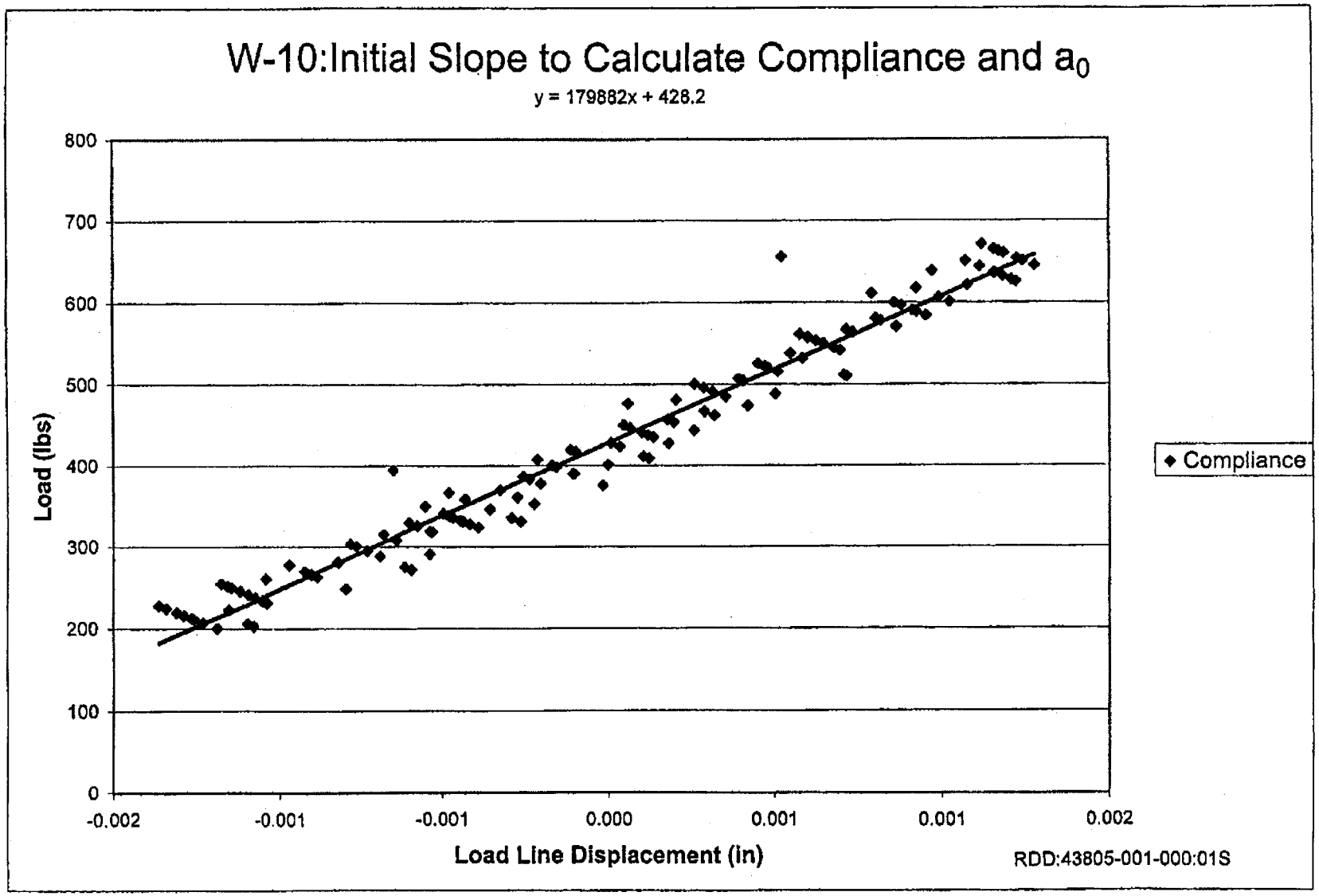
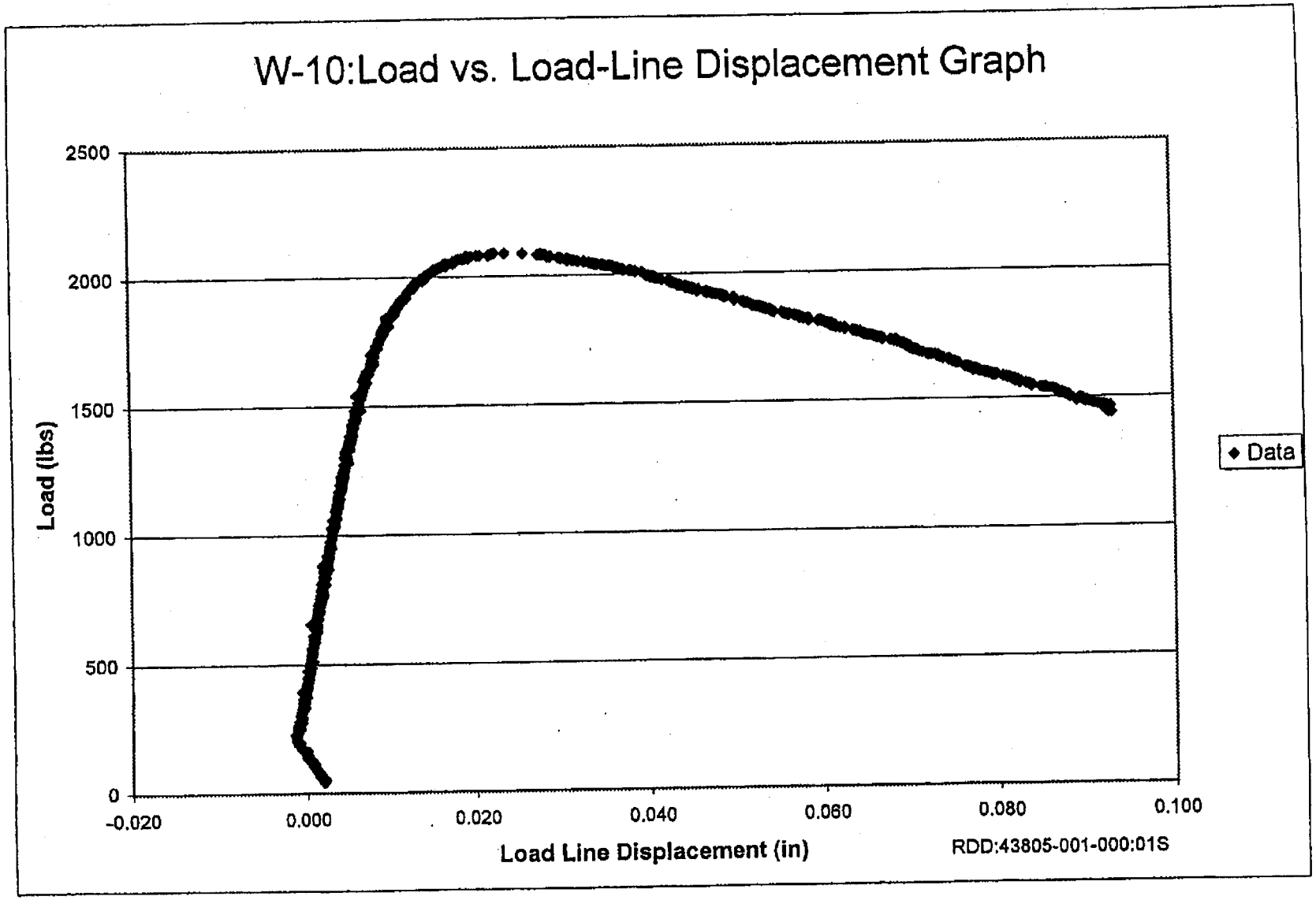
