RESEARCH PROJECT

"LOAD RESPONSE INSTRUMENTATION OF SHRP PAVEMENTS – THE UNIVERSITY OF AKRON"

STATE JOB NO. 14585(0)

FINAL REPORT

Submitted to:

Ohio Department of Transportation
and
Federal Highway Administration

Prepared by:

Allen L. Sehn

Prepared in Cooperation with the
Ohio Department of Transportation and the
U.S. Department of Transportation, Federal Highway Administration

Department of Civil Engineering
University of Akron
Akron, Ohio

August 2000

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16. Abstract

During the early 1990s the Ohio Department of Transportation developed a plan to construct and instrument a series of pavement test sections on U.S. 23 in Delaware County. The test pavements were constructed primarily during the 1995 construction season. The project includes pavements in four of the Specific Pavement Studies (SPS) of the Strategic Highway Research Program (SHRP). The calibration of the earth pressure cells and the procedures used to install them in the pavement test sections are presented herein. The pressure cells were each calibrated twice in the laboratory prior to installation in the pavement test sections. The calibration procedure used to simulate field conditions is presented. The results of the two calibrations for each of the sixty-four pressure cells are presented in the appendix. Information on the pavement test sections is also summarized.

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Disclaimer Statement

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Introduction

During the early 1990s the Ohio Department of Transportation developed a plan to construct and instrument a series of pavement test sections on U.S. 23 in Delaware County. The test pavements were constructed primarily during the 1995 construction season. The project includes pavements in four of the Specific Pavement Studies (SPS) of the Strategic Highway Research Program (SHRP). The SPS sections present in the project include: 1) SPS-1 Structural Factors for Flexible Pavements, 2) SPS-2 Structural Factors for Rigid Pavements, 3) SPS-8 Environmental Effects in the Absence of Heavy Loads, and 4) Asphalt Program Field Verification Studies.

The instrumentation for the pavement test sections was installed through a coordinated effort involving the Ohio Department of Transportation, the contractors for the project, and research teams from six universities throughout Ohio. The universities involved in the project included: 1) Case Western University, 2) Ohio State University, 3) Ohio University, 4) University of Akron, 5) University of Cincinnati, and 6) University of Toledo. Development of the instrumentation plan and coordination of the installation of the instrumentation was handled by the research team from Ohio University. Each of the participating universities was responsible for particular segments of the instrumentation. The responsibility of the University of Akron research group was to calibrate and install the earth pressure cells.

This report presents the procedures used to calibrate and install the earth pressure cells and contains detailed information on the calibration factors for each of the earth pressure cells installed in the Ohio SHRP SPS Test Road.

Instrumentation Plan

The vertical pressure in the pavement section is measured using Geocon Model 3500 earth pressure cells. These earth pressure cells consist of two circular stainless steel plates

placed one-above-the-other with a small distance between the two plates. The plates are then welded together along the outer edge to form a thin disk-shaped cavity that is filled with a fluid that will not freeze at the expected service temperatures. A length of high-pressure stainless steel tubing connects the cavity to a pressure transducer. During the manufacturing process, the cavity, the tubing, and the pressure transducer are all carefully deaired and filled with the fluid to insure saturation of the system. When pressure is applied to the face of the pressure cell, it causes an increase in the pressure in the cavity. The pressure in the cavity is transmitted to the pressure transducer through the stainless steel tubing that connects the cavity to the transducer. Since the system is filled with a fluid that is virtually incompressible over the range of pressures encountered in this application, the amount of movement or deflection of the sensing face of the pressure cell in response to an applied pressure is extremely small. This allows the earth pressure cell to accurately indicate the applied pressure. The pressure transducer is an electrical device that produces an output signal that is proportional to the pressure applied to the face of the pressure cell.

The purpose of the laboratory calibration of the pressure cells is to document the relationship between the pressure applied to the earth pressure cell and the output signal of the pressure transducer.

Each pressure cell installed in the test pavements by research personnel from the University of Akron was calibrated in the laboratory prior to installation. Since there is no way to check the calibration of the pressure cell or to recalibrate it after installation, each pressure cell was calibrated two times so that the results could be compared to insure that the calibration was successful and that the instrument gave repeatable results.

Once the pressure cells had been calibrated, they were installed in the pavement test sections in the number and locations called for in the overall project instrumentation plan as described in Report No. FHWA/OH-94/019 (Sargand, 1994). Sargand (1994) also contains

detailed information on the other instrumentation used in the Ohio SHRP Test Road. A total of 62 pressure cells were calibrated and installed. Table 1 summarizes some of the characteristics of the asphalt concrete pavement test sections of the project, and Table 2 summarizes some of the characteristics of the Portland cement concrete test sections of the project. The following sections describe the laboratory calibration and field installation procedures in detail.

Laboratory Calibration of the Earth Pressure Cells

Two procedures were used to calibrate the earth pressure cells. For the pressure cells to be installed into pavement sections with an asphalt concrete traffic layer, the pressure cells were embedded in a layer of fine sand during calibration. For the pressure cells to be installed in pavement sections with a Portland cement concrete traffic surface, the pressure cells were embedded into a 2-inch thick concrete slab measuring 12 inches by 28 inches. The sensitive face of the pressure cell was positioned flush with the surface of the concrete.

During laboratory calibration, the pressure cell being calibrated was embedded in a layer of sand and a uniform pressure was gradually applied to the surface of the sand. As the pressure was applied to the sand, the actual applied pressure and output signal of the earth pressure cell were recorded using one of the MegaDAC data acquisition systems from the project. This is the same data acquisition equipment that will be used to record the data from the earth pressure cells after they are installed in the pavement sections.

To facilitate the calibration, a special calibration chamber was constructed. The calibration chamber consists of a heavy-walled steel box with interior dimensions of 30 in. x 14 in. x 5 in (L x W x D). The bottom and sides of the calibration chamber are made of 1-inch-thick cold-rolled steel. The calibration is fitted with a cover that carries an inflatable thin latex bladder on its inside face. The latex bladder is approximately 0.75 inch thick and just slightly smaller than the 30-inch by 14-inch plan-view dimensions of the calibration chamber. The latex bladder was fabricated

Table 1) Summary of SPS-1, SPS-8, and SPS-9 Asphalt Concrete Pavement Test Sections

SPS Experiment	SHRP Test Section Number	Experiment Design Number	Asphalt Concrete Thickness (inches)	Base Thickness and Type	Edge Drain	Number of Earth Pressure Cells
SPS-1	390101	J1	7	8" DGAB	No	2
SPS-1	390102	J2	4	12" DGAB	No	2
SPS-1	390103	J3	4	8" ATB	No	2
SPS-1	390104	J4	7	12" ATB	No	2
SPS-1	390105	J5	4	4" ATB / 4" DGAB	No	none
SPS-1	390106	J6	7	8" ATB / 4" DGAB	No	2
SPS-1	390107	J7	4	4" PATB / 4" DGAB	Yes	2
SPS-1	390108	J8	7	4" PATB / 8" DGAB	Yes	2
SPS-1	390109	J9	7	4" PATB / 12" DGAB	Yes	2
SPS-1	390110	J10	7	4" ATB / 4" PATB	Yes	2
SPS-1	390111	J11	4	8" ATB / 4" PATB	Yes	2
SPS-1	390112	J12	4	12" ATB / 4" PATB	Yes	2
SPS-1	390160	S7	4	11" ATB / 4" DGAB	Yes	2
SPS-1	390159	K24	4	15" ATB / 4" PCTB / 6" DGAB	Yes	none
SPS-8	390803	K13	4	8" DGAB	No	Note 1
SPS-8	390804	K14	7	12" DGAB	No	none
SPS-9	390902	SHRP	4	12" ATB / 4" PATB / 6" DGAB	Yes	2
SPS-9	390901	ODOT	4	12" ATB / 4" PATB / 6" DGAB	Yes	2

DGAB = Dense Graded Aggregate Base
PATB = Permeable Asphalt Treated Base
PCTB = Permeable Cement Treated Base
ATB = Asphalt Treated Base

Note 1: Two earth pressure cells were installed by others prior to the start of this research project.

Table 2) Summary of SPS-2 and SPS-8 Portland Cement Concrete Pavement Test Sections

SPS Experiment	SHRP Test Section Number	Experiment Design Number	Lane Width (ft.)	Portland Cement Conc. Layer Properties		Base Thickness and Type	Edge Drain	Number of Earth Pressure Cells
				Modulus of Rupture (psi)	Thickness (in.)			
SPS-2	390201	J1	12	ODOT mix design	8	6" DGAB	No	2
SPS-2	390202	J2	14	900	8	6" DGAB	No	2
SPS-2	390203	J3	14	ODOT mix design	11	6" DGAB	No	2
SPS-2	390204	J4	12	900	11	6" DGAB	No	2
SPS-2	390205	J5	12	ODOT mix design	8	6" LCB	No	2
SPS-2	390206	J6	14	900	8	6" LCB	No	2
SPS-2	390207	J7	14	ODOT mix design	11	6" LCB	No	2
SPS-2	390208	J8	12	900	11	6" LCB	No	2
SPS-2	390209	J9	12	ODOT mix design	8	4" PATB / 4" DGAB	Yes	2
SPS-2	390210	J10	14	900	8	4" PATB / 4" DGAB	Yes	2
SPS-2	390211	J11	14	ODOT mix design	11	4" PATB / 4" DGAB	Yes	2
SPS-2	390212	J12	12	900	11	4" PATB / 4" DGAB	Yes	2
SPS-2	390259	S1	12	900	11	6" DGAB	Yes	none
SPS-2	390261	S2	14	ODOT mix design	11	4" PCTB / 4" DGAB	Yes	2
SPS-2	390262	S3	12	ODOT mix design	11	4" PCTB / 4" DGAB	Yes	2
SPS-2	390263	S4	14	ODOT mix design	11	6" DGAB	Yes	2
SPS-2	390264	S5	12	ODOT mix design	11	6" DGAB	Yes	2
SPS-2	390265	S10	12	ODOT mix design	11	4" PATB / 4" DGAB	Yes	none
SPS-8	390809	J1	12	550	8	6" DGAB	No	Note 1
SPS-8	390810	K15	12	550	11	6" DGAB	No	none

DGAB = Dense Graded Aggregate Base
PATB = Permeable Asphalt Treated Base
PCTB = Permeable Cement Treated Base
LCB = Lean Concrete Base

Note 1: Two earth pressure cells were installed by others prior to the start of this research project.

over a light aluminum frame that holds the bladder in the proper shape and location. The bladder assembly is attached to the underside (inside) face of the calibration chamber cover plate. The cover plate is equipped with connection ports for the pressurization line and the pressure transducer used to register the applied pressure.

During setup for a calibration run for an earth pressure cell not cast into a concrete block, fine dry sand is carefully placed and densified into the calibration chamber to a depth of 2.0 inches. A screed is used to produce a uniform and level surface on the sand bedding. The pressure cell to be calibrated is placed on the sand bedding with its sensitive face on top. Additional sand is placed over the pressure cell to a depth of about 2 inches and tamped to densify it. After densification, excess sand is removed using a screed to produce a uniform level surface.

Calibration setup for an earth pressure cell that has been cast into a concrete slab is very similar. Initially a thin layer of fine sand is placed into the calibration chamber and leveled off using a screed. The concrete slab containing the pressure cell is then placed onto the bedding sand with the sensitive face of the pressure cell on top. The concrete block is firmly bedded into the sand by twisting it slightly while pressing down from the top. After seating the concrete block into the bedding sand, additional sand is placed over the concrete block and the pressure cell as for the previously described case. Once the sand is in place, the remaining steps are the same for both cases.

Following placement of the sand over the pressure cell, the cover plate and pressurization bladder are placed on top of the calibration chamber. The calibration chamber is attached to a large lower platen of a compression machine, and the upper platen of the compression machine is used to hold the cover plate assembly securely against the top edge of the side walls of the calibration chamber during the calibration process.

A closed-loop computer-controlled pressure controller is used to control the pressure during the calibration procedure. Before beginning the actual calibration record, the system is pressurized and depressurized through one full cycle to seat the pressure cell and sand in the calibration chamber and to exercise the pressure transducer. Following completion of the initial pressurization cycle, the applied pressure is slowly incremented from 0 to 40 psi and then decremented from 40 psi back to zero psi. Throughout this calibration cycle, the data acquisition system is used to record the applied pressure and the output signal of the earth pressure cell at one-second intervals. The pressure is increased and decreased at a nominal rate of 4 psi per minute. At this rate, one complete calibration cycle lasts about 20 minutes with about 1200 data pairs being recorded.

During calibration of the pressure cells embedded into the concrete slabs, some minor cracking of some of the concrete slabs was noticed. For these units, the pressure cells were removed from the concrete and new concrete slabs were cast. To alleviate the cracking problem, the remaining calibrations for pressure cells cast into concrete were in the pressure range from zero to twenty psi. Based on discussions with the instrumentation coordinator, Dr. Sargand at Ohio University, this was deemed acceptable because the pressures beneath the Portland cement concrete pavements are not expected to exceed the 20-psi calibration range.

Upon completion of the calibration, the sand is removed from the calibration chamber using a special vacuum material handling system to return the sand to the hopper used to fill the calibration chamber during setup. For each pressure cell, two calibrations are completed to verify the accuracy of the results. The two calibrations for a particular earth pressure cell are completed on separate days and the pressure cells are removed from the calibration chamber between calibrations. As prescribed in the instrumentation plan outlined by Sargand (1994), the calibration factors from two separate calibrations of the same earth pressure cell shall not differ by more than 2.0% of the average of the two values. All of the earth pressure cells calibrated for this project

satisfied this quality assurance criterion. The calibration data for the earth pressure cells calibrated for this project are summarized in Table 3. A detailed record for each calibration is presented in the figures in Appendix A.

Field Installation of the Earth Pressure Cells

The location of each earth pressure cell within the pavement test section and within the pavement profile is prescribed in the instrumentation plan (Sargand, 1994). The procedure used to install the earth pressure cells depends on whether the pavement surface layer is asphalt concrete or Portland cement concrete. For the pavement sections with an asphalt concrete surface layer, all of the pressure cells were installed using the same procedure. For the pavement sections with a Portland cement concrete surface layer, the installation procedure depended on the material used for the uppermost layer of the base course.

For pressure cells installed in test sections with an asphalt concrete surface layer, the pressure cells were installed at the interface between the subgrade and the bottom layer of the base course material. The pressure cells have a maximum pressure rating of 50 psi to protect against damage during construction. To install the pressure cell, a small excavation approximately two inched deep was created in the subgrade. The excavation was filled with compacted dry sand to an elevation just below the surface of the subgrade. With the aid of a steel frame and a screed, the surface of the sand was made to be flat and parallel to the surface of the subgrade. The elevation of the sand was such that after placing the pressure cell on the sand, the pressure sensitive face of the pressure cell was in the plane of the top of the subgrade. The pressure cells were installed with their pressure sensitive face on top. Additional sand was then placed around the pressure cell with a thin covering of approximately 0.5 inches of sand over the pressure cell. The base course material was then placed over the sand covered pressure cells as part of the normal construction procedure.

Table 3) Earth Pressure Cell Calibration Factors

SHRP Test Section Number	Earth Pressure Cell Number	Rigid of Flexible Pavement Section	Calibration Factor from First Calibration (volts/psi)	Calibration Factor from Second Calibration (volts/psi)	Average Calibration Factor (volts/psi)	Percent Difference in Calibration Factors
390204	550	R	0.1017	0.1021	0.1019	0.4092
390204	551	R	0.1033	0.1031	0.1032	0.2703
390212	552	R	0.1002	0.0997	0.1000	0.5032
390901	553	F	0.1004	0.1010	0.1007	0.6069
390212	554	R	0.0998	0.1001	0.0999	0.2833
390210	555	R	0.0999	0.0999	0.0999	0.0240
390210	556	R	0.0998	0.0996	0.0997	0.1735
390901	557	F	0.1013	0.1006	0.1010	0.6964
390202	558	R	0.1003	0.1011	0.1007	0.8728
390202	559	R	0.1005	0.1005	0.1005	0.0000
390206	560	R	0.1007	0.1008	0.1008	0.1459
390206	561	R	0.1011	0.1011	0.1011	0.0059
390205	563	R	0.0999	0.0999	0.0999	0.0300
390205	566	R	0.1008	0.1003	0.1005	0.5153
390201	567	R	0.1006	0.0999	0.1002	0.7244
390201	568	R	0.1004	0.0999	0.1001	0.4814
390264	569	R	0.0990	0.0990	0.0990	0.0323
390264	570	R	0.1016	0.1018	0.1017	0.1327
390261	571	R	0.1009	0.1005	0.1007	0.3793
390902	572	F	0.1012	0.1014	0.1013	0.1610
390261	573	R	0.0997	0.1000	0.0998	0.2985
390211	574	R	0.1009	0.1011	0.1010	0.1851
390211	575	R	0.1008	0.1007	0.1008	0.0605
390203	576	R	0.1006	0.0988	0.0997	1.7720
390203	577	R	0.1003	0.1010	0.1007	0.7789
390207	578	R	0.0942	0.0942	0.0942	0.0117
390902	579	F	0.1008	0.1006	0.1007	0.1878
390207	580	R	0.1002	0.1005	0.1003	0.3070
390112	581	F	0.1015	0.1019	0.1017	0.3843
390208	583	R	0.1010	0.1020	0.1015	0.9917
390208	584	R	0.1008	0.1013	0.1010	0.5009
390262	585	R	0.1009	0.1003	0.1006	0.6431

Table 3 continued) Earth Pressure Cell Calibration Factors

SHRP Test Section Number	Earth Pressure Cell Number	Rigid of Flexible Pavement Section	Calibration Factor from First Calibration (volts/psi)	Calibration Factor from Second Calibration (volts/psi)	Average Calibration Factor (volts/psi)	Percent Difference in Calibration Factors
290262	586	R	0.1018	0.1014	0.1016	0.3985
290263	587	R	0.1018	0.1022	0.1020	0.4168
290112	588	F	0.1018	0.1015	0.1017	0.3679
290111	610	F	0.1010	0.1010	0.1010	0.0624
290111	611	F	0.1006	0.1017	0.1012	1.0270
290108	613	F	0.1015	0.1013	0.1014	0.1676
290104	614	F	0.1018	0.1011	0.1014	0.7149
290104	615	F	0.1013	0.1014	0.1013	0.0977
290101	616	F	0.1008	0.1009	0.1009	0.1467
290101	617	F	0.1019	0.1015	0.1017	0.3844
290107	618	F	0.1015	0.1018	0.1016	0.3650
290107	619	F	0.0931	0.0932	0.0932	0.1503
290102	620	F	0.1009	0.1012	0.1010	0.2821
290102	621	F	0.1012	0.1014	0.1013	0.1757
290160	622	F	0.1011	0.1010	0.1011	0.1346
290160	623	F	0.1007	0.1009	0.1008	0.1637
not used	624	F	0.1009	0.1015	0.1012	0.5793
not used	625	F	0.1008	0.1014	0.1011	0.6104
290109	626	F	0.1016	0.1018	0.1017	0.1200
290109	627	F	0.1013	0.1014	0.1014	0.0690
290110	628	F	0.1013	0.1003	0.1008	1.0133
290110	629	F	0.1017	0.1016	0.1016	0.1083
290263	630	R	0.1024	0.1013	0.1019	1.1025
290103	631	F	0.1010	0.1017	0.1014	0.6886
290103	632	F	0.1014	0.1015	0.1014	0.0375
390209	633	R	0.1015	0.1014	0.1014	0.0641
390209	634	R	0.1019	0.1017	0.1018	0.2013
290106	635	F	0.1012	0.1010	0.1011	0.1424
290106	636	F	0.1013	0.1003	0.1008	1.0125
290108	651	F	0.0921	0.0926	0.0924	0.4645

For pressure cells installed in pavement sections with Portland cement concrete surface layers, the installation procedure depended on the material used for the top layer of the base course. For sections with an upper base course material of dense-graded aggregate base (DGAB), the installation of the earth pressure cells involved the excavation of about 1.5 inches of the base course. The excavation was filled with compacted dry fine sand to an elevation corresponding to that of the top surface of the base course. The surface was leveled using a portable guide frame and a screed to prepare a planar surface. After preparation of the sand bedding, the concrete block containing the pressure cell was placed on top of the sand with the pressure sensitive face of the earth pressure cell in contact with the sand bedding layer. As the concrete paving machine approached the pressure cell, concrete was carefully placed around the concrete block containing the pressure cell prior to the paving operation passing over the pressure cell. This minimized the likelihood that the paving operation would disturb the pressure cell.

Pressure cells for the sections with permeable asphalt-treated base (PATB) material were installed in much the same manner as described for the DGAB base material. For the PATB base materials, it was necessary to treat the excavated area prior to placing the bedding sand because of the large voids in the PATB material. The objective in treating the bottom and sides of the excavation was to prevent loss of the sand into the voids of the PATB. Commonly available crack sealer for asphalt driveways was used for this purpose. Fine sand was added to the sealed and the mixture was applied with a large brush and worked into the void structure. Generally two or three applications were needed to close all of the voids. Upon completion of the sealer application, placement of the sand and installation of the concrete block containing the pressure cell proceeded as described for installations involving DGAB.

For the pavement test sections with the lean concrete base material (LCB), no excavation of the base material was used. The concrete block containing the pressure cell was bonded to the top surface of the LCB layer using a quick setting hydraulic anchoring cement. The anchoring

cement was prepared to a soft paste consistency and a thin layer was applied to the pressure cell and the surface of the concrete block. A small mound of the anchoring cement was placed in the area to receive the pressure cell, and the concrete block containing the pressure cell was pressed into the plastic anchoring cement forcing the excess material to be squeezed out around the edges of the concrete block. The final thickness of the anchoring cement bonding the concrete block and pressure cell to the surface of the LCB layer was between 0.12 inches and 0.25 inches.

The pressure cells installed in pavement sections containing permeable cement treated base (PCTB) material were installed in a manner similar to those installed on LCB base layers. The primary difference for the PCTB installations was that the voids in the surface of the PCTB layer were filled prior to placement of the concrete block and pressure cell. The voids were filled with the same hydraulic anchoring cement used to bond the pressure cell to the surface. For this application, the anchoring cement was prepared to a stiff consistency and pressed into the voids with a trowel. The anchoring cement sets within 10 to 15 minutes, allowing the installation to proceed with placement of the pressure cell. From this point on, the installation of the concrete block containing the pressure cell proceeded as described for the LCB material.

The identification numbers for the pressure cells installed in each pavement section are presented in Table 4 for the test sections with asphalt concrete surface layers and in Table 5 for the test sections with Portland cement concrete surface layers. In these tables, the notation of Location 1 or Location 2 corresponds to the notation of the earth pressure cell locations prescribed in the instrumentation plan for the project (Sargand, 1994).

Upon completion of the installation of each pressure cell, prior to covering the pressure cell with the next layer of the pavement section, the operation of the pressure cell was confirmed. To accomplish this, power was applied to the pressure cell using a battery pack, and the output signal was monitored with a portable digital voltmeter. Pressure was applied to the pressure cell

Table 4) Earth Pressure Cell Assignments for the Flexible Pavement Sections of the Ohio SPS Test Pavements

SHRP Section Number	Earth Pressure Cell Number
390101, Location 1	616
390101, Location 2	617
390102, Location 1	620
390102, Location 2	621
390103, Location 1	631
390103, Location 2	632
390104, Location 1	614
390104, Location 2	615
390105, Location 1	paved without notification
390105, Location 2	paved without notification
390106, Location 1	635
390106, Location 2	636
390107, Location 1	618
390107, Location 2	619
390108, Location 1	613
390108, Location 2	651
390109, Location 1	626
390109, Location 2	627
390110, Location 1	628
390110, Location 2	629
390111, Location 1	610
390111, Location 2	611
390112, Location 1	581
390112, Location 2	588
390160, Location 1	622
390160, Location 2	623
390902, Location 1	572
390902, Location 2	579
390901, Location 1	553
390901, Location 2	557

Table 5) Earth Pressure Cell Assignments for the Rigid Pavement Sections of the Ohio SPS Test Pavements

SHRP Section Number	Earth Pressure Cell Number
390201, Location 1	567
390201, Location 2	568
390202, Location 1	558
390202, Location 2	559
390203, Location 1	576
390203, Location 2	577
390204, Location 1	550
390204, Location 2	551
390205, Location 1	563
390205, Location 2	566
390206, Location 1	560
390206, Location 2	561
390207, Location 1	578
390207, Location 2	580
390208, Location 1	583
390208, Location 2	584
390209, Location 1	633
390209, Location 2	634
390210, Location 1	555
390210, Location 2	556
390211, Location 1	574
390211, Location 2	575
390212, Location 1	552
390212, Location 2	554
390261, Location 1	571
390261, Location 2	573
390262, Location 1	585
390262, Location 2	586
390263, Location 1	587
390263, Location 2	630
390264, Location 1	569
390264, Location 2	570

and the change in the output signal of the pressure cell, as observed on the voltmeter, indicated that the pressure cell was functional.

Conclusion

The work performed during this project consisted primarily of calibration and installation of sixty earth pressure cells for the ODOT SHRP pavement instrumentation project on U.S. Route 23 in Delaware County.

Results of the calibration phase of the project indicate that each of the pressure cells functioned properly at the time of calibration and repeatable pressure cell response to applied pressure was confirmed.

The pressure cells were successfully installed in the appropriate pavement test sections as indicated in Tables 4 and 5. The only exception to this is that the pressure cells planned for installation in the pavement test section designated as SPS-1, 390105, J5 were not installed. This test section was paved without notification of the University of Akron participants.

Appendix A

Earth Pressure Cell Calibration Data

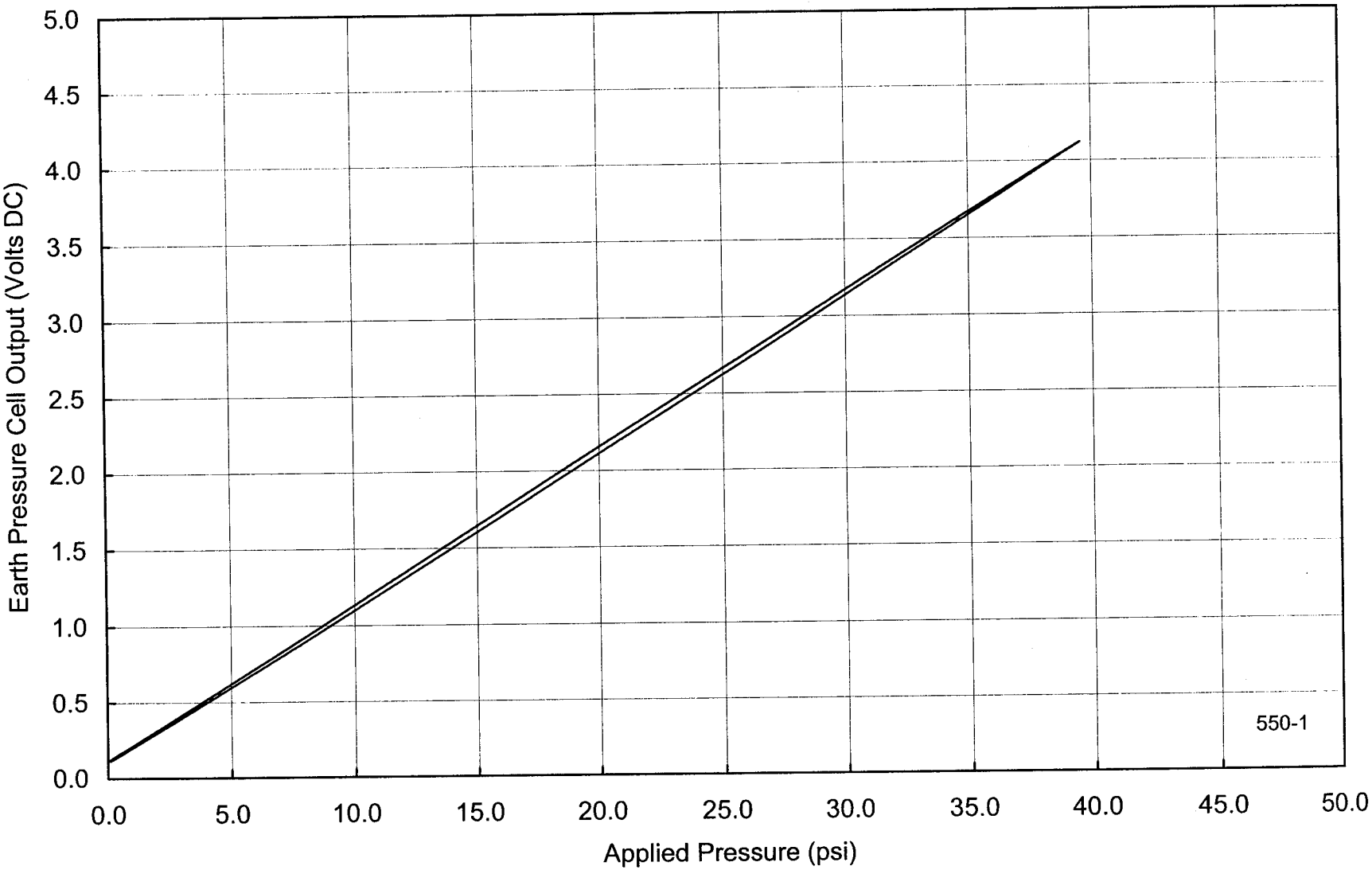

Figure A-1) Calibration record for the first calibration of earth pressure cell number 550 for the ODOT SHRP Test Road, Section 390204

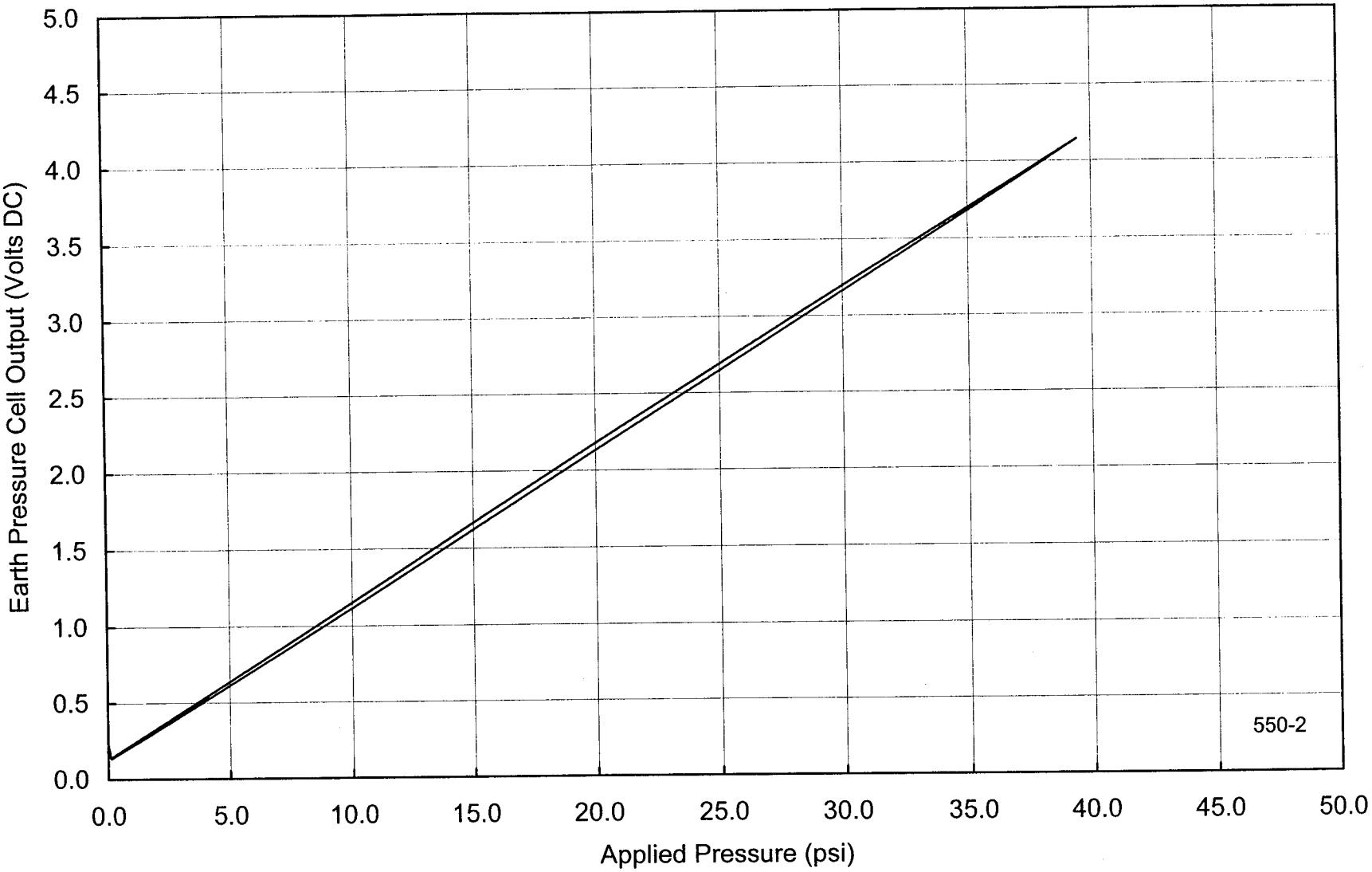

Figure A-2) Calibration record for the second calibration of earth pressure cell number 550 for the ODOT SHRP Test Road, Section 390204

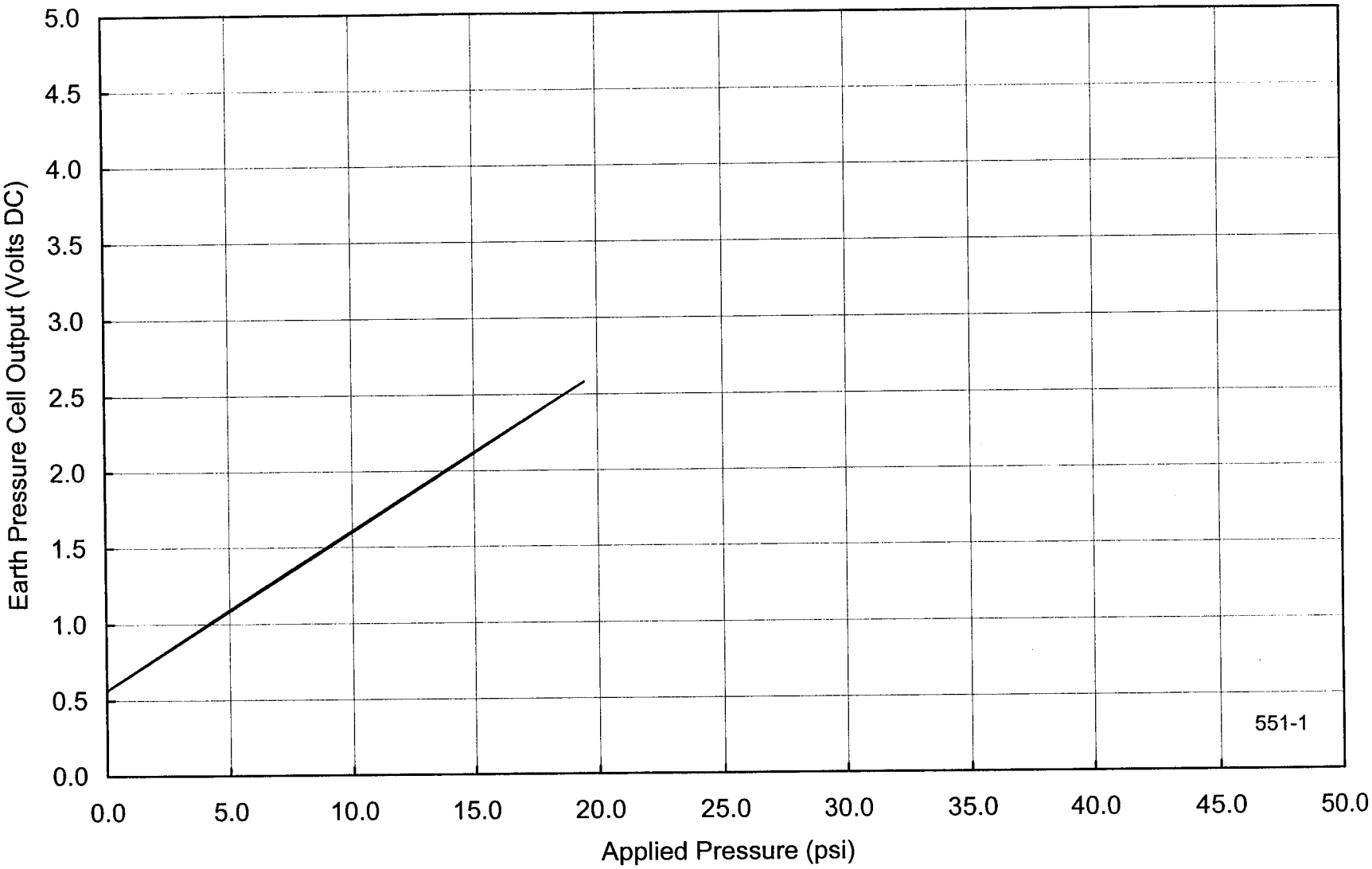

Figure A-3) Calibration record for the first calibration of earth pressure cell number 551 for the ODOT SHRP Test Road, Section 390204

