OTC 5903

Drilling Operations Planning and Drill Deck Strengthening for Extended-Reach Wells From an Existing Platform

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ABSTRACT

With the ever increasing need to maximize the efficiency of capital spending dollars, the use of extended reach wells to explore and/or develop previously unreachable acreage from existing platforms has become a more attractive and feasible option. These types of wells can eliminate the need for platforms or difficult subsea completions. Besides challenging drilling operations problems, increased loads must be examined and compared to original platform design requirements so modifications can be made to the existing structure, if required. These increased loads can come from longer casing strings, larger drilling rigs needed to handle greater depths, and increased drag from high wellbore inclinations.

INTRODUCTION

During the summer of 1988, Union Oil Company of California dba UNOCAL, drilled two high angle, extended reach exploratory/development wells from its Platform Gina on OCS P-0202 block to the Giant Beaver structure on UNOCAL's adjacent OCS P-0203 block (FIGURE 1). The two wells, P-0203 #H-13 and #H-14 (which exceeded angles of 87° and horizontal displacement of 10,800'), posed potential drilling and structural problems for Platform Gina. Potential drilling problems included long high angle hold sections, a 27° turn and 9° build from the 13-3/8" casing shoe in P-0203 #H-14, and sticking from clay rich formations. Potential structural problems included large loads resulting from long casing strings, a larger than originally designed rig size, and drill strings being pulled through clay rich formations.

References and illustrations at end of paper

The initial development plan for the Hueneme Field in P-0202 called for Platform Gina to handle 6000'MD, low angle oil producers and water injectors. Structural design of the platform in 1980 was centered around this development plan. New high angle hole rig loads were estimated, and the drill deck strengthened to accomodate these higher rig reactions. Actual loads were measured. Deck stresses were computed, and compared to design stresses with and without reinforcing. Structural support requirements were analyzed for additional wells in a proposed cantilevered wellroom.

Drilling these wells from Platform Gina also helped UNOCAL avoid potential political confrontations which might have delayed permitting. Potential political problems included drilling near a marine sanctuary and heavily traveled shipping lane. In the past, operators in Offshore California have been denied drilling permits by these and other sensitive California political issues.

DRILLING OPERATIONS PLANNING

In order to reach the bottomhole target of 10,834' displacement at 6300'VD for P-0203 #H-13, UNOCAL felt it needed to implement a 3.5°/100 ft build rate and hold angle at 67°. This build rate was chosen from operational experience in offshore California in order not to create doglegs which would result in excessive drag. The casing design centered around field and extended reach well experience to minimize the time that water sensitive formations and build sections of the hole would be uncased.

A seawater Saponite/Cypan mud system with the Saponite prehydrated in fresh water was to be used to provide good hole cleaning and lubricity. With this system, it was desired that chloride levels be kept below 14,000 ppm and calcium below 300 ppm in order to keep material cost down and retain good fluid loss properties. It was felt that a well maintained solids control system of a shaker, desander, desilter would be sufficient to keep total solids below 7%. UNOCAL has successfully used this type of mud system several times in the area.

Although casing strings would be laying at high inclinations, it was originally felt standard bow centralizers would give sufficient standoff for good cementing results. It was planned to keep the fluid loss of cement slurries below 100 cc/30 min and free water between a trace and zero in high angle sections of the hole.

Since long, high angle sections of hole were planned for P-0203 #H-13, the use of steerable mud motor was examined to minimize trips for bottom hole assembly (BHA) changes. UNOCAL had tried steerable systems in the past in the Santa Barbara Channel with poor results. This was due to the difficulty of holding angle in very unconsolidated formations. Therefore, it was decided to use conventional bottom hole assemblies for directional work.

In an effort to help ensure drilling strings had sufficient weight on bit and casing strings would fall to bottom, an onsite computer program was proposed. This torque and drag program, written by Maurer Engineering and modified by UNOCAL Science and Technology Division, was planned for use by the drilling foreman and drilling engineer. The program output provided up and down weights for particular strings every 100 ft. based on hole conditions.

Logging operations included measurement while drilling (MWD) information in all sections of the hole and conventional open hole logs in prospective producing intervals. Due to the high angle, drill pipe conveyed logs would need to be implemented.

Although UNOCAL had successfully used a top drive drilling rig in its operations further north on Platform Irene (OCS P-0441) to drill extended reach wells, it was felt a conventional rotary table rig could handle exploratory drilling in the Giant Beaver structure area. UNOCAL could not justify the incremental cost to modify a rotary table rig to handle a top drive system for a one or two well program. Operations would be examined at the end of the drilling program to determine if a top drive system would be useful and if the cost of such a system could be spread out over a development program.

ESTIMATED RIG LOADS AND DECK CAPACITIES

Rig reactions used in the original design of the platform to size the primary north and south deck trusses supporting the drilling rig were 324^k (1 kip = 1,000 lbs) and 418^k respectively. Pad loads were assumed symmetrical, 6'-9" either side of the well centerline. These were maximum reactions anticipated for the shallow, low angle holes planned.

Revised rig reactions anticipated for drilling deep, directional wells are summarized in TABLE 1. They are evaluated for two slot locations, slot #10 and slot #13. The original plan was to drill one well through slot #10 but, in case slot #13 would be drilled in the future, loads for slot #13 were also analyzed. Reactions were expected to reach 758^k for slot #10 and 853^k for slot #13. Note the reactions are not symmetrical. They are caused by the dead load of the rig, plus 650^k hook load and 300^k setback.

Load bearing capacities of deck elements in the primary load paths were analyzed for these revised loads, as well as for the original design loads. These deck elements include the skid beam webs, the drill deck plate girders, the diagonal knee bracing, and the knee brace/leg joints. FIGURE 2 is a sketch of the main bracing system. Stress levels under the original rig reactions were all below basic AISC allowable stress levels (no 1/3 increase was assumed).

Stress levels under rig loads anticipated for deep wells in slots #10 and #13 caused overstress in the skid beam web, the knee braces and the knee brace/leg joints, in the south truss line only. In slot #13, the brace and joint stresses exceeded basic AISC working stress levels by approximately 50% and 93%, respectively. Based on the estimated maximum rig reactions, joint failure would have been likely without reinforcement since safety factors including improved material properties provide about a 90% overload margin before actual failure.

The reinforcement sketched in FIGURE 3 was designed to accomodate these additional loads and maintain stress levels in all elements below basic AISC allowables.

DRILLING OF P-0203 #H-13

P-0203 #H-13 was spudded on June 5, 1988 in slot #10. Problems were experienced immediately when the drill string became stuck at 629'MD (434'BML) due to insufficient hole cleaning. The other wells on Platform Gina had 20" conductor pipe set at 230' BML. In this well, the conductor pipe was planned to be set at 405' BML in order to start building angle directly out of the casing shoe. It was felt as much vertical section of the hole as possible should be used in order to take advantage of drill string weight being unaffected by hole inclination. The drill string was backed off, and the well was respudded in slot #13 two days later.

