EVALUATION OF EXPLOSIVE CANDIDATES FOR A THERMOBARIC M72 LAW SHOULDER LAUNCHED WEAPON

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INTRODUCTION

In 2003 Naval Surface Warfare Center Indian Head Division (NSWC IHD) and Talley Defense Systems (TDS) worked together to define and demonstrate a solid thermobaric (TB) fill in a lightweight shoulder launched penetrating warhead for the M72 LAW system. In this joint effort, NSWC IHD was responsible for explosive development and evaluation. TDS was responsible for the warhead design and demonstration testing. Merging these technologies lead to a successful demonstration of the concept warhead package.

This paper describes the NSWC IHD evaluation of a number of existing and developmental explosive compositions on pressure and impulse results in a modified two-room structure at Blossom Point, MD. Based on the outcome of three series of tests plus maturity of the explosive candidates, PBXIH-18 was selected as the composition for the demonstration tests.

APPROACH

Based on the results of other TB programs where moderately-to-heavily aluminized compositions have been shown to provide high overpressures in enclosed spaces, initial explosive evaluation was undertaken using a combination of pressed, cast, and gel formulations, most having moderate-to-high fuel content. The compositions tested in the first series are listed in Table 1. Explosive volume was approximately 500 cc for cast and pressed charges. For several of the pressed compositions, the fuel was in a porous surround matrix. PBXIH-135 was used as a baseline for performance comparisons since it is the explosive in the shoulder launched weapon SMAW NE. For cast and pressed compositions, surrogate hardware (shown in Figure 1) was used to mimic the explosive volume, material of construction, and wall thickness of the initial TDS warhead design. A pressed PBXN-5 booster (35.7 grams) and a RP-83 detonator were used to initiate the charges. The booster pellet was the same diameter as the MK 420 fuze which would be used in the final TB warhead design. For some of the gel compositions, heavier wall hardware, a 60 gram C-4 center burster charge, and a RP-83 detonator were used.

Candidate compositions were tested in the modified two-room reinforced concrete structure (where one room had been blocked off) at Blossom Point, MD. The window in the test room was also blocked off. HKS pressure gauges were used to measure pressure and impulse at multiple locations in the structure. The test structure and gauge locations are shown in Figure 2.

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The gauges were mounted at approximately mid-height between floor and ceiling of the room. An attempt was made to use thermal flux gauges to measure temperature rise, however these gauges did not survive the test environment. The explosive charge was suspended from the ceiling so that its center point was 15 inches from the back wall, 42 inches from the side wall and equidistant between floor and ceiling.

The compositions of the first series were screened on the basis of explosive output. The evaluation criteria used are provided in Table 2. The higher the score, the better the explosive's performance. PBXIH-135 was used as the baseline throughout this program for performance comparisons.

For the second series of formulation testing, composition types with performance greater than PBXIH-135 along with several additional concepts were tested in the Blossom Point structure. The test hardware was the initial TDS warhead design (a split case where the top and bottom sections could be loaded separately and then joined). The explosive volume was 353 cm^3. A PBXN-5 pellet (1.26 in diameter and 0.625 in length) with a RP-83 detonator was used to initiate the test charges. The test structure and charge location were unchanged. One floor mounted gauge was removed (see Figure 3) because case fragments frequently damaged this gauge. Pressure and impulse results were evaluated using the ranking scheme shown in Table 3 simplifying the Series 1 methodology.

The two compositions with the best pressure-impulse ranking from Series 2 were tested in Series 3 in the final TDS warhead design. PBXIH-135 was used as a baseline for pressure and impulse comparisons. The warhead design was a unitary case. The explosive volume was 353 cm^3. For loading simplicity, a PBXW-128 booster charge was used for cast compositions and a PBXN-5 booster was used for the pressed composition. The test structure and charge and gauge locations were unchanged from test Series 2.

Down selection between the final 2 candidate compositions was based on explosive output as well as maturity of the explosive compositions since a goal of this effort was to field a TB version of the M72 LAW as quickly as possible.

RESULTS

Plots of the Series 1 test results for peak pressure and impulse at 50 msec are provided in Figures 4 through 8, for gauges 1, 2, 3, 4, and 6. Gauge 5 was damaged in many of the shots. The ranked explosives scores are given in Table 4. The best performers were PBXIH-135EB, PBXIH-18, and the lower aluminum content variations of PBXIH-18.

Based on the results of Series 1, the compositions carried into the second series of tests (which were in initial TDS warhead design hardware) were: PBXIH-135EB (energetic binder), PBXIH-18, a variation of PBXIH-18 at reduced density, an energetic binder version of HAS-4 and a blend of PBXW-11 and Mg/Al alloy. It was thought that an intimate mixture of a high HMX content explosive composition (PBXW-11) and the Mg/Al alloy would react more quickly than the explosive/fuel surround configuration. Also, an ammonium perchlorate-containing composition, PBXIH-136, was included in this matrix.

Compositions of the second series are given in Table 5. Plots of the Series 2 test results are provided in Figures 9 through 13. The ranked explosive scores are given in Table 6. In this ranking scheme, low score is best. The two explosives with highest output were PBXIH-18 and PBXIH-135EB. These compositions were carried forward into Series 3 testing.

The hardware for Series 3 tests was the final Talley warhead design. Since it was a unitary warhead design, ease of loading necessitated using a cast booster for the cast compositions PBXIH-135EB and PBXIH-135 (baseline) and a pressed booster for the pressed PBXIH-18 composition. The configuration and instrumentation of the Blossom Point test structure was kept the same as in Series 2 tests. Compositions of the third series are given in Table 7. Pressure and impulse results are shown in Figures 14 through 16.

Overall, slightly higher peak pressures were obtained for PBXIH-18 relative to PBXIH-135EB, whereas, PBXIH-135EB tended to have slightly higher impulse.

Factors in addition to explosive output that were considered in down selection between PBXIH-18 and PBXIH-135EB were ingredient cost and availability, sensitivity, producibility, storage issues, and mechanical properties. Ingredient cost and availability and explosive sensitivity are similar for the two compositions. “Storage issues” refer to whether it would be necessary to monitor stabilizer level over time such as for a nitrate ester containing composition. PBXIH-135EB contains a stabilizer, PBXIH-18 does not. PBXIH-18 is more like the current fill (aluminized Comp A3) in the LAW system in terms of mechanical properties than is PBXIH-135EB. Finally, the qualification testing for PBXIH-18 has recently been completed and the request for qualification of this explosive composition will soon be submitted. PBXIH-135EB is still a developmental composition.

CONCLUSIONS

Based on a combination of explosive output and the maturity of the explosive composition, PBXIH-18 was selected as the explosive fill for the dynamic demonstration tests for this program.

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Glossary

Al	aluminum
AN	ammonium nitrate
DOA	dioctyl adipate
EC	ethyl cellulose
EG	ethylene glycol
FL	fluorolube oil
HTPB	hydroxyl terminated polybutadiene
HyTemp	polyacrylic binder
IPN	isopropyl nitrate
Mg	magnesium
PCP	polycaprolactone polymer
TMETN	trimethylolethane trinitrate
Zr	zirconium

Table 1. Explosive Compositions in First Series of Tests

Charge No.	Explosive	Explosive Composition	Fuel Surround	Explosive Density, g/cc
1	PBXIH-135	HMX/Al/HTPB binder	N/A	1.68
2				
3				
4	PBXIH-135EB (energetic binder)	HMX/Al/PCP-TMETN binder	N/A	1.79
5				
6				
7	HAS-4	HMX/Al/HTPB binder	N/A	1.65
8				
9				
10	PBXIH-18	HMX/Al/HyTemp/DOA binder	N/A	1.91
11				
12				
13	PBXIH-18, mod 1	HMX/Al/HyTemp/DOA binder	N/A	1.77
14				
15				
16	PBXIH-18, mod 2	HMX/Al/HyTemp/DOA binder	N/A	1.84
17				
18				
19	PBXW-11 w/ Al surround	HMX/HyTemp/DOA binder	H5 Al	1.67
20				1.70
21				1.69
22	PBXW-11 w/ Mg/Al surround	HMX/HyTemp/DOA binder	Mg/Al	1.64
23				1.64
24				1.65
25	PBXW-11 w/ C surround	HMX/HyTemp/DOA binder	Coal	1.35
26				1.35
27				1.36
28	Talley Mix 5640	Mg/IPN/EC	N/A	1.3
29				
30				
31	Talley Mix 5672	Al/Zr/IPN/EC	N/A	2.21
32				
33				
34	EG/AN/Al	ethylene glycol/AN/Al	N/A	1.23
35				1.09
36				1.18
39	FL/AN/Al	Fluorolube/AN/Al	N/A	1.56
40				
41				

explosive volume for cast and pressed charges: 504 cc
explosive volume for Talley Mix 5640 and 5672 charges ~350 cc; center burster of 60g C4 used
explosive volume for EG/AN/AL and FL/AN/AL gel charges (including C4 burster charge): 504 cc
booster charge was 35.7g PBXN-5

