Cable Injector & Wireline Spooling Unit Operating Manual

Version 4

10,000 psi Working Pressure

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Chapter 1
Introduction

This chapter describes the background behind the development of the cable injector and its components.

Safety Guidelines

Lifting

During assembly, operation and maintenance of the cable injector system, various lifting operations are required. Always ensure that lifting slings and lifting equipment used are suitable for the loads being lifted. Inspect all lifting gear prior to use. Avoid working under suspended loads.

Pressure

Pressures observed during installation and removal of cables will vary depending upon a number of parameters including coiled tubing size and length, cable type and size, fluid temperature and pump rate. Observe all pumping safety guidelines developed under your Company Safety Policy.

Ensure that all treating iron used in the rig up is rated to the pressures expected during cable installation or removal. If possible do not use flexible hoses for high pressure treating fluids except on return lines where pressures are low.

Rotating Equipment

During operation, the cable injector itself has no exposed rotating components.

Do not operate the wireline spooling unit with the chain guard removed from the drive assembly. The drum of cable rotates as the cable is fed into the cable injector. It is not practical to place a full guard around the cable drum so ensure that prior to commencing operations, the immediate area around the wireline spooling unit and to the cable injector is cordoned off in order to control access to the area. If operating at night, ensure that satisfactory lighting is available.

Under no circumstances hold onto the cable at any point as it is being injected or removed. Normally cable removal from the cable drum will be smooth but occasional changes in cable velocity can result in the cable jerking. When spooling cable onto the cable drum during a cable removal operation, more jerking may be observed as it is not possible to re-spool the cable back onto the drum as neatly as is done at the cable manufacturers or cable service centers.

Background

The CTES cable injector was developed as part of a Joint Industry Project (JIP). Participants in the JIP were:

- Atlas Wireline
- Schlumberger - Dowell
- Halliburton
- Nowsco Well Service (now BJ Services)
- Quality Tubing
- Precision Tube Technology

CTES was limited to selling the cable injector to participants in the JIP until the beginning of the year 2000. After that time, the cable injector is openly available.

Coiled Tubing (CT) logging technology was first developed in 1987. Without a cable injector, wireline cables are installed inside of CT by either hanging the CT in a well and dropping the cable in or laying the CT out straight and pumping the cable through. The total cost of one of these installations is typically in excess of $20,000. This high installation cost has hampered the growth of the CT with wireline telemetry industry by making it uneconomical in some markets.

Tests showed that it would be possible to pump a cable into and out of a reel. However, this process required inserting the cable into the flow of water by pushing it through a seal or “stuffing box” against the pump pressure. A “cable injector” was needed to pull the cable through the stuffing box.

To get cable moving inside CT on the reel, the water must flow fast enough to become turbulent. The turbulence makes the cable flutter, which reduces frictional drag between the cable and the CT. The water flowing past the cable causes viscous shear drag on the cable. As long as the viscous shear drag is greater than the frictional drag against the CT, the cable will continue to flutter and move through the tubing. During a cable installation, the cable fluttering inside the CT is quite audible. Note that a plastic-coated cable is injected and removed much more easily than a conventional cable.

Configurations

The cable injection system can be provided in 2 basic configurations. These are:

1. Certified version without hoist (see *Figure 1*)
2. Non-certified version with hoist (see *Figure 2*)

Grease Control Head

During an installation, the cable unwraps from the spool and enters the grease control head, sometimes referred to as a “stuffing box”. The item is a standard Texas Oil Tools Grease Injection Head #DG43 (see enclosed TOT operations manual). Water and cable go through a pack off assembly and three flow tubes with close tolerance. The purpose of the grease control head is to seal around the cable going into the cable injector. Accordingly, the element in the pack off and the flow tubes must be sized to the cable being injected. Details of these requirements are shown in the TOT manual. Never use parts that are too small for the cable being injected as the cable could be permanently damaged.

The TOT manual 1031 A found in section 5 of this cable injector manual specifies flow tubes with the internal diameter sized to 0.005" greater than the cable diameter. This size requirement is critical when the injector control head is being used for running wireline into wells. However, when the control head is used with a cable injector the size is not as critical. Cable installations have been performed with the internal diameter of the flow tubes as large as 0.050" greater than the cable diameter. A larger clearance makes it easier to install the cable through the flow tubes. The leakage of water through the control head and back to the tank is increased, so the pump flowrate must be increased.

The grease control head was designed to operate with high pressure grease when used when running wireline into wells. High pressure grease is used to form a seal and prevent any of the well hydrocarbons from leaking. However, in the case of a cable installation, the only fluid being used is water. So high pressure grease is not needed. In fact, using high pressure grease is not recommended because it coats the cable with grease and makes it more difficult for the capstan to pull. Instead of using grease, the water that flows through the flow tubes is returned to the tank through a hose.

There is a fluid return between the pack-off assembly and the first flow tube (see *Figure 3*). With uncoated cable, about 10% of the water pumped returns to the fluid tank. The water flows through the channels in the armor wires on the cable. However, this return is negligible for plastic coated cable.

The grease control head is not required during cable removal as it is at the low pressure side of the system (the fluid enters the other end of the reel) but it remains in place in order to prevent too much fluid being lost during the cable removal.

Note that at the time of publishing this manual, the largest size cable that can be used with the TOT DG43 grease control head is 0.42”. A revised version of the tool is being designed that will allow cables up to 0.46” to be

installed. It is possible that the design could be further revised to allow slightly larger cables to pass but the pressure rating of the system would need to be reduced to 7500 psi. Please contact CTES if larger sizes are required.

Capstan

The purpose of the capstan is to pull the cable through the stuffing box. The capstan is a rotating wheel powered by a hydraulic motor (see *Figure 4*). The cable wraps around the capstan six times. The capstan is a tension multiplier, converting the small viscous shear drag against the cable inside the CT into a much larger tension acting on the cable in the stuffing box.