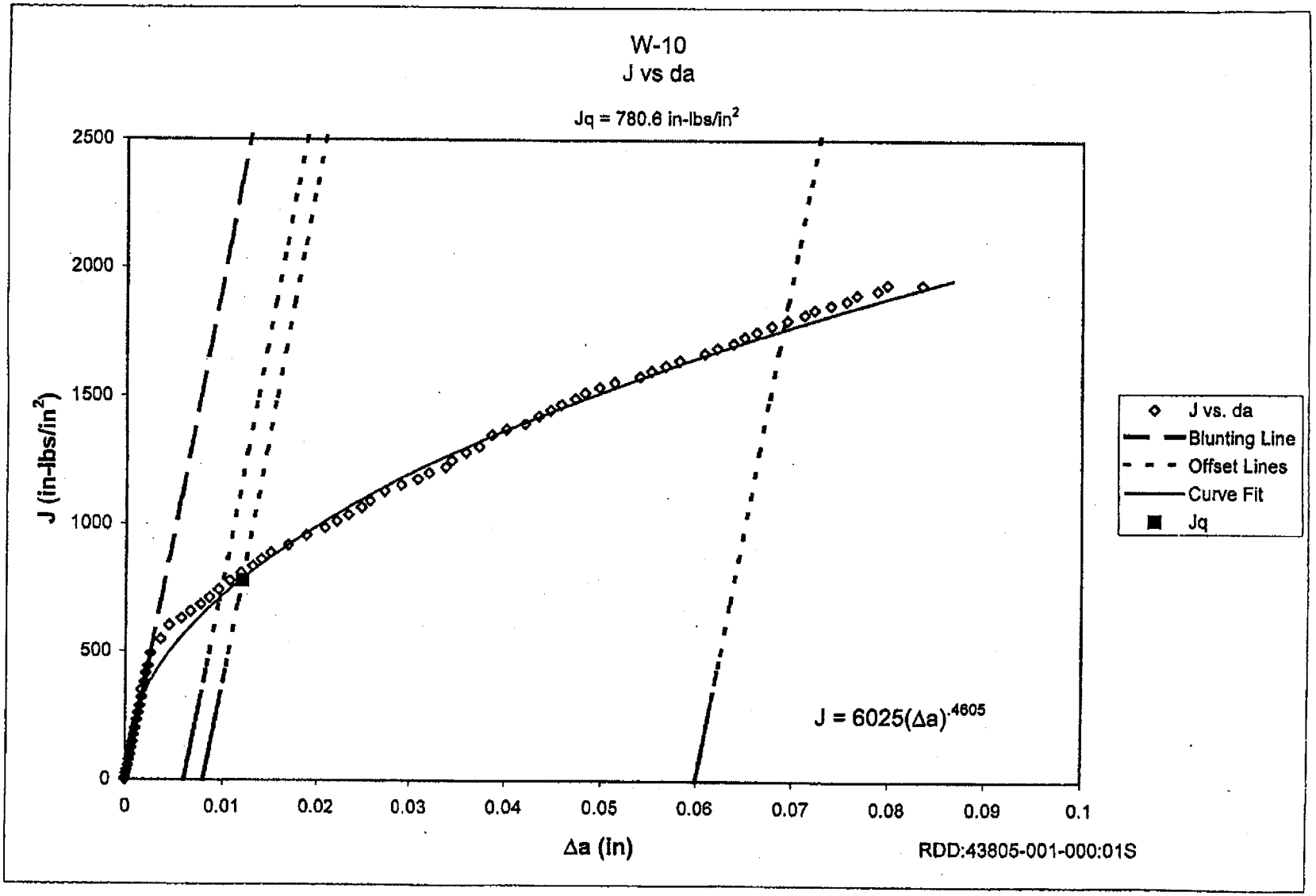