Table 2. Criteria Used to Screen Explosives in First Test Series

Criteria	Maximum Points
Explosive Output	**100**
Gauge 1 Results	**20**
Peak Pressure	10
Impulse	10
Gauge 2 Results	**20**
Gauge 3 Results	**20**
Gauge 4 Results	**20**
Gauge 6 Results	**20**

Note: in most cases Gauge 5 was lost due to fragment damage

Table 3. Criteria Used to Screen Explosives in Second Test Series

Criteria	Ranking Methodology
Gauge 1 Results	
Peak Pressure, (normalized by weight, psi/lb)	rank from 1 to 7, with 1 having highest peak pressure
Impulse	rank from 1 to 7, with 1 having highest impulse
Gauge 2 Results	
Peak Pressure, (normalized by weight, psi/lb)	rank from 1 to 7, with 1 having highest peak pressure
Impulse	rank from 1 to 7, with 1 having highest impulse
Gauge 3 Results	
Peak Pressure, (normalized by weight, psi/lb)	rank from 1 to 7, with 1 having highest peak pressure
Impulse	rank from 1 to 7, with 1 having highest impulse
Gauge 4 Results	
Peak Pressure, (normalized by weight, psi/lb)	rank from 1 to 7, with 1 having highest peak pressure
Impulse	rank from 1 to 7, with 1 having highest impulse
Gauge 5 results	
Peak Pressure, (normalized by weight, psi/lb)	rank from 1 to 7, with 1 having highest peak pressure
Impulse	rank from 1 to 7, with 1 having highest impulse

Table 4. Pressure and Impulse Ranking for Explosives of First Test Series

Pressure and Impulse	Score
PBXIH-135 EB	87.8
PBXIH-18	79.9
PBXIH-18 mod 2	76.3
PBXIH-18 mod 1	73.5
PBXW-11 Mg/Al Surround	64.5
PBXW-11 Al Surround	62.8
PBXIH-135 (baseline)	50.6
HAS-4	47.9
PBXW-11 C Surround	47.7
FL/AN/AL	43.1
Talley 5672	36.0
EG/AN/AL	27.4
Talley 5640	15.5

Note: Higher score indicates higher performance

Table 5. Explosive Compositions in Second Series of Tests

Charge No.	Explosive	Explosive Composition	Explosive Density, g/cc
1	PBXIH-135	HMX/Al/HTPB binder	1.68
2			
3			
4	PBXIH-135 EB	HMX/Al/PCP-TMETN binder	1.74*
5			1.94
6			1.95
7	HAS-4 EB	HMX/Al/PCP-TMETN binder	1.73
8			1.61
9			1.85
10	PBXIH-136	RDX/AP/Al/PCP-TMETN binder	2.03
11			
12			
13	PBXIH-18	HMX/Al/HyTemp/DOA binder	1.92
14			
15			
16	IH-18 LD	HMX/Al/HyTemp/DOA binder	1.78
17			
18			
19	YKT-21	PBXW-11 / Mg/Al alloy	1.70
20			1.69
21			1.69

LD: low density
Booster charge was 25g PBXN-5.
** did not use in calculating output averages*

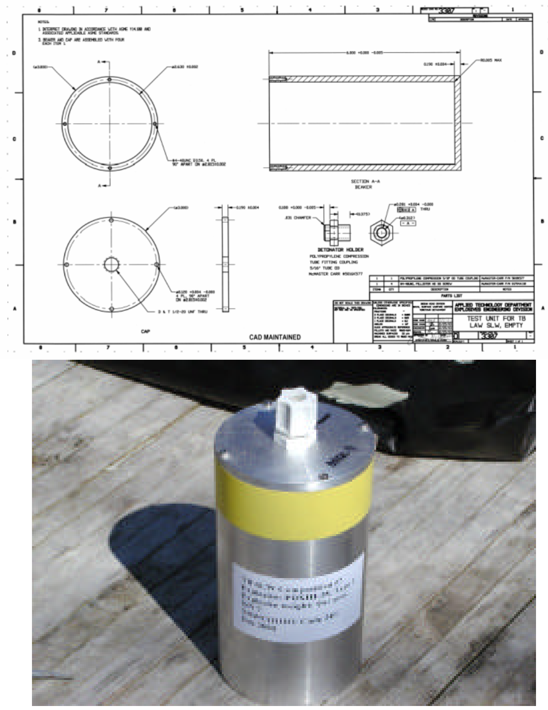
Table 6. Pressure and Impulse Ranking for Explosives of Second Test Series

Pressure and Impulse	Score
PBXIH-18	20.3
PBXIH-135 EB	25.8
PBXIH-18 LD	31.0
HAS-4EB	35.3
YKT-21	38.7
PBXIH-135 (baseline)	54.7
PBXIH-136	59.5

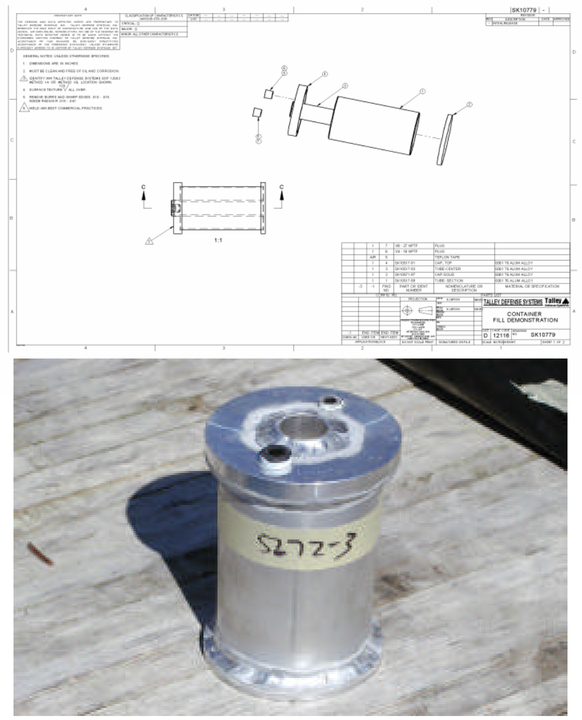
Note: In this ranking scheme, low score is best.

Table 7. Explosive Compositions in Third Series of Tests

Charge No.	Explosive	Explosive Composition	Density, g/cc	Booster
1	PBXIH-18	HMX/Al/HyTemp/DOA binder	1.95	PBXN-5
2				
3	PBXIH-135EB	HMX/Al/PCP-TMETN binder	1.94	PBXW-128
4				
5	PBXIH-135 (baseline)	HMX/Al/HTPB binder	1.69	PBXW-128
6				

