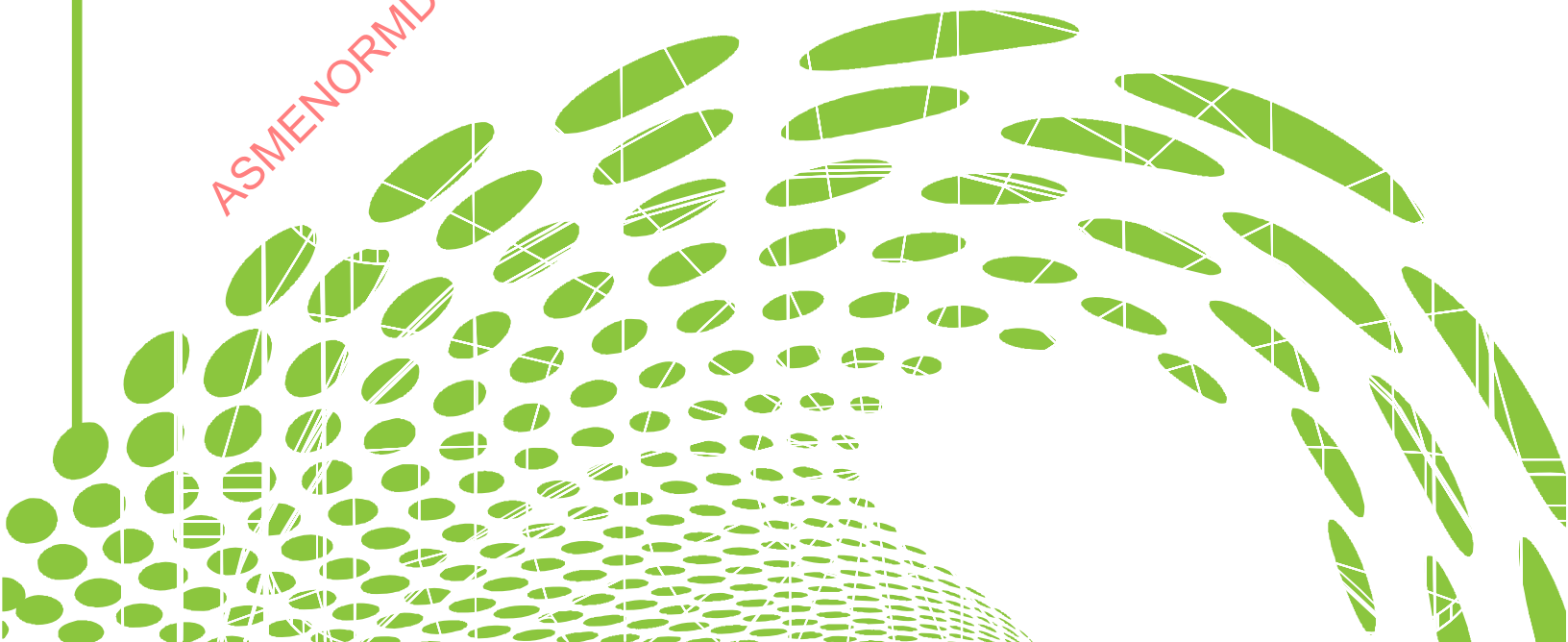
ASME STANDARDS TECHNOLOGY, LLC

STP-PT-097

STRESS INTENSIFICATION FACTOR, K-FACTOR, AND SUSTAINED STRESS INDEX DEVELOPMENT–PHASE II



STP-PT-097

STRESS INTENSIFICATION FACTOR, K-FACTOR, AND SUSTAINED STRESS INDEX DEVELOPMENT – PHASE II

Prepared by:

Anthony W. Paulin, P.E.
Paulin Research Group
Houston, TX, USA

And

Chris Hinnant, P.E.
K&H Fabricators, Inc.
Smithville, TX, USA

ASME STANDARDS TECHNOLOGY, LLC

Date of Issuance: August 16, 2023

This publication was prepared by ASME Standards Technology, LLC ("ASME ST-LLC") and sponsored by The American Society of Mechanical Engineers ("ASME").

ASME Standards Technology, LLC
Two Park Avenue, New York, NY 10016-5990

ISBN No. 9780791876398

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

We would like to express our thanks to Mr. Glynn Woods, GCS Consulting Services., Mr. Willy Lock and Dr. Delin Wang of PRG (Paulin Research Group), Dr. Hans Bos of Dynaflow Research Group bv., Mr. Ron Haupt of Pressure Piping Engineering Associates, Inc., Mr. Randy Bethea, Tim Pline, and Russ Diedrich of Huntington Ingalls Industries – Newport News Shipbuilding, and Mr. Doug Knode and Edwin Avila of Evident Scientific/Olympus. Their assistance, comments and recommendations are very much appreciated.

Established in 1880, the ASME is a professional not-for-profit organization with more than 135,000 members and volunteers promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit https://www.asme.org/ for more information.

ASME ST-LLC is a not-for-profit Limited Liability Company, with ASME as the sole member, formed in 2004 to carry out work related to new and developing technology. ASME ST-LLC's mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology, and providing the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit http://asmestllc.org/ for more information.

ABSTRACT

In support of ASME B31J and B31H standards, physical testing for stress intensification factors (SIFs), flexibility factors (k-Factors), and sustained stress indices (SSIs) can be used to confirm differences between the Markl and Hinnant curves in the low-cycle ranges and finite element predictions of fatigue, stiffness, collapse and burst.

Improvement in analytical capability since the 1950s (when Markl developed the basic rules in the B31 piping codes used today) has improved the ability to numerically predict stress states. Unfortunately, not all piping components are well defined geometrically or dimensionally in ASME standard documents. Large D/T (ratio of mean header diameter to header nominal thickness) and d/D (ratio of mean branch diameter to mean header diameter) failures involve nonlinear characteristics that may not be well represented by elastic analyses. In these cases, verification by test is considered essential to verify the predicted values and the method of analysis considered.

This publication documents the results of phase II of work undertaken to investigate deficiencies in the existing test data sets identified during the data collection effort from ST-LLC Publication STP-PT-073.

ABBREVIATIONS AND ACRONYMS

ASME	- American Society of Mechanical Engineers
MTR	- Material Test Reports
NPS	- Nominal Pipe Size
NPT	- American National Standard Taper Pipe Thread
PRG	- Paulin Research Group
SCH	- Pipe Schedule
SIF	- Stress Intensification Factors
SSI	- Sustained Stress Indicators
STD	- Standard
ST-LLC	- Standards Technology, Limited Liability Company
WRC	- Weld Research Council

1 INTRODUCTION

Twelve straight pipe specimens were fabricated, material properties independently evaluated, and each specimen was pressurized to rupture at K&H Fabricator's facility in Smithville, Texas. The specimens were segregated into stainless and carbon groups, each group consisting of six specimens: three seamless specimens and three longitudinally welded specimens. Pipe specimens for each group of three tests were made from the same heat so that theoretically three identical specimens could be tested. A significant finding of these results is stainless steel samples failed at a consistently lower pressure than would otherwise be predicted for the same specimen made of carbon steel. This supports prior findings by Rodabaugh in [1].

2 TEST PROGRAM

This research program consisted of burst testing twelve specimens in total with multiple samples from a single parent pipe. The primary goal was to determine the material strength properties and rupture pressure for similar specimens of carbon steel and stainless steel, each with and without a longitudinal weld seam. A summary of the twelve test specimens and the burst pressure for each is given in Table 2-1.

Table 2-1 – Summary of Test Specimens and Burst Pressure

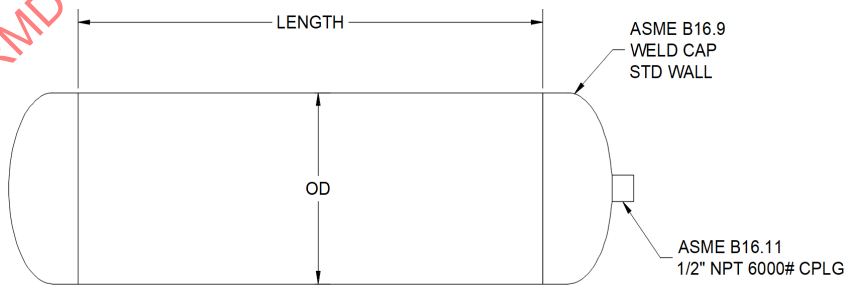
#	ID	Matl	Heat #	Type	Spec/Gr	Pipe Size	Length[1]	Pb
							Inches	psi
1	CS1W	Carbon Steel	21023922	Welded	A53-B	10” SCH 40	60	4,720
2	CS2W							4,714
3	CS3W							4,658
4	CS1S	Carbon Steel	LX0174	Seamless	A106-B	10” SCH 40	60	5,198
5	CS2S							5,200
6	CS3S							5,207
7	SS1S	Stainless Steel	126109	Seamless	A312-TP304/304L	10” SCH 40S	60	5,259
8	SS2S							5,270
9	SS3S							5,370
10	SS1W	Stainless Steel	15950	Welded	A312-TP304/304L	12” SCH 10S	67	1,910
11	SS2W							1,976
12	SS3W							1,937

Table 2-1 Footnotes:

1. “Length” represents the cut length of the pipe between the circumferential welds joining the B16.9 STD (Standard) wall pipe caps to the pipe. Additional cylindrical length exists within the straight flange of the B16.9 pipe caps.

Specimens were fabricated from straight pipe conforming to ASME B36.10M and ASME B36.19M with material specifications including A53-B, SA-106-B, and SA-312-TP304/304L. Material Test Reports (MTR’s) are provided for materials in Appendix A. NPS (Nominal Pipe Size) 10 and NPS 12 pipes were used in the testing. Each specimen consisted of a single length of straight pipe with ASME B16.9 weld caps at each end as shown in Figure 2-1. One 1/2" NPT (American National Standard Taper Pipe Thread) 6000# coupling was located in the center of one weld cap to allow for filling and pressurization.

Figure 2-1 – Typical Test Specimen Design. See Table 2-1 for Dimensions. Drawing Not to Scale.



For each specimen, the length of pipe was selected using Equation 1 to ensure the length of pipe was not relevant and end conditions would not influence the results. This methodology was developed by Paulin Research Group using results from elastic-plastic large strain finite element results and correlated with burst

tests in straight pipe. Comparisons were also made using the approach by Kalnins and Updike [2] and found Equation 1 provides a conservative limit for the required length of pipe.

$$L = D_m \left[\frac{1 - 0.4378}{0.6866}\right]^{-\frac{1}{0.1191}} \qquad \text{(Equation 1)}$$

The ASME B16.9 weld caps (STD wall thickness) were attached at both ends of the pipe specimens using full penetration welds completed by welders and weld procedures qualified to ASME IX. Since the selected length was sufficient to eliminate end effects, carbon steel weld caps were used on all specimens, including the stainless steel pipe specimens. STD wall pipe caps were used on the 12" SCH (Pipe Schedule) 10S pipe samples for simplicity.

A short sample from each parent pipe was removed to allow for circumferential and longitudinal tensile tests. Tensile tests were conducted for the base metal and weld metal, where applicable. Tests were performed in accordance with ASTM E8 by Bryan Labs in Houston, TX. Tensile test results are summarized in Table 2-2 with detailed reports in Appendix B. It should be noted that stress-strain curves shown in Appendix B do not terminate at fracture. Instead, the end of the curve represents the point when the extensometer was removed to avoid damage during fracture.

Table 2-2 - Summary of Measured Material Properties in Hoop Direction

		Minimum			Average			Maximum		
#	ID	Sy	Su	eu[1]	Sy	Su	eu[1]	Sy	Su	eu[1]
		psi	psi	psi	psi	psi	psi	psi	psi	psi
1	CS1W	61,400	71,500	0.0789	61,767	71,567	0.0816	62,200	71,600	0.085
2	CS2W									
3	CS3W									
4	CS1S	54,300	76,500	0.1071	55,533	77,500	0.1172	56,200	78,400	0.1255
5	CS2S									
6	CS3S									
7	SS1S	50,400	90,300	0.2985	53,567	91,767	0.3034	56,500	92,900	0.3109
8	SS2S									
9	SS3S									
10	SS1W	45,200	92,900	0.3385	45,400	93,200	0.3385	45,600	93,700	0.3450
11	SS2W									
12	SS3W									

Table 2-2 Footnotes:

1. eu is the true strain at the ultimate load.

As-built thickness measurements for each sample are reported in Table 2-3. Multiple thickness samples were taken around the circumference at several locations and along the weld seam where applicable. Based on these initial readings, an attempt to identify a "critical" thickness location was made. In this case, a "critical" location is one where the minimum thickness exists over a longitudinal length of approximately sqrt(R*T), essentially creating a local thin area that might create a rupture initiation site.

Table 2-3 – Measured Wall Thickness Before Burst Test

#	ID	Nominal	Min	Avg	Max	Critical[1]
			Inches	Inches	Inches	Inches
1	CS1W	0.365	0.342	0.357	0.366	0.341
2	CS2W	0.365	0.357	0.360	0.367	0.341
3	CS3W	0.365	0.342	0.353	0.371	0.342
4	CS1S	0.365	0.366	0.376	0.392	0.362
5	CS2S	0.365	0.357	0.371	0.389	0.362
6	CS3S	0.365	0.364	0.381	0.389	0.362
7	SS1S	0.365	0.376	0.386	0.396	0.378
8	SS2S	0.365	0.376	0.387	0.394	0.380
9	SS3S	0.365	0.380	0.388	0.402	0.382
10	SS1W	0.180	0.160	0.161	0.162	0.160
11	SS2W	0.180	0.160	0.161	0.163	0.160
12	SS3W	0.180	0.160	0.161	0.163	0.160

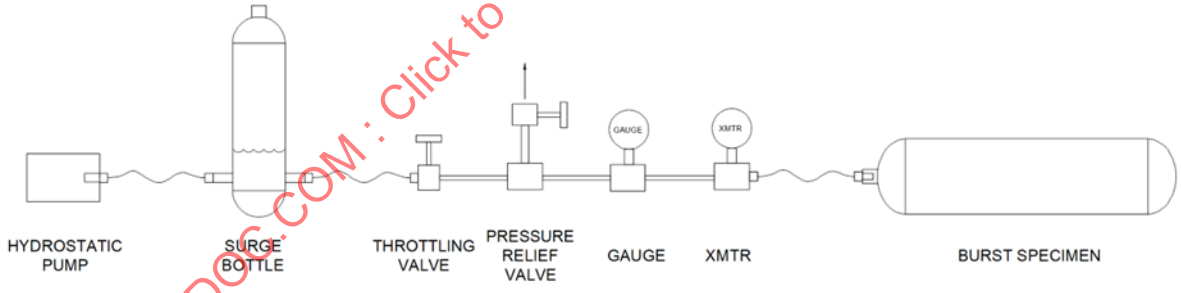
Table 2-3 Footnotes:

1. "Critical Thickness" is the minimum uniform thickness of a local thin having a longitudinal length of approximately sqrt(RT).

Ambient temperature during testing varied from approximately 65°F to 85°F during testing over this period. In all cases, specimens were filled with tap water at least one day prior to testing and stored outdoors. The water temperature at the time of testing was near ambient temperature.

A simplified schematic showing the primary components of the test arrangement is given in Figure 2-2.

Figure 2-2 – Experimental Arrangement for Burst Tests.

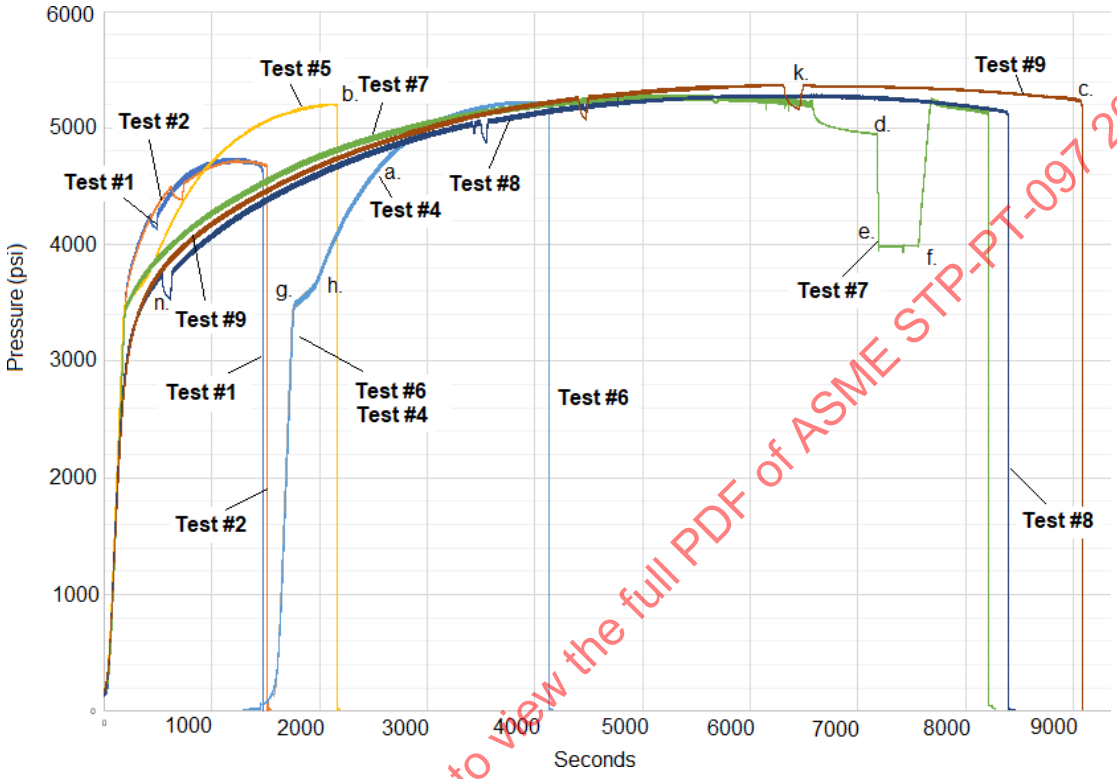


A pneumatically driven hydraulic pump capable of 30,000 psi was used for the test. Pressure throughout each test was monitored & recorded using an Omega PX309 pressure transducer with a maximum pressure capacity of 10 ksi and accuracy of 0.50% of the full scale range (i.e. 50 psig). Pressure readings were taken at a sample rate of 20ms using a LabView package and data acquisition system. Figures 2-3 thru 2-7 provide typical pressure time history plots for the tests. Additionally, a 10 ksi pressure dial gauge was used for simple visual verification and back-up during the test.

