TENSA
GRUPPO DE ECCHER

VOLUME	PRODUCTS CATALOGUE
02	**POST TENSIONING**

YOUR CHALLENGES,
OUR SOLUTIONS

High Speed Train line from Milan to Naples, Piacenza viaduct, Placenza (Italy)

01

COMPANY PROFILE

Our mission is to constantly improve the methods
and the quality of construction processes
through research, innovation and cooperation
with designers, engineers and contractors worldwide.

TENSA

Tensacciai, now renamed TENSA, was founded in 1951 with headquarters in Milan, Italy.
It is now active in over 50 countries with a direct presence in 14 countries. TENSA is a leader in stay cables, post-tensioning, anti-seismic devices, structural bearings and expansion joints. TENSA has extensive references and numerous certifications for its products worldwide.

HISTORY

1951: Beginning of activity
1964: In the sixties Tensacciai undergoes a phase of remarkable growth in Italy. Post-tensioning is just at the beginning of its history and its application is still experimental.
1970: A programme of technological renewal begins with the adoption of the steel strand.
1980: Tensacciai develops new tensioning systems and equipment in the field of ground anchors, combining innovation with versatility and ease of use.
1990: New subsidiaries established in Brazil, India and Australia and in Europe sister companies in Portugal, Greece and the Netherlands.
2000: The internationalization process of Tensacciai continues unabated.
2010: The company becomes directly involved in projects in all five continents.
2011: Tensacciai is acquired by Deal - world leading solutions provider in the field of bridge construction - and becomes part of De Eccher Group. Tensacciai is now member of an organisation capable of designing, manufacturing and installing systems everywhere in the world, thanks to specialised technicians, engineers in the technical department and quality control. All production and delivery processes are attested by the ISO9001 certification.
2012: Tensacciai merges with Tesit, another successful concrete specialist contractor with international experience in post-tensioning, steel bars, structural bearings and expansion joints becoming a prominent player in the field of specialised subcontracting.
Tensacciai enters into a Worldwide Exclusive License Agreement with Rome-based TIS (Tecniche Idraulico-Stradali S.r.l.) - a leading company with experience in designing and producing structural bearings, expansion joints and anti-seismic devices since 1973.
2014: TIS is acquired by Tensacciai.
2015: TENSA is formed from the merging and development of the three important companies mentioned above: Tensacciai, Tesit, TIS.

MISSION

Our mission is to constantly improve the methods and the quality of construction processes through research, innovation and cooperation with designers, engineers and contractors worldwide. A strong commitment to quality is the only way to ensure safe and long-lasting structures. We support the design from the initial stage, challenging standards to develop custom solutions. We value timely execution and service as keys to building long-term relationships.

Our core knowledge lies within stay-cables and post-tensioning systems, anti-seismic devices, structural bearings and expansion joints as well as all the related accessories, equipment and services.
TENSA strives to push its vast experience towards new methods and variations of applications, developing ingenious solutions for building new structures, whether they are buildings or infrastructures, as well as the rehabilitation of existing ones.

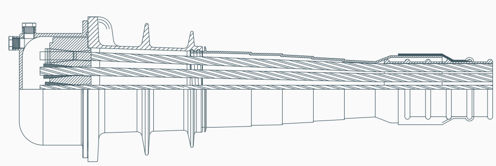
PRODUCT CATALOGUES

Highway viaduct, Loureiro (Portugal)

02

STRAND POST TENSIONING SYSTEMS

The post-tensioning system is suitable
for concrete, composite and steel structures.
A wide range of different systems is available.



GENERAL OVERVIEW

Post tensioning is a highly efficient structural reinforcement system that offers many benefits in a wide range of construction, repair and rehabilitation applications.
It can be applied in all types of construction, which include, without limitation, general buildings, special slabs, bridge decks, storage tanks, pavements and other geotechnical applications.

Compression stresses to concrete can be applied with the use of post tensioning tendons made of steel strands or steel bars.
When such tendons are fully installed in ducts within the concrete, post tensioning systems are defined as internal.
If the main tensile elements are in full adherence with the structure, the systems are defined as bonded, while they are unbonded in the other case.
In the event that the tendons are placed in ducts outside the concrete structure, such post tensioning systems are referred to as external.

Tendons are usually made of several strands (multi-strand systems), but mono-strand systems are also widely used.

Tagliamento viaduct, A4 highway Milano-Trieste (Italy)

A post tensioning system employing strands is usually composed of:

PROPRIETARY COMPONENTS

Wedge: device capable of gripping the single strand and transferring the load to the anchor plate through the conical hole in it.
Anchor plate: steel disk hosting strands and wedges, resting over the cast-iron block embedded into the concrete.
Cast-iron block: piece designed to transfer the load to the surrounding concrete. In some systems it can also be designed to directly accomodate holes for wedges that grip the strand.
Deviation rear trumpet: when present, it is joined to the cast-iron block and permits the deviation of the entire bundle of strands entering the duct.
Confinement and bursting reinforcement: spiral-shaped reinforcement and rebars properly placed around the anchorage to ensure the bearing of local high stresses and the containment of local tension-induced bursts.
Permanent protection cap: made of steel or fibre reinforced plastic, if required, it is used to cover the entire anchor plate and protect it from atmospherical agents.

STANDARD COMPONENTS

Seven wire steel strand: main tensile element transmitting the load through the entire tendon.
Ducts: they create void conduits where the bundle of strands is threaded.
Grout: a mix of water and cement-like materials required to fill the voids within the duct, providing protection and full bonding.
Corrosion protection injection compounds: materials used to protect the main tensile elements and the anchorages as a better performing alternative to simple grouting.

QUALITY AND CERTIFICATIONS

Post tensioning systems have been stringently tested under the requirements of the most important International Standards such as European Technical Approval Guideline ETAG013 and AASHTO LRFD Bridge Construction Specifications.
Through the process of testing and Approval Bodies evaluation, post tensioning systems have been granted European Technical Assessment ETA 08/0012, ETA 11/0007, and ETA 15/0023.
Systems are also provided with relevant Certificates of Constancy of Performances (CE marking).
Approval and Certification Bodies continuously monitor production and quality control activities carried out by TENSA over the post tensioning systems.

As a specialized contractor with decades of experience in its specific field, TENSA does not only provide supply and installation services of the finished products, but it is also capable of providing a wide range of associated services, starting with the design, moving on to the assembly and laboratory testing, including the definition of operating manuals and installation procedures, and ending with the provision of all engineering services related to the installation and maintenance throughout the life of the post-tensioned works. All this is carried out by TENSA's own teams of specialised and highly experienced technicians under a system that promotes full accountability and is in compliance with the standards of ISO9001.

Member of:

POST-TENSIONING INSTITUTE ®

fib CEB-FIP

BUREAU VERITAS 1828

European Technical Approval No. ETA-08/0012
(English language translation, the original version is in French language)
Version of 07th June 2013
Trade name: TENSACCIAI Post-tensioning system
Holder of approval: DEAL S.r.l.
Kit manufacturer: TENSACCIAI S.r.l.

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Authorised and notified according to Article 10 of the Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products (89/106/EEC)

MEMBRE DE L'EOTA
MEMBER OF EOTA

European Technical Approval No. ETA-11/0007
(English language translation, the original version is in French language)
Version of 22nd November 2011

Nom commercial Trade name	Procédé de précontrainte « TESIT 1C15 » monotoron "TESIT 1C15" monostrand post-tensioning system
Détenteur de l'ATE Holder of approval	DEAL S.r.l. Via Buttrio, Fraz. Cargnacco 33050 Pozzuolo del Friuli Udine - Italy
Type générique et utilisation prévue du produit de construction	Kit de précontrainte monotoron de structures par post-tension
Generic type and use of construction product	Monostrand post-tensioning kit for bonded and unbonded internal prestressing of structures
Valid from: to:	22/11/2011 11/02/2016
Producteur du procédé Kit manufacturer	TENSACCIAI S.r.l. Via Venti Settembre 24 20123 Milano (Italy)
This version replaces the last version of 11st February 2011 with holder of approval :	FINEST S.p.A Via Venti Settembre 24 20123 Milano - Italy
Le présent agrément technique européen contient	35 pages comprenant 16 pages d'annexes (dessins)
This European Technical Approval contains	35 pages including 16 pages of annexes (drawings)

EOTA
Organisation pour l'Agrément Technique Européen
European Organisation for Technical Approvals

European Technical Assessment
ETA 15/0023 of 18/01/2015

CERTIFICATE OF CONFORMITY
No. 1683 - CPD - 0006
PRESTRESSING POST-TENSIONING SYSTEMS
Certified Product : TENSACCIAI System

SYSTEM COMPONENTS

STEEL STRAND

Post tensioning tendons are usually made of strands with a 15.7 mm (0.62") or 15.2 mm (0.6") diameter.

Tendons can also be made of 12.7 mm (0.5") diameter strands: this system is less used but remains available in TENSA's product range.

Dimensions and properties of 7-wire strands according to prEN 10138-3 [1], ASTM A416 and BS5896

STEEL DESIGNATION		Y1860S7	Y1860S7
Tensile strength R_m (f_{pk}) [MPa]		1860	1860
Diameter D [mm]		15.7	15.2
Cross sectional area S_n (A_p) [mm^2]		150	139
Mass M [g/m]		1172	1086
Permitted deviation on nominal mass [%]		-	±2
Characteristic value of maximum force F_m (F_{pk}) [kN]		279	259
Maximum value of maximum force F_{m-max} [kN]		329	306
Characteristic value of 0.1% proof force $F_{p0.1}$ ($F_{p0.1k}$) [kN]		246	228
Minimum elongation at maximum force A_{gt} ($L_0 \geq$) [%]		3.5	3.5
Relaxation after 1000 hours	at 0.7 F_m [2] [%]	2.5	2.5
	at 0.8 F_m [3] [%]	4.5	4.5
Modulus of elasticity E [MPa]		195000	195000

(Notations according to prEN 10138-3, in rounded brackets to ETAG013 where possible)
Other types of strands are available on request, according to main international standards.
(1) Until prEN 10138-3 remains a draft norm, standards and regulations valid at the place of installation can be used.
(2) The requirement for 70% F_m is mandatory.
(3) Values for 80% F_m may be agreed between supplier and purchaser.