During cable removal, the capstan spins freely, acting as a buffer between the CT and wireline cable spool. It is possible to remove a cable without using the capstan, but the cable will come out erratically. Using the capstan makes spooling the cable much easier.

Capstan Theory

The tension amplification caused by the rotating wheel or capstan is referred to as the “capstan effect”. The capstan amplification is a function of the friction between the cable and the wheel, and the number of degrees of revolution the cable makes around the wheel.

The capstan amplification effect is expressed by the following equation:

$$\frac{T_{output}}{T_{input}} = e^{\beta\mu}$$

Where:

T_{output} = Tension on cable after amplification
T_{input} = Tension on cable before amplification
ß = Number of wraps multiplied by 2 radians
μ = Friction coefficient between cable and wheel

Cable Accelerator

As explained above, the capstan is a tension multiplier. It requires sufficient input tension (tension on the CT side of the cable injector) to multiply to obtain the required output tension to pull the cable through the stuffing box (grease injection head). In some cases, the input tension created by pumping the cable through the reel is not sufficient. In that case, the “Cable Accelerator” creates a small input force (on the order of one to two

pounds). The accelerator consists of a flow tube with a larger diameter than the flow tubes in the stuffing box (see *Figure 5*). This flow tube is in-line between the capstan and the CT. It is between two laterals connected to the pump truck. The connection after the flow tube has a choke valve in line. Under normal operating conditions, the choke valve is open to bypass water around the flow tube. If the cable stops moving, the operator can send more water through the flow tube by partially closing the choke. The increased velocity through the flow tube creates enough viscous drag to pull on the cable, giving the capstan enough pre-tension to work. A cable injection can be performed without using the cable accelerator. However, if the cable gets stuck, starting it moving again will be difficult. CTES highly recommends using the cable accelerator during a cable injection.

The accelerator is not needed during a cable removal, but it can remain in place.

Wireline Spooling Unit

Cable can develop residual torque (twist) with normal use and then tends to untwist or bird nest. Bird nesting during a cable installation will cause the installation to fail, and may permanently damage the cable. The residual torque stored in the cable must be removed ahead of the stuffing box to prevent bird nesting. Even new or “normalized” (torque has been removed) used cable can create this problem when fed directly into the cable injector. A Wireline Spooling Unit is necessary to perform reliable cable injections (see *Figure 7*).

A Wireline Spooling Unit provides a means to unspool cable from and spool cable onto a cable drum. The spool axis is generally mounted in the horizontal direction. To be able to remove residual torque, the entire cable drum must be able to be rotated about the vertical axis. A sheave system must be present to allow for this rotation. A brake must be present to control spool acceleration as cable is being spooled off the real. To reel cable in, a drive system must be present.

For new cable, the cable drum may or may not need to be counter rotated (rotated in a direction opposite that of the residual torque) a few times. For used cable, it is expected that the cable drum will have to be counter rotated a number of times. One method of deciding when to rotate the cable drum is to mark the cable where it leaves the spooling unit with a grease stick. The mark is then followed, counting the number of times it rotates, until it enters the Grease Injection Head. As a general rule, if it rotates more than one and a half turns (1½), counter rotate the cable drum once. It will be necessary to check used cable more frequently than new cable.

CTES has designed and manufactures a Wireline Spooling Unit for use with the Cable Injector (see *Figure 6*). The cable drum mounts on a hori-

zontal axle supported inside a Y-shaped yoke with the base of the Y pointing down. The yoke is free to rotate about its vertical base.

If cable torque is not thought to be an issue, the cable can be run directly from the cable drum, under a sheave wheel on a manually operated level wind mechanism and into the Cable Injector. With this type of rig up, the yoke on the Wireline Spooling Unit cannot be rotated as the cable injection proceeds.

If torque is a concern, a different rig up is utilized that allows the yoke to be rotated as the cable is injected. A vertical upper sheave (horizontal axle) hangs from a swivel above the cable drum and in line with the vertical axis of rotation of the yoke. Another sheave is mounted on a manually operated level wind mechanism fixed to the spooling unit base outside the radius of rotation for the yoke. The cable travels upward from the cable drum, over the upper swiveling sheave, under the level wind sheave, and over to the cable injector. Note that some means of supporting the upper sheave wheel above the cable drum must be provided. On certified units where the optional lifting gantry has been purchased, the gantry can be used to support the upper sheave wheel.

The Wireline Spooling Unit uses a hydraulic motor and a chain drive to rotate the cable reel during cable removal and a mechanical caliper brake on the drive axle is used to provide some resistance (tension) during cable installation. For a cable installation, the spooling unit motor is not used. The spool drive mechanism should be decoupled from the cable drum axle. This can be achieved by either removing the drive chain or by using a short jumper hose between the inlet and outlet ports on the hydraulic motor (if this last method is used, periodically to check the motor to ensure it is not getting hot). The mechanical caliper brake is applied as needed to keep some tension in the cable. For a cable removal, hydraulic lines are connected to the spooling unit motor and the hydraulic motor is operated at a proper speed to keep tension in the cable. The hand-crank on the level wind is used to manually guide the cable onto the spool.

Hoist

The standard non-certified cable injector, for use on land, comes with an intergral hoist assembly (see *Figure 1*). For the offshore non-certified unit, the hoist is optional (see *Figure 2*). On certified units, a skid mounted hoist is not supplied and a separate certified gantry is supplied as an option.


For more information about the cable injector, refer to Tab 3, which contains a reprint of SPE paper number 30679, *Development of a Coiled Tubing Cable Installation System*, by K.R. Newman, N.A.Haver, L.R. Stone, and D. Tong.