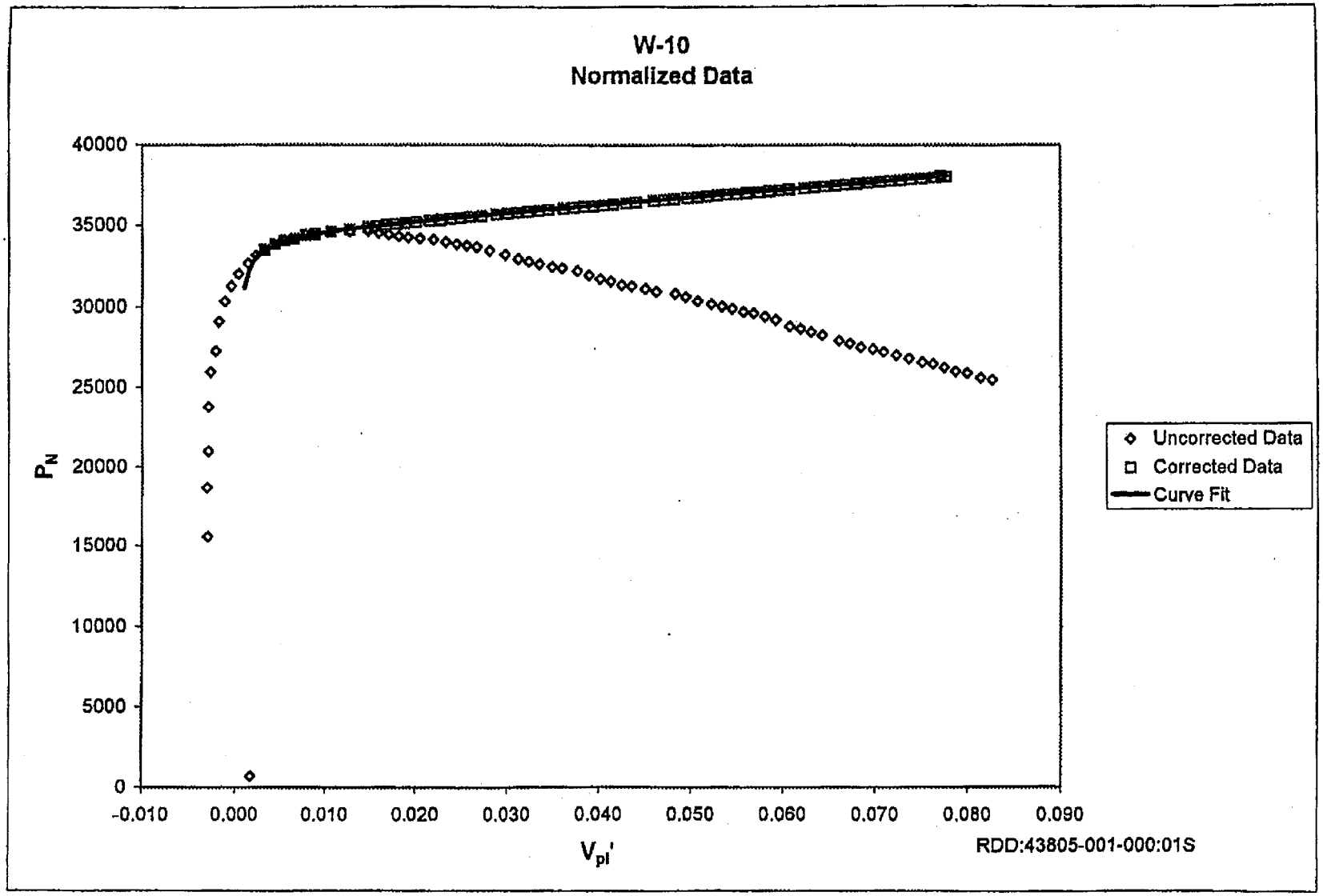
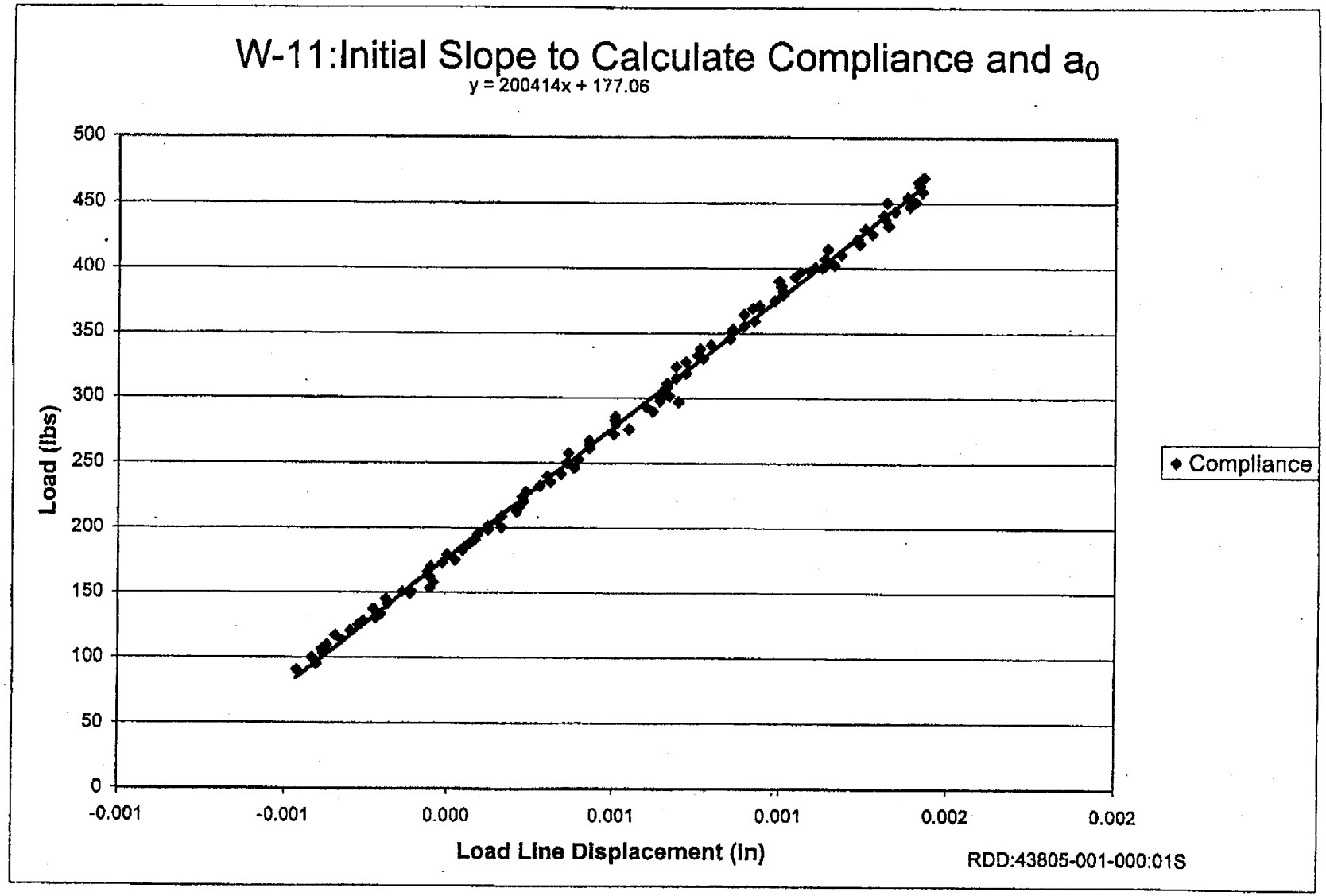
