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January 31, 2014

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Re: Final Revised Hydraulic Pulse Interference Test Report
Olin Chemical Superfund Site. Wilmington, Massachusetts
GeoSierra Project Number G206001

Dear Mr. Thompson:

GeoSierra Environmental, Inc. is pleased to provide AMEC Environment and Infrastructure (AMEC) this revised final report based on comments received May 10, 2013 and January 21, 2014 detailing the results of hydraulic pulse interference activities completed in December 2012 at the above referenced site.

We appreciate the opportunity work with AMEC on this project and look forward to working together during subsequent testing phases at the site. If you have any questions, please feel free to contact me at your earliest convenience at 609.975.6400.

Thank You,

GeoSierra Environmental, Inc.

Kevin D. Dyson, P.E.
Senior Project Manager

Cc: Peter Palko, P.E., CHMM, LSRP - **GeoSierra** Environmental, Inc.

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EXECUTIVE SUMMARY

This Hydraulic Pulse Interference Test (HPIT) report has been prepared for the Olin Chemical Superfund Site (the Site) located in Wilmington, Massachusetts on behalf of Olin Corporation (Olin) by **GeoSierra Environmental, Inc.** (**GeoSierra**) under contract to AMEC Environment & Infrastructure, Inc. (AMEC). This report discusses the Phase 1 Baseline Testing Program described in Section 5 of the *Final Addendum II Hydraulic Pulse Interference Testing of the Slurry Wall at the Containment Area (AMEC, 2012)*, as conditionally approved by the United States Environmental Protection Agency (USEPA) on February 18, 2012. In 2001, Olin constructed the Slurry Wall/Cap Containment structure (the Containment Area) around the on-property portion of the Upper DAPL Pool as a Release Abatement Measure (RAM) consistent with the Massachusetts Contingency Plan (MCP). The intent of this source control action was to eliminate, to the extent feasible, the on-Property DAPL source material as a source of dissolved constituents to overlying groundwater. The containment structure is comprised of a three foot thick soil – clay perimeter slurry wall keyed into bedrock and a temporary cap to minimize infiltration of precipitation into the Containment Area.

GeoSierra was retained by AMEC to assist Olin in developing a site-specific HPIT protocol at the request of USEPA to test the competence of the slurry wall along with determining other hydrogeologic parameters. HPITs are used to compute the in-situ hydraulic properties (hydraulic conductivity and specific storage) of subsurface materials in the saturated groundwater zone between two wells. The primary objective of the HPIT is to measure the hydraulic properties of the slurry wall by conducting measurements from wells placed on either side of the slurry wall. The approved baseline testing program was designed to evaluate flow rates and pressure pulse dissipation (known herein as "shut in") intervals that provide the best signal response for the hydrogeologic conditions at the Site. Specifically, testing was performed to determine over what distances signals could be reliably transmitted and received, and if communication existed between interior and exterior monitoring well pairs by hydraulically pulsing the aquifer using source wells and monitoring interior and/or exterior receiver well response pressures. Baseline HPIT activities were completed in December 2012 in accordance with the approved work plan. The program included testing a total of eight (8) existing monitoring well pairs including wells located outside of the slurry wall, wells inside the slurry wall and finally well pairs on opposite sides of the slurry wall. By testing in this manner, **GeoSierra** was able to determine the

response to HPIT through multiple hydrogeologic units as well as evaluate if communication from specific interior to exterior well pairs through the slurry wall was occurring.

The Baseline HPIT program was designed to determine the applicability of the technology to the Site and identify any potential limitations based on site hydrogeologic conditions including the use of existing wells which were not specifically designed for HPIT testing. Based on the results, HPIT testing appears to be a viable approach to testing well pairs at the Site; however, limitations were identified involving the use of existing shallow wells along with pulse propagation distance. A number of existing water table wells that have well screens which straddle the water table do not provide consistent and verifiable HPIT results. The HPIT data collected from one well pair located on opposite sides of the slurry wall in the northeast test quadrant (GW-6D and GW-CA3D) indicates direct hydraulic communication between the wells tested. The hydraulic conductivity computed from this test pair is high but consistent with historical slug test data from wells in the vicinity of the Containment Area. It is not possible to determine from this test result if the indicated hydraulic pathway is directly through the wall, its connection to bedrock, or through weathered bedrock immediately underlying the wall. The hydraulic gradient between these wells is inward toward the Containment Area.

Taken together, the results of this test indicate that the HPIT test is a reasonable method of evaluating the structural integrity of the slurry wall. However, the resulting data must be reviewed carefully with other ancillary information to draw appropriate conclusions.

1.0 SITE BACKGROUND

1.1 Slurry Wall / Containment Area

Background information on the Olin Chemical Superfund Site (Site) is included in the RI/FS Work Plan (MACTEC Engineering and Consulting, Inc, 2009). The Olin Property is situated over glacial outwash deposits that overly glacial till and igneous and metamorphic bedrock. The glacial outwash deposits consist mainly of unconsolidated fine to coarse sands and gravel, with variable amounts of silt. Process waters and liquid wastes discharged to unlined ponds at the former facility resulted in the formation of a dense aqueous phase liquid (DAPL) which pooled in a series of bedrock depressions.

One of these DAPL pools, the Upper DAPL pool has On-Property and an Off-Property portion. Olin constructed the Slurry Wall/Cap Containment structure (the Containment Area) around the On-Property portion of the Upper DAPL Pool as a Release Abatement Measure (RAM) consistent with the Massachusetts Contingency Plan (MCP) in 2001. The intent of this source control action was to eliminate, to the extent feasible, the On-Property DAPL source material as a source of dissolved constituents to overlying groundwater. The containment structure is comprised of a perimeter slurry wall keyed into bedrock and a temporary cap to minimize infiltration of precipitation into the area. Construction of the slurry wall was preceded by a pre-design boring program to determine the depth to bedrock. The slurry wall contains, to the extent practical, the on-property Upper DAPL and overlying groundwater located within the containment structure. The relationship of the slurry wall, the DAPL pool and the bedrock surface were presented in the work plan.

The slurry wall is a 3-foot wide containment wall installed from ground surface into the top of bedrock completely surrounding the on-property Upper DAPL pool. The location of the slurry wall (perimeter of the containment structure) and associated wells are shown on Figure 1. The slurry wall is comprised of a mixture of 65 percent excavated soil, 30 percent imported clayey glacial till, 3 percent processed attapulgite clay, and 2 percent bentonite clay. Independent laboratory tests of the slurry wall backfill material indicate a permeability of approximately 5.0 x 10^{-8} centimeters per second (cm/sec). The temporary cap is an 8-mil thick scrim reinforced polyethylene sheet cover, with sewn seams, held in place by sandbags. A gravel roadbed was

installed around the eastern and southern perimeter of the temporary cap and slurry wall to allow vehicle access to the southwest area of the Site and to provide ballast for edges of the temporary cap.

The maximum depth of the slurry wall is approximately 35 feet below ground surface. A 40-foot long gravel equalization window was installed across the water table on the western up-gradient side of the slurry wall to maintain equal hydraulic pressure between groundwater inside and outside of the containment structure. This equalization window is monitored by wells GW-CA1 and GW-CA2, which are located at either end of the equalization window.

1.2 HPIT Objectives

In April 2012, AMEC and Olin submitted the "*Final Addendum II – Hydraulic Pulse Interference Testing of the Slurry Wall at the Containment Area Final Remedial Investigation/Feasibility Study Work Plan*" (Work Plan) to the United States Environmental Protection Agency (USEPA). USEPA provided conditional approval of the Work Plan on February 12, 2013. The April Work Plan submittal addressed EPA requests to conduct the HPIT testing in two phases. The primary objective of the entire proposed HPIT program is to measure the hydraulic properties of the slurry wall by conducting measurements from wells placed on either side of the slurry wall. The objective of the Phase 1 Baseline program was to evaluate flow rates and shut-in intervals that provide the best signal response for the hydrogeologic conditions at the Site. The Baseline program tested well pairs located outside and inside the containment area separately to evaluate the distance hydraulic pulse signals can be propagated and received. The Baseline testing also tested well pairs that will provide information on the potential effect of the equalization window on hydraulic pulse propagation over the slurry wall. A HPIT was also conducted between GW-6S/D and GW-CA3S/D to evaluate if a hydraulic pulse can be transmitted through the slurry wall.

The mathematical basis, preparation for testing, field activities performed and the results of the baseline testing program are discussed in the following sections.

2.0 HYDRAULIC PULSE INTERFERENCE TESTING

2.1 Background

HPIT has been utilized in the petroleum industry since the mid-1960s, [Johnson et. al. (1966), Earlougher (1977), Lee (1982), Kamal (1983) and Horne (1995)], primarily as fully penetrating aquifer tests, but in some cases as vertical pulse interference tests [Burns (1969) and Hirasaki (1974)]. The test involves a cyclic injection or withdrawal of fluid from the source well followed by a shut-in period, and by high precision measurement of the pressure pulse in a neighboring well, detailed hydraulic characterization between wells can be made (Figure 2). Because the HPIT is highly sensitive to hydrogeological properties between the pulse source and receiver wells, and relatively insensitive to conditions immediately adjacent to the wells (e.g. wellbore storage effects), the time delay and attenuation of the hydraulic pulse enable the formation hydraulic properties to be computed. Since the test is a transient test, both the formation transmissivity and storativity can be calculated for a wide variety of aquifer types.

HPIT has only recently been used in the groundwater field, primarily for site characterization, hydraulic integrity testing of slurry wall containment structures and testing of permeable reactive barriers (Hocking and Wells, 1997; and Hocking, 2001). To obtain maximum hydraulic property resolution, the HPIT can be constructed as a point source utilizing single or straddle packers in the injector well depending on the well construction and aquifer type. The flow rate into the source injector well is rate controlled and set at a constant flow rate, which will depend on the site hydrogeologic conditions. High precision pressure transducers are located in receiver wells and isolated from receiver borehole storage effects by single or straddle packers. Thus the pulse is of point source origin and borehole storage effects are eliminated from both the injector and receiver wells. The injector well is pulsed for a set time, shut in for the same time period, and the test is either terminated as a single pulse test, or the cycle repeated for a multiple pulse test. The pulse source and receivers can be located at differing depth locations in their respective wells, yielding a detailed quantification of the site's hydrogeological properties (Hocking, 2004).

2.2 Mathematical Model

The point source hydraulic pulse interference test can be modeled from the solution of a continuous point source in an infinite isotropic homogeneous medium (Carslaw and Jaeger, 1986) as given by equation (1). This fundamental solution can be modified to incorporate finite

aquifer systems, confined and unconfined conditions, anisotropic and heterogeneous conditions in a similar manner as the line source solution has been modified in the petroleum literature. This line source solution for continuous injection is the exponential integral, whereas the point source solution for a single or cyclical pulse/shut-in test scenario is the complimentary error function. The pressure response in a receiver well is given by the following equation:

$$\Delta p(t) = \frac{q}{4\pi K r_w r_D} erfc\left(r_D \Big/ \sqrt{4t_D} \right) \quad (1)$$

Where $\Delta p(t)$ is the pressure response at a given time, K is the formation hydraulic conductivity, q is the injection flowrate, S_S is the formation specific storage, r_w is the well bore radius of a source well, r_D is the dimensionless distance equal to r/r_w in which r is the distance from the receiver well to the source well, t_D is the dimensionless time defined in equation (2) and p_D is denoted as the dimension pressure defined in equation (3):

$$t_D = \frac{Kt}{r_W{}^2 S_S} \quad (2)$$

$$p_D = \frac{4\pi K r_W \Delta p(t)}{q} \quad (3)$$

Where t is the elapsed time since the start of the injection. For the solution of the pulse interference test, equation (1) needs to account for the periodic nature of the injection flow rate in the source well. The time intervals of injection and shut in do not need to be the same, but an accounting for their periodic nature needs to be included. The dimensionless time interval for injection and shut in are assumed to be the same, therefore the dimensionless time interval for injection, tp_D, is defined as:

$$tp_D = \frac{Ktp}{r_W{}^2 S_S} \quad (4)$$

Where tp is the pulsed injection time interval (Hocking, 2001). These four (4) equations represent the fundamental solutions utilized to evaluate HPIT results, and were used to evaluate the data from HPIT activities at the Olin Site.

3.0 HYDRAULIC PULSE INTERFERENCE TESTING ACTIVITES

3.1 Pre-Mobilization Receiver Transducer Calibration

Prior to the mobilization to the site, calibration procedures were performed on the highly sensitive and precise pressure transducers used to monitor the pulse pressure in the receiver well. The calibrations were completed utilizing new Magnehelic gauges to develop the appropriate calibration coefficients for data logging by the data acquisition system. Following calibration, all equipment was then tested against known water pressures to ensure accuracy and repeatability. By calibrating the equipment and developing up to date receiver well transducer calibration coefficients, **GeoSierra** confirmed the accuracy of the monitoring equipment prior to mobilization to the site.

The receiver transducer calibration data, associated best fit curve and polynomial equations are included in Appendix A. The best-fit polynomial coefficients were then utilized within the data acquisition system during testing as the receiver well calibration coefficients.

3.2 Pre-HPIT Testing Video Inspections

Prior to HPIT, each well was inspected utilizing a GeoVision borehole video camera and viewer system to verify the well construction, log screen depths, verify the elevation of the water table relative to the screen interval, and generally inspect the condition of the screen prior to testing. Detailed notes were taken during the video inspection of the condition of the well, and any modifications to the proposed baseline testing program were made based on the visual observations.

The only unexpected observation made during the video inspections was the diameter of GW-6S compared to the well construction logs. During video inspection it was found that well GW-6S reduced to a 1.5” diameter approximately 2.1 feet below top of casing. The well construction required, due to the diameter of the testing equipment, is a 2-inch well diameter; therefore HPIT testing could not be performed on well pairs that included GW-6S. An additional test was added to replace the GW-6S tests using well LPB-44 as discussed below.

3.3 Hydraulic Pulse Interference Testing Activities

Based on the approved HPIT Work Plan, a total of eleven (11) well pairs were proposed for testing during the baseline testing event. Each well pair consisted of one source well and one receiver well with varying screen lengths, depths and intervals. During video inspections as noted above, tests associated with GW-6S were not possible due to the reduced well diameter; therefore the test of GW-34SR to LPB-44 was substituted in place of the GW-34SR - GW-6S well pair for the well pair testing conditions outside of the slurry wall. No additional well pairs were deemed available during baseline testing to replace the other HPIT tests associated with GW-6S. As such, a total of eight (8) tests were conducted as opposed to the eleven (11) proposed as shown on Table 1.

3.4 HPIT Field Procedures

As discussed above, baseline HPIT activities at the Olin Chemical Superfund Site consisted of eight (8) tests in the vicinity of the slurry wall in four different scenarios based on their locations relative to the slurry wall. As shown on Table 1, two (2) well pairs were tested where both wells were located exterior to the slurry wall, three (3) well pairs were tested where both wells are located interior to the slurry wall, two (2) well pairs were tested in a line that resulted in tests through the slurry wall and one (1) well pair was located inside the bounds of the slurry wall, however the receiver well (GW-CA1) was located inside the equalization window.

Setup of each pulse test included installation of the source and receiver systems in the defined well pair. The source well injection system consists of an inflatable packer to isolate the injection horizon from atmospheric dampening effects (when possible), a pressure transducer that is placed in the source well to monitor injection pressures, and a downhole injection system as shown on Figure 2. The receiver well system also consists of an inflatable packer isolating the high precision pressure transducer from well bore storage effects by sealing the screen interval from the atmosphere within the well seal (where possible). During testing, the injection flow rate is controlled by a constant flow rate direct drive pump with solenoid adjustable time interval switching values to precisely modulate the periodic time injection and shut-in of the source well.

During HPIT, the source well's flow rate and pressure are monitored along with the receiver well pressure. The receiver well pressure transducers are of high precision and can detect changes in

pressure as low as 1/10,000 pounds per square inch (psi). The flow rate and pressures are continuously monitored and recorded at high data acquisition rates throughout the tests. To ensure the test parameters (shut-in interval and flowrate) are repeatable, the pulse switching mechanism is automatically controlled by a timed relay switch and recorded by the data acquisition system as increases and decreases in pressure within the source well. To optimize the resolution of the test, the source well injection flowrate and shut-in time interval are typically varied during initial testing depending on site conditions.

During initial testing utilizing GW-34D as the source well and GW-6D as the receiver well, a total of four (4) tests were run to determine the injection flowrate and shut-in interval that provided the cleanest response at the receiver well. Based on the evaluation of the initial four (4) data sets onsite, a flowrate of approximately 12-gallons per minute (GPM) and a shut-in interval of 45-seconds were selected as the appropriate parameters for baseline testing. For the remaining well pairs tested, 2 – 3 tests were run for each well pair. During data reduction activities, these individual tests were identified as tests A, B or C and are listed on Table 1 accordingly.

Additionally, to rule out the effects of packer inflation on the receiver well results, an inflation test was conducted by inducing no pulse from the source well, inflating the packers within both the source and receiver wells and logging the data within the data acquisition system. As shown on the raw data graph in Appendix B, there was no noticeable effect from simply the inflation of the packers on receiver well data. Additionally, the data indicates that the conditions adjacent to the slurry wall were quiescent with little to no variations in pressures over the 10-minute logging interval.