On the second attempt, the 20" conductor pipe was set at 436'MD (241'BML). The well was still kicked off at 600'MD. With a 2-1/2° kick sub on a mud motor, angle building started behind the proposed directional program. UNOCAL felt the lag was not sufficient enough to warrant a plug back and it was determined to increase angle build to 69° before holding. The 16" casing was set at 1539'MD, 1500'VD at 28.4° without significant problems.

An inclination of 69° was reached at 3169'MD, 2551'VD. A stiff BHA was run to hold angle to the 13-3/8" casing point. The 13-3/8" casing was set at 5926'MD, 3467'VD at 71.8° with cement volumes reflective of a possible redrill from the 16" casing shoe. The casing was reciprocated through almost the entire cement job. However, the casing needed to be landed in the wellhead early as the tail slurry reached the shoe. This was due to a complete loss of down weight. The maximum hook load while reciprocating this string was 311,000 lbs.

UNOCAL found while drilling the 14-3/4" and 12-1/4" hole that BHA performance was different at higher angles (60°- 65°) than the same assembly's performance at lower angles. Consequently, it was difficult to hold angle and get the directional performance that was desired. Numerous BHA changes were made to keep from straying far from the proposed hole inclination.

Up weights resulting from low drag factors while drilling 12-1/4" indicated that total depth could be reached with this size of hole. Structurally, the geologic target came in higher than anticipated and total depth was reduced to 12,800'MD, 6158'VD. Total closure was 10,314' with a maximum hole angle of 73.3°. Maximum dogleg severity was 4.3°/100 ft.

After running open hole logs, management decided to complete the well further up the hole. A cement plug was laid from 11,938' to 11,438'. The 9-5/8" casing was cemented at 11,425'MD, 5560'VD at 61.2°. Reciprocation of the casing string was achieved through the entire job. Cement volumes took into account a possible redrill from the 13-3/8" casing shoe. A cement bond log was run showing good bond over the entire productive interval.

The actual wellbore configuration is shown in FIGURE 4. The actual and proposed directional profile for P-0203 #H-13 is shown in FIGURE 5.

DECK LOADS DURING DRILLING

As discussed, P-0203 #H-13 was respudded in slot #13. On this well, maximum hook load was measured during cementing and reciprocating of the 9-5/8" casing string at 615^{k}, with 284^{k} setback. FIGURE 6 shows actual up weight hook loads with depth. This translates into the rig reactions shown in TABLE 2. Comparison of expected and measured maxima show the measured maximum reaction within 1% of the predicted value. The reinforcement was evidently adequate to support the design load. Without reinforcing, the actual stress would have been 1.92 times the basic allowable stress, and joint failure would have very likely occurred. Joint failure would cause overturning of the rig. This points up the need for vigilance on behalf of those responsible for the structural integrity of offshore facilities when deep, long-reach wells are planned.

FIGURE 7 shows a generic real time record of hook load while running and reciprocating 9-5/8" casing during cementing. The large number of high load cycles, with a frequency of around 2 minutes, should be noted. Rough calculations show only about 8000 cycles of significant hook load can be tolerated before cracking develops in the knee brace/leg joint welds. Jarring effects are excluded, and will reduce this limit. A one well operation of this type induces about 250 load cycles. Adequate joint fatigue resistance as well as strength are important in the primary deck components.

Component capacities were analyzed using working stress design (WSD) and load and resistance factored design (LRFD) procedures. Because drilling loads can be estimated more accurately than environmental loads, capacities using LRFD were about 15% higher than WSD. An inspection of a typical real time hook load record, shows hook loads are not transient in the same manner as extreme environmental events, therefore, no increases in the basic allowable stresses were used, particularly given the cyclic nature of the load.

REDRILL PLANNING

After drill stem testing several intervals in P-0203 #H-13, UNOCAL management made the decision to redrill the well as P-0203 #H-14. Provisions had been made in designing cementing volumes in the original hole to accommodate a redrill. Several redrill directional plans had been generated weeks earlier. After reviewing drilling operations of P-0203 #H-13, it was decided to attempt the more difficult of the redrill programs. This called for redrilling from the 13-3/8" casing shoe, building angle 9° to 81° and turning 27° to the south, reaching the top of the first producing interval and dropping angle to 71° and holding that angle to total depth (FIGURE 8).

The original redrill casing program was designed to set 9-5/8" casing at the bottom of the first producing interval (at 71°) and a 7" liner across the bottom interval.

Because of the difficulty of drilling operations, it was originally agreed only MWD logs would be used for open hole log evaluation. UNOCAL geologists felt MWD logs would provide sufficient information. Since UNOCAL had never experienced open hole at such large inclinations for extended periods of time in the Santa Barbara Channel, the amount of time the wellbore remained uncased would be kept to a minimum.

DRILLING OF P-0203 #H-14

After the 9-5/8" casing had been cut and pulled from 6100' and a kickoff plug laid, two different kick subs were used with a mud motor to turn and build angle out of the 13-3/8" casing shoe. Finally, a 2-1/2° kicksub had built the hole angle to 83° and turned the well 34° to the south. Additionally, more weight than expected was needed to overcome sliding friction to enable the mud motor to drill.

As experienced in the original hole, BHA performance was difficult to predict and control. Hole angle in 12-1/4" hole had drifted up to 87.7° at 10,133'MD, 4042'VD and at the time, a BHA could not be found to drop angle. Concurrently, the hole condition was deteriorating at the build and turn section of the redrill due to time exposure.

It was determined to run a semi-radical dropping assembly to change the drilling trend then set 9-5/8" casing at the top of the first producing interval. The assembly (milled tooth bit, 11-3/4" undergauge stabilizer, 2' float sub, 10' lead collar, full gauge stabilizer, MWD tool, and full gauge stabilizer) was able to drop angle to 83° at 10,255' MD, 4055'VD. A mild dropping assembly was run for 283' to the 9-5/8" casing point.

UNOCAL feels the tooth profile of the milled tooth bit was a key reason the assembly took effect as opposed to the insert bit assemblies that are normally run in this interval. The outer row of insert bit teeth sit away from the edge of the hole while the outer row of mill tooth bits have teeth next to the edge. Insert bit assemblies did not have enough down force at the bit for the teeth to bite on the low side of the hole and break the drilling trend.

Since hole angles were higher than originally planned, it was determined to run the 9-5/8" casing string as a liner. This gave several advantages:

1. Drill collars and heavy weight drill pipe could be run in the upper section of the hole to help supply down weight to get the string to bottom.
2. Casing wear in the upper section of the hole in 9-5/8" casing would be eliminated. A tie-back recepticle was run if tie-back to surface was needed at a later date.
3. The well cost was reduced by the elimination of 5250' of 9-5/8" casing.

