Section 8: PRESTRESSING OPERATION

A. Preparation for Stressing Inspection

One of the most essential preparations for stressing inspection is the calculation of theoretical elongations due to jacking. Recommended practice is to calculate 80% of theoretical elongation, to compare with field measurements taken between 20% and 100% of jacking force. A measurement taken at 20% should eliminate the effect of dead end seating loss, cable slack, and variation in the modulus of elasticity (E) of the strand at lower stress ranges. If variations are encountered or long cable lengths are to be stressed, one can base comparisons on a calculated 70% or 75% of the theoretical elongation.

It is the responsibility of the Contractor to submit elongation calculations as part of the shop drawings. Structure Design and the Structure Representative then check the Contractor's calculations. Appendix D gives an acceptable method of calculating elongations as well as force factors.

Tendon elongations are calculated on the basis of an assumed modulus of elasticity (E) – usually 28,000 ksi (193,000 MPa) for strand. The strand area is commonly assumed to be 0.153 in^2 for 0.5-inch strand, and 0.207 in^2 for 0.6-inch strand. The actual Young's modulus (E) and cross-sectional area (A) for the individual strand packs must be used to re-calculate tendon elongations. While the values of (E) and (A) from the quality assurance testing performed by METS will be recorded on the materials release tag for the prestressing steel, these values represent averages as determined from the limited samples performed on the lots. The current policy is to utilize the actual values for (E) and (A) provided by the strand fabricator on the individual strand packs to calculate elongations. Often packs of strand arrive with varying (E) and (A). In this case, it is best to separate the strand packs so that all strand in a given tendon are the same. If the variations are small, tracking the varying strands in each tendon and using an average (E) and (A) is acceptable. Appendix D gives examples of elongation calculations.

Prior to stressing, it is also necessary to make preparations for monitoring the jacking force. The *Standard Specifications*[24] requires the Contractor to have two pressure gages or one pressure gage and a load cell for each jack. During the stressing operation, the Contractor does not have to use both pressure gages at the same time. The intent of the extra gage requirement is to have a calibrated back-up gage on hand if needed. Re-certification of the Contractor's gages and jacks is required every 12 months. State pressure cells usually monitor the Contractor's jack and gage during the stressing operation. Up-to-date information regarding jack calibration is available by accessing the Structure Construction web page.[25]

The Structure Representative or Assistant Structure Representative should be familiar with the calibration chart and pressure cell prior to stressing. Appendix B gives instructions in the use and

[24] 2010 SS, Section 50-1.01D(3), *Equipment and Calibration.*
[25] http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/ps-pt_jack_calibration.pdf .

care of the pressure cell, and the *Bridge Construction Records and Procedures Memo* 160-3.0 gives administrative instructions relevant to the pressure cell.

B. Field Inspection

The practice of stressing both simple-span and shorter continuous frames from one end only is common, and must be shown on the contract plans or specifications. When two-end stressing is required, the Contractor must stress both ends to P_{jack} and show the actual method and sequence of stressing on the shop drawings.

In order to minimize the possibility of undesirable construction stresses, the *Standard Specifications*[26] states, "Sequence the stressing of post-tensioned bridge girders such that no more than 1/2 of the prestressing force in any girder is applied before an equal force is stressed in the adjacent girders. The maximum temporary force variation between girders must not exceed the prestressing force of the largest tendon used in all girders. Do not apply an eccentric force about the centerline of the structure that exceeds 1/6 of the total prestressing force at any time during the prestressing."

Structure Design is responsible for checking for compliance to the requirements of Standard Plan B8-5. In addition, Structures Design will check the shop drawings to confirm the correct duct profiles, prestressing force, elongation calculations, and anchorage systems used before approval. If compliance with these requirements is overly difficult because of field conditions, Structure Design should be consulted before deviating in any manner from the authorized shop drawings.

Duct ties are always required in girder flares near the exterior girder prestress anchorages. Refer to Standard Plan B8-5 for limits and details of these ties. *Bridge Memos to Designers,* 11-31, *Curved Post-Tensioned Bridges*, applies to girders with horizontal radii of 2,000 ft. or less.[27] The limits of, and details of these ducts ties and stirrup ties should be included in the contract plans. See Figure 8-1. If the duct ties are not shown in the plans or there is a question about installation, contact the designer.

[26] 2010 SS, Section 50-1.03B(2)(a), *General.*
[27] http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/bridge-memo-to-designer/page/Section%2011/11-31.pdf.

