PHOTOGRAMMETRIC SURVEY OF A LARGE OFFSHORE PLATFORM DURING A DYNAMIC PHASE

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ABSTRACT:

Platforms for offshore oil field development are generally constructed in onshore building yards. Then they are loaded onto boats and carried towards their final destination in the open sea.
This paper describes the control survey of the jacket of platform Luna B (Agip Spa) - one of the biggest oil production platform ever installed in Italian water - during its loading operation onto a pontoon. The target of this survey was to evaluate the extent of the elastic deformation of the structure during the entire operation, and to verify if the loading procedure employed was fully compatible with the mechanical stress the structure could tolerate. By analizing the results if would then be possible to intervene in similar operations.
The loading of the jacket was carried out with a sequence of pull-stop phases, making it possible to use stereophotogrammetry. For this purpose three wide-angle cameras with roll film devices were used. The images obtained were processed through an analytical stereoplotter, and then collected date were analyzed for structural purposes.

KEY WORDS: Industrial, Photogrammetry, Close-range, Offshore, Hydrocarbon

1. INTRODUCTION

1.1 Introduction

Agip Spa is the leading Italian oil company. It works on the exploration and exploitation of hydrocarbon fields.
After the energy crisis of the 1970s and subsequent difficulties involved in procuring oil, an increasing share of the investments was directed towards offshore fields. The work of exploiting an offshore hydrocarbon reservoir, located in shallow-medium depth water, is carried out generally from a fixed platform which offers support for drilling, production and sometimes also the storage work.
The difficult environmental conditions and great loads involved mean that a high technological engagement is needed to construct and install these structures. It is therefore understandable that adequate dimensional controls of the structure must be carried out in order to guarantee the construction's dimensional tolerance values.

1.2 Dimensional control

Agip has a department which is in charge for the dimensional control of structures using traditional topographic and photogrammetric methods. Step by step dimensional control is carried out by the construction company's topographers while Agip intervene in final controls or during the most important phases such as;

- Checking the interaxes of the legs at the bottom of the deck, the part above the sea level, and at the top of te jacket; during this phase any ovalisation of the tubes is measured.

- Checking the correct alignment of the slots to be used for drilling.

- Measuring the structure after the installation and dimensional monitoring over a period of time.

In special cases other controls are made, such as the control of the prefabricated nodes (M.Rampolli, E.Bonora, 1990).

1.3 Aim of the work

The construction of two large platforms, Giovanna (120 m water depth) and Luna B (115 m water depth) was completed in December 1989 and May 1990 respectively. Given the exceptional sizes it was decided to measure the deformations undergone by the structures during their load-out, i.e. transfer from the yard to the transport pontoon.
The aim of this paper is to describe the measurements made during the Luna B platform jacket's loading.

2. JACKET LOAD-OUT

The jacket of a medium-large sized platform (>40m) is generally built lengthways, i.e. with the larger size horizontal in order to simplify its construction. In this case a system is designed which allows the structure to be slid to the quay. The structure is then equipped with a launching skid while the launching beams are continuous. The contact surface is covered with a low friction coefficient material, generally grease or teflon. When the jacket has been constructed, it is moved along these beams to the end of the quay and from here it is pushed onto a pontoon which is also equipped with special supports for exceptional loads. Subsequently, at the and of transport phase, the structure will be slid into the sea in a spectacular launching operation.
The interest aroused by this measurement campaign derives from the fact that in this situation the metallic structure has very particular restrictive conditions. In fact, the launching beams are not continuous between yard quay, and the pontoon. This problem is generally solved by adopting special procedures such as an accurate ballasting procedure of the boat while the jacket is being loaded and stretched ropes between the boat and the quay. For these reasons, and also because it is difficult to define exactely the boundary conditions, this condition is not examined during the structural analysis.
We therefore attempted to establish if the structure undergoes stress which could cause damage during this operation, in particular plasticization which may compromise future reliability.
For this reason it was necessary to measure the coordinates of some important points and to

compare them to the undeformed situation. The points selected were the following:

- points near the joints, i.e. the intersection points of the tubular roads. These are important points both from a geometrical and structural point of view for the whole structure;

- points near the quarters of the lenght of the bracings; in this case it was kept in consideration that beams that have fixed boundaries undergoing deformations have the maximum relative movements in these positions.

