

## LIGO Technical Report

## MEASUREMENTS OF STAINLESS STEEL HYDROGEN CONTENT

## INTRODUCTION

This memo is a record of all the measurements of hydrogen content made to date on 304L stainless steel samples, by the LIGO Project.

The measurements were made by two commercial test laboratories.

MTC  
Metallurgical Testing Corporation  
15750 Salt Lake Avenue  
City of Industry, CA 91745  
818/968-0404 and 213/283-2020

Luvak  
722 Main Street  
Boylston, MA 01505  
617/869-6401

These laboratories used different methods for the hydrogen measurements:

- a) MTV used the LECO method, which melts the sample, and measures the gas emitted with a Pirani gage.
- b) Luvak used the ASTM-E-146 method, which heats sample, and measures the gas emitted with a McCloud gage.

Most of the samples were from steel made by:

J&L Specialty Products Corp.  
P.O. Box 920  
1500 W. Main St.  
Louisville, Ohio 44641  
216/875-6200

## RESULTS OF MEASUREMENTS

The results are presented as hydrogen ppm by weight.

Samples from a variety of sources are listed in Table I. These include a welded piece of a 24" diameter tube, 1000' long. The weld had much higher hydrogen content than the adjacent material.

Also shown is a sample from NKK, specially processed for low hydrogen.

### J&L Experiment

J&L took samples at various steps in the manufacture of Coil 7942391. The results of both Caltech and J&L measurements are shown in Table II and in Fig. 1. Note that 0.3 ppm was measured on two samples by Luvak.

TABLE I  
SAMPLES—MISCELLANEOUS  
All are 304L stainless steel

#	Date Tested	Sample Source & ID	Lab	H <sub>2</sub> Content ppm by weight
1.	12/31/87	Allegheny Ludlum, 2B Finish	MTC	2.0
2.	12/31/87	Allegheny Ludlum, Ground Finish	MTC	3.7
3.	12/31/87	Allegheny Ludlum, Hot Rolled, Annealed & Pickled	MTC	1.7
4.	12/31/87	J&L, 2D Finish, Section of 24" Pipe	MTC	1.5
5.	12/31/87	J&L, Weld Cut From 24" Pipe above	MTC	3.2
6.	12/31/87	Naylor Pipe, #1 Hot Rolled, Annealed & Pickled	MTC	2.6
7.	6/10/88	NKK Steel, Low Hydrogen Processed	Luvak	0.8

TABLE II  
 SAMPLES TAKEN AT VARIOUS STEPS IN PROCESSING  
 March 1988

COMPARISON OF HYDROGEN CONTENTS  
 BY LECO AND HOT EXTRACTION METHODS ON  
 STAINLESS 304L SHEET, COIL 7942391

	<u>CAL TECH</u> MTC - LECO METHOD	<u>J&amp;L</u> LUVAK - HOT EXTRACTION
Hot Rolled	(PPM) 2.4	(PPM) 1.9 Head 1.5 Tail
		1.5 Head } With Oxide 1.4 Tail } Ground Away
Bake 1500° F (Approx. 24 Hrs.)	1.0 Head 1.2 Tail	0.5 Head 0.9 Tail
		0.3 Head } With Oxide 0.3 Tail } Ground Away
After Continuous Anneal at 2150° F	1.7 Head 1.4 Tail	0.8 Head 0.8 Tail

The averages of the head and tail samples in the unground condition are plotted in the attached graph. (Fig. 1)

