AADE-11-NTCE-32
Wireless Pipe Recovery System (WIPR)

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Abstract

Warrior Energy Services recently developed a patent-protected pipe recovery system (acronym WIPR) that does not require the use of electric line to recover stuck drill pipe.

It was developed to give the operator an alternative in situations where the following conditions are present:

a) Rig spread costs are very high

b) Conventional response times are very long due to a shortage of services and equipment

c) Possible unpredictable weather delays

d) Situations where high well deviations make some conventional pipe recovery operations difficult

Introduction

The WIPR system is based on a series of profiles (fig 1) installed strategically in the drill string (fig 2) as it is run in the hole. The system uses a drop assembly featuring a pressure activated firing head to jet cut a designed sacrificial sub positioned just below the installed seat.

The system is designed to have greater strength than the drill pipe or heavyweight above and below it in torque and with sufficient strength in tension to withstand more pull than it would be subjected to at depth.

Following the clean cut, an easily fishable stub remains. The operator can either POOH and return to retrieve the fish or the operator can immediately cement the pipe in place (through the firing head) with the drop system still in the hole. No dressing of the stub is required.

The sacrificial sub is specifically designed to be cut by the jet cutter which has the advantage of known geometry and guaranteed centralization due to the seat being just above where the cut is made.

The pipe does not require rotation (hence no tongs), and pressure control is necessary only to the extent that the drop assembly needs to be dropped or pumped into position.

Components of the WIPR

The Drop Assembly

The working part of the drop assembly is a tapered pressure activated firing head with an attached jet cutter (fig 3). Each firing head/jet cutter combination is specific to the intended seat where it is to land. Centralizers help the assembly through tool joints and jars while swab cups slow the descent rate or aid in pumping the assembly down as the situation warrants.

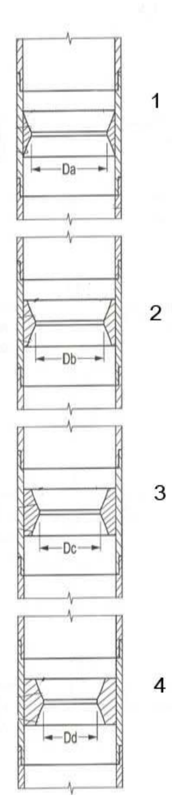


Fig1 Profiles in descending order

Fig 2 3 profiles in ascending depth order left to right

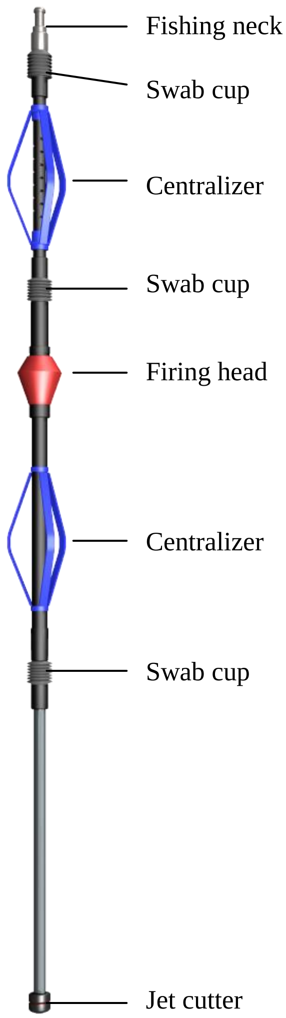


Fig 3 Drop assembly with tapered firing head

The Cutaway Sub

When the tapered firing head reaches the appropriate profile, the jet cutter is designed to be exactly opposite a sacrificial sub just below the seat sub.

The sacrificial sub is a cutaway sub (fig 4) where the jet cut will be made. The inner diameter of the Cutaway Sub is determined either by tool joint ID size or jar ID size, depending on its location in the drill string.

Its thickness is the maximum that a jet cutter is designed to cut given the ID restrictions of the string (fig 4a).

