# NEW ISOLATOR FOR CONTROLLING BHA VIBRATIONS

William E. Turner*
APS Technology
P.O. Box Q
Hellertown, PA 18055
*member ASME

Mark Wassell
Baker Hughes INTEQ
2001 Rankin Road
Houston, TX 77073

## ABSTRACT

This paper describes a new drill string isolator (Isolation Sub) that has been developed to reduce the damaging transmission of torsional, lateral and axial shock pulses from a drill bit to sensitive BHA components. Its unique robust design features two helical sections that lock together and into which an elastomeric material is injected. The elastomeric material is fully constrained, providing high load carrying capacity as well as damping in all directions. The isolation characteristics can be tuned by changing key geometric variables such as the helical pitch, the number of pitches, the elastomer thickness, as well as the elastomer durometer.

## INTRODUCTION

It is well known that vibration during drilling operations has a large effect on both the bottomhole assemblies and the drill bit. While large vibration levels cause reduced rates of penetration and catastrophic failures, lower levels may lead to a reduced operating life if allowed over a sufficient time period. In the past, much effort has been invested in measuring and understanding vibration. The benefits of addressing this problem are obvious and include reduced drilling time and costs, reduced maintenance, and lower equipment turnover.

Many of the previous attempts to isolate MWD tools from the drilling environment have resulted in marginal improvement. The development of the Isolation Sub began with our examination of the performance of a MWD tool that was already isolated from vibration. It was determined that improved shock and vibration isolation was needed to reduce frequent maintenance and prevent the less-frequent failure. For example, the first commercial MWD tool built by Teleco Oilfield Services was a suspended tool within a drill collar. Both the sensor and transmitter assemblies were suspended by individual elastomeric isolators, and motion was restricted by elastomeric elements called shock bumpers (see Figure 2).

**MWD TOOL**

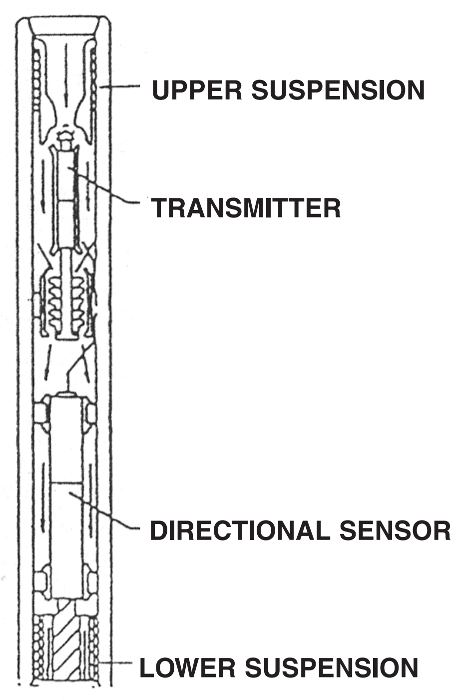



**FIGURE 2**

Under a steady load, such as when suspended vertically or with a pressure differential acted across the tool, the isolators provided support. Under dynamic loads, the isolators would flex, allowing the tool to move until contact was made with the shock bumpers at which the stiffness increased exponentially. Torsional loads were absorbed entirely by the isolators. In general, the field performance of this suspension was functional, and the reliability was adequate. However, the isolators took a permanent set due to the static load, and shock bumpers were subject to erosion and breakdown of the elastomer, thus requiring frequent overhauls. Whenever the tool was returned to a maintenance facility, the suspension was rebuilt, and all elastomeric components were replaced. In addition, occasional bond failures in the isolators had the potential of allowing rotation of the sensor or transmitter relative to the housing; therefore, these elements required special scrutiny. These problems were determined to be unacceptable, and several improvements were attempted, including: improved elastomers, improved bonding techniques, and replacement of the elastomeric isolators and shock bumpers with coiled spring designs and with belleville spring designs. All efforts led to some improvement, but no design was free of the high maintenance costs.