Luna B jacket was loaded at the Intermare Sarda yard at Arbatax (Italy). In this case it was slid on teflon coated guide lines. The pushing mechanism was formed by a pair of oleodynamic pull/push units applied on each guide.
The jacket then moved without continuity, with a piston expulsion phase and, at the end of the stroke, with a recovery phase of the cylinders and control panel applied to them. The frequency was about 90 seconds.
Given the type of operation it was not possible to use a traditional topographic method to control the structure because the time needed to take the reading at the points between one phase and another was insufficient. It was needed to use stereophotogrammetry which, with particular adjustments, allows shooting photograms in rapid succession of a moving subject.

3. STEREOPHOTOGRAMMETRY

Stereophotogrammetry is a special application of photogrammetry and it is used generally in a close-range context.
It consists of photogrammetric takes of an object using two metric cameras simultaneously. In this way it is possible to measure moving objects as long as the movements which occur during the exposition time are negligible.
In the sector of offshore industrial applications this technique is often indespensable. Below a list of examples of the most frequency cases:

- measuring structures at open sea where there is no fixed support on which to place the equipment;

- measuring large metallic structures in the shipyard where quick thermal variations can greatly alter the distances to be measured;

- measuring geometrically complex structures in sunny environments where the different positions of the shade may compromise the operator's stereoscopic vision.

For these reasons Agip has developed the stereophotogrammetric technique so that it may be used onshore, offshore and also from helicopters (G.Bozzolato, 1988; M.Rampolli, 1990).
In fact, in 1988 the S.E.R. (Supporto Eliportato Ruotabile) was produced with financial aid from the EEC. The system, derived from idea of G. Bozzolato, is patented by Agip.
S.E.R. allows the application of two large sized metric cameras on a 6.5 m beam fixed to a helicopter. The results obtained were positive in the industrial and geological/architectonic fields. In February 1992 The Valley of Temples (Agrigento) was surveyed using this method, with good results.

4. MEASURING OPERATIONS

4.1 Instruments used

The following equipment was used:

- 3 AUS JENA 10/1318 cameras.
  During the reference survey a single camera was used in the four station positions (figure 1). During loading 3 cameras were used: two of these were connected to each other and synchronised and the third one was isolated but with manual synchronisation.

- WILD T2000 electronic theodolite with a WILD GRE 3 data recorder. This instrument was used to measure the data points.
  During loading the theodolite was equipped with a WILD DI4 diastimeter which allowed the immediate reading of the coordinates of some reflector prisms installed on the structure.

4.2 Preparation

Every photogrammetric survey is divided into 3 main steps:

- marking of the points to be collimated during plotting to have greater precision;

- triangulation of the data points for every pair of photograms to allow subsequent orientation;

- photographic shooting.

The following operations were carried out in the survey discussed in this report.

During a preliminary stage the area was inspected and the survey's various stages were planned so that the shipyard could cooperate in terms of means and personnel.
The shooting bases were chosen as a function of some determining factors such as the sunlight and shipyard obstacles. The accurate definition and materialisation of the station points were carried out on the basis of the area covered by the photograms and on the precision required (figure 1). There were 7 station points divided into 4 shooting bases. In particular, since the structure must be measured in the initial undeformed situation, bases 1 and 2 were chosen. For shooting during loading, bases 3 and 4 were chosen, near the quay.
The points on the structure to be measured when plotting were identified using 200x200 mm self adhesive targets with a Malta cross.
The data points, deermined topographically, and to be used for orientation operations, were distributed in order to have a good coverage of the photographed area. They were placed on suitable locations on the ground and on the structure for measuring the underformed structure. Analogously, 13 data points were identified on land and on the runway for the dynamic phase survey.
It was difficult however to put data points in the high part in order to have a good orientation of the ohotograms. In fact, the large moving structure excluded any suitable position.
It was therefore decided to place 3 data points directly on the structure at a height of about 20 meters and to apply reflecting prisms at these points.
In this way it would be possible to determine the coordinates directely using a wave diastimeter exploiting the time when the structure is stationary during loading operations.

