R. E. GINNA CONTAINMENT VESSEL TENDONS REVIEW OF NRC SAFETY EVALUATION REPORT[1]

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INTRODUCTION

The overall conclusion from the NRC Safety Evaluation of the Ginna containment vessel tendons is that the structural adequacy of the containment vessel is assured. The Safety Evaluation concurs that excessive stress relaxation was reasonably established as the cause of past larger-than-expected tendon force losses and that lift-off data from the July 1981 and July 1983 surveillances indicate that the tendon forces are stable and there are no abnormal force losses. However, the staff suggested that four (4) recommendations from the FRC report (below) be incorporated into the tendon surveillance program, and that the results of the 1985 surveillance be submitted to the NRC for review.

Recommendations:

1. Since there are insufficient data upon which the refined relaxation prediction methods are based, the licensee should maintain lift-off force surveillance of the wall tendons to offset the deficiency.
2. Continue the experimental investigation of tendon wire relaxation using a larger and broader sample of test specimens. This would provide a better foundation of knowledge to guide future lift-off surveillance programs and aid in the explanation of any further unexpected behavior.
3. Introduce more accurate measurement and recording methods for tendon elongation and stressing jack displacements to enable comparative estimates of tendon system behavior in an effort to discern rock anchor slippage.
4. Re-examine previous analysis for rock creep and provide analysis based upon more comprehensive methods including shear mode effects and extrapolation of rock test data.

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[1]Letter from J. A. Zwolnski of NRC to R. W. Kober of RG&E, dated August 19, 1985, Subject: Safety Evaluation Containment Vessel Tendon Surveillance Program, R. E. Ginna Nuclear Power Plant.

The following discussion addresses these recommendations, which are in three main categories: (1) the stress relaxation tests; (2) tendon elongation measurements; and (3) the rock creep calculations. The results from the 1985 surveillance are also included, along with the 1981 and 1983 surveillance results.

1.0 STRESS RELAXATION

The first NRC recommendation, to continue the lift-off force surveillance of the tendons, will be implemented as part of the current containment vessel surveillance program as defined in the Technical Specifications. As part of this program, three surveillances have been performed since the tendons were retensioned in June 1980. The surveillances were in July 1981, July 1983, and August 1985. Future surveillances will be conducted at 5-year intervals. In the completed surveillances, a total of 57 lift-off tests were performed on 31 different tendons of the 160 tendon total. In each test, the measured lift-off force was compared with its predicted value. The results are presented in Table 1. The predicted force is equal to the lock-off force at either the June 1980 or May 1969 retensioning, minus specific predicted losses in tendon force. These predicted losses include stress relaxation of the tendon wire, which accounts for the largest force loss.

The stress relaxation loss was calculated for each tendon based on the methodology and test data described in GAI's final report on the stress relaxation test program (GAI Report No. 2499). As indicated in Table 1, the measured and predicted forces are in good agreement. This would seem to indicate that both the Base stress relaxation curve and the retensioning ratios applied to this curve provide for an accurate prediction of the stress relaxation experience by the actual tendons and the additional recommended laboratory testing does not appear to be necessary.

The second NRC recommendation, to continue and expand the stress relaxation test program, appears to be based on two findings in the FRC report concerning the number of specimens tested. One finding pertains to the retensioned wire tests, which maintains that only three test specimens from the same tendon wire were involved. Actually, as Table 1 of GAI Report No. 2499 indicates (Reference 14 in the FRC report), there were seven specimens that were retensioned. These specimens covered all three test wire heats for temperature conditions of 68°F and 104°F, and for three time decades. Figures 3-E through 3-K in GAI Report No. 2499 indicate that confirming test data was sufficient to establish the retensioning ratios for the retensioning times of interest, nominally 1,000 hours and 100,000 hours after initial stressing in 1969.

The second FRC finding pertains to the number of specimens used to establish the Base relaxation. The concern is whether the test results based on test specimens from two tendon wires, representing two wire heats, sufficiently represent all six wire heats used in the tendons. The balance of Section 1.0 addresses this concern.

Base Stress Relaxation Tests

The Base test results refer to the stress relaxation curves, and 40 yr. extrapolations, obtained prior to retensioning seven of the specimens. The Base relaxation values were used in the "investigation-of-cause" phase and, later, in the construction of the retensioning ratios. These ratios were applied as multiplying factors to the Base values in order to account for the effect of retensioning on stress relaxation in future tendon force predictions. As pointed out above, the FRC review questions whether the test results from two tendon wires (76 and 51) that represent two wire heats (#30091 and #19477, respectively) sufficiently represent all six heats of wire material used in the tendons. As indicated in GAI Report No. 2347 (Reference 10 of FRC report), the results from the third remaining tendon wire specimen (tendon 150) were also used in the "cause" investigation, except that the test data required evaluation and could not be used directly because of the atypical behavior from one specimen, namely 150-B.

The relaxation test results which FRC has questioned have been used in the Factor Method and with the 16% Base relaxation curve to predict the forces in the 31 tendons involved in the 1981, 1983, and 1985 surveillances, with very good results. This was demonstrated by the comparison of measured and predicted tendon forces in Table 3 and Figure 6 of GAI Report No. 2499 for the 1981 surveillance (Reference 14 of FRC's Report) and in Table 2 and the Appendix D figures of the GAI Report No. 2512 for the 1983 surveillance (Reference 9 in FRC's Report). A similar comparison was developed for the recently completed 1985 surveillance. These results, along with those reported previously for the 1981 and 1983 surveillances, appear in the attached Table 1. In addition, a comparison of the measured tendon forces with the predicted force-time curves is provided in attached Figures 1 through 31. These results indicate that the forces measured in all tendons, regardless of wire heat, can be predicted and monitored to an acceptable degree of accuracy using the existing test results and force prediction methodology. A closer examination of the surveillance results is provided below.

Table 2 tabulates all 160 Ginna tendons by the wire heat comprising the tendons. A total of 73 tendons (45.6% of the 160 total number of tendons) contain wires from the same heat as test heats #30091 and #19477, and 60 of these tendons are made up of wires solely from either heat #30091 or from heat #19477. The test heat which contains the one questionable specimen (150-B) is heat #10355, and the next-to-smallest number of tendons, 14, are composed of wires solely from this heat.

The 31 tendons which have had lift-off forces measured at the 1981, 1983, and 1985 surveillances are identified in Table 2. Of these 31 tendons, 24 are each made up from wires from only one (identifiable) heat. These 24 tendons are tabulated by their respective wire heat in attached Table 3.

In Table 3, the tendons are arranged according to the percent difference between measured to predicted forces. For example, for the seven (7) tendons containing wires solely from heat #30091, the measured forces ranged from 5.0% greater-than-predicted to 2.9% less-than-predicted. The tendons which appear twice have been involved in more than one surveillance (see Table 1).

As another example, consider the three (3) tendons composed of wires solely from the heat #10355. This heat contained the questionable specimen, 150-B. The forces in these tendons exceeded their predicted values within the narrow range of 3.2% to −2.9%. Moreover, these results are entirely consistent and within the range of values for tendons made up solely of wires from heat #30091 and from heat #19477, the heats which were used to establish the 16% Base Relaxation curve used in the predicted force calculations. The same can also be said for all the other tendons shown in the table. This would not be the case if the 16% Base Relaxation curve were not representative, as the FRC finding suggests.

Stress Relaxation - Conclusions

The stress relaxation tests, including both the number of different heats tested and the number of specimens involved, appear to be sufficiently adequate. These results were evaluated in detail and were used to establish the 16% Base Relaxation curve and the retensioning ratios, which have in turn yielded predicted tendon forces that agree very well with the forces measured at the tendon surveillances performed thus far. The data and methodology continue to provide an effective means of monitoring the tendon forces, and additional tests are not needed.

The Code governing concrete containments, ASME Section III, Division 2, Subsection CC, contains the rules for stress relaxation testing of prestressing elements (wires). These rules appear in paragraph CC-2424 of the Code. The rules state: "A minimum of three relaxation tests of 1000 hours duration shall be performed ..." and "...the tests shall be performed on material previously manufactured to the same ASTM or other applicable specifications, and produced in the same plant utilizing the same procedures that will be employed to produce the prestressing elements for the production tendons." The Code rules do not require stress relaxation tests on each different heat of wire to be used in the tendons. From this standpoint, the stress relaxation tests performed on the Ginna tendon wires have significantly exceeded the Code requirements.

2.0 TENDON ELONGATION MEASUREMENTS

The third NRC recommendation is based on the conclusion in the FRC report that the accuracy of tendon elongation measurements, taken during the surveillance lift-off tests, can be improved.

Actually, in "stressing" a tendon during a lift-off test, the bearing force between the upper anchorhead of the tendon and the bearing plate is merely transferred to the stressing ram, which reacts against the bearing plate. During this process, no significant tendon elongation occurs, as the FRC review comment seems to suggest. A small amount of ram piston displacement does occur (1/4" maximum) as the ram is loaded from 0 to the lift-off force, which was in the neighborhood of 700 kips at the 1983 surveillance. However, the 1/4 inch ram extension under the 700 kip load increase occurs primarily within the ram system and is accurately measured to the nearest 1/16 inch.

During the history of the tendons, accurate rock anchor and tendon elongation measurements have been taken at various times. During the stressing of the rock anchors in 1969, the ram position was measured at seven (7) points up to maximum load for every rock anchor. This allowed accurate load-elongation curves to be plotted for each rock anchor. In addition, one rock anchor (No. 46) was taken through a complete loading and unloading cycle. These results were presented previously in Response to USNRC Review Comments on Tendon Evaluation (Reference 13 of FRC's Report), and they demonstrated the linear response and integrity of the anchors. Again in 1969, when the wall tendons were stressed, displacement measurements were taken which showed the tendon elongations to be predictable and again demonstrated the integrity of the rock anchors, as discussed previously in GAI Report No. 2347 (FRC Report Reference 10).

In the June 1980 tendon retensioning, the wall tendons were stressed from the force level existing in each tendon at that time to the final lock-off value. In this retensioning, the tendon elongations were measured and found to be in the neighborhood of 2 inches versus 7-1/2 inch elongations when the tendons were stressed originally. The June 1980 retensioning elongations were compared with their predicted values in Appendix A of GAI Report No. 2347 (FRC Reference 10), and good agreement was shown to exist. This again demonstrated the integrity of the rock anchors.

Tendon Elongation - Conclusions

The FRC comments on increasing the accuracy of the tendon elongation measurements are not applicable for the lift-off tests. However, past tendon elongation measurements, as recent as the June 1980 retensioning, tend to demonstrate the integrity of rock anchors.

3.0 ROCK CREEP

The fourth NRC recommendation is based on the finding in the FRC report that the creep extrapolation previously reported is not correct, and that consideration of rock creep in a shear mode would increase the calculated tendon loss, above that previously reported. The FRC conclusions are based on the review by their geotechnical consultant, Geotechnical Engineers, Inc. (GEI), appearing in Section 3.4 of the consultant's report.

We concur with the comment that the creep extrapolation in GAI Report No. 2347 (FRC Reference 10) is not correct, but there is reason to believe that the tendon loss due to rock creep is much closer to the 8 kip value rather than 122 kips, the range given in GEI's report. An explanation follows.

GEI's report includes Figure 4.5 from Farmer's text Engineering Properties of Rock (1968), which was the basic reference used for the rock creep strain calculations in GAI Report No. 2347 (FRC Reference 10). This figure is reproduced as Figure 32 herein, and it indicates that the creep exponent, n, used to determine the creep strain in the rock increases with increasing compressive stress in the rock. Two curves are shown in the figure which bound test data from different types of rock at various stress levels. From the figure, and as GEI reports, at the 472 psi (33 kg/cm^2) compressive stress used for the creep calculation, the upper bound curve gives a value of 1.4 for n while the lower bound curve yields a value of 1.1 for n. For n = 1.4, a rock creep strain is calculated which would result in an 8 kip loss in the tendons. For n = 1.1, the tendon force loss is calculated to be 122 kips. Actually, the type of rock at Ginna would appear to exhibit a creep characteristic more closely represented by the upper bound curve that gave 8 kips as the calculated tendon loss. This is seen from the creep data discussed in Section 2.2 of GAI Report No. 2347 (FRC Reference 10). Here, a value of n = 1.91 was obtained from a creep test on Ginna site rock under 10,000 psi (703 kg/cm^2) sustained compressive stress. If the value for n of 1.91 is plotted on Figure 4.5 from Farmer at 703 kg/cm^2, the data point lies close to the upper bound curve (see Figure 32). Consequently, based on the existing calculations, the tendon loss would likely be much closer to 8 kips than 122 kips.

A value for tendon loss due to rock creep in the neighborhood of 8 kips is larger than the 0.08 kip value reported previously. But this difference does not alter the previous conclusion that stress relaxation of the tendon wires is the primary reason for the larger-than-predicted tendon force losses. One reason for maintaining this conclusion is due to the fact that the excessive relaxation (in excess of the original 12% curve) accounted for much more than 8 kips loss of tendon force. Another important reason has to do with the conservatism of the rock column model which yielded the value of

472 psi compressive rock stress. This model was originally chosen because it was convenient and, at the same time, would yield conservatively high values of compressive stress in the rock, and consequently conservative values of rock creep strain, which at the time were determined to be insignificantly small based on the calculations that resulted in the 0.08 kip value. The rock column model, in effect, uses the 472 psi bearing stress under the ring footing on the rock surface and assumes that this level of stress exists uniformly along the entire 34-foot height of the rock anchors. This conservatively ignores the fact that the force corresponding to the 472 psi bearing actually spreads out in the rock below the footing. This effect would reduce the creep strain in the rock, and consequently the tendon loss; below that determined using the rock column assumption. This assumption is also expected to be conservative enough to overcome any additional loss that might be calculated by including the shear deformation of the rock in a less conservative, and more realistic, calculational model for the rock.

Rock Creep - Conclusions

Correcting the error pointed out by GEI in the previous rock creep calculation appearing in GAI Report No. 2347 increases the calculated value of tendon loss from that reported previously. But the revised value is based on a very conservative calculational model for the rock; and still, its magnitude is not large enough to alter the previous conclusion that stress relaxation is the primary reason for the larger-than-predicted tendon losses which occurred prior to the June 1980 retensioning. This point is further emphasized by the fact that subsequent to the June 1980 retensioning, the tendon forces measured on three separate occasions at the 1981, 1983, and 1985 surveillances are predictable even ignoring rock creep. This is to be expected since any rock creep that may still be occurring would be doing so at a creep rate that is insignificantly small considering that the rock has been stressed by the rock anchors for 16 years.

TABLE 1. GINNA SURVEILLANCE TENDONS(PAGE 1 OF 2)

ITEM NO	TENDON NO.	HEAT NO.	SURVEILLANCE 1981	PERIOD 1983	1985	MEASURED FORCE (KIPS)	PREDICTED FORCE (KIPS)	PERCENT DIFFERENCE
1	13	19477	X			730	721	1.2%
2	13	19477		X		730	711	2.7%
3	17	MIXED	X			727	734	-1.0%
4	17	MIXED			X	717	715	0.3%
5	18	30091		X		727	721	0.8%
6	18	30091			X	705	714	-1.3%
7	21	21504	X			725	723	0.3%
8	21	21504			X	723	704	2.7%
9	33	10355	X			679	670	1.3%
10	33	10355			X	673	665	1.2%
11	35	10355		X		662	650	1.8%
12	35	10355			X	653	648	0.8%
13	36	MIXED	X			657	664	-1.1%
14	36	MIXED		X		664	661	0.5%
15	40	30091		X		731	711	2.8%
16	40	30091			X	724	704	2.8%
17	51	19477	X			710	723	-1.8%
18	51	19477		X		709	712	-0.4%
19	53	19477	X			734	722	1.7%
20	53	19477		X		731	711	2.8%
21	60	21504		X		711	707	0.6%
22	60	21504			X	702	700	0.3%
23	62	21504	X			716	730	-1.9%
24	62	21504		X		715	720	-0.7%
25	63	21504	X			722	730	-1.1%
26	63	21504			X	713	711	0.3%
27	71	MIXED			X	705	707	-0.3%
28	73	30091			X	654	624	4.8%
29	74	10355	X			731	708	3.2%
30	74	10355			X	710	690	2.9%
31	75	30091		X		723	709	2.0%
32	*75	30091	–		X	518	460	12.6%
33	76	MIXED	X			713	714	-0.1%
34	76	MIXED		X		700	704	-0.6%
35	76	MIXED			X	703	696	1.0%
36	77	21504			X	723	702	3.0%
37	84	21504	X			714	713	0.1%
38	84	21504			X	710	695	2.2%
39	93	39377	X			713	721	-1.1%
40	93	39377		X		706	711	-0.7%
41	103	21504			X	703	699	0.6%
42	111	UNSPEC	X			646	647	-0.2%
43	111	UNSPEC			X	643	642	0.2%
44	116	UNSPEC	X			690	658	4.9%
45	116	UNSPEC		X		693	656	5.6%
46	120	UNSPEC		X		680	661	2.9%
47	120	UNSPEC			X	679	659	3.0%
48	125	30091	X			705	726	-2.9%
49	125	30091		X		702	716	-2.0%
50	126	30091			X	692	659	5.0%
51	128	30091		X		709	703	0.9%
52	128	30091			X	711	696	2.2%

TABLE 1. GINNA SURVEILLANCE TENDONS(PAGE 2 OF 2)

ITEM NO.	TENDON NO.	HEAT NO.	SURVEILLANCE 1981	PERIOD 1983	1985	MEASURED FORCE (KIPS)	PREDICTED FORCE (KIPS)	PERCENT DIFFERENCE
53	133	39377	X			734	718	2.2%
54	155	19477	X			738	713	3.5%
55	155	19477		X		745	703	6.0%
56	160	19477		X		721	709	1.7%
57	160	19477			X	705	702	0.4%
TOTAL	57		18	18	21	702 AVE	693 AVE	1.38% AVE

* Tendon no. 75 retensioned to 518 kips subsequent to wire breakage accident. Predicted force of 460 kips based on 16% Base stress relaxation curve without Retensioning Ratio.