**HELICAL ISOLATOR**

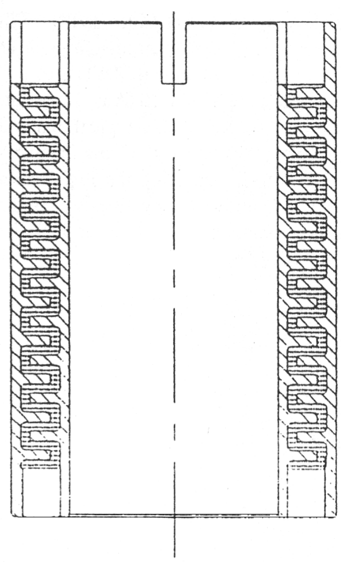


**FIGURE 3**

APS Technology, along with Baker Hughes INTEQ, has been working on methods of improving the shock isolation of sensitive components from the drilling environment. We proposed a helical isolator concept about three years ago (see Figure 3) to address the problems. Initially we designed and built ten prototypes that were deployed in the North Sea in 1994. These units have been running for two years with over 10,000 accumulated downhole operating hours without a single failure.

Concurrently we had applications for improved flex couplings for Moineau style downhole pumps. These employ a similar concept to the helical isolator but use two helical elastomeric sections with a connecting shaft in between (see Figure 4). This design is a Hooke style coupling and was developed and tested successfully in the lab but has not yet been used downhole. This work allowed us to develop the torque transmitting capability of the Isolation Sub.

**FLEX COUPLING**

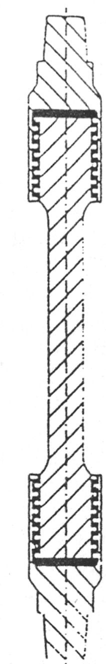


**FIGURE 4**

Approximately 18 months ago, we started development of the Isolation Sub design that would be used as a drill string isolator (Figure 5). We felt the design would have several applications, including:

- a drill string dampener to improve performance of bits.
- an isolator to protect MWD tools from the damaging high frequency vibrations, particularly for those tools which have collar mounted electronics.
- a flex sub to isolate drill string components from excessive bending moments.
- an isolator for acoustic tools to prevent echoes from corrupting the measurement.
- a control of drill string vibratory frequency.

Our initial effort focused on a 4-3/4" tool. We completed manufacturing in August and have just completed static testing. It is anticipated that drill string simulator tests will be performed this spring and downhole tests by the summer. The analysis and testing of this design will be outlined in this paper.

## DESCRIPTION OF ISOLATION SUB

The Isolation Sub consists of two loosely threaded cylindrical members with rubber molded into the thread cavity. The rubber is one of the variations of nitrile, which was selected for its ability to operate in the oilfield environment. The spiral nature of the thread form significantly increases the rubber-to-metal bond area. The rubber is constrained in all directions and

**ISOLATION SUSPENSION**

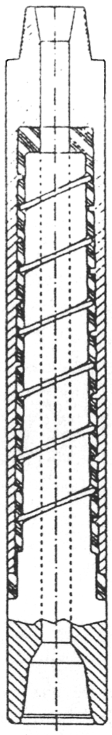


**FIGURE 5**

becomes relatively stiff. Very large axial and torsional loads can be carried by this design, but it still provides shock isolation and damping of vibrations. Stiffness and damping are controlled by varying the elastomer hardness and geometry.

Specifically, the joint assembly consists of longitudinally arranged male and female threaded portions or sections. These sections are threaded together to interlock with one another but dimensioned such that a tortuous helical space remains between them. This space is entirely filled with an elastomer which is bonded to the threaded portions (Figure 5). By virtue of this structure, the elastomer is highly restrained by the interlocked threading. Consequently, the elastomer is only slightly compressible in the longitudinal direction and somewhat more compressible in response to torque because of the continuous helical nature of the elastomeric portion. The two portions are pivotable with respect to one another in all directions to a limited, but sufficient, degree. Since torsional loads are transmitted by a combination of shear and compression via the jack screw effect through the entire helical length, the torsional load capacity is greatly increased. Thus, an important aspect of the concept is provision of an elastomeric joint assembly with improved torsional capacity. Further, because the relatively moving surfaces are completely isolated from the surrounding environment, there is no potential for abrasives or contamination to enter.