The work of marking the more than 200 points, among which the data points to be used for orientation and those to be measured, was very expensive. 3 people were needed for 4 days and a crane for access to the structure's higher areas.

The onshore data point's coordinates were determined using the topographic technique of forward intersection carried out using a WILD T2000 theodolite.
3 sets of measurements were made, each with double straight/reverse readings. The points on the structure were defined during the loading phase. In this case an operator collimated the 3 points with a prism using a diastimeter in the few seconds that the structure was stationary.
A single reference system was used for all the data points' coordinates defined topographically. This system will then be used also for measurements carried out at the stereoplotter.
Precision reached in defining the data points was ± 1 mm.

4.3 Photogrammetry

The survey to give an undeformed reference geometry was carried out from bases 1 and 2 (figure 1), shooting respectively the structure's bottom and top.
The bases were distributed following an alignment parallel to row 2 of the jacket and 50 meters away. One metric camera placed at each of the four positions was used.
8 photograms were taken with a vertical inclination of +15°.
The survey of the loading was carried out from a double base with 3 cameras. In fact it was necessary to sufficiently cover the jacket's surface with the photograms. And, if this was easy to achieve onshore it was not easy for the part in the boat. The problem was overcome by horizzontally inclining the cameras.
Three cameras were used, two were connected to each other and a third was independent but synchronised manually.
Loading operations were carried out from 5.00pm to midnight on 10/5/90. The most important phases of the operation therefore took place at night and very long exposition times were needed. Compatibly with the loading movements, exposition times of 15-20 seconds during some of the extended stops. 27 shots were taken using a KODAK PAN 200 film with a 24 DIN sensitivity. Every camera had a container for roll-films equipped with an aspirator to keep the film flat at the moment of shooting.

5. MEASUREMENT OPERATIONS

5.1 Photogram orientation

The topographic calculations were made using a PC Olivetti M24 with dedicated software.
Plotting was made using a WILD AC1 analytical plotter conected to a Nova 4X Data General, with a PMO package programs.
The photograms were selected on the basis of qualitative criteria and in such a way as to have a detailed description of the loading phases.
Despite the availability of three photograms for each phase, having used 3 metric cameras to shoot the loading phase, only the photograms of the two A and AR cameras of base 4 (sea-side) were used. In fact, the third photogram did not offer great improvements for the number of points and the precision of the measurements. This photogram was used only in one case where the orientation of a sea side couple was difficult.

5.2 Plotting

14 pairs of photograms were plotted giving a good description of the structure's deformative phenomenon.
The point which can be collimated by the operator were measured for each stereoscopic model.
Contrary to expectations, the measuring procedure's limits were not the lack of visibility of the points due to lack of light or great distance. The biggest problem was the blocked view because of different types of obstacles. In fact, to be used, each point had to be seen on 4 photograms, two for the reference pair and two for the comparison pair.
On the other hand it was decided not to measure the points without a target to avoid reducing the precision.
The quality of the measurements obtained by the plotting may be estimated approximately on the basis of the measurements at the data points defined topographically.
These data were included on the plot protocols. The average of the standard deviation on the data point readings was the following:

reference pairs

$$Py = 0.0014 \text{ mm}$$
$$Dn = 1.43 \text{ mm} \quad Dh = 1.69 \text{ mm}$$

pairs during loading

$$Py = 0.0023 \text{ mm}$$
$$Dn = 2.21 \text{ mm} \quad Dh = 2.83 \text{ mm}$$

where Py is the residual parallax value, Dn is the accuracy in the plane normal to the optical axis and Dh is the accuracy of the coordinates in the direction parallel to the optical axis.