# COMPARISON OF HYDROGEN CONTENTS BY LECO & HOT EXTRACTION METHODS ON STAINLESS 304L SHEET, COIL 7942391

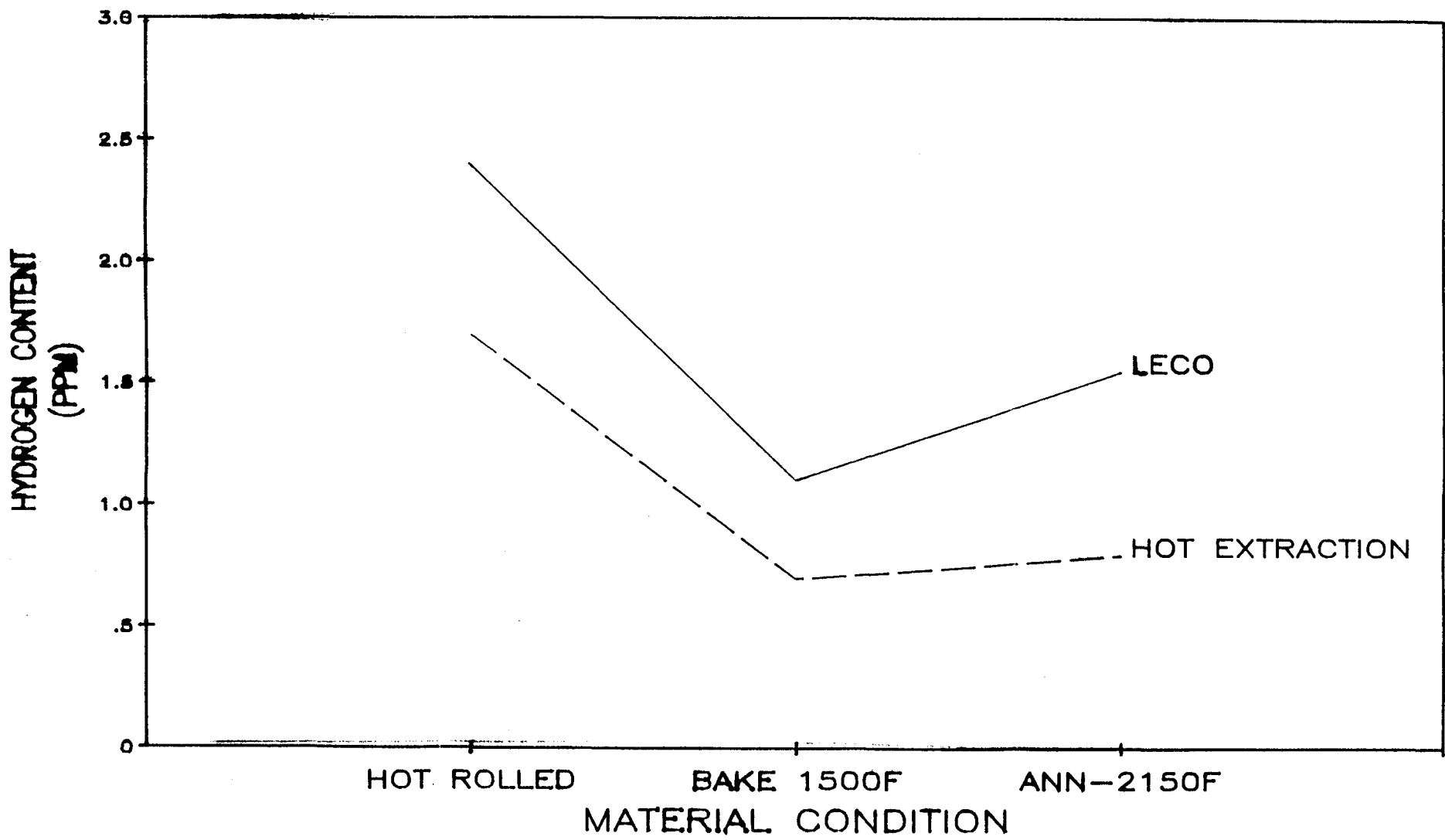


Figure 1

## J&L Low Hydrogen Steel

Five sheets of 304L stainless steel, processed for low hydrogen content, cut from Coil 7964169, were received from J&L. These were used to make four small vacuum chambers.

Samples were taken by J&L at various stages during manufacture. The hydrogen content of these samples is presented in Table III.

An additional sample was cut from the edge of each sheet at Caltech. The hydrogen content of these samples is presented in Table IV.

A strip was then cut from one sheet across the full width of the coil. Samples were taken from this strip and measured by both Luvak and MTC. The results are presented in Table V.

The properties of Coil 7964169 are shown in Fig. 2.

TABLE III  
 SAMPLES FROM COIL 7964169  
 AT VARIOUS STEPS DURING MANUFACTURE  
 Samples Taken by J&L, and Measured by Luvak.

HYDROGEN CONTENTS - COIL 7964169  
 TYPE 304L AFTER VARIOUS PROCESS TREATMENTS

Tests were taken from the same end of the coil corresponding to the end on which sample pieces were sent to Cal Tech.