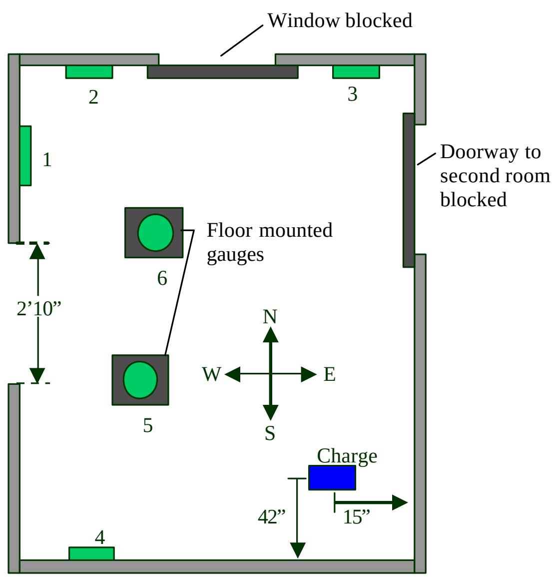


Case for cast, pressed and some gel formulations



Case for Talley gel formulations

Figure 1. Test hardware for Series 1 tests

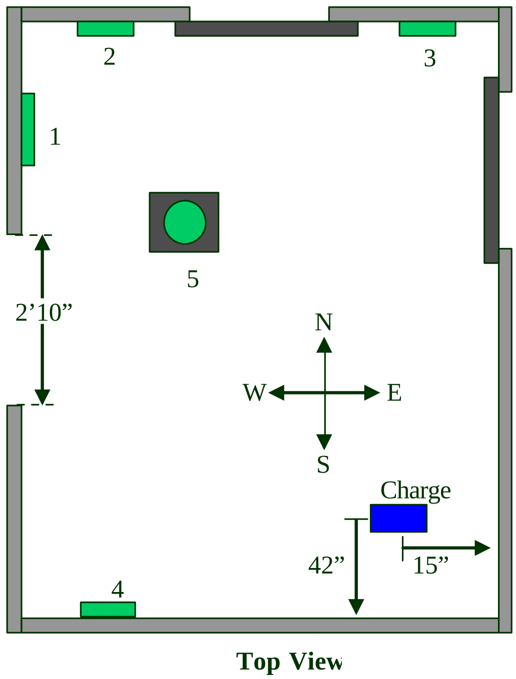


Top View

12 x 15 x 7 ft room