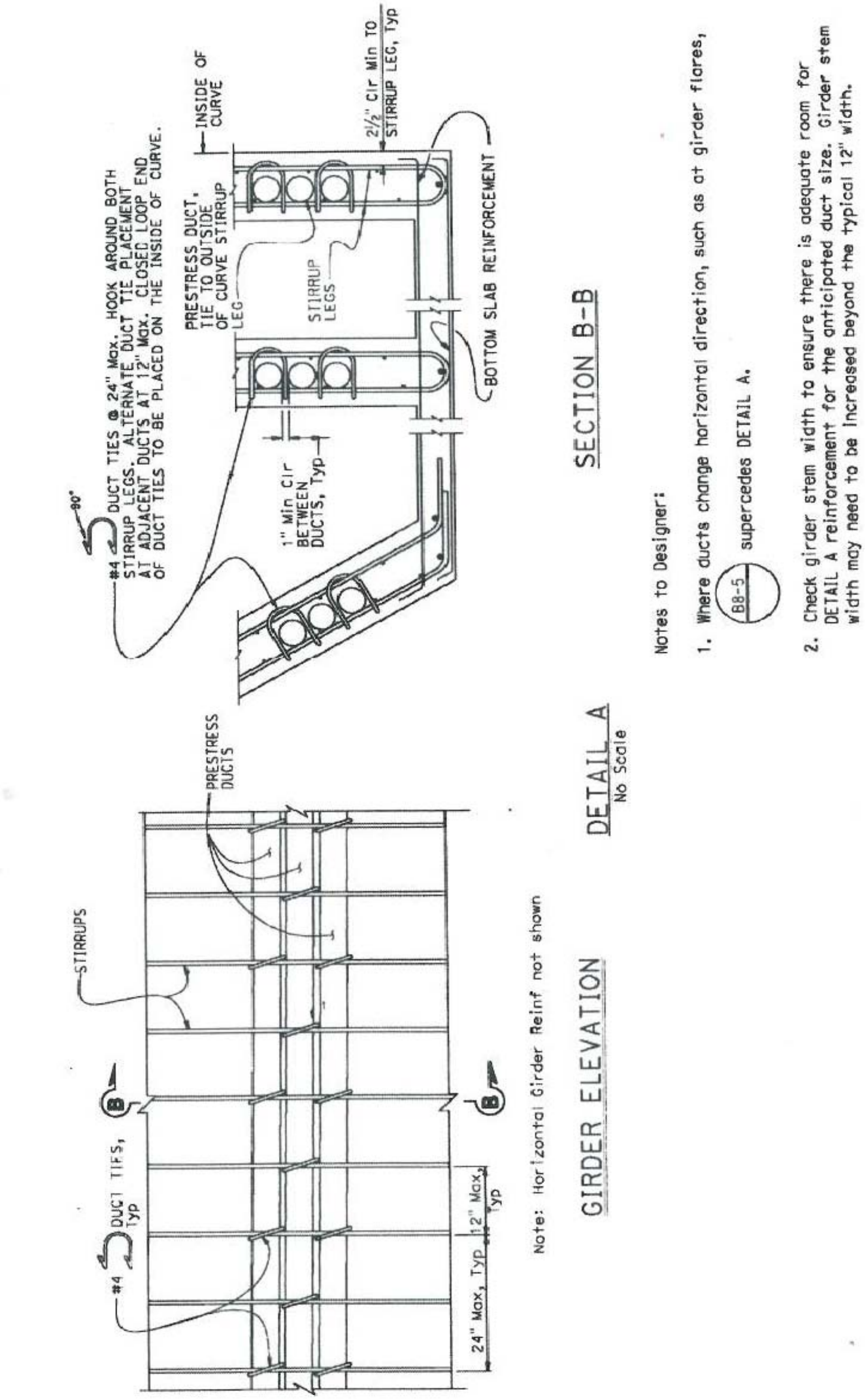


Figure 8-1 From Memo to Designers 11-31, *Curved Post-Tensioned Bridges* – October 2012, Figure 4.

