried out from unstable sighting station. He describes the test of a 230 ft. dia telescopic gasometer at Edison-Gas works at Milano-Bovisa, Italy. Said test was made possible only by use of an automatic level (Filotecnica Salmoiraghi 5173).

The writer is a Professor of "Teoria e Pratica delle Misure" at the "Istituto di Geodesia, Topografia e Fotogrammetria del Politecnico di Milano", which was in charge of the test.

The 4.6 million cu.ft. gasometer of the Edison-Gas works at Bovisa, Milan, is of the telescopic type, four sections, hydraulic controlled with « Dempster » helicoidal guide system. The gasometer consists (see figures 1 and 2) of a 230 ft. dia fixed section and 4 sections. They freely lift and fit one into the other according to the gas pressure and are only guided by 45° inclined rails located on the outside wall. Contrary to the gasometers of the conventional type, no outside metal structure guides the moving sections; therefore particular care had to be taken in checking the structure and the smoothness of movements. The gasometer size was an innovation for structure of the kind in 1958 and the first in Italy; this led the Company to perform special and careful checks of the movements, thus eliminating the possibility of too large, and perhaps dangerous, anomalies.

Besides other numerous types of mechanical and geometric tests, the « Istituto di Geodesia, Topografia e Fotogrammetria del Politecnico di Milano » was requested to make leveling of the different positions of the moving sections corresponding to different filling stages. The different positions were obtained by independent geometric leveling, performed on each of the top edges of the gasometer moving sections, and connecting 8 to 10 points fixed to the structure.

The various leveling results made it possible to calculate the relative elevation variations of the points fixed to the section structure. In turn, from the elevation variations it was possible to determine the value of the horizontal rotation of a section in its subsequent positions, the direction of the horizontal rotation axis, and, finally, the maximum slope direction.

The above is naturally valid in the probable hypothesis that the section deformations were not of such a value as to make said movements undetectable.

On the other hand, the variations of measured elevation allowed to confirm said hypothesis. In fact, if the section, although varying its position, remains rigid, the elevation variations of the various points - as drawn up on the section developed length, consist of a normal diagram of the sinusoidal type.

The two requirements mentioned, i.e. determination of rotation value and check for possible deformations, made it necessary, however, a very high accuracy in measurement of the elevation variation. Major problems made measurements difficult to think of.

First problem: when each moving section was raised from its support because of inside pressure, it was in a floating hence unstable condition so as to make almost impossible to keep the bubble of conventional levels centered during the time of rod reading.

Second problem: the inside pressure variations of the movement due to leaks and sun radiations produced movements of the cover and consequently of all elements connected to it.

Third problem, also connected with the floating condition: in order to perform the leveling it was necessary to move loads over the element which, for every position of these loads, had different situation of equilibrium.

The moving loads, that is operator, clerk and instrument, were quite small; besides they were balanced by placing equivalent weight in symmetrical position. Because of this balancing, the third problem affected measurements very slightly. The first and second problems could be overcome only by using an automatic level.

For this type of instrument the small movements due to oscillation, slow vibration, shift of the support, did not influence the proper measurement of the difference in elevation between two following points, because the instrument line of sight sets automatically horizontal. This eliminated the first problem.

The instrument faster setting up allowed to greatly reduce the time of operation and nearly eliminate the effects of the internal pressure variations. The second problem was thus overcome.

The choice felt on Salmoiraghi automatic level model 5173 (fig. 3) of new construction at that time. This instrument was chosen also for the following reasons:

— reduced size and weight (7 1/4 x 7 1/2 x 13 in. 7 1/2 lbs., without case),
— simplicity of operation, as the bubble is in the telescopic field and can be seen as rod readings are taken,
— possibility to read .1 mm (.00033 ft.) when fitted with the micrometric rod reader device 5180. This device consists of a system moving the instrument up and down within a range of 10 mm (.033 ft.).**

The use of the normal tripod was clearly impossible. A proper bracket was therefore provided. This bracket had to be fixed tightly to the rail surrounding the top of each section and was equally spaced between the two rods. In this way it was possible to take the advantages of balanced sight leveling.

In order not to increase the number of sights, the rods had to protrude from the section edges. The solution as in fig. 4 was adopted. The supports of the pendulous rods were accurately positioned and rigidly connected to the structure of the corresponding moving section. The rods were suspended in special housings at the end of the brackets. Ten brackets and therefore sighting points, were located in the developed length of each section. The distance between level and rod varied, being in general not greater than 50 ft. At this distance it was easy to perform sighting with an error not higher than .1 mm (.00033 ft.).

The gasometer tests required a total of 28 leveling operations performed at different elevations over the different sections. The operations were performed with rapidity. Every sight required an average time of 5 minutes, which was a short time, taking into consideration the difficulties encountered by the operating staff, moving over the edges and the loss of time caused by setting the instrument on the bracket.