The net effect is a centralized jet cutter opposite a thickness that it was specifically designed to cut (fig 5).

fig 5 Typical jet cut

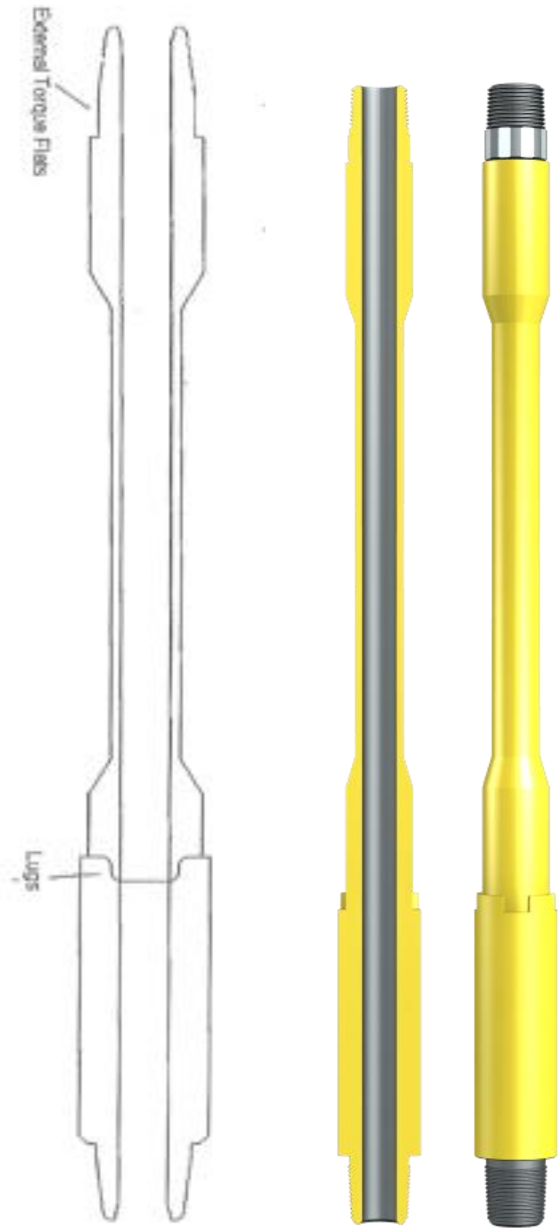


Fig 4 WIPR assembly Cutaway Sub

fig 4a Cutaway Sub and Profile Dimensions for Three Currently Available System Sizes

Depth	5 ¼"		7"		8 ¼"	
	Seat ID (in)	Cutaway Sub Wall Thickness (in)	Seat ID (in)	Cutaway Sub Wall Thickness(in)	Seat ID (in)	Cutaway Sub Wall Thickness (in)
Above Jars	2.3	.44	2.75	.50	3.00	.50
Below jars	2.12	.34	2.50	.44	2.90	.44
Above BHA	1.99	.34	2.30	.44	2.80	.44

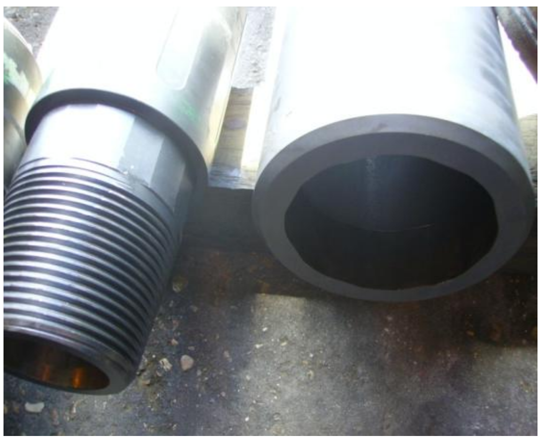


Fig 6 Top of cutaway sub and sleeve featuring machined flats

Fig 7 Bottom section of cutaway sub and sleeve featuring splines

Wireless Pipe Recovery Tension and Torque Allowables

System Size	5 ¼"	7"	8 ¼"
Max. Tension (lbs)	304313	561560	641474
Max. Torque-mandrel (ft-lbs)	17610	41788	45043
Max. Torque- sleeve (ft-lbs)	65975	139267	237061
Max. Corresponding Pipe Torque (lbs)	23100	59000	95500

Distributing Torque

The problem with the system described thus far is that it is relatively fragile in torque. Tension is not a problem as these subs are found deeper in the well and have plenty of tensile strength relative to the upper part of the string. In other words, the uphole string will part well before this sub lets go.

