LUMINOUS CONICAL SIGNAL FOR DAY AND NIGHT-TIME SURVEYS

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Abstract

Practical experience based upon measurements conducted on offshore installations has shown the trig target currently in use unsuitable for dimensional checks or microgeodetic surveys of large, inaccessible constructions - particularly steel structures.
Consequently a new model of tri-conical signal ®, particularly suitable for night-time triangulation and dawn photogrammetric surveys, is illustrated.
The new model is based upon a procedure that:
a) - keeps thermal deformations within reasonable limits;
b) - reduces time and cost of pre-targeting;
c) - facilitates linkage of stereo models according to ORIENT and CRABS softwares.
An illustration is provided of a number of applications and of the satisfactory results yielded by the new target.

1) FOREWORD

The problem of suitably targeting points for which one wants to accurately measure the planimetric (x, y) and altimetric (z) coordinates, seemed definitely solved. Since 1970 however, owing to the evolution in survey techniques, it has again been subject to debate. The application of photogrammetric dimensional cheks, in large sea and land construction especially, led to a redefinition of the signals according to the environmental and operative aspects. It is a well known fact that the quality of the signal is of primary importance in exactly determining a point.
More recently (end of the 70's), new conditions and difficulties have cropped up during dimensional cheks on large metal carpentry structures. We know that, in the more industrially advanced countries, efforts are being made to help the surveyor in his job, by improving the signals.
Thanks to its direct operations on large metal structures, AGIP has built up the experience which enable the writer to devise a new model signal which is specially suitable to construction yard operations.
The signal was designed for use in micro-geodetic and photogrammetric measurements and was patented in 1985.

2) TARGETING OF POINT AT 20 TO 200 METERS

Flat signals, for short distance

Mankind's better known and most commonly used signal is the "bull's eye target"; it consists of a number of concentric rings of strongly contrasting alternated colours (black-white or red-white).
Though this target is highly visible it is unsuitable for measurements.

Therefore in geodetics and topography other types of signals have been used. These also consist of strongly contrasting colours, and are luminous for night-time surveys.
Basically their patterns are made up of isosceles triangles placed either horizontally and vertically to form a white "Maltese cross", (sometimes with an elongated arm) on which the cross-hairs of the goniometer stand out well.
Modern signals are made up of a metal rectangle with a cross-like outline which can rotate round its vertical axis on a pivot. The pivot is fitted to a triangular base which can be made level (by means of three adjustement screws) and fitted to a tripod or pillar.
The outlines which are commonly considered the best are those shown in Figure 1.
To enable a point to be accurately determined it must be collimated from a number of converging directions (multiple intersection), which should be distributed all around the object. Considering that all the signals illustrated are collimated from distances of no more than 200 metres, the operator, or an assistant, may easily reach the point targeted and rotate the signal so that each time it faces the goniometer station.

Long-distance large size signal
The solution of reaching the signal and rotating it towards the appropriate station each time becomes unpractical and impossible with very long distance where, to be seen, the signal must be large and cannot therefore be rotated.
Signals used in these cases reach out in three directions so they are still tied to the simple or multiple isosceles triangle pattern.

Short-distance industrial photogrammetry signals
The overall problem of visibility and collimation is common both to topography and photogrammetry. Thus, given the same conditions and distances, photogrammetry signals are the same "Maltese cross" type as in topography. Except for some minor changes and obvious exceptions (e.g. "bull's eye target" stickers used in checking the polished surfaces of large marine propellors).
When, as is often the case, the point to be determined lies on the surface of the object to be checked, photogrammetry signals printed on self-adhesive plastic (with centre-hole for perfect centering on punched points) are stuck on the object which must undergo the dimensional check (see Fig.2)
This procedure is frequently applied in architectural surveys and in building and naval checks when the surface to be checked is a facade or, in any case, a plane or curved surface.
When instead the point is outside the object, the classical topographic signals placed on tripods serve their purpose adequately.

3)THE NEW PROBLEM IN THE SURVEY OF LARGE LATTICE STEEL STRUCTURES
Photogrammetry has widely proved to be the safest and most thorough method for dimensionally checking large metal structures.

It's well known fact that the photogrammetric method requires prior determination of a number of trig points by means of triangulations. These are necessary for an accurate reconstruction of the scale and lay of the 3-D optical model of the object photographed. The accuracy required in the micro-geodetic determination of trig points and control points is +/- 1 mm.
The number of control points necessary is easily determined if one bears in mind that each stereoscopic pair needs 5 control points.
So, if one imagines the survey of a parallelipiped shaped construction with six sides (of which one cannot be photographed because it lies on the ground), at least 5 stereoscopic pairs are needed, therefore 25 control points must be determined.
Survey operators are now faced with radically new conditions in the dimensional checking of large metal structures, which may be summarized as follows:
A) The location of signal bearing tripods on the ground is impossible owing to the presence of yard materials and machinery; such as mobile cranes, compressors, rams, tractors, winches, cherry pickers.
B) High levels of the structures are difficult to reach.
C) The relative "trasparency" of the structures allows sighting, that is the measurement view through its trussing.
D) The need to consider and survey the constructions in their full spatiality (not only the survey of facades that is, but the survey of polyhedrons with directly connected faces).
E) The need to complete the measurements in relatively short times so that the formes may be homogeneous and valid. It should be noted that a large steel structure in the open undergoes noticeable and diverse deformation during the day, owing to the effect of the heat developed by the sun's rays.
A typical situation under these new conditions is clearly illustrated in Fig. 3.

