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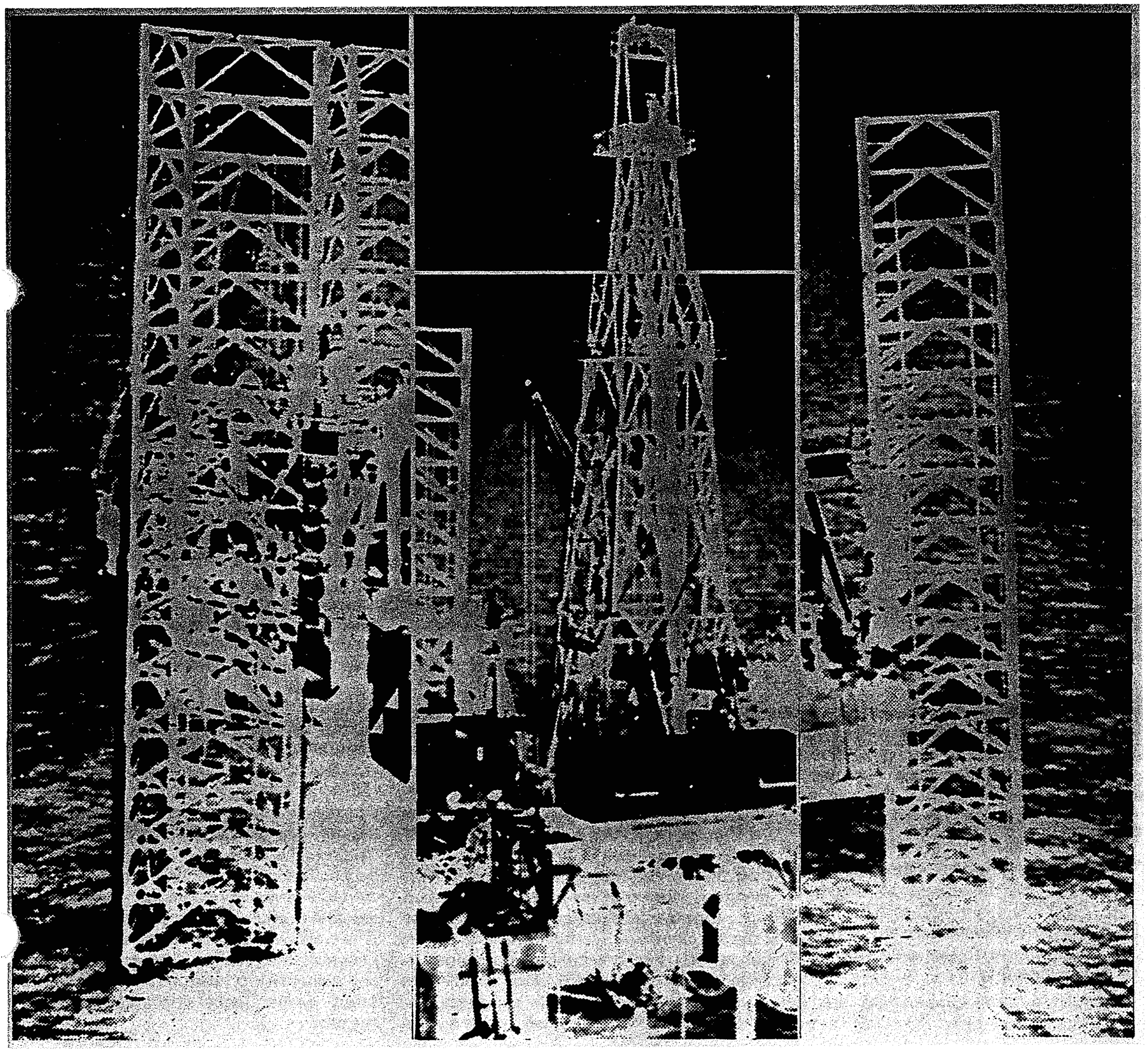
Why not a Jack-up for 400 ft. water?

New developments in piping analysis



WHY NOT A JACK-UP FOR 400-FT. WATER?

Drilling operations in water depths greater than 300 ft. have been the exclusive preserve of semi-submersible and floater type drilling units. Why not use Jack-up units for 300 to 500 ft. water depths? Which provides the most capability for the most economy? Let's look at recent and future trends relative to the use of Jack-ups and semi-submersibles and the inherent problems to be solved for Jack-up operations 400 ft. and beyond.