Pressure gauge locations numbered

Figure 2. Blossom Point test structure



12 x 15 x 7 ft room

Figure 3. Blossom Point test structure gauge locations for Series 2 and 3 tests

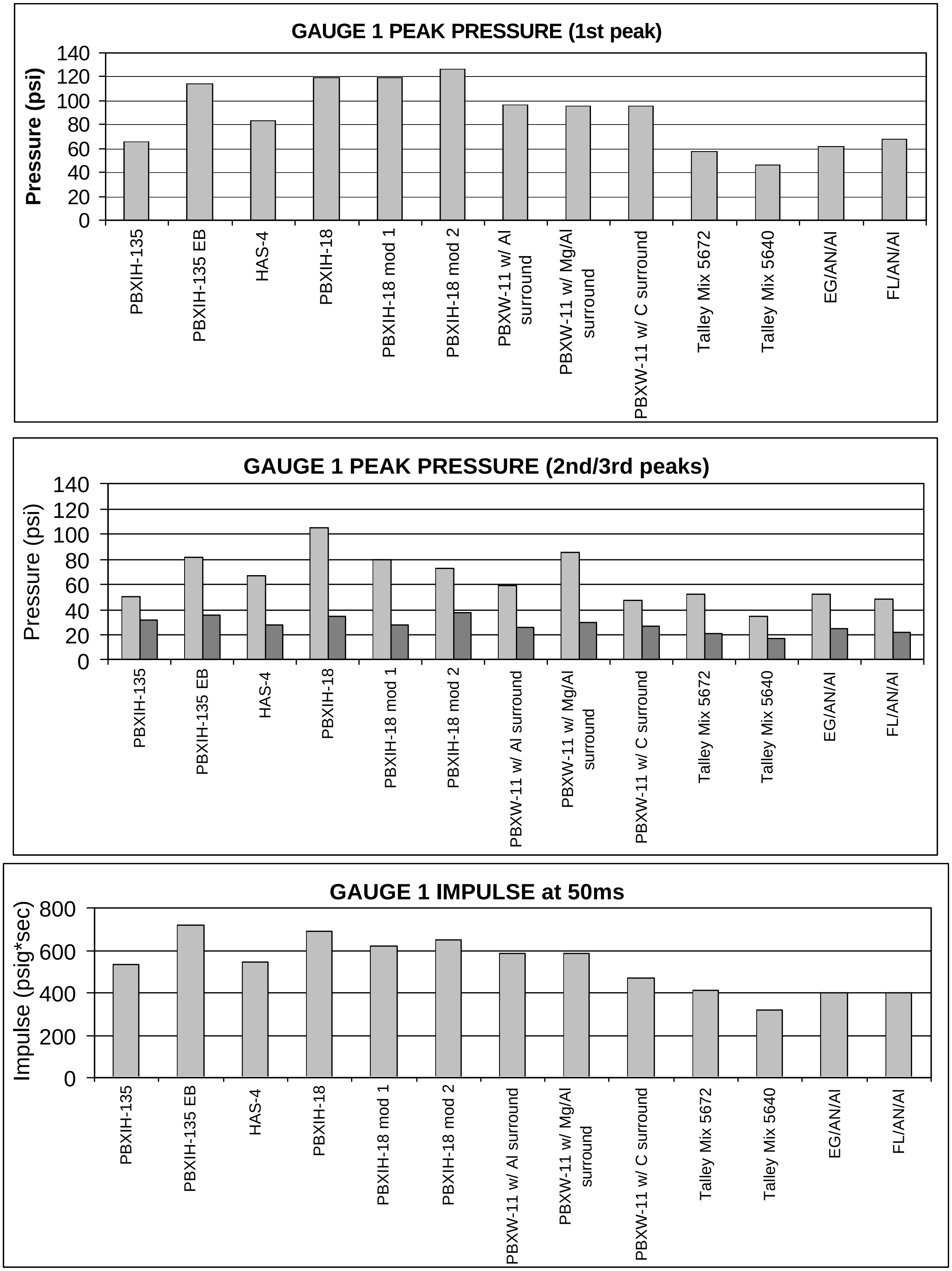


Figure 4. Series 1 gauge 1 results

