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Performance Testing of Historically Appropriate Blast-Resistant Windows Volume 2 – Test Data

Julie L. Webster and Patrick E. Reicher,
ERDC-CERL

September 2007

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Construction Engineering
Research Laboratory



**US Army Corps
of Engineers®**
Engineer Research and
Development Center

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Performance Testing of Historically Appropriate Blast-Resistant Windows

Volume 2 – Test Data

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Final Report

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Prepared for Legacy Resource Management Program
Washington, DC

Under Reimbursable Order 97/0100/701/A/W31RY041533803/PO

ABSTRACT: This study leverages findings of Legacy Project 03-176, *Antiterrorism Measures for Historic Properties*. The authors identified few sources of UFC 4-010-01-compliant replacement windows appropriate for historic building applications. Most window suppliers will quote a job to produce prototype windows, but they (1) have no current blast test data for their product, and (2) have no experience with historic building applications. This suggested a need for window testing to help ensure that DoD has multiple trusted sources for historically compatible blast-resistant window products.

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Preface

This study was conducted by the U.S. Army Engineer Research and Development Center (ERDC) for the Office of the Deputy Under Secretary of Defense for Environmental Security under the Legacy Resource Management Program; Reimbursable Order 97/0100/701/A/W31RYO41533803/PO, *Blast Testing of Historically Appropriate Blast-Resistant Windows*, dated 23 July 2004. The technical monitor was L. Peter Boice, Director, ODUSD (ES) EQ-LP.

The work was performed by the Land and Heritage Conservation Branch (CN-C) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The project manager was Julie L. Webster. Christopher M. White was Chief, CEERD-CN-C, and Dr. John T. Bandy was Chief, CEERD-CN during preparation of this report. Dr. William D. Severinghaus was the Technical Director of the Military Lands business area. Dr. Kirankumar V. Topudurti was the Deputy Director of CERL, and Dr. Ilker R. Adiguzel was Director.

Blast consulting and review services were provided by Edward J. Conrath and William J. Veys of the U.S. Army Corps of Engineers-Protective Design Center, Omaha, NE.

The Commander and Executive Director of ERDC was COL Richard B. Jenkins and the Director was Dr. James R. Houston.

Test Results

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Shock Tube Testing for Historic Windows

Prepared for:

**US Army Engineering Research and Development Center
Construction Engineering Research Laboratory**

Conducted at:

ABSC Shock Tube Test Range
San Antonio, Texas
August 28-29, 2007

ABSC Project Number 1650234

Report date:

September 19, 2007

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Introduction

ABSG Consulting, Inc. (ABSC) conducted testing of two window systems for the US Army Engineering Research and Development Center - Construction Engineering Research Laboratory (ERDC). Testing was conducted to evaluate the ability of commercially available products, which match historic windows, to provide blast mitigation that meets UFC 4-010-01 for buildings subject to 36 CFR Part 67, *Secretary of the Interior's Standards for Rehabilitation* (SOI Standards). Testing was conducted at the ABSC facilities in San Antonio, Texas, USA on August 28-29, 2007.

This report describes the test fixture, test samples, and test results. Data sheets for each test item are included in Appendix A. Drawings of test items supplied by the window vendors are also included in Appendix B.

Test Protocol

Testing was conducted in accordance with ASTM F1642, *Standard Test Method for Glazing and Glazing Systems Subject to Air-blast Loading*. Data sheets for each test item contain the information required by the test protocol.

Windows were received at the ABSC test range prior to testing. Windows were marked to identify the vendor and specimen number. Prior to testing, dimensions of the framing and glazing, including glass type and thickness, were verified to insure compliance with the drawings. Prior to testing, glazing and ambient temperatures were recorded.

Windows were installed in a sub-frame by the vendors and mounted in the test cubicle. Blast gauges were mounted on each side and above the test window. Photographs were taken of test specimens and the test setup prior to and following each test to document window performance. The shock tube was anchored to the test cubicle to limit leakage pressures and provide a reaction mechanism to prevent movement of the cubicle.

A Yokogawa data acquisition system, sampling at 1 MHz, was used to record pressure-time histories for the installed gauges. Following application of the blast load, the floor of the test cubicle was inspected for glass fragments. The witness panel was also inspected for fragment impact. Frame and glass panel deflections were recorded. For this testing, no fragments or penetrations were observed in the witness panel. Only glass dusting was observed on the interior of the cubicle. A hazard level was assigned to each test specimen based on the observed fragmentation using the rating system prescribed in the ASTM protocol as shown in Figure 1.

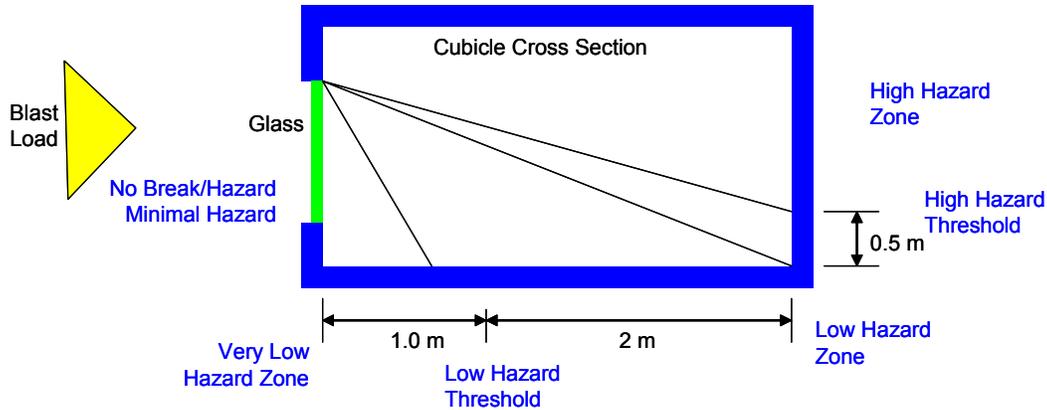


Figure 1 Hazard Level Diagram per ASTM F-1642

Test Equipment

Blast loads were applied using a “shock tube” as shown in Figure 2. This device uses a sudden burst of compressed air to create a blast pulse, which travels down the tube and is applied to the test specimen mounted in an enclosure (test cubicle) attached to the end. The blast load creates a specified positive blast pressure and impulse on the test specimens. Negative phase blast loads are developed but are typically less than the negative pulse typical of a high explosive load.

Test windows were mounted in sub-frames by the manufacturers. These sub-frames were mounted in the test cubicle fully supported by a steel angle on all sides from the rear (non-loaded) face and by a flat “capture” plate on the front (loaded) face to restrain the window during rebound. A general elevation and section of this arrangement is shown in the fixture drawings in Appendix C.

Applied Blast Loads

Testing commenced with blast loads prescribed by ERDC: peak pressure = 9.6 psi, positive impulse = 41.6 psi-ms within minus 5%. The same nominal blast pressure was applied to each specimen although loads for individual tests varied somewhat. A change in diaphragm material created loads significantly lower for one test specimen. A total of three tests were performed on this test item to develop the target blast load.



Figure 2. ABS Consulting Shock Tube Apparatus

Test Specimens

Two vendors (Custom and Kawneer) prepared the complete window system for each test item. Windows were installed in steel sub-frames by the vendors. These units were then installed in a fixture in the test cubicle. Drawings for the two window systems are included in Appendix B. Three test specimens were prepared for each of the two window systems. Glazing for all of the windows tested consisted of laminated insulated glass units [IGU].

Custom Windows were double hung units. Kawneer windows were fixed lite on top and bottom with an operable project-out vent in the center section. Non-structural sealant was applied to the junction of the frame and the steel channel sub-frame for both window systems. Window frame assemblies were rigidly supported on all four sides. Window anchorage and attachment to the wall substructure was not evaluated in the testing. Figure 3 shows a typical window mounted in the test sub-frame affixed to the test fixture.

Test Cubicle

The test cubicle, nominally 10 feet deep, 51 inches wide, and 96 inches high, was enclosed to prevent blast pressures from wrapping around the structure and reaching the back side of the window. This represents a typical window installation on an exterior wall. A witness panel was provided on the back wall to detect the impact of glass shards. The witness panel is nominally 10 ft. from the test window. Actual distance varies with window configuration. For the double

hung windows, the glazing components are at different locations along the axis of the cubicle. The minimum distance from glazing to the witness panel is approximately 110 in. This produces a somewhat conservative rating of hazard level with respect to fragments on the witness panel since fragments travel less than 120 in.



Figure 3. Steel Sub-frame with Window Mounted in Test Cubicle

Test Instrumentation

Blast pressure gauges measuring reflected pressure were mounted on the front of the test cubicle facing the oncoming blast wave, immediately adjacent to the test specimen (see Figure 4). Data are recorded on a digital oscilloscope and waveforms are converted to pressure-time histories in DPlot format for each gauge.

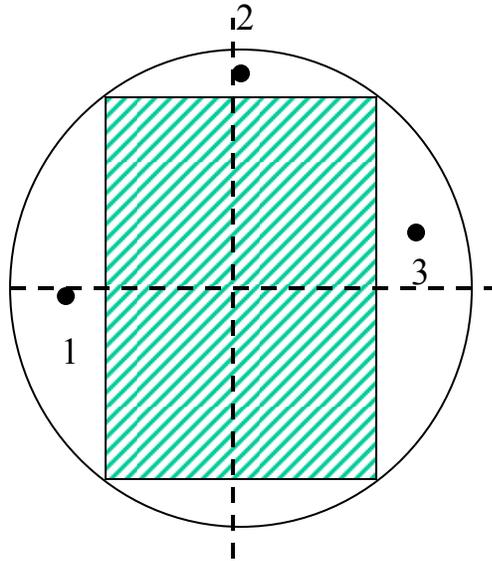


Figure 4 Pressure Gauge Locations

Discussion of Results

Both glazing systems performed well in the tests. All samples resulted in a Minimal Hazard level rating which means there was only glass dusting inside the test cubicle. This dusting was insufficient to weigh and created by flexure of the laminated inside lite. Three samples of each type were tested which is sufficient to obtain a rating in accordance with ASTM F-1642.

Only one instance of pvb interlayer tearing was noted (Test 3). This may have been caused by impact from the non-structural muntin. No frame or fastener failure was noted during the tests. In all cases, windows remained operable although significant force was typically required due to interference from deformed laminated glass lites.

Blast pressure-time histories for gauges in test 1 were not recorded due to an error in the acquisition system setup. Since the blast pressure duration and impulse are controlled by the driver burst pressure, it was possible to determine the blast loads for this test based on the recorded pressure-time histories for test 2 and 3. The burst pressure for test 2 and 3 was within 0.3% of the burst for test 1. The average pressure, duration and impulse for tests 2 and 3 were reported as the blast load for test 1.

New diaphragm material was used beginning with test 5 due to the presence of scratches in the diaphragms made from the original material. This material exhibited a significantly lower burst pressure than that used for tests 1-4. Consequently, the blast loads for test 5 were much lower, and in fact, did not produce glass breakage in sample K-2. New diaphragms were installed and

K-2 was retested (recorded as test 5A). The new diaphragm material again burst at a lower driver pressure although somewhat higher than test 5. The original diaphragm material was located and installed for another retest of K-2. This retest was recorded as test 5B. Blast loads for this test were consistent with tests 1-4 and met the target loads. Original diaphragm material was used for the final test 6.

During test 6, gauge 3 did not record data. This was attributed to a gauge connection failure. The remaining two gauges recorded data consistent with previous tests.

Submitted by:



Darrell D. Barker
Test Director
ABS Consulting

Appendix A

Data Sheets

Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	C1
Description:	Double Hung
Test Date:	8/28/2007
Test Number:	1
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
Notes:	See drawing 01651 Page 1, D1

Frame Information

Width (in):	42
Height (in):	76
Width:	5.5
Material:	Aluminum

Note: Anchored to C channel with #12x2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	11.31	11.38	11.31
Height (in):	16.34	16.34	16.22
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	1/4		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	93	93
Glass Surface (F):	91	90

Blast Pressure Information

	Gauge Number				Average ¹	Note 1:
	1	2	3			
Peak Reflected Pressure (psi)					11.0	Data traces not captured by instru Diaphragm burst = 112 psi. Test burst = 111.6 psi. Loads are ave from test 2 and 3
Positive Phase Duration (ms)					16.9	
Positive Phase Impulse (psi-ms)					42.8	

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	Dust	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: Inside and outside lites fractured, no fragments in cube, operable following test

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	Yes
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	C1
		Other Specimens:	C2, C3

Pre-Test Photograph



Post-Test Photograph



Blast Trace

Not available. See Note 1

Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	C2
Description:	Double Hung
Test Date:	8/28/2007
Test Number:	2
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
Notes:	See drawing 01651 Page 1, D1

Frame Information

Width (in):	42
Height (in):	76
Width:	5.5
Material:	Aluminum

Note: Anchored to C channel with #12x2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	11.31	11.38	11.31
Height (in):	16.34	16.34	16.22
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite	Outer Lite	
Thickness (in):	1/4	1/4	
Glass Type:	Annealed-Laminated	Annealed-Monolithic	
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	89	86
Glass Surface (F):	89	91

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	11.2	10.6	11.3		11.0
Positive Phase Duration (ms)	16.4	16.8	17.3		16.8
Positive Phase Impulse (psi-ms)	45.7	36.8	44.4		42.3

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	Dust	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: Inside and outside lites fractured, no fragments in cube, operable following test

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	Yes
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	C2
		Other Specimens:	C1, C3

Pre-Test Photograph

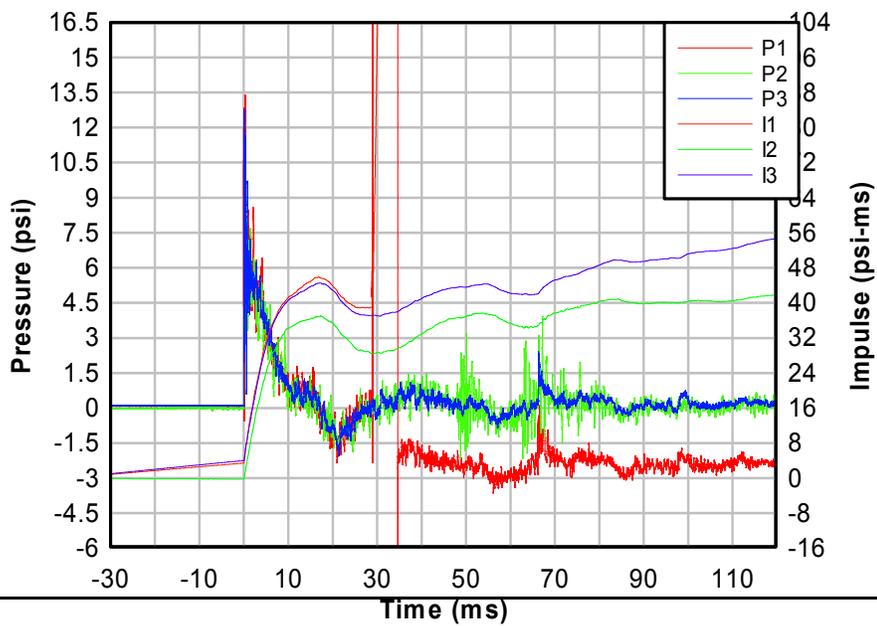


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 2**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	C3
Description:	Double Hung
Test Date:	8/28/2007
Test Number:	3
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
Notes:	See drawing 01651 Page 1, D1

Frame Information

Width (in):	42
Height (in):	76
Width:	5.5
Material:	Aluminum

Note: Anchored to C channel with #12x2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	11.31	11.38	11.31
Height (in):	16.34	16.34	16.22
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite	Outer Lite	
Thickness (in):	1/4	1/4	
Glass Type:	Annealed-Laminated	Annealed-Monolithic	
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	82	79
Glass Surface (F):	82	81

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	12.4	10.5	10.2		11.0
Positive Phase Duration (ms)	16.7	17.0	17.3		17.0
Positive Phase Impulse (psi-ms)	45.7	38.7	45.1		43.2

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	Dust	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	1-1/4"	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: Inside and outside lites fractured, no fragments in cube, operable following test

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	Yes
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	C3
		Other Specimens:	C2, C3

Pre-Test Photograph

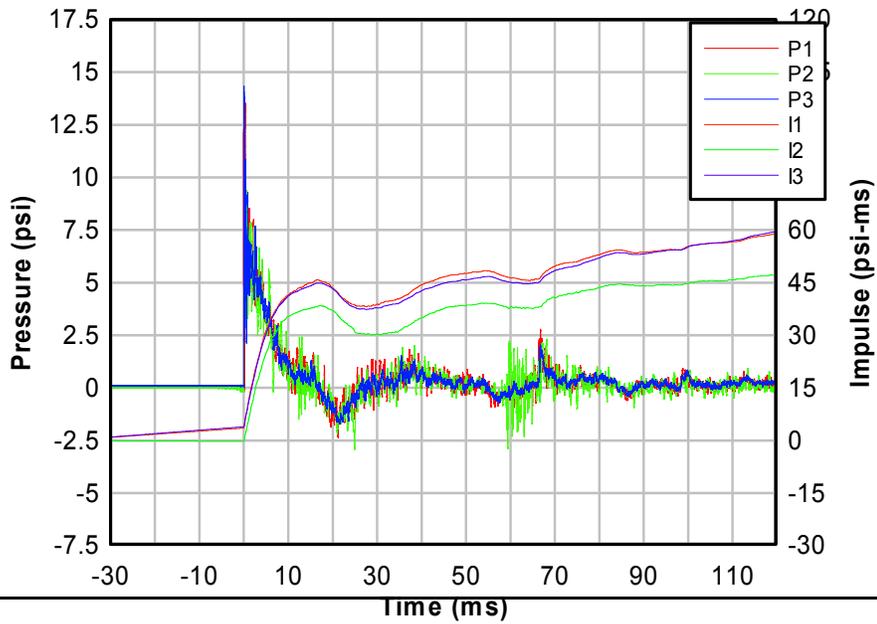


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 3**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	K1
Description:	Fixed/Project Out
Test Date:	8/29/2007
Test Number:	4
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
Notes:	See Kawneer drawings KUD325801-01 thru 05

Frame Information

Width (in):	42.00
Height (in):	66.00
Width:	3.25
Material:	Aluminum
Note:	Achored to C channel with 1/4" x 2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	37.88	35.00	
Height (in):	13.50	27.00	
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	5/16		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	84	88
Glass Surface (F):	84	88

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	11.5	10.8	11.4		11.2
Positive Phase Duration (ms)	16.8	18.6	17.0		17.5
Positive Phase Impulse (psi-ms)	42.7	44.1	42.3		43.0

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	Dust	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: Inside and outside lites fractured on project out, no break of fixed, no fragments in cube, operable following test

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	Yes
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	K1
		Other Specimens:	K2, K3

Pre-Test Photograph

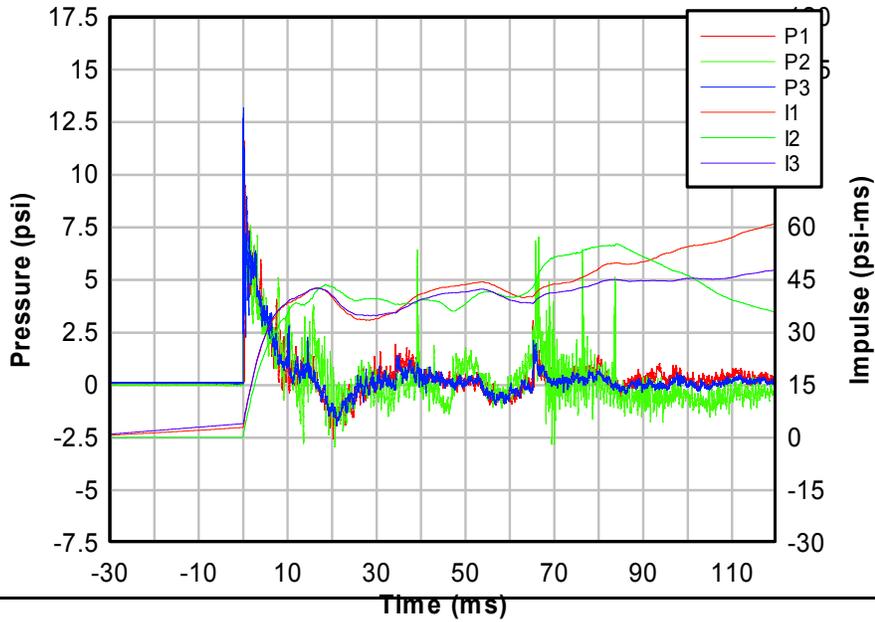


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 4**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	K2
Description:	Fixed/Project Out
Test Date:	8/29/2007
Test Number:	5
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
	See Kawneer drawings KUD325801-01 thru 05
Notes:	Diaphragm material new lot, low burst

Frame Information

Width (in):	42.00
Height (in):	66.00
Width:	3.25
Material:	Aluminum
Note:	Achored to C channel with 1/4" x 2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	37.88	35.00	
Height (in):	13.50	27.00	
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	5/16		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	84	83
Glass Surface (F):	84	84

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	9.3	7.4	9.3		8.7
Positive Phase Duration (ms)	16.3	17.3	15.9		16.5
Positive Phase Impulse (psi-ms)	28.9	28.7	30.4		29.2

