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IMPACT TEST ON DERRICK FLOORS OF DRILLING PLATFORMS

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This revision of PTS **34.19.60.30** - Impact Test On Derrick Floors of Drilling Platforms (**February 2010, Revision 1**) has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic font*.

The previous version of this PTS 20051 (**August 1978**) will be removed from PTS binder / e-repository from herein onwards.

Document Approval

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CONTENTS

PREFACE.....	1
1 INTRODUCTION.....	4
2 OBJECTIVES OF INVESTIGATION	4
3 PREVIOUS WORK ON IMPACT ANALYSIS	4
3.1 Contractor Calculations	5
4 IMPACT TESTS.....	7
4.1 Cormorant 'A' Drilling Floor	7
4.2 Brent 'A' Drilling Floor (Deutag Platforms)	7
4.3 Brent 'C' Drilling Floor	8
5 CONCLUSIONS AND RECOMMENDATIONS FOR MODIFICATION.....	8
REFERENCES	10
FIGURES.....	11
<i>APPENDIX A - THEORETICAL ANALYSIS OF IMPACT ON STEEL PLATES USING EMPRICAL FORMULAE</i>	<i>30</i>
<i>APPENDIX B – PROPERTIES OF DRILLING FLOOR</i>	<i>34</i>
<i>APPENDIX C – EXAMPLE OF APPLICATION OF IMPACT RESISTANT PANELS.....</i>	<i>36</i>

LIST OF FIGURES

FIGURE 1: SETUP FOR IMPACT TESTS.....	11
FIGURE 2: CORMORANT 'A' TEST DECK	12
FIGURE 3: CORMORANT 'A' DRILLING FLOOR BEFORE AND AFTER TEST	13
FIGURE 4: STRAINS IN WOODEN LAYER OF CORMORANT 'A' DRILLING FLOOR.....	14
FIGURE 5: STRAINS IN WOODEN LAYER OF CORMORANT 'A' DRILLING FLOOR.....	15
FIGURE 6: ACCELERATION OF SKID DURING IMPACT ON CORMORANT 'A' DRILLING FLOOR.....	16
FIGURE 7: FORCE OF DRILL COLLAR ON CORMORANT 'A' DRILLING FLOOR AFTER DROPPING (DROP HEIGHT 2.92 M)	17
FIGURE 8: DEFORMATION IN 6-mm STEEL OF CORMORANT 'A' DRILLING FLOOR.....	18
FIGURE 9: BRENT 'A' DRILLING FLOOR	19
FIGURE 10: STRAIN-GAUGE LOCATIONS ON BRENT 'A' (DEUTAG) DRILLING FLOOR.....	20
FIGURE 11: BRENT 'A' (DEUTAG) DRILLING FLOOR BEFORE AND AFTER TEST	21
FIGURE 12: STRAINS IN STEEL PLATE OF BRENT 'A' DRILLING FLOOR DURING IMPACT	22
FIGURE 13: STRAINS IN STEEL PLATE OF BRENT 'A' DRILLING FLOOR DURING IMPACT	23
FIGURE 14: BRENT 'C' TEST DRILLING FLOOR	24
FIGURE 15: LOCATION OF STRAIN GAUGES DURING IMPACT ON BRENT 'C' DRILLING FLOOR.....	25
FIGURE 16: BRENT 'C' DRILLING FLOOR BEFORE AND AFTER IMPACT TEST	26
FIGURE 17: PROFILE OF IMPACT DENT IN UPPER STEELPLATE OF BRENT 'C' DRILLING FLOOR	27
FIGURE 18: STRAINS IN LOWER PLATE DURING IMPACT ON BRENT 'C' DRILLING FLOOR.....	28
FIGURE 19: STRAINS IN LOWER PLATE DURING IMPACT ON BRENT 'C' DRILLING FLOOR.....	29

1 INTRODUCTION

An investigation has been carried out to determine the ability of different types of drill floor to sustain the impact of drill collars accidentally dropped from the hoist.