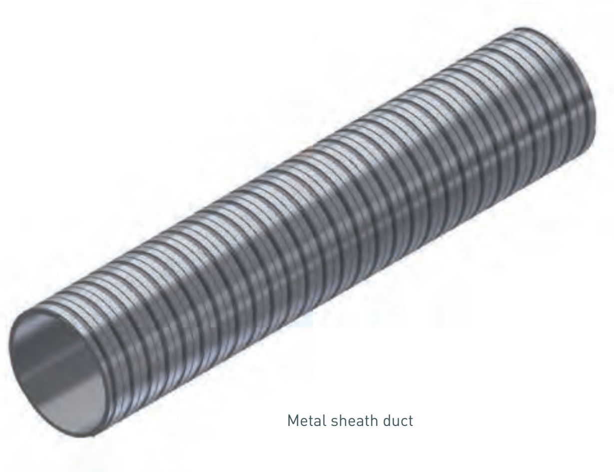
DUCTS

Ducts are made of bright or galvanized steel sheaths or plastic material (polyethylene or polypropylene).

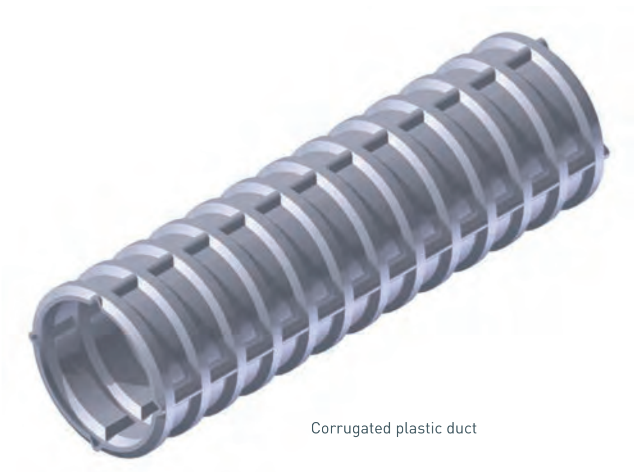
They have a corrugated outside surface that guarantees adequate bond transfer to the surrounding concrete.

In the case of the metal sheath, the thickness varies from 0.3 to 0.6 mm (on request), whereas with the plastic ducts it ranges from 2.5 to 4 mm.

These dimensions are only an indication and in any case the ducts must comply with national standards and be in accordance with operating conditions.



Metal sheath duct



Corrugated plastic duct

Suggested technical specifications

STRAND NO.	4	7	9	12	15	19	22	27	31	37
Internal Ø [mm] for metal sheath duct	45	62	72	80	85	95	100	110	115	130
Internal Ø [mm] for plastic duct	48	58	76	76	85	100	100	109	115	130
Grout requirement [l/m]	1.2	2.3	2.8	3.6	3.8	4.7	5.2	6.2	6.9	8.6
Cement [kg/m]	1.9	3.6	4.5	5.8	6.1	7.5	8.4	9.9	10.8	13.8

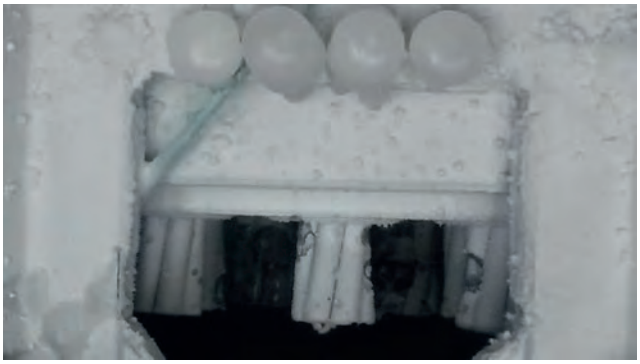
MULTI STRAND POST TENSIONING SYSTEMS

Multi-strand systems are provided with a wide range of anchorages and solutions for different construction needs.
They can be used in concrete and composite structures, both for new construction and the rehabilitation of existing structures where an increase in resistance is required.

INTERNAL MTAI LIVE ANCHORAGE

The live anchorage MTAI is the most used and widely spread type of anchorage, whose compact geometry and reduced deviation angle provides a competitive advantage in all project applications, combined with high performance standards and ease of installation. It can be also used in the unbonded MTAIU version, where single sheathed strands are used.

MTAI SYSTEM IN CRYOGENIC APPLICATIONS



System has been successfully tested at cryogenic conditions as per ETAG013 and SR 88/2. Compliance for use in LNG tanks and special structures has been completely assessed by Third Party Laboratories.

INTERNAL MTAIM DEAD ANCHORAGE

It is a non-accessible (dead) anchorage which is used in case accessibility during the stressing phases is not allowed.
In such a case strands are placed before pouring the concrete of the structure.

MTG COUPLER ANCHORAGE

MTG system is the type of anchorage suitable for the coupling of tendons.
It is fully integrated with the MTAI system and allows installation of a secondary tendon after the primary one has been completely installed.

MTAID ELECTRICALLY INSULATED ANCHORAGE

MTAID anchorage for electrically insulated post tensioning is designed to meet the demand for a total and permanent protection of post tensioning tendons from corrosive agents. This protection is granted by the tendon's complete envelopment, which is made of:

- MTAID anchorage with anchor plate separated from the cast-iron block by means of rigid dielectric disks, plastic connectors positioned inside the cast-iron block and connected to the corrugated ducts by means of tight joint seals:
- full covering plastic protection cap
- plastic ducts in the free length

The electrically insulated post tensioning system offers measurable advantages:

- electrical insulation of the cable from the surrounding environment and consequent protection against corrosion caused by electrochemical phenomena, oxidation and chlorides attack;
- possibility of controlling the protection's integrity through electrical resistance measures during the structures's lifetime.

This system has been widely used and tested in the world's largest full scale application of its kind, the 4.3 km long Piacenza viaduct (Italy).
This system is in compliance with class PL-3 requirements of PTI/ASBI M50.3-12 "Guide Specification for Grouted Post-tensioning".

EXTERNAL MTAIE ANCHORAGE

This anchorage can be used in external tendons and comes in different versions, such as:

- fully dismountable (MTAIE), through the presence of an inner steel cone that separates strands and inner protective injection from the surrounding elements in the anchorage zone;
- restressable (MTAIER) by means of a special long protection cap and the use of greased and coated strands;
- not exchangeable (MTAIEX).

PTSE FLAT ANCHORAGE

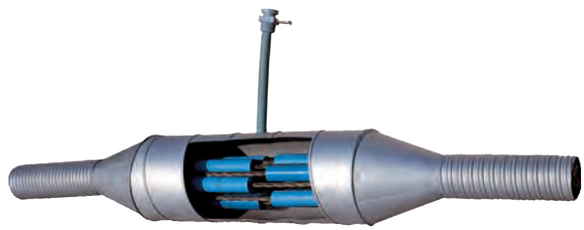
The new improved system for thin slabs post tensioning is the PTSE, whose compact size is the best performing in the market.
Range is from 2 up to 5 strands and can be used as a bonded system with plastic / metal ducts or unbonded with plastic coated strands.

INTERNAL PTS FLAT ANCHORAGE

Bonded post tensioning of slabs or thin walls can be performed with the use of flat anchorages PTS, whose range is from 2 up to 5 strands, whose special shape requires reduced space for installation.
It can be used both with corrugated metal sheath and plastic ducts.

CU COUPLING SYSTEM

Single strand CU couplers are used to connect tendons built in different stages. Connection is made with single strand CU couplers, to be placed in different layers enabling a compact shape.



DF ANNULAR ANCHORAGE

Special rectangular anchorages are used for ring and intermediate post tensioning: these anchorages also use a special deviator for tensioning with mono-strand jacks.

ST ANCHORAGE

It is used as a dead end anchorage, done by creating
a bulb end on each of the strands composing the tendon.

MONO STRAND POST TENSIONING SYSTEMS

Mono-strand systems are used for post tensioning of concrete slabs, pavements, separation walls and special concrete structures such as underground car parks, silos and tanks.
They can be used for unbonded or bonded applications. The most widely-used is the unbonded application, where the use of greased and coated strands allows fast installation of mono-strand tendons without duct placing and absence of bond between plastic coating and concrete.
In such a case, the main advantages are:
• strands are covered with special corrosion inhibitor grease and with a proof PE coating;
• high performance in service conditions (SLS);
• possibility to maximize cables' eccentricity;
• rapidity of installation;
• reduction of cracking phenomena.

Isozaki Tower, Milan (Italy)

Suggested technical specifications

STEEL DESIGNATION	Y1820S7G	Y1860S7	Y1860S7
Diameter [mm]	15.2	15.2	15.7
Ultimate strength [MPa]	1820	1860	1860
Area [mm²]	165	139	150
Maximum load [kN]	300	259	279

In the case of bonded solutions, it is required to place corrugated metal sheaths or plastic ducts before concreting the structure and thread steel strands at the time of stressing.
Grout injection is then necessary to complete corrosion protection and guarantee the bond between the tensile elements and the surrounding duct and concrete.

Regione Piemonte Tower, Turin (Italy)

LIVE END TESIT 1C15 UL/BL

This anchorage is made of a single cast-iron piece which transfers the load from the tensile element to the concrete and hosts the wedge that grips the strand.
It is available either in the unbonded version 1C15UL or in the bonded 1C15BL, both complete with covering caps.

DEAD END TESIT 1C15 UD/BD

It is used where anchorage is not accessible for stressing operations.
It can be provided both in the unbonded version 1C15UD or in the bonded 1C15BD version, complete with their relevant wedge spring and fixing cap.

COUPLER TESIT 1C15 UC/BC

This system allows direct mechanical coupling of tendons that have been placed during different construction phases.

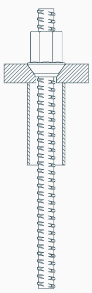
Isozaki Tower, Milan (Italy)

Red Line North Elevated viaducts, Doha (Qatar)

03

BAR POST TENSIONING SYSTEMS

Threaded steel bars can be used in different applications and structures, providing safe and reliable application of post tensioning.