TABLE 2. GINNA TENDONS - BY WIRE HEAT									
#30091(76) (Test Heat)		#19477(51) (Test Heat)		#10355(150) (Test Heat)	#21504		#39377	#22332	Unspecified Heat
3*	125	1	145	3*	14*	83	29	47*	110
4	126	2	149	15	19	84	31*	49*	111
16	127	5	152	17*	20	85	32*		112
17*	128	6	153	33	21	86*	36*		113
18	129	7	154	34	22	87*	86*		114
30	130*	8	155	35	41*	90*	87*		115
31*		9	156	36*	42	101	88		116
32*		10	157	37	43	102	89		117
39		11	158	38	44	103	90*		118
40		12	159	71*	50	104	91		119
41*		13	160	72	59	134*	92		120
45		14*		74	60	146	93		121
46		23		76*	61	147	94		122
47*		24		107*	62	148	95		
48		25		123	63		96		
49*		26		124	64		97		
55		27		139	65		98		
56		28		140	66		99		
57		51		150	67		100		
58		52		151	68		105		
71*		53			69		106*		
73		54			70		130*		
75		137			77		131		
76*		138			78		132		
106*		141			79		133		
107*		142			80		134*		
108		143			81		135		
109		144			82		136		

* = Tendons with mixed wire heats
Bold Face = '81, '83 or '85 Surv. Tendons (circled)

TABLE 3. WIRE HEAT AND 1981, 1983 and 1985 SURVEILLANCE TENDONS **									
#30091(Test)		#19477(Test)		#10355(Test)		#21504		#39377	
Tendon	Δ	Tendon	Δ	Tendon	Δ	Tendon	Δ	Tendon	Δ
126	5.0	155	6.0	74	3.2	77	3.0	133	2.2
73	4.8	155	3.5	35	1.8	21	2.7	93	−1.1
40	2.8	53	2.8	33	1.3	84	2.2	93	−0.7
40	2.8	13	2.7	33	1.2	103	0.6		
128	2.2	53	1.7	35	0.8	60	0.6		
75	2.0	160	1.7	74	−2.9	60	0.3		
128	0.9	13	1.2			63	0.3		
18	0.8	160	0.4			21	0.3		
18	−1.3	51	−0.4			84	0.1		
125	−2.0	51	−1.8			62	−0.7		
125	−2.9					63	−1.1		
						62	−1.9		
Ave.	1.37	Ave.	1.78	Ave.	0.9	Ave.	0.5	Ave.	0.1

NOTES:

$$\Delta = \text{\% Difference in Tendon Force}: \frac{\text{Measured - Predicted}}{\text{Predicted}} \times 100\%$$

** Predicted tendon forces are based on stress relaxation values from the 16% Base Relaxation curve multiplied by applicable Retensioning Ratios

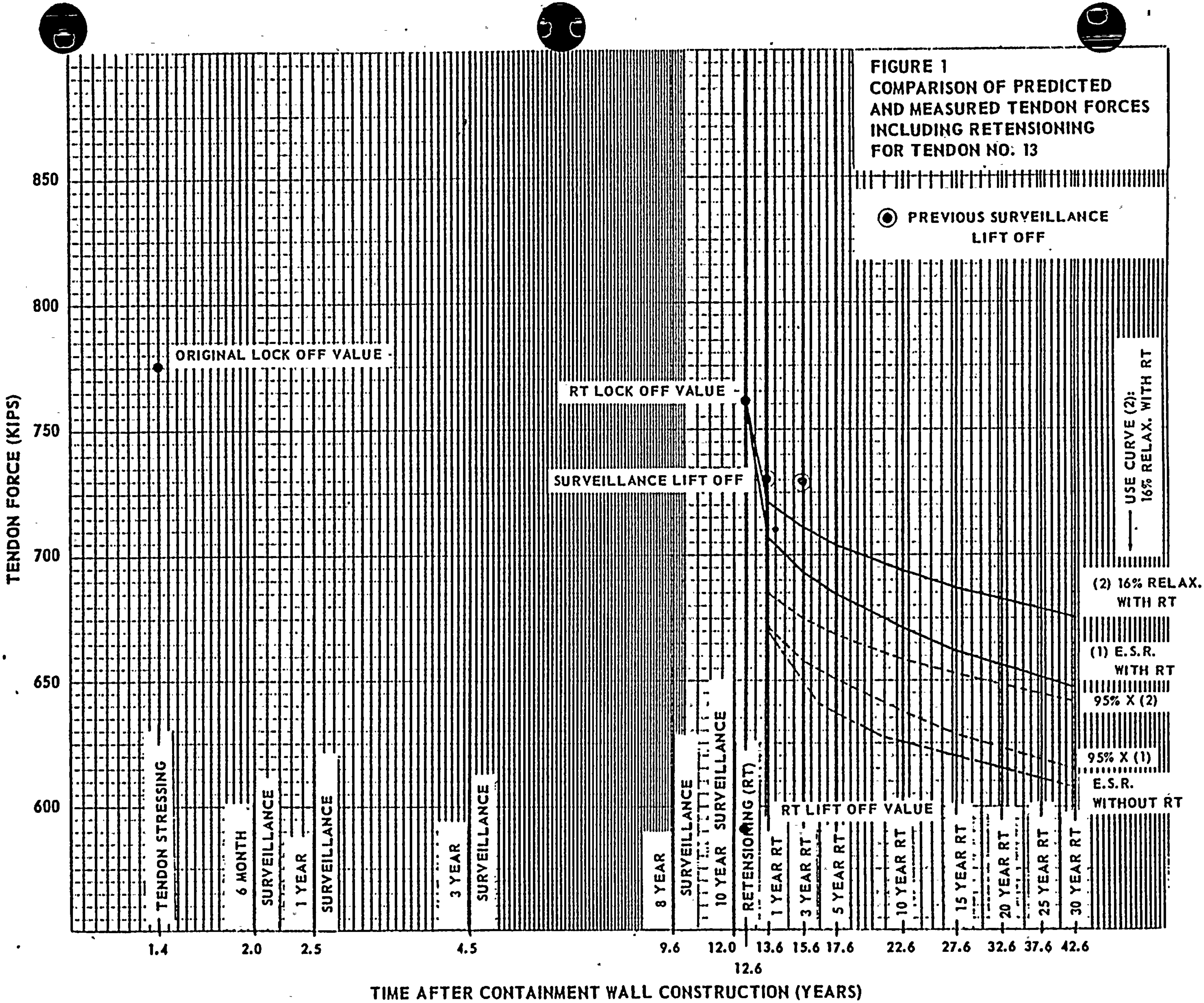


FIGURE 1
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 13
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
(1) E.S.R. WITH RT
95% X (2)
95% X (1)
E.S.R. WITHOUT RT
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

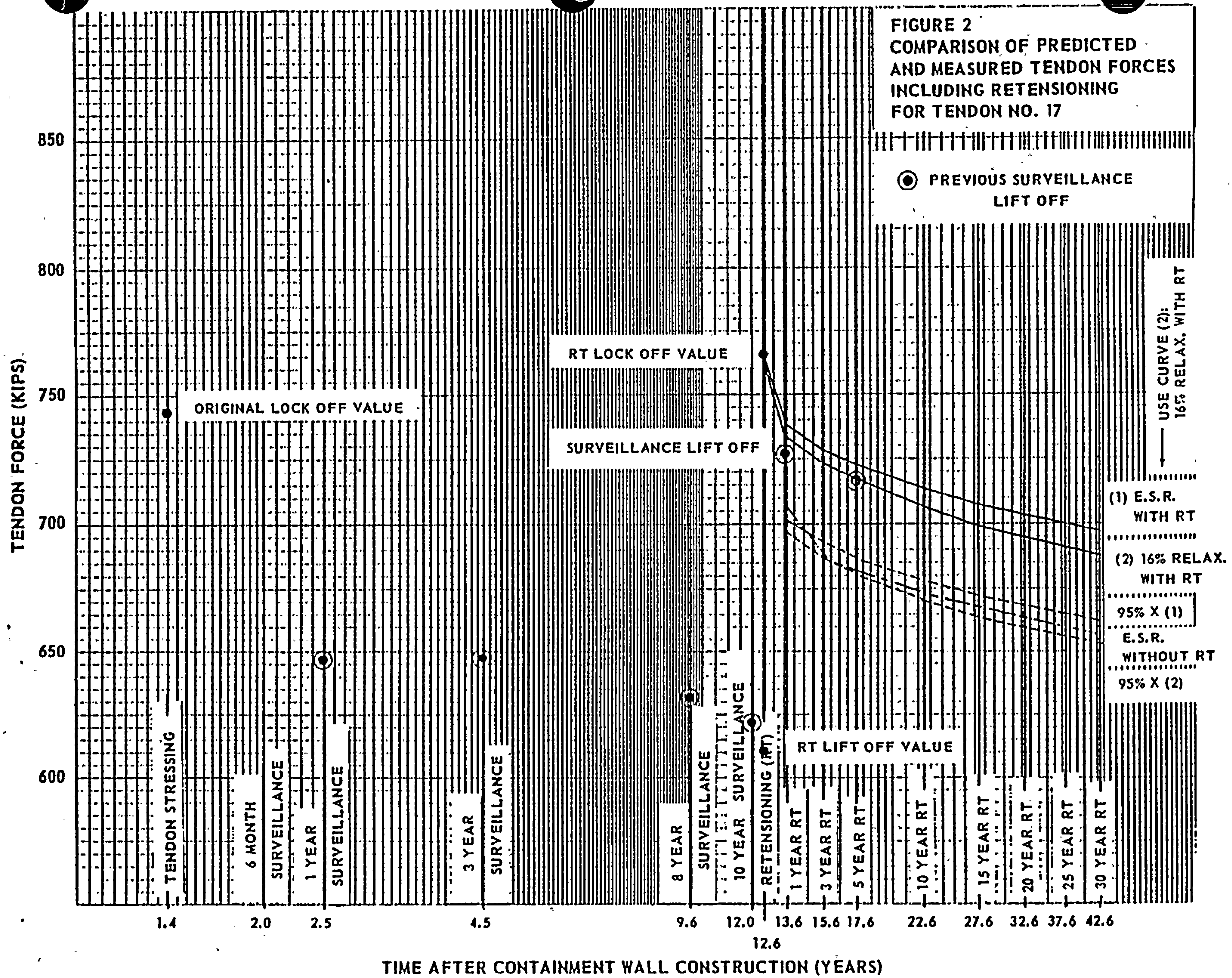


FIGURE 2
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 17

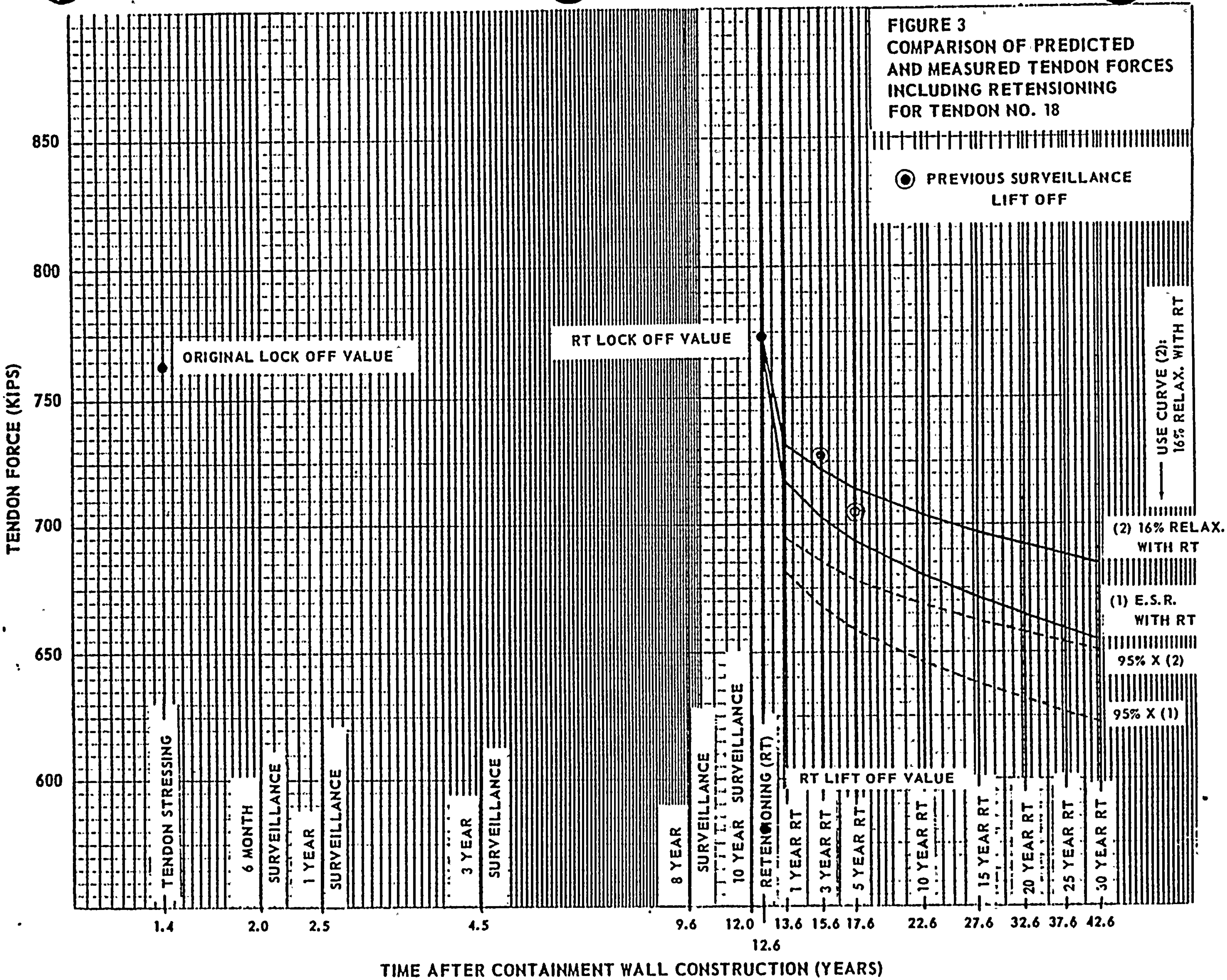
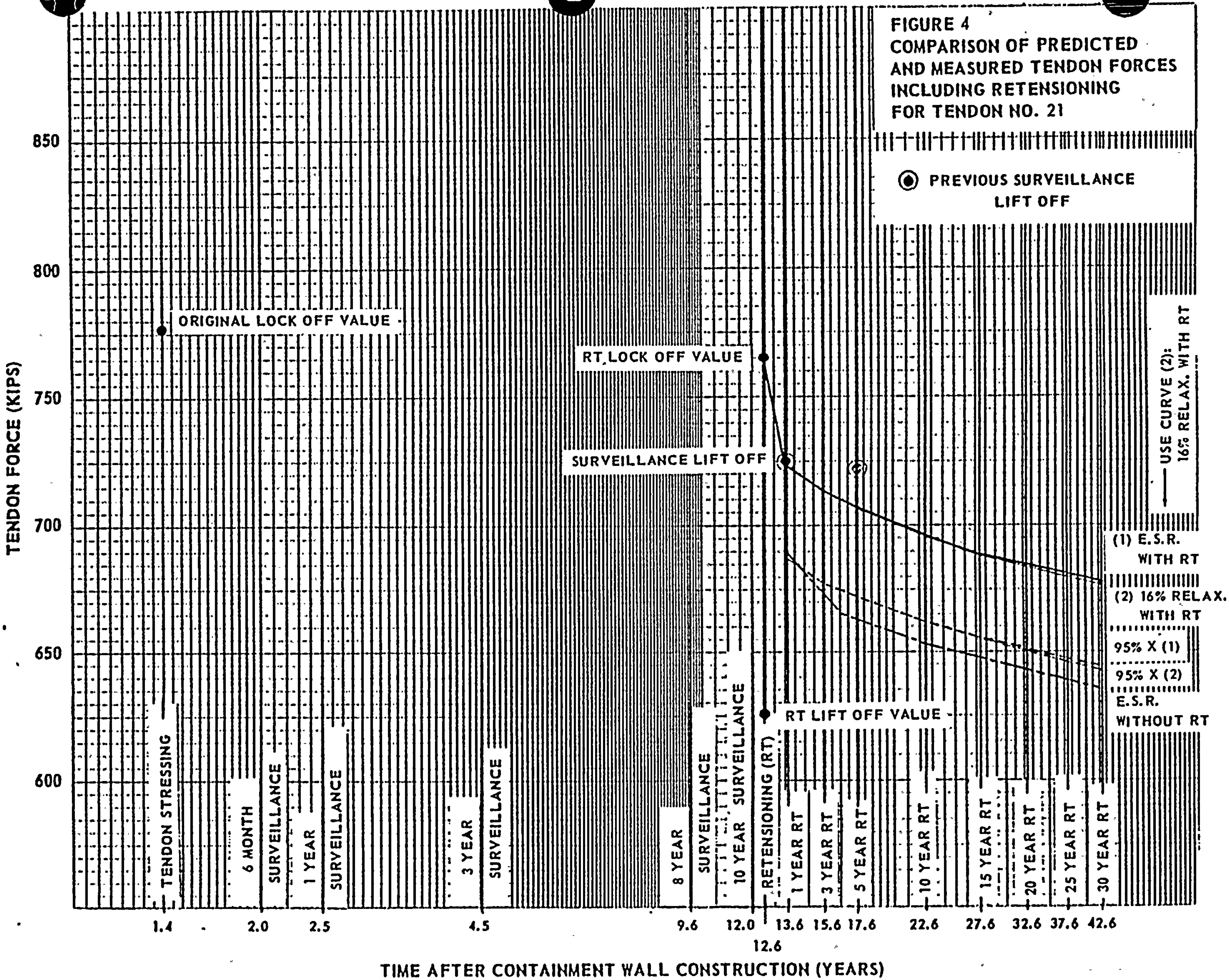


FIGURE 3
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 18
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
(1) E.S.R. WITH RT
95% X (2)
95% X (1)
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