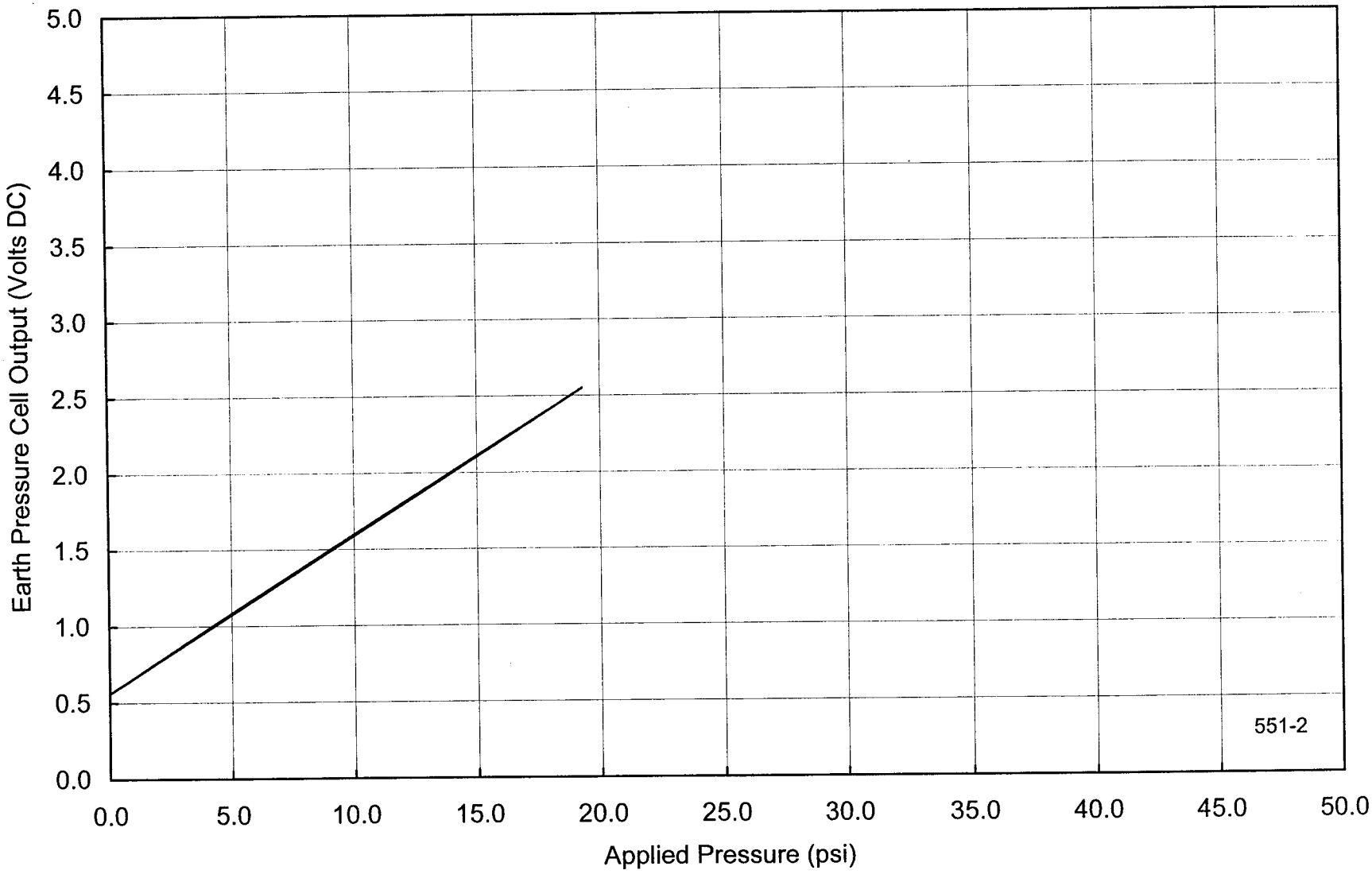

Figure A-4) Calibration record for the second calibration of earth pressure cell number 551 for the ODOT SHRP Test Road, Section 390204

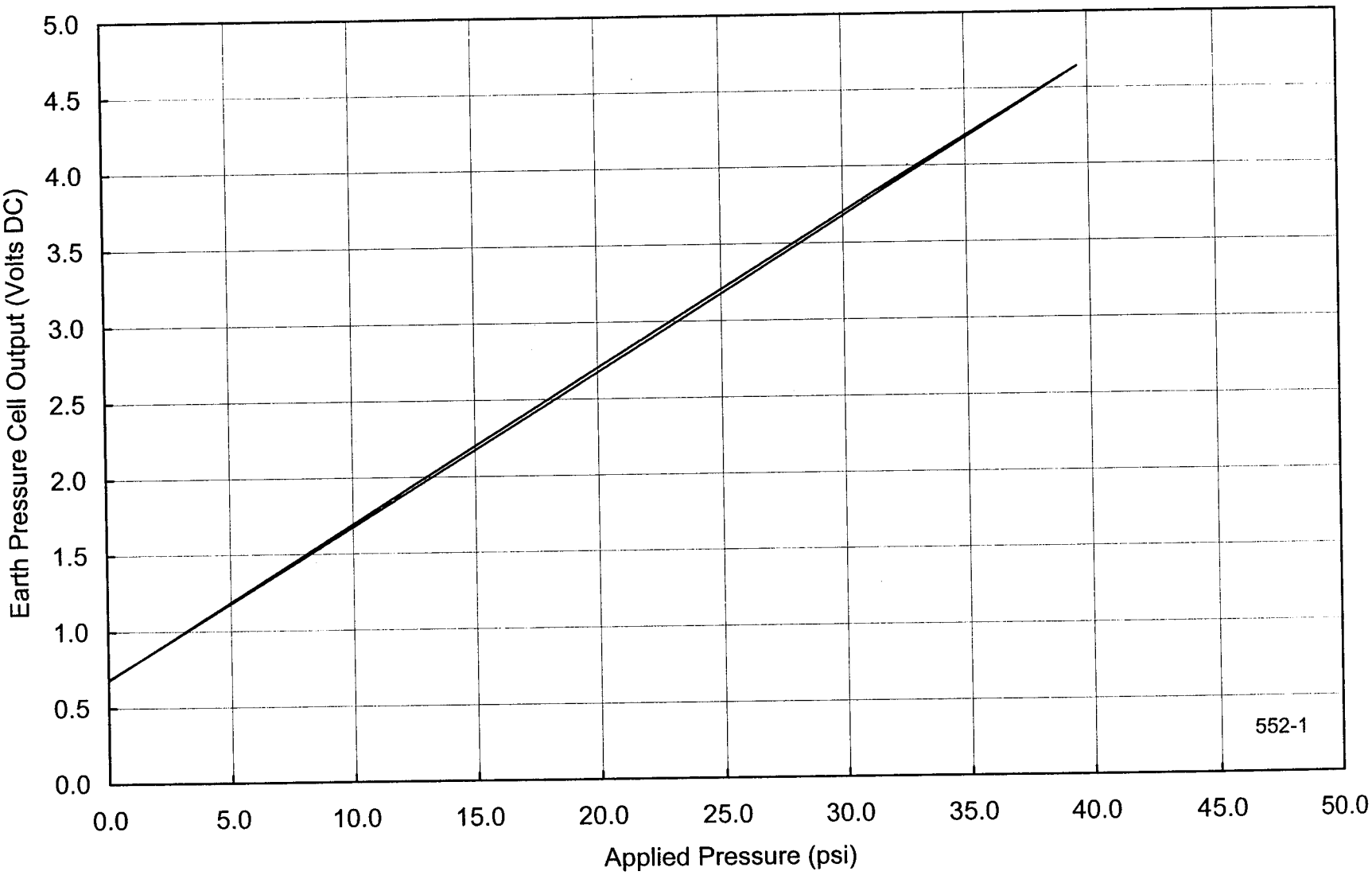

Figure A-5) Calibration record for the first calibration of earth pressure cell number 552 for the ODOT SHRP Test Road, Section 390212

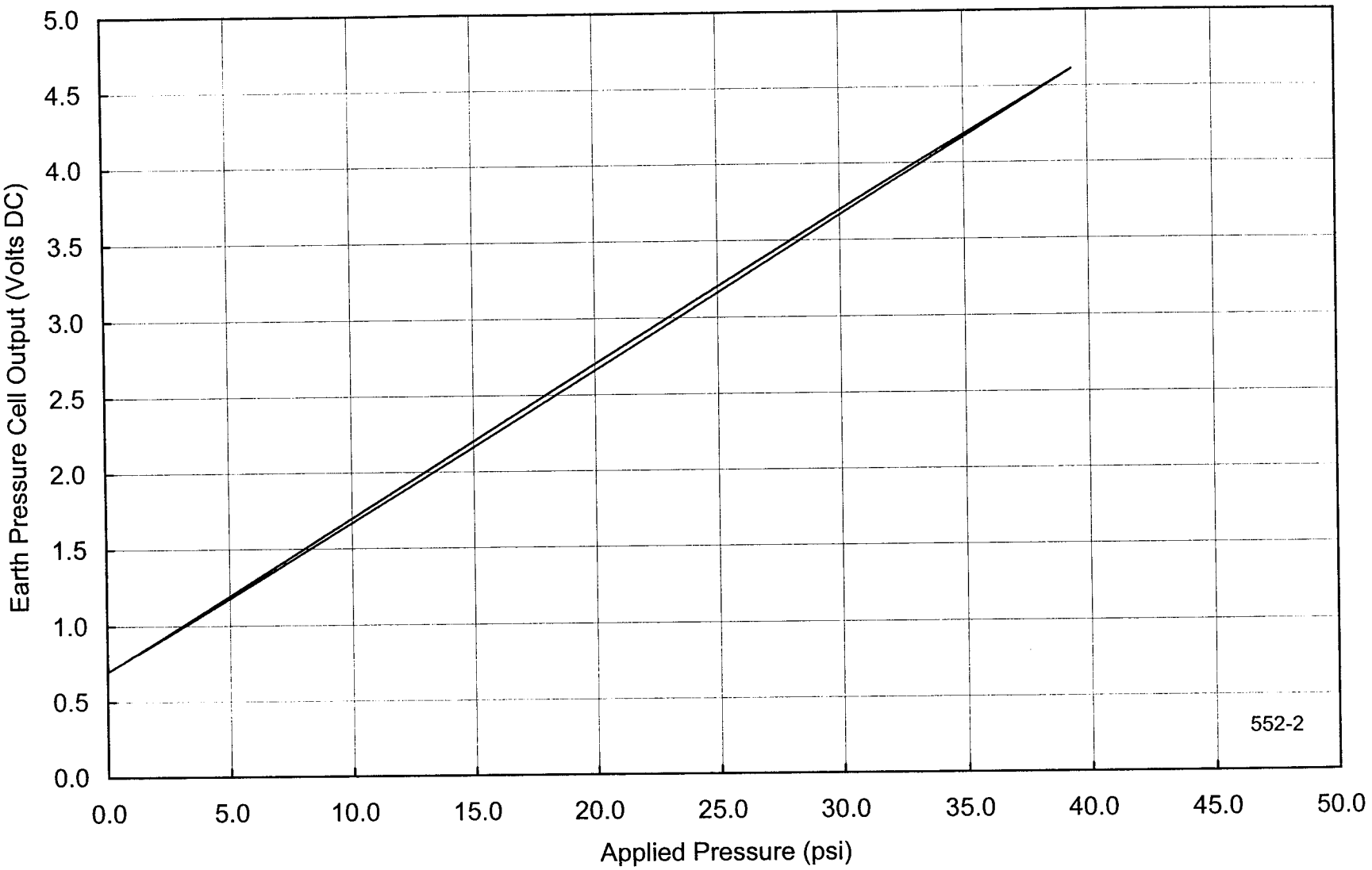

Figure A-6) Calibration record for the second calibration of earth pressure cell number 552 for the ODOT SHRP Test Road, Section 390212

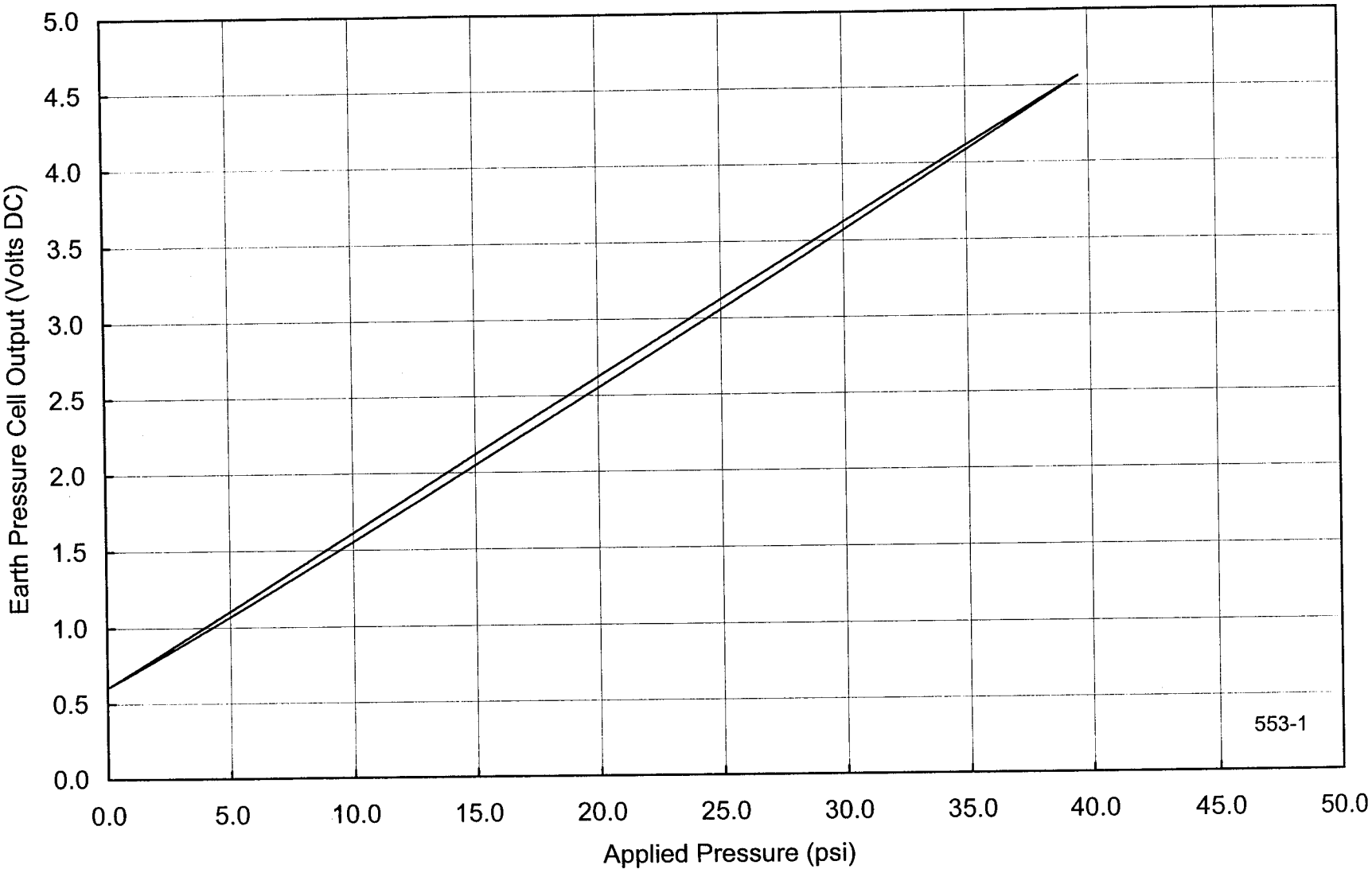

Figure A-7) Calibration record for the first calibration of earth pressure cell number 553 for the ODOT SHRP Test Road, Section 390901

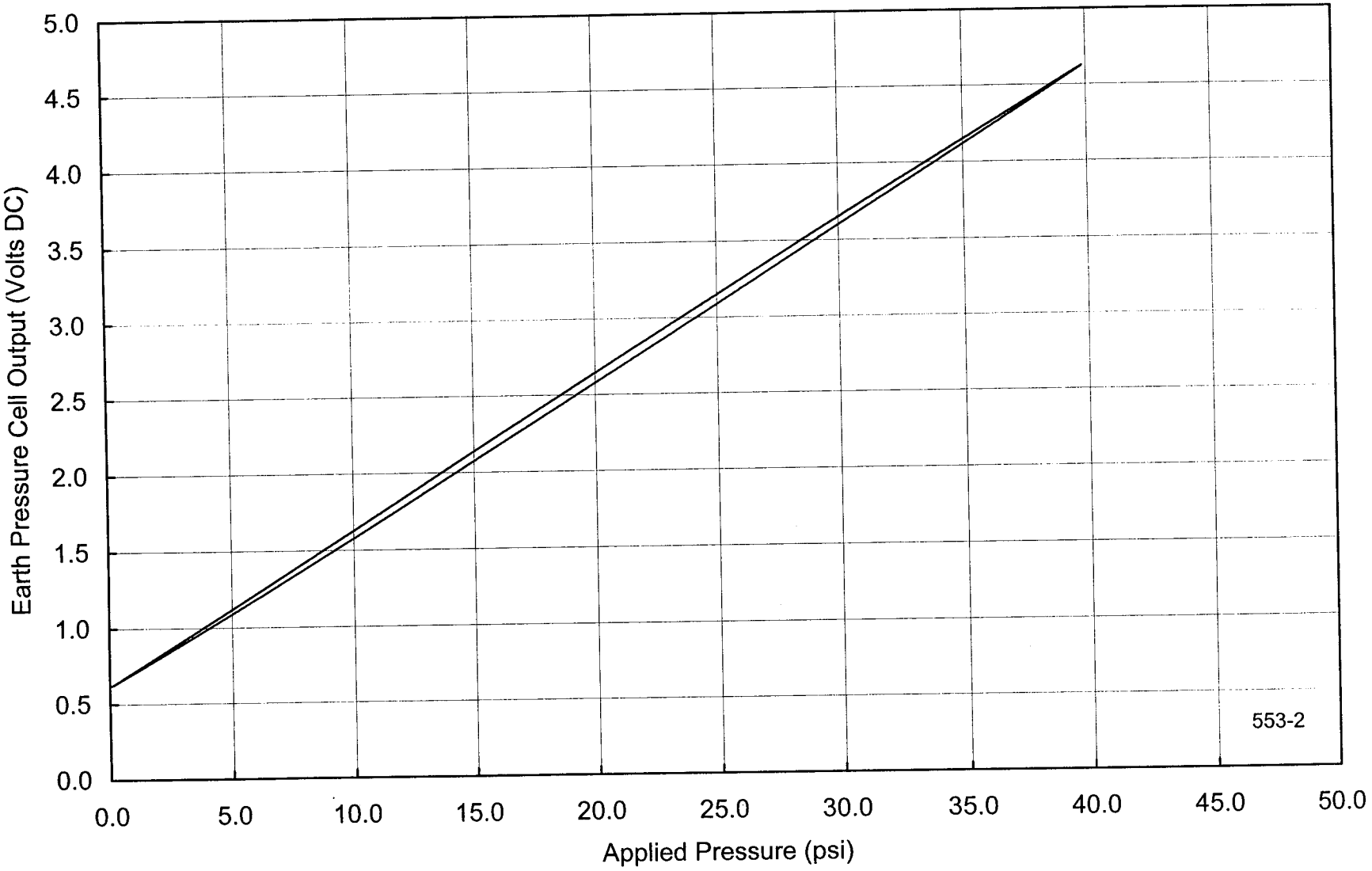

Figure A-8) Calibration record for the second calibration of earth pressure cell number 553 for the ODOT SHRP Test Road, Section 390901

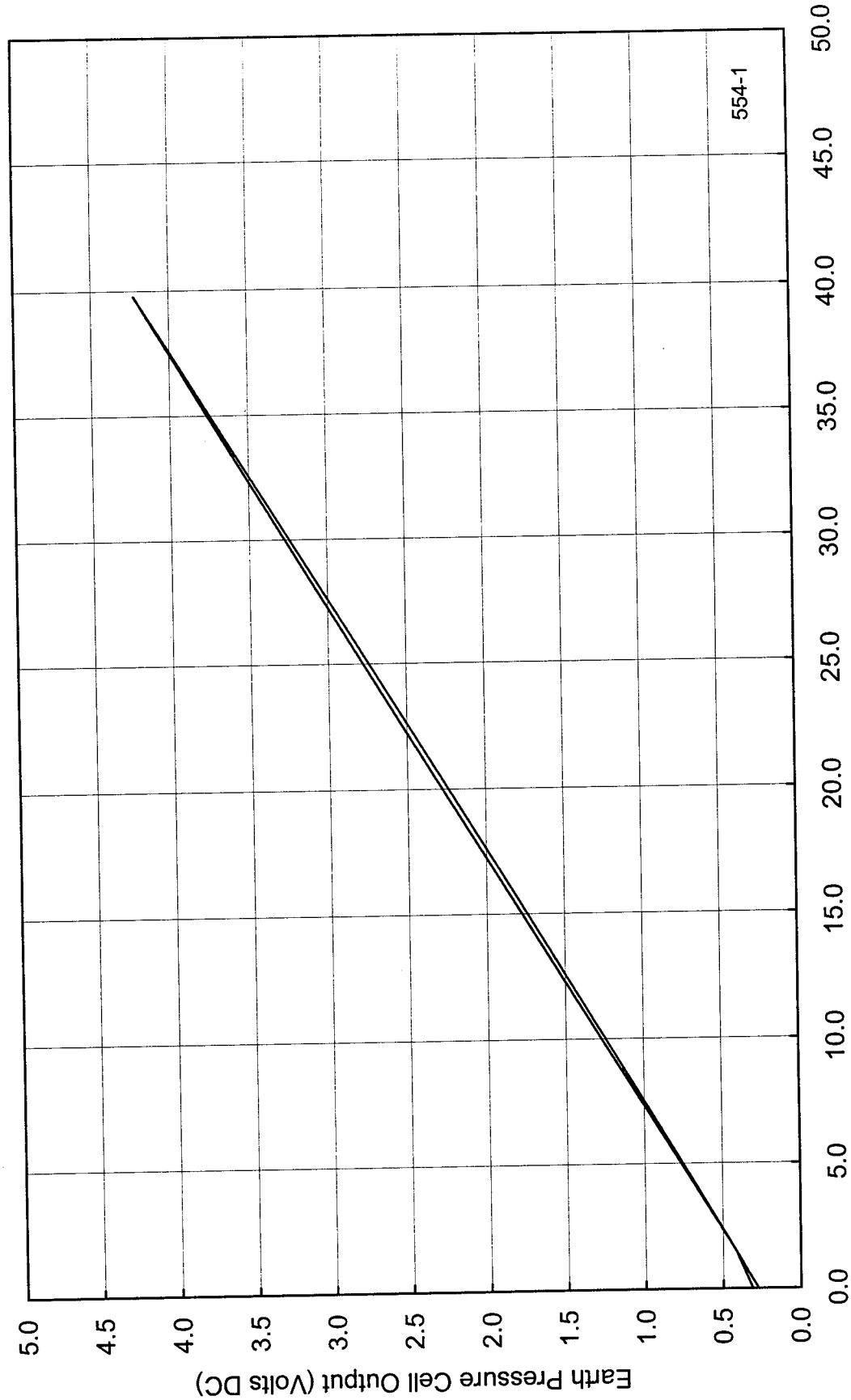

Figure A-9) Calibration record for the first calibration of earth pressure cell number 554 for the ODOT SHRP Test Road, Section 390212

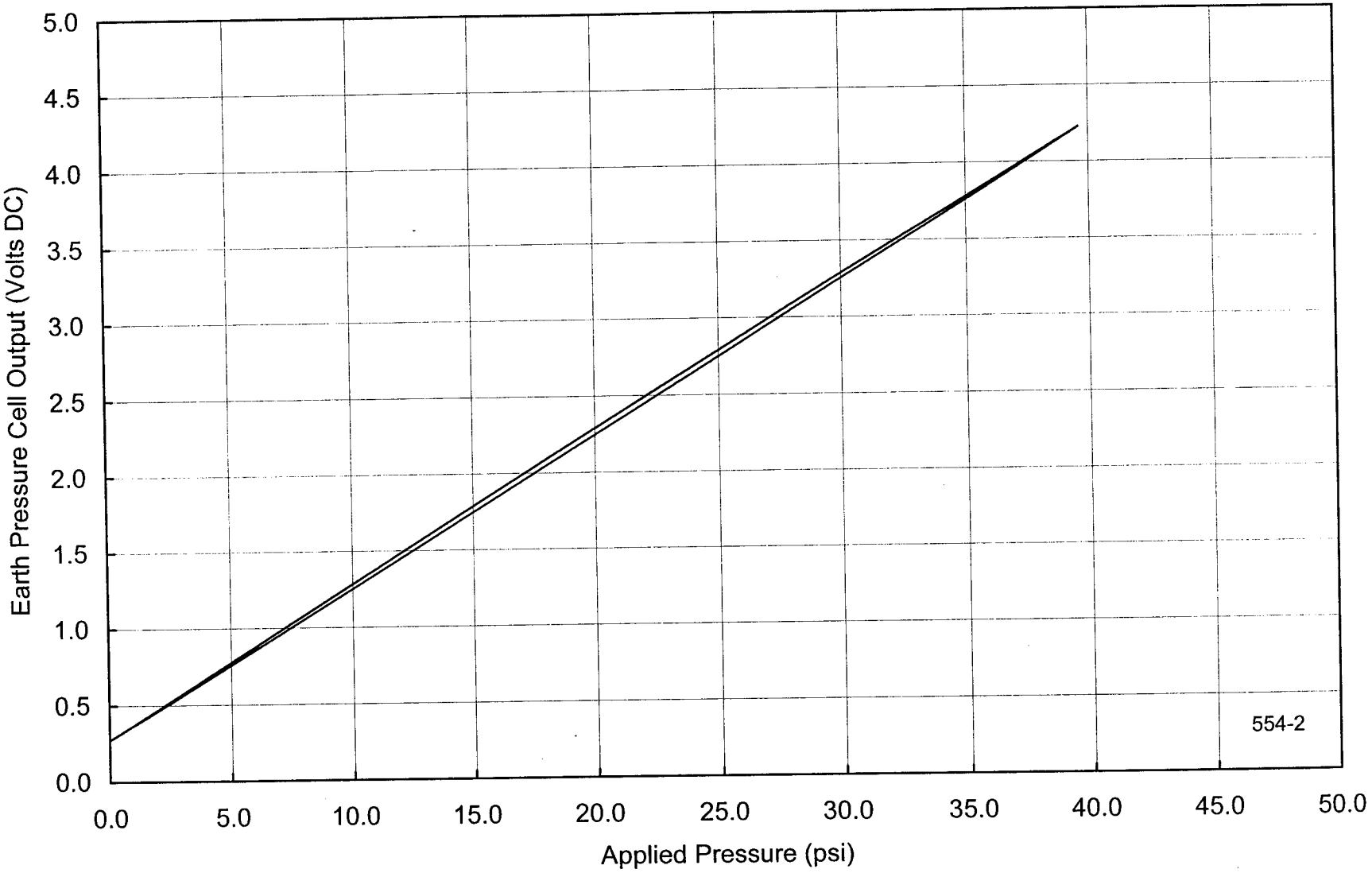

Figure A-10) Calibration record for the second calibration of earth pressure cell number 554 for the ODOT SHRP Test Road, Section 390212

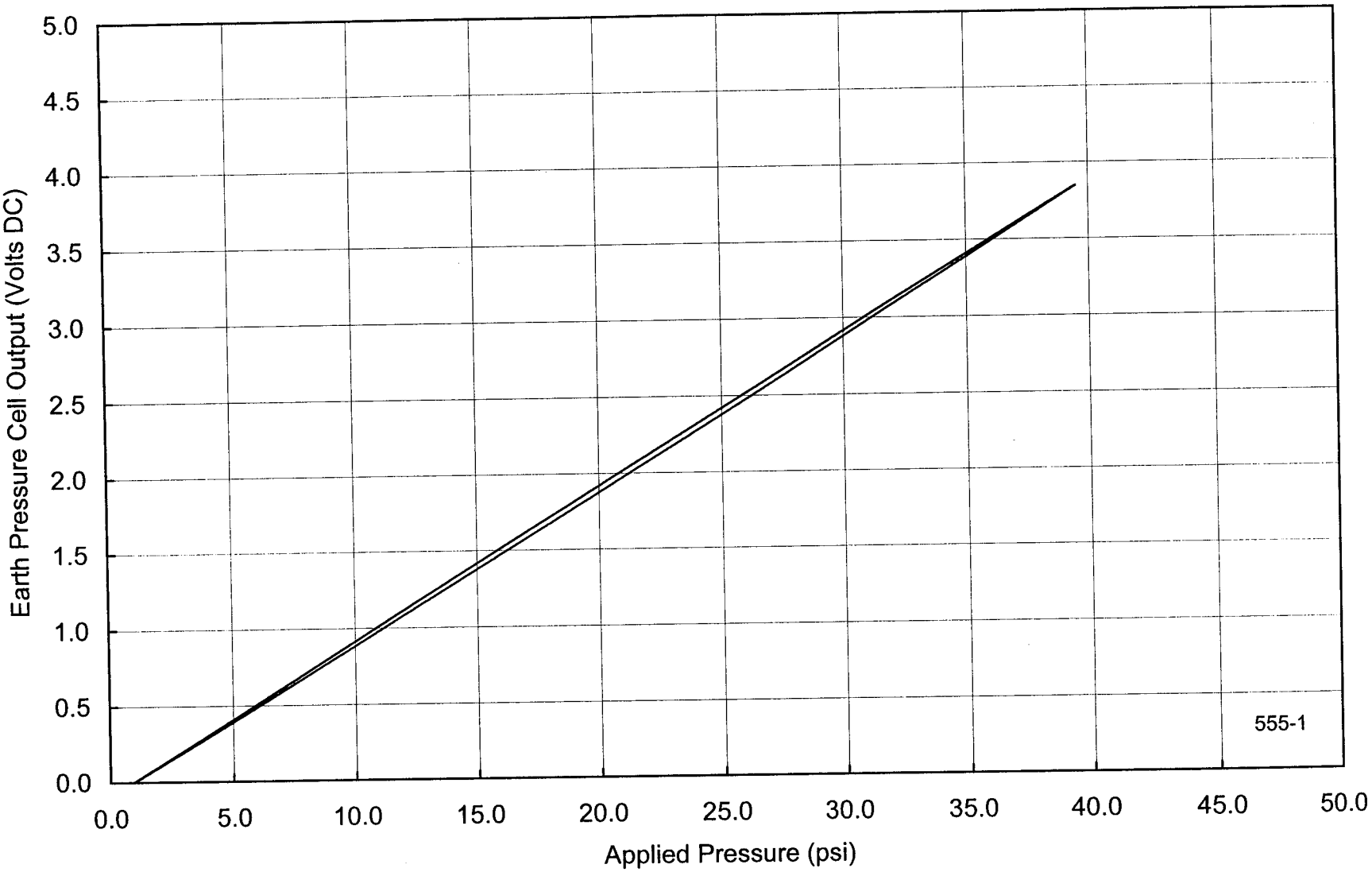

Figure A-11) Calibration record for the first calibration of earth pressure cell number 555 for the ODOT SHRP Test Road, Section 390210

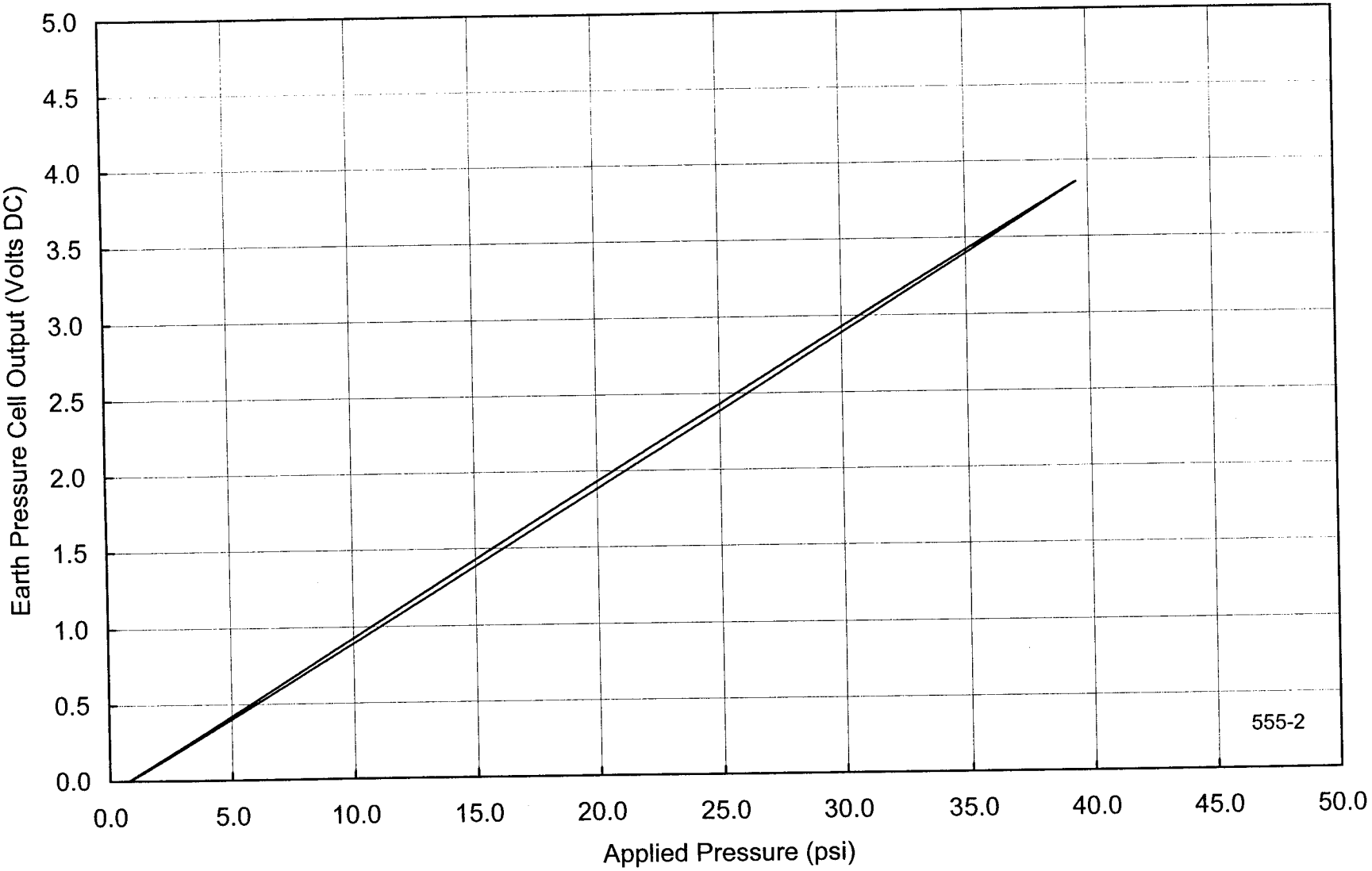

Figure A-12) Calibration record for the second calibration of earth pressure cell number 555 for the ODOT SHRP Test Road, Section 390210

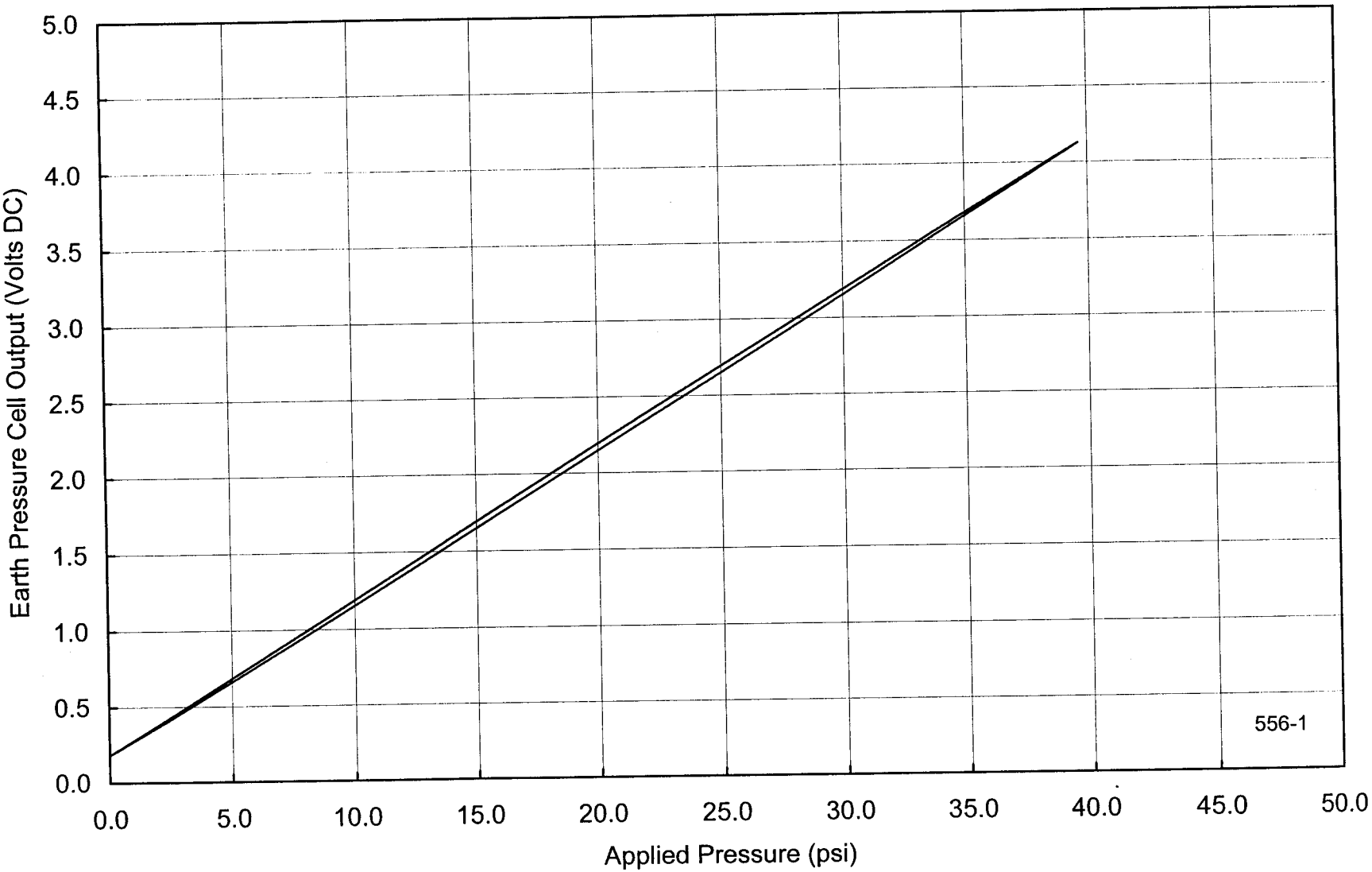

Figure A-13) Calibration record for the first calibration of earth pressure cell number 556 for the ODOT SHRP Test Road, Section 390210