3.5 HPIT Results

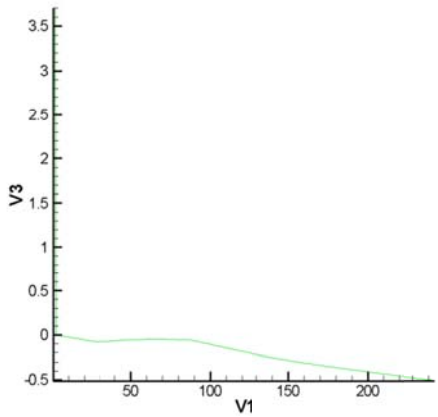
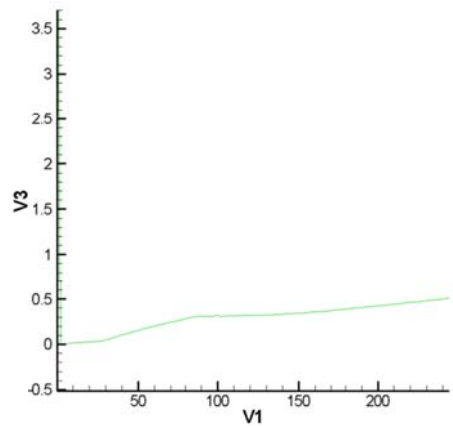
The interpretation of the point source hydraulic pulse interference test follows similar procedures to line source interpretation procedures using type curves as detailed in Hocking (2001). The hydraulic pulse interference test arrangement, typical curve matching analysis (Figure 3) and theoretical source data verification curves generated via a check program are shown on Figure 4. The following sections of this report provide details on the HPIT data reduction activities and actual results obtained.

3.5.1 Data Reduction Activities

Following testing onsite, the data was brought back to **GeoSierra**'s office and reduced in accordance with a standard procedure for development of the type curves accounting for site conditions, and reduction of collected raw data for curve matching commenced. The raw data response from the tested well pairs is located in Appendix C. The type curve data and analysis are located in Appendix D.

The type curve graphs were generated as both an unconfined and confined types, finite and semi-finite aquifer depending on the location of the tested well pair relative to the slurry wall. Based on the curve fit data and the verification program output from the results (discussed further herein), the shallow aquifer at the Site appears to respond as a confined aquifer to the hydraulic pulses as the confined aquifer type curve fitting yielded the cleanest data match and the most reasonable, verifiable results for the wells. This may be due to horizontal layering of finer silty material in upper portions of the unconsolidated deposits. Development of the confined aquifer type curves assumed a confined aquifer from the top of the water table (approximately 6 to 7 feet bgs) down to the top of bedrock, or a total depth of 40 feet. A summary of the parameters utilized to develop the type curves are shown on Table 2 including aquifer type (finite, semi-infinite, free surface, upper or lower confining layers), top and bottom of aquifer, source and receiver well positions.

Following downloading of the raw data, the data is zeroed to the start of the HPIT test, converted to minutes (raw data logs in seconds) and graphed on a logarithmic scale to allow for curve type matching. For receiver wells that exhibited a negative slope response (common response at the Olin Site), a transformation was applied to convert to positive slope to allow for analysis, as log scale analysis cannot be conducted on data with negative values. The negative slope transformation utilizes the initial negative slope of the receiver response, calculates the absolute value of the slope and multiplies the receiver response by the pressure response, time and slope value to invert the curve from the same zero point. An example of negative slope and the resultant transformation is below:

	
Raw Data Prior to Slope Correction	**Raw Data Post Slope Correction**

Negative slope responses occur when the aquifer responds to the hydraulic pulse with reducing water levels in the receiver wells as opposed to the expected increasing water level response. Normally caused by some type of tidal influence or sites with a significant downward gradient trend, the Olin site had neither of these known conditions. As such, **GeoSierra** can only theorize that the interactions of the pulse with surrounding formation, potentially the underlying bedrock, the slurry wall and/or the equalization window caused a temporary downward gradient within the test zone. One final potential impact was the construction of the shallow wells and their screens bridging the water table; however, there was no discernible trend to which receiver well resulted in an initial negative data slope.

To evaluate the negative slope response (indicated as a decreasing water level during pulse testing) and ensure it was not an artifact of the data acquisition system, baseline inflation and aquifer resting-state testing was conducted (Appendix B). This baseline inflation test was used to evaluate the effects on the water table from inflation of the packers with no active injection in the source well. As shown by Appendix B, the negative slope was not an artifact of the testing equipment and therefore is considered a response as a result of HPIT activities. As such, the negative slope transformation was used to allow the data to be reduced similar to the positive slope data.

The specific storage and hydraulic conductivity are estimated through the type curve matching process. Once the type curves are generated for the aquifer type and the raw data is reduced, the two curves are overlaid and fit to where the two curves best match. From that curve match, the values for time and dimensionless time are arbitrarily selected on the matched curve, pressure and dimensionless pressure are read from the Y-Axis; from those values storativity and conductivity are calculated using the equations previously presented.

To ensure the accuracy of the matched curves and validate the calculated specific storage and conductivity values, a verification program is used to back calculate and plot the theoretical receiver response using the test conditions/results including flow rate, shut-in interval, storativity and conductivity from a re-arrangement of Equations 1 - 4. This theoretical response is then overlaid onto the actual raw data receiver response and the curves are compared. The outputs from the check program used to evaluate data reduction accuracy from Baseline HPIT conducted at the Olin Site are included in Appendix E. The red line represents the theoretical response while the green lines represent the actual receiver response. When the theoretical curves match the actual raw data receiver data, the graphs verify that the appropriate curve match was used and corresponding values for conductivity and storativity were calculated accurately. If the theoretical response does not match the actual receiver data, then the data collected from that test is not verifiable. If the data is not verifiable with the check program, the data is considered suspect, or potentially not useable.

3.5.2 Results Discussion

There are three evaluation criteria that **GeoSierra** utilizes to evaluate the quality of the data obtained during testing. These evaluations include:

- *Response Received* – this is a qualitative determination that the pulse was received at the receiver well as a result of injections into the source well;
- *Reproducible Response* – during subsequent testing and following data reduction, did the data collected from multiple tests result in a similar receiver response; and
- *Theoretically Verified Response* – following data analysis, was the data verifiable through matching of the theoretical receiver response versus actual response as discussed above.

These are the three primary criteria that were utilized to evaluate the usability of data collected at the Olin Site. A detailed evaluation for each well pair tested included below.

Based on the data reduction and results contained within the attached Tables and Appendices, mixed results were obtained from the onsite HPIT testing activities. During testing, a response was received in eight (8) out of the 8 well pair tests indicating hydraulic communication, while six (6) tests were found to be considered reproducible and three (3) tests (1,2 and 7) met all three criteria for response, reproducibility and were theoretically verifiable with the check program. For the five (5) tests that were not theoretically verifiable, data sets were matched against type curves and conductivities were calculated; however, those values could not be verified using the check program where a receiver response is recreated. There are a number of potential causes for results not being verifiable and those causes are discussed further below on a test by test basis.

Test #1 - Source Well GW-34D - Receiver Well GW-6D (Exterior to Slurry wall)

This well pair served as the initial baseline evaluation for injection volume and shut-in interval at the start of HPIT testing activities. Data from this well pair met all three evaluation criteria above and with the 12-gallon per minute injection rate and 45-second shut-in interval, resulted in the cleanest, most responsive raw data sets during testing. As shown on Table 2 with supporting data in Appendices C – E, the approximate conductivity between GW-34D and GW-6D, outside of the slurry wall, is 40.5 ft/day with a calculated specific storage of 6.59×10^{-7} ft^{-1}. As shown on Table 1, this well pair was located approximately 294 feet apart, has well constructions that are conducive to HPIT based on the results, and by meeting all three criteria above indicated that this well pair was in direct hydraulic communication during HPIT activities.

Test #2 - Source Well GW-6D – Receiver Well GW-CA3D (Exterior and Interior to Slurry wall)

This well pair exhibited the cleanest, most reproducible data set of all tests collected. This is most likely due to the well separation distance, deep construction of the screen intervals and the ability of the packer systems to isolate the atmospheric effects from the test by sealing against the casing and grout seal of both monitoring wells. The data for the GW-6D to GW-CA3D test met all three evaluation criteria and resulted in a hydraulic conductivity between the wells of 46.4 ft/day and a calculated specific storage of 3.25×10^{-7} ft^{-1}. As shown on Table 1, this well pair is located approximately 89-feet apart, has well constructions that are conducive to HPIT based on the results, and by meeting all three criteria above indicated that this well pair was in direct hydraulic communication during HPIT activities. It is not clear why the hydraulic pulse

was observed at the receiving well and not clear if the pulse propagated through the wall or under the wall given the depth of the respective well screens. It should be noted that there is no DAPL in contact with the wall between these two wells and the local hydrogeology indicates an inward gradient from outside to inside the wall. The clear indication, however, is that HPIT can serve as an appropriate testing mechanism given appropriate well construction details.

Test #3 - Source Well GW-34SR – Receiver Well LPB-44 (Exterior to Slurry Wall)

The data from the GW-34SR to LPB-44 well pair does not appear to be usable when graphed against both confined and unconfined aquifer type curves as it only met the receiver response criteria discussed above. While curve matching against the confined aquifer yields a match, the results obtained from that curve match are not reproducible, nor are they verifiable or even appear possible. With an estimated hydraulic conductivity of over 1,100 ft/day, which is about two orders of magnitude higher than reasonable, the well construction apparently does not yield data commensurate with the assumptions or necessary conditions upon which the methodology is based. Both GW-34SR and LPB-44 have shallow screen intervals. The screen intervals and grout seals are located above the water table which likely led to results that are not consistent with a test completely sealed and isolated from the atmosphere. Because the distance between this well pair is inside the distance of other well pairs (GW-34SR – LPB-44 are 215 feet apart) that resulted in data meeting all three evaluation criteria above, propagation distance does not appear to be a limiting factor during this well pair test.

Test #4 - Source Well GW-35S – Receiver Well GW-CA3D (Interior to Slurry Wall)

The data collected from the GW-35S to GW-CA3D test, while not verifiable with the check program, has very reproducible trends that allowed matching against the type curves for a confined aquifer. As such, it meets two of the three evaluation criteria. Based on the data result from this well pair, a hydraulic conductivity range of 44 – 75 ft/day and a specific storage of 2.41 x 10^{-5} to 3.61 x 10^{-5} ft^{-1}were estimated. The screen interval and grout seals are both proximate to the water table and as a result, some interaction of the hydraulic pulse with the atmosphere from GW-35S may have caused the un-verifiable result. Because the distance between this well pair is inside the distance of other well pairs (GW-35S – GW-CA3D are 261 feet apart) that resulted in data meeting all three evaluation criteria above, propagation distance does not appear to be a limiting factor during this well pair test.

Test #5 - Source Well GW-35S – Receiver Well GW-30DR (Interior to the Slurry Wall)

While the data from the GW-35S to GW-30DR test was matched against the type curve, the data were not verifiable with the check program, therefore, meeting two of the three evaluation criteria. As shown in Appendix E, although the theoretical curve matches the actual data for the first 3 minutes of the test, the pulse attenuation did not match the check program as expected for the remaining test duration. As such, while the data collected indicates a hydraulic conductivity of 27.8 ft/day and a specific storage of 1.12×10^{-5} ft^{-1}, this data is considered suspect. Similar to other shallow well tests, the likely cause is the potential for impacts from the shallow screen interval in GW-35S that may straddle the water table. Because the distance between this well pair (190 feet) is less than the distance of other well pairs that met all three evaluation criteria above, propagation distance does not appear to be a limiting factor during this well pair test.

Test #6 - Source Well GW-35S – Receiver Well GW-76S (Interior and Exterior to Slurry Wall)

Similar to the results for the GW-35S – GW-30DR well pair, this test also resulted in data that while it was matched to the type curves with good agreement, the verification program was unable to match the attenuation of the curve, therefore the data is considered suspect. While the data meets two of the three evaluation criteria, the likely cause is the potential for impacts from the shallow screen interval in GW-35S that may straddle the water table. The data indicates a lower hydraulic conductivity compared to other wells onsite (7.78 ft/day) but a higher hydraulic conductivity than Test 7 along a similar alignment. The lack of attenuation of the pulse signal compared to the check program results in the data being questionable. Because the distance between this well pair (291 feet) is less than the distance of other well pairs that met all three evaluation criteria above, propagation distance does not appear to be a limiting factor during this well pair test. Based on the proximity of GW-76S and alignment along the equalization window, **GeoSierra** is unable to rule out the potential for pulse propagation through the window and its effect on estimated conductivity results for GW-76S.

Test #7 - Source Well GW-35S – Receiver Well GW-CA1 (Interior to the Slurry Wall)

The data from GW-35S – GW-CA1 test is both verifiable and matches well against the type curves, meeting all three evaluation criteria. Although there is a slight deviation of the check program versus the actual data at the tail of the test (at approximately 14 minutes), the check

program appears to verify that the pulse was received in the equalization window as shown in Appendix E. A hydraulic conductivity of 0.366 ft/day and a specific storage of 2.02 x 10^{-6} ft^{-1} were estimated from the data set. As shown on Table 1, this well pair is located approximately 164 feet apart and by meeting all three criteria above, the data indicates that this well pair was in direct hydraulic communication during HPIT activities.

Test #8 - Source Well GW-35S – Receiver Well GW-CA4S (Interior to the Slurry Wall)

Although the data from GW-35S to GW-CA4S was matched against the type curves, the data was not verifiable nor does the data compare to other verified data collected onsite. With a 230 ft/day conductivity estimated from the test and the lack of matching during verification analysis, the data from this test does not appear usable. Additionally, by meeting only one of the three evaluation criteria, this data set likely had significant error during testing. There are two possible reasons for the data not matching the verification check program. These include both the distance of the test (319' between wells) and the very shallow screen interval of GW-CA4S (1.7' below ground surface to top of screen). Both of these factors may have influenced the data that resulted in its failure of meeting all three criteria above.

4.0 SUMMARY

HPIT was completed on eight (8) monitoring well pairs of various shallow and deep well constructions at the Olin Chemical Superfund Site located in Wilmington, Massachusetts. The primary goal of the baseline testing event was to evaluate the use of HPIT as a method for further testing of the previously constructed slurry wall onsite. Ultimately, the purpose of testing is to determine if communication between interior and exterior monitoring well pairs may exist by hydraulically pulsing the aquifer in a source well and monitoring interior and/or exterior monitoring wells as receiver wells. Well pairs in which both wells were located outside of the slurry wall, both were located inside of the slurry wall and the well pairs were located on opposite sides of the slurry wall were tested during this baseline HPIT event.

A response was received at all eight (8) well pairs tested, six (6) data sets are considered reproducible, while three (3) of the eight (8) tests met all three criteria for response, reproducibility and verification with the check program. For the remaining five (5) tests, data sets were matched against the type curves with conductivities calculated but were not verifiable with the theoretical check program. Because the results are not verifiable with the theoretical check program, the data from these well pairs is considered suspect. Suspect well pair tests were further investigated for potential causes of un-verifiable results.

The primary reason for data that was not verifiable was well construction details not suitable for HPIT (e.g. screens straddling water table, screens set extremely shallow, etc.). This can be inferred from data sets from the deeper well pairs that met all three evaluation criteria while most shallow well pairs did not. These results indicate that HPIT is a viable test method for testing of the slurry wall at the Site where wells with proper construction are utilized and allow for complete isolation of the wellbore and screen from the atmosphere.

5.0 REFERENCES

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TABLES

Table 1. Hydraulic Pulse Interference Testing Summary. Olin Chemical Superfund Site. Wilmington, Massachusetts.

Test Number	Source Well	Screen Interval (feet)	Receiver Well	Screen Interval (feet)	Testing Rationale	Distance Between Well Pair (feet)	Number of Tests Run	Test Data Utilized[3]	Response Received	Reproducible Response	Theoretically Verified Response	Calculated Hydraulic Conductivity (ft/day)	Calculated Hydraulic Conductivity (cm/sec)	Calculated Storativity (1/ft)
Test #1	GW-34D	23 – 33	GW-6D	17.9 – 27.9	Outside Slurry Wall	294	4	C	YES	YES	YES	40.5	1.43E-02	6.59E-07
Test #2	GW-6D	17.9 – 27.9	GW-CA3D	12.0 – 22.0	Across Slurry Wall	89	2	B	YES	YES	YES	46.4	1.64E-02	3.25E-07
Test #3[2]	GW-34SR	4.5 – 14.5	LPB-44	5 – 15	Outside Slurry Wall	215	2	A	YES	NO	NO	1130	3.99E-01	4.41E-05
Test #4	GW-35S	8.1 – 18.1	GW-CA3D	12.0 – 22.0	Inside Slurry Wall	261	3	C	YES	YES	NO	75.3	2.66E-02	3.61E-05
Test #5	GW-35S	8.1 – 18.1	GW-30DR	26.9 – 36.9	Inside Slurry Wall	190	2	A	YES	YES	NO	27.8	9.81E-03	1.12E-05
Test #6	GW-35S	8.1 – 18.1	GW-76S	3.2 – 13.2	Across Slurry Wall	291	2	B	YES	YES	NO	7.78	2.74E-03	1.32E-06
Test #7	GW-35S	8.1 – 18.1	GW-CA1	1.7 – 6.7	Inside Slurry Wall (Equalization Window)	164	2	A	YES	YES	YES	0.366	1.29E-04	2.02E-06
Test #8	GW-35S	8.1 – 18.1	GW-CA4S	1.3 – 11.2	Inside Slurry Wall	319	2	B	YES	NO	NO	230	8.11E-02	2.07E-05
Test #9[1]	GW-6S	9.7 – 14.7	GW-CA3S	2.0 – 11.8	Across Slurry Wall	92	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Test #10[1]	GW-34D	23 – 33	GW-6S	9.7 – 14.7	Outside Slurry Wall	289	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Test #11[1]	GW-34SR	4.5 – 14.5	GW-6S	9.7 – 14.7	Outside Slurry Wall	284	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