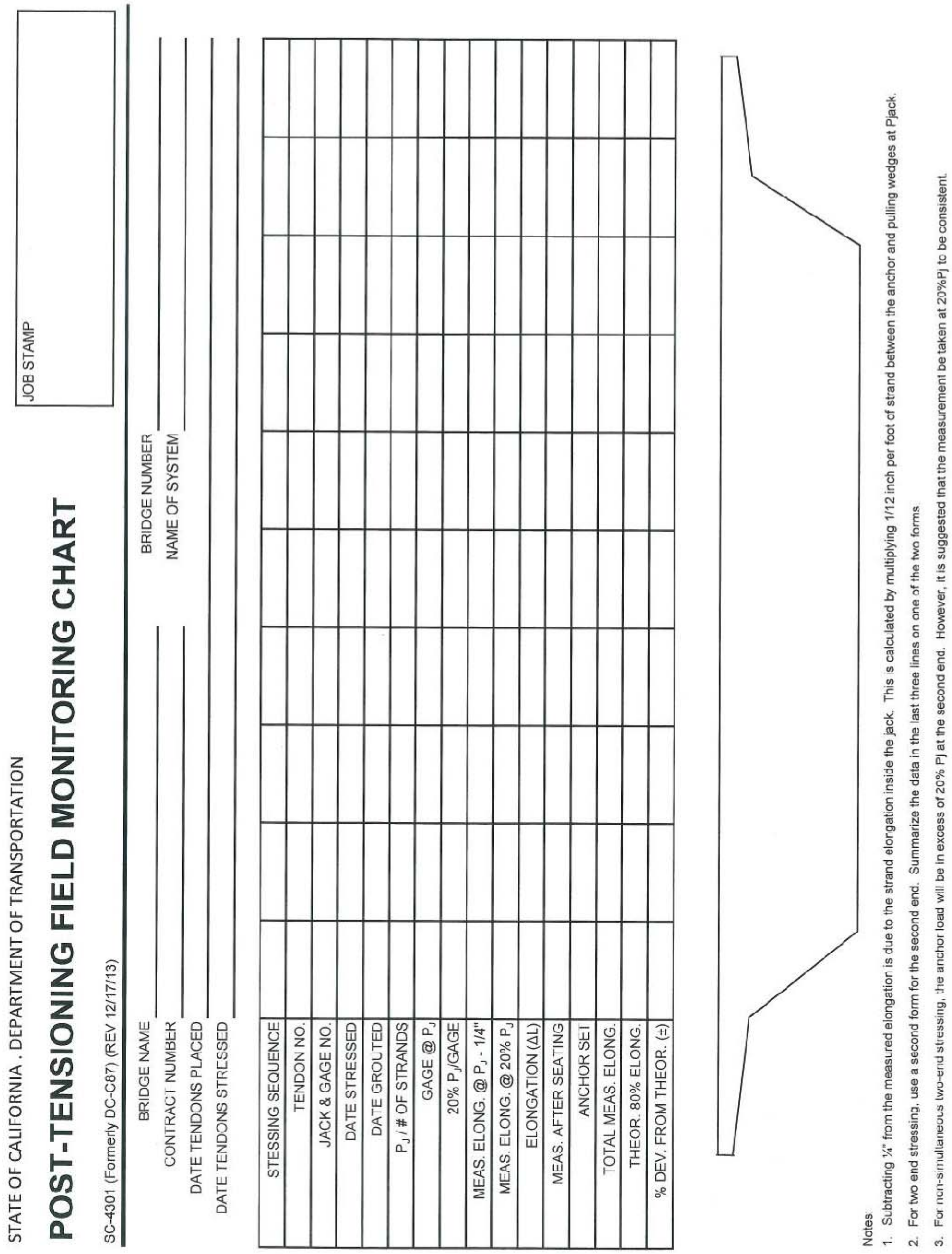
In order to efficiently monitor stressing operations, a record in chart form must be kept for each tendon stressed. Figure 8-2 shows form SC-4301 (formerly DS-C87) titled *Post-Tensioning Field Monitoring Chart.*[28] Note that some of the information shown can be entered prior to stressing. Remember, that this form is a guide. You may custom design your own chart. After completion, place this form in the job files.

Each individual strand should be marked or painted at both ends of the structure to measure elongation and check for slippage. Tendons should be checked during and after stressing for any strand slippage or dead end seating loss. The actual area of ½″ prestressing strand typically varies between 0.151 (97.4 mm^2) and 0.154 (99.4 mm^2) square inches. However, some strands have been received with an area as small as 0.149 square inches (96.1 mm^2). Such small strand has presented problems with proper seating of the wedges. Particular care should be used when stressing any strand with an area below 0.151 square inches (97.4 mm^2). With the Dywidag bar system, counting the turns of the anchor nut during stressing can also monitor the elongation.