BAR POST TENSIONING SYSTEMS

TENSA supplies bars with continuous thread for post tensioning applications in buildings, roads, bridges and viaducts, tunnels and mine shafts.
These systems can be provided in diameters varying from 12 to 75 mm, and are used worldwide in post tensioning and in pre-tensioning systems applications.
The advantages of using these post tensioning systems are several and are supported by excellent results achieved on various project sites.
Different corrosion protection systems and steel grades are available.

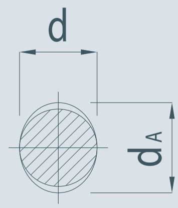
The main advantages are:
• Easy handling on-site;
• Continuous thread along the entire length of the bar, which ensures optimal adhesion to the cast in situ concrete;
• Cut to size and possibility of extension using couplers in any position of the bar;
• Different possibilities for protection against corrosive phenomena: galvanized, hot dip galvanized, epoxy coated, painted in accordance to different standards .

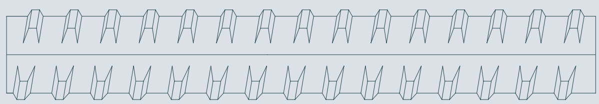
For special applications further steel grades are available.

Arch Bridge over the Railway in Souk Ahras (Algeria)

STEEL BAR CHARACTERISTICS

CONTINUOUS LEFT HAND, THREADED BAR, HOT ROLLED AND RIBBED





SAS 670/800										
d []	18	22	25	28	30	35	43	57.5	63.5	75
max d_A [mm]	21	25	26	32	34	40	48	63	70	82
f_{yk} / f_{tk} / A_{gt}	670 N/mm² / 800 N/mm² / ≥ 5%									
F_{yk} ($F_{0.2k}$) [kN]	170	255	329	413	474	645	973	1740	2122	2960
F_{tk} [kN]	204	304	393	493	565	770	1162	2077	2534	3535
A [mm²]	254	380	491	616	707	962	1452	2597	3167	4418

CONTINUOUS THREAD BARS RIGHT HAND, HOT ROLLED

SAS 950/1050 SAS 835/1050									
d [mm]	18	26.5	32	36	40	47	57	65	75
max d_A [mm]	21	31	37	42	46	53	64	72	82
$f_{p0.1k}$ / f_{pk} / A_{10} [1]	950 N/mm² / 1050 N/mm² / ≥ 7 %						835 N/mm² / 1035 N/mm² / ≥ 7%		
F_{yk} ($F_{0.1k}$) [kN]	230	525	760	960	1190	1650	2155	2780	3690
F_{pk} [kN]	255	580	845	1070	1320	1820	2671	3447	4572
A [mm²]	241	551	804	1020	1257	1735	2581	3331	4418

[1] A_{10} = ultimate elongation in a gauge length to 10 bar diameters

Several types of accessories are available to meet all design requirements. Full range of couplers, nuts and anchor plates, including special pieces can be provided on request. TENSA is able to provide a wide range of product customization, for applications requiring new and different shapes.

End caps are always placed when it is necessary to provide a protective injection in the anchorage zone.

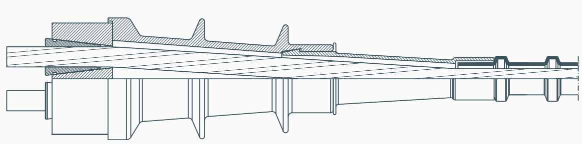
Bars can be provided with different corrosion protections such as spray galvanization, hot galvanization or epoxy coating.

Manhattan West Platform, New York City (USA)

04

SYSTEM PROPERTIES AND DIMENSIONS

An overlook of all the properties
and dimensions
listed in tables for each system.



MAIN FEATURES OF MULTI STRAND TENDONS

STRAND DIAMETER 15.7 mm

NOMINAL CROSS SECTION AREA 150 mm^2

NOMINAL MASS 1172 g/m

CHARACTERISTIC TENSILE STRENGTH F_{PK} = 1860 MPa

STRAND NO.	4	7	9	12	15	19	22	27	31	37
Nominal cross section area of steel A_p [mm^2]	600	1050	1350	1800	2250	2850	3300	4050	4650	5550
Nominal mass of steel [kg/m]	4.69	8.20	10.55	14.06	17.58	22.27	25.78	31.64	36.33	43.36
Characteristic ultimate resisting force of tendon F_{pk} [kN]	1116	1953	2511	3348	4185	5301	6138	7533	8649	10323

STRAND DIAMETER 15.2 mm

NOMINAL CROSS SECTION AREA 139 mm^2

NOMINAL MASS 1086 g/m

CHARACTERISTIC TENSILE STRENGTH F_{PK} = 1860 MPa

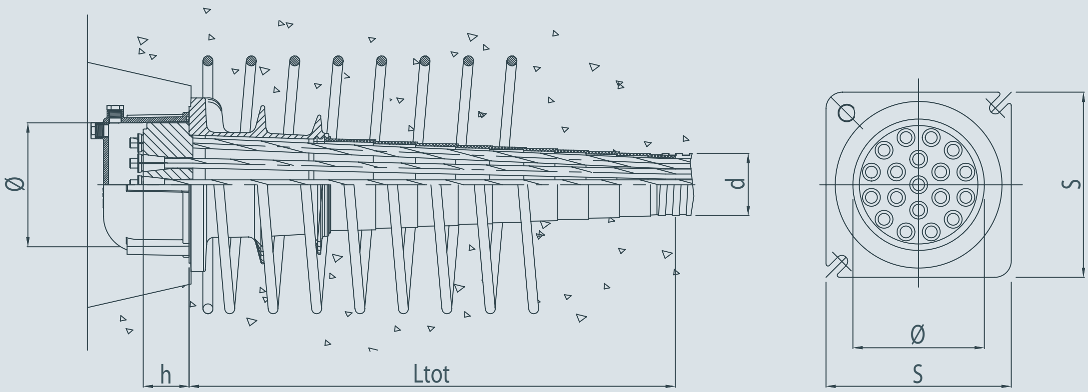
STRAND NO.	4	7	9	12	15	19	22	27	31	37
Nominal cross section area of steel A_p [mm^2]	556	973	1251	1668	2085	2641	3058	3753	4309	5143
Nominal mass of steel [kg/m]	4.34	7.60	9.77	13.03	16.29	20.63	23.89	29.32	33.66	40.18
Characteristic ultimate resisting force of tendon F_{pk} [kN]	1036	1813	2331	3108	3885	4921	5698	6993	8029	9583

Steel strand properties according to prEN10138-3. Systems can also be used with strands in accordance with ASTM A416.

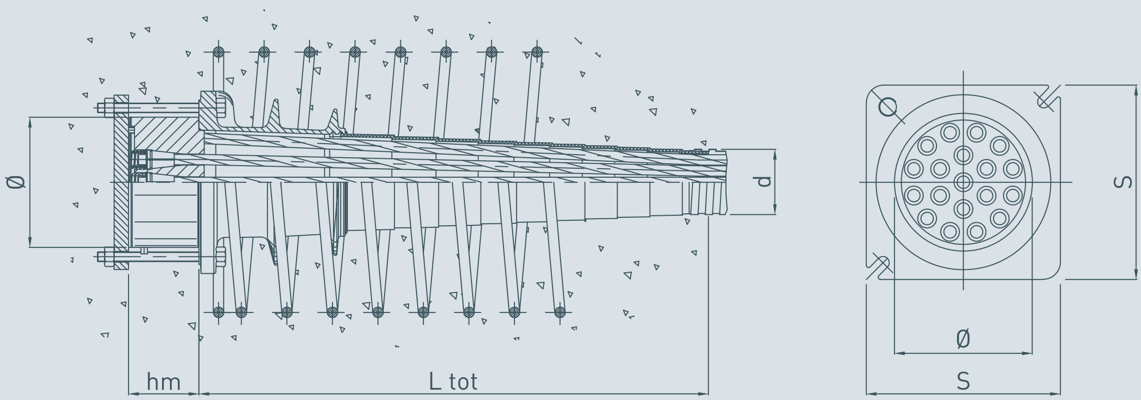
The maximum pre-stressing force to be applied on the tendon is specified in the national standards and regulations in force in the place of use.

MULTI STRAND POST TENSIONING SYSTEMS

MTAI SYSTEM



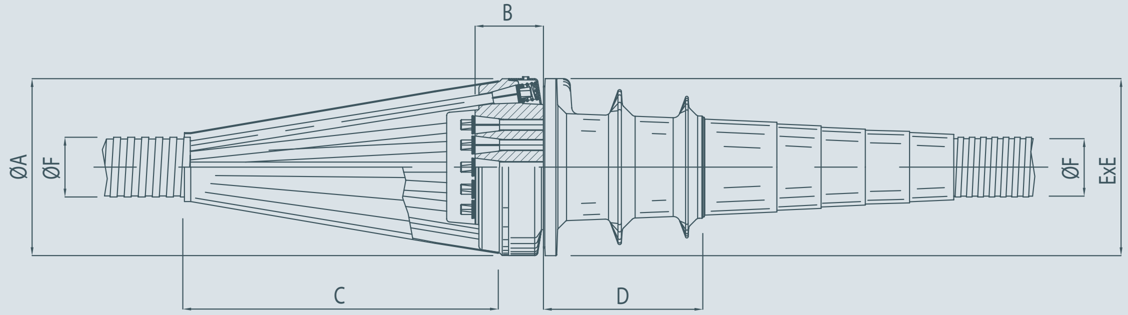
MTAIM SYSTEM



MTAI/MTAIM SYSTEM SIZE	4	7	9	12	15	19	22	27	31	37
Ltot [mm]	475	531	688	708	736	783	823	848	1009	1107
S [mm]	150	180	200	220	250	280	300	325	350	400
Φ [mm]	105	125	146	160	176	200	230	250	270	280
h [mm]	45	49	52	62	69	74	80	87	91	96
hm [mm]	77	84	84	92	98	106	110	115	122	131
d (int/ext) [mm]*	45/50	62/67	72/77	80/85	85/90	95/100	100/105	110/115	115/120	130/135