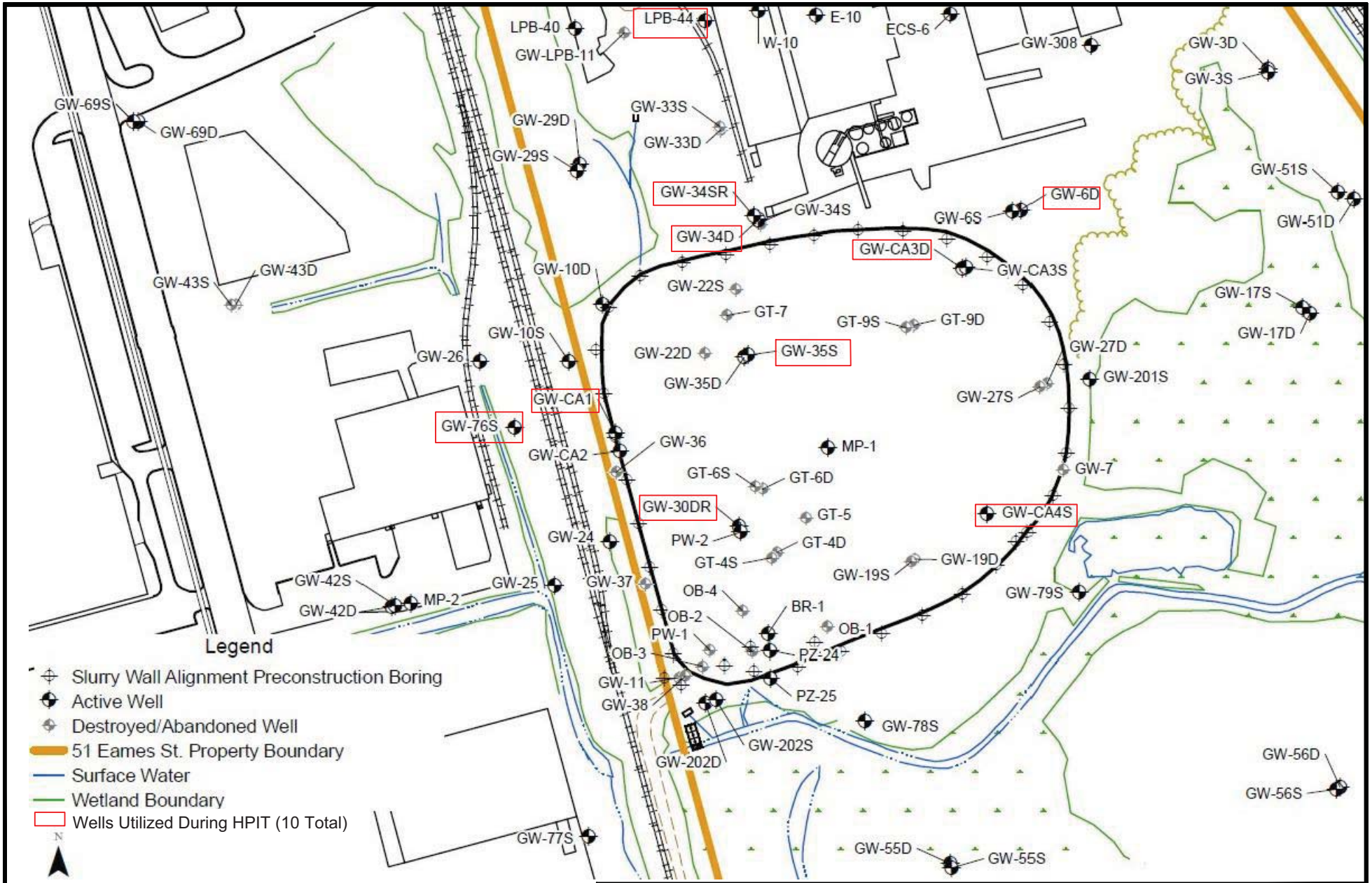
1. Tests could not be performed due to the size reduction of the well casing to 1.5" inside of well GW-6S
2. Test was substituted in place of the tests that included well GW-6S
3. Two to four tests were conducted for each well pair with individual tests designated A, B or C.

N/A: Not Analyzed

OLIN HPIT TYPE CURVE GENERATION PARAMETERS					
Evaluation #1 - Unconfined Aquifer					
Well Pair	Aquifer Type	Top of Aquifer (Feet BGS) [1]	Bottom of Aquifer (Feet BGS)	Source Position	Receiver Position
GW-34D - GW-6D	Semi Infinite, Free Surface (3)	9	40	(0,0,29)	(0,294,23)
GW-6D - GW-CA3D	Semi Infinite, Free Surface (3)	9	40	(0,0,26)	(0,89,18.5)
GW-34SR - LPB-44	Semi Infinite, Free Surface (3)	7.5	40	(0,0,15)	(0,215,15)
GW-35S - GW-CA3D	Finite, Free Surface (5)	7.5	40	(0,0,16)	(0,261,23)
GW-35S - GW-30DR	Finite, Free Surface (5)	6	40	(0,0,16)	(0,190,32)
GW-35S - GW-76S	Semi Infinite, Free Surface (3)	7.5	40	(0,0,16)	(0,291,9)
GW-35S - GW-CA1	Finite, Free Surface (5)	7	40	(0,0,16)	(0,164,9)
GW-35S - GW-CA4S	Finite, Free Surface (5)	7	40	(0,0,16)	(0,319,8)
Evaluation #2 - Confined Aquifer					
Well Pair	Aquifer Type	Top of Aquifer (Feet BGS) [1]	Bottom of Aquifer (Feet BGS)	Source Position	Receiver Position
GW-34D - GW-6D	Semi Infinite, Upper Confining Layer (2)	9	40	(0,0,29)	(0,294,23)
GW-6D - GW-CA3D	Semi Infinite, Upper Confining Layer (2)	9	40	(0,0,26)	(0,89,18.5)
GW-34SR - LPB-44	Semi Infinite, Upper Confining Layer (2)	7.5	40	(0,0,15)	(0,215,15)
GW-35S - GW-CA3D	Finite, Upper and Lower Confining Layers (4)	7.5	40	(0,0,16)	(0,261,23)
GW-35S - GW-30DR	Finite, Upper and Lower Confining Layers (4)	6	40	(0,0,16)	(0,190,32)
GW-35S - GW-76S	Semi Infinite, Upper Confining Layer (2)	7.5	40	(0,0,16)	(0,291,9)
GW-35S - GW-CA1	Finite, Upper and Lower Confining Layers (4)	7	40	(0,0,16)	(0,164,9)
GW-35S - GW-CA4S	Finite, Upper and Lower Confining Layers (4)	7	40	(0,0,16)	(0,319,8)

Note: 1) The shallowest measurement of depth to water between the receiver and source well was used to identify the top of the aquifer

FIGURES



REFERENCE: "LOCATION OF SLURRY WALL AND ASSOCIATED BORINGS AND WELLS" AMEC 3/20/12

GeoSierra Environmental, Inc.

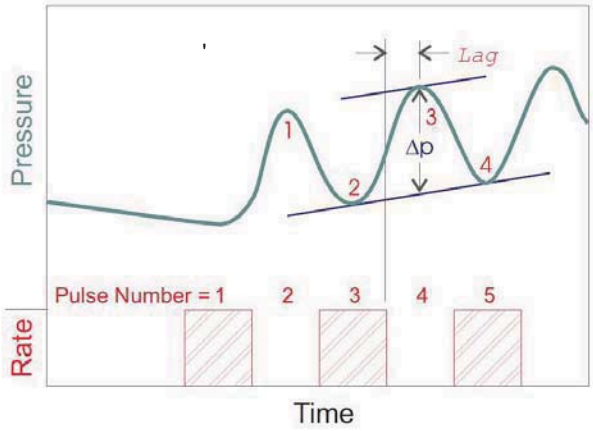
MEDFORD, NEW JERSEY
ATLANTA, GEORGIA

DWG. NO.	G20600101
REV. NO.	JOB NO. G206001
DATE 1/13	DRAWN SML
SCALE NONE	CHECKED KDD
FILE NO.	REVIEWED KDD

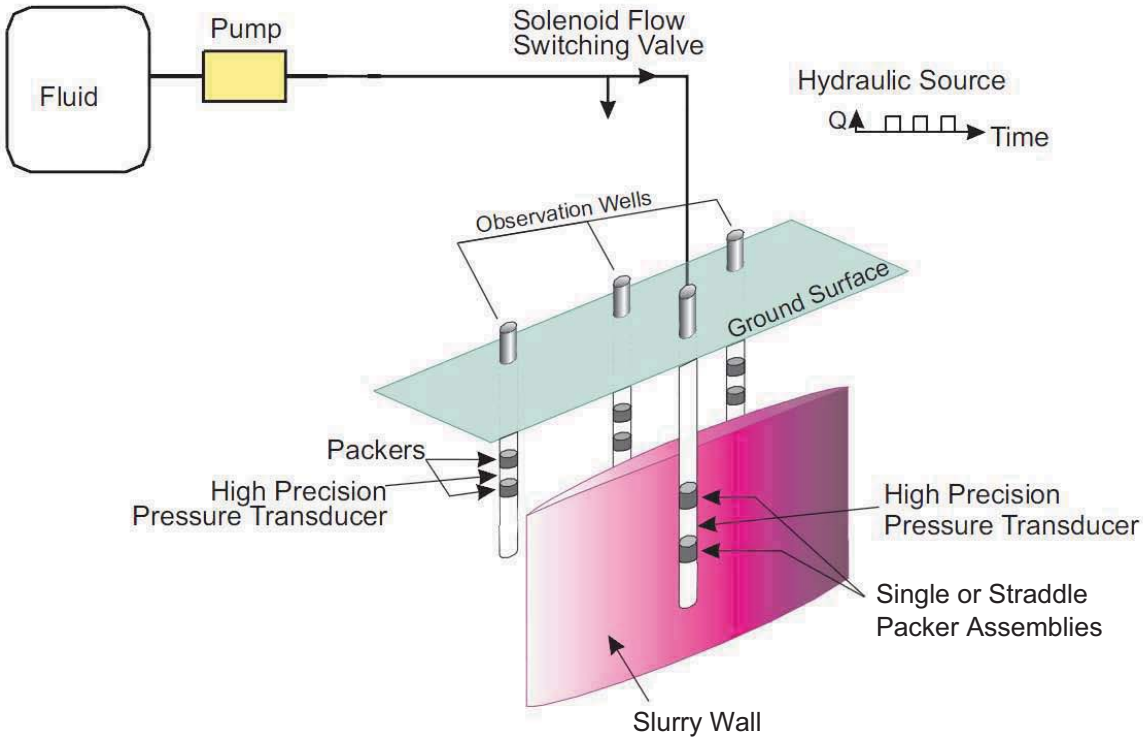
CLIENT/PROJECT
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

TITLE
SITE PLAN AND MONITORING
WELL LOCATION MAP

FIGURE NO.
1

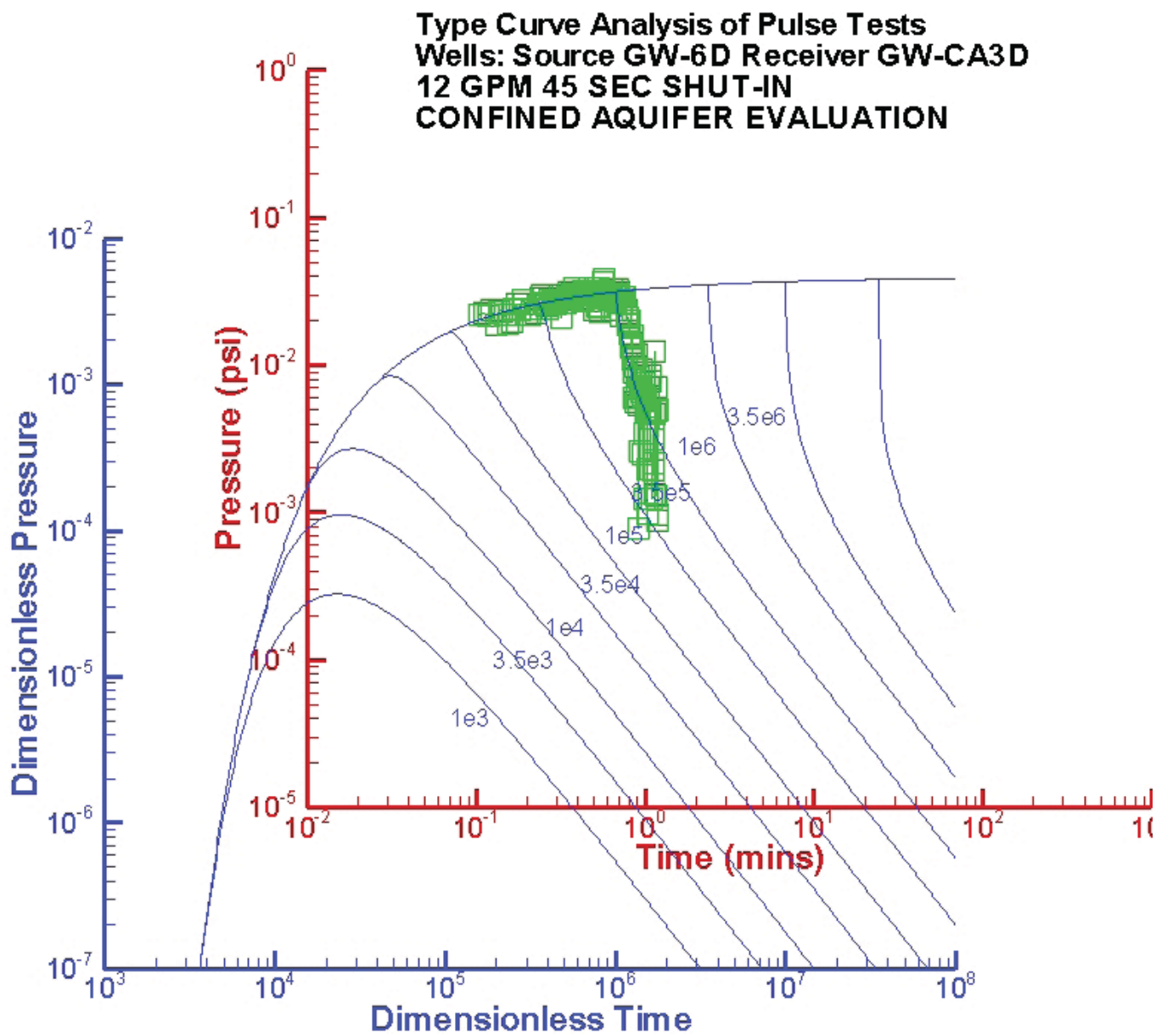


PULSE INTERFERENCE TYPE ANALYSIS



HYDRAULIC PULSE INTERFERENCE TESTING

GeoSierra Environmental, Inc. Medford, NJ Atlanta, GA	TITLE HYDROGEOLOGIC CHARACTERIZATION USING HPIT			
CLIENT/PROJECT OLIN CHEMICAL SUPERFUND SITE WILMINGTON, MASSACHUSETTS	DRAWN S.M.L.	DATE 1/3/2013 08/08/12	JOB NO. G206001	
	CHECKED K.D.D.	SCALE NTS	DWG NO.	REV. NO.
	REVIEWED K.D.D.	FILE	SUBTITLE	FIGURE NO. 2



BLUE — TYPE CURVES GENERATED BASED ON AQUIFER TYPE

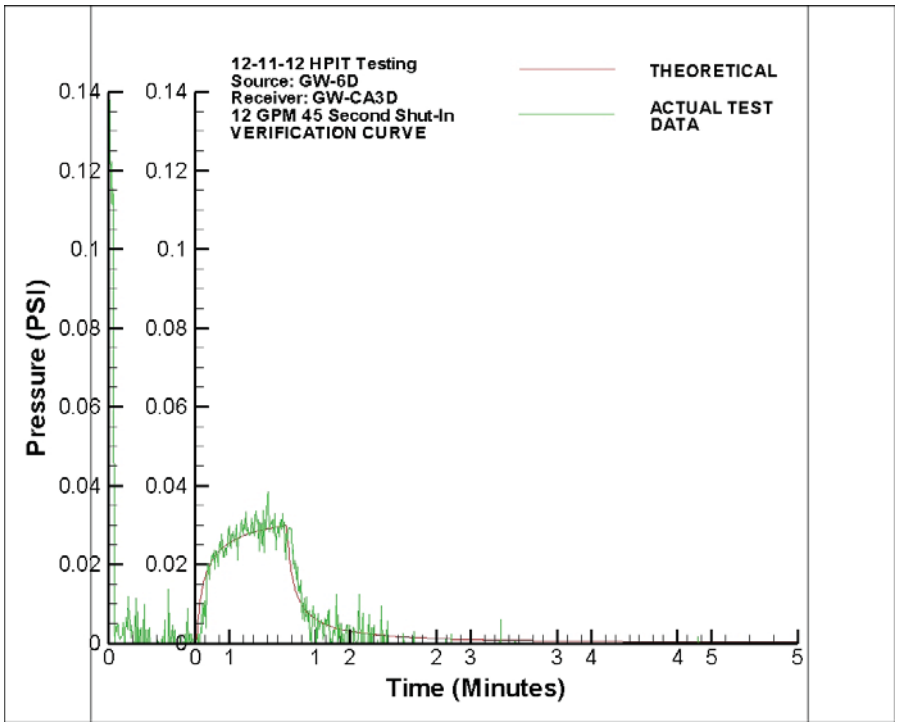
RED — ACTUAL HPIT DATA

GeoSierra Environmental, Inc.
Medford, NJ
Atlanta, GA

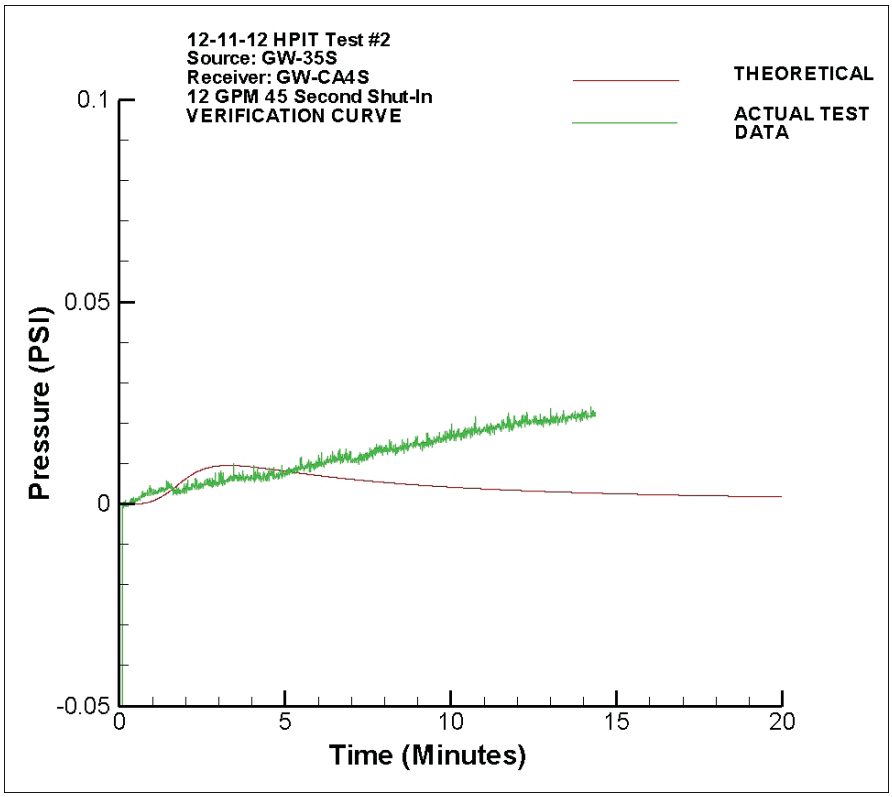
TITLE: TYPICAL TYPE CURVE ANALYSIS THROUGH HYDRAULIC PULSE INTERFERENCE TESTING

CLIENT/PROJECT: OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

DRAWN S.M.L.	DATE 1/3/2013 08/08/12	JOB NO. G206001	
CHECKED K.D.D.	SCALE NTS	DWG NO.	REV. NO.
REVIEWED K.D.D.	FILE	SUBTITLE	FIGURE NO. 3



