WORKOVER ON MILOS 2 GEOTHERMAL WELL

Alberto Bottai [1] , Efrossini Delliou [2] , Nicolaos Koutroupis [2], Gian Paolo Mezzetti [1]

[1] ENEL S.p.A. DPT-VDT/G, Via Andrea Pisano 120, 56122 Pisa (Italy)
[2] P.P.C. (PUBLIC POWER CORPORATION), Navarinou 10, 106 80 ATHENS (Greece)

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ABSTRACT

The Milos 2 geothermal well (Milos Island, Greece) blew out on September 1993 due to a serious damage occurred below the wellhead base flange.

The flow of brine and steam coming from the well quickly destroied the concrete of the cellar and produced a big crater around the well.

Several solutions were studied and a specific workover, based on the repairing of the wellhead was selected.

Sixteen days were necessary to dismantle the old wellhead, to assemble the new one shipped from Italy and to plug the well with cement.

All the operations before killing and cementing job were performed with the well m flowing conditions.

1. INTRODUCTION

The Milos 2 well was drilled in 1982 during the deep exploration of Milos Island (Greece) which revealed the presence of a geothermal reservoir at a depth of about 1000-1500 m, constituted by water with a saline content very similar to that of sea water.

The well was used for electric power generation (about 2000 kW) for about nine months m 1989 until it had to be interrupted due to Milos people reaction? against geothermal development.

The well has remained inoperative since that date.

In September 1993 it blew out through a failure in the production casing below the ground level.

The collaboration of ENEL to supervise and carry out safety operations on the well was requested by the PUBLIC POWER COMPANY (the Greece electric board) which managed the well and the annexed power plant.

2. WELL CHARACTERISTICS

The well is about 1400 m deep.

Figure 1 presents a schematic illustration of the well's technical profile and wellhead, which during the blow out was still anchored to the 13 3/8"casing.

Under static conditions the well characteristics were as follows:

. wellhead pressure 24 bar;
. water-filled up to ground level.

The generating plant had been built near the well itself.