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	N/A	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: No breaks

ASTM F-1642 Hazard Level:	No Break	Certified for Test Pressure per ASTM F1642:	No
		Certified Performance Level:	
		Specimen Number:	
		Other Specimens:	

Pre-Test Photograph

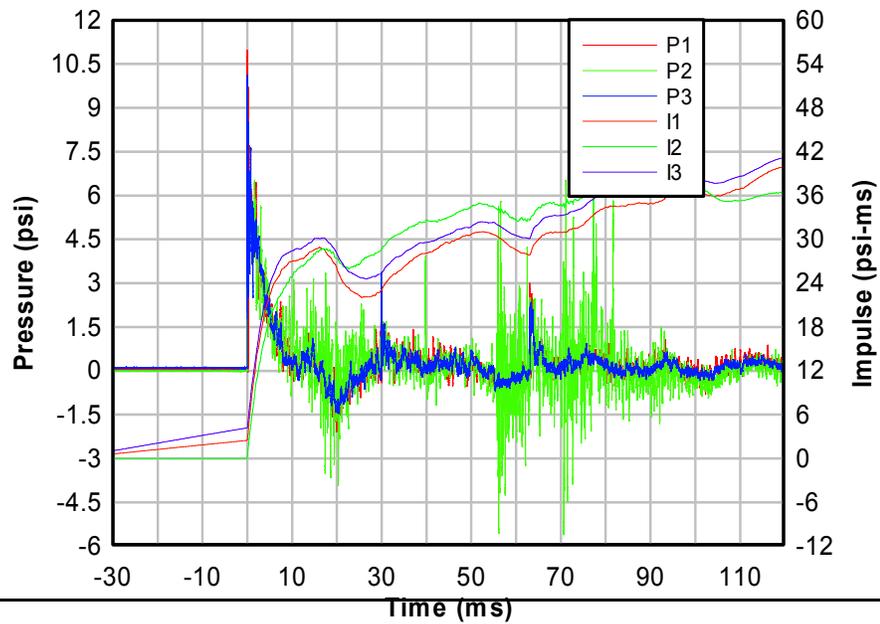


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 5**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	K2
Description:	Fixed/Project Out
Test Date:	8/29/2007
Test Number:	5A
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
	See Kawneer drawings KUD325801-01 thru 05
Notes:	Second test on same test item. Diaphragm material new lot, low burst

Frame Information

Width (in):	42.00
Height (in):	66.00
Width:	3.25
Material:	Aluminum
Note:	Achored to C channel with 1/4" x 2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	37.88	35.00	
Height (in):	13.50	27.00	
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	5/16		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	83	83
Glass Surface (F):	83	83

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	10.2	9.1	10.2		9.8
Positive Phase Duration (ms)	16.6	17.8	16.6		17.0
Positive Phase Impulse (psi-ms)	36.7	36.7	36.3		36.6

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	N/A	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

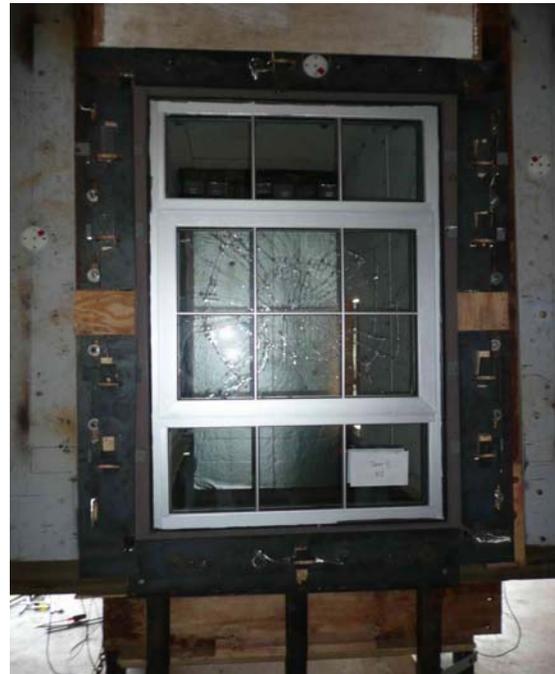
Notes: Inside and outside lite fractured on project out, no other breaks

ASTM F-1642 Hazard Level:	No Hazard	Certified for Test Pressure per ASTM F1642:	No
		Certified Performance Level:	
		Specimen Number:	
		Other Specimens:	

Pre-Test Photograph

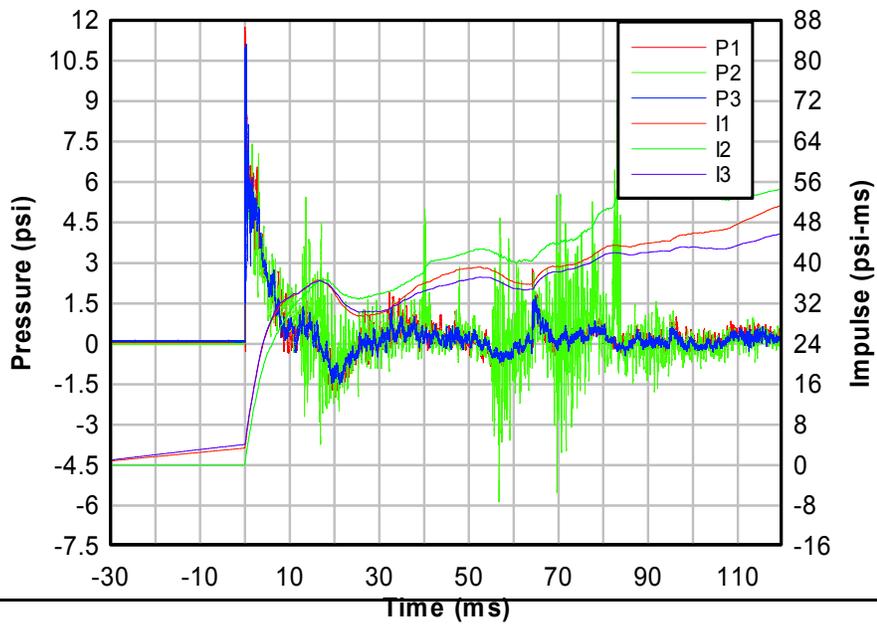


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 5A**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	K2
Description:	Fixed/Project Out
Test Date:	8/29/2007
Test Number:	5B
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
	See Kawneer drawings KUD325801-01 thru 05
Notes:	Third test on same test item. Diaphragm material old lot, correct burst

Frame Information

Width (in):	42.00
Height (in):	66.00
Width:	3.25
Material:	Aluminum
Note:	Achored to C channel with 1/4" x 2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	37.88	35.00	
Height (in):	13.50	27.00	
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	5/16		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	83	82
Glass Surface (F):	83	82

Blast Pressure Information

	Gauge Number				Average
	1	2	3		
Peak Reflected Pressure (psi)	11.6	9.5	11.6		10.9
Positive Phase Duration (ms)	16.8	16.8	17.3		17.0
Positive Phase Impulse (psi-ms)	48.2	49.6	47.4		48.4

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	N/A	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

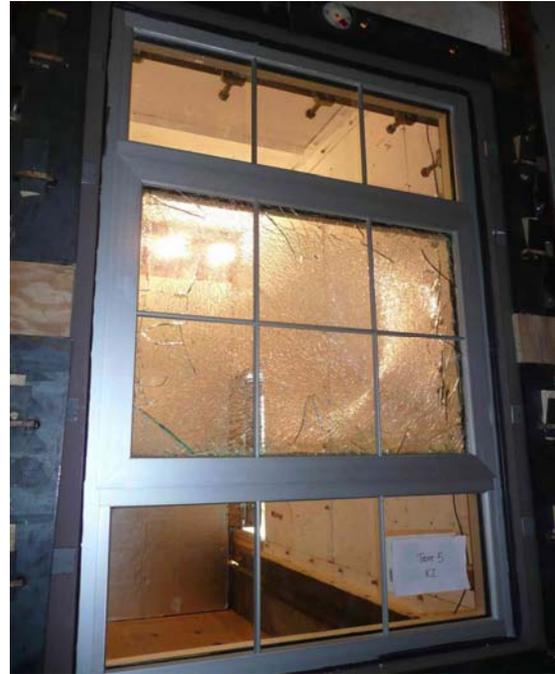
Notes: Inside and outside lite fractured on project out, no other breaks

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	No
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	K2
		Other Specimens:	K1, K3

Pre-Test Photograph

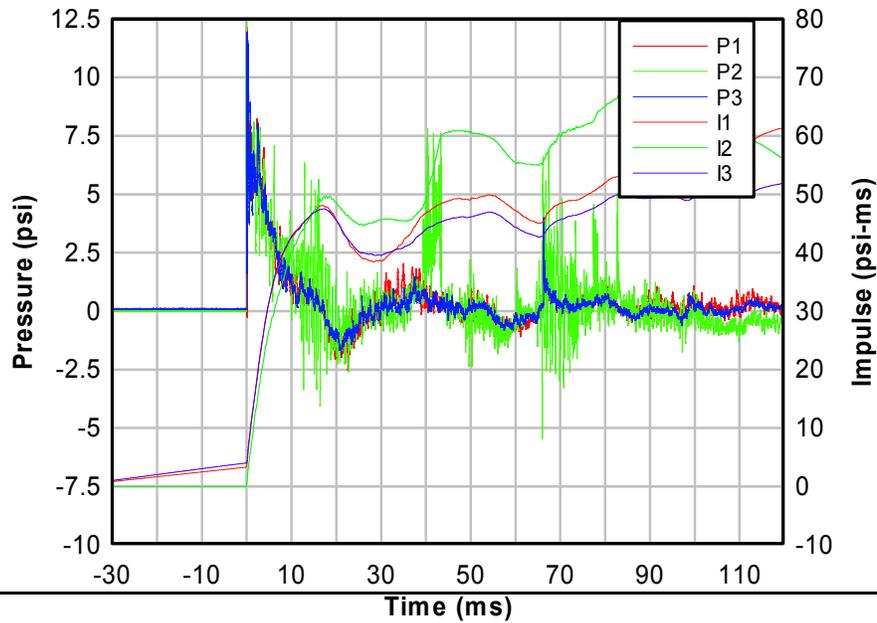


Post-Test Photograph



Blast Trace

**ERDC Historic Windows
Test 5B**



Data Sheet
Test Information

Client:	ERDC
Project Number:	1650234
SPECIMEN Number:	K3
Description:	Fixed/Project Out
Test Date:	8/29/2007
Test Number:	6
Test Report Number:	1650234
Report Date:	9/19/2007
Test Location:	ABS Test Range

Test Method:	• ASTM F-1642-04 "Standard Test Method for Glazing and Glazing Systems Subjected to Airblast Loadings"
Notes:	See Kawneer drawings KUD325801-01 thru 05

Frame Information

Width (in):	42.00
Height (in):	66.00
Width:	3.25
Material:	Aluminum
Note:	Achored to C channel with 1/4 x 2" screws @ 6" o.c.

Glazing Information

Multiple Lites?	Yes		
	Lite 1	Lite 2	Lite 3
Width (in):	37.88	35.00	
Height (in):	13.50	27.00	
IGU?	Yes	Air Gap (in):	1/2
	Inner Lite		Outer Lite
Thickness (in):	5/16		1/4
Glass Type:	Annealed-Laminated		Annealed-Monolithic
Notes:	0.060" PVB interlayer		

Temperature

	-30 min	-5 min
Ambient (F):	82	80
Glass Surface (F):	81	84

Blast Pressure Information

	Gauge Number				Average	Note:
	1	2	3			
Peak Reflected Pressure (psi)	12.7	8.9	N/A		10.8	Gauge 3 malfunctioned No Data
Positive Phase Duration (ms)	17.0	17.9	N/A		17.5	
Positive Phase Impulse (psi-ms)	48.2	51.9	N/A		50.1	

Damage Summary

	0-1m	1m-3m
Mass of Glass (g)	N/A	N/A
United Dimension (in):	~0	~0
	Interior	Perimeter
Length of Tears and Pullout (in):	0	0

Witness Panel Information

	Low Hazard	High Hazard
Perforations	N/A	N/A
Indents	N/A	N/A

Notes: Inside and outside lites fractured on project out, no break of fixed, no fragments in cube, operable following test

ASTM F-1642 Hazard Level:	Minimal Hazard	Certified for Test Pressure per ASTM F1642:	No
		Certified Performance Level:	Minimal Hazard
		Specimen Number:	K2
		Other Specimens:	K1, K3

Pre-Test Photograph

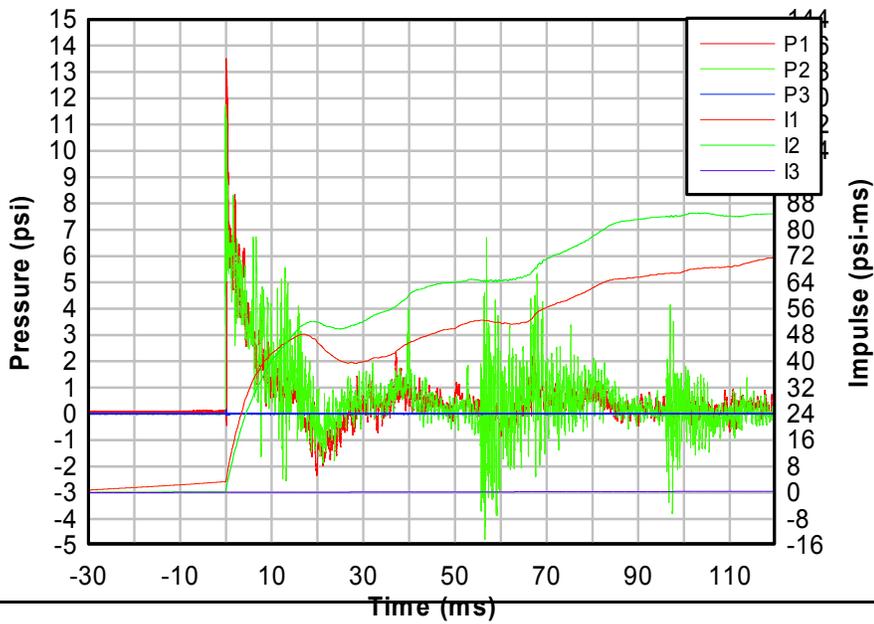


Post-Test Photograph



Blast Trace

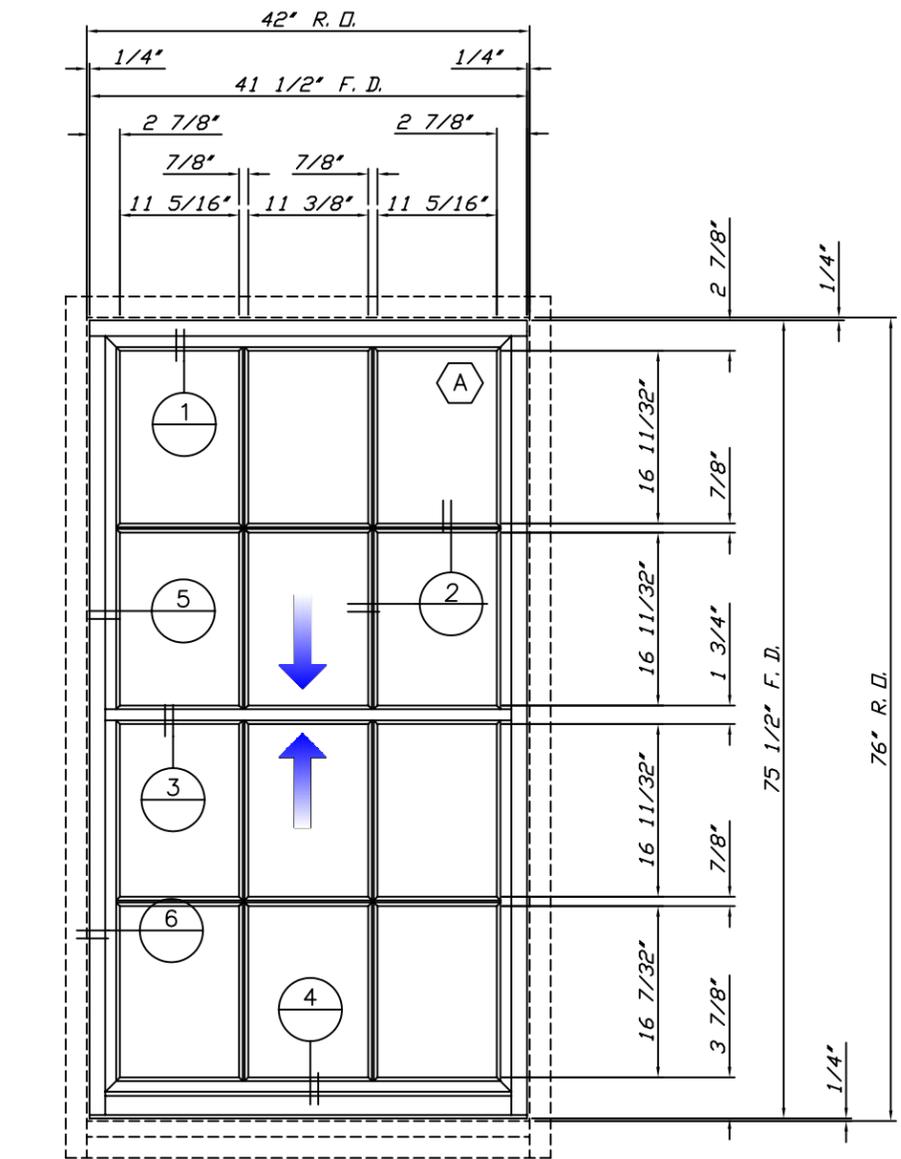
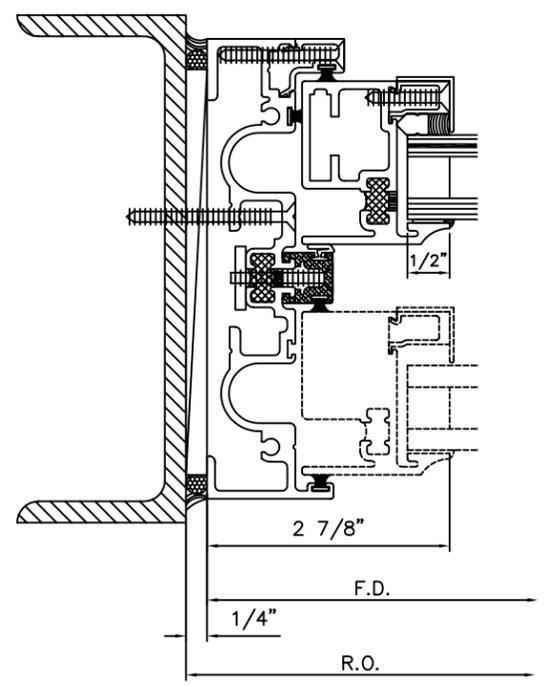
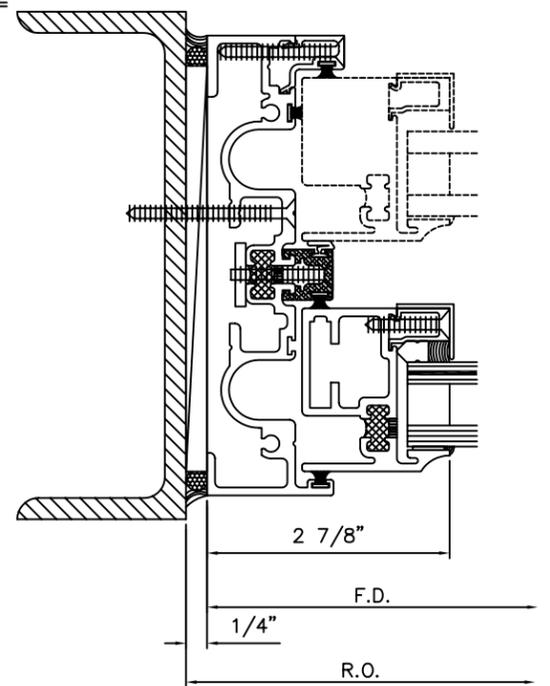
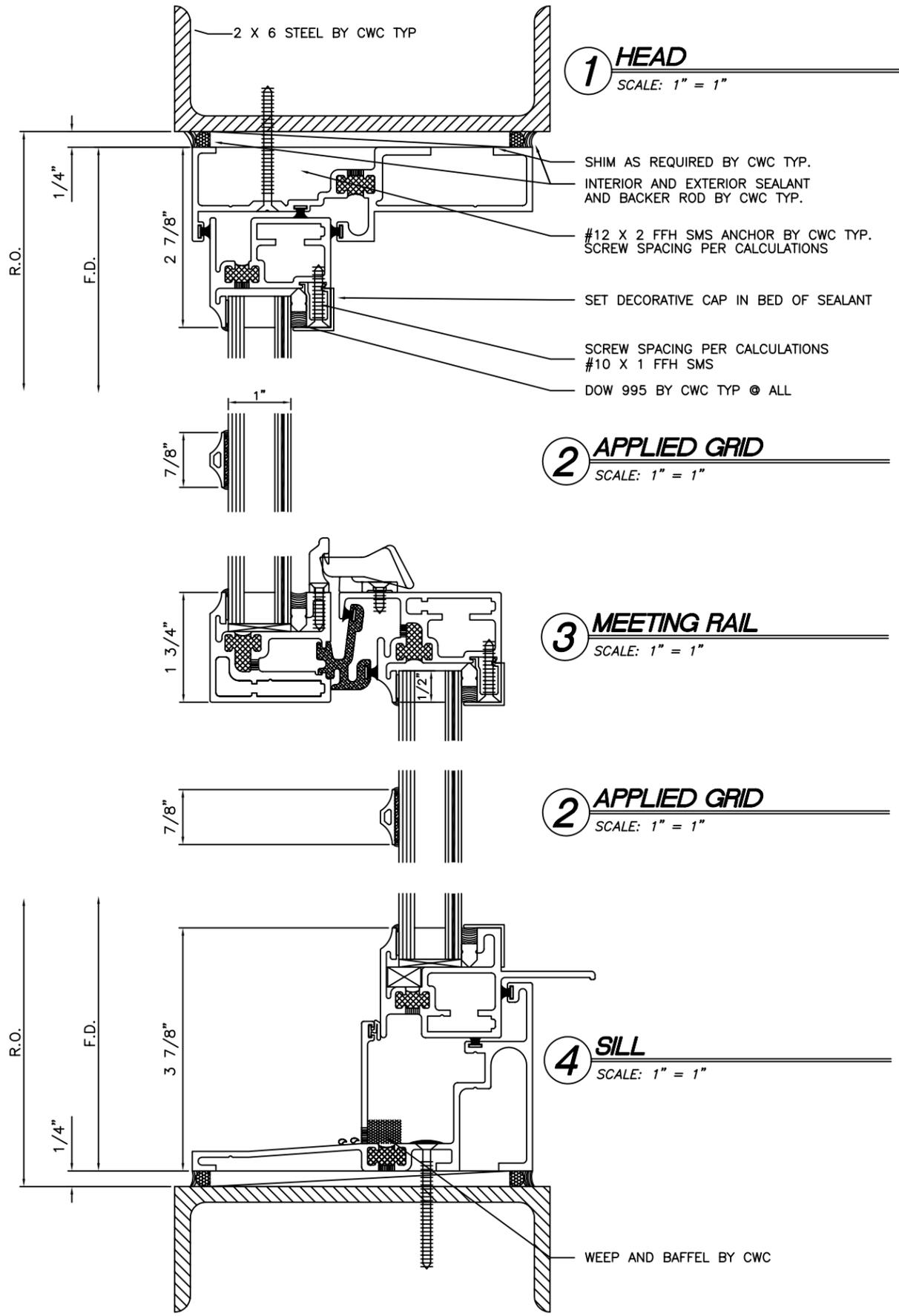
**ERDC Historic Windows
Test 6**



Appendix B

Window Drawings

NOTE: CONDITIONS SURROUNDING WINDOW PERIMETER ARE DRAWN FOR REFERENCE ONLY, AND NOT THE RESPONSIBILITY OF CUSTOM WINDOW.