* = in case of use of metal sheath ducts

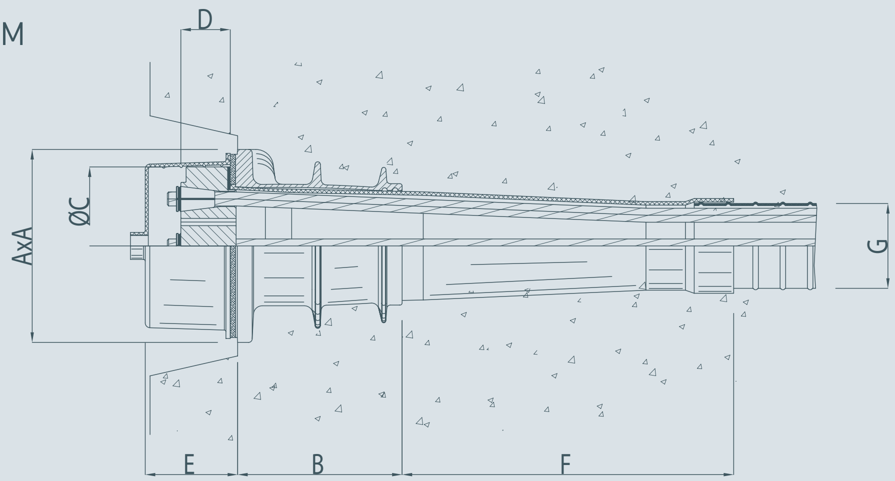
MTG COUPLER SYSTEM



MTG SYSTEM SIZE	4	7	9	12	15	19	22	27	31	37
A [mm]	185	215	230	248	265	280	340	340	390	430
B [mm]	110	110	110	110	115	125	130	140	140	150
C [mm]	330	380	400	430	460	460	600	600	730	815
D [mm]	100	120	180	190	208	225	240	250	300	360
E [mm]	150	180	200	220	250	280	300	325	370	400
F (int/ext) [mm]*	45/50	62/67	72/77	80/85	85/90	95/100	100/105	110/115	115/120	130/135

* = in case of use of metal sheath ducts

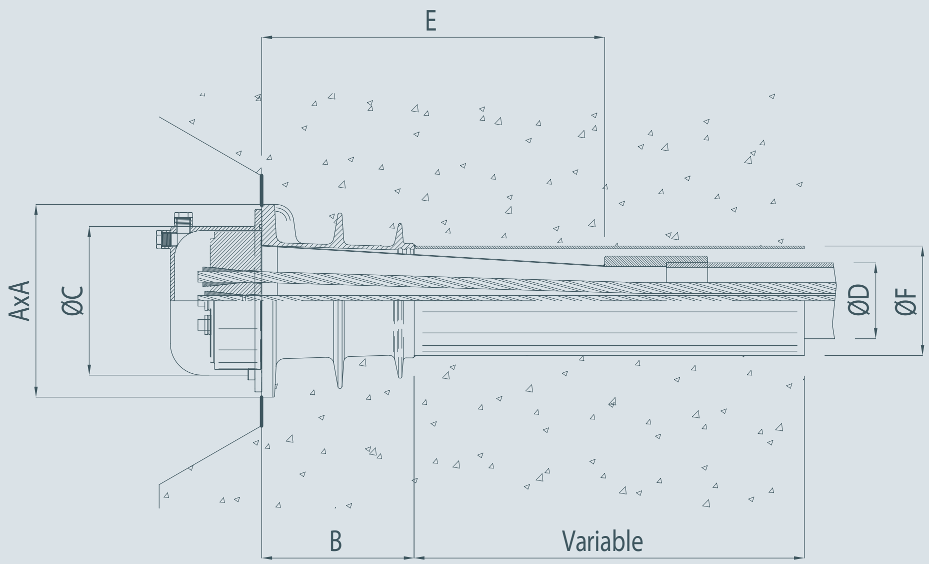
MTAID SYSTEM



MTAID SYSTEM SIZE	4	7	9	12	15	19	22	27	31	37
A [mm]	150	180	200	220	250	280	300	325	350	400
B [mm]	100	120	180	190	208	225	240	250	300	360
C [mm]	110	135	160	180	200	220	250	270	285	305
D [mm]	45	49	52	62	69	74	80	87	91	96
E [mm]	90	90	90	90	95	100	110	115	125	135
F [mm]	390	565	500	505	382	560	490	615	610	795
G (int/ext)][mm]*	48/73	59/74	76/91	85/100	100/116	100/116	115/134	115/134	130/150	130/150

* = only with plastic ducts

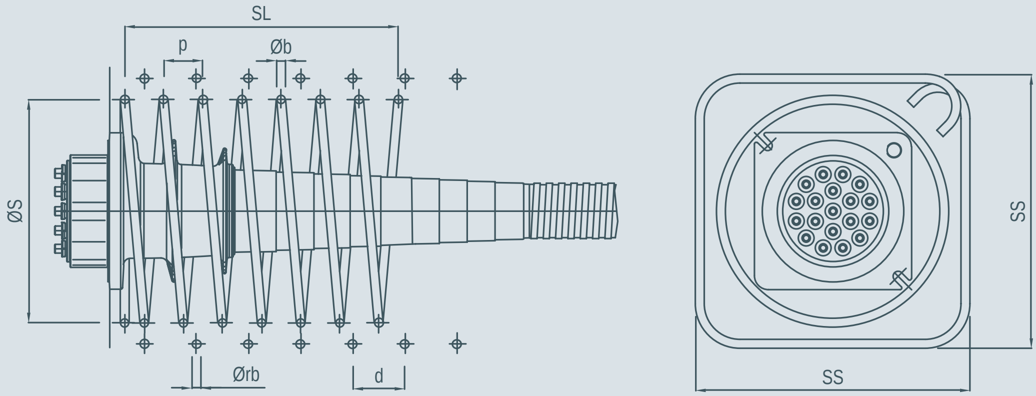
MTAIE SYSTEM



MTAI SYSTEM SIZE	4	7	9	12	15	19	22	27	31	37
A [mm]	150	180	200	220	250	280	300	325	350	400
B [mm]	100	120	180	190	208	225	240	250	300	380
C [mm]	135	160	177	195	210	245	265	295	330	330
D [mm] / thickness [mm]*	63/3.6	75/4.5	90/5.4	110/6.6	110/6.6	125/7.4	125/7.4	140/8.3	160/9.5	160/9.5
E [mm]	310	360	430	450	520	600	660	700	750	800
F [mm]	80	102	120	140	145	159	193.7	193.7	219	229

* = with use of smooth plastic ducts

CONFINEMENT AND BURSTING (ADDITIONAL) REINFORCEMENT

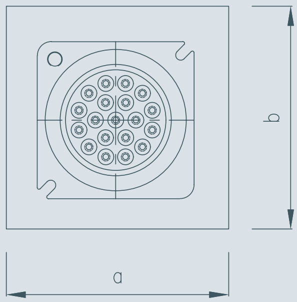


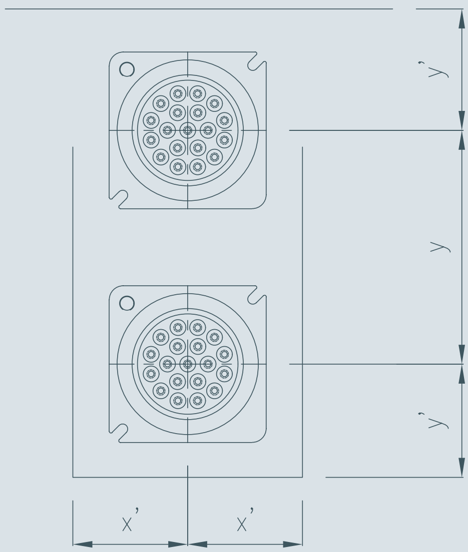
MTAI SYSTEM SIZE	4			7			9			12			15		
Concrete strength $f_{cm,0\text{-}cyl}$ [MPa]	25	33	45	25	33	45	25	33	45	25	33	45	25	33	45
Φs [mm]	200	160	130	250	200	175	290	255	215	340	295	235	380	335	275
Φb [mm]	10	12	12	12	14	14	12	14	14	14	16	16	14	16	16
SL [mm]	200	180	180	300	270	240	360	330	300	420	350	300	450	375	350
p [mm]	50	60	60	60	60	60	60	60	60	60	50	50	50	50	50
No. of turns	5	4	4	6	5.5	5	7	6.5	6	8	8	7	8.5	8.5	8
Φrb [mm]*	8	8	8	10	10	10	10	10	10	10	12	12	12	12	12
d [mm]*	50	50	50	55	60	60	55	60	60	55	60	60	60	50	50
SS [mm]*	230	180	165	310	260	220	380	310	250	440	355	285	490	400	325
No. of stirrups*	4	4	5	6	6	6	6	6	7	7	7	8	9	9	9

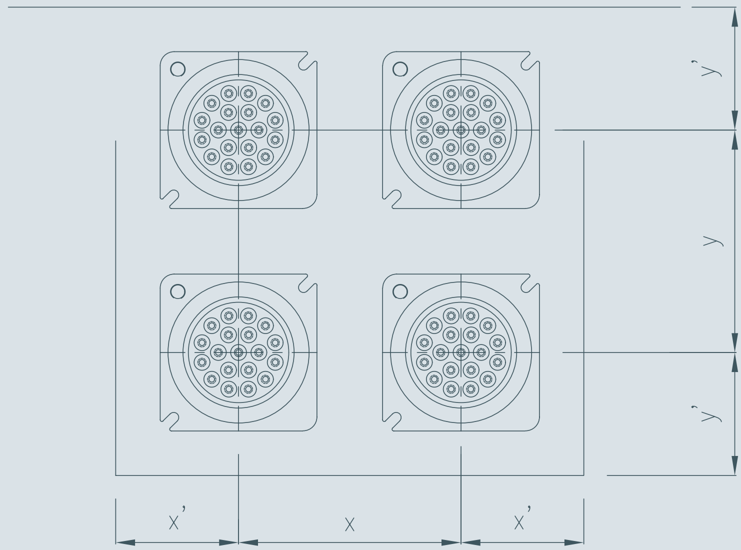
MTAI SYSTEM SIZE	19			22			27			31			37		
Concrete strength $f_{cm,0\text{-}cyl}$ [MPa]	25	33	45	25	33	45	25	33	45	25	33	45	25	33	45
Φs [mm]	410	360	315	470	400	340	500	440	390	540	480	410	560	500	430
Φb [mm]	16	16	16	16	20	20	20	20	20	20	20	20	20	20	20
SL [mm]	510	425	400	600	480	420	660	540	480	690	600	540	720	660	600
p [mm]	60	50	50	60	60	60	60	60	60	60	60	60	60	60	60
No. of turns	9.5	9.5	9	11	9	8	12	10	9	12.5	11	10	13	12	11
Φrb [mm]*	12	12	12	12	12	12	14	14	14	14	14	14	16	14	14
d [mm]*	60	50	50	60	50	50	65	50	50	65	50	50	65	50	50
SS [mm]*	540	450	365	610	490	395	680	540	430	720	585	470	800	650	520
No. of stirrups*	9	10	11	9	10	12	11	12	13	11	13	15	14	15	16