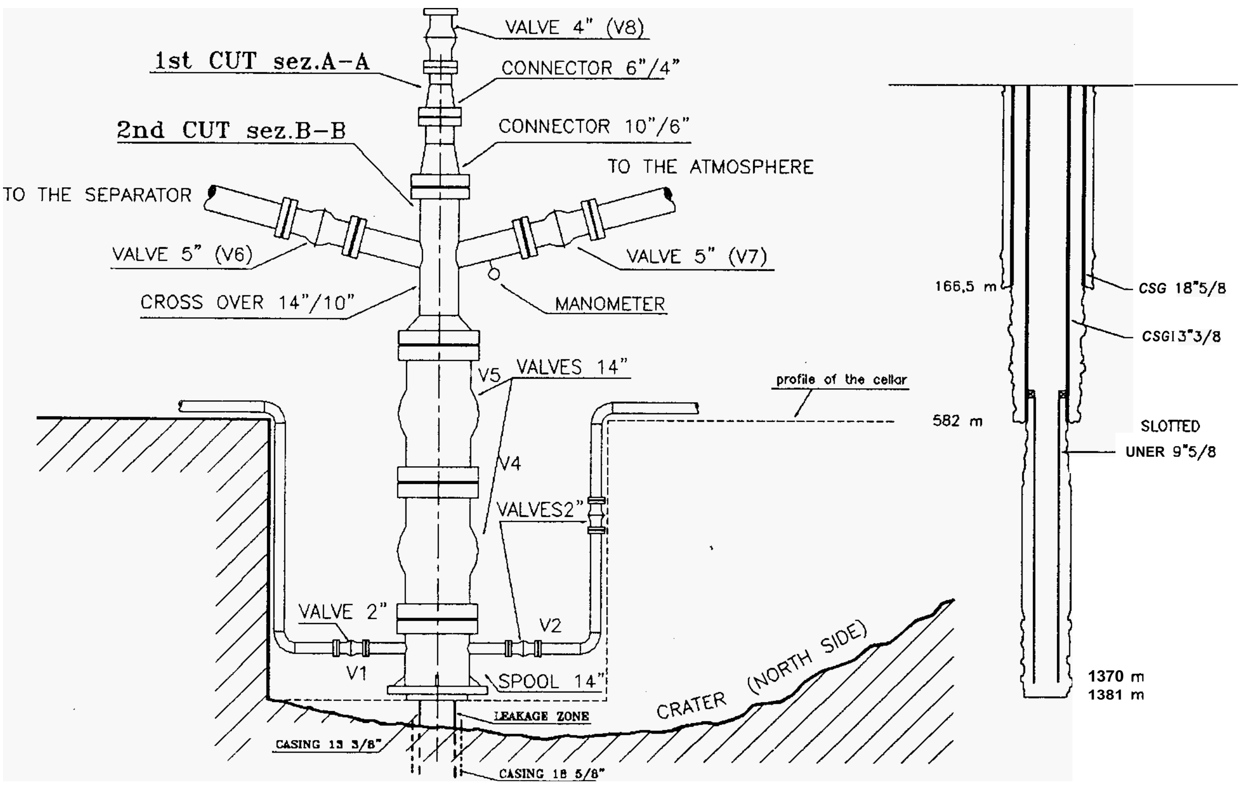

Figure 1. - Wellhead and casing profile

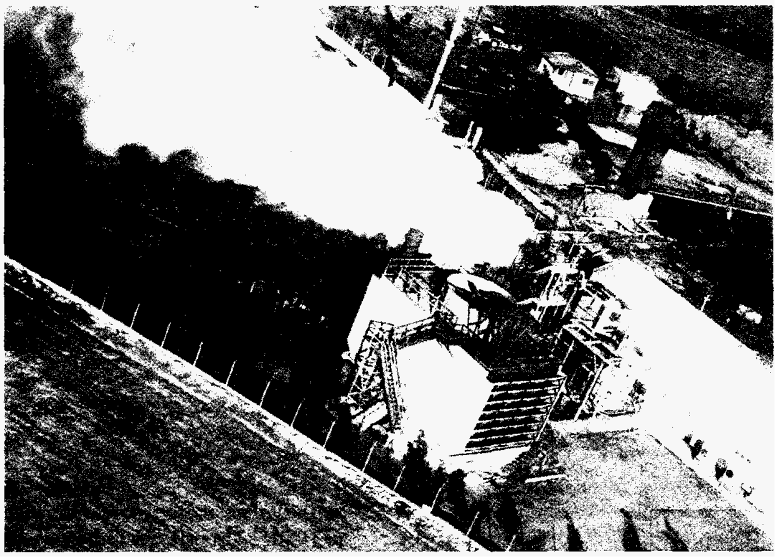

Figure 2. - General view of the plant

3. DESCRIPTION OF PHENOMENON AND CONTOUR CONDITIONS

The blow out occurred suddenly and violently after a first phase of a week of slight leakage of hot water into the well cellar. The situation was as shown in fig. 2 and fig. 3.

Fluid emission was estimated at about 50 t/h, of which 20 t/h steam and 30 t/h water. that is to say similar to the maximum flow-rate.

A first inspection permitted verifying that:

- the flwd loss was located in the cellar bottom below the base flange;
- localization of the precise site of failure was rendered impossible by the emanation of steam which hindered cellar access and visibility;
- one half of the cellar was practically destroyed by the fluid jet that had also formed a completely fluid-filled crater on the northern side (fig. 1, fig 4)
- much of the metallic structures for pipelines and separators had became unsafe as the ground on which their concrete basements were anchored had been washed away