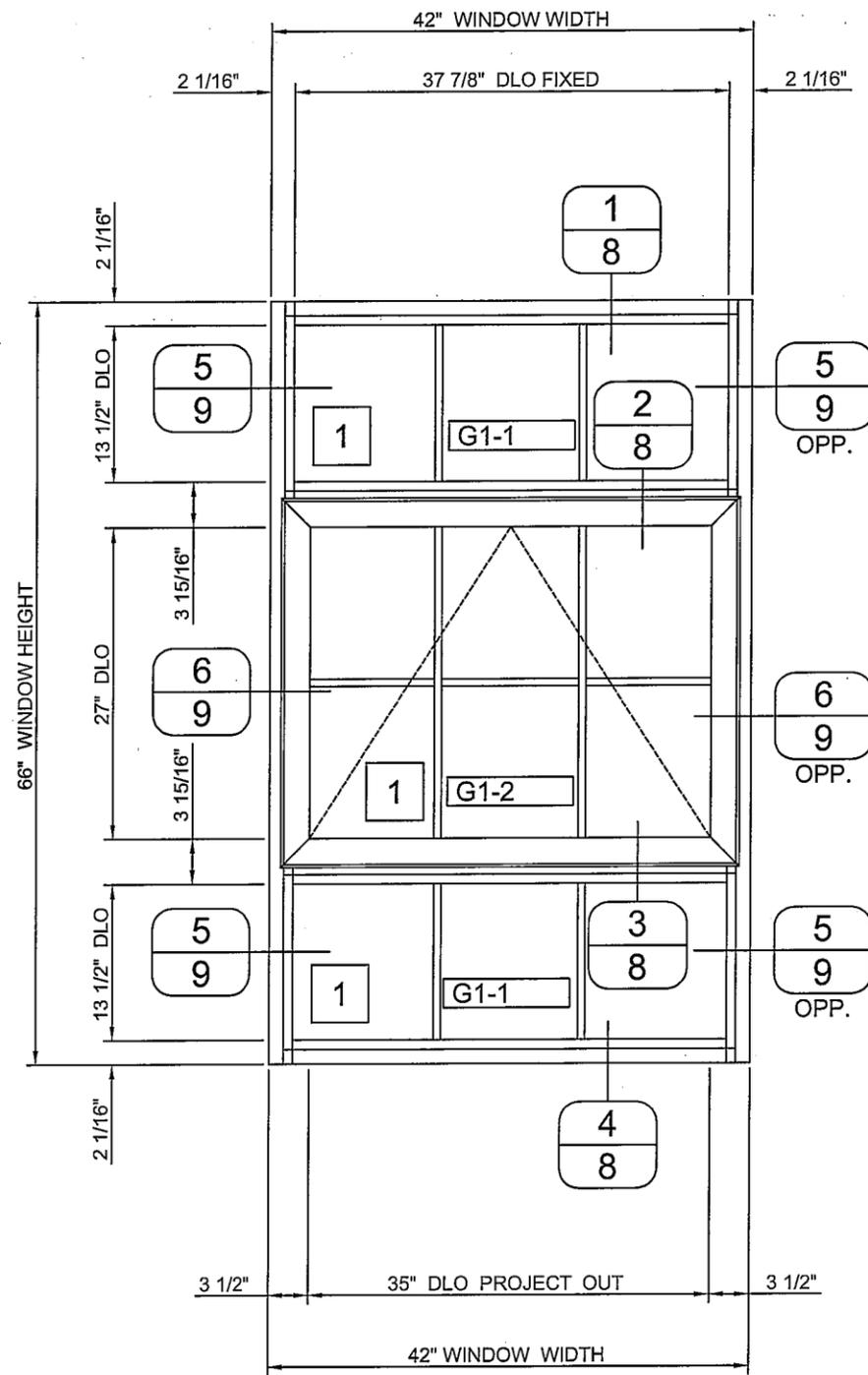
Custom Window

2727 S. SANTA FE DR.
ENGLEWOOD, CO 80110
303 722 0822
FAX 722 1993
800 255 1820

PROJECT: HISTORIC BLAST WINDOW
DRAWN BY: SHAWN
ARCHITECT: AS SHOWN
GLAZING CONTRACTOR: AS SHOWN
GENERAL CONTRACTOR: AS SHOWN

BY: SR
DATE: 5-9-07
SUBMISSION: 1 ST.

PRICE: **D1**



**8325TL WINDOW - FIXED/PROJECT-OUT/FIXED
(3) THUS REQUIRED**

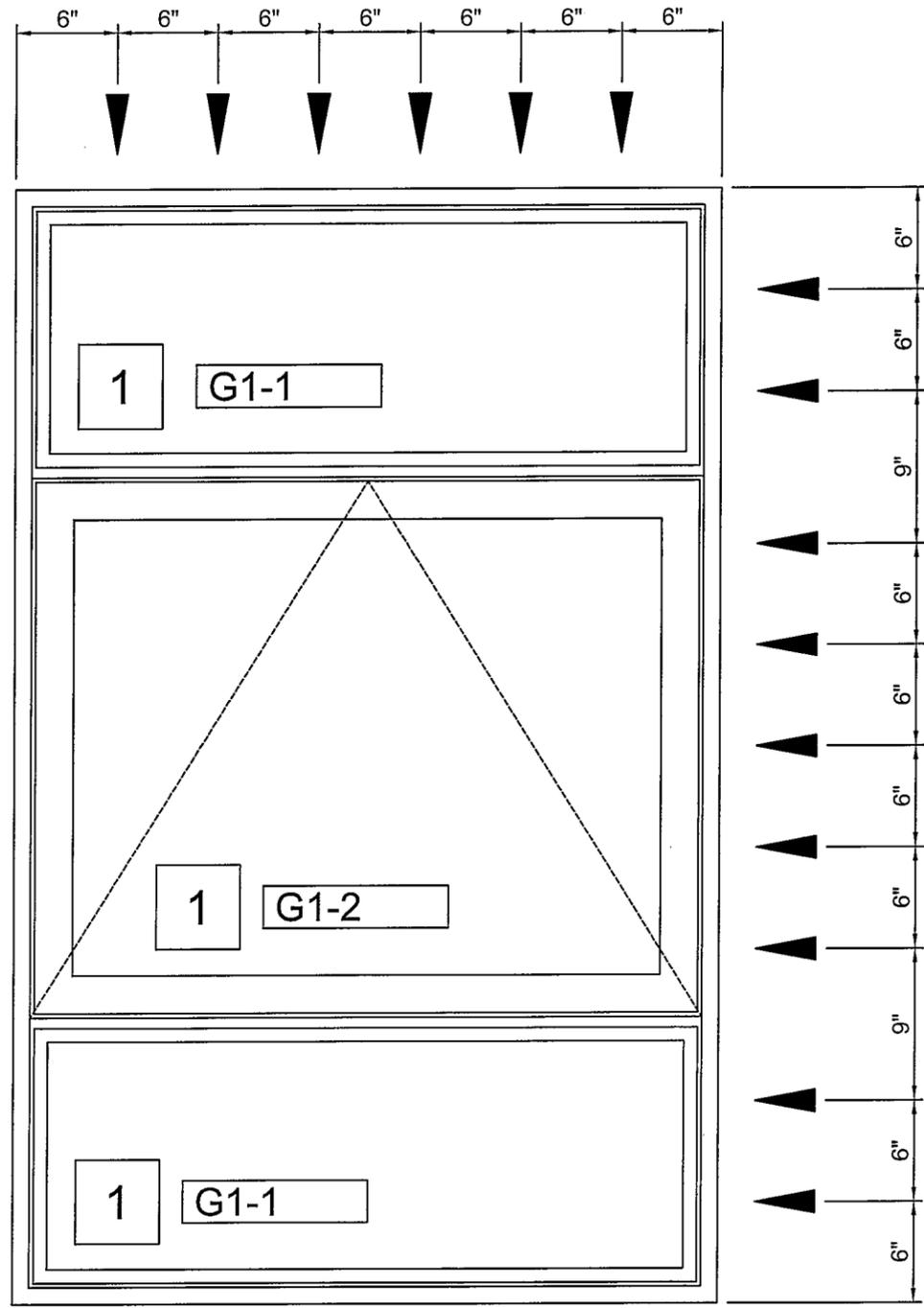
TESTING CRITERIA:
 PEAK APPLIED PRESSURE: 9.6 PSI
 POSITIVE PHASE IMPULSE: 42 PSI-MSEC

GLAZING SCHEDULE			
TYPE	NOMINAL THICKNESS	TYPICAL THICKNESS	DESCRIPTION
1	1"	1.028"	1/4" ANNEALED OUTBOARD / 1/2" AIR SPACED / 1/8" ANNEALED / .060 PVB / 1/8" ANNEALED
GLASS SIZE FORMULA: DLO + 1"			
<u>GLASS SIZES:</u>			
G1-1: 38-7/8" X 14-1/2" = 8 REQ'D.			
G1-2: 36" X 28" = 4 REQ'D.			

NOTES

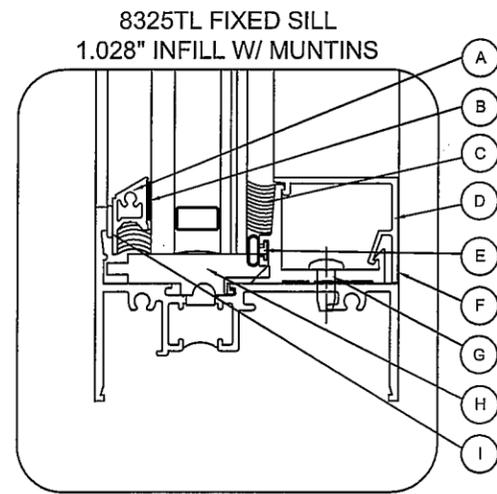
1. FINISH TO BE #17 CLEAR ANODIZED.
2. WINDOWS SHIPPED FABRICATED, ASSEMBLED, AND GLAZED.
3. SEE SHEET 2 OF 5 FOR FASTENER SCHEDULE, PERIMETER FASTENER LOCATIONS.
4. SEE SHEET 2 OF 5 HARDWARE SCHEDULE.
5. SEE SHEET 2 OF 5 FOR TYPICAL GLAZING DETAIL.
6. SILICONES USED:
 TREMCO TREMSIL 600 - WEATHER SEALS (E)
 TREMCO SPECTRUM II - PERIMETER SEALS (E)
 TREMCO PROGLAZE SSG - STRUCTURAL SEALS (S)

REV.	DATE	REQUEST LETTER	BY
E.C. NO.		95502-11 ??-??-07	
CONFIDENTIAL AND PROPRIETARY INFORMATION KAWNEER COMPANY INC.		THESE DRAWINGS ARE THE SOLE AND EXCLUSIVE PROPERTY OF KAWNEER AND CONTAIN SENSITIVE, PRIVILEGED OR CONFIDENTIAL INFORMATION WHICH MAY BE USED ONLY FOR ITS BENEFIT. THE DISCLOSURE OF THESE DRAWINGS TO UNAUTHORIZED PERSONS IS STRICTLY PROHIBITED. THIS DOCUMENT AND ALL COPIES MUST BE RETURNED UPON DEMAND. © COPYRIGHT KAWNEER COMPANY, INC., 2005	
THIS DRAWING IS FOR BLAST MITIGATION PRODUCT TESTING ONLY			
KAWNEER 555 GUTHRIDGE COURT NORCROSS, GEORGIA 30092 PHONE (770) 449-5555 FAX (770) 734-1560		TEST UNIT DRAWINGS 8325TL FIXED / PROJECT OUT / FIXED PERFORMANCE OF HISTORICALLY APPROPRIATE BLAST-RESISTANT WDWs ASTM f 1642, & UFC 4-010-0 SCALE: NONE	
DRAWN BY DEH		DATE 04/16/07	
TUD325801-01			
SHEET 1 of 5			



FASTENER SPACING SAME AS RIGHT JAMB

FASTENER SPACING SAME AS HEAD



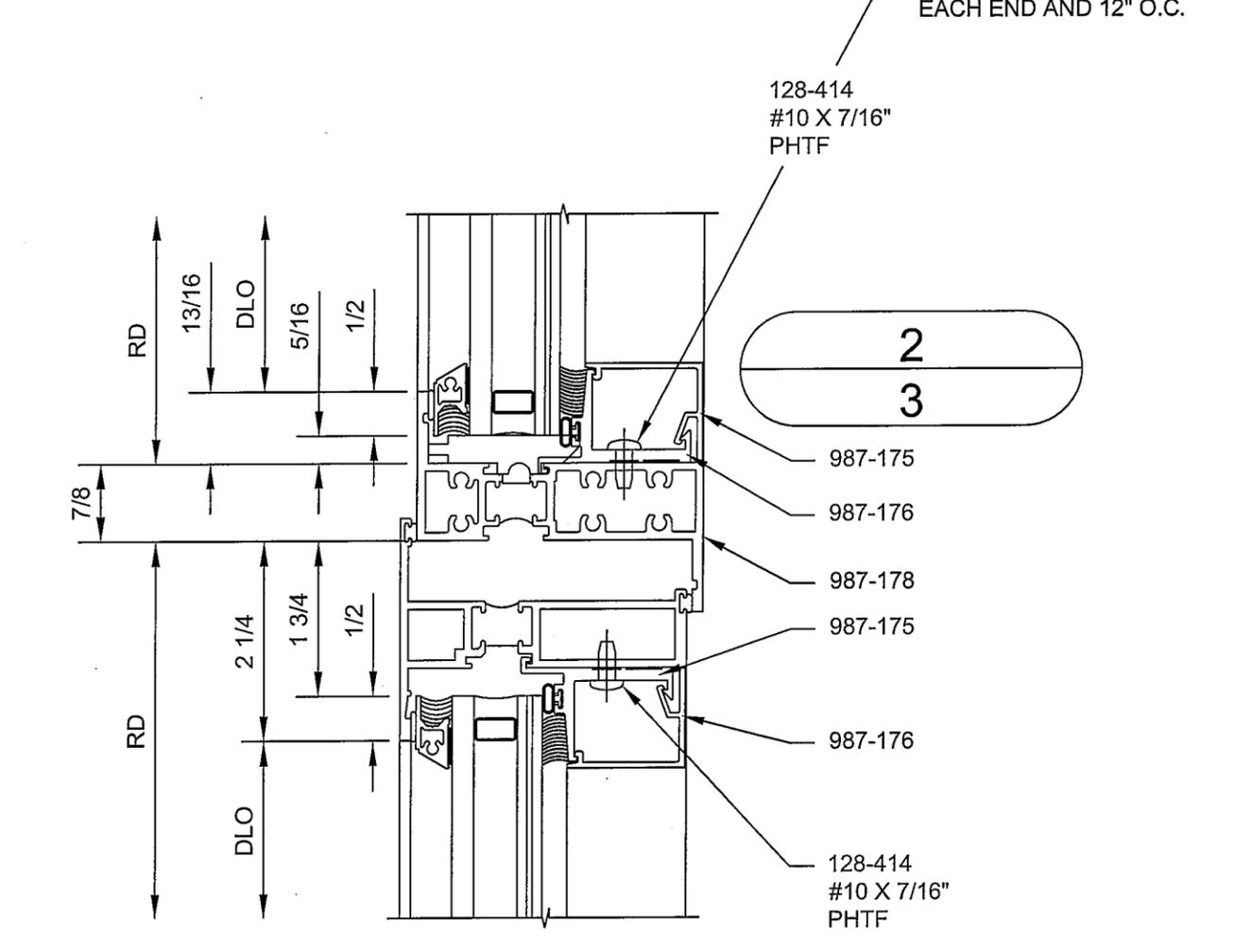
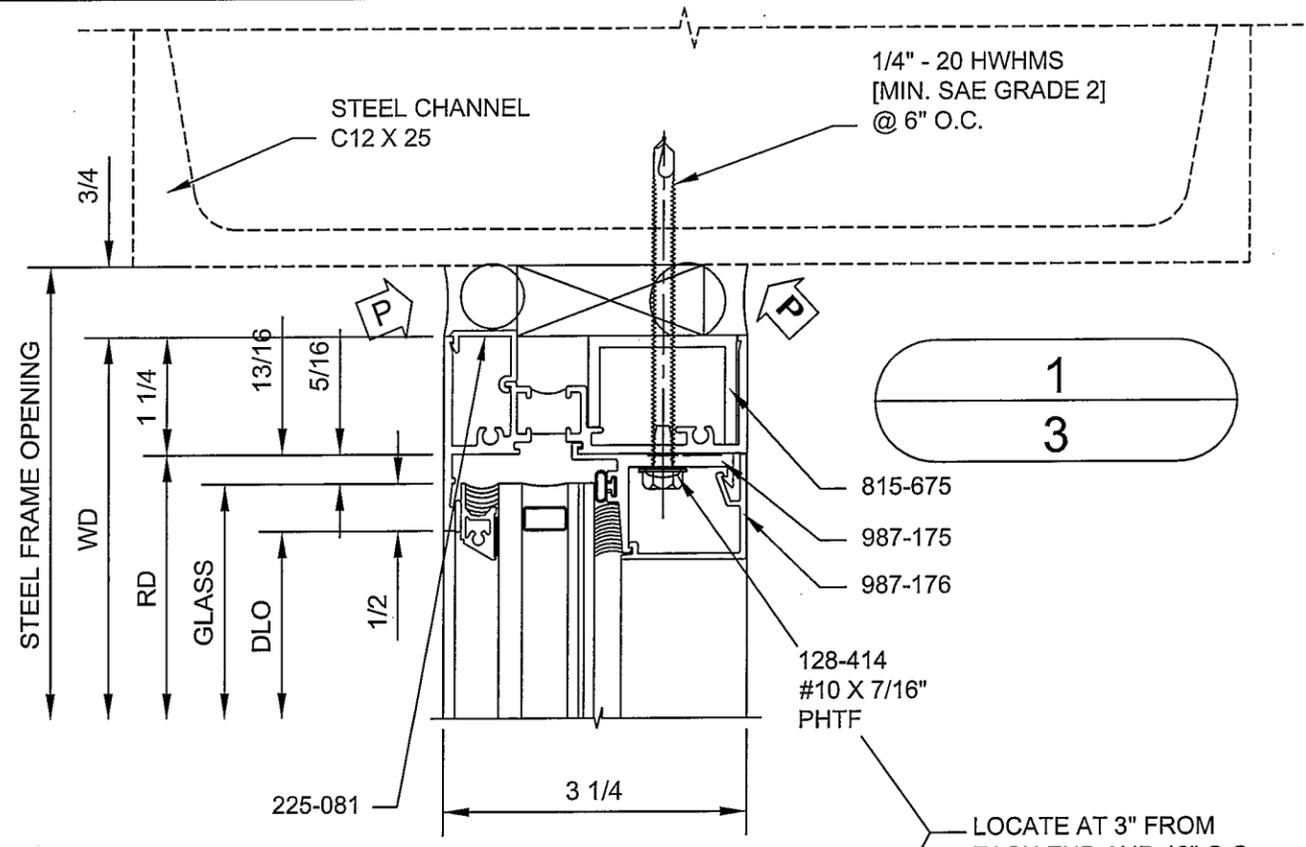
INFIll SIZE FORMULA
DLO + 1" UNLESS OTHERWISE NOTED.