FIGURE 4
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 21



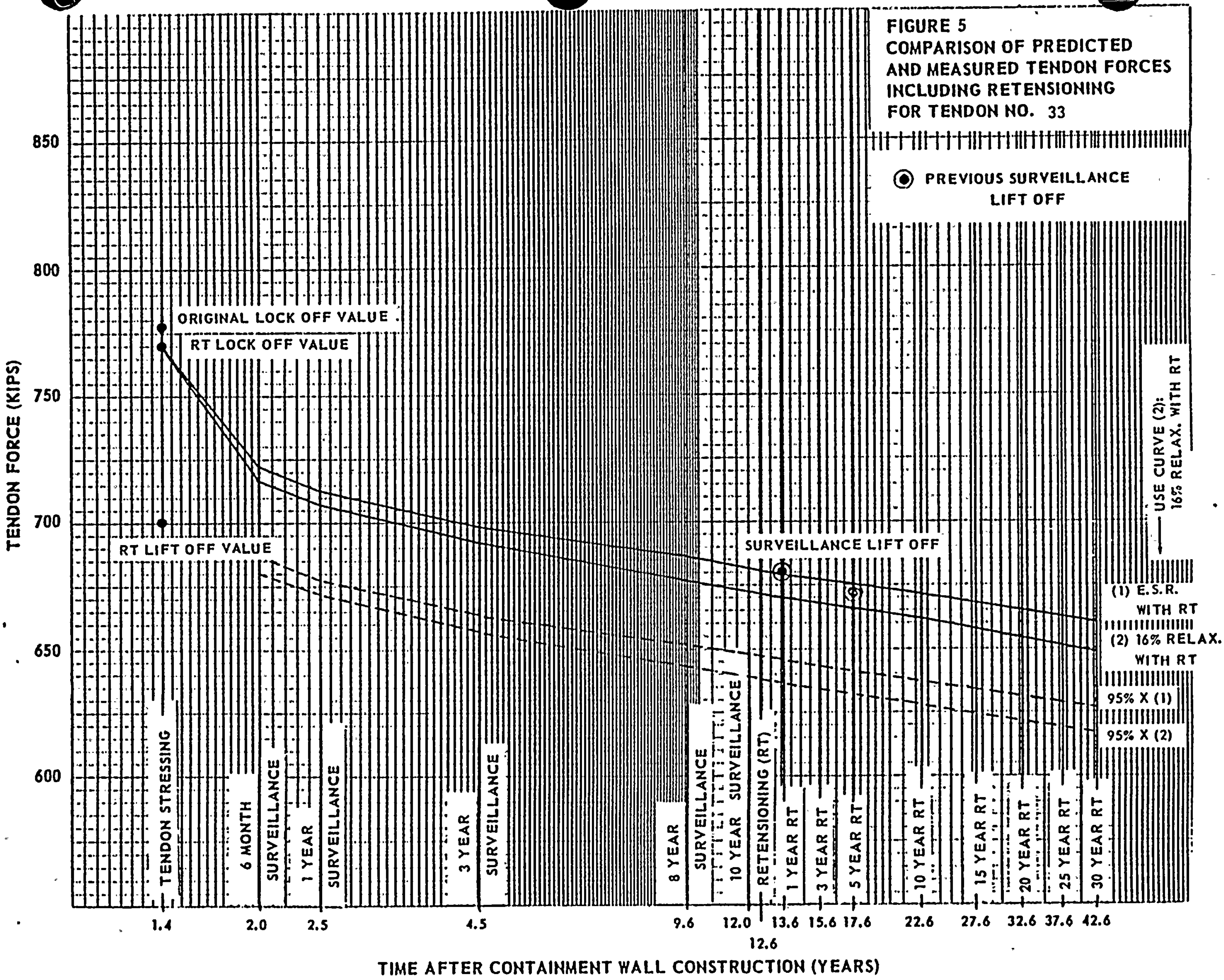


FIGURE 5
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 33
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

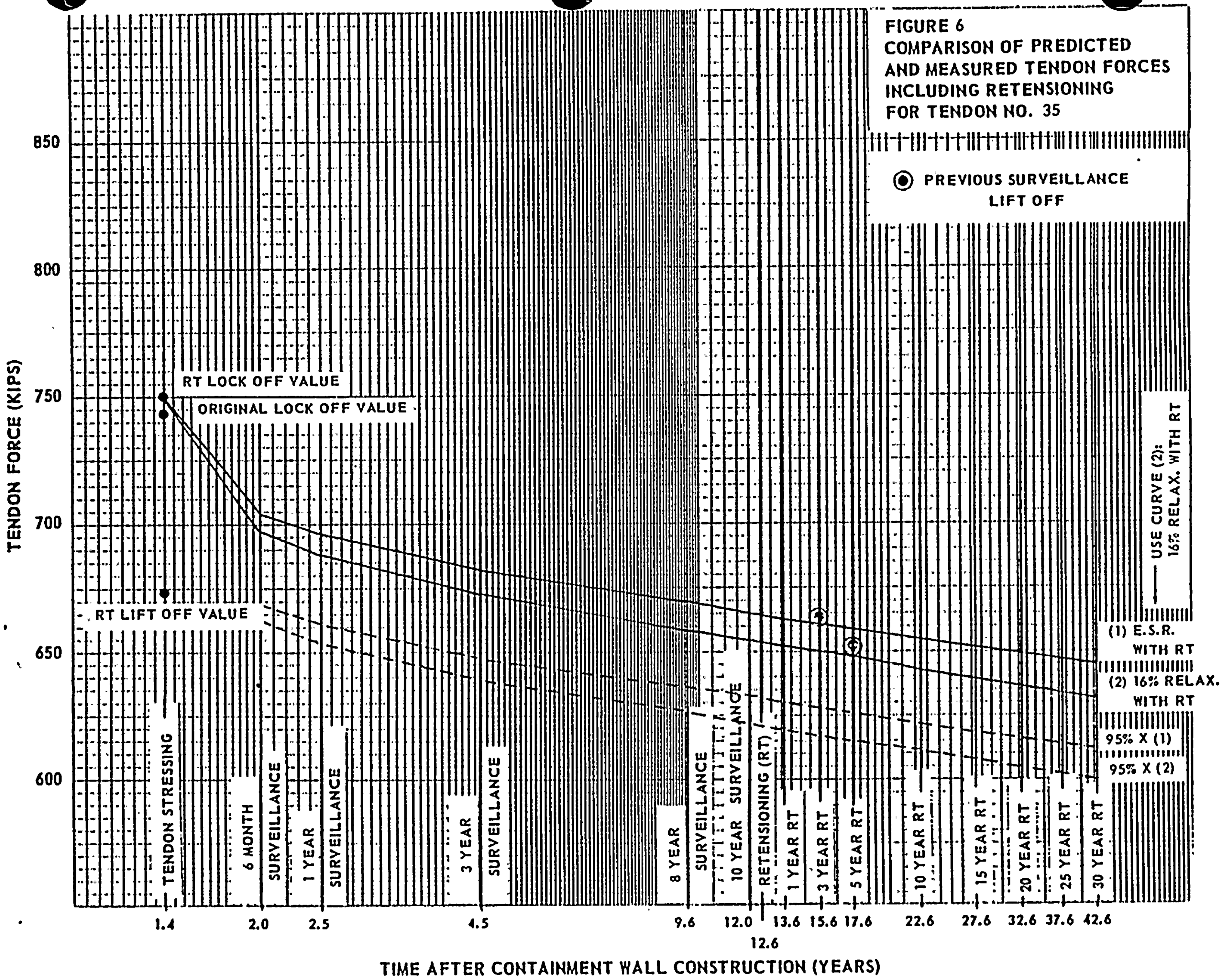


FIGURE 6
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 35
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
RT LIFT OFF VALUE
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

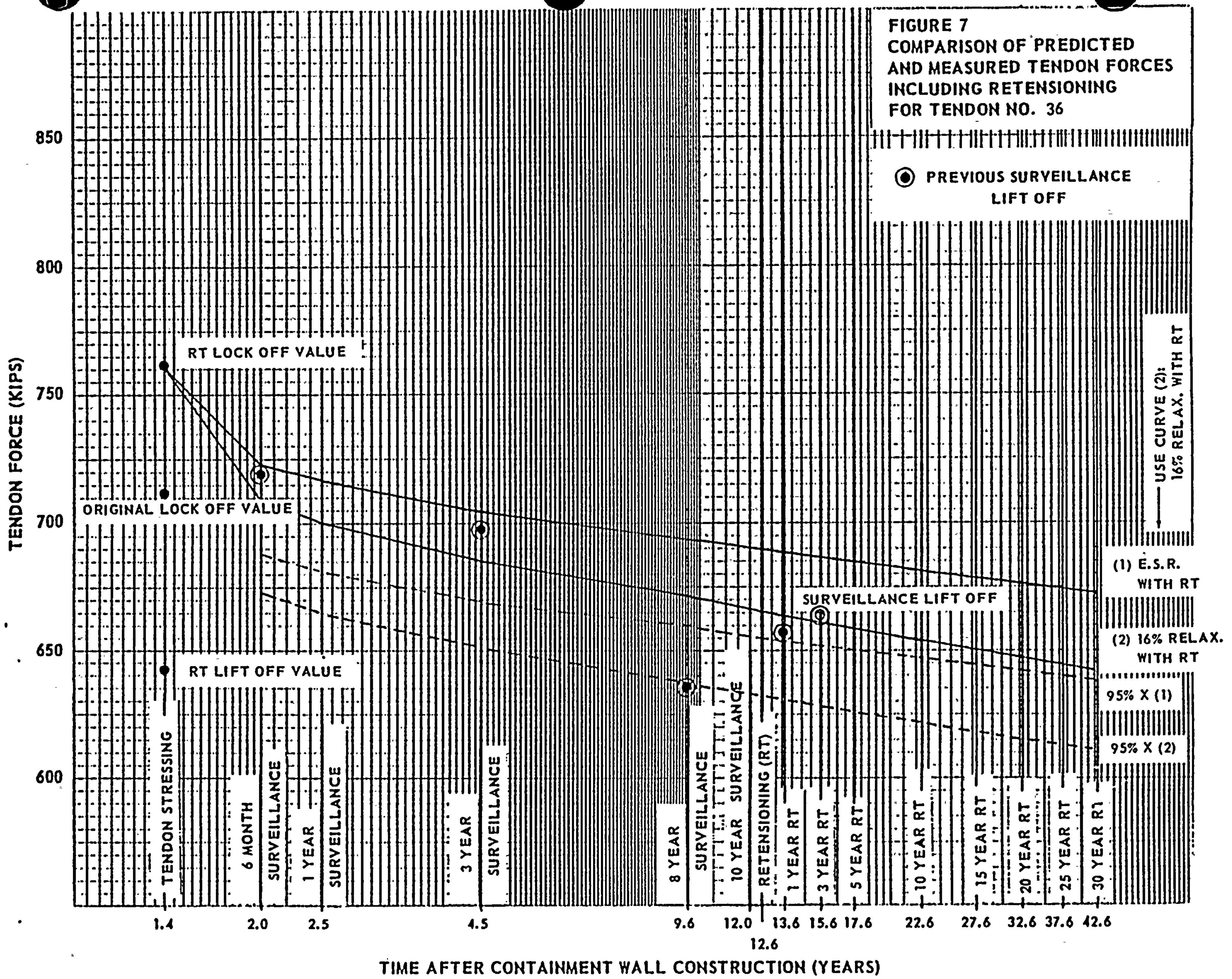


FIGURE 7
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 36
PREVIOUS SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
RT LIFT OFF VALUE
SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

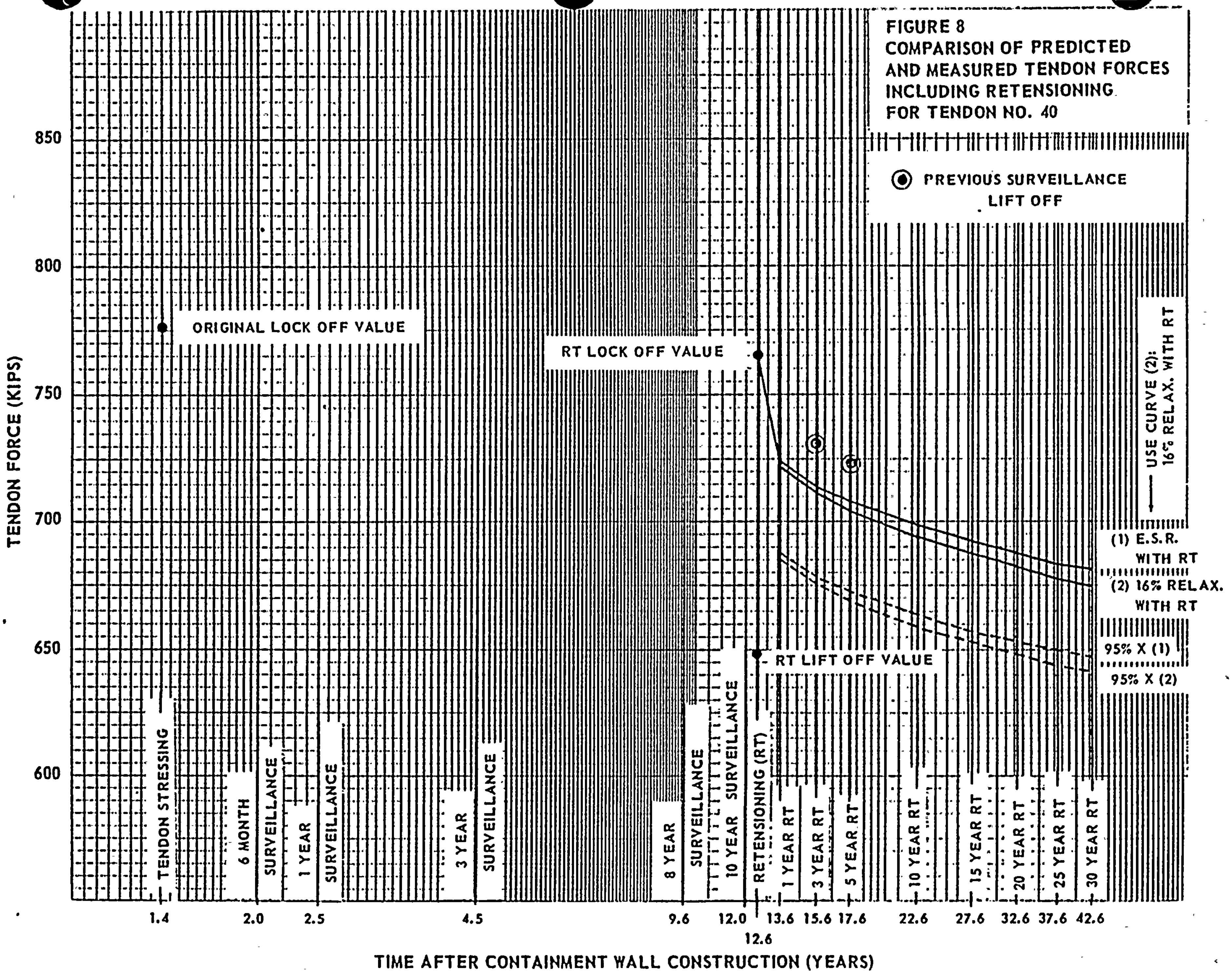


FIGURE 8
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 40

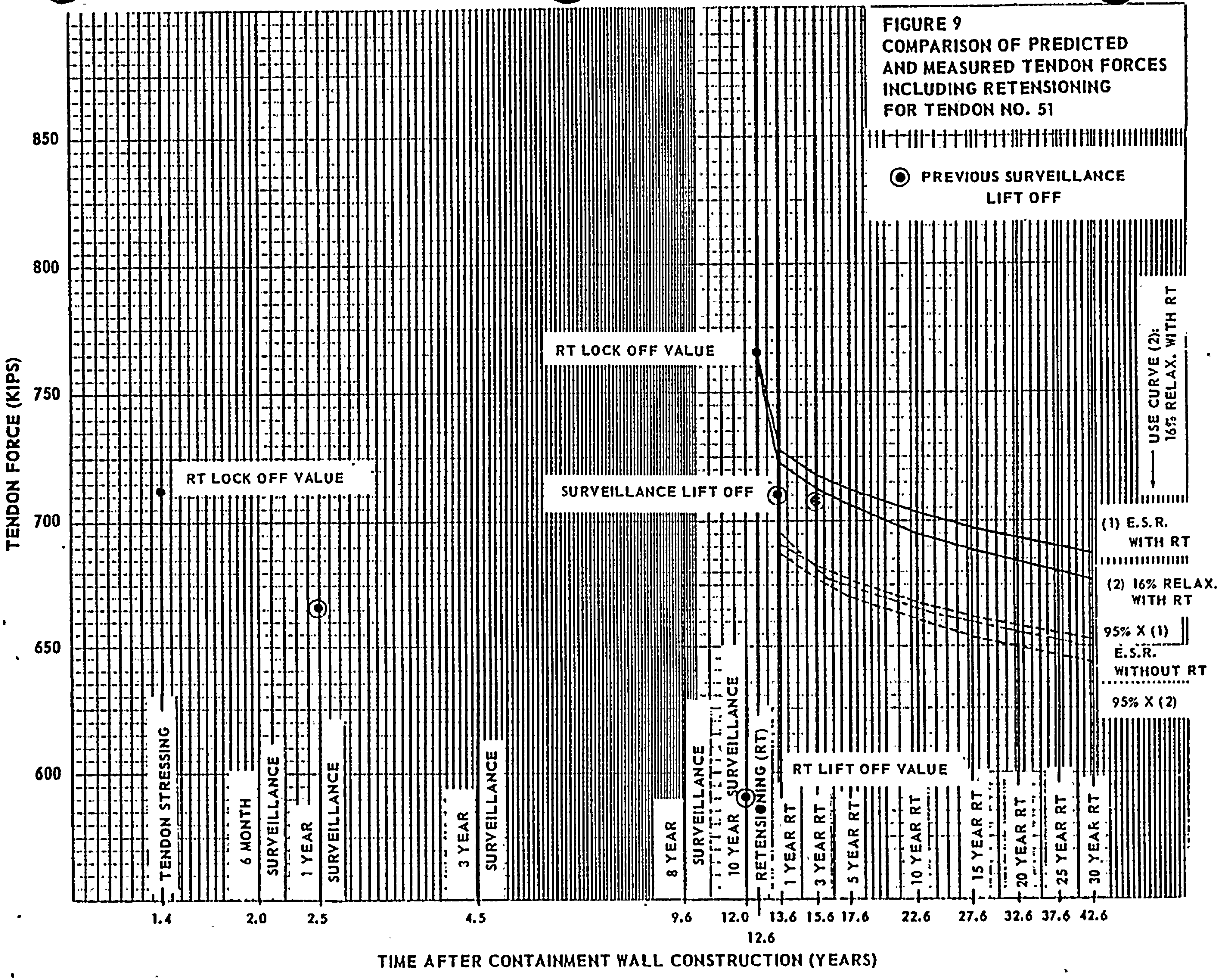
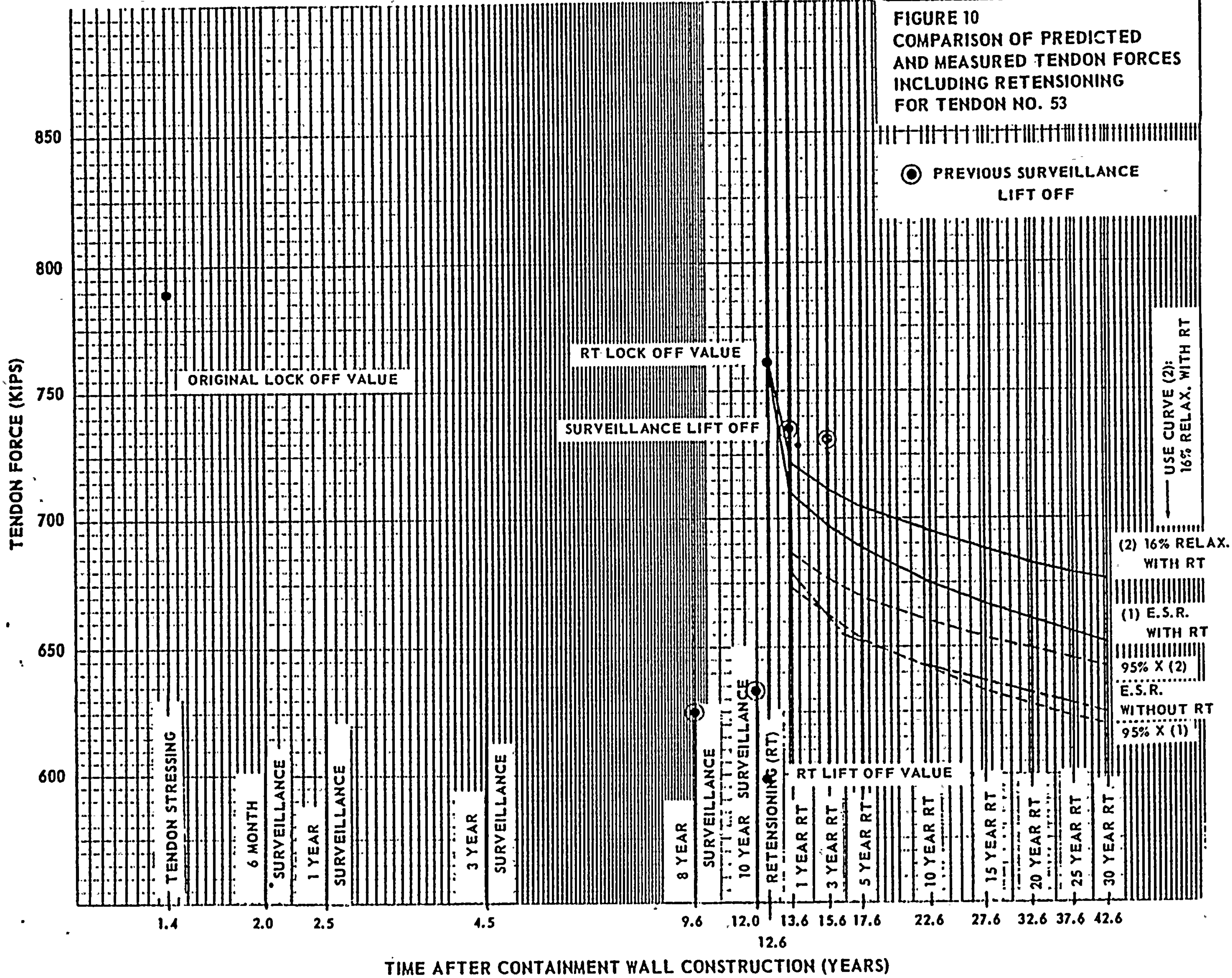