4) <u>INADEQUACY OF THE EXISTING TRIG TARGETS TO THE NEW CONSTRUCTION YARD NEEDS.</u>

<u>Classical signals</u>

Classical plate-signals, shown in Figures 1 are definitely unsuitable for the peculiar operative needs of a steel carpentry yard for off-shore.
In fact, when these are placed on tripods on the ground they are not easily visible and constitute an obstacle to normal operations. They are often removed, upset or damaged by mistake.
When instead they are placed on props located in dominating positions, they do not disturb and may be visible from all sides, provided somebody rotates them each time towards the station, from which the surveyor is making the measurements in that moment.
This procedure causes considerable inconveniences because obviously the dominating positions are high up on the structures (see Fig. 4), which may be dozens of metres high. So each time somebody must climb up and back down (if there are ladder-scaffolding or rung ladders) or else make use of a cage lifted by a crane.

Should the latter not be available, and for some reason the scaffolding has been removed, one is forced to do without the measurements on control points whose location is now inaccessible. The result being that dimensional checks become lacking and uncertain.

Modifying traditional signals.

AGIP technicians soon concluded that to contain costs and times within acceptable limits, and to reduce the risk involved in climbing up and down long rung ladders (topography staff are not always well acquainted with the yard environment), the trips should be limited to the first positioning and final removal of the signals. Therefore a signal which exhibited the same pattern from every angle was essential.

On various occasions photogrammetry operators themselves manufactored a variety of new versions of modified signals in the yard workshops. Results were hardly ever fully satisfactory, but they did reinforce the realization that a signal with a radically new design had to be created.

In fact the following negative conclusions arose:

A) The "stem" signal with a pointed tip, is subject to deformation and is not visible enough. Moreover the yard vibrations make the tip oscillate thus making collimation impossible. So it must be rejected.

B) The "double banner" signal (well known to land-surveyor) is well and safely visible, but the stem must be 14 mm. diameter steel rod to make it rigid. This thickness makes it unsuitable for measurements for which the accuracy must be within +/- 1 mm. Therefore this solution must also be rejected.

5)NEW MODEL OF SIGNAL FOR GEODETIC AND PHOTOGRAMMETRIC qINDUSTRIAL SURVEYS

The concept

By working on the basis of the many negative (and a few positive) results, the writer came to the conclusion that the ideal signal could be created by rotating the classical plate signal round its vertical axis.

The result was an "hour-glass" shaped solid; a perfectly logical conduct. News has it that similar solution, though for different applications, has been developed in East Germany.

However, the solid double coaxial cone pattern, one upright the other inverted ("hour-glass"), has its weak point at the joining point of the two tips. A signal made in this way would be either fragile or deformable according to the material used in manifacturing it.

If, though, one digs out two coaxial cones from a transparent cylinder, the joining point of the two tips complies with the strength and stability required.

In this way one obtaines a "spatial" (non flat) signal which is particularly suitable to high accuracy short distance plane measurements, but cannot be used for altimetric measurements, owing to the deviation of the optical rays caused by the refraction index difference between air and the transparent material used (glass, plexiglass, etc.).

In fact, any optical ray directed towards the centre of the circular section vertical cylinder and lying on a vertical plane undergoes no horizontal deviation. On the other hand,any tilted ray directed towards the centre of the cylinder behaves

as if it were striking a plate, therefore there is a variable deviation, which is a function of the angle of incidence and of the refraction index of the denser means.
So an external index, a third cone (or cylinder) positioned above the hour-glass signal, became necessary for the determination of altitudes with the same accuracy as in plane measurements.
In the event of night-time surveys, when yard operations are at a standstill and so measurements are better performed, illuminating the signal from the inside was also considered.
These were the starting concepts on which the new "TRI-CONICAL SIGNAL FOR DAY AND NIGHT-TIME INDUSTRIAL SURVEYS, 1983 MODEL" was based and, subsequently, patented.