The shoe of the 9-5/8" liner was set at 10,583'MD, 4105'VD at 78.4°. It was discovered after cementing operations, the drill pipe dart never left the cementing head resulting in a poor cement job. Since all production would be below this shoe, cement squeezing of the liner lap and the casing shoe would ensure isolation of formation fluids. From a well control standpoint, the vertical depth of the 13-3/8" shoe was sufficient to handle any possible well control pressures. Squeeze cementing was performed without operational problems.

An 8-1/2" drilling assembly was used to maintain angle and drill to 13,439'MD, 5088'VD total depth. The final inclination was 67.2° with a total closure of 10,817' from surface location. The actual and proposed well profile is shown in FIGURE 9. A BHA was found that held angle well in approximately 67° hole. It consisted of an insert bit, a full gauge stabilizer, a 5.6' lead collar, a full gauge stabilizer, a 14' lead collar, a full gauge stabilizer, an MWD tool and a full gauge stabilizer.

A last minute decision was made by UNOCAL to run drill pipe conveyed open hole logs. No pipe sticking problems were encountered. However, due to the high angle, the density/neutron readings were affected by less than full pad contact with the side of the hole at intervals. The decision was then made to complete and test the well.

COMPLETION OF P-0203 #H-14

In an effort to maximize inner diameters and ensure sand control in the lowest producing interval, UNOCAL decided to gravel pack a prepack liner in place. Running a prepack liner would guarantee some type of formation control, while gravel packing the prepack would help reduce the tendency of the prepack liner acting as a filter and plugging off.

In order to accomplish this, the 7" liner would need to be set off of bottom. To keep cement from falling down hole during cementing, a 300' polymer/salt pill[1] was set below the 7" shoe depth. On initial attempt, the 7" liner with bow centralizers failed to get to the bottom of the hole. It was determined by the torque and drag computer model that this was due to erroneous drag forces being applied to the centralizers. Although the 7" liner never reached open hole, many of the bow centralizers were destroyed. To ensure positive standoff from the side of the hole, solid cast aluminum and welded blade centralizers were run.

The cement slurry contained zero free water and had 66 cc/30 min fluid loss. UNOCAL was able to reciprocate the liner string through the entire cement job. The 7" shoe was set at 12,898'MD, 4882'VD at 68.2° while the hanger was set at 9947'MD, 4037'VD at 87.5°. A cement bond log was not run because it was believed the hole angle would effect readings. However, firm cement was cleaned out 200 ft above the liner top and a water shutoff test run at a later date during a workover operation resulted in a dry test indicating excellent cementing results.

Transport of the gravel pack sand and dehydration of the slurry proved to be the biggest problems during the final completion of P-0203 #H-14. After underreaming the hole below the 7" casing shoe to 11", a 5-1/2" x 3-1/2" prepack liner was run. HEC polymer mixed at 540 cp viscosity was used to transport 12-20 gravel at a 1-1/2 lb/bbl concentration at 3 BPM. High pump pressures limited the pumping rate and it was found that the gravel fell out of suspension in the high angle sections of the hole. In the future, a light weight proppant and a different carrier fluid may be tried to achieve lower pump pressures and higher pumping rates.

The configuration of the prepack string greatly contributed to failure of the gravel packing phase of the operation. Two joints of slotted tubing were run above the prepack liner in order to establish a gravel reservoir in case pack sloughing occured (common in offshore California operations). However, in this situation, the slotted pipe proved to be detrimental and caused dehydration of the slurry resulting in sand out with only 43% of the theoretical volume in place. In future operations, the slotted pipe will be eliminated.

Testing of this lower interval at a later date gave no indication of the prepack acting as a filter and plugging off. The initial decision to run a prepack liner to ensure some type of sand control proved to be wise, but only long term production will indicate if the gravel packing was necessary to prevent plugging.

The actual wellbore configuration of P-0203 #H-14 is shown in FIGURE 10. The actual up weight hook loads for this well are graphed against measured depth in FIGURE 11.

SLOT EXPANSION

In order to develop additional potential reserves in the proximity of the platform, more well slots than the fifteen that were designed into the platform will be required. The feasibility and cost of adding 5 to 10 more slots was investigated. Preliminary results show such additions are feasible and cost effective, compared with attempting to install a separate, satellite platform. The complexity and therefore cost of the additions will be reduced in part because of the seismic criteria used in the platform's original design.

The decks, jacket and pilings were designed to respond elastically to the ductility level seismic event. Most platforms' components are designed to yield or buckle under such loading, but still maintain the platforms' overall stability. In the case of Platform Gina, the money spent on extra engineering associated with the nonlinear analyses necessary to track component failures was considered less beneficial than the addition of extra steel to accomodate ductility level seismic loads through linear elastic response. This simplified the original design, and also allows for the expansion of the facility without significant strengthening of the original structure.

REASONS FOR SUCCESS

1. Personnel - UNOCAL insisted on top field service personnel to run tools and perform contract services. This included tool pusher, drillers, mud men, directional men, cementers, loggers, tester, etc.
2. Planning - Input for planning came from the drilling foreman and contract personnel knowledgable with the area and with high angle drilling operations.
3. Decision Making - The drilling foremen, drilling engineer and district drilling superintendent made most of the daily decisions on drilling operations. Management decisions mainly involved major objectives and geological targets.
4. Cementing - Low fluid loss cement slurries, the reciprocation of casing during cementing operations and the use of positive standoff centralizers maximized the possibility of good cement jobs. A liquid additive system also allowed for fine tuning of slurries based on labratory tests and minimized problems experienced with bulk lines plugging during cement. With silos filled with neat cement, if one line plugged, another could be used until the former line was unplugged.
5. Drilling Fluids - The fresh/seawater Saponite/Cypan system provided good hole cleaning and lubricity qualities while maintaining a low fluid loss.
6. Drilling Rig - Rig components in good condition with quality personnel kept problems from occurring which would have shut down or hampered operations.
7. Torque and Drag Modeling - The onsite program allowed the drilling foreman to quickly estimate up and down weights of prospective drill strings and evaluate hole conditions. Unnecessary trips due to inadequate weight were avoided. Also, it was quickly determined the initial attempt to run 7" liner failed because of centralizer problems and not inadequate down weight.
8. Bit Selection - Research of bit records and choosing of proven bits allowed for more on-bottom rotating time.

AREAS FOR IMPROVEMENT

Directional Drilling - Lack of experience with BHA performance over 65° caused numerous trips for correction runs. A computer model which predicts relative BHA performance could increase on-bottom rotating time. Additionally, although UNOCAL has not had much success in the Santa Barbara Channel with steerable mud motors, they may warrant further investigation.