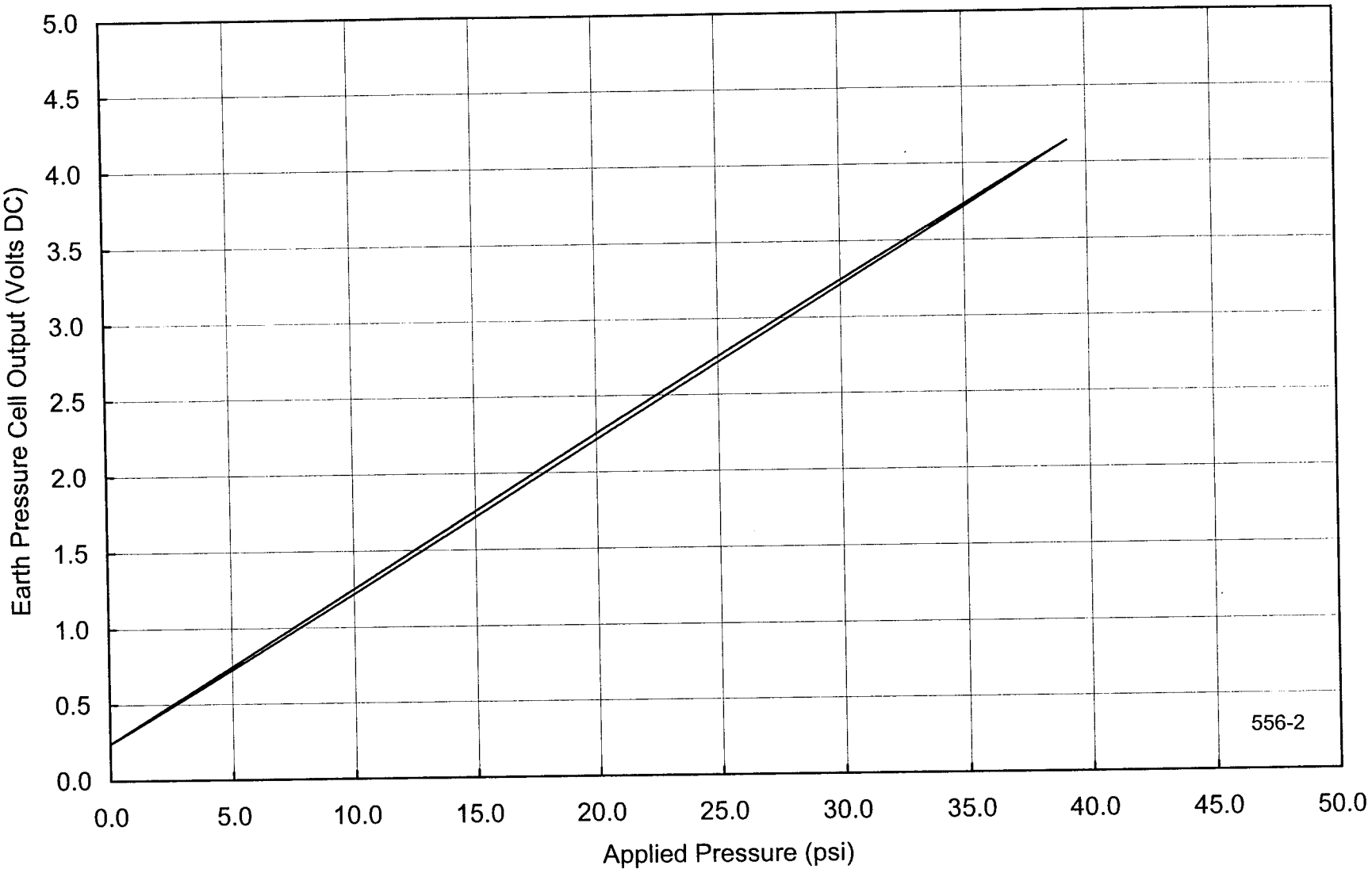

Figure A-14) Calibration record for the second calibration of earth pressure cell number 556 for the ODOT SHRP Test Road, Section 390210

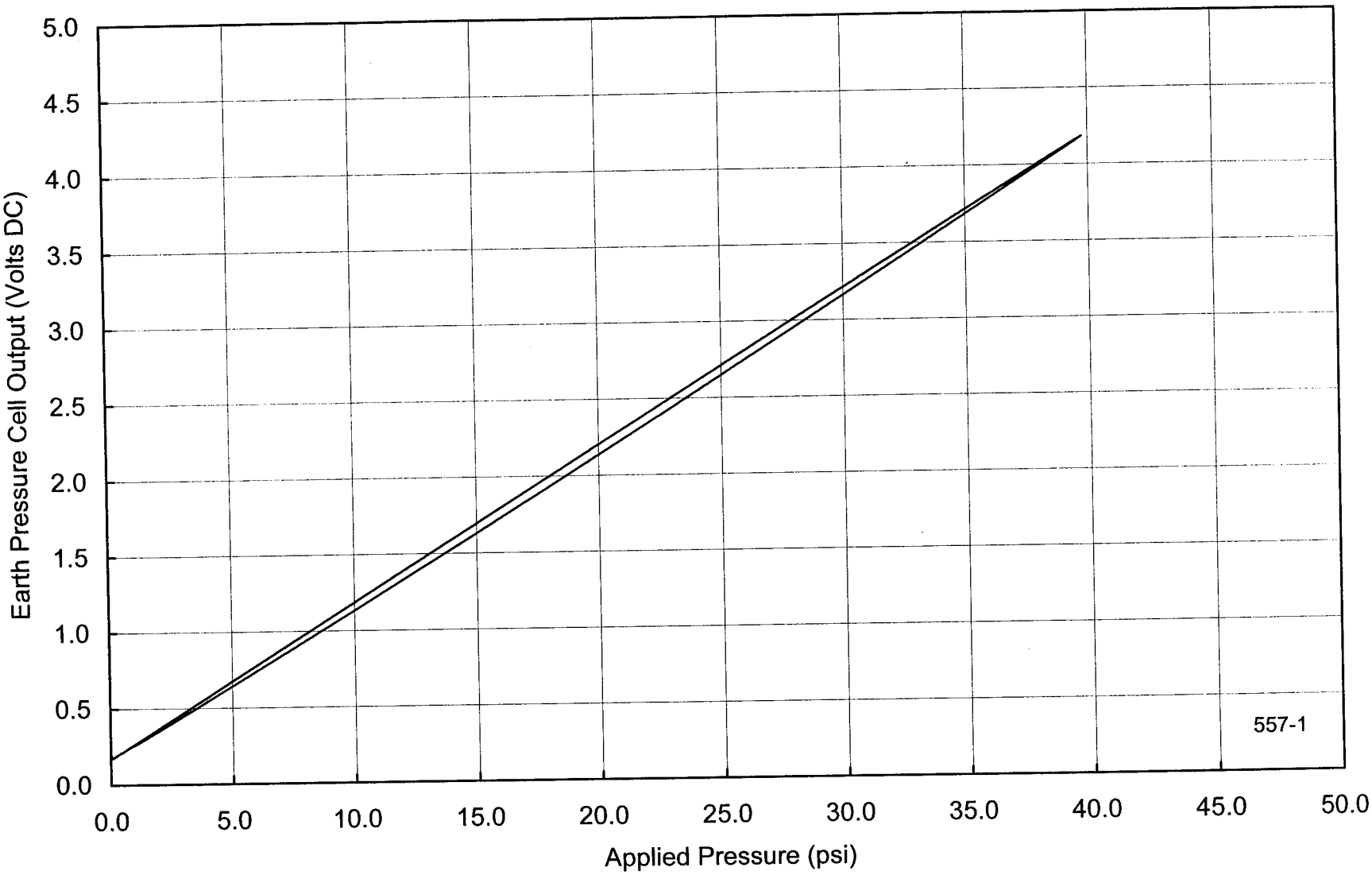

Figure A-15) Calibration record for the first calibration of earth pressure cell number 557 for the ODOT SHRP Test Road, Section 390901

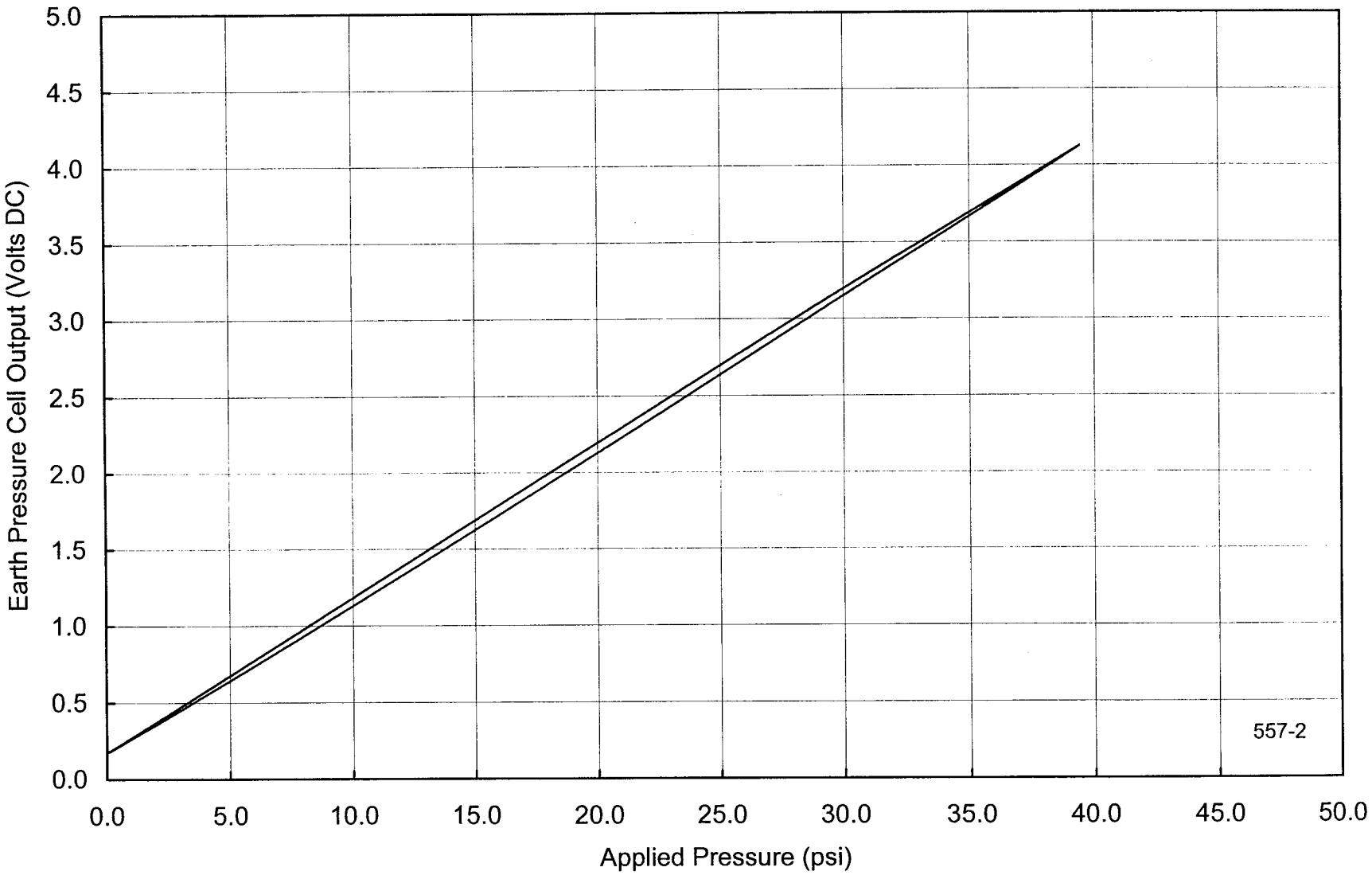

Figure A-16) Calibration record for the second calibration of earth pressure cell number 557 for the ODOT SHRP Test Road, Section 390901

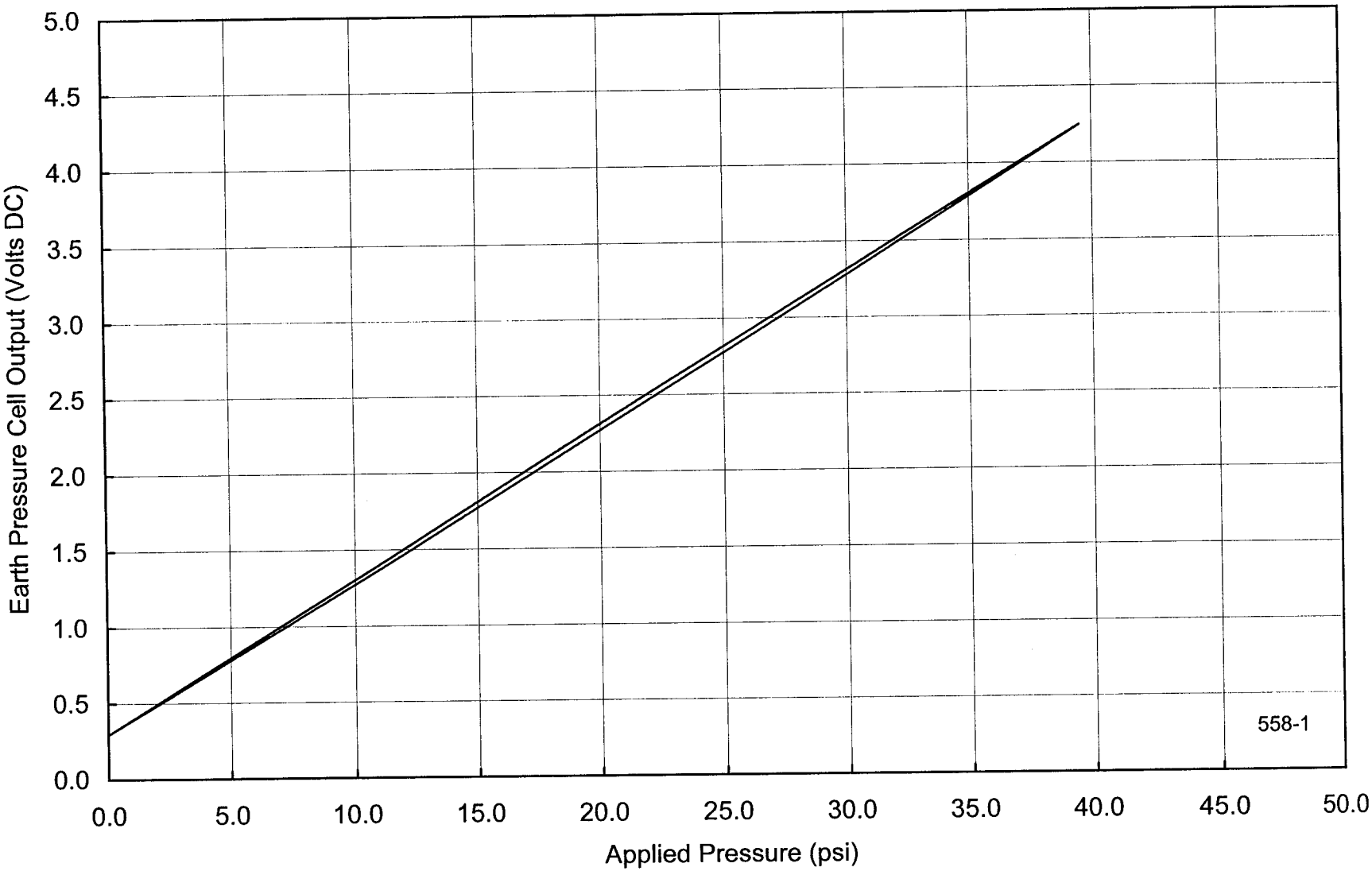

Figure A-17) Calibration record for the first calibration of earth pressure cell number 558 for the ODOT SHRP Test Road, Section 390202

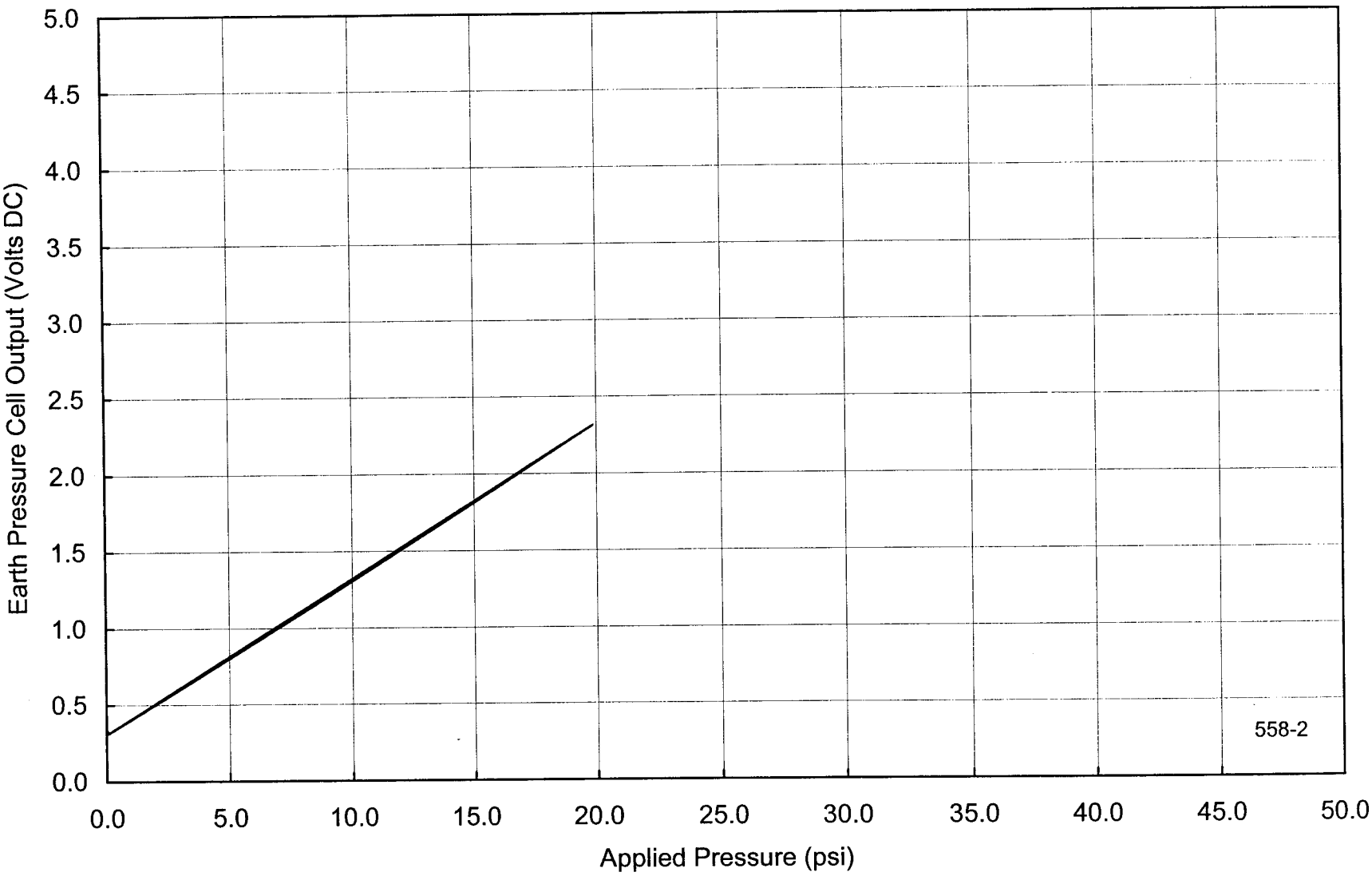

Figure A-18) Calibration record for the second calibration of earth pressure cell number 558 for the ODOT SHRP Test Road, Section 390202

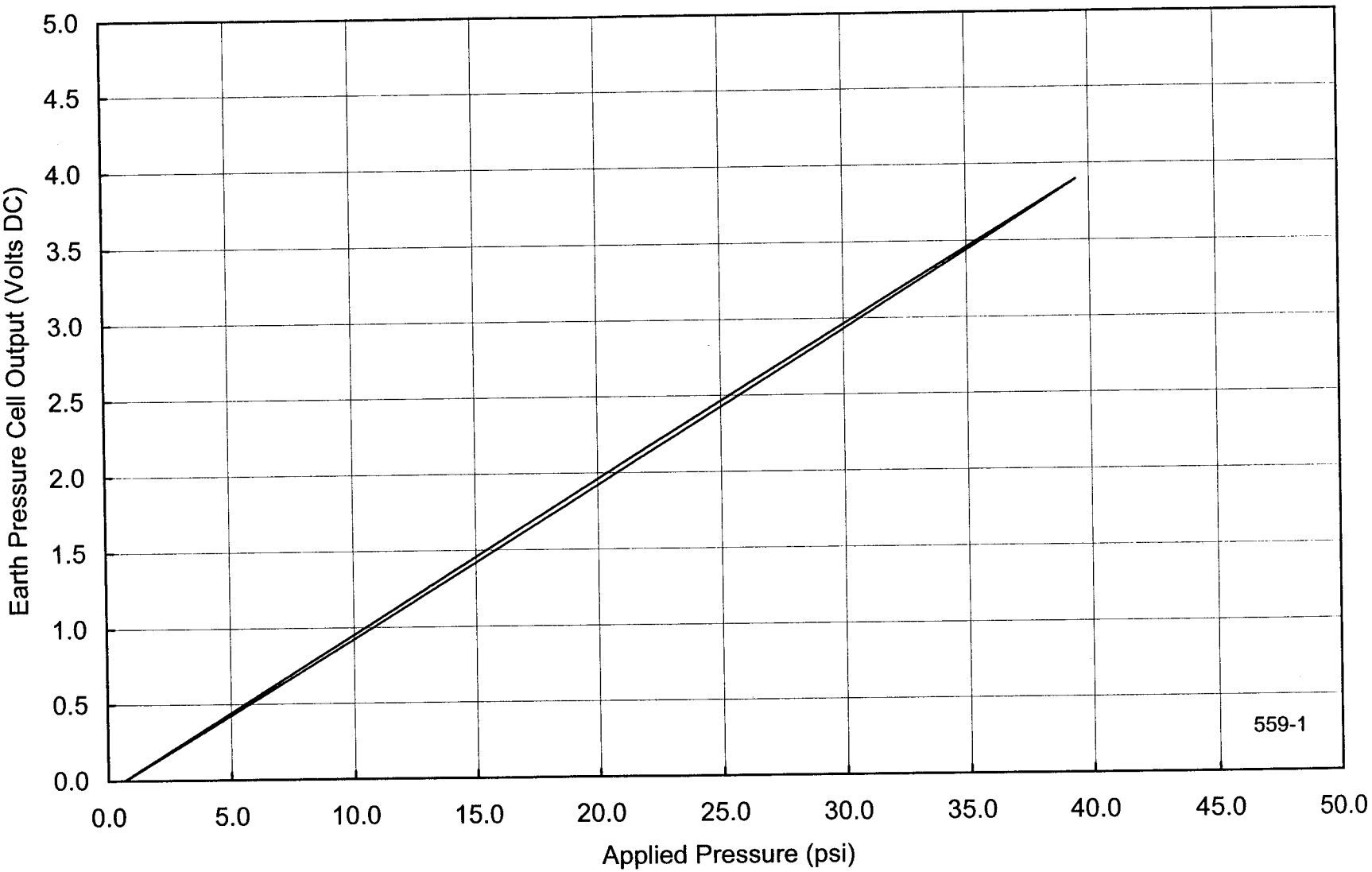

Figure A-19) Calibration record for the first calibration of earth pressure cell number 559 for the ODOT SHRP Test Road, Section 390202

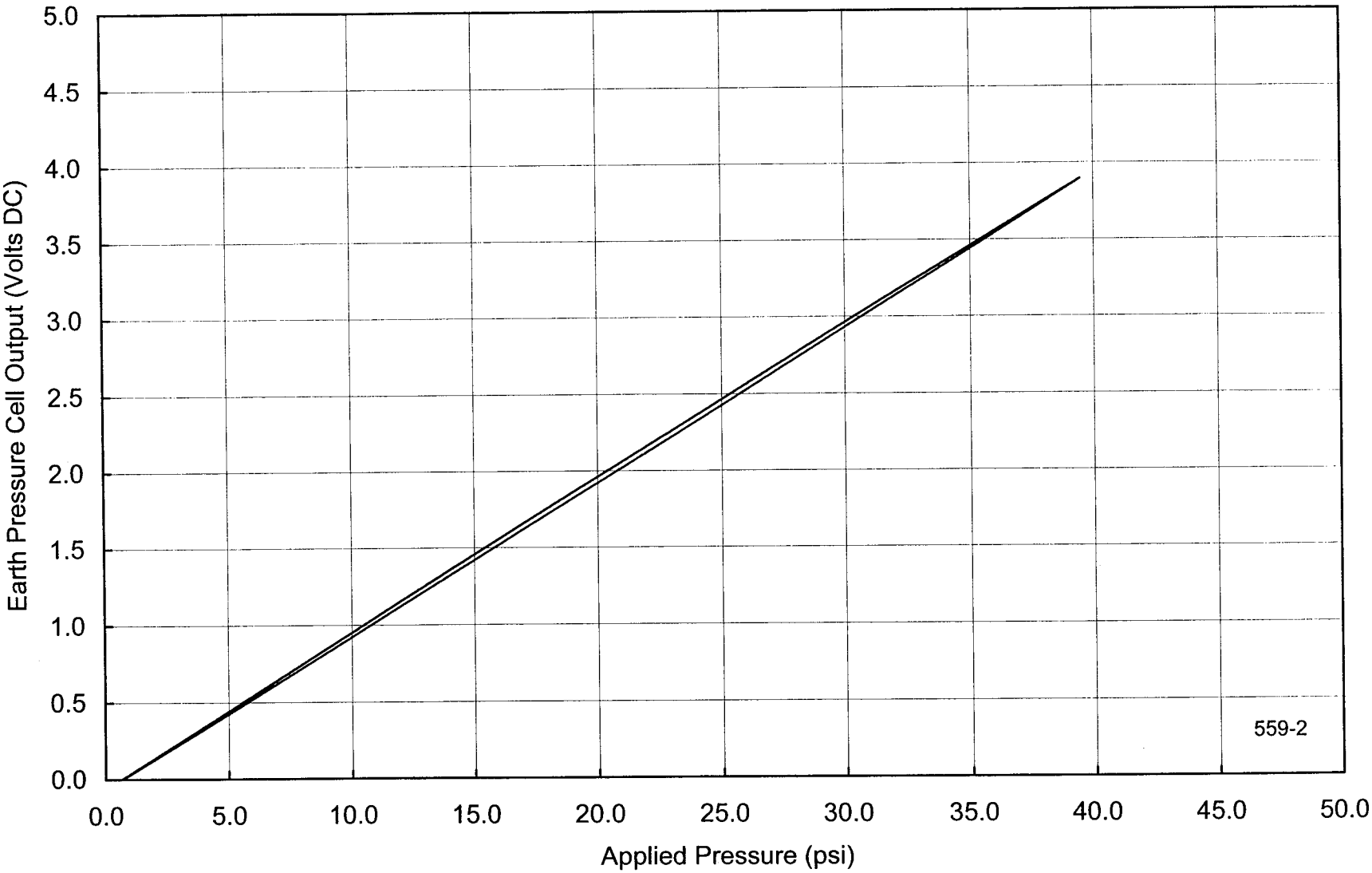

Figure A-20) Calibration record for the second calibration of earth pressure cell number 559 for the ODOT SHRP Test Road, Section 390202

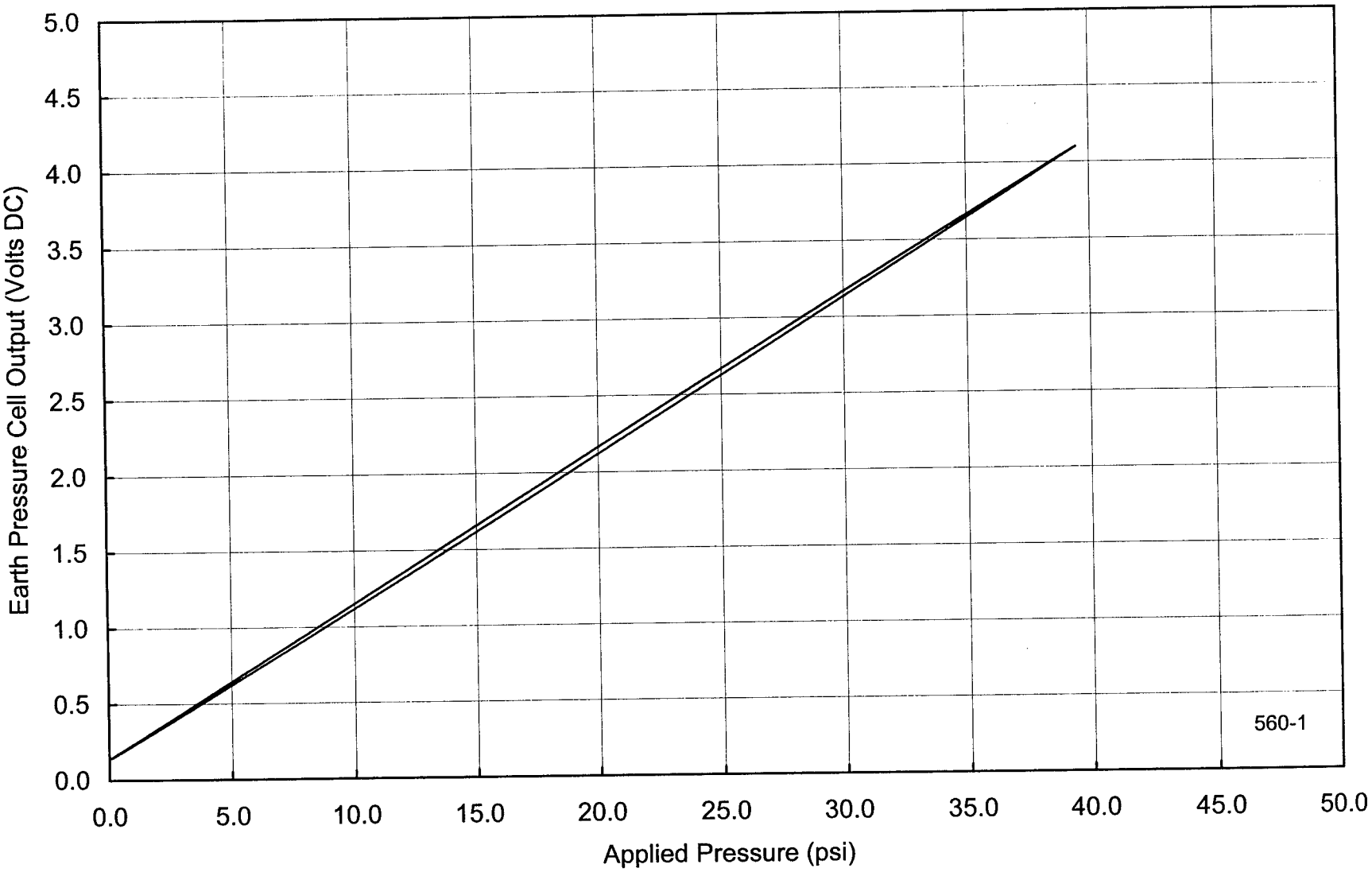

Figure A-21) Calibration record for the first calibration of earth pressure cell number 560 for the ODOT SHRP Test Road, Section 390206

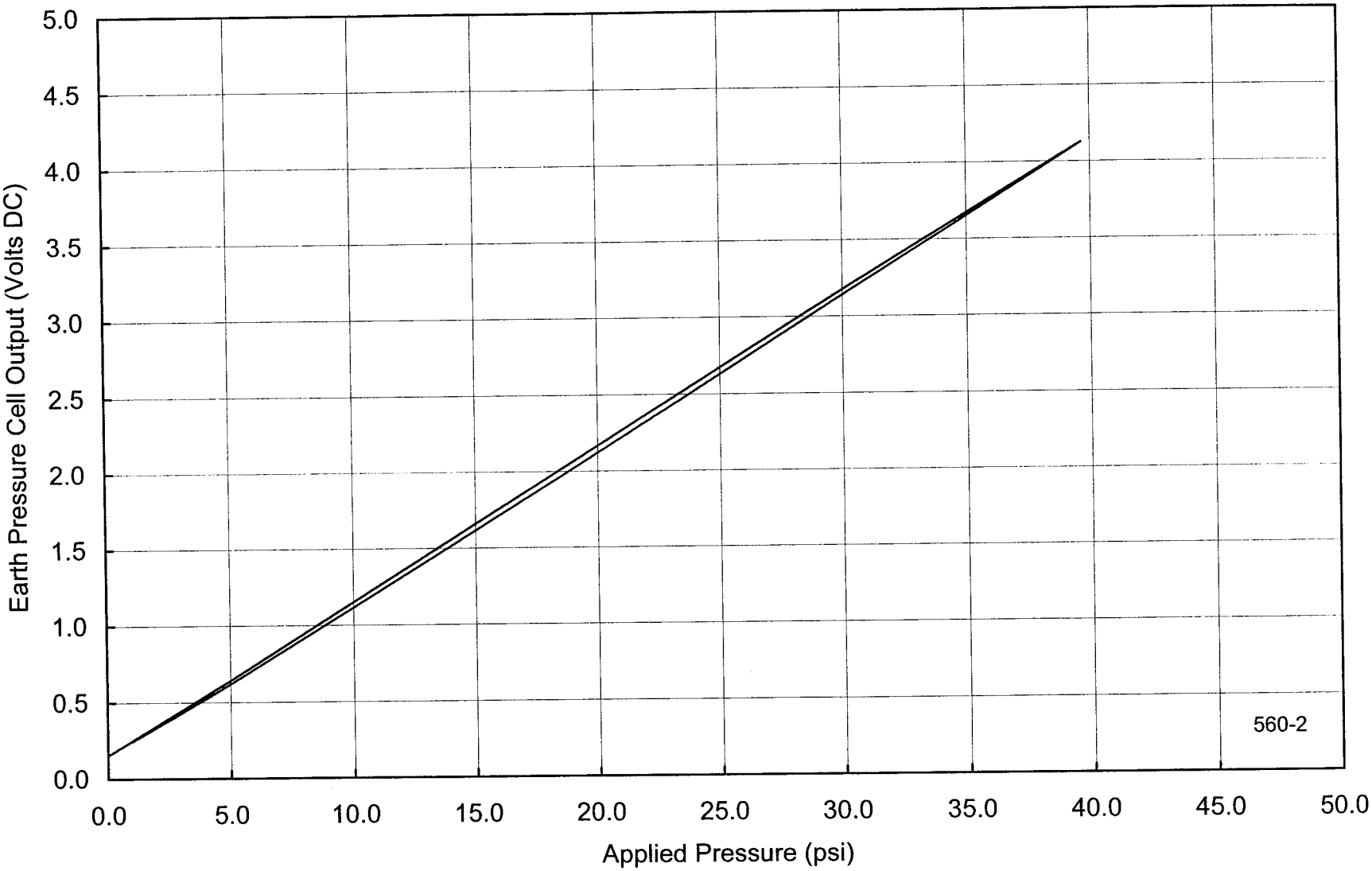

Figure A-22) Calibration record for the second calibration of earth pressure cell number 560 for the ODOT SHRP Test Road, Section 390206

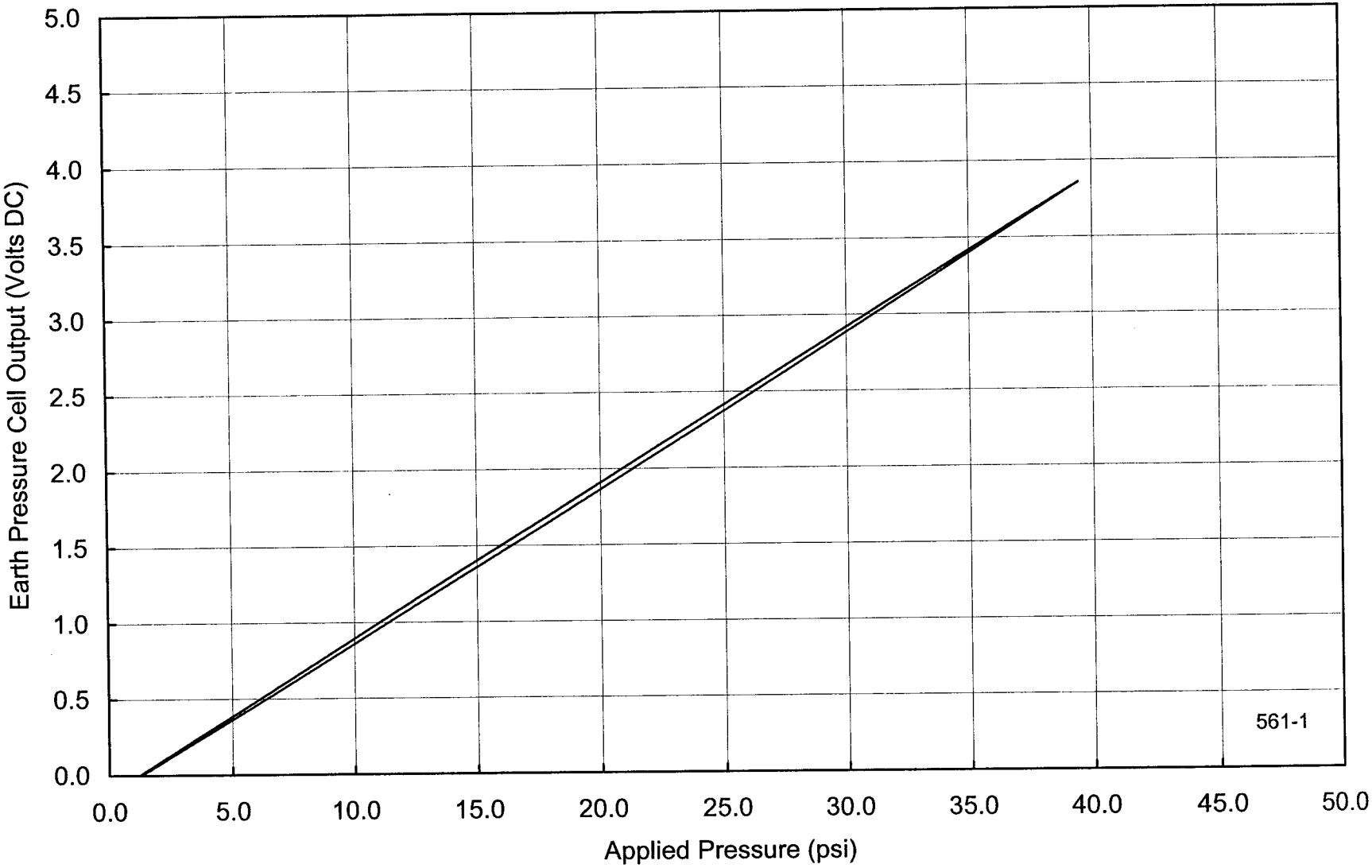

Figure A-23) Calibration record for the first calibration of earth pressure cell number 561 for the ODOT SHRP Test Road, Section 390206