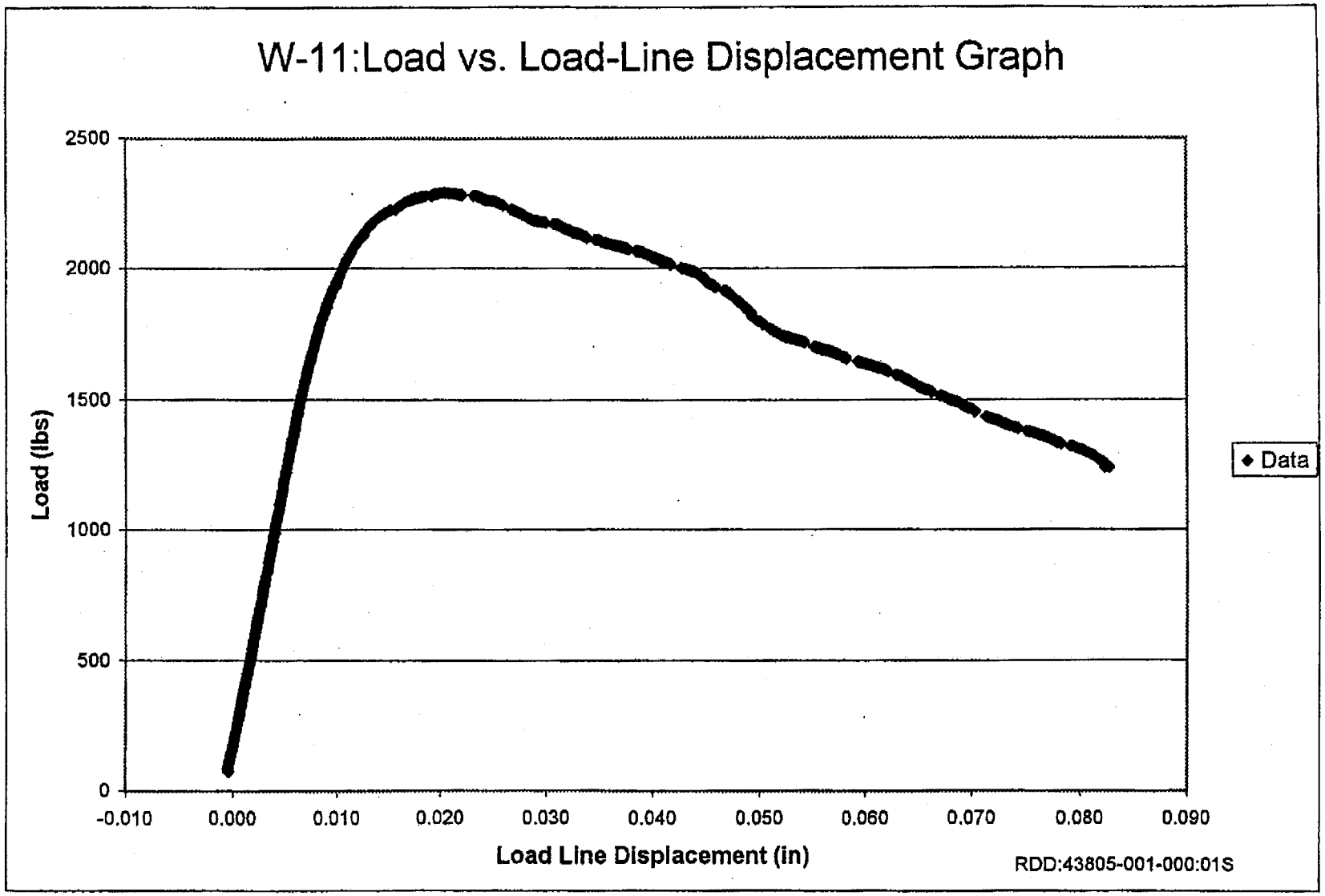