Specifications

General

Maximum Pressure	10,000 psi
Hoist / Structure weight	1 ton

Hydraulic Motor

Theoretical Torque per 100 psi	2034 in-lb (169.5 ft-lb)
Peak Pressure	2000 psi
Continuous Pressure	1500 psi
Recommended Max Flow	40 GPM
Theoretical Speed	1.8 RPM per gallon
Speed at Max Flow	72 RPM

Chapter 2
Assembly

This chapter describes the procedure for assembling the cable injector from its component parts. To disassemble the cable injector for maintenance or repair, reverse the procedure outlined here. For instructions for assembling and disassembling the cable injector during normal operations, see Chapter 3, “Operation”.

Hoist

The non-certified version of the Cable Injector comes with an integral hoist. The hoist consists of a frame with bearings, a mounting position on the skid, and either a mechanical or electrical hoist. The bearing surfaces should be well greased. The frame is simply inserted into the mounting frame on the skid. The free bearing should shoulder against the fixed bearing. The trolley and hoist mechanisms are assembled onto the frame per the manufacturer's instructions.

Capstan Housing

The capstan housing contains the capstan drum, housing plug, and hydraulic motor. Please refer to the referenced Figures for CTES part numbers and their location unless otherwise noted. Use graphite grease on all threads and seal surfaces unless otherwise stated.

1. Install the two ¾" lifting eyes that are supplied for assembly / disassembly (*Figure 4 – Item 40*) and two bolt spacers (*Figure 4 – Item 11*) into two opposing outer holes on the top of the cable injector housing (the capscrews (*Figure 4 – Item 34*) may need to be removed first). Using a suitable sling and lifting equipment, pick up the injector housing to gain access the underside of the component.

2. Mount the four legs (*Figure 4 – Item 12*) to the injector housing with ¾"-10UNC x 1 ½" Grade 8 plated bolts (p/no. 7190-0005-24) and lock washers (p/no. 7190-0005-23). Carefully lower the injector housing onto the 4 bolts on the skid and bolt the legs to the injector skid with nylon lock nuts (*Figure 4 – Item 2*) and 1" washers (*Figure 4 – Item 39*). Make sure that the outlet port (lower hole) points to the rear of the skid (short end) and the inlet port (upper hole) points towards the front of the skid (long end). Remove the lifting eyes and bolt spacers and screw in the flathead screws (*Figure 4 – Item 34*) to blank off the holes.

3. Coat the OD surface of the stator ring (*Figure 4 – Item 28*) with grease. Carefully lower the stator ring into the capstan housing. The tolerance between the housing and the stator is very close, so precise alignment of the two parts is essential. Never force or hammer the stator into place; it will insert smoothly if properly aligned with the housing. Make sure the 2 large holes in the stator align with the inlet and outlet in the housing. Attach the stator ring to the housing with 4 bolts (*Figure 4 – Item 31*).

4. Thoroughly grease the large Polypak seal (*Figure 4 – Item 21*) using graphite grease and install it into the bottom groove in the injector housing, orienting it such that the exposed O-ring end of the seal faces

the bottom of the housing. The seal is stiff and is not easy to install – proceed carefully so as not to damage the seal surfaces.

5. Grease and Install the O-ring (*Figure 4 – Item 29*) and the back up ring (*Figure 4 – Item 33*) on the inlet cable guide (*Figure 4 – Item 10*) with the back up ring on the side of the O-ring that is furthest from the external thread.

6. Screw the inlet cable guide into the inlet port.

7. Install the O-ring (*Figure 4 – Item 29*) and back up ring (*Figure 4 – Item 34*) on the outlet cable guide (*Figure 4 – Item 6*) with the back up ring on the side of the O-ring that is furthest from the external thread.

8. Slide a union nut (*Figure 4 – Item 36*) over the cable outlet guide with the threaded side facing the large end. Screw the outlet assembly into the outlet port.

9. Assemble the pipe clamp (*Figure 1 – Item 5*) around the outlet assembly and adjust the pipe support height so that the outlet assembly is level.

10. Screw in the four radial jacking screws (*Figure 4 – Item 17*) in the 4 holes located at 90 degree increments around the circumference of the housing so that they do not protrude into the shear ring groove. These screws are used to push the shear ring sections out of their groove during disassembly of the capstan housing.

11. The journal bearing (*Figure 4 – Item 5*) must now be pressed into the housing plug (*Figure 4 – Item 9*) – it is an interference fit. The journal bearing is inserted from the bottom of the housing plug and so the housing plug must be inverted. The top side of the housing plug has a number of tapped holes in it and the bottom side has only two. Lifting eyes can be installed in the two ¾" tapped holes in the top and bottom of the housing plug to enable it to be manipulated and moved safely.

 The circumference of housing plug is machined to very close tolerances with a smooth surface finish to provide the sealing surface for the Polypak seal. Be careful not to damage the sealing surface during installation. The housing plug weighs more than 500 lbs, so handle it with care.

There are two methods to insert the journal bearing into the housing plug. The preferred method is to use a 10 tonne hydraulic press if available. If not, then the journal bearing must be cooled sufficiently so that it contracts and can then be tapped into the housing plug using a soft

mallet. The temperatures in a conventional food freezer or icemaker are low enough shrink the journal bearing. It is recommended to place the journal bearing in the freezer overnight to allow complete contraction of the component.

12. Immediately prior to inserting the journal bearing into the housing plug, grease the O-ring (*Figure 4 – Item 25*) and install it in the external groove on the journal bearing. Press or tap the journal bearing into place until the flange contacts the bottom surface of the bearing housing.