6. DATA PROCESSING

The data obtained by the plotting measurements were recorded according to the string type:

ID, X, Y, Z

where ID is the identifier for each point, and X, Y and Z are the coordinates according to the absolute reference system. A file was created for every position of the platform during the load-out.
These data were then transferred to a personal computer where the subsequent processing was carried out.
In the first phase the points were ordered according to the identifier's progressive order. Then every data file for each loading phase was compared with the file obtained during the reference phase following this process:

ID, X(0), Y(0), Z(0) reference phase file
ID, X(i), Y(i), Z(i) loading phase file

$$DX(i) = X(i) - X(0)$$
$$DY(i) = Y(i) - Y(0)$$
$$DZ(i) = Z(i) - Z(0)$$

In order to simplify the interpretations, only the DZ(i) vertical displacement were considered in the following steps.
Table 1 shows the results obtained by this operation. Each column represents the movements of all the points for each phase. The points which were not measured in any of the loading phases or in the reference situation were

excluded, i.e. those where comparison was not possible.
A vectorial diagram was also traced in which each vector indicates the differences between the examined and reference phases.
From these results it was noted that the maximum vertical displacement was 16.6 mm reached during phase 30 (figure 2).
Another processing was carried out in order to control the platform's tensional level. For this, the points were subjected to rigid rototranslation, i.e. maintaining the reciprocal distances in order to minimise the deviations. The result obtained was that of greatly reducing the size of the deviations passing to a maximum value of 6 mm. It was thus assumed that the deformations were mainly due to rigid movements of the structure and so the tensional state of the elements were not increased greatly during the loading operation.

7. CONCLUSIONS

The survey results showed that the structure undergoes small stresses. So, from a structural point of view, the jacket had no problem during the load out.
The photogrammetric survey gave good results in terms of accuracy and quantity of data.
Stereophotogrammetry was tested in detail in shipyard surveys and did not create special problems even although it was used in very bad environmental conditions with little nightime light and the shooting had to be carried out in very limited times.
The survey could not have been carried out using any other method because the topographic measuring requires times which would have been unacceptable.
One possible adjustment to allow a better structural analysis could be to evaluate the lowering of the boundaries ie. the launching beam and the boat by geometric levelling.
The main result is undoubleddly that of having verified the possibility of using stereophotogrammetry to measure large structures which may even be in movement.
This method also gives results in a very simple form which may be processed for other aims such as structural analysis or CAD representation.

8. ACKNOWLEDGMENTS

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TABLE 1 - VERTICAL DISPLACEMENT OF MEASURED POINTS DURING LOAD-OUT PHASES
values in cm - positives toward the ground