THEORETICALLY VERIFIED DATA MATCH



THEORETICALLY UN-VERIFIABLE DATA MATCH

GeoSierra Environmental, Inc.
Medford, NJ
Atlanta, GA

TITLE
EXAMPLE THEORETICAL DATA VERIFICATION CURVES

CLIENT/PROJECT
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

DRAWN S.M.L.	DATE 1/3/2013 08/08/12	JOB NO. G206001	
CHECKED K.D.D.	SCALE NTS	DWG NO.	REV. NO.
REVIEWED K.D.D.	FILE	SUBTITLE	FIGURE NO. 4

APPENDICES

APPENDIX A

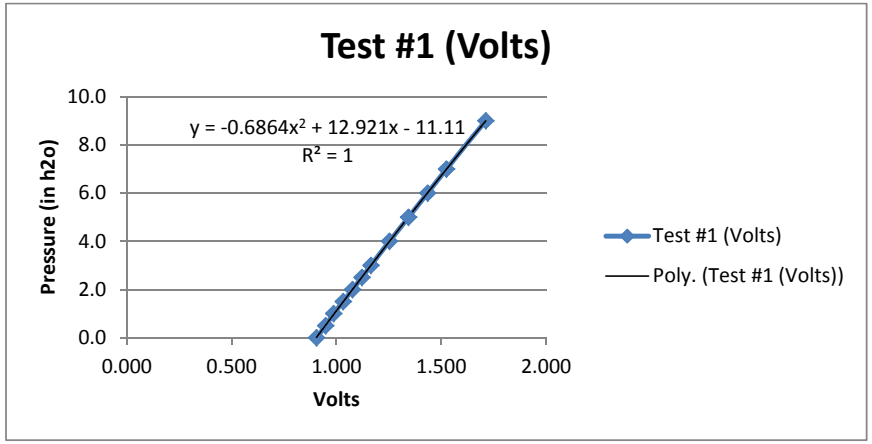
RECEIVER WELL TRANSDUCER CALIBRATION CURVE

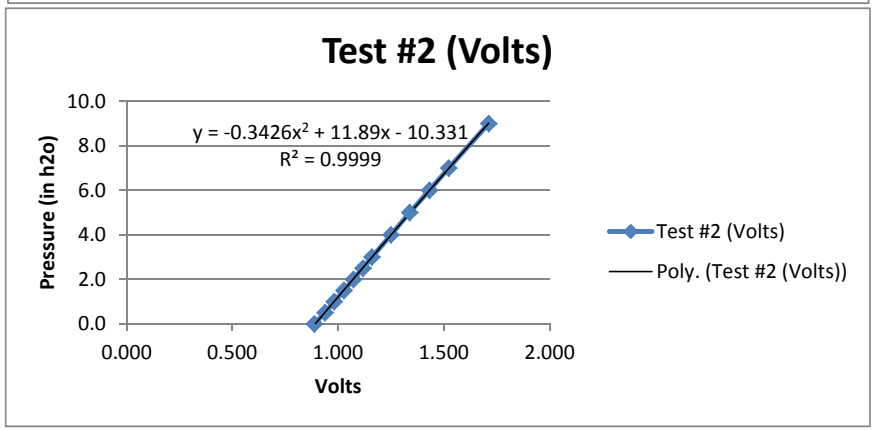
Pressure (PSI)	*Test #1 (Volts)*	*Test #2 (Volts)*	*Test #3 (Volts)*
0.0	0.904	0.887	0.874
0.5	0.948	0.938	0.923
1.0	0.986	0.981	0.964
1.5	1.032	1.027	1.012
2.0	1.076	1.073	1.054
2.5	1.121	1.117	1.098
3.0	1.164	1.160	1.143
4.0	1.252	1.250	1.235
5.0	1.343	1.338	1.325
6.0	1.435	1.432	1.413
7.0	1.524	1.523	1.504
9.0	1.712	1.712	1.696

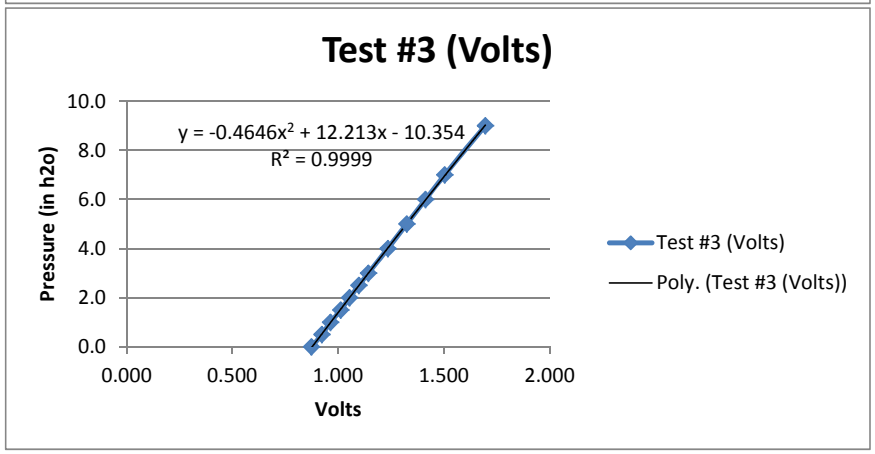
Check Voltage Test #1			
Pressure	*Voltage*	*Pressure from Eq.*	*%RPD*
0.0	0.904	0.00874	
0.5	0.948	0.52129	4.2%
1.0	0.986	0.96180	-3.9%
2.5	1.121	2.51076	0.4%
5.0	1.343	5.00354	0.1%

Check Voltage Test #2			
Pressure	*Voltage*	*Pressure from Eq.*	*%RPD*
0.0	0.887	-0.05412	
0.5	0.938	0.52039	4.0%
1.0	0.981	1.00339	0.3%
2.5	1.117	2.52267	0.9%
5.0	1.338	4.96448	-0.7%

Check Voltage Test #3			
Pressure	*Voltage*	*Pressure from Eq.*	*%RPD*
0.0	0.874	-0.03473	
0.5	0.923	0.52279	4.5%
1.0	0.964	0.98758	-1.2%
2.5	1.098	2.49575	-0.2%
5.0	1.325	5.01256	0.3%

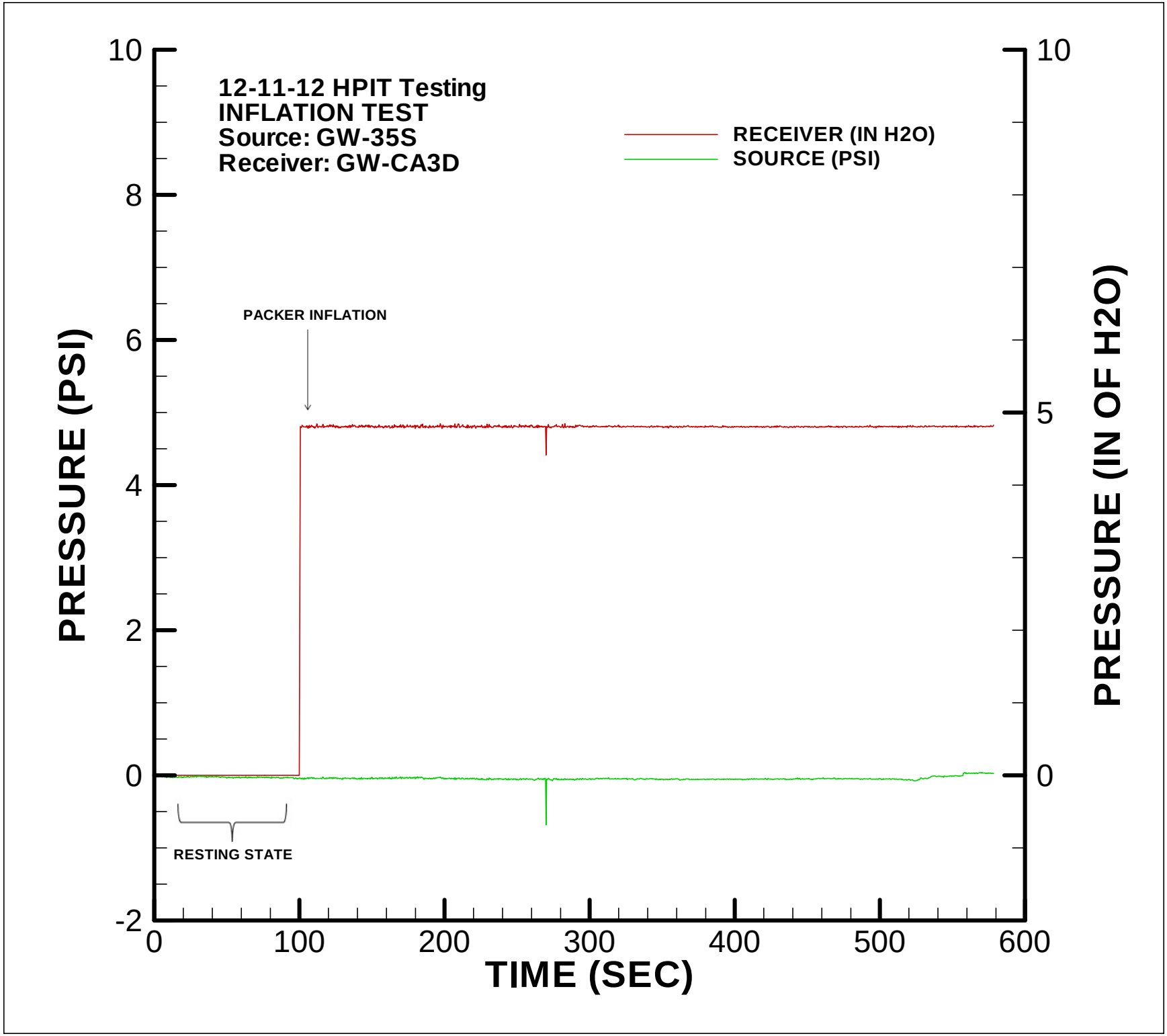






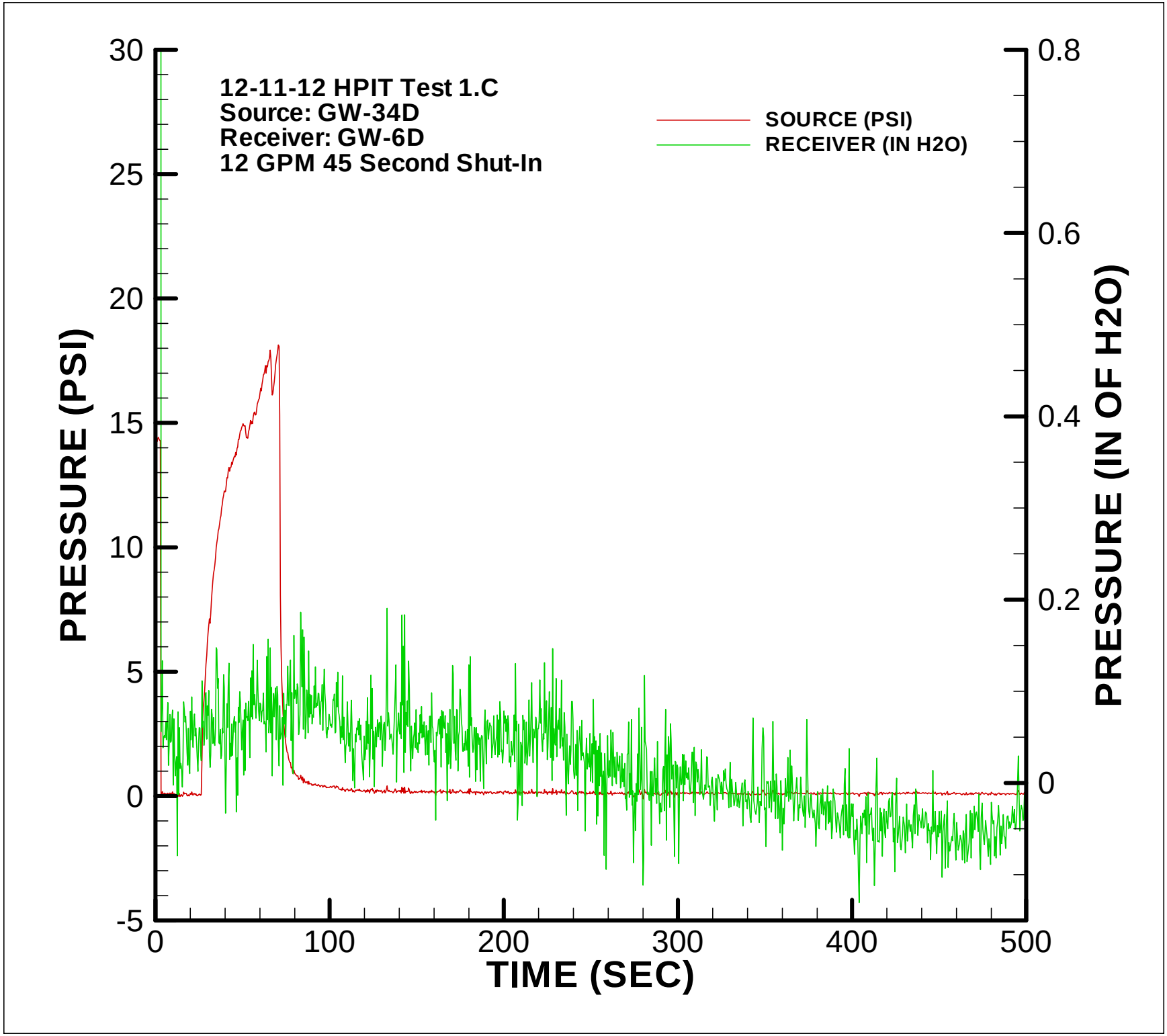
APPENDIX B

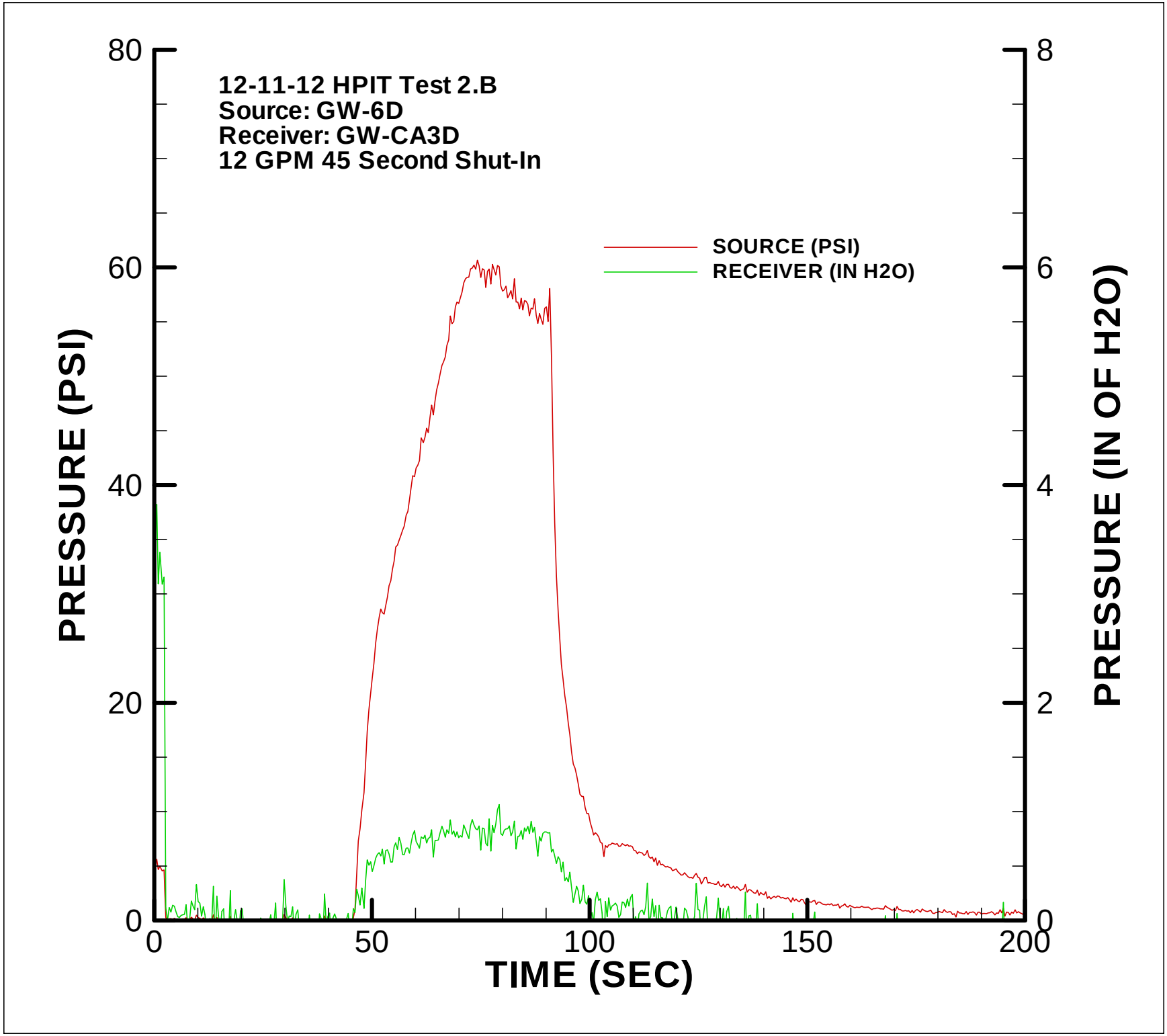
ONSITE PACKER INFLATION TEST DATA OUTPUT

