

Not the Same Old Brake

A Discussion about Drawworks Brake Systems

Oilfield Drawworks brake systems have remained the same for the last 75 years till the disc-brake systems developed in the mid-late 1980 where introduced as new technology to the industry basically borrowed from the automotive industry.

Prior to that bench mark in new equipment development the industry relied upon band brakes with various modifications to improve their performance, mainly materials, with no great leaps in improvement till the disc brake introductions mentioned above. And in fact many rigs today still operate with the old band brake systems, as operators are continuously attempt to squeeze all the profits they can out of what they have to work with.

During the mid 1980 this writer was working in the Dallas / Ft. Worth area as a sales engineer for a local firm supplying hydraulic and electronic equipment and systems to the oilfield industry, prior to that I had worked as a design engineer and project engineer in the R&D company known as NADM or National Automatic Drilling Machines of National Supply Co. This is where a great number of the basic concepts of subsystems we see today on the drill floor where first developed and later refined into products to improve and automate the rig floor, IE.. Iron Rough Neck, know then as the “Make Break Device”, Top Drive then called a “Hydraulic Power Swivel”, and the one man control room equipped with a Harris 300 series computer then, now known as the Drillers Cabin.

During this time a company in the area familiar with the writer engaged in discussions of development of a new brake system that would use computer or later called PLC controls to automatically control the WOB and other drilling functions enhancing the drilling operations and introducing the industry to new technology that basically came up thru the automotive industry, and called a ABS brake system. This system utilized a PLC program written to take advantage of a patent held by the drilling equipment supplier to monitor the Hook Load and the rate of fall that could be achieved to minimize the cycle time for tripping operations safely and without damaging the equipment or endangering personal. And thus was born the disc brake systems that we know today and has come to be accepted by the industry in general as the standard world wide as state of the art.

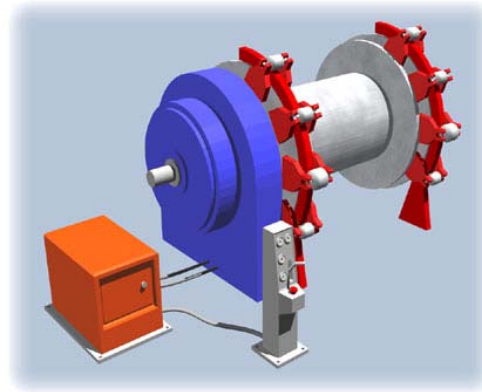
The basic system is comprised of the following components to form a sub-system of the drilling operation, a very important system that controls the real reason why a drilling rig exist “To manufacture a hole in the ground” as a good friend of mine once stated, a very expensive hole or conductor of fluid “Oil” that seems to keep getting more expensive everyday.

Hydraulic Disc Brake Systems

The hydraulic disc brake system consists of a pair of brake discs mounted on the drawworks drum. Instead of the brake rim, a constant open and close brake tong set mounted on the support arm and a control cabin fitted with the brake handle and the hydraulic power device. By means of a lever arm, brake tong applies the spring force to both sides of the brake disc in the direction opposite from the rotating direction of the friction block. The constant-close brake tong releases the force that is produced by the spring in the cylinder by means of the hydraulic pressure. The hydraulic pressure required by the brake tong is from the hydraulic power device that includes two electric constant-pressure variable plunger pumps, filtering, circulating and cooling purpose and one manual large-displacement emergency pump. During the normal running, one plunger pump provides all power required by the brake system, the other is standby pump. There are hydraulic accumulators that not only provide the short-time power source for the brake system, but makes the braking response more sensitive. The main brake valve provides the normal operation of the drawworks with the adjustable control of the main brake. The emergency brake valve is used to handle the emergency or apply the brake after the driller leaves the control cabin, it is connected to the line of the emergency brake so when the anti-collision valve acts the emergency brake is applied.

The Control System

A dual hydraulic brake actuators is connected to the drawworks' existing brake shaft and is controlled by a small joystick. The joystick is installed either on a pedestal type console, or integrated with the armrest of a driller's chair. The system provides the necessary feedback for the driller to continuously feel the load and, together with the auxiliary brake sometimes known as a Elmago brake, control hook velocity at high precision all the way down to creep speed.



