Coiled Tubing string Fatigue Management in High Pressure Milling Operation- Case Study

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Abstract:

Increasing life of coiled tubing string to prevent any failure and economically extend and optimize its usage is important in pipe management practices.

There were some problems about annulus pressure of high pressure gas wells in offshore platform. Some wells' annulus pressure after completion, perforation and well flow raised up. In order to prohibit formation damage for new work over operations, the 7" SVCR drillable bridge plug installed in top of liner and then the completion string retrieved from well. After pull out of completion and running new production string in the well, the plug planned to be milled. Milling the bridge plug using snubbing unit was in schedule, but due to logistic problem plan had been changed to milling using coiled tubing.

Milling operation with coiled tubing requires high pressure pumping which this pumping has an improper effect on the pipe life. Having fatigue spikes in special depth of coiled tubing string and repeating operation in target depth was the concern of this kind of operation. So fatigue management of coiled tubing string has to be considered to do the job, keep the operation safe and save the extra costs in offshore operation.

This paper will share the journey and lessons learnt of this project starting from assessment, planning to execution phase. The experiences gained during this project will be valuable input for milling operations for other wells of this gas field in terms of safety, performance, and reliability and cost saving.

Keywords: ***coiled tubing, string, fatigue, milling, plug***

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Introduction:

Coiled tubing services were provided for a large scale gas project in the South Pars gas field in Persian Gulf, Iran. The coiled tubing unit (CTU) was utilized on the project for a wide variety of job types; however, the bulk of the CTU work consisted of milling out bridge plugs after plug and perforation operations.

CT string management, including string design, fatigue tracking and management, and pipe life forecasting, was one of the main concerns of coiled tubing service provider. The financial benefit to the service company was directly linked to the life span of the coiled tubing strings, and running meters was used as criteria to judge the performance due to a lot of coiled tubing accidents and huge cost for supplying coiled tubing strings

The main challenge which the coiled tubing service company faced was maximizing running meters during bridge plug milling operation. The string was operated in a high pressure environment and allowable trips in target depths with high pressure conditions were limited. Focusing on string design and fatigue management was critical for improved performance and increased economic benefit.

Statement of Theory and Definitions:

Real time force monitoring is very important for fatigue management in coiled tubing operations. Monitoring the used life of CTU string versus length of string, we can find out about fatigue spikes and none homogeneous used life via string length.

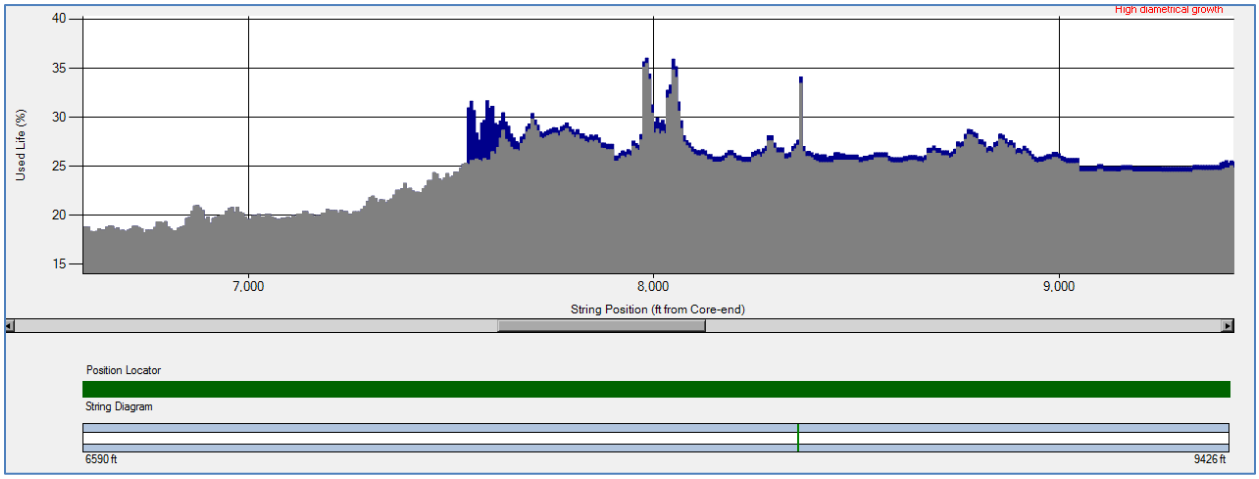

Figure 1- Effect of First Milling Run on Coiled Tubing String Used Life

Milling Using Coiled Tubing Unit:

Coiled Tubing Milling can provide significant economic benefits when applied in the proper field setting. In addition to potential cost advantages, it can provide other benefits: safer and more efficient pressure control, faster tripping time, smaller footprint and weight, faster rig-up and rig-down, reduced environment impact, operations with fewer personnel, and high-speed telemetry.