Description of the signal

The design features are illustrated in Fig. 5, 6, where the three coaxial cones are visible.
Between the two lower cones there is a little cylinder purposely developed to improve collimation from the longer distances (60 to 200 meters).
On the tip of the third cone (the highest) there is another cylinder which ends in a pointed tip for high accuracy altimetric measurements; the tip is protected by a screw-on cap which should be lifted for high accuracy measurements only.(Fig. 7)
The cylindrical base pivot may be fitted to the standard Jenoptik/Jena topographic signal base plates, which are in turn compatible with Wild/Heerbrugg tripods and props. (*)
The base pivot cylinder also lodges a 1.5 V battery which feeds the signal lighting. Inside the base of the lowest cone there is a parabolic reflector with a light-bulb. When the latter is on, part of the light passes through the lower cone and, owing to refraction, lights the upper cone by reflection.
Another part of light runs straight through the cylindrical bottle-neck. This light hits a spherical dome which acts like a lens. The light is thus concentrated on a point which coincides with the tip of the smaller pointed cone. The tip of the smaller cone lights up like a little star (see Figure 6).
The two lower cones are painted red (they are luminescent by day and transparent enough to allow light through by night).
The third, upper, metal cone is also used as a photogrammetric signal for day-time surveys from above. The different conditions and uses in day and night time are illustrated in Figures 5 and 6.

Summary of the innovative features of the signal

The main features of the model are:
1 - Its triconical shape which ensures accurate altimetric and planimetric collimation both in the yard (microgeodetic) and in the lab (photogrammetric).
2 - The studied assimmetry of the two cones which ensures good visibility in the worst conditions (collimating from below).
3 - Full visibility and collimation through 360°

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*JENOPTIK and WILD are the best known manufactures of industrial photogrammetry equipment.

4 - Its vertical microgeodetic visibility and collimation through a wide range both downward (-55°) and upward ($+45^{\circ}$); that is equal to the range of existing topographic instruments.
5 - Its vertical photogrammetric visibility and collimation through 270°, which ensures the possibility of "tilted upward" and "vertical from below" surveys.
6 - The possibility, if necessary (for surveys of structures from below), of upending the signal by screwing it on upside down so that it may be measured vertically through 270°, which overlap through 180°as mentioned in point (4). In this case collimation is both microgeodetic and photogrammetric.
7 - The inside lighting's triple effect; by transparency (first cone), by reflection (second cone), and by diffusion (third, upper cone for accurate collimation, especially altimetric).
8 - The inside colouring which is luminescent by day and transparent by night, so as to ensure sighting and accurate measurements.
9 - Photogrammetric targeting of the upper cone.

6)OPERATIVE FEATURES OF "AS BUILT" SURVEYS OF STEEL STRUCTURES BY MEANS OF THE TRICONICAL SIGNAL

Having taken into account all the above said, the most logical and rational procedure to operate an "as built" dimensional check on a large reticular steel structure (so as to avoid any outside influence), should be as follows:
1) The survey team goes to the site when the structure has been completed, and uses the remaining scaffolding (or a cage lifted by a crane) to position the triconical signals. They are fitted to large bolts welded to the top of the construction. These operations should take place during the afternoon preceding the night measurements are to be made, because at present the batteries only have a 16 hour capacity.
2) All obstacles and remaining scaffolding which could block sightings should be removed as necessary.
3) At the same time, and during the first evening hours, pre-targeting of the lower levels should be conducted and microgeodetic measurements prepared. In the meantime the structure (which had been heated by the sun) will be slowly cooling, and though with some delay, takes on the environment temperature.
4) During the second half of the night, trigonometric measurements are performed. The signals are well visible from a distance, tanks to the red luminous glass-hour and are measured at the luminous tip at their tops.
5) Soon after dawn the simultaneous stereo-photogrammetric survey is performed, when daylight is diffuse, and the sun's rays have not yet heated the metal. The triconical signals are now well visible, also thanks to the luminiscent red paint of the hour-glass, so they will also appear in the photographs.
6) At the end of operations the signals must be gathered by means of a crane. The batteries are expendible.

7)PRECISION CHECKING OF THE MEASUREMENTS MADE ON THE TRICONICAL TARGET

The new model signal has been used both for on-shore (petroleum platforms under construction) and off-shore (installed platforms and floating super-tankers) surveys with positive results.

However, though the operators claimed to be satisfied with the practical features exhibited, there was some reasonable doubt concerning the effect of so-called "phase-error", in measurements which may be required with very high accuracy.
Recently a first check was conducted as follows:
-A triconical signal was positioned in station on a tripod, inside a barely lighted warehouse which was thermally well isolated.
The target was strongly illuminated from the left with a 1000 W spotlight placed at 2.90 metres.
Having fixed an origin, azimuthal measurements were performed collimating the centre of the hour-glass from a station located 18.87 metres from the signal. Then the spotlight was placed to the right of the signal and the trig measurements repeated.
A second station was located at 37.74 metres and the entire procedure was repeated. All angles were measured with an electronic T2000 WILD/HEERBRUGG theodolite. The results are summarized in the table below.