Gravel Packing - Elimination of slotted pipe above the prepack liner, a light weight proppant and/or different carrier fluid would greatly improve results in high angle gravel packing operations.

CONCLUSIONS

1. High angle, extended reach wells can be drilled from existing platforms if proper planning is implemented to maximize drilling operations efficiency and ensure proper deck strength for increased loading. This can eliminate secondary platforms and expensive, hard-to-service subsea completions.

2. Intelligent, well trained field personnel in all areas are essential for success on such difficult wells since onsite evaluation is essential to project success.

3. Management support in daily field decision making is necessary. Decisions need to be made by the personnel dealing with high angle drilling problems on a daily basis. The confidence of UNOCAL's management and organizational style was essential in completing this project.

4. Cement slurries with trace to zero free water and less than 100cc/30 min. fluid loss, along with casing strings run with positive standoff centralizers and reciprocation of casing during cementing operations resulted in good cement jobs in high angle holes.

5. Bottom hole assembly performance over 65° is much different than the same assembly's performance in hole inclination under 65°.

6. Onsite computer programs can make easy, quick predictions of whether tubular strings have sufficient weight and will fall downhole.

7. A fresh/seawater Saponite/Cypan mud system can supply good hole cleaning and lubricity properties, while maintaining a low fluid loss.

8. From a structural standpoint, the following lessons can be drawn:
   a) Be aware of deep, high angle drilling programs on platforms designed to support the drilling of shallow, straight wells.

b) More conservative criteria used in platforms' original design can potentially reduce remedial costs when expansions are considered, and/or platform service lives are extended.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the large contribution of the UNOCAL drilling foremen involved with the project, Glen P. Anthony, Glen T. Olivera, and Evan K. Harness. Also vital to the success of the project were the personnel of the service companies involved. A special acknowledgement needs to go to UNOCAL's Western Region Drilling manager Jim R. Callender and Southern California District Drilling Superintendent Robert M. Hinkel whose contribution was essential to the success of the project. We thank the management of UNOCAL for the permission to publish this paper.

REFERENCES

1 R.H. Relley, J.W. Black, T.O. Stagg, D.A. Walters, and G.R. Atol: "Improved Liner Cementing in High-Angle/Horizontal Wells," World Oil (July 1988) 69-74.

TABLE 1 ESTIMATED MAXIMUM RIG REACTIONS FOR P-0203 #H-13

RIG REACTIONS, KIPS

SLOT #	R^1	R^2	R^3	R^4
10	595	758	198	253
13	670	853	124	158

Hook Load = 650^k
Setback = 300^k

*Refer to FIGURE 3 for locations.

TABLE 2 ACTUAL MAXIMUM RIG REACTIONS FOR P-0203 #H-13

RIG REACTIONS, KIPS

SLOT #	R^1	R^2	R^3	R^4
13	648	845	114	150

Hook Load = 615^k
Setback = 284^k

*Refer to FIGURE 3 for locations.

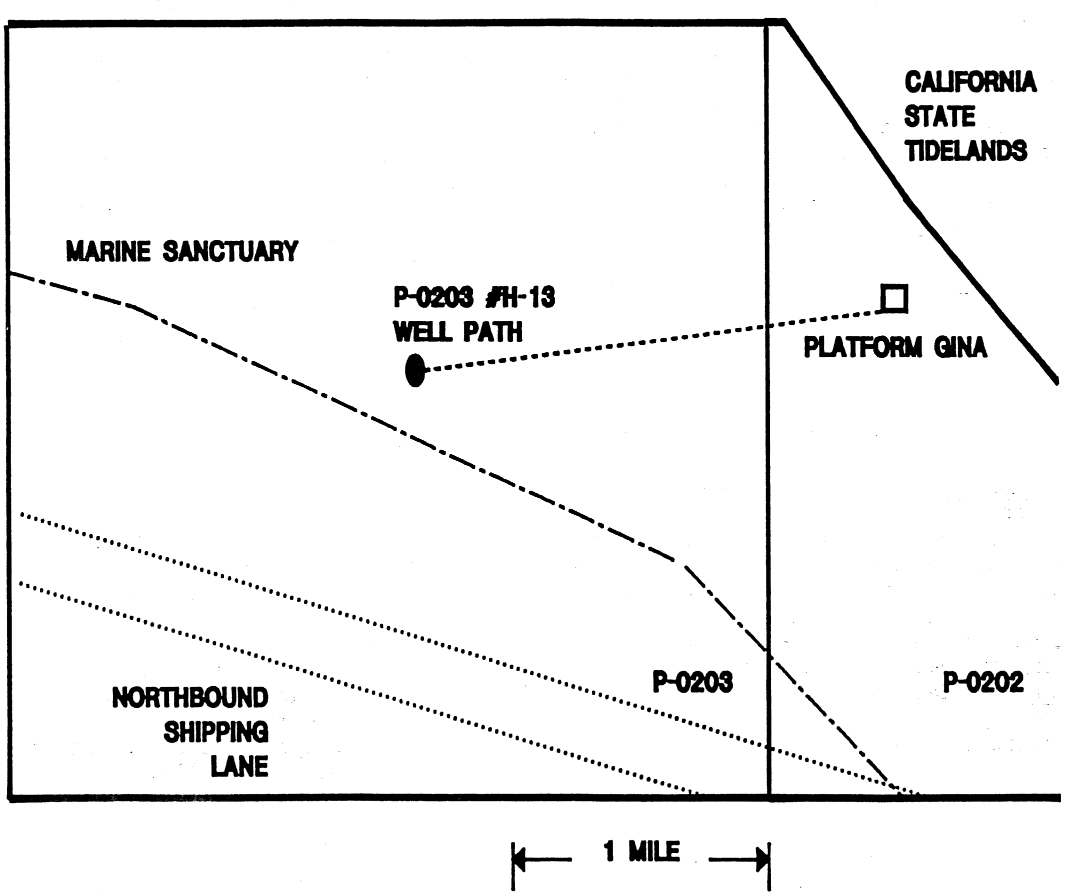


Fig. 1—P-0202 and P-0203 lease blocks.