There are some factors which have to be considered for a successful milling operation;

- Pumping Rate
- Pumping Pressure
- Torsional Yield Strength of coiled tubing string
- Weight
- Coiled Tubing Pipe Load Body Yield
- Solid Transportation

Milling bridge plug in 7" liner is performed with many companies all around the world, but the common specification for these kind of operations is as below;

- 2-7/8" Positive Displacement Motor, PDM.
- 2"-2-3/8" OD Coiled Tubing String

There was another concern about number of trips in specific depth with specific circulating pressure. Based on simulation results for current 1.75" OD, 0.145" wall thickness HS-80 CT string, 18 trips estimated before 80% fatigue safety limit reached based on working pressure 5,500 psi and depth of 2,700 m.

So number of trips with high circulating pressure has to be monitored to avoid extra run in target depth and the fatigue spike has to be shifted in next operation.

The life of coiled tubing has a reverse relation with pressure, as you can see the predicted life vs. pressure curve for HS-80, 1.75" coiled tubing string in below photo.

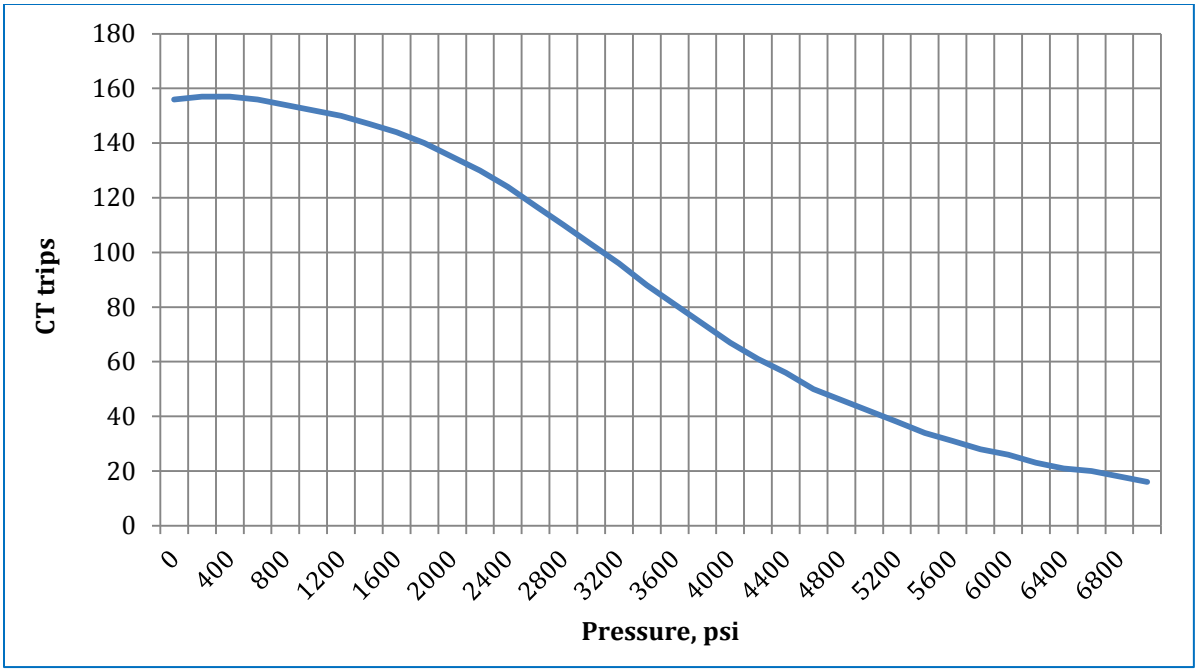

Figure 2- Predicted Life vs Pressure for HS-80, 1.75" OD, 0.145" thickness Coiled Tubing String

Description and Application of Equipment and Processes:

The concern of operation was using 1-3/4" coiled tubing string with 2-7/8" positive displacement motor which it requires at least 60 GPM circulating fluid to have a good performance to mill a 7" SVCR drillable bridge plug at depth of 2,721 m RKB in one of gas wells in offshore platform in South Pars gas field, Persian Gulf. So higher circulating pressure was needed in respect to conventional coiled tubing operations.