- A 225-196 MUNTIN GRID
- B 028-488 GLAZING TAPE
- C 127-136 TREMCO PROGLAZE SSG
- D 987-175 GLASS BEAD
- E 127-074 BULB GASKET (SHORE "A" 65±5 DUROMETER TPE)
- F 987-176 GLASS BEAD COVER
- G 128-414 #10 X 7/16" PHTF
- H 027-884 SETTING BLOCK (SHORE "A" 85±5 DUROMETER EPDM)
- I SILICONE (127-104 WHEN FACTORY GLAZED)

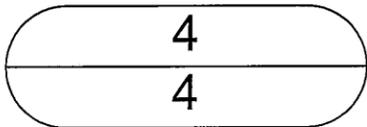
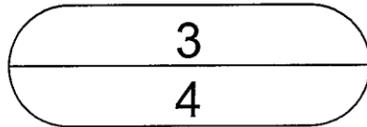
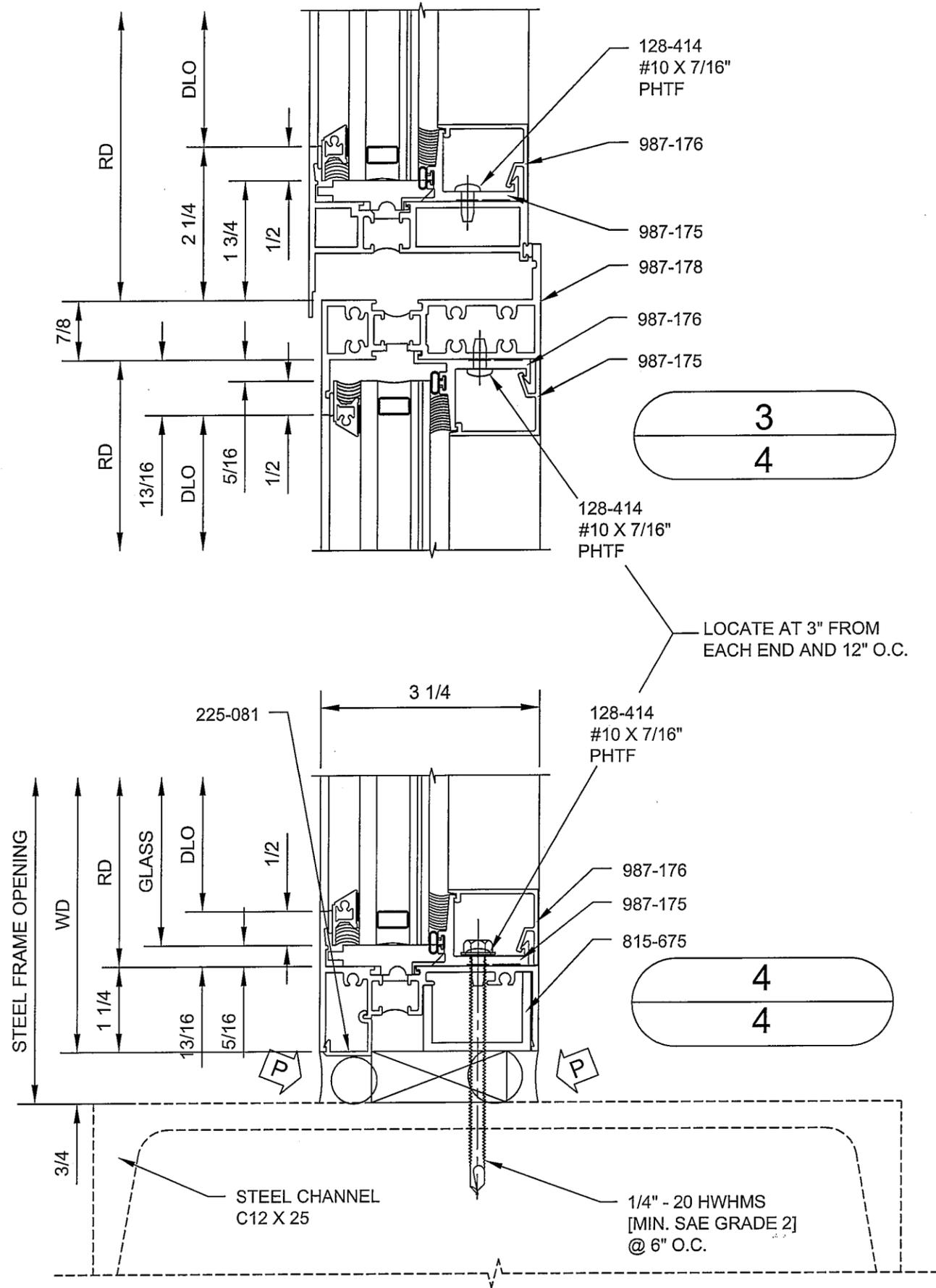
FASTENER SCHEDULE

MATERIAL	DESCRIPTION	SUBSTRATE	LOCATION	MIN. EMBED.	MAX. SPACING
GRADE 5 STEEL	1/4" X 1 1/2" ELCO DRILFLEX	STEEL	HEAD/SILL/JAMB	FULL	SEE ELEVATION

WINDOW HARDWARE:
 (4) BAR HINGES
 CAM HANDLES [(3) PER VENT]
 SNUBBERS



REV.	DATE	REQUEST LETTER	BY
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THIS DRAWING IS FOR BLAST MITIGATION PRODUCT TESTING ONLY			
			
<small>555 GUTHRIDGE COURT NORCROSS, GEORGIA 30092 PHONE (770) 449-5555 FAX (770) 734-1560</small>			
<small>TEST UNIT DRAWINGS 8325TL FIXED / PROJECT OUT / FIXED PERFORMANCE OF HISTORICALLY APPROPRIATE BLAST-RESISTANT WDWS ASTM f 1642, & UFC 4-010-0 SCALE: NONE</small>			
DRAWN BY DEH		DATE 04/16/07	
DRWG. NO. TUD325801-03			
SHEET 3 of 5			



REV.	DATE	REQUEST LETTER	BY

E.C. NO. 95502-11 ??-??-07

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KAWNEER
 555 GUTHRIDGE COURT
 NORCROSS, GEORGIA 30092
 PHONE (770) 449-5555
 FAX (770) 734-1560

DRAWN BY DEH	DATE 04/16/07
DRWG. NO. TUD325801-04	
SHEET 4 of 5	

SCALE: NONE

REV.	DATE	REQUEST LETTER	BY

E.C. NO. 95502-11 ??-??-07

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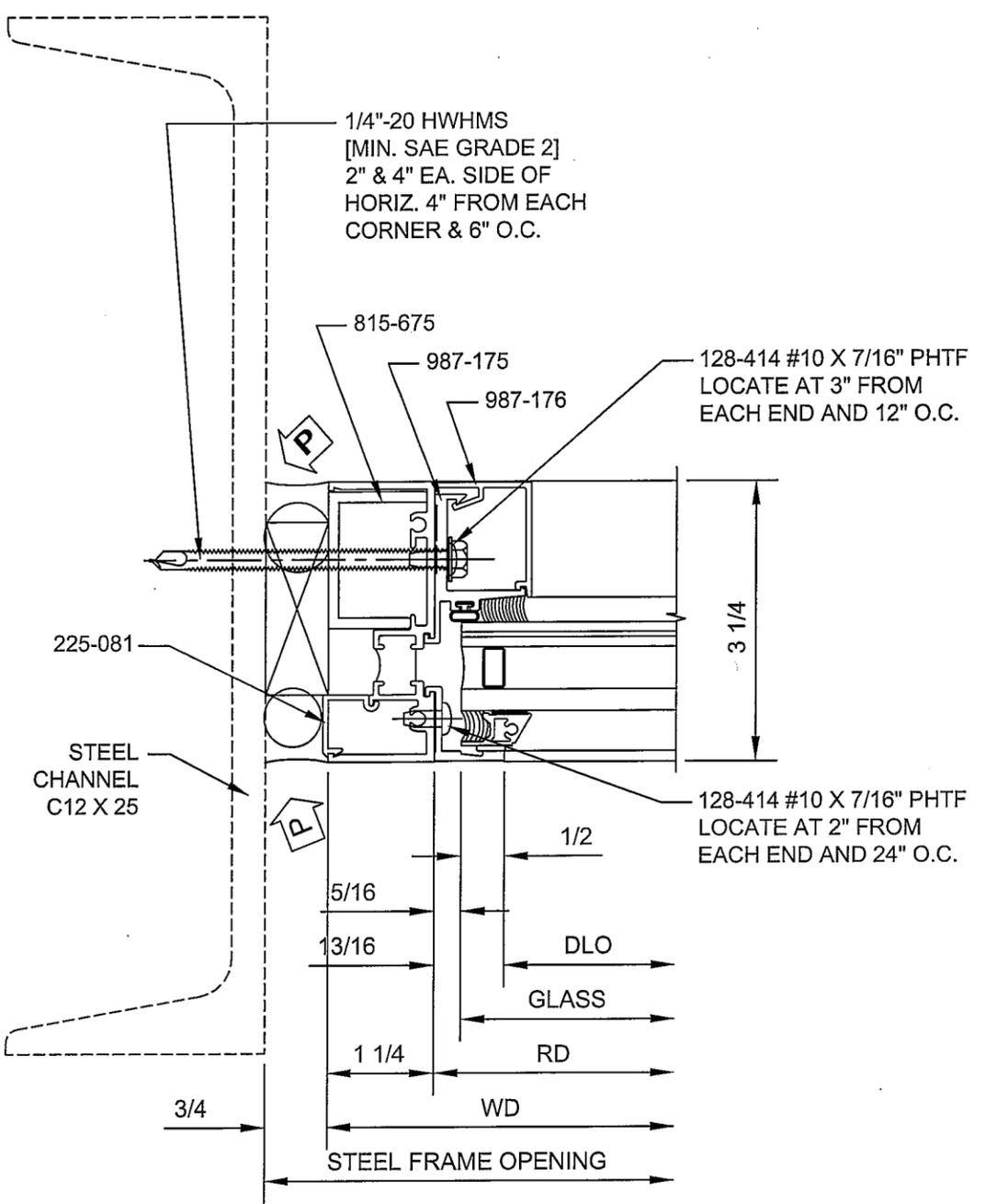
THIS DRAWING IS FOR BLAST MITIGATION PRODUCT TESTING ONLY

KAWNEER
 555 GUTHRIDGE COURT
 NORCROSS, GEORGIA 30092
 PHONE (770) 449-5555
 FAX (770) 734-1560

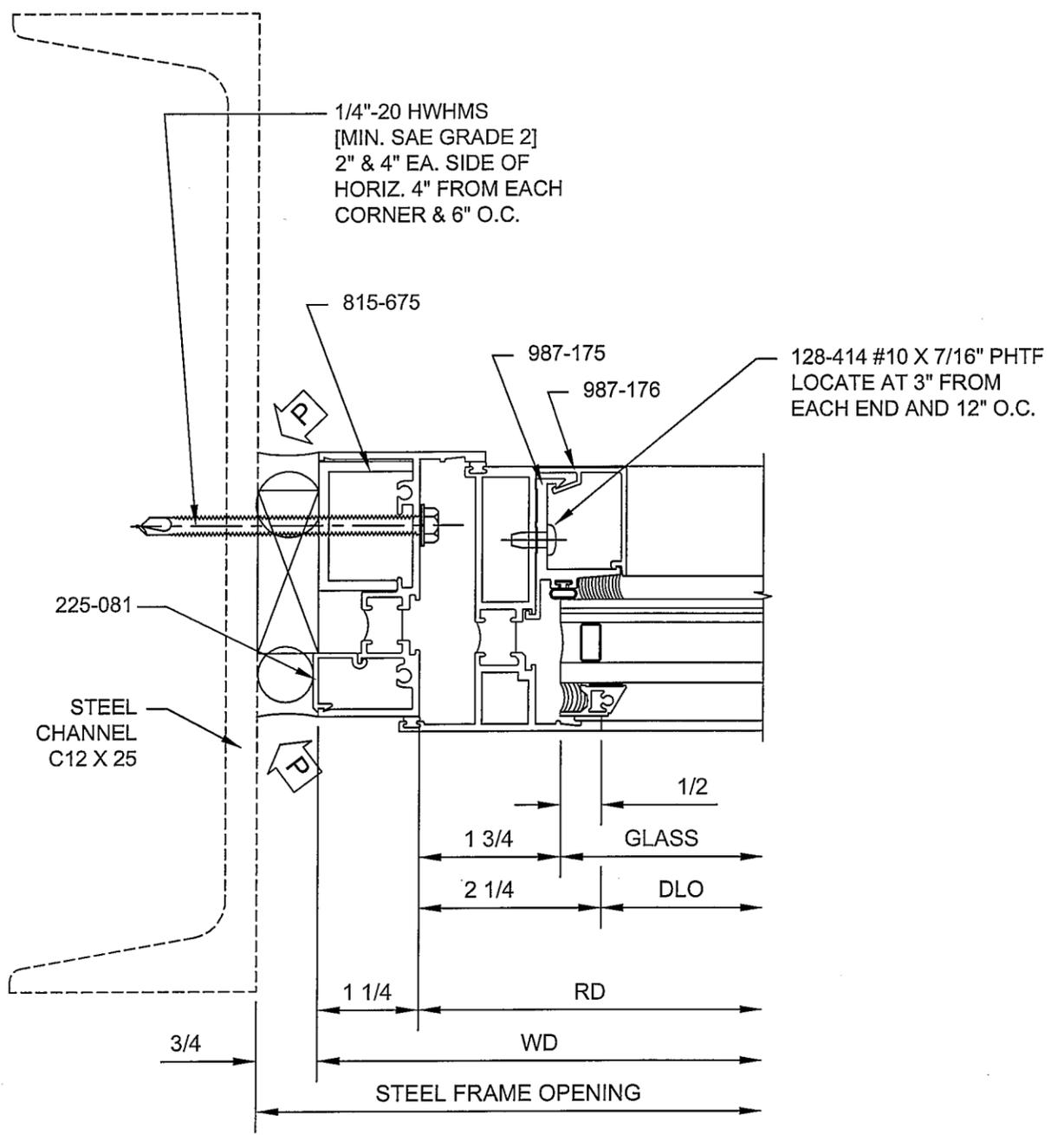
DEH DATE 04/16/07

TUD325801-05

SHEET 5 of 5



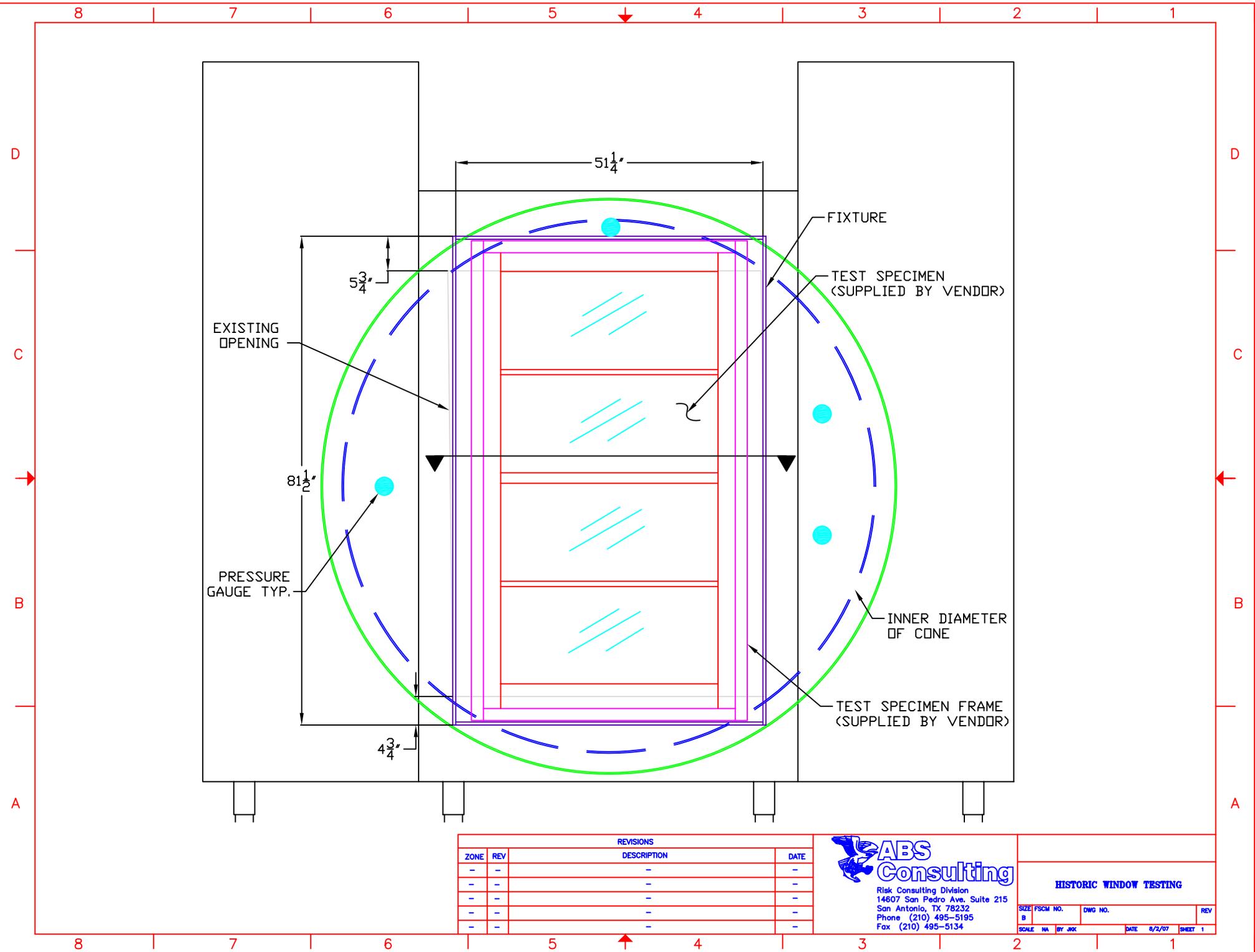
11



12

Appendix C

Fixture Drawings



REVISIONS			
ZONE	REV	DESCRIPTION	DATE
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

ABS Consulting
 Risk Consulting Division
 14807 San Pedro Ave, Suite 215
 San Antonio, TX 78232
 Phone (210) 495-5195
 Fax (210) 495-5134