FIGURE 9
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 51
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
RT LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
RT LIFT OFF VALUE
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
E.S.R. WITHOUT RT
95% X (2)
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

FIGURE 10
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 53



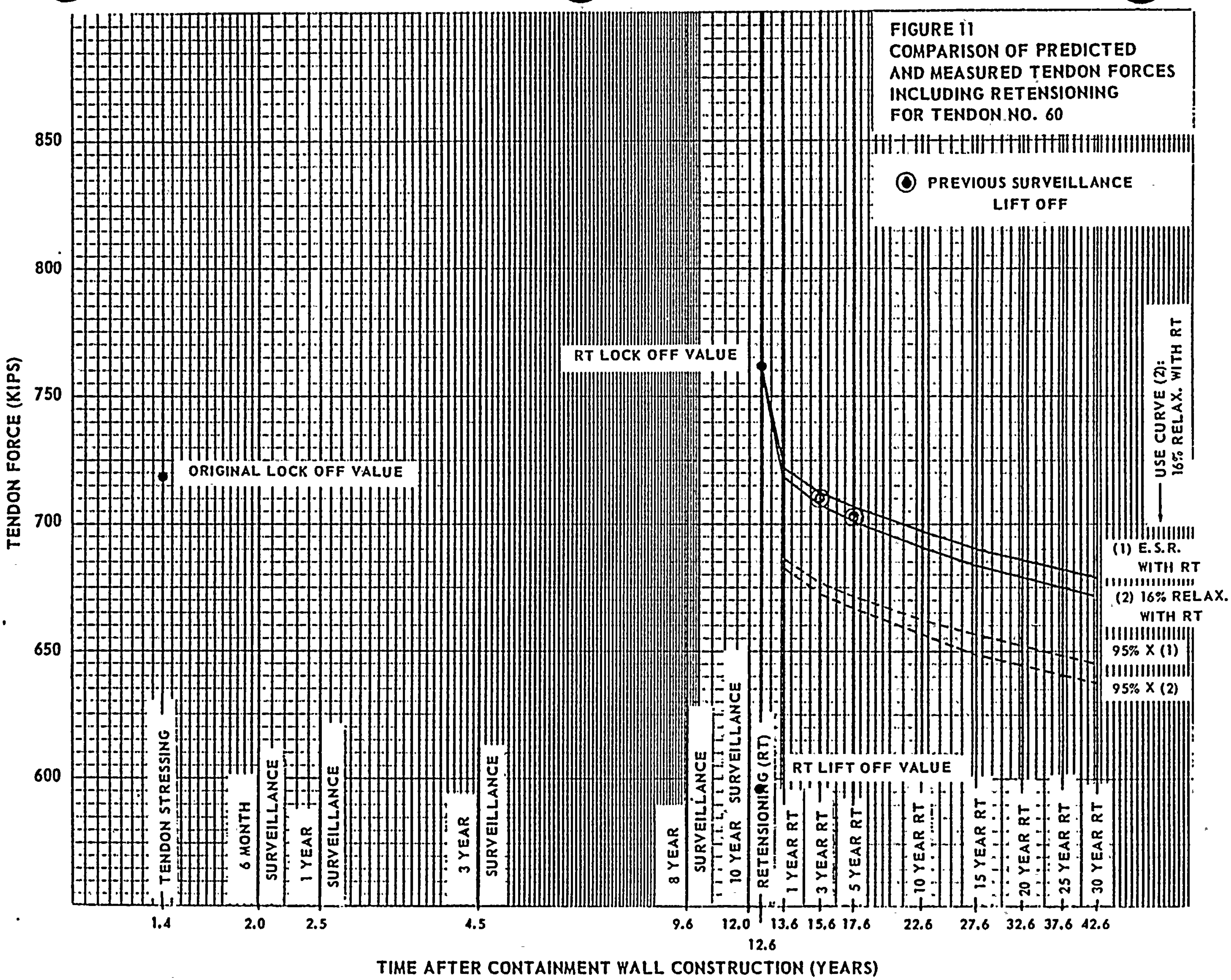


FIGURE 11
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 60
PREVIOUS SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
RT LIFT OFF VALUE
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

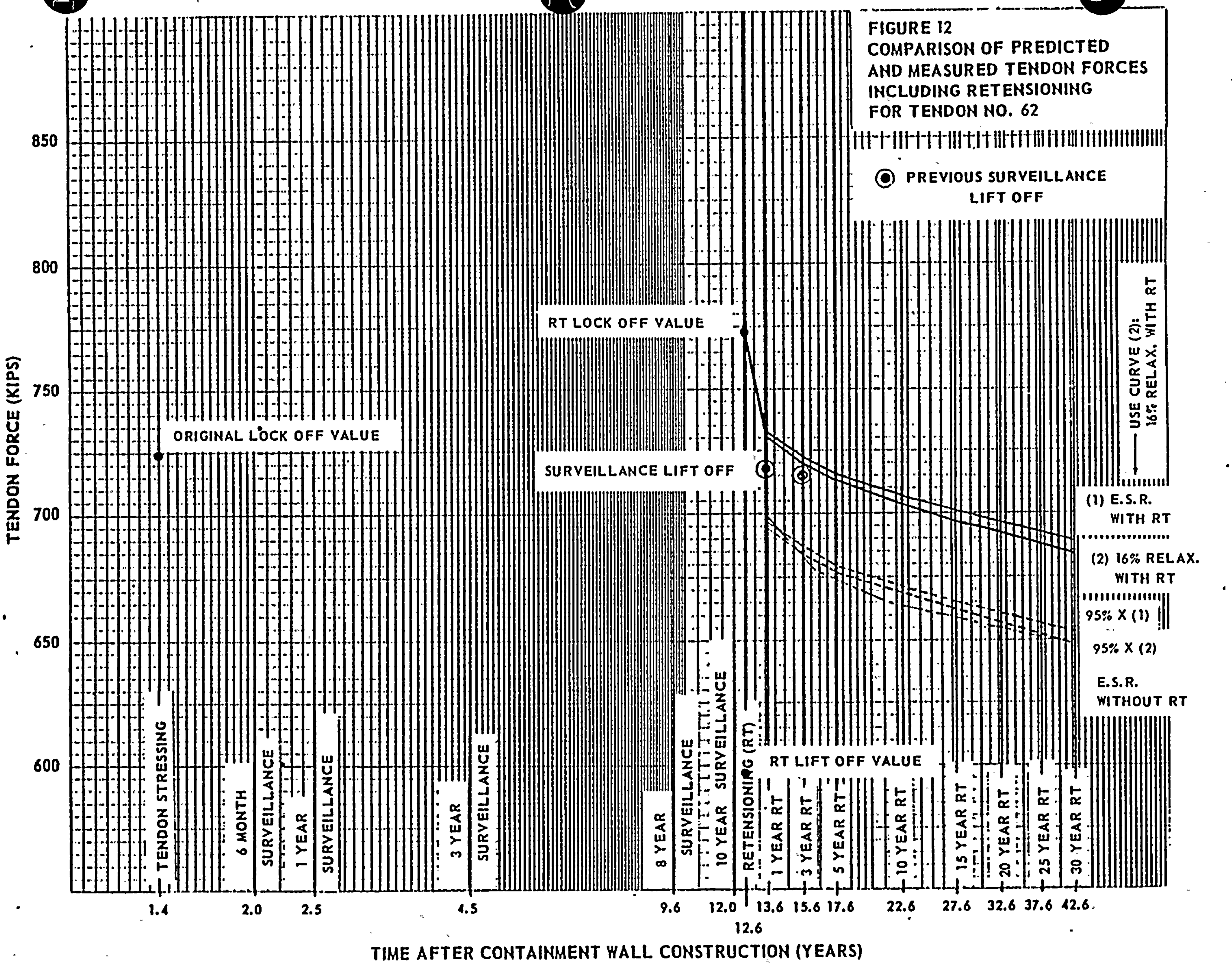


FIGURE 12
COMPARISON OF PREDICTED
AND MEASURED TENDON FORCES
INCLUDING RETENSIONING
FOR TENDON NO. 62
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
E.S.R. WITHOUT RT
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

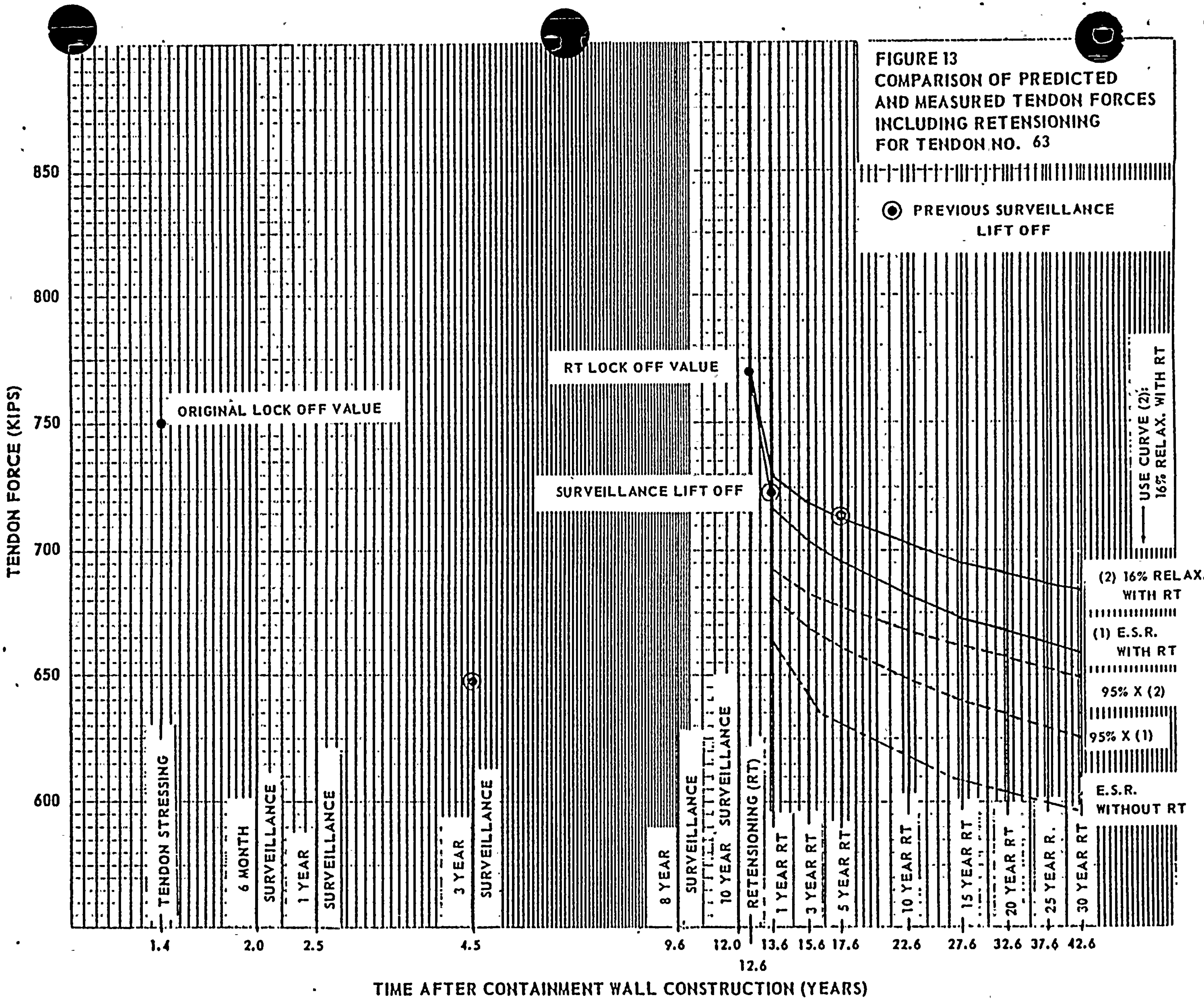


FIGURE 13
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 63
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
(1) E.S.R. WITH RT
95% X (2)
95% X (1)
E.S.R. WITHOUT RT
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR R.
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

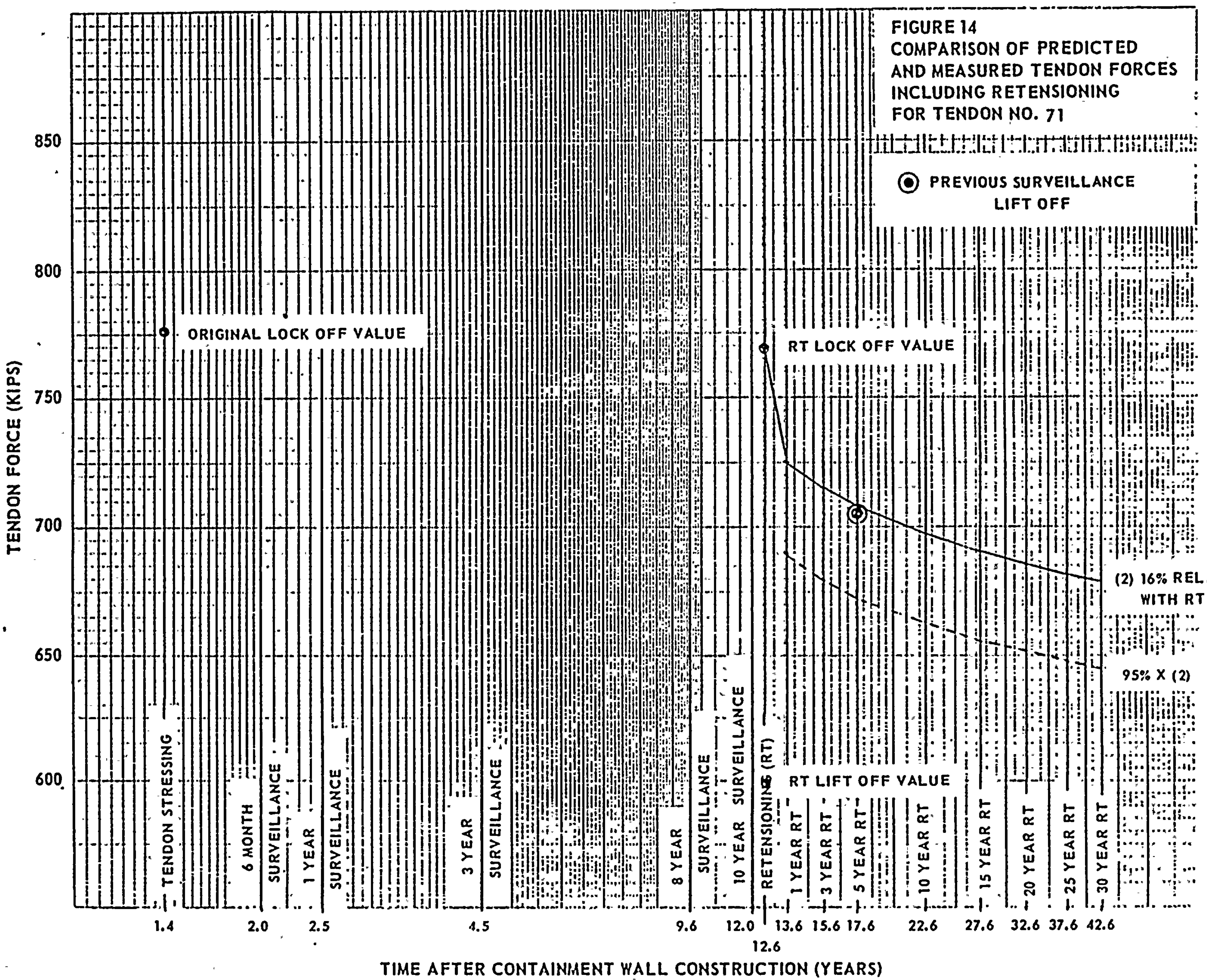


FIGURE 14
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 71
PREVIOUS SURVEILLANCE LIFT OFF
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
(2) 16% RELAX. WITH RT
95% X (2)
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

