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12755 Ashford Hills Drive Houston, TX 77077 • ph: 281.597.8784
www.dynamictubulars.com

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High Ratio, Elastic Region Tubular Expansion

Hart E&P Techwatch

Author, Jeffery A. Spray
Confluent Systems and DTS Corporation

BACKGROUND

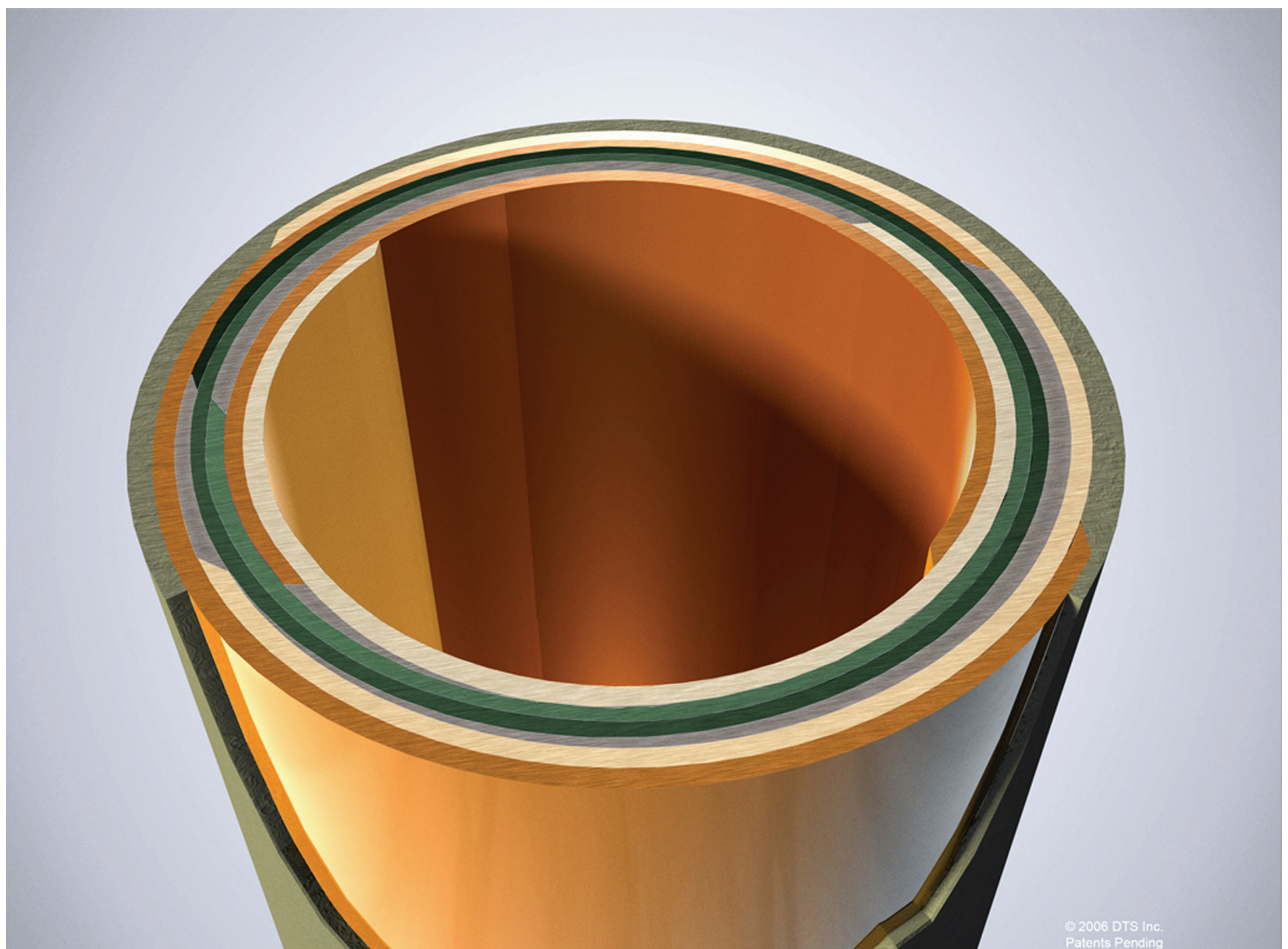
The energy industry has been slow to act on its recognition that the majority of its drilling costs are actually due not to ROP, but to the costs of *stopping* drilling in order to control troublesome geology. These non-productive periods often also add major investments in running and cementing numerous casing strings. Only in the last decade has increased activity in deepwater exploration, along with inflating costs in other E&P, led to aggressive development of expandable tubulars which promised to address serious challenges. Many accomplishments have been made and important new goals identified through expandables R&D. Expandable technology has not yet dramatically changed the mainstream industry, but that time now appears to be close at hand.