HISTORIC WINDOW TESTING

SIZE	FSCM NO.	DWG NO.	REV
B			
SCALE	MA	BY JJK	DATE 6/2/07 SHEET 1

FIXTURE
 TEST SPECIMEN FRAME
 TEST SPECIMEN

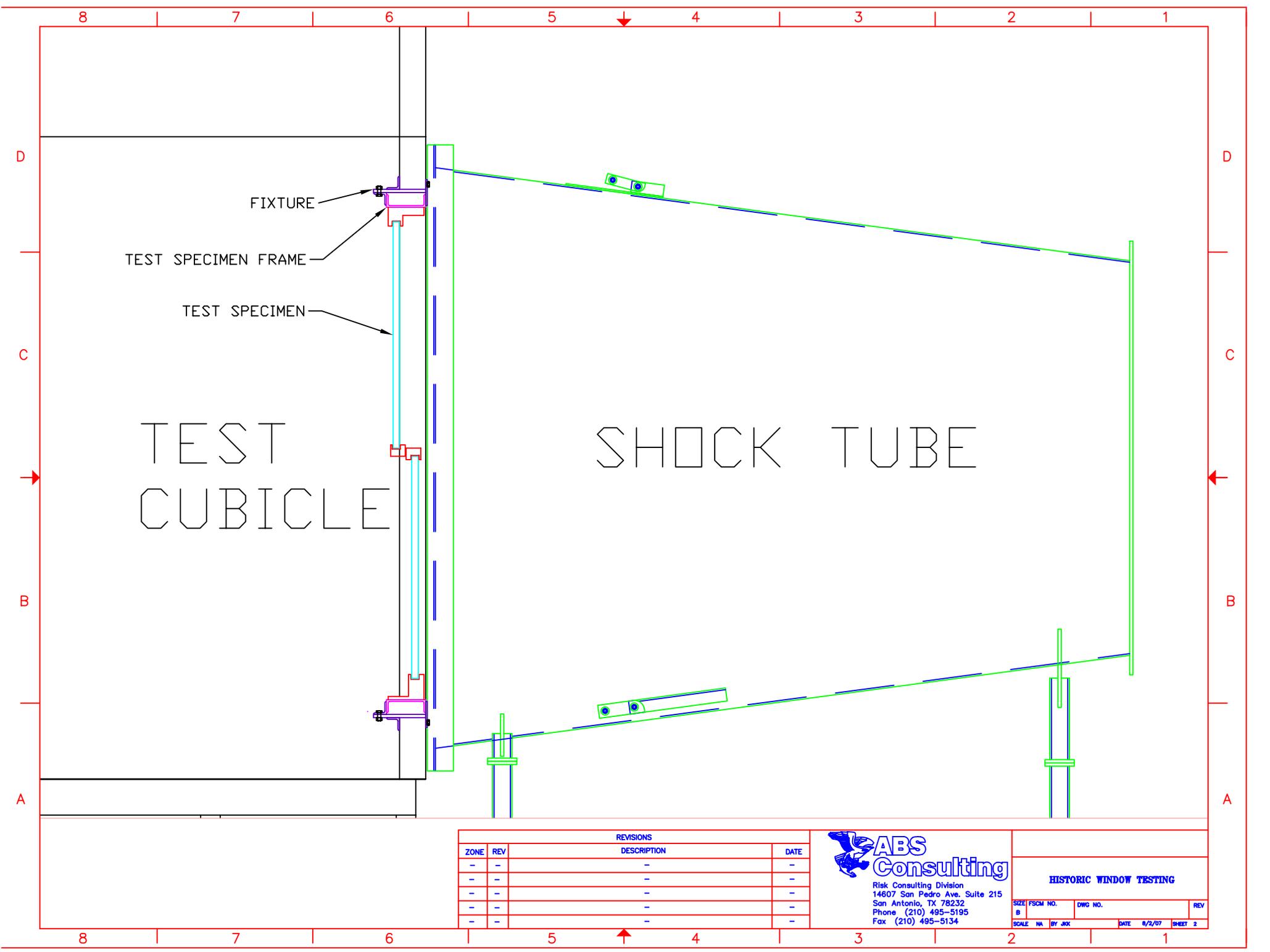
TEST CUBICLE

SHOCK TUBE

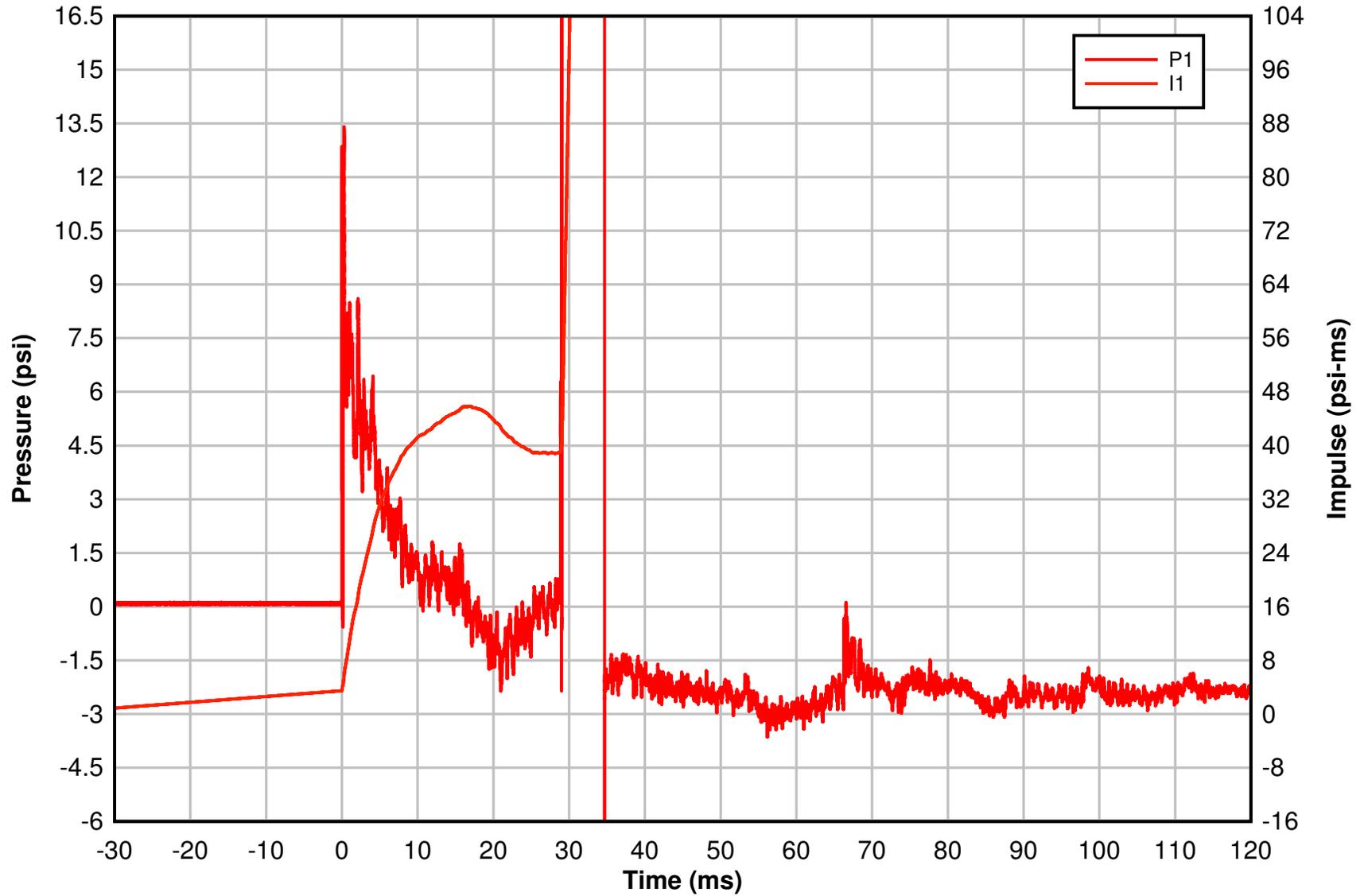
REVISIONS			
ZONE	REV	DESCRIPTION	DATE
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-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-


ABS Consulting
 Risk Consulting Division
 14607 San Pedro Ave. Suite 215
 San Antonio, TX 78232
 Phone (210) 495-5195
 Fax (210) 495-5134

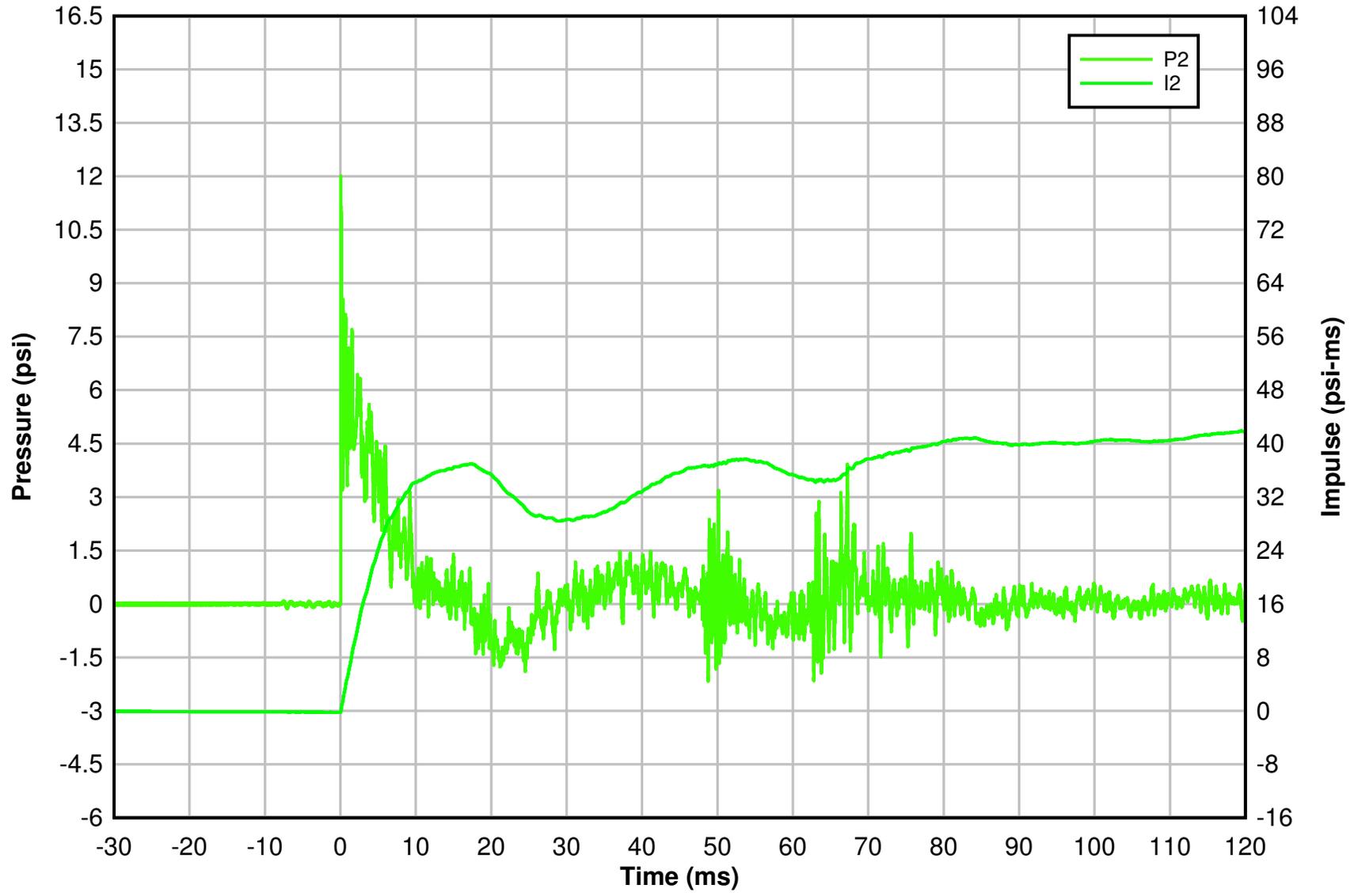
HISTORIC WINDOW TESTING			
SCALE	BY	DATE	SHEET
B	JJK	8/2/07	2