W-10:Initial Slope to Calculate Compliance and a_0
y = 179882x + 428.2
800
700
600
500
400
300
200
100
0
Load (lbs)
-0.002
-0.001
-0.001
0.000
0.001
0.001
0.002
Load Line Displacement (in)
Compliance
RDD:43805-001-000:01S

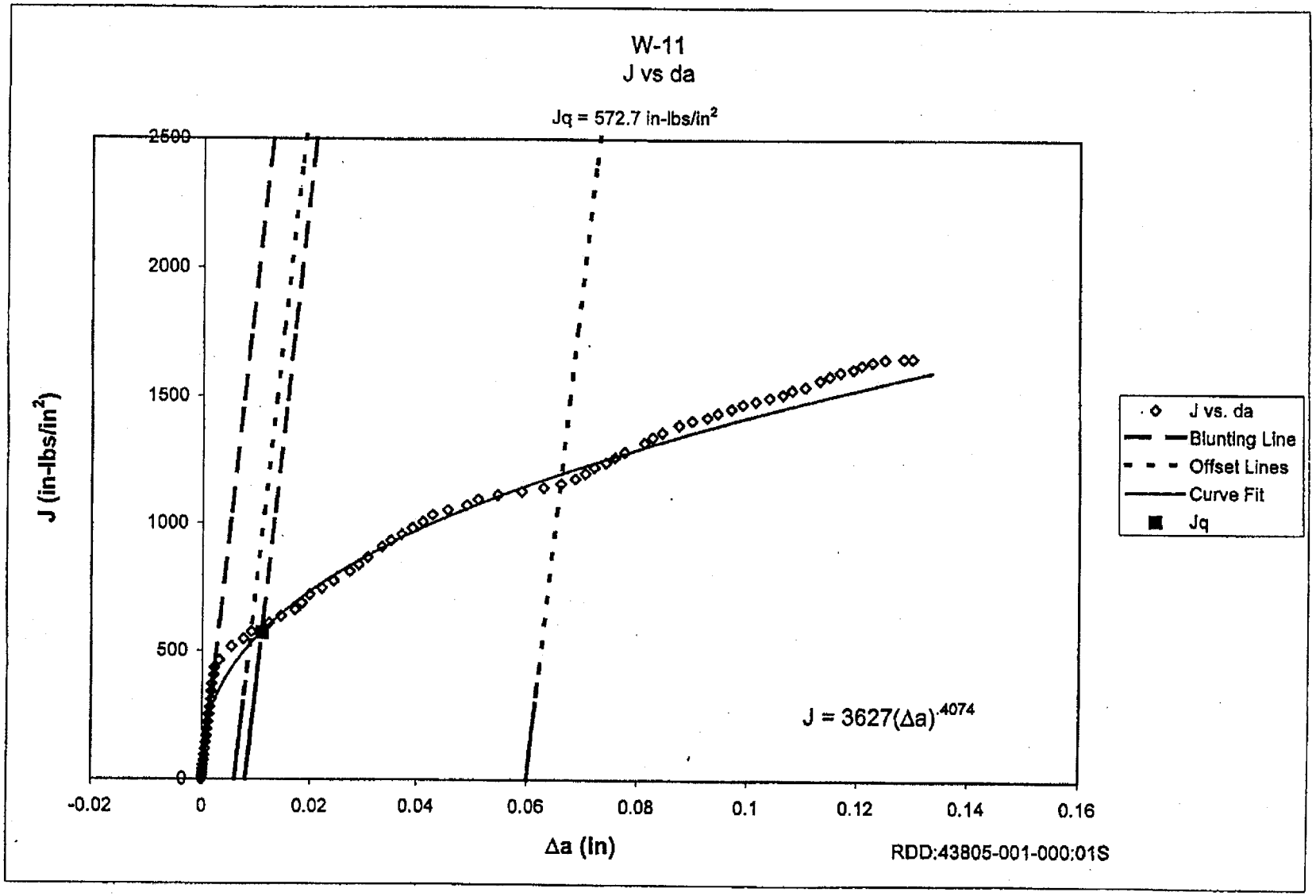

W-10:Load vs. Load-Line Displacement Graph
2500
2000
1500
1000
500
0
Load (lbs)
-0.020
0.000
0.020
0.040
0.060
0.080
0.100
Load Line Displacement (in)
Data
RDD:43805-001-000:01S