* = suggested bursting (additional) reinforcement in the anchorage zone to be verified by the Designer in accordance with Regulations in force at the place of use

CENTRE AND EDGE DISTANCE







MTAI SYSTEM SIZE	**4**	**7**	**9**	**12**	**15**	**19**	**22**	**27**	**31**	**37**
Tested block dimensions a=b [mm]										
$f_{cm,0-cyl}$ = 25 MPa	270	355	400	465	520	580	630	700	755	840
$f_{cm,0-cyl}$ = 33 MPa	220	290	330	380	425	475	515	570	615	680
$f_{cm,0-cyl}$ = 45 MPa	180	240	270	310	350	390	420	465	500	550

The actual spacing / center distance and edge distance in the structure shall comply with:

$$A_c = x \cdot y \geq a \cdot b$$

$$x \geq 0.85 \cdot a$$

$$y \geq 0.85 \cdot b$$

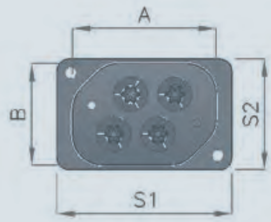
$$x' \geq 0.5 \cdot x + \text{concrete cover} - 10\ [\text{mm}]$$

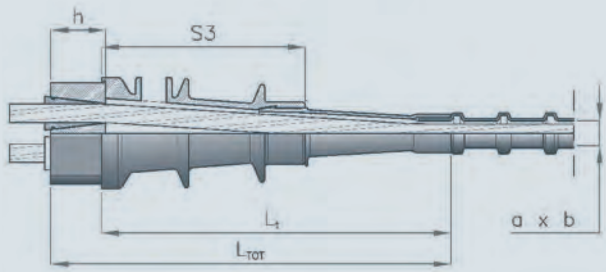
$$y' \geq 0.5 \cdot x + \text{concrete cover} - 10\ [\text{mm}]$$

Concrete cover in accordance with European Standard EN 1992-1-1 and national regulations valid at the place of use.

PTSE SYSTEM

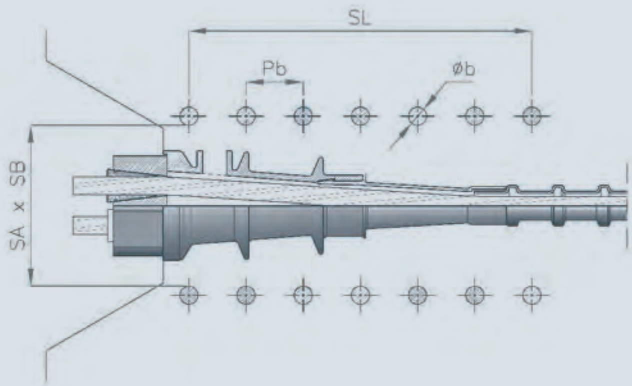
PTSE SYSTEM SIZE	2	4	5
LTOT [mm]	24	344	374
S1 [mm]	115	150	185
S2 [mm]	75	95	95
S3 [mm]	150	175	190
A [mm]	88	123	150
B [mm]	67	87	87
h [mm]	47	47	47
Lt [mm]	240	300	330
a x b (int) metal sheet [mm]	42 / 18	70 / 21	90 / 21
a x b (int) plastic [mm]	38 / 22	72 / 21	90 / 21





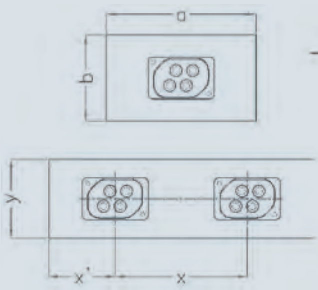
CONFINEMENT REINFORCEMENT

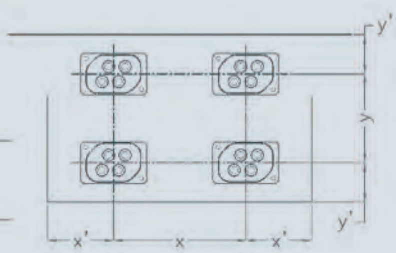
PTSE SYSTEM SIZE	2	4	5
Concrete strength $f_{cm,0-cyl}$ [MPa]	20	20	20
Φb [mm]	12	16	16
SA [mm]	135	200	235
SB [mm]	120	140	160
SL [mm]	180	300	350
Pb [mm]	45	50	50
No. of stirrups	5	7	8



INTERAXIS AND EDGE DISTANCES

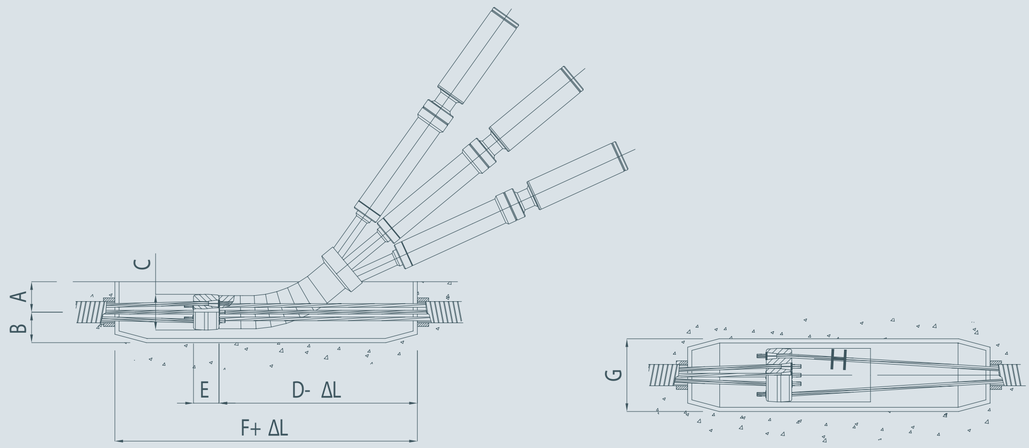
PTSE SYSTEM SIZE	2	4	5
Tested block dimensions **a**	220	340	380
Tested block dimensions **b**	160	195	220
Minimum slab thickness	140	165	190





The actual spacing / centre distance and edge distance in the structure shall comply with:

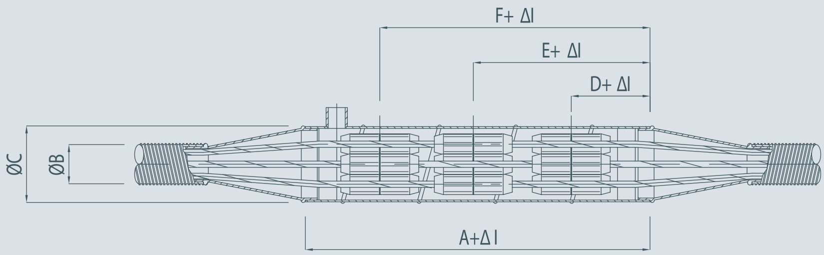
$Ac = x \cdot y \geq a \cdot b$
$x \geq 0.85 \cdot a$
$y \geq 0.85 \cdot b$
$x' \geq 0.5 \cdot x$
$y' \geq 0.5 \cdot y$



DF SYSTEM SIZE	2	4	6	8	12
A [mm]	85	90	110	115	120
B [mm]	55	60	80	85	90
C [mm]	90	100	140	150	160
D [mm]	100	160	230	320	400
E [mm]	70	80	100	130	160
F [mm]	560	710	860	950	1200
G [mm]	170	200	240	300	330
H [mm]	140	170	210	270	300

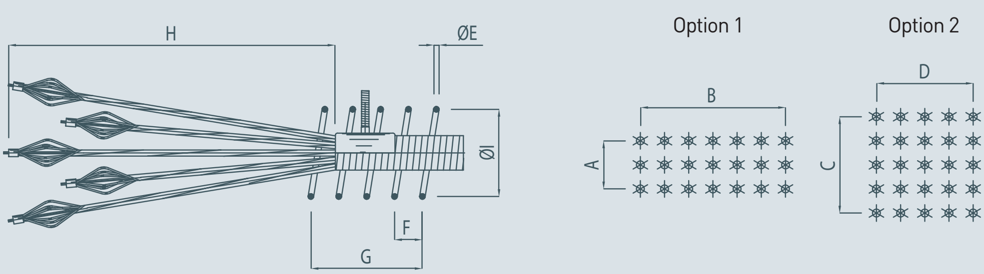
Additional sizes available on request.