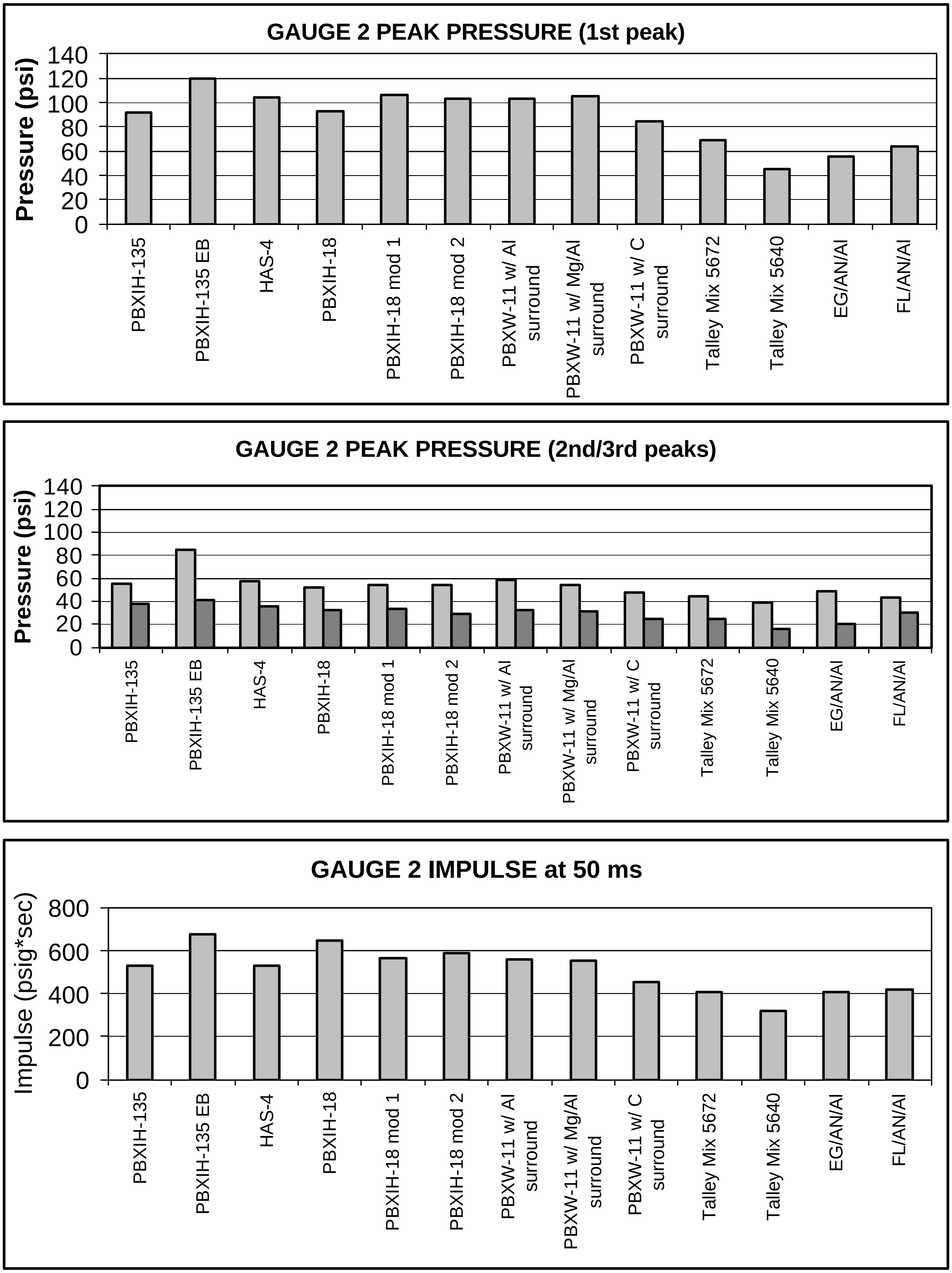


Figure 5. Series 1 gauge 2 results

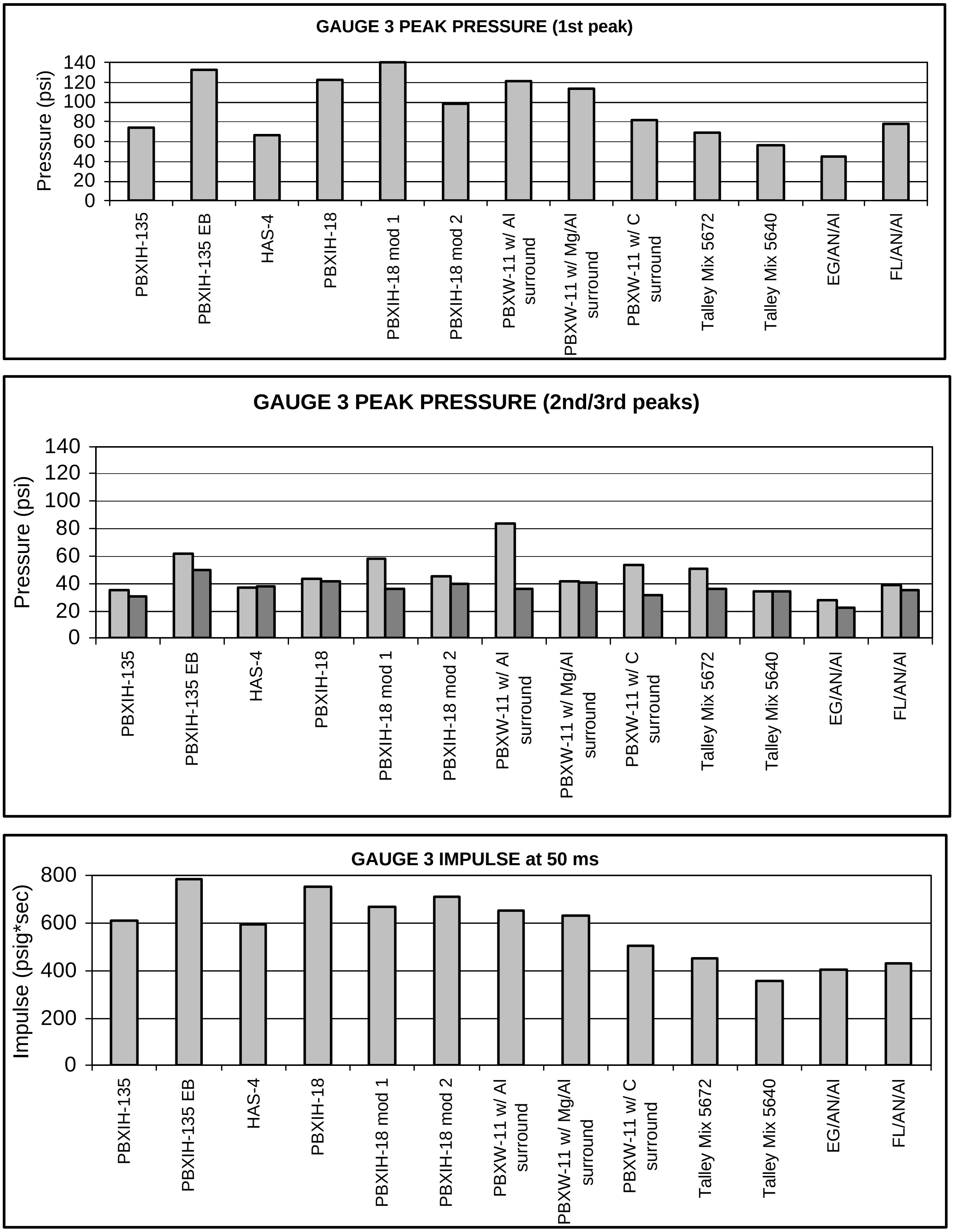


Figure 6. Series 1 gauge 3 results

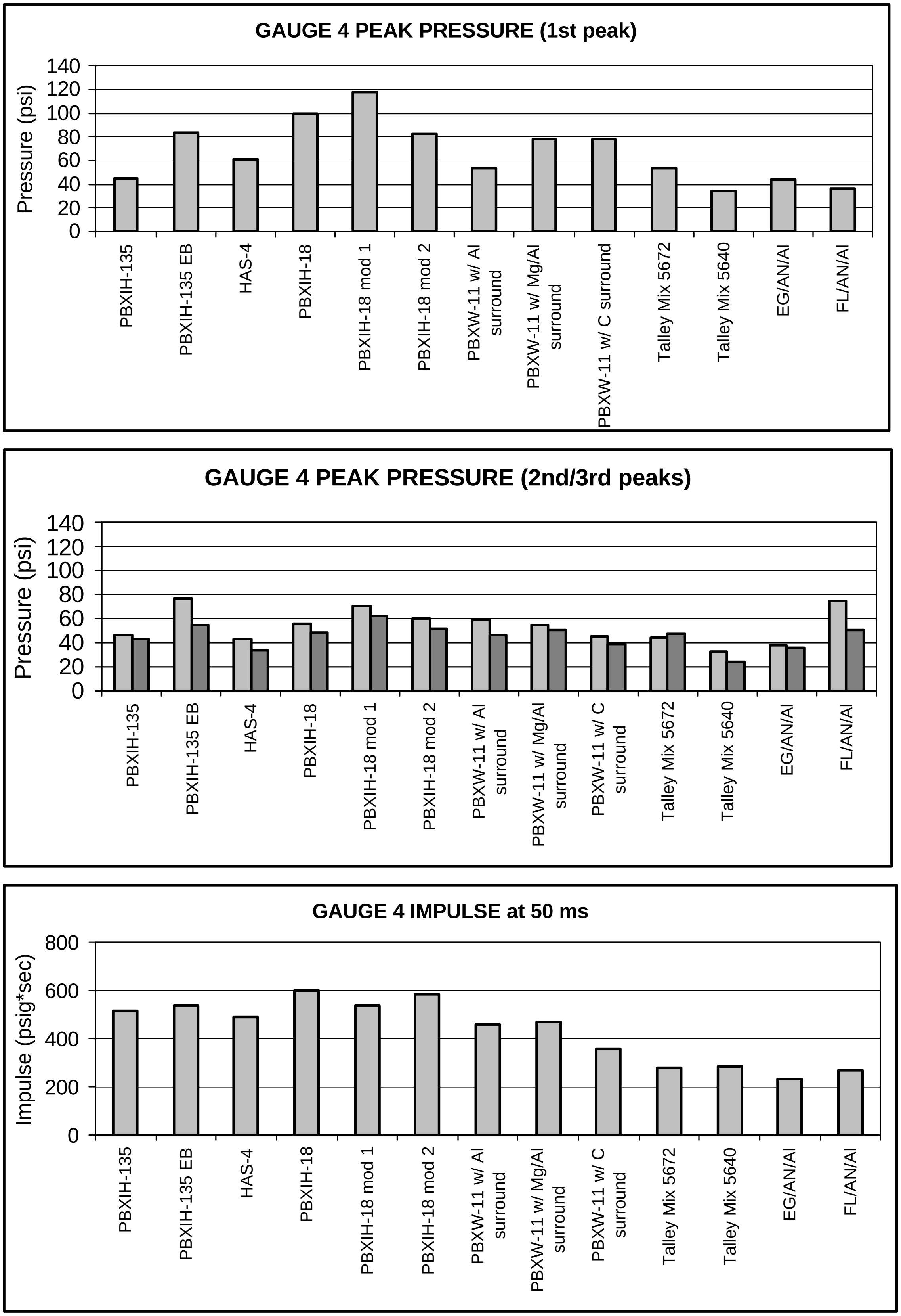
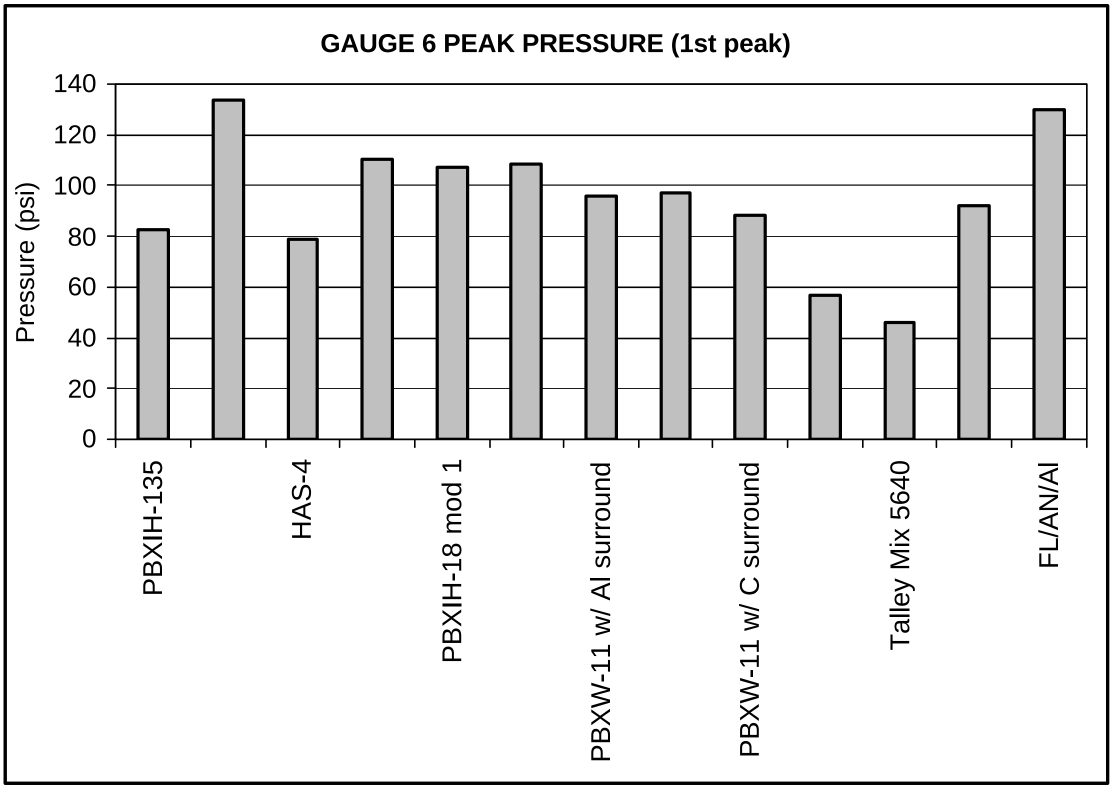