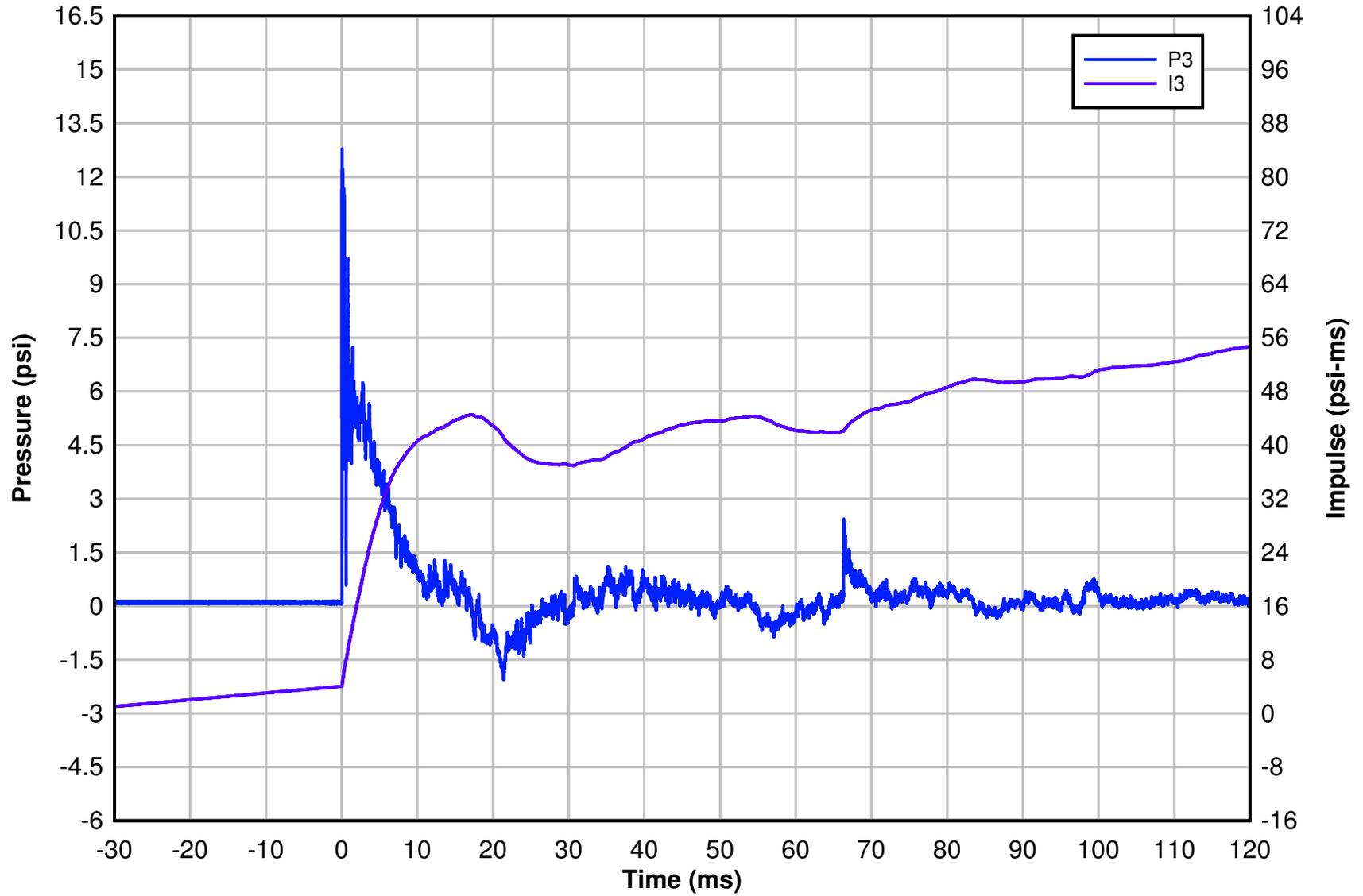
ERDC Historic Windows Test 2



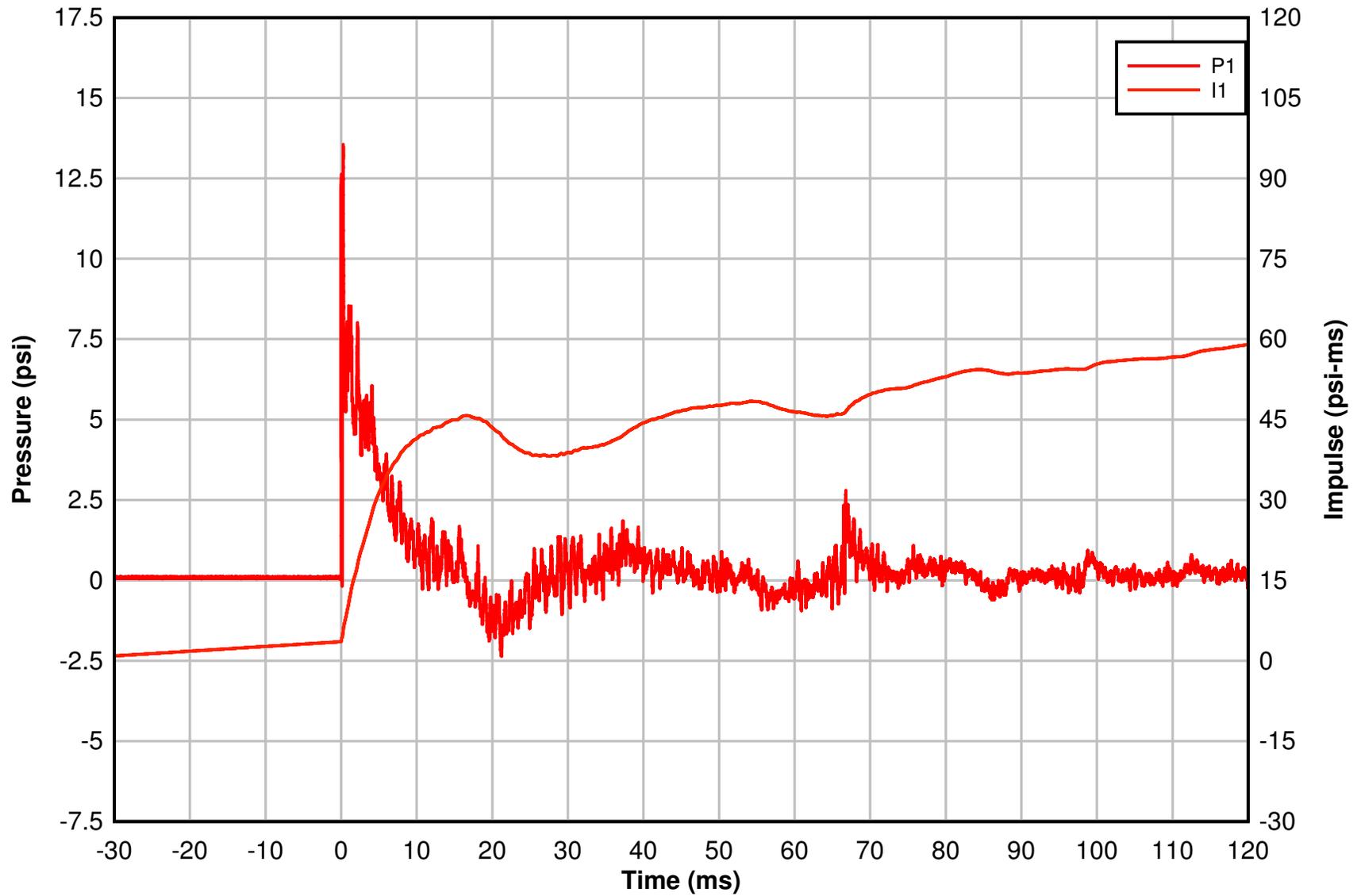
ERDC Historic Windows Test 2



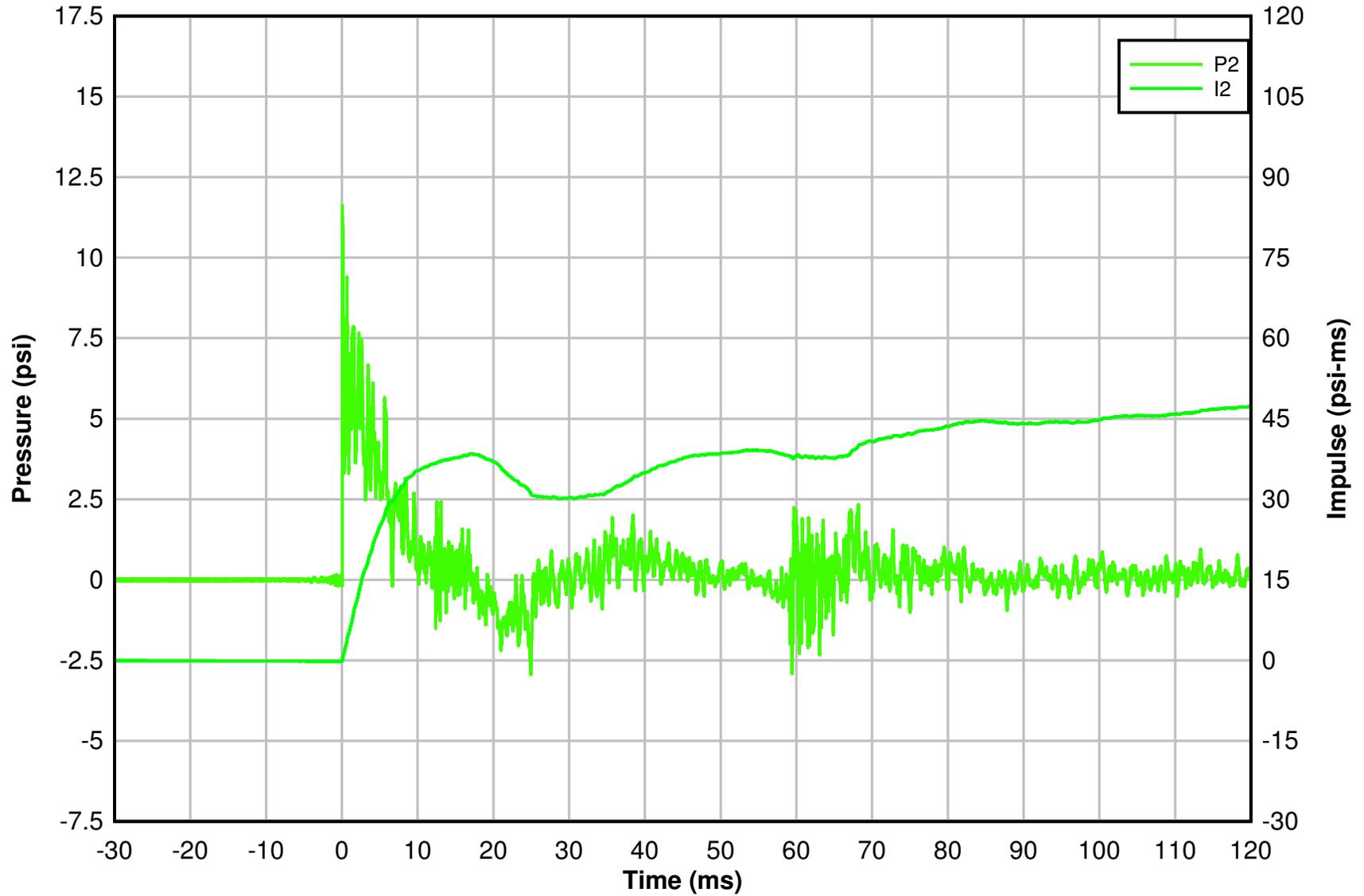
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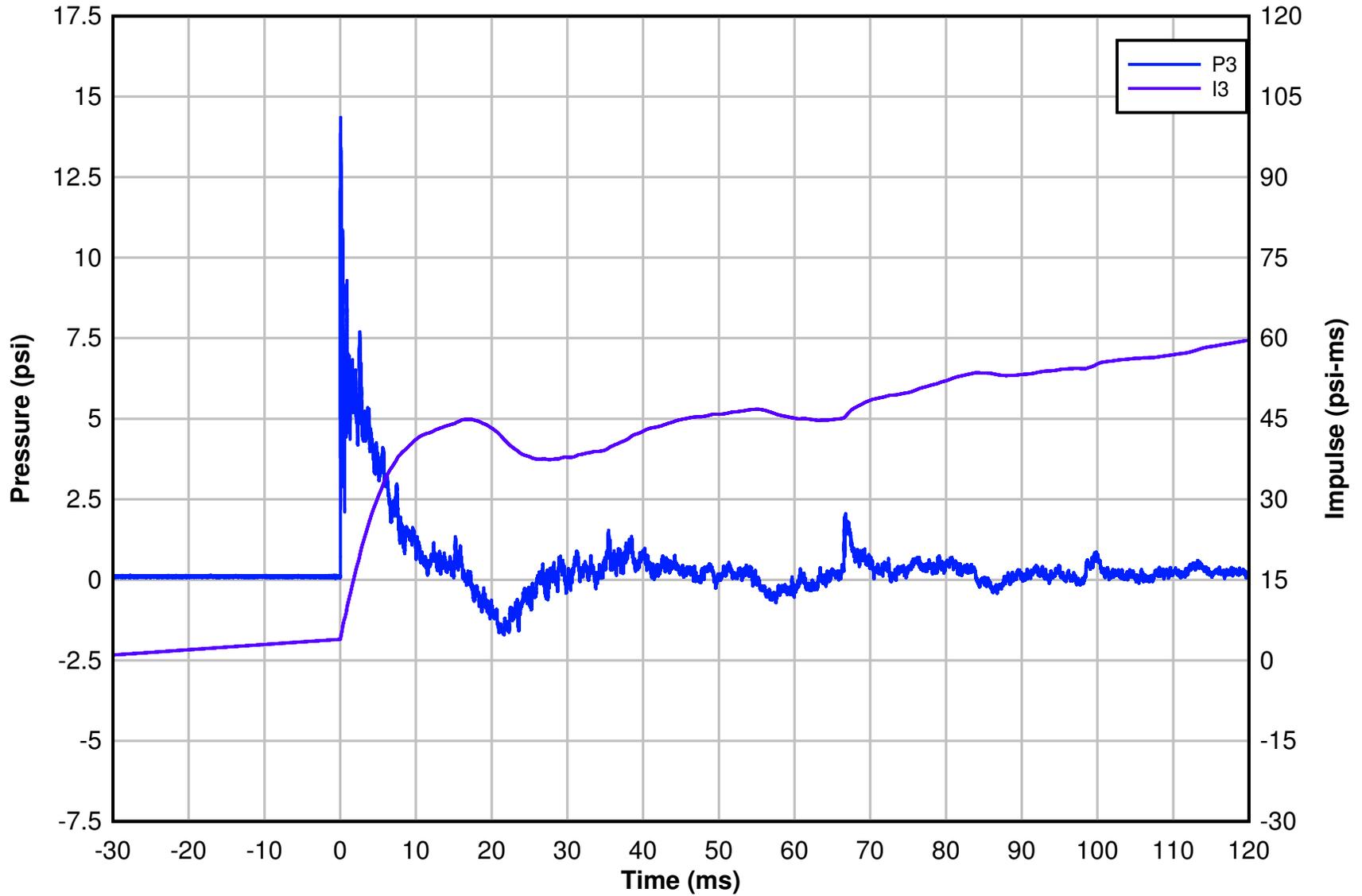
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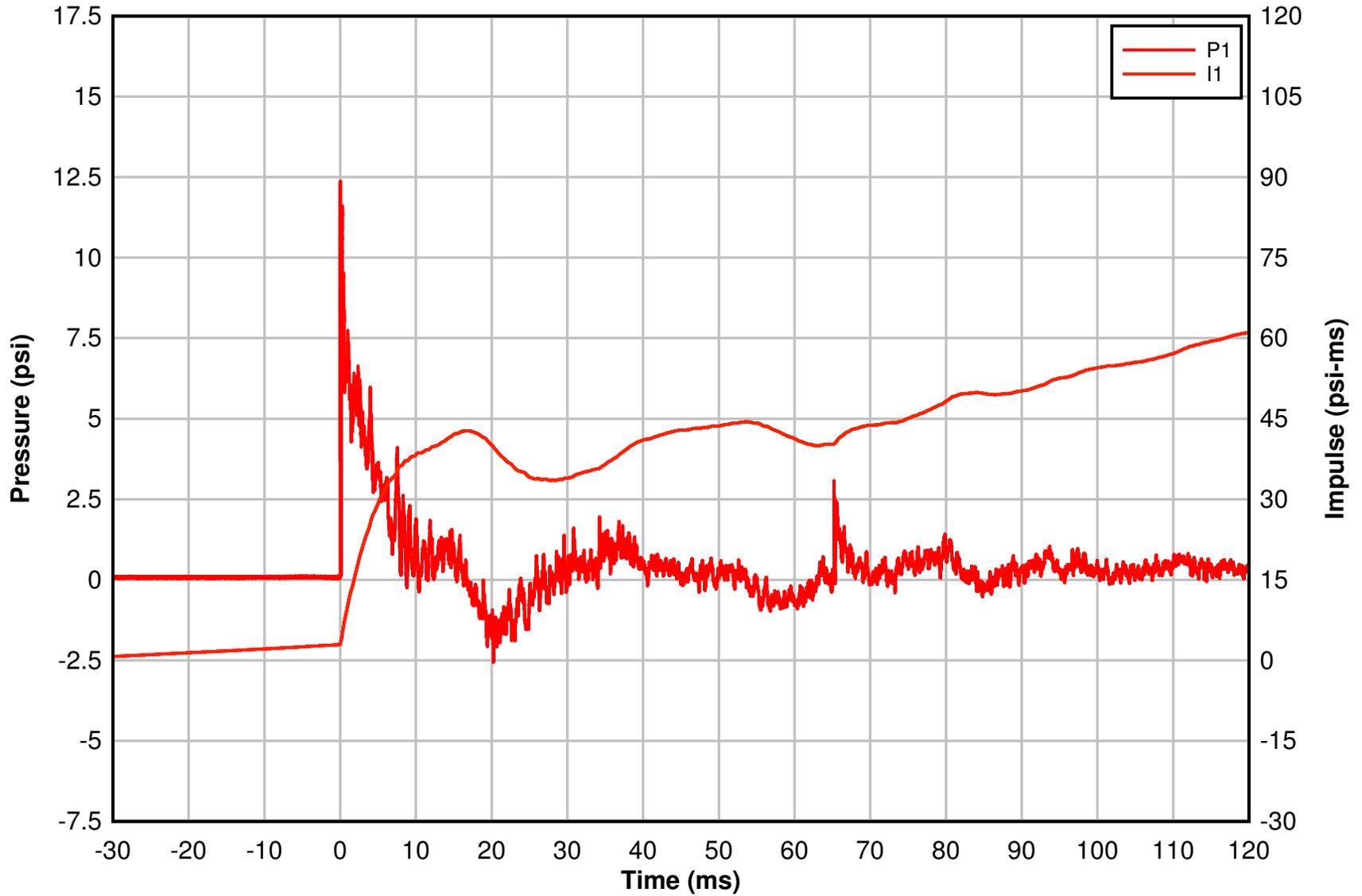
ERDC Historic Windows Test 3



ERDC Historic Windows Test 3

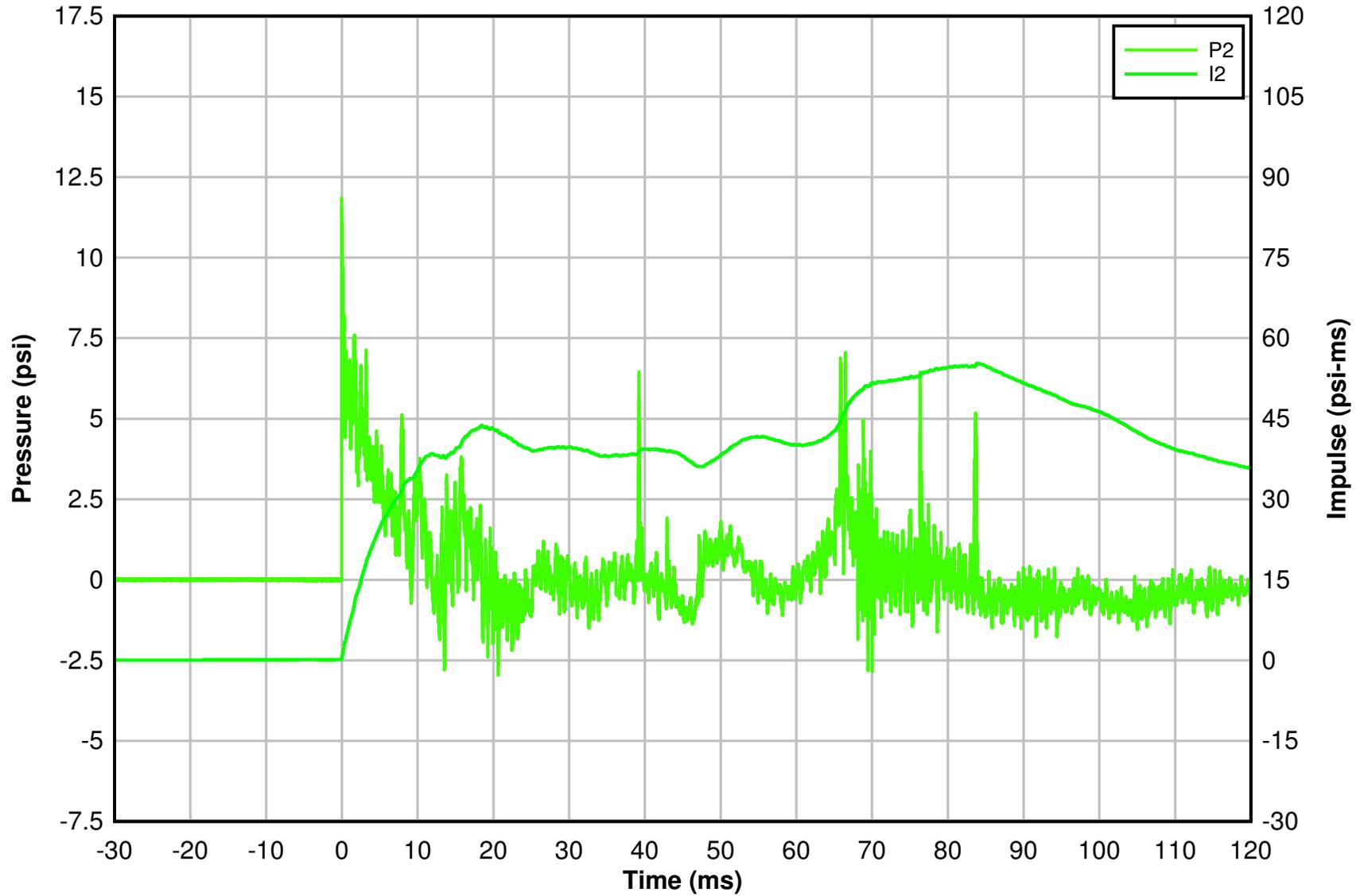


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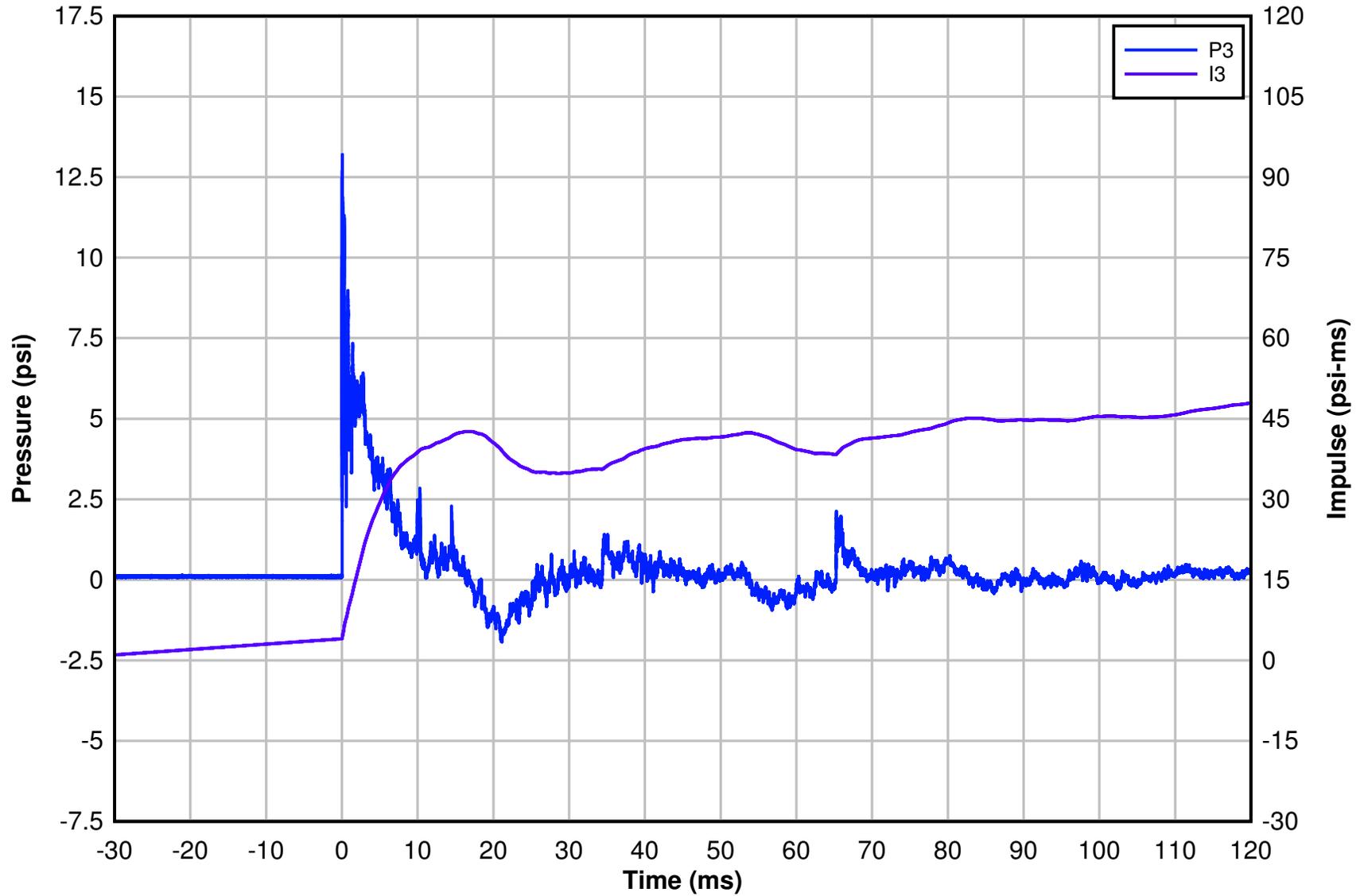