	1	2	3	4	5	6	7	8	9	10	11
5			1,7	-0,3	-3,8	-2,6	-3,1				
6	-2,2		2,2	-0,7							
10						-1,1	1,3		0,5	-0,0	1,6
11					-0,5	-2,8	0,4	-2,3	-2,7	-1,8	0,6
15								3,3	2,9		
16							1,3	-0,6	-0,9	-1,2	-0,4
17							-0,1	-4,3	-4,3	-4,3	-2,1
18	-1,7		1,3	-0,3	-2,8	-2,9	-0,6				
32										4,0	2,2
33								4,6	3,6	3,1	
34									5,5	4,2	3,4
35								4,7	4,2	3,2	2,6
36								2,2	1,8	0,8	1,3
38								2,0	1,4	0,7	0,7
39								0,4	-0,2	-0,8	-0,7
40							1,2	0,1	-0,5	-0,9	0,5
41							1,7	-0,3	-0,7	-1,0	0,1
42							1,0	-0,7	-1,0	-1,5	-0,9
43							1,1	-0,9	-1,2	-1,9	-1,2
44					-1,2	-1,5	0,7	-1,7	-2,1	-2,1	-1,3
45					-1,4	-2,0	-0,1	-3,9	-4,0	-3,6	-2,1
46					-0,4	-1,9	0,8	-1,3	-1,4	-1,6	-0,0
47					-1,1	-2,3	-0,0	-3,7	-3,2	-3,4	-1,6
48					-0,9	-1,3	0,5	-2,4	-2,8	-3,3	-2,3
49					-1,5	-1,7	-0,3	-4,2	-4,4	-4,1	-2,9
50					-0,1	-2,1	1,2	-3,2	-2,7	-2,5	1,0
51					-1,0	-1,9	0,5	-4,4	-3,8	-3,7	
56			0,4	-0,5	-2,1	-3,7	-0,1	-6,1	-4,6		-1,7
57				-0,4	-2,9	-2,1	-0,6				
58	-2,3		1,4	-0,1	-2,3	-3,7	-0,3				
59	-1,7		1,1	-0,6	-2,8	-3,3	-0,9				
60	-1,6		1,6	-0,2	-3,1	-2,6					
61	-1,7		1,7	-0,2	-3,4	-2,6	-1,1				
62	-3,4		-0,1	-1,2	-3,3	-4,6	-1,7				
63	-2,3		0,9	-0,5	-3,4	-3,4	-1,1				
64	-1,9		1,8	-0,5	-4,4	-3,3	-2,1				
65	-2,8	3,0	0,6	-0,9	-4,5						
66	-2,7	3,1	1,1	-1,1	-4,8						
67	-2,4	3,0	1,4	-1,2	-4,9						
71	-2,2	3,3	1,7	-1,0							
72								4,0	3,3		
73								3,8	3,0	1,8	1,8
74								3,2	2,6	1,6	1,2
75								3,2	2,5	1,7	1,2
76	-2,4		2,3	-1,1							
110					0,7	-0,2	2,2	-3,0	-1,9		-0,2
111			1,9	0,3	0,0		-0,2			-6,1	-2,3
112				2,0	-0,1	-1,2	-0,4	-9,5	-6,8	-7,4	
113	0,8		1,5		-1,1	-4,4	-4,6	-13,8	-9,4		
116					-0,3		0,8	-4,9		-4,8	-2,9
117				0,4			0,6	-8,6	-6,6	-7,8	-3,8
118	1,3		0,8	0,0	-2,4	-2,6	-2,3				
120		3,5									
130									4,3		
131								4,1	4,4		
132								2,2		1,7	1,4
134								3,2	3,6	2,2	2,2
142					0,3	0,2	2,4			-3,9	-2,3
145				0,7				-8,1	-5,5	-6,8	-3,7
146					0,7					-4,8	-1,5
147				0,4		-0,7		-7,8	-5,3	-6,9	-3,5
148											
149			1,3	0,2	-0,9	-0,6	0,7	-8,2	-6,2		-4,3
150			1,2	-0,0			0,5		-11,2	-6,5	-3,1
151	1,9		1,6	0,4				-8,0	-6,3		
152			1,3	0,1	-0,8		0,4			-8,0	-4,3
153	1,1		1,1	0,3	-0,5		0,6	-9,0	-7,0	-8,2	-4,7
155	1,5		1,3	0,5	-0,0					-7,7	-4,3
158			0,5		-1,4	-3,5	-2,0	-12,2	-9,5		
162	1,8				-2,1			-13,0		-9,2	-4,7
165	0,8		1,1	-0,0	-4,1	-4,1	-3,7	-16,6	-13,6		
166	0,6	2,2		-0,1	-3,9	-4,0	-3,9				
188		2,6			0,5	-1,1	-0,6			-7,0	-2,9
192	0,7	0,8			-1,6				-8,8	-9,6	-5,5
193				0,0	0,1	-1,0					-3,9
194	1,2		1,6	-0,2						-8,7	-4,9
196				-0,1	-0,2	-0,4	0,9		-5,6	-7,0	-4,4
197				0,3		-0,2		-8,3	-6,3	-7,5	-4,3
200	1,0		1,7	0,4	-4,5						