The nature of the thread form makes this a fail-safe device. In the event of bond failure, the parts screw together due to drilling torque (right hand thread). Four pins are installed prior to molding to make this a fail-safe device in reverse rotation. This design is protected by US Patent 5,447,472 and other US and foreign patent applications pending.

Dareing has indicated that shock absorbers can lead to instability. This is overcome by increasing the stiffness of the absorber[1,4]. Dareing demonstrated this by examining an absorber with a stiffness of 43000 lb/in. This was increased by a factor of five and resulted in full isolation of the drill string from cutter head vibrations. One goal of our design was to keep the damping ratio as high as possible.

**4-3/4" Tool Design Specifications**

| Parameter | Property |
|---|---|
| Weight on bit *(lb)* | 36750 |
| Torque *(ft-lb)* | 10000 |
| Rotary speed *(rpm)* | 250 |
| Axial stiffness *(lb/in)* | $1.2 \times 10^6$ |
| Torsional stiffness *(in-lb/deg)* | 3200 |
| Axial critical damping | 8% |
| Temperature *(°F)* | 300 |

## ANALYTICAL EXAMPLES OF EFFECT ON BHA

The Isolation Sub was modeled through Finite Element Analysis to determine its response to shock.

**The Drill String Model:**

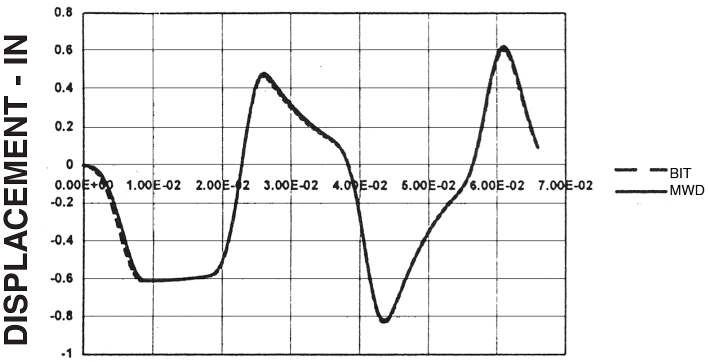
Various shock excitations were analyzed, comparing a typical BHA to a BHA with an Isolation Sub position between the bit and an MWD tool. A time-history finite element model was used for the analysis. The time-history analysis predicts the isolation characteristics of the BHA above the isolator sub from excitations and shocks induced at the bit. The BHA model (Figure 1) is made up of 150 feet of 4-3/4 drill collars represented using beam elements. A mass on the uppermost node represents the drill pipe above the BHA. A vertical force on this node applies the hook load achieving the proper WOB. The Isolation Sub is modeled as a damped spring element.

Forced sinusoidal displacements at the bit apply the shock load into the BHA. Two excitations are applied to the bit. One is a high-frequency shock of 100 Gs of an 11 milliseconds duration. This represents the shock due to an impact on the bit. The second shock is a lower-frequency shock of 1 G and 0.133 seconds duration. This excitation assumes the drill string is rotating at 150 rpm over an upset of one third of the circumference.

Figures 6 through 9 show the comparison of the bit response compared to the MWD tool without the Isolation Sub. Displacements and accelerations are compared for different excitations, showing the effect of the Isolation Sub.