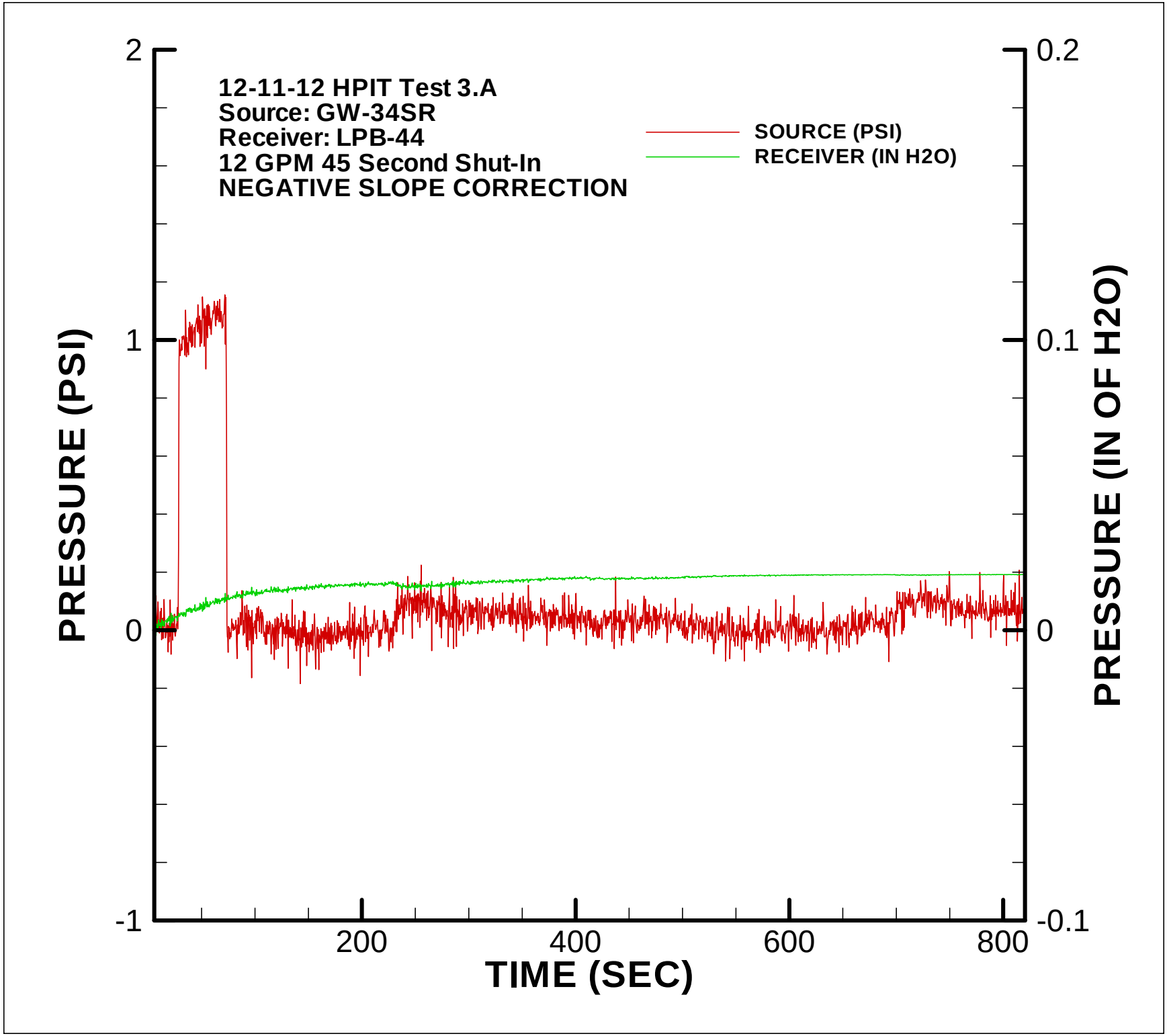

12-11-12 HPIT Testing
INFLATION TEST
Source: GW-35S
Receiver: GW-CA3D
RECEIVER (IN H2O)
SOURCE (PSI)
PACKER INFLATION
RESTING STATE
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
10
8
6
4
2
0
-2
10
5
0
0
100
200
300
400
500
600

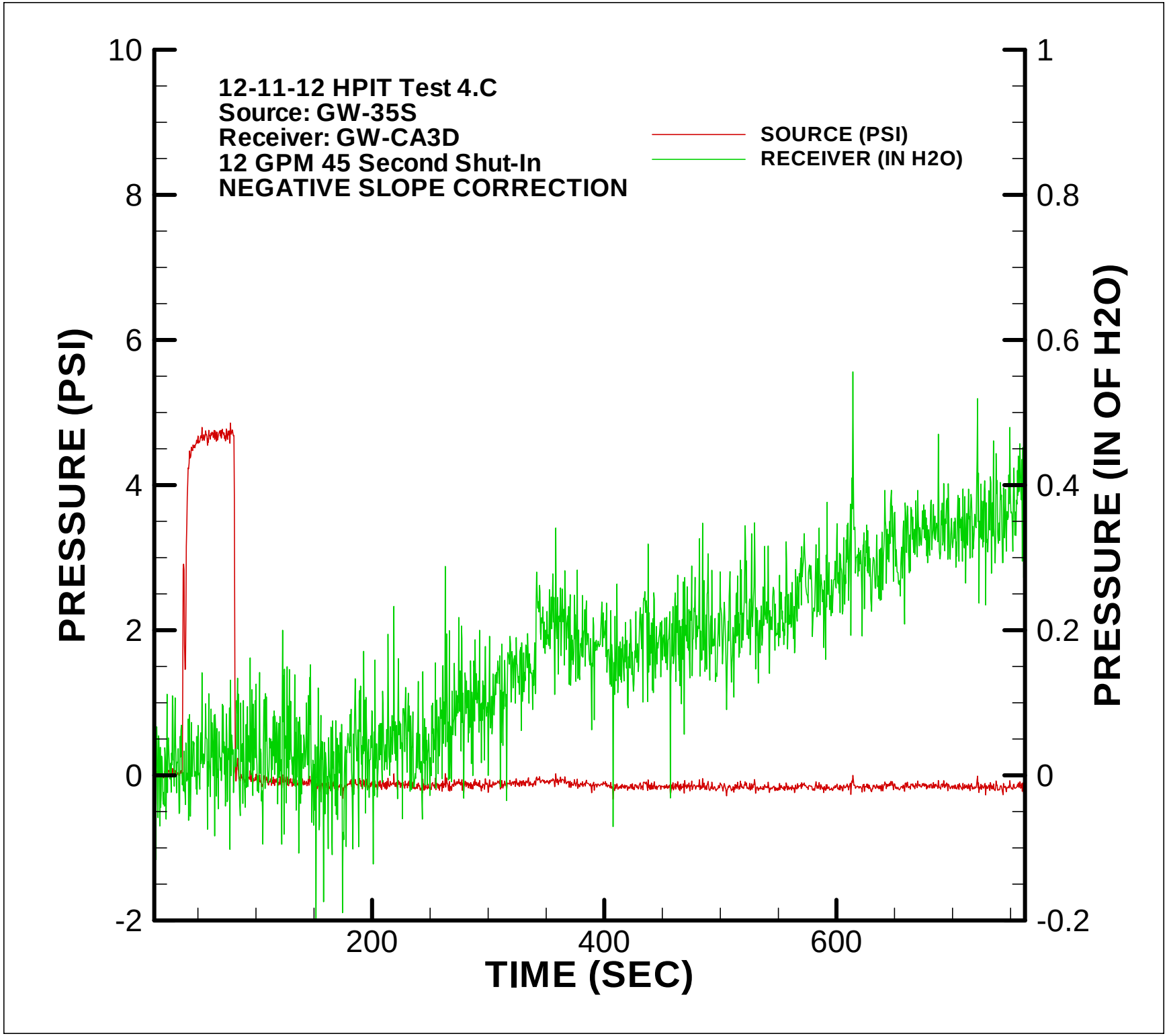
APPENDIX C

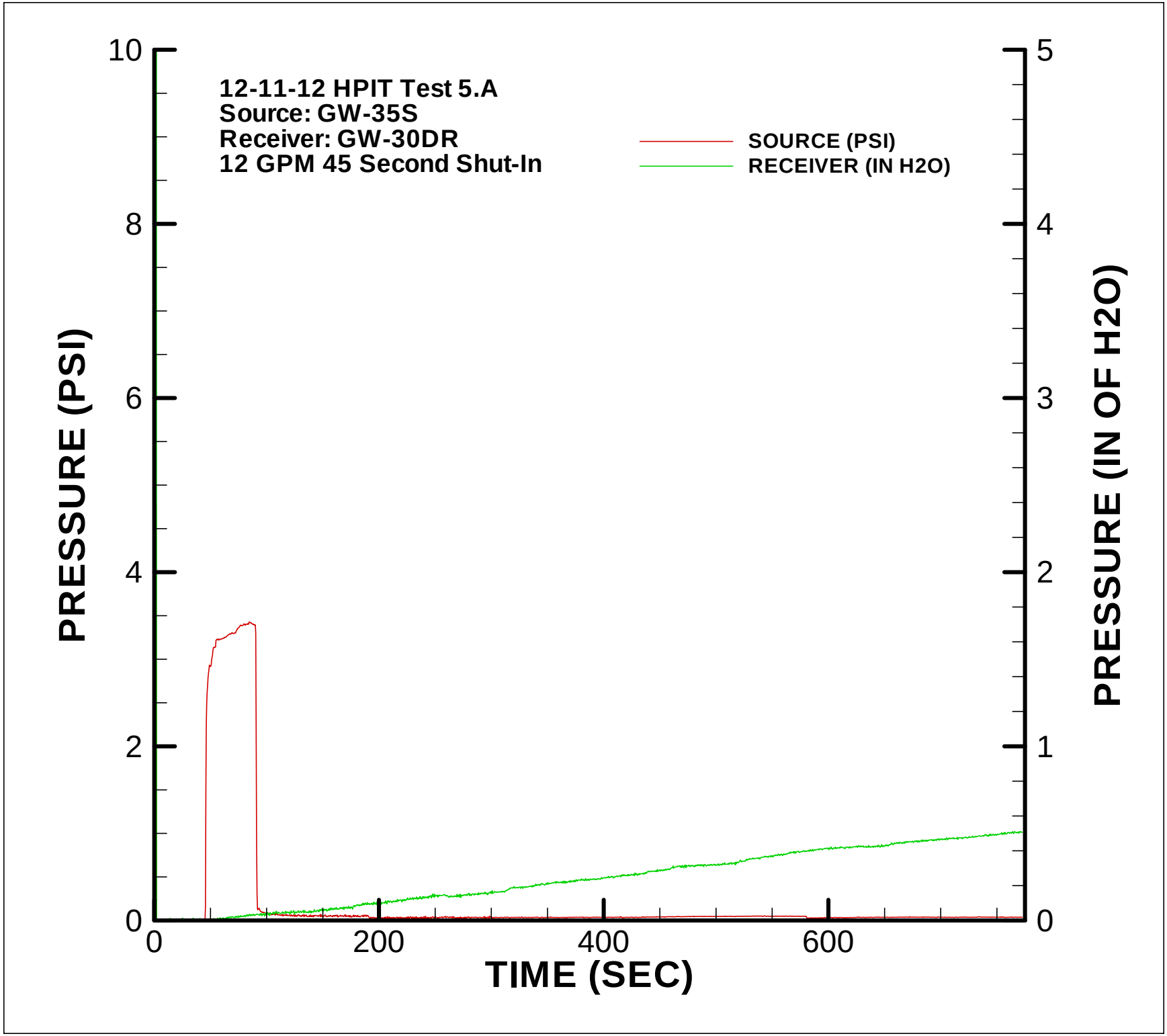
HPIT RAW DATA PLOTS

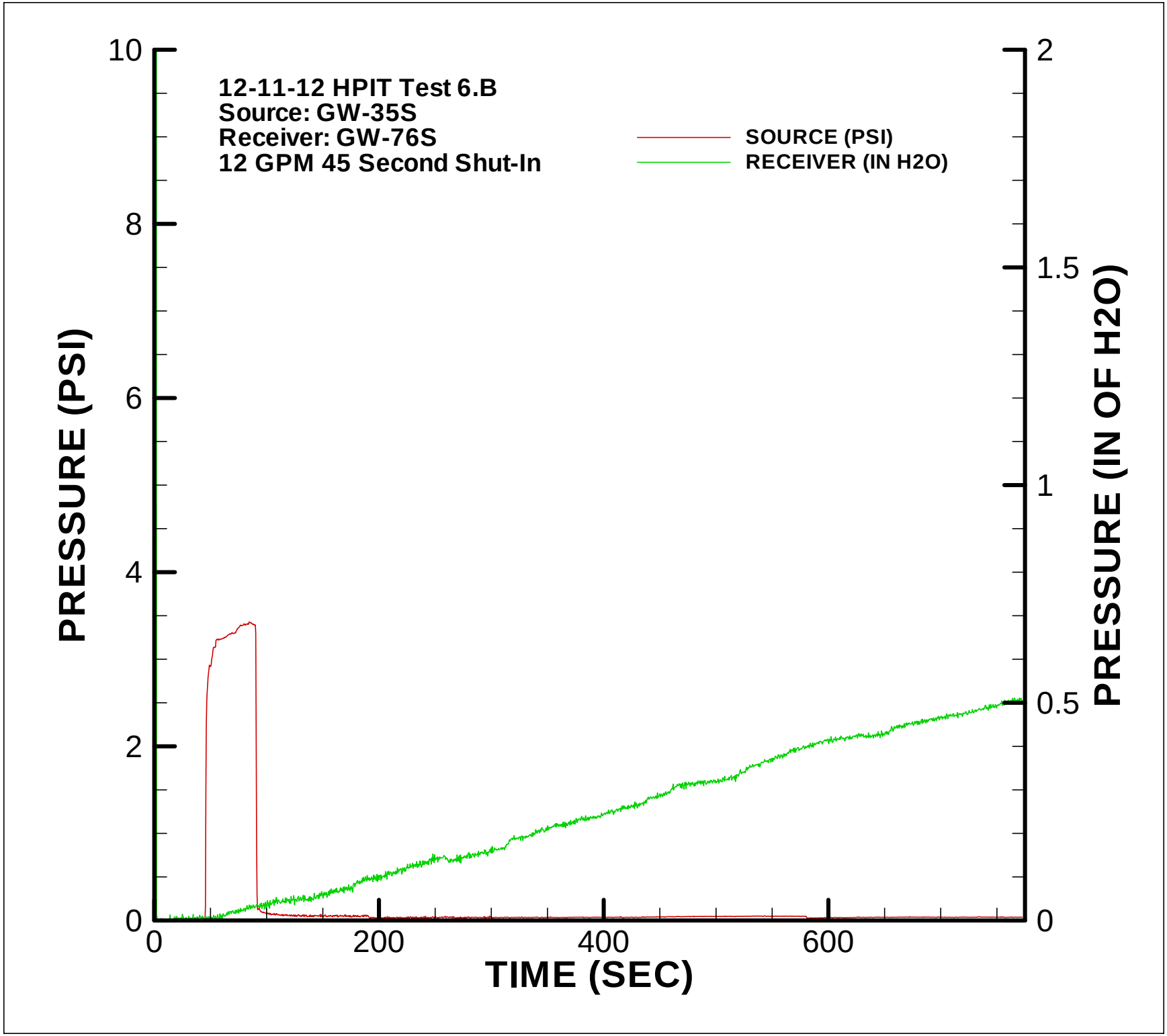

12-11-12 HPIT Test 1.C
Source: GW-34D
Receiver: GW-6D
12 GPM 45 Second Shut-In
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
30
25
20
15
10
5
0
-5
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500