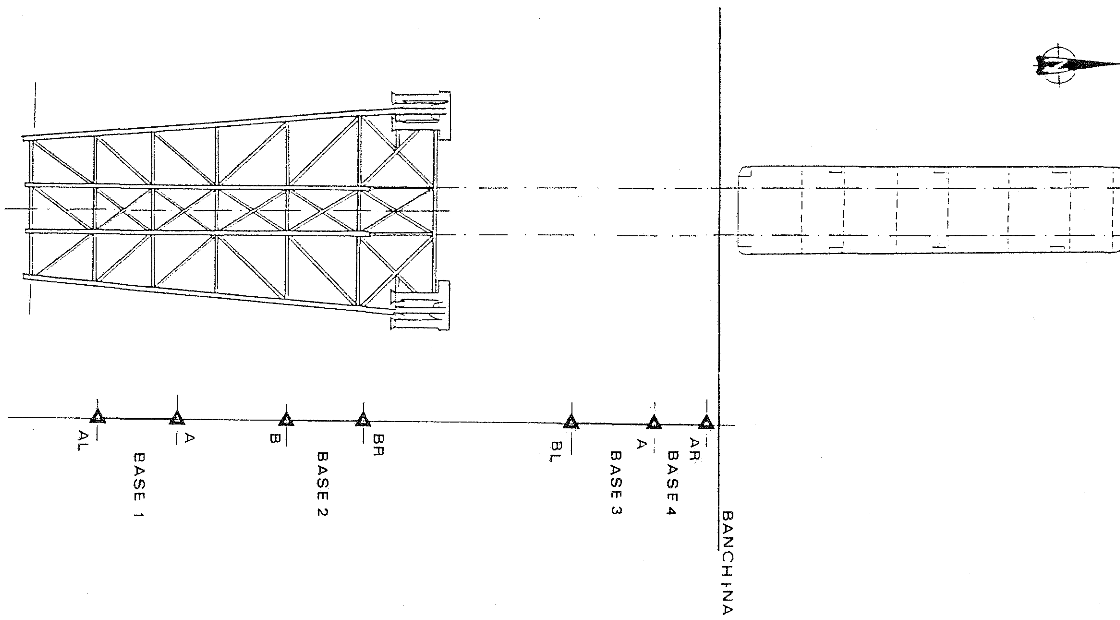

Figure 1 - Planimetric arrangement

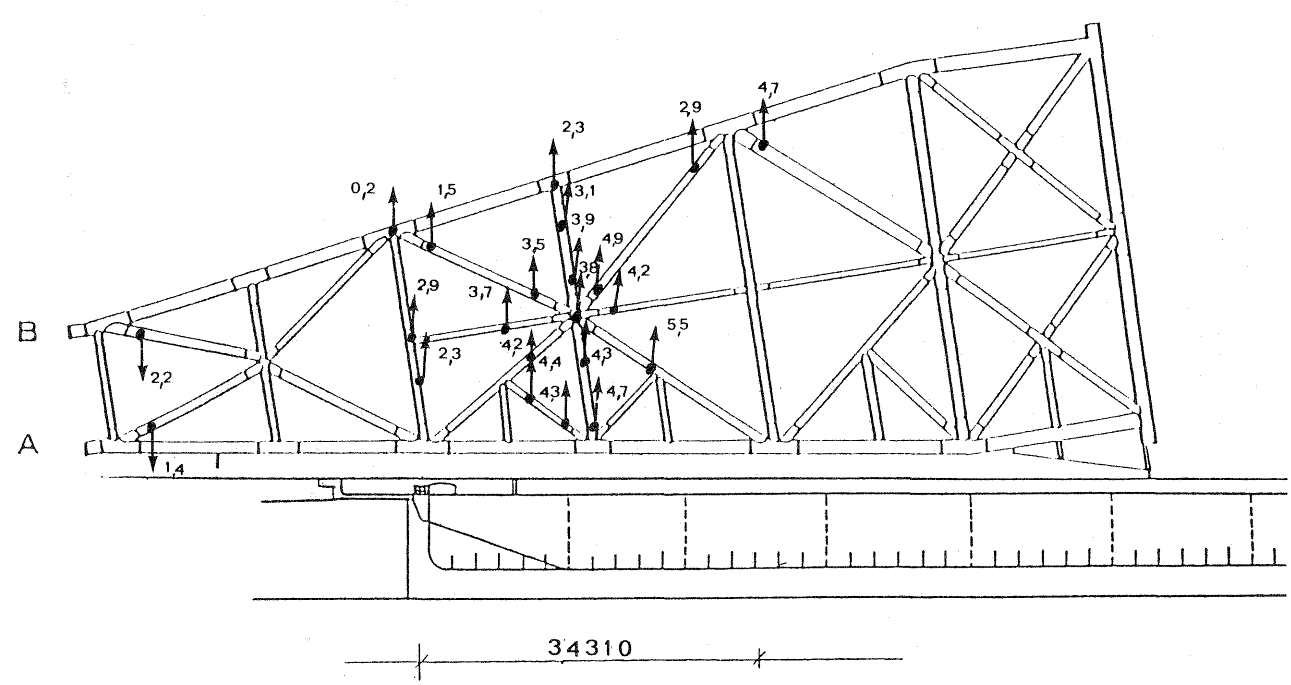