Initial results during the first test (Sample #10, SS1W) showed a fluctuating pressure range due to the single acting piston type pump used for the test. To reduce the pressure fluctuations, a surge bottle was designed, fabricated, and incorporated into the test arrangement. The surge bottle reduced the pressure fluctuations to approximately 0.5% to 1.0% of the burst pressure. During testing, it was noted that minor adjustments to

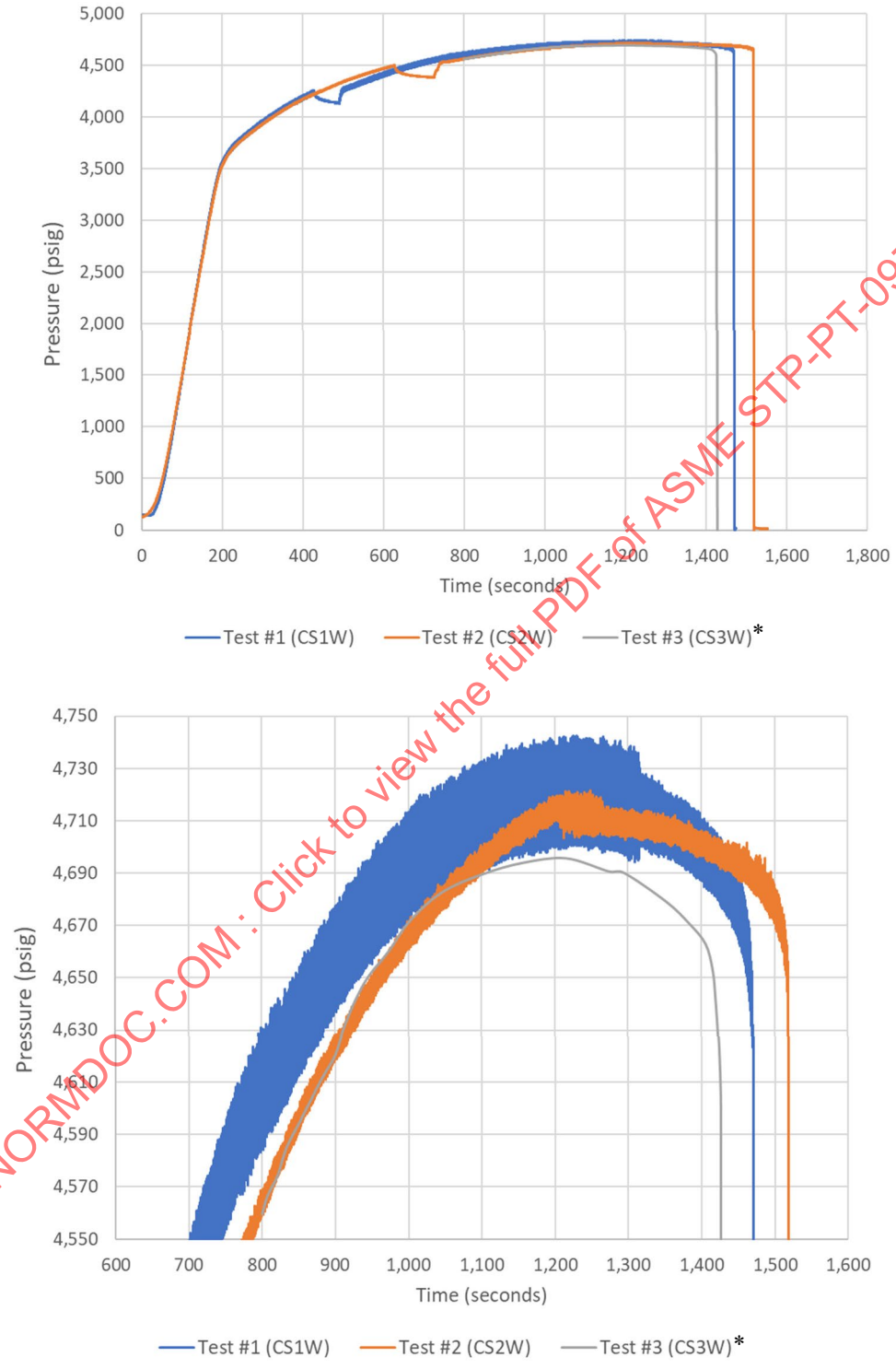
the flow using the throttling valve could reduce the pressure fluctuation and improve the performance of the surge bottle, particularly when pressure upstream of the throttling valve was higher than that downstream.

Figure 2-3 – Labeled and Shifted Results for Pressure vs. Time for Tests 1 - 9



Note: Because the horizontal axis is time, it has little usefulness in the calculations and so plots shown here are shifted to align with their elastic rise time. Tests 1,2,5,7,8 and 9 all have the same elastic rise time. Tests 4 and 6 were shifted together at around 1500 sec. so that their "g." to "h." undulation could be visualized. Tests 10,11 and 12 are shown in the following figures.

Figure 2-4 – Pressure vs. Time History for Tests 1, 2, and 3



* Test 3 data was errantly not recorded, but a screen shot of the time history was saved. This screen shot was scaled and digitized to recover the data.

Figure 2-5 – Pressure vs Time History for Tests 4, 5, and 6

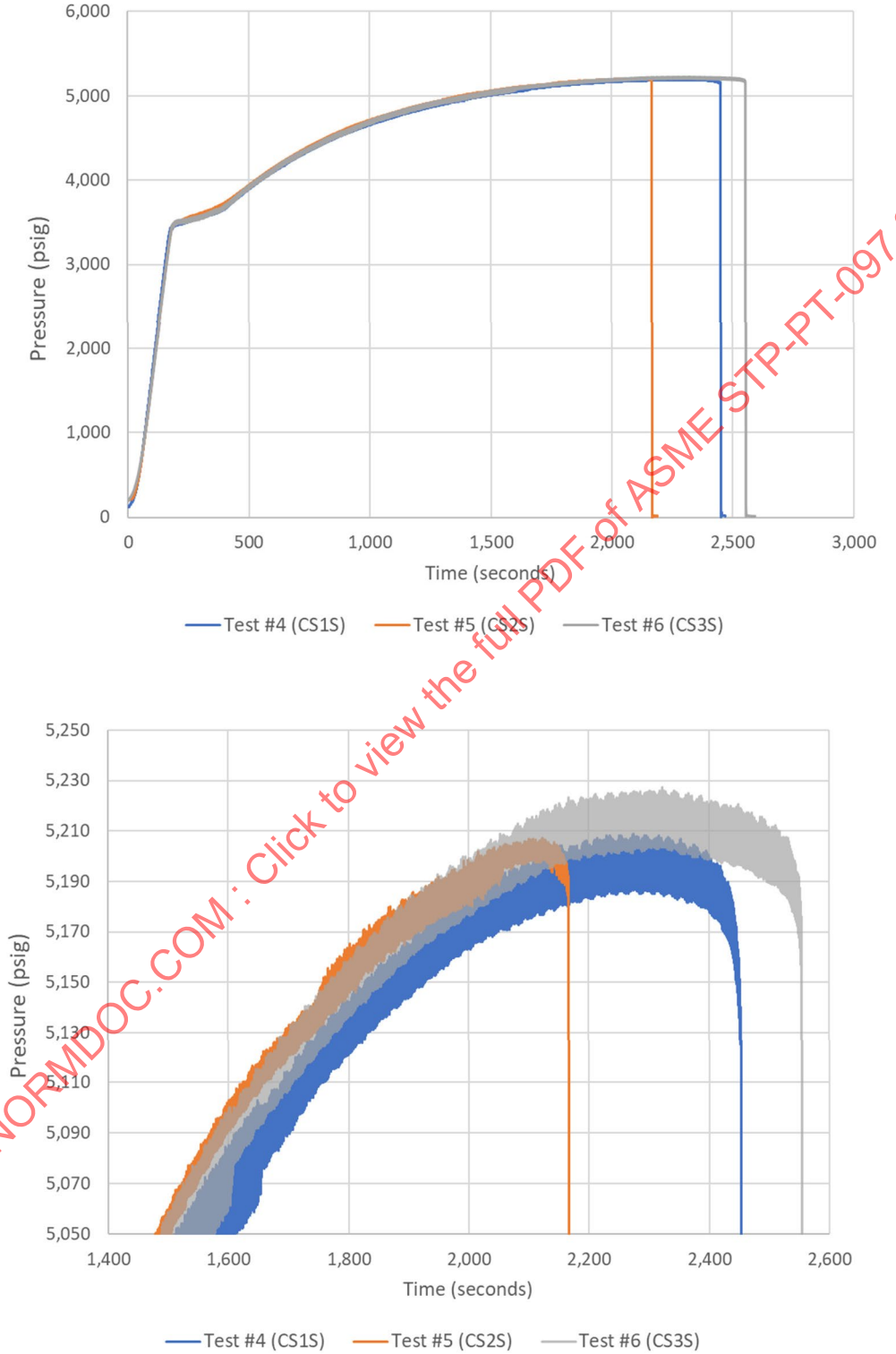


Figure 2-6 – Pressure vs. Time History for Tests 7, 8, and 9

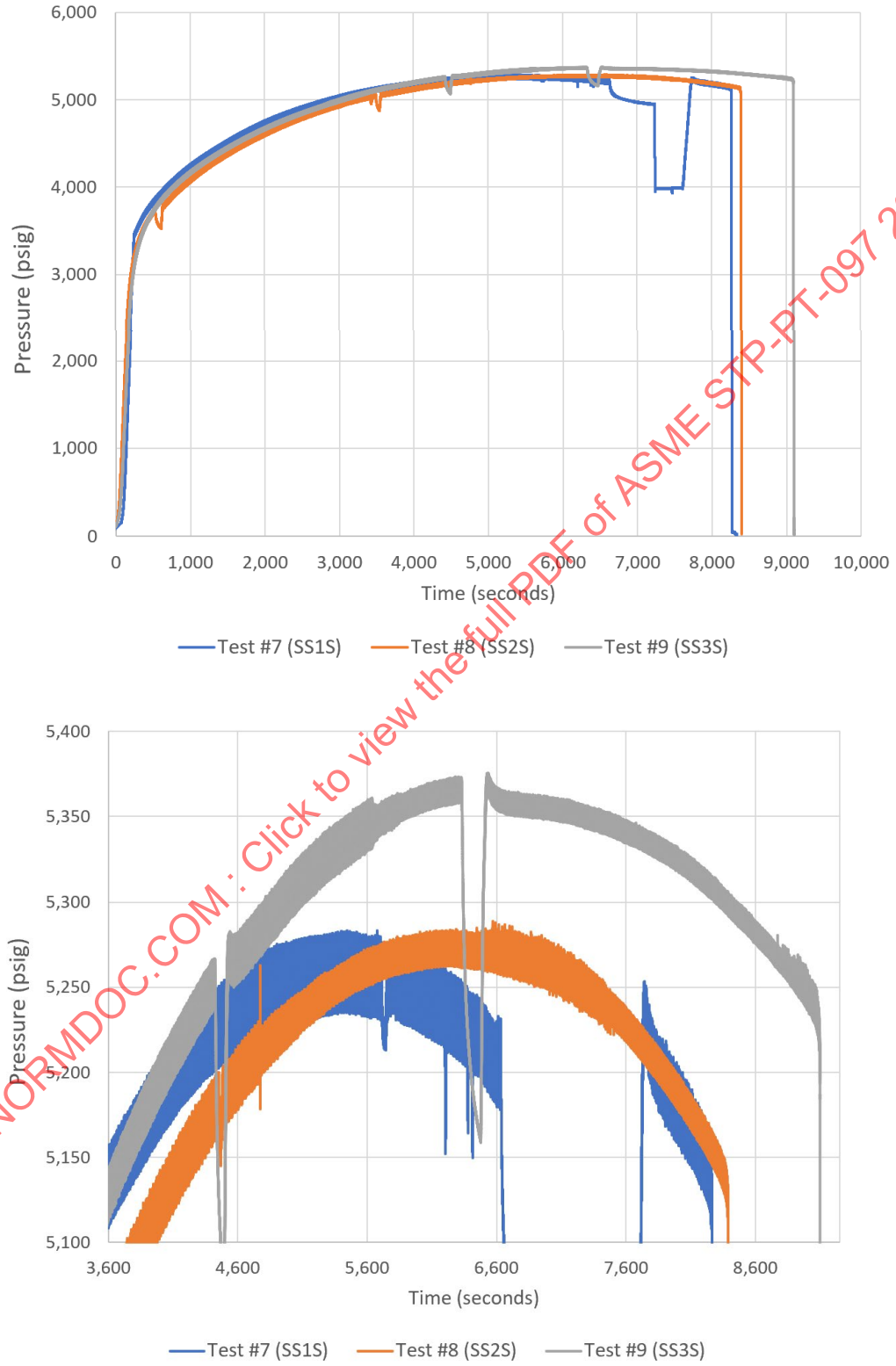
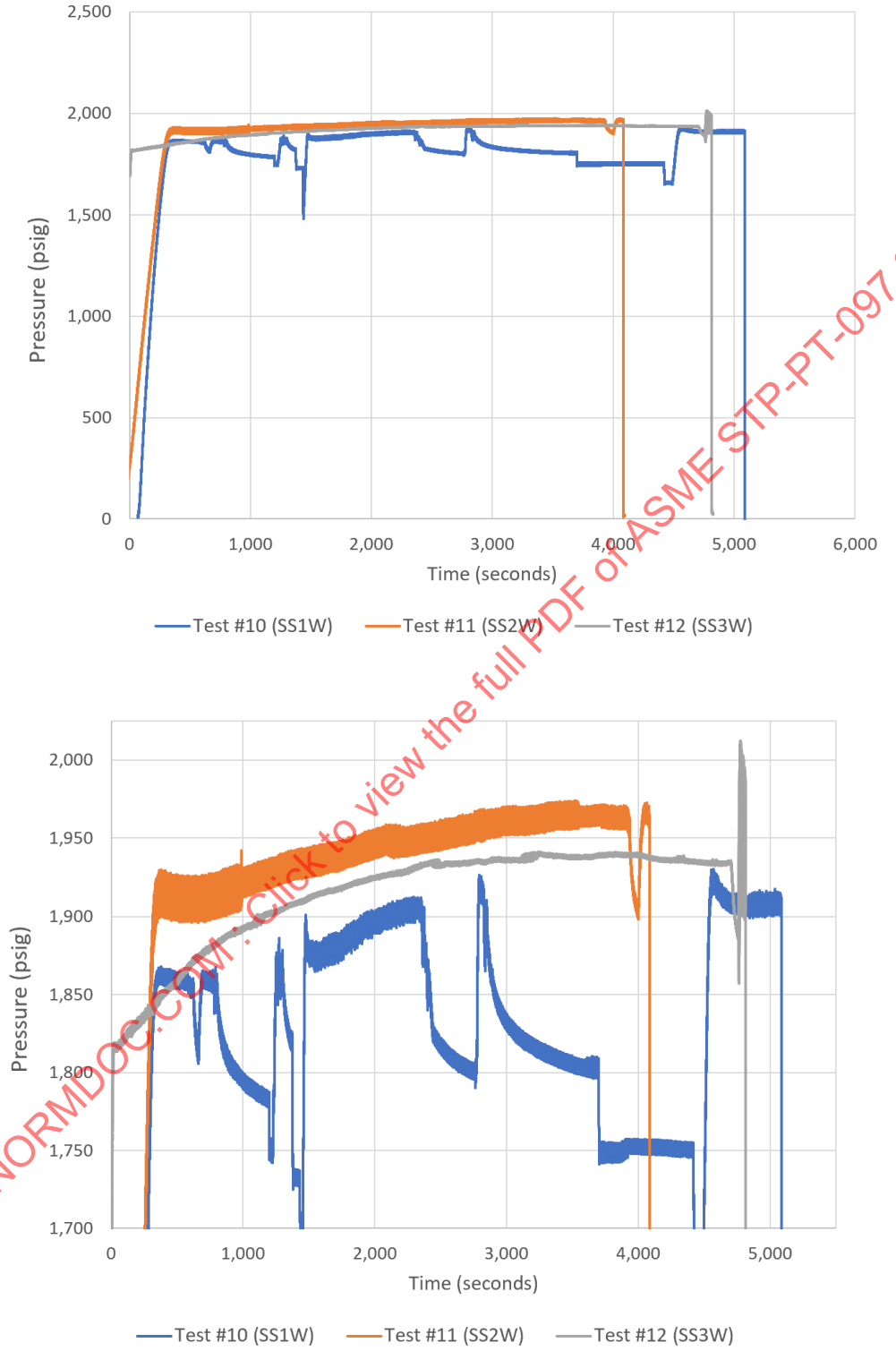


Figure 2-7 – Pressure vs. Time History for Tests 10, 11, and 12



3 EXPERIMENTAL RESULTS

The burst tests were completed in Smithville, Texas on February 27, May 24, and May 25 of 2023. Various photos of the test specimens are included in Figures 3-1 through 3-9.

Figure 3-1 – Carbon Steel Samples Prior to Burst Testing Showing As-Built Thickness Measurements.

Figure 3-2 – Stainless Steel Samples Prior to Burst Testing Undergoing Thickness Measurements.

Figure 3-3 – 12” Welded Stainless Steel Specimen (Left) Undergoing Pressurization With 10” Seamless Stainless Samples (Right) Ready for Testing.

Figure 3-4 – 10” Carbon Steel Specimen at Moment of Rupture.

Figure 3-5 – Carbon Steel Specimens Captured at the Moment of Rupture (CS1W bottom and CS3W top).

Figure 3-6 – 10” Carbon Steel and 12” Stainless Steel Samples after Rupture.

Figure 3-7 – Specimen #10 (SS1W) After Rupture

Figure 3-8 – Specimen #10 (SS1W) After Rupture.

Figure 3-9 - Stainless Steel Specimens After Rupture

Up to the yield point, the pressure response curve followed the linear elastic slope and increased rapidly. Once yielding began, the slope of the pressurization curve reduced as plasticity resulted in increasingly greater change of internal volume. As the point of instability was reached, the slope of the pressurization curve neared zero. In the stainless steel tests, once the point of instability was reached, noticeable bulges or more advanced swelling of the test specimens was noted. These bulges were not noticeable in the carbon steel tests. After instability developed, the pressure would typically drop even under a constant pump rate as significant plastic flow began and the system attempted to reach an equilibrium with the rate at which water was being introduced. A similar response was observed by Ellyin in WRC (Weld Research Council) Bulletin 230 [3]. This reduction in pressure can be seen in the pressure charts, for samples 1 thru 3.

In this report, the burst pressure is defined as the average pressure at the point of instability. Average refers to the mean of the range of pressure fluctuation. The point of instability is considered the point at which the slope of the pressure-time curve inverts. An ideal example of a point of instability is shown for samples 1, 2, and 3 near time 1,200 seconds. Where a clear inversion did not exist, the burst pressure is taken as the highest uniform pressure. For example, Test 10 near 5,000 second is such a case.

An alternative definition for the burst pressure could have been that at the time of rupture or fracture. However, this is not an ideal choice as it does not represent the maximum load carrying capacity of the specimen. Such an approach would be akin to using the stress at fracture from a tensile test rather than the ultimate stress. Had the pump rate been increased to hold the pressure at the point of instability and not allowed to reduce as plastic flow began, the pressure to cause fracture would have been equal to that at the point of instability.

Details of the measured pressure range near the point of instability are given in Table 3-1.

Table 3-1 – Detailed Rupture Pressure Results

		Pressure at Point of Instability				
#	ID	Min[1]	Avg[1]	Max[1]	Range	Range[2]
		psig	psig	psig	psig	%
1	CS1W	4,700	4,721	4,742	42	0.89%
2	CS2W	4,704	4,712	4,721	17	0.36%
3	CS3W	4,667	4,696	4,724	57	1.21%
4	CS1S	5,185	5,196	5,208	23	0.44%
5	CS2S	5,197	5,202	5,207	10	0.19%
6	CS3S	5,202	5,214	5,226	24	0.46%
7	SS1S	5,235	5,259	5,283	48	0.91%
8	SS2S	5,262	5,273	5,284	22	0.42%
9	SS3S	5,363	5,369	5,375	12	0.22%
10	SS1W	1,901	1,908	1,915	14	0.73%
11	SS2W	1,960	1,966	1,972	12	0.61%
12	SS3W	1,937	1,939	1,941	4	0.21%

Table 3-1 Footnotes:

1. Min, Avg, and Max refer to the minimum, average, and maximum of the pressure fluctuation range at the point of instability.
2. Range % is the range of pressure fluctuation from min to max divided by the average pressure.

4 DISCUSSION OF RESULTS

Irregularities in the middle of the tests are periods where hydrostatic pump was temporarily paused.

Numerous formulas for predicting the rupture strength of straight hollow cylindrical shells are available in the literature. It is not the intent of this report to develop an exhaustive comparison of these results with such formulas. However, as a simple means of comparison, the predicted burst pressure using two methods has been presented in Table 4-1. These estimates include Barlow's equation using the mean diameter which has been proposed for a recent draft copy of B31.H and Turners [4] equation which is identical to that used in ASME VIII-2, Part 4. It is noted that for the diameter-to-thickness ratios considered here, these equations provide nearly the same result.

As shown in Table 4-1, the rupture pressure of the carbon steel samples is predicted reasonably well. In comparison, the rupture pressure for the stainless steel samples is approximately 80% to 84% of that predicted by these equations. These findings for the stainless steel match similar results reported by Rodabaugh [1]. Further evaluation of these findings for stainless steel and the impact on design rules in the ASME Codes is suggested.

