Multistrand Post-tensioning

MEXPRESA

DEL®
SISTEMAS CONSTRUCTIVOS

Foreword

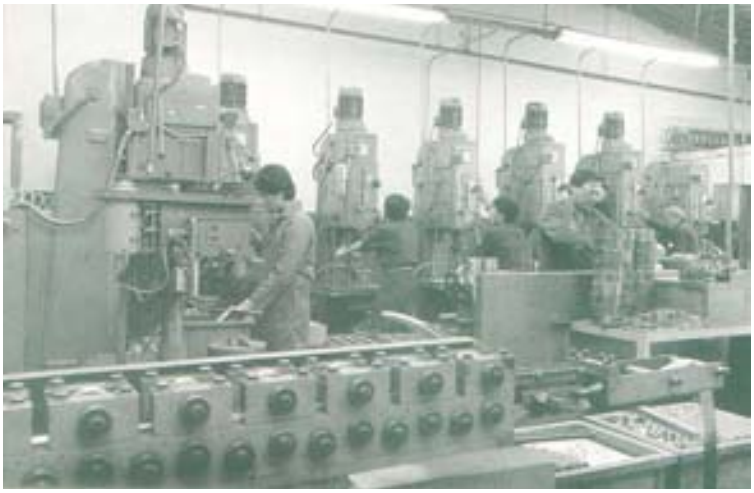
The DEL Pos-tensioning Systems are the result of a constant, ongoing evolution in Materials, Equipment and Techniques, focusing in field installation simplicity, while assuming the necessary requirements of quality, reliability, safety, serviceability, practicability and durability of structures in which 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.

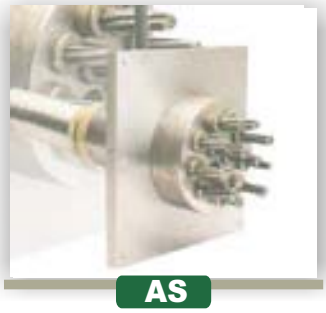
This DEL brochure of Multistrand Post-tensioning offers to the customers a complete line of Materials- anchorages, couplers, sheaths- and Equipment-jacks, pumping units and machines for grounting, strand pushing and sheath fabrication-, to cover the most common needs, including the more recent applications 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 appropiate solutions, per DEL clients' requests: a variety of purpose designed/manufactured 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.



ANCHORAGES



AS

AS 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.

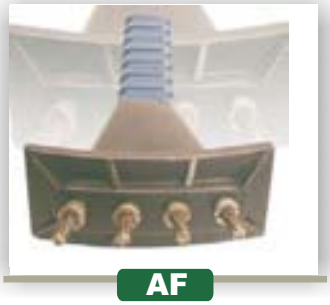
Design may specify active anchorages on both ends of a P.T. tendon even though stressing is carried out at one only. For wedge seating loss recuperation, shims canbe placed between wedge plate and bearing plate, through a lift-off.

AR

NOTE:
- For AR and AF the dimensions are the same as for AS, except "D", variable with adjusting lenght.

AR Active,Adjustable

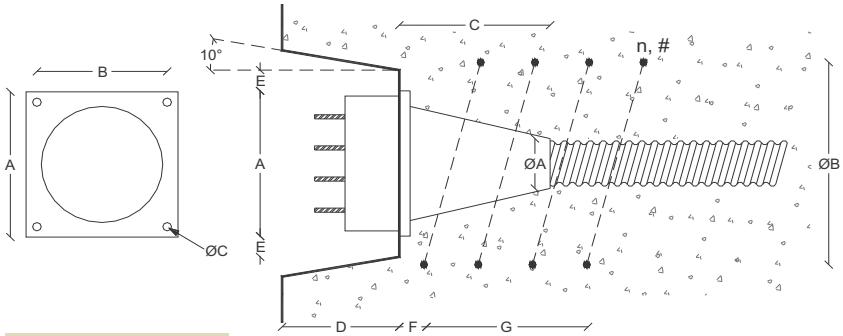
For tension adjustment after lock-off.They are supplied complete as for AS type, including adjusting nut.