		LIGHT FROM THE LEFT		LIGHT FROM THE RIGHT	
	Nr.	READINGS	DEVIATIONS FROM AVERAGE	READINGS	DEVIATIONS FROM AVERAGE
N	1	37.37 36	0.0009	37.37 19	- 0.0015
E	2	" 37 30	0.0003	" 37 32	- 0.0002
A	3	" 37 42	0.0019	" 37 34	0.0000
R	4	" 37 28	0.0001	" 37 05	- 0.0029
	5	" 37 24	- 0.0003	" 37 45	0.0011
H	6	" 37 18	- 0.0009	" 37 43	0.0009
I	7	" 37 40	0.0013	" 37 57	0.0023
G	8	" 37 35	0.0006	" 37 18	- 0.0016
H	9	" 36 91	- 0.0036	" 37 53	0.0019
ARITHM. MEAN		37.37 27		37.37 34	
M.S.E.		0.00 16		0.00 17	

LEFT LIGHT OBSERVATION 37.37 27
RIGHT LIGHT OBSERVATION 37.37 34

PHASE ERROR - 0.0007
M.S.E. 0.00145
PHASE ERROR < AVERAGE OF THE MEAN SQUARE ERRORS

		LIGHT FROM THE LEFT		LIGHT FROM THE RIGHT	
	Nr.	READINGS	DEVIATIONS FROM AVERAGE	READINGS	DEVIATIONS FROM AVERAGE
F	1	21.14 91	0.00 05	21.14 92	0.00 08
A	2	" 14 92	0.00 04	" 14 87	0.00 13
R	3	" 14 94	0.00 02	" 15 20	0.00 20
	4	" 14 90	0.00 06	" 15 00	0.00 00
	5	" 15 01	0.00 06	" 15 13	0.00 13
H	6	" 14 99	0.00 04	" 14 97	0.00 03
I	7	" 14 93	0.00 03	" 15 09	0.00 09
G	8	" 16 90	0.00 06	" 14 93	0.00 07
H	9	" 18 07	0.00 12	" 14 92	0.00 08
	10	" 14 98	0.00 03		
ARITHM. MEAN		21.14 96		21.15 00	
M.S.E.		0.00 04		0.00 11	

LEFT LIGHT OBSERVATION 21.14 96
RIGHT LIGHT OBSERVATION 21.15 00

PHASE ERROR - 0.00 04
M.S.E. 0.00 075
PHASE ERROR < AVERAGE OF THE MEAN SQUARE ERRORS

N	1	40.97 43	0.00 02	40.97 59	0.00 07
E	2	" 97 82	0.00 17	" 97 45	0.00 21
A	3	" 97 54	0.00 11	" 97 76	0.00 10
R	4	" 97 56	0.00 09	" 97 52	0.00 14
	5	" 97 47	0.00 02	" 97 66	0.00 00
L	6	" 97 64	0.00 01	" 97 83	0.00 17
O	7	" 97 64	0.00 01	" 97 62	0.00 04
W	8	" 97 48	0.00 03	" 97 82	0.00 16
ARITHM. MEAN		40.97 45		40.97 66	
M.S.E.		0.00 08		0.00 14	

LEFT LIGHT OBSERVATION 40.97 65
RIGHT LIGHT OBSERVATION 40.97 66

PHASE ERROR - 0.00 01
M.S.E. 0.00 011
PHASE ERROR = AVERAGE OF THE MEAN SQUARE ERRORS

F	1	22.95 14	0.00 12	22.95 20	0.00 07
A	2	" 95 02	0.00 00	" 95 15	0.00 02
R	3	" 95 06	0.00 04	" 95 13	0.00 00
	4	" 94 90	0.00 12	" 95 04	0.00 09
	5	" 95 07	0.00 05	" 95 09	0.00 04
L	6	" 95 07	0.00 05	" 95 18	0.00 05
O	7	" 94 97	0.00 05	" 95 13	0.00 00
W	8	" 94 94	0.00 08	" 95 09	0.00 04
ARITHM. MEAN		22.95 02		22.95 13	
M.S.E.		0.00 08		0.00 05	

LEFT LIGHT OBSERVATION 22.95 02
RIGHT LIGHT OBSERVATION 22.95 13

PHASE ERROR - 0.00 11
M.S.E. 0.00 065
PHASE ERROR > AVERAGE OF THE MEAN SQUARE ERRORS

PHASE ERROR AVERAGE 0.00 05 75
M.S.E. AVERAGE 0.00 07 88

Bearing in mind the short distances between the signals and the stations it is fairly obvious that there is some phase error, but it is smaller than the difference between repeated readings.
In this way, the angle 0,000575 gon of the **average** phase error for the longer distance considered, 37,74 metres, would correspond to a segment of 0,3 millimetres. This would have no significant consequences in the usual industrial surveys of large constructions.
However a further development of this study has been planned and results should be available within a few months.