In 1965 the first Jack-up designed for 300 ft. of water was put in service.[1] By December of 1971 there were 10 Jack-ups already in operation for 300 ft. of water and deeper and 11 more being built.[2,3] These 11 units for 300 ft. of water and above make up 69 percent of the Jack-ups currently being built. The future seems to point toward deeper water units. Three of the 11 currently under construction are for use in water depths to 350 ft. Further, the demand for semi-submersibles has also increased (see Figure 1) which is indicative of the demand for drilling capability in deeper water. Historically, the trend has been towards exploration drilling in more hostile environments, thereby going to the limits of existing technology. Floating units have been the only means of drilling in rough conditions in deep water. The use of units sitting on the bottom for such areas now is feasible.

Figure 1

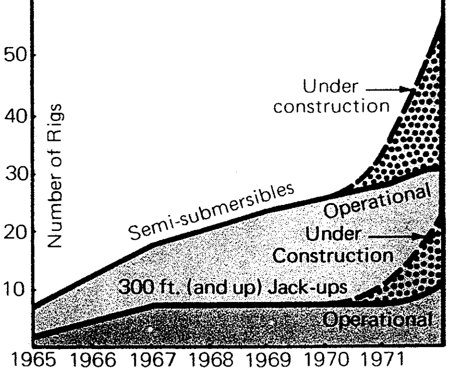
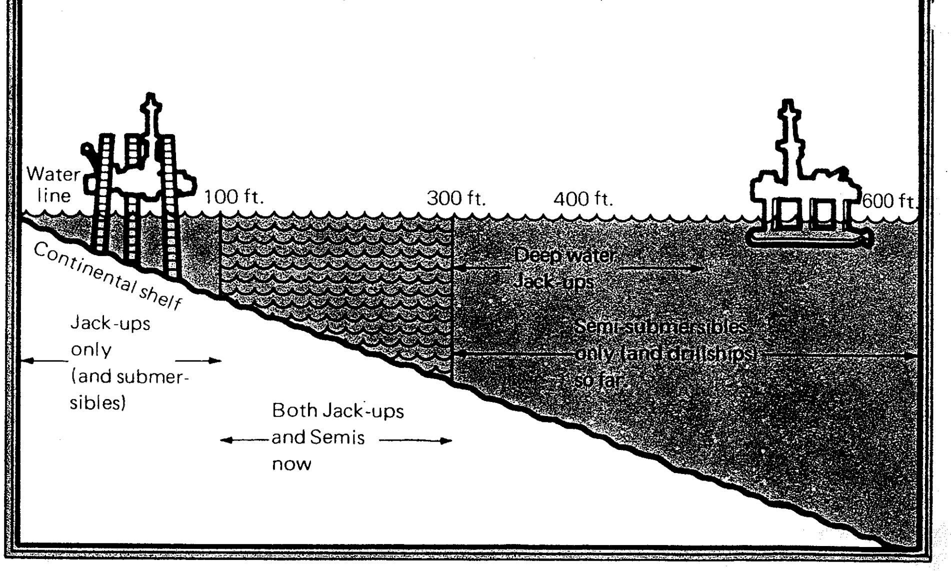


Figure 2 Water Depth Ranges For Semis and Jack-ups



Currently, a semi-submersible or floater type drilling unit is required for drilling on the outer reaches of the Continental Shelf from 300 to 600 ft. (see Figure 2). Furthermore, semi-submersibles are often used for drilling jobs down to 100 ft. water depths because of convenience and rig availability. Shouldn't Jack-ups be used more extensively in depths to 400 ft.? The following arguments could be advanced:

- Using semi-submersibles in shallow water is a costly proposition. These units are expensive to construct, typically from \$12 to \$25 million. With this size investment, it is more economical to use a Jack-up wherever possible.
- While semi-submersibles are designed and rated for 600 ft. plus water depth, many are really working in much shallower water today. At what depths are semi-submersibles really working now? It seems that most are working at the 300 to 450 ft. water depth range. Thus, all you may really need for most jobs is capability to 450 ft.
- Even if one found gas or oil at 600 ft. water depth, in rough seas, can it be produced with present technology? Shouldn't one concentrate instead on working in 400 ft. or less?