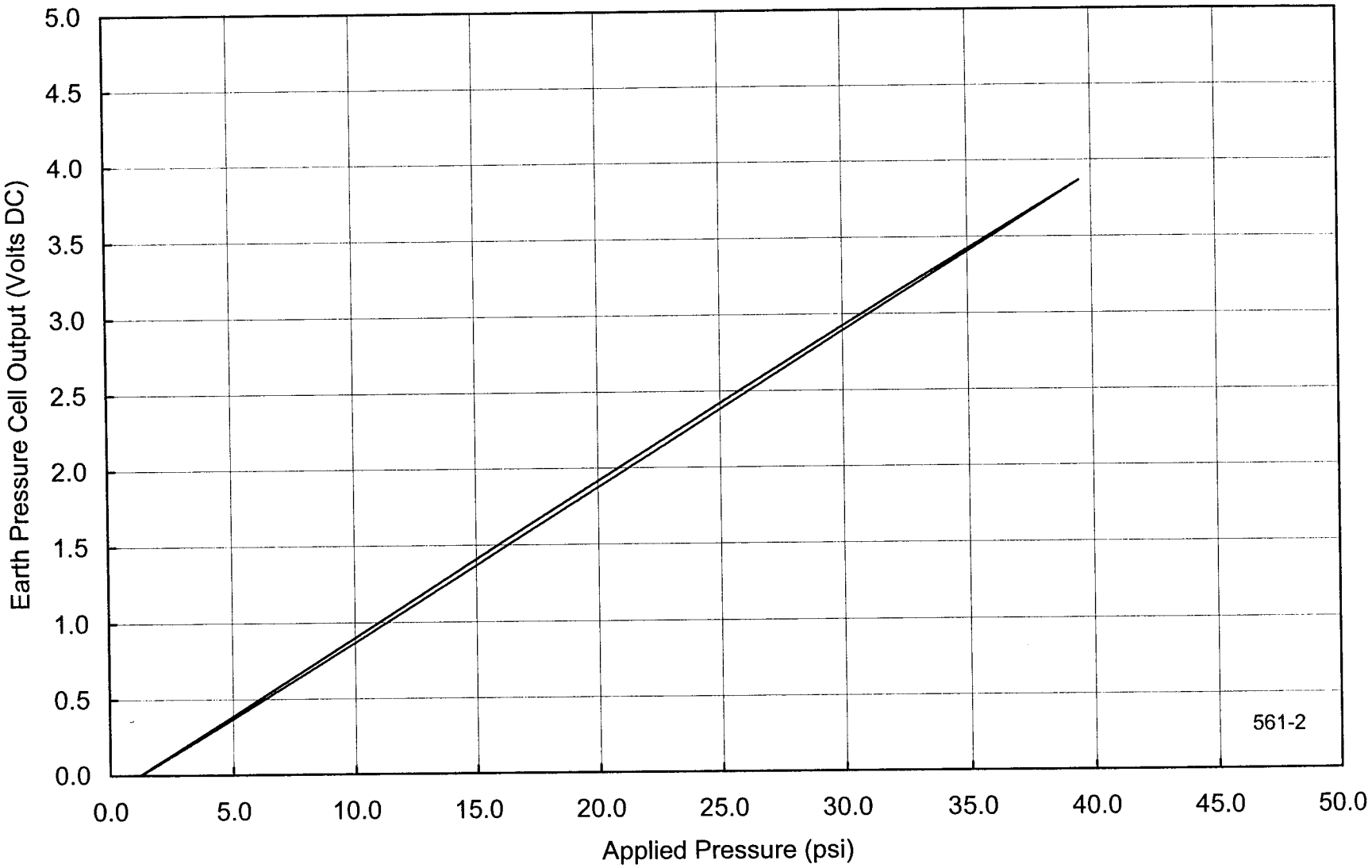

Figure A-24) Calibration record for the second calibration of earth pressure cell number 561 for the ODOT SHRP Test Road, Section 390206

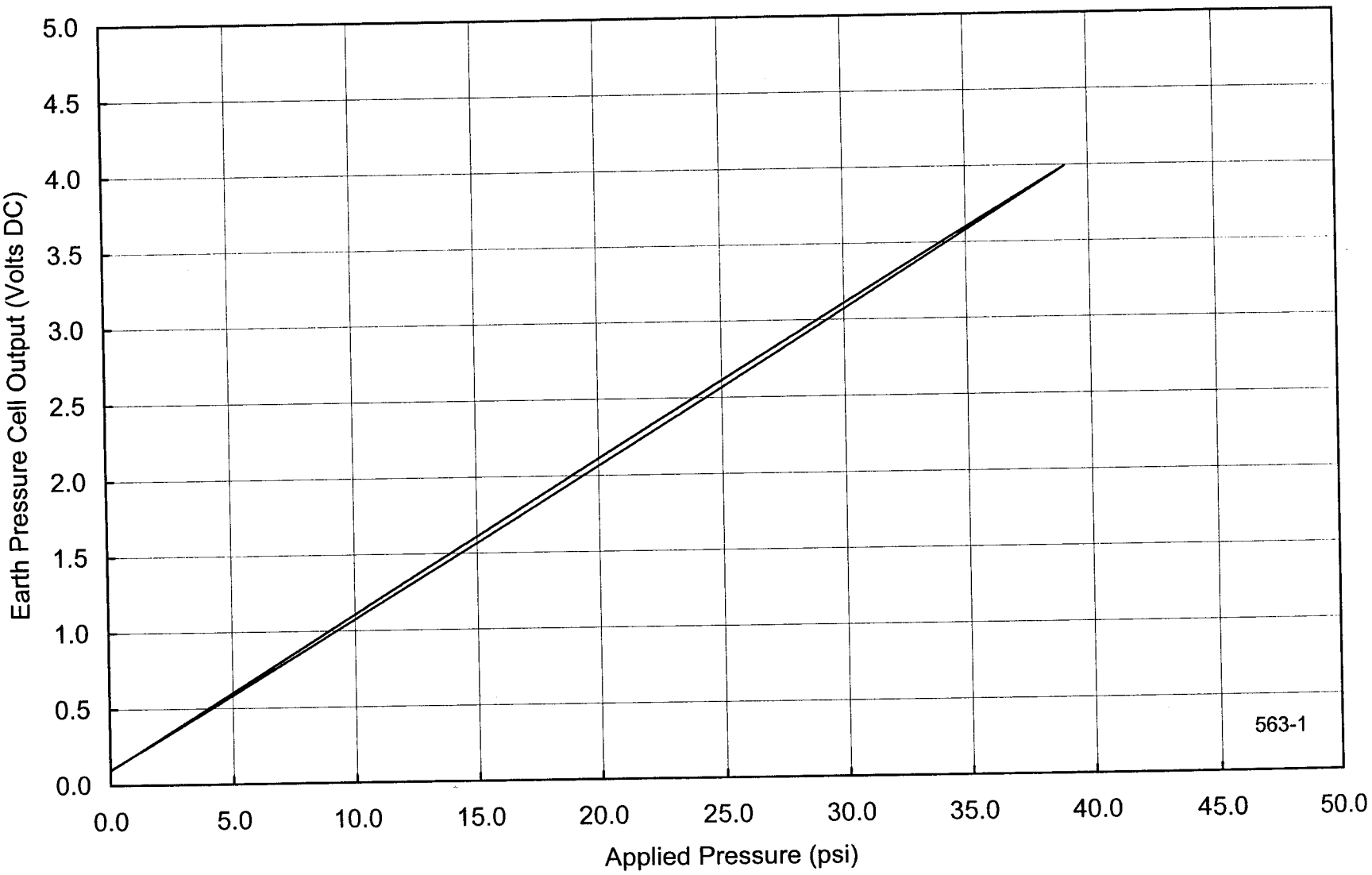

Figure A-25) Calibration record for the first calibration of earth pressure cell number 563 for the ODOT SHRP Test Road, Section 390205

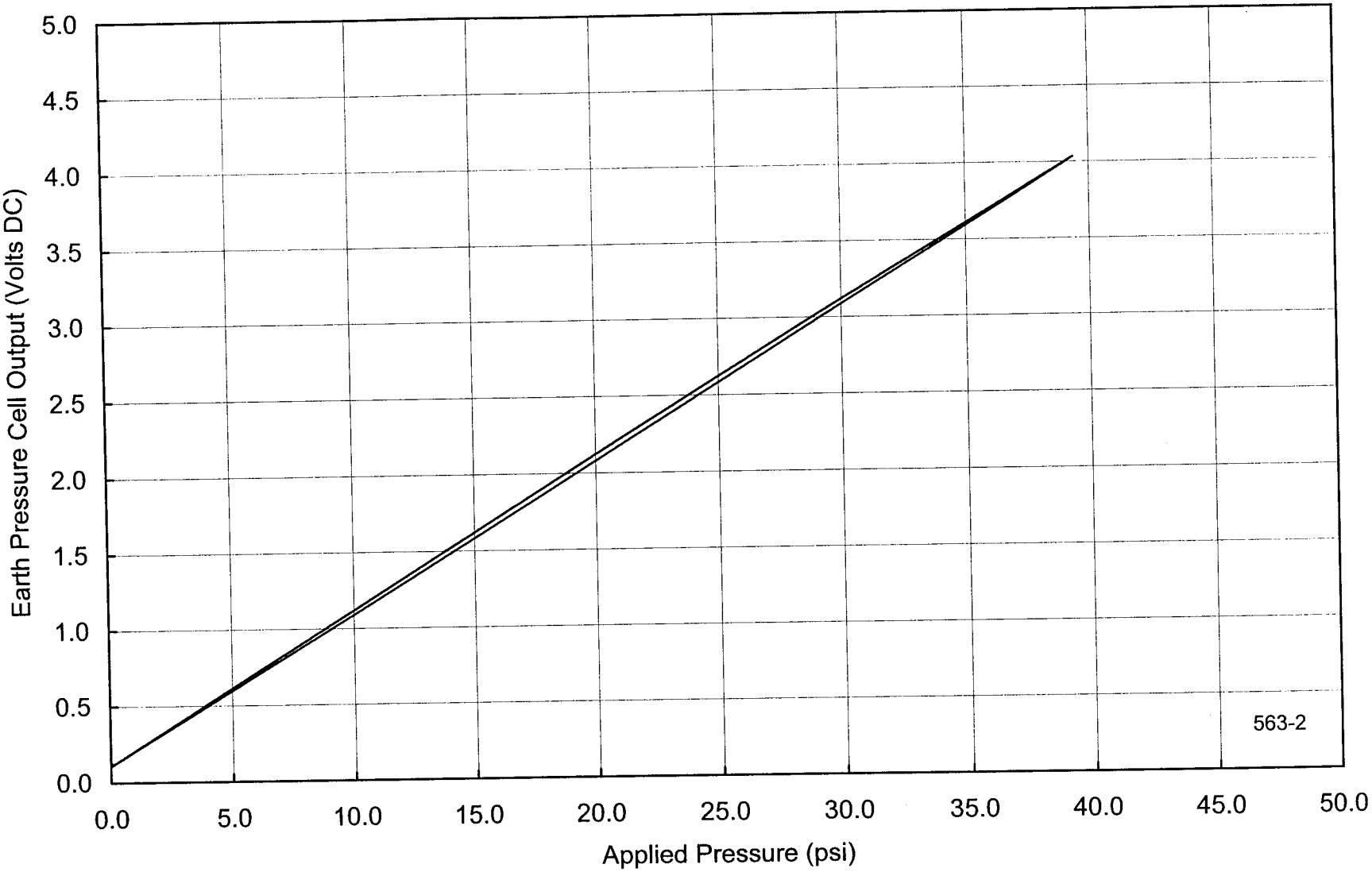

Figure A-26) Calibration record for the second calibration of earth pressure cell number 563 for the ODOT SHRP Test Road, Section 390205

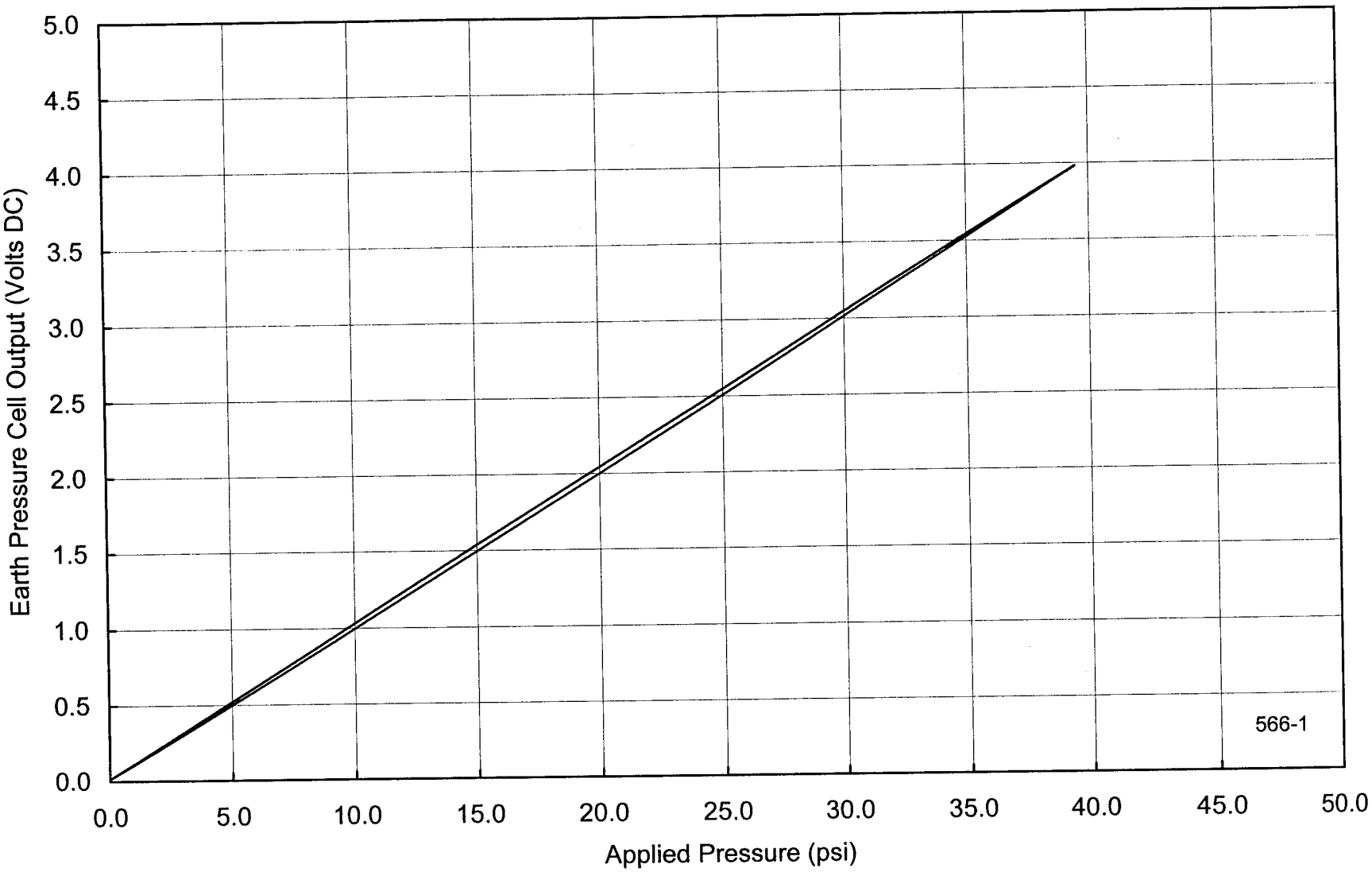

Figure A-27) Calibration record for the first calibration of earth pressure cell number 566 for the ODOT SHRP Test Road, Section 390205

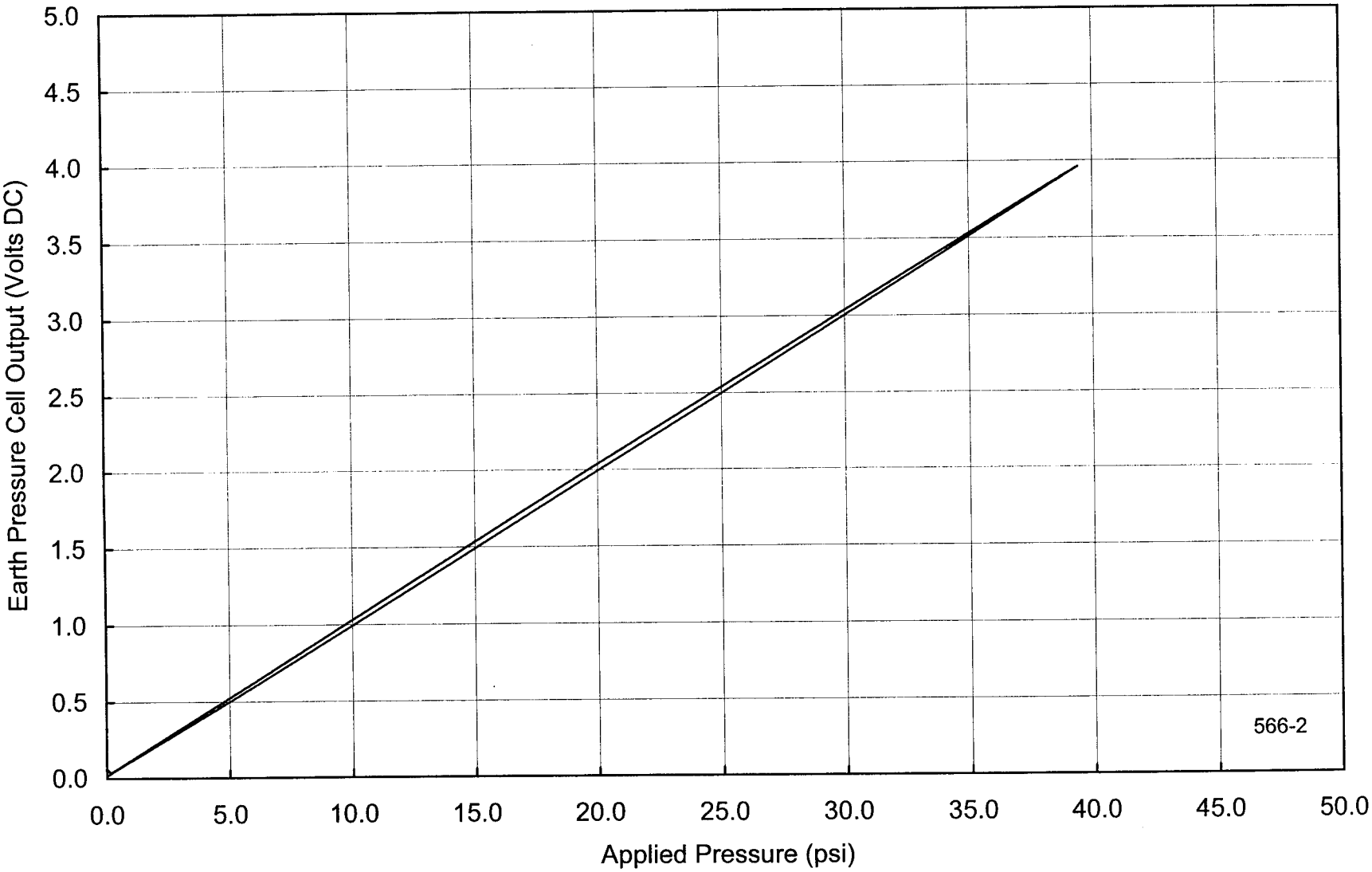

Figure A-28) Calibration record for the second calibration of earth pressure cell number 566 for the ODOT SHRP Test Road, Section 390205

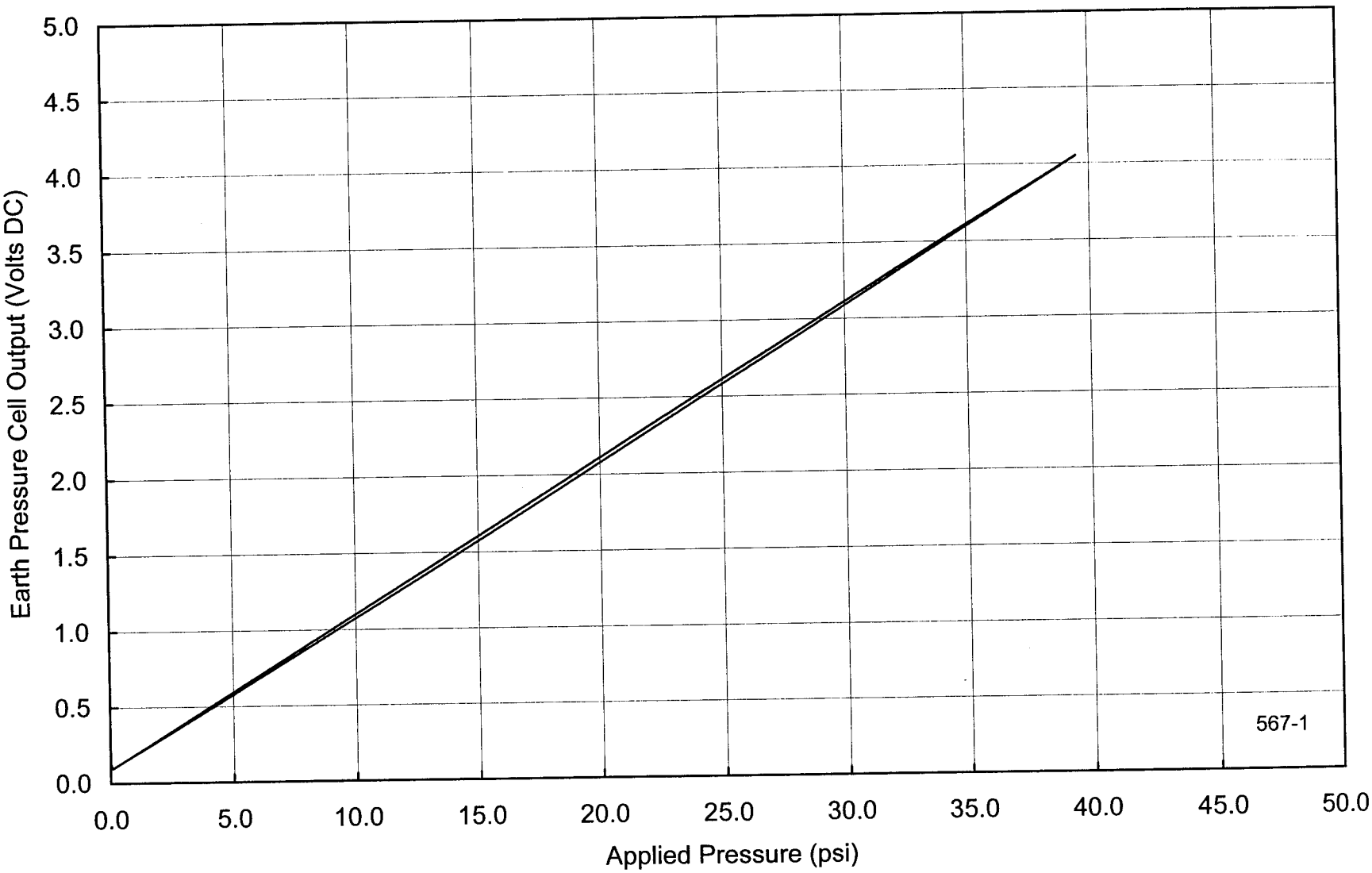

Figure A-29) Calibration record for the first calibration of earth pressure cell number 567 for the ODOT SHRP Test Road, Section 390201

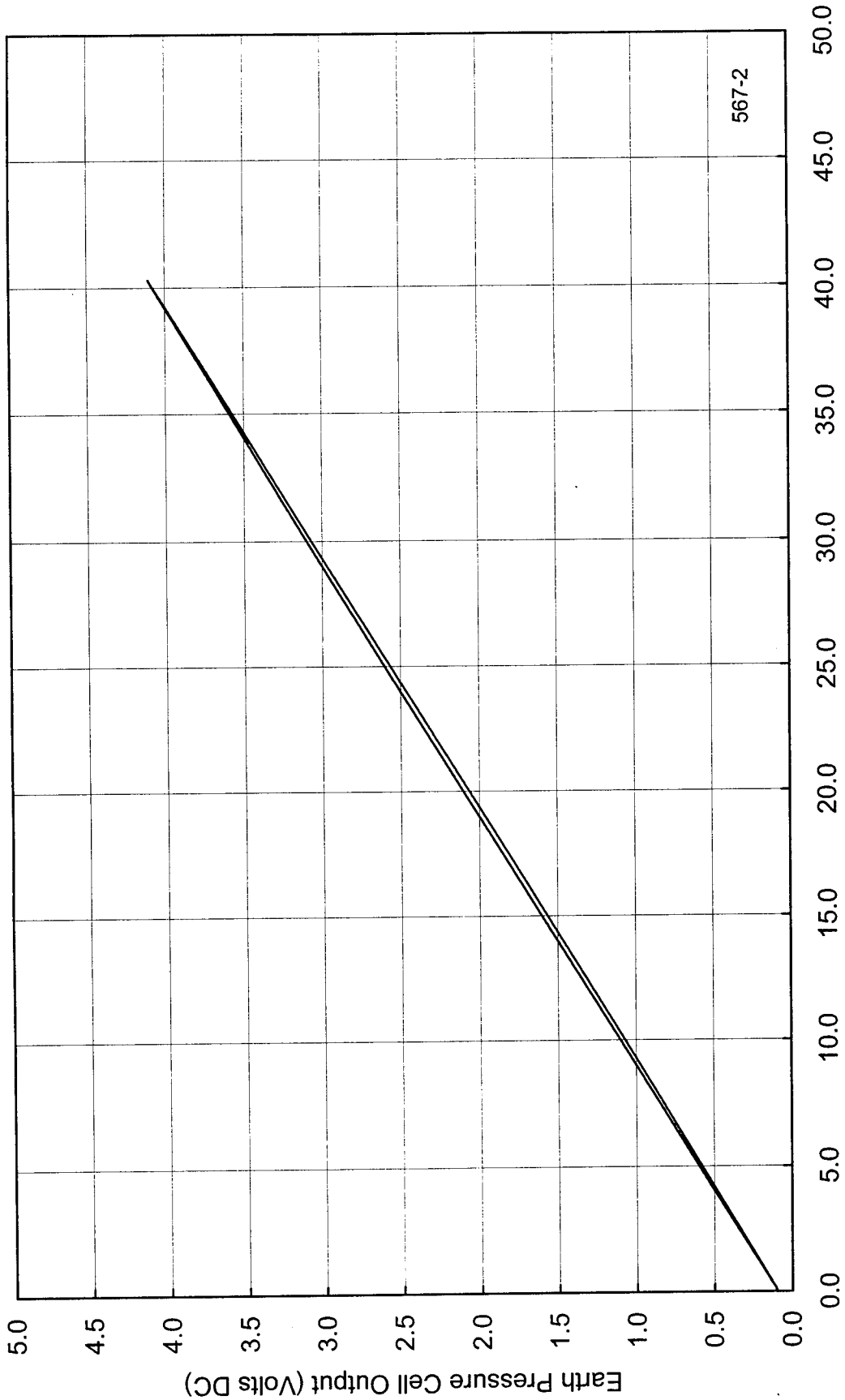

Figure A-30) Calibration record for the second calibration of earth pressure cell number 567 for the ODOT SHRP Test Road, Section 390201

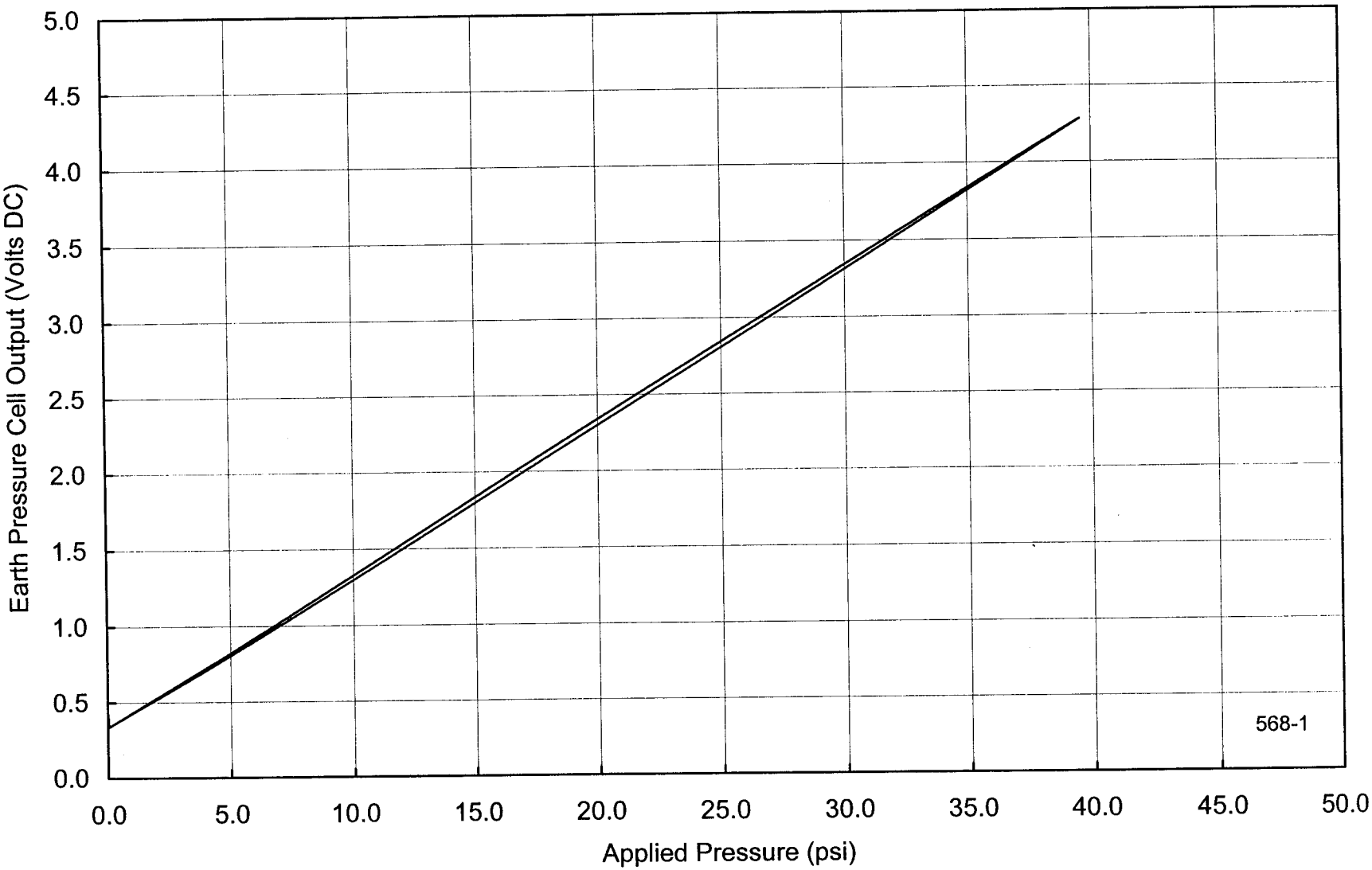

Figure A-31) Calibration record for the first calibration of earth pressure cell number 568 for the ODOT SHRP Test Road, Section 390201

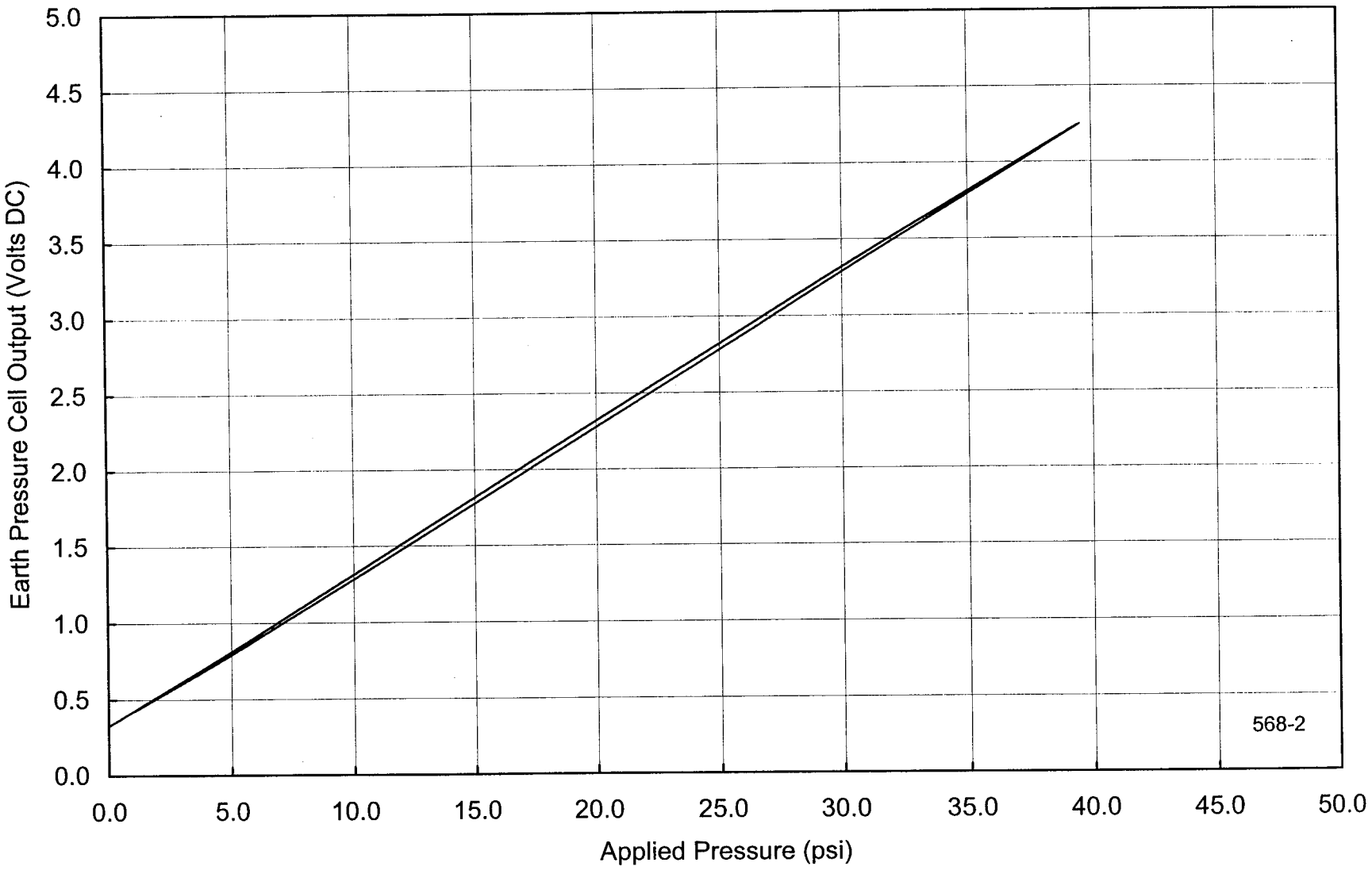

Figure A-32) Calibration record for the second calibration of earth pressure cell number 568 for the ODOT SHRP Test Road, Section 390201

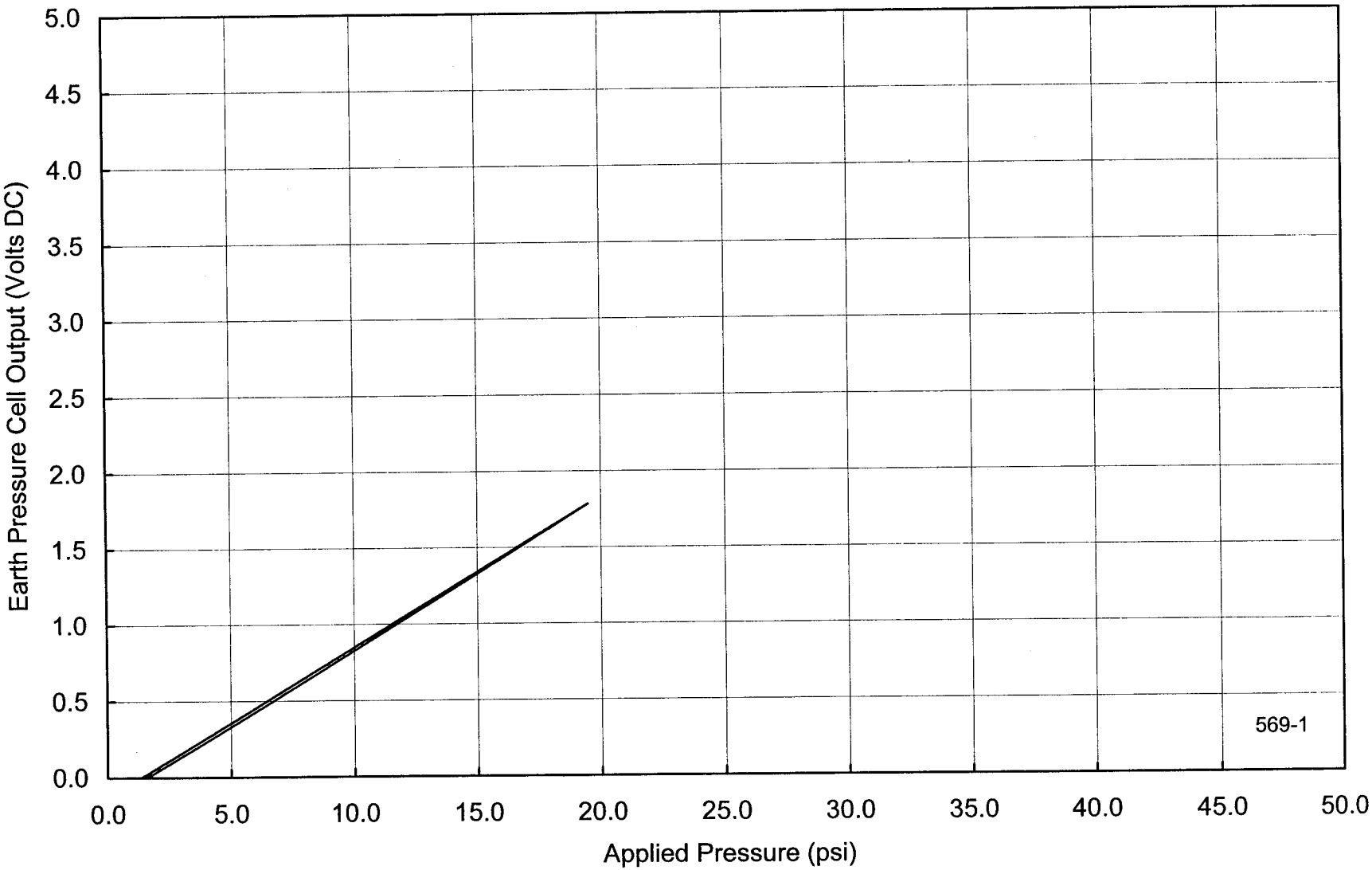

Figure A-33) Calibration record for the first calibration of earth pressure cell number 569 for the ODOT SHRP Test Road, Section 390264

