Multistrand
Post-tensioning
Foreword

The **DEL** Post-tensioning Systems are the result of a constant, ongoing evolution in Materials, Equipment and Techniques, focusing in field installation simplicity, while assuming the necessary requirements of quality, reliability, safety, serviceability, practicability and durability of structures in which they may be used, otherwise stated in the main international post-tensioning standards.

After 20 years of designing, testing, manufacturing and installing, originally in Mexico, then elsewhere, **DEL** Post-tensioning products, as well as the related Construction Systems have won a deserved reputation for service and dependability.

This **DEL** brochure of Multistrand Post-tensioning offers to the customers a complete line of Materials- anchorages, couplers, sheaths- and Equipment- jacks, pumping units and machines for grouting, strand pushing and sheath fabrication-, to cover the most common needs, including the more recent applications in External and Flat cables.
Other like Cable Stays and Unbonded Monostrand, are purposely excluded and treated in other brochures.

Multistrand Post-tensioning, as an Engineering Speciality, is an Adaptable Technology. **DEL** Engineers are prepared to give the appropriate solutions, per clients’ requests: a variety of purpose designed/manufactured **DEL** products have been and are constantly appearing in the market, other than the line products described herein.

Special attention is paid to Installation Basics, in accordance with **DEL** philosophy of making Post-tensioning available to Construction Companies’ field personnel thus contributing to their optimal productivity: an updated “Installation” section has been included at the end of this brochure.
**Materials**

**Active, Standard**

Active or Stressing anchorages are those located at the stressing ends of tendons. AS anchorages are supplied including wedges, wedge & bearing plates, transition and grout port. Grout caps, when and as required. Design may specify active anchorages on both ends of a P.T. tendon even though stressing is carried out at one only. For wedge seating loss recuperation, shims can be placed between wedge plate and bearing plate, through a lift-off.

**Active, Adjustable**

For tension adjustment after lock-off. They are supplied complete as for AS type, including adjusting nut.

**Active, for Flat tendons**

They are typically used in bridge or building slabs and tank walls, when concrete cover is a must for corrosion protection. Stressing is done strand by strand with standard Monosstrand Jacks. Available in sizes up to 4 strands, they are supplied with wedges, wedge/bearing plate, transition and grout port. Pocket formers and grout caps, whether and as required.
Anchorages

**Active, for external Post-tensioning**

Adjustable and easy to install and remove, AE anchorages have been specially developed to withstand the dynamic actions occurring at the ends of external tendons, and to ensure a correct grouting or filling of protective pipes. They are supplied complete with wedges, threaded wedge plate & nut, capsule, bearing plate, form tube, strand concentrator and grout vent. Where adjusting is not required, shims are provided instead of nut. For Multistrand Ground Anchors, AE type anchorages adapting to Design’s needs are used at the stressing end.

### AE Anchorages

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<tr>
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**Passive, with swage Heads**

Same as PA when room for bond length is not available. Supply includes base, bearing and head retention plates, and transition. They may be substituted by AS anchorages with a wedge isolation box.

### PC Anchorages

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Passive, Bonding

Passive or Fixed Anchorages are those used at the non stressing ends, for which room must be provided in the Design. Supply includes base, bearing and head retention plates, and transition. They may be substituted by AS anchorages with a wedge isolation box.

### PA Anchorages

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**NOTE:**
- Forces, nominal in MTon
- Dimensions in mm.
- Bursting reinforcement (n,#), to be installed only when design does not define it.
- Sizes not listed, supplied by order.
- Recess dimensions, minimum for jack alignment.
### Mobile

For multistrand cable extension. Used mostly in repair jobs for big size cables. They are supplied complete with strand concentrators & deviators, single couplers, shell and grout ports.

**NOTE:** □ A, B, C, D, F, G, ØA, ØB, ØC, n, # as for AS

### F Coupler

Used for prestressed concrete elements’ post-tensioned connection. Also called Continuity Anchorages

**NOTE:** □ A, B, C, D, F, G, ØA, ØB, ØC, n, # as for AS
Sheaths

corrugated steel and plastic, flat and circular sheaths are supplied at client's convenience, as per current quality standards. Supply includes grout vents to be placed at selected points. There is a sheath size for every anchorage size & type as shown in table. For steel galvanized or bright circular sheaths, machines are available. This is a recommended option for remote sites. See equipment pages for details.