AF

AF 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 Monostrand 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.

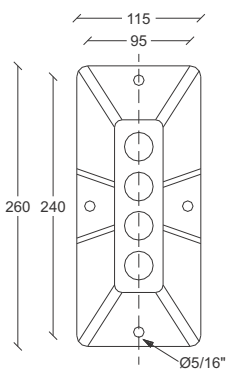


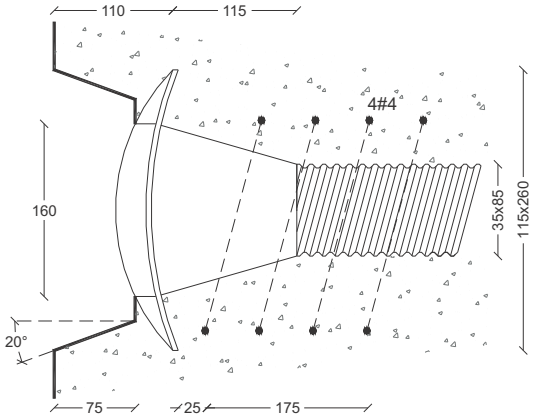
AS Anchorages

AS Anchorages

TYPE	FORCE	A	B	C	D	E	F	G	ØA	ØB	ØC	n	#
4-5	60	140	120	139	108	20	25	175	48	195	5/32"	4	4
7-5	105	180	160	160	110	20	25	250	63	265	5/32"	7	4
9-5	240	210	190	190	110	20	25	270	68	305	5/32"	4	5
12-5	180	250	225	225	110	25	30	285	78	350	5/32"	5	5
19-5	285	310	280	280	120	30	35	340	98	450	9/32"	7	5
23-5	345	350	315	315	125	35	40	410	103	470	9/32"	10	5
28-5	420	390	350	350	130	40	50	500	108	510	9/32"	12	6
31-5	465	410	370	370	135	40	55	555	113	565	9/32"	13	6
37-5	555	430	390	390	140	45	65	560	133	620	9/32"	14	6
4-6	780	150	460	460	150	55	95	940	143	740	7/16"	16	8
7-6	1370	210	560	560	155	65	140	1400	168	890	7/16"	18	8
9-6	191	250	225	225	110	25	30	305	78	280	5/32"	5	5
12-6	255	290	260	260	115	30	35	310	88	410	9/32"	9	5
15-6	2935	320	290	290	125	30	40	400	98	465	9/32"	9	6
19-6	404	360	325	325	130	35	50	480	108	520	9/32"	13	6
28-6	595	440	395	395	140	44	70	710	118	600	9/32"	13	6
31-6	659	470	425	425	145	50	80	785	123	670	9/32"	14	6
37.6	786	510	460	460	150	55	95	940	143	740	7/16"	16	8
55-6	1168	620	560	560	155	65	140	1400	168	890	7/16"	18	8

NOTE:
- Forces, nominal, in TON
- Dimensions en mm.
- Bursting reinforcement (n,#), to be installed only when design does not define it.
- Size not listed, provided by order.

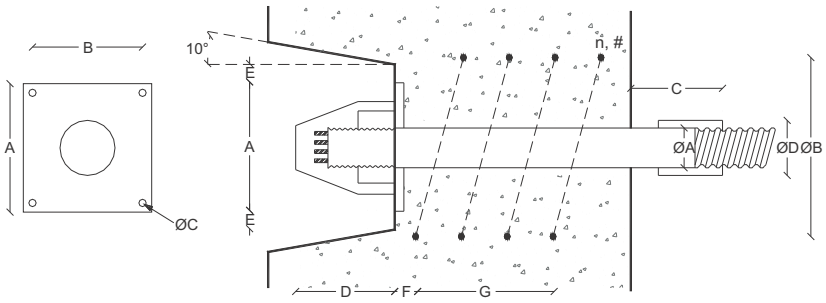




AF Anchorages

AE

NOTE:
- Forces, nominal, in TON
- Dimensions en mm.