It is increasingly understood that some fundamental limitations exist for conventional expansion processes. For industry-wide acceptance of expandables to occur, they must overcome the three challenges of demonstrating reliability, strength, and efficient delivery of integrated solutions. An innovative new technology has now arrived which more reliably expands, is considerably stronger, and demonstrates notable value potential. It is currently emerging as a source of major improvements in the expandables industry.

CONVENTIONAL EXPANSION

Conventional tubular expansion utilizes cold-working processes to permanently deform low-alloy steel. Basically, a specialized mandrel is forced through standard casing, which has been modified slightly to accept the cold-work processes. High mud pump pressure is applied internally to assist the expansion work. While applying expansive stresses to commonly available casings was a logical starting approach for early development, many technical drawbacks also exist. These technical and operational disadvantages have prevented wide-scale uptake of the technology by the E&P industry.

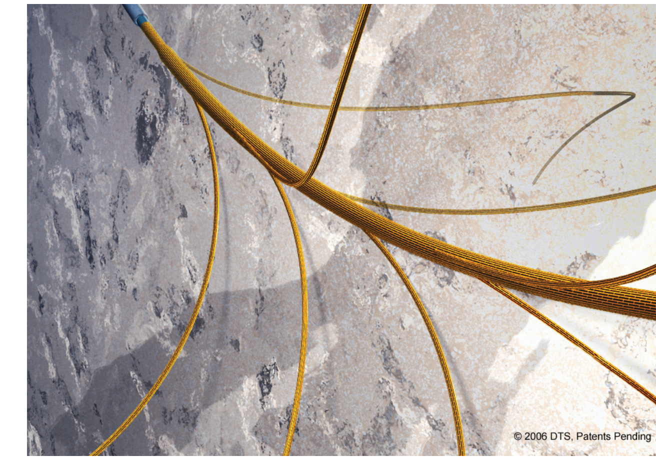
Figure-1, Self-expanding casing design. Heavy-wall, 135% expansion device constructed with complementary-shape elastic members and elastomeric sleeves.



The forces required to initiate deformation of oil field casings are deliberately high. Obtaining full expansion of such material is difficult when the already resistant casing assembly is placed into complex downhole environments, such as in eccentrically-loaded, deviated or stuck conditions. Additionally, abrasion or other surface damage as shallow as .012" or less creates stress risers as metallurgy is later altered through plastic regions–regardless of the effects of further stresses externally. Maintaining the mechanical and pressure integrity of an entire assembly of such material while it is being subjected to compound expansion stresses–particularly through the coupled intervals–is a notable but unreliable engineering accomplishment.

In addition to the intended radial growth, one unintended by-product of the deformation work is shrinkage along the longitudinal axis of the tubular assembly. This is due to the reorientation of the steel's microstructure, effectively contracting the material. The effect is unavoidable and is inherent to all conventional expansion systems. If the longitudinal material 'feeding' requirement is not almost perfectly supplied, further significant stress is working against expansion reliability and final integrity.

Simple expansion reliability downhole is the first major technical difficulty and most common industry complaint. Technical difficulties affecting reliability are inherent, however, given the high amounts of work required to alter steel, particularly while negotiating difficult well conditions. Currently, in order to mitigate risks of deployment failure in the field, the wellbore must be thoroughly conditioned and control maintained throughout cementing and expansion operations. For the driller to provide essentially ideal



Conceptual view of microhole production enhancement and proactive sand-control system.

conditions in problem zones downhole comes with high costs. These costs are proving a barrier to wide-scale acceptance and ultimately to commercial value potential.

Solid expandables are increasingly being used as cladded casing extensions in order to help prevent premature loss of telescoped-casing ID. Currently, these extensions come with not only the conventional casing-job-costs, including, first, the need to repair and condition the problem downhole; then, the added costs associated with the risk of expansion failure; and, finally, the costs for the expandable products and services themselves. For most drilling operations, these combined costs and risks are not at acceptable economic levels.