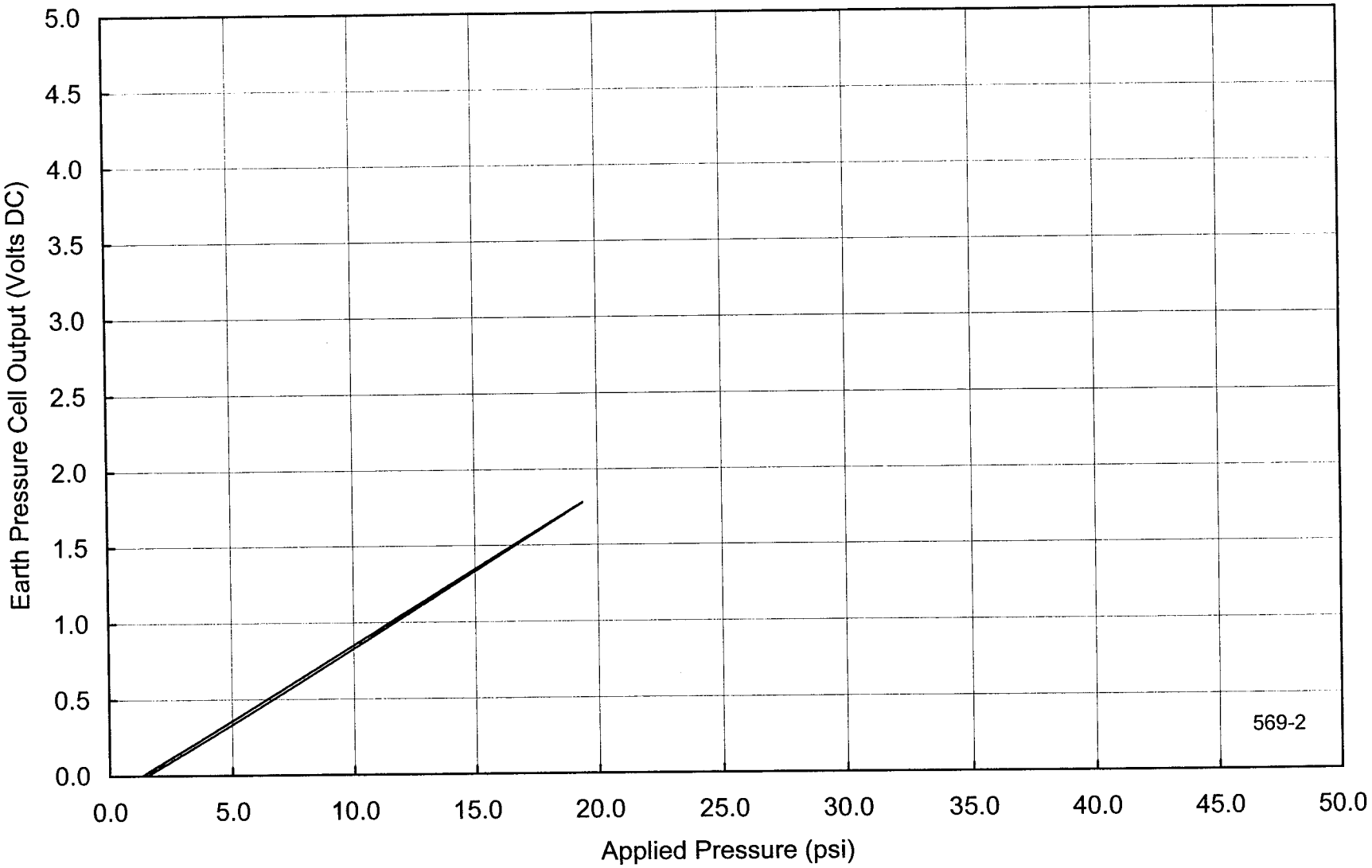

Figure A-34) Calibration record for the second calibration of earth pressure cell number 569 for the ODOT SHRP Test Road, Section 390264

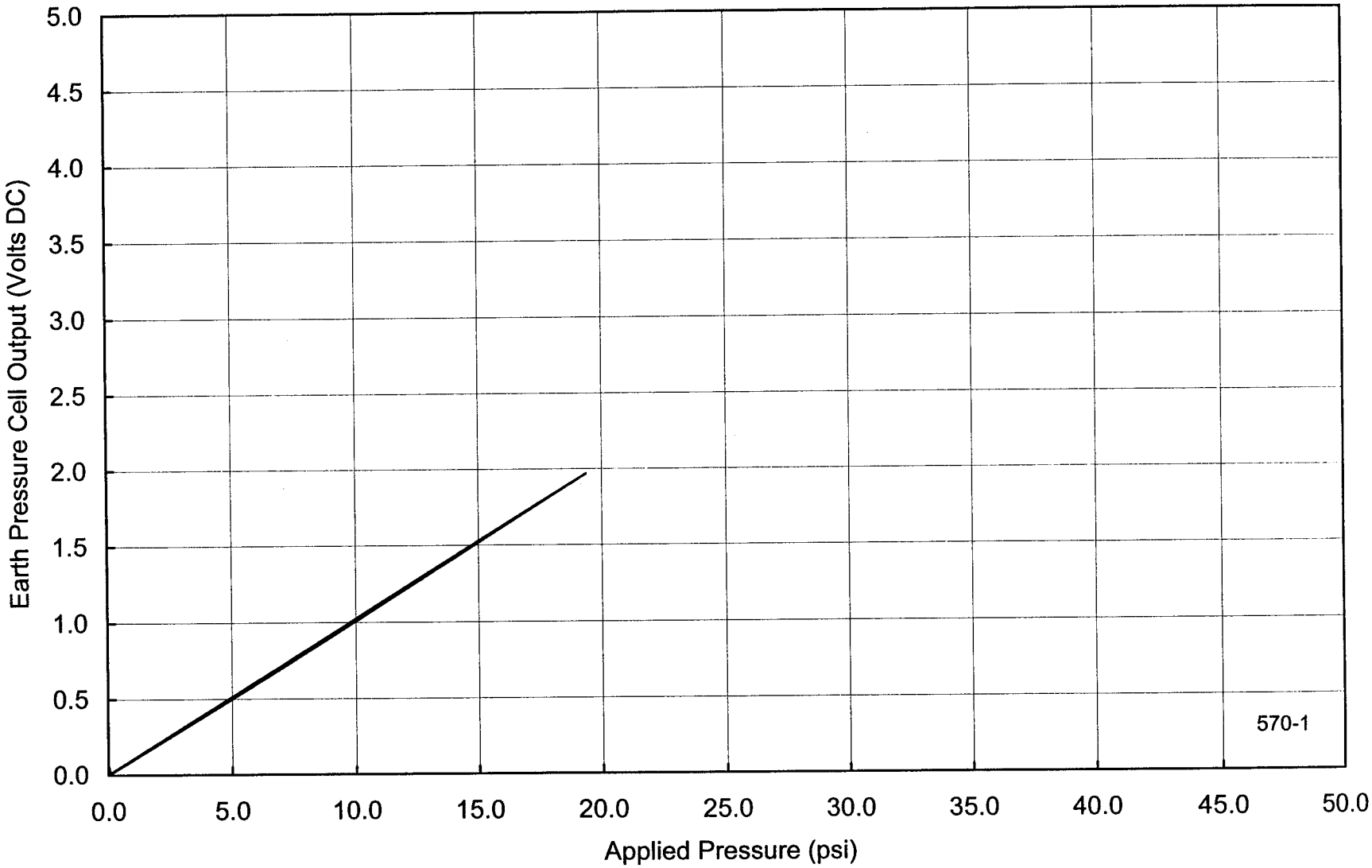

Figure A-35) Calibration record for the first calibration of earth pressure cell number 570 for the ODOT SHRP Test Road, Section 390264

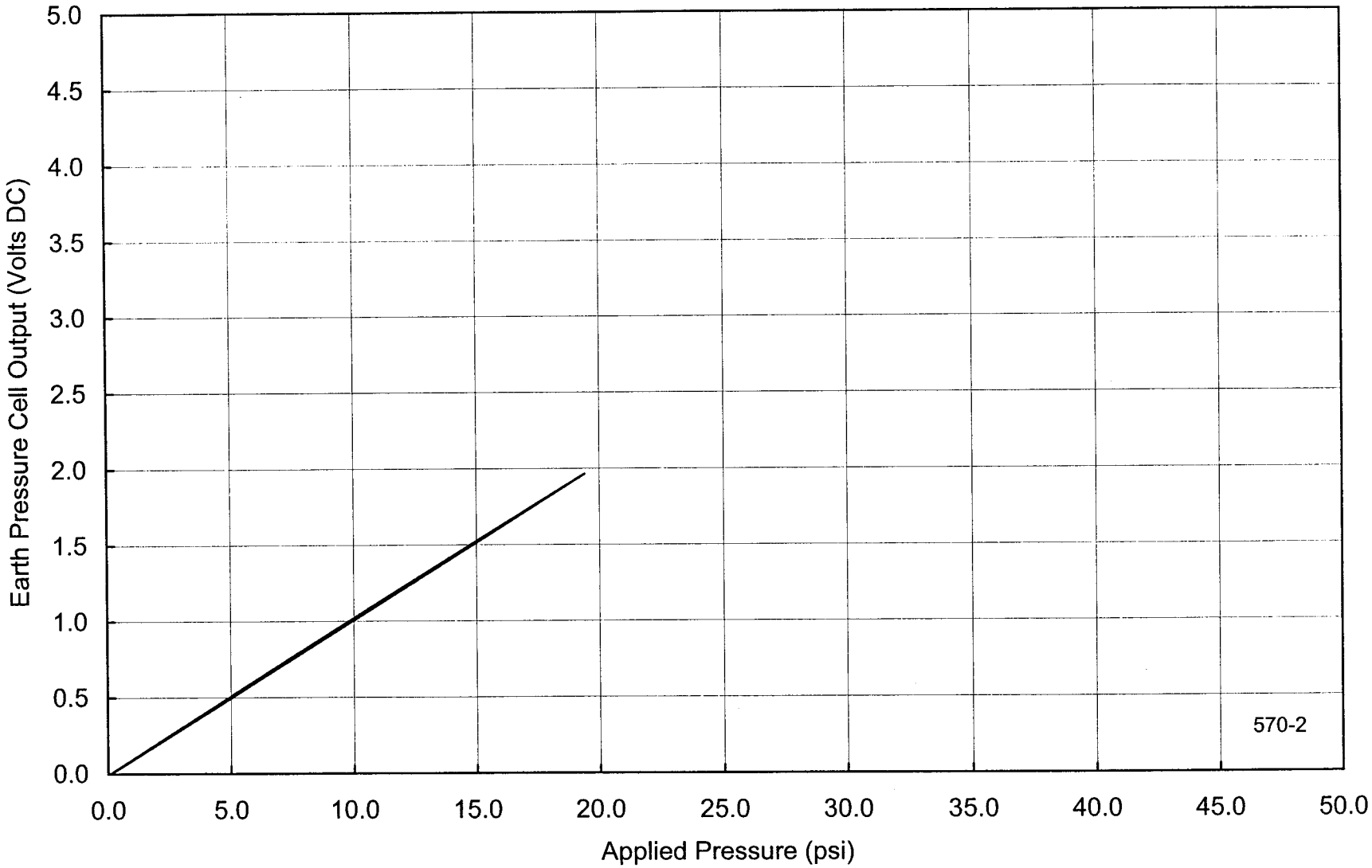

Figure A-36) Calibration record for the second calibration of earth pressure cell number 570 for the ODOT SHRP Test Road, Section 390264

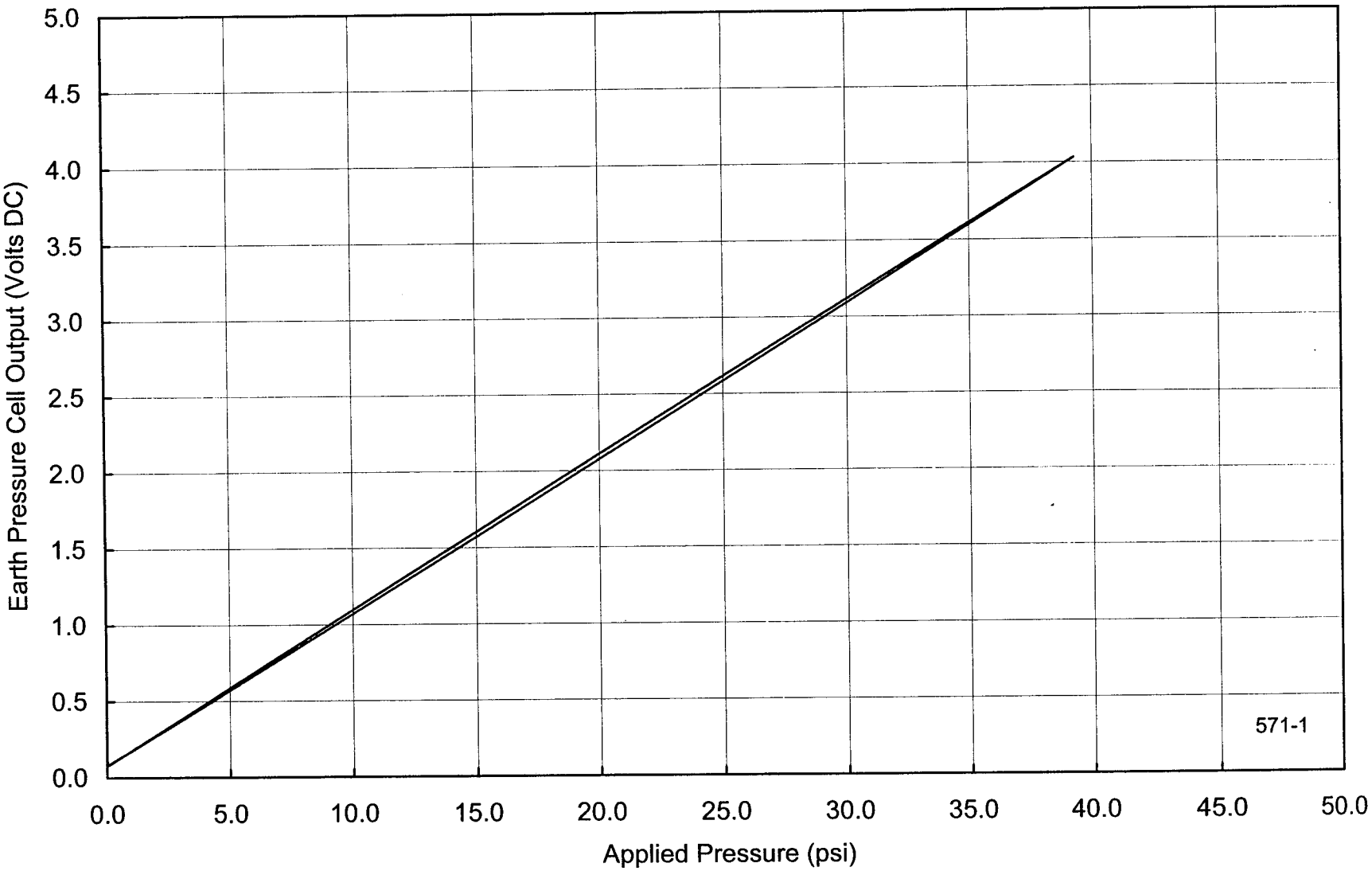

Figure A-37) Calibration record for the first calibration of earth pressure cell number 571 for the ODOT SHRP Test Road, Section 390261

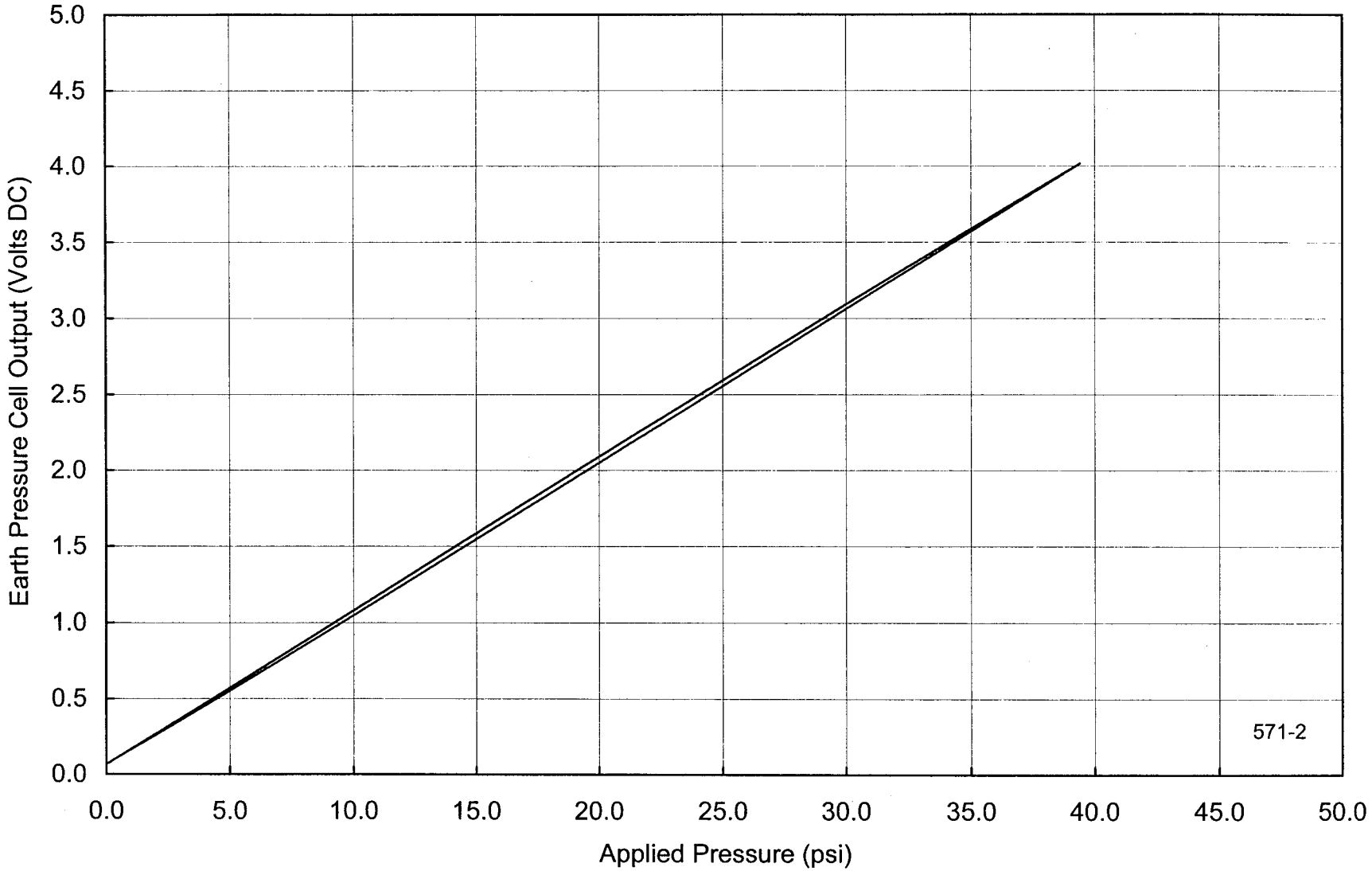

Figure A-38) Calibration record for the second calibration of earth pressure cell number 571 for the ODOT SHRP Test Road, Section 390261

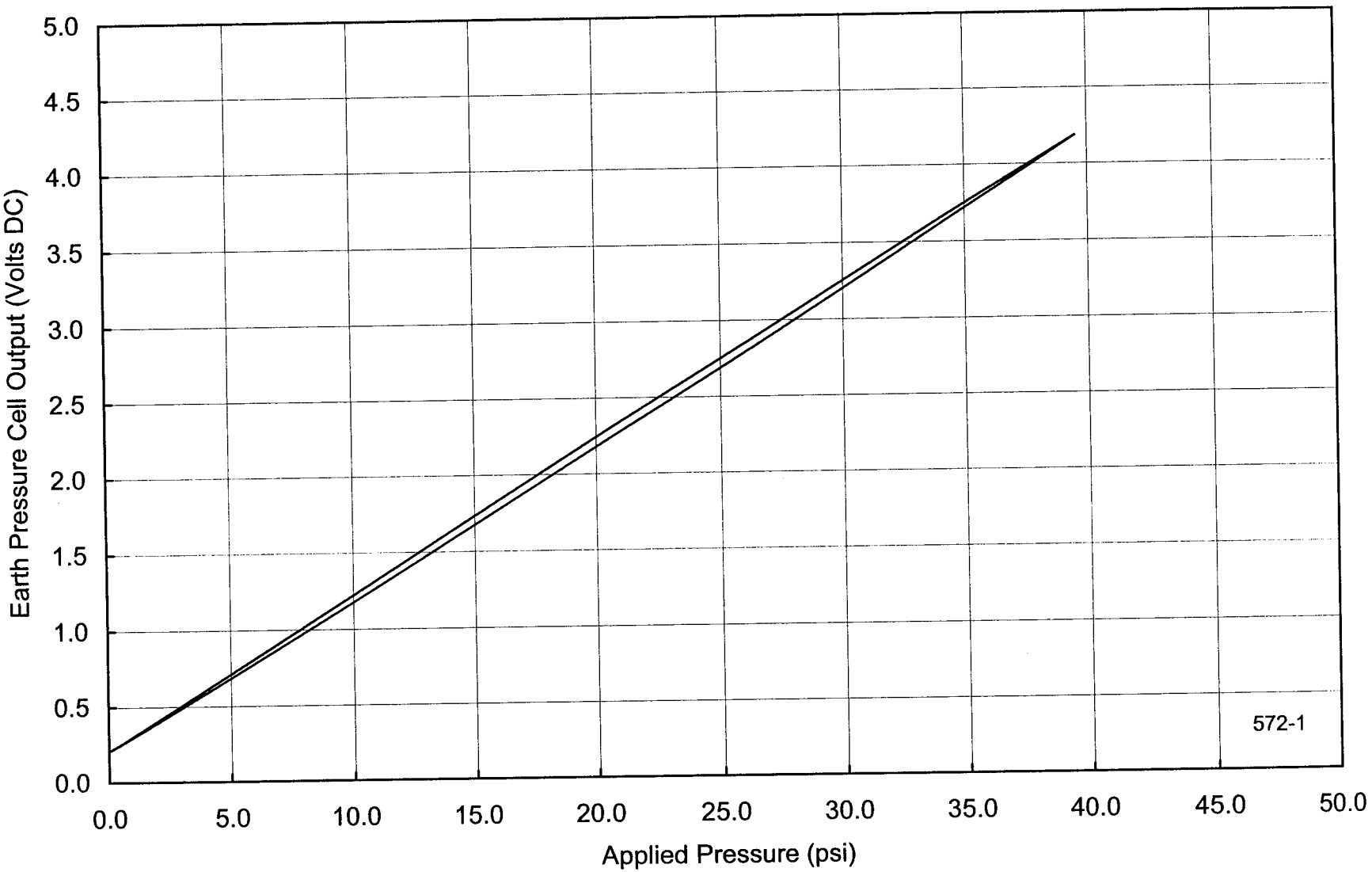

Figure A-39) Calibration record for the first calibration of earth pressure cell number 572 for the ODOT SHRP Test Road, Section 390902

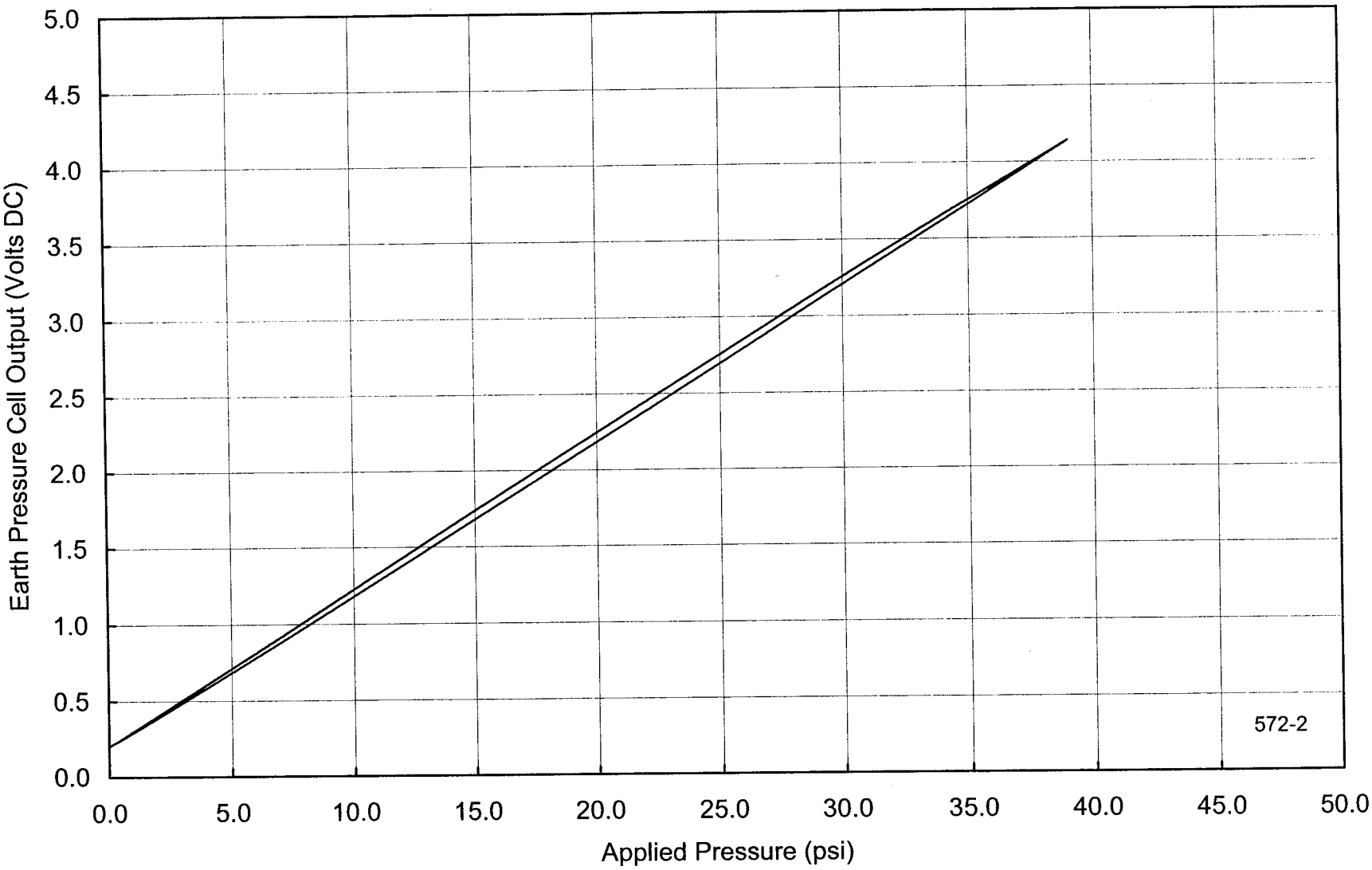

Figure A-40) Calibration record for the second calibration of earth pressure cell number 572 for the ODOT SHRP Test Road, Section 390902

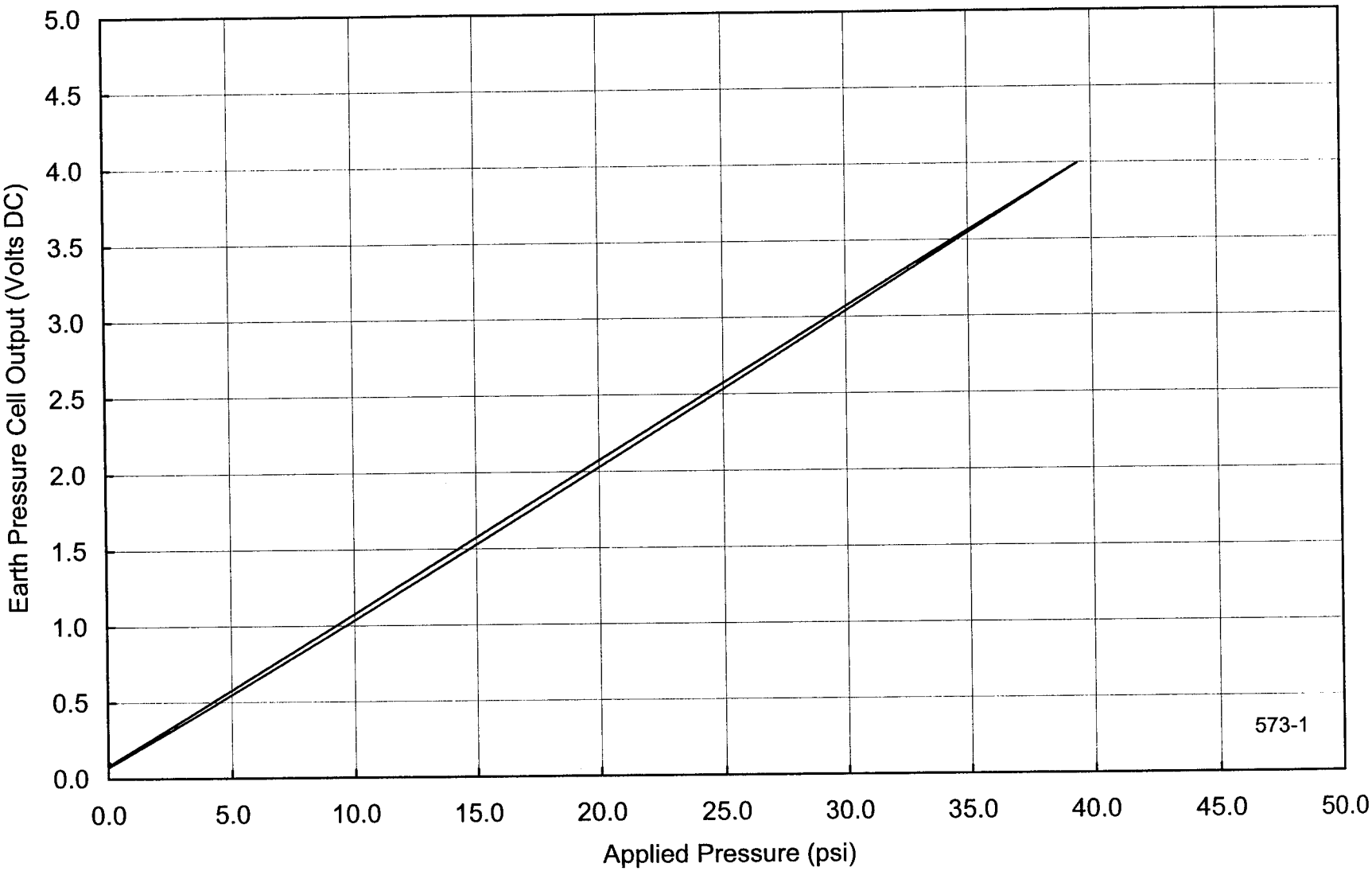

Figure A-41) Calibration record for the first calibration of earth pressure cell number 573 for the ODOT SHRP Test Road, Section 390261

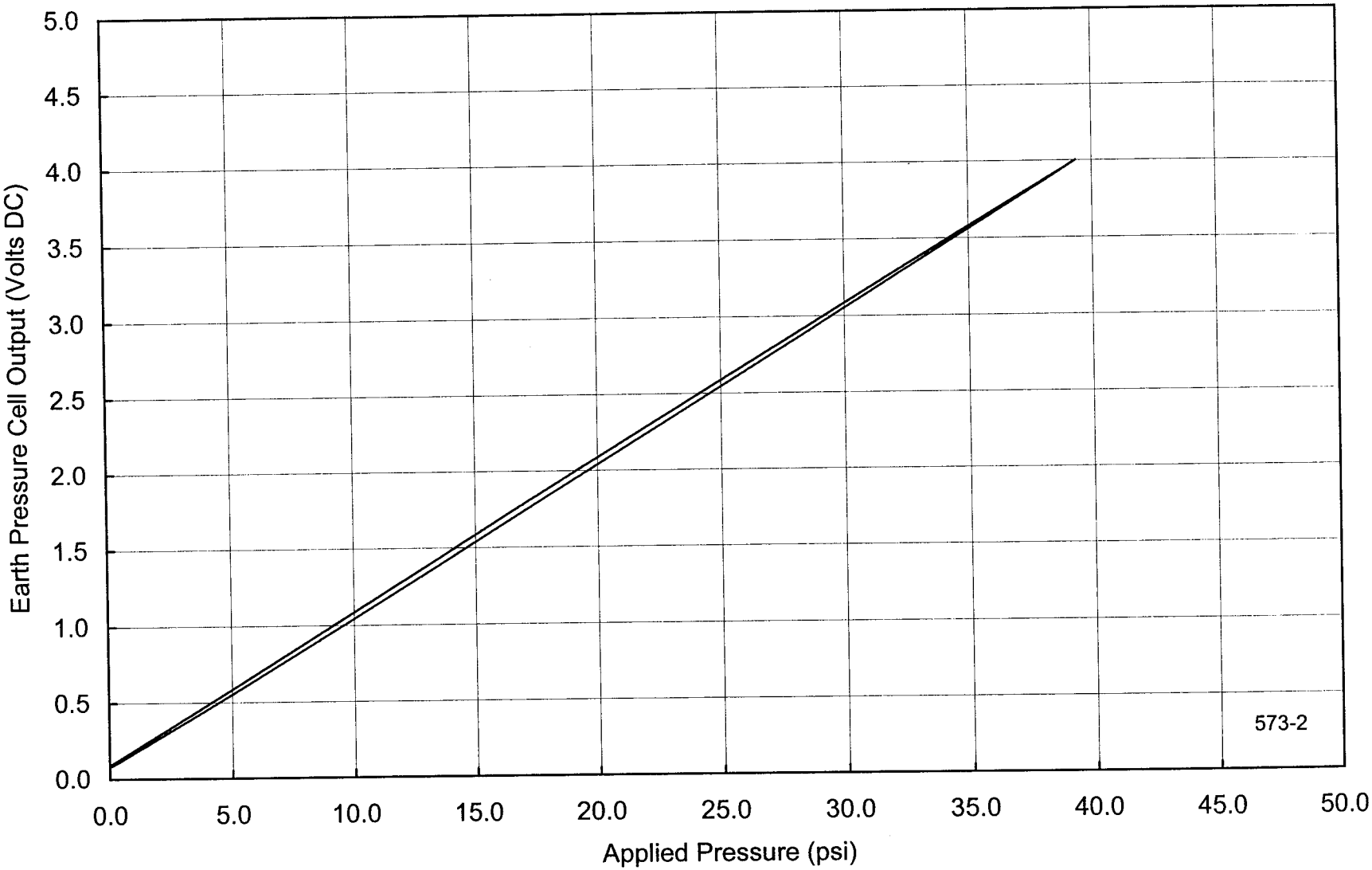

Figure A-42) Calibration record for the second calibration of earth pressure cell number 573 for the ODOT SHRP Test Road, Section 390261

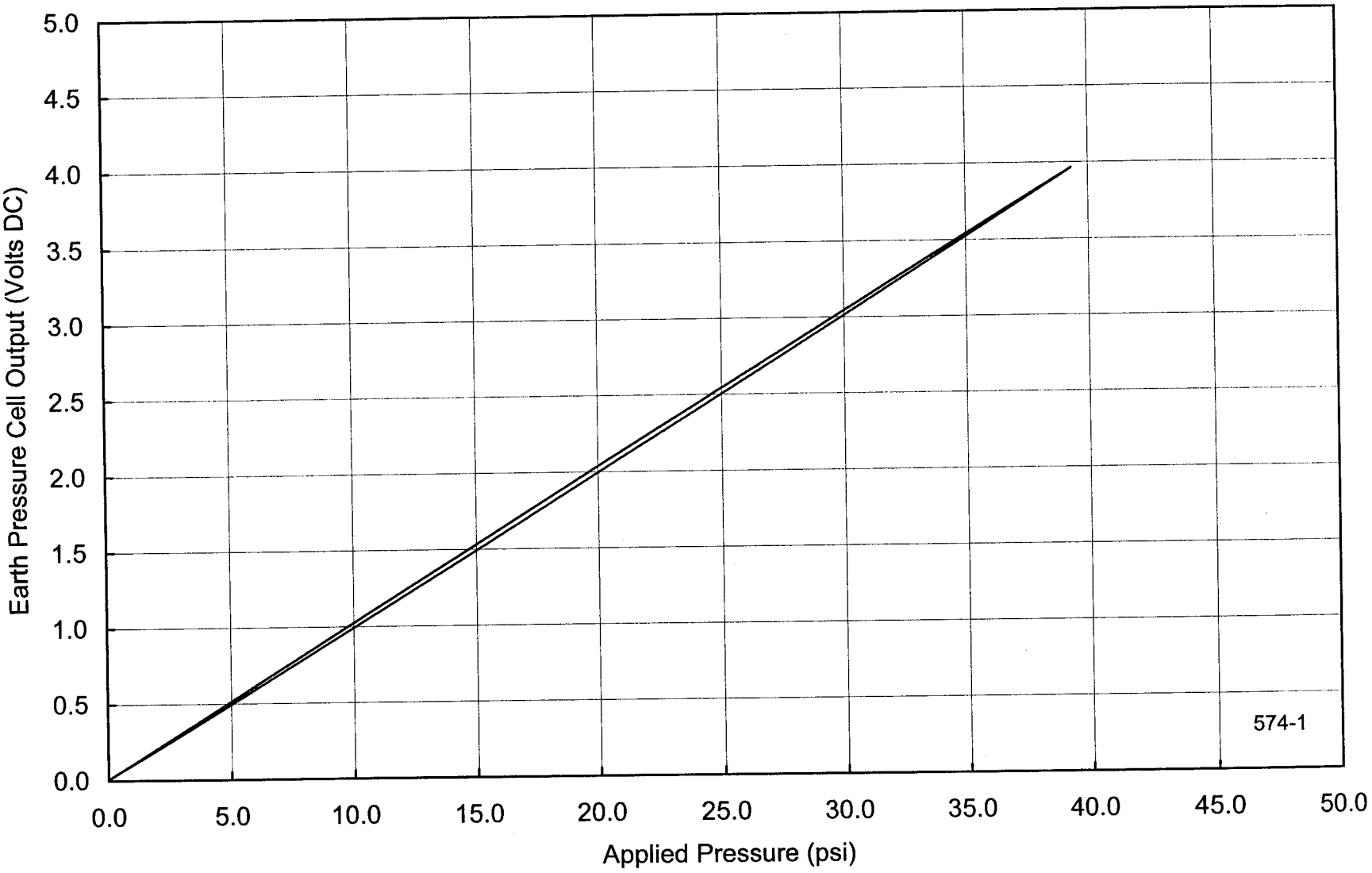

Figure A-43) Calibration record for the first calibration of earth pressure cell number 574 for the ODOT SHRP Test Road, Section 390211