8) ACKNOWLEDGEMENTS

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The Author is also grateful to those Industrial Photogrammetry operators who, indirectly but substantially, contributed to the birth of the new model illustrated; namely Messrs. E. Bonora, F. Botti, B. Contardi and S. Piacenti.

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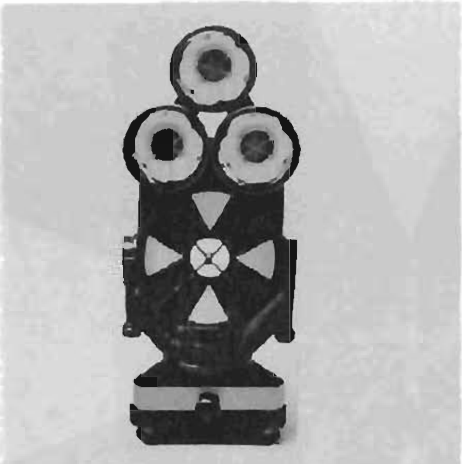

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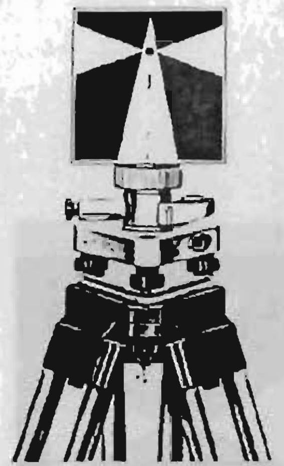

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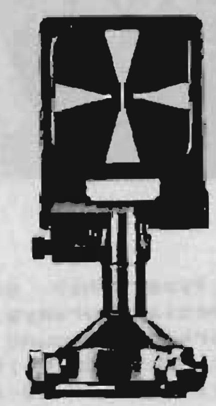

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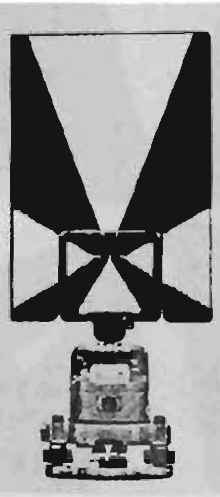

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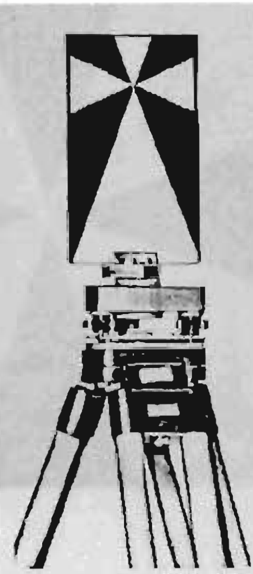

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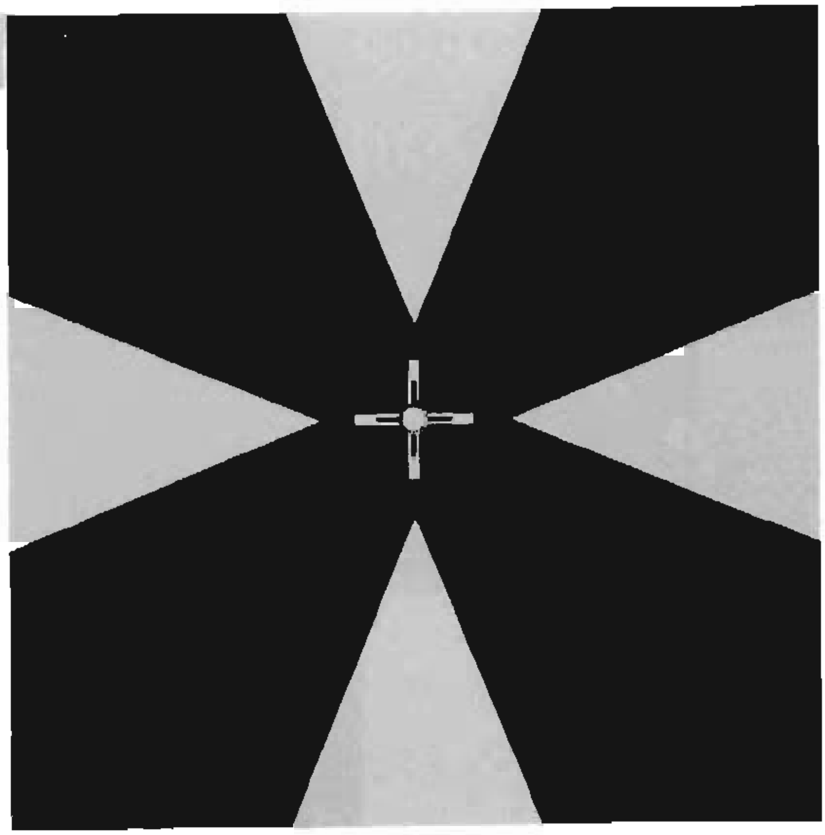