13. Grease the Polypak seal (*Figure 4 – Item 26*) and install it into the internal groove on the journal bearing orienting it such that the exposed O-ring side is facing the large face of the journal bearing (see *Figure 4 – Detail B* for orientation). Install the retaining ring (*Figure 4 – Item 38*) into the groove in front of the Polypak seal.

14. With the top of the housing plug facing upwards, move the housing plug to a location next to the injector housing and then carefully set the assembly down on two supports (preferably wooden blocks) at least 6” high. Thoroughly grease the bearing surface on the drive shaft (*Figure 4 – Item 7*) and insert it, small diameter first, through the journal bearing.

15. Coat the 2 thrust washers (*Figure 4 – Item 14*) and the needle roller bearing (*Figure 4 – Item 15*) with new SAE 90W gear oil. Install one thrust washer in the onto the top flange on the drive shaft. Install the needle roller bearing on top of the thrust washer. Install another thrust washer on top of the needle bearing (see *Figure 4 – Detail A* for orientation).

16. Grease the O-ring seal (*Figure 4 – Item 24*) and insert into the O-ring groove on the top of the housing plug.

17. Lift the bearing housing (*Figure 4 – Item 3*) into position over the drive shaft and lower into place. Orient the bearing housing so that the cut out in it’s body is facing the side of the injector housing with the inlet and outlet cable guides. Using a torque wrench, tighten the five hex head cap screws (*Figure 4 – Item 19*). Tighten the screws evenly in a crossing pattern to 50 ft-lbs torque.

18. Place the capstan on two wooden blocks at least 6” high. Note that capstan is not symmetrical. The thicker section of the capstan OD should be facing up when the capstan is placed onto the blocks.

19. Lift up the housing plug, bearing housing, and drive shaft assembly to gain access to the end of the drive shaft. Insert the drive shaft /capstan key (*Figure 4 – Item 16*) into the keyway in the drive shaft. Tap into

position with a soft mallet if necessary. Coat the end of the drive shaft and key with graphite grease.

20. Swing the housing plug into position over the capstan so that the end of the drive shaft is directly over the hole in the capstan hub.

21. Slowly lower the housing plug and insert the end of the drive shaft into the capstan hub. Turn the drive shaft until the key aligns with the key slot in the capstan hub.

22. Gently lower the housing plug until the shoulder on the drive shaft contacts the capstan hub. Do not rest the full weight of the housing plug on the capstan.

23. Reach underneath the capstan and using the bolt (*Figure 4 – Item 1*), lock washer (*Figure 4 – Item 27*) and shaft end plate (*Figure 4 – Item 13*) secure the capstan to the drive shaft. It is advisable to place blue Loctite on the threads of the bolt prior to make up. Do not use red Loctite. Once the bolt is screwed in, the assembly can be lifted so that bolt can be tightened securely to minimum of 50ft-lbs of torque. The assembly is now ready to be placed into the cable injector housing.

24. Ensure that the large Polypak seal already in the housing and the OD seal surface of the housing plug assembly have been well coated with graphite grease.

25. Center the capstan / housing plug assembly over the housing and slowly lower the capstan / housing plug assembly into the housing. Orient the plug so that each eyebolt is directly in line with one of the four hex head cap screws (*Figure 4 – Item 17*) through the wall of the housing. If the plug is centered properly with the housing, the weight of the plug will be sufficient to seat it in the housing. Do not force the plug into the housing. Gently rotating the capstan / housing plug assembly back and forth may ease the seating process.

26. Disconnect the hoist from the eyebolts and remove the two eyebolts and spacers from the housing plug.

27. Install the four sections of the shear ring assembly (*Figure 4 – Item 8*) in the groove in the housing bore above the housing plug. Make certain each shear ring section is properly seated in the groove and the four holes for the eyebolts are unobstructed.

28. Install the four bolts (*Figure 4 – Item 22*) and spacers (*Figure 4 – Item 11*). It is not necessary to use significant torque on these bolts as they are only to keep the shear rings in place.

29. Carefully screw in the 4 bolts (*Figure 4 – Item 17*) used for pushing out the shear rings until they just touch the shear ring. Do not over tighten the bolts

30. Install the motor (*Figure 4 – Item 30*) on the bearing housing (*Figure 4 – Item 3*). Align the key on the motor shaft with the key slot in the drive shaft. Align the holes for the speed sensor (if purchased as an option) in the motor and bearing housing. Align the bolt holes in the gasket (*Figure 4 – Item 23*) with the bolt holes on the bearing housing and the bolt holes on the motor. Slide the dust plug (*Figure 4 – Item 36*) over the hall effect sensor (note that this sensor is only installed if the optional electronics package was specified) and bolt the motor onto the bearing housing with the four hex head cap screws (*Figure 4 – Item 18*) and accompanying washers (*Figure 4 – Item 21*).

31. Using a torque wrench, tighten the four bolts (*Figure 4 – Item 18*) holding the motor to the bearing housing. Tighten the screws evenly in a crossing pattern to 50 ft-lbs torque.

32. Screw the oil level gage (*Figure 4 – Item 37*) into the hole on the side of the bearing housing. The oil level gage has an integral snap-lid filler cap. Fill the bearing cavity through this filler cap. Fill the cavity with SAE 5W10 oil to approximately mid length of the sight glass.

33. Install 2 flush hex head ¼" NPT plugs (*Figure 4 – Item 32*) in the housing drain holes (see *Figure 4* for location). Use Teflon tape on the plugs.

34. Install 4 flush hex head ¼" NPT plugs (*Figure 4 – Item 32*) in the four holes leading to the modified shoulder screws (*Figure 4 – Item 31*) (see *Figure 4* for location). Use Teflon tape on the plugs. Once installed these plugs are not normally removed.