The well was with 7" Monobore completion system, 10561 ft total depth, 9920.38 ft true vertical depth and maximum inclination of 27.04^{o} (Figure No.3- Deviation Survey, Figure No.4- Completion Schematic).

The coiled tubing injector head with 80Klbf pulling force and HS-80, 1-3/4" outside diameter string and 0.145" wall thickness (Table 1- Coiled Tubing String Specifications) has been mobilized for milling operation.

There were two scenarios for bottomhole assembly, one for milling (Table 2) and second one for Venturi Junk Basket (Table 3).

The main concern for coiled tubing milling is proper flow rate to get the maximum output of the PDM. So we tried to find the optimum parameters with the available equipment and rates. However while operation different data has been recorded and using PDM Dyno tester data lead

to onsite modification, we have decided to use 65 GPM rate to obtain a minimum possible performance.

The Pumping pressure is next concern which has a direct relation with pumping rate. The higher the working pressure, the lower the life of 1.75" CT string. A little increase in pumping rate requires exponential pumping pressure increase.

There was a concern of solid transportation while milling, but with 4,700 psi reservoir pressure and previous production flowrate of 80MM SCF/D, the fluid velocity after performing successful milling operation was around 4,300 ft/sec and well production could handle solid transportation to surface.

Presentation of Data and Results:

The cementing unit over pressure shut down has been set on 5,000 psi to control sudden pressure increase and working in safe side.

The working pressure of PDM for 65 GPM pumping rate was around 3,500-3,900 psi and had a 150-300 psi differential pressure. So we have tried to keep these operational parameters and prevent reaching PDM stall pressure.

Conclusions:

- ✓ To be sure about a clean target for milling we recommend to run Venturi junk basket tool with coiled tubing before milling run. In current case too much junk was on top of plug due to completion and work over operations.
- ✓ As the higher pressure increases the used life of CT string exponentially, and in milling operation the depth variation is in small interval, so the fatigue of that depth of CT string have to be controlled and after allowable number of trips before 80% fatigue safety limit reaches, the string POOH and 5-10 meter of it have to be cut. This helps to shift the fatigue on the string uniformly.