CU COUPLING SYSTEM



CU SYSTEM SIZE	4T15	7T15	9T15	12T15	15T15	19T15	22T15	27T15
A [mm]	675	800	950	1250	1250	1300	1385	1700
B [mm]	45/50	62/67	72/77	80/85	85/90	95/100	100/105	110/115
C [mm]	140	159	177	193	193	193	219	244
D [mm]	300	340	400	400	400	400	400	400
E [mm]	-	-	800	800	800	800	800	600
F [mm]	-	-	-	1200	1200	1200	1800	1400

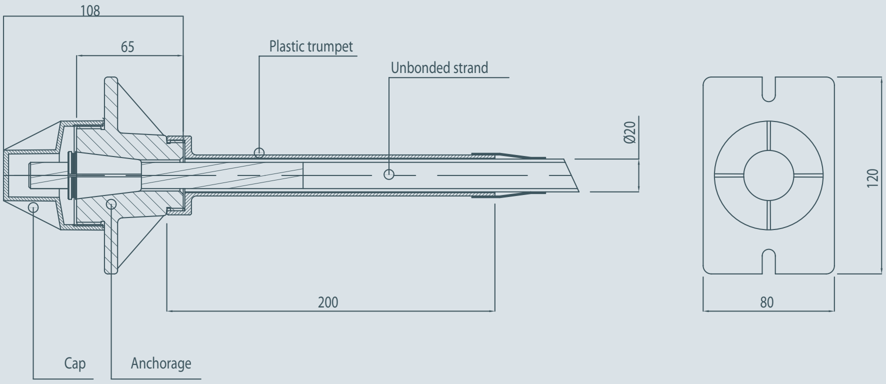
ST DEAD END SYSTEM



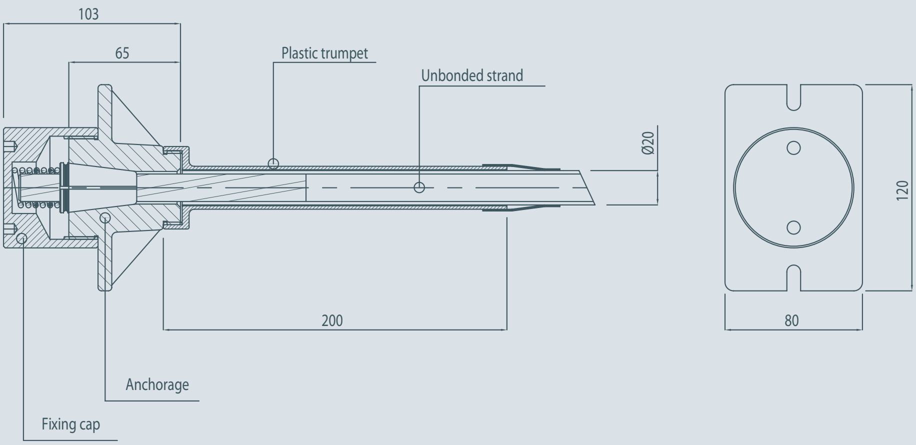
ST SYSTEM SIZE	4	7	9	12	15	19
A [mm]	-	80	-	80	-	-
B [mm]	210	240	-	400	-	-
C [mm]	80	-	160	160	160	240
D [mm]	80	-	160	160	160	240
E [mm]	10	10	12	14	14	14
F [mm]	50	50	60	60	60	60
G [mm]	250	350	400	400	400	400
H [mm]	800	800	800	800	800	900
I [mm]	100	100	150	150	150	220

MONO-STRAND POST TENSIONING SYSTEMS

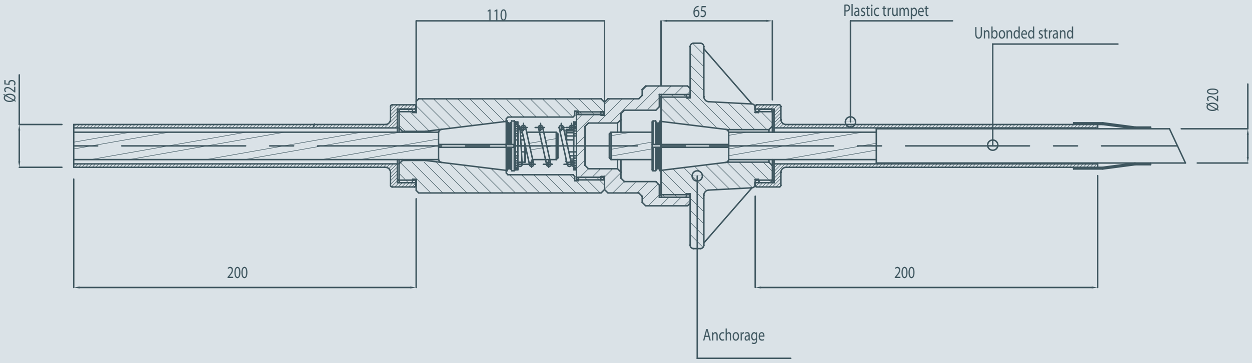
TESIT 1C15-UL



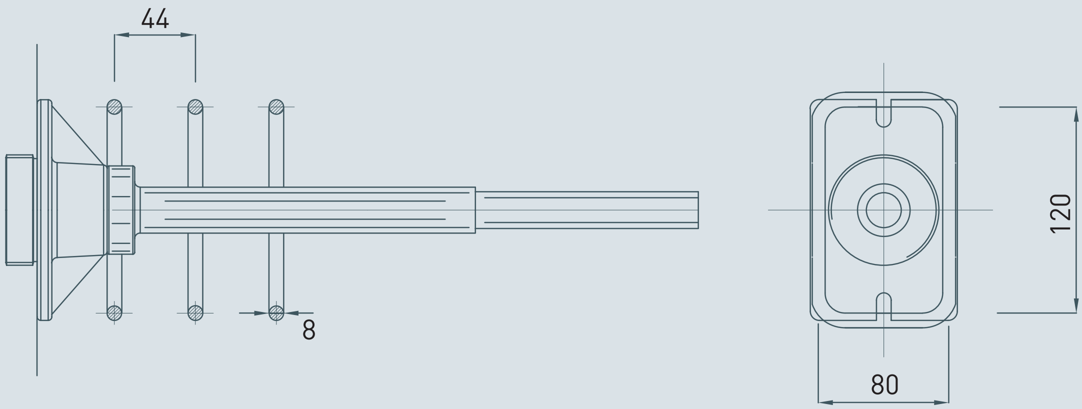
TESIT 1C15-UD



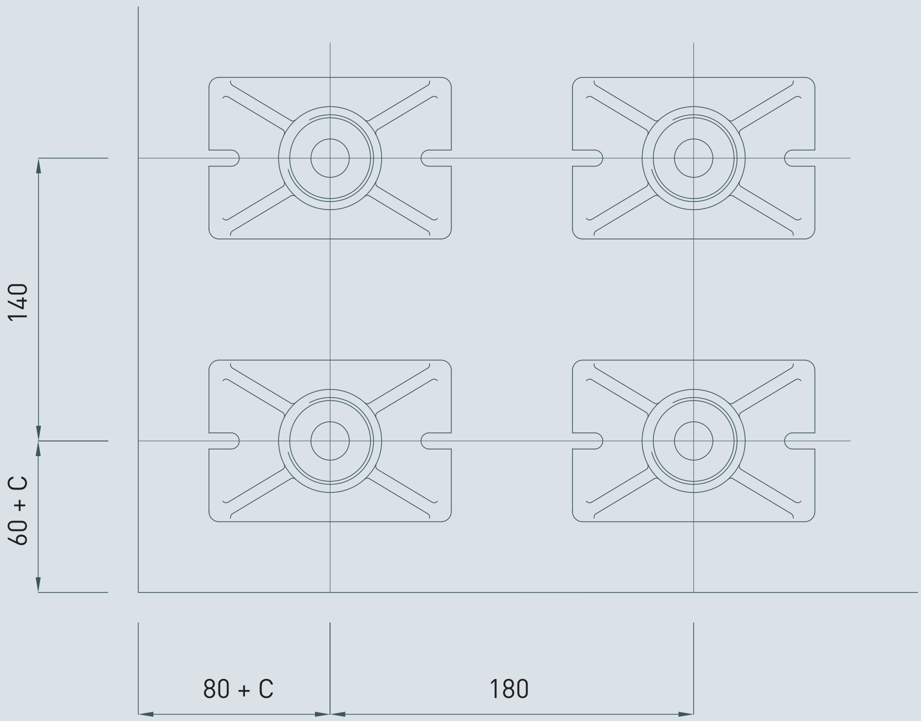
TESIT 1C15-UC



CONFINEMENT REINFORCEMENT



CENTRE AND EDGE DISTANCES



Values valid for $f_{cm,0-cyl} \geq 16.5$ MPa

c = concrete cover in accordance with European Standard EN 1992-1-1 and national regulations currently in force applicable in the country of utilisation

CALCULATION NOTES

FRICTION LOSSES

The calculation of the loss of pre-stressing force due to friction and wobble effects inside tendons is usually made starting from the following equation (source: EN 1992-1-1):

$$\Delta P_{\mu\ (x)} = P_{max}\ (1-e^{-\mu(\theta+kx)})$$

where:
$\Delta P_{\mu\ (x)}$ = loss of pre-stressing force from 0 up to x distance [kN]
x = distance from the stressing point [m]
P_{max} = force at the stressing end [kN]
μ = friction coefficient between strands and ducts [1/rad]
θ = sum of the angular deviation from 0 up to x distance, irrespective of direction or sign [rad]
k = non-intentional angular deviation inside tendons, wobble coefficient [rad/m]

Values for friction coefficient μ are between 0.18 and 0.22 while k values are between 0.005 and 0.01.

Recommended values for calculation are μ = 0.19 [1/rad] and k = 0.005 [rad/m].

BASIC ELONGATION EVALUATION FACTORS

The elongation of the tendon, under the action of one or two jacks, is determined by the designer and verified at the construction site. The elongation calculation must clearly specify the theoretical elongation calculation and the corrective elements taken into account. It must be possible to establish with great accuracy the relationship between calculated elongation and measured elongation. In fact, secondary terms should be added to the elongation of the tendon along its length up to the anchorages, to obtain the real elongation. Real elongation measured at the construction site is thus defined as the sum of the following elements:

- ΔL_a: theoretical elongation of the strand, calculated on the basis of the length between the anchorages, at one or two ends, depending on whether one or two jacks are used.
- ΔL_b: concrete elastic shortening. This piece of data, since it is extremely small, is usually disregarded.
- ΔL_r: accumulation of deformations of the anchorage devices, for the deflection of the anchorages into the concrete and for the draw-in of the wedges.
- ΔL_v: draw-in of the strand wedges within the jack and jack deformations.

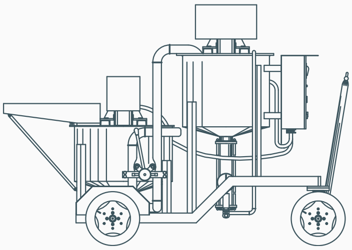
$$\Delta L_o = \Delta L_a + \Delta L_b + \Delta L_r + \Delta L_v$$

Jamal Abdul Nasser Street, Kuwait City (Kuwait)

05

INSTALLATION

Our teams take care of all installation phases,
thanks to a decades-long experience in the filed
and dedicated working procedures.