35. Install 1 flush type ¼" NPT plug (*Figure 4 – Item 32*) in the air bleed hole on the top of the housing plug.

36. The Capstan Housing Assembly is now complete.

Wireline Pressure Control Equipment

The cable injector is shipped with a Texas Oil Tools (TOT) Grease Injector Head #DG43 capable of 10,000 psi working pressure. The entire unit is simply laid over the cable clamps (*Figure 1 – Item 4*, or *Figure 2 – Item 4*) and screwed onto the end of the inlet cable guide. The cable clamps are then assembled to hold the Grease Injection Head in place.

For more information, refer to the TOT manual.

Chapter 3
Operation

This chapter describes how to inject cable into and remove cable from a reel of CT.

Safety

As with all oilfield equipment the cable injector should be operated safely with regard to normal safety guidelines. All your normal safety rules for pumping and CT operations should apply when injecting cable in CT. There are several areas of consideration when working with this particular equipment.

Releasing Pressure before Disassembly

Never disassemble the capstan housing without first making sure the housing has no pressure on it. Even a few psi over the large flange area can result in a large force. Either remove the piping from the inlet or outlet, or remove the pressure gage from the housing to relieve any pressure.

Lifting and Moving

The cable injector is mounted on a skid for ease of use and moving. It weighs close to 8000 lbs. Pockets for moving with a fork lift have been provided and are located at the center of gravity. Use these to move the unit. Do not lift it from underneath as this may cause damage to the injector and or pose a safety hazard.

When removing the Capstan/Housing Plug Assembly remember that it weighs over 800 lbs.

Pumping Pressure

The cable injector is rated to 10,000 psi working pressure and is tested to 15,000 psi. The working pressure should never be exceeded during normal operations.

The pump or piping system must be equipped with a pressure relief valve.

Hot Water

Depending on how large the holding tank is and how much time the cable injection takes, the water can get hot. Be aware of this when touching any water pipe or the water itself. Use gloves, etc. if necessary.

Planning and Preparations

Required Equipment

The following equipment and supplies are required to operate the cable injector:

- Cable injector.
- Cable spool and means to rotate the cable about its longitudinal axis (Wireline Spooling Unit).
- Appropriately sized Grease Injector Head Packer/flow tube kit for the cable to be injected.
- 1502 Weco unions (thread half) installed on the inlet and outlet of the CT reel.
- A pump with enough hydraulic HP to deliver the required water flow rate.
- A tank with at least 50 bbl capacity for the pump suction/return.
- Appropriate piping, including a “Y”, ball valve, adjustable choke, and two 1502 Weco laterals used to connect the pump, cable injector, CT, and the tank.
- A hoist or fork lift with a minimum capacity of 9000 lbs.
- Miscellaneous hand tools including a 24” and 36” pipe wrench.
- 5 minute cure, 2 part epoxy.
- 1 foot length of heat shrink tubing sized for the cable to be injected.
- Hydraulic Powerpack.

Work Site

The work site must be large enough to accommodate the cable injector, CT reel, Wireline Spooling Unit, pump, tank and hydraulic powerpack. Also, the site must allow approximately 40 ft between the cable spool and cable injector. Cable injector operation typically requires at least 50 bbls of water. An acceptable method for disposal of this water after the job must be available.

Cable Condition

Scale and corrosion on the cable and residual torque (twist) in the cable can seriously affect the cable injector performance. The cable should be cleaned, lubricated, and neutralized (residual torque removed) by a competent wireline servicing shop. The cable must be spooled with the tool end of the cable at the core of the reel.

Coiled Tubing

Both ends of the CT must have 1502 Weco unions (thread half) to connect to the piping. Use the fewest number of pup joints, elbows, and other fittings that will provide a smooth connection between the CT and the cable injector. The CT exiting the reel core must follow a smooth curve to minimize drag on the cable. Abrupt turns or constrictions in the flow path could snag the cable or impede its progress.

Flow Rate

Viscous shear drag on the cable and the amount of turbulence around it govern how the cable moves through the reel. Adequate flow rate through the CT is the key ingredient for both. The piping dimensions and configuration, CT ID and length, water properties, and cable diameter determine the pump pressure required for a given flow rate. The Excel spreadsheet, “Cable Injection Delta Pressure.xls”, delivered with the cable injector, can estimate the required pump pressure for a given set of operating conditions. A velocity of 750-800 fpm inside the CT is a good starting point for the calculations. Actual pump pressure during a cable injection may differ from the predicted value because the calculations are very sensitive to the assumed properties of the water. The density and viscosity of water are strong functions of temperature, and they can increase substantially during a cable injection. Also, up to 25% of the flow will bypass the CT.

Preliminary Steps

The following section describes the steps for setting up the cable injector and associated equipment.

Layout of Equipment

The equipment layout will depend on the site, but general considerations are:

- A means for hanging a sheave the proper height above the Wireline Spooling Unit. (see *Figure 7*)

- Location of a hydraulic power pack and routing of hydraulic hoses for the cable injector and cable spooling unit (if used).
- Positioning the Cable Injector and the Wireline Spooling Unit at least 40 ft apart.
- Location of the suction/return tank close to the pump.

Wireline Spooling Unit

New cables are relatively free of residual torque, but can still twist and ball up ahead of the grease head. Used cables must be neutralized (torque removed) prior to injection into CT. For these reasons, the Wireline Spooling Unit should allow the spool to rotate around its longitudinal axis while cable is being pulled off the spool. The optional CTES Wireline Spooling Unit was designed for this purpose.

Pump

The pump must have adequate hydraulic HP to supply the required flow rate at the predicted pressure. Pulsations from the pump seem to aid cable injection. Consequently, a pulsation dampener on the pump discharge is undesirable. Pumping time is inversely proportional to the cable injection speed and cannot be predicted until the operation is in progress. Adequate fuel for several hours of high speed operation should be available.