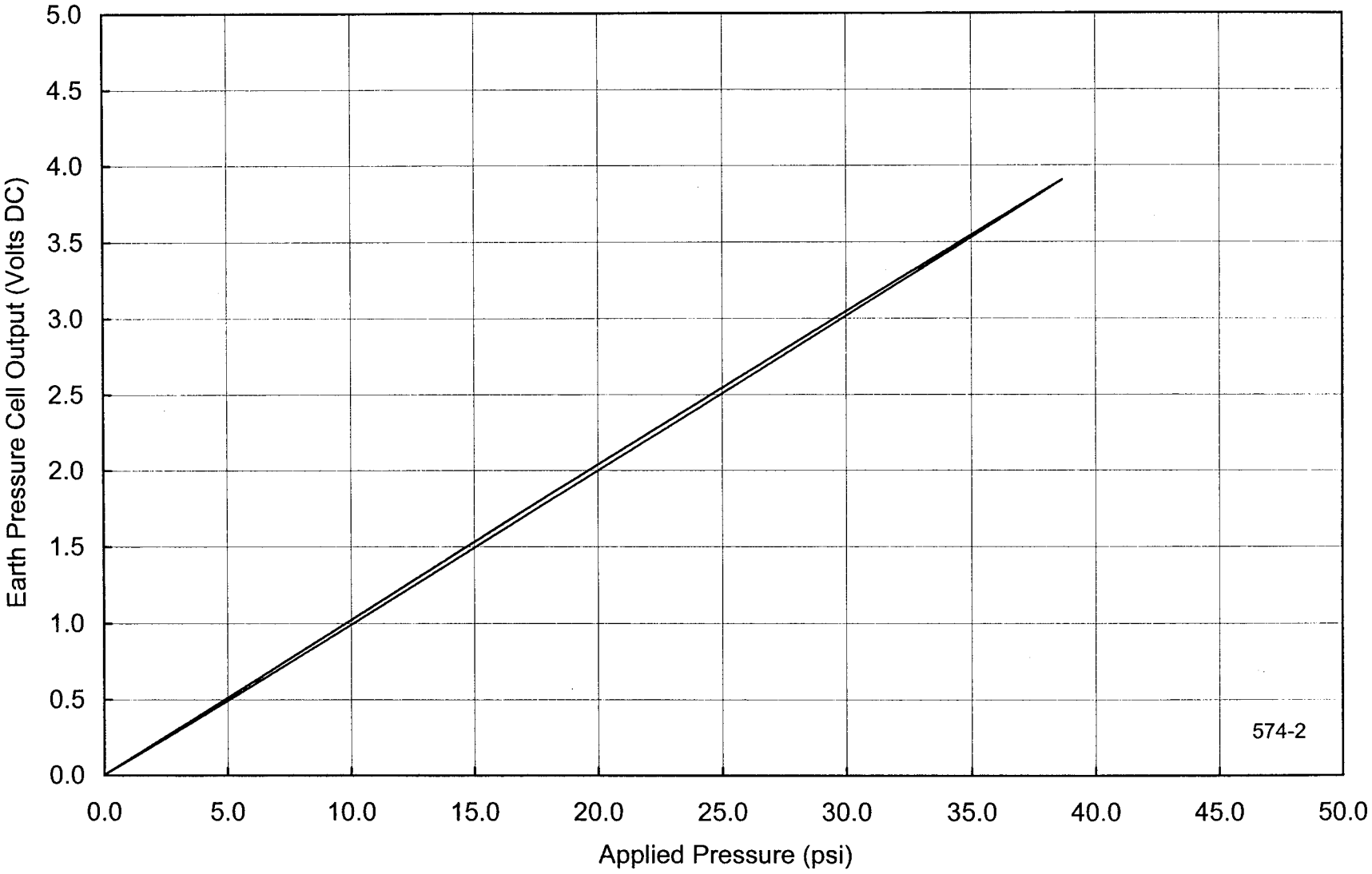

Figure A-44) Calibration record for the second calibration of earth pressure cell number 574 for the ODOT SHRP Test Road, Section 390211

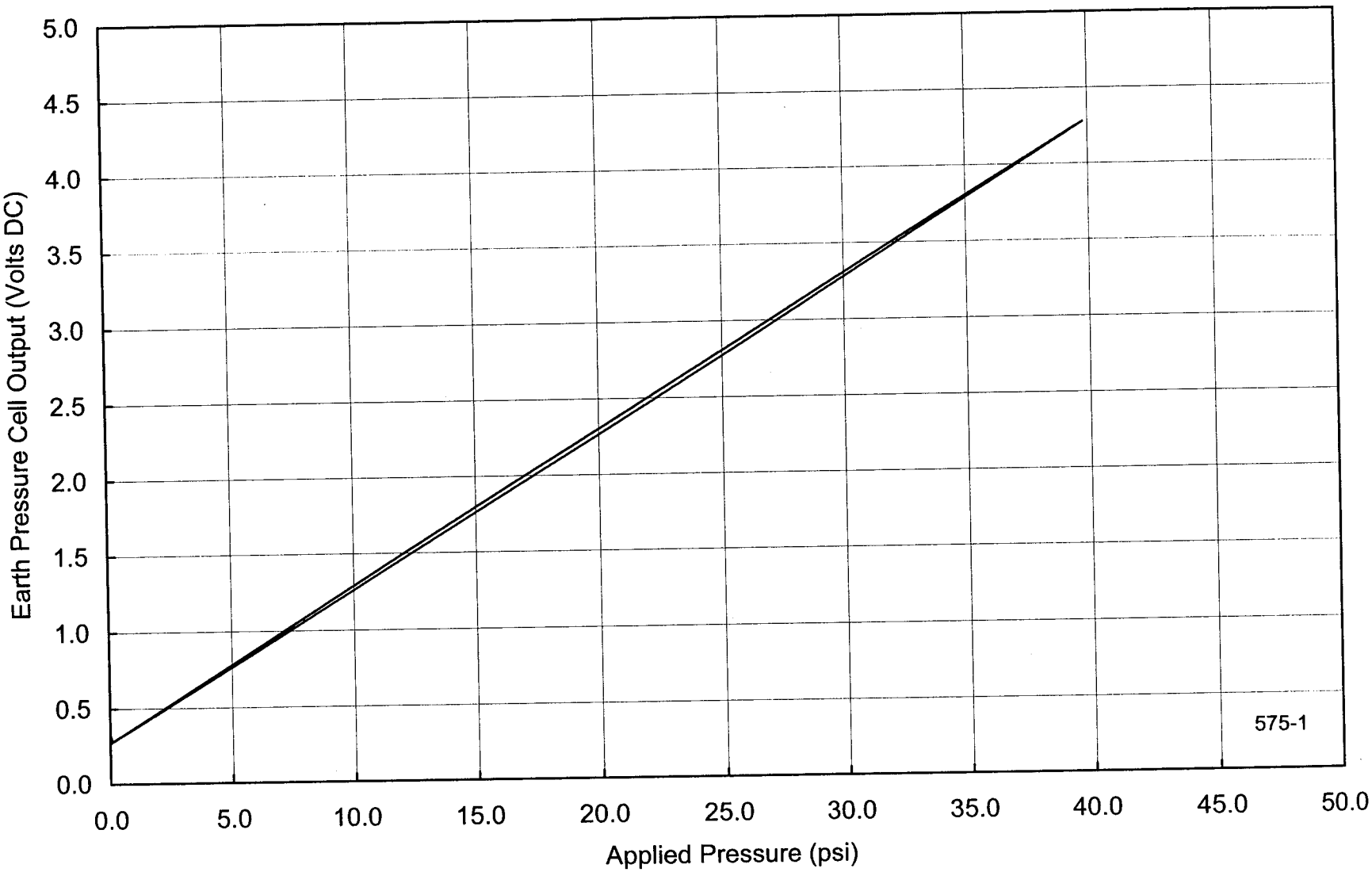

Figure A-45) Calibration record for the first calibration of earth pressure cell number 575 for the ODOT SHRP Test Road, Section 390211

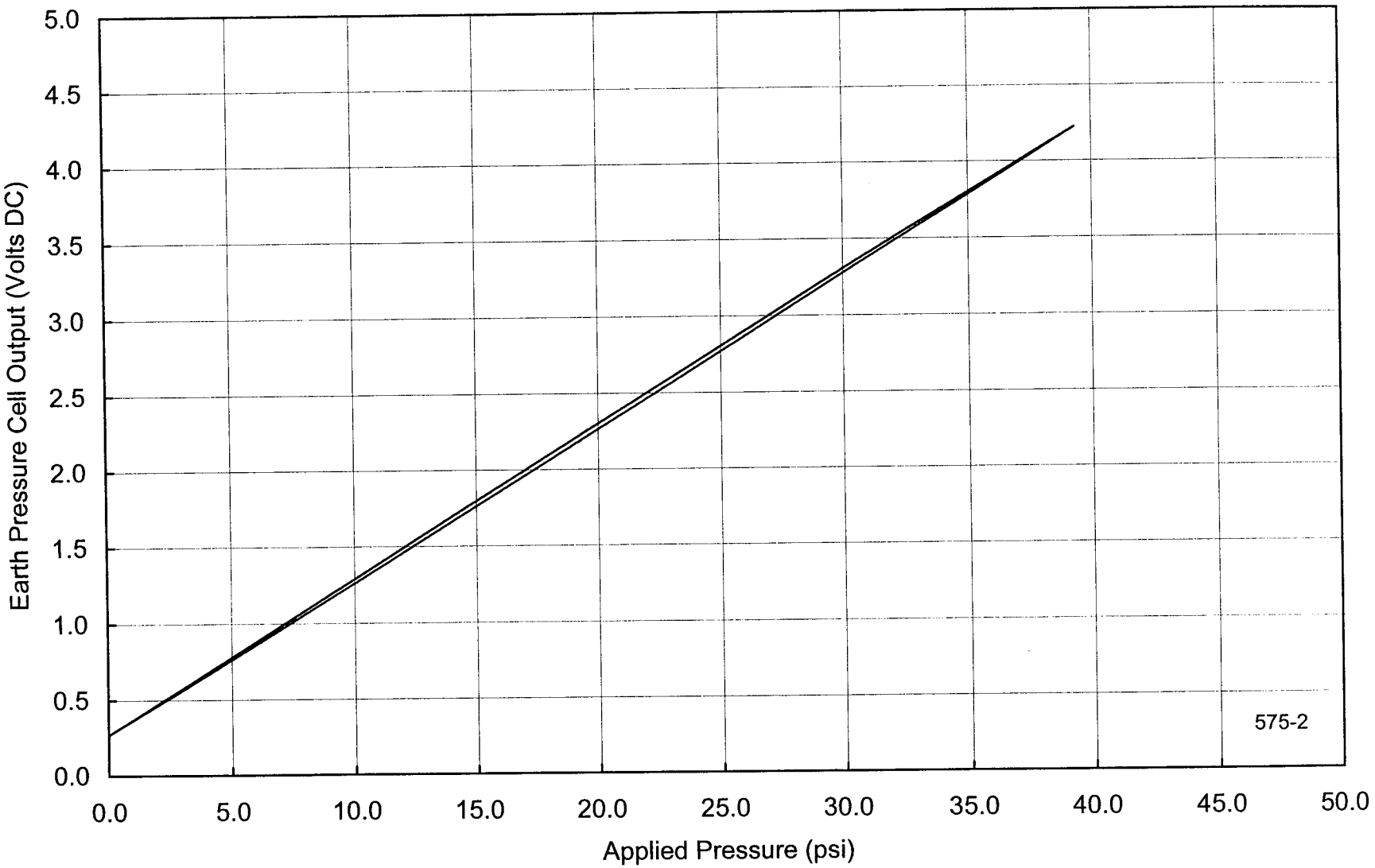

Figure A-46) Calibration record for the second calibration of earth pressure cell number 575 for the ODOT SHRP Test Road, Section 390211

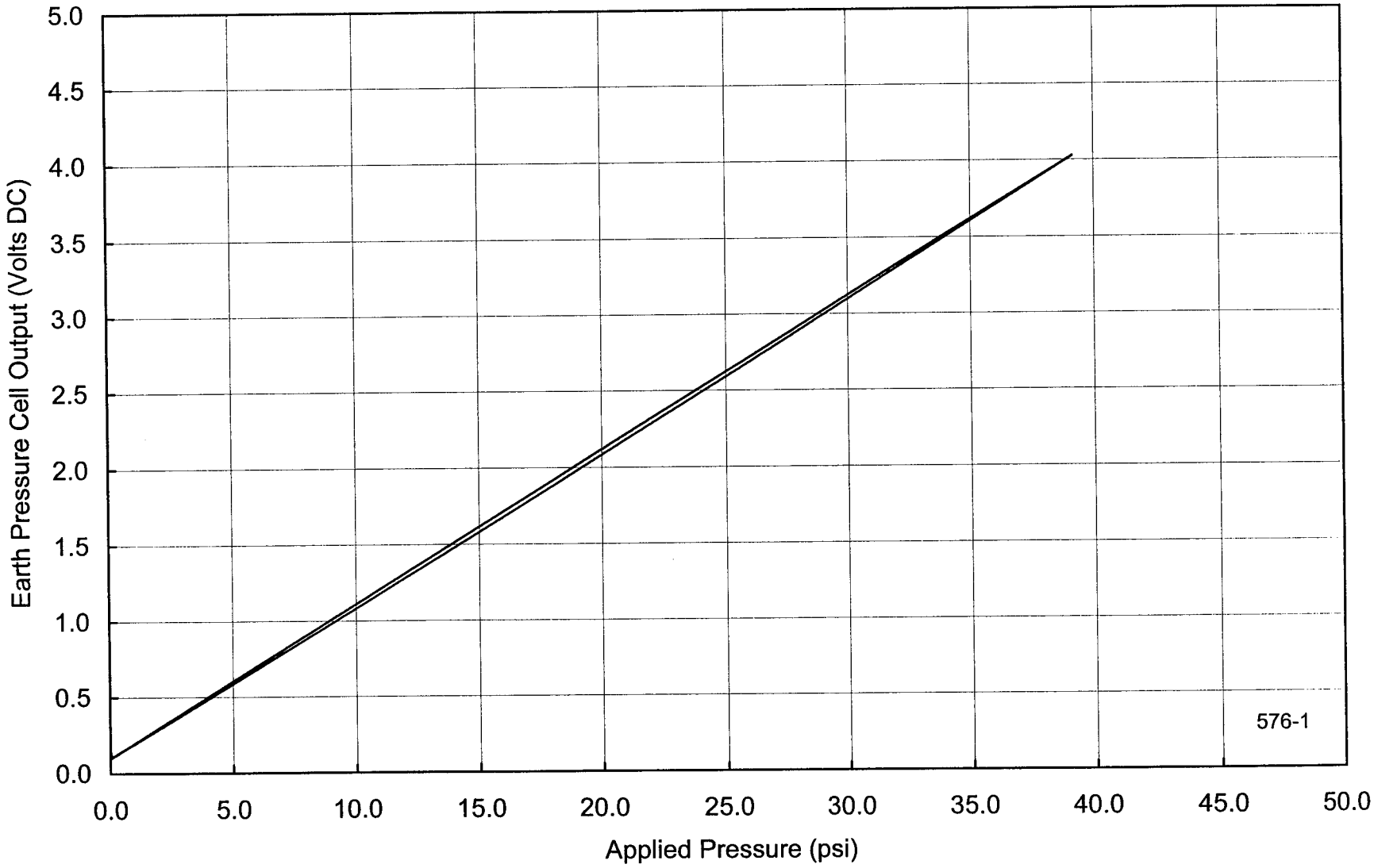

Figure A-47) Calibration record for the first calibration of earth pressure cell number 576 for the ODOT SHRP Test Road, Section 390203

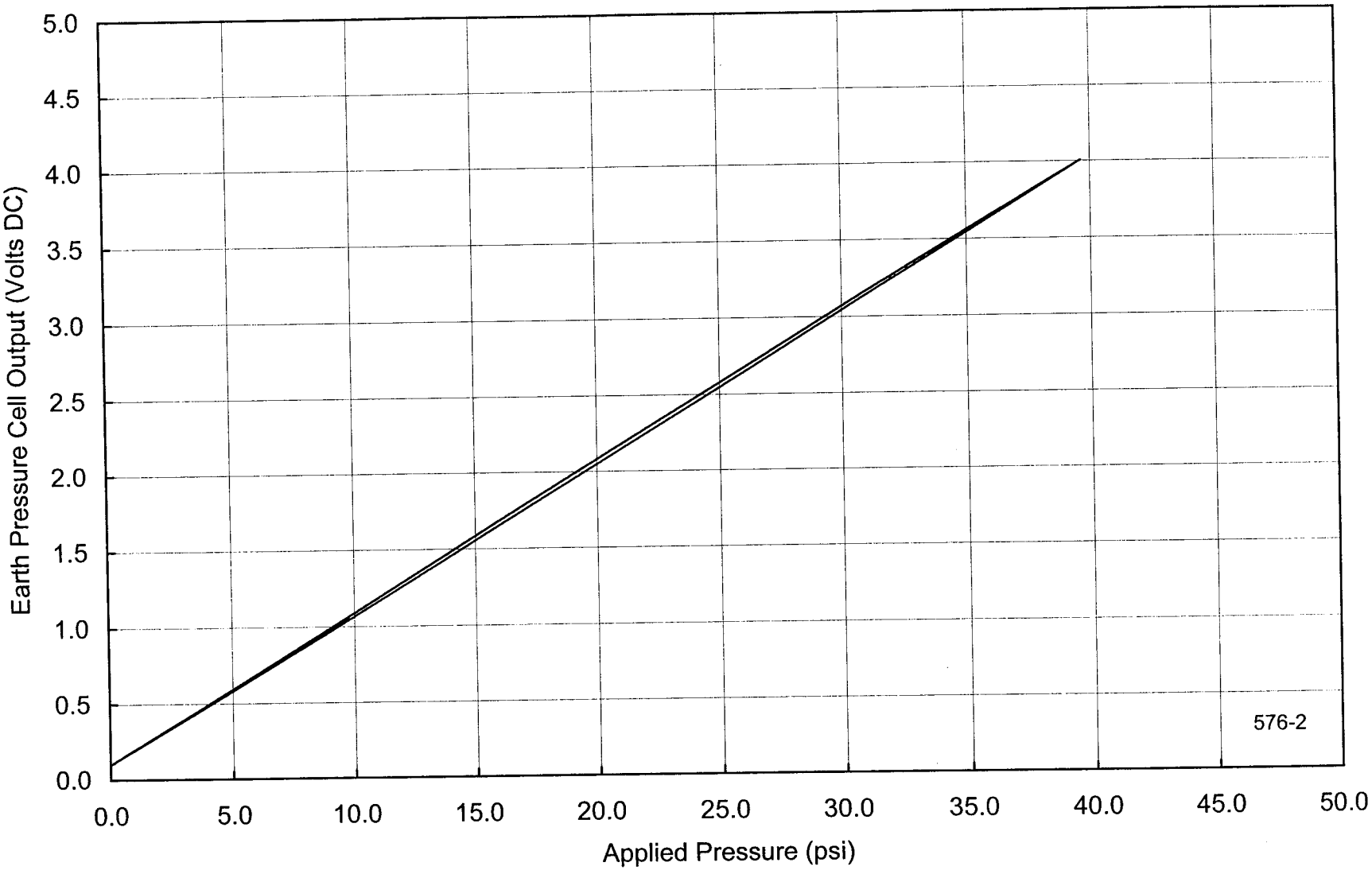

Figure A-48) Calibration record for the second calibration of earth pressure cell number 576 for the ODOT SHRP Test Road, Section 390203

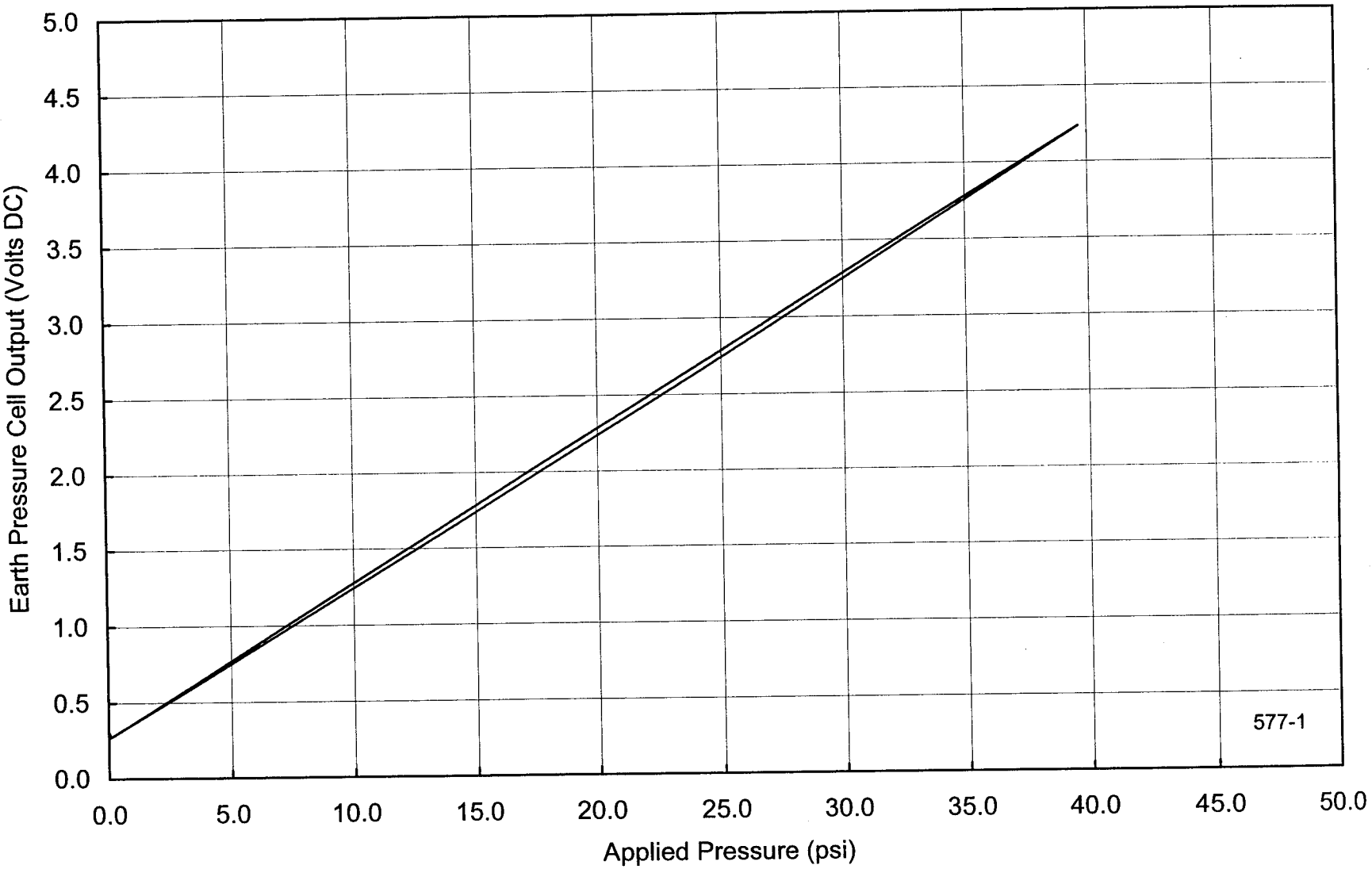

Figure A-49) Calibration record for the first calibration of earth pressure cell number 577 for the ODOT SHRP Test Road, Section 390203

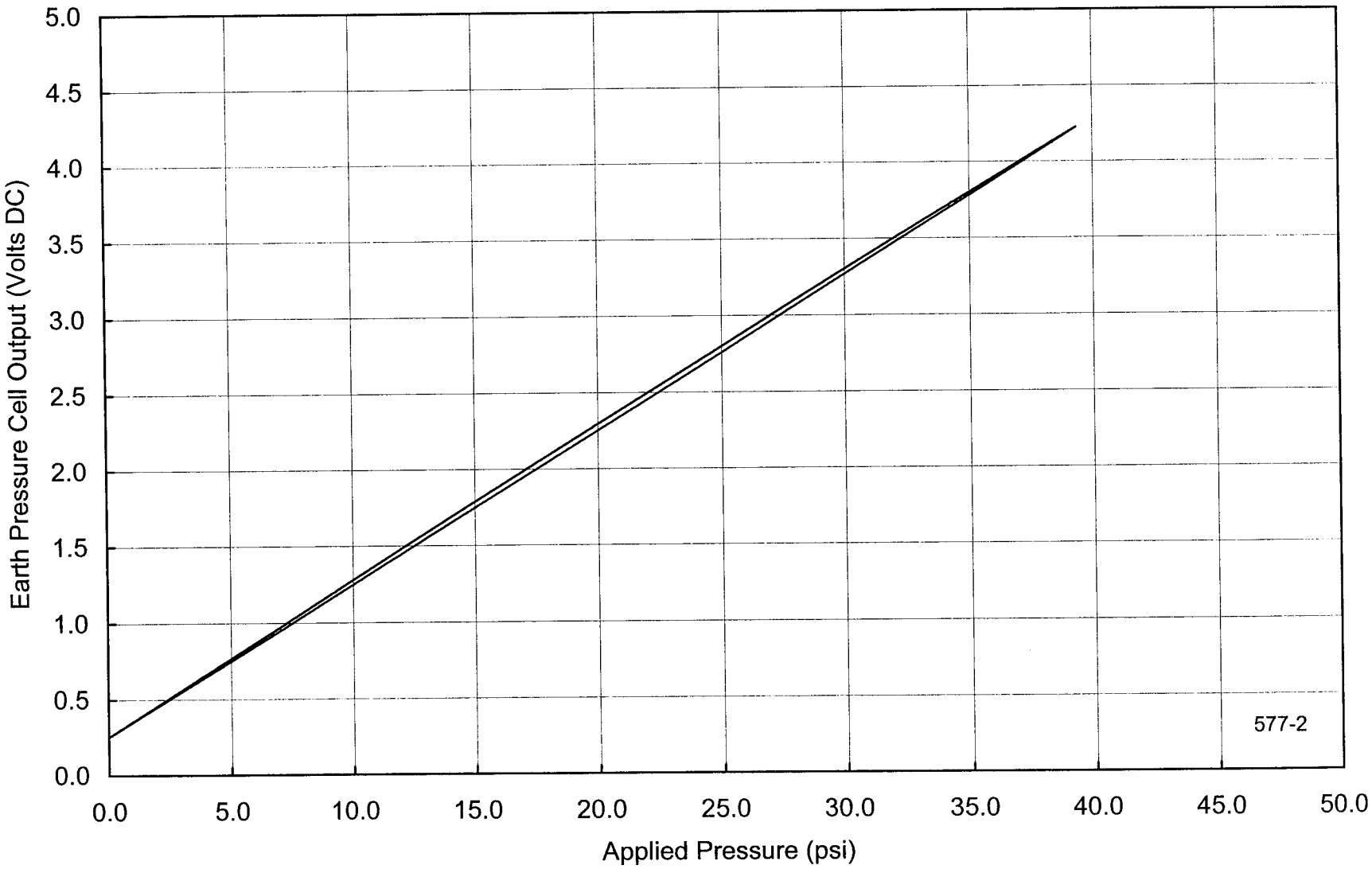

Figure A-50) Calibration record for the second calibration of earth pressure cell number 577 for the ODOT SHRP Test Road, Section 390203

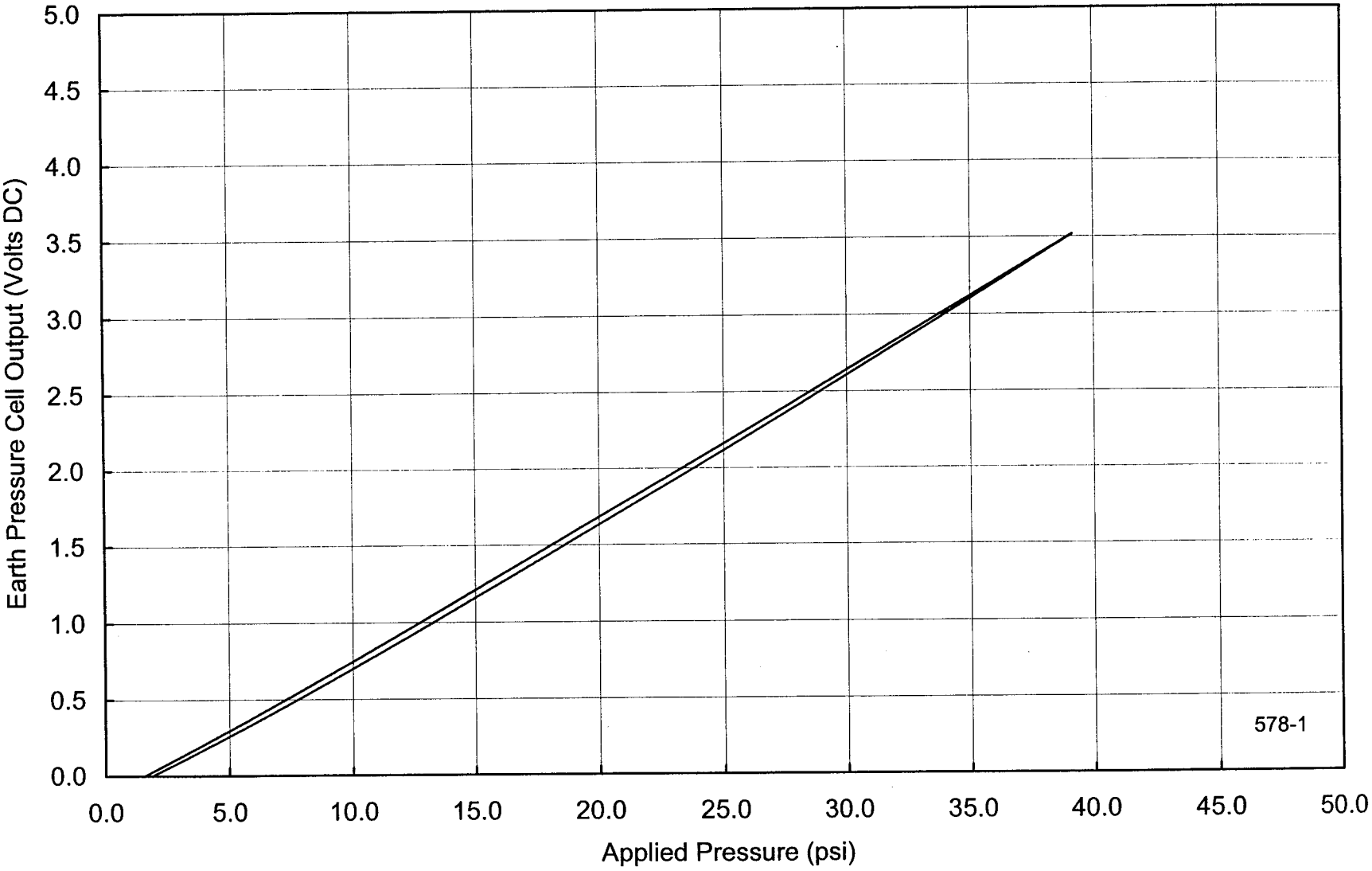

Figure A-51) Calibration record for the first calibration of earth pressure cell number 578 for the ODOT SHRP Test Road, Section 390207

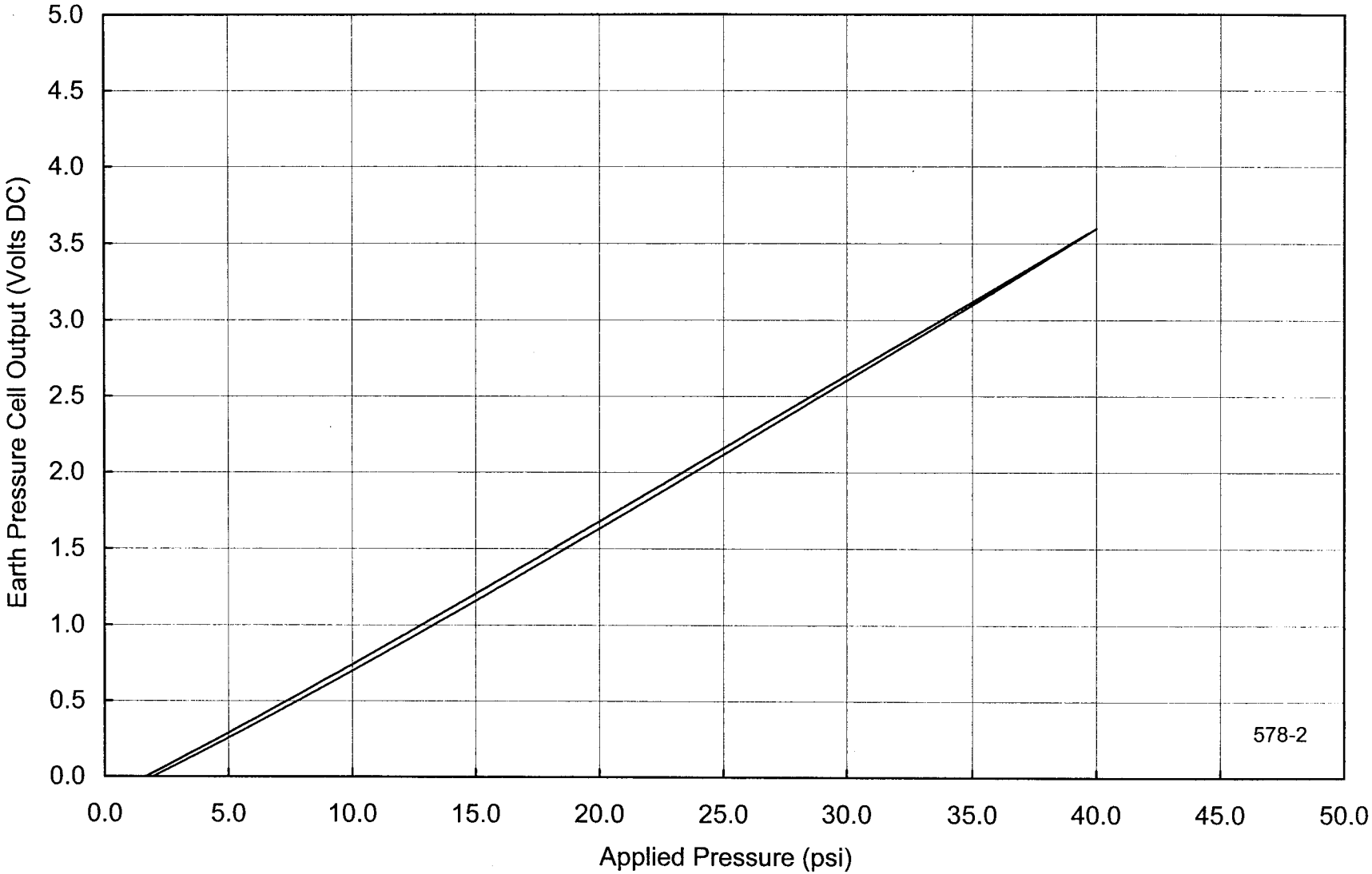

Figure A-52) Calibration record for the second calibration of earth pressure cell number 578 for the ODOT SHRP Test Road, Section 390207