An important requirement of prestressing inspection is obtaining the anchor set shown on the plans. Anchor set is the amount of strand movement at the time of force transfer to the bridge. This is usually 3/8″ (10 mm) for continuous structures and per shop plans for simple spans. In most prestress systems, elongation of the tendon occurs within the jack itself. At 0.75 f'_s the tendon elongates approximately 1/12″ per foot (0.72% strain) of jack measured from the anchorage to the pulling head. When measuring or computing anchor set loss, do not include the length of the tendon within the jack. Refer to Appendix D for calculating the effect that anchor set has on tendon stress. For a complete jacking sequence including anchor set, see Figure 8-3, which is provided by the VSL Corporation.

Structure Construction procedures state that the pressure cell is used at the start of stressing to verify the Contractor's calibration chart and at least one calibration curve must be made per structure of frame. The Structure Representative may require additional monitoring of the prestressing operation as needed. Figures 8-4 and 8-5 are examples of completed forms SC-4302 and SC-4202A[29] for recording the Contractor's gage readings versus pressure cell readings. After completion, place these forms in the job files.

[28] http://onramp.dot.ca.gov/hq/oscnet/sc_manuals/crp/vol_1/crp016.htm.
[29] http://onramp.dot.ca.gov/hq/oscnet/sc_manuals/crp/vol_1/crp016.htm.



STATE OF CALIFORNIA . DEPARTMENT OF TRANSPORTATION

POST-TENSIONING FIELD MONITORING CHART

SC-4301 (Formerly DC-C87) (REV 12/17/13)

JOB STAMP

BRIDGE NAME ____________ BRIDGE NUMBER ____________

CONTRACT NUMBER ____________ NAME OF SYSTEM ____________

DATE TENDONS PLACED ____________

DATE TENDONS STRESSED ____________

STESSING SEQUENCE										
TENDON NO.										
JACK & GAGE NO.										
DATE STRESSED										
DATE GROUTED										
P_J / # OF STRANDS										
GAGE @ P_J										
20% P_J/GAGE										
MEAS. ELONG. @ P_J - 1/4"										
MEAS. ELONG. @ 20% P_J										
ELONGATION (ΔL)										
MEAS. AFTER SEATING										
ANCHOR SET										
TOTAL MEAS. ELONG.										
THEOR. 80% ELONG.										
% DEV. FROM THEOR. (±)										

Notes:

1. Subtracting ¼" from the measured elongation is due to the strand elongation inside the jack. This is calculated by multiplying 1/12 inch per foot of strand between the anchor and pulling wedges at Pjack.
2. For two end stressing, use a second form for the second end. Summarize the data in the last three lines on one of the two forms.
3. For non-simultaneous two-end stressing, the anchor load will be in excess of 20% Pj at the second end. However, it is suggested that the measurement be taken at 20%Pj to be consistent.

Figure 8-2 SC-4301 Post-Tensioning Field Monitoring Chart.