Figure 7. Series 1 gauge 4 results



Note: no data collected after initial pressure peak for several shots

Figure 8. Series 1 gauge 6 results

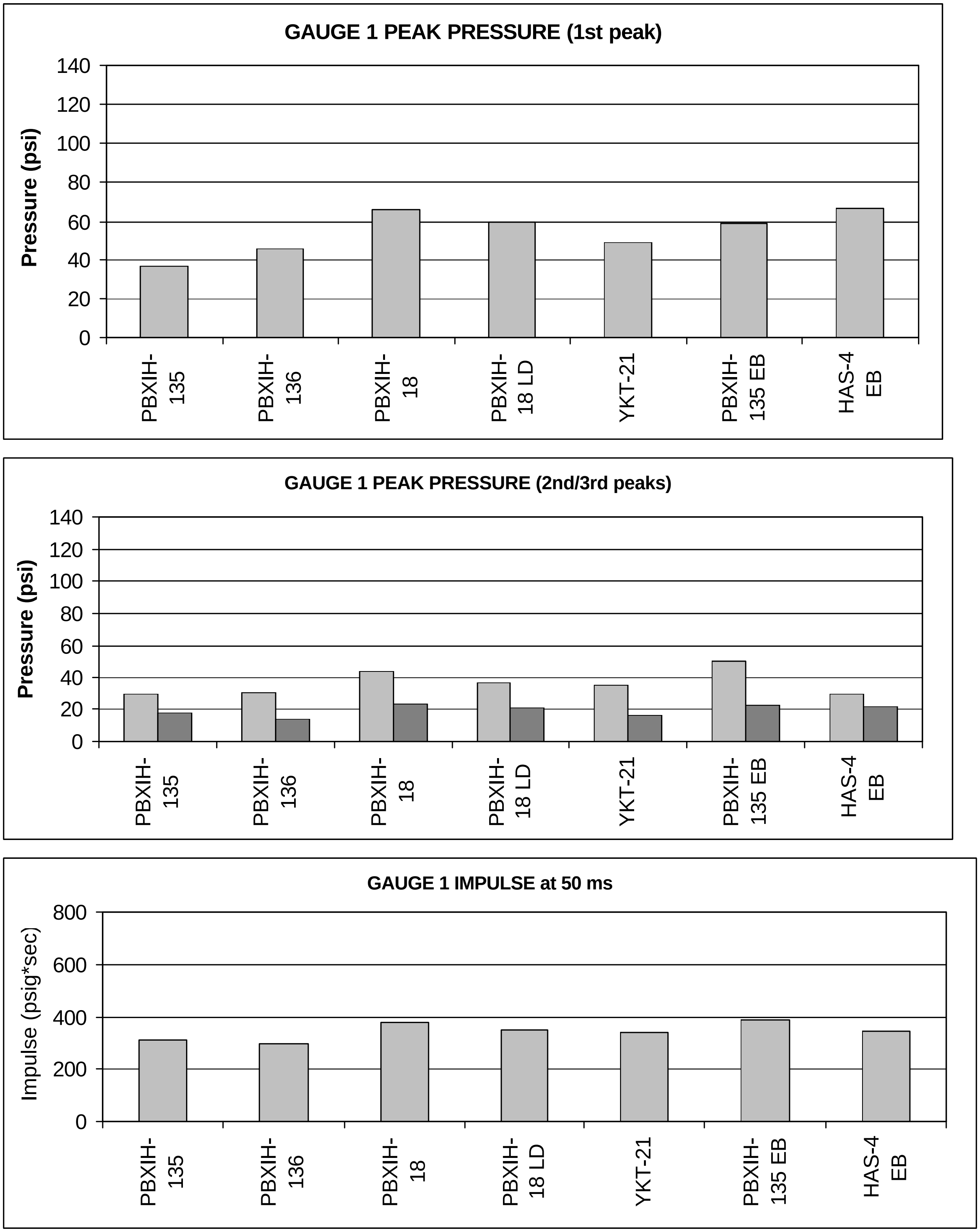


Figure 9. Series 2 gauge 1 results