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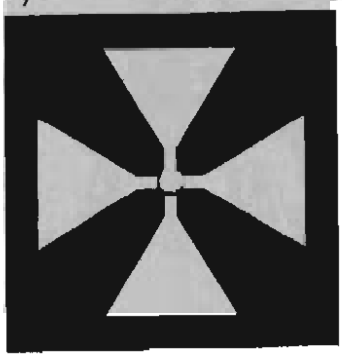

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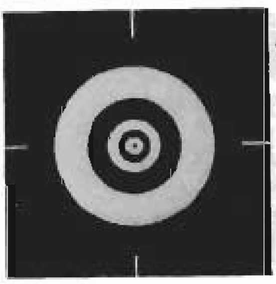

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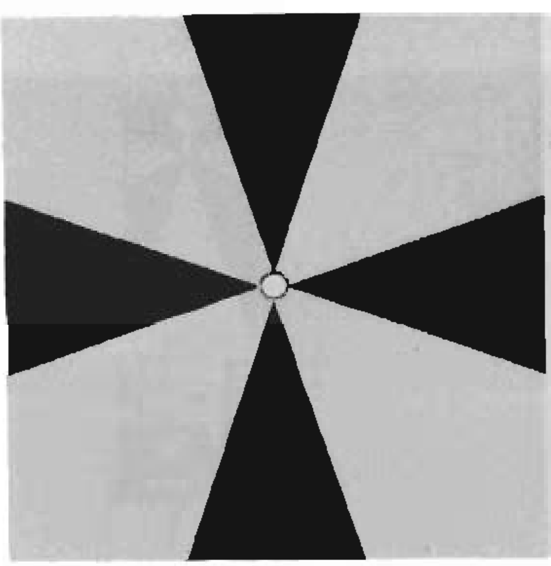
2) Target for special surveys, I.G.N., PARIS (F), 1975
3) Target for dark background (45°rotat.), AGIP (I) 1978
4) Operational target for multiple measurements, AGIP (I)1980
5) Operational target for 50-60 m dist., AGIP (I) 1982

3



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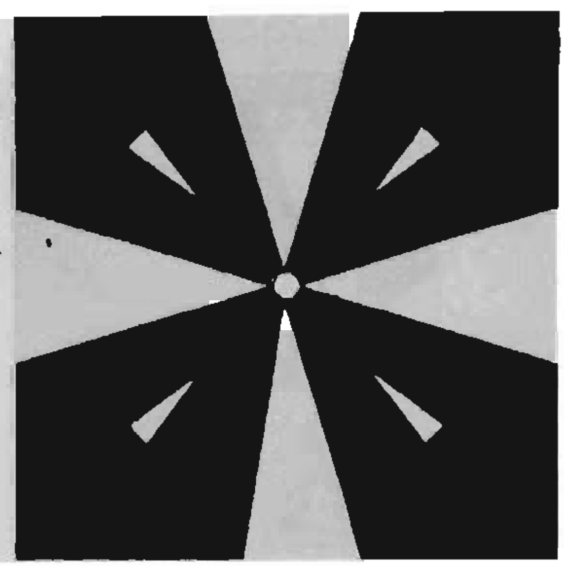

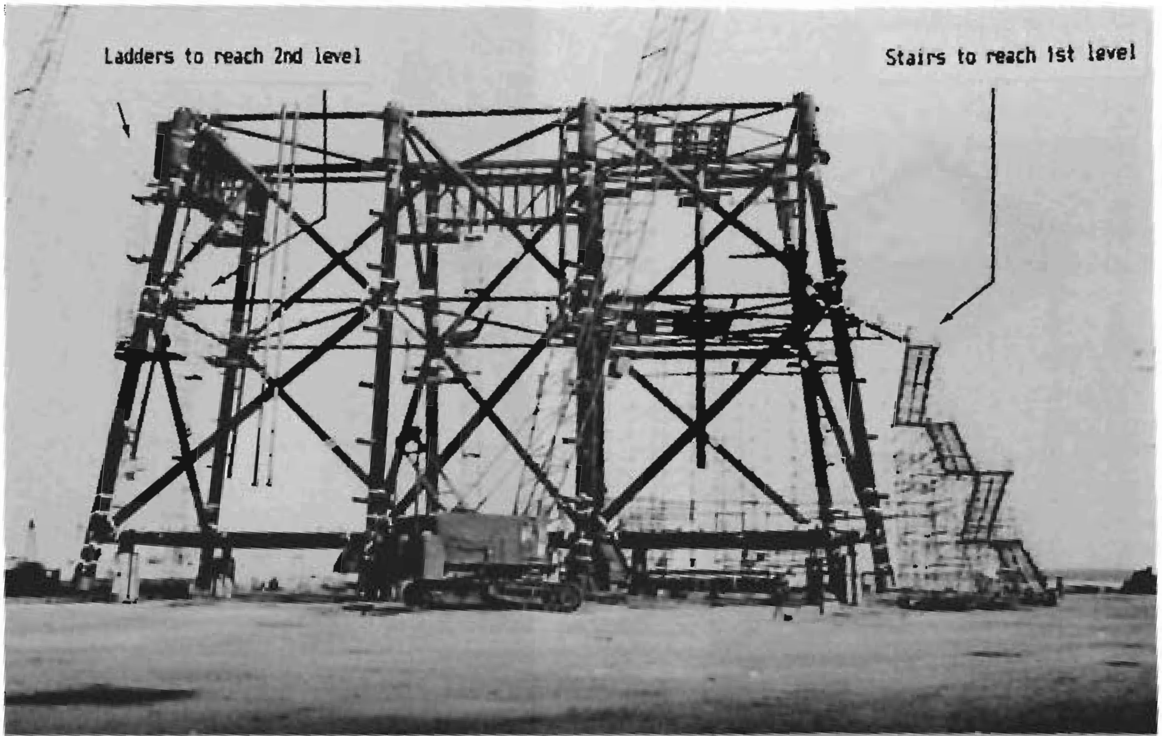
Ladders to reach 2nd level
Stairs to reach 1st level