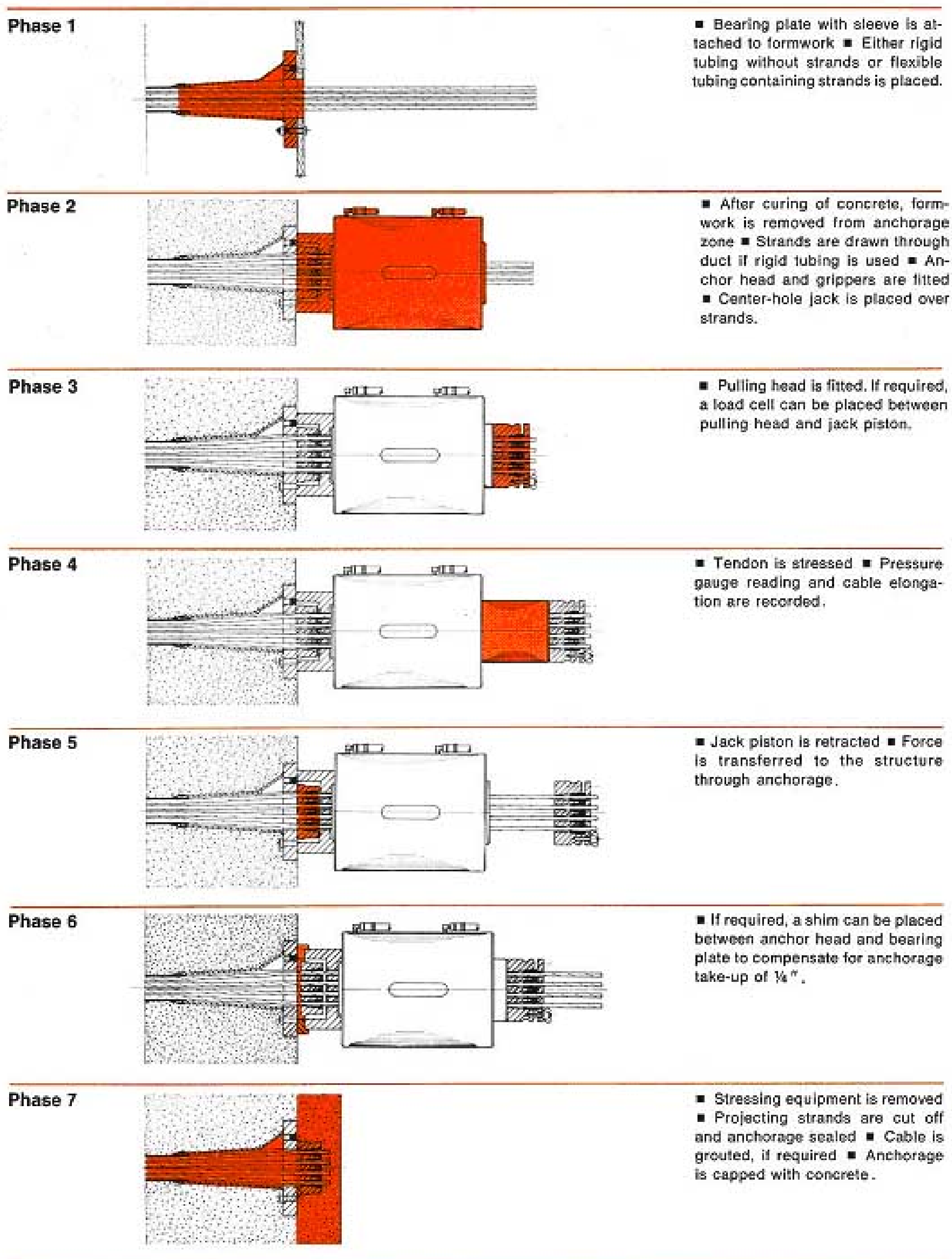


Figure 8-3 – The Complete Jacking Sequence.

STATE OF CALIFORNIA.DEPARTMENT OF TRANSPORTATION

PRESTRESS CALIBRATION
MONITORING SHEET

JOB STAMP
04-SC1-85-3 0/5.3
04-123454
Wide River Bridge

SC-4302 (Formerly DS-C86) (REV 12/17/13)

DATE	1/30/2014	BRIDGE	
NAME OF SYSTEM	VSL	INSPECTOR(S)	I. Girder
JACK NO.	6-10-43		T. Beam
GAGE NO.	6-10-43B		I. M. Lost
STRESSING FOREMAN			

	(K)	X	(#STRANDS / TENDON)	=	(Pj)
FOR 1/2 " 270 KSI STRAND ABSOLUTE MAX...Pj 31^K X #STRANDS/TENDON =	31	X	48	=	1488
FOR 0.6" 270 KSI STRAND ABSOLUTE MAX.....Pj 44^K X #STRANDS/TENDON =	44	X		=	
CONTRACT REQUIRED....Pj					
THEORETICAL MAX GAGE PRESSURE...Pj / RAM AREA =	1488	/	179.1	=	8.308

MAX GAGE PRESSURE FROM LATEST CONTRACTOR'S CALIBRATION 8750 psi

STRAIN GAGE INDICATOR CHC 13686

ELECTRO HYDRAULIC CELL NO. 18

NUMERICAL DISPLAY SETTING 1094

ACTUAL GAGE FACTOR 0.72

MEASURABLE ELONGATION = 8 TOTAL ELONGATION = 28.5"

GAGE READING	LOAD FROM INDICATOR	LOAD FROM CALIBRATION CHART			REMARKS
1680	297	300			20%
2000	352	350			
3000	523	520			
4000	692	690			
5000	855	855			
6000	1025	1025			
7000	1198	1195			
8000	1365	1360			
8720	1488	1480			Meas Elong = 29"