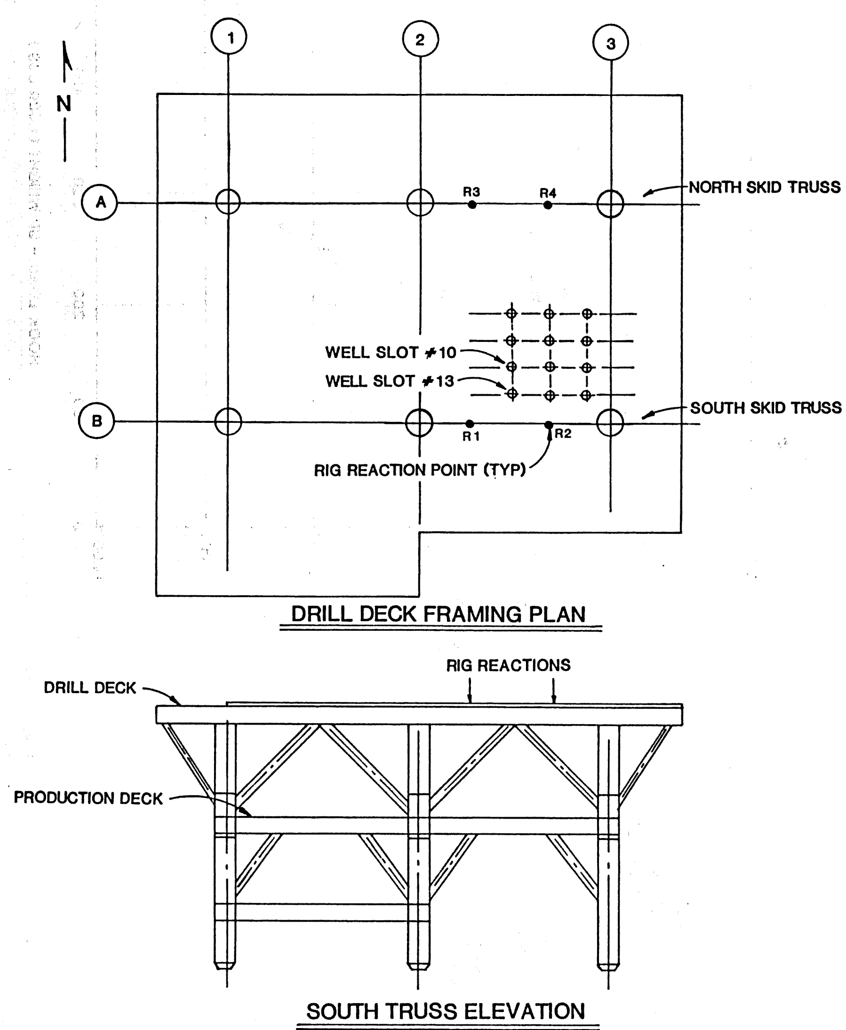
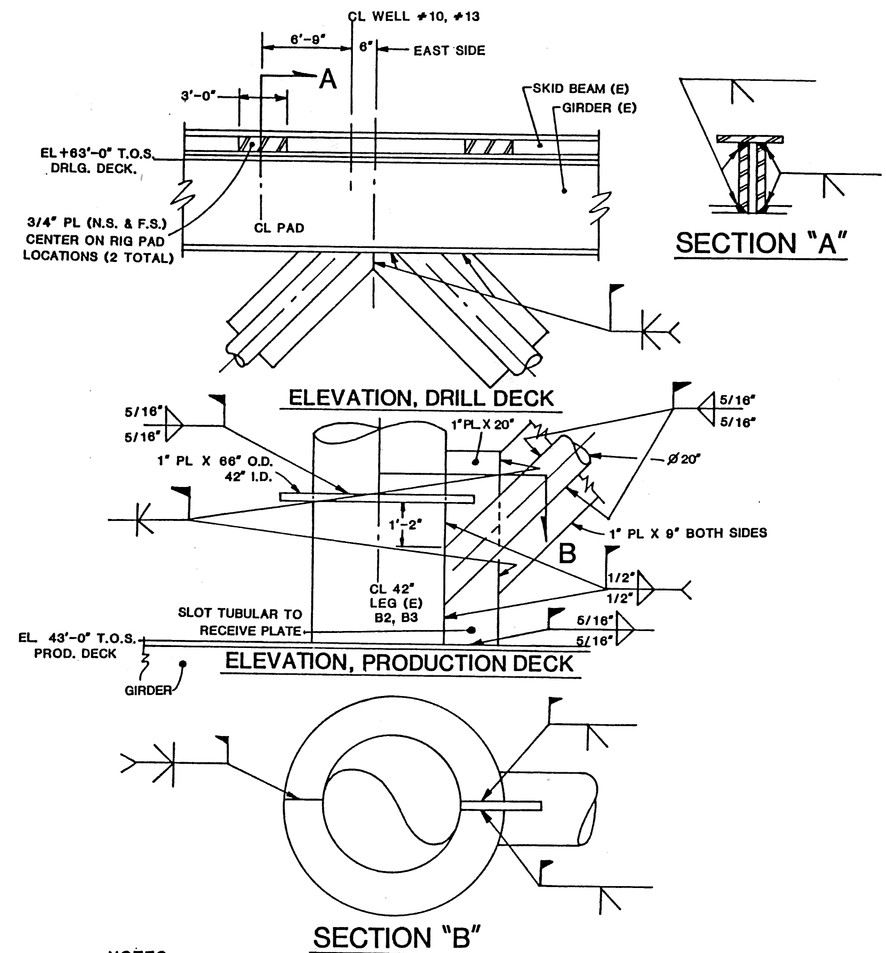


Fig. 2—Platform Gina's framing and slot layout.



NOTES:

- ASTM A-36 PLATE
- WELDING PER AWS D1.1 W / DRY E7018 ROD
- (E) EXISTING

Fig. 3—P-0203 No. H-13 reinforcing, Platform Gina—Truss B, east side.

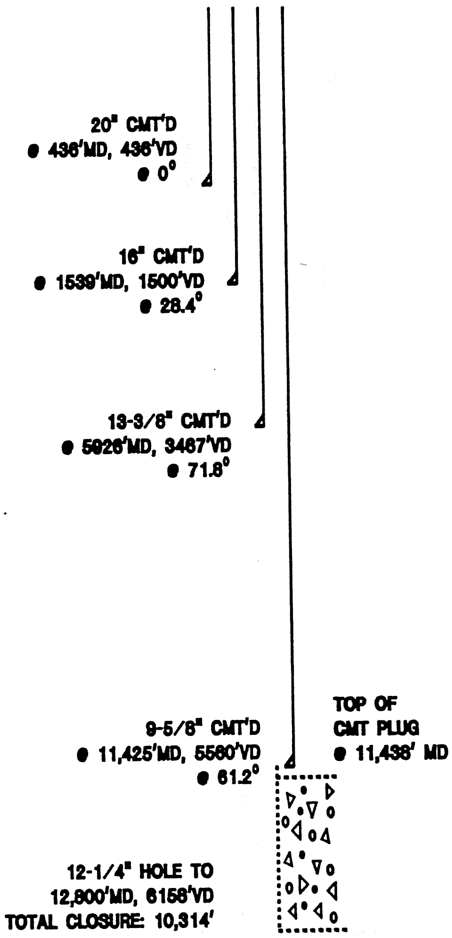


Fig. 4—Wellbore configuration P-0203 No. H-13.