Every rod reading was repeated twice. The table enclosed gives the errors of closure of the 28 levelings, divided in 13 groups. Each group includes the levelings performed on the different sections. The leveling groups Nos. 1 and 13 were performed at the beginning and at the end of the testing, when the sections were lying against the bottom, while the other groups were performed when the

** Said device is also available with English graduation. In this case the vertical movement mes .020 ft., with divisions every .0002 ft.

sections were supported by the inside pressure.

The errors of closure of the groups 1 and 13 were naturally smaller than those pertaining to all the other groups.

The mean square value of the error of closure in the first case (groups 1 and 13) was ± .9 mm (.003 ft.), while in the second (groups 2 to 12) was ±2.2 mm (.007 ft.).

This considerable increase of the error of closure was clearly to be attributed to the slow settling movements of the sections during the testing stages.

The leveling on the first section had errors of closure entirely positive and justified the presence of a systematic error; for instance, a variation of the elevation during the operation due to the slow decrease of inside pressure.

Being 10 the numbers of sights for each leveling and assuming error of closure due only to the accidental errors, it resulted that the standard error in determining the difference in elevation between two following points was of ± .3 mm (.001 ft.) in the first case and ± .7 mm (.002 ft.) in the second case.

The values allowed to conclude that the performance of the instrument was quite satisfactory.

The relative elevation referred to the initial point A of each leveling was determined for the point of each section, through the 28 levelings. The relative elevations of the points of a section, during the intermediate testing stages, were compared. Such comparison gave the variations of relative elevation of the various points, caused by the section position changed because of the lifting. These variations of elevation were plotted in function of their position on the developed length of the circumference of each section to which the points were fixed.

Point A of each section was the reference point, and had therefore no variation. A continuous curve was interpolated between the points. The curve resulted to be very similar to a sinusoid, however, in some cases, deformations could be noticed.

In fig. No. 5 were reported, as an example, the curves of elevation variation over the 4 sections, obtained with the leveling group No. 5.

The position of the single points deviated very little from the interpolated curves. Such deviations were assumed not to be caused by local deformation of the structure but only by measuring errors. The limited dispersion of the points confirmed consequently that the measurements had a good precision The position of the points of all other graphics related to other operations, was similar to the one reported in fig. No. 5.

From the curves of the elevation variation the measure of the rotations of the sections during the gasometer filling stage and the position of the horizontal rotation axis was obtained. The first datum was obtained from the oscillation total excursion A of the curve of the elevation variation.

In the example of fig. No. 5 the excursion was indicated on the right side of each graphic. If D was the section diameter, the angular value Ø in minutes of the rotation was calculated by the relationship:

$$Ø' = A/D.\ \text{arc}\ 1'$$

The second datum, the direction of the horizontal rotation axis, was obtained with small precision.

If the curve of the elevation is a perfect sinusoid, the horizontal rotation axis can be easily located over the perimeter of the section, because it cuts said perimeter in correspondence of the abscissas of the points of the sinusoid intersecting the parallel straight line to the abscissas and equidistant from the maximum and minimum points of the curve.

The deformation of the section alters however the sinusoidal form of the curve of elevation variation of each section.