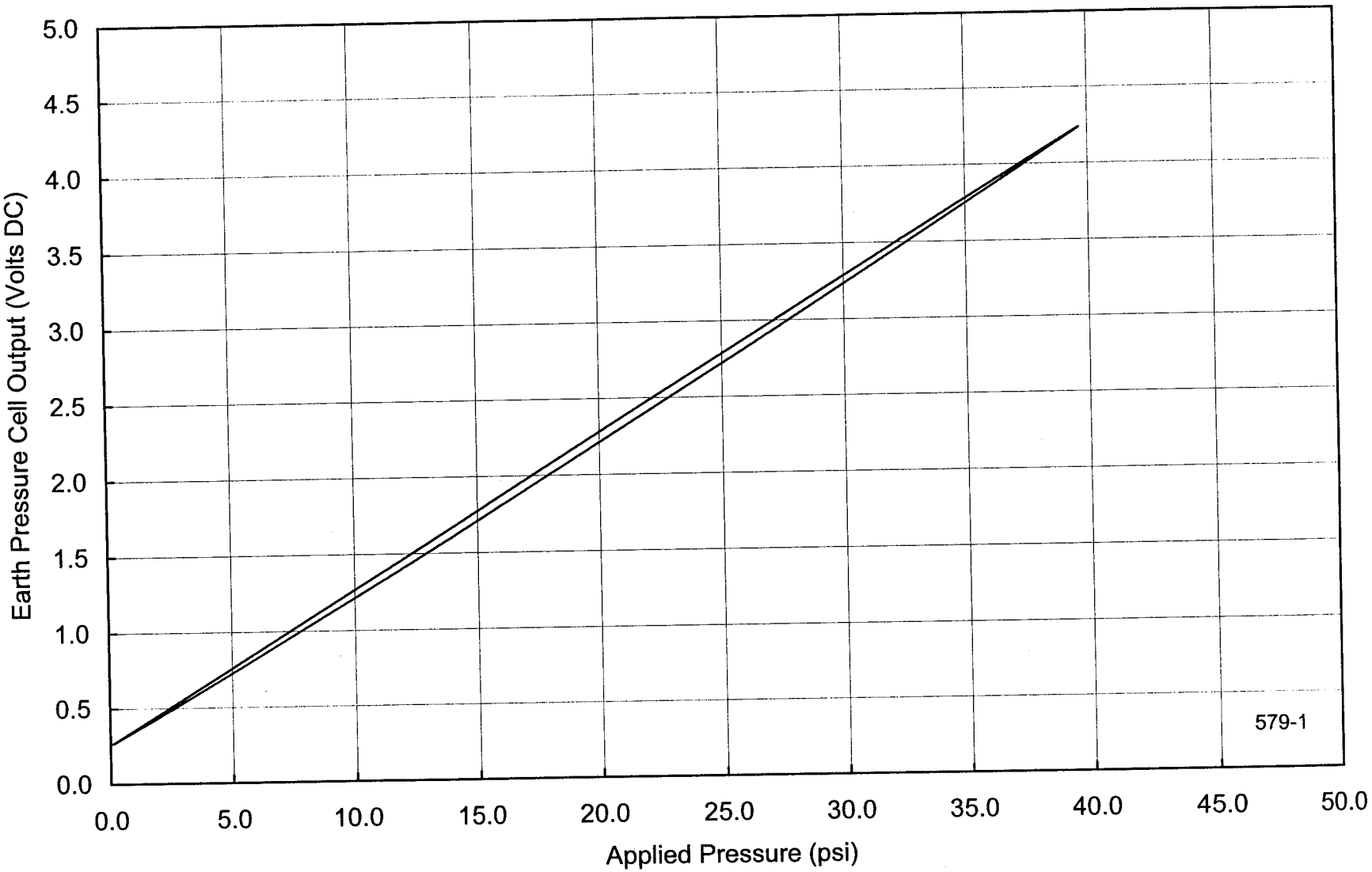

Figure A-53) Calibration record for the first calibration of earth pressure cell number 579 for the ODOT SHRP Test Road, Section 390902

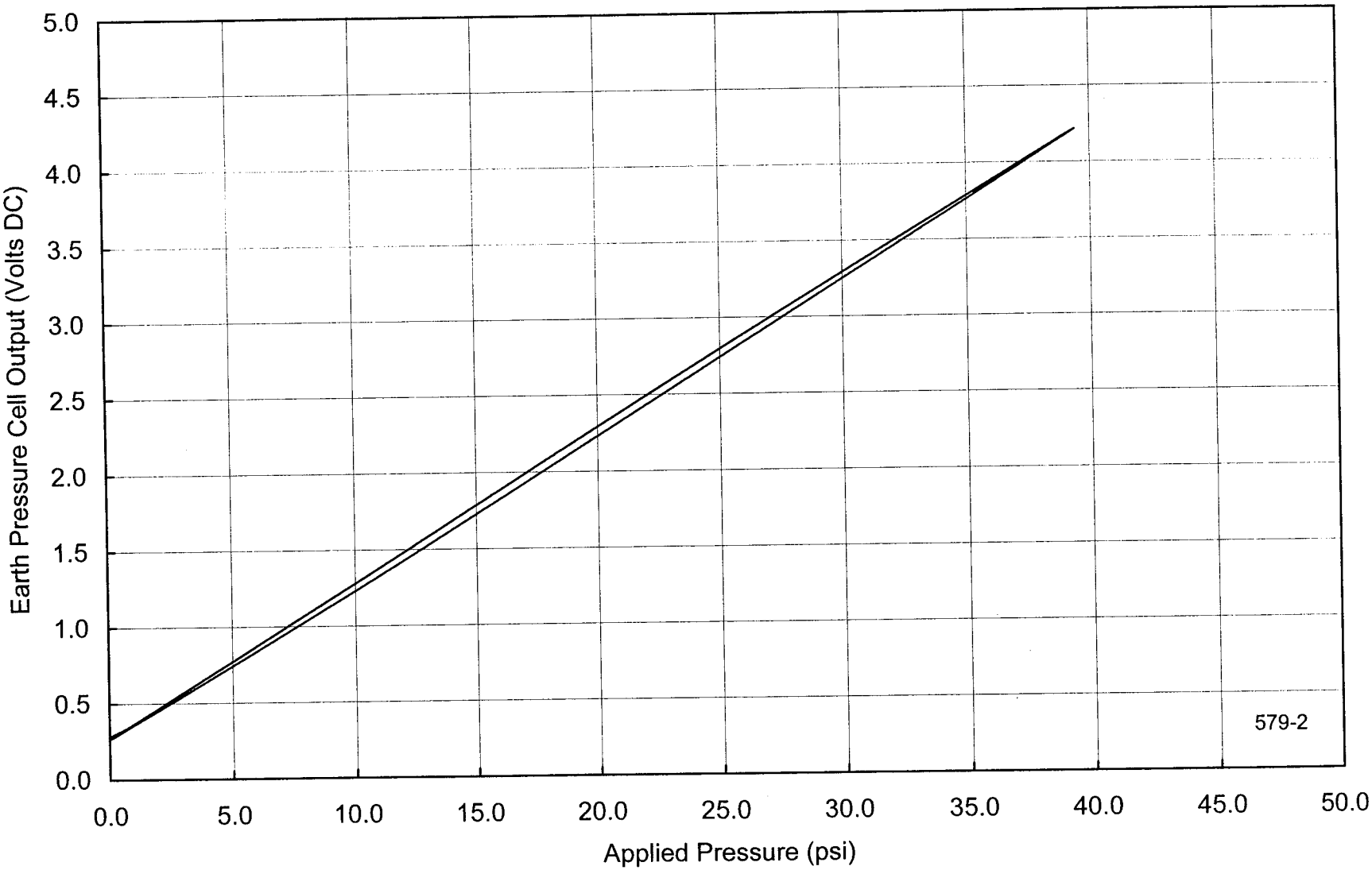

Figure A-54) Calibration record for the second calibration of earth pressure cell number 579 for the ODOT SHRP Test Road, Section 390902

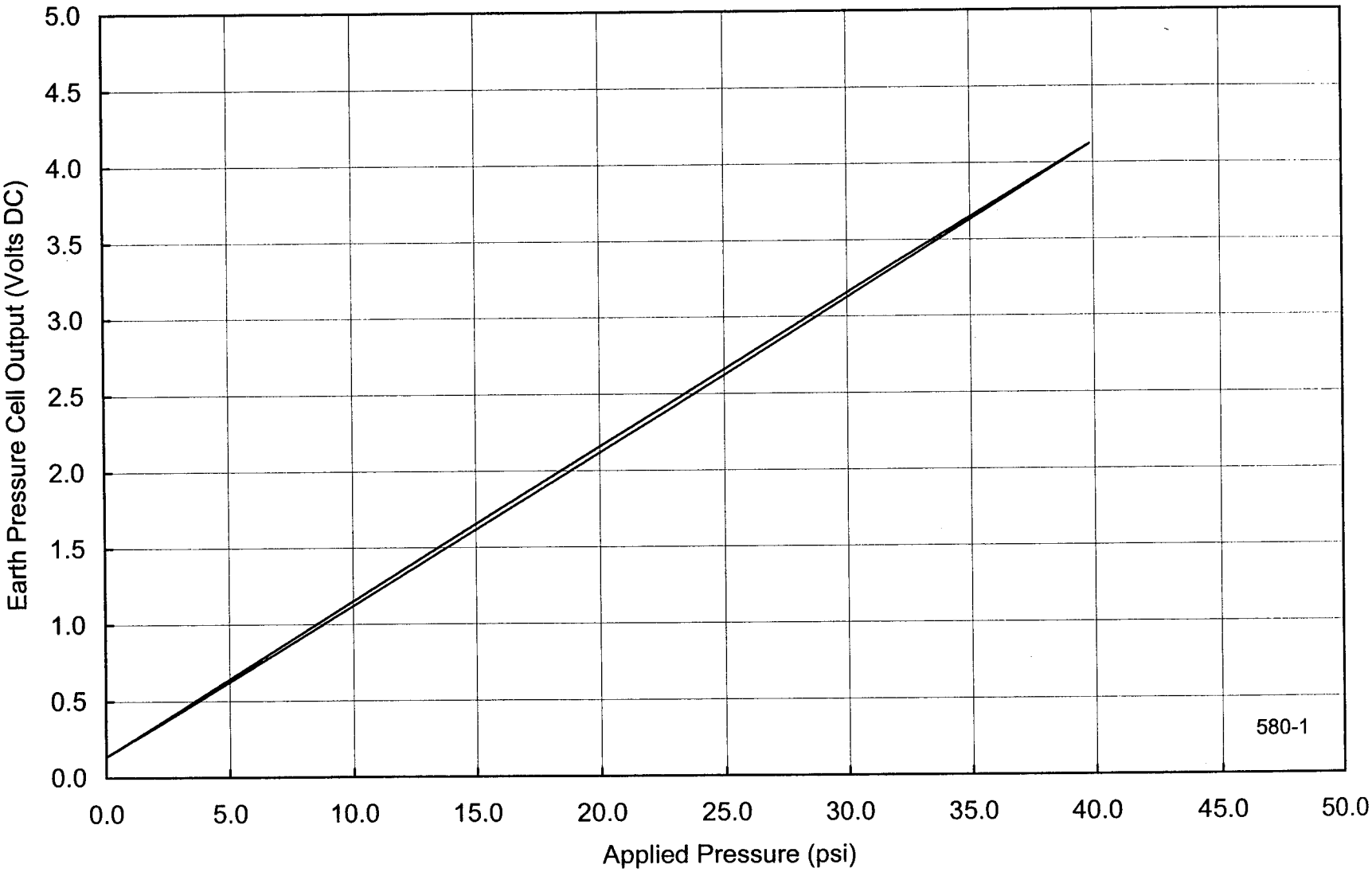

Figure A-55) Calibration record for the first calibration of earth pressure cell number 580 for the ODOT SHRP Test Road, Section 390207

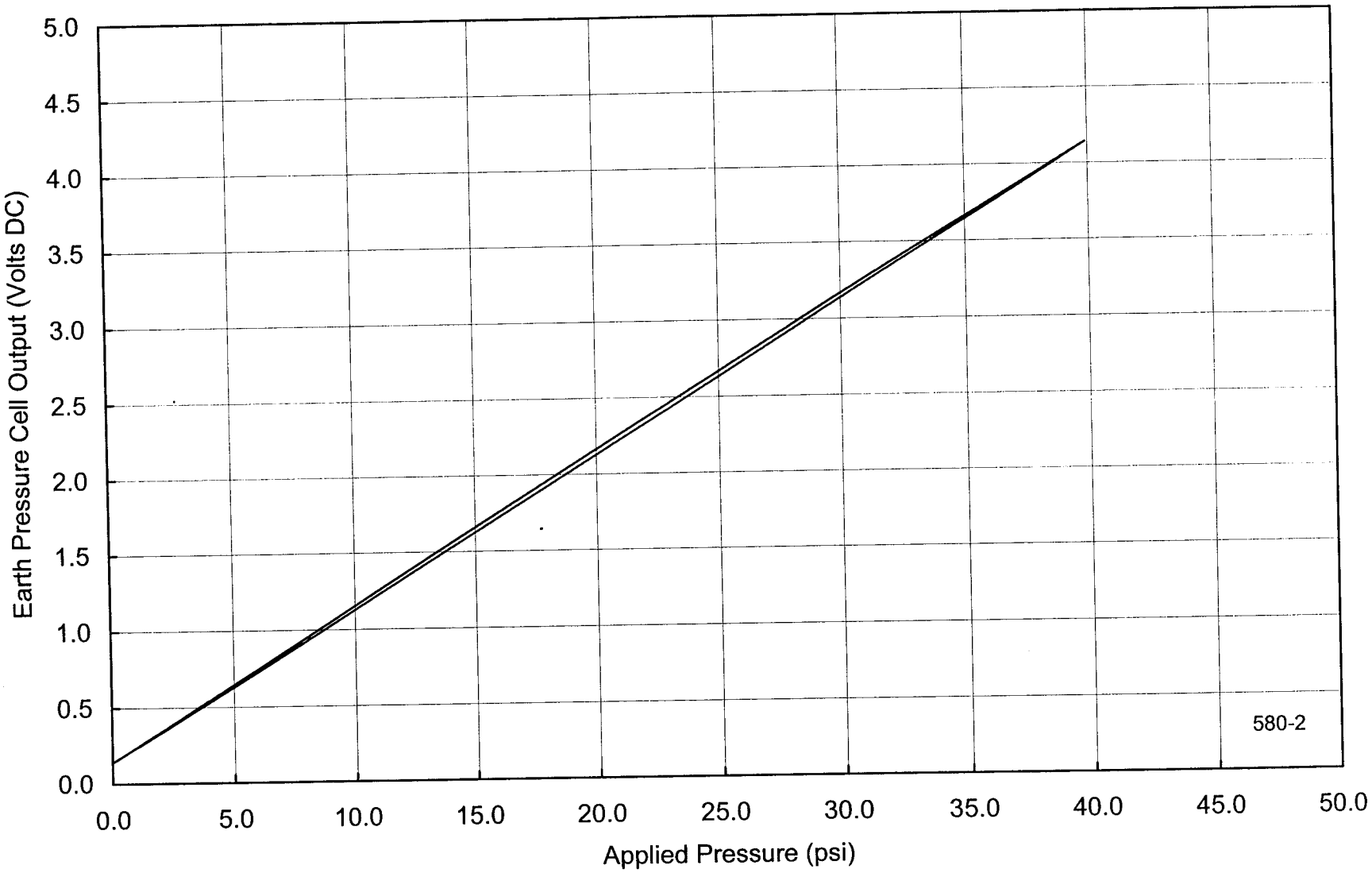

Figure A-56) Calibration record for the second calibration of earth pressure cell number 580 for the ODOT SHRP Test Road, Section 390207

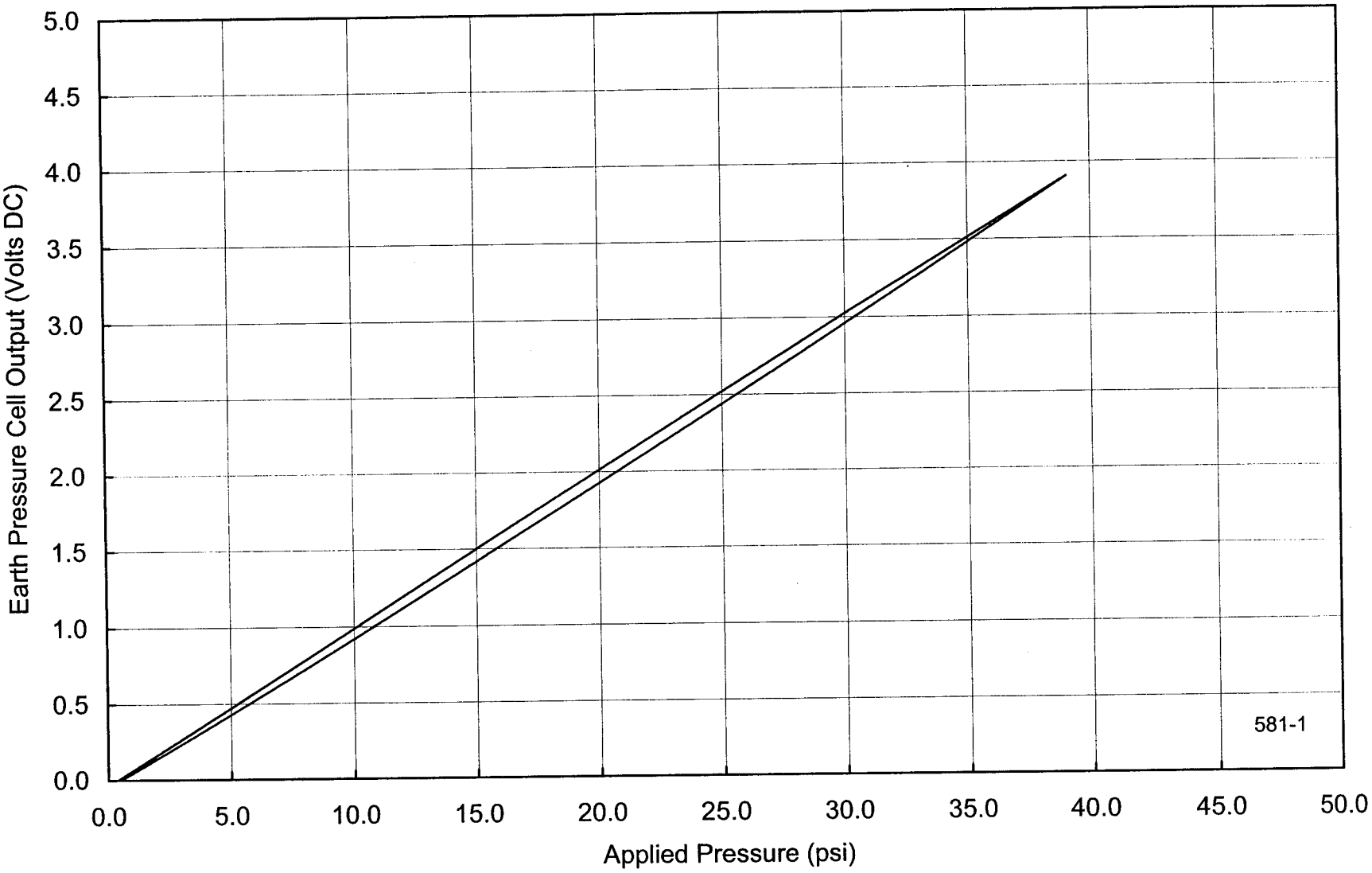

Figure A-57) Calibration record for the first calibration of earth pressure cell number 581 for the ODOT SHRP Test Road, Section 390112

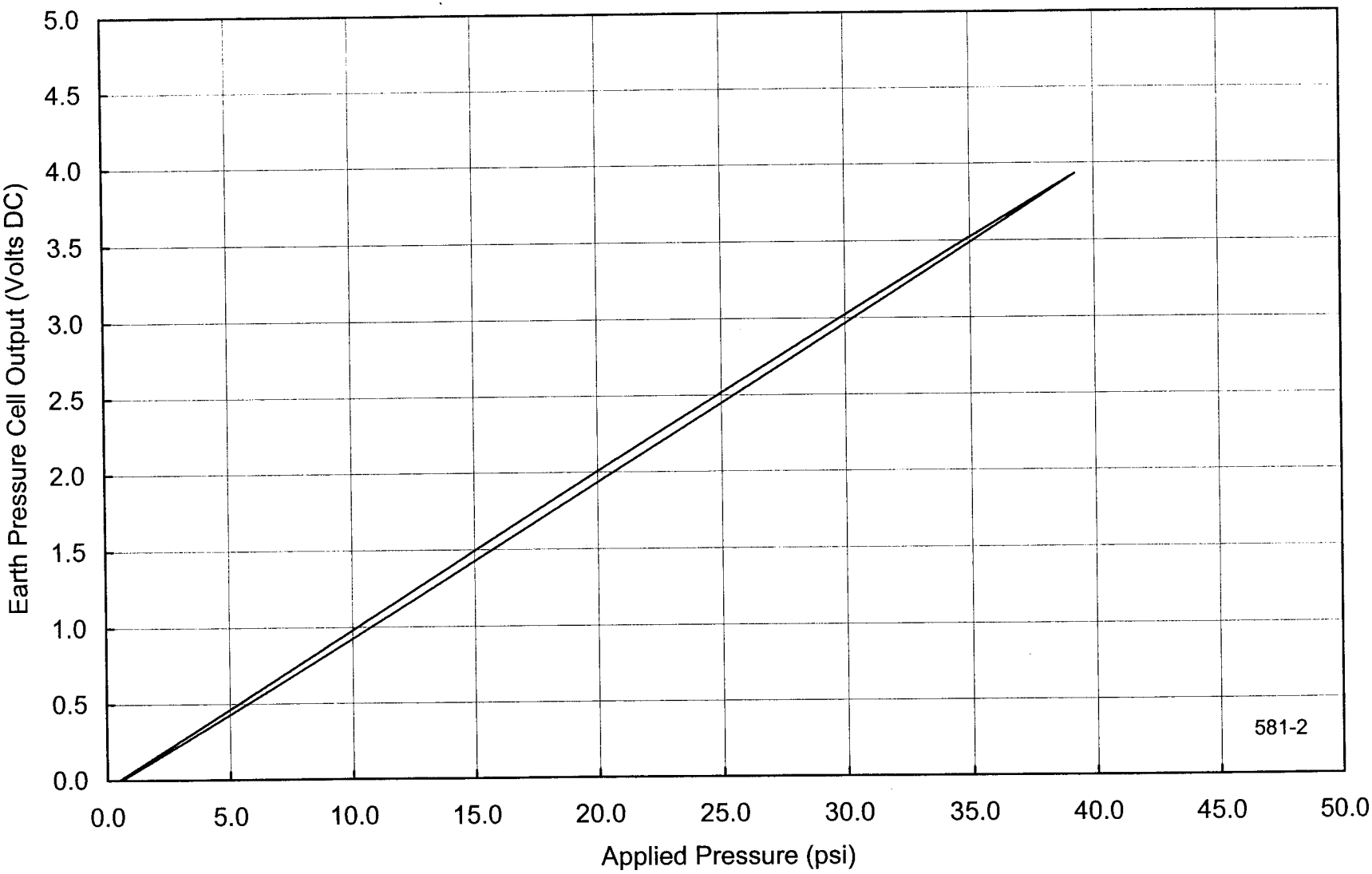

Figure A-58) Calibration record for the second calibration of earth pressure cell number 581 for the ODOT SHRP Test Road, Section 390112

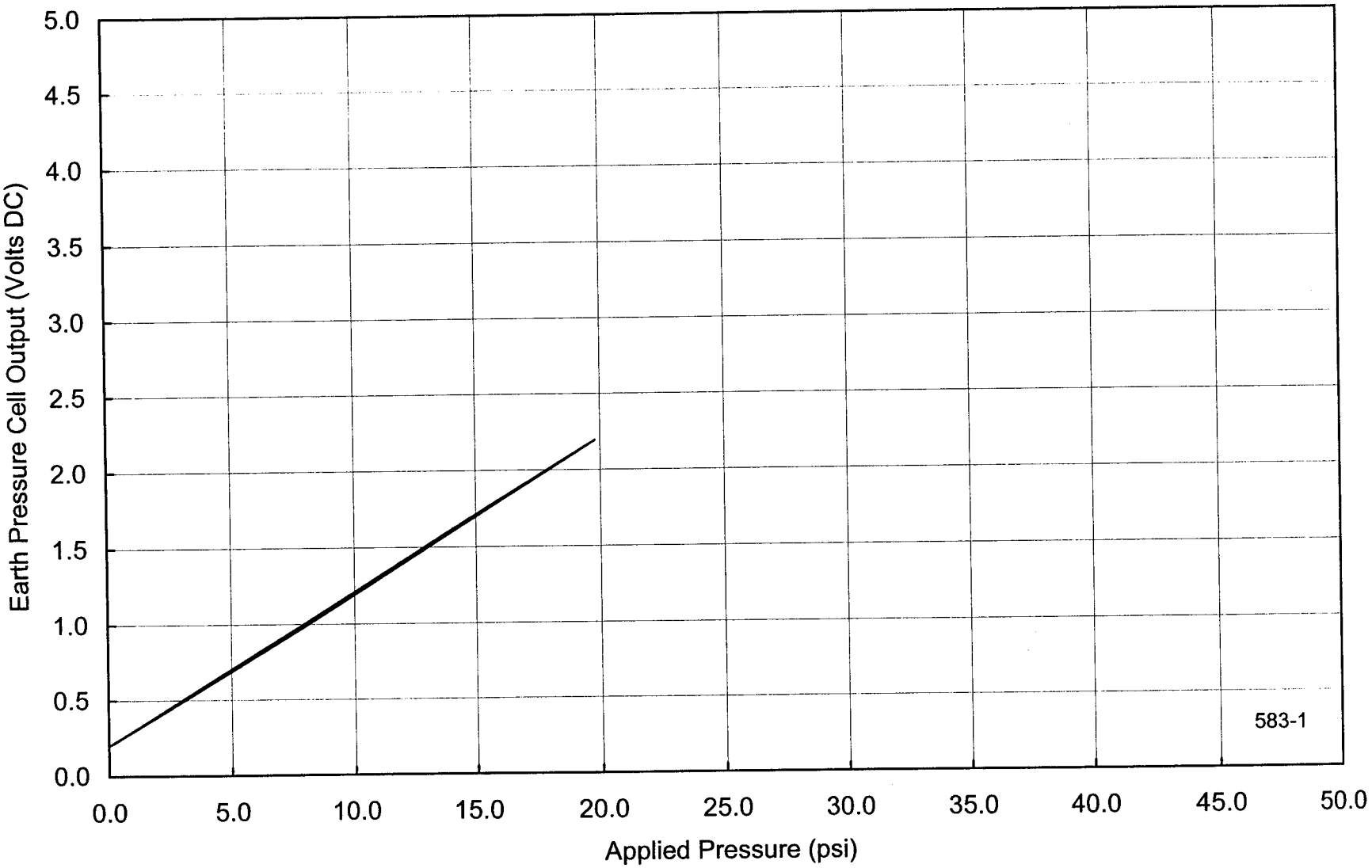

Figure A-59) Calibration record for the first calibration of earth pressure cell number 583 for the ODOT SHRP Test Road, Section 390208

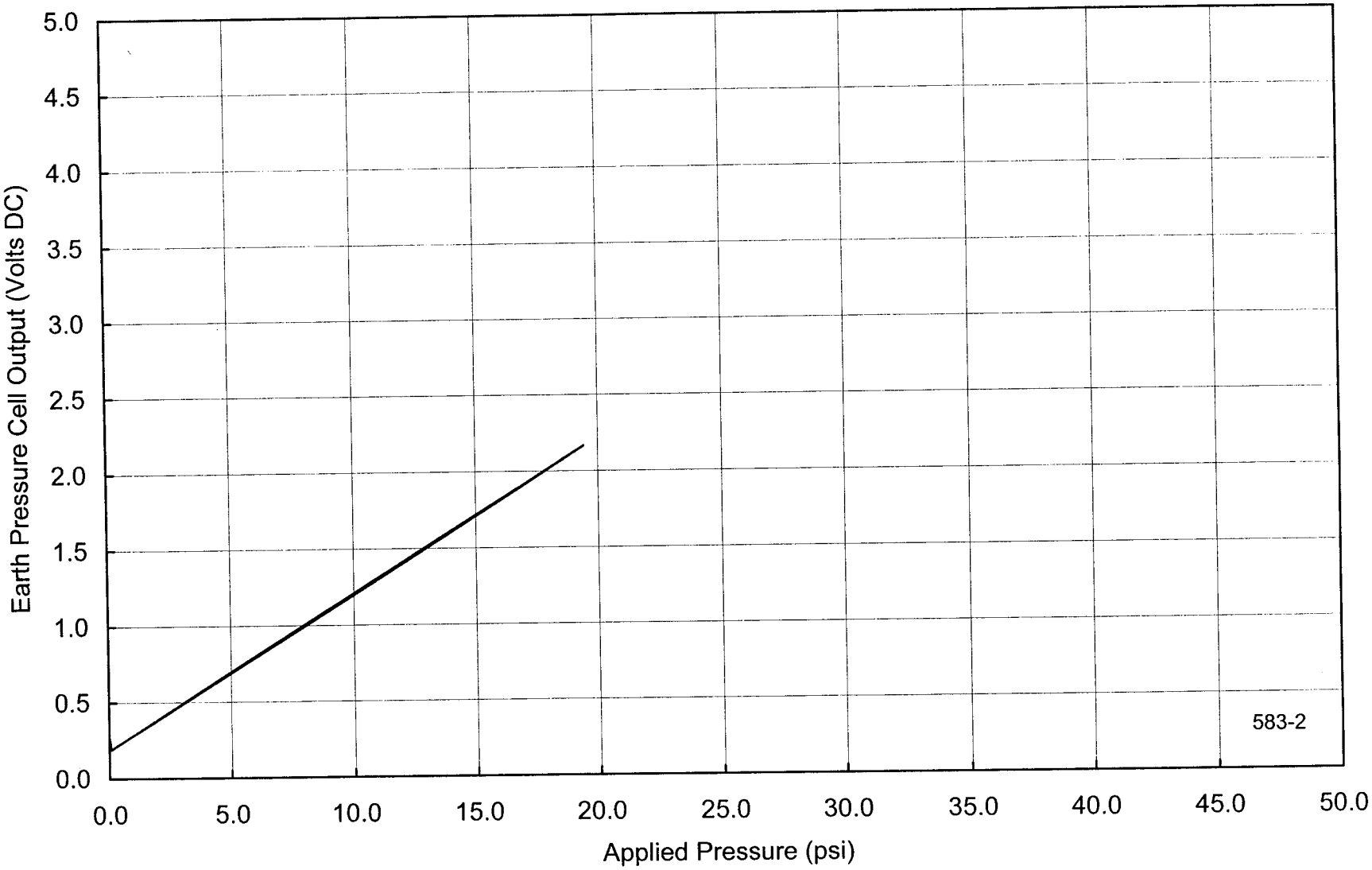

Figure A-60) Calibration record for the second calibration of earth pressure cell number 583 for the ODOT SHRP Test Road, Section 390208

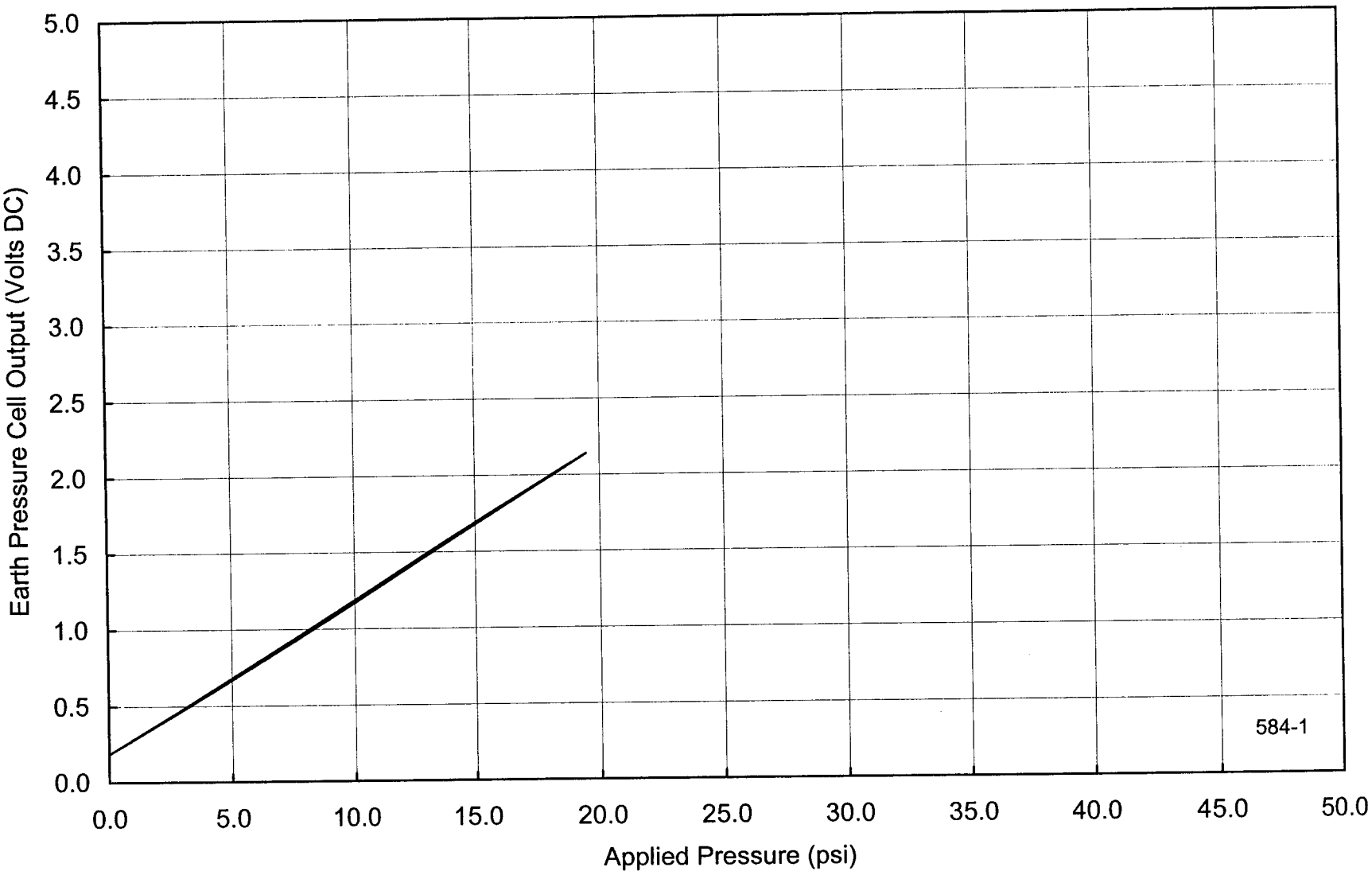

Figure A-61) Calibration record for the first calibration of earth pressure cell number 584 for the ODOT SHRP Test Road, Section 390208

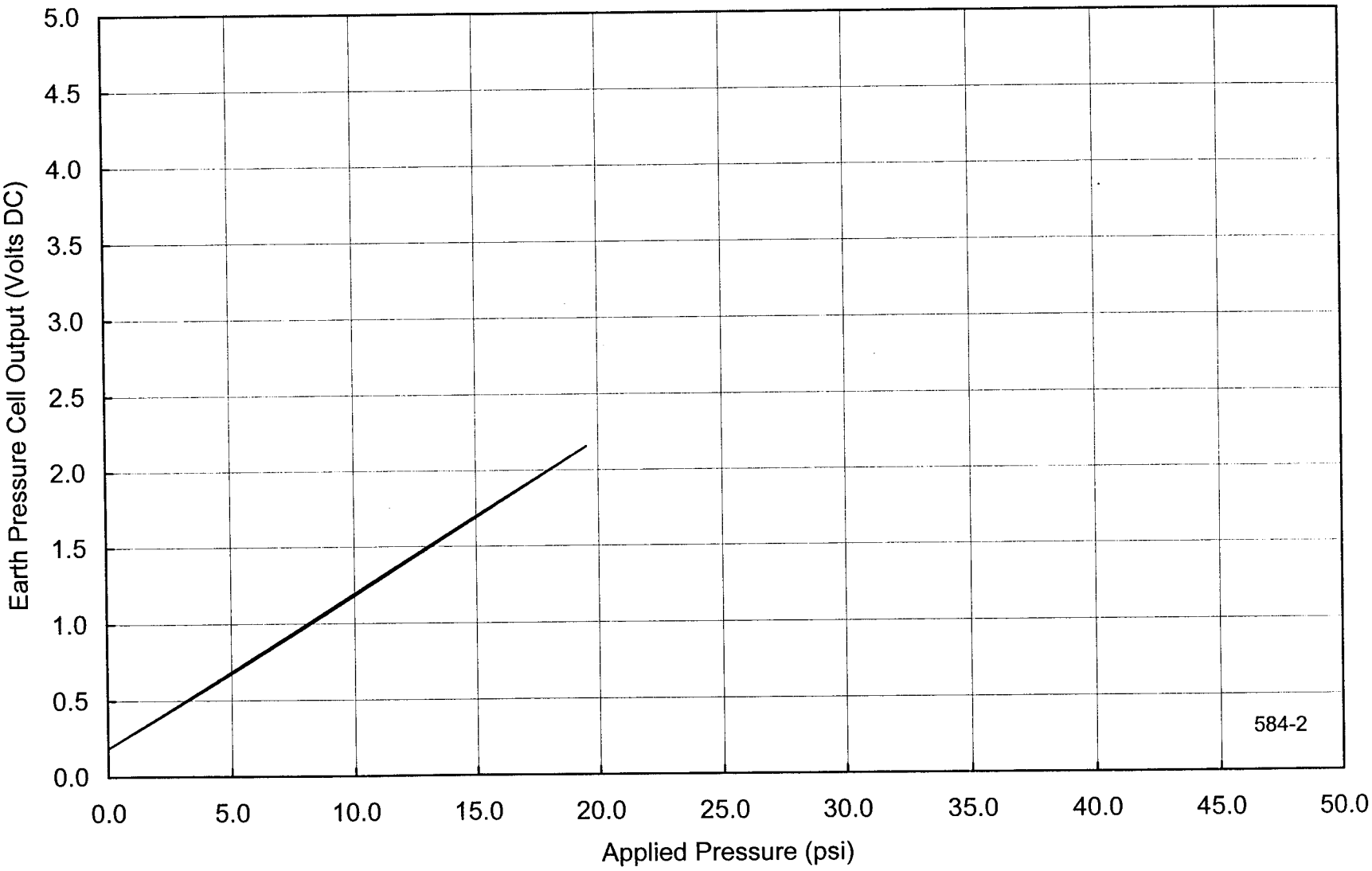

Figure A-62) Calibration record for the second calibration of earth pressure cell number 584 for the ODOT SHRP Test Road, Section 390208