Thus far design technology has limited the Jack-up units to water depths of 300 ft. and less. However, substantial design work has been done and the technology is now available to build a Jack-up unit for water depths of 350 to 450 ft.* Design studies show that a Jack-up at these depths *can* safely withstand the more severe wind and wave stresses imposed. Let's analyze briefly the problems encountered:

- Greater difficulty in getting on and off location
- More severe wind and wave conditions
- Size and costs for current types of designs increase almost exponentially with operating water depth.

Getting On and Off Location

Getting on and off location has already proved to be a serious problem with unusual sea conditions such as off certain parts of West Africa and Australia. The difficulty of getting a Jack-up on and off location increases with increasing water depths and the consequent increases in leg lengths. Motion of the hull causes the spud can to move at a velocity proportional to the leg length – thus the impact on the leg as it first hits bottom increases dramatically with longer legs. This problem is further compounded by the rough sea conditions that prevail in areas where such a large unit may be used: the unit may have to get on location with fifteen foot swells running or higher, confused seas. To get such a mammoth unit on and off location in relatively rough weather new breakthroughs are needed. Such design breakthroughs have been achieved and are currently available.*

Wind and Wave Conditions

As the operating water depths get greater, the wind and wave storm criteria usually become more severe. Stresses caused by storm action tend to increase exponentially with wave height and wind velocity. Construction costs go up with water depth more than linearly, the effect being a sudden steepening of the cost curves at around the 250' to 300' water depth as shown in Figure 3. One aspect of this, however, is that a rig designed for the severe storm criteria typical of 400 ft. of water in the North Sea, would probably be good for 500 ft. of water under less severe conditions such as in the Gulf of Mexico during the non-hurricane season or off the Coast of West Africa. To be useful, and safe, in the areas of the world where 400 ft. Jack-up rigs are needed, such a rig must be able to withstand at least 125 mph winds and 80 ft. waves. Preliminary figures* show that these wind and wave criteria can be met at competitive costs. Factors of safety should perhaps be less for a 100-year storm (1.1 to 1.2) than for a 10-year storm (1.5 to 1.7). Careful analysis, design, and construction are needed, because stresses increase dramatically with increased wave height and wind velocity. At deeper water depths the structure must meet increased storm criteria. This causes a relatively large increase in the structure's cost. Therefore it is worthwhile to consider the trade off between lower safety factors, lower cost and higher risk on the one hand and higher safety factors, higher cost and less risk on the other.

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*Engineering Technology Analysts, Inc. design data.

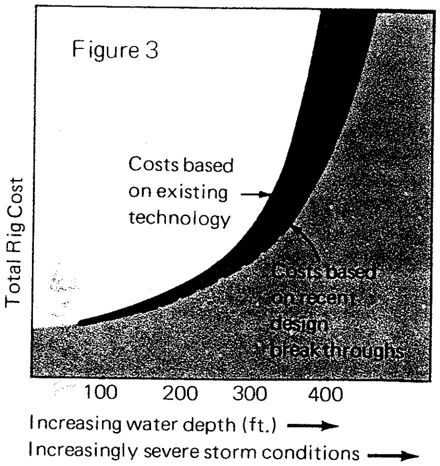
Figure 3

Size and Cost

A 400 ft. Jack-up requires a deck about 530 ft. above the mudline and legs about 580 ft. long. This allows for a 60 ft. air gap (for waves 80 ft. from trough to crest and 30 ft. of penetration). Such a unit has a maximum weight on location of around 34 million pounds, suggesting a cost range of $17 to $19 million. This price range is even more attractive, however, when we consider the production records of Jack-ups vs. semi-submersibles; that is, their increased number of drilling days and their fewer days of waiting on weather.

One authority[4] has set this productive time record at 86 percent drilling time for Jack-ups versus 75 percent for semi-submersibles in the North Sea. This comparative data was compiled over a period when 155 holes were drilled by semi-submersibles and Jack-ups. None of these were drilled in over 400 ft. of water (up to January 1, 1970) and only a small percentage of these were in more than 270 ft. of water. This suggests a performance ratio of 75:86 = 0.87:1.0. Using this performance ratio to factor costs reduces the $17 to $19 million cost range to $14.8 to $16.6 million for comparable drilling performance per dollar. All of this assumes that these or future semi-submersible units would be operated at this efficiency in the even more extreme sea conditions found in 400 ft. water depths in the North Sea. There is little data to go on at this point, but it seems probable that a 'fixed' drilling platform such as a Jack-up unit would spend a larger proportion of its time in these rough conditions making hole, and making money for its owner.