Tank

The suction/return tank should be empty and clean prior to the cable injection. The minimum volume of the tank depends on the internal volume of the CT and piping; typically at least 50 bbls. The volume of water should be as large as possible to help minimize the temperature increase caused by pumping in a closed loop.

Cable Injection Setup

Removing and Testing the Capstan Housing

Refer to *Figure 4*.

1. Remove the bolts and spacers retaining the shear rings.
2. Remove the shear ring pieces from the capstan housing and set aside. The hex head cap screws located around the housing (*Figure 4 – Item 17*) can be tightened, one at a time, to push each shear ring piece out.

3. Loosen the four hex head cap screws (*Figure 4 – Item 17*) until they do not intrude into the shear ring groove in the housing.

4. Install eyebolts and spacers.

5. Attach the hoist chains to the eyebolts and remove the housing plug and capstan from the housing. Set the assembly on wooden blocks.

6. Confirm that the bearing housing is full of new SAE 10W (or equivalent) oil. If not, fill it to the mid-level of the site glass.

7. Make certain the capstan and housing plug are secure and stable on the wooden blocks. Rotate the housing plug by hand to insure it will rotate freely.

8. Connect the hydraulic motor to the hydraulic power pack. The two large ports on the motor are for pressure/return lines. The small port is the drain.

9. Using lifting equipment, pick up the capstan and housing plug assembly. Make certain all personnel and foreign objects are clear of the capstan. Start the hydraulic power pack and slowly increase flow (pressure) to the cable injector motor. Rotate the capstan at slow speed to insure it operates properly with hydraulic power.

10. Disconnect the hydraulic lines from the hydraulic motor once the motor and capstan are deemed functional.

Loading the Cable

This operation requires at least two people.

The cable injector is shipped with a Texas Oil Tools (TOT) Grease Injector Head #DG43 with 10,000 psi working pressure. Make sure that the grease injector head has been prepared according to TOT instructions for the size cable to be run and is ready for installation on the cable injector. Please refer to *Figure 3*.

1. Cut the cable so that the end is flat and even all around with no armor wires sticking up. Grind a radius around the end of the cable, if possible, to facilitate threading the cable through the grease head.

2. Insert the cable into the Wireline Measuring Device (*Figure 1 – Item 9*) on the skid. Thread the cable into the hole on the front of the Wireline Measuring Device. Lift up on the spring returned handle to lift the top

wheel off of the bottom wheel and thread the cable between the two wheels. Release the handle.

3. Install the cable through the grease control head (*Figure 3*).

4. Slide the cylinder assembly containing the cylinder, piston, and cylinder head over the cable.

5. Slide the large spring up inside the cylinder and over the piston.

6. Install the upper brass split bushing over the cable and slide into the piston. Slide the packer element over the cable and shoulder it against the upper split bushing.

7. Slide the retainer ring over the cable.

8. Install the line guide over the cable.

9. Slide the packer body over the cable and the Line Guide and install the retainer ring in its groove.

10. Slide the packer body over the packer.

11. Screw the bottom and top portions of the “Pack-off” together, **making sure all element and bushing halves stay aligned. A misaligned split bushing can grab the cable**.

12. Slide one of the three sleeves over the cable and up to the pack off and begin to thread it onto the pack off. It is not necessary to make up the thread completely now.

13. Slide one of the three flow tubes onto the cable, and push it up inside the sleeve. Since the ID of the flow tube closely matches the OD of the cable, it will take some effort to thread the cable through the flow tube.

14. Thread the cable through one of the three connectors and screw it onto the already installed sleeve.

15. Thread the cable through the second sleeve and screw it onto the connector.

16. Thread the second flow tube onto the cable, and push it up inside the Sleeve.

17. Repeat step 10 for the second of three connectors.

18. Repeat step 11 for the third sleeve.

19. Repeat step 12 for the third flow tube.

20. Screw the third connector onto the third sleeve.

21. Lay the grease injection head on the pipe supports and install it on the capstan housing inlet cable guide, making sure to thread the cable into the inlet of the capstan housing such that the cable can be grasped inside the capstan housing. **Make up all threads at this time**. Install the pipe clamps (*Figure 1 – Item 4*) on each pipe support to hold the grease injection head in place.

22. Unreel approximately 40 ft of cable from the spool. This will provide enough cable to fill the 7 grooves in the stator ring, exit the outlet, and leave the end free for insertion into the CT.

23. Station one person at the inlet and another over the capstan housing. While the first person slowly feeds cable into the grease injector head, the second person must help the cable travel around the stator and into the outlet. The cable must press firmly against the wall of the stator ring in the spiral path formed by the grooves. Continue feeding cable through the housing to get approximately 6 ft of cable extending from the outlet.

24. **It is necessary to install an outlet port on the Grease Injection Head that will be ducted to the return tank. This outlet port should be placed in the hole marked on *Figure 3*. Without allowing some of the fluid to flow out of the Grease Injection Head at this location, the pressure will build up and tend to "milk" the cable. This will cause the cable to birdnest. The result will be a failed injection and a damaged cable.**

Installing the Capstan into the Capstan Housing

1. Station one person at the inlet to the Wireline Measuring Device, and one person at the outlet of the Capstan Housing.

2. Lift the Capstan off the wooden blocks using the hoist. Carefully lift the housing plug capstan assembly until the bottom of the Capstan clears the top of the housing. Position the capstan directly over the opening in the housing.

3. At this point, the person stationed at the inlet and the person stationed at the outlet should be instructed to push the cable into the Capstan housing. The effect of this will be to force the cable against the stator. They should continue to push on the cable until the Capstan is fully installed.