INSTALLATION PHASES

The installation of TENSA's post tensioning systems consists of the following phases:

PLACING OF THE DUCTS AND ANCHORAGE BODY

For internal post tensioning, ducts are placed before concreting, fixed to the reinforcing steel of the structure to avoid that their position changes during the pouring phase.
For longitudinal post tensioning they are usually placed following a parabolic layout.
Anchorage bodies are securely fastened to the formwork.

THREADING OF STRANDS

Strands are threaded one by one inside the placed duct, using special strand pushing machines.
Threading operations are carried out with care to avoid any damage to the strand or to the duct.
If required in special cases, it is also possible to have strands pulled together through ducts.

TENSIONING

Stressing is carried out using multi-strand or mono-strand jacks, depending on the system used and local jobsite conditions, all provided with automatic hydraulic lock-off system.

GROUTING

Grouting of tendons is performed to protect strands from corrosion and can be performed either with cement grout or soft anti-corrosion compounds.
Tendons' ducts are provided with air vent pipes at the highest points to ensure absence of vacuum pockets and must be completely tight. In case of a complex tendon layout or special applications, vacuum injection may be performed through the use of dedicated equipment.
In case of use of flexible filler, both for internal and external tendons, injection may be carried out with use of vacuum pumps.
Together with its post tensioning system TENSA has developed a range of dedicated installation equipment, including multi and mono stressing jacks, hydraulic pumps, grouting pumps and load cells.
Nowadays TENSA is proudly involved in the design and production of new stressing jacks, applying technology and experience to achieve higher performing results.

Sa Carneiro Airport, Porto (Portugal)

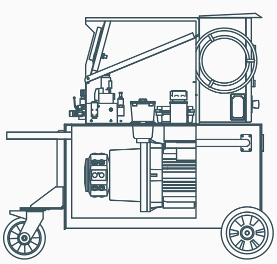
Isozaki Tower, Milan (Italy)

Manhattan West Platform, New York City (USA)

06

INSTALLATION EQUIPMENT

A wide range of equipment for tendons installation
that ensures a complete and safe work.



MULTI-STRAND AND MONO-STRAND JACKS

TENSA manufactures several types of "MT" stressing jacks (mono-group), ranging from 1000 up to 10000 kN.
They have been designed and built considering the following stressing needs: minimum strand waste (300 mm to 500 mm), automatic lock-off, easy removal and control of the wedges, jack rotation around its own axis.

MTA SERIES

MTA series jacks are the latest development of TENSA's multi-strand jacks, designed with front end master wedges gripping and short strands overlength needed.
Sizes and weights are combined to provide a good balance between performance and site needs. Jacks are completed as usual with automatic lock-off system and easy transport and movement connections.

MT SERIES

The "MT" jacks have been designed and built by TENSA considering the following stressing needs: minimum strand waste, jack built-in hydraulic circuit, controlled lock-off, easily removed and controlled wedges, jack rotation around its own axis, making it easier to place and wedge onto the tendon.
The high functionality and high quality of the material have made this line of jacks very successful under the most severe operating conditions.

MTX SERIES

The "MTX" series jacks, as natural evolution of the "MT" series jack, have been designed and built for stressing in very confined areas, where the overall dimensions of the jack are a fundamental factor.

MTP SERIES

MTP series jacks are the latest evolution of TENSA's stressing equipment. This series has been designed bearing in mind all the lessons learnt from many years of experience on project sites all around the world, and is designed to guarantee top performance during installation.

PT SERIES (MONO-STRAND)

TENSA manufactures four types of mono-strand "PT" series jacks, which differ in terms of tensioning section, weight and dimensions. All jacks of the "PT" series are equipped with the automatic lock-off system.

STRESSING PUMP

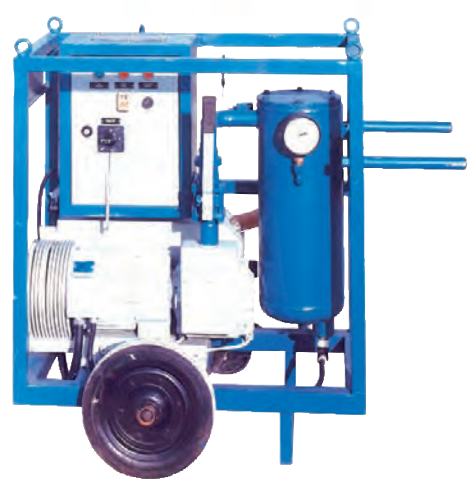
TENSA offers a wide range of hydraulic pumps, which differ in terms of performance ratings, dimensions and weight. The "PT" series jacks require stressing pumps with power ratings ranging between 2.2 and 10 kW.
The MT, MTX and MTP series jacks require stressing pumps with power ratings ranging between 7.5 and 30 kW.
All TENSA pumps are equipped with an automatic lock-off circuit.

GROUTING PUMP

The "GP" pump is available in various models, which differ in terms of performance ratings. The grouting pump consists of an eccentric screw pump, a mixer and a turbomixer.
All the machines are equipped with a push-button control panel.

AIR PUMP

TENSA offers vacuum pumps with power ratings ranging from 4 kW to 7.5 kW. This pump is used to inject grout under a vacuum, thus guaranteeing perfect grouting without any immission of air.



STRAND PUSHING MACHINE

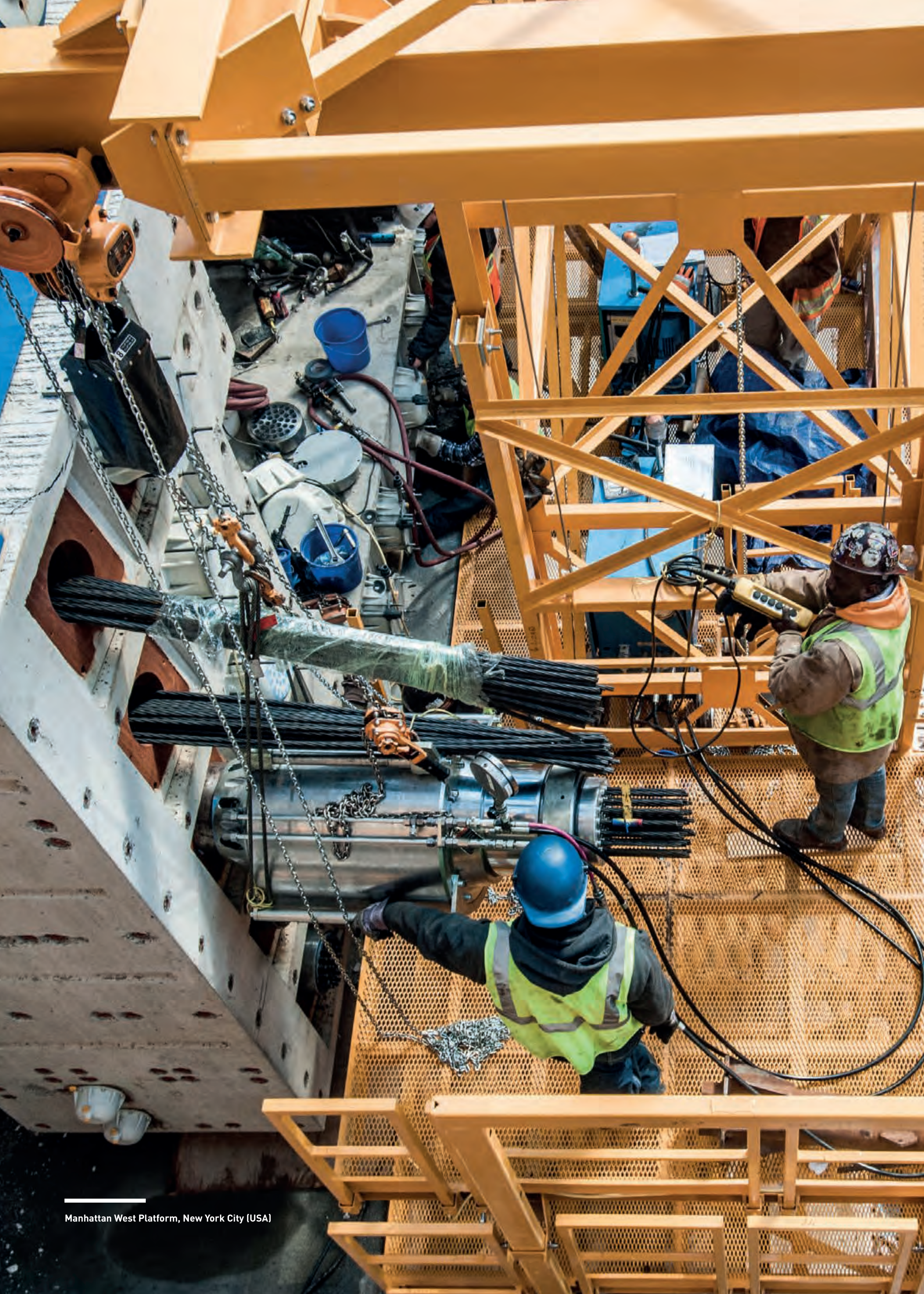
This equipment, designed to insert strands into the ducts, consists of a hydraulic pump and a unit able to push strands for long distances inside the conducts.
The two units can be installed at a remote location.
TENSA offers various models to meet all construction site requirements.

EXTRUSION JACK

The equipment consists of a high powered portable jack (XG2), fed by a hydraulic pump. This jack extrudes passive anchorages (compression grips) at the ends of the strands.
The jack drive will vary depending on the type of pump to which it is connected.

EQUIPMENT FOR ST DEAD ANCHORAGE

The equipment consists of an automatic pump XST/3" and an operating unit (jack UST/3") that opens the strand.
The bond end operation is completely automatic, controlled by an electronic device regulating the duration and the intensity of the force applied.