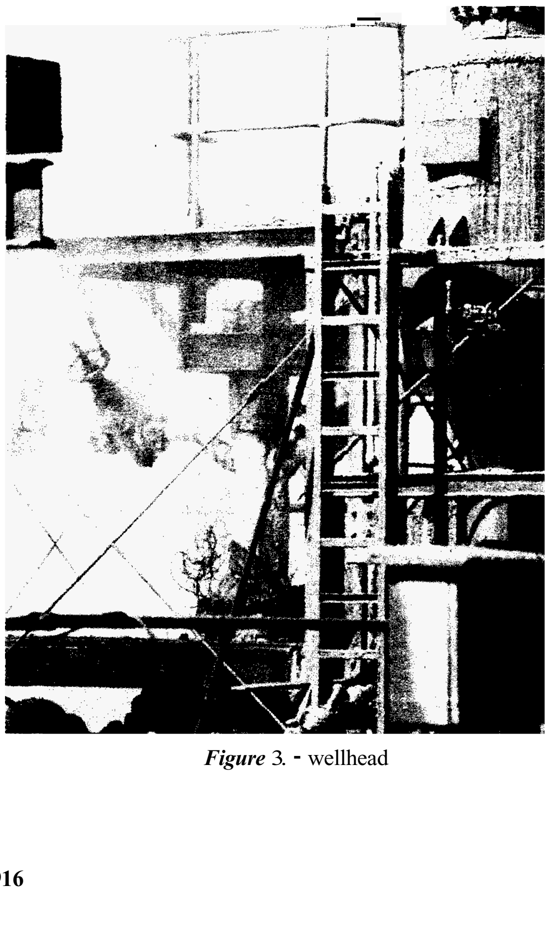

Figure 3. - wellhead

valves VI, V2, V8 (fig. I) were inoperative and stuck in the closed position probably by the salt producet during the blow-out.

The wellhead pressure could not be measured reliably; this notwithstanding, the probable value at the wellhead was 6 bar, as revealed bv a manometer on a connecting pipe of the well to a separator

4. PRELIMINARY OPERATIONS AND ANALYSES

A preliminary safety measure had the purpose to stop the crater propagation and procuring the necessary time io organize the operations to put the well in safety conditions. For this purpose, the lateral valves V6 and V7 were opened to reduce both the wellhead internal pressure and the flow through the damaged casing.

Subsequently to this operation the manometric pressure dropped from 6 to 4 bar.

Analysis of available production data (wellhead pressure and estimated fluid flow rate) indicated that the failure involved a section of the 13 3/8" production casing of at least 100 sq cm, independently of its location.

This was considered symptomatic of a possible significant weakening of the part of the casing which acted as a supporting structure for the wellhead. Moreover, the residual strength of the *casing* was not determinable.

5. PROJECT

Two possibilities for remedial action were considered.

The first consisted in the drilling of a deviated well through which the existing well could be killed by pumping mud and water; the second possibility was a workover of the well in order to replace the damaged wellhead with a suitable one to allow the operations necessary to put the well in safety conditions

On the basis of technical consideration.., including the work time-schedule, risks and cost-effectiveness, the second solution was chosen, despite the greater effort involved in order to insure suitable safety conditions during the work.

In the light of the foregoing, the project was organized according to the following criteria:

a) limiting as much as possible the load on the wellhead, as data for predicting the residual resistance were not available;
b) working at a distance as far as possible from the well, for safety reasons, at least during the critical phases;
c) proceeding with limited and controllable operations from the safety stand-point, in order to produce a safer general well situation than the proceding one.

The feasibility of the work presupposed the availability of equipment for cutting wellhead elements at a safe distance.

The technique deemed most suitable was the cut with diamond cable because it allows:
a) working with low forces on the wellhead;
h) keeping the operator enough far from the well (8÷10 m)

Beforehand, a preliminary test of the technique was performed on piping pressurized to 6 bar by water and steam.

The step-by-step operation sequence was as follows:
1) removal of valve V8 by means of a cut in section AA (fig. 1)
2) partial demolition of the metallic structure encircling the wellhead;
3) removal of the 10"-6" cross-over by a cut in section BB (fig. 1);
4) removal of valve V5 (fig. 1);
5) digging around the well and demolition of the cellar,
6) removal of valve V4 (fig. 1) and checking the casing failure;
7) assembling a 21 1/4" flange on the 18 5/8" casing;
8) installing a new pre-assembled and tested wellhead;
9) valve closure, killing and cementing of the well.

6. WORK ORGANIZATION

At the time, the facilities, equipment and materials necessary to perform the operation were unavailable on Milos Island.

In order to meet the need for immediate action, a self-sufficent "task force" was set up to manage the work and provide for any eventualities.

ENEL was charged with designing, overseeing the operation, and supplying the equipment and the materials for the work.

The PPC provided the earth moving equipment as well as logistic support.

All equipment was transported from Italy to Milos on an expressly chartered ship, thus insuring the promptness and reliability of the work.

7. EXECUTION

The undertaking was canied out, with few variations, in conformity with the planned project.

Cutting was performed at a safe distance and involved sections AA and BB (fig. 1).