Table 4-1 – Comparison of Calculated and Actual Burst Pressure

#	ID	T	Su	Dm	P1 = 2TSu/Dm [1]	P2 = ln(OD/ID)*Su [2]	Pb	Pb/P1
		inches	inches	inches	psi	psi	psi	
1	CS1W	0.341	71,500	10.409	4,685	4,686	4,720	1.007
2	CS2W	0.341	71,500	10.409	4,685	4,686	4,714	1.006
3	CS3W	0.342	71,500	10.408	4,698	4,701	4,658	0.991
4	CS1S	0.362	76,500	10.388	5,331	5,334	5,198	0.975
5	CS2S	0.362	76,500	10.388	5,331	5,334	5,200	0.975
6	CS3S	0.362	76,500	10.388	5,331	5,334	5,207	0.977
7	SS1S	0.378	90,300	10.372	6,581	6,585	5,259	0.799
8	SS2S	0.38	90,300	10.37	6,617	6,621	5,270	0.796
9	SS3S	0.382	90,300	10.368	6,654	6,657	5,370	0.807
10	SS1W	0.16	92,900	12.59	2,361	2,361	1,910	0.809
11	SS2W	0.16	92,900	12.59	2,361	2,361	1,976	0.837
12	SS3W	0.16	92,900	12.59	2,361	2,361	1,937	0.820

Table 4-1 Footnotes:

1. For the calculation of the estimated burst pressure, P1 = 2TSu/Dm, the "critical" thickness and minimum measured tensile strength (Su) has been used. The goal of this method is to calculate a lower bound estimate of the burst pressure using measured properties.
2. P2 is equivalent to the pressure calculation in ASME VIII-2, Part 4 for cylindrical shells and is based on the Tresca stress limit approach as established by Turner [4]. For the range of D/T examined here, it is noted that the simple mean diameter equation, P1, gives approximately the same solution as Turner's method.

5 CONCLUSIONS

Burst test results for twelve straight pipe samples have been reported. These samples included carbon steel and stainless steel, with and without longitudinal weld seams. Tensile test results have been developed to document the physical strength properties of the test specimens. In addition, thorough measurements were taken to document the actual wall thickness for each test. Results for the carbon steel samples appear to be in line with predicted burst pressures. However, stainless steel samples consistently showed lower than predicted burst pressures. Future work should examine the potential impact of these findings in ASME Codes where burst predictions are developed or design pressures are established for stainless steel components and shells.

REFERENCES

[1] Rodabaugh, E.C. and Eiber, R.J., "Final Report on Pressure Capacity of MSS SP-75 Fittings to Line Pipe Research Supervisory Committee of the Pipeline Research Committee of the American Gas Association", Battelle Memorial Institute, Columbus Laboratories, Columbus, Ohio, 1995

[2] Kalnins, Arturs and Updike, Dean, "Limit Pressures of Cylindrical and Spherical Shells", 2000 ASME Pressure Vessel and Piping Conference, Seattle, WA

[3] Ellyin, Fernand, "An Experimental Study of Elasto-Plastic Response of Branch-Pipe Tee Connections Subjected to Internal Pressure, External Couples, and Combined Loadings", Welding Research Council Bulletin 230, 1977

[4] Turner, L.B., "The Stresses in a Thick Hollow Cylinder Subjected to Internal Pressure", Transactions of Cambridge Philosophical Society, Vol 21 (1910), pp 337-396

APPENDIX I

MATERIAL TEST REPORTS

TK corporation

INSPECTION CERTIFICATE

(EN 10204: 2004 3.1 / ISO 10474: 2013 3.1)

117-12, Noksan Saneop Daero,
Gangseo-gu, Busan,
46752 Korea
Tel : 82-51-970-6666
Fax : 82-51-831-6886

#1

Customer	Allied Fitting L.P.	Certificate No.	20220200189	Date	2022/02/07
P.O No.	PO33114	Project Name	STOCK (C/S)		
Job No.					
Specification for Material	ASTM/ASME A/SA234 WPB(2019Ed.)NACE MR0175/ISO 15156-2 Region 3 AND NACE MR0103-2015	Starting Material	STEEL PLATE		
Specification for Inspection	ASME B16.9-2018 & CSA Z245.11-17	Dimension and Visual Inspection	GOOD		

Heat Code No [HCN]	No.	Descriptions	Q'ty (Pcs)	Heat Treatment		Item Code
EU430	0027	CAP STD B.W 10"	53	N: 910℃		FCS10

CHEMICAL COMPOSITION(%)

Heat Code No [HCN]	Spec.	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V	C.E	Raw Heat No
	Max.	0.22	0.35	1.06	0.050	0.058	0.40	0.40	0.15	0.40	0.080	0.42	
	Min.	-	0.10	0.70	-	-	-	-	-	-	-	-	
EU430	L	0.1165	0.261	0.904	0.0118	0.0029	0.009	0.022	0.001	0.010	0.001	0.273	SF34277
	P	0.10	0.23	0.87	0.009	0.001	0.008	0.020	0.002	0.008	0.002	0.251	

MECHANICAL PROPERTIES

Heat Code No [HCN]	Spec	Y.S	T.S	E.L		Hardness Test					
		ksi		(%)		HBW					
	Max.	-		-		197					
	Min.	35	60	17		-					
EU430	P	42.5	62.8	30.4		129	130	132			

We hereby certify that the material herein has been made and tested in accordance with the above specification and also with the requirements called for by the above order.
Any forgery or falsification of this certificate will be subjected to the full extent of the criminal prosecution. Please contact us by the below Fax or E-mail if you have any inquires on this certificate.
Fax: +82 831 6886 / E-mail: tkqaqc@tkbend.co.kr

Remark: *All material supplied is certified to be free of mercury contamination & no mercury bearing euipment was used during manufacturing.
*Mn/C Min2.51
-EU430 : 7.75
*Direction of Tensile Specimen : Transverse
*CSA Year of Edition : Z245.11-17
*Dimension & Tolerance shall be in accordance with ASME B16.9
*Specification for Material Shall be dual certified with ASTMASME A/SA234 and CSA Z245.11 Gr241 CAT I Sour Service

Legend:
HB:Brinell
ST:Solution Treatment
SR:Stress Relieving
N:Normalized
T:Tempered
A:Annealed
Q:Quenched
Y.S:0.2% Offset Method
(G):Hot-Dip Galvanized Coating
(P) : Poly Ethylene Coating
AC:Air Cool
OC:Oil Cool
WQ:Water Quenched
WC:Water Cool
B:Base
W:Weld
H:Haz
L:Ladle
P Product

☐Reviewed by:

☐Witnessed by: _____

Approved by: W. S. Kim

Head of Quality Control Dep't

4957682-25012

#2

TECTUBI RACCORDI S.p.A.
ALLIED GROUP
Via Roma 150,29027 Podenzano (PC), Italy
mail info@tectubiraccordi.com
Tel ++39 0523555111
Fax ++39 0523555318

INSPECTION CERTIFICATE EN 10204 – 2004

☒ 3.1 ☐ 3.2

NUMBER 178201 -1
REVISION 0
DATE 20/01/2022

CLIENT: ALLIED FITTING L.P

ORDER: PO24364

JOB:

CLIENT ITEM	ITEM	Q.ty	DESCRIPTION	HEAT	SPECIFICATION	MATERIAL	STEEL MAKER	CERT.N.	RAW MATERIAL
155	155	713	CAP 12" STD Y52 Product Code 5PCS12-TI3	1NAL52	ASTM A860/A860M-'18 MSS SP-75 Ed. 2019	WPHY52	METINVEST TRAMETAL	525276	PLATE

CHEMICAL COMPOSITION ☒ BY LADLE ANALISYS * ☒ BY CHECK ANALYSIS () **

HEAT	Test	C	Mn	Si	P	S	Cr	Ni	Ti	Cu	V	Nb	Mo	Al	V+Nb	CE	B	Cu+Ni+Cr+Mo		
min.			1,00	0,15																
max		0,20	1,45	0,40	0,03	0,01	0,30	0,50	0,05	0,35	0,10	0,04	0,25	0,06	0,12	0,42	0,0010	1,00		
1NAL52	LADLE*	0,170	1,160	0,260	0,007	0,002	0,040	0,190	0,005	0,070	0,005	0,022	0,005	0,033	0,027	0,39	0,001	0,31		
1NAL52	CHECK**	0,160	1,150	0,280	0,007	0,002	0,040	0,200	0,001	0,070	0,026	0,020	0,005	0,030	0,046	0,38	0,000	0,32		

The chemical values and tensile properties are a true and correct copy of the certificate issued by the supplier of raw materials or by the laboratory which has determined them

MECHANICAL PROPERTIES ☐ ON RAW MATERIAL * ☒ ON FINISHED FITTINGS ** ☐ SUPPLEMENTARY REQ ***

Tensile Test	Temp. °C:	+20		Impact Test		Temp. °C: -46					
	Y.S. MPA	U.T.S MPA	E%	Senso Direct	Dim. Sample	KCV (Joule)	Shear Area %	Lat Exp mm	Hardness HBW	Red Area %	REMARKS
min	360	455	25			min 28		min 0,53	min		Melting process Electric Furnace
max.	465	625				average 34			max 235		Manufacturing method Hot Formed (780°C ÷ 980°C)
											Heat treatment : Normalised at 920°C (1H/1" WTH) still air cooling
201704	408	516	36,6	T	10 x 7.5	168-174-162	90-95-95	1,69-1,70-1,78	166÷170	79,07	
											Visual and dimensional examination in accordance with
											ASME B16.9 - Ed. 2012
											ASME B16.25 - Ed. 2012
											Material according to
											NACE MR 01-75 ISO 15156 & NACE MR 01-03 Latest Edition
											Ultrasonic Examination of Wth Through the Body Satisfactory
											All material supplied is certify to be free of mercury contamination & no mercury bearing equipment was used during manufacturing

ACTIVITIES						
CERTIFICATE						
RESULT						
ACTIVITIES						
CERTIFICATE						
RESULT						

Work inspector

TECTUBI RACCORDI S.p.A. S. AMORINI

DATE SIGNATURE

Customer inspector

DATE SIGNATURE

Third part inspector

DATE SIGNATURE

We hereby certify that the materials listed below have been manufactured in compliance with the order and mentioned rules

☒ 2014/68/EU Directive - Annex I § 4.3

#2

MATERIAL TEST & INSPECTION CERTIFICATE

SUNGKWANG BEND CO., LTD.(SKB)
26 Noksansandan 262-ro, Gangseo-Gu, Busan, Korea
TEL : 82-051-3300-450
FAX : 82-051-3300-335
http://www.skbend.com

CUSTOMER: ALLIED FITTINGS
PROJECT NAME: N/A

According to
DIN 50049 3.1 / EN 10204 3.1 / ISO 10474 3.1

PURCHASE ORDER NO	101618SB	SPEC. FOR MATERIAL	ASTM/ASME A/SA420WPL6-S 16/17ED A/SA234WPB-S 17/17ED	CERTIFICATE NO.	OCLH2019060511
PJT NO.	N/A	SPEC. FOR INSPECTION	ASME B16.9	DATE OF ISSUE	2019.06.19
STARTING MATERIAL	STEEL PLATE	SKB NO.	2018102303	VISUAL & DIMENSION	SATISFACTORY

NO.	SEQ/LINE/ITEM NO	DESCRIPTION	QTY	HEAT NO.	MFG ID NO.	MILL MAKER	POR/CODE/TAG NO
109		CAP STD 12" B.W SMLS Black	35	SF05128	SF05128	POSCO	PCS12-SB

CHEMICAL COMPOSITION(%) (L : LADLE, P : PRODUCT)

STD. / HEAT NO.	SPEC.	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V	Nb	N	Al	B	Zr	Fe	Ti	C.E
	MIN		0.15	0.50															
	MAX	0.22	0.40	1.35	0.035	0.040	0.40	0.30	0.12	0.40	0.08	0.02							0.42
SF05128	L	0.11	0.25	0.94	0.013	0.004	0.01	0.04	0.003	0.02	0.002	0.001							0.28
	P																		
	L																		
	P																		

TENSILE TEST

SPEC.	Y.S 0.2% offset	T.S	EL.	R.A
	KSI	KSI	%	%
MIN	35.0	60.0	30.0	
MAX		85.0		
	48.7	65.3	39.0	

IMPACT TEST / HEAT NO.	TEST TEMP.	SIZE OF SPECIMEN(mm)		ABSORBED ENERGY STD. /8/10R-lbf Min./Avg. VALUE			AVG.	LATERAL EXPANSION STD. / VALUE			AVG.	PERCENT SHEAR STD. / VALUE			AVG.
SF05128	-50	10X7.5	B/M	52.20	60.00	58.00	56.73								
			H.A.Z												
			W/M												
			B/M												
			H.A.Z												
			W/M												

HARDNESS HBW

MIN			
MAX	197		
HBW	135	133	

HEAT TREATMENT	NORMALIZED 900℃ 30Min. 'Air'
PMI	N/A
FLATTENING TEST	N/A
BENDING TEST	N/A
HYDROSTATIC TEST	N/A
CORROSION TEST	N/A
GRAIN SIZE TEST	N/A
HIC TEST	N/A
N.D.E	N/A

**MEMO

NACE MR0175/ISO15156 MR0103
SK-190529ALL-01 / CSA Z245.11 Gr241 CAT II

WE CERTIFY THIS MATERIAL HAS BEEN MANUFACTURED AND EXAMINED IN ACCORDANCE WITH AL REQUIREMENTS OF THE SPECIFICATION AND THE RESULTS OF ALL EXAMINATION ARE ACCEPTABL

REVIEWED BY
WITNESSED BY

CHIEF QUALITY OFFICER

SKE-8903

#3

TEXAS PMW, LLC
315 NORTH WAYSIDE DRIVE HOUSTON, TX 77020
(713) 679-7900 – FAX (713) 679-7920

PENNSYLVANIA MACHINE WORKS, LLC
201 BETHEL AVENUE ASTON, PA 19014
(610) 497-3300 – FAX (610) 497-3325

US DROP FORGE CO.
P.O. BOX 131 – ROUTE 551
1366 AUBURN ROAD WOOLWICH TOWNSHIP, NJ 08085
(856) 467-0500 – FAX (856) 467-4598

CERTIFIED MATERIAL TEST REPORT

INDUSTRIAL VALCO-HOUSTON
3135 E ANA ST
RANCHO DOMINGUEZ, CA 90221

P.O. PM032HA
ORDER # 01 793496
4/25/22

1/2 6MTD HFCP A105 QTY: 25

HEAT CODE: 4J2C
ASTM SPEC: A105
UNS NUMBER: K03504

MATERIAL: A105
SPEC. YEAR: 21 SPEC. REV:

CHEMICAL ANALYSIS (%)

C	MN	P	S	SI	NI	CR	MO	CU	AL	V
.200	1.030	.006	.004	.250	.050	.080	.020	.110	.027	<.001

PHYSICAL ANALYSIS

YS (PSI)	TS (PSI)	%EL 4D % 4D	%RA %	HARDNESS (HB)	HARDNES2 (HB)	GRAIN	C.E=
50667	79900	30.000	56.000	162	161	8.00	.40

Original Mill Name: STEEL DYNAMICS,. Original Heat Code: A216027. Bar Size: 1.500

Cust PN: 3NM-D

Country of Origin: United States. Country of Origin is Country of Melt.
Manufactured to: ASME B16.11 – 2016

MATERIAL IS CAPABLE OF PASSING A HYDROSTATIC TEST COMPATIBLE WITH THE RATING OF THE FINISHED FITTING
CERTIFICATE I/A/W EN 10204:2004 TYPE 3.1 AND ISO10474:2013 TYPE 3.1
ANSI/NACE MR0103/ISO17945:2015 SECTION 5.2
ANSI/NACE MR0-175/ISO15156-2:2015 SECTIONS A.2.1.2 AND A.2.1.3
ASME SECTION II SA105 2019 ED
MATERIAL IS FULLY KILLED
MATERIAL IS FINE GRAIN PRACTICE PER ASTM A29 ALUMINUM CONTENT
DURING MANUFACTURE AND PROCESSING, THIS PRODUCT DID NOT COME IN DIRECT CONTACT WITH POLYCLORINATED BIPHENYLS (PCB'S), MERCURY OR ANY OF ITS COMPOUNDS NOR WITH ANY MERCURY CONTAINING DEVICE THAT EMPLOYED A SINGLE BOUNDARY OF CONTAINMENT.
NO WELD REPAIRED MATERIAL - MADE IN THE U.S.A.
AS OF THE ORIGINAL MTR PRINT DATE, ARTICLES AS SUPPLIED BY PENN MACHINE HAVE NO INTENDED SUBSTANCE RELEASE, NOR CONTAIN ANY SIGNIFICANT AMOUNT (DO NOT EXCEED 0.1 WT%) OF CHEMICAL COMPOUNDS ON THE EU CANDIDATE LIST OF SVHC (ARTICLE 59(10)) PER ECHA GUIDELINE RIP 3.8, AND THUS THERE IS NO OBLIGATON TO REGISTER THEM UNDER REACH.
THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER, AND IN WHICH PMW SUPPLIES TEST RESULTS.

WE HEREBY CERTIFY THAT THE REPORTED FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION.

(ES-ELECTRONIC SIGNATURE)
MICHAEL BARRON
QA Manager

MANUFACTURERS OF Penn FORGED PIPE FITTINGS
QUALITY • SERVICE • PARTNERSHIP
www.pennusa.com

vallourec

2669 Martin Luther King Jr Blvd
Youngstown,OH 44510

VALLOUREC STAR LP

Seamless Tubular Products

Certified Test Report
01/27/2022
Revision: 0

Order: Y-221120659-001 **Desc:** Seamless Line Pipe - As Rolled

Grade: API 5L X42/B R-BR PSL2 46th Edition April 01, 2018

OD(in): 10.750 **Wall(in):** 0.365 **Lbs/Ft:** 40.52 **Length:** Double Random

End Finish: Plain End Beveled

Customer: Ferguson Enterprises, Inc.

Customer Order: C295-24

SLN / (Heat): LX0174

Split: 01

Comments: Melted and Manufactured in Youngstown, Ohio USA

Pipe is also manufactured to: ASTM A106B/C-19a, ASTM A53B-20, ASME SA106B/C-2021, ASME SA53B-2021. Vallourec Star's QA program meets the requirements of DIN EN10204-2004 Type 3.1. Satisfies NACE MR0175/ISO15156:2015 and ANSI/NACE MR0103/ISO17945:2015.
No repair welding has been conducted. Material is free from Mercury.

Mechanical Properties

		Tensile Size Specimen Cross Section			Strength (ksi)			Elongation		
Orientation	Type	Width (in)	Thick (in)	Area (sqin)	Yield	Tensile	Y/T Ratio	Gage Length	% Elong	% RA
Longitudinal	Strip	1.500	0.383	0.5800	47.7	74.3	0.64	2	40.4	51.0

Required Min/Max Yield Strength (ksi): 42.1/71.8 **Required Min/Max Tensile Strength (ksi):** 70/95 **Calculated Max Internal Yield (psi):** 2832

Required Min Elongation(%): 30

Supplemental Requirements

Flattening Test	PASS
Hardness 3 Point	82.3 avg HRBW
Hydrostatic Pressure	2500 psi
Hydrostatic Hold Time	5 seconds

Chemical Analysis

Chem Spec: 61M

WT%	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Nb	V	Al	Ca	B	Ti	N	C.E.
Heat	0.21	0.69	0.011	0.007	0.23	0.20	0.07	0.13	0.02	0.009	0.000	0.001	0.029	0.0019	0.0001	0.002	0.0100	0.37
Product 1	0.20	0.68	0.012	0.006	0.23	0.21	0.06	0.13	0.02	0.008	0.000	0.001	0.031	0.0016	0.0001	0.003	0.0094	0.37
Product 2	0.22	0.69	0.012	0.006	0.23	0.21	0.07	0.13	0.02	0.008	0.000	0.001	0.033	0.0014	0.0001	0.003	0.0107	0.38

Charpy Impact Testing

	Notch	Direction	Size	Temp °F	Ft Lbf 1	Ft Lbf 2	Ft Lbf 3	Ft Lbf Avg	Shear 1	Shear 2	Shear 3	Shear Avg
Min Target	--	Transverse	3/4	32	11	11	11	15	NR	NR	NR	NR
Actual	V	Transverse	3/4	32	30	35	32	32	15	15	10	13

NR - Not Required

This material has been produced and tested in accordance with the requirements of applicable specifications unless otherwise listed below. We hereby certify that the above test results are representative of those contained in the records of the company. Any modification to this certification as provided by Vallourec Star without the expressed written consent of Vallourec Star negates the validity of this test report. Vallourec Star is not responsible for the inability of this material to meet specific applications.