AE Anchorages

AE Active for External Post-tensioning

Adjustable an esay to install and remove, DEL AE anchorages have been specially developed to withstand the dynamic actions ocurring at the ends of external tendons, and to ensure a correct grouting or filling of protectio 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.

NOTE:
- Forces, nominal, in TON
- Dimensions en mm.
- Bursting reinforcement (n,#), to be installed only when design does not define it.
- Size not listed, provided by order.

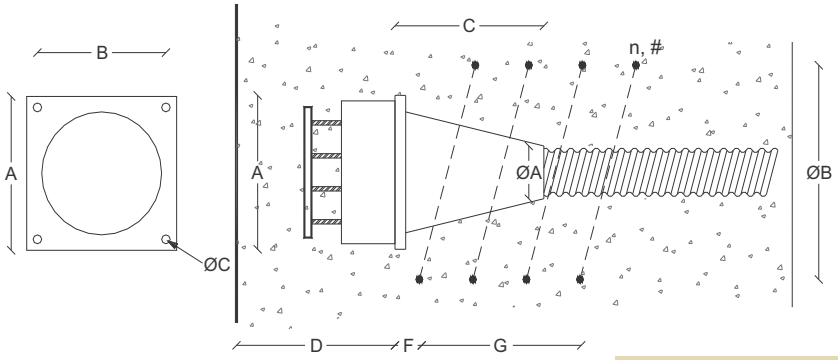
AE ANCHORAGES

TYPE	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-5	4-6	7.6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	131	180	285	345	420	465	555	254	252	191	255	183	404	595	659	786	1168
C	100	115	131	157	187	187	187	254	262	254	252	151	183	183	183	252	252	262	312
∅A	48	60	73	89	114	114	114	168	168	168	168	89	114	114	114	168	168	168	219
∅D	60	75	91	107	137	137	137	194	202	194	202	111	143	143	143	202	202	202	252

PC

PC Passive with Swage Heads

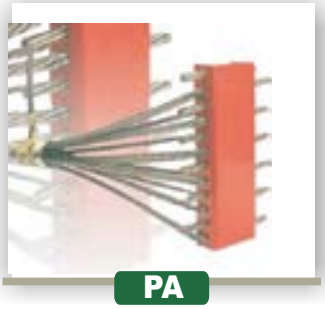
Same as PA when room for bond length is not available. Supply includes base, bearing and head retention plates, and transition. They may be substituted by AS anchorages with a wedge isolation box.