The preliminary study indicated that no satisfactory method is yet available to predict theoretically the permanent damage to a drill floor as a result of such an impact. As a consequence full-scale impact tests were carried out on three types of derrick floors similar to those designed for Brent 'A', Brent 'C' and Cormorant 'A'. The full-scale tests showed that the best derrick-floor construction to resist impact penetration is a sandwich construction made of steel - wood – steel with an overlaid wooden work floor.

KEYWORDS

Impact, derrick floor, drill collars, impact strength, platform.

2 OBJECTIVES OF INVESTIGATION

The objectives of this investigation were:

- a. To review the calculations made to date by contractors to derrick-floor strength.
- b. To test experimentally the strength of the proposed derrick-floor constructions for the Shell Expro platform rigs.
- c. To propose a preferred type of deck for future drilling floors.
- d. To derive, if possible, a general theoretical method to calculate derrick floor strength with particular reference to their ability to resist drill collar impact.

3 PREVIOUS WORK ON IMPACT ANALYSIS

In the United States, local impact effects due to 'hard' missiles have been measured and empirical formulae derived for penetration depth, perforation and scabbing thickness. Some of these formulae have at least a partial theoretical background. 'Hard' missiles are defined as those which suffer only small deformation as a result of impact compared with the depth of penetration of the missile into the target. These formulae are based upon experimental results obtained before 1946 for projectiles and bombs hitting or perforating concrete slabs. The two formulae most commonly used in the USA are the modified National Defence Research Committee (NDRC) formula^{1,2} and the Ballistic Research Laboratory (BRL) formula^{1,2}

NDRC formula

The penetration depth x can be derived from:

$$G(x/d) = KNd^{0.2}D(V/1000)^{1.8}$$

where

$$G(x/d) = \left\{ \left(\frac{x}{2d} \right)^2, \text{ for } x/d \leq 2.0 \right\}$$
$$G(x/d) = \left\{ \left(\frac{x}{d} \right), \text{ for } x/d \geq 2.0 \right\} \quad \dots(1)$$

and

K = concrete penetrability factor
 N = projectile-shape factor
 d = projectile diameter (in)
 D = W/d (i.e. calibre density of projectile)
 W = weight of projectile (lb)
 V = striking velocity of projectile (ft/s)

and

$$K = 180 / (f_c')^{\frac{1}{2}} \dots (2)$$

where

$$f_c' = \text{ultimate comprehensive strength of concrete (lb/in}^2\text{)}$$

Equations (1) and (2) are referred to this report as the modified NDRC formula for penetration.

BRL formula

The Ballistic Research Laboratory formula predicts the perforation by

$$\frac{e}{d} = \frac{427 D d^{0.2}}{(f_c')^{\frac{1}{2}}} \left(\frac{V}{1000} \right)^{1.33} \dots (3)$$

where

$$e = \text{perforation (in)}$$

Both these formulae have limitations because of the restricted range of available test data. In most of the tests the striking missile was an essentially non-deformable projectile of armour-piercing steel, while the target was solid. Study of the results in references 1 and 2 indicates that only the modified NDRC formula adequately predicts the effect of impact by larger-diameter, low velocity missiles on solid material, i.e. the situation when a drill collar is dropped on a drilling floor.

Further research is currently being undertaken by various investigators who are using energy principles to describe impact forces on deformable targets. However, to date no significant results have been published.

3.1 Contractor calculations

For calculating the impact of drill collars on the Cormorant 'A' drill floor, Westburne Engineering, as contractor, has used an approximate formula based upon Roark theories⁴. For the Brent 'A' and Brent 'C' decks no calculations were carried out by the contractors to determine the strength of the drill floors due to impact. The construction of these decks was determined on the basis of earlier deck constructions.