Some strength properties resulting from plasticized expansion are similarly not compliant with industry preferences. Strength of most any conventional tubular is based on specific performance of its diameter to wall-thickness ratio. The wall-thickness of a tubular device must increase in proportion to increases in its expanded radius, so as to maintain equivalent pressure ratings. This is not what results from the cold-work processes. Often, tremendously lowered pressure ratings occur in the expanded form. In order to provide more acceptable post-expansion properties, one potential solution is to substantially increase the beginning wall-thickness. This can increase the initiating force requirements and exacerbate local shrinkage issues, particularly in the threaded sections.

The initial goal of expandable technology was to lower the costs and risks of drilling challenging wells. Among the major approaches towards this goal were proposals to develop monodiameter or nested-type well systems, where the diameters and volumes related to excavation work, casing design, drilling fluids, cement, and waste generation are significantly reduced. Monodiameter schemes are excellent in their numerous progressive goals, but very difficult to achieve due to the many issues already discussed and others not presented in a short article. There is increasing industry recognition that even the numerous incremental benefits of prospective MoD system realization will still not lead to step-changes in E&P economics. This is due partly to the ever-present reliability factors of current expansion designs, but is mostly attributable to conventional expandable technology not providing actual solutions downhole and not providing efficient delivery of such integrated solutions. Currently, identical costs for rig-time to repair trouble zones, condition, trip, and wait must still be incurred every time a casing string or liner is run–whether expanded or not. R&D which incrementally improves expansion methods or the quality of the expanded casing is not enough to realize any meaningful goals or to bring value to E&P industries

The updated goal of expandable technologies must be to create significant value by mitigating, or, in some respects, eliminating altogether, many conventional casing and stabilization related steps and their costs These steps ultimately represent more than 50% of all investment for drilling wells. The most direct approach to reduce the extensive conventional cost items and to realize technological value is to deliver the expandable in a manner more seamless with the actual drilling process, while simultaneously integrating some former casing-job-cost items into the expandable system itself. Conventionally, this type of advanced development has had low feasibility due to limited expansion ratio capability, generally less than 125%; due to the robust support needed to initiate expansion; and due to the deleterious effects which abrasive and cyclic drilling stresses cause to steel, further disrupting integrity potential and thus precluding their use in drilling operations.

INNOVATIVE EXPANDABLE TECHNOLOGY

A new technological approach is emerging which utilizes opposite, elastic-phase processes to reliably expand high-strength pipe. The elastic process is also demonstrating abilities to minimize or eliminate conventional problems by completely designing-out problem sources. The new technology, under development by Houston-based Confluent Systems, through its affiliate, Dynamic Tubulars Corp., is called CFEX© and is slated for field trials in 2007.

The new technology is constructed from compressible cells and other types of strain-energized members which are formed into a tubular with a naturally oversized OD. The device is temporarily compressed during manufacture and held in the reduced diametric condition by removable bonds and integral wrappings. Once placed into the well, the temporary bonds are removed by electric, mechanical and chemical means. The result is a strain-energized assembly having natural dimensions larger than its nominal sizing requirements.

The technological concept facilitates expansion reliability by performing most of this work during fabrication. Where needed, high amounts of conventional hydraulic and mechanical force compound the tubular's ever-outward energy. By augmenting the device's natural bias, tremendous amounts of downhole work can now be utilized to produce substantial expanded stability downhole. The tubular's proficiency also includes high-pressure sealing capability as an integral benefit.

Since residual strain-energy is exerted against the formation, there is no 'spring-back' effect to create voids. This provides foundation for high-pressure wellbore sealing. The tubular's structure is also adjustable during expansion making the device highly compliant to irregular wellbore surfaces. In a preferred approach, more effective use of compounded expansion forces can actually reshape local geology, according to the tubular's optimal fit. Contrary to other approaches seeking to comply with the well environ, the new system does not substantially sacrifice strength properties as sealing geometry is obtained. High-pressure sealing