Flats and Splines

To address the torque issue, the Cutaway Sub has two additional design features. A series of flats are machined just below the upper threads, (fig 6) and a series of splines (fig 7) are machined below the neckdown section.

The Sleeve

As can be seen from the above charts, this cutaway sub has quite a bit of inherent strength in and of itself. Nevertheless, the torque numbers are not acceptable so a sleeve is added to the overall design to absorb all of the torque and essentially leave the cutaway sub in a torque neutral position.

The design of the sleeve is such that it slides over the designed flats at the top of the cutaway sub while simultaneously matching up to the splines machined in the lower part. It is held in place by the double-box seat sub which houses the profile into which the firing head lands. The sleeve transfers the torque from the Cutaway Sub so that the Cutaway Sub only has to sustain tension. The sleeve absorbs essentially all of the torque of the system (fig 8).

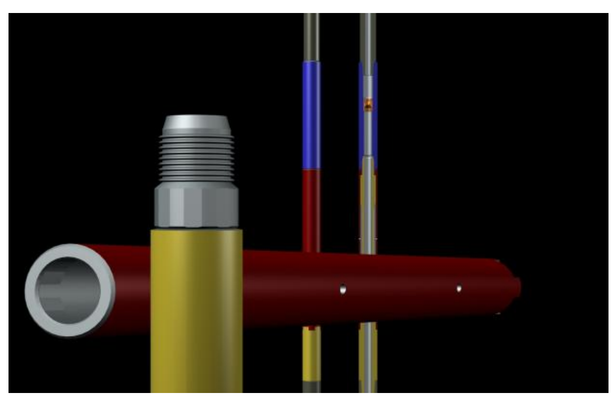


Fig 8 Flats and sleeve

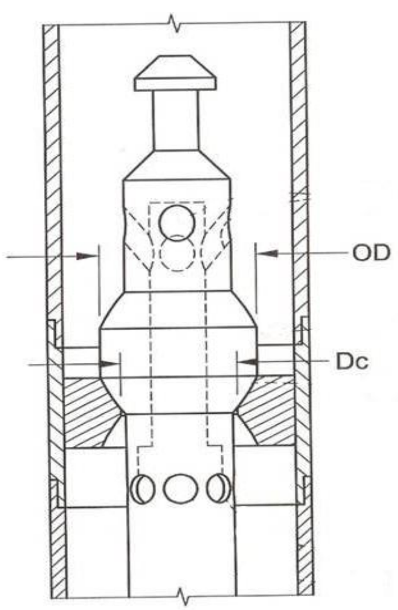
Firing Head

The tapered firing head is pressure activated and rated to 30kpsi (fig 9a). It is designed to withstand the impact of the landing into the profile or any potential jolts while descending. This is accomplished by the internals of the firing head unconventionally shifting up rather than down to release the firing pin. All the firing head moving parts rest on a shoulder until deployment so that a downward shock cannot initiate the system.

Additionally, the firing head is designed such that when fired, it shifts internally (fig 9b) creating a hydraulic connection between holes in the lower and holes in the upper part of the firing head. This allows fluid to drain naturally when the pipe is pulled with the firing head in place on the seat. It also allows fluid to be pumped from the surface through the firing head while it is on seat and into the hole below.

This feature allows immediate abandonment after the pipe is cut by pumping cement through the firing head. In situations where the operator has well control issues and is using the firing head as a temporary plug to guard against uncontrolled fluid loss, once the firing head is on seat the pipe above the firing head is filled with the desired mud and additives, and then the initiation of the firing head allows this fluid to be pumped through the firing head into the formation.