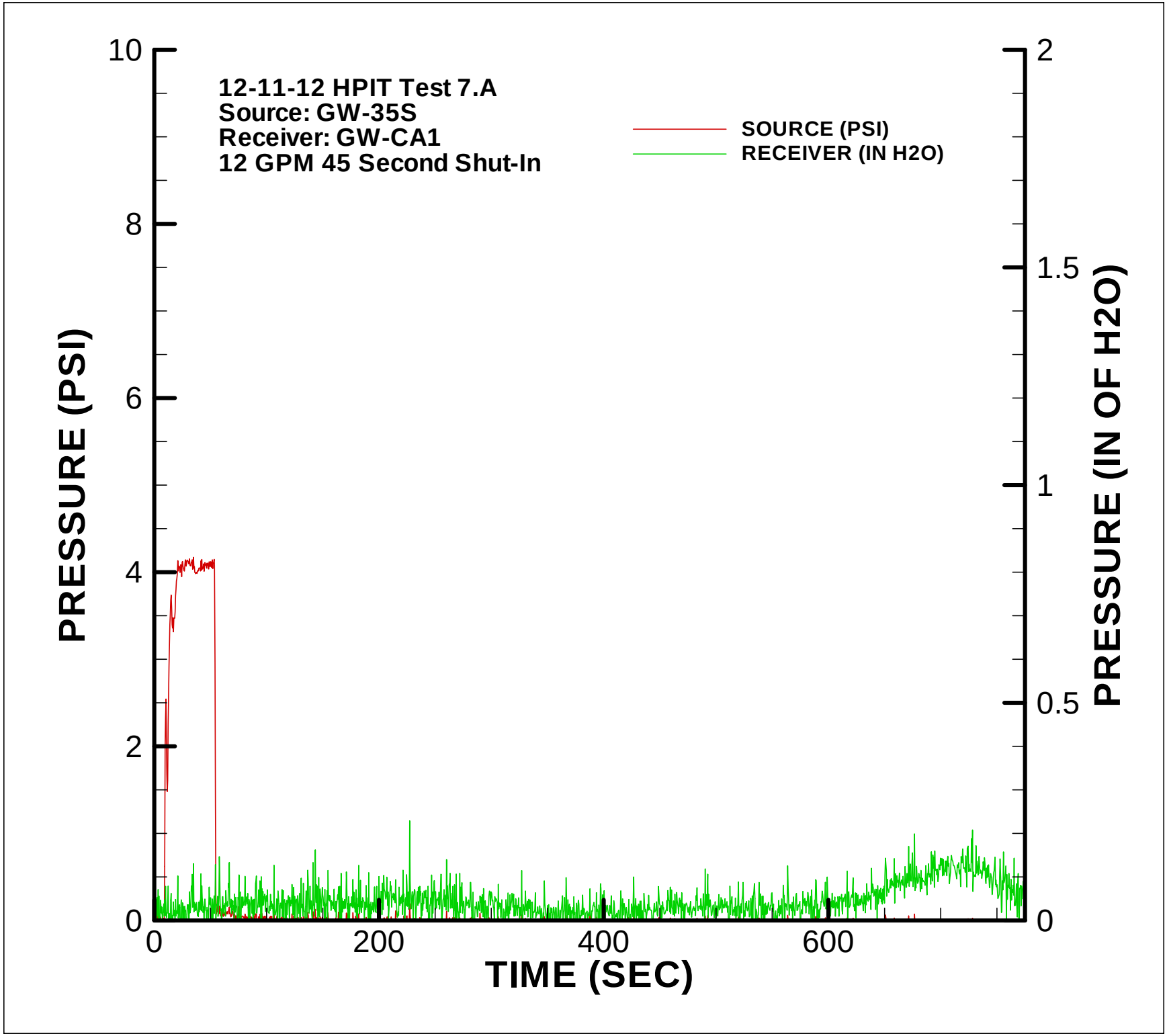

12-11-12 HPIT Test 2.B
Source: GW-6D
Receiver: GW-CA3D
12 GPM 45 Second Shut-In
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
0
20
40
60
80
0
2
4
6
8
0
50
100
150
200

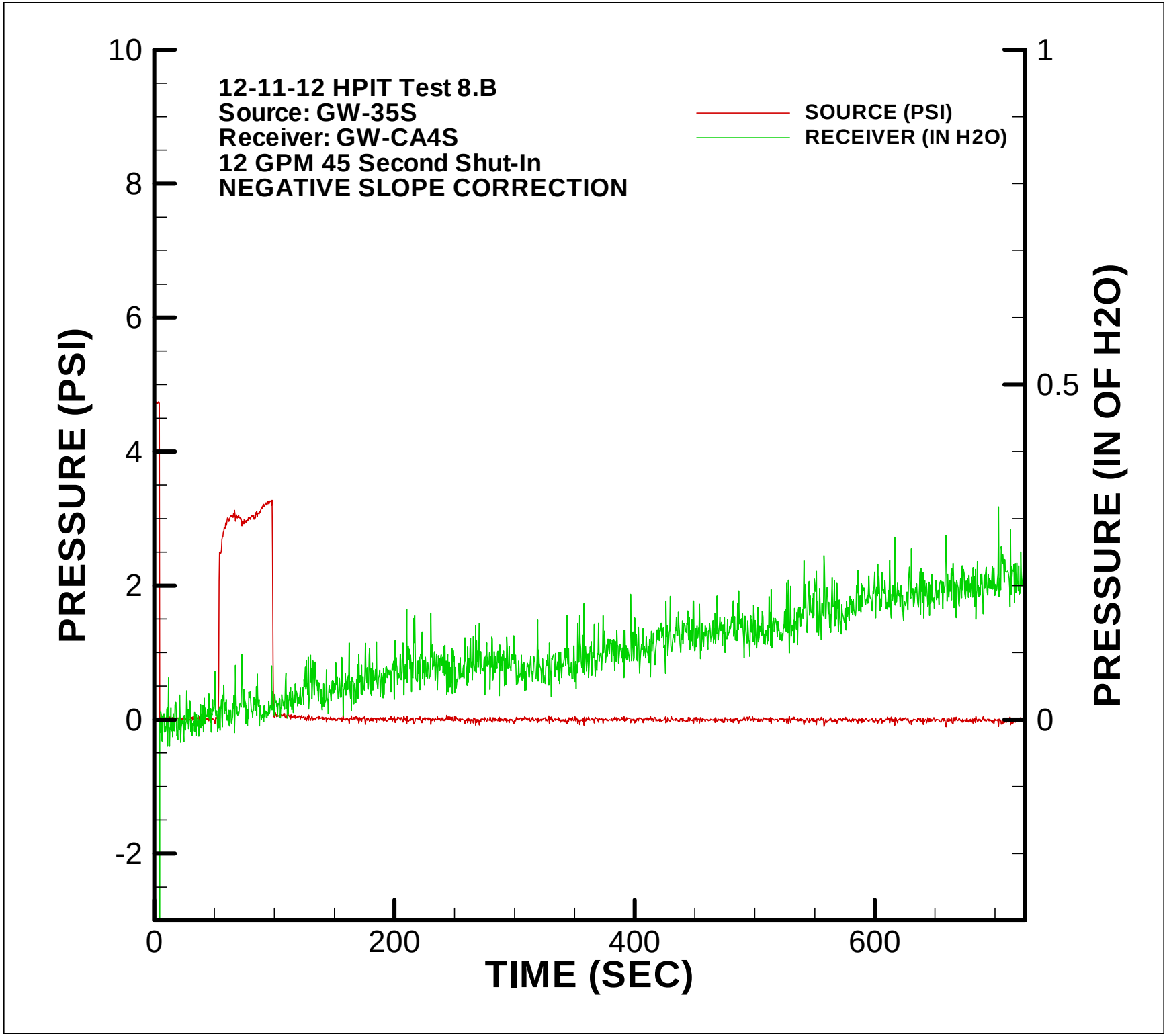

12-11-12 HPIT Test 3.A
Source: GW-34SR
Receiver: LPB-44
12 GPM 45 Second Shut-In
NEGATIVE SLOPE CORRECTION
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
2
1
0
-1
0.2
0.1
0
-0.1
200
400
600
800


12-11-12 HPIT Test 4.C
Source: GW-35S
Receiver: GW-CA3D
12 GPM 45 Second Shut-In
NEGATIVE SLOPE CORRECTION
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
10
8
6
4
2
0
-2
1
0.8
0.6
0.4
0.2
0
-0.2
200
400
600


12-11-12 HPIT Test 5.A
Source: GW-35S
Receiver: GW-30DR
12 GPM 45 Second Shut-In
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
0
2
4
6
8
10
0
1
2
3
4
5
0
200
400
600


12-11-12 HPIT Test 6.B
Source: GW-35S
Receiver: GW-76S
12 GPM 45 Second Shut-In
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
0
2
4
6
8
10
0
0.5
1
1.5
2
0
200
400
600


12-11-12 HPIT Test 7.A
Source: GW-35S
Receiver: GW-CA1
12 GPM 45 Second Shut-In
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
0
2
4
6
8
10
0
0.5
1
1.5
2
0
200
400
600


12-11-12 HPIT Test 8.B
Source: GW-35S
Receiver: GW-CA4S
12 GPM 45 Second Shut-In
NEGATIVE SLOPE CORRECTION
SOURCE (PSI)
RECEIVER (IN H2O)
PRESSURE (PSI)
PRESSURE (IN OF H2O)
TIME (SEC)
10
8
6
4
2
0
-2
1
0.5
0
0
200
400
600

APPENDIX D

HPIT DATA CALCULATION SHEETS

HYDRAULIC PULSE INTERFERENCE TEST 1.C
SLURRY WALL TEST OLIN SITE SOURCE: GW-34D RECEIVER: GW-6D

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

K = formation hydraulic conductivity

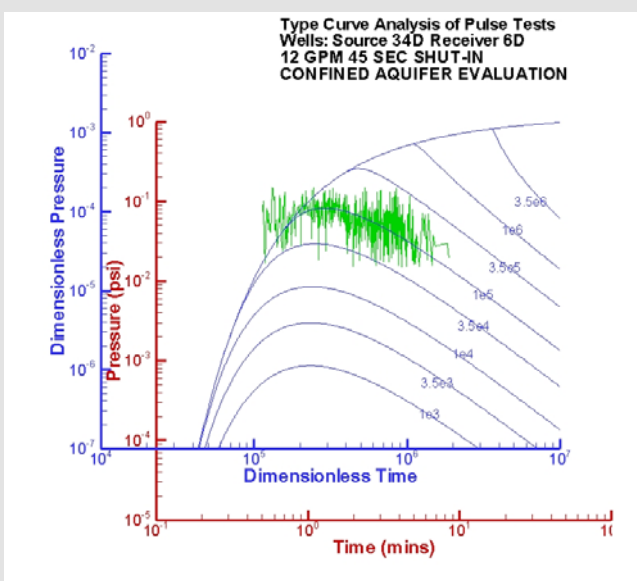
$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA		
q =	12.00	gpm
r_w =	0.25	ft
TYPE CURVE MATCH PARAMETERS		
Δp =	0.0155	psi
pD =	8.54E-04	
t =	2.00	mins
t_D =	1367730.00	

RESULTS		
K =	4.05E+01	ft/day
S_s =	6.59E-07	1/ft



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 2.B
SLURRY WALL TEST OLIN SITE SOURCE: GW-6D RECEIVER: GW-CA3D

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

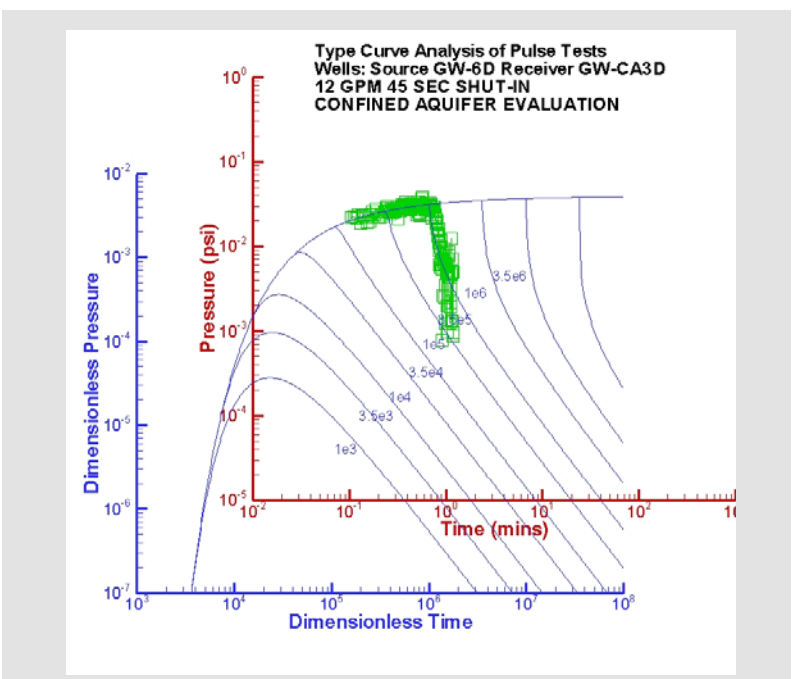
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	4.64E+01	ft/day
Δp =	0.0309	psi	S_s =	3.25E-07	1/ft
pD =	1.95E-03				
t =	0.71	mins			
t_D =	1116860.00				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 3.A
SLURRY WALL TEST OLIN SITE SOURCE: GW-34SR RECEIVER: LPB-44

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

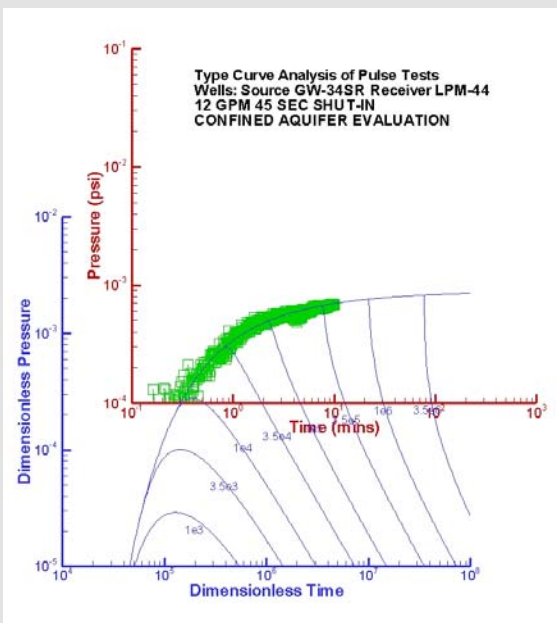
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	1.13E+03	ft/day
Δp =	0.0003	psi	S_s =	4.41E-05	1/ft
pD =	4.06E-04				
t =	0.71	mins			
t_D =	201372.00				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 4.C
SLURRY WALL TEST OLIN SITE SOURCE: GW-35S RECEIVER: GW-CA3D

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

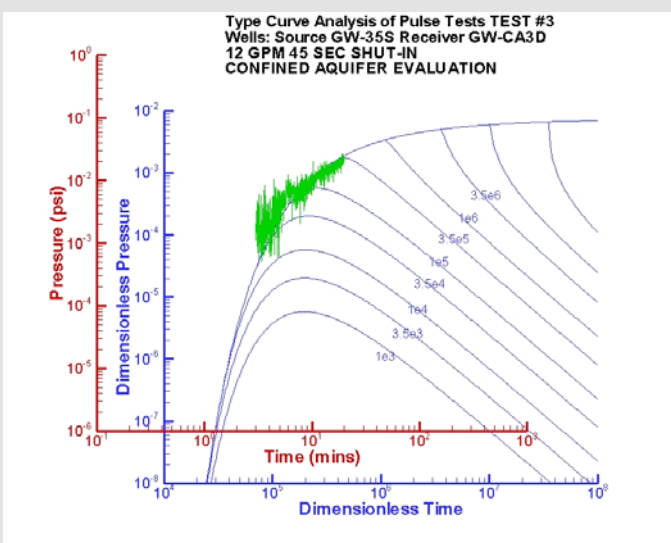
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	7.53E+01	ft/day
Δp =	0.0164	psi	S_s =	3.61E-05	1/ft
pD =	1.68E-03				
t =	17.51	mins			
t_D =	405509.00				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 5.A
SLURRY WALL TEST OLIN SITE SOURCE: GW-35S RECEIVER: GW-30DR

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

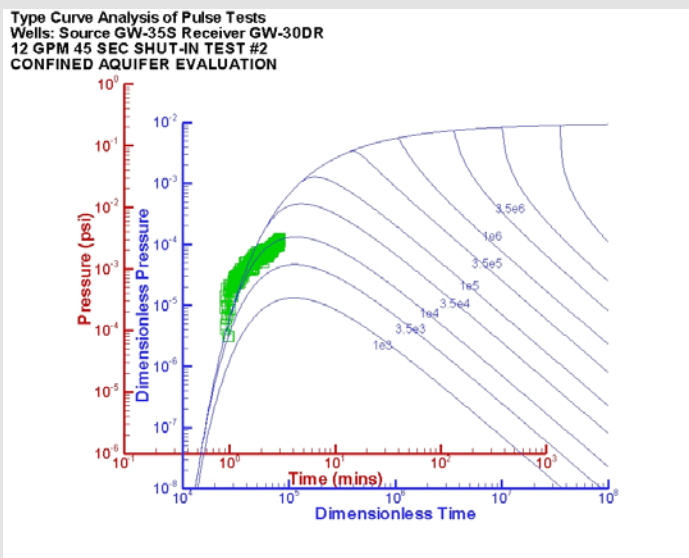
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	2.78E+01	ft/day
Δp =	0.0031	psi	S_s =	1.12E-05	1/ft
pD =	1.18E-04				
t =	2.90	mins			
t_D =	80167.80				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 6.B
SLURRY WALL TEST OLIN SITE SOURCE:GW-35S RECEIVER: GW-76S

$$K = \frac{q p_D}{4\pi r_w \Delta p}$$

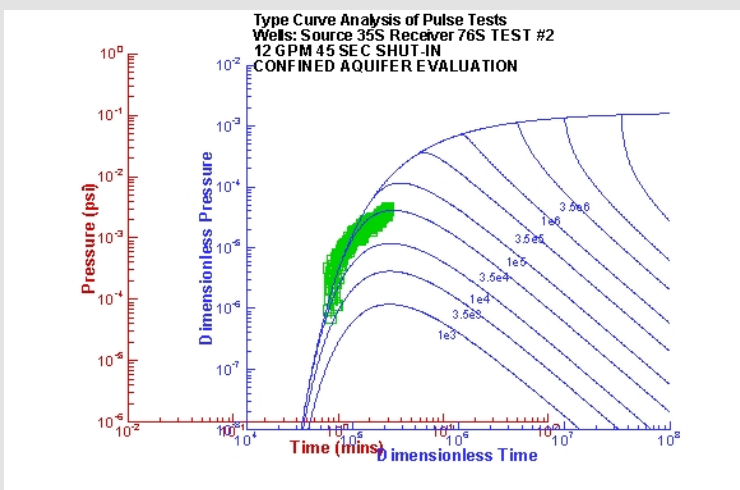
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	7.78E+00	ft/day
Δp =	0.0038	psi	S_s =	1.32E-06	1/ft
pD =	4.01E-05				
t =	3.25	mins			
t_D =	212814.00				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 7.A
SLURRY WALL TEST OLIN SITE SOURCE: GW-35S RECEIVER: GW-CA1

$$K = \frac{qp_D}{4\pi r_w \Delta p}$$

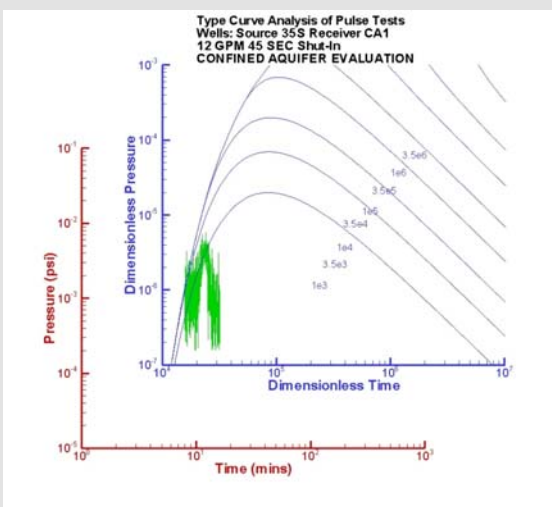
K = formation hydraulic conductivity

$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA			RESULTS		
q =	12.00	gpm			
r_w =	0.25	ft			
TYPE CURVE MATCH PARAMETERS			K =	3.66E-01	ft/day
Δp =	0.0032	psi	S_s =	2.02E-06	1/ft
pD =	1.58E-06				
t =	10.01	mins			
t_D =	20137.20				



Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

HYDRAULIC PULSE INTERFERENCE TEST 8.B
SLURRY WALL TEST OLIN SITE SOURCE: 35S RECEIVER: CA4S

$$K = \frac{qp_D}{4\pi r_w \Delta p}$$

K = formation hydraulic conductivity

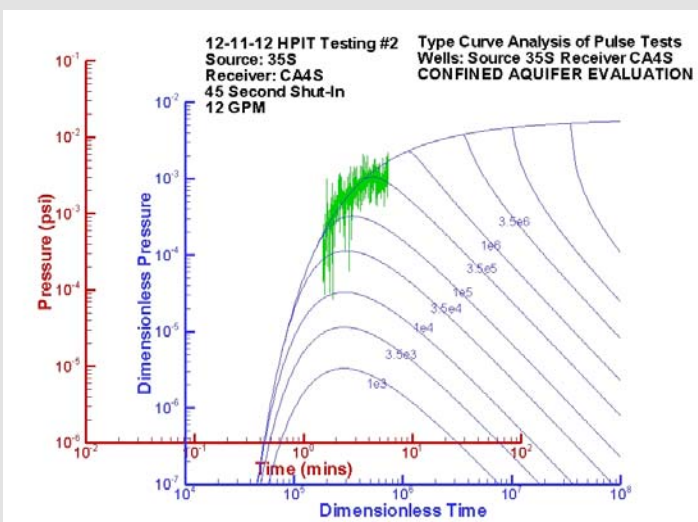
$$S_s = \frac{Kt}{r_w^2 t_D}$$

S_s = formation specific storage

where:
- q = flow rate
- p_D = dimensionless pressure
- r_w = well bore radius of source well
- Δp = dimensionless pressure
- t = time
- t_D = dimensionless time

PULSE TEST DATA		
q =	12.00	gpm
r_w =	0.25	ft
TYPE CURVE MATCH PARAMETERS		
Δp =	0.0032	psi
pD =	1.00E-03	
t =	5.00	mins
t_D =	619441.00	

RESULTS		
K =	2.30E+02	ft/day
S_s =	2.07E-05	1/ft

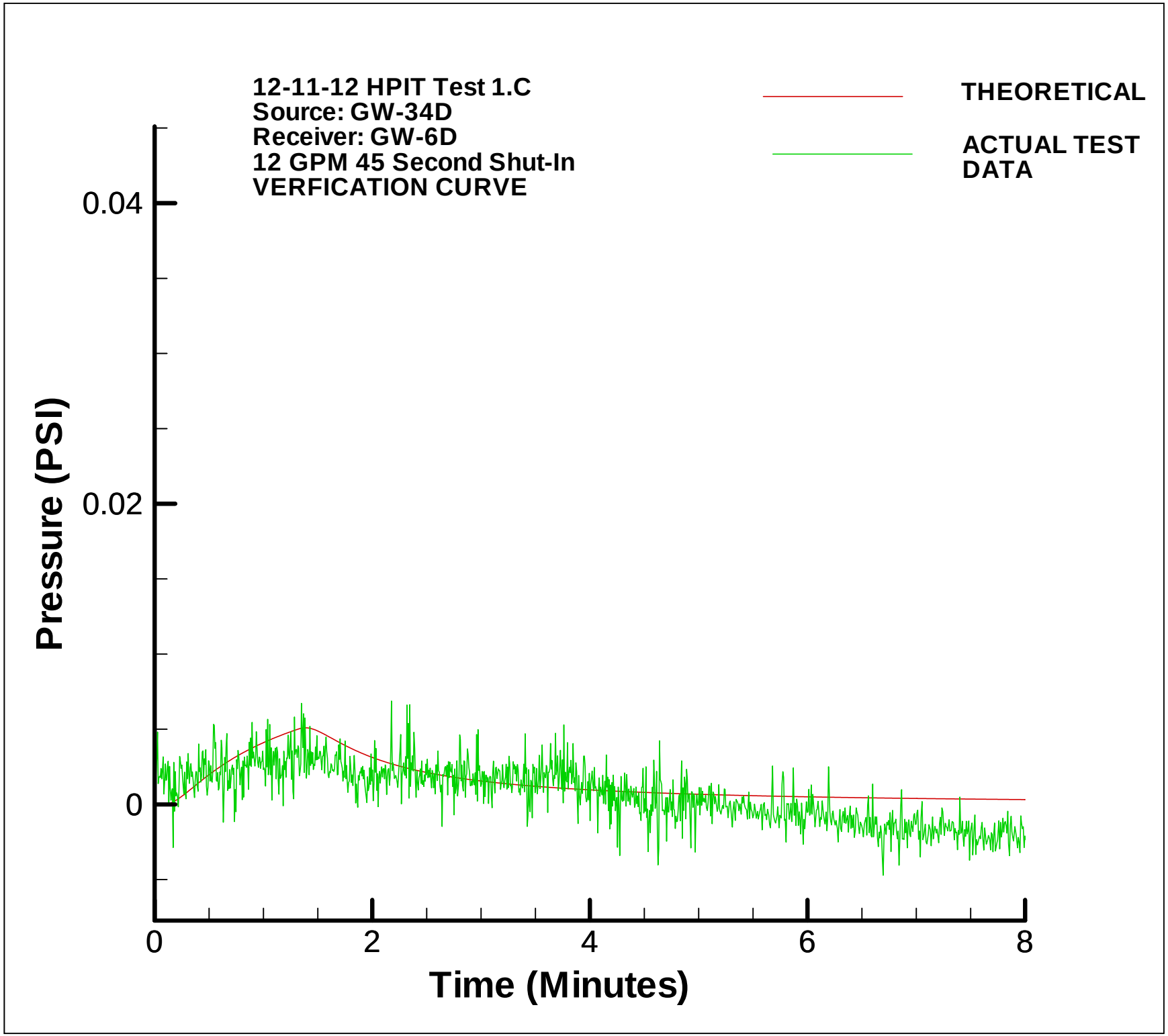


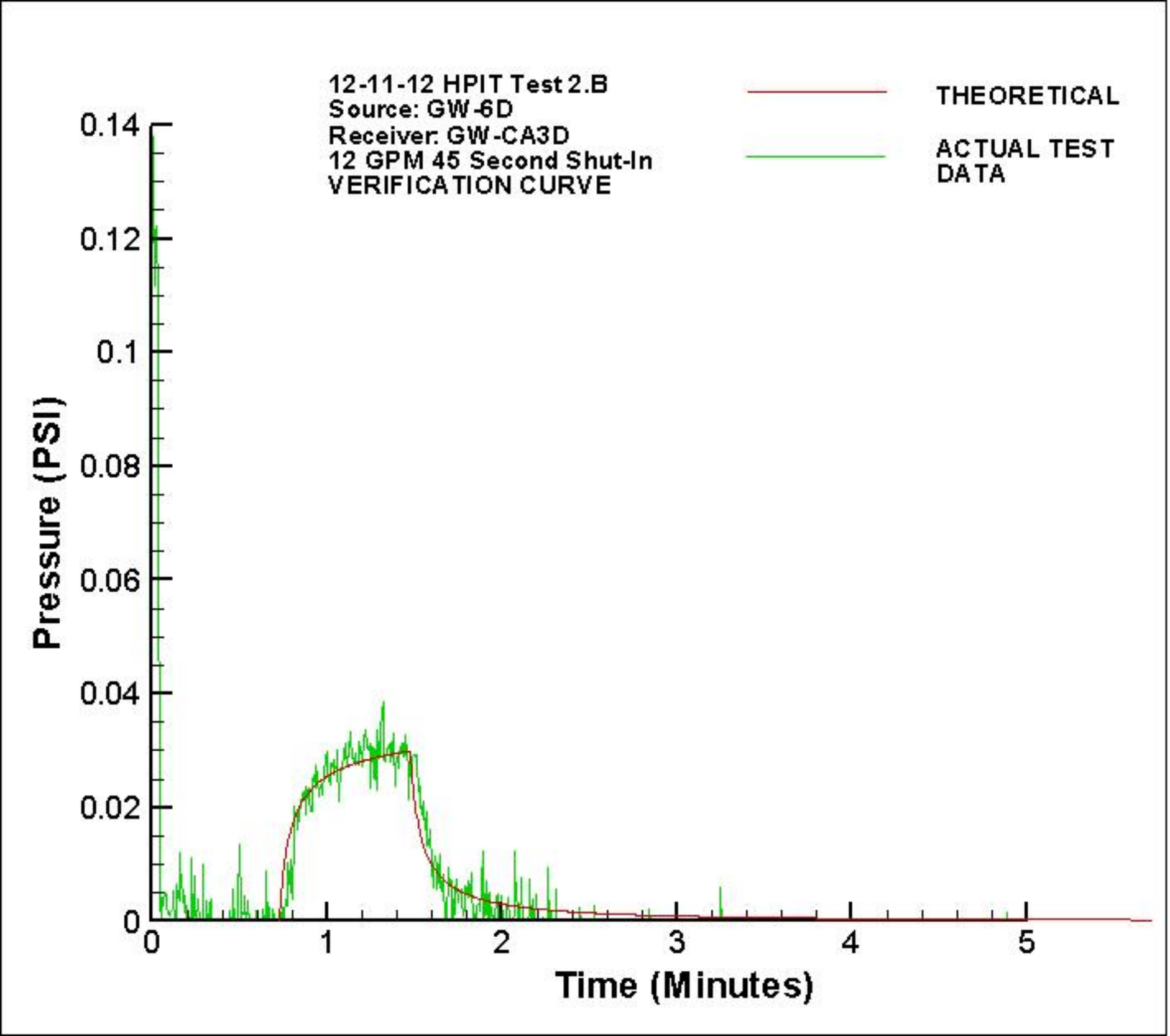
Project Name: OLIN Facility, Wilmington, Massachusetts
Project No.: G206001
Test Date: 12/11/2012

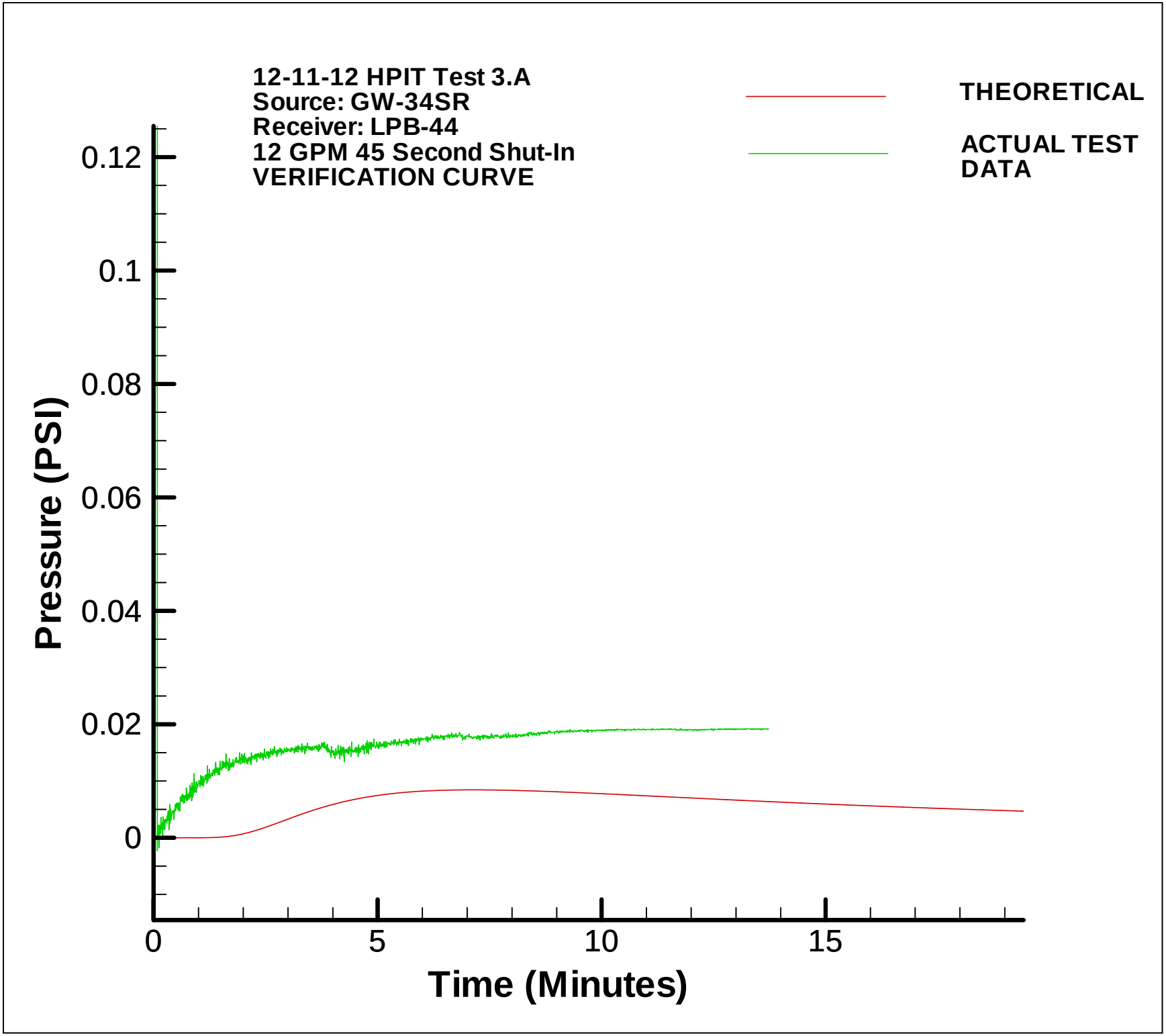
Analysis By: SML
Checked By: KDD
Reference: Hocking (2001)