The efficacy of the cutting procedure was confirmed and the expected pressure reductions with each stage were obtained.

Therefore, with each pressure reduction the fluid jet at the base was reduced. Consequently, visibility and safety conditions were gradually restored and the well access became easier and safer.

The sequence of actions is shown in the following figures:
fig 5, cutting with diamond cable in section AA;
fig. 6, cutting with diamond-cable of the 10"-6" cross-over in section BB.

Further cutting of the wellhead, after the above partial depressurization, were performed by means of traditional methods:
fig. 7, removal of valve V5;
fig. 8, digging around the cellar;
fig. 9, the 13 3/8" casing - site of the failure;
fig. 10, assembling the new wellhead after the welding of a new 21 1/4" flange on the 18 5/8" casing.

8. WELL KILLING AND CEMENTING OPERATIONS

Fig. 11 shows the well during the final phase of the work.

The injection started during the closing operation of the valve.

The water flow rate was firstly 200 l/m and it reached 1200 l/m after the valve was completely closed.

The maximum pressure was 12 bar, but it degrease gradually up to zero and remained constant. After three hours of water injection at the maximum flow rate the water level in the well was controlled.

Bentonitic mud injection (30 cm) preceded the cement slurry injection: 60 t of cement were necessary to fill the well from 500 m depth up to ground level.

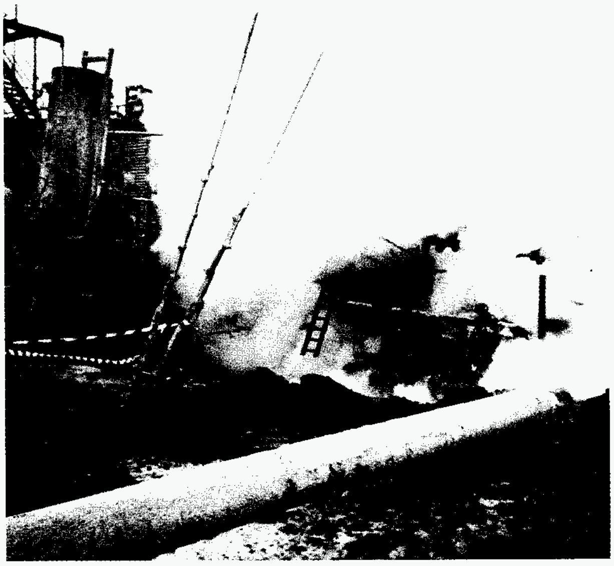

Figure 4. - North side crater

Figure 5. - Removal of valve V8

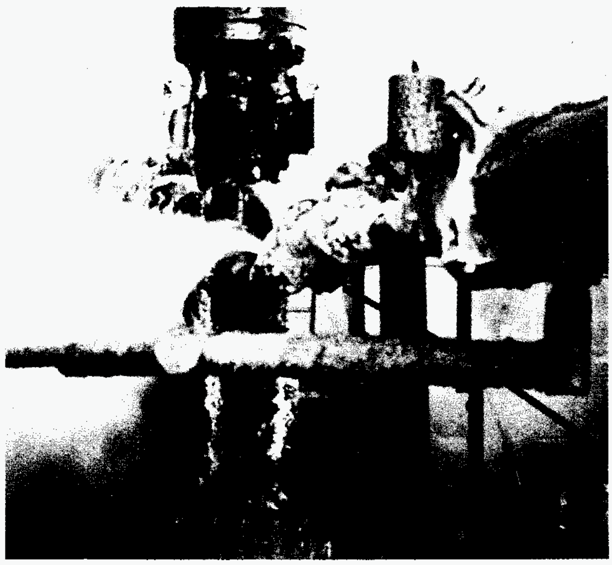

Figure 6. Removal cross over 10" ÷ 6"