THIS CERTIFICATE IS NOTARIZED ONLY WHEN REQUESTED

Signed: Jeff Schultz

Name: Jeff Schultz, Lab Supervisor

Date Approved: 01/27/2022

This document is uncontrolled when printed. Always refer to the MTR System for the most current version. FS-VMS-8.2 4.1.1 Rev 7

46568-25 #5

MILL TEST CERTIFICATE

AXIS PIPE AND TUBE

AXIS PIPE AND TUBE, LLC.
1451 Louis E. Mikulin Rd.
Bryan TX 77807
TEL. (979) 703-6847 FAX(979) 703-6847

Customer:	Sales Order:	Invoice No.:
Prolamsa Inc	0030086549	1600039844
16420 Park Ten Place	PO:	Date of Issue:
Houston,TX,77084	A295-2206	11/12/2021

Certificate No.:	1600039844-2
Product Description:	ASTM A53 B 10.750X0.365 42.00 PE LAC M
Specification:	ASTM A53/A53M-20

Heat No.	Mat No.	Steel Making / Coil Rolling
21023922	324396	Big River Steel LLC, Osceola - AR - US / Big River Steel LLC , Osceola - AR - US

Mechanical Properties

Tensile Test - Strip Specimen Gauge Length 2"

Loc. / Orien	Size	Y.S. (psi)	U.T.S. Body (psi)	U.T.S. Weld (psi)	Y/T Ratio	E.L. (%)	Hardness (HRB)
T180°	1 1/2"	65146	74973	79667	0.87	31.00	84

CVN - Impact Testing

	Body (ft-lbf)				Shear Area (%)				Weld (ft-lbf)				Shear Area (%)				Temp (F)	Size	Loc. / Orien	Acceptance Criteria (ft-lbf)
	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg				
Lateral Expansion									Lateral Expasion											

Analysis (H/P)	Chemical Composition (Max %)																	
	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V	Al	Nb	Ti	B	Ca	N	CEpcm (API Max. A.C.)	CE Results
H	0.21	0.020	0.35	0.005	0.003	0.04	0.04	0.01	0.09	0.002	0.025	0.000	0.001	0.0002	0.0022	0.0065	0.2500	0.287
P	0.21	0.030	0.34	0.009	0.005	0.05	0.05	0.01	0.13	0.002	0.030	0.000	0.001	0.0001	0.0019	0.0082	0.2500	0.291
P	0.21	0.029	0.34	0.009	0.005	0.05	0.05	0.01	0.13	0.002	0.030	0.000	0.001	0.0001	0.0020	0.0082	0.2500	0.291

Following Controls / Tests have been satisfactorily performed:
1.- Hydrostatic Testing: 1,430.00 psi Pressure for 5.00 seconds
2: Ultra Sonic Tested to N10 Notches - passed
3: Seam Annealed min 1,600 F
4: Flattening Test Passed

Remarks:
1: This material meets: Grades ASTM A53/A53M-20

2: Made and Melted in USA
3:This material was manufactured by the HFW Welding Process
4: Date of Manufacture 07/2021

Acronyms:
L = Longitudinal
Y.S. = Yield Strength
E.L. = Elongation
P = Product Analysis
UB = Un-Broken
T = Transverse
U.T.S. = Ultimate Tensile Strength
H = Heat Analysis
A.C. = Acceptance Criteria
N/A = Not Applicable

We hereby certify that the material herein has been made and tested in accordance with the above specification and also with the requirement called for by the above order.

Josha Roland

Quality Manager

#6

NIPPON STEEL

NIPPON STEEL CORPORATION
KANSAI WORKS WAKAYAMA AREA
1850, MINATO, WAKAYAMA, JAPAN

INSPECTION CERTIFICATE

CERTIFICATE NO. :WYYK1698-03 PAGE : 1/2 DATE :2022-02-27

CUSTOMER :ALLIED STAINLESS GROUP INC
ORDER NO. :28372
SHIPPER :070 125-PC7099 2-848-N3-5-1-5756-01
COMMODITY :SEAMLESS HOT FINISHED STAINLESS STEEL PIPE
STANDARD :ASTM A312-19 / ASME 2019 EDITION SA-312 TP304
ASTM A312-19 / ASME 2019 EDITION SA-312 TP304L
ASTM A376-19 / ASME 2019 EDITION SA-376 TP304
SPECIFICATION :
MILL WORK NO. :WYYK1698 O.D. :NPS10 W.T. :SCH40S LENGTH:MIN. 20feet MAX. 24feet QUANTITY:6pcs.
TOTAL LENGTH:139.48feet MASS:2564kg (5648lbs)

HEAT NO. :F124085 F126109
PRODUCTS PCS. :1 5

HEAT TREATMENT :SOLUTION TREATED(1922°F X 5min. W.Q.)

CHEMICAL COMPOSITION(%)

		*1	C *4	Si	Mn	P *4	S *4	Cr *3	Ni *3	Mo	N *5	Pb	*PI *2
SPEC. MIN.		L	–	–	–	–	–	180	80	–	–	–	–
MAX.		L	35	75	200	45	30	200	110	–	–	1	–
MIN.		P	–	–	–	–	–	180	80	–	–	–	–
MAX.		P	35	75	200	45	30	200	110	–	–	1	–
HEAT NO.													
F124085		L	14	39	147	24	0	182	92	30	1151	0	21
		P	16	39	147	24	0	182	92	–	–	0	–
F126109		L	15	42	137	24	0	182	92	15	1100	0	20
		P	14	42	137	24	0	182	92	–	–	0	–

*1 L:LADLE ANALYSIS P:PRODUCT ANALYSIS *2:X1 *3:X10 *4:X1000 *5:X10000 OTHER:X100
*PI PITTING INDEX:Cr+3.3Mo+16N

TENSILE TEST

		*1 *2	YS *3	TS *3	EL %
SPEC. MIN.		L B	P 30.0	P 75.0	35
MAX.		L B	P –	P –	–
HEAT NO.					
F124085		L B	P 46.0	P 86.7	65
F126109		L B	P 44.8	P 85.1	67

TYPE OF SPECIMEN:STRIP 1-1/2in. WIDTH *1 SAMPLING DIRECTION L:LONGITUDINAL *2 SAMPLING POSITION B:BASE METAL
*3 UNIT P:ksi GAUGE LENGTH:2.0in. KIND OF YS:0.5% EXTENSION UNDER LOAD

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MADE IN ACCORDANCE WITH THE RULES OF THE CONTRACT.

T. Satsuki

TAKAFUMI SATSUKI
HEAD OF DEPARTMENT
QUALITY ASSURANCE DEPARTMENT

NO. 319063W22

#6

NIPPON STEEL

NIPPON STEEL CORPORATION
KANSAI WORKS WAKAYAMA AREA
1850, MINATO, WAKAYAMA, JAPAN

INSPECTION CERTIFICATE

CERTIFICATE NO. :WYYK1698-03 PAGE : 1/2 DATE :2022-02-27

CUSTOMER :ALLIED STAINLESS GROUP INC
ORDER NO. :28372
SHIPPER :070 125-PC7099 2-848-N3-5-1-5756-01
COMMODITY :SEAMLESS HOT FINISHED STAINLESS STEEL PIPE
STANDARD :ASTM A312-19 / ASME 2019 EDITION SA-312 TP304
ASTM A312-19 / ASME 2019 EDITION SA-312 TP304L
ASTM A376-19 / ASME 2019 EDITION SA-376 TP304
SPECIFICATION :
MILL WORK NO. :WYYK1698 O.D.:NPS10 W.T.:SCH40S LENGTH:MIN.20feet MAX.24feet QUANTITY:6pcs.
TOTAL LENGTH:139.48feet MASS:2564kg (5648lbs)

HEAT NO. :F124085 F126109
PRODUCTS PCS. :1 5

HEAT TREATMENT :SOLUTION TREATED(1922°F X 5min. W.Q.)

CHEMICAL COMPOSITION(%)

		*1	C *4	Si	Mn	P *4	S *4	Cr *3	Ni *3	Mo	N *5	Pb	*PI *2
SPEC. MIN.		L	-	-	-	-	-	180	80	-	-	-	-
MAX.		L	35	75	200	45	30	200	110	-	-	1	-
MIN.		P	-	-	-	-	-	180	80	-	-	-	-
MAX.		P	35	75	200	45	30	200	110	-	-	1	-
HEAT NO.													
F124085		L	14	39	147	24	0	182	92	30	1151	0	21
		P	16	39	147	24	0	182	92	-	-	0	-
F126109		L	15	42	137	24	0	182	92	15	1100	0	20
		P	14	42	137	24	0	182	92	-	-	0	-

*1 L:LADLE ANALYSIS P:PRODUCT ANALYSIS *2:X1 *3:X10 *4:X1000 *5:X10000 OTHER:X100
*PI PITTING INDEX:Cr+3.3Mo+16N

TENSILE TEST

		*1 *2	YS *3		TS *3		EL %
SPEC. MIN.		L B	P	30.0	P	75.0	35
MAX.		L B	P	-	P	-	-
HEAT NO.							
F124085		L B	P	46.0	P	86.7	65
F126109		L B	P	44.8	P	85.1	67

TYPE OF SPECIMEN:STRIP 1-1/2in. WIDTH *1 SAMPLING DIRECTION L:LONGITUDINAL *2 SAMPLING POSITION B:BASE METAL
*3 UNIT P:ksi GAUGE LENGTH:2.0in. KIND OF YS:0.5% EXTENSION UNDER LOAD

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MADE IN ACCORDANCE WITH THE RULES OF THE CONTRACT.

T. Satsuki

TAKAFUMI SATSUKI
HEAD OF DEPARTMENT
QUALITY ASSURANCE DEPARTMENT

NO. 319063W22

#6

NIPPON STEEL

NIPPON STEEL CORPORATION
KANSAI WORKS WAKAYAMA AREA
1850, MINATO, WAKAYAMA, JAPAN

INSPECTION CERTIFICATE

CERTIFICATE NO. :WYYK1698-03 PAGE : 2/2 DATE :2022-02-27

HARDNESS TEST(HRB)

		*1*2	*3		
SPEC. MIN.		B C	-		
MAX.		B C	100		
HEAT NO.			(1)	(2)	(3)
F124085		B C	82	83	83
F126109		B C	82	82	82

*1 SAMPLING POSITION B:BASE METAL *2 LOCATION C:CROSS SECTION *3 EACH (1)～(3): IMPRESSION NO.

CORROSION TEST(ASTM A262-E): ACCEPTABLE
CORROSION TEST(MIL-P-24691/3): ACCEPTABLE
FLATTENING TEST: ACCEPTABLE
VISUAL & DIMENSIONS: ACCEPTABLE
ULTRASONIC EXAMINATION STANDARD PRACTICE REFERENCE DISCONTINUITIES(ASME SA-999/SE-213 U-SHAPED NOTCH): ACCEPTABLE
POSITIVE MATERIAL IDENTIFICATION TEST: ACCEPTABLE
NO WELD REPAIR
CERTIFIED ACCORDING TO PED2014/68/EU, ANNEX I, PAR. 4. 3 BY TUEV RHEINLAND INDUSTRIE SERVICE GmbH
(NOTIFIED BODY, ID-No. 0035/CERTIFICATE No. 01 202 J/Q-02 0017)
MATERIAL WOULD NOT BE AFFECTED BY MERCURY CONTAMINATION
COUNTRY OF MELT: JAPAN
NACE MR0175/ISO 15156, NACE MR0103/ISO 17945 HARDNESS: GUARANTEED
PICKLED AND PASSIVATED CONDITION
PMI100%
MATERIAL FREE OF DETECTABLE RADIOACTIVE CONTAMINATION DURING PRODUCTION
CONTAMINATION BY CARBON STEEL AND HALOGENS/CHLORIDES WOULD NOT BE DETECTED
4ISSS10
EN 10204 3. 1

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MADE IN ACCORDANCE WITH THE RULES OF THE CONTRACT.

T. Satsuki

TAKAFUMI SATSUKI
HEAD OF DEPARTMENT
QUALITY ASSURANCE DEPARTMENT

NO. 319063W22

APPENDIX II

TENSILE TEST REPORTS

BRYAN LABORATORY, INC.

METALLURGICAL CONSULTATION - INSPECTION - TESTING
ANALYTICAL SERVICES - FAILURE ANALYSIS
6919 ALMEDA ROAD (77021)
P. O. BOX 300366
HOUSTON, TX 77230-0366
TELEPHONE 713/747-7470 800/922-7470 FAX 713/747-7477

REPORT

Lab. No. B2L2-0693A **November 4, 2022**

ON: Steel Pipe

TO: Paulin Research Group
11211 Richmond Ave., Suite 109
Houston, Texas 77082-2671
Attention: Mr. Tony Paulin

IDENTITY: A sample identified as a seamless pipe, marked *CS - Seamless, Pi 10" SCH40 S/O 46568 HT. LX0174 A106-B PO# 46568-25012*

TENSION TESTS

Specimens - 1-1/2" wide reduced sections, Transverse (T) and Longitudinal (L)

Sample	-	T - 1	T - 2	T - 3
Yield Strength*, psi	-	56,100	56,200	54,300
Tensile Strength, psi	-	77,600	78,400	76,500
Elongation in 2", %	-	36.1	37.6	32.1

Sample	-	L - 1	L - 2	L - 3
Yield Strength*, psi	-	49,600	49,400	48,700
Tensile Strength, psi	-	76,800	77,000	76,300
Elongation in 2", %	-	39.2	38.5	38.9

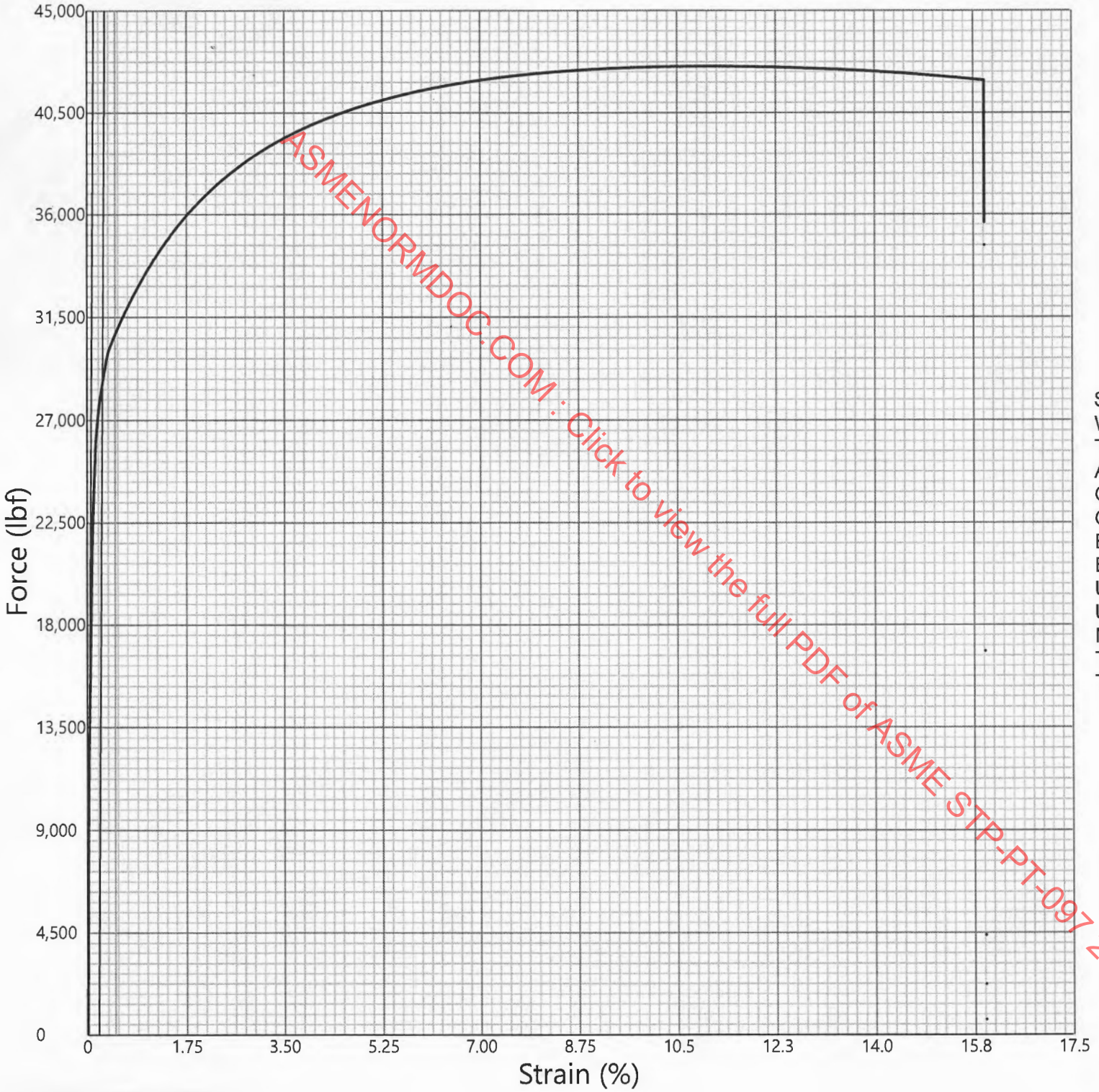
*At 0.5% total extension

Respectfully submitted,
BRYAN LABORATORY, INC.