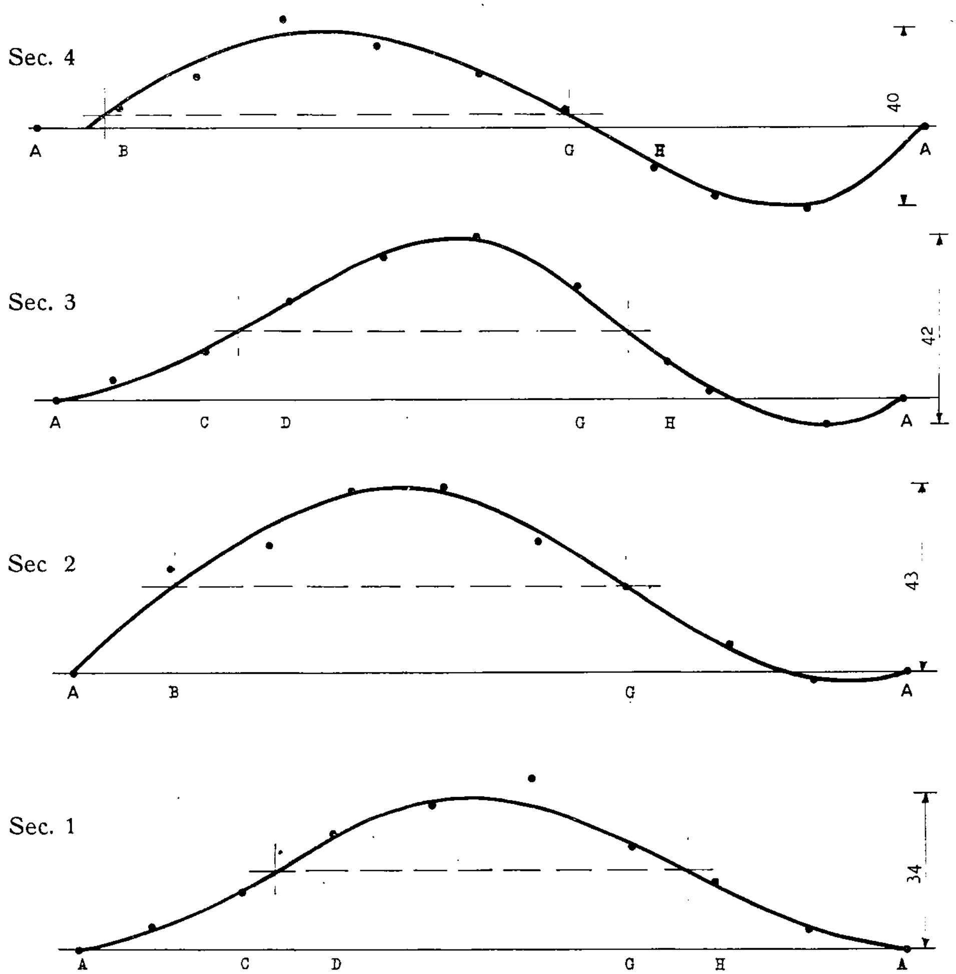
If the above outlined method for the determination of the horizontal rotation axis is used, errors of a certain magnitude can be made. It is possible to estimate roughly the magnitude of such error by measuring the segment intercepted by the positive wave of the curve, on the straight line parallel to the abscissas and equidistant from the extremes.

For the sinusoid such length has to be equal to half ofth e entire developed length of the section.

The experimental curves give differences, with respect to the theoretical length, of about 1/8 of the entire circumference. This value, i.e. 1/8 of 360° = 45°, can be taken as approximate indication of the standard error of the direction of the horizontal rotation axis of the section.

Leveling groups	Sections 1	2	3	4	Sections 1	2	3	4
	mm	mm	mm	mm	ft	ft	ft	ft
1	+ .6	+ 1.2	.0	+ 1.7	+ .002	+ .004	.000	+ .006
2	+ 2.5				+ .008			
3	+ 1.3	+ 2.5			+ .004	+ .008		
4	.0	— 1.4	+ .3		.000	— .005	+ .001	
5	+ 3.0	+ 2.1	— 3.2	— 1.5	+ .010	+ .007	— .010	— .005
6	+ 2.0				+ .007			
7	+ 2.4	— 1.0	+ .1		+ .008	— .003	+ .0003	
8	+ 3.5				+ .011			
9	+ .4	+ .5			+ .001	+ .002		
10	+ 4.4				+ .014			
11	+ 1.8				+ .006			
12	+ 2.4				+ .008			
13	— .8	+ 1.1	— .3	+ .3	— .003	+ .004	— .001	+ .001