Figure 7. - Removal valve V5

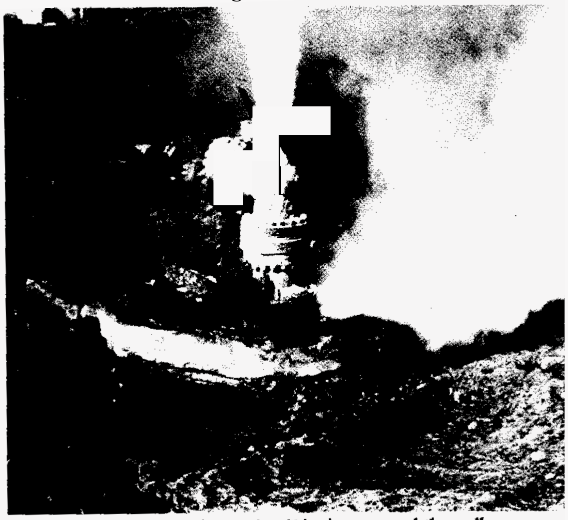

Figure 8. - Digging around the cellar

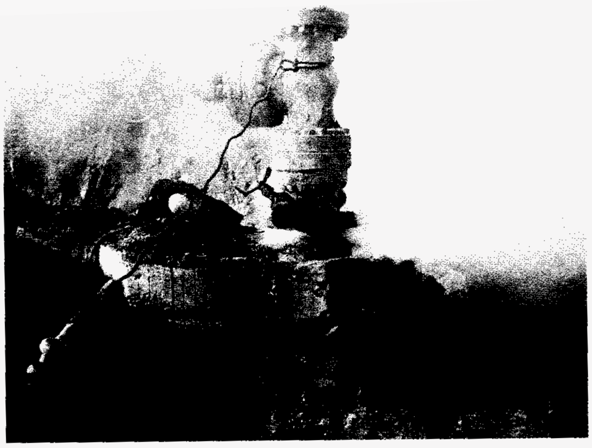

Figure 9. - Casing failure

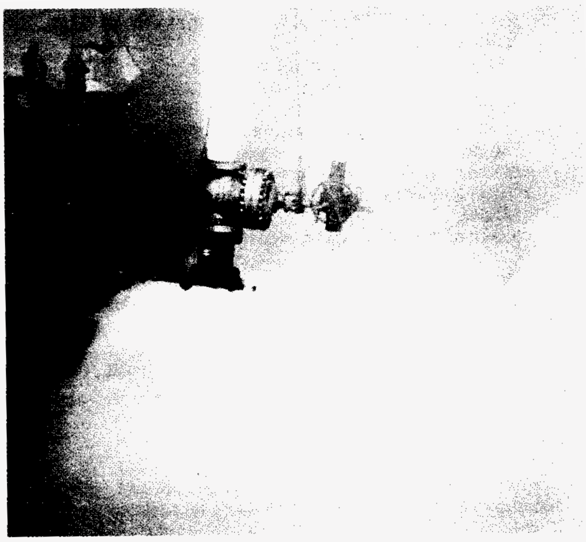

Figure 10. - Wellhead assembling operations

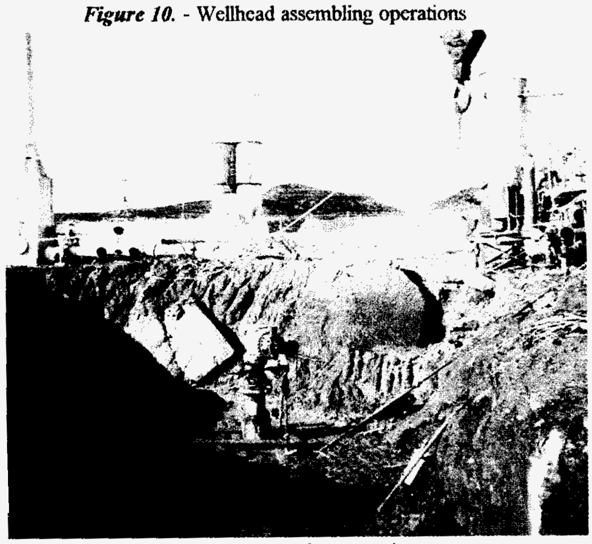

Figure 11. - Cementing operations

9. CONCLUSIONS

This kind of operations are often complicated by unexpected occurrences that negatively affect the operation plan defined at the outset.

In the current case, with the aim to cut down that risks, the base programme was studied to be extremely detail4 for the whole activity.

Moreover for each micro-activity an alternative procedure was studied and defined with the aim to solve the possible difficulties arising in the realization of the base programme.

The analysis also determined the priority with which the different equipment was to be used on the basis of its supposed efficacy and associated risks.