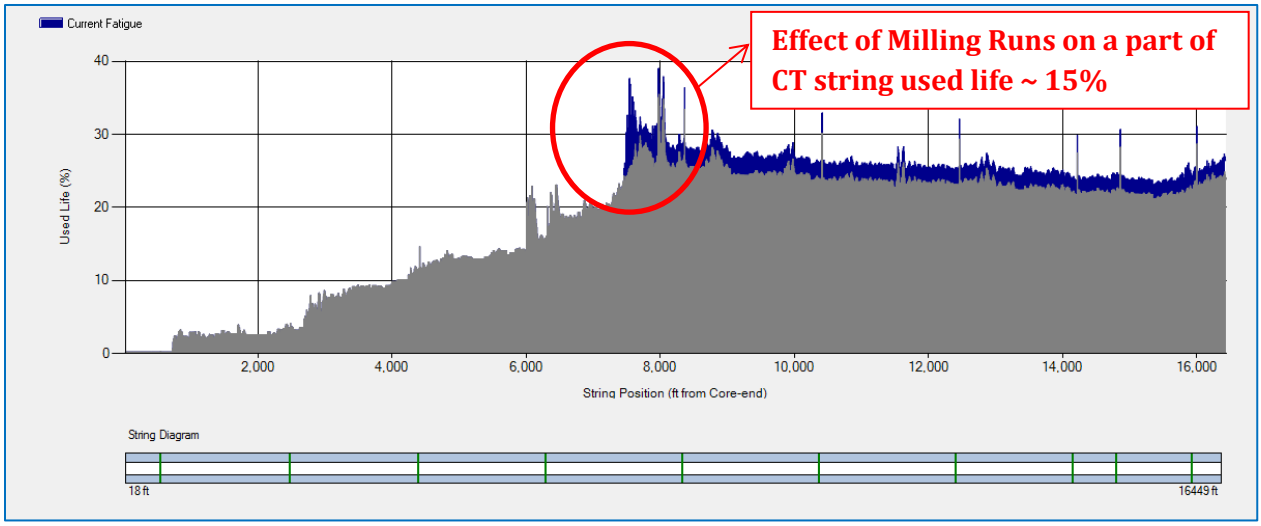

Figure 3- Effevt of milling runs on a part of CT string used life

- ✓ Using Cement pump unit with accurate controlling equipment unit for milling operation on any rig. Because using controlled rate and pressure setting for shut down the pump higher than limitation pressure is highly recommended.
- ✓ Analysis of operation data shows that the optimum pumping rate and pressure for milling was 1 bpm.

References:

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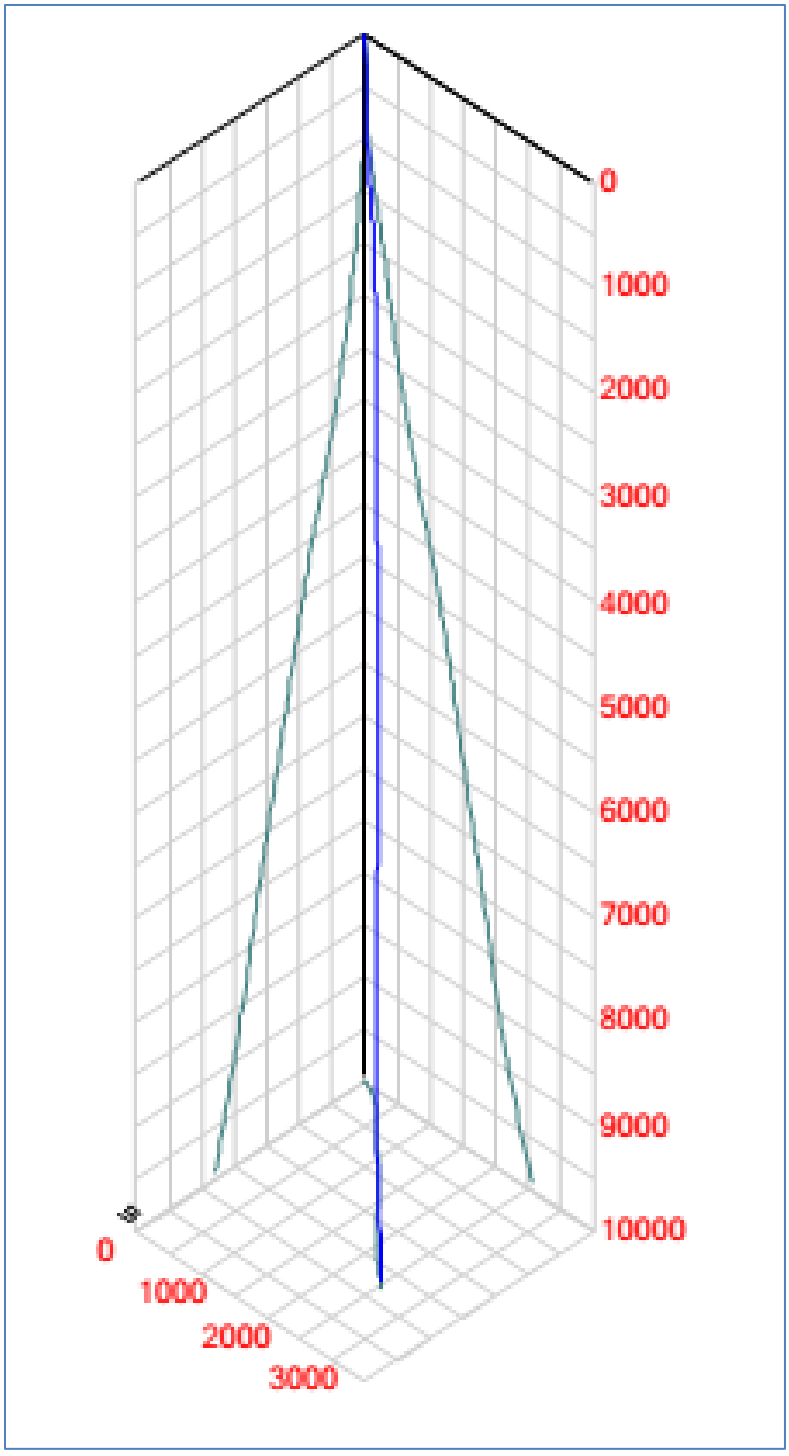
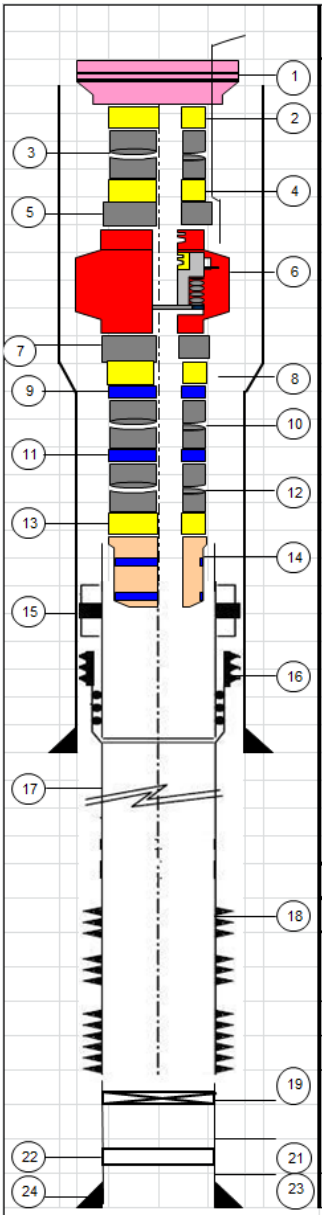