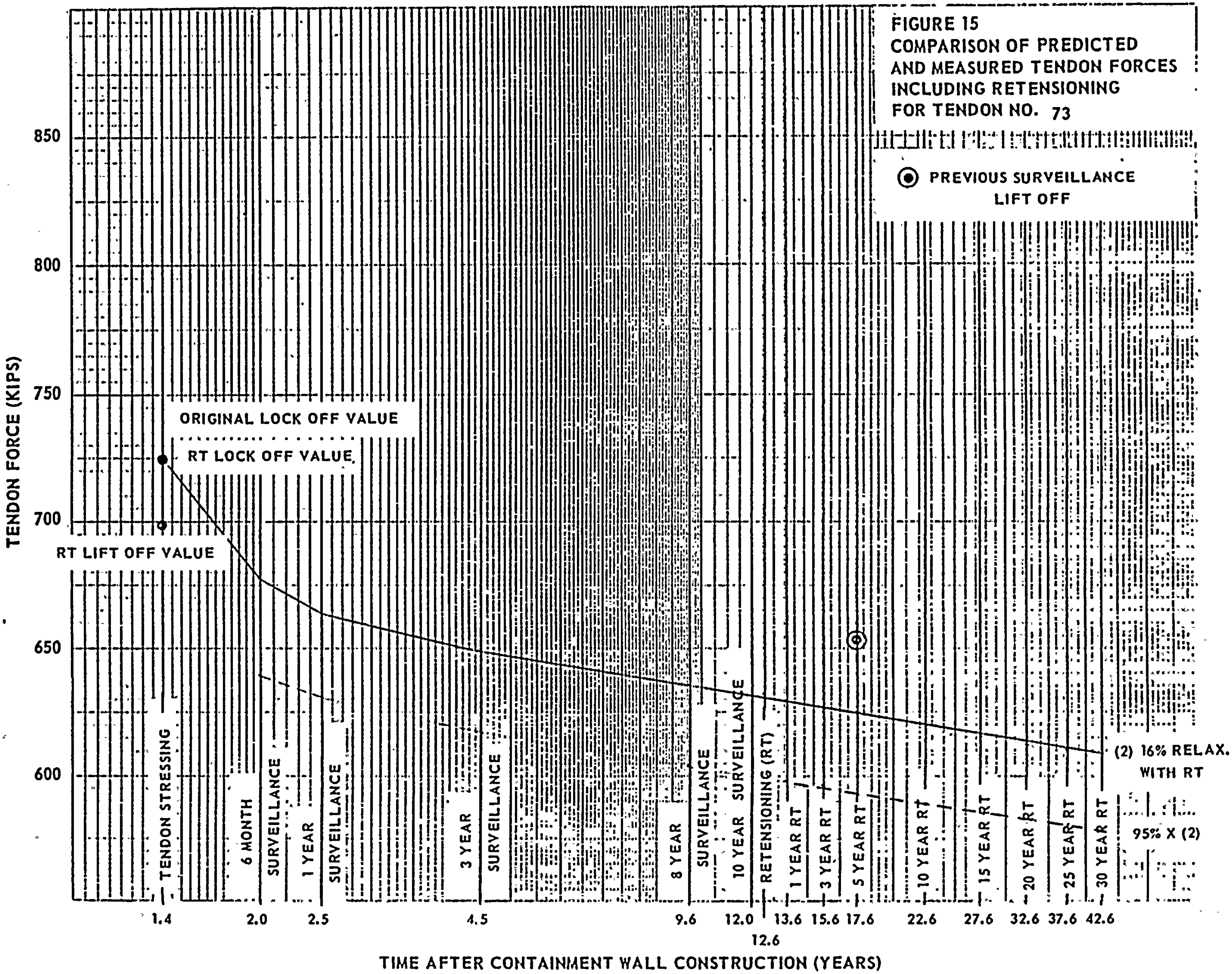


FIGURE 15
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 73
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
(2) 16% RELAX. WITH RT
95% X (2)
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

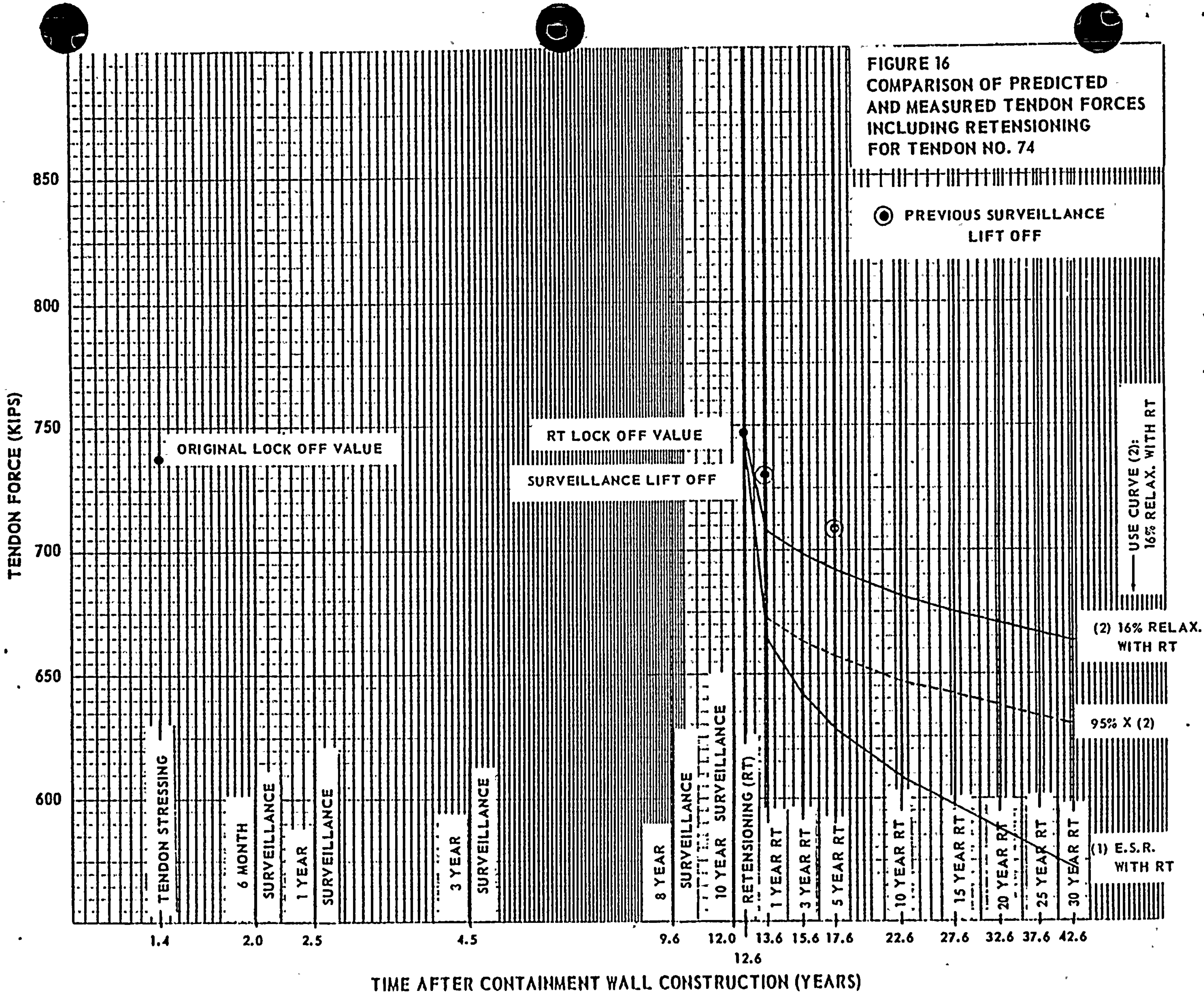


FIGURE 16
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 74
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
95% X (2)
(1) E.S.R. WITH RT
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

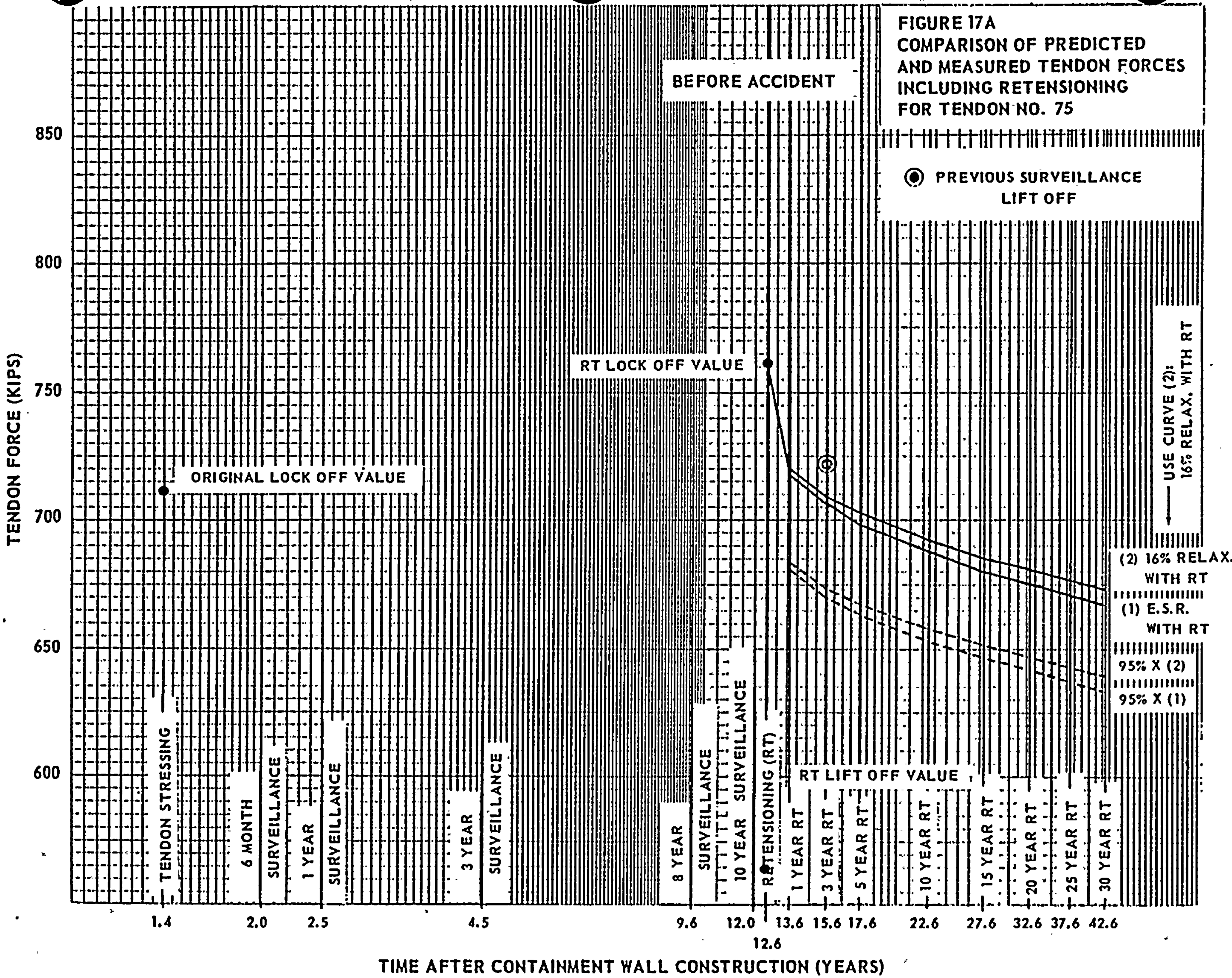


FIGURE 17A
COMPARISON OF PREDICTED
AND MEASURED TENDON FORCES
INCLUDING RETENSIONING
FOR TENDON NO. 75
BEFORE ACCIDENT
PREVIOUS SURVEILLANCE
LIFT OFF
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
USE CURVE (2):
16% RELAX. WITH RT
(2) 16% RELAX.
WITH RT
(1) E.S.R.
WITH RT
95% X (2)
95% X (1)
RT LIFT OFF VALUE
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

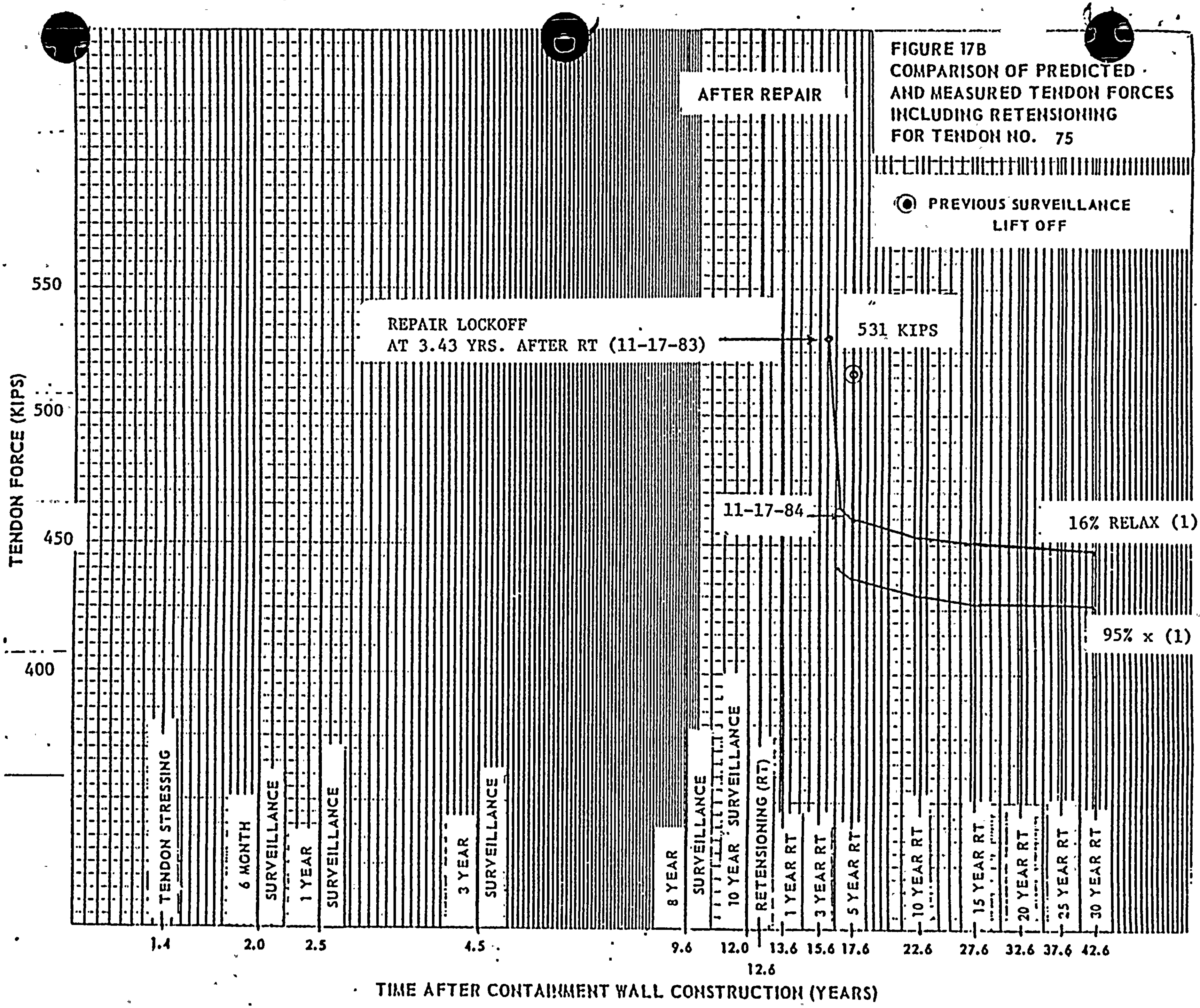


FIGURE 17B
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 75

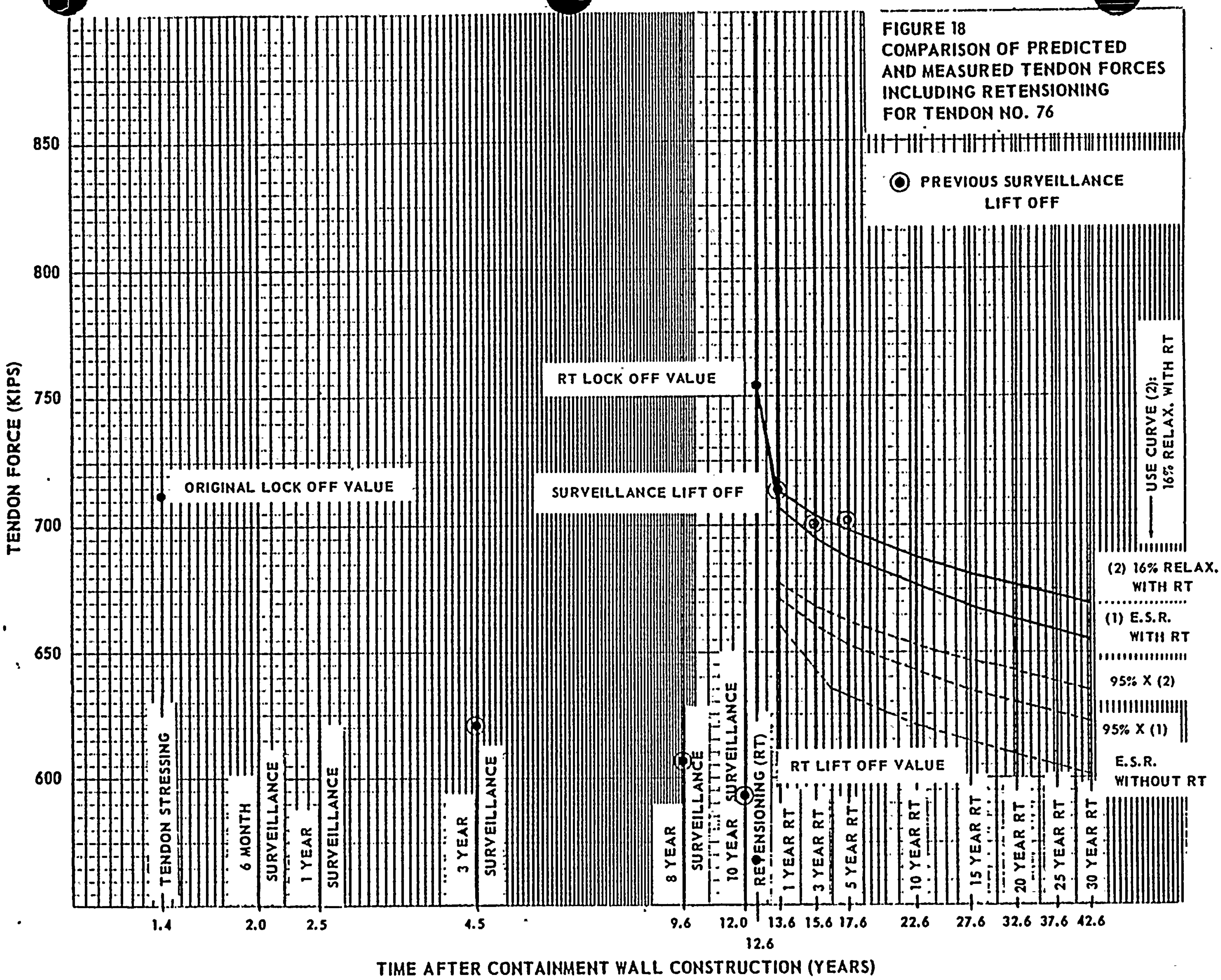


FIGURE 18
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 76
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
(1) E.S.R. WITH RT
95% X (2)
95% X (1)
E.S.R. WITHOUT RT
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