The ADS Auto-driller system is an integral function of the creep speed qualities of the brake servo valve with a closed loop feed off control for steady rate of penetration (ROP) from 0 to 120 m/h. The unique feed off system automatically catches the braking equilibrium or “sweet spot” for starting and maintaining the drum's feed off motion. Via a control knob on the console, the driller increases the feed off rate manually until the desired weight on bit (WOB) reads on the hook load indicator. Pressing a button on the control console sets the current WOB value. The electronic WOB control automatically provides small adjustments of the feed off rate necessary to stay within narrow WOB limits. Signals from delta-p and drill string torque sensors may be integrated to the system, as these sensors relate to the control of the feed off rate the same way the WOB does. Should the string torque go high and a sudden string rise is required, the Auto-driller automatically goes into override mode,

These systems have improved and many companies are now producing the similar systems for use in the drilling industry, although the basic disc brake system has stayed the same. The improvements have come in the area of



control development, drillers are now accepting of hydraulics on the drill floor, “man that took a while to get done” and electronics are accepted by most rather than the mechanical control systems of the past, and of course the new generation of “video game” drillers that are streaming into the industry now, and they all like that aspect of the drill floor rather than a “Brake Handle” in a open floor environment of the past.

Auxiliary Brakes System

The auxiliary brakes are mainly used for control of load and not stopping a load or maintaining a WOB setting. Tripping “controlled decent from the top as fast as you can” is the main function envisioned by the original designers.

Water brakes, water cooled eddy current and now water cooled dry disc friction brakes all have been used as auxiliary brake systems, with the eddy current “Elmago” being the most prominent in the industry to date. The eddy current brakes work well for the original purpose but as we all do in this industry we try to get just a little more out of every thing and some times that comes back to haunt us.

The Eddy current brakes also are very heavy “lots of copper”, take up rig floor space, and have several support systems required to be able to do the job, these include water supply and cooling systems, electric switch gear at the MCC, and batteries. Those batteries are necessary when the brake is running below 50 RPM so that a magnetic field can be maintained to provide resistance for the braking operation at those lower speeds, not the original intent of the design.

And in some cases now companies are actually over-running the eddy current brakes in parrell to the disc-brakes in an attempt to smooth the start-stop “jerky” action caused by the primary disc brake system during drilling operations.

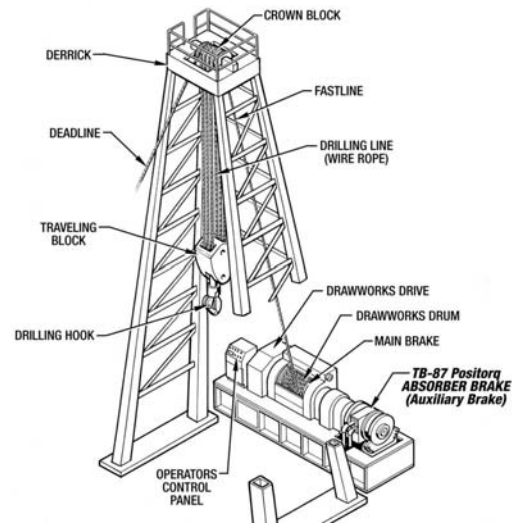
So What’s Really Happening

If we take a fresh look at the braking system overall we can come to some conclusions that may interest you.

Several things are in play here and I will break it down one by one to gain a better understanding of the inherent problems, as those individual systems combined.

1. Disc brakes where the best solution at the time “1985” for rigs to improve the performance of the rig, manual drilling operation where the norm then, various companies had tried to introduce automation to the industry thru the years but that drillers handle was just not going to go away, “who needs to improve anyway” .

After great effort and trials and tribulations the disc brake system was sold, Santa Fe Drilling received the first one and it still operates today. This disc brake system was just part of the deal though, because if you could operate the brake system by means of a hydraulic valve, “ABS” remember, then you could



automate the braking operation and therefore the drilling operation in general, “Progress finely” and if that was true you could also introduce automated controls, as in “PLC’s” Programmable Logic Controller and automate the drill floor, “boy we are going to get back to NADM some how” not quite.

So the rebirth of automatic drilling begins in earnest, and it has been very successful and saved many a drillers back and made lots of money for the industry, which is what we are after in the end, the bottom line is what counts.