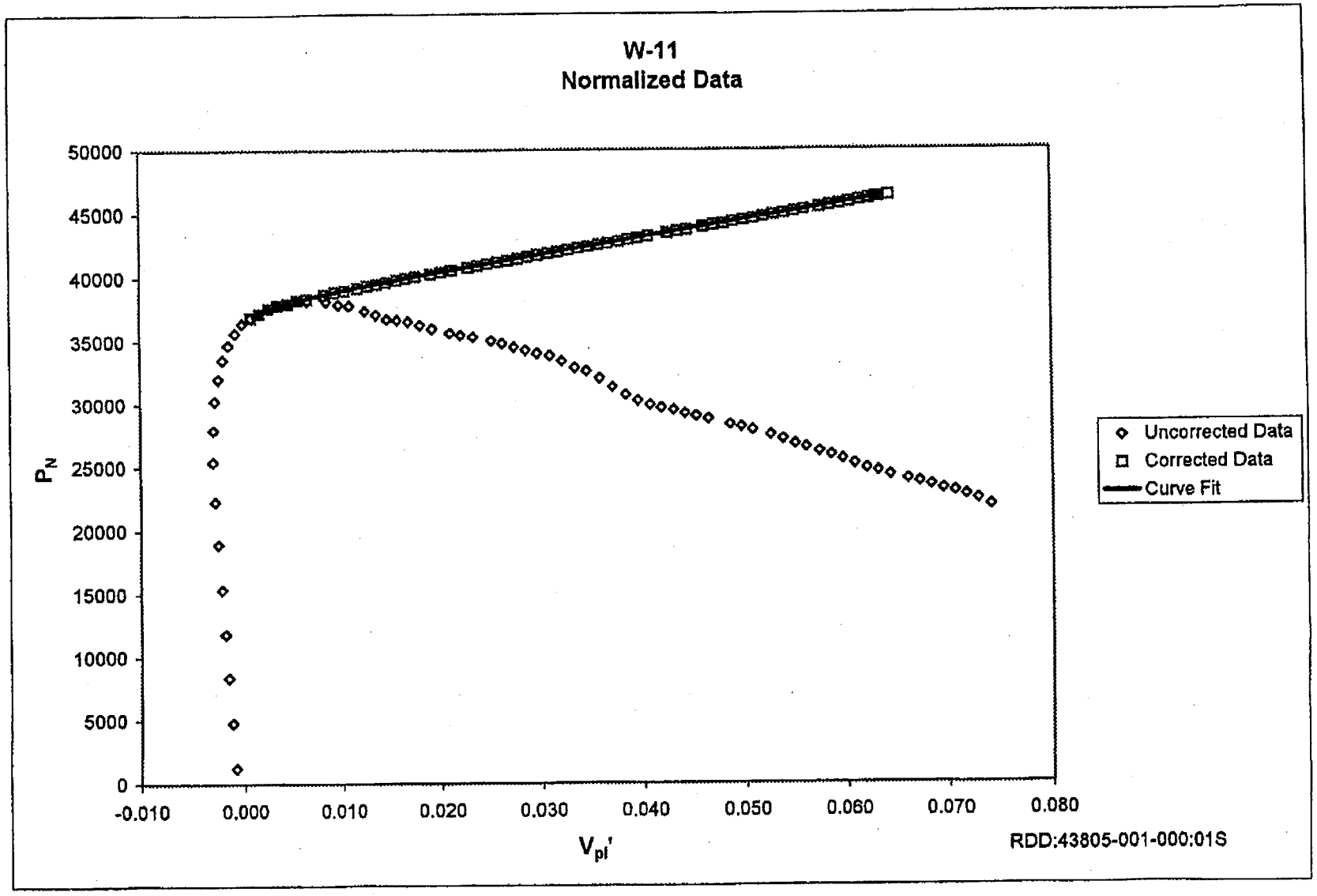

W-10
J vs da
Jq = 780.6 in-lbs/in2
2500
2000
1500
1000
500
0
J (in-lbs/in2)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Δa (in)
J = 6025(Δa).4605
J vs. da
Blunting Line
Offset Lines
Curve Fit
Jq
RDD:43805-001-000:01S


W-10
Normalized Data
40000
35000
30000
25000
20000
15000
10000
5000
0
P_N
-0.010
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
V_{pl}'
Uncorrected Data
Corrected Data
Curve Fit
RDD:43805-001-000:01S


W-11:Initial Slope to Calculate Compliance and a_0
y = 200414x + 177.06
500
450
400
350
300
250
200
150
100
50
0
Load (lbs)
-0.001
-0.001
0.000
0.001
0.001
0.002
0.002
Load Line Displacement (In)
Compliance
RDD:43805-001-000:01S


W-11:Load vs. Load-Line Displacement Graph
2500
2000
1500
1000
500
0
Load (lbs)
-0.010
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
Load Line Displacement (in)
Data
RDD:43805-001-000:01S


W-11
J vs da
Jq = 572.7 in-lbs/in²
J (in-lbs/in²)
2500
2000
1500
1000
500
0
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Δa (in)
J = 3627(Δa)^.4074
J vs. da
Blunting Line
Offset Lines
Curve Fit
Jq
RDD:43805-001-000:01S


W-11
Normalized Data
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
P_N
-0.010
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
V_{pl}'
Uncorrected Data
Corrected Data
Curve Fit
RDD:43805-001-000:01S

Lynchburg Technology Center

B & W

Nuclear Environmental Services, Inc

EVALUATION OF ADVANCED TEST REACTOR IRRADIATED BEND AND TENSILE SPECIMENS

PREPARED FOR
LOCKHEED IDAHO TECHNOLOGIES CO.

LTC:96:0135-01:01

AUGUST, 1995

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EVALUATION OF ADVANCED TEST REACTOR IRRADIATED BEND AND TENSILE SPECIMENS

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AUGUST, 1995

B&W NUCLEAR ENVIRONMENTAL SERVICES INC.
LYNCHBURG TECHNOLOGY CENTER

QUALITY ASSURANCE STATEMENT

B&W NESI CONTRACT #475-0135

Lockheed Idaho Technology Co. #C94-160838

B&W Nuclear Environmental Services, Inc., hereby certifies that the item(s) or service(s) provided on this order are in accordance with the requirements of the above specified purchase order.

This project was conducted in accordance with the requirements of B&W Nuclear Environmental Services, Inc., Nuclear Materials Engineering, QA Plan, Rev 1 (01 September 1994) for the project entitled "Evaluation of Advanced Test Reactor Irradiated Bend and Tensile Specimens".