Conclusion

Preliminary analysis of the problems of getting on and off location, the more severe wind and wave conditions, the construction costs and operating efficiencies, point to the practicality of a 400 ft. Jack-up — today. It is only a matter of time before someone launches out and builds one — or several.

References

(1) "Third Annual Offshore Contractors and Equipment Directory" the Petroleum Publishing Company, Tulsa, Oklahoma, pp. 184-199.

(2) "Mobile Units — Rigs Under Construction" *Offshore* Vol. 31 No. 12, p. 89, November 1971.

(3) "New Offshore Rigs total $595 Million" *Ocean Industry,* Vol. 6 No. 12, pp. 32-33, December 1971.

(4) Starink, A., West, F. G., "Various Types of Exploration Drilling Rigs for non-shallow water depths. (50 ft-600 ft)", Symposium on Offshore Drilling Rigs, Royal Institution of Naval Architects, London, paper No. 2., November, 1970.

NEW DEVELOPMENTS IN PIPING ANALYSIS

Public opinion, plant management, and federal regulatory agencies are forcing a closer look at piping design codes. Important developments are in effect that merit investigation for new and existing installations, and planned expansions and modifications.

The Situation

Piping design codes have always been important and are essential for general safety and safe engineering design. Bursts in transmission lines, refinery explosions, and environmental considerations for long-haul surface pipelines such as the proposed arctic pipelines, are forcing closer scrutiny by the public, industry, insurance companies, and the federal government. Several piping design codes are now nationally accepted. These codes are well-meaning, however, and do not present impossible obstacles to engineering management nor the piping engineer. Thus, a brief look into New Developments In Piping Analysis is appropriate.

Piping Design Codes

First, let's clarify for purposes of this presentation, that we are concerned with exposed piping at compresser and pumping stations, crude lines, gas transmission lines, refinery piping, power plants, steam plants, etc. For example, it is now illegal to operate a transmission line in the United States without passing the requirements of ANSI B31.8. This code was prepared under the auspices of the American Society of Mechanical Engineers. It has been incorporated as a set of rules by the Department of Transportation and is enforced by the DOT's Office of Pipeline Safety. Piping stress code requirements of B31.8 must be met for all Gas Transmission and Distribution Piping Systems.

Other similar codes, such as B31.1 and B31.3, for Power Piping and Petroleum Refinery Piping, respectively, help enforce safety for refineries, chemical plants, and power plants. Plant owners and insurance companies often desire proof of plant safety. Similarly, nuclear power station piping must be reliable to prevent radioactive pollutants getting into the environment. Code B31.7, for Nuclear Power Piping, helps enforce such reliability and is a very stringent code. Code B31.4, for Liquid Petroleum Transportation Piping Systems, is similar in its effects to B31.8.

The Problem

It is desirable, and oftentimes essential, to show conclusively that these piping design codes are satisfied. Federal authorities have the right to enter any plant where safety standards are in doubt, and should working conditions be dangerous, personnel would be banned from working in that area, effectively shutting down the plant in many such cases. The costs for extended shutdown can be catastrophic. In fact, the cost of piping system failures, in any situation, becomes more and more unbearable.

Computer Analysis Tool

Computer generated stress analysis is being specified more frequently by plant owners, engineering management, and insurance and federal regulatory inspectors. The "Mare Island" piping flexibility analysis program, originally developed by Mare Island Naval Shipyard in San Francisco, has been widely used and accepted. It was released in 1964, has been thoroughly "de-bugged", and is highly reliable.

The Mare Island approach has been improved, up-dated, and customer-oriented through the ETA/Extended Piping Flexibility Analysis Program (ETA/EPFAP)*. Mare Island format conventions have been retained because of their familiarity to many engineers.

Applications

- Equipment loadings are determined clearly and accurately.
- Automatic calculation of bending, weight and expansion stress criteria.
- Every possible loading and combination of loading effects can be determined using thermal, pressure, and weight factors.
- Forces, moments, stresses, and deflections at every point can be determined.
- Any of above for new installation designs and existing system modifications.

A problem inherent in many computer analysis outputs is that they are difficult to interpret. ETA/EPFAP overcomes this problem by generating two output reports for piping code comparisons: One lists each element and compares actual stress values against allowable values. The second report gives only the elements that do not meet code requirements so that a quick glance will tell the piping engineer whether

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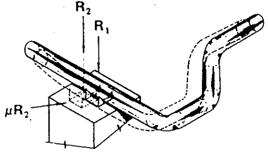
*ETA/EPFAP is an innovation of Engineering Technology Analysts, Inc.

his system is within code standards or requires changes to meet standards.