But some how we keep adding on sub-systems that catch up to us later and cause problems that reduces that bottom line “profits” rather than taking a fresh look at what’s available to us and here in lies the problem.

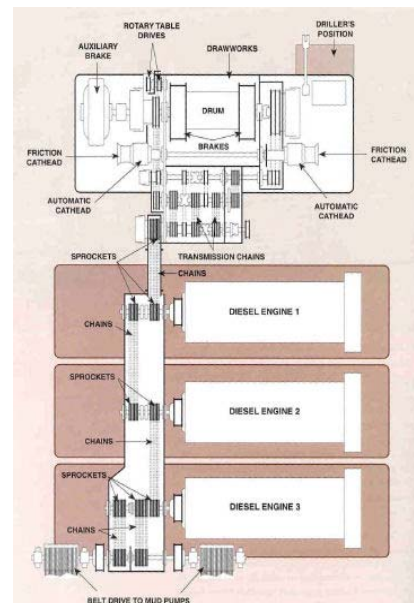
2. The drawworks today are basically the same mechanical systems of my father and grandfather, although he did work on a steam driven system in Burkburnett, Texas and those mechanical systems require mechanical transmission of power.



When we adopted the hydraulics with response times of 20 m Sec, and some even faster and added a PLC control systems even faster, to automate the drill floor

“ a good thing” we did not consider the mechanical transmission of the drawworks.

You see disc-brakes do a job really well, they stop a load quickly and if automated they can restart a load or “release a load in this case to free fall” and stop it again in a precise time interval, that’s auto-drilling. All this start-stop-start action causes mechanical transmissions to do the same thing and wear occurs prematurely which cost the bottom line in added maintenance and down time “those day rates” for the rig in general. It is easy to see this added cost, just check your records but there is another added cost that we may not see right off.



This leads to another cause and effect area from add-ons, we have basic mechanical transmission equipment that is being driven by VFD systems now, and it has its own closed loop monitor sub-system, the brake system has its own cell “WOB” and a 3000 closed loop monitor sub-system, connected to a load releases the brakes based upon its own internal settings and program functions, that dives the drawworks toward the load or the bit end. And the action is again “jerky” and at the other end of the drive train is the SCR/FVD system(s) with its own system restraining the

drive train every time it sees that “Jerk” that’s why your transmission down time is so high or greater than it use to be when people where making those judgments of when to push and when to pull.

3. All this start-stop-start action causes another problem, “bit bounce” , basically if you take the drill line and run it thru the traveling block assembly(x 10-12 times) and “jerk” the drawworks end of it, you get a multiplying effect of the jerking action at the other end, and that is the business end of the drill string. This in turn affects the ROP of the drill bit and number of trip times, which makes those Days, of Day rates increase. The faster we “manufacture that hole in the ground” the better our customers like it.
4. So we over-run the auxiliary brake system during drilling to attempt to “smooth” that jerking naturally caused by the disc brake system.

Not what it was intended to do?

5. Also the start-stop action of the brake system, which is actually acceleration and deceleration of the load, has another under lying effect on the bottom line, fuel cost and at today’s rates that is a greater consideration. Basically it revolves around starting and stopping a load from a complete stop, vs. a continuous variable speed or torque regulating device that is more efficient.

In general you could relate it to another piece of equipment we have been involved with Jacking Systems, everybody knows the Bethlehem jacking systems are start and then stop and start, they where good for the time and in some cases still are today. But most if not all, new rigs are built now with continuous jacking systems, keep that load moving, “it is much easier on the equipment and the efficiency of the system is much higher.

Not the Same Old Brake

So let us consider another alternative, by starting where we did when disc brakes came on the seen, by use of a different hydraulic solution. And this solution comes right out of the auto industry as well, but not the car it’s self but the manufacturing process. In fact this brake has been operating in the industrial market for the last 25 years with great success and very little if none of the same problems pointed out in our prior discussion.

In some cases the brakes we are about to discuss have been running on paper mill applications “2500 hp” for up to 8 years with no maintenance required, and only .003 wear on any of the contact surfaces. This is a tensioning application which relates to a drawworks WOB application directly, and it is able to hold an overall tolerance of +/- .001 of the load it is controlling, so much for “bit bounce”.

Have I got your attention yet?