The drop assembly with which the firing head is deployed has a fishing neck to allow withdrawal of the firing head and drop assembly from the seat as necessary, should the operator decide to do so.



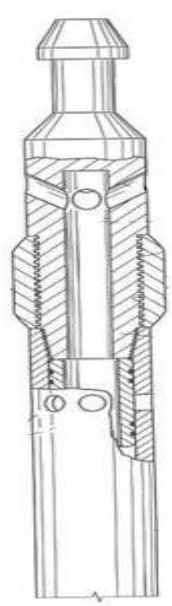


fig 9a Firing head landed in seat fig 9b shifted firing head

The System

The Seat Sub, Cutaway Sub and Sleeve are all pretorqued to pipe specs at the shop prior to transport to the rig. They are attached to a pair of handling subs so that the total shipped length is 30ft. This allows convenient handling at the rig and the ability to fit into the pipe rack without any issues.

The drop assembly, firing heads, explosives and all other necessary parts are stored on the rig and require minimal assembly in preparation for use. Reaction time to stuck pipe situations is almost immediate, so the situation can be resolved before the problem gets worse. The technician can be flown to location (or can remain aboard the rig as the operator chooses) and can assemble the drop assembly in less than an hour.

Once the drop assembly has been dropped or pumped into position and the firing head lands on seat, applied pressure initiates the system and the cutaway sub is cut by the jet cutter. The pipe is withdrawn leaving an easily fishable stub to retrieve if that is what the operator desires to do (fig 10).

The firing head is fully pinned when stored and pins are removed prior to use to achieve the desired firing pressure as calculated for the depth and mud weight used. The removed pins are stored so that the number of pins in the firing head can always be verified.

Provided the well has normal circulation, the firing head cannot be initiated unless it is on the seat as the firing pressure cannot be achieved otherwise.

The jet cutter design is intended to cut the Cutaway Sub not the actual pipe, therefore minimal damage to the pipe would be the most likely result of an improbable uphole initiation.

No pressure control is required beyond being able to drop or pump the drop assembly into position. In situations where the well has no circulation, a differential pressure firing head can be used.

The same delivery system can be used to set plugs into a designed space, perforate, sever the pipe or even run string shot (to be spaced out to the next connection).

In completion operations, the WIPR can be used to complement a right hand release to increase confidence in that system. It can also be run in situations where jars are impractical due to the delicate nature of the hardware being run below such as a screen.

The WIPR System Sequence (fig 10)