FIG.3

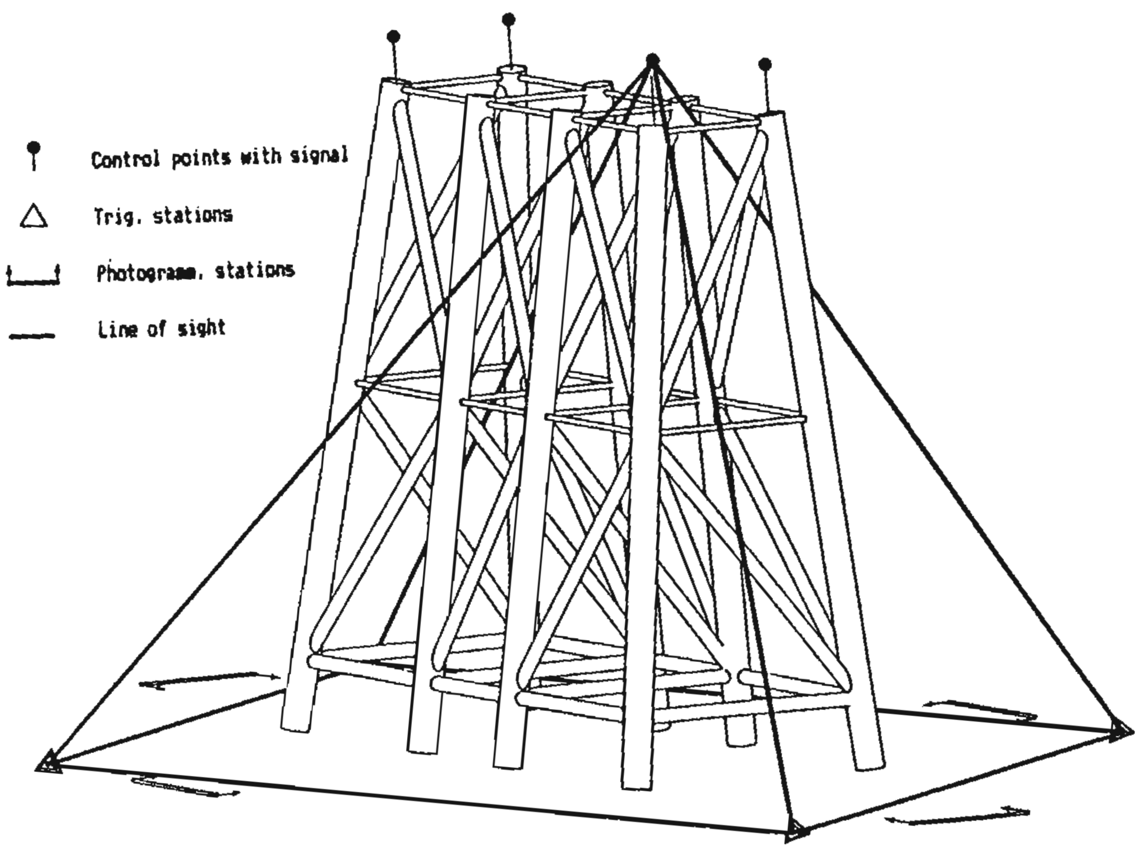
Control points with signal
Trig. stations
Photogramm. stations
Line of sight