The brake has in general the following capabilities and benefits when used in a drawworks application:

Smooth Consistent Control – Precise “WOB” (see chart >>>>>)

- State of the Art friction materials and fluids have been developed for very smooth and consistent operation; jerks, steps, chatter, etc. have been virtually eliminated.
- Controlled fluid temperature through the brake improves consistency for precision drilling. **Please note there is NO curve, this is linier.**

Stable Torque Control

- Smooth, consistent actuation with low piston hysteresis is experienced by using Teflon Liners over the O-Rings to seal the non-rotating piston. This eliminates stick slip often associated with O-Rings seals.
- Torque is controlled by actuation pressure and is independent of speeds above the residual (minimum) drag torque.

Low Speed Capability

- Operational speeds at levels down to **0 RPM “Dynamic”** are precisely controlled without chatter, stick slip or torque variation, a overall **tolerance of +/- .001 full range torque** is common practice.
- Speed-up drives which can influence drill results are eliminated.

High Torque and Horsepower Capability

- Various sizes available from 500 – 5000 HP and is capable of continuous heat absorption due to thermal horsepower during tripping or high casing loads.

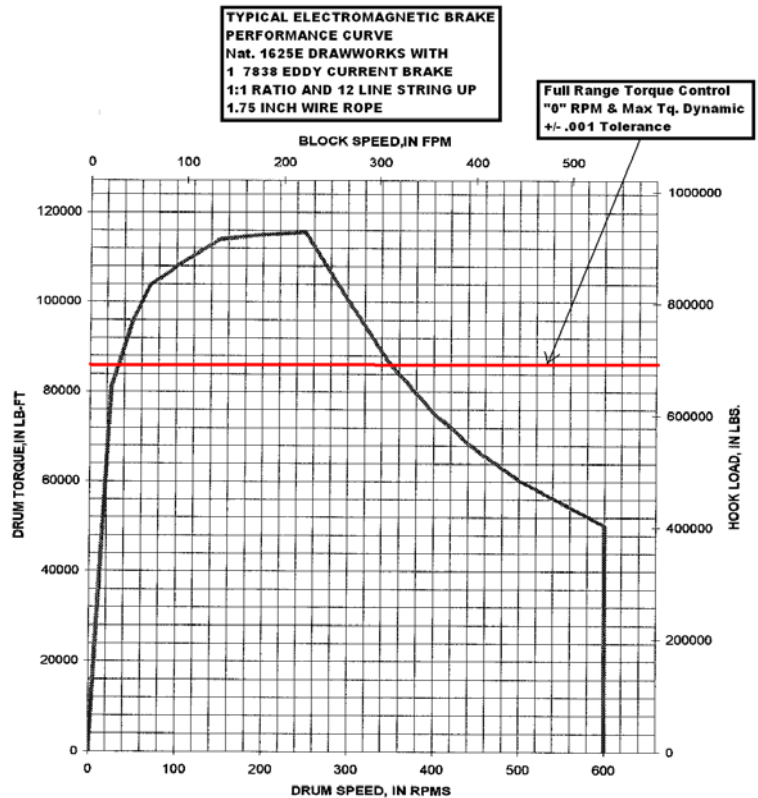
Quiet Operation

- Extremely quiet operation with noise levels of the brake system below 65 db.

Quick Response for Computer Control – Auto Driller

- Quick, precise piston actuation produces excellent response to manually or computer generated signals, 200 ms total cycle time.
- Low rotating mass inertia for increased responsiveness to changes in torque requirements.

No Adjustment Required



- Adjustment is not required making it very useful for long continuous drilling of many months duration without shutting down for brake adjustments or repairs.

Long Service Life

- Oil shear technology nearly eliminates the frictional wear of the disc stack. Therefore long life and low maintenance costs are experienced inexpensive repair kits are available from stock. Repairs can be made on the drill floor.
- An external wear indicator indicates the need for impending stack replacement long before actual failure would occur.

Totally Enclosed Design

- The totally enclosed design eliminates any contamination from salt air or fluids at the drill floor with friction materials or other harmful contaminants.

How It Works

OIL SHEAR PRINCIPLE

In a true hydroviscous drive, torque is transmitted through the shearing of an oil film.

Fig. 1 shows how this shearing action takes place and illustrates the factors involved.