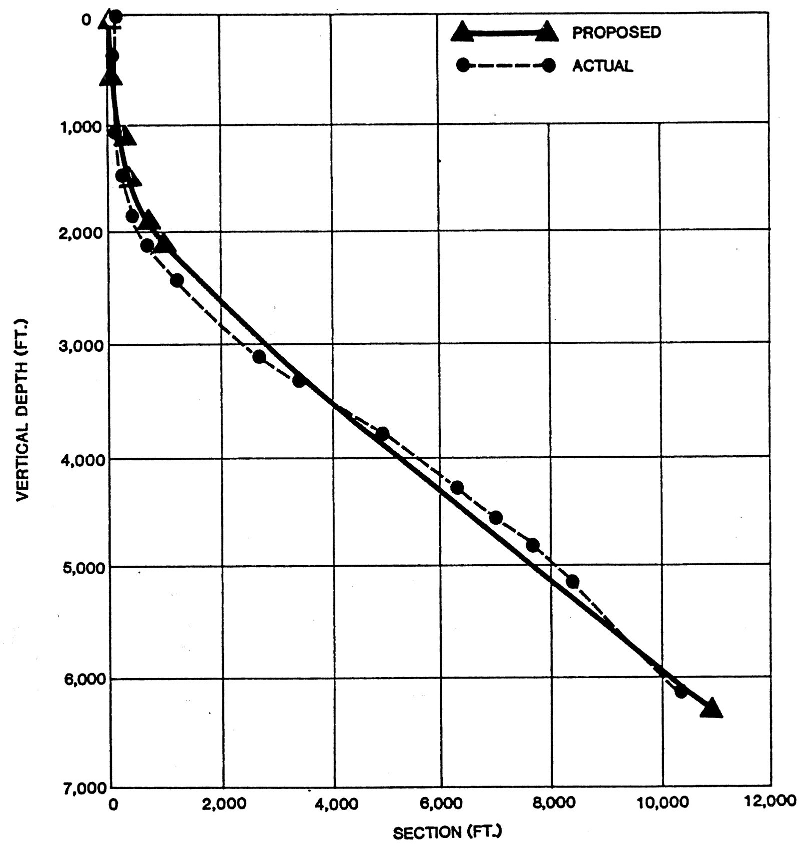


Fig. 5—Actual and proposed directional profile P-0203 No. H-13.

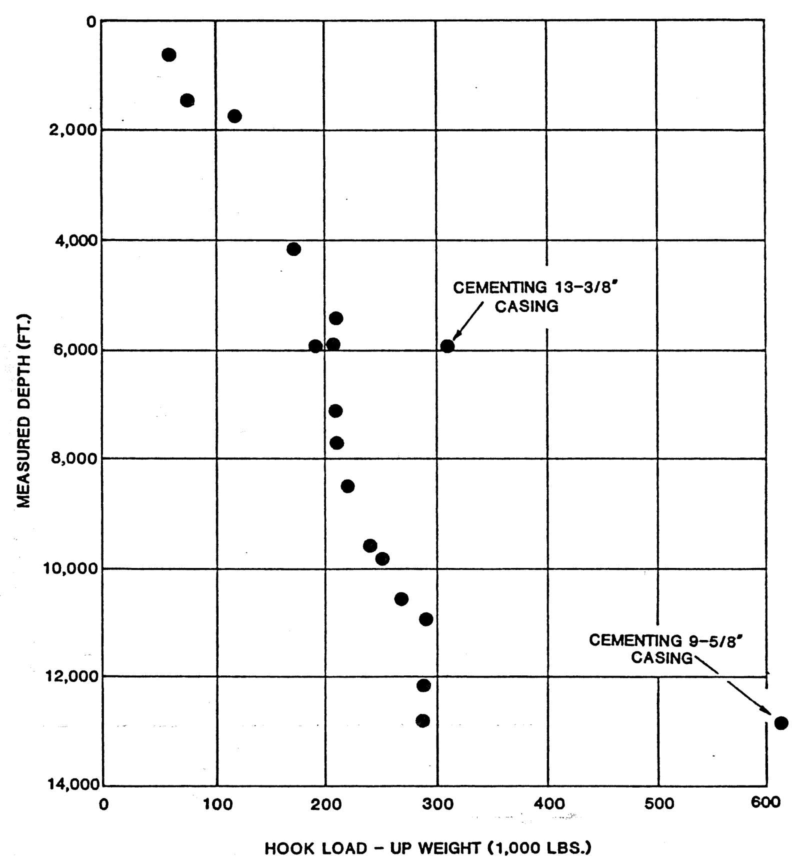


Fig. 6—Maximum hook loads while drilling and completing P-0203 No. H-13.

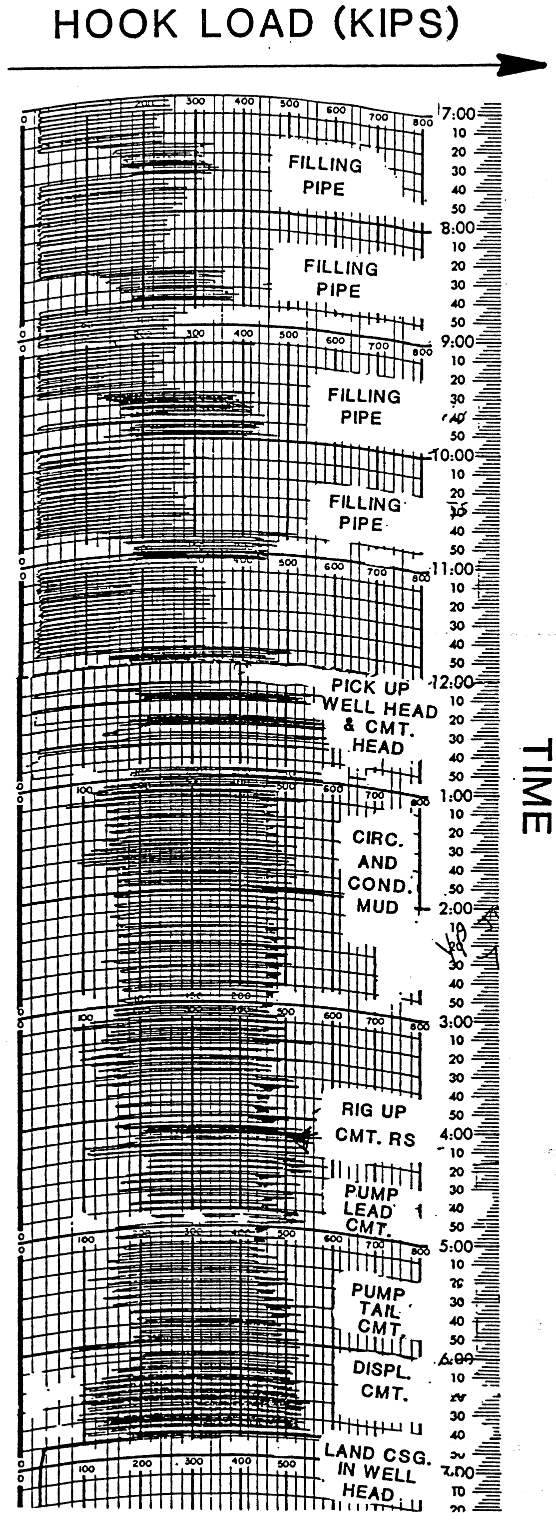


Fig. 7—Generic real time record of running and cementing 9⅝-in. casing.