Signature on original only

Sam A. Bryan

/cd

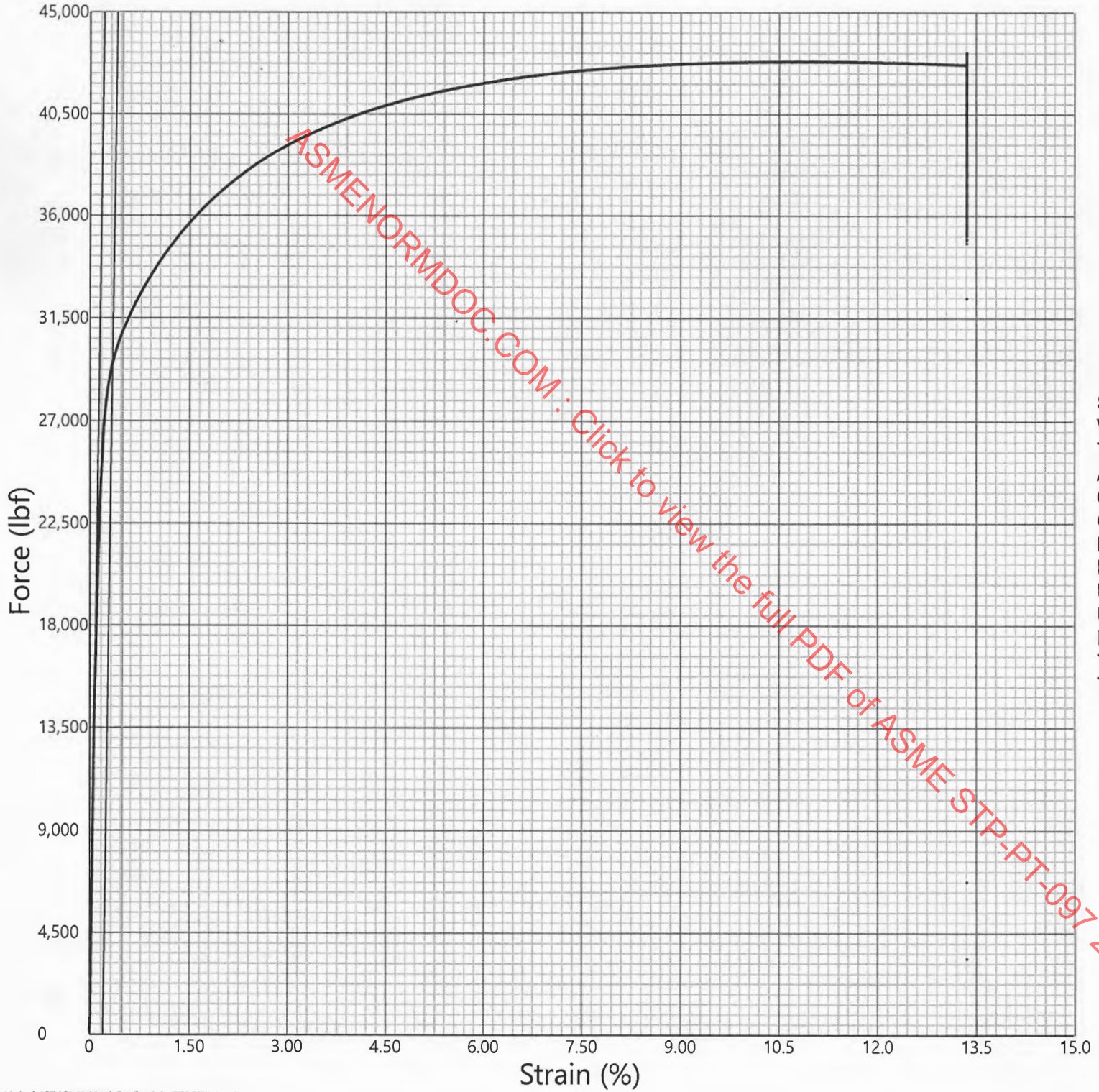


BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

Lab No: B2L2-0693
Operator: JS

Sample ID:	1 TBT T1
Width:	1.5060 in
Thickness:	0.36400 in
Area:	0.54818 in²
OS @ 0.2%:	28618 lbf
OS @ 0.2%:	52200 psi
EUL @ 0.5%:	30772 lbf
EUL @ 0.5%:	56100 psi
Ultimate Force:	42564 lbf
Ultimate Stress:	77600 psi
Modulus:	69500000 psi
TE (Manual):	36.1 %
Test End :	11/1/2022 1:22 PM



BRYAN LABORATORY, INC

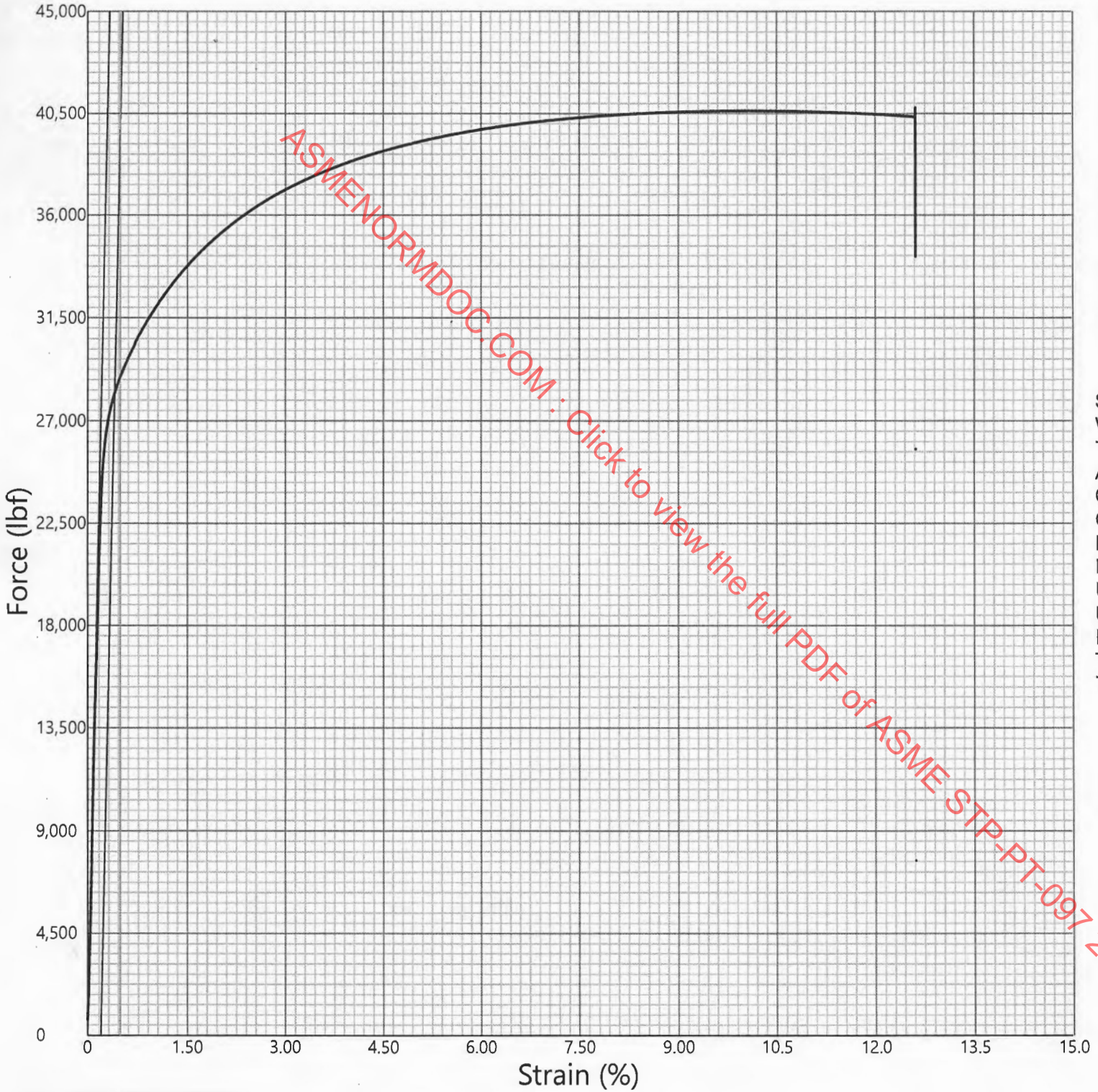
ASTM E8 Metals Tensile

Lab No: B2L2-0693
Operator: JS

Sample ID:	1 TBT T2
Width:	1.5100 in
Thickness:	0.36500 in
Area:	0.55115 in²
OS @ 0.2%:	29534 lbf
OS @ 0.2%:	53600 psi
EUL @ 0.5%:	30974 lbf
EUL @ 0.5%:	56200 psi
Ultimate Force:	43225 lbf
Ultimate Stress:	78400 psi
Modulus:	38300000 psi
TE (Manual):	37.6 %
Test End :	11/1/2022 1:37 PM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/1/2022 1:40 PM



BRYAN LABORATORY, INC

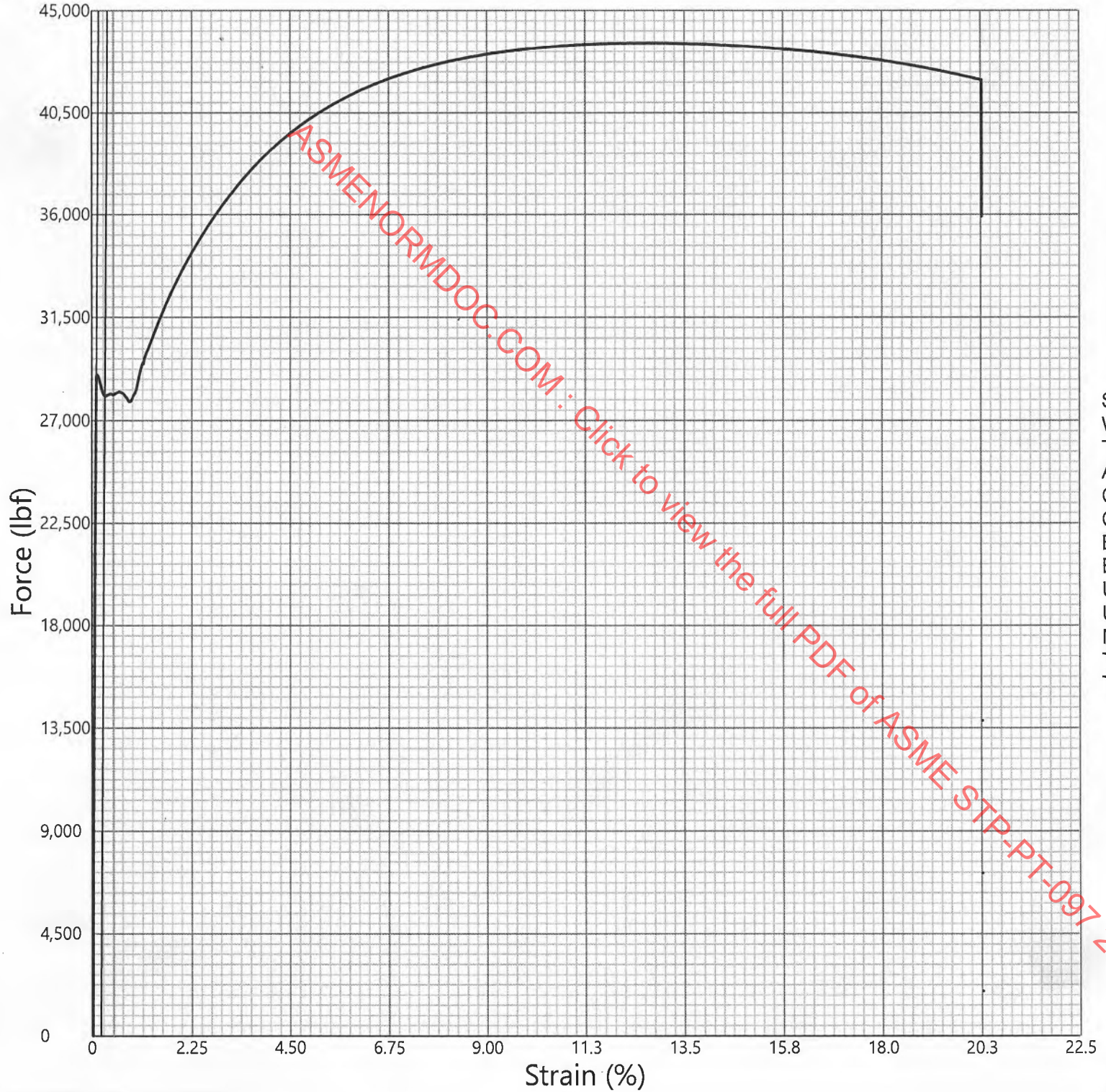
ASTM E8 Metals Tensile

Lab No:	B2L2-0693
Operator:	JS

Sample ID:	1 TBT T3
Width:	1.5100 in
Thickness:	0.35300 in
Area:	0.53303 in²
OS @ 0.2%:	28228 lbf
OS @ 0.2%:	53000 psi
EUL @ 0.5%:	28968 lbf
EUL @ 0.5%:	54300 psi
Ultimate Force:	40769 lbf
Ultimate Stress:	76500 psi
Modulus:	25200000 psi
TE (Manual):	32.1 %
Test End :	11/1/2022 1:53 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No:	B2L2-0693
Operator:	JS

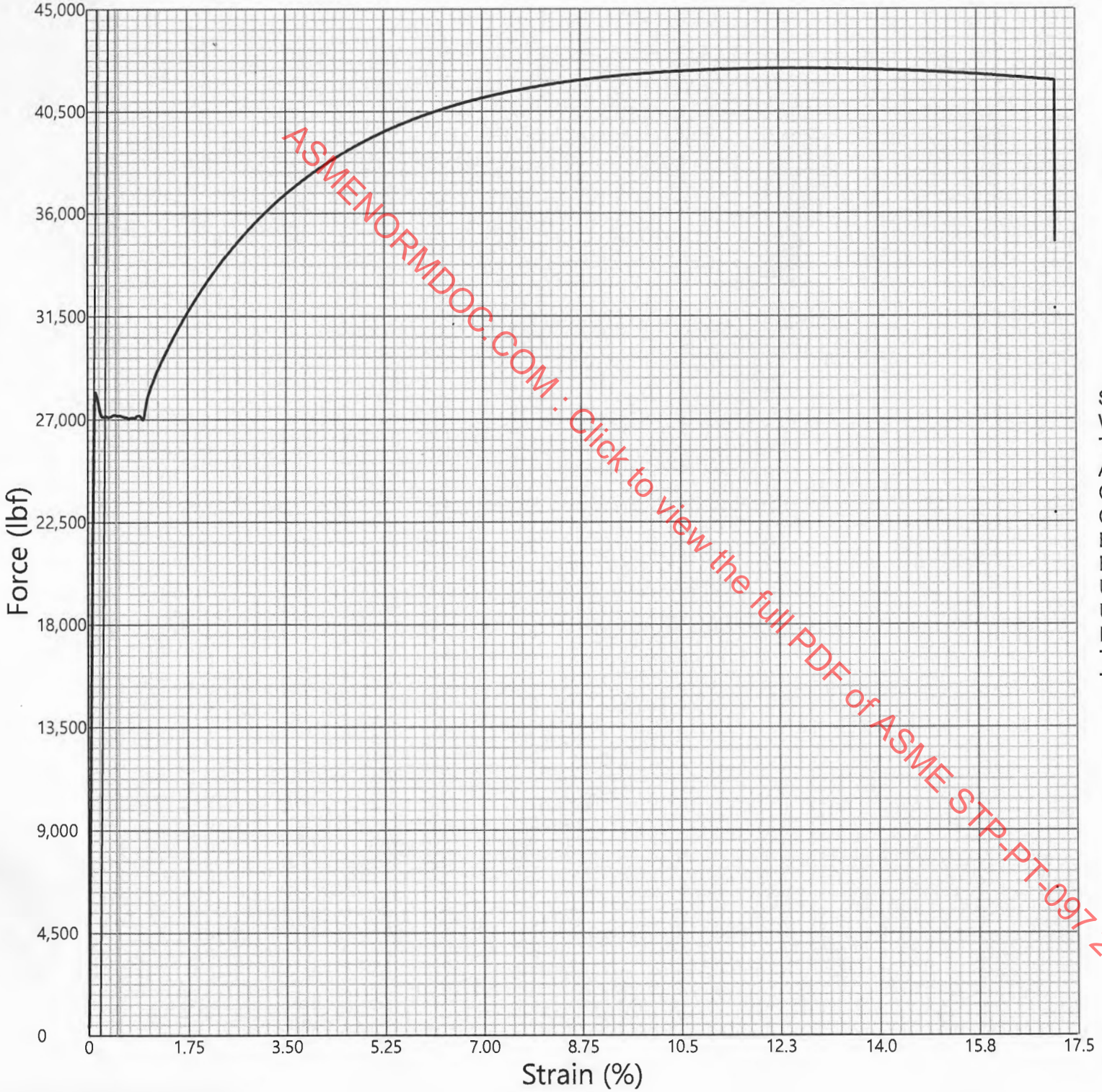
Sample ID:	1 LT T1
Width:	1.5050 in
Thickness:	0.37700 in
Area:	0.56739 in²
OS @ 0.2%:	28092 lbf
OS @ 0.2%:	49500 psi
EUL @ 0.5%:	28135 lbf
EUL @ 0.5%:	49600 psi
Ultimate Force:	43584 lbf
Ultimate Stress:	76800 psi
Modulus:	50800000 psi
TE (Manual):	39.2 %
Test End :	11/1/2022 11:19 AM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic : 60000lbf. Printed: 11/1/2022 11:29 AM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

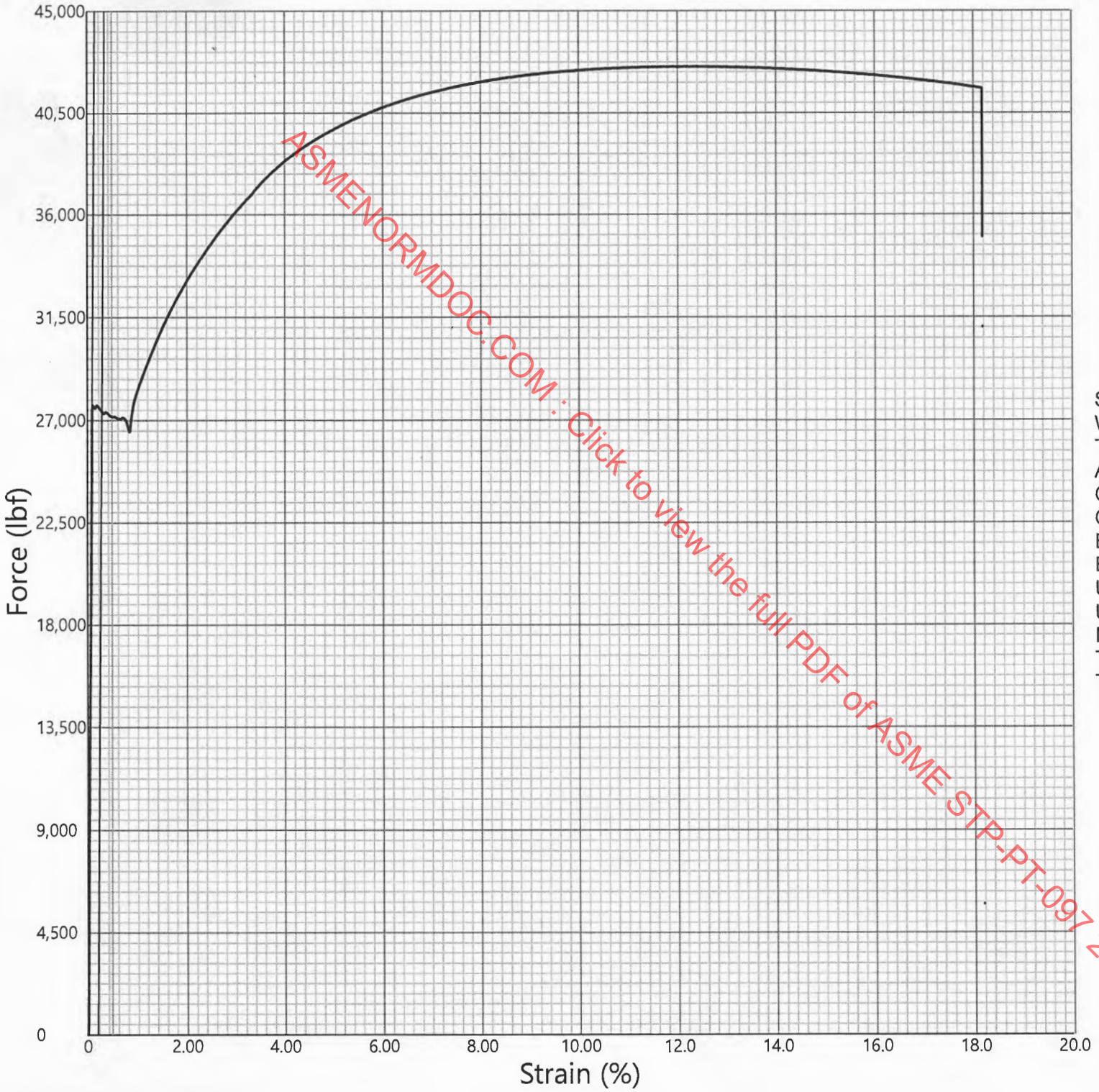


Lab No:	B2L2-0693
Operator:	JS

Sample ID:	1 LT T2
Width:	1.5050 in
Thickness:	0.36600 in
Area:	0.55083 in²
OS @ 0.2%:	27133 lbf
OS @ 0.2%:	49300 psi
EUL @ 0.5%:	27192 lbf
EUL @ 0.5%:	49400 psi
Ultimate Force:	42407 lbf
Ultimate Stress:	77000 psi
Modulus:	45800000 psi
TE (Manual):	38.5 %
Test End :	11/1/2022 11:50 AM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/1/2022 11:51 AM



BRYAN LABORATORY, INC
ASTM E8 Metals Tensile

Lab No: B2L2-0693
Operator: JS

Sample ID:	1 LT T3
Width:	1.5070 in
Thickness:	0.37000 in
Area:	0.55759 in²
OS @ 0.2%:	27393 lbf
OS @ 0.2%:	49100 psi
EUL @ 0.5%:	27175 lbf
EUL @ 0.5%:	48700 psi
Ultimate Force:	42558 lbf
Ultimate Stress:	76300 psi
Modulus:	52600000 psi
TE (Manual):	38.9 %
Test End :	11/1/2022 12:07 PM

BRYAN LABORATORY, INC.