Figure 4- Deviation Survey



Item	Description	Length (m)	Top Depth (m MD)	Drift ID (inch)	OD (inch)
0	Elevation RT- Top Hanger	0.00	18.56		
1	7" Nipple & Tubing Hanger FMC Inconel 718	1.41	18.56	6.125	13.248
2	One Pup Jnt 7" Vam Top HC 26#, SM2535-110	2.42	19.97	6.151	7.565
3	Tubing 7" Vam Top HC 26#, SM2535-110 (13 Jnt)	146.26	22.39	6.151	7.565
4	Pup Jnt 7" Vam Top HC 26#, SM2535-110	3.13	168.65	6.151	7.565
5	Flow Coupling 7" Vam Top HC, Mat: Incoloy Alloy 925	1.71	171.78	6.151	7.565
6	DHSV 7" Baker TSM-8, Mat: Inconel 718	2.34	173.49	6.000	9.300
7	Flow Coupling 7" Vam Top HC, Mat: Incoloy Alloy 925	1.71	175.83	6.151	7.565
8	Pup Jnt 7" Vam Top HC 26#, SM2535-110	1.77	177.54		
9	X-Over 7" Vam Top 23# Pin × 7" Vam Top HC 26# Box	0.85	179.31	6.151	7.000
10	Tubing 7" Vam Top 23#, SM2535-110 (185 Jnt)	2033.86	180.16	6.241	7.488
11	X-Over 7" Vam Top HC 26# Pin × 7" Vam Top 23# Box	0.87	2214.02	6.151	7.000
12	Tubing 7" Vam Top HC 26#, SM2535-110 (33Jnt)	358.91	2214.89	6.151	7.656
13	Pup Jnt 7" Vam Top HC 26#, SM2535-110	2.42	2573.80	6.151	7.656
14	SISOSR Seal Assembly w/Anchore Latch (CTR)	1.05	2576.22	6.000	7.256
15*	Liner Tie-Back Pakcer, CTR w/Upper PBR & Lower Seal Stem	6.13	2577.27	6.000	8.353
16**	Liner Hanger, CTR w/Lower PBR	4.56	2583.40	7.264	8.353
17	Liner 7" Vam Top 26#, SM2535-110 (16 Jnt)	170.89	2587.96	6.151	7.565
18	Liner 7" Vam Top 26#, L-80, 13% Cr (34 Jnt)	418.39	2758.84	6.151	7.565
19	Landing Collar, LDC	0.33	3177.23	----------	----------
20	Liner 7" Vam Top 26#, L-80, 13% Cr (2 Jnt) (Float Jnt)	25.49	3177.56	6.151	7.565
21	Float Collar	0.33	3203.05	----------	----------
22	Liner 7" Vam Top 26#, L-80, 13% Cr (1 Jnt)	12.67	3203.38	6.151	7.565
23	Shoe	0.94	3216.06		
25	Bottom of Shoe		3217.00		