ERDC Historic Windows

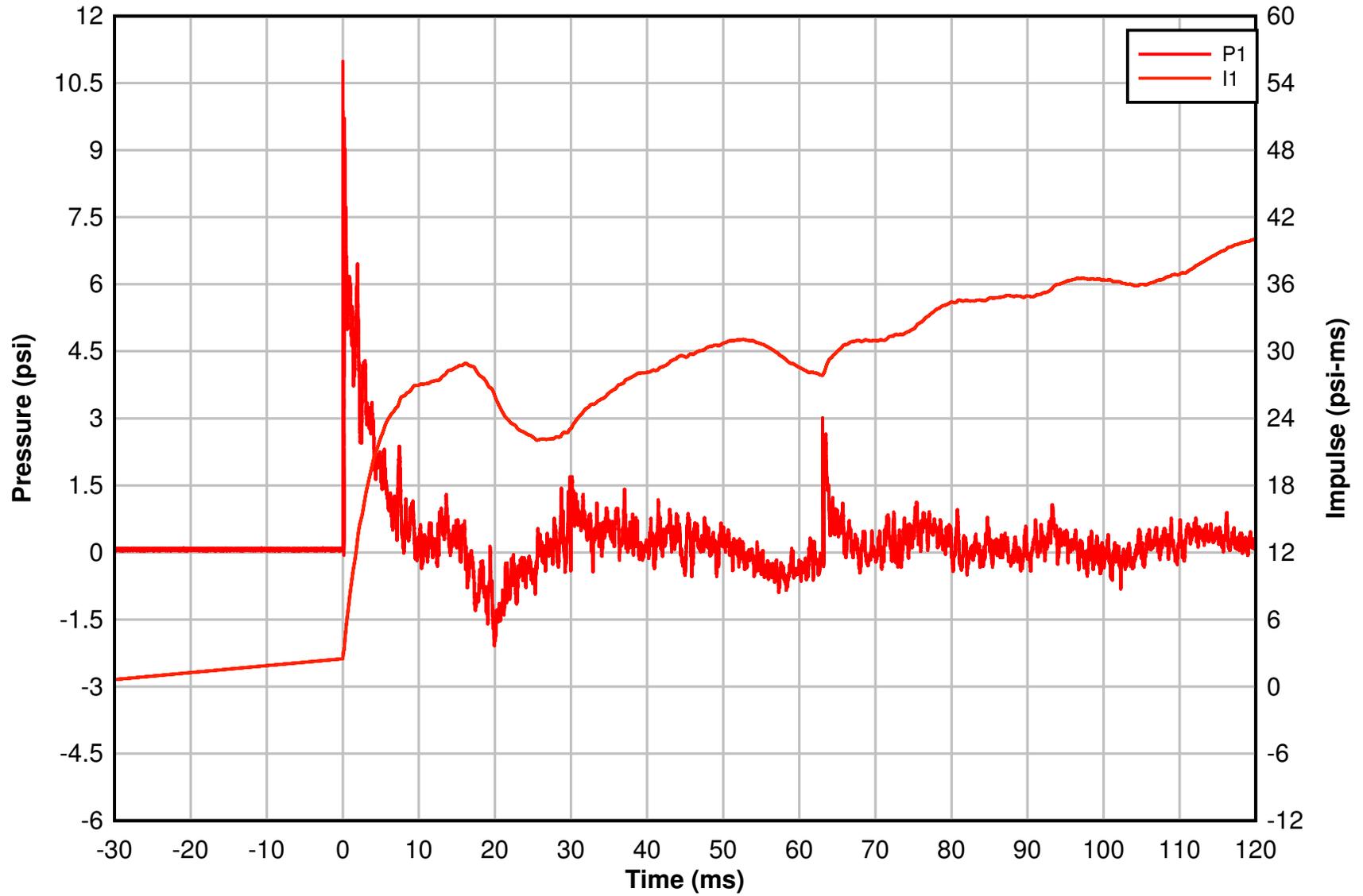
Test 4



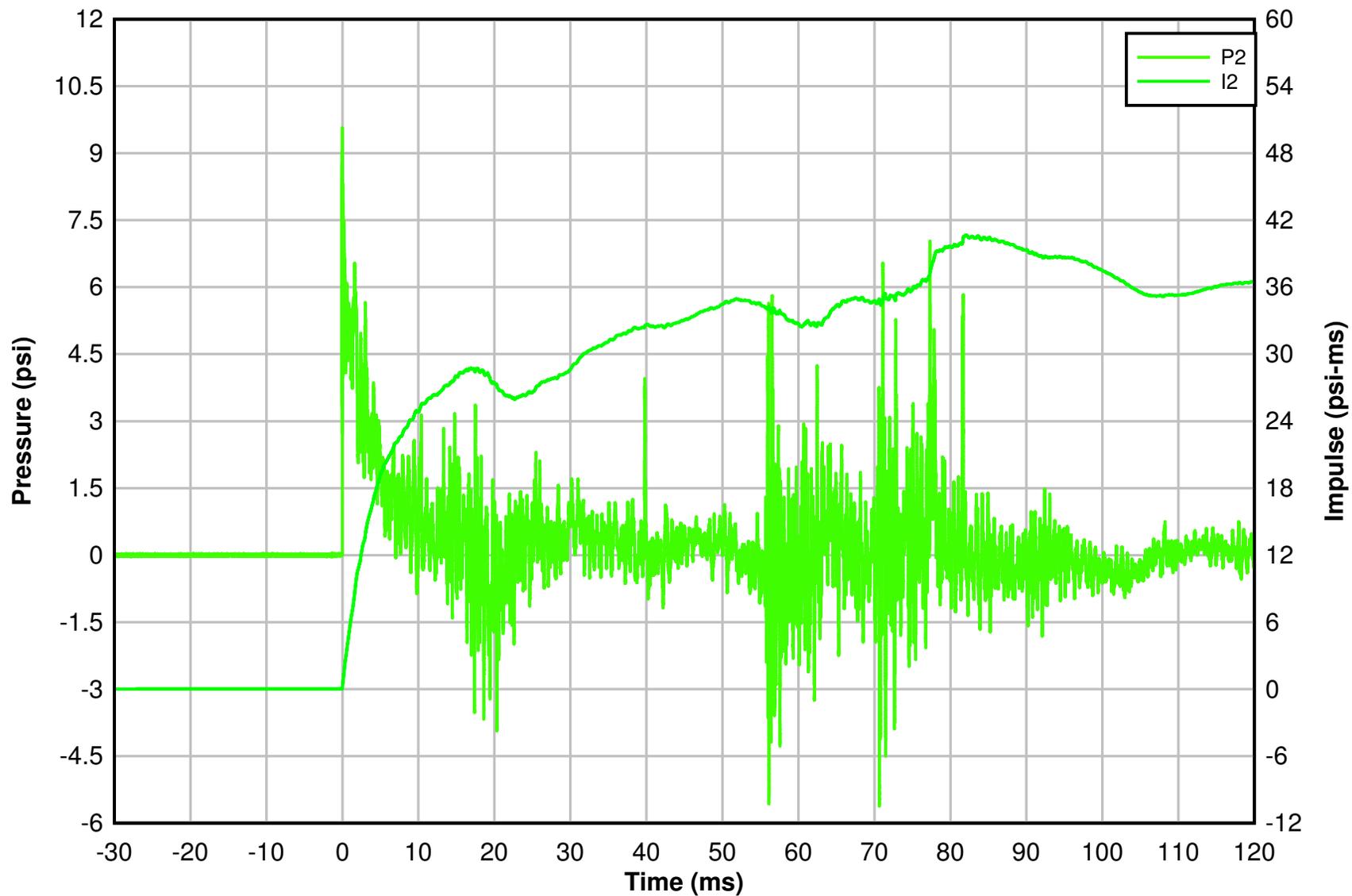
ERDC Historic Windows Test 4



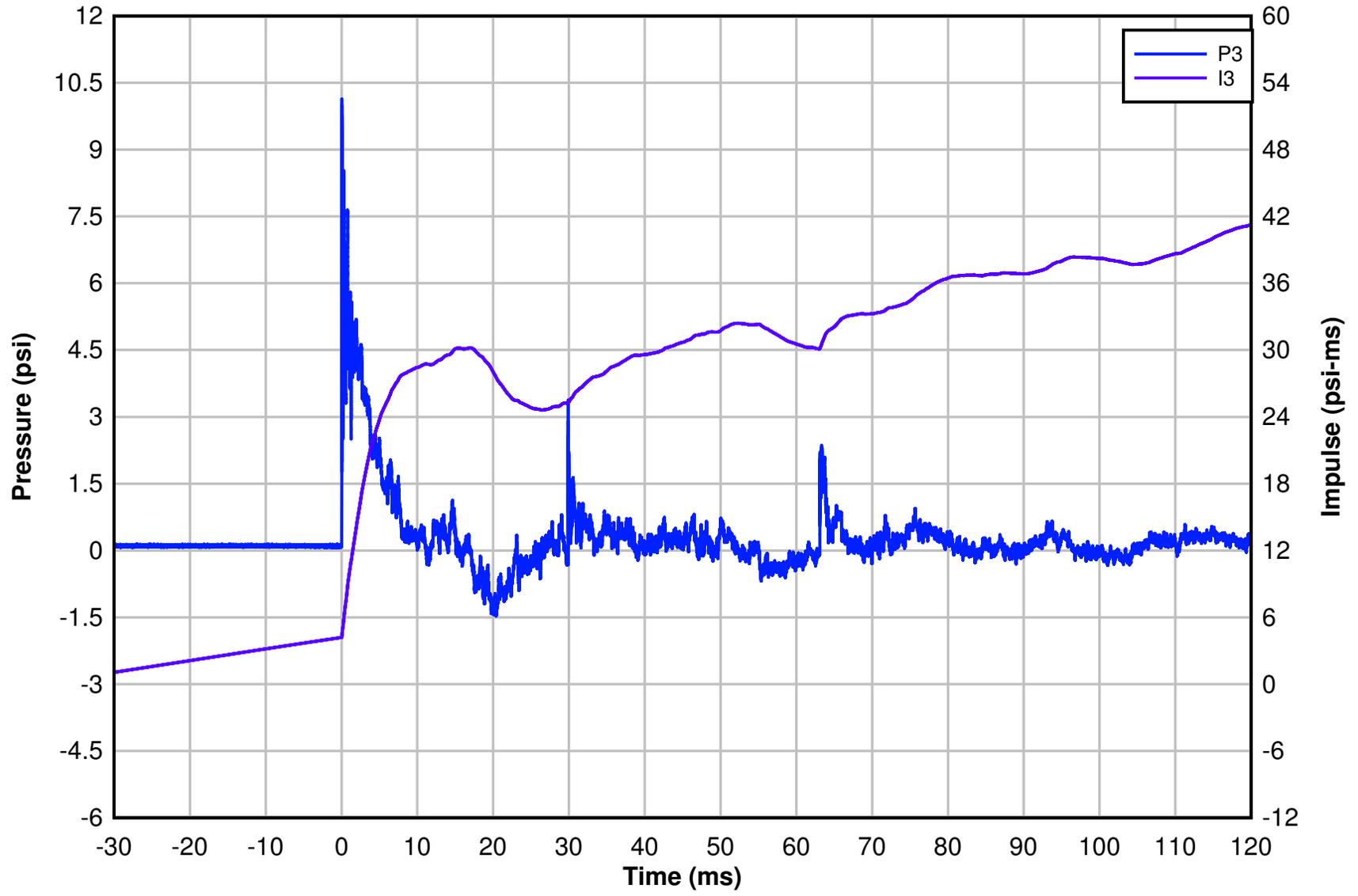
ERDC Historic Windows Test 5



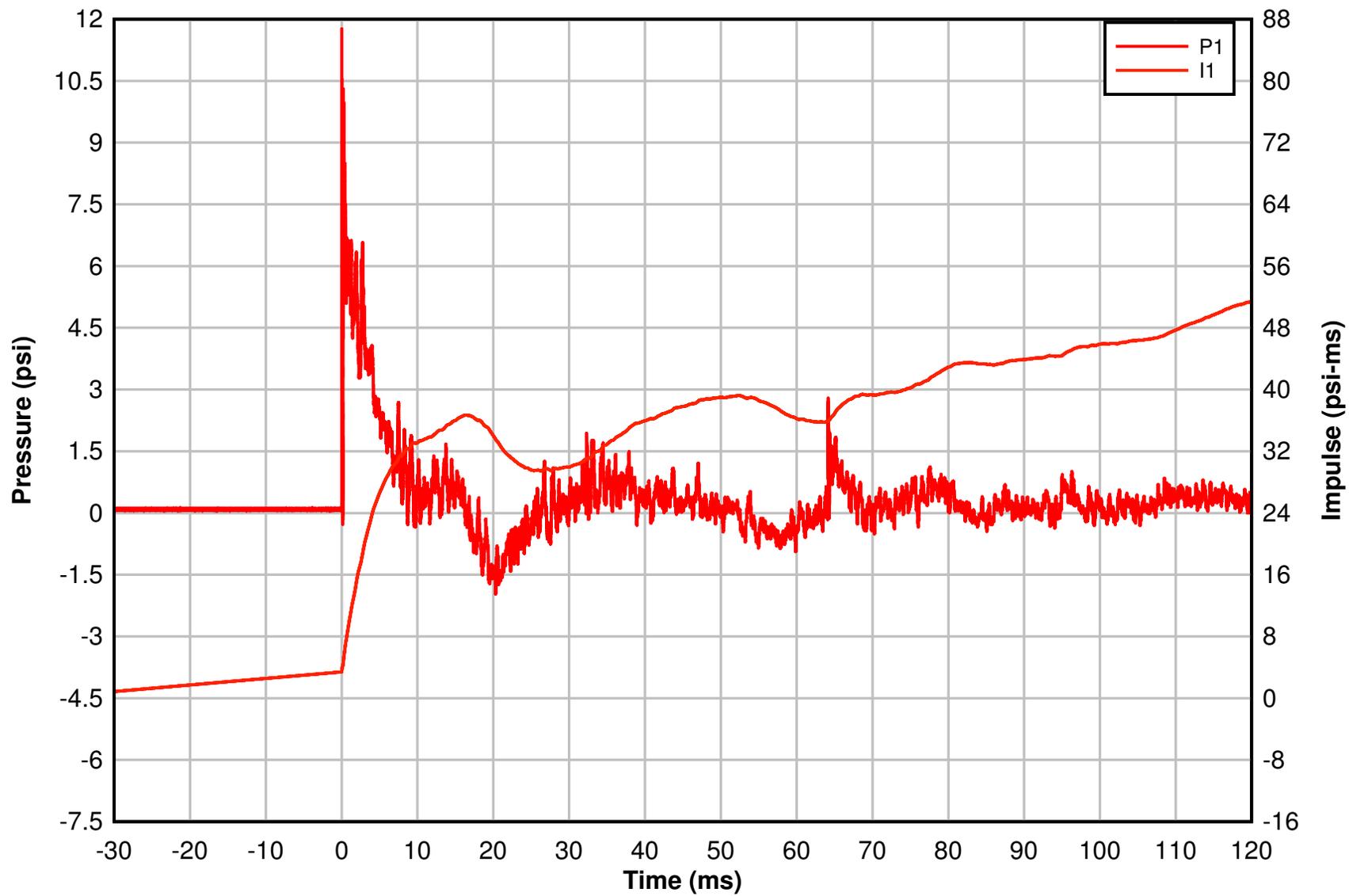
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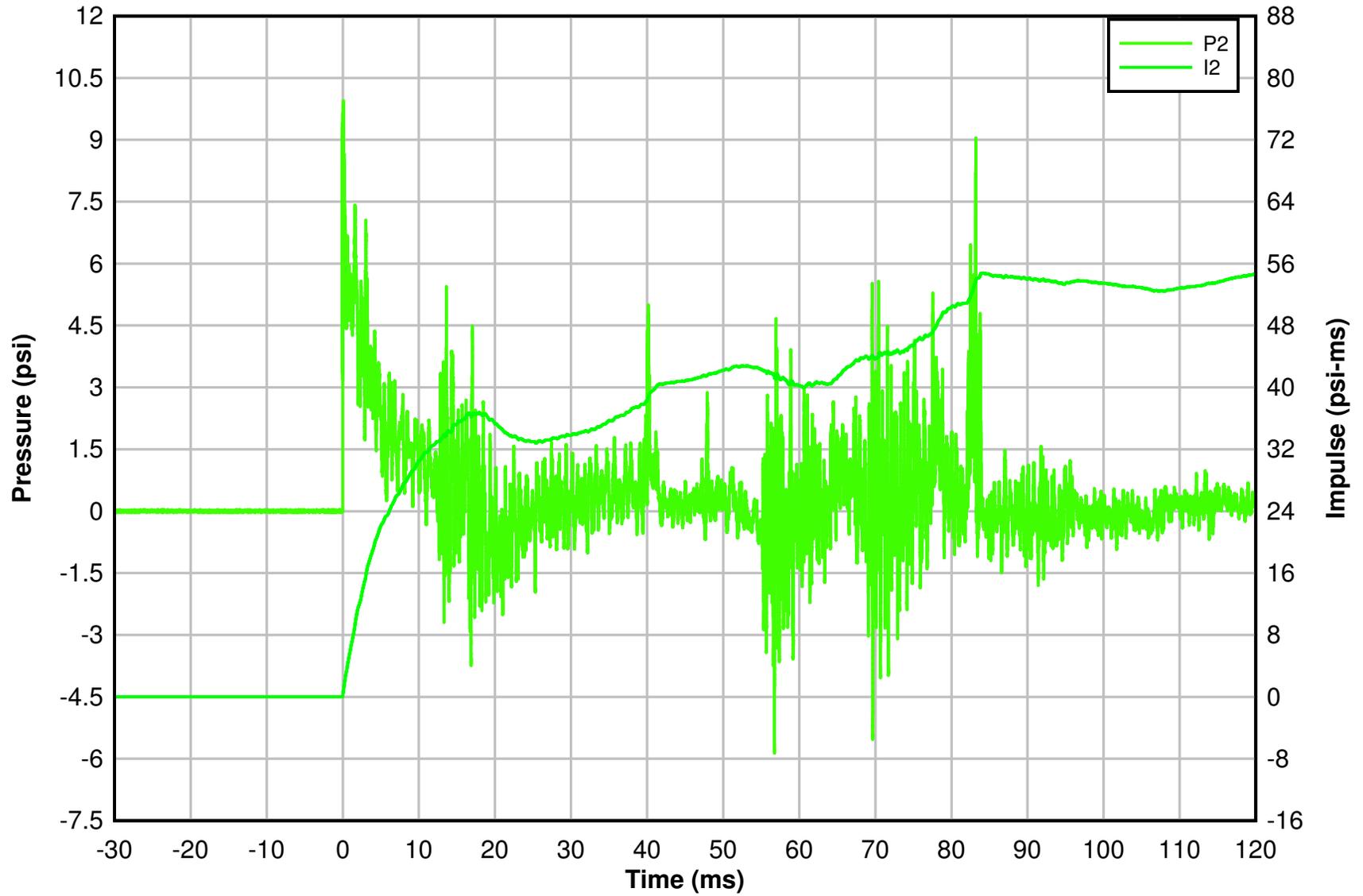
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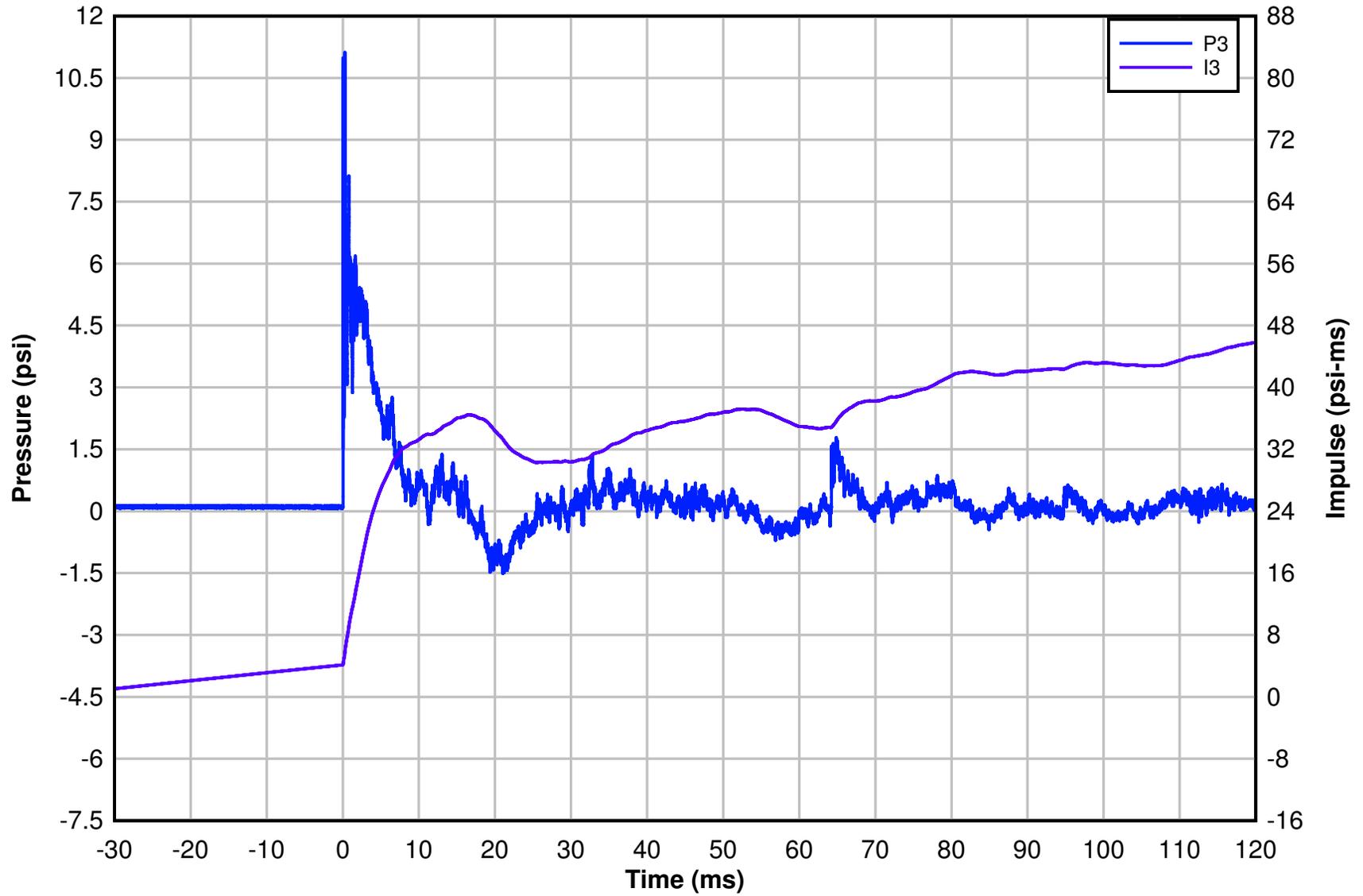
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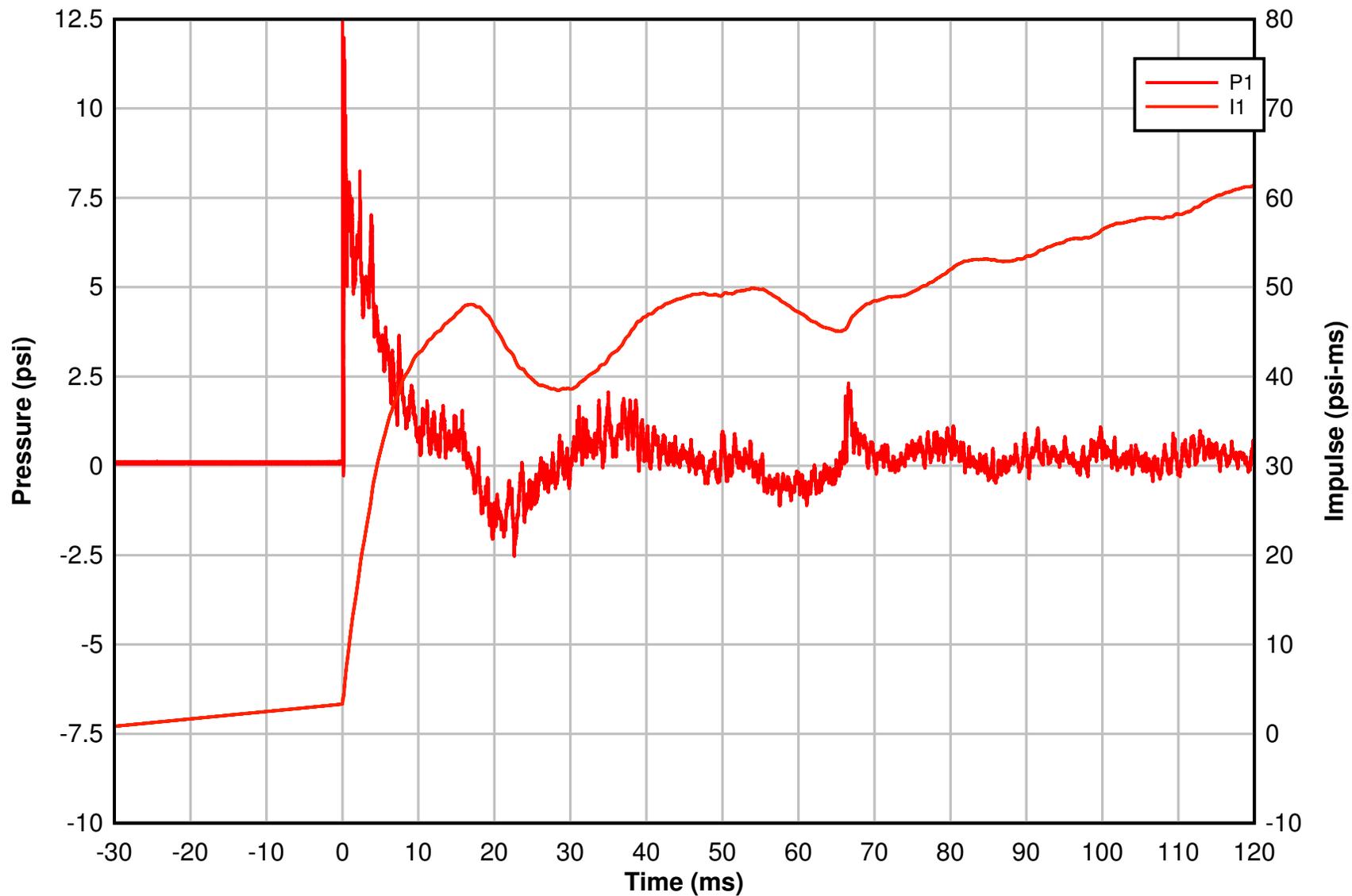
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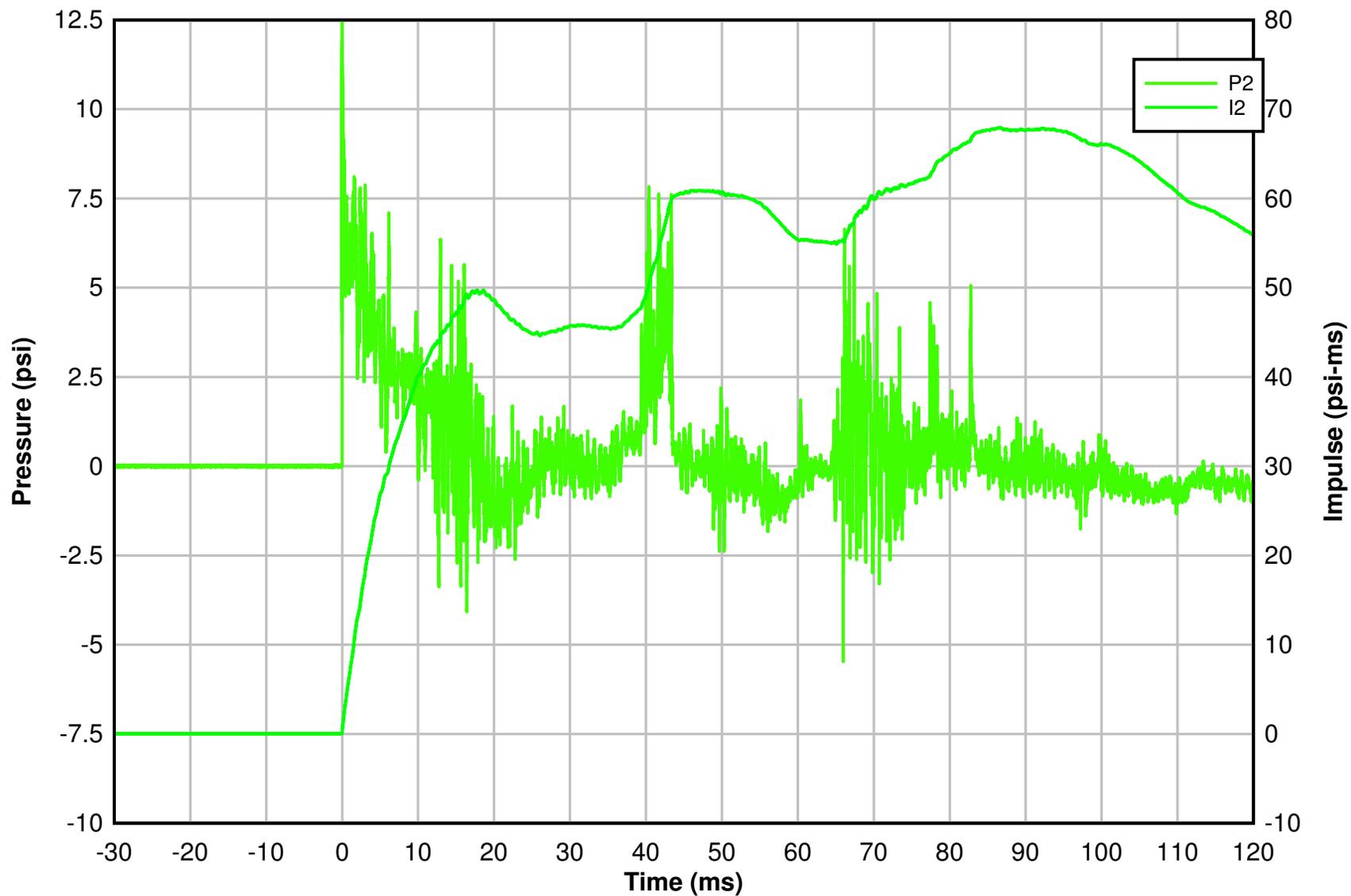
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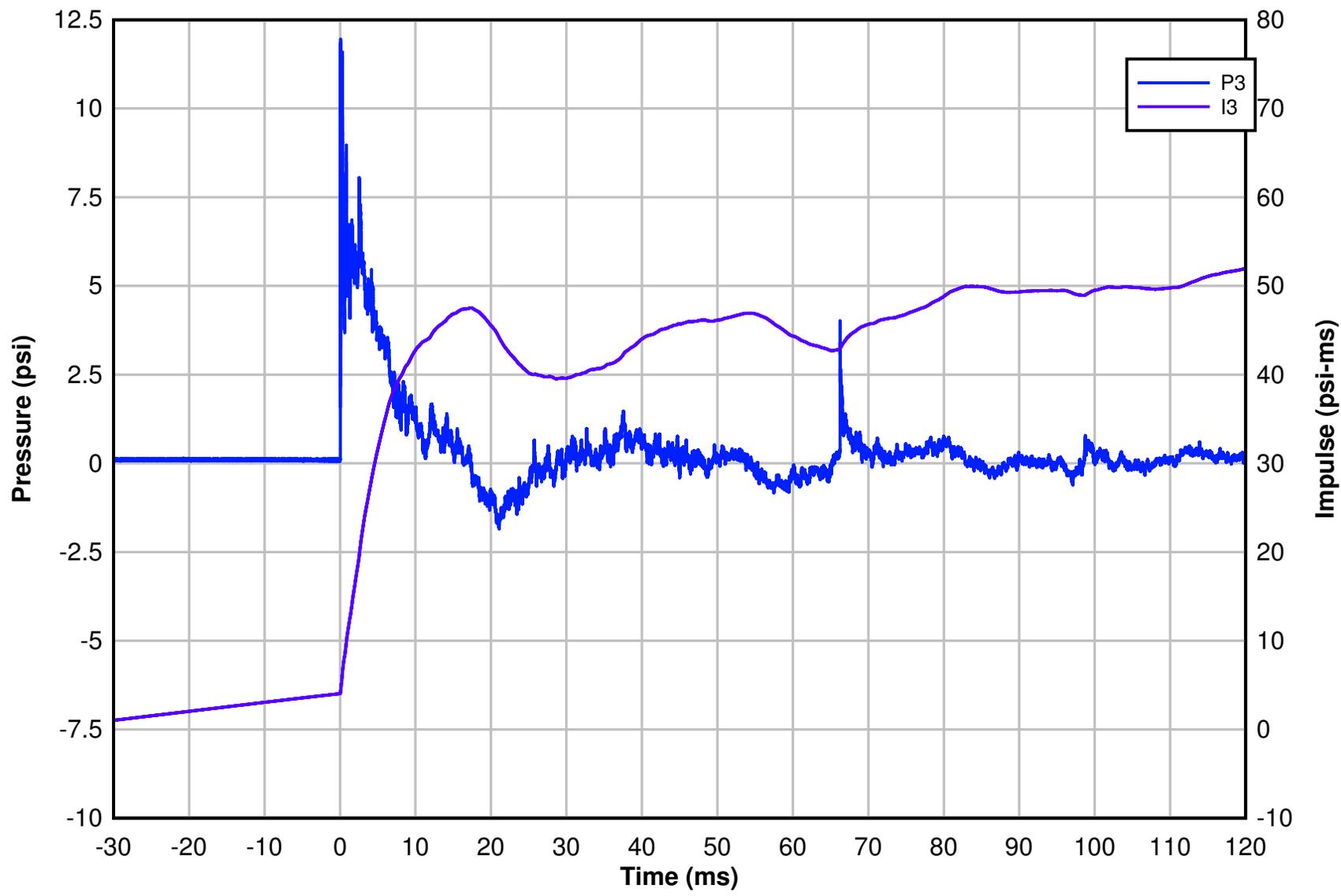
ERDC Historic Windows Test 5B