METALLURGICAL CONSULTATION - INSPECTION - TESTING
ANALYTICAL SERVICES - FAILURE ANALYSIS
6919 ALMEDA ROAD (77021)
P. O. BOX 300366
HOUSTON, TX 77230-0366
TELEPHONE 713/747-7470 800/922-7470 FAX 713/747-7477

REPORT

Lab. No. B2L2-0693B **November 4, 2022**

ON: Steel Pipe

TO: Paulin Research Group
11211 Richmond Ave., Suite 109
Houston, Texas 77082-2671
Attention: Mr. Tony Paulin

IDENTITY: A sample identified as a welded pipe, marked *CS - Welded - ERW Pi 10" SCH40 PO# 46568-25012 HT. 21023922 A53-B*

TENSION TESTS

Specimens - 1-1/2" wide reduced sections, Transverse, 180° from the weld (Body), across the weld (Weld) and Longitudinal, 90° from the weld (Long)

Sample	-	Body - 1	Body - 2	Body - 3
Yield Strength*, psi	-	61,400	62,200	61,700
Tensile Strength, psi	-	71,600	71,600	71,500
Elongation in 2", %	-	35.4	34.7	37.5

Sample	-	Weld - 1	Weld - 2	Weld - 3
Tensile Strength, psi	-	79,300	80,000	79,600

Sample	-	Long - 1	Long - 2	Long - 3
Yield Strength*, psi	-	58,000	60,800	60,100
Tensile Strength, psi	-	74,700	72,900	71,100
Elongation in 2", %	-	33.5	33.4	36.3

*At 0.5% total extension

Respectfully submitted,
BRYAN LABORATORY, INC.

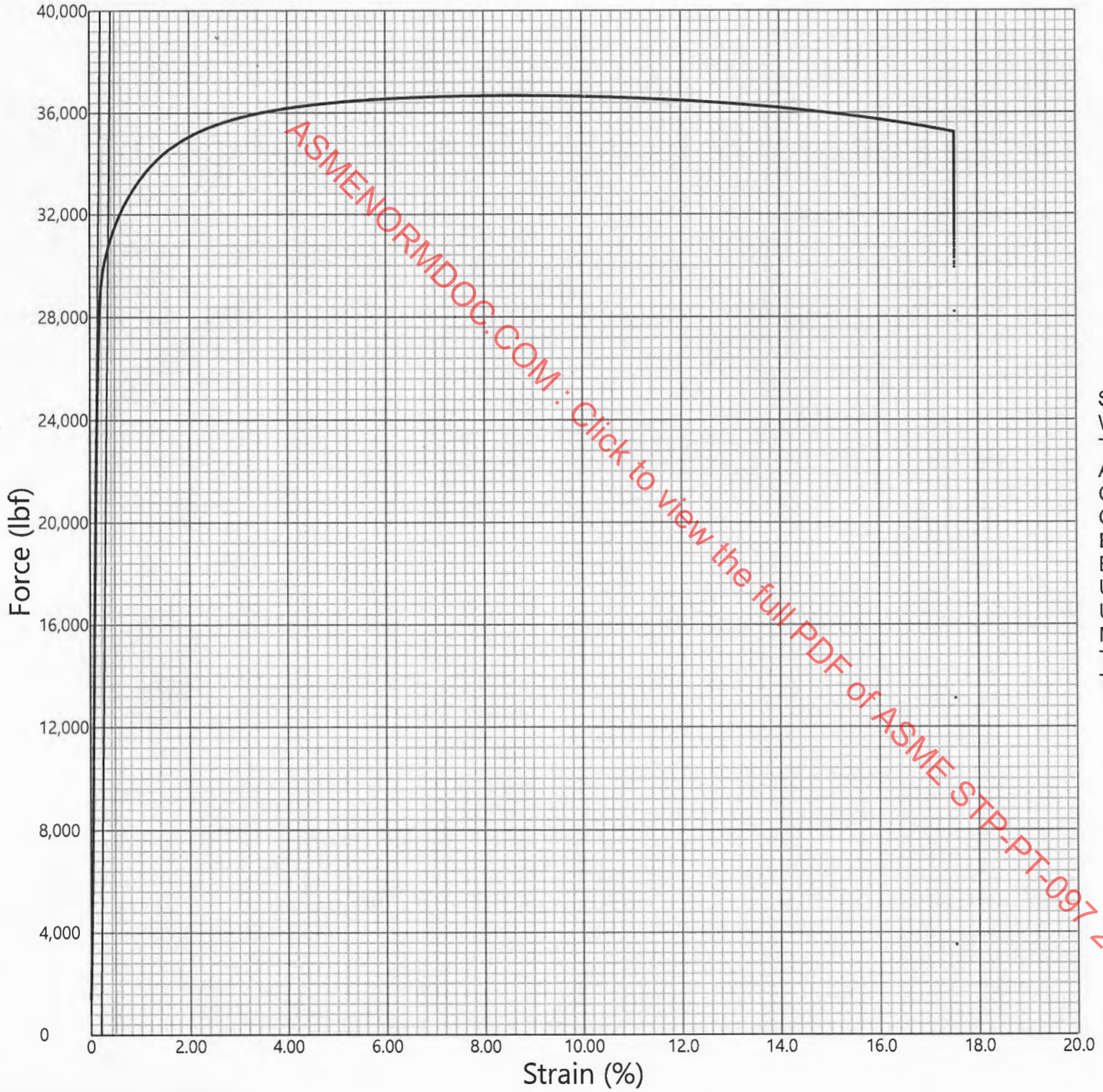
Signature on original only

Sam A. Bryan

/cd

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

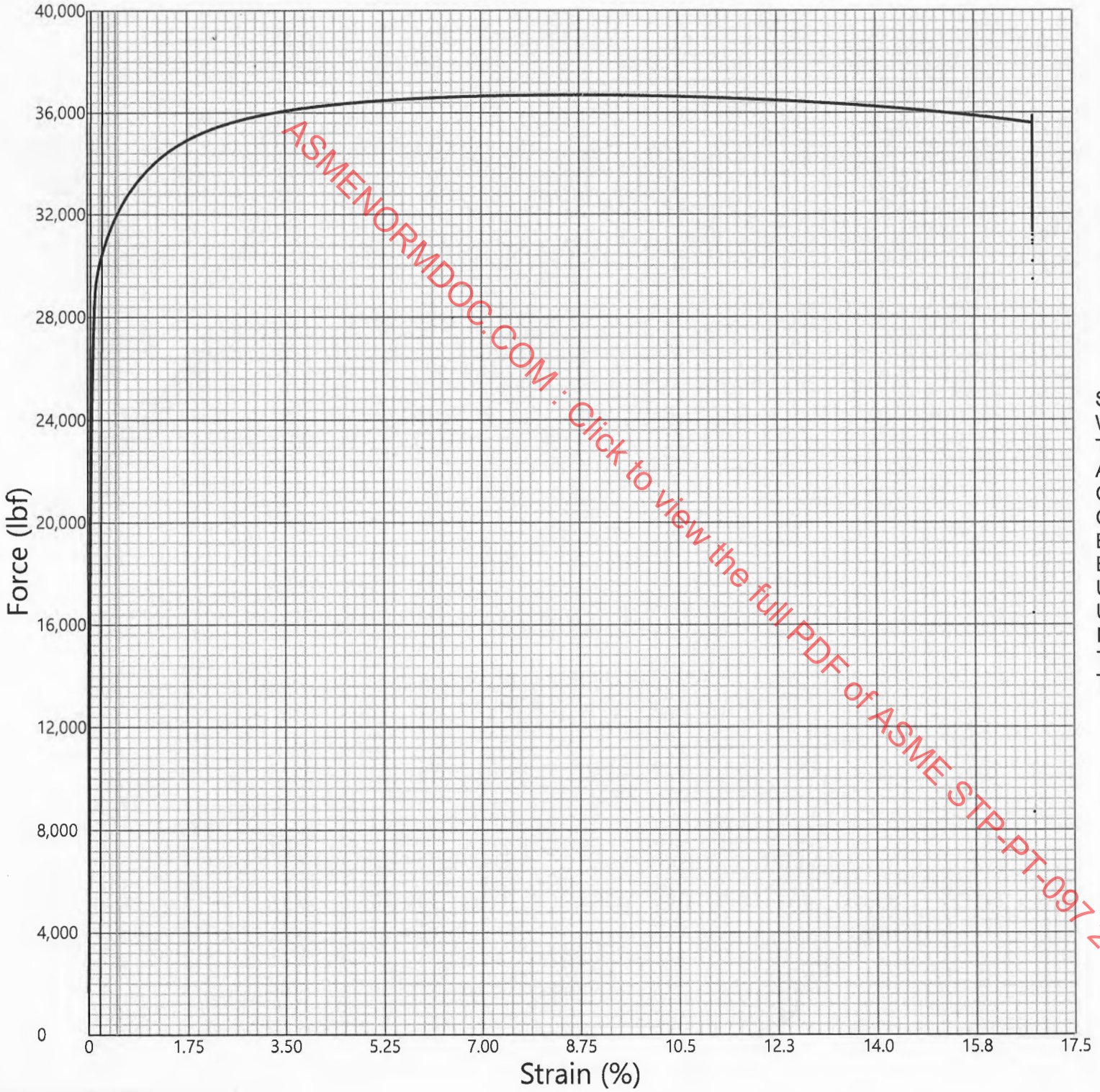


Lab No: B2L2-0693
Operator: JS

Sample ID:	2 TBT T1
Width:	1.5080 in
Thickness:	0.34000 in
Area:	0.51272 in²
OS @ 0.2%:	30721 lbf
OS @ 0.2%:	59900 psi
EUL @ 0.5%:	31470 lbf
EUL @ 0.5%:	61400 psi
Ultimate Force:	36692 lbf
Ultimate Stress:	71600 psi
Modulus:	34500000 psi
TE (Manual):	35.4 %
Test End :	11/1/2022 3:08 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

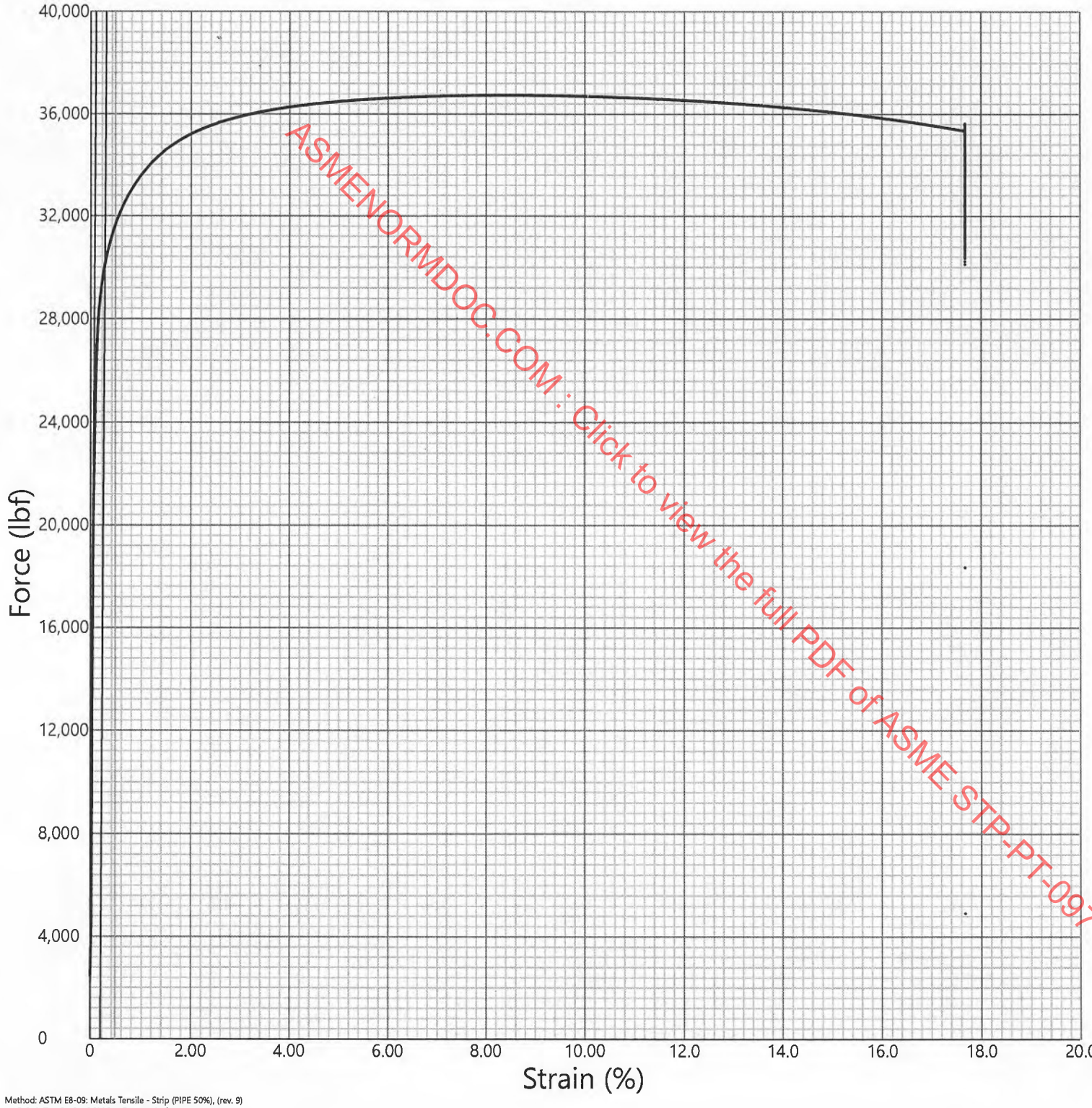


Lab No: B2L2-0693
Operator: JS

Sample ID:	2 TBT T2
Width:	1.5070 in
Thickness:	0.34000 in
Area:	0.51238 in²
OS @ 0.2%:	30424 lbf
OS @ 0.2%:	59400 psi
EUL @ 0.5%:	31868 lbf
EUL @ 0.5%:	62200 psi
Ultimate Force:	36709 lbf
Ultimate Stress:	71600 psi
Modulus:	103000000 psi
TE (Manual):	34.7 %
Test End :	11/1/2022 3:25 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

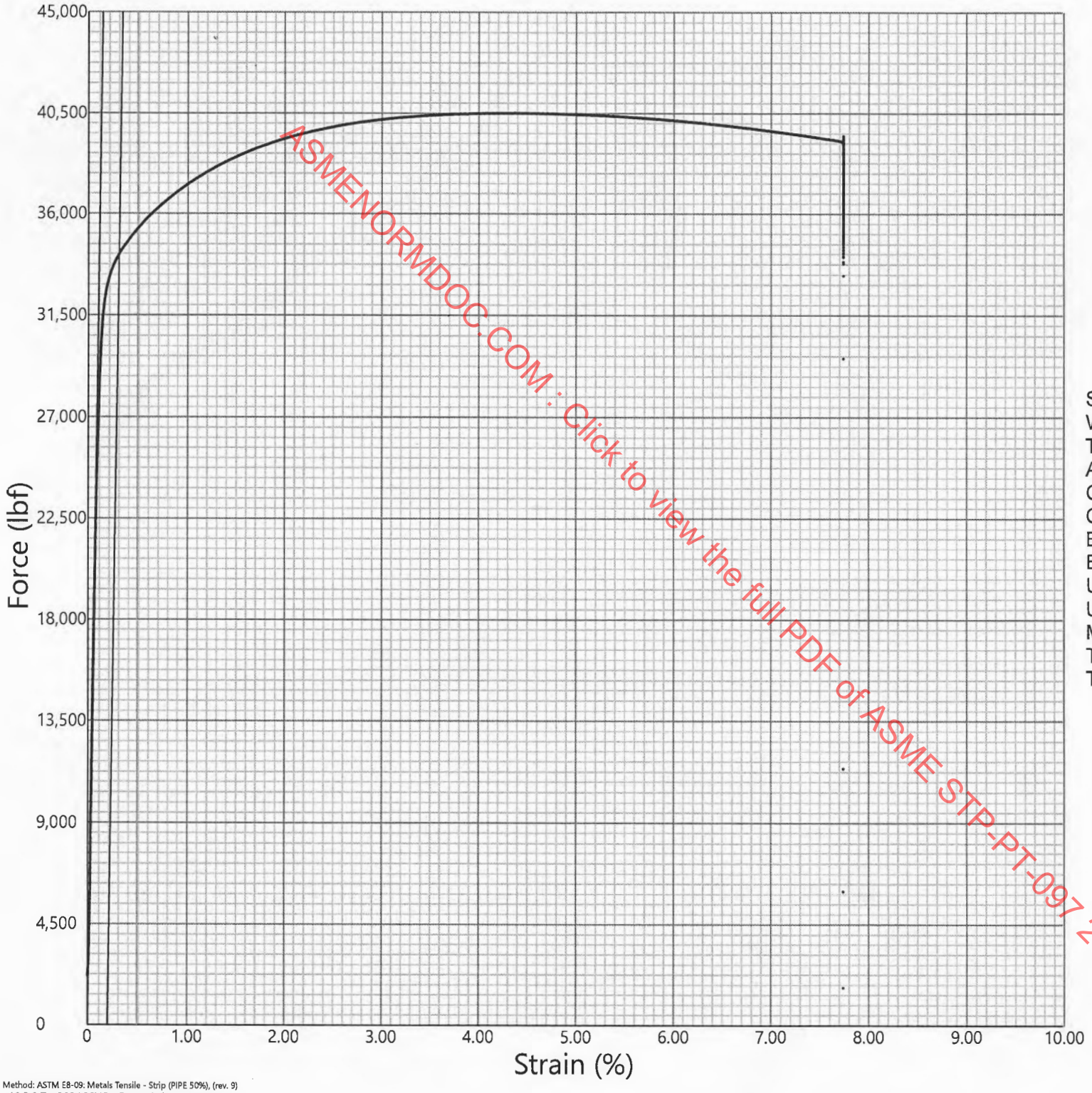


Lab No: B2L2-0693
Operator: JS

Sample ID:	2 TBT T3
Width:	1.5110 in
Thickness:	0.34000 in
Area:	0.51374 in²
OS @ 0.2%:	30111 lbf
OS @ 0.2%:	58600 psi
EUL @ 0.5%:	31680 lbf
EUL @ 0.5%:	61700 psi
Ultimate Force:	36752 lbf
Ultimate Stress:	71500 psi
Modulus:	69300000 psi
TE (Manual):	37.5 %
Test End :	11/1/2022 3:40 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No:	B2L2-0693
Operator:	JS