FIG.4

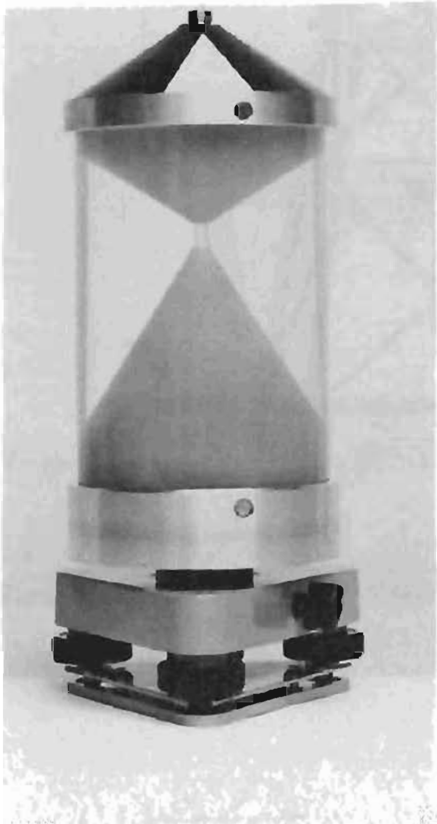

FIG.5

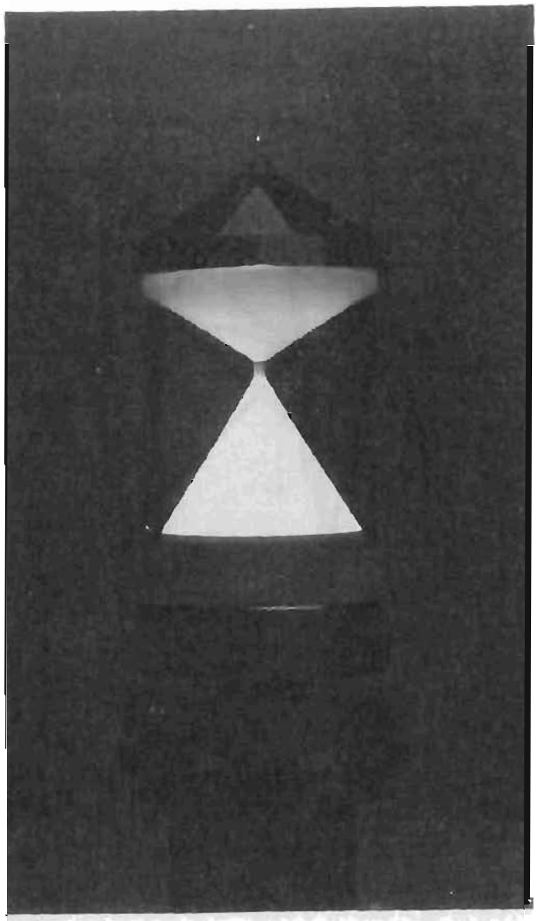

FIG.6

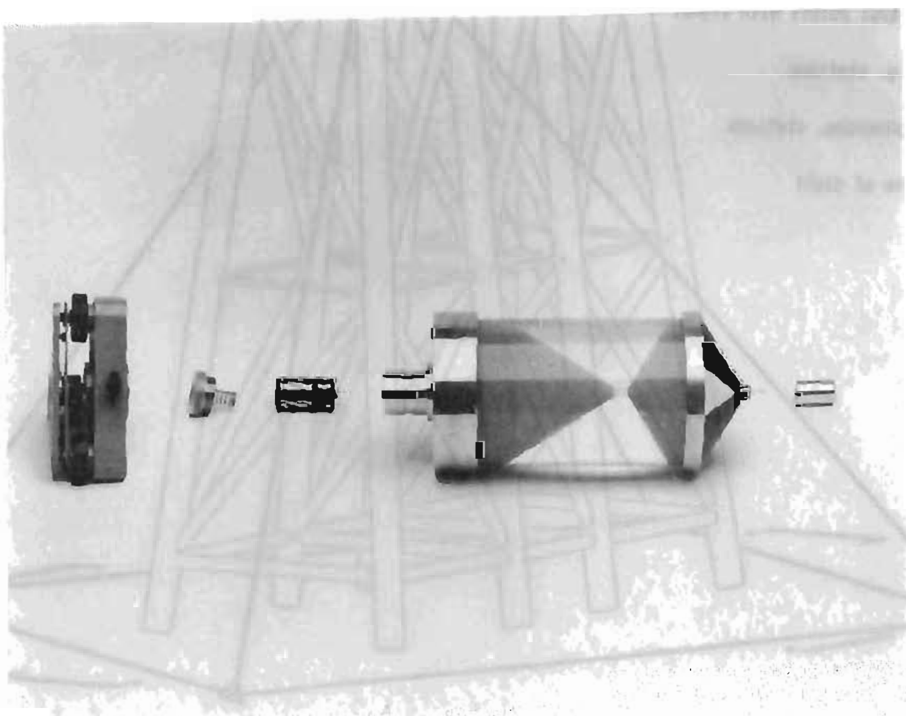

FIG.7