The formulae arising from the 'Roark theories' are based on the criterion that the vertical deformation d_i and the stress s_i produced in a plate by the vertical impact of a body falling from a height R are larger than the deformation d and stress s produced by the weight of the same body applied as a static load in the ratio:

$$\alpha = \frac{d_i}{d} = \frac{s_i}{s} = 1 + \sqrt{1 + 2 \frac{h}{d}} \dots (4)$$

This ratio is called 'the impact factor'

where

- d = vertical deformation due to static loading
- d_i = vertical deformation due to vertical impact
- s = stress due to static loading
- s_i = stress due to vertical impact
- h = drop height

For a supported square flat plate, the maximum stress as a result of a uniform load over a small concentric circular area of radius r_o is :

$$s = \frac{3W}{2\pi^2} \left[(1+\nu) \log \frac{2b}{\pi r_o} + \nu - \beta \right] \dots (5)$$

where $\beta = 0.565$
 $\nu = 0.3$
 b = plate width
 t = plate thickness
 r_o = drill-collar radius
 W = total load applied

The vertical deflection of this plate is :

$$d = \alpha \bullet \frac{Wb^2}{Et^3} \dots (6)$$

where $\alpha = 0.1267$
 E = Young's modulus

According to Roark, equations (4), (5) and (6) can be used to calculate the dynamic stresses due to impact on flat plates. The formulae assume that impact deforms the elastic body similarly to static loading and that the kinetic energy of the falling body equals the potential energy of the plate at maximum deformation. This would imply that the distribution of stress and strain under impact loading is the same as that under static loading.

Although there is a difference in the definition due to static and impact loading, for low velocities it is less marked than for high velocities. In Appendix A, a calculation is given of the impact strength of steel plates using the above-mentioned theory. The results show that no satisfactory comparison with the permanent lateral deflections could be found, i.e. the stresses due to the impact far exceed the yield stress of the material.

The contractor, Westburne Engineering attempted to Cormorant 'A' drilling floor on the basis of the above theories but, since they could not arrive at a satisfactory answer, they were forced to make a design based only on experience. Since no acceptable theoretical approach for calculating the impact resistance could be found, a series of experiments was set up to determine the actual effect of impact of drill collars on drill floors.

4 IMPACT TESTS

To simulate the dropping of a drill collar on to a drill floor, a full-scale test set-up was constructed, as shown in [Figure 1](#). This consisted of a frame holding a guide tube in which a 9 5/8" drill collar (length 9.45 m, mass 3 000 kg) was mounted. Under this frame various types of floors (maximum span 2 m) could be installed for testing. A cable winch was used to raise the drill collar to its dropping position 3 m above the floor, and an automatic uncoupling mechanism was designed to allow the drill collar to fall freely into the test floor.

The impact specifications are based on a full stand (three joints each of 9 m length) of 9 5/8" drill collars falling 1 m on to the drill floor. However, in the test rig the same impact was obtained by dropping one drill collar (9 m long) from a height of 3 m. The higher impact velocity in the test has been shown by Kennedy's to have only a small influence on the penetration depth. Because of the male thread connection at the end of the drill collar the impact diameter was only 0.1445 m. For all test floors, the width was limited to the width of the frame i.e. 2 m.

The drill collar and floor frame were both instrumented with accelerometers to measure the acceleration during impact. The steel plates and wooden layer of the floors were provided with strain gauges to measure both the elastic and plastic strains at the same time.

The impact tests were carried out for two existing floors, viz the Cormorant 'A' type floor and the Brent 'A' type floor (Deutag platform). In view of the results of these tests, KSEPL were asked by Shell Expro to propose and test a suitable deck construction for the Brent 'C' platform.

4.1 CORMORANT 'A' DRILLING FLOOR

The Cormorant 'A' drill floor was designed by TRI OCEAN and built at RDM in Rotterdam. This floor consists of a 6-mm steel plate sandwiched between a supported 300-mm thick timber beam and a 80-mm wooden work floor (see [Figure 2](#)). The, maximum span in this construction was 2 m. For the test, the undersides of the lower timber layers were fitted with three strain gauges.

[Figure 3](#) shows the situation before and after impact and [Figures 4-6](#) the strains in the floor sections and accelerations in drill collar and frame throughout the impact test. The forces on the floor derived from the deceleration measurements on the drill collar are shown in [Figure 7](#). The rebound of the drill collar after the initial impact is clearly shown in this figure. The test demonstrated that this type of floor has a large inherent damping and a large load-carrying capacity. It can be concluded that it meets the EXPRO specifications satisfactorily. Although the timber work-floor layer was penetrated and badly damaged, the steel plate suffered only a small indentation to a maximum depth of 14 mm, as shown in [Figure 8](#). The 300-mm thick timber beam beneath the steel plate suffered only slight cracking at the supports.