Perforation

Formation	Depth (m BRT)		Thickness	Guns	Remarks
	From	To			
K1	2,782	2,822	40	3 3/8 HMX 6 SPF	
K2	2,861	2,900	39	3 3/8 HMX 6 SPF	
K3	2,910	2,953	43	3 3/8 HMX 6 SPF	
	2,981	2,996	15		
	3,026	3,038	12		
K4 (Gas Zone)	3,040	3,172	132	3 3/8 HMX 6 SPF	

NOTE:

Item	Description	Length (m)	ID (inch)	OD (inch)
15* (1)	CTR Upper PBR, Mat: Sanicro 28	4.80	7.264	8.353
15* (2)	CTR Liner Tie-Back Packer, Mat: Sanicro 28	1.44	6.055	8.353
15* (3)	CTR Lower Seal Stem, Mat: Sanicro 28	2.29	6.000	7.256
16** (1)	CTR 8.353" Hydraulic Pocket Slips Liner Hanger, Mat: AISI 4145	0.91	7.343	8.353
16** (2)	CTR 7.291" Lower PBR, Mat: Sanicro 28	2.05	7.264	8.353

Figure 5- Completion Schematic

Table 1- Coiled Tubing String Specifications

Outside Diameter (in)	Wall Thickness (in)	Inside Diameter (in)	Nominal Weight (lb/ft)	Pipe Metal Cross sectional Area (in^2)
1.75	0.145	1.46	2.492	0.699
Pipe Load Body Yield Minimum (lb)	**Pipe Load Body Tensile Minimum (lb)**	**Internal Yield Minimum (psi)**	**Internal Hydro Test Pressure (psi)**	**Torsional Yield Strength (ft.lb)**
58,500	64,300	12,400	11,200	2,011

Table 2- BHA No. 1- Milling Bottom hole Assembly

Item	Description	OD	Length, m	End Connection
1	CT Dimple Connector	2.875”	0.24	2-3/8” PAC PIN
2	MOTOR-HEAD ASSEMBLY	2.875”	0.91	2-3/8” PAC BOX-PIN
3	NON-ROTATING STABILIZER C/W SLEEVE	4.5”	0.46	2-3/8” PAC BOX-PIN
4	Well Explorer Alfa	2.875”	0.60	
5	HIGH TORQUE DRILL MOTOR	2.875”	4.20	2-3/8” PAC BOX-BOX
67	BLADED INSERTED CARBIDE MILL	4.875”	0.30	2-3/8” PAC PIN

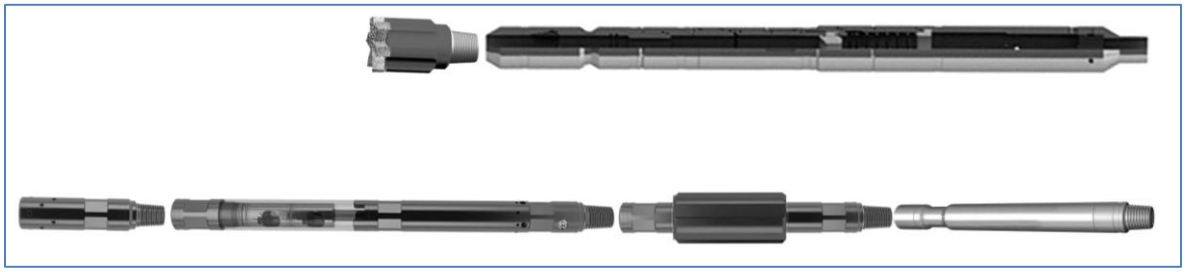


Figure 6- Milling BHA

Table 3- BHA No2- Venturi Junk BAsket

Item	Description	OD	Length, m	End Connection
1	CT Dimple Connector	2.875”	0.24	2-3/8” PAC PIN
2	MOTOR-HEAD ASSEMBLY	2.875”	0.91	2-3/8” PAC BOX-PIN
3	NON-ROTATING STABILIZER C/W SLEEVE	5.500”	0.46	2-3/8” PAC BOX-PIN
4	CROSSOVER	2.875”	0.30	2-3/8” PAC BOX-BOX
5	VENTURI JET JUNK BASKET	3.125”	1.34	2-3/8” PAC PIN