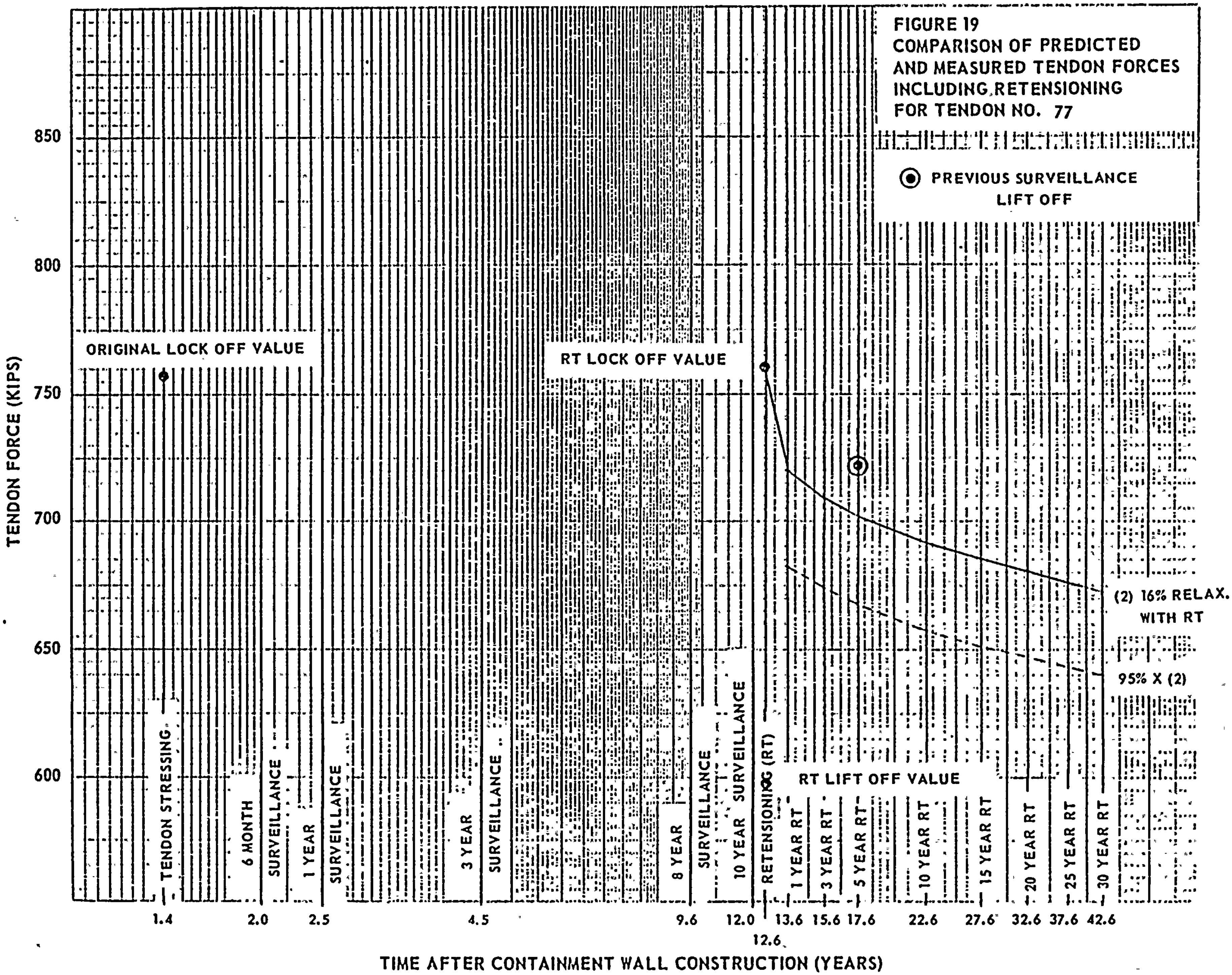


FIGURE 19
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 77
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
(2) 16% RELAX. WITH RT
95% X (2)
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

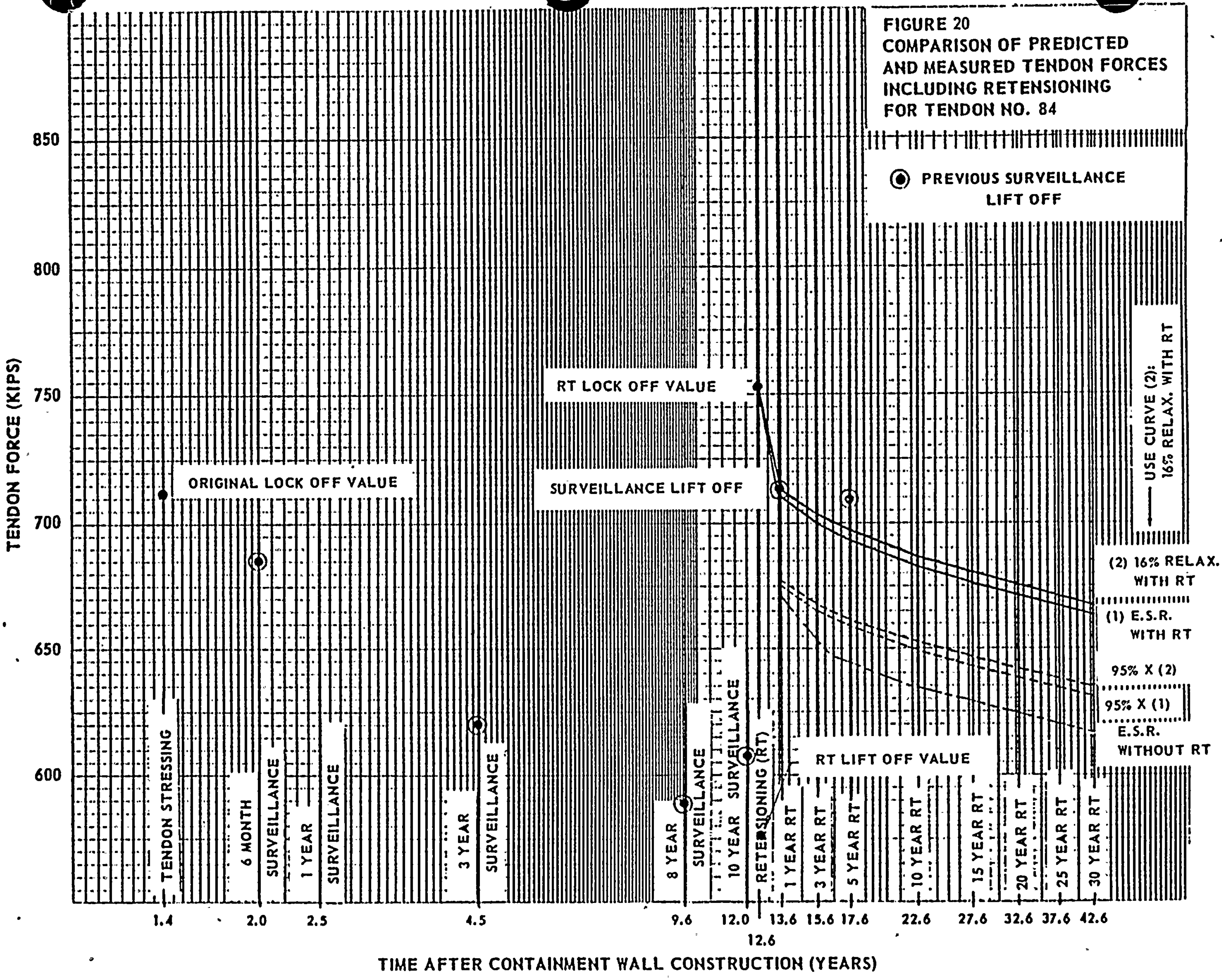


FIGURE 20
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 84

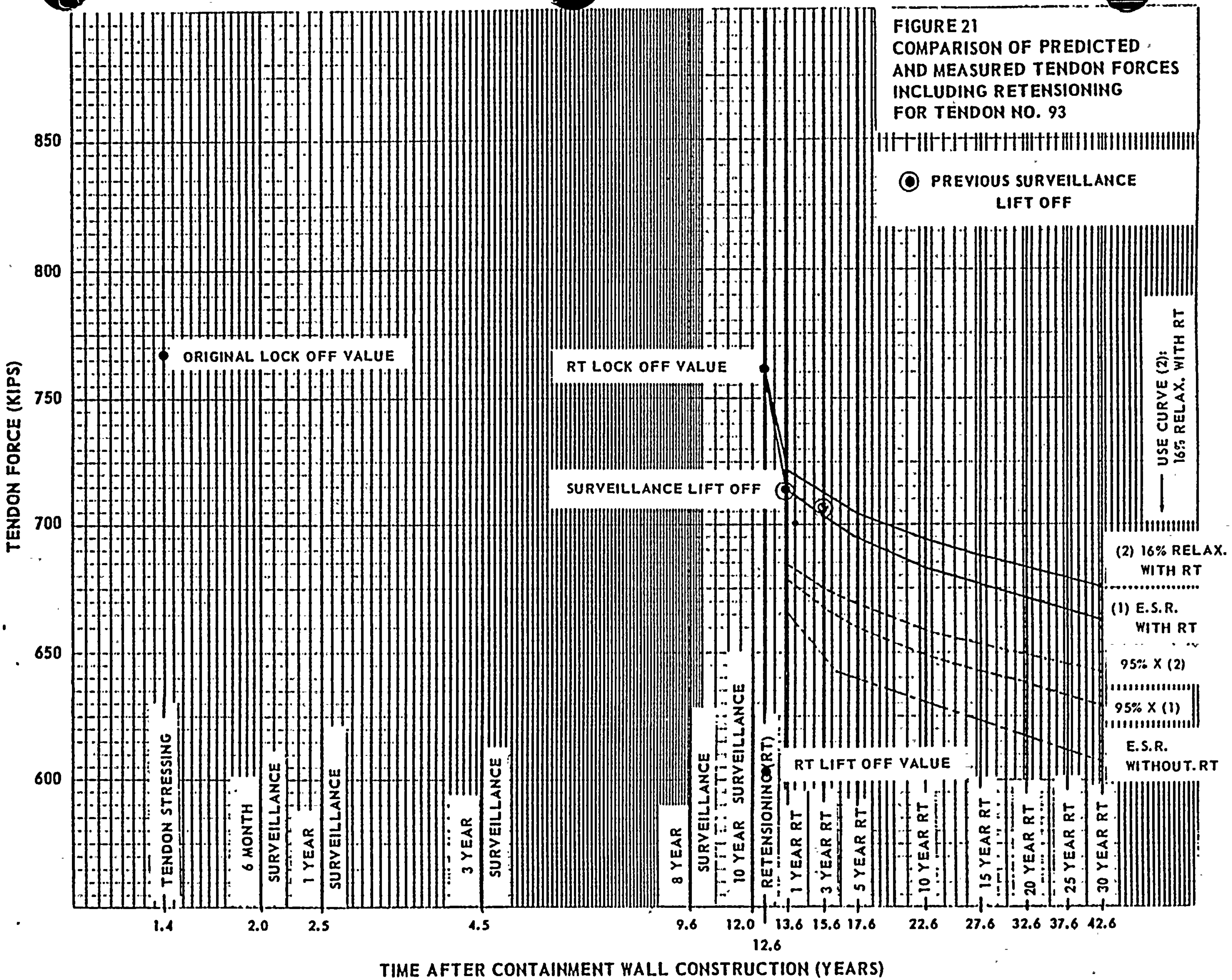


FIGURE 21
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 93
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
RT LIFT OFF VALUE
USE CURVE (2): 16% RELAX. WITH RT
(2) 16% RELAX. WITH RT
(1) E.S.R. WITH RT
95% X (2)
95% X (1)
E.S.R. WITHOUT RT
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

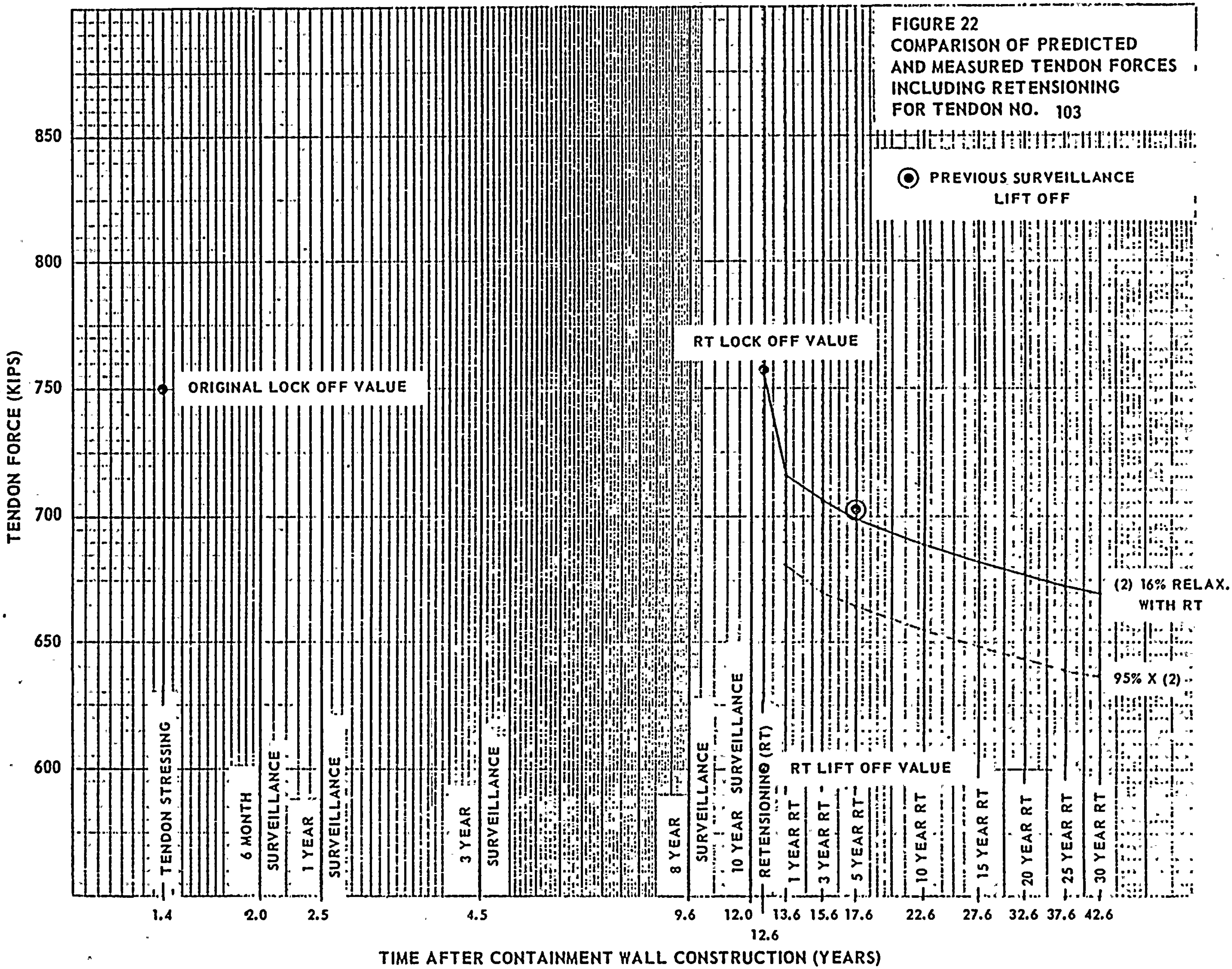


FIGURE 22
COMPARISON OF PREDICTED
AND MEASURED TENDON FORCES
INCLUDING RETENSIONING
FOR TENDON NO. 103
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
(2) 16% RELAX. WITH RT
95% X (2)
RT LIFT OFF VALUE
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