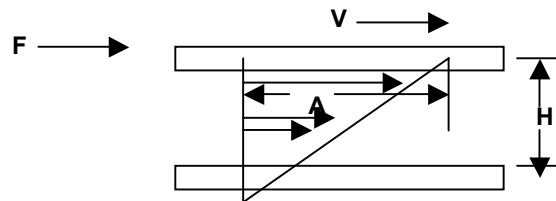


Fig. 1 – Flow between parallel plates

The upper plate moves with velocity V . The lower plate is stationary. A very thin layer of fluid adheres to the upper plate. This layer of fluid moves with velocity V . We will assume that the fluid flows in parallel layers or laminas, and that no secondary irregular fluid motion is superimposed on the main flow. This kind of flow is called laminar.

F is the force required to maintain the flow to slide the fluid layers relative to each other by overcoming internal fluid resistance. If A is the area of the plate in contact with the fluid, then the shear stress is F/A . Fig.1 shows the linear velocity distribution in the fluid. The rate of shearing the fluid is V/h . During each unit of time there is an angular change equal to V/h . Viscosity of the fluid is defined as dynamic viscosity or u .

$$u = \frac{\text{shearing stress}}{\text{rate of shearing}}$$

$$\text{or, dynamic viscosity } \mu = \frac{F/A}{V/h}$$

$$\text{Rearranging, } F = \frac{\mu VA}{h}$$

You will note that force (or, in rotary motion, torque) is directly proportional to viscosity, relative velocity of the surfaces and the area in contact. It is inversely proportional to the thickness of the oil film.

There is no metal-to-metal contact until relative velocity approaches zero, at which time energy levels of the input and output parts are virtually equal. Therefore, there is very little energy transfer, thus no wear.

Now examine the variables involved and notice the effect of each on F, which in the case of the hydroviscous drive equals torque output.

F is proportional to μ (dynamic viscosity coefficient).

The range of operation of a hydroviscous drive covers three distinct areas; boundary, mixed film, and full film lubrication. Boundary lubrication exists with low relative velocities, and full film lubrication is present with high relative or slip velocities, with mixed film lubrication present in between.

Boundary lubrication occurs very near lockup, where apparent dynamic coefficient of friction approaches the static coefficient of friction. For the materials and oils used, the static and dynamic or sliding coefficient of friction have values between 0.06 and 0.13. The effective coefficient of dynamic viscosity (or apparent coefficient of friction) is considerably below these figures under mixed and full film lubrication conditions.

As h increases, or there exists an increase in separation of mating surfaces, V (relative velocity or slip PRM) also increases to maintain constancy of torque. This is due to the hydrodynamic wedge effect. This inherent stability also exists in the reverse direction.

This relationship may be interesting from an academic standpoint, but how do we put this principle to constructive use?

We said that torque transmitted by an oil shear film varies inversely with film thickness. Direct control of film thickness, in multiple disc assemblies is impractical. Film thickness can be controlled, however, by controlling clamping pressure on the multiple disc pack.

The clamping pressure or force against the disc stack is a function of the area behind the piston (thrust mechanism) and the actuating pressure. This leads us to the practical relationship of torque transmitting capacity being directly proportional to actuating pressure.

It can readily be seen that the hydroviscous relationship is only valid when an oil film is present between the working surfaces. Since relative velocity goes to zero at the same time h or separation height goes to zero, the value of F or the torque producing force would seemingly go to infinity or zero, neither of which is practical.

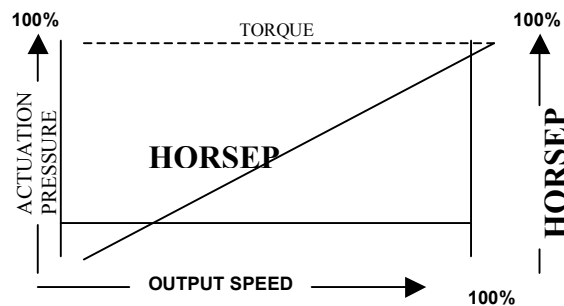
For operation at or very near lockup, the condition exists which is described by the following relationship.

$$\text{Torque, } T = F u N r$$

Where: **F** = force on the disc pack
U = effective coefficient of friction
N = number of working surfaces
R = mean effective radius of disc working surface

This relationship shows that for a given device design, meaning that N (number of working surfaces), r (mean effective radius) and u , or effective coefficient of friction (type oil and friction materials) have been established, output torque is again a function of force on the disc pack.