Analysis of Friction Supports
An especially significant technical advance is the development of a solution algorithm for non-linear problems such as occurs with friction (sliding) supports. It is an adjunct to ETA/EPFAP. This algorithm has been used on production problems.



Important elements of this algorithm are:

- Friction Force can act in any direction parallel to the friction surface.
- Friction Force = Coefficient of Friction x Reaction normal to the friction surface.
- Friction Force always acts coincident and in opposite direction to the deflection.
- Problem uses an iterative scheme, typically requiring 3 to 5 iterations to get within 2-3% of the final solution.

User Benefits
Aside from overall convenience, many time saving benefits are available to the user through ETA/EPFAP for the applications discussed.

Minimum input – Only an isometric piping drawing and specified loading conditions required.
  - No need for program coding or other inputting complexities.
  - Set-up and analysis performed by experienced engineers familiar with the program.

Easy-to-interpret output – Computer output self contained with all terms explained, definition of stresses quoted, and maximum values of stresses and deflections printed and locations given.
  - Areas flagged where code criteria exceeded.
  - Direct B31 piping code comparisons.
  - Separate printout of problem areas, support design, and equipment design.

Response time – Normally a 2-5 day turnaround.

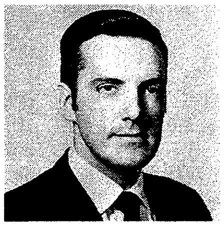
Conclusions
Computerized piping flexibility analysis techniques are state-of-the-art and provide modern-day convenience. Piping system stresses and Federal agency imposed design codes can now be compared one for one using innovative computer check techniques. Hundreds of piping stress analysis applications, for major oil, gas, and transmission companies in the U. S. and Canada, have been solved using ETA/EPFAP.

Future Subjects for ETA INNOVATION
- Marine Pipe Laying
- Naval Architecture for Unusual Hull Shapes
- Simulation of Uni-directional Pipe Supports

The founders and prime movers of

Engineering Technology Analysts, Inc.

Peter Lovie is a registered professional engineer and a chartered engineer (U.K.). He founded Engineering Technology Analysts, Inc. in early 1970, and is its President. He has a M.S. degree in Applied Mechanics from the University of Virginia and a B.Sc. degree in Civil Engineering from the University of Glasgow. Mr. Lovie developed the ETA Extended Piping Flexibility Analysis Program (EPFAP). He has been responsible for innovations in the use of Naval architectural and structural analysis computer systems.



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ABOUT ENGINEERING TECHNOLOGY ANALYSTS

Engineering Technology Analysts (ETA) is people – Specialists in piping flexibility analysis, design and analysis of offshore structures, and naval architecture. ETA talent combines sophisticated engineering analysis techniques, state-of-the-art computer analysis methods, and careful, practical, engineering judgment. The outstanding success of ETA, since its formation in early 1970, is built upon a staff of 17 highly skilled professionals and technicians expert in ETA's areas of activity. These professionals are dedicated to a unified philosophy of:

1) Quick response to the client's needs
2) Loyalty to the client's interests
3) Good, reliable work completed on time and within budget.

ETA's clientele includes major oil and gas companies, offshore companies, petrochemical refiners, power plants, and utilities. Typical problems solved routinely include:

- Piping flexibility analysis for gas transmission, refineries, power plants, etc.
- Calculation of stresses and deflections of marine pipe laying operations.
- Mobile Offshore Drilling Units
  - Classification by American Bureau of Shipping or Lloyd's Register of Shipping
  - Determine the maximum wave height that a unit can withstand
  - What modifications are necessary to operate in new storm criteria?
  - What changes are necessary for ocean tow?
- Complete design of a Jack-up unit for unprecedented water depths
- Curves of form and stability calculations for conventional shape hulls and new design semisubmersible units.

State-of-the-art computer equipment and software are used – which are compatible tools for ETA's staff. A remote batch terminal at ETA's facility accesses any one of several large batch-oriented computers available to ETA. Thus, the essential efficiencies and economies are obtained in computer usage and engineering time. The installation is used in structural analysis, naval architecture, and piping flexibility projects. Less complex computational work is performed on a portable interactive time sharing terminal.

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