PC Anchorages

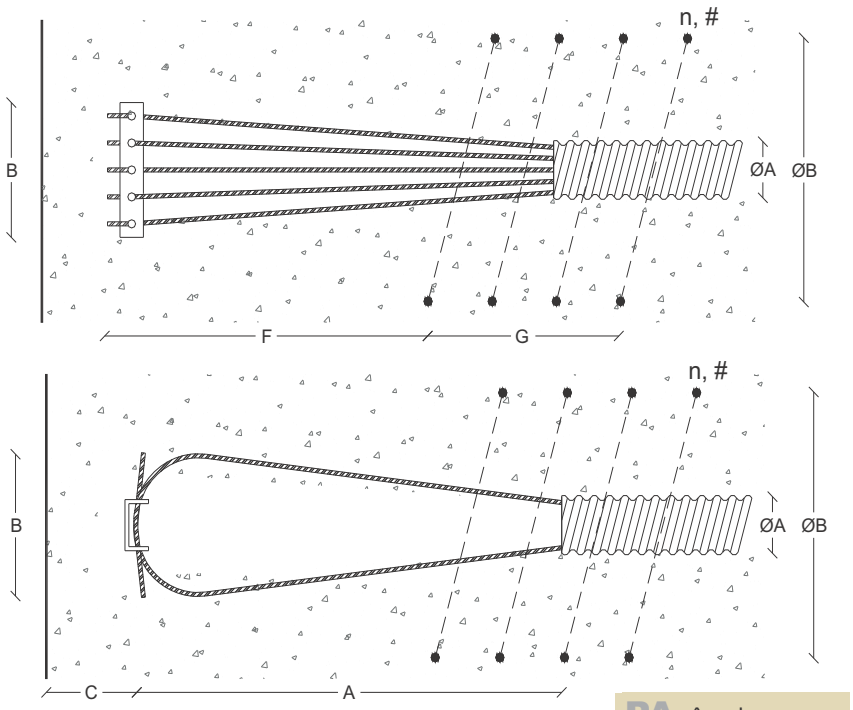
PC ANCHORAGES

TYPE	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-5	4-6	7-6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	60	180	285	345	420	465	555	45	1140	191	255	90	404	595	659	786	1168
D	148	150	150	150	160	165	170	175	180	150	155	150	155	160	160	180	185	190	200



PA 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.

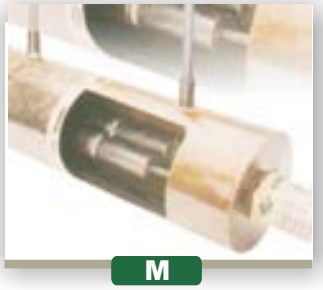


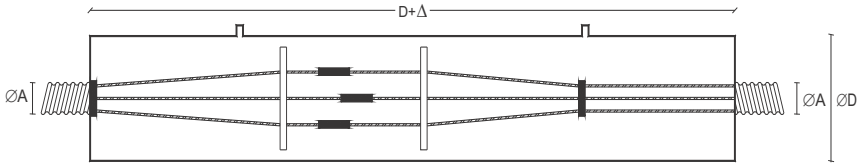
PA Anchorages

PA ANCHORAGES

TYPE	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-5	4-6	7-6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	60	180	285	345	420	465	555	45	1140	191	255	90	404	595	659	786	1168
A	600	600	700	700	800	900	11000	12000	13000	800	800	800	800	900	900	1300	1300	1400	1500
B	100	180	250	300	480	585	710	785	935	262	346	262	346	430	510	794	878	1046	1550
C	70	70	70	70	70	100	100	100	100	70	70	70	70	70	100	100	100	120	120
F	250	450	500	550	610	710	942	1110	1110	604	642	604	642	7000	742	1095	1095	1130	1190
G	200	200	240	264	316	316	316	316	380	272	316	272	316	316	316	405	450	535	795
∅B	170	170	200	220	260	260	260	260	310	230	262	230	260	260	260	385	425	500	750
n	5	5	5	6	8	8	8	8	9	7	8	7	8	8	8	10	11	13	19
#	4	4	5	5	5	5	6	6	6	5	5	5	5	5	5	6	6	8	8

NOTE:
- Forces, nominal, in TON
- Dimensions en mm.
- Bursting reinforcement (n,#), to be installed only when design does not define it.
- Size not listed, provided by order.





M Mobile

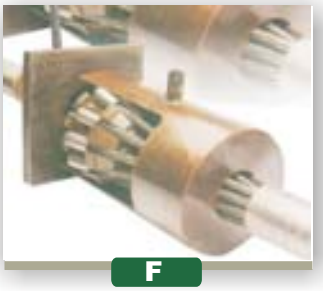
For multistrand cable extension. Used mostly in repair jobs for big size cables. They are supplied complete with strand concentrators & deviators, single couplers, shell and grout ports.