**BHA RESPONSE**

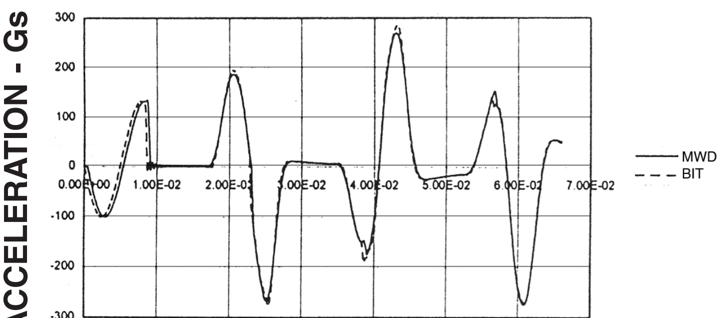
***W/O ISOLATOR - 100 GS. 11 MSEC SHOCK***




**TIME - SEC.**
**FIGURE 6**

**BHA RESPONSE**

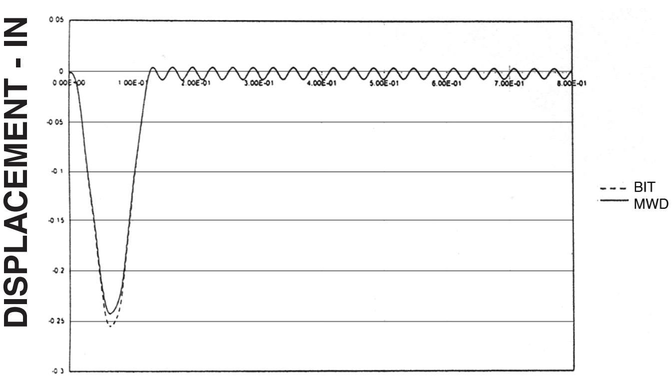
***W/O ISOLATOR - 100 GS. 11 MSEC SHOCK***




**TIME - MSEC.**
**FIGURE 7**

**BHA RESPONSE**

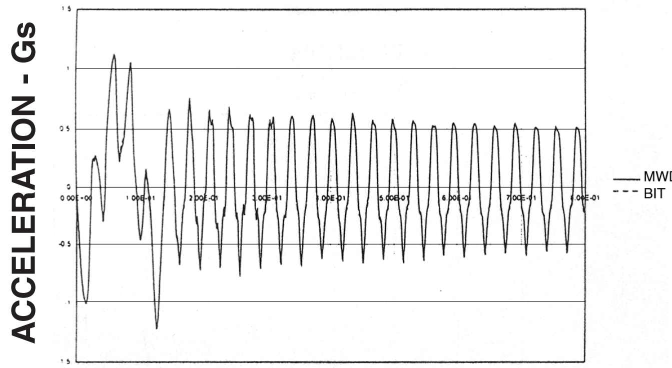
***W/O ISOLATION SUB - 1G, .133 SEC. SHOCK***




**TIME - SEC.**
**FIGURE 8**

**BHA RESPONSE**

***W/O ISOLATION SUB - 1G, .133 SEC SHOCK***

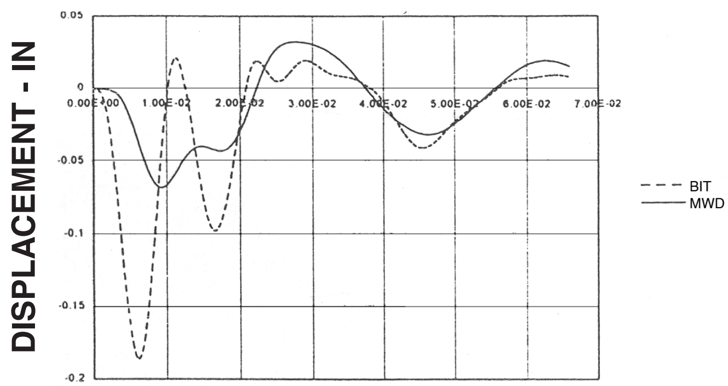



**TIME - SEC.**
**FIGURE 9**

Figures 10 through 13 show the same comparisons with an Isolation Sub positioned between the bit and an MWD tool.