Figure 12 presents a Gantt diagram of the entire operation structured on the basis of two criteria. one "optimistic"and the other "probable".

The "real" path confirms that the work was completed, not only tecnically satisfactory, but in adherence to the original plan.

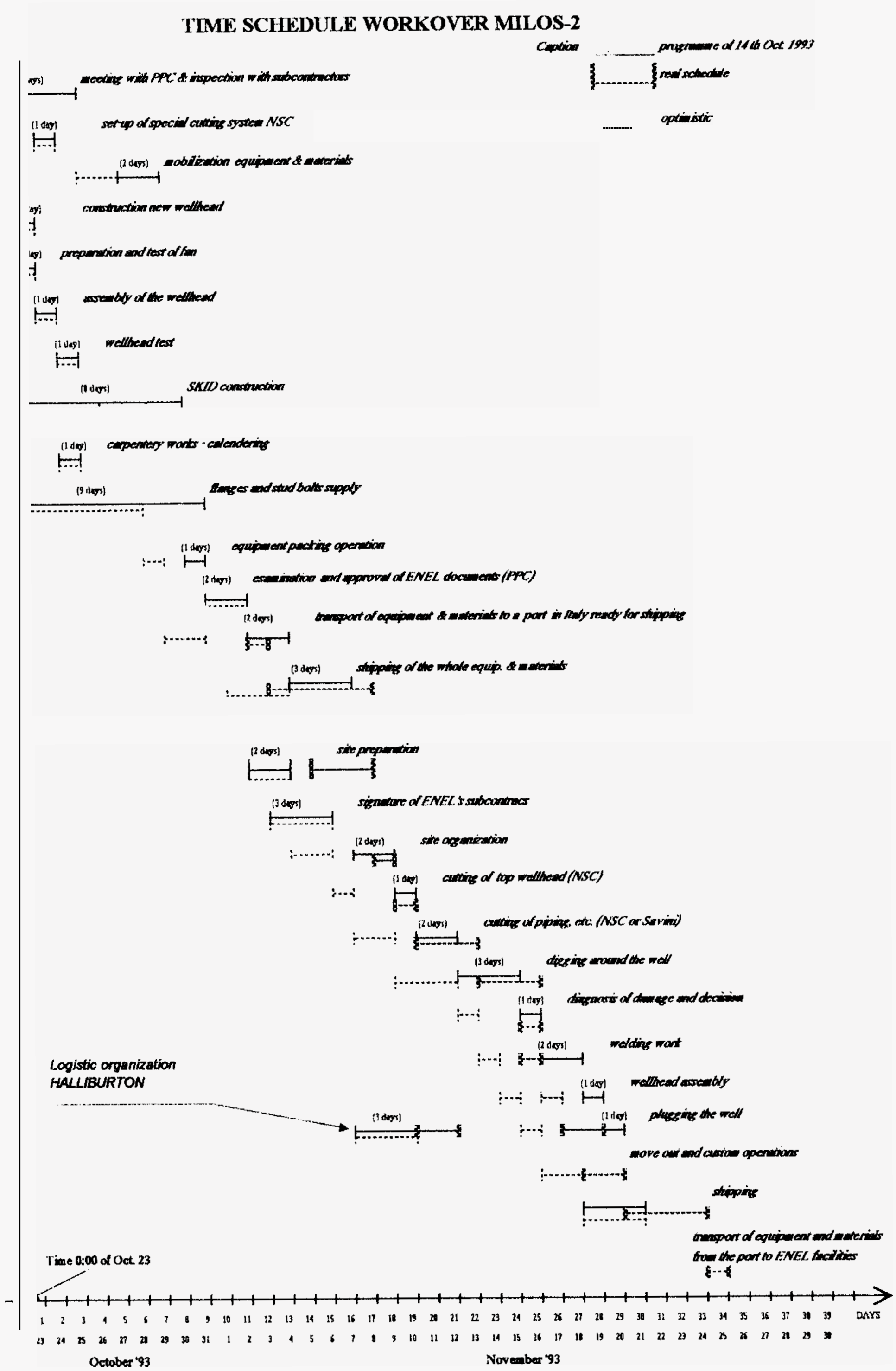

Fig. **12** - Time schedule