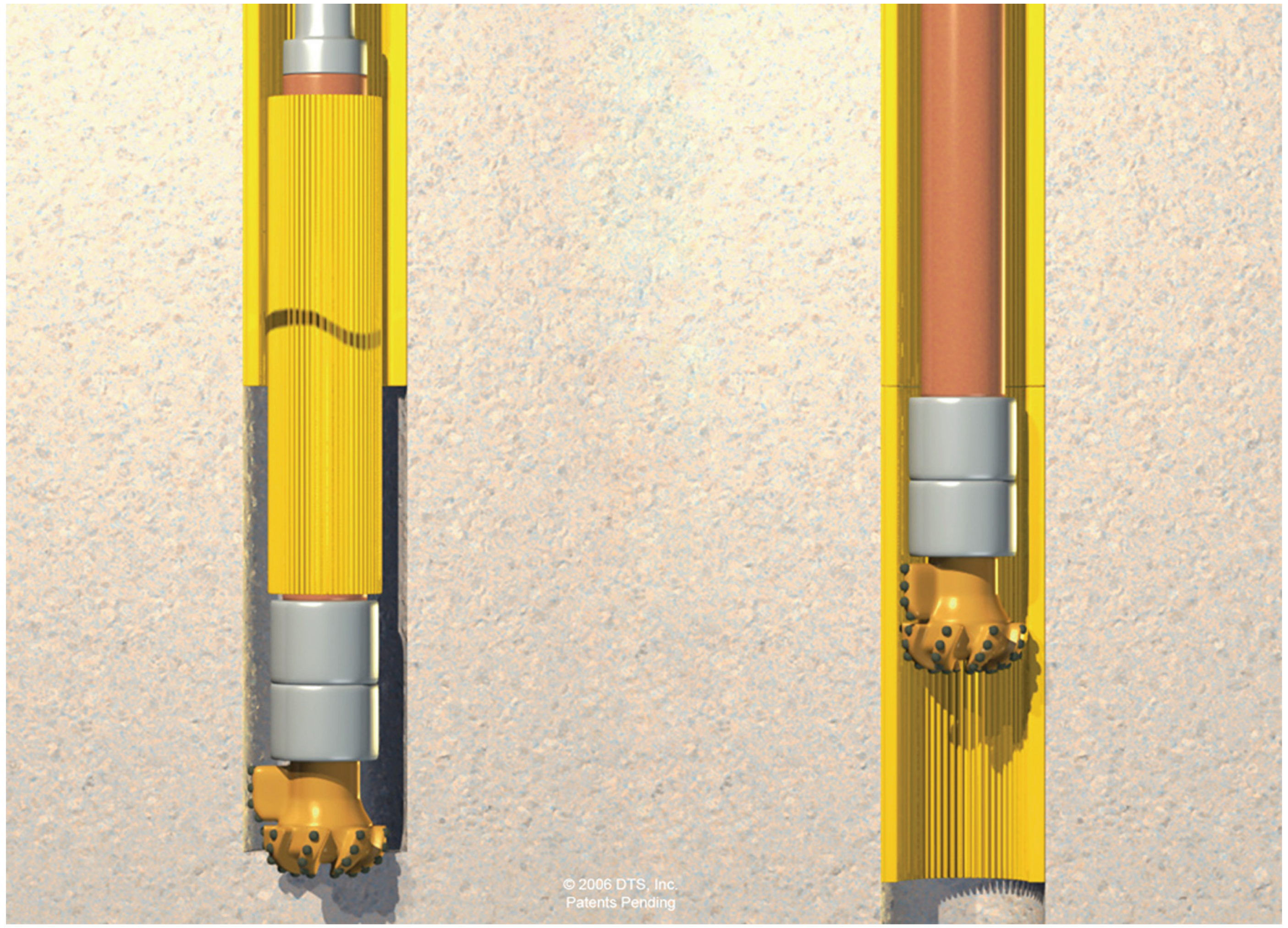
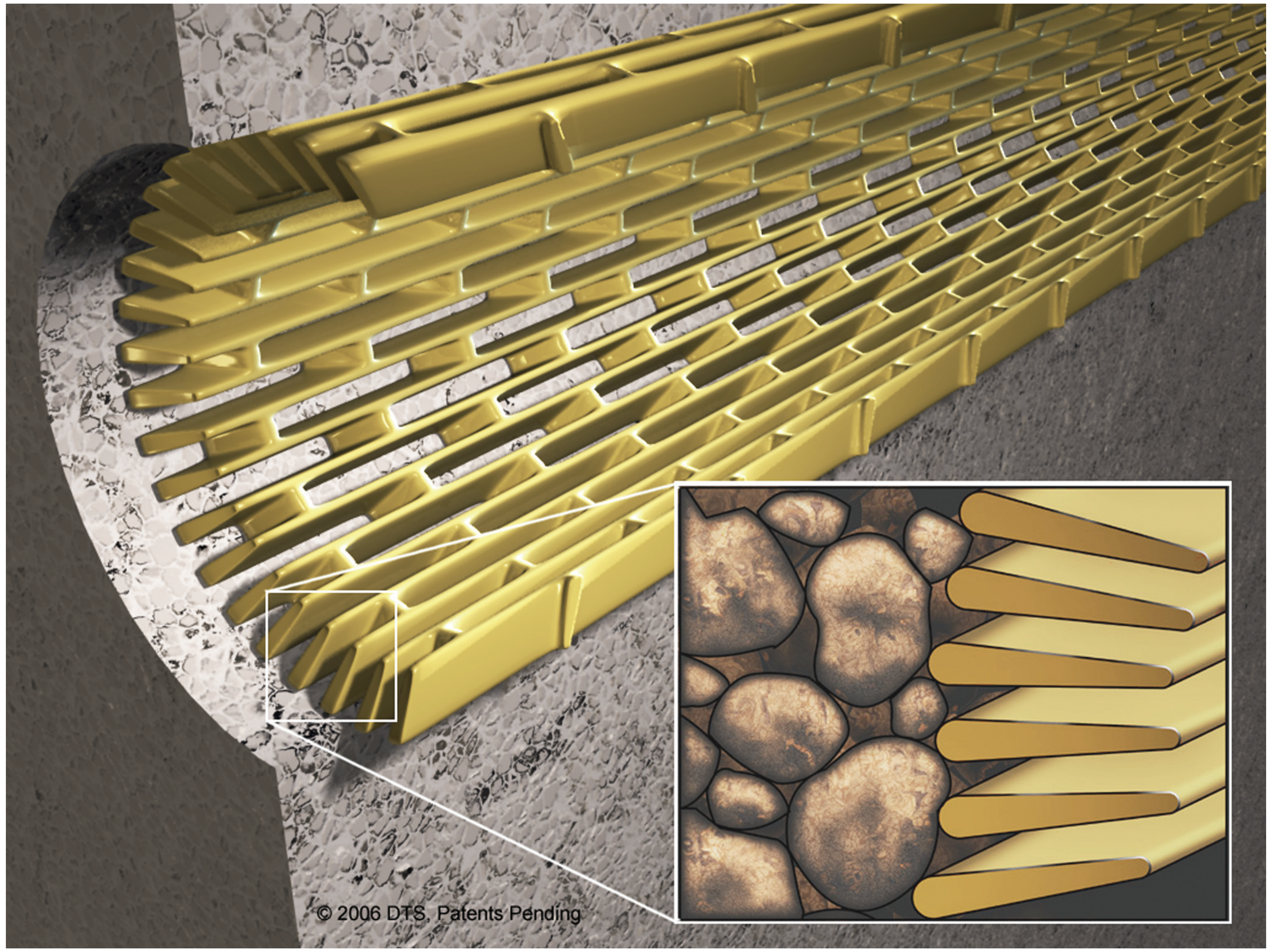