From this relationship it follows that relative velocity or slip speed is not a factor, and that torque is virtually constant for a given actuation pressure on a given multiple disc device over the entire operating speed range. Graphically, it develops a typical curve as seen below.



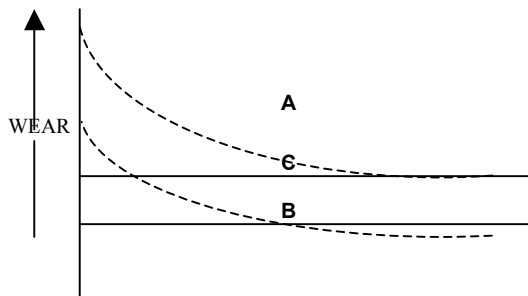
Why do we use a multiple disc pack instead of two large surfaces working against each other? The most obvious reason is that the package size for a particular torque rating is of a smaller diameter with multiple discs. A more subtle, but more important reason in accel-decel devices is that inertia increases as the 4th power of the diameter. Since energy per engagement of a clutch or brake is a function of the inertia that must be brought up to speed or to a stop, any excess internal inertia just adds to the starting or stopping load and the subsequent heat level.

One of the inherent problems with multiple disc devices is uneven loading between working surfaces during an engagement. This is due to spline and lug friction resisting the axial movement of each plate and disc when clamping pressure is applied. As more

and more clamping pressure is used to move the disc pack on the spline and lugs, less pressure is being transmitted to the working surfaces farthest away from the piston.

Oil film pressures in a hydroviscous drive between mating surfaces under constant slip conditions and full load sharing is quickly achieved. In drives over 100 H.P. at 1750 RPM spring separations between plates are used to aid load sharing.

In all clutch/brake or brake devices, however, uneven loading, if not compensated, leads to uneven wear of the working surfaces.



DISC PACK WEAR PROFILE WITH THE PISTON LOCATED ON THE LEFT

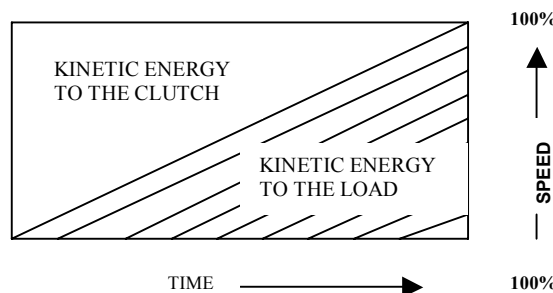
Curve A is a wear profile for a dry friction type or dipping type brake.

Curve B indicates the wear profile of a multiple disc device with an equal amount of oil applied to each working surface.

Curve C indicates an optimum even wear condition which can be obtained by virtually flooding oil through the working surfaces closest to the external actuation source or piston. This is the method used in the Posidyne Drive, which is explained in detail in the manufacturer's catalog.

The above wear/oil flow relationship is important to note and further explain because it is the unique feature that allows hydroviscous drives to exhibit their characteristic long lives.

First, it is necessary to isolate the cause of wear in a brake. The simple answer is heat. A brake is an energy transfer device, which transmits the kinetic energy of the drive motor to the load. An examination of this energy transfer during a typical brake engagement follows:



The curve is based on a constant torque being applied over a full acceleration period.

It should be noted that as much energy is transformed into heat as is transferred to the load. In a properly designed hydroviscous drive, this heat is generated in the oil film rather than the actual working surfaces. The constantly replenished film carries the heat of engagement to the unit sump, where it may be removed by any of several methods.

For pure inertia loads, the amount of kinetic energy involved in any one engagement is a function of the inertia involved and the differential speed and is defined by the following relationship:

$$\begin{aligned} \text{KE} &= 1.7 \text{WK}^2 \left\{ \left[\frac{N_1}{100} \right]^2 - \left[\frac{N_2}{100} \right]^2 \right\} \\ \text{KE} &= \text{Lb. -ft.} \end{aligned}$$

where **N** = speed in RPM

WK² = inertia, lb. -ft.²

The total kinetic energy for any one engagement is not a function of acceleration time. However, the rate at which kinetic energy is put into the brake is a function of total acceleration time.