BY ______________________

REPORTING PARTY

Figure 8-4

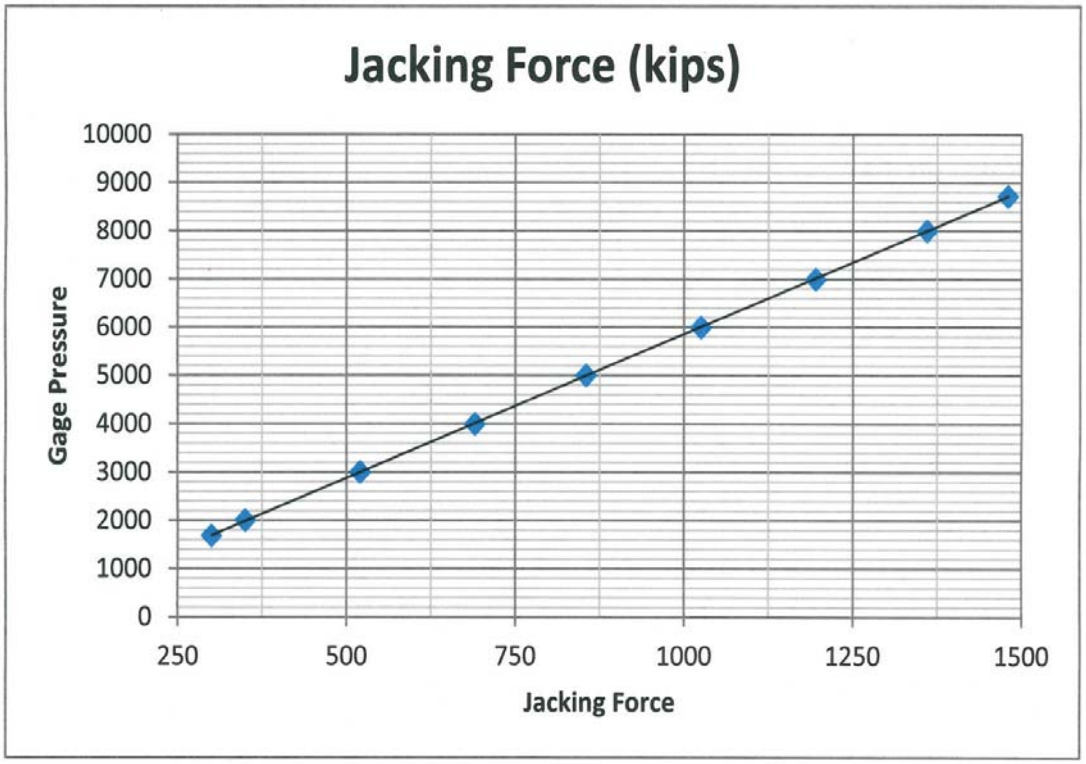


Figure 8-5 – Gage Pressure vs. Jacking Form (Form SC-4302A).

C. Overstressing of Prestressing Steel

Technically, prestressing strand develops high strength and excellent creep characteristics through cold drawing. During the cold drawing process, the grain structure is elongated and aligned into a condition resulting in specific physical and mechanical properties.

Due to the possibility of strands being of unequal length within a tendon, some of the strands could be stressed to their yield strength, even when the tendon is not overstressed. Therefore, when the jacking force exceeds the 75% limitation, some of the wires or strands in the tendon may be seriously overstressed. When steel, such as prestressing strand, is stressed beyond its elastic limit or yield strength, some of its physical characteristics change. The most significant changes are in the modulus of elasticity (E) and the creep rate. If these properties are changed by permanently overstressing, the significance of elongation measurements is questionable. Remember, if it appears that the 75% limit is being exceeded **- STOP!**

The effect of permanent overstressing on physical properties of strand has been demonstrated by laboratory tests in a 100 ft. pretensioning bed as follows:

Initial Jacking Force (kips)	Initial Percent of Ultimate Load (%)	Residual Load at 72 Hours (kips)	Percent Stress Loss At 72 Hours (%)
34	82.3	26	23.5
28	67.8	27	3.6

This example indicates that strand, when kept in an overstressed condition (greater than 0.75 f'_s), results in a significant reduction of prestressing force due to the change in creep properties of the strand. This is one reason why the maximum anchor stress may not exceed 70% of the ultimate strength of the steel; and the jacking force must not be exceeded.