**BHA RESPONSE**

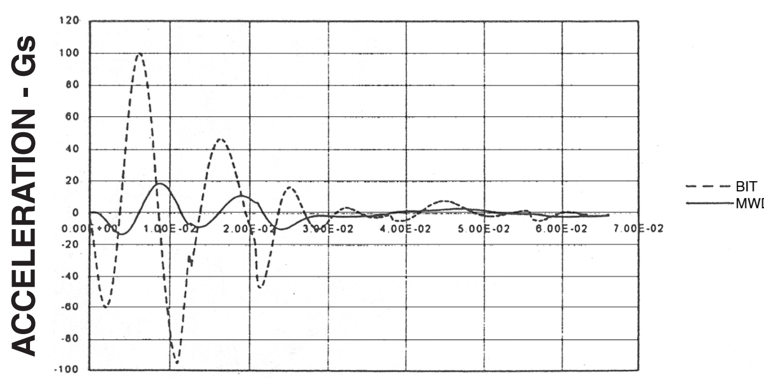
***W/ ISOLATION SUB - 100 Gs, 11 MSEC SHOCK***




**TIME - SEC.**
**FIGURE 10**

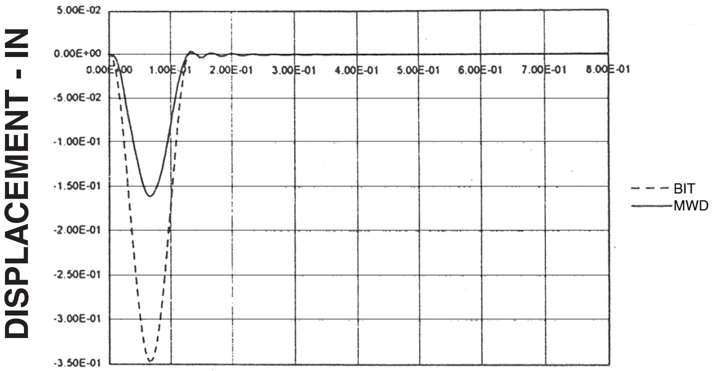
**BHA RESPONSE**

***W/O ISOLATION SUB - 100 Gs, 11 MSEC SHOCK***



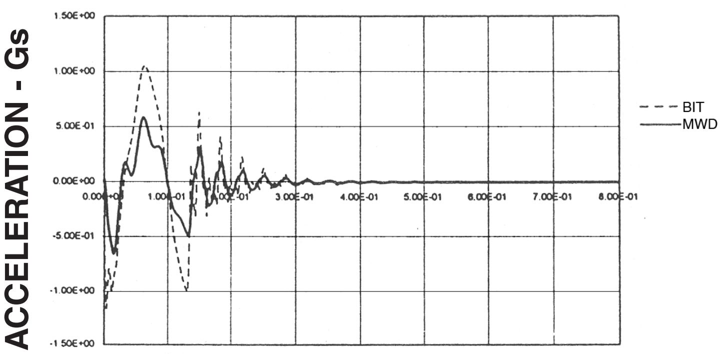

**TIME - SEC.**
**FIGURE 11**

**BHA RESPONSE**
***W/ ISOLATION SUB - 1 G, .133 SEC SHOCK***




**TIME - SEC.**
**FIGURE 12**

**BHA RESPONSE**
***W/ ISOLATION SUB - 1 G, .133 SEC SHOCK***




**TIME - SEC.**
**FIGURE 13**

The damping for the BHA is .1% log decrement (.02% critical damping), which is the typical material damping for steel. The damping value for the isolation sub was determined to be 51% by test-measuring the log decrement decay (8% critical). Figure 14 shows the hysteresis damping for an applied load of 8,600 lb. applied in 1 second. The stiffness was determined by load testing.

The analysis shows the isolation Sub provides significant vibration isolating capabilities. The shock from the high-frequency shock is reduced by 90 percent to the MWD tool. Figure 6 shows the effects of the bit bouncing off bottom resulting in increased shocks of 300 Gs that are much greater than the applied 100 Gs. The Isolation Sub absorbs this impact, reducing the shock at the bit to the 100 Gs input excitation, while reducing the MWD shock to 20 Gs. The low-frequency shock at the MWD tool is reduced by 50 percent. The increased damping capability of the Isolation Sub also dampens out the vibration much quicker.