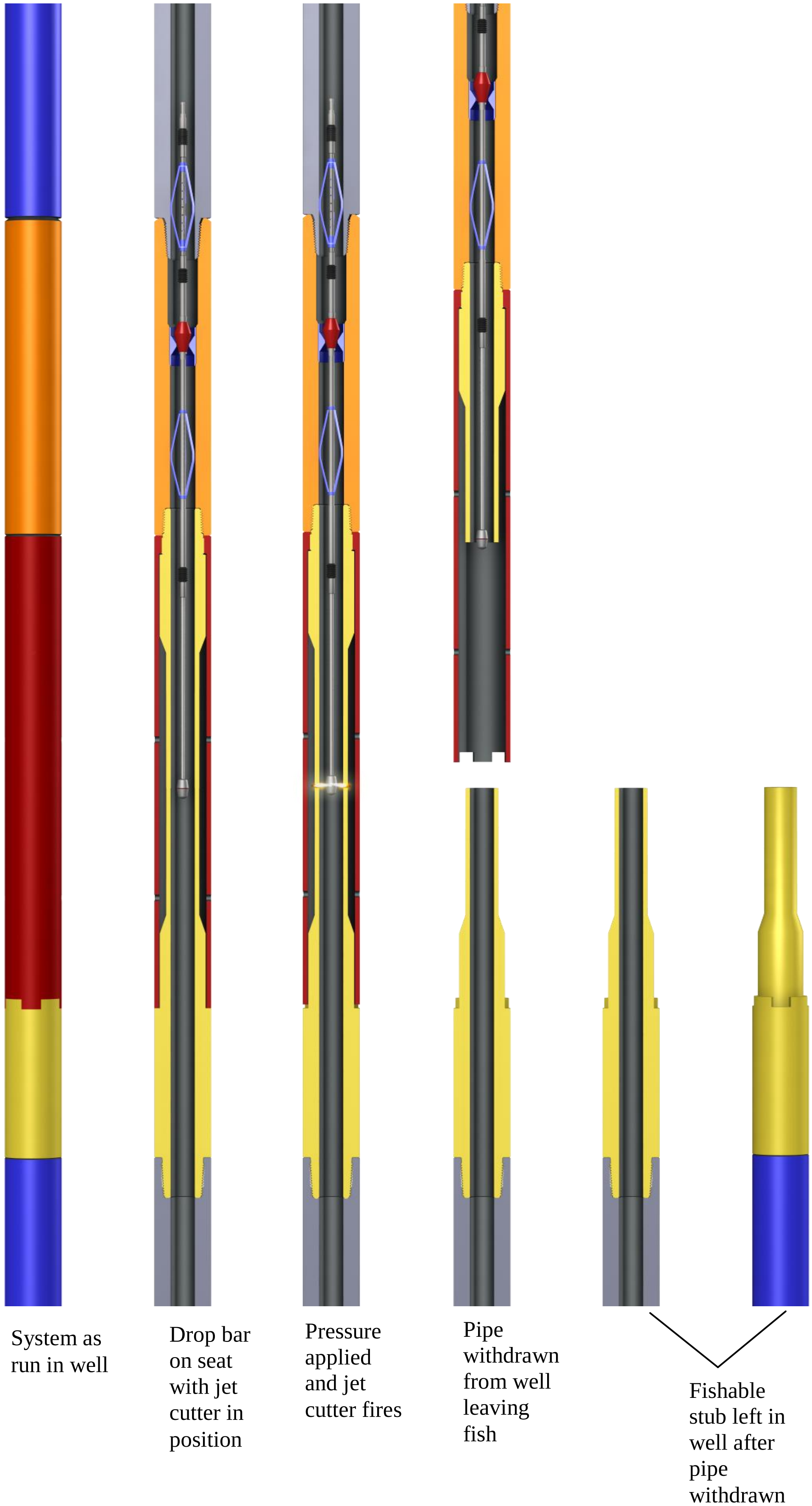


fig 11 The following is usage history for 2010 following the tool's introduction to the field in 4/10:

Field	Date	L/off/dw	WiPR Days	Drilling Time (Hours)	Subs
High Island #129	3/22/2010	offshore			
EI 95	4/23/2010	offshore	25 days	132.5	675-010,011,012/ 675-013,014,015/675-016,017,018
HI 129	4/26/2010	offshore	26 Days	138	675-001,001-1,001-2/675-022,002-1,002-2/675-003,003-1,003-2
HI 129	4/26/2010	offshore			
MC109	6/23/2010	Deep Water		n/a	700-028,029-030/700-031,032,033/700-034,035,036
VM 78	6/23/2010	Offshore	54.7 Days	290	700-019,020,021/700-022,023,024/700-025,026,027
VM 78	6/23/2010	Offshore			512-010,011,012/512-013,014,015/512-016,017,018
SMI 280	6/23/2010	Offshore	4 days	21.5	512-001,002,003/512-004,005,006/512-007,008,009
NW Myette Point	7/27/2010	inland			Never Used
Garden Banks 293	7/30/2010	deep water		n/a	700-028,029,030/700-031,032,033/7000-034,035,036
Ewing Banks	7/30/2010	offshore	28 days	150	700-019,020,021/700-022,023,024/700-025,026,027
Ewing Banks	8/13/2010				Lost Tools
EB 826	8/23/2010	offshore			
HI 129	8/30/2010	offshore	42 days	222.75	700-037,038,039/700-040,041,042/700-043,044,045
HI 129	8/30/2010	offshore			700-037,038,039/700-040,041,042/700-043,044,045
MC109	8/31/2010	Deep Water			512-013,014,015/512/016,017,018
EI 330	9/30/2010	offshore	19.5	103	700-028,029,030/700-031,032,033/700-034,035,036
Matagorda Isl 685	9/30/2010	offshore			700-046,047,048/700-049,050,051/700-052,053,054
MC 109	9/30/2010	dw	12 days	63	512-013.014,015/512-016,017,018
MC 109	9/30/2010	dw	20days	105	512-013,014,015/512,016,017,018
EI 330	10/23/2000	offshore	20days	105	700-028,029,030/700-031,032,033/700-034,035,036
Lake Pagie	10/28/2010	inland	11days	58	700-019,020,021/700-022,023,024/700-025,026,027
MC 109	10/28/2010	Deep Water	7days	37	512-013,014,015/512-016,017,018
MC 109	10/28/2010	Deep Water			Rental Basket Ticket
EI 330	10/28/2010	Offshore	5days	24	700-028,029,030/700-031,032,033/700-034,035,036
EI 330	10/28/2010	Offshore	4days	20	700-028,029,030/700-031.032,033/700-034,035,036
Matagorda 685	10/29/2010	Offshore	19days	100	512-019,020,021/512-022,023,024/512-025.026,027
Ship Shoal #259	10/29/2010	Offshore	6days	32	700-046,047,048/700-049,050,051/700-052,053,054
Matagorda 685	10/29/2010	Offshore	11days	59	700-037.038,039/700-040,041,042/700-043,044,045
SS 259	11/24/2010	offshore	22days	116	700-046,047,048/700-049,050,051/700-052,053,054
Miss Canyon 109	11/30/2010	offshore	28days	148	512-022,023,024/512-025,026,027
Matagorda Isl 623	11/30/2010	offshore	10days	53	700-037,038,039/700-040,041,042/700-043,044,045
Matagorda Isl. 623	12/30/2010	offshore	19 days	100.7	700-037,038,039,040,041,042,043,044,045
SS 259	12/31/2010	offshore	21 Days	111.3	700-046,047,048,049,050,051,052,053,054
Miss Canyon 109	12/31/2010	offshore	4 Days	21.2	512-067,068,069,070,071,072
Miss Canyon 109	12/31/2010	offshore	7 Days	37.1	700-019,020,021,022,023,024,025,026,027

Conclusions

In remote, expensive or difficult operating circumstances, new technology is being developed to address various drilling situations that do not require electric line, tongs or pressure control and can save significant reaction time for the operator.

It is now possible to recover stuck drill pipe, set a plug in a designed space, or perform any number of other functions initiated by a pressure activated firing head without the use of electric line.

There are several completion related applications as well. The WIPR is an alternative to a right-hand release, or a way to recover delicate screens or other hardware where jars are not a viable option.

In well control situations, just landing the drop assembly on a seat can temporarily stop severe fluid loss while the operator has a chance to catch up with the situation and pump lost circulation material through the firing head.

The technology is evolving daily and has future capabilities in both drilling and completion situations that have not yet recognized.

The table above (fig 11) gives the tools usage history since its introduction in April of 2010 and the tables (figs 11a, b, c) below are the engineering tension and torque analyses for the 3 most common size systems.

Nomenclature

OD = Outer diameter

ID = Inner diameter

POOH = Pull out of hole

Appendix

<u>Wireless Pipe Recovery 5 ¼" System fig 11a</u>

WIRELESS PIPE RECOVERY SYSTEM TENSION & TORQUE ANALYSIS 4/20/2010

5.25" OD THIRD GENERATION

DRAWING 109-551 REV A

Design factor 1

CALCULATION OF MAXIMUM ALLOWABLE INDIVIDUAL LOADS:

	TOP SUB				MANDREL								SLEEVE				MANDREL TO	
Section Location	1A	1B	1C	1D	2A	2B	2C	2D	2E	2F-slotted	2G	2H	3A	3B	3C	3D-slotted	SLEEVE FLATS	
Material yield (psi)	110000				110000								110000					
OD (in)	5.25	5.25	5.25	5.25	3.27	3.8	4.38	2.93	4.38	5.25	5.25	3.27	5.25	5.25	5.25	5.25		
ID (in)	4.5	3	2.75	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	3.81	4.425	4.4	4.425		
Area (sq in)	5.74	14.58	15.71	17.67	4.42	7.37	11.09	2.77	11.09	14.36	17.67	4.42	10.52	6.27	6.44	1.55		
Polar moment of inertia (in^4)	34.32	66.63	68.97	72.07	8.71	17.95	33.62	4.72	33.62	72.07	72.07	8.71	53.90	36.94	37.79	18.47		
Radius of gyration (in)	2.44	2.14	2.10	2.02	1.40	1.56	1.74	1.31	1.74	2.24	2.02	1.40	2.26	2.43	2.42	3.45		
	Ratings below from Grant Prideco				Ratings below from Grant Prideco							Ratings below from Grant Prideco						
Allowable tension (lbs)	725000	1603685	1727876	1943860	725000	810158	1220045	304314	1220045	1579600	1943860	725000	N/A	N/A	N/A	N/A		
Allowable torsion (ft lbs)	23100	116339	120420	125830	23100	43312	70354	17610	70354	125830	125830	23100	94103	64502	65975	32251	2846	From FEA

Minimum tension from above	304314
Minimum torsion from above	17610

CALCULATION OF ALLOWABLE COMBINED LOADING:

Assumed tension load (lbs)	0	25000	50000	75000	100000	125000	150000	175000	200000	300000
Tension stress (psi)	0	9037	18073	27110	36147	45184	54220	63257	72294	108441
Allowable torsion stress (psi)	63509	63294	62645	61550	59982	57903	55257	51957	47866	10655
Mandrel allow torque (ft lbs)	17706	17655	17500	17238	16864	16367	15735	14946	13969	5078

CALCULATION OF COMPRESSIVE STRENGTH

Length of tool (in)	96
Min radius of gyration (in)	1.310
Ratio L/r	73
Critical buckling stress (psi)	53296
Critical buckling force (lbs)	392532

Wireless Pipe Recovery 7" System fig 11b

WIRELESS PIPE RECOVERY SYSTEM TENSION & TORQUE ANALYSIS 4/20/2010
7" OD THIRD GENERATION
DRAWING 109-545 REV A

Design factor 1

CALCULATION OF MAXIMUM ALLOWABLE INDIVIDUAL LOADS:

	TOP SUB				MANDREL								SLEEVE				MANDREL TO SLEEVE FLATS	
Section Location	1A	1B	1C	1D	2A	2B	2C	2D	2E	2F-slotted	2G	2H	3A	3B	3C	3D-slotted		
Material yield (psi)	110000				110000								110000					
OD (in)	7	7	7	7	4.5	5.25	6	3.75	6	7	7	4.5	7	7	7	7		
ID (in)	4.5	4	3.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	5.26	6.125	6.025	6.125		
Area (sq in)	22.58	25.92	27.44	32.54	9.96	15.71	22.33	5.11	22.33	27.43	32.54	9.96	17.04	9.02	9.97	2.25		
Polar moment of inertia (in^4)	195.46	210.58	216.30	230.10	34.64	68.97	121.62	13.80	121.62	230.10	230.10	34.64	160.57	97.54	106.35	48.77		
Radius of gyration (in)	2.94	2.85	2.81	2.66	1.86	2.10	2.33	1.64	2.33	2.90	2.66	1.86	3.07	3.29	3.27	4.66		
	Ratings below from Grant Prideco				Ratings below from Grant Prideco							Ratings below from Grant Prideco						
Allowable tension (lbs)	1422400	2850995	3018383	3579943	1422400	1727876	2456824	561560	2456824	3017300	3579943	1422400	N/A	N/A	N/A	N/A		
Allowable torsion (ft lbs)	59000	275766	283254	301325	59000	120420	185808	41788	185808	301325	301325	59000	210264	127737	139267	63868	8056	From FEA