D. Elongation Measurements and Calculations
The measured elongation should substantially agree with the calculated elongation. The January 2005 edition revised the May 1992 edition of this manual, changing the friction coefficient (μ) from 0.20 to a frame length dependant value (0.15 to 0.25 and higher), and the wobble coefficient (K) has been reintroduced as 0.0002/foot (0.00066/meter).

Frame Length (feet)	Wobble Coefficient "K"	Friction Coefficient "μ"
0 - 600	0.0002	0.15
600 - 900	0.0002	0.20
900 - 1200	0.0002	0.25
> 1200	0.0002	See Post-tensioned Concrete Committee

However, due to a variety of different reasons, field measured elongations can differ by as much as 5% to 10%, even with the updated coefficients. This is acceptable as long as the variations are understood and explained; but deviations between elongations of similar tendons of the same bridge should not vary more than 4% +/-. Remember, each case must be carefully examined to ensure compliance with the working force required.

The following are possible reasons for elongations not being within the calculated range:

1. Incorrect number of strands placed in the tendons.
2. Excessive wobble of ducts increases friction and decreases elongation.
3. Unusually smooth duct placement decreases friction and increases elongation.
4. Even, layered strand placement reduces friction and increases elongation, particularly when strands are 'pushed' into the duct.
5. A pressure cell does not detect a change in jack efficiency. This may cause faulty readings.
6. Elongation calculations may be wrong due to the following:
   a. Incorrect modulus of elasticity (E) or area of strand (A).
   b. Incorrect or varying tendon lengths due to skew or sharp radii.
   c. Differing coefficient of friction between girders on sharply curved structures.
   d. Different tendon paths in a girder.
7. Incorrect method of measuring elongations.
8. Slippage of strand during stressing, especially if the strand area is small (below 0.151 in^2 or 97.4 mm^2).
9. Gage damaged or indicator not zeroed.

The cause of any inconsistent elongations among the tendons of a structure must be determined as soon as possible. Do not cut off excess strand until the problem is resolved. In the event it is necessary to de-tension a tendon, stressing contractors must have suitable equipment available for this purpose. The Contractor's de-tensioning plan must be acceptable to the Engineer. It is recommended that the Engineer discuss the de-tensioning procedure with the Post-Tensioned Concrete Committee.[30]

When a frame is stressed from two ends, first end stressing results should be compared to theoretical first end calculations. Including the first and second end results will usually make any discrepancies less apparent, because second end results tend to offset some of the difference. As a general practice, strands should not be cut off until all tendons in the structure are fully stressed.

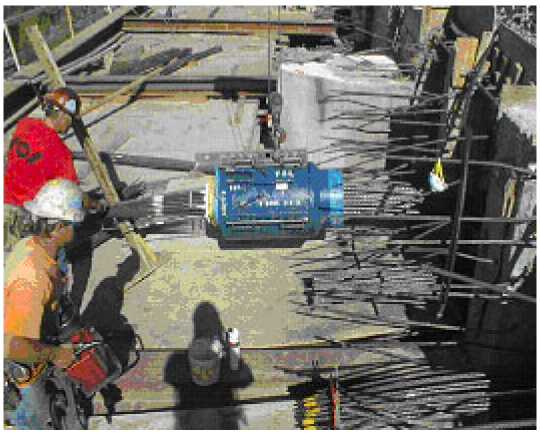


Photo 8-1 – Long Frame Stressing.

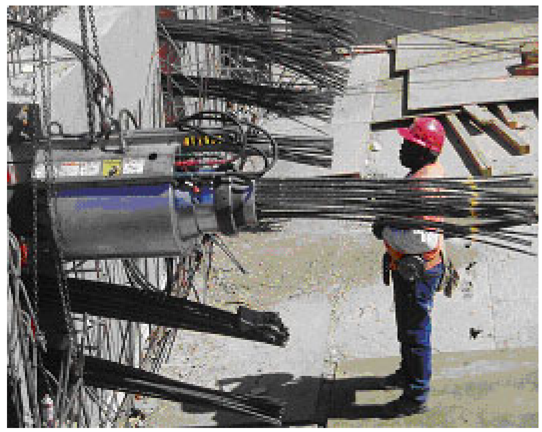


Photo 8-2 – Paint Marks Show 4 ft. Elongation.

[30] http://onramp.dot.ca.gov/hq/des/committees/posttensioned_concrete/.