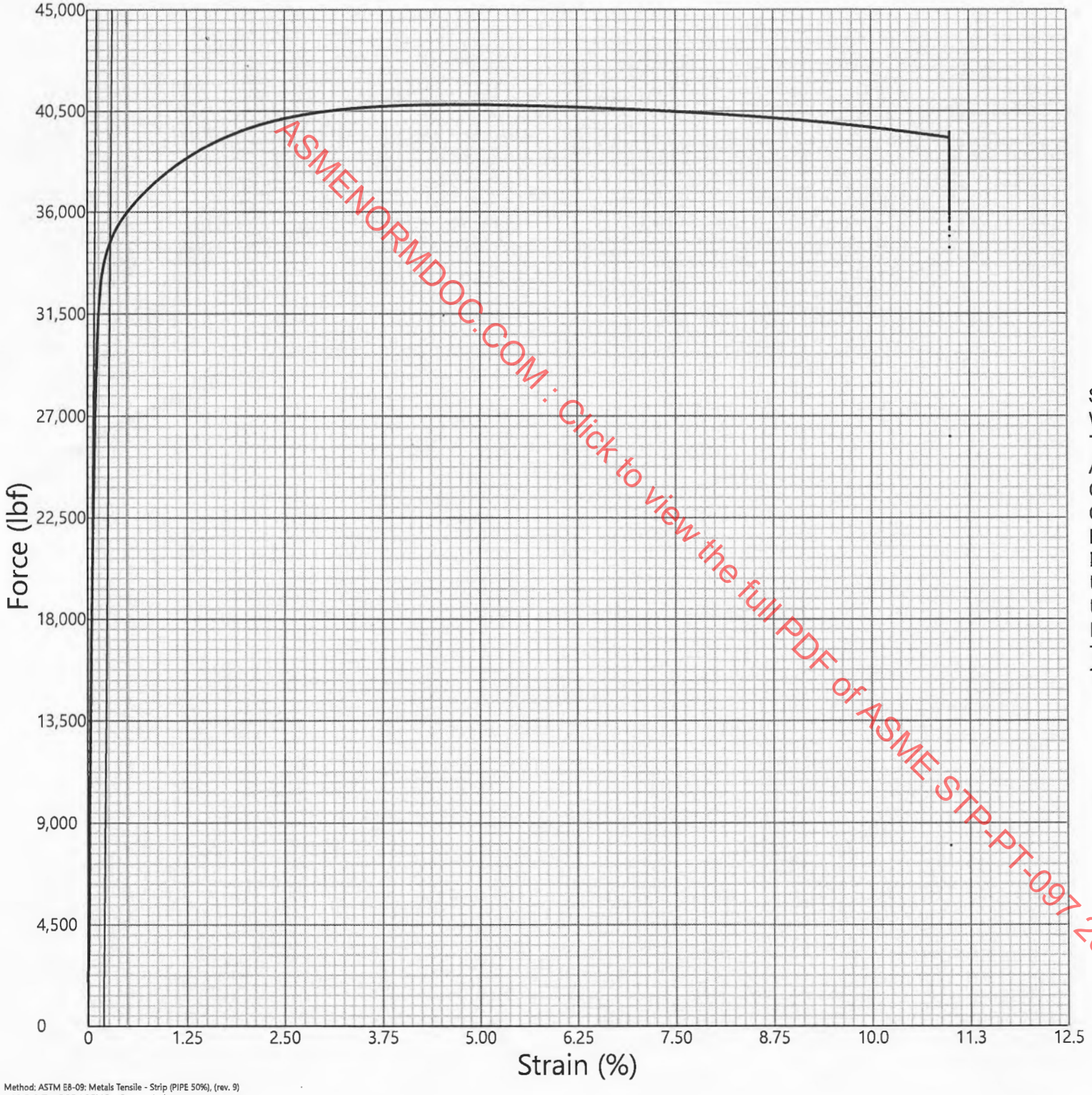
Sample ID:	2 TWT T1
Width:	1.5070 in
Thickness:	0.33900 in
Area:	0.51087 in²
OS @ 0.2%:	34176 lbf
OS @ 0.2%:	66900 psi
EUL @ 0.5%:	35322 lbf
EUL @ 0.5%:	69100 psi
Ultimate Force:	40526 lbf
Ultimate Stress:	79300 psi
Modulus:	60600000 psi
TE (Manual):	23.5 %
Test End :	11/1/2022 4:01 PM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/1/2022 4:03 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No: B2L2-0693
Operator: JS

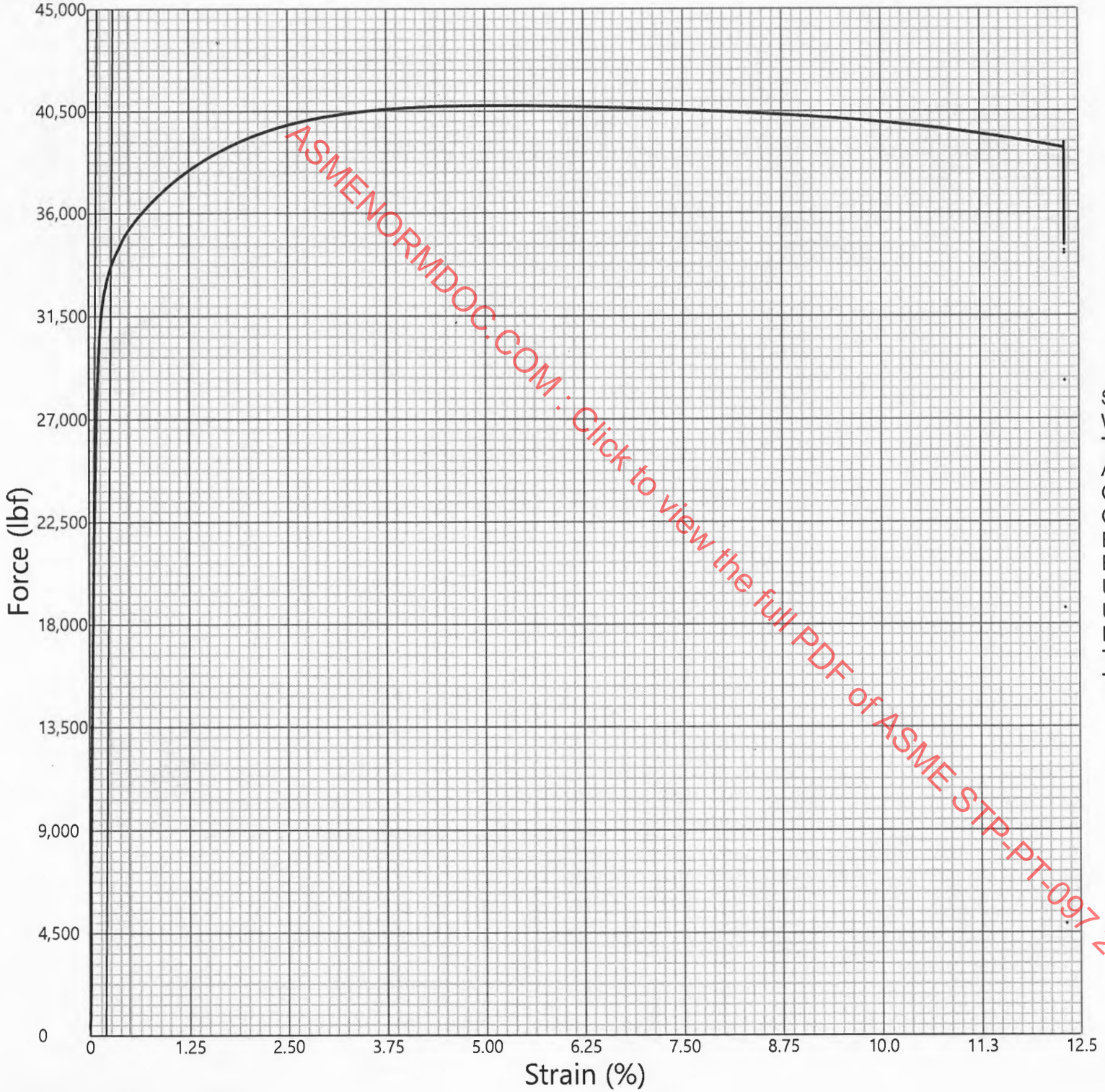
Sample ID:	2 TWT T2
Width:	1.5050 in
Thickness:	0.33900 in
Area:	0.51019 in²
OS @ 0.2%:	34688 lbf
OS @ 0.2%:	68000 psi
EUL @ 0.5%:	35968 lbf
EUL @ 0.5%:	70500 psi
Ultimate Force:	40803 lbf
Ultimate Stress:	80000 psi
Modulus:	74000000 psi
TE (Manual):	24.6 %
Test End :	11/1/2022 4:14 PM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/1/2022 4:17 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No: B2L2-0693
Operator: JS

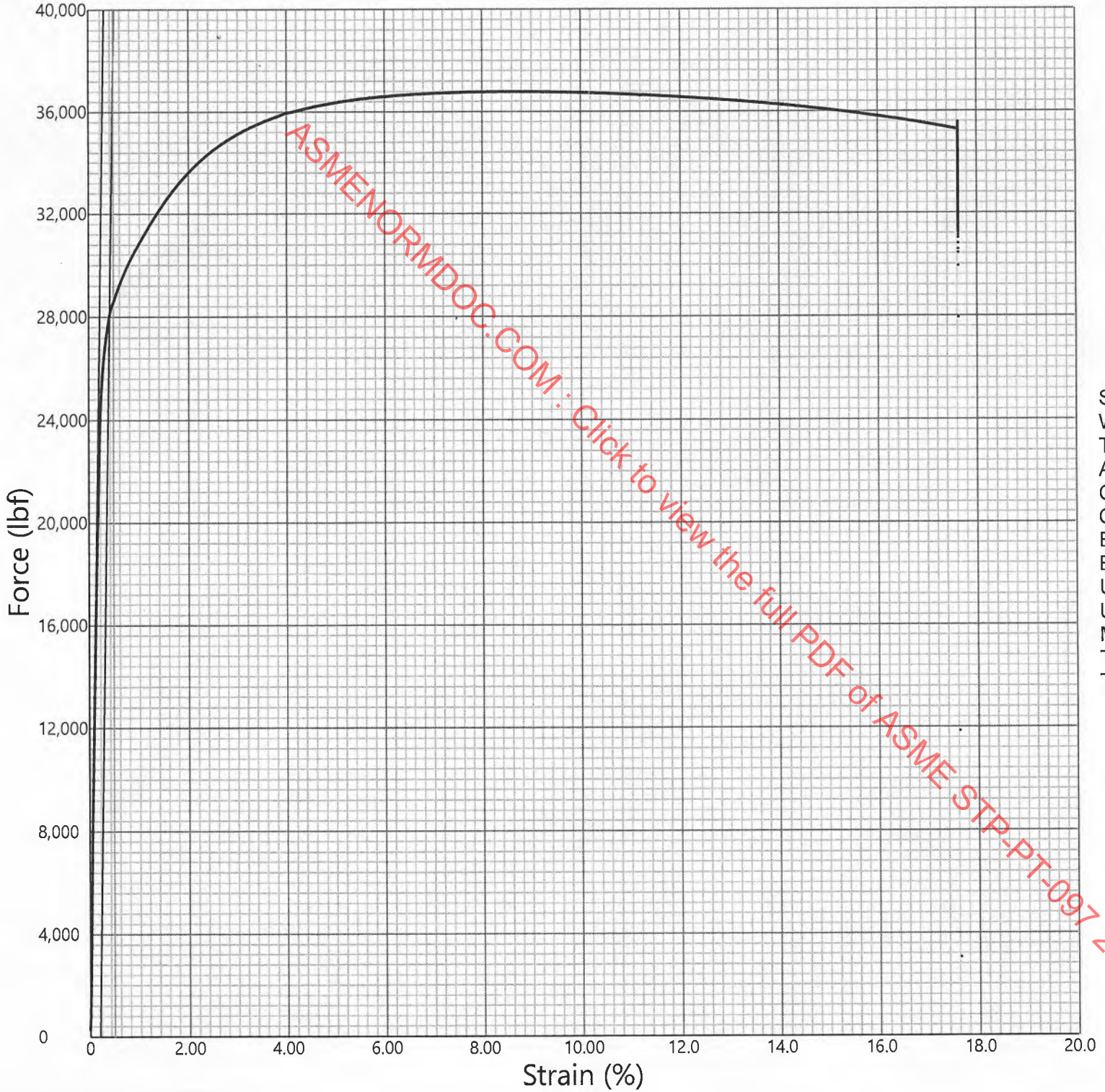
Sample ID:	2 TWT T3
Width:	1.5060 in
Thickness:	0.34000 in
Area:	0.51204 in²
OS @ 0.2%:	33686 lbf
OS @ 0.2%:	65800 psi
EUL @ 0.5%:	35259 lbf
EUL @ 0.5%:	68900 psi
Ultimate Force:	40769 lbf
Ultimate Stress:	79600 psi
Modulus:	79800000 psi
TE (Manual):	23.9 %
Test End :	11/1/2022 4:27 PM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/1/2022 4:29 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No:	B2L2-0693
Operator:	JS

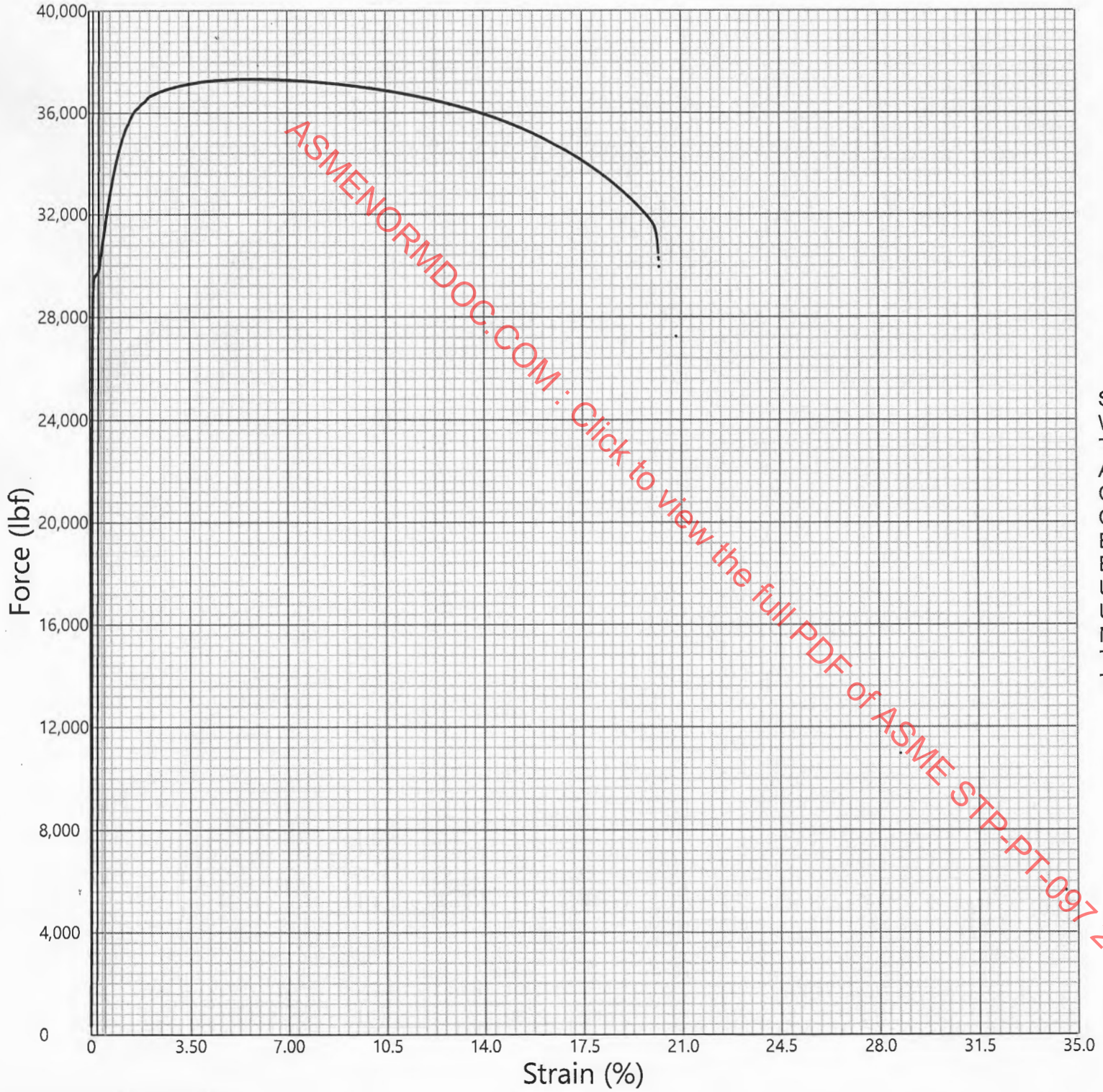
Sample ID:	2 LT T1 RETEST
Width:	1.4980 in
Thickness:	0.32900 in
Area:	0.49284 in²
OS @ 0.2%:	28080 lbf
OS @ 0.2%:	57000 psi
EUL @ 0.5%:	28574 lbf
EUL @ 0.5%:	58000 psi
Ultimate Force:	36796 lbf
Ultimate Stress:	74700 psi
Modulus:	25900000 psi
TE (Manual):	33.5 %
Test End :	11/2/2022 1:20 PM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/2/2022 1:21 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

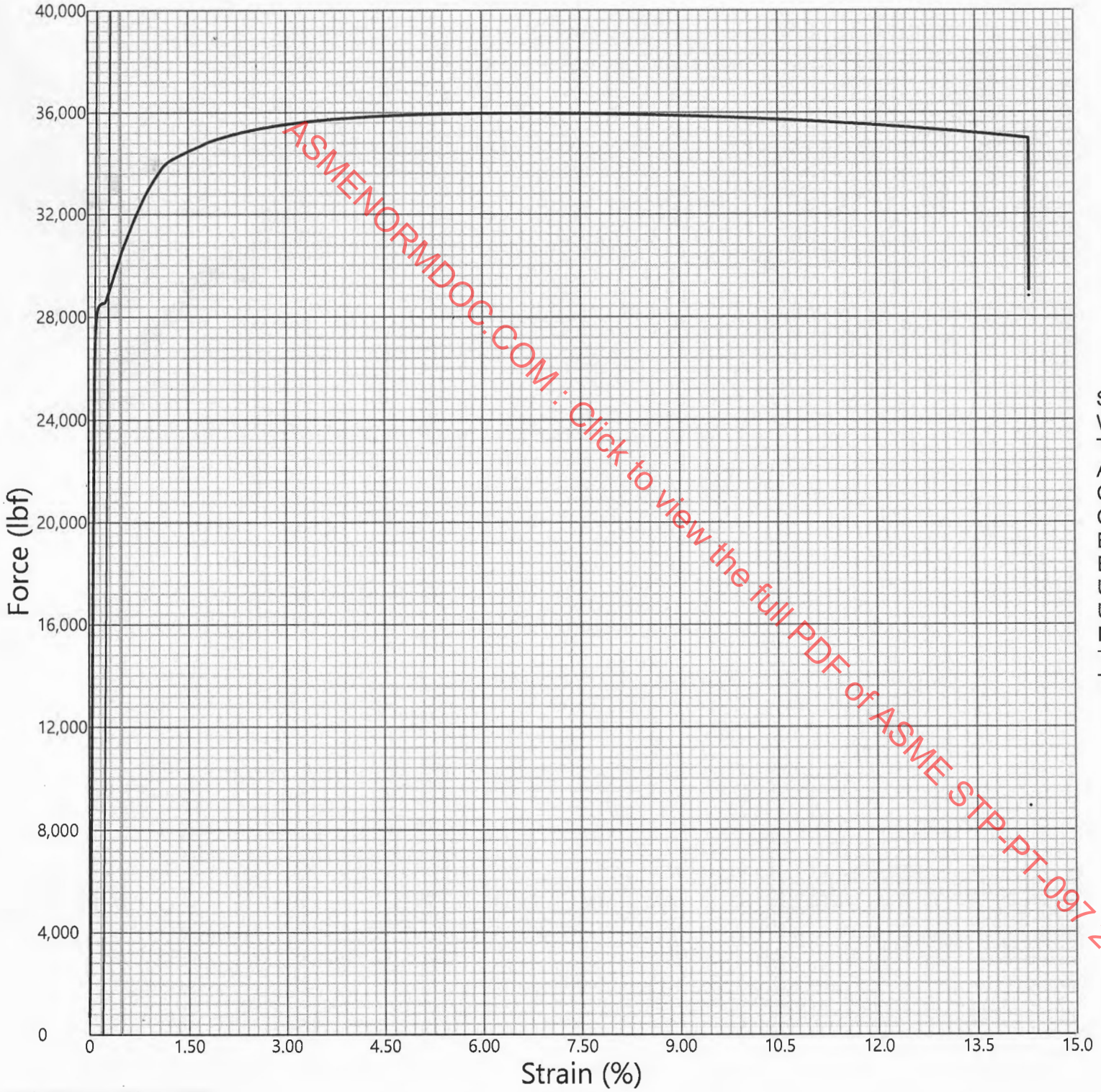


Lab No: B2L2-0693
Operator: JS

Sample ID:	2 LT T2
Width:	1.5100 in
Thickness:	0.33900 in
Area:	0.51189 in²
OS @ 0.2%:	29775 lbf
OS @ 0.2%:	58200 psi
EUL @ 0.5%:	31113 lbf
EUL @ 0.5%:	60800 psi
Ultimate Force:	37331 lbf
Ultimate Stress:	72900 psi
Modulus:	50300000 psi
TE (Manual):	33.4 %
Test End :	11/1/2022 2:34 PM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No: B2L2-0693
Operator: JS

Sample ID:	2 LT T3
Width:	1.5070 in
Thickness:	0.33600 in
Area:	0.50635 in²
OS @ 0.2%:	28923 lbf
OS @ 0.2%:	57100 psi
EUL @ 0.5%:	30454 lbf
EUL @ 0.5%:	60100 psi
Ultimate Force:	35990 lbf
Ultimate Stress:	71100 psi
Modulus:	53500000 psi
TE (Manual):	36.3 %
Test End :	11/1/2022 2:53 PM

BRYAN LABORATORY, INC.