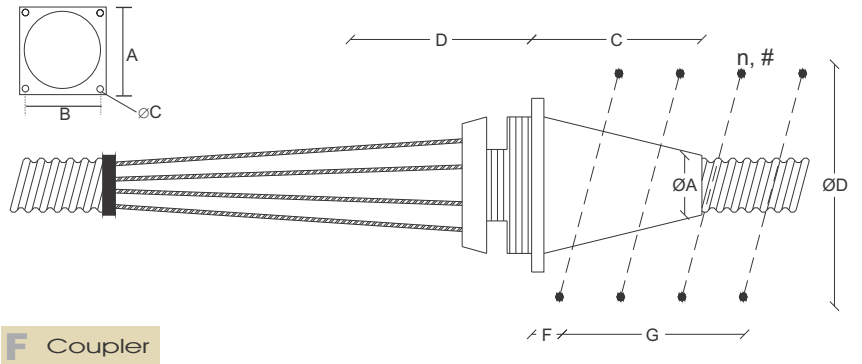
M Coupler

Δ = Elongation of tendon between passive end and coupler.

M COUPLER

TYPE	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-5	4-6	7-6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	60	180	285	345	420	465	555	45	1140	191	255	90	404	595	659	786	1168
D	350	350	360	372	600	640	735	784	791	990	1140	430	505	600	685	915	990	1140	1595
ØD	112	144	178	205	233	280	312	328	344	376	408	200	232	265	288	352	376	408	496





F Fixed

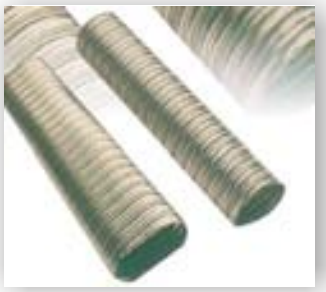
Used for prestressed concrete elements' post-tensioned connection. Also called Continuity Anchorages

F Coupler

F COUPLER

TYPE	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-5	4-6	7-6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	60	180	285	345	420	465	555	45	1140	191	255	90	404	595	659	786	1168
D	1221	1276	1451	1566	1652	1977	2159	2250	2250	2471	2562	1561	1678	1805	1886	2341	2471	2562	3277
ØD	170	216	267	307	350	420	468	462	516	564	612	300	348	398	432	528	564	612	744

SHEATHS



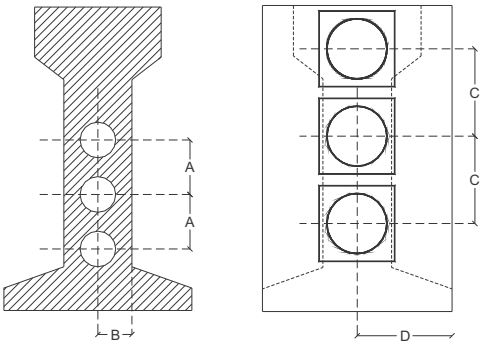
Steel Sheaths

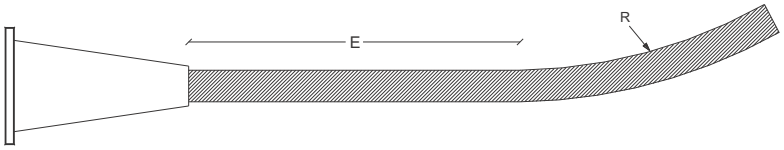
Plastic Sheaths

Corrugated steel and plastic, flat and circular DEL 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 DEL machines are available. This is a recomended option for remote sites. See equipment pages for details.