4. Slowly lower the housing plug and capstan into the housing. Orient the plug such that the hydraulic pressure/return connections on the motor can be accessed from the hydraulic powerpack. Center the capstan over

the housing. If the plug is aligned properly with the housing, the weight of the plug will be sufficient to seat it in the housing. Do not force the plug into the housing. A slight twisting motion back and forth may help seat the plug in the housing.

5. Disconnect the hoist from the eyebolts and remove the eyebolts and their spacers from the housing plug.

6. Install the four sections of the shear ring assembly (*Figure 4 – Item 8*) in the groove in the housing bore above the housing plug. Make certain each shear ring section is properly seated in the groove and the four holes for the eyebolts are unobstructed.

7. Install the four bolts and their spacers to secure the shear rings.

8. Tighten the four hex head cap screws (*Figure 4 – Item 17*) into the housing to lock the shear ring sections in place. Tighten each cap screw until it presses its shear ring section against the eyebolt.


If the hex head cap screws are not tightened into the indents in the shear ring pieces, torque from the hydraulic motor can cause the motor, plug, and shear ring to rotate. This will twist up the hydraulic hoses.

9. Connect the hydraulic hoses from the power pack to the cable injector motor. The two large ports are the pressure/return lines and the small port is the drain.

10. Pull on the cable at the outlet while running the hydraulic motor of the capstan forward to get about 15 feet of cable on the outlet side. It is necessary to pull on the cable even though the capstan is running.

11. Remove one of the drain plugs (*Figure 4 – Item 2*) and install a 10,000 psi pressure gage (not included). The hole is tapped with a ¼” NPT thread.

Accelerator Assembly

Please refer to *Figure 5*.

1. Select the correct flow tube (*Figure 5 – Item 3* or *Figure 5 – Item 4*) for the size cable being installed.

2. Verify that O-ring (*Figure 5 – Item 10*) and 2 back up rings (*Figure 5 – Item 9*) are installed in the flow tube housing (*Figure 5 – Item 1*).

3. Choose the appropriately sized flow tube (*Figure 5 – Item 3* or *Figure 5 – Item 4*). Grease the OD of the flow tube and install the flow tube into the flow tube housing, larger bevel end first, until it shoulders against the upset in the housing internal diameter.

4. Install the retaining ring (*Figure 5 – Item 2*) into the groove in the flow tube housing (*Figure 5 – Item 1*) to hold the flow tube in place.

5. Check that a Weco union seal (*Figure 5 – Item 10*) is in place in the threaded end of the cable accelerator.

6. Work the large retaining ring (*Figure 5 – Item 7*) over the rounded end and onto the shoulder of the non-threaded side of the cable accelerator housing.

7. Slide the 1502 Weco union nut (*Figure 5 – Item 8*) over the rounded end, unthreaded side first.

8. Slide the 3 retainer segments (*Figure 5 – Item 6*) into the union nut, groove side first, and push out so that the grooves of all 3 segments are exposed on the other side of the nut.

9. Install the retainer ring (*Figure 5 – Item 7*) into the grooves in the retainer segments.

In the next three steps, thread the cable through each part and then follow the step instructions. Refer to *Figure 7*.

10. Install a Weco 1502 lateral onto the outlet cable guide. Do not hammer union tight.

11. Install the Cable Accelerator assembly on the lateral. Do not hammer union tight.

12. Install a Weco 1502 lateral on the end on the flow tube assembly. Do not hammer union tight.

13. On the upstream lateral connect a ball valve.

14. On the downstream lateral connect an adjustable choke.

15. Use a “Y” pipe or lateral to split the pump feed (high pressure) into two lines. Connect the ball valve to one line and the adjustable choke to the other line from the “Y”.

16. While pulling on the cable at the outlet of the Weco Union, run the capstan motor forward until approximately 40 ft of cable is pulled out.

Preparing the Cable

The cable that is to be injected needs to be protected not only from the mechanical damage caused by being pumped through the CT but also from the high pressure fluid that can work its way in between the conductor and insulation of each wire. CTES recommends potting the end of the cable with fast hardening epoxy and covering it with heat shrink tubing to protect the cable. Follow the procedure outlined below.

1. Cut the end of the cable with a die grinder or other suitable cutting tool. Make sure the cut is clean and the armor has a minimum of disruption. This is key to a good end prep.

2. If the cable is coated, remove about 4” of the coating.

3. Cut off about 2” of the exterior armor by going around the cable and cutting each singular piece of armor wire off with a wire cutter.

4. Cut two lengths of heat shrink tubing: one 4” long and one 8” long.

5. Slide the 8” long piece of heat shrink tubing onto the cable and completely onto the exterior armor.

6. Mix a small amount of 5 minute cure, 2 part epoxy. Dip the end of the inner armors in epoxy.

7. Slide the 4” piece of tubing over the epoxy and shoulder the edge of the tubing against the cut exterior armor.

8. Heat the 4” piece of tubing and shrink it tight to the cable. The end will tighten smaller than the diameter of the wire, forming a nipple.

9. Fold over the nipple formed from the 4” piece of shrink tubing. Slide back the 8” piece of heat shrink. Align it such that the end of the cable shows but the folded over nipple is trapped inside the tube.

10. Heat the 8” piece of tubing, starting at the end of the cable, and moving along the cable until it is completely shrunk.

A Cable Ready to be Injected

Final Make Up

1. Position the skid and piping so that the end of the last lateral is about three feet from the end of the CT.

2. Push the end of the cable into the CT until it stops; then pull it back about five feet. If you run out of cable before it stops, do not pull any cable back out.

3. While pulling on the cable at the inlet, run the motor backwards until all the cable slack between the end of the last lateral and the CT has been removed.

4. With care not to kink the cable, push the skid into place with the end of the last lateral mated to the end of the CT. Screw together the 1502 Weco union.