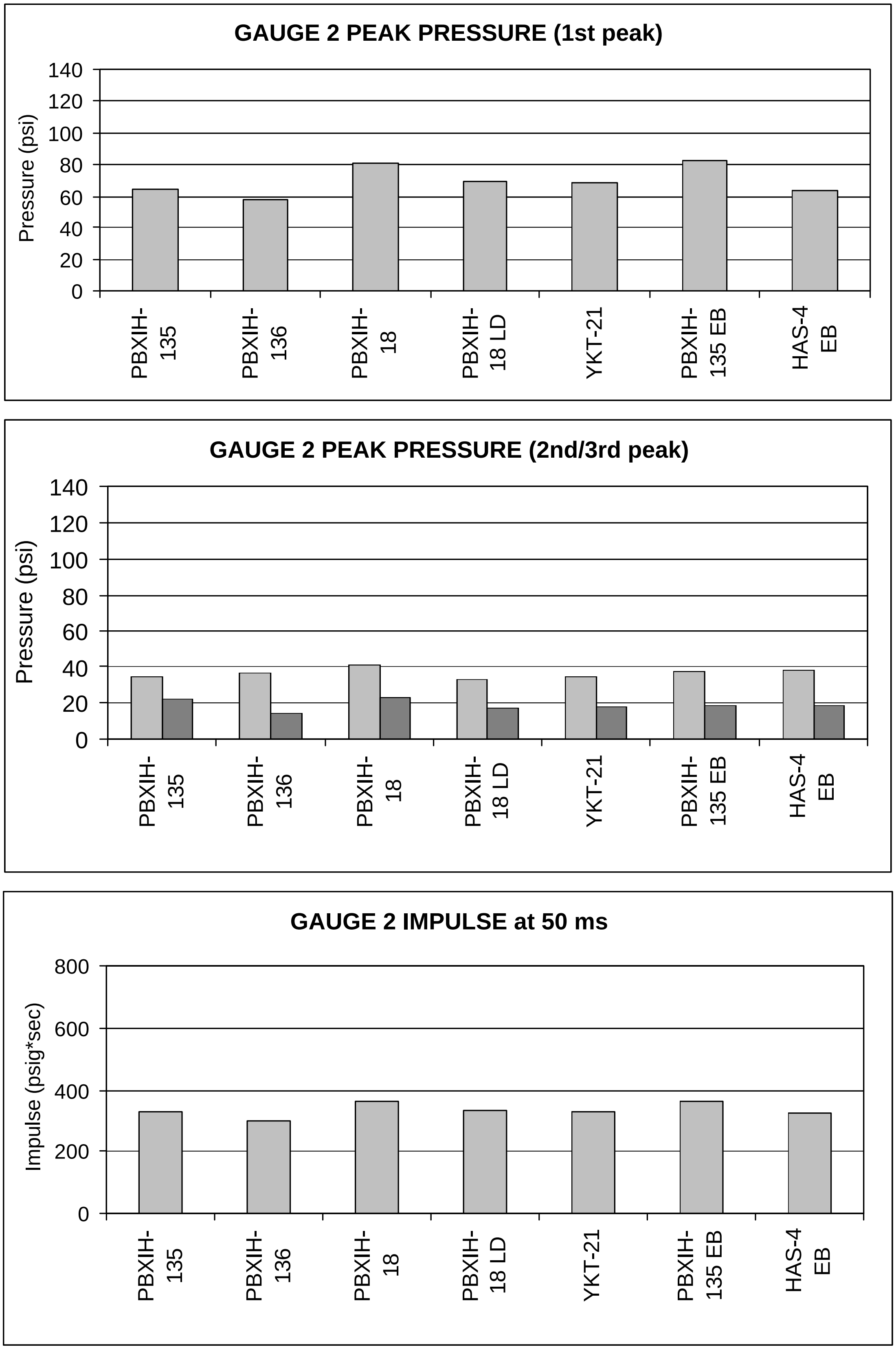


Figure 10. Series 2 gauge 2 results

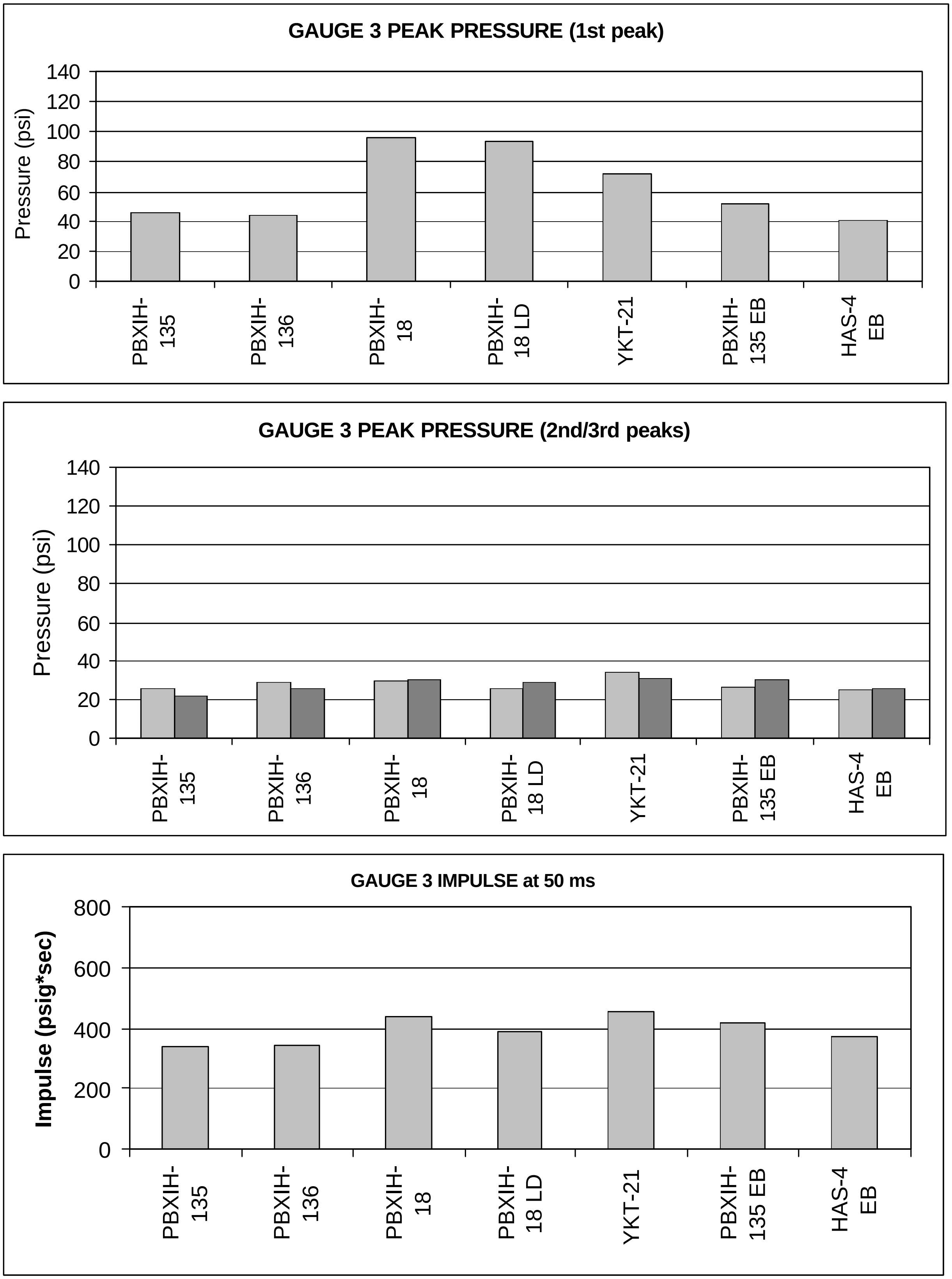


Figure 11. Series 2 gauge 3 results

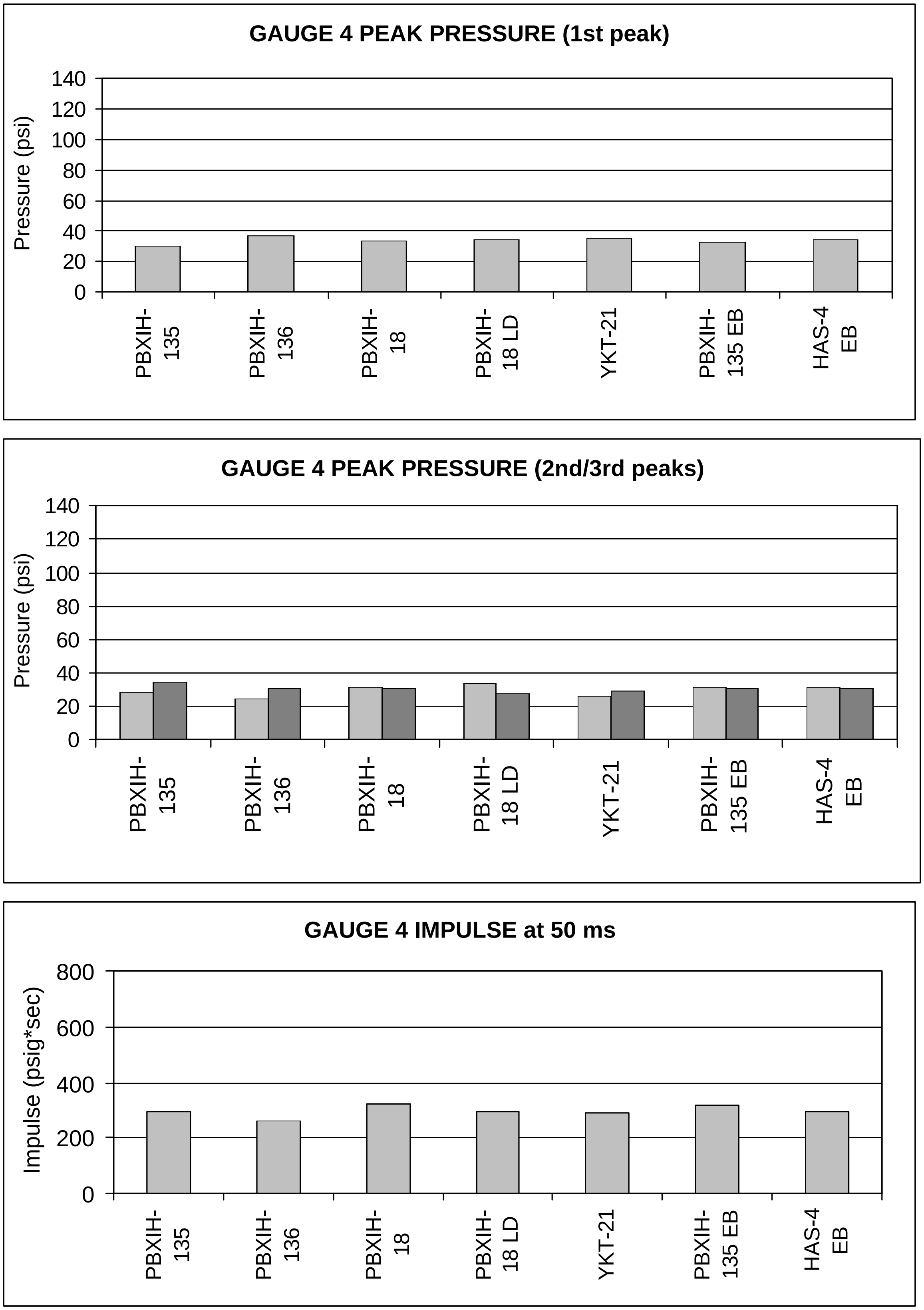
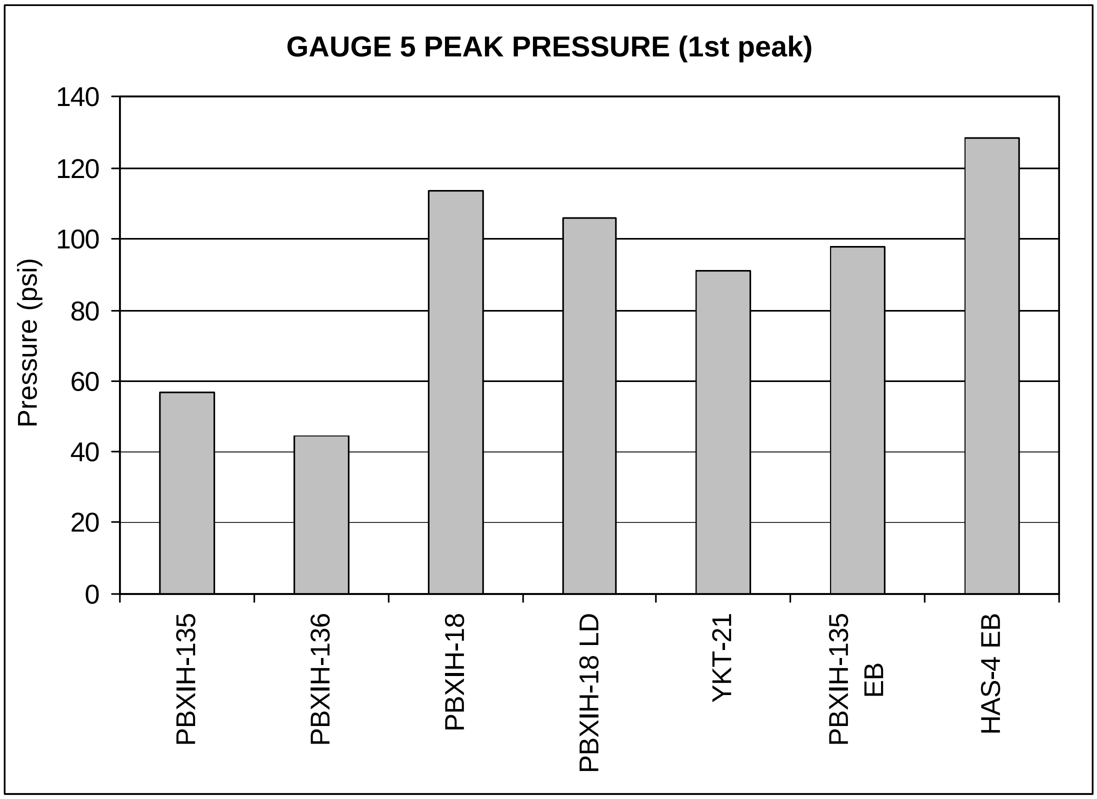