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**Jacks**

**E Jack**

Multistrand Pumping Units include all the hydraulic control devices for the operation. They have been ergonomically designed for heavy duty and low maintenance. Electrical or gas power, optionally. Two circuit, for Stressing and Retraction. They work at mid-high oil pressure for lowest maintenance, in accordance with their corresponding E jacks.

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. Tendon</th>
<th>Pressure Area</th>
<th>Weight</th>
<th>A</th>
<th>B</th>
<th>C</th>
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**NOTE:**
Dimensions In mm.
A-gripping distance.
Piston strokes, D, can be of different lengths, by order.
Jacks will be longer or shorter depending on D.
**NOTE:**
Dimensions in mm.
A-gripping distance.
Piston strokes, D, can be of different lengths, by order.
Jacks will be longer or shorter depending on D.

**T Jacks**
Three circuit, for Stressing, Retraction and Wedge Seating, they feature 2 gauges for superior control.
Used with T jacks.

<table>
<thead>
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<th>Model</th>
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<th>Pressure Area</th>
<th>Weight</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D*</th>
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<td>445</td>
<td>680</td>
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<tr>
<td>T-1170</td>
<td>55-6</td>
<td>1718.7 cm²</td>
<td>1840 Kg</td>
<td>330</td>
<td>475</td>
<td>600</td>
<td>355</td>
<td>525</td>
<td>795</td>
</tr>
</tbody>
</table>

---

**Diagram**

**Model MA**

**Diagram**

**Model MB**
Multistrand Pumping Units include all the hydraulic control devices for the operation. They have been ergonomically designed for heavy duty and low maintenance. Electrical or gas power, optionally.

**T Pumps**

Three circuit, for Stressing, Retraction and Wedge Seating, they feature 2 gauges for superior control. Used with T jacks.

**E Pumps**

Two circuit, for Stressing and Retraction. They work at mid-high oil pressure for lowest maintenance, in accordance with their corresponding E jacks.

### Grouting Machines

The mixture of cement, water and admixtures must be done under a strict mixing time and velocity control and must not contain lumps nor any air bubbles during injection into the ducts.

**DEL** grouting machines include the mixing and injecting operation in a single piece of equipment, easily handled, with pressures of up to 25 bar, without the presence of air bubbles, using any type of cements and admixtures.

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**SPECIFICATIONS**

<table>
<thead>
<tr>
<th></th>
<th>T-690-4</th>
<th>T690-16</th>
<th>E-500-4</th>
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<tbody>
<tr>
<td>Operating Jacks:</td>
<td>T-105 to 420</td>
<td>T-555 to 1170</td>
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<tr>
<td>Nominal Pressure: (bar)</td>
<td>690</td>
<td>690</td>
<td>500</td>
</tr>
<tr>
<td>Nominal volume of flow: (lt/min)</td>
<td>3.8</td>
<td>3.9 &amp; 10.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Type of hydraulic oil: (SAE)</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Net weight: (Kg)</td>
<td>490</td>
<td>252</td>
<td>210</td>
</tr>
<tr>
<td>Oil Capacity (lt)</td>
<td>40</td>
<td>50</td>
<td>20</td>
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<tr>
<td>Outer Dimensions (mm)</td>
<td>1150x750x1030</td>
<td>1308x850x1000</td>
<td>720x700x1050</td>
</tr>
<tr>
<td>Required electrical power: (kw)</td>
<td>10</td>
<td>20</td>
<td>4</td>
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</tbody>
</table>

(220 or 440 Volt 3-phase A.C.)
Strand Pushing Machines

**SPECIFICATIONS**

- **Operation:** Hydraulic (2 velocities)
- **Pushing velocity:** 2 y 4 m/seg
- **Range:** 200 mts.
- **Strand diameters:** 0.5” y 0.6”
- **Net weight:** 356 Kgs.
- **Exterior dimensions:** 850 x 700 x 1340 mm
- **Required electric power:** 8 Kw

Used to place the strands inside the ducts when manual placement is difficult.