NOTE:
- Forces, nominal, in TON
- Dimensions en mm.
- Cable weight+Sheath, in kg/lm
- Cement, necessary for grounting, in kg/lm
- ∅ sheath, Nominal=inner

SHEATHS

TIPO	4-5	7-5	9-5	12-5	19-5	23-5	28-5	31-5	37-6	4-6	7-6	9-6	12-6	15-6	19-6	28-6	31-6	37-6	55-6
Force	60	105	60	180	285	345	420	465	555	45	55	191	255	90	404	595	659	786	1168
∅ Sheath	40	55	60	65	90	95	100	105	125	45	55	70	80	90	100	110	115	135	160
A	80	95	105	110	130	135	140	145	165	165	155	110	120	130	140	150	155	175	205
B	50	58	62	65	85	88	90	95	102	102	98	65	70	80	90	95	98	108	125
C	160	200	240	270	330	370	410	430	450	170	230	270	310	350	380	460	490	540	640
D	95	115	135	150	180	200	220	230	240	240	360	150	170	190	205	245	360	280	335
E	600	800	900	1000	1200	1200	1200	1400	1400	1400	1400	1000	1000	1100	1200	1400	1400	1600	2100
R	3000	3000	3000	4000	4000	4000	5000	5000	5000	5000	5000	4000	4000	4000	5000	5000	5000	5000	6000
Weight Kg/ml	3.5	6	8	10	16	19	23	25	30	5.0	8.5	11	14	18	22	32	35	42	63
Cement Kg/ml	1	2.5	3.5	4	6.5	7	7.5	8.5	13	1.5	2.1	4	5.5	7.5	8.5	9	10	15	22

JACKS

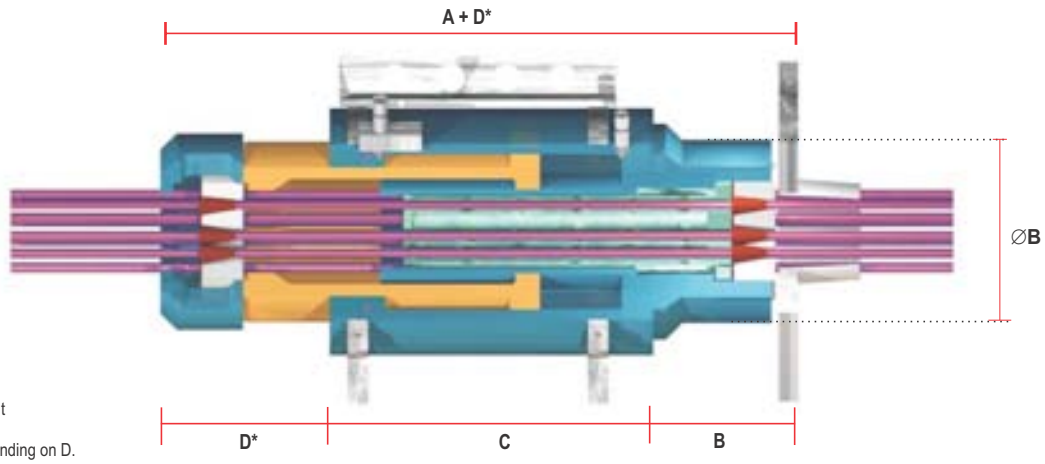
E JACKS

DEL 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.

E JACKS

MODEL	MAX.CABLE		PRESSURE AREA	WEIGHT	A	B	C	D*	∅B	∅C
E-105	7-5		215.1 cm2	65 Kg	575	135	330	200	160	225
E-195	12-5	9-6	401.8 cm2	134 Kg	595	155	390	250	225	3000
E-285	19-5	12-6	589.0 cm2	250 Kg	730	165	505	320	250	375
E-420	28-5	19-6	854.6 cm2	415 Kg	785	180	535	335	285	465
E-555	37-5	28-6	1123.7 cm2	585 Kg	840	195	570	345	345	535