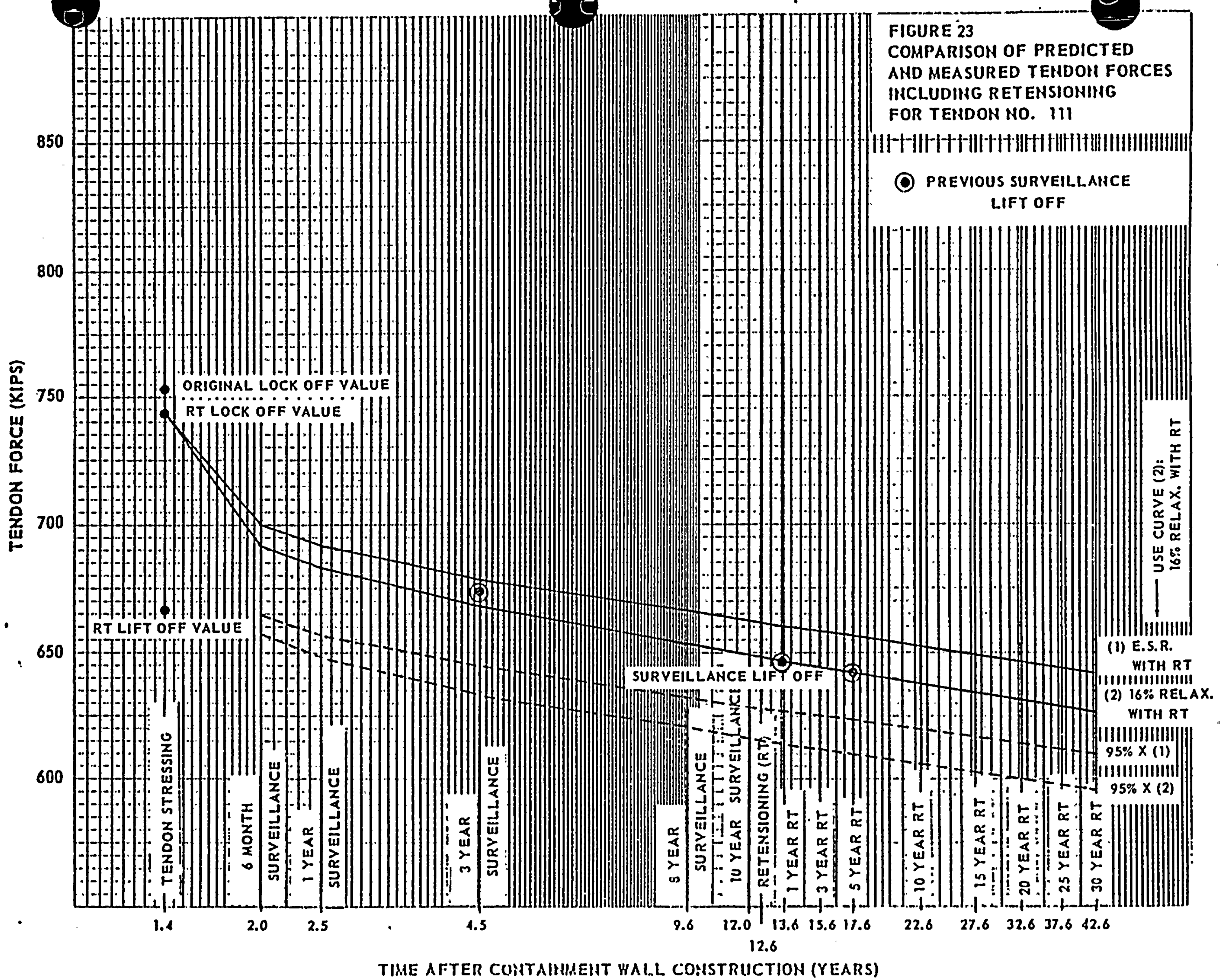


FIGURE 23
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 111
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

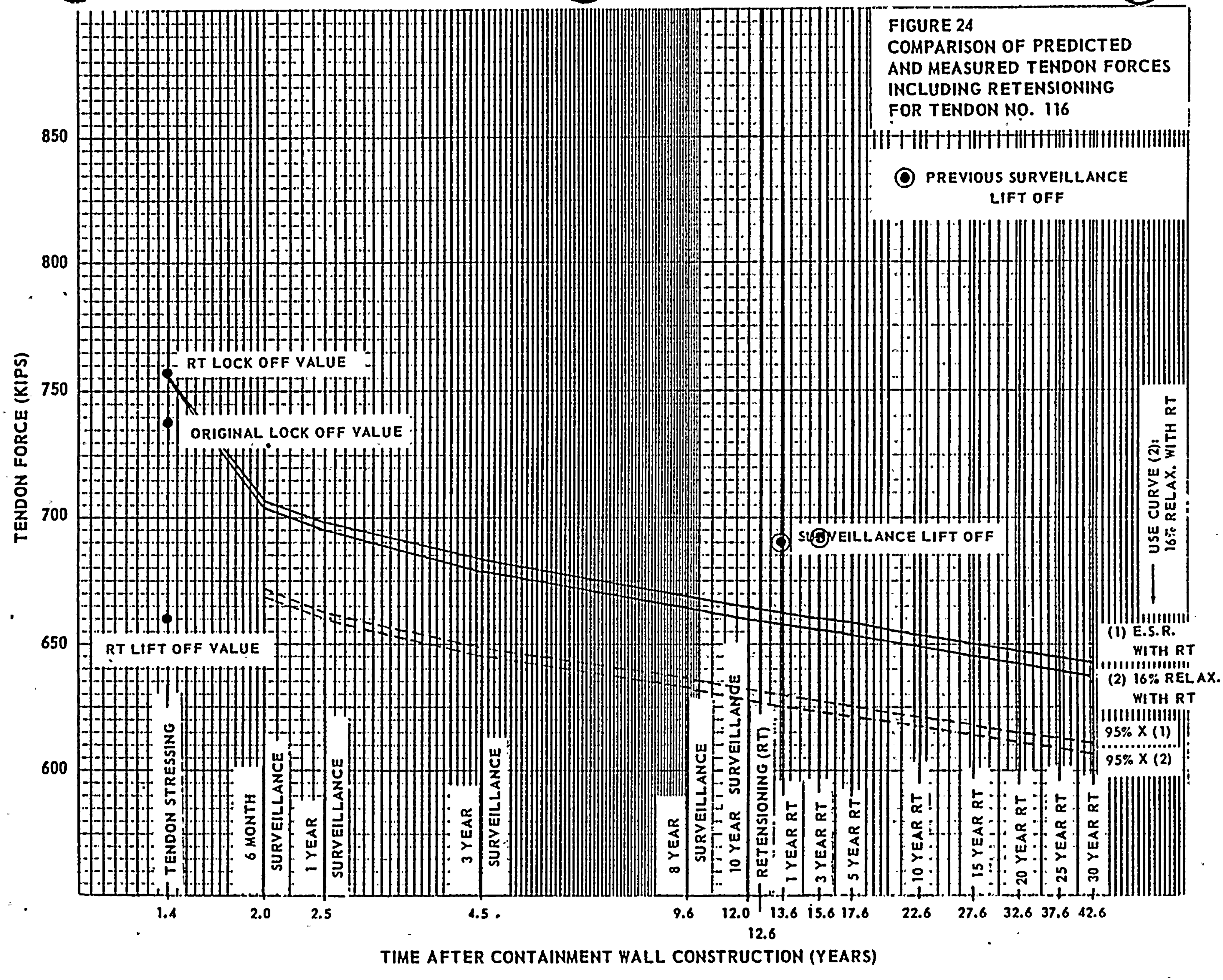
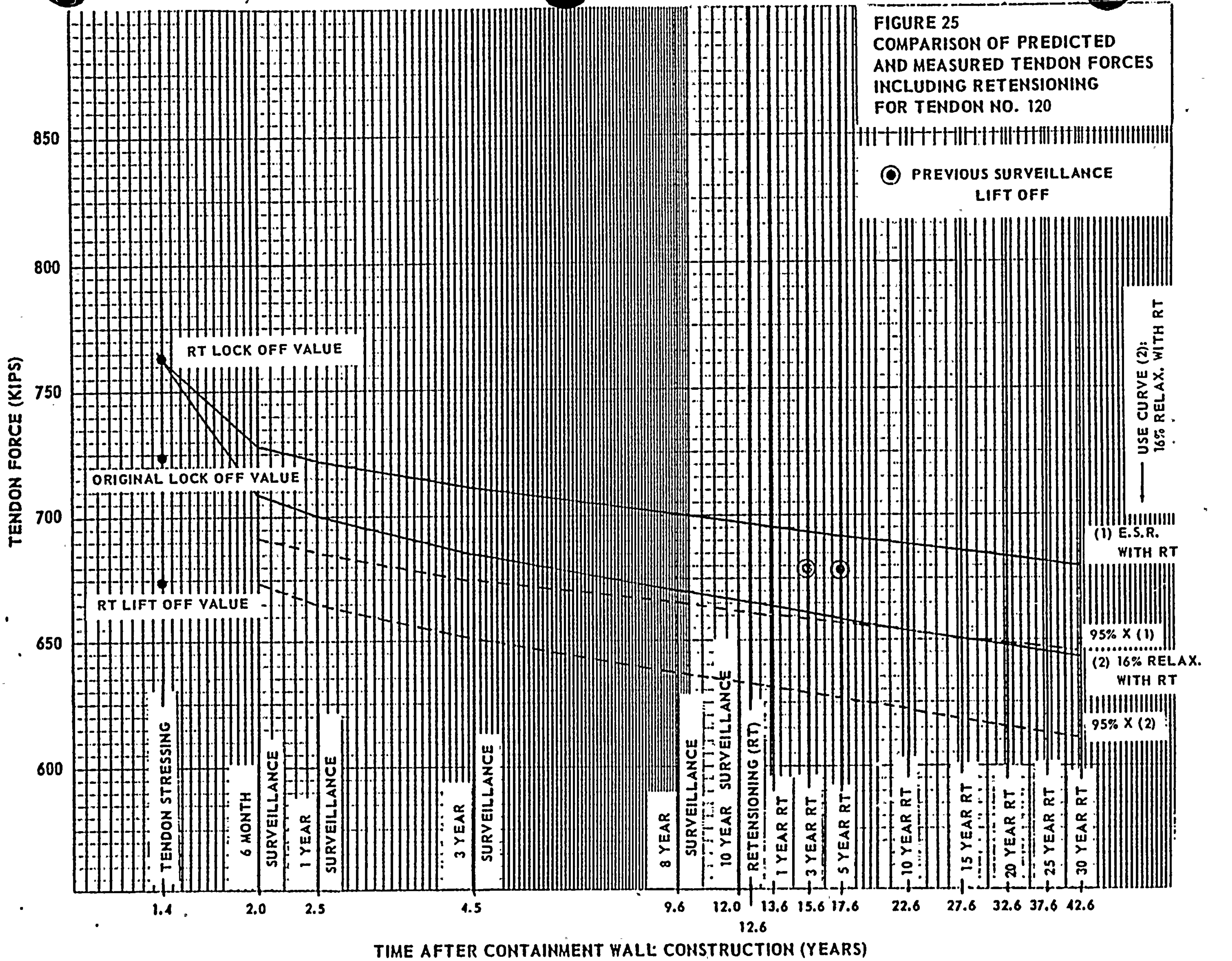


FIGURE 24
COMPARISON OF PREDICTED
AND MEASURED TENDON FORCES
INCLUDING RETENSIONING
FOR TENDON NO. 116
PREVIOUS SURVEILLANCE LIFT OFF
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
RT LIFT OFF VALUE
SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

FIGURE 25
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 120



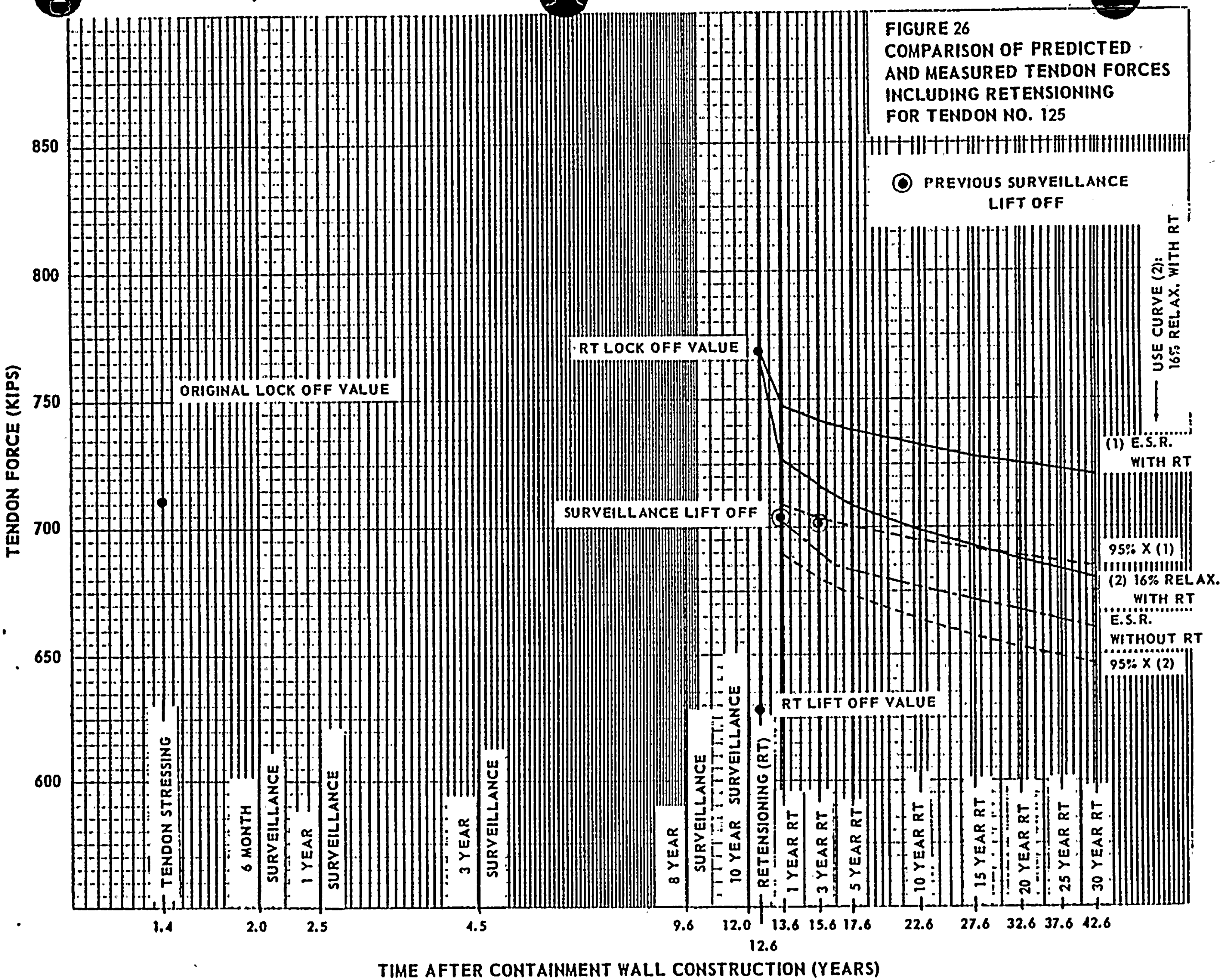


FIGURE 26
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 125
PREVIOUS SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
TENDON FORCE (KIPS)
850
800
750
700
650
600
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
SURVEILLANCE LIFT OFF
RT LIFT OFF VALUE
(1) E.S.R. WITH RT
95% X (1)
(2) 16% RELAX. WITH RT
E.S.R. WITHOUT RT
95% X (2)
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

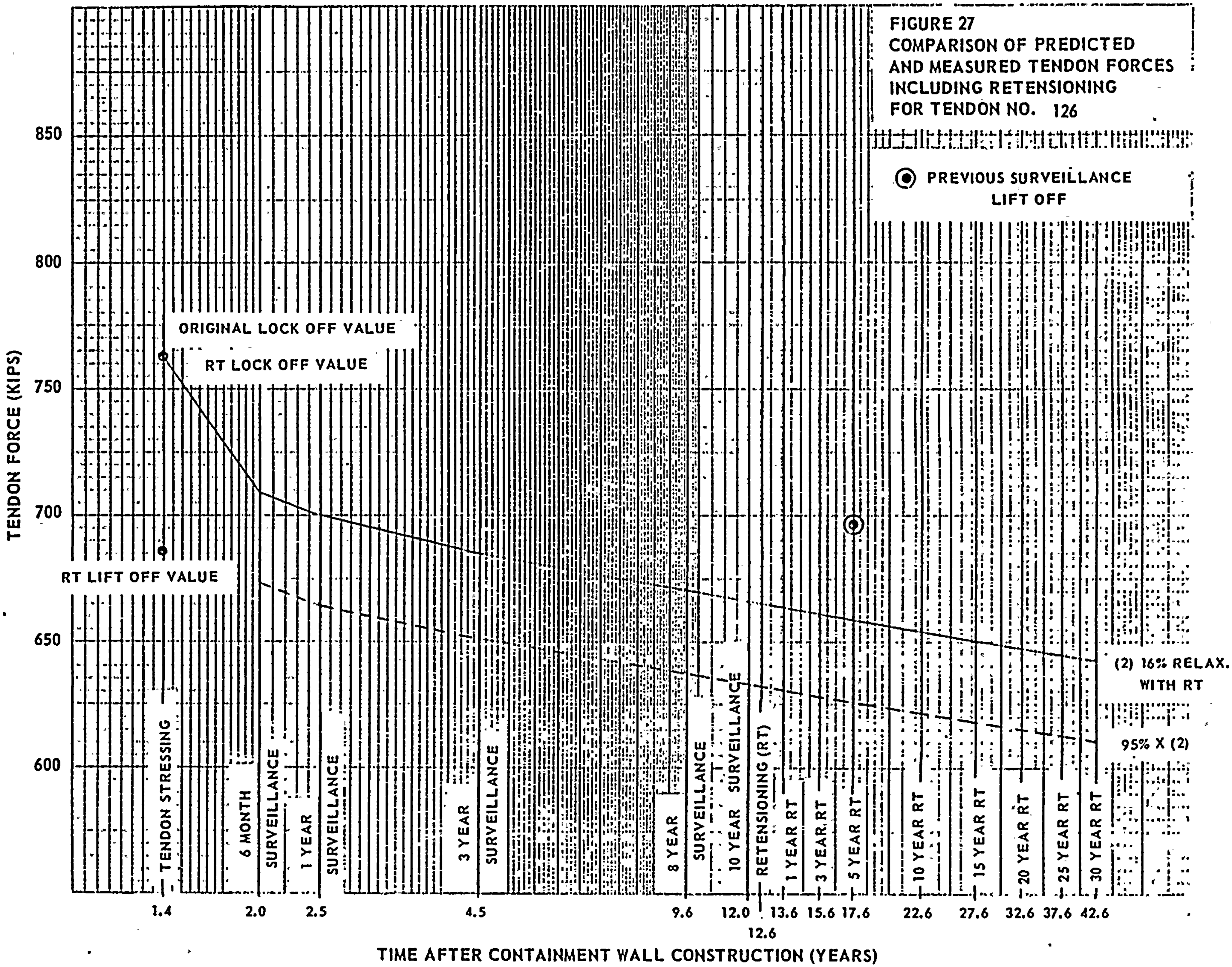


FIGURE 27
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 126
PREVIOUS SURVEILLANCE LIFT OFF
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
(2) 16% RELAX. WITH RT
95% X (2)
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