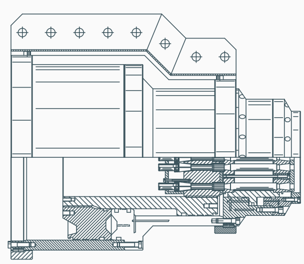
Manhattan West Platform, New York City (USA)

Covas Viaduct, Galicia (Spain)

07

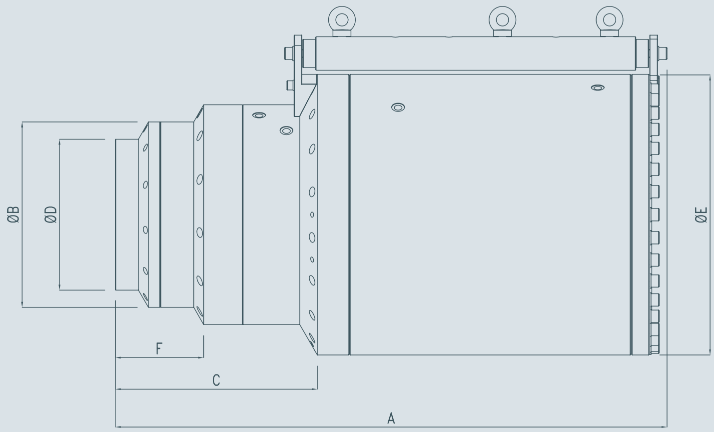
EQUIPMENT PROPERTIES AND DIMENSIONS

An overlook of all the properties and dimensions listed for each equipment.



MULTI-STRAND STRESSING JACKS

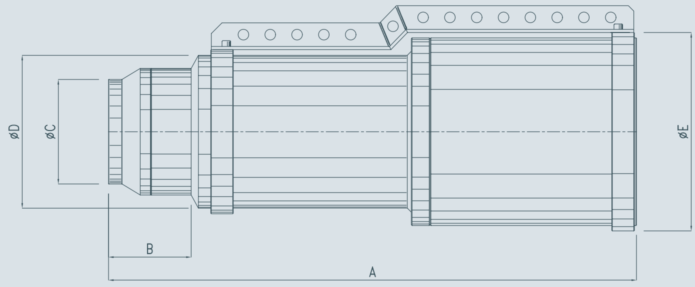
MTA SERIES



TYPE OF JACK	MTA 950kN	MTA 1700kN	MTA 2200kN	MTA 2900kN	MTA 3600kN	MTA 4600kN	MTA 5300kN	MTA 6500kN	MTA 7400kN	MTA 8800kN
N° of strands	4	7	9	12	15	19	22	27	27-31	37
Capacity [kN]	950	1700	2200	2900	3600	4600	5300	6500	7400	8800
Stroke [mm]	250	250	250	250	250	250	300	325	300	300
Weight [kg]	150	350	450	560	650	750	1050	1055	1340	1683
Tensioning section [cm^2]	173.72	317.42	404.06	520.72	706.27	841.16	989.62	1193.81	1340.78	1658.76
Max. tensioning pressure [bar]	550	550	550	550	550	550	550	550	550	550
Max. return pressure [bar]	130	130	130	130	130	130	130	130	130	130
Max. locking pressure [bar]	110	110	110	110	110	110	110	110	110	110
Tensioning over length with lock-off [cm]	70	70	70	70	70	70	80	80	80	80
A [mm]	800	850	932	945	948	957	1121	1072	1125	1145
B [mm]	195	230	240	270	285	315	345	360	380	435
C [mm]	283	291	298	311	315	324	453	359	412	464
D [mm]	137	168	186	203	225	258	285	293	340	400
E [mm]	320	340	370	385	425	470	520	545	585	660
F [mm]	123	126	118	130	135	143	247	153	205	210

For recesses and clearances design please refer to detailed technical data sheets and instruction manuals, available on request.

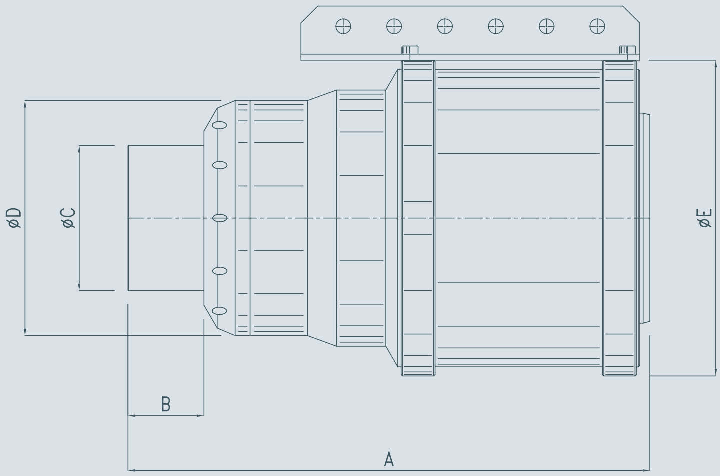
MT SERIES



TYPE OF JACK	MT1000kN	MT1500kN	MT2500kN	MT3000kN	MT3500kN	MT4500kN	MT6000kN	MT9000kN
N° of strands	4	7	7-9	9-12	12-15	19	22-27	31-37
Capacity [kN]	1000	1500	2500	3000	3500	4500	6000	9000
Stroke [mm]	250	250	250	250	250	250	300	150
Weight [kg]	100	180	290	350	420	600	1000	1250
Tensioning section [cm^2]	155.51	302.18	361.00	400.55	492.44	725.71	879.60	1624
Max. tensioning pressure [bar]	600	500	700	700	700	700	700	700
Max. return pressure [bar]	180	180	180	180	180	180	180	180
Max. locking pressure [bar]	165	165	165	165	165	165	165	165
Tensioning over length with lock-off [cm]	35	37	37	38	38	45	51	52
A [mm]	1003	987	997	1032	1019	1169	1317	1115
B [mm]	208	186	196	202	196	262	287	290
C [mm]	161	185	213	236	252	310	380	407
D [mm]	185	218	243	285	309	369	450	480
E [mm]	224	290	325	350	390	464	554	650

For recesses and clearances design please refer to detailed technical data sheets and instruction manuals, available on request.

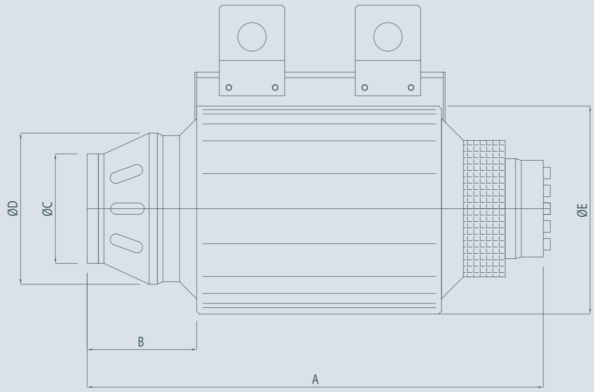
MTX SERIES



TYPE OF JACK	MTX3000kN	MTX4500kN
N° of strands	7-9-12	15-19
Capacity [kN]	3000	4500
Stroke [mm]	100	100
Weight [kg]	380	500
Tensioning section [cm²]	564.22	636.43
Max. tensioning pressure [bar]	660	660
Max. return pressure [bar]	100	100
Max. locking pressure [bar]	100	100
Tensioning over length with lock-off [cm]	43	43
A [mm]	808	797
B [mm]	150	133
C [mm]	214	255
D [mm]	347	400
E [mm]	466	537

For recesses and clearances design please refer to detailed technical data sheets and instruction manuals, available on request.

MTP SERIES

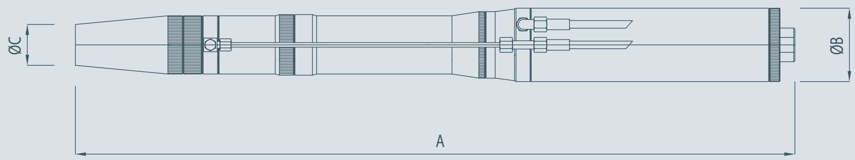


TYPE OF JACK	MTP (MS) 850kN	MTP (MS) 1500kN	MTP (MS) 2600kN	MTP (MS) 3000kN	MTP (MS) 3500kN	MTP (MS) 4800kN	MTP (MS) 6800kN	MTP (MS) 7000kN	MTP (MS) 9750kN
N° of strands	4	7	12	9-12-15	12-15	19-22	22-27	31	31-37
Capacity [kN]	850	1500	2600	3000	3500	4800	6800	7000	9750
Stroke [mm]	150	250	250	250	250	300	300	295	300
Weight [kg]	100	195	320	320	365	750	1185	1200	1770
Tensioning section [cm^2]	194.78	278.02	549.78	549.78	639.12	876.51	1237.01	1258.00	1772.45
Max. tensioning pressure [bar]	440	550	550	550	550	550	550	550	550
Tensioning over length with lock-off [cm]	50	75	80	80	78	105	115	120	120
A [mm]	533	924	973	951	903	1197	1242	1275	1274
B [mm]	267	209	232	266	259	242	274	283	285
C [mm]	150	166	195	230	230	258	310	329	340
D [mm]	205	235	270	270	285	330	395	391	470
E [mm]	230	280	370	370	390	470	560	540	680

For recesses and clearances design please refer to detailed technical data sheets and instruction manuals, available on request.

MONO-STRAND STRESSING JACKS

PT SERIES



TYPE OF JACK	PT 150 kN	PT 200 kN	PT 250 kN	PT 300 kN	K 472	T3	T3-LS	T3-SS	T4
Capacity [kN]	150	200	250	300	212	250	250	250	320
Stroke [mm]	100	200	200	200	100	165	435	80	175
Weight [kg]	16	23	23	28	17	21	32	16	32
Tensioning section [cm^2]	32.80	47.20	47.20	58.32	47.12	46.54	46.54	46.54	62.64
Max. tensioning pressure [bar]	550	450	550	550	450	500	500	550	500
Max. return pressure [bar]	180	180	180	180	180	350	350	350	250
Max. locking pressure [bar]	165	165	165	165	165	165	165	165	165
Connection	2 tubes	2 tubes	2 tubes	2 tubes	2 tubes	2 tubes	2 tubes	2 tubes	2 tubes
Tensioning over length with lock-off [cm]	30	35	35	35	25	25	25	25	25
A [mm]	685	957	930	874	642	685	1235	490	720
B [mm]	115	97	97	107	98	101	101	101	124
C [mm]	40	53	54	57	50	50	50	50	62

For recesses and clearances design please refer to detailed technical data sheets and instruction manuals, available on request.

TENSA
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Job title		Job No.
Design by	Date	Sheet No.
Item		

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