5. Hammer tight all the hammer unions.

6. Install the pressure gauge in the drain port on the capstan housing.

7. Install a return line from the return port on the grease injection head to the fluid storage tank.

8. Connect the hydraulic hand pump to the injector head pack-off.

9. Connect a return line from the end of the CT, at the core of the reel, to the fluid storage tank.

Pumping Operations

After the cable has been installed inside the cable injector and the piping has been rigged up, pumping can begin. There are several considerations concerning pumping that involve safety and should be addressed by the practices of the company pumping the fluid.

With the cable injector system there are many factor that can be adjusted, each having some effect on the injection process. The main items are the pump pressure, pump rate, the cable accelerator setting (choke setting), and the capstan speed. CTES recommends leaving the pump, and cable accelerator on a fixed setting, and using the capstan speed to “drive” or control the injection process.

Pump Pressure and Rate

In planning the job, the flow rate necessary to move cable must be calculated. This flow rate will not change during the injection process. CTES supplies a Excel spreadsheet for these calculations.

As the cable moves into the CT the pressure necessary to keep the same rate will need to be increased. By adjusting the pressure, the goal is to maintain the rate of fluid flow returning from the CT. If the rate is less, the cable will not have enough drag to pull it through and a higher rate will pin the cable to the wall of the tubing keeping it from moving.

When the fluid flow rate is within the appropriate range, the cable inside the tubing will make a jingling noise. This noise should be used as an indicator. When the noise is present, the cable will move easily. When the noise is gone the cable will be more difficult or impossible to inject.

Setting the Cable Accelerator

At the start of the injection, the cable inside the CT is short and there is very little drag on the cable. As a result, the capstan has very little tension on it. With very little tension the capstan can not pull in cable. To overcome this a cable accelerator or pre-tensioner was included in the injector design. The flow tube of the cable accelerator creates an additional drag force on the cable when fluid is pumped through it. This drag provides additional tension for the capstan. The choke connected to the downstream lateral controls the amount or flow that goes through the flow tube, thereby controlling the amount of pre-tension force on the cable.

To start the cable moving, begin pumping fluid at the predetermined rate. Run the capstan motor at the predetermined speed and begin closing the choke. This will divert fluid through the flow tube. Continue closing the

choke until the cable begins to move. Leave the choke set at that setting for the remainder of the injection.

 Do not close the choke too far. Closing the choke too far causes a large force on the cable at the flow tube and may damage the cable.

Cable Tension

The tension on the cable should be generated by viscous forces on the cable in the tubing and by the cable accelerator. The cable spooling unit should not provide any back tension. The spooling unit brake should, however, be set to keep the cable reel from free wheeling. It should take 10 or 20 pounds of pull to get the cable reel to turn.

Capstan Speed

The capstan speed is controlled by the hydraulic pressure supplied to the motor. Therefore, the hydraulic controls for the motor need to be sensitive in order to control the speed easily. CTES recommends a target cable speed of 100 feet per minute. The cable speed can be controlled by the capstan speed.

Grease Injection Head

Note that some flow of fluid out of the end of the grease injection head is normal. Grease can be injected to load the packer and reduce this flow, but **too much pressure on the packer will stall the cable**. Allow for this leakage when setting up the job.

 It is necessary to install an outlet port on the grease injection head that will be ducted to the return tank. Without allowing some of the fluid to flow out of the grease injection head at this location, the pressure will build up and tend to “milk” the cable. This will cause the cable to birdnest. The result will be a failed injection and a damaged cable.

Removing Cable by Pumping

The set-up is the same for removing cable as for injecting, but the pump is connected to the core of the reel and returns are taken from the two laterals at the cable injector. The flow rate and pressure considerations are the same as injecting cable.

The force to remove the cable from the CT is provided by the viscous forces generated by the fluid. The drive mechanism on the Wireline Spooling Unit merely provides tension to produce an even spooling of the cable onto a reel. Cable tends to come out of the CT reel in spurts. The capstan acts to smooth out the cable removal, acting like an accumulator.

It may take up to a half of an hour of pumping to achieve noticeable movement of the cable. CTES suggests varying the pumping rate to help to get the cable moving.

Chapter 4
Maintenance and Support

This chapter includes a list of part numbers for the seal kit and contact information for CTES.

General Maintenance

After a cable injection, the Capstan Housing should be drained of water. Two drain holes can be opened by removing NPT plugs located on the bottom edge of the housing (*Figure 4 – Item 2*). Simply remove these plugs and allow the housing to drain. (Be sure to replace and torque these plugs to re-establish a seal before conducting another injection).

To prevent rusting, CTES suggest lightly oiling the capstan and stator ring with a light oil before storing the Cable Accelerator.

 Do not use grease on the capstan or stator ring. Grease will lower the coefficient of friction, reducing the capstan effect.

Check the oil level gage and confirm that the oil is filled to about half way up the sight glass. If not, add SAE 90 weight oil until that fill height is reached.

Note that there are two grease fittings on the hoist for greasing the hoist bearings.

Seal Kit Parts List

CTES recommends replacing all of the seals after any seal failure. To order a full seal kit, order part number **7190-1008-05**. However, if a single seal is needed, locate the part number for the item you need from the list below.

Figure	Item	Description	Part Number
4	21	Polypak	7190-0000-47
4	23	Gasket	7100-1003-02
4	24	O-ring	7190-0005-34
4	25	O-ring	7190-0007-27
4	26	Polypak	7190-0007-28
4	29	O-ring	7190-0005-38
4	33	Back Up Ring	7190-0005-40
4	35	Dust Plug	7100-1002-98
5	9	Back Up Ring	7190-0005-61
5	10	O-ring	7190-0005-62
5	12	2” FMC 1502 Seal	7190-0005-55

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