	HYDROGEN CONTENT (PPM) (HOT EXTRACTION METHOD - LUVAK)	
	<u>Avg.</u>	<u>Individual Results</u>
<u>As Hot Rolled (.155" x 50")</u>		
Edge Area	3.2	(3.1, 3.5, 3.0)
Crown Area	2.5	(2.8, 2.3, 2.5)
<u>1500° F - Approx. 24 Hours</u>		
Edge Area	0.8	(0.8, 0.6, 0.9)
Crown Area	0.9	(0.8, 1.0, 0.8)
<u>After Continuous Anneal at 2100° F and Pickled</u>		
Edge Area	1.2	(1.3, 1.0, 1.3)
Crown Area	1.2	(1.1, 1.3, 1.1)
<u>After Final Bake (650° F - 24 Hours)</u>		
Edge Area	1.5	(0.7, 2.3, 1.6)
Crown Area	0.5	(0.5, 0.4, 0.6)

TABLE IV  
SAMPLES FROM COIL 7964169  
(Used to make 4 LIGO chambers for VTF)

Samples were taken, one from the edge of each sheet, and tested by MTC 5/16/88.

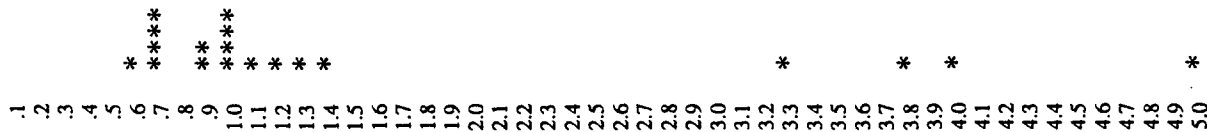
Sample	PPM by Weight
1	1.1
2	1.2
3	1.3
4	1.6
5	2.4

TABLE V  
 SAMPLES ACROSS WIDTH OF COIL 7964169  
 X Scale = 0" at one edge of coil, and 50.5" at other edge  
 All samples = 1" long x  $\frac{1}{2}$ " wide (except last one,  $\frac{1}{2}$ " long)

X	Luvak	MTC
1" to 2"	A2 = 1.0	
$6\frac{7}{8}$ - $7\frac{7}{8}$	A4 = .9	
$12\frac{3}{4}$ - $13\frac{3}{4}$	A6 = 3.3, 1.3, 5.0	
$18\frac{5}{8}$ - $19\frac{5}{8}$	A8 = 1.4, 1.2	
24.5-25.5	A10 = .9	B10 = 1.9
$30\frac{3}{8}$ - $31\frac{3}{8}$	A12 = 1.0	B12 = 1.9
$36\frac{1}{4}$ - $37\frac{1}{4}$	A14 = 1.0	
$42\frac{1}{8}$ - $43\frac{1}{8}$	A16 = 3.8, .7, 1.0	
48-49	A18 = .7, .7	B18 = 2.4
49-50	A19 = 4.0, .7, .6	
50- $50\frac{1}{2}$	No # = 1.1	
	Average, 19 tests = 1.59	Average, 3 tests = 2.07

This test was repeated by J&L with fresh material taken from the coil. Of 12 samples measured by Luvak, all were less than 0.7 ppm, while the lowest was 0.4 ppm.

The histogram below shows the distribution of Luvak measurements.





**PRELIMINARY TEST REPORT**

BOX 20 LOUISVILLE, OHIO 44641

CODE 30	MILL ORDER NO 69930	CUSTOMER PART NO 304L	DESCRIPTION HR A&P				SHIPPER DATE 04/22/88	SHIPPER NO L71602 PAGE 1 OF 1									
END USE		1.1600 NOM	IN	48.000	IN	38.700	IN										
		4.06	MM	1219.20	MM	982.98	MM										
MATERIALS PRODUCED TO AND CONFORM WITH NONE							P.O. NO. SAMPLE										
S O L D T O	J & L SPECIALTY PRODUCTS CORP. ACCOUNTS PAYABLE P.O. BOX 3373 PITTSBURGH, PA 15230		LIFT NO. S27398	HEAT NO. 76653	COIL NO. 7964169	PIECES 5	NET WEIGHT LBS 480 KG 218										
	S H I P T O	CALIFORNIA INSTITUTE OF TECHNO 391 SOUTH HOLLISTON AVENUE PASADENA, CA 91125			TOTALS	5	480	218									
HEAT NO. L 76653		C .026	MN 1.70	P .027	S .021	SI 0.57	Cr 18.19	Ni 08.67	Mo 0.19	Cu 0.21	Co .08	N <sub>2</sub> .082	Al	Ti			
COIL/LIFT NO. 7964169	SIDE	HARDNESS RB 87.5	YIELD PSI 51,200 MPA 353		TENSILE PSI 89,000 MPA 614		ELONG % 56	OLSEN	BEND TEST 1XT	ANGLE 180	KAZ XXXR						
COIL/LIFT NO. 7964169	GRAIN SIZE	CORROSION	GSM														

Figure 2 - Properties of 304L Coil 7964169

R. W. MC CABE  
04/22/88