D.W. Jacobs
QA Administrator

__07-29-96__
Date

SUMMARY

Presented in this report are the test results for tensile and bend specimens that were irradiated in Advanced Test Reactor (ATR) to fluence levels of 1.0×10^{18} and 1.2×10^{19} n/cm^2. These specimens were made of 304 stainless steel (SS) base metal and 308 SS weld metal. The fracture toughness and tensile strength data obtained from the irradiated specimens will be used to evaluate the conservatism of the values used in ATR's reactor vessel structural integrity analysis.

The tests were conducted in accordance with ASTM E8-94a (for tension tests) and ASTM E813-89 and ASTM E1152-87 (for fracture toughness tests). Test results show that radiation embrittlement was observed on both tensile and fracture toughness test results for the weld metal. Both base and HAZ metals show significant ductility in the fracture toughness tests. No comparison to unirradiated specimens was made due to the fact that only a minimum J value was reported for the unirradiated specimens. However, radiation-induced embrittlement was observed in the tensile testing for these two metals.

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Appendix

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D. Photographs for Bend Specimen Fracture Surfaces

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F. Metallography for HAZ Tensile Specimens

1.0 INTRODUCTION

This testing program is part of the ATR's Reactor Vessel Integrity Surveillance Program to monitor mechanical properties degradation due to irradiation. Tension specimens and bend specimens made of type 304 stainless steel (base metal) and type 308 stainless steel (weld metal) were irradiated in the Advanced Test Reactor (ATR) to two fluence levels, namely, 1.0 x 10^{18} and 1.2x 10^{19} n/cm^2. These specimens were then stored in the ATR for two to three years prior to being sent to B&W NESI Lynchburg Technology Center (LTC) for testing. Test results from fracture toughness testing on bend specimens will be used to show that the reactor vessel steel has appropriate margin for degradation of toughness due to irradiation embrittlement.