Figure 2 - Vectorial diagram at phase 8

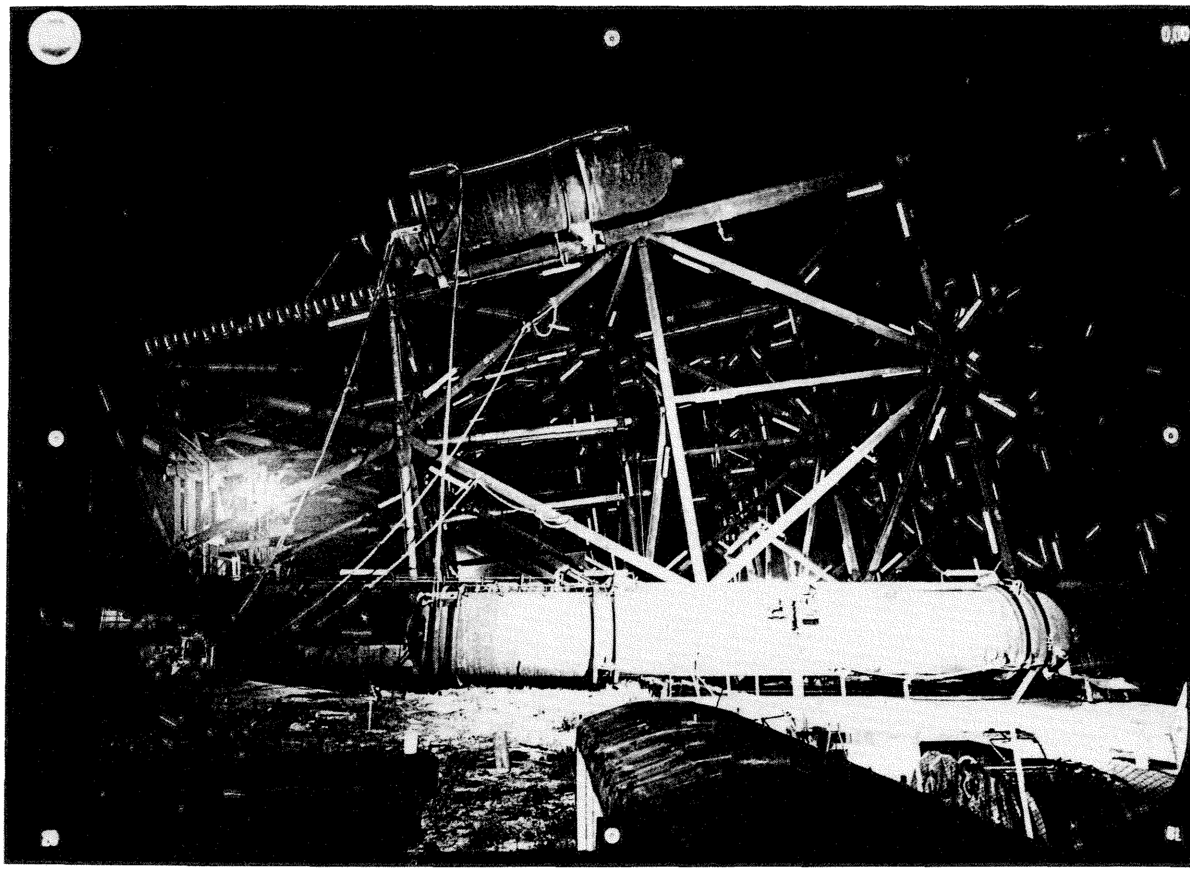

Figure 3 - Photogram at phase 8

Figure 4 - Photogram at phase 11