## APPLICATIONS

The tool is used below an MWD tool to damp the high-frequency shock and vibration and therefore increase the reliability of the MWD tool. It will be particularly useful for the new generation of tools being developed, which are unsuspended or have collar mounted electronics. The design is particularly useful for:

- Isolating sensitive components such as MWD electronics and sensors from shock and high-frequency vibration and whirl initiated by the drill bit or other sources.
- Isolating downhole acoustical tools from noise. These new tools extend the radial detection range beyond current resistivity tools and provide direct measurement of the well position referenced to acoustical reflectors. However, the tools are sensitive to excessive drilling

**DRILL STRING MODEL**

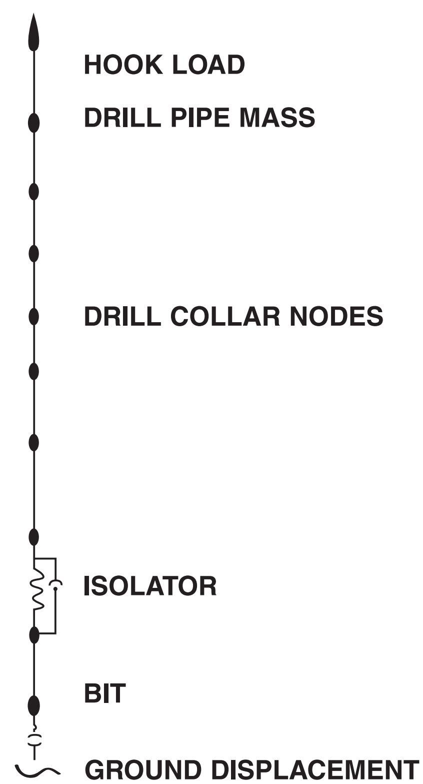



**FIGURE 14**

noise and vibrations from mudmotors. Measurements are ideally performed during pipe connections[3]. The Isolation Sub may increase the conditions under which the acoustic measurements can be successfully obtained.

- Changing the natural frequencies of BHAs.
- Improved PDC bit performance through reduction of bit bounce by the ability to absorb shock, vibration, and whirl. Dareing has shown how shearing action between drag bit cutters and rock cause drillstrings to self-excite, leading to dynamic instability[4].
- Absorbing the high-frequency shocks of tri-cone bit teeth.
- Isolating specialized tools from bending moments.

**Benefits include:**

- increased MWD tool life
- increased bit life due to isolating it from drill string bounce
- damping and shock isolation over a wide range of drilling parameters
- increased rate of penetration of PDC bits
- short length (6') compared to shock subs (16')

## REFERENCES


1. Zamudio, C.A., Tlusty, J., and Dareing, D.W., 1988, "Effect of Shock Absorber on Drag Bit Chatter, Proceedings," SPE 17194, 1988 IADC/SPE Drilling Conference, SPE, Richardson, TX, pp 153-160.

2. Lindley, P.B., 1978, "Engineering Design With Natural Rubber," Malaysian Rubber Producer's Research Association, Hertford, GB,

3. Nakken, E.I., 1995, "A New MWD Concept for Geological Positioning of Horizontal Wells," SPE 30454, SPE 1995 Annual Technical Conference and Exhibition, SPE, Richardson, TX, pp. 851-856.

4. Zamudio, C.A., Tlusty, J.L., and Dareing, D.W., 1987, "Self-Excited Vibrations in Drillstrings," SPE 16661, SPE 62nd Technical Conference and Exhibition, SPE, Richardson, TX, pp. 117-124.

5. Schabtach, Carl and Fehr, R.O., June 1943, "Measurement of the Damping of Engineering Materials during flexural Vibration at Elevated Temperatures." Journal of Applied Mechanics, pp. A86-A92.