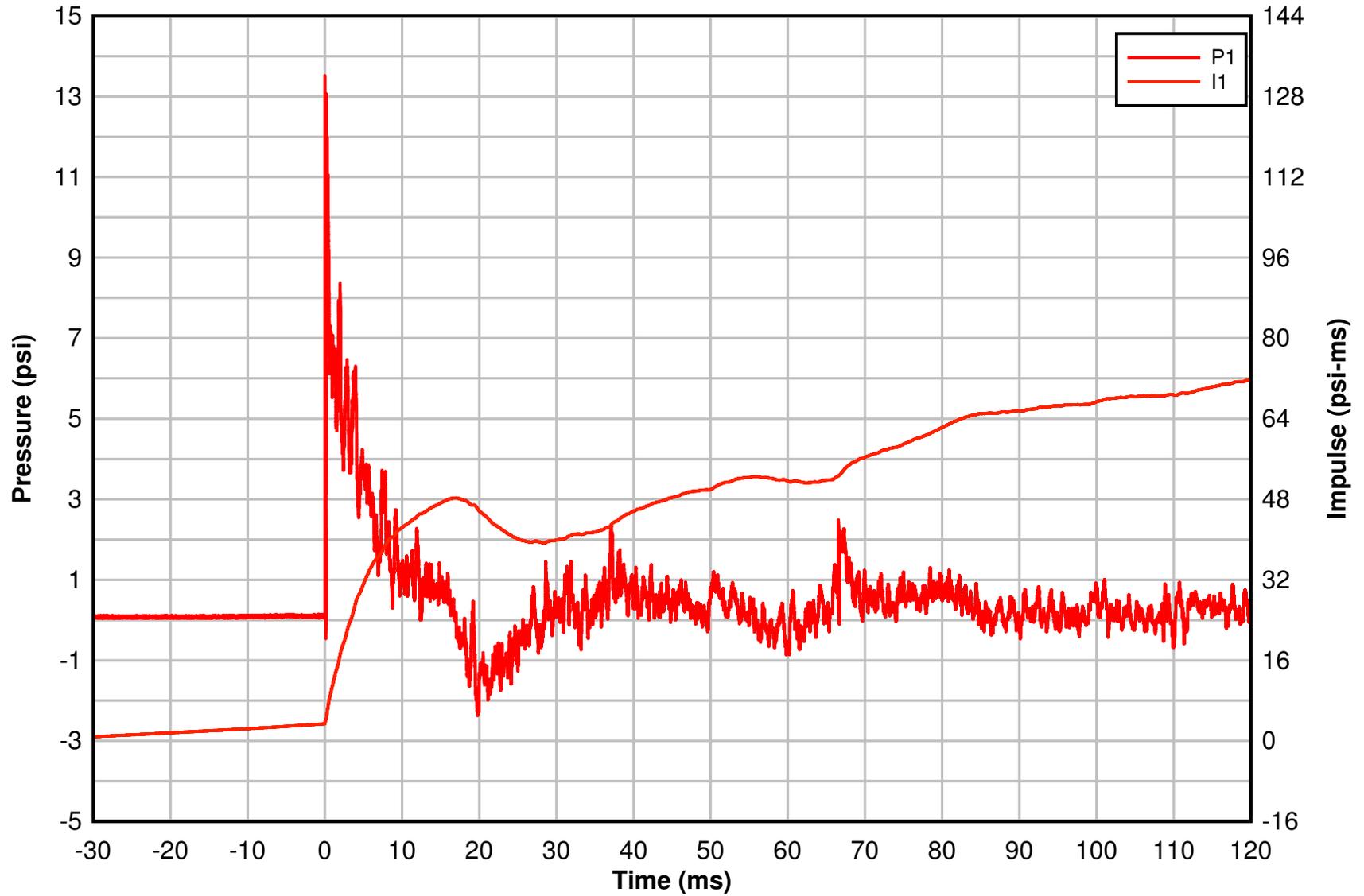
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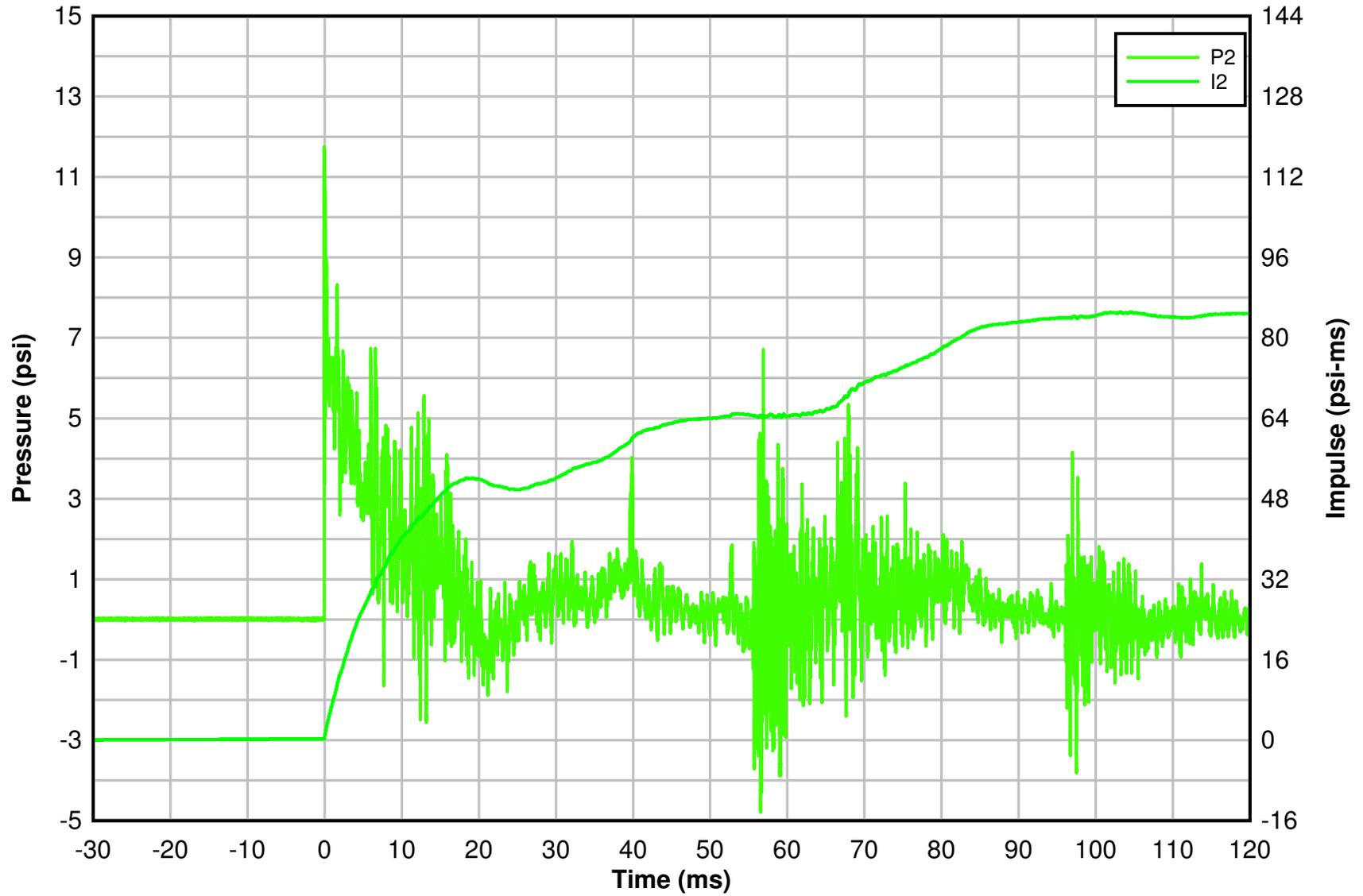
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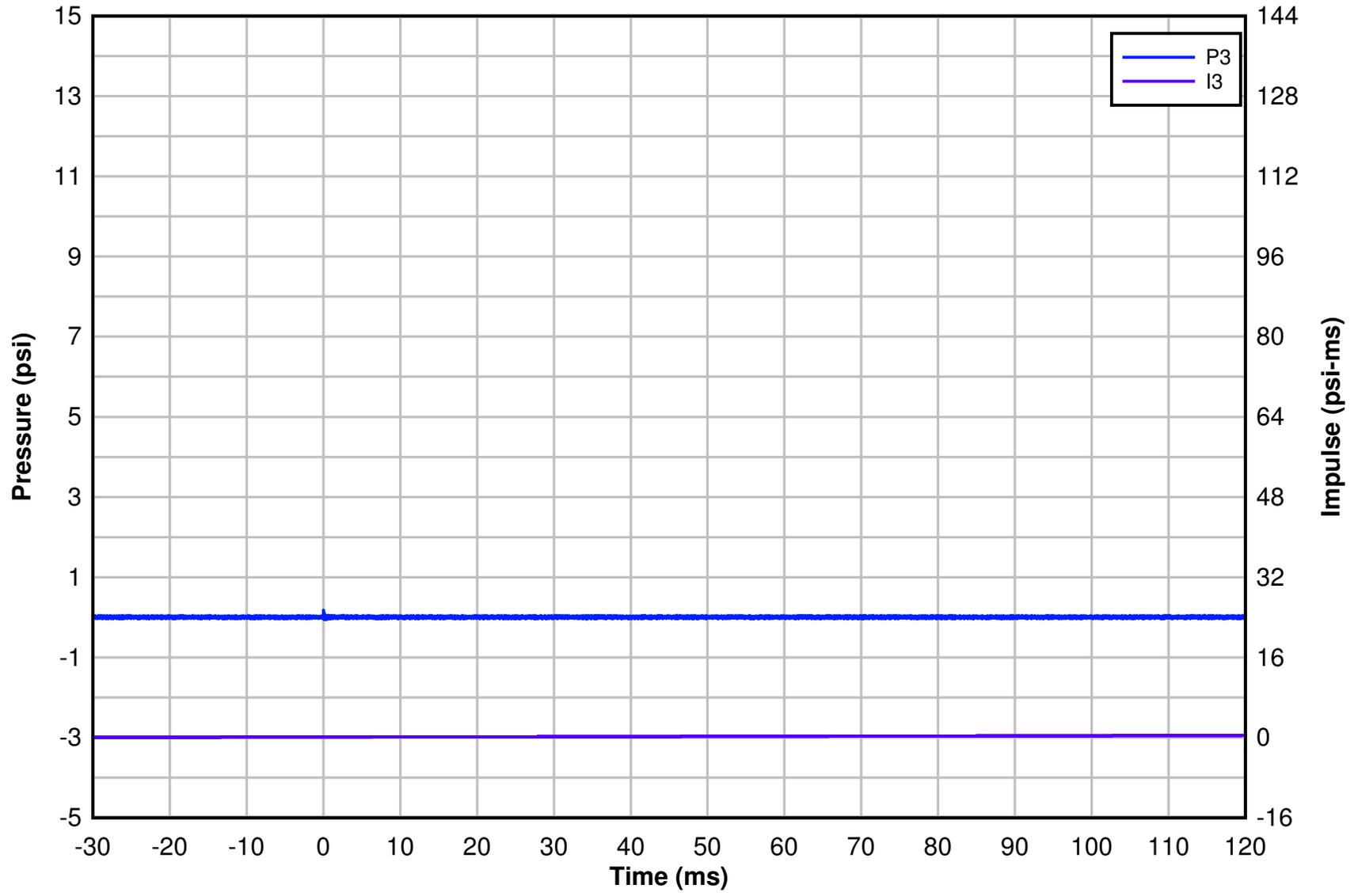
ERDC Historic Windows Test 6



ERDC Historic Windows Test 6



ERDC Historic Windows Test 6



Historic Windows Test 1



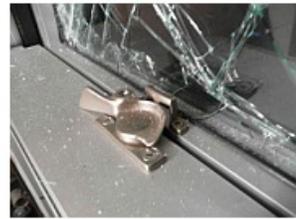
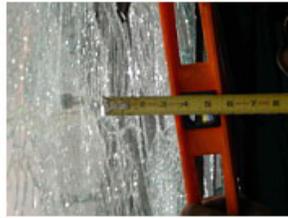
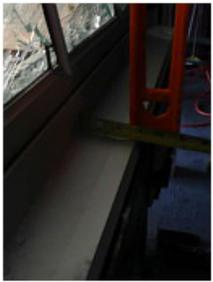
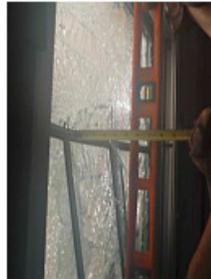
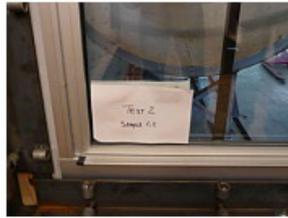
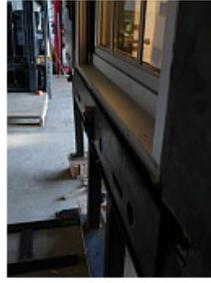
Historic Windows Test 1



Historic Windows Test 1



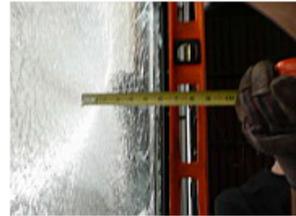
Historic Windows Test 2



Historic Windows Test 2



Historic Windows Test 3



Historic Windows Test 3



Historic Windows Test 4



Historic Windows Test 4



Historic Windows Test 5



Historic Windows Test 5A



Historic Windows Test 5B



Historic Windows Test 6



REPORT DOCUMENTATION PAGE

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