4.2 BRENT 'A' DRILLING FLOOR (Deutag Platforms)

The Brent 'A' deck fabricated by Dentag consisted of a 10-mm steel plate overlaid with a 80-mm thick timber work floor (see [Figure 9](#)). The maximum span between supports of this floor was 0.80m. For the test the steel plate was fitted with strain gauges on the underside ([Figure 10](#)). [Figure 11](#) shows photos of the deck before and after the impact of the drill collar. This floor failed completely with the impact of the drill collar and the deformations were so large that part of the energy was absorbed by the test-rig foundation.

The drill-collar acceleration and strains in the plate are shown in [Figures 12](#) and [13](#). This shows that most of kinetic energy was absorbed by the concrete of the test-rig foundation during the first impact, indicating that the damping afforded by the floor, in this case, was very small.

4.3 BRENT 'C' DRILLING FLOOR

Based on the results of the Cormorant 'A' and Brent 'A' tests, the Brent 'C' floor was constructed as a "sandwich" consisting of a 10-mm steel plate - an 80- mm timber layer - a 6-mm steel plate with an 80-mm timber work floor on top of it (see Figure 14). The timber used was 'Oregon Pine', which is a lightweight wood with properties as given in Appendix B. Stiffeners were used at the lower plate to increase the bending capacity of the deck over the longer spans.

The floor was instrumented with strain gauges at the bottom of the 10-mm steel plate (see Figure 15).

Figure 16 shows the floor before and after the impact by the drill collar. Despite the complete penetration of the first wooden layer, it can be concluded that the design of this floor was adequate to withstand the impact of the drill collar. The total floor panel deflected vertically 13 mm. In actual practice, however, the deflection of the whole drilling floor under such an impact will be less owing to the presence of adjacent steel plates in the actual floor.

The 6-mm steel plate showed a maximum local indentation of 22 mm (see Figure 19). At some locations the welds between the 10-mm steel plate and the frame gave way. This indicates that the floor should be fabricated with full penetration welds and thoroughly inspected during construction.

Figures 18 and 19 show the acceleration of the drill collar and the strain in the steel plate during impact. The maximum deceleration was 17 g, which is somewhat lower than the value found in the Cormorant 'A' test. The total kinetic energy damped out very quickly, although the strain measured in the plate directly under the impact of the drill collar was so high that the strain gauge failed.

5 CONCLUSIONS AND RECOMMENDATIONS FOR MODIFICATION

The following conclusions and recommendations for modification of the various floors can be made:

Conclusions

Cormorant 'A' drilling floor

This type of drilling floor withstood the impact of the drill collar successfully and fulfils Shell Expro's criteria.

Brent 'A' drilling floor

This test set-up, although not an exact simulation of actual conditions, was a valid representation of the edge panels of the drill floor. In practice, the interior panels will derive some support from adjacent panels but further study will be necessary before this can be quantified. It is therefore recommended that this floor be modified to a sandwich construction as follows:

bottom to top - 10-mm steel plate
 80-mm wooden layer (Oregon pine)
 6-mm steel plate
 80-mm work floor (Oregon pine)

Brent 'C' drilling floor

This deck was designed on the basis of the previous test results to withstand the drill-collar impact. It can be improved further by completely enclosing the timber layer between two steel sections (I-section DIN10 - Figure 14). To prevent excessive bending of the floor owing to impact, the maximum span

between the sections should not exceed 2 m.

Recommendations

From the test it can be concluded that a preferred solution for the drill floor is to use a sandwich construction of wood-steel-wood-steel with an overlaid wooden work floor similar to that given in the Brent 'C' proposal. The steel plates should be 6-8 mm thick and the timber layers approx. 80 mm thick.

Since many existing derrick floors are constructed of steel plate, further theoretical work is planned to arrive at a better quantification of the effect of drill-collar impact on such installations. We hope that specifications can be developed for future derrick-floor installations.

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