Minimum tension from above 561560
Minimum torsion from above 41788

CALCULATION OF ALLOWABLE COMBINED LOADING:

Assumed tension load (lbs)	0	25000	50000	75000	100000	125000	150000	175000	200000	300000	400000	500000	561000
Tension stress (psi)	0	4897	9794	14691	19588	24485	29382	34280	39177	58765	78353	97942	109890
Allowable torsion stress (psi)	63509	63446	63256	62940	62493	61915	61201	60346	59344	53686	44575	28911	2835
Mandrel allow torque (ft lbs)	41836	41802	41698	41525	41282	40966	40576	40110	39563	36474	31501	22950	8717

CALCULATION OF COMPRESSIVE STRENGTH

Length of tool (in)	96
Min radius of gyration (in)	1.640
Ratio L/r	59
Critical buckling stress (psi)	83530
Critical buckling force (lbs)	1312088

Wireless Pipe Recovery 8 1/4" System fig 11c

WIRELESS PIPE RECOVERY SYSTEM TENSION & TORQUE ANALYSIS 01/06/11
8.25" OD BOTTOM WIPER, DRAWING 109-865 Rev A REV: A
SRC 10-1639
Design factor 1

CALCULATION OF MAXIMUM ALLOWABLE INDIVIDUAL LOADS:

	TOP SUB					MANDREL							SLEEVE		
Section Location	1A	1B	1C	1D	1E	2A	2B	2C	2D	2E	2F	2G	3A	3B	3C
Material yield (psi)	110000					110000							110000		
OD (in)	8.245	8.245	8.245	8.245	8.245		5.775	3.995	6.995	8.245	8.245		8.245	8.245	8.245
ID (in)	4	4.005	3.755	3.005		3.005	3.005	3.005	3.005	3.005	3.005	3.005	5.954	7.035	7.035
Area (sq in)		40.79	42.32	46.30			19.10	5.44	31.34	38.82	46.30		25.55	14.52	7.26
Polar moment of inertia (in^4)	6 5/8 FH	428.43	434.18	445.69	HT55	HT55	101.19	17.00	227.04	445.69	445.69	6 5/8 FH	330.32	213.23	106.61
Radius of gyration (in)	Reg Box	3.24	3.20	3.10	Box	Pin	2.30	1.77	2.69	3.39	3.10	Reg Pin	3.60	3.83	3.83
Allowable tension (lbs)	2105300	4487294	4654898	5092914	1765100	1765100	2101149	598709	3447113	4269650	5092914	2105300	N/A	N/A	N/A
Allowable torsion (ft lbs)	99500	476327	482710	495509	95500	95500	160621	39012	297526	495509	495509	99500	367241	237061	118531
								see combined		slotted					slotted
combined torsion 2C+3C	157542														

Minimum tension from above	598709
Minimum torsion from above	95500

CALCULATION OF ALLOWABLE COMBINED LOADING:

Assumed tension load (lbs)	0	50000	100000	200000	300000	400000	500000	598700
Tension stress (psi)	0	9186	18373	36746	55119	73491	91864	109998
Allowable torsion stress (psi)	63509	63287	62616	59860	54960	47255	34933	349
Mandrel allow torque (ft lbs)	95500	95166	94158	90014	82646	71058	52530	524

CALCULATION OF COMPRESSIVE STRENGTH

Length of tool (in)	105
Min radius of gyration (in)	1.767
Ratio L/r	59
Critical buckling stress (psi)	81670
Critical buckling force (lbs)	1560007

* Calculated from: Polar Moment=pi/32 * (OD^4-ID^4)
** Calculated from: Rad of Gyration=sqrt(Polar Moment/Area)
*** Calculated from: Tension=Material Yield * Area
**** Calculated from: Torsion=Material Yield/2*Polar Moment of Inertia/(OD/2)/12