If the rate at which energy is put into the clutch exceeds the heat absorption capacity of the oil flow through the brake, a residual heat buildup in the working surfaces will result. This condition can lead to degradation or wear of these working surfaces.

Combining Functions

As you can see this brake provides the ability to do both the drilling brake function and the tripping function as a single unit, therefore saving cost, space and weight and it will do it in a much higher level of performance capabilities than presently exist within the industry.

The brake is retro-fit able to existing drawworks, careful consideration must be taken in the area of the drawworks shaft attachment as some drawworks manufactures shaft designs are not rated for full torque capabilities of the drawworks.

A cooling unit must accompany the unit to regulate the hydraulic fluid temperature in the same way the cooling water system of a Elmago Eddy current brake functions to dissipate the kinetic energy absorbed, no switch gear or batteries required though.

One set of drawworks calipers or band brake are required to be used as emergency stop only and as a parking brake.

A manual control package accompanies the brake, and a auto-driller system is also available, both standard and custom engineered.

Field Experience

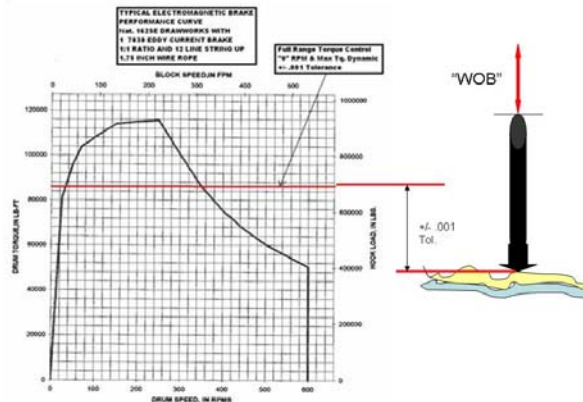
At the time of this writing Diamond Offshore is running a 2500 hp unit on a National 1625 Drawworks, offshore GOM.

Conclusion

Based upon 30 years of combined design and field experience we believe the next generation of braking systems has arrived.

The system will perform as specified; it is not a new design or technology but a proven piece of equipment that is making a transfer to another industry, much as the disc brake system did in the 1980's.

The performance of the system from the drilling side will greatly improve the rig ROP by reducing "bit bounce" and therefore make the rig more competitive, it will reduce maintenance and operations cost. Operators will find that it is more forgiving when applying the brake, reducing line bunching or bird nesting on the drill floor.



The rig floor area will be less crowded as these units are very compact, weigh considerably less than an eddy current brake, and allowing for greater set-back on the drill floor.

These brakes are applicable to other rig functions, such as mooring, and anchor handling where they offer the same smooth and high performance capabilities.

We offer brakes for BOP handling systems, skidding, and jacking systems that also are type approved by ABS. We are presently operating on Varco PRS pipe racking systems, where we improved performance and reduced down time overall.

This is “**Not Just the Same Old Brake**” of the past but more **like the future**.

To obtain additional information or discuss an application please contact:

Doug Hines (center), Jim Ingle (Rt)
Offshore Source LLC
dhines@off-shore-source.com



11325 NASA Pwky Suite 310
Houston, TX 77058

OTC/ASME Award Lunch 2004

Offshore Source LLC

We at Offshore Source want to introduce to you updated information regarding our company’s services and equipment we offer. Offshore Source is a provider of equipment and support services for the land and offshore drilling industry. We offer technologically advanced equipment with cost saving benefits and durability.

Some of our primary products are jacking systems, BOP handling, skidding systems, drawworks, mud pumps, tubulars including drill pipe and drill casing, and our exclusive Force Control oil shear braking systems.

We are also a turn-key operation offering complete drilling packages with support and full engineering from our experienced staff in Houston, Texas USA and Dong Ying City, Shandong, China.

The included brochure provides more details regarding some of these products and services. We want to invite you to visit our web sites at www.off-shore-source.com and www.offshoresource-china.com.

Our goal is to bring positive designs with cost advantages to our clients and their operations. We design, build, commission and service our equipment worldwide and would welcome an opportunity to demonstrate those capabilities to you, our customer.

We look forward to your request for information and meeting to discuss your requirements.