Figure-2, One delivery method for self-expanding tubulars, temporarily affixing a sleeved liner to the BHA.

development is one approach to provide integrated solutions and reduce some unnecessary, albeit standard, casing-job costs.

One casing design pictured in **Figure–1** is constructed from high-deflection members. This type of tubular design provides many mechanical capabilities well beyond even the optimistic promises of early expandables development. For example, the expansion capability of this type configuration is in excess of 200%. This high-rate capability allows for broad applications of the technology, ranging from relatively simple clads, to through-tubing products, to expandable drill collars. Generally, an expansion ratio of 135% is required for an expandable device to be integrated into drilling operations, allowing for adequate supply of both wall-thickness and circulating annulus. The 3 technology's diametric capabilities as a drilling tubular are practically unlimited, ranging from <3" to >28".

Though unnecessary for most applications, numerous elastic members can be arranged to form a device with considerable thickness, as shown by **Figure— 1**. A further important aspect of the technology is that it can be constructed from very high-yield materials. Performance specifications are then practically limitless, increasing directly according to the quality and quantity of material supplied. By way of example new expectations for large-diameter well design, a bi-center bit program for 16" casing can be provided casing with 1.5" or greater wall-thickness, 250-ksi+ material construction, 135%+ expansion capability, and with no loss of standard 16" ID. Similarly, a 2" or greater thickness expandable can be implemented into con-



Simplified approach for self-expanding production screen. Designs increase flow, strength, and are being developed for light-duty drilling capability.

ventional 16” casing programs. Towards more typical sizes, 9-5/8” casing using high-yield materials and 1” or greater wall is also in reasonable range of the technology.