TABLE No. 1 — ERRORS OF CLOSURE



CURVER OF ELEVATION VARIATION LEVELING GROUP No. 5

Fig. 1

GASOMETER AT 100% CAPACITY

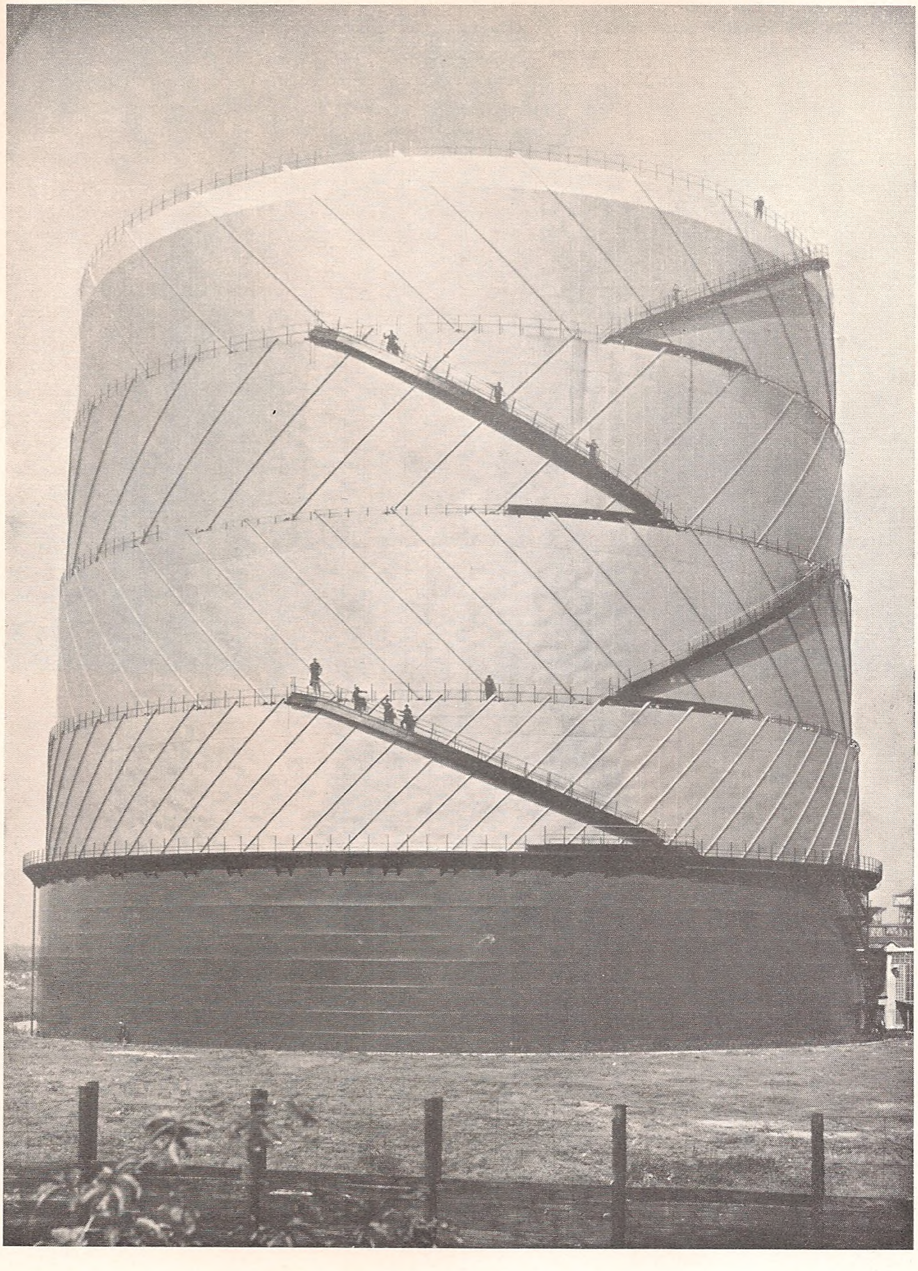


Fig. 2

GASOMETER AT 50% CAPACITY

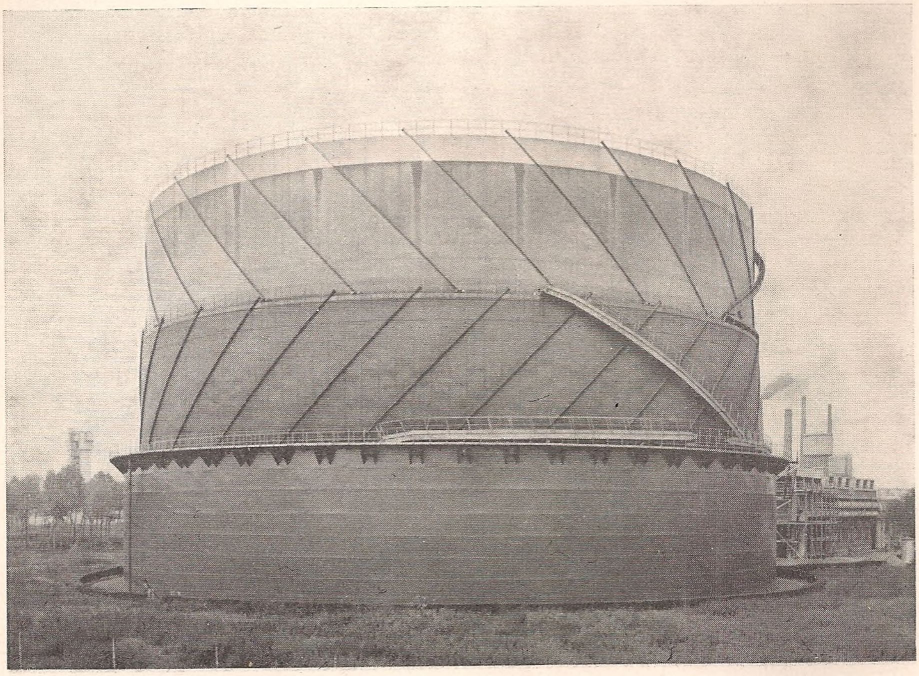


Fig. 3

AUTOMATIC LEVEL SALMOIRAGHI 5173

WITH MICROMETRIC ROD READER 5180