Hydraulic-action pushing machines have been successfully used in cables more than 100 meters long in all diameters and types of curvatures.

Sheath Fabricating Machines

**SPECIFICATIONS**

- **Production rate:** 1500 m / 8 hrs (Ø 45) 800 m / 8 hrs (Ø 160)
- **Section lengths:** 6 m.
- **Net weight:** 500 Kgs.
- **Outer dimensions:** 1500 x 650* x 1050 mm *Add 6m section container
- **Required electric power:** Main: 12Kw Cutting: 1Kw

They work with bare or galvanized steel sheets and are able to fabricate sheaths up to 200 mm inner diameter at the highest speed.

They are supplied complete with deformation tools, feeding reel and cutting device diameters and types of curvatures.
A series of recommendations follow on how to completely carry out a multistrand post-tensioning job, from the planning, up to the final reception of work.

The list is not restrictive and emphasizes those aspects directly related to the supplier of post-tensioning services.

Post-tensioning in concrete elements is referred to. In case of post-tensioning in other materials or for other Multistrand post-tensioning applications, DEL shall provide recommendations accordingly.

Design

Proper design must include as a minimum, in drawings and specifications:

• Geometrical definition of each one of the cables; sketch of axis and position of the anchorages and couplers.

• Prestressing steel characteristics: breaking strength and area or nominal diameter.

• Function of anchorages (active or passive).

• Definition of local reinforcement in zones close to anchorages (bursting reinforcement).

• Stressing and grouting sequence.

• Jacking force (maximum) and wedging force (minimum) for each tendon end being stressed.

• Expected variation of tensioning force along tendon due to friction, at the moment of stressing and for an indefinite period of time. The expected tendon elongation is inferred from the above.

• Concrete characteristics: Consistency and compression strength required for prestressing.

• Definition of grout proportioning and types of cement and water. Properties specified for additives should they be required.

• Grouting pressure.

• Expected deformation of prestressed structure.

• Dimensions necessary for design, using the DEL System, are indicated in tables.
Handling and Storage

The prestressing strand is provided in reels. These should not be unrolled nor placed outside, and require covered storage areas on bases that prevent their turning over. In humid or saline environments, anti-rust oil should be applied to reels.

Each reel of stands shall be identified and have its characteristics report (as a minimum; diameter, nominal area, unit weight, and modulus of elasticity). These characteristics are needed at different moments during installation.

- Anchorages, sheaths, couplers and complementary material shall be protected from atmospheric changes and stored in a way that will prevent damaging of pieces.

- Site installation shall also include a covered space where equipment can be stored and where maintenance operations can be carried out.

Post-tensioning Placement

This is normally carried out along with the REBAR work.

1. Tendon layout and saddle placement for sheaths: The forms must be in place for this operation, since the distances that define the design trajectories and referred to them. Exterior diameters of sheaths are indicated in tables.

2. Preparation, lining and water tight closure of corrugated sheaths: The sheath sections are connected by means of couplings into which they are screwed. Next, all points at which cement could enter at the moment of pouring are tape sealed.

3. When placing bearing plates and transitions will be bursting reinforcement, each bearing plate shall be fixed to the concrete form next to the anchorage. This form shall have the inclination indicated in the design, so that the concrete face is perfectly perpendicular to the trajectory of the cable. The end of the connecting sheath is introduced into the transition and the connection is tape sealed. If Design does not define bursting reinforcement, the one recommended in the ANCHORAGE tables must be used.

4. Placement of injection attachments: Grout vents are tied to the sheaths at the following points.
   - At anchorage transitions.
   - Every 20 meters along the sheath.
   - At high points when tendon has various curvatures.

   Should passive anchorages be used, the strands shall be placed inside the duct before pouring. In this case, depending on the lifting equipment available at the job-site, it may be pre-inserted, then the combination tendon-sheath placed.