Figure 12. Series 2 gauge 4 results



Note: no data collected after initial pressure peak for several gauges

Figure 13. Series 2 gauge 5 results

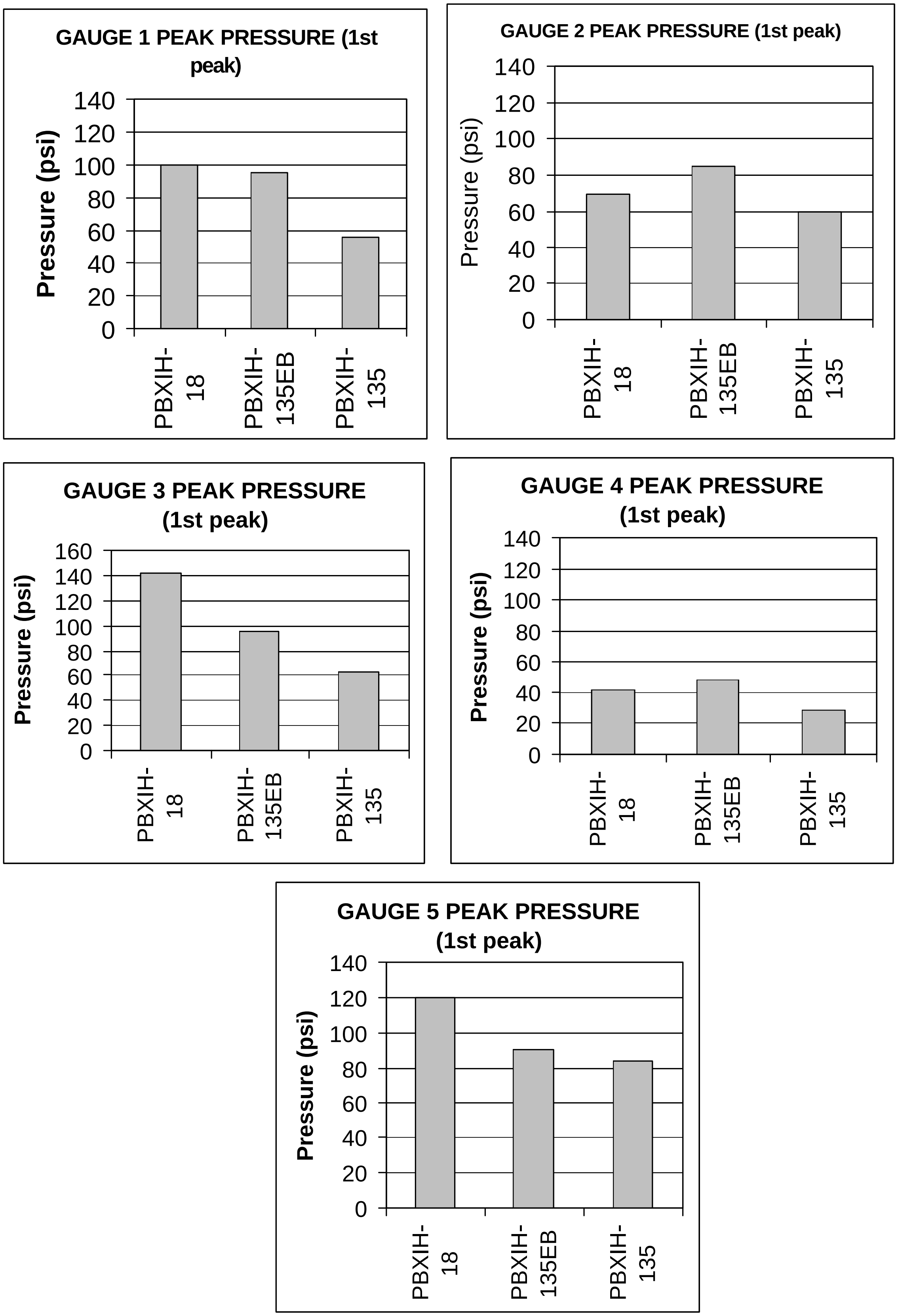


Figure 14. Series 3 pressure (1st peak) results

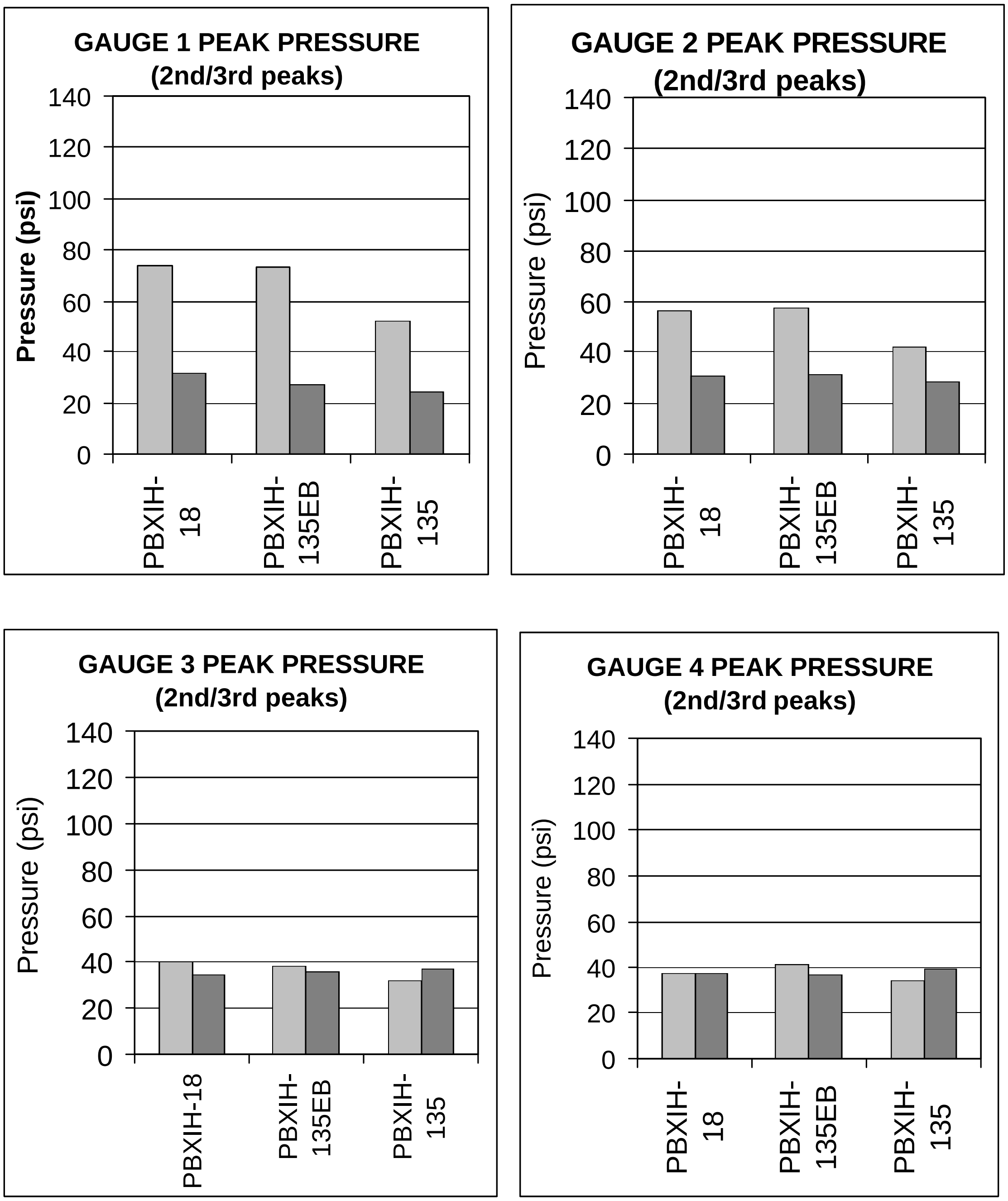


Figure 15. Series 3 pressure (2nd/3rd peak) results

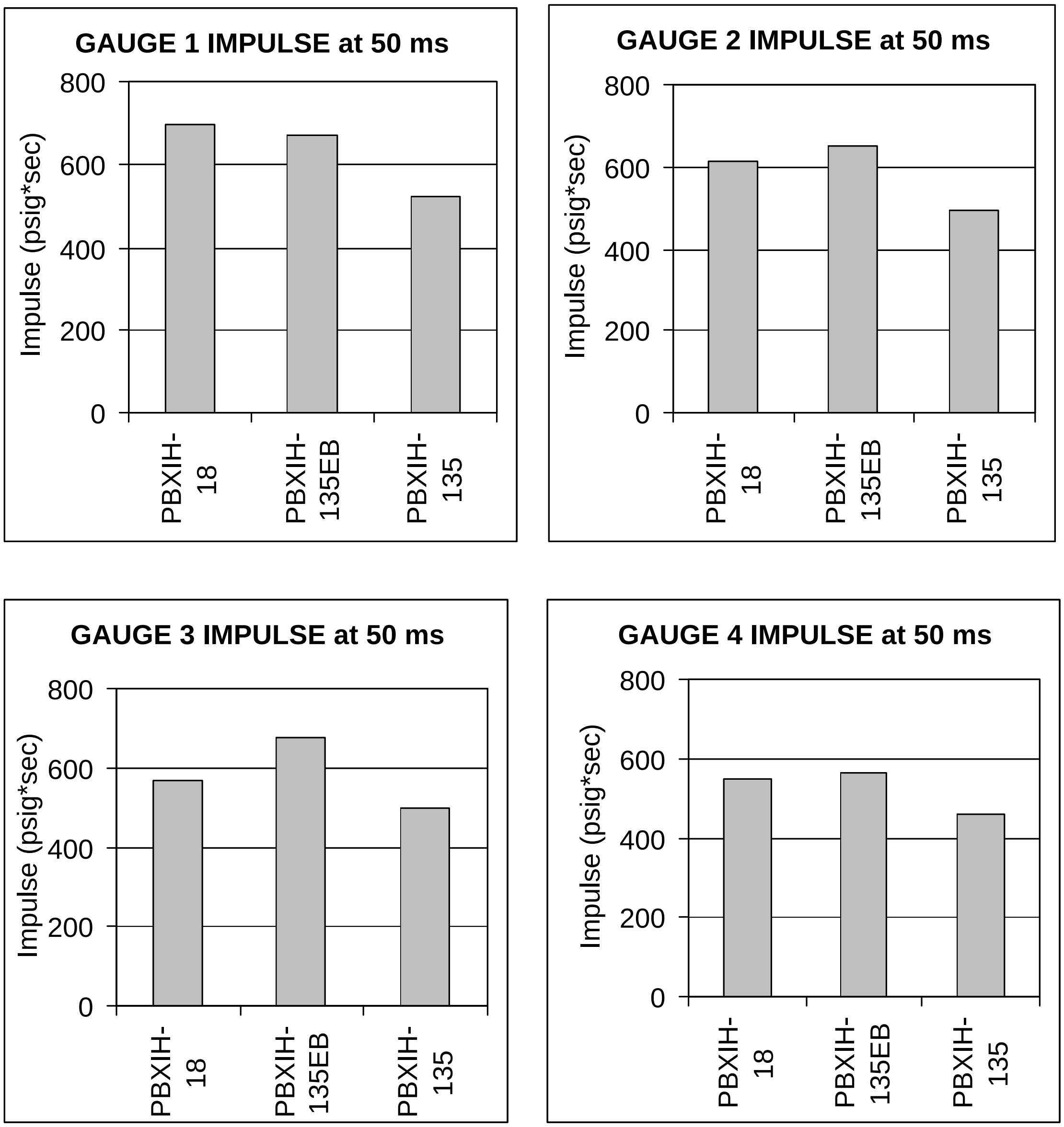


Figure 16. Series 3 Impulse at 50 msec results