METALLURGICAL CONSULTATION - INSPECTION - TESTING
ANALYTICAL SERVICES - FAILURE ANALYSIS
6919 ALMEDA ROAD (77021)
P. O. BOX 300366
HOUSTON, TX 77230-0366
TELEPHONE 713/747-7470 800/922-7470 FAX 713/747-7477

REPORT

Lab. No. B2L2-0693C **November 4, 2022**

ON: Stainless Steel Pipe

TO: Paulin Research Group
11211 Richmond Ave., Suite 109
Houston, Texas 77082-2671
Attention: Mr. Tony Paulin

IDENTITY: A sample identified as a seamless pipe, marked *SS - Seamless Pi 10" SCH40 S/O 46568 PO# 46568-25012 HT. 126109 304L*

TENSION TESTS

Specimens - 1-1/2" wide reduced sections, Transverse (T) and Longitudinal (L)

Sample	-	T - 1	T - 2	T - 3
Yield Strength*, psi	-	56,500	50,400	53,800
Tensile Strength, psi	-	92,100	90,300	92,900
Elongation in 2", %	-	69.1	68.9	72.2

Sample	-	L - 1	L - 2	L - 3
Yield Strength*, psi	-	46,300	46,700	49,800
Tensile Strength, psi	-	90,200	90,000	90,200
Elongation in 2", %	-	72.8	70.9	73.3

*At 0.5% total extension

Respectfully submitted,
BRYAN LABORATORY, INC.

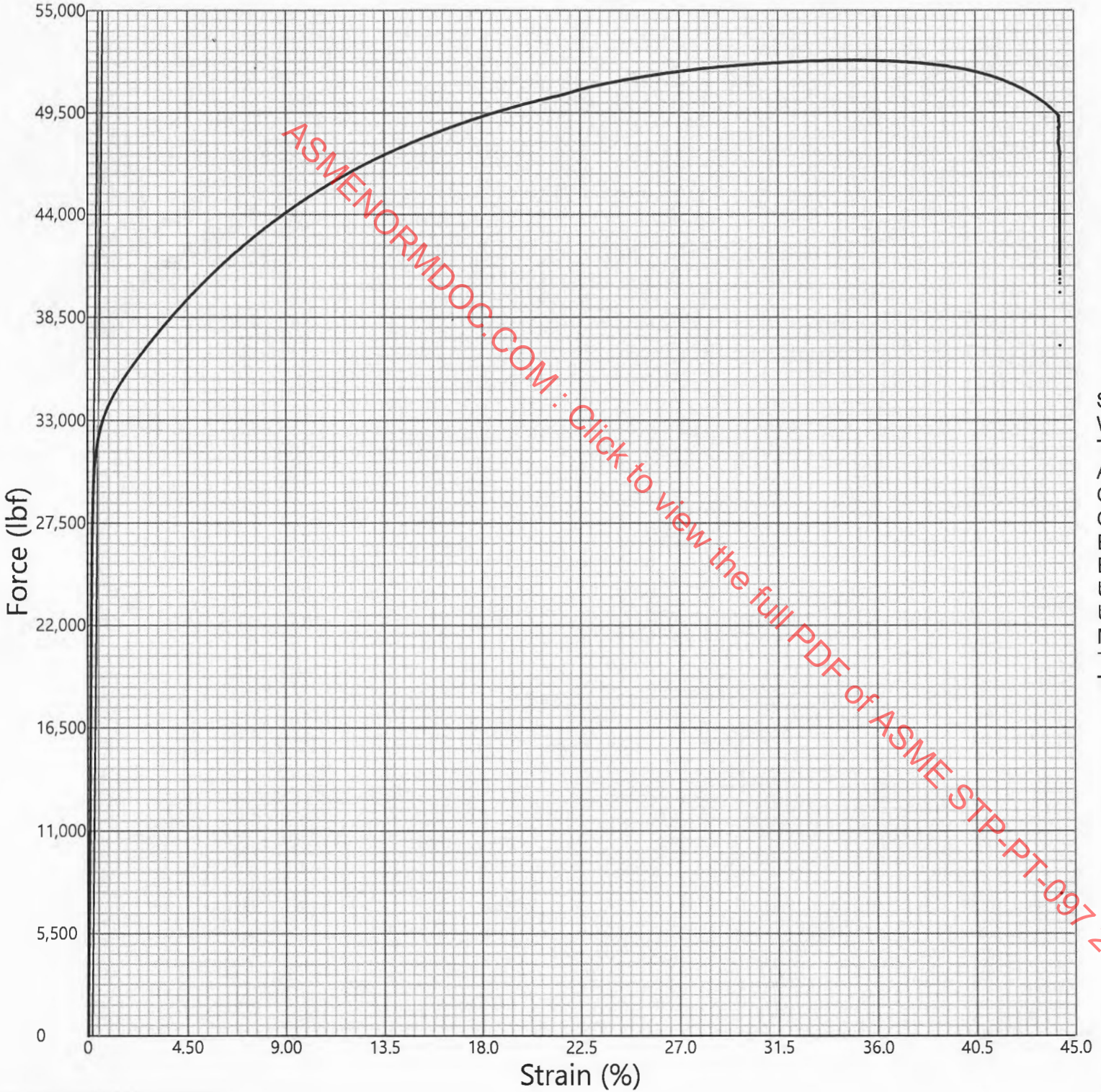
Signature on original only

Sam A. Bryan

/cd

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile



Lab No: B2L2-0693
Operator: JS

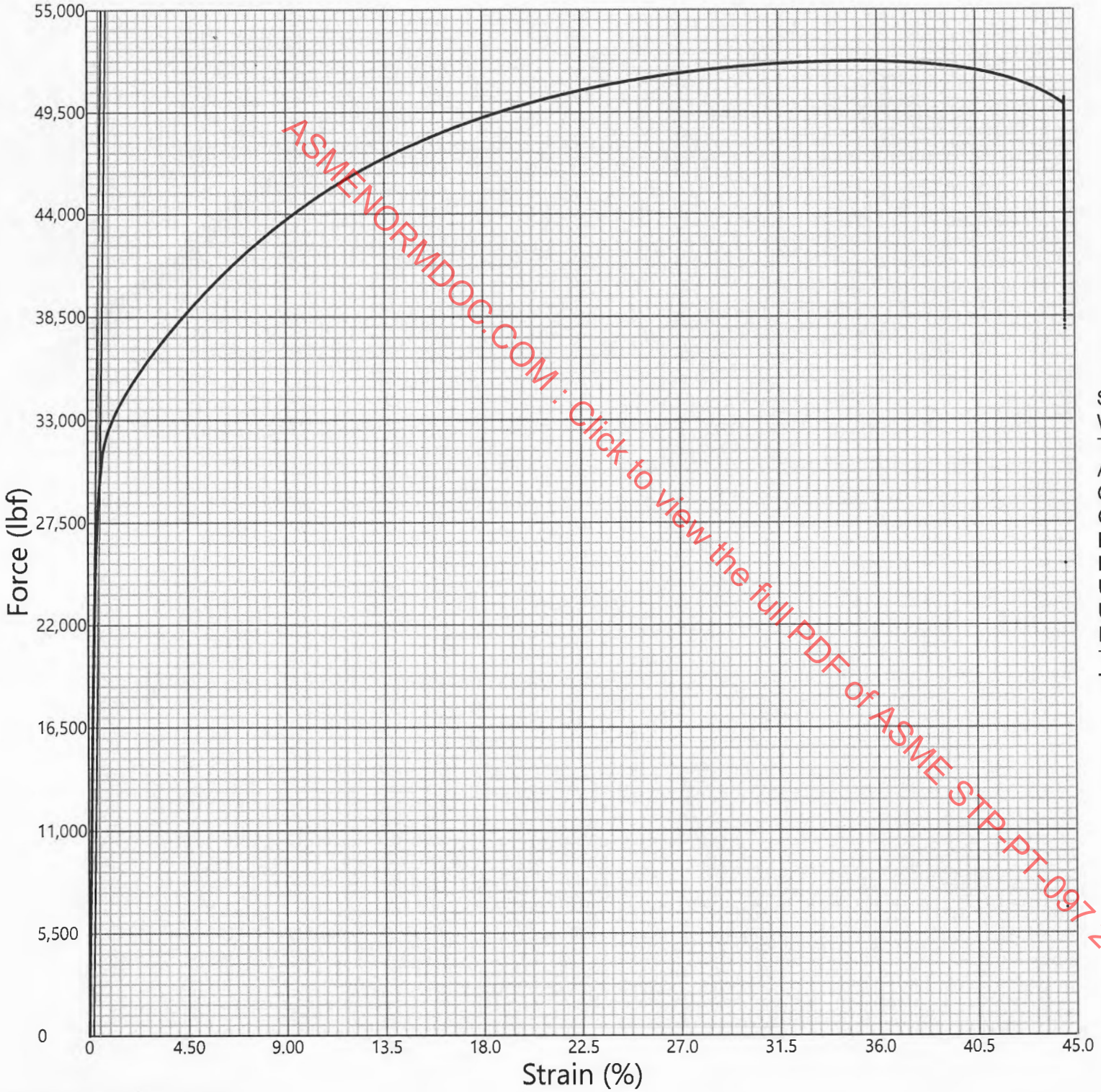
Sample ID:	3 TBT T1
Width:	1.5070 in
Thickness:	0.37700 in
Area:	0.56814 in²
OS @ 0.2%:	32028 lbf
OS @ 0.2%:	56400 psi
EUL @ 0.5%:	32117 lbf
EUL @ 0.5%:	56500 psi
Ultimate Force:	52340 lbf
Ultimate Stress:	92100 psi
Modulus:	19800000 psi
TE (Manual):	69.1 %
Test End :	11/2/2022 8:41 AM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/2/2022 8:42 AM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

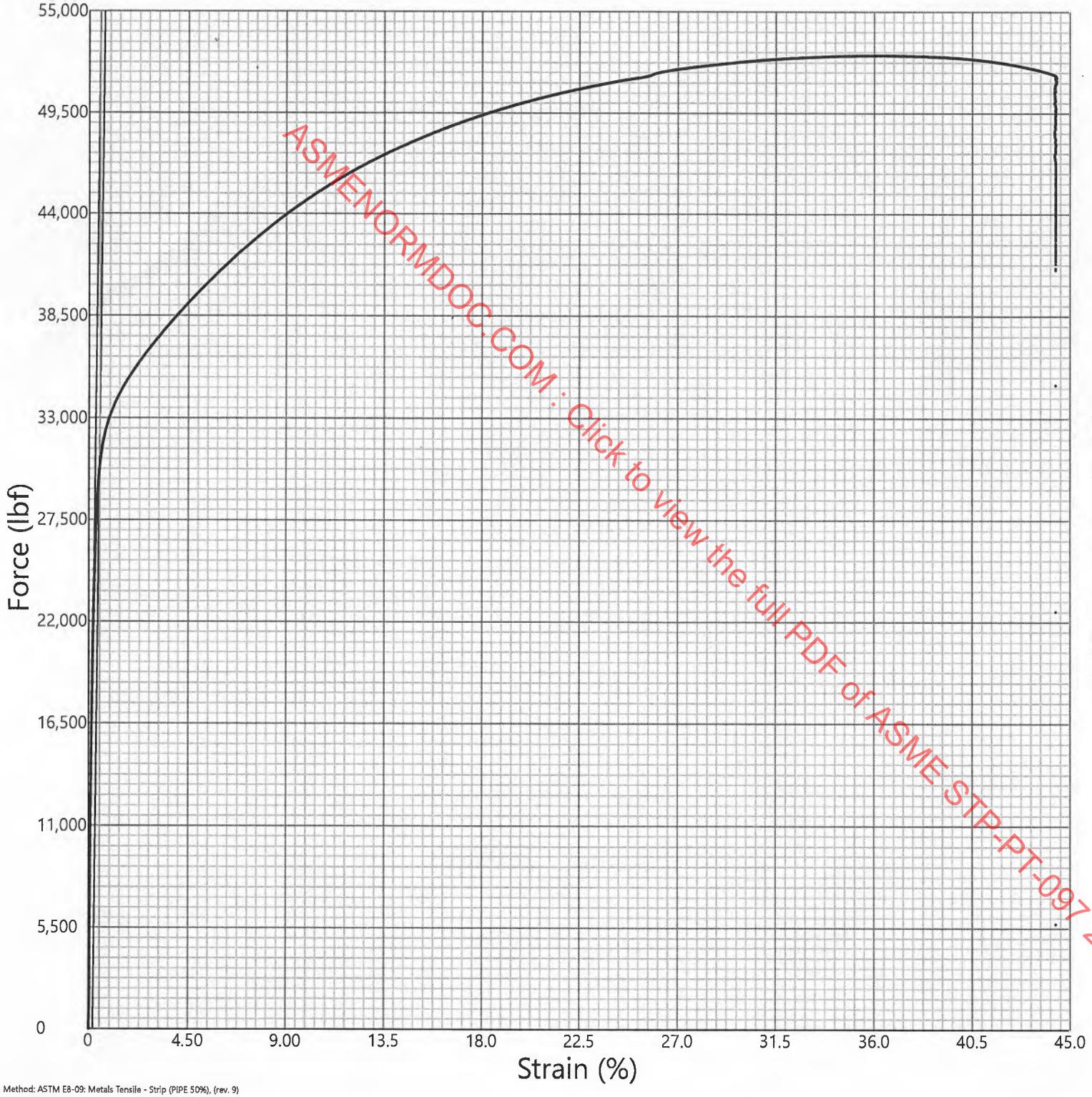


Lab No: B2L2-0693
Operator: JS

Sample ID:	3 TBT T2
Width:	1.5070 in
Thickness:	0.38400 in
Area:	0.57869 in²
OS @ 0.2%:	29868 lbf
OS @ 0.2%:	51600 psi
EUL @ 0.5%:	29147 lbf
EUL @ 0.5%:	50400 psi
Ultimate Force:	52239 lbf
Ultimate Stress:	90300 psi
Modulus:	14600000 psi
TE (Manual):	68.9 %
Test End :	11/2/2022 9:18 AM

BRYAN LABORATORY, INC

ASTM E8 Metals Tensile

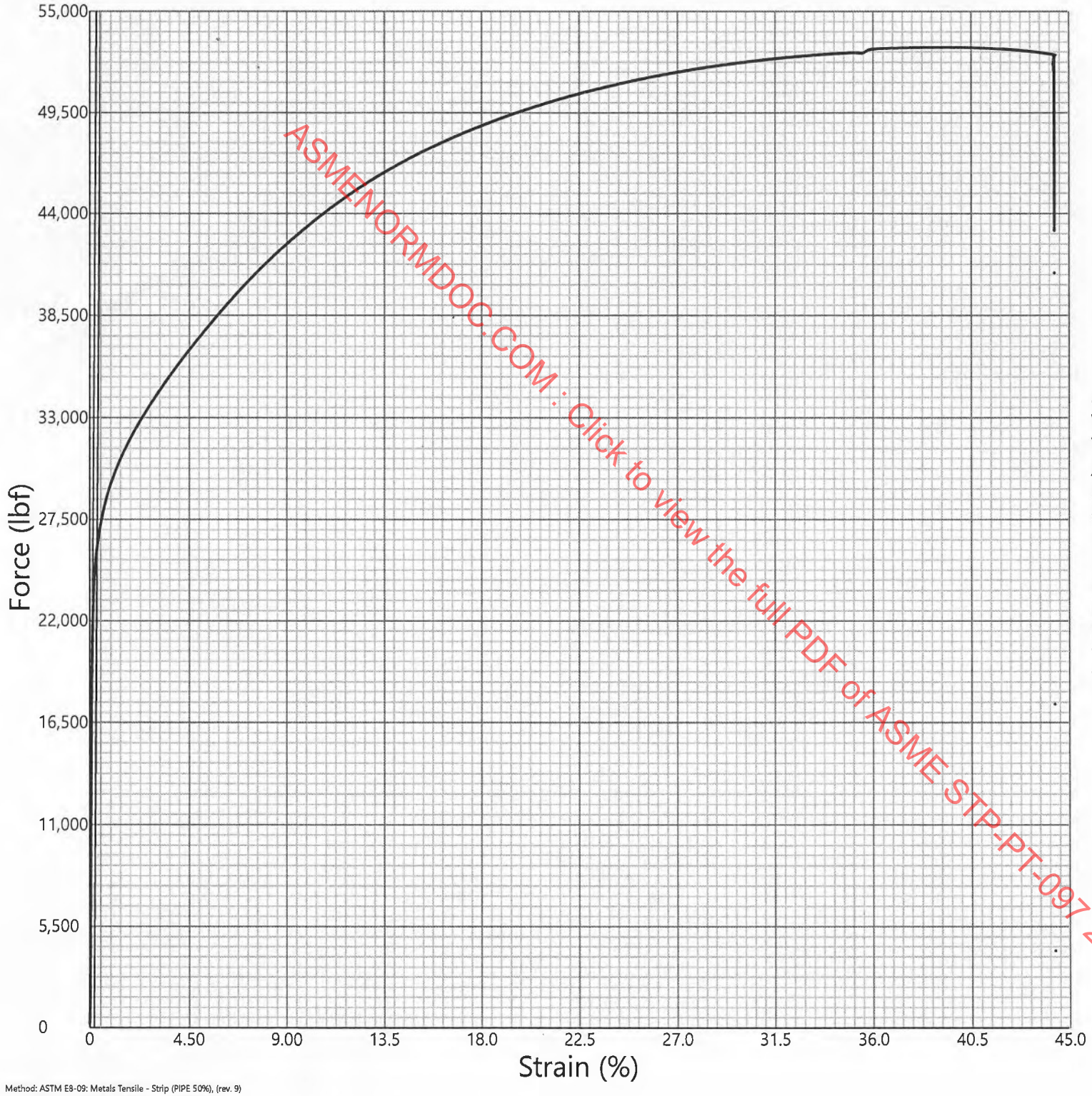


Lab No: B2L2-0693
Operator: JS

Sample ID:	3 TBT T3
Width:	1.5070 in
Thickness:	0.37600 in
Area:	0.56663 in²
OS @ 0.2%:	30222 lbf
OS @ 0.2%:	53300 psi
EUL @ 0.5%:	30504 lbf
EUL @ 0.5%:	53800 psi
Ultimate Force:	52650 lbf
Ultimate Stress:	92900 psi
Modulus:	19300000 psi
TE (Manual):	72.2 %
Test End :	11/2/2022 9:57 AM

Method: ASTM E8-09: Metals Tensile - Strip (PIPE 50%), (rev. 9)
v10.3.0.7 - 323166US - Bryan Laboratory

Output: ASTM E8-09: Metals Tensile - Strip (PIPE 50%) (rev. 6)
Hydraulic (602)/2.23 : 60000lbf. Printed: 11/2/2022 9:59 AM



BRYAN LABORATORY, INC
ASTM E8 Metals Tensile

Lab No: B2L2-0693
Operator: JS

Sample ID:	3 LT T1
Width:	1.5090 in
Thickness:	0.39000 in
Area:	0.58851 in²
OS @ 0.2%:	25983 lbf
OS @ 0.2%:	44100 psi
EUL @ 0.5%:	27246 lbf
EUL @ 0.5%:	46300 psi
Ultimate Force:	53074 lbf
Ultimate Stress:	90200 psi
Modulus:	31500000 psi
TE (Manual):	72.8 %
Test End :	11/2/2022 10:39 AM