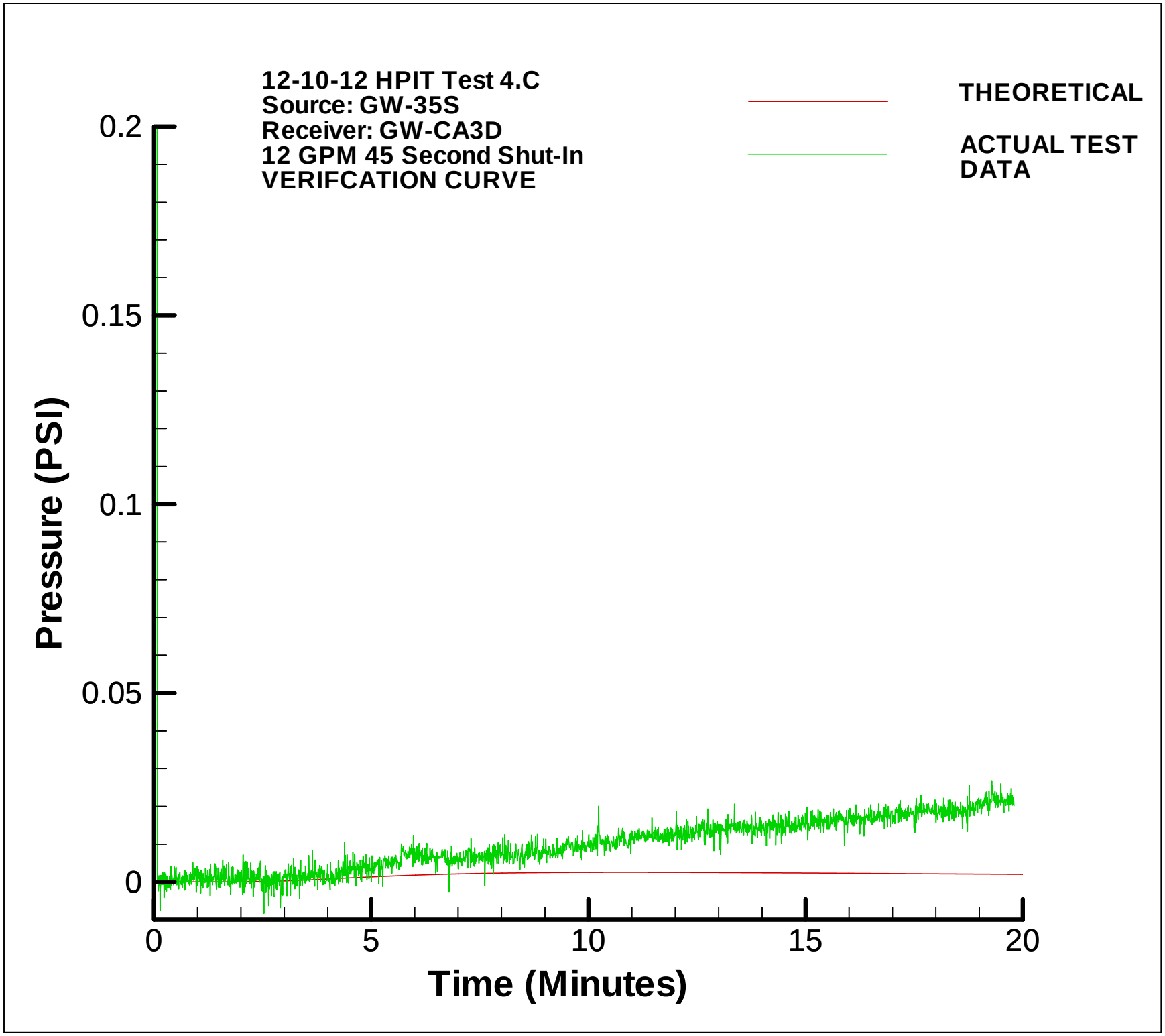
APPENDIX E

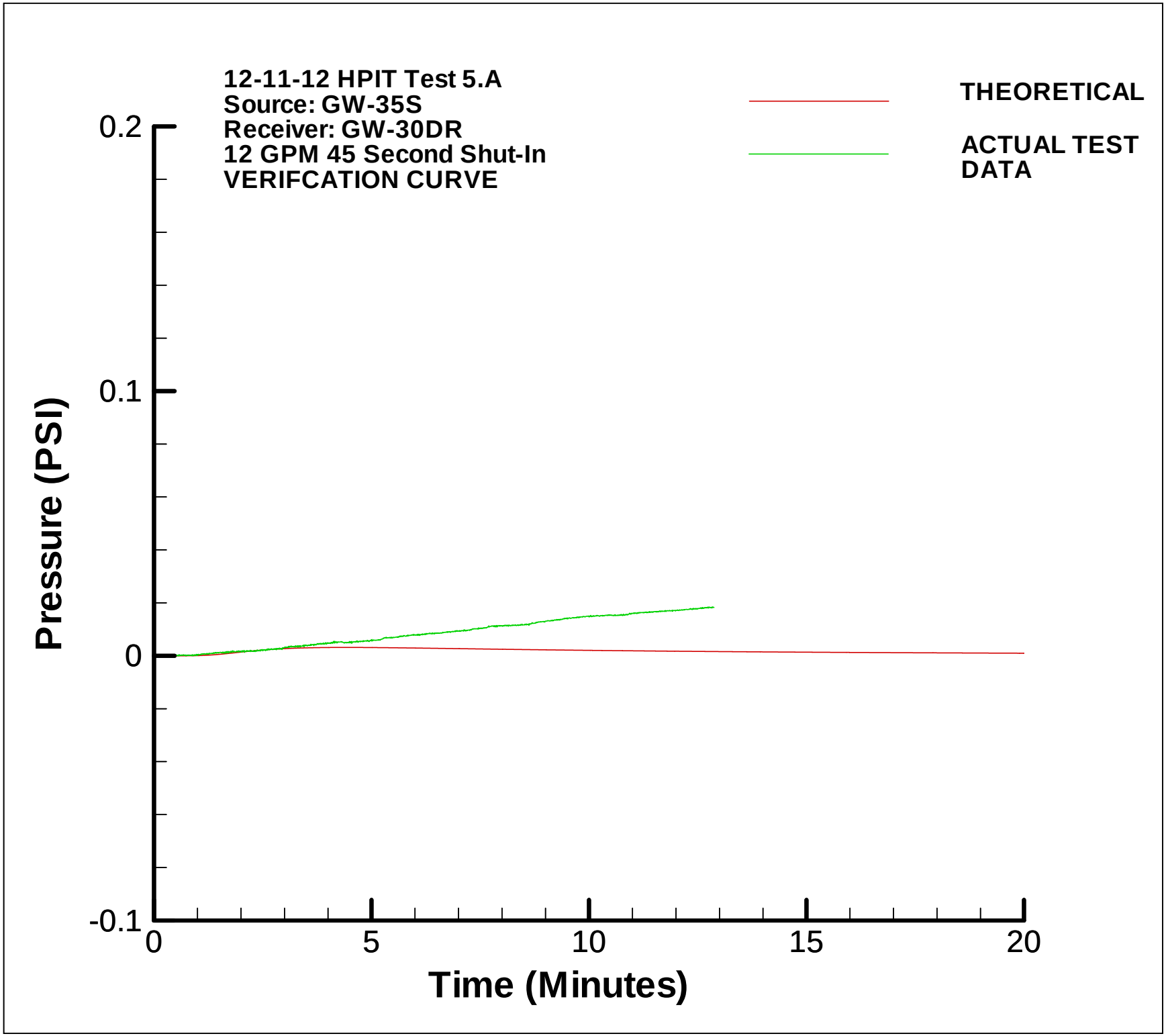
CHECK PROGRAM DATA VERIFICATION PLOTS

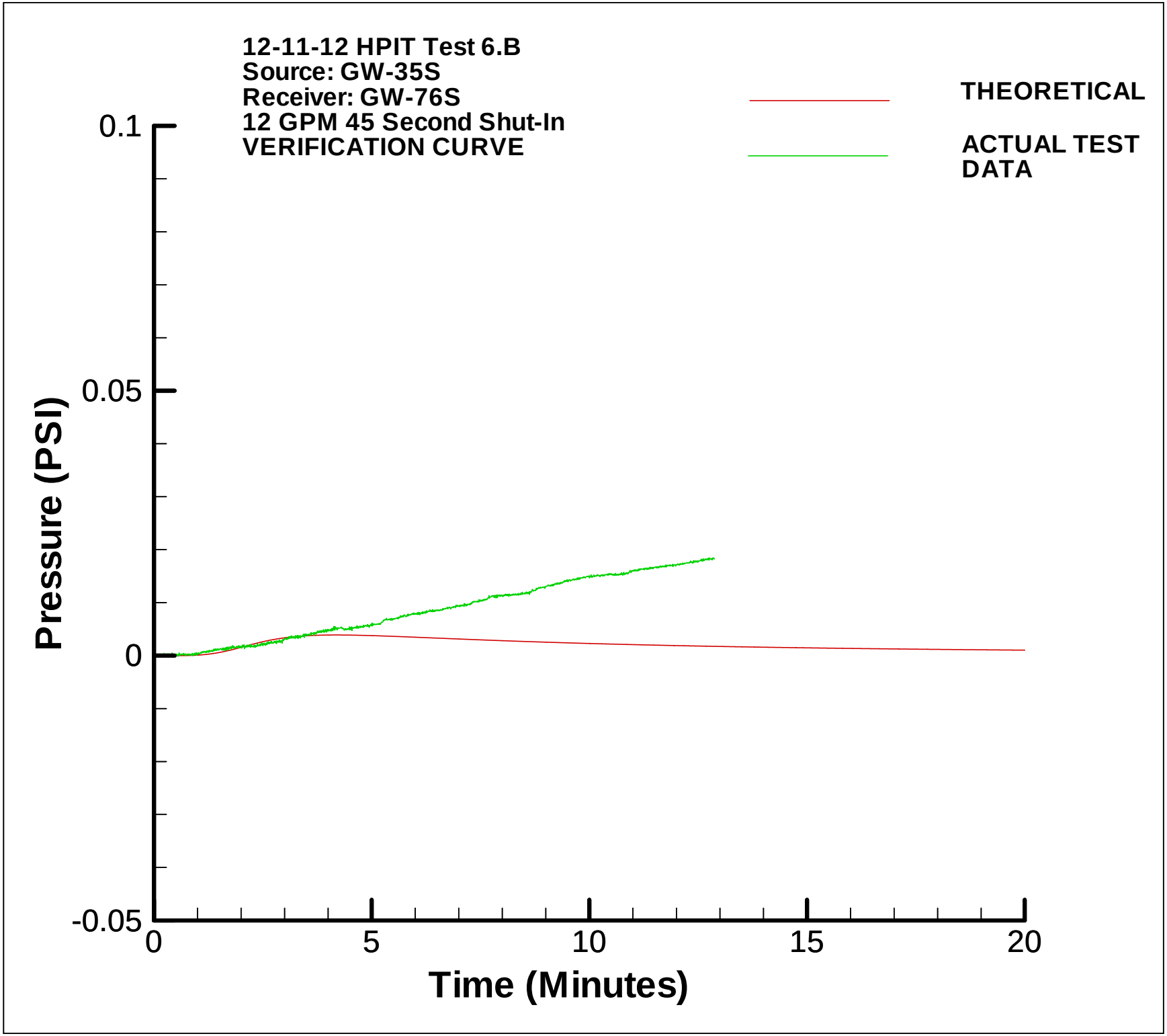

12-11-12 HPIT Test 1.C
Source: GW-34D
Receiver: GW-6D
12 GPM 45 Second Shut-In
VERFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.04
0.02
0
0
2
4
6
8
Time (Minutes)

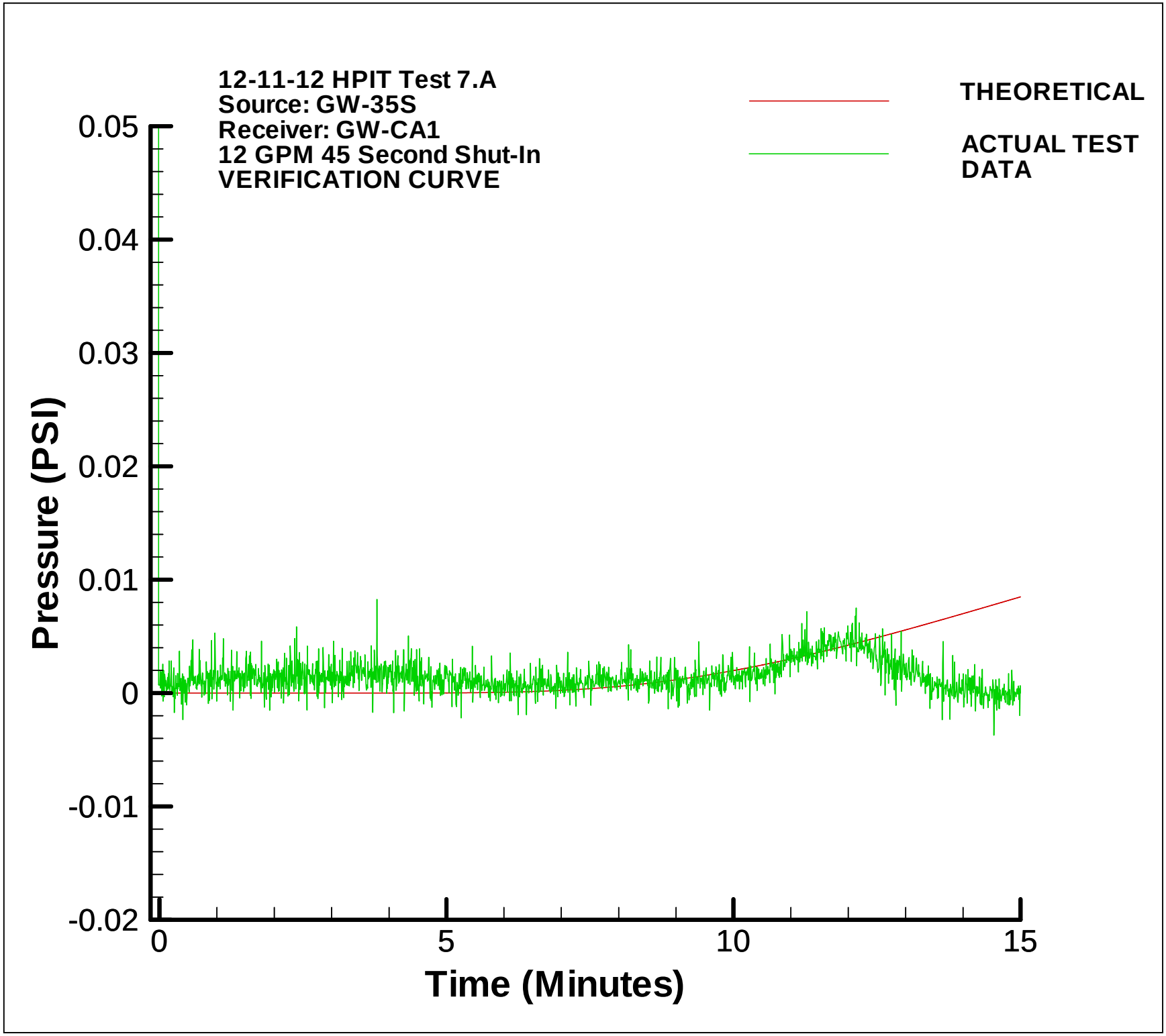

12-11-12 HPIT Test 2.B
Source: GW-6D
Receiver: GW-CA3D
12 GPM 45 Second Shut-In
VERIFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
Time (Minutes)

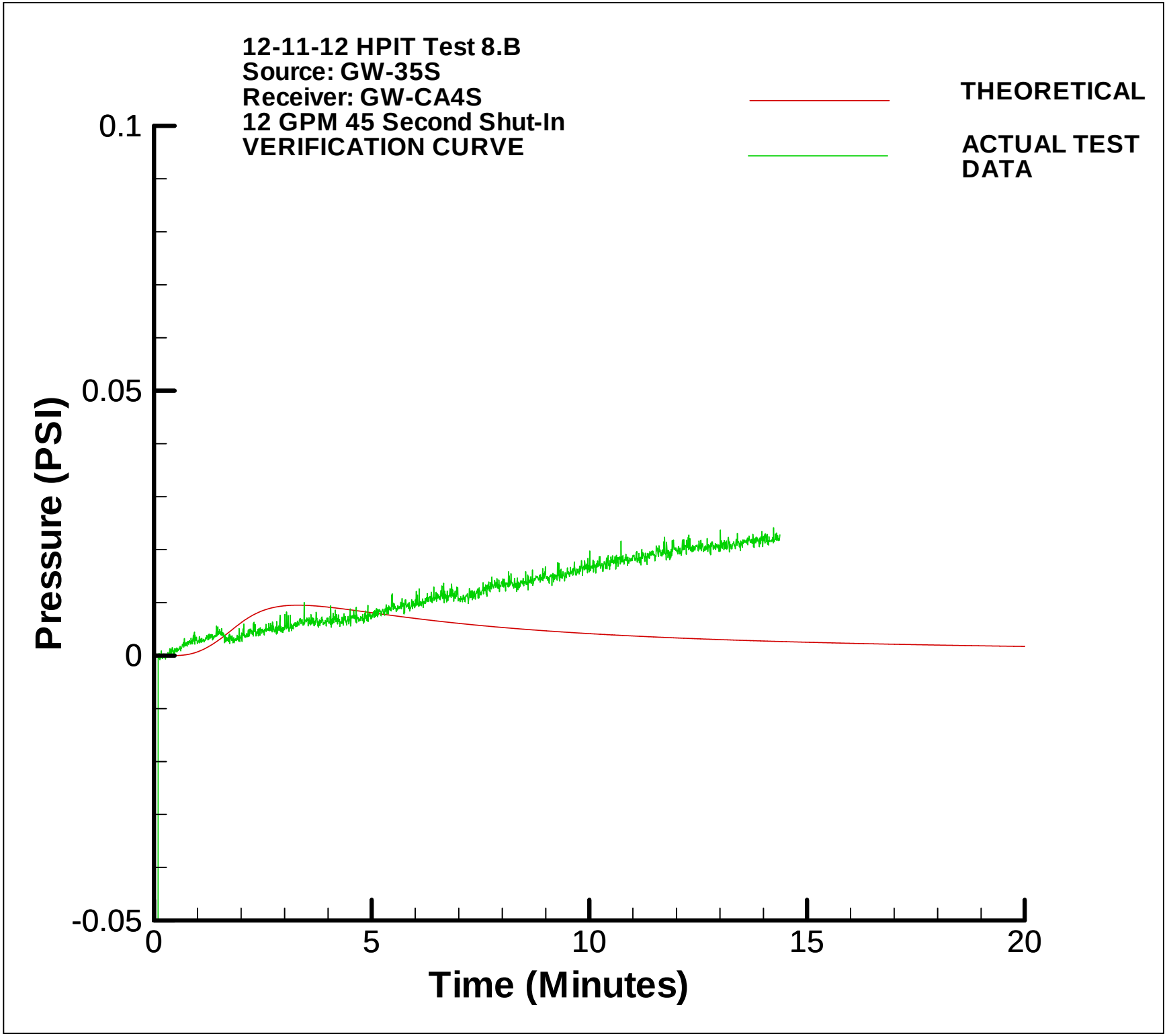

12-11-12 HPIT Test 3.A
Source: GW-34SR
Receiver: LPB-44
12 GPM 45 Second Shut-In
VERIFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
Time (Minutes)


12-10-12 HPIT Test 4.C
Source: GW-35S
Receiver: GW-CA3D
12 GPM 45 Second Shut-In
VERIFCATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.2
0.15
0.1
0.05
0
0
5
10
15
20
Time (Minutes)


12-11-12 HPIT Test 5.A
Source: GW-35S
Receiver: GW-30DR
12 GPM 45 Second Shut-In
VERIFCATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.2
0.1
0
-0.1
0
5
10
15
20
Time (Minutes)


12-11-12 HPIT Test 6.B
Source: GW-35S
Receiver: GW-76S
12 GPM 45 Second Shut-In
VERIFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.1
0.05
0
-0.05
0
5
10
15
20
Time (Minutes)


12-11-12 HPIT Test 7.A
Source: GW-35S
Receiver: GW-CA1
12 GPM 45 Second Shut-In
VERIFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
5
10
15
Time (Minutes)


12-11-12 HPIT Test 8.B
Source: GW-35S
Receiver: GW-CA4S
12 GPM 45 Second Shut-In
VERIFICATION CURVE
THEORETICAL
ACTUAL TEST DATA
Pressure (PSI)
0.1
0.05
0
-0.05
0
5
10
15
20
Time (Minutes)