Construction of the new expandable from elastic-region components provides development feasibility for device integration into the actual drilling operation. This is the primary principle towards delivery of the expandable on a more realtime basis. Since the new tubular needs only certain regions of elastic function in order to properly become opened, drilling stresses do not automatically destroy the material's expansive integrity. Additionally, the types of robust casing specifications capable of the new method can be viewed also as BHA specifications. The expectation is that simultaneous benefits from efficient BHA, drill-with-casing, and expandable promises can soon be delivered as a standard operation in the field. One method of integrating expandables into the actual drilling process is depicted in **Figure–2**.

CONNECTING SECTIONS

Emphasis on the use of elastic structures and high wall-thickness provides opportunities to incorporate optimal elements from many different connection types. Because so much engagement material is available from high wall-thickness, the connections are designed completely non-upset. The flush-coupled arrangement also maximizes working and circulating clearances downhole. Connecting tube segments uses familiar elements from threaded, quick-couple, and high-pressure sealing designs.

Connection integrity is further improved due to the elimination of the previous, contradictory shrinkage issues, as the new technology provides for complete control over longitudinal behavior. Control over the unpredictable longitudinal ‘feeding’ problem also provides opportunities to advance MoD system development since the previous reliance on forming complex, ‘connecting’ overlaps to integrate separate casing assemblies is also now simplified and able to be exact.

PRODUCT COST

Absent the capability for immediate delivery of solutions during drilling, the new technology recognizes that the value-potential of most expandable products is limited currently. For conventional cladding applications, the value is some risk-discounted percentage obtained from extending casing ID and, perhaps, salvaging a large or critical drilling investment needing to reach specific TD.

Currently underway are analyses fully detailing manufacturing systems and costs of the new technology. The preliminary estimates and commercially acceptable range of fabrication costs is some 2X – 6X over similarly rated oil field tubulars. Use of commodity pipe pricing references are meaningful only to the extent that the basis is familiar, but it is not highly relevant.

The value of the final commercial forms of the new technology will have to be determined on the basis of real costs for wells–evaluation of the technology's cost against the sum of nearly all currently non-productive drilling costs and the costs of capital due to any failure to reach drilling targets. Approximately one-half of $100 billion spent annually for drilling and remedial work goes positively toward producing information, hydrocarbons or safety. The other one-half, which includes costs for excess mud losses, WOO, hole-conditioning, services, trips, tubulars, running casing, cementing, WOC, TD-failure, and even some fishing expenditures are expected in large part to be avoidable through application of the new technology.

CURRENT RESULTS

This new technology is now proceeding in detailed-analysis, testing, and field demonstration phases. The development program continues to refine the new technical area through rigorous FEA, testing, and prototyping. Analytical and physical modeling show the system functioning readily within purely elastic regions. Physical testing of components consistently confirms conservative analytical predictions for basic mechanical functions. Pressure testing criteria for thick-walled expandable test-specimen, equivalent 9-5/8” casing is 10,000-psi. The column tensile and buckling properties of the system range between ratings given by premium casing and those for heavy-wall drilling tubulars.

Preliminary testing conclusions are that the new expandable properties correlate well with all levels of modeling rigor. These design properties approximate 75% - 90% of the values of equivalent solid tubes. This is to say that the new, tunable expandable technology can exceed the performance of conventional, non-expanded tubulars by supplying necessary amounts of pre-expanded material and better structural functionality throughout.

COMMERCIAL EXPECTATIONS

This new expandable technology has generated interest and support from major energy producers and US-DOE. Given the properties consistently indicated in analysis and testing, aggressive development is planned also for highly challenging drilling operations. Novel uses of suitably robust expandables in subsalt, HTHP, ultradeep water, thermal recovery, and unconventional resources can very reasonably be expected. DTS is also developing products for remedial, workover, subsidence mitigation, and other applications. There is currently substantial interest for use of the technology in burgeoning microhole and re-entry markets. The US Department of Energy-NETL Microhole Technology Program supports the technology, including its permutations as high-flow production tubulars.

To obtain further information, contact info@dynamictubulars.com or visit http://www.dynamictubulars.com on the web.