   Coupler placement is carried out in the same way as the anchorages placement with some preparation instructions provided by DEL upon delivery.

   External Post-tensioning components placed prior to pouring (form tubes and deviators) must be connected to concrete forms and rebar in a way similar to the one described for bearing plates, transitions and sheaths. Components placed after casting (anchorages, pipes and strands) come with specific DEL placement recommendations.

Concrete Casting

If the strands are no previously inserted into the ducts, it is necessary to insert poly-duct or similar sheathing into the ducts to avoid their cramming should grout leak into them.

Vibration should be carried out very carefully to avoid knocking the ducts and close to anchorages to assure that no hollows are left that could cause collapse during tensioning. Also great care shall be taken to avoid damaging the exiting grout vent ducts.

If possible, form contact vibration is preferable.
**Stressing**
The operational sequence with type T Jacks & Pumps is as follows:

- The tendon ends are cut at the gripping distance (see “A” in Jack table) - plus 15 cm when the possibility of the tensioning is foreseen - and 10 cm on the side of the passive anchorage.

- Sheath excesses remaining on the inside of the anchorage transitions are eliminated and the wedge plate with its wedges is placed.

- The bearing frame, the wedging plate, then the jack are positioned, the latter suspended from its carrying device.

- The stressing is carried out in gradual steps of 100 bar hydraulic pressure of equivalent according to gage’s units. This is done by simply moving the pumping unit’s STRESSING lever. The strands are gripped automatically.

- During stressing the partial piston displacement are recorded for every pressure step except that from 0 to 100 bar which is obtained as the average of all partial displacements of 100 bar. Thus the apparent displacement, caused by the initial accommodation of the jack and cable, is absorbed.

- The sum of all partial displacements gives the real cable elongation relative to the structure, which must be compared to the expected elongation determined from Design’s data and strand characteristics.

- Wedge seating is accomplished by releasing the stressing pressure at the pumping unit. Strand return due to wedge seating is 12 mm.

- The piston returns to its initial position by simply moving the pumping unit’s RETRACTION lever. Degripping is automatic when retraction is completed, freeing the jack for tensioning again.

The operational sequence with type E Jacks & Pumps is similar to the one for type T, with the following changes:

1. Tendon end cuts are considerably longer (see “A” in Jack Table).

2. There is no need for bearing frame in front on the Jack. Once the wedge plate is positioned, the tensioning device, separated from the jack is inserted, prior to the positioning of the jack.

3. Gripping when stressing is not automatic. Rather, the rear gripping plate, with its wedges, and the detension bell must be positioned manually. Care must be taken for the wedges to be graphite-greased on their outside.

4. Wedge seating is accomplished by releasing the stressing pressure at the pumping unit. Strand return due to wedge seating is 12 mm.

5. At the end of the RETRACTION, gripping wedges come automatically loose and must be manually retired. The equipment is then ready for the next operation.

**Grouting**

Once the Supervision has approved the tensioning and within a time limit of suitably no more than a week:

- The tendon ends are cut at 2 cm from the wedges.

- If the prestressed concrete element has pokets at anchorage ends, these are poured with 25 MPa concrete to form plugs for the injection. If not, caps secured with screws are placed on the bearing plates which serve the same function.

- Compressed air is introduced into one of the injection ducts. (Sometimes this is not specified).

- The grouting machine is connected to one of the injection ducts.

- Water is pumped through the duct, thus facilitating the subsequent passage of the mixture.

- The mixture of water, cement and additive, is done in the mixing pan for a minimum of 2 minutes, with the qualities and proportions indicated by design or provision.

- The mixture is passed to the injection pan where it is automatically kept moving.

- The mixture is pumped until it comes by its own consistency out of all the injected cable ducts. The ducts are then closed without stopping the pump, which increases the pressure. When the pressure reaches 8 bar or the value indicated by design, the entry is closed and disconnected. Pumping may be interrupted at any time, recycling the mixture in the injection pan.

- All outlets shall be checked 24 hours after injection and if cement level is very low, they shall be manually refilled.