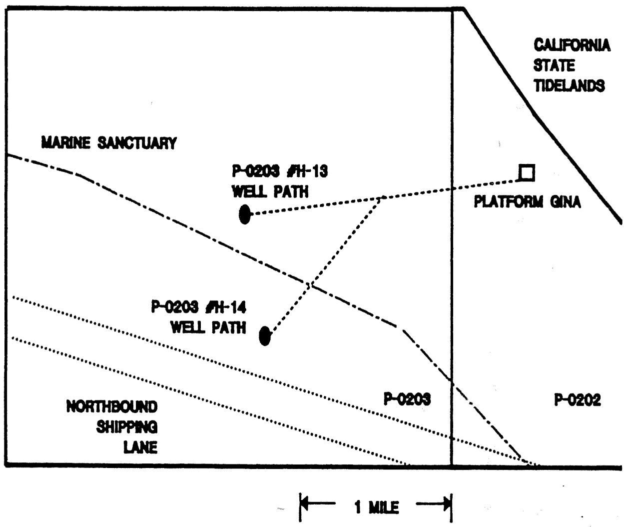


Fig. 8—Redrill plan for P-0203 No. H-14.

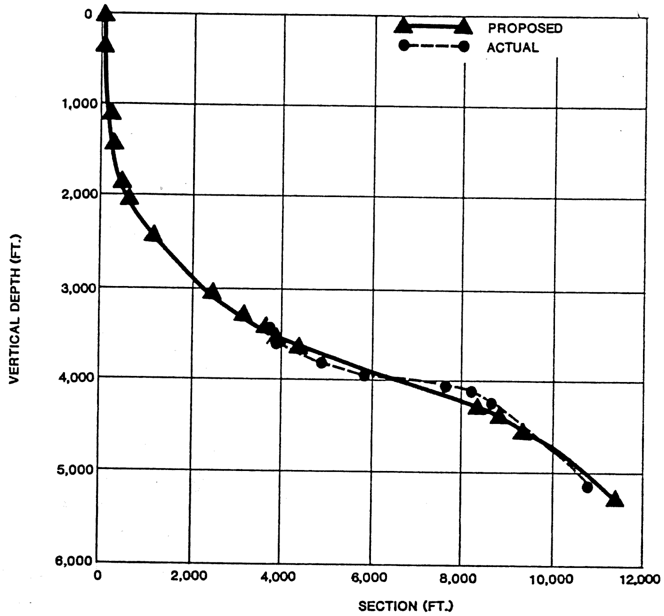


Fig. 9—Actual and proposed directional profile P-0203 No. H-14.

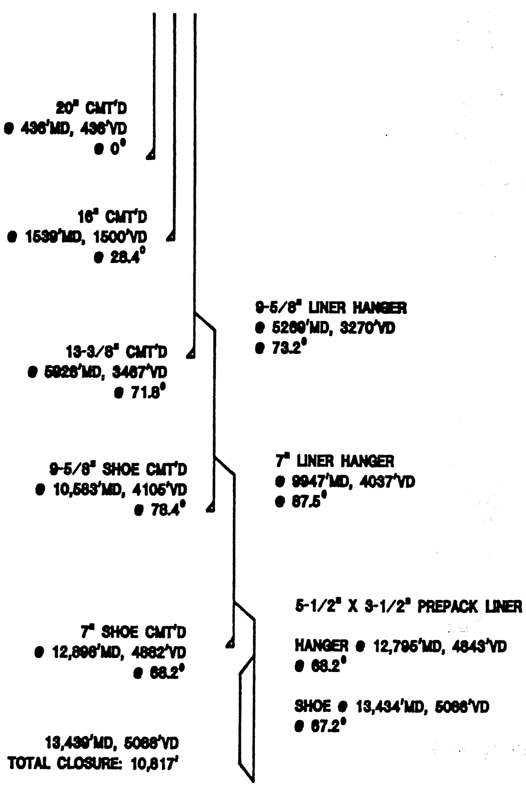


Fig. 10—Wellbore configuration P-0203 No. H-14.