2.0 CAPSULE RECEIPT AND DISASSEMBLY

A GE-100 cask containing sixteen (16) tensile specimens and eighteen (18) bend specimens was received at LTC on May 19, 1994. The specimens were unloaded from the GE-100 cask and stored in the Cask Handling Area Pool. The following shows the results of the radiation survey before the specimens were stored in the pool.

Distance	Radiation levels (Rem/hr)
2 inches	>1000
12 inches	150
1 meter	15

Due to the high radiation levels, additional shielding was designed and added in various working areas to reduce radiation exposure to operators.

Prior to testing, specimens were decontaminated in an ultrasonic bath filled with water and small amount of mild detergent. After decontamination, the specimens were transferred to the Fatigue and Fracture Laboratory for testing.

3.0 TENSION TEST RESULTS

Tensile testing was performed in accordance with B&W technical procedure TP-78 (Rev. 12) which is in compliance with ASTM E8-94a and ASTM E21-92. All tensile specimens were subsize round type specimens. The first type was 3 inches in length and 0.25 inch in diameter. The second type was 2 inches in length and 0.16 inch in diameter. The tests were performed using an MTS servohydraulic testing machine. The test machine is interfaced with the MTS TestStar digital system. A B&W NESI certified program TNSLTEST was used to control the machine and acquire the data during the test. All tensile tests were run using stroke control with initial actuator travel rates ranging from 0.005 inch per minute to 0.01 inch per minute depending on specimen size. This initial rate was used through the yield point. Following specimen yielding, higher actuator speeds ranging from 0.02 inch per minute to 0.04 inch per minute were used. The test was performed in an ATS split type furnace and temperature was controlled to within ± 5 °F of the test temperature.[1]

Difficulty was experienced when loading four weld specimens which had smaller diameters (W-5, W-6, W-7, W-8). The threads of the specimens and specimen adapters were examined. It was found that the specimen threads were slightly larger than they should have been. However, this small difference prevented full threading of the specimens into the adaptor. After consulting with the ATR Project Manager, B&W NESI was instructed to use a die to clean up the specimen threads. After the specimen threads were cleaned, the specimens were loaded into the specimen adaptor (still with some difficulty) for testing. Note that cracks were found in the threaded region of specimen W-8 (see Figure 1). W-8 was not tested.

The test results of W-5, W-6, and W-7 should be used with caution. Sufficient torque may have been applied while cleaning up the threads to introduce a small amount of cold work.

The reason for apparent increase in thread size for these four specimens was unknown. One possibility is the radiation-induced swelling effects. However, these effects are observed in many types of stainless steels at higher temperatures and fluences. The other possibility was that the specimens were not machined to the specifications. Given the fact that specimens usually were vigorously examined for their compliance to the specifications prior to being sent for irradiation, the chance for that to happen is low.

---

[1]Since the radiation levels for the specimens are high, no thermocouple wire was attached onto the specimen surface for temperature measurement. A mock-up specimen (unirradiated) was placed in the oven and heated up to 115, 120, and 125°F, respectively. The temperature measurements on the specimen surface and those from furnace thermocouple wire were compared. It was found that the difference between these two readings are within 1°F.

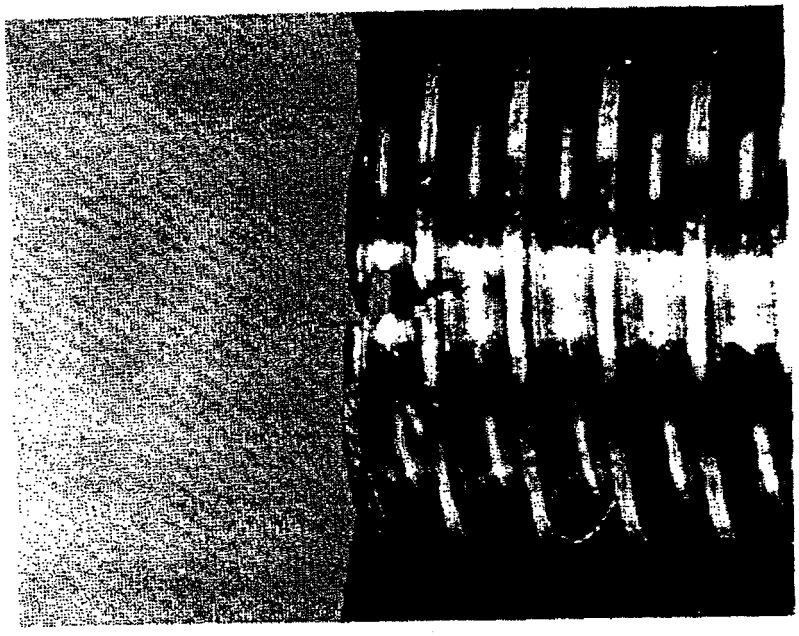

Figure 1. A crack was identified in one of the tension specimens.

Figure 2. A bend specimen is placed on the fixture.