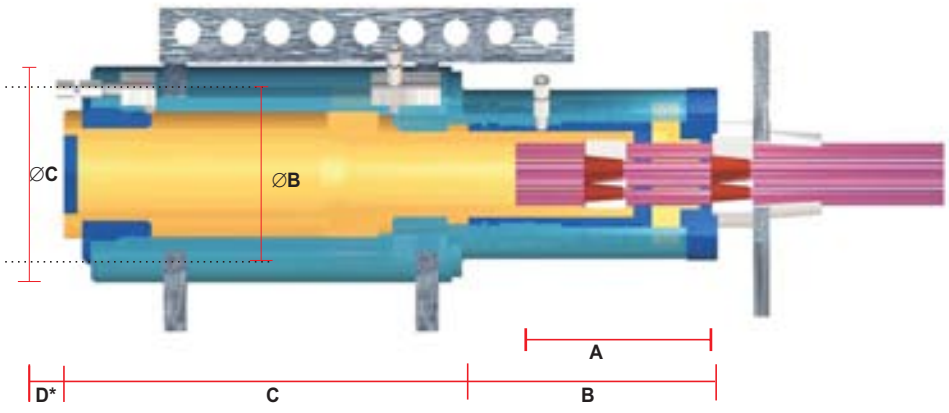
NOTE:
- Dimensions In mm.
  A-gripping distance.
- Piston strokes, D, can be of different lengths, by order.
- Jacks will be longer or shorter depending on D.

T JACKS

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

T JACKS

MODEL	MAX.CABLE		PRESSURE AREA	WEIGHT	A	B	C	D*	∅B	∅C
T-105	7-5		154.4 cm2	110 Kg	195	275	350	210	180	245
T-195	12-5	9-6	290.4 cm2	275 Kg	195	330	390	250	245	330
T-285	19-5	12-6	424.7 cm2	395 Kg	225	405	535	320	285	405
T-420	28-5	19-6	617.6 cm2	660 Kg	255	425	560	335	345	485
T-555	37-5	28-6	812.8 cm2	830 Kg	290	460	580	345	365	545
T-825		37-6	1213.2 cm2	1390Kg	315	470	590	350	445	680
T-1170		55-6	1718.7 cm2	1940Kg	330	475	600	355	525	795



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.

PUMPING UNITS

DEL 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.

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

(220 or 440 VOLT 3-phase A.C.)

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.

SPECIFICATIONS	
Tank capacity:	100 liters
Mixing velocities:	9 and 16.5 r.p.m.
Type of pumping:	continuous flow
Volume of flow:	12.5 l/min a 8 bar
Height to which cement mixture can be pumped:	80 m.
Weight when empty:	350 Kg.
Outer dimensions:	1150 x 700x 1750 mm
Required electric power:	8 Kw

(220 or 440 VOTL 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: (220 or 440 VOLT three-phase AC)	8 Kw

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

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

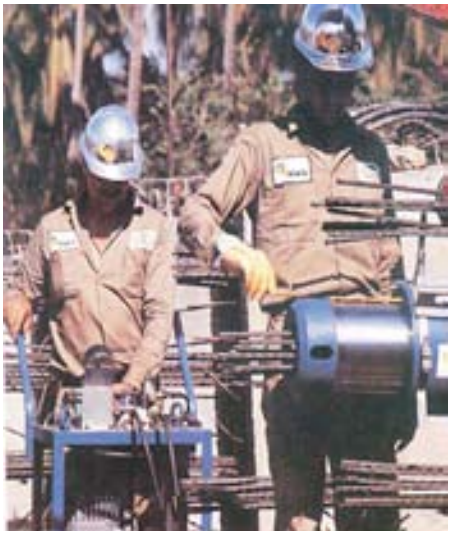
SHEATH FABRICATING MACHINES

SPECIFICATIONS

Production rate:	1500 m / 8 hrs (∅ 45) 800 m / 8 hrs (∅ 160)
Section lenghts:	6 m.
Net weight:	500 Kgs.
Outer dimensions:	1500 x 650* x 1050mm *Add 6m section container
Required electric power: (220 or 440 VOLT three-phase AC)	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.

Installation process



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 busting 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 busting 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 prefereable.

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 forseen -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 carried out simply by moving the pumping unit's LOCKING lever. Hydraulic pressure may be observed in the gage and rises to a previously fixed limit, lower than 200 bar.

- 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:

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

- 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.

- 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.

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

- 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.

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