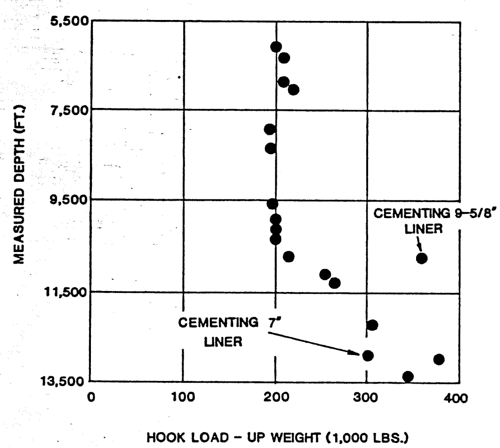
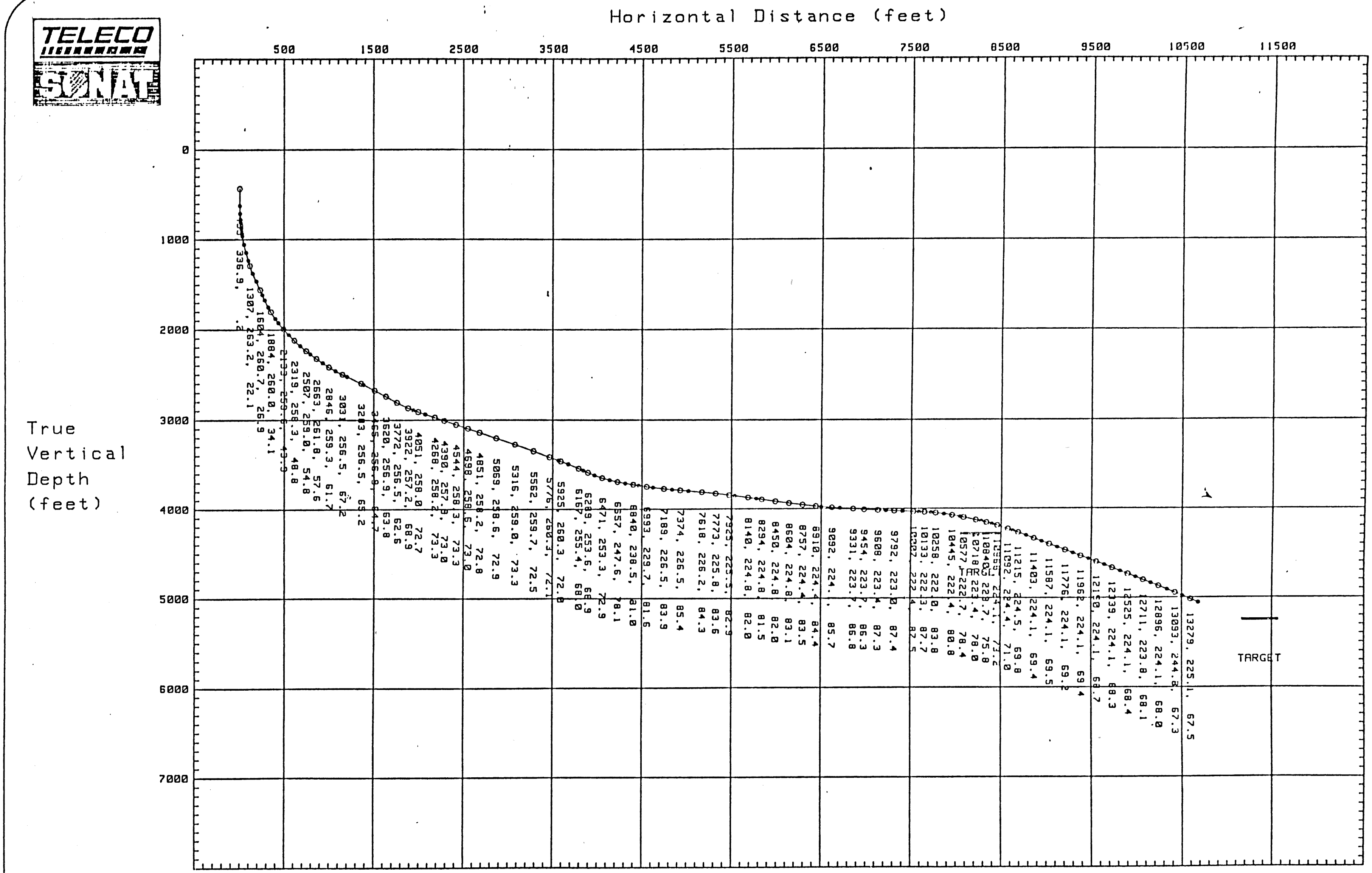


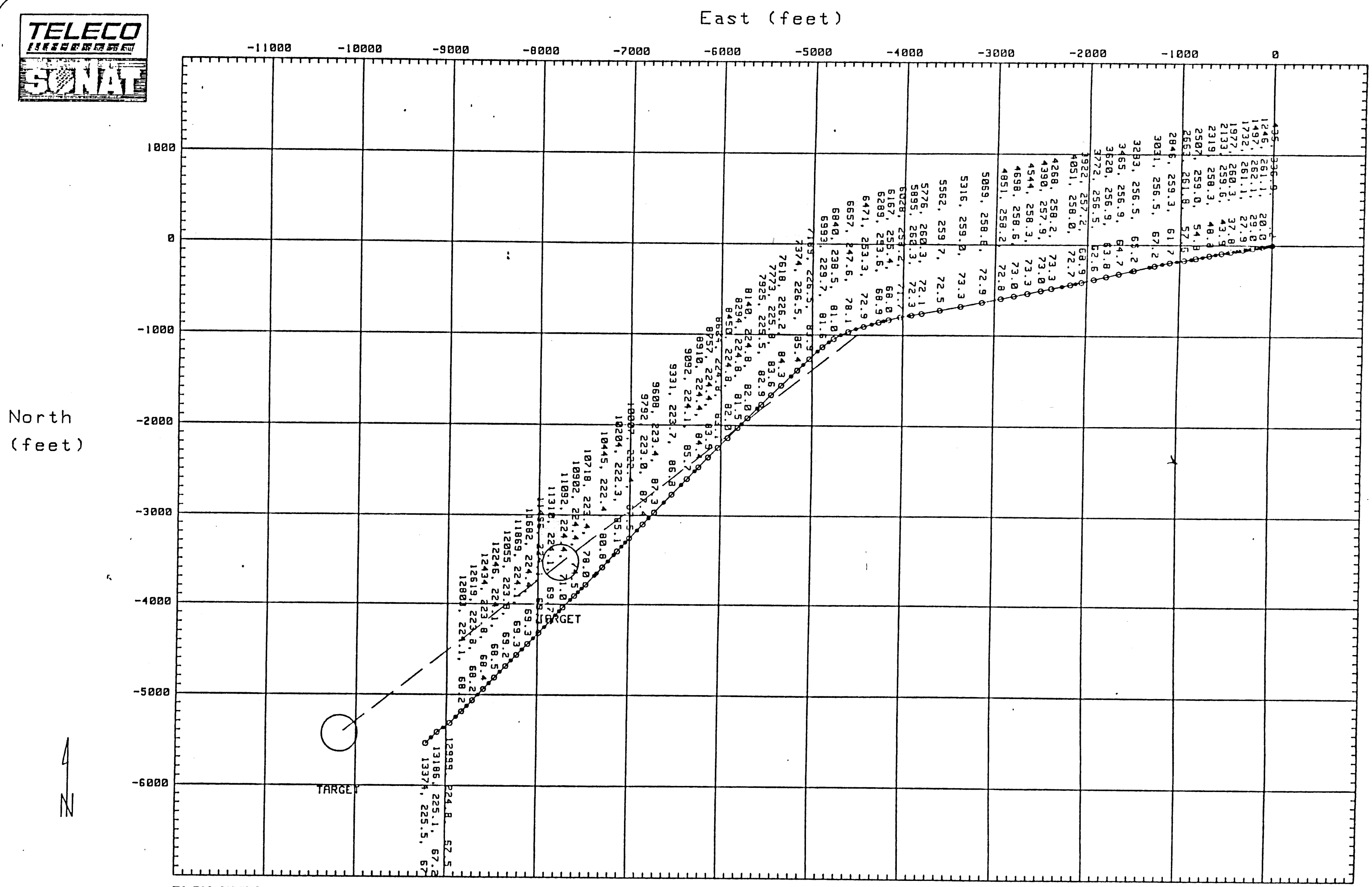
Fig. 11—Maximum hook loads while drilling and completing P-0203 No. H-14.



VERTICAL SECTION
Company: UNOCAL
Well: H-14

Labeled Surveys: M.Depth Azimuth Inclination
V.S. Calc. Method: Incremental
Date: 13 Sep 1988

Scale: 1in=1000(feet)



PLAN VIEW

Company: UNOCAL

Well: OCS-P-203 H-14

Labeled Surveys: M.Depth Azimuth Inclination

Date: 13 Sep 1988

Scale: 1in=1000(feet)