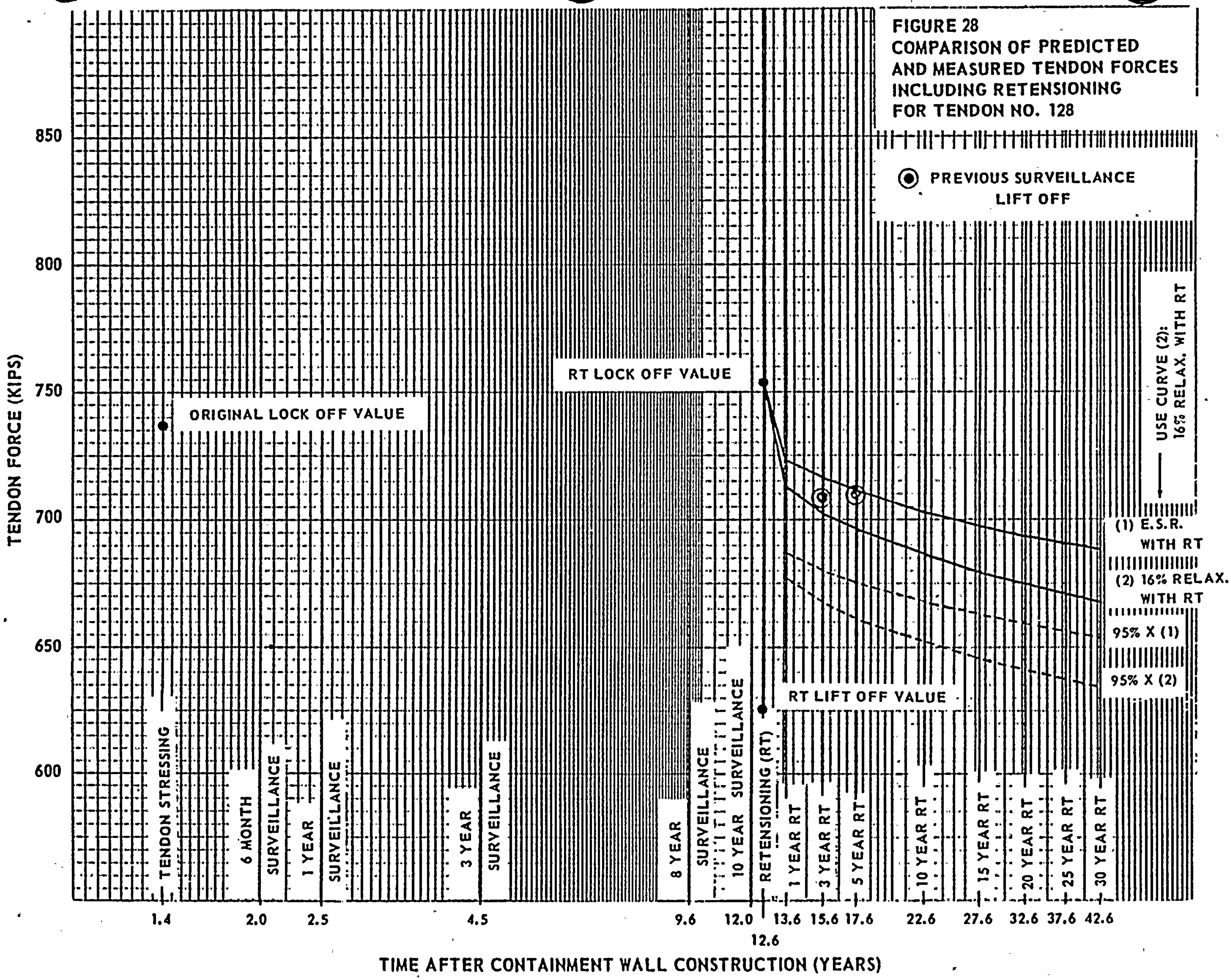
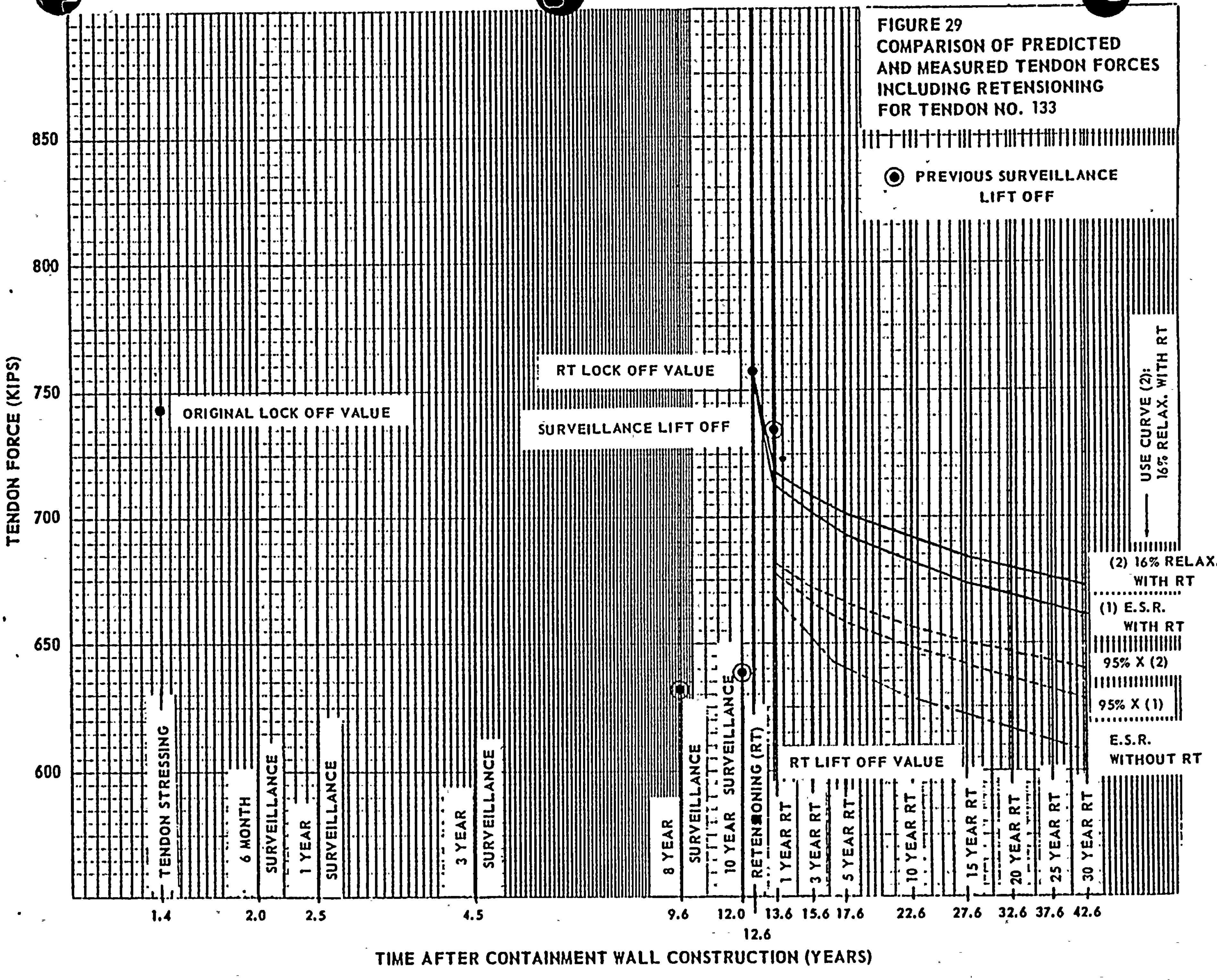


FIGURE 28
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 128
PREVIOUS SURVEILLANCE LIFT OFF
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
RT LOCK OFF VALUE
ORIGINAL LOCK OFF VALUE
RT LIFT OFF VALUE
TENDON FORCE (KIPS)
850
800
750
700
650
600
TENDON STRESSING
6 MONTH SURVEILLANCE
1 YEAR SURVEILLANCE
3 YEAR SURVEILLANCE
8 YEAR SURVEILLANCE
10 YEAR SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

FIGURE 29
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 133



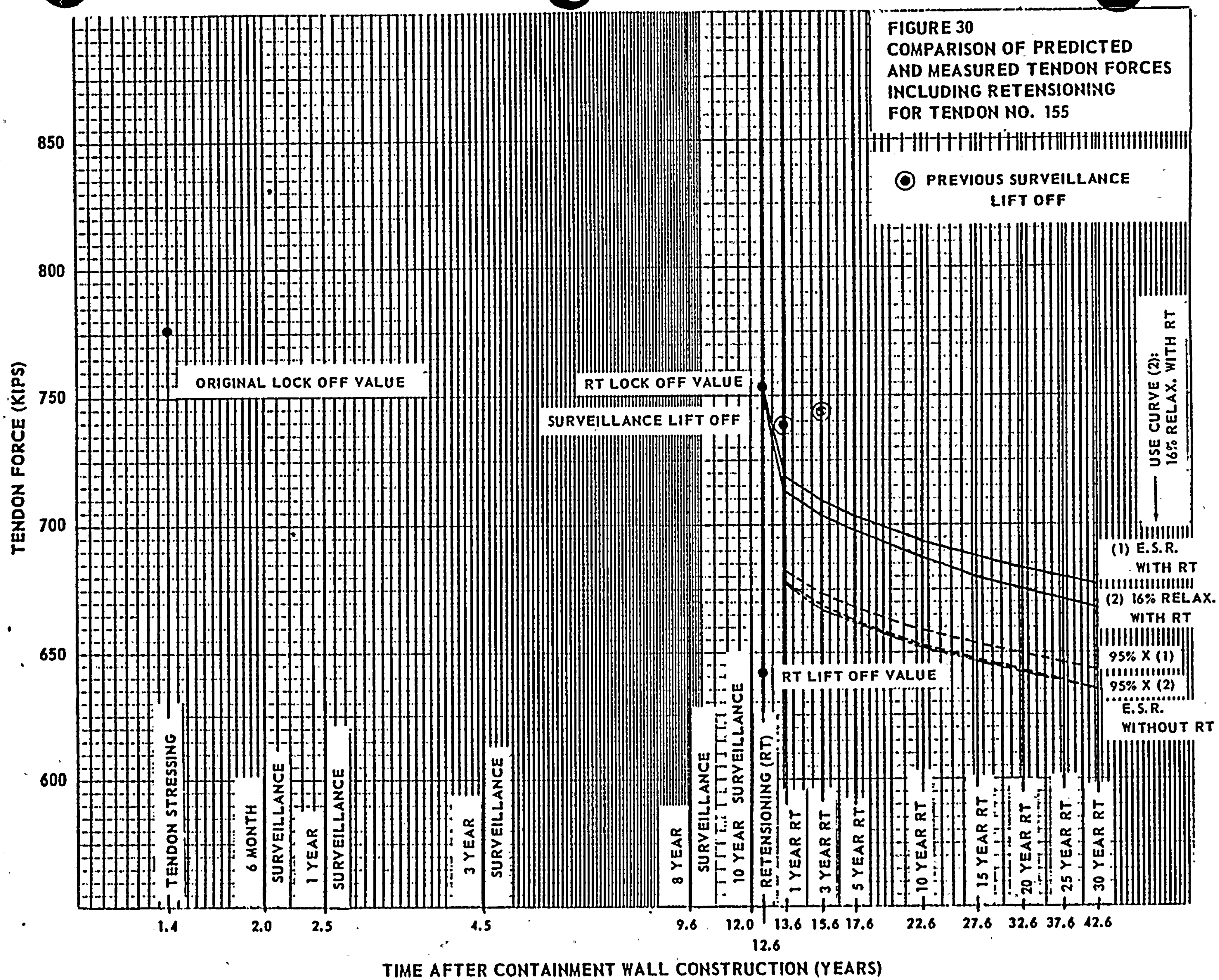


FIGURE 30
COMPARISON OF PREDICTED AND MEASURED TENDON FORCES INCLUDING RETENSIONING FOR TENDON NO. 155
PREVIOUS SURVEILLANCE LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
SURVEILLANCE LIFT OFF
RT LIFT OFF VALUE
USE CURVE (2): 16% RELAX. WITH RT
(1) E.S.R. WITH RT
(2) 16% RELAX. WITH RT
95% X (1)
95% X (2)
E.S.R. WITHOUT RT
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

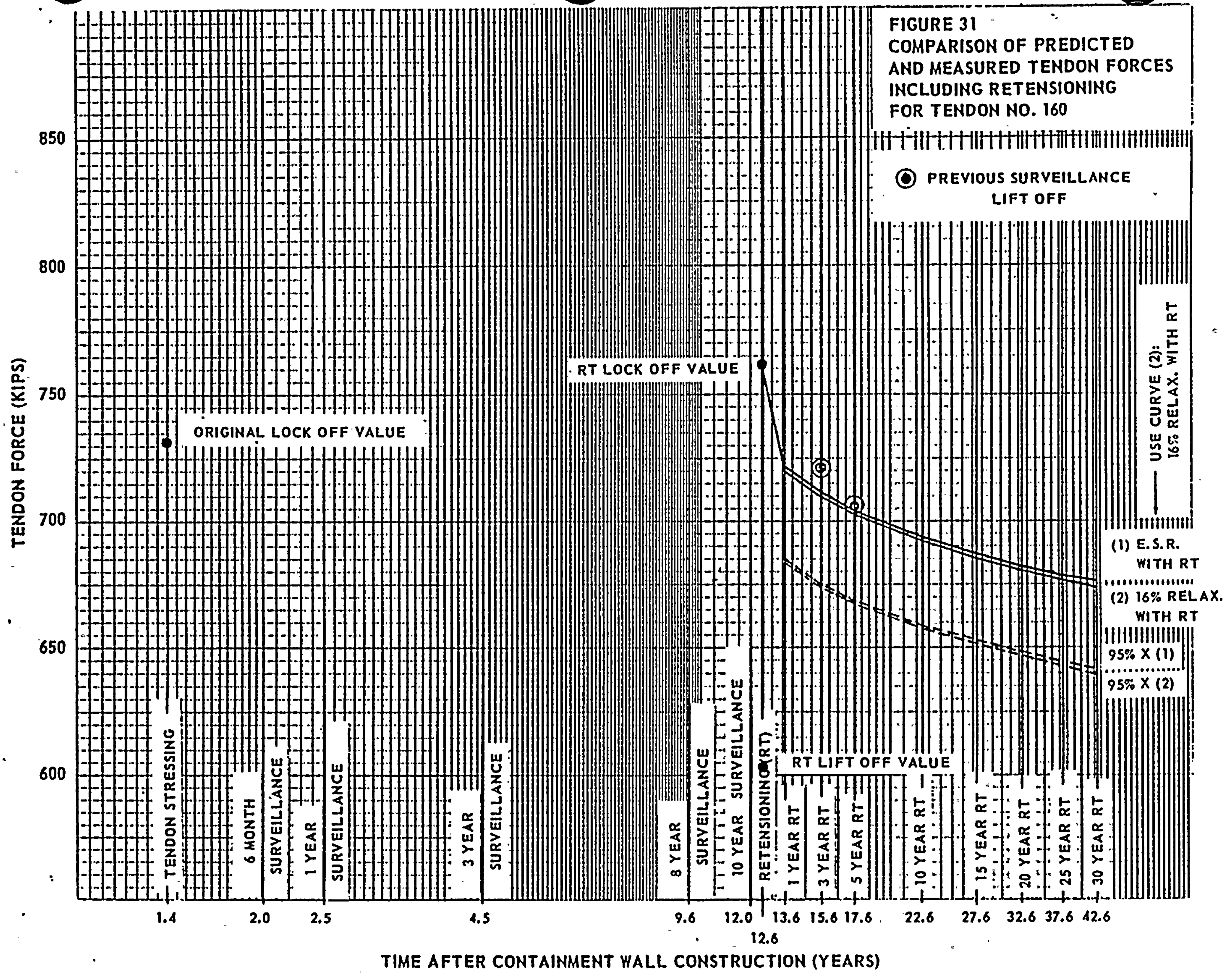


FIGURE 31
COMPARISON OF PREDICTED
AND MEASURED TENDON FORCES
INCLUDING RETENSIONING
FOR TENDON NO. 160
PREVIOUS SURVEILLANCE
LIFT OFF
TENDON FORCE (KIPS)
850
800
750
700
650
600
ORIGINAL LOCK OFF VALUE
RT LOCK OFF VALUE
RT LIFT OFF VALUE
USE CURVE (2):
16% RELAX. WITH RT
(1) E.S.R.
WITH RT
(2) 16% RELAX.
WITH RT
95% X (1)
95% X (2)
TENDON STRESSING
6 MONTH
SURVEILLANCE
1 YEAR
SURVEILLANCE
3 YEAR
SURVEILLANCE
8 YEAR
SURVEILLANCE
10 YEAR
SURVEILLANCE
RETENSIONING (RT)
1 YEAR RT
3 YEAR RT
5 YEAR RT
10 YEAR RT
15 YEAR RT
20 YEAR RT
25 YEAR RT
30 YEAR RT
1.4
2.0
2.5
4.5
9.6
12.0
12.6
13.6
15.6
17.6
22.6
27.6
32.6
37.6
42.6
TIME AFTER CONTAINMENT WALL CONSTRUCTION (YEARS)

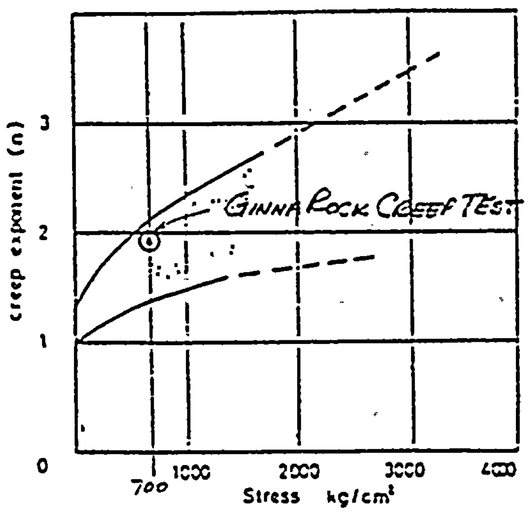


Figure 4.5 Relationship between creep exponent and stress.

Reproduced from: I. W. Farmer, Engineering Properties of Rock, 1968

FIGURE 32. CREEP EXPONENT VERSUS STRESS

Attachment (B)

1985 GINNA TENDON SURVEILLANCE

Lift-Off Results

Tendon Number	Force (Kips)
17	717
18	705
21	723
33**	673
35**	653
40	724
60	702
63	713
71	705
73**	654
74	710
75*	518
76	703
77	723
84	710
103	703
111**	643
120**	679
126**	692
128	711
160	705

* Tendon damaged during 1983 Surveillance

** Tendons retensioned in 1969

Weighted Average Lift-Off Force
(all tendons)

A) Average Lift-off force, tendons retensioned in 1969 - 666 Kips
(Note: 23 tendons total)

B) Average Lift-off force, tendons retensioned in 1980 - 711 Kips
(Note: 136 Tendons total, excluding No. 75)

C) Lift-off force for Tendon No. 75 - 518 Kips

Weighted Average Lift-Off Force:

$$F = \frac{(23 \times 666 \text{ Kips}) + (136 \times 711 \text{ Kips}) + (1 \times 518 \text{ Kips})}{160}$$

$$F = 703 \text{ Kips}$$

Attachment (C)