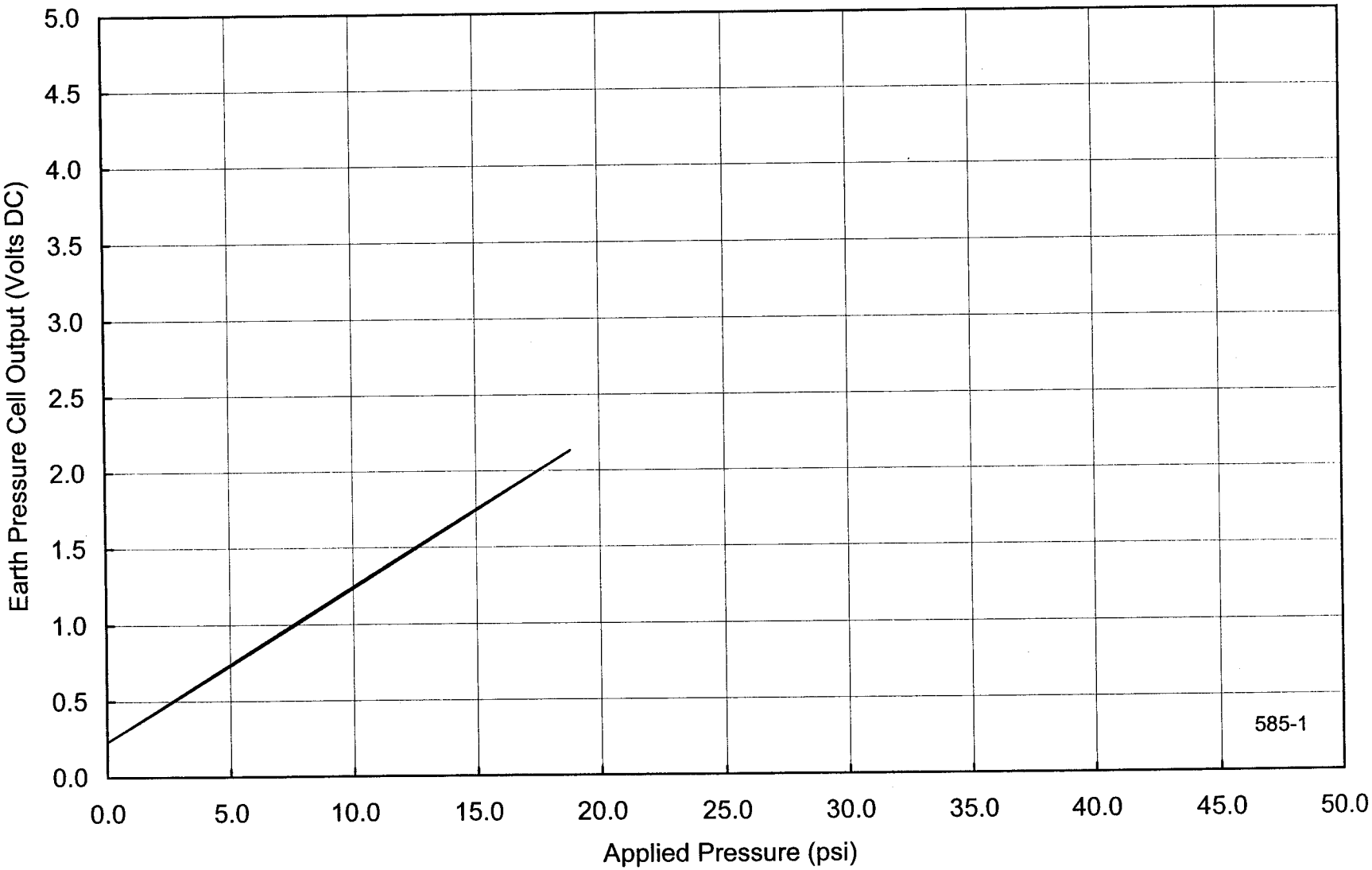

Figure A-63) Calibration record for the first calibration of earth pressure cell number 585 for the ODOT SHRP Test Road, Section 390262

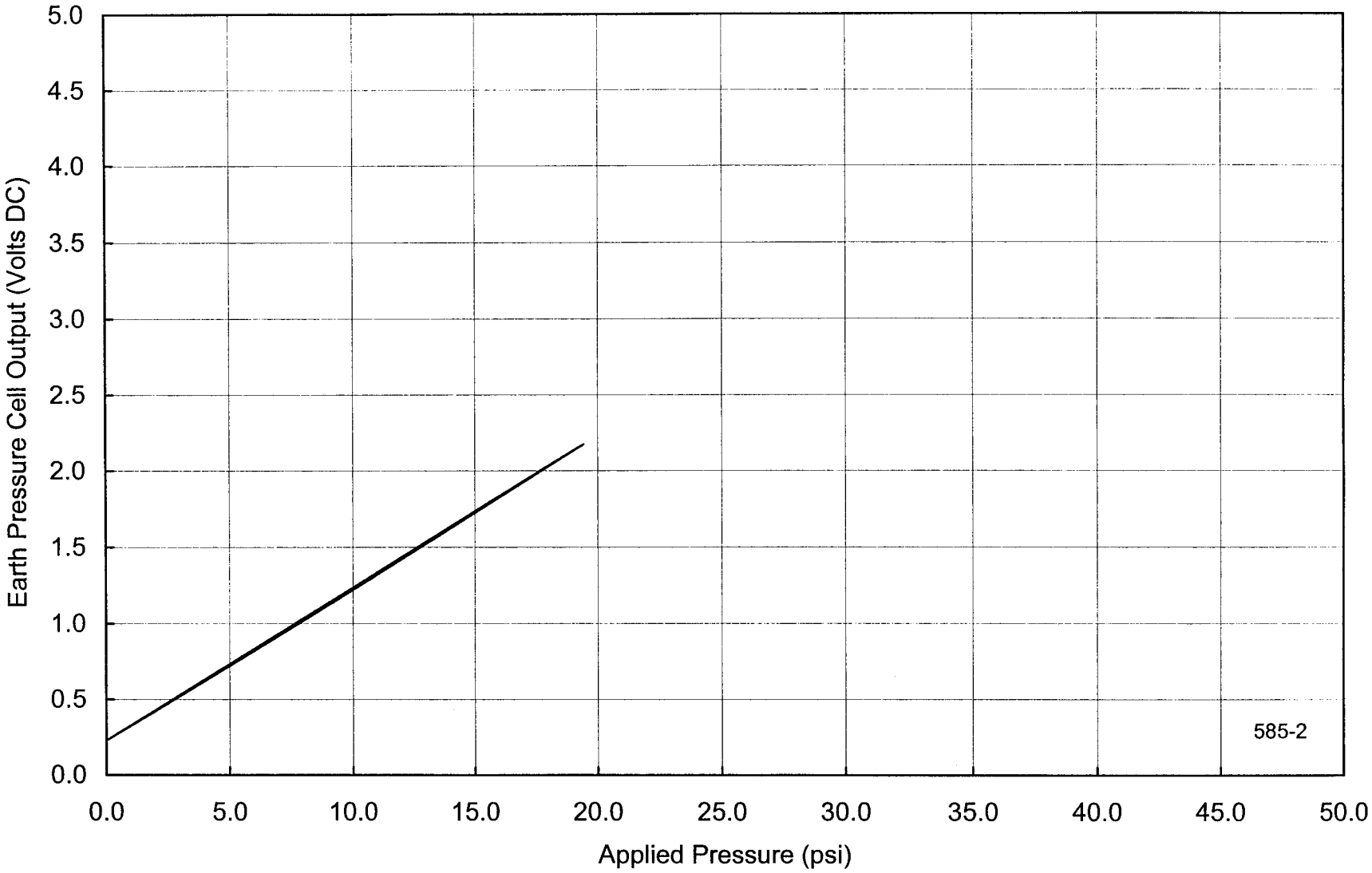

Figure A-64) Calibration record for the second calibration of earth pressure cell number 585 for the ODOT SHRP Test Road, Section 390262

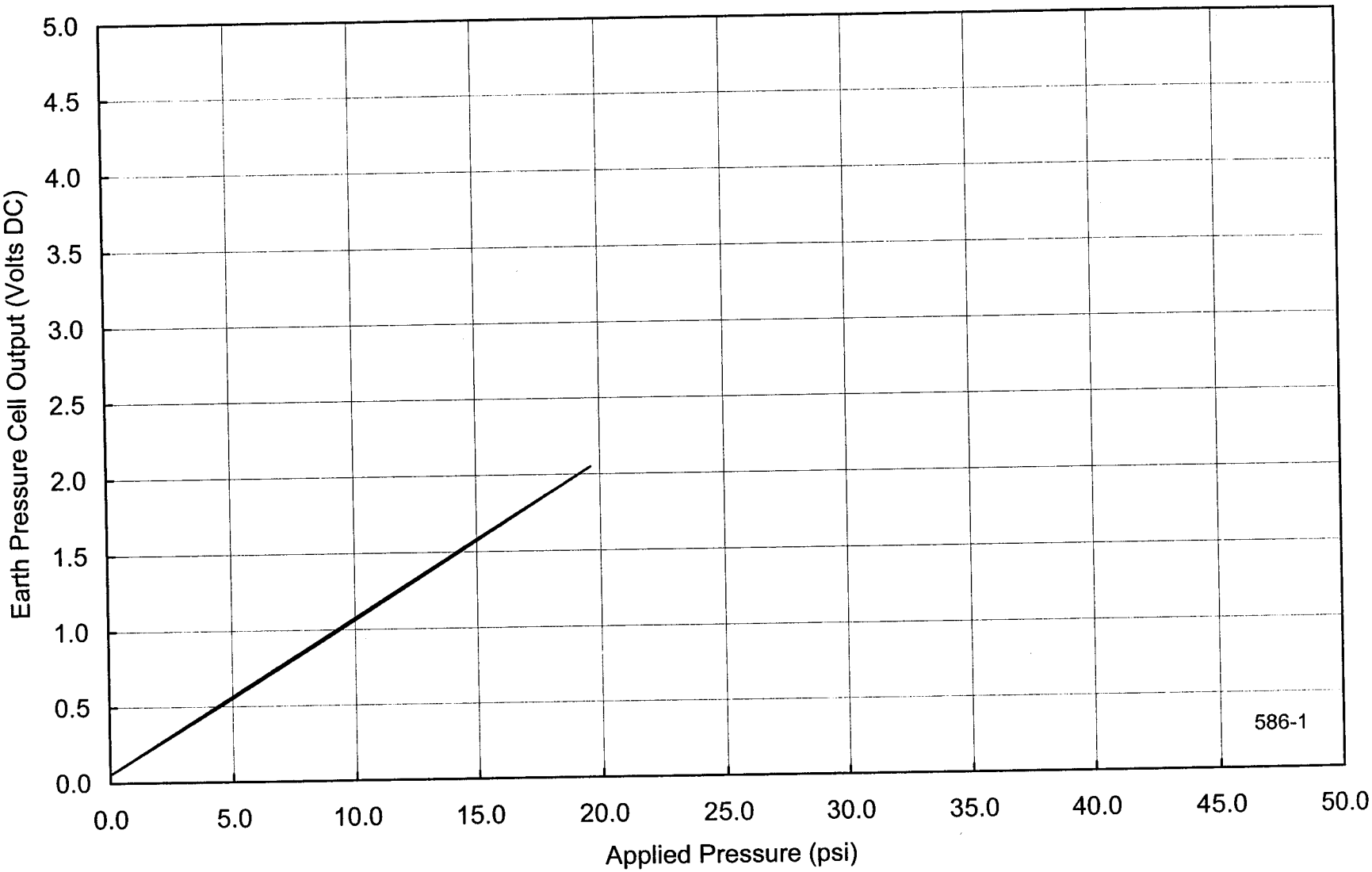

Figure A-65) Calibration record for the first calibration of earth pressure cell number 586 for the ODOT SHRP Test Road, Section 390262

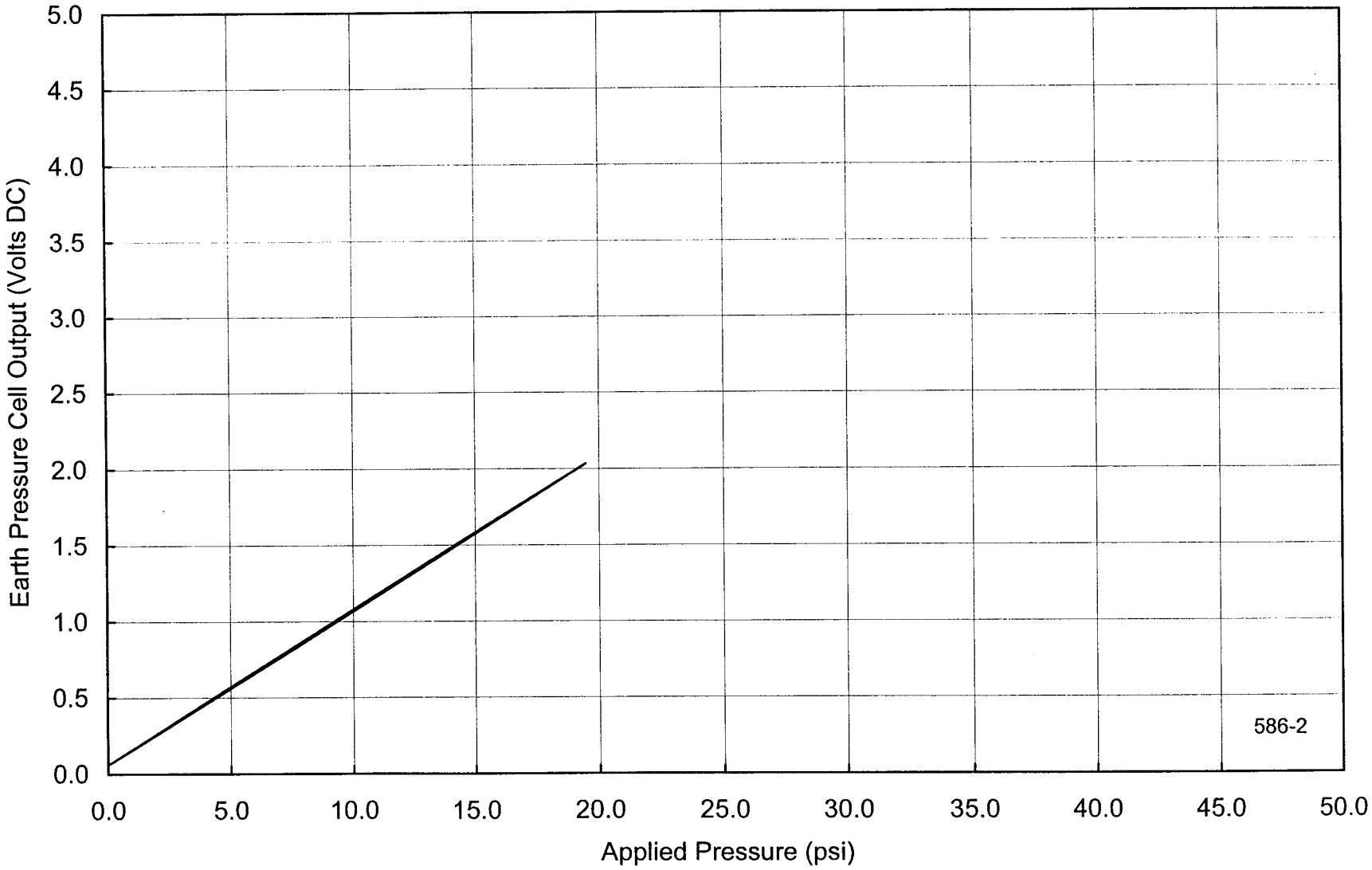

Figure A-66) Calibration record for the second calibration of earth pressure cell number 586 for the ODOT SHRP Test Road, Section 390262

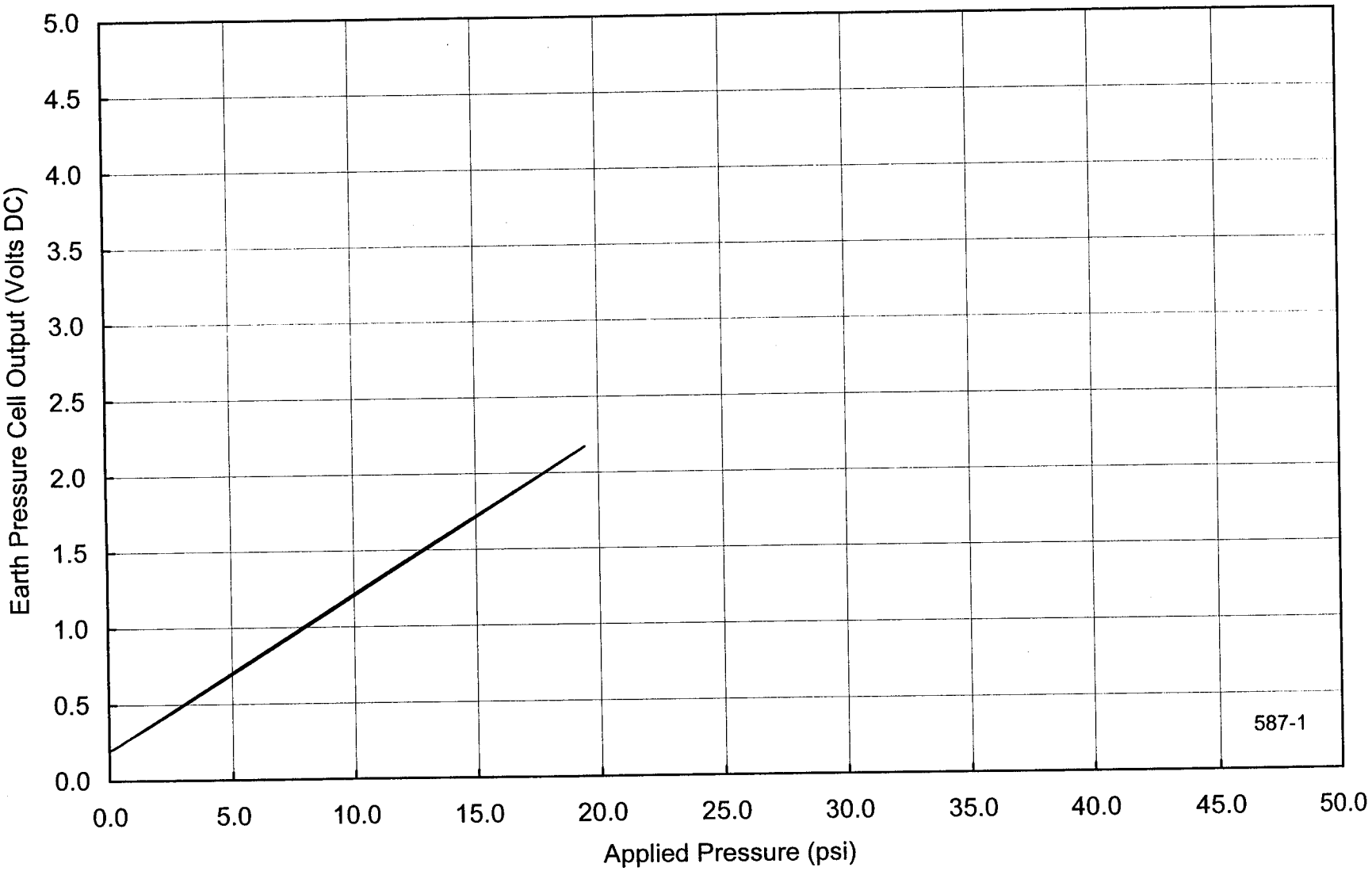

Figure A-67) Calibration record for the first calibration of earth pressure cell number 587 for the ODOT SHRP Test Road, Section 390263

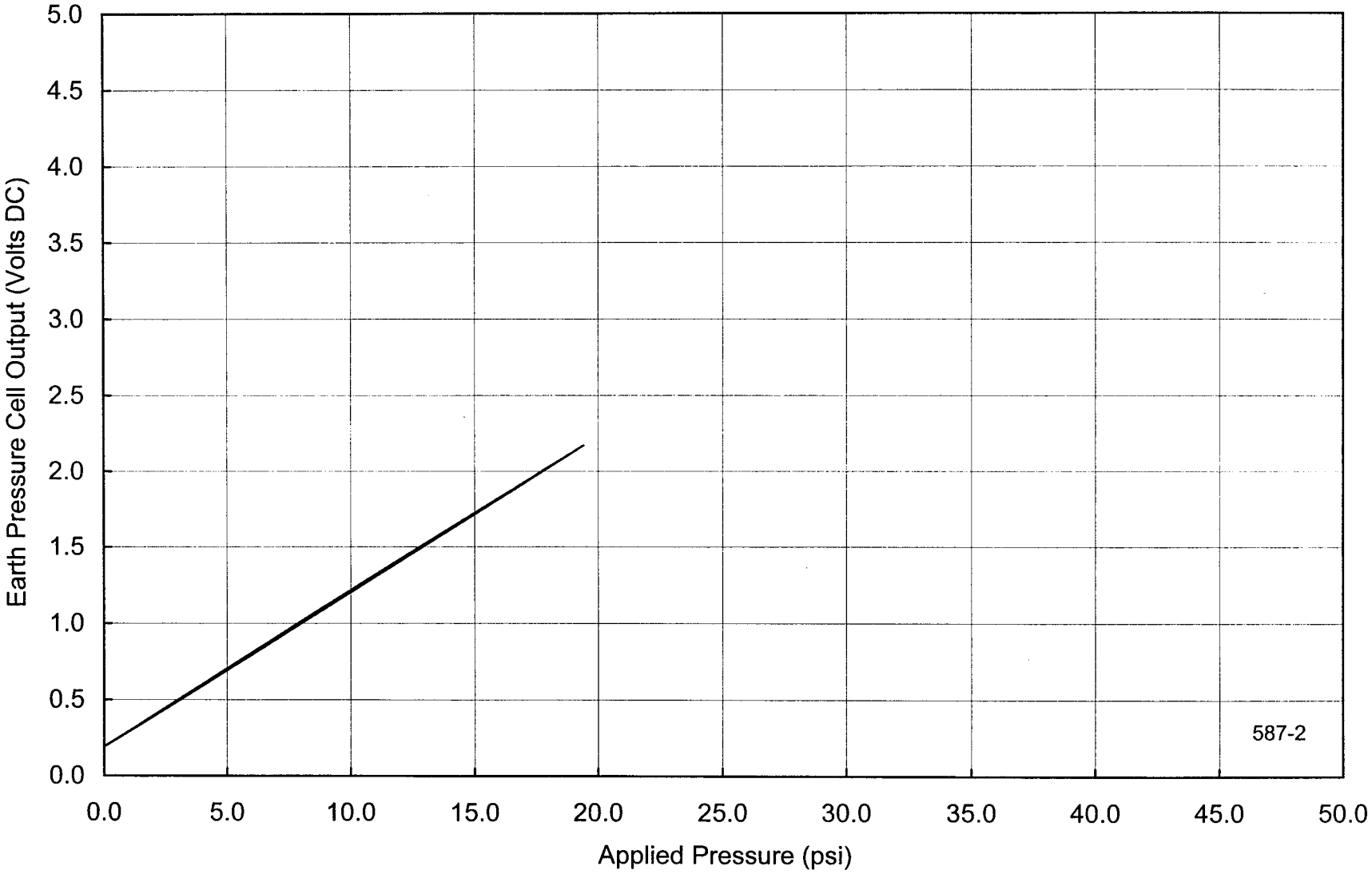

Figure A-68) Calibration record for the second calibration of earth pressure cell number 587 for the ODOT SHRP Test Road, Section 390263

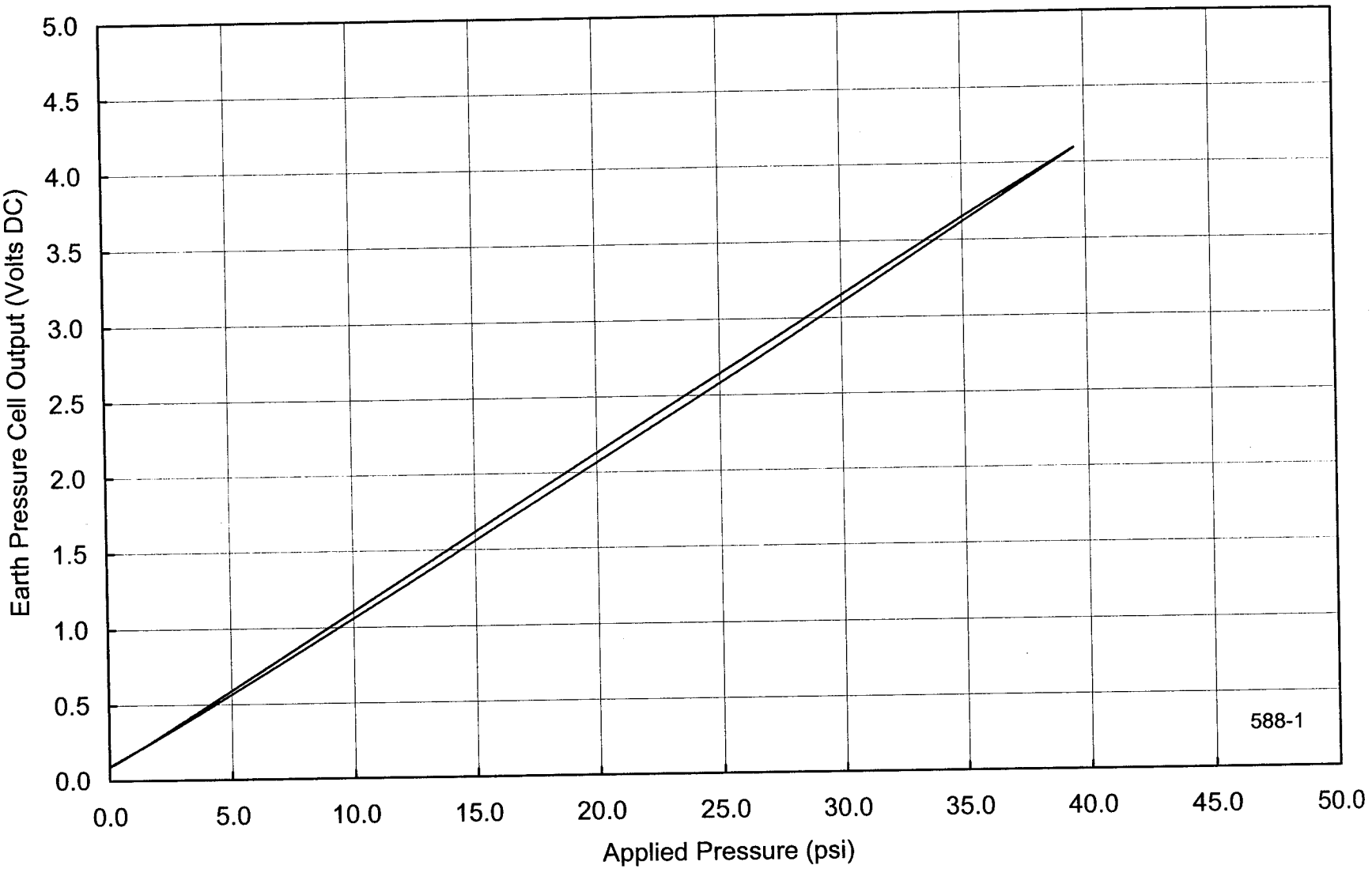

Figure A-69) Calibration record for the first calibration of earth pressure cell number 588 for the ODOT SHRP Test Road, Section 390112

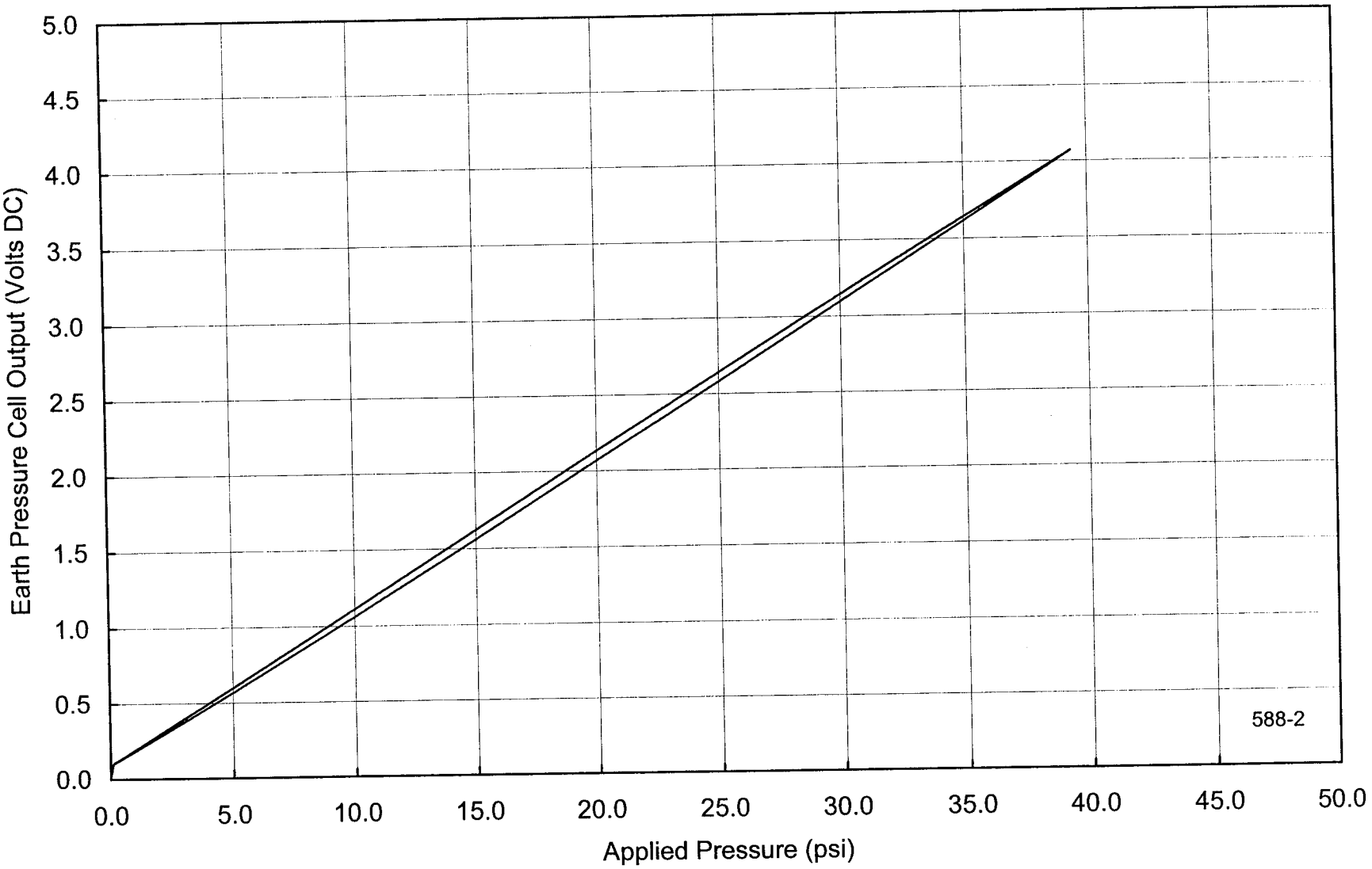

Figure A-70) Calibration record for the second calibration of earth pressure cell number 588 for the ODOT SHRP Test Road, Section 390112

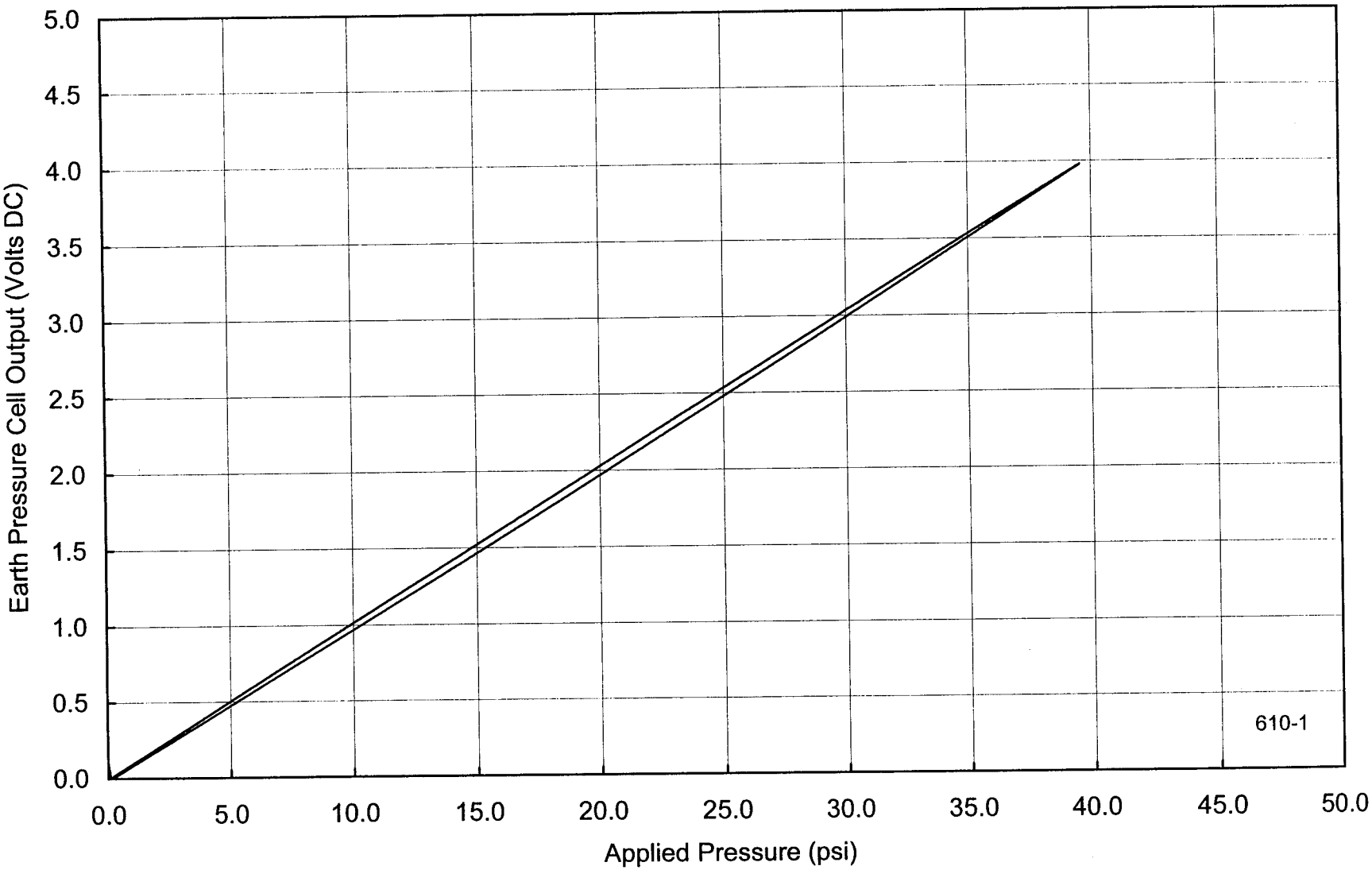

Figure A-71) Calibration record for the first calibration of earth pressure cell number 610 for the ODOT SHRP Test Road, Section 390111

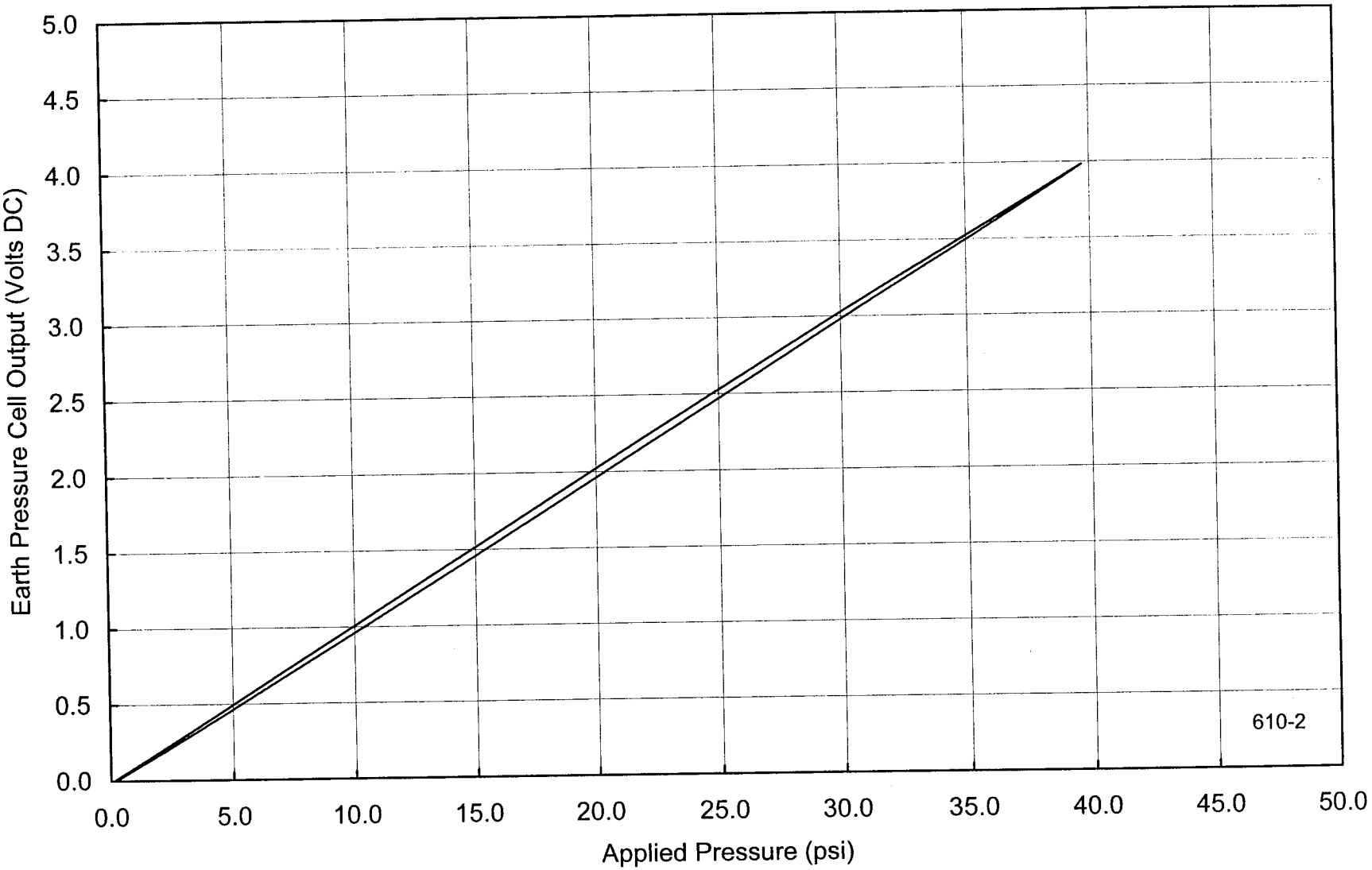

Figure A-72) Calibration record for the second calibration of earth pressure cell number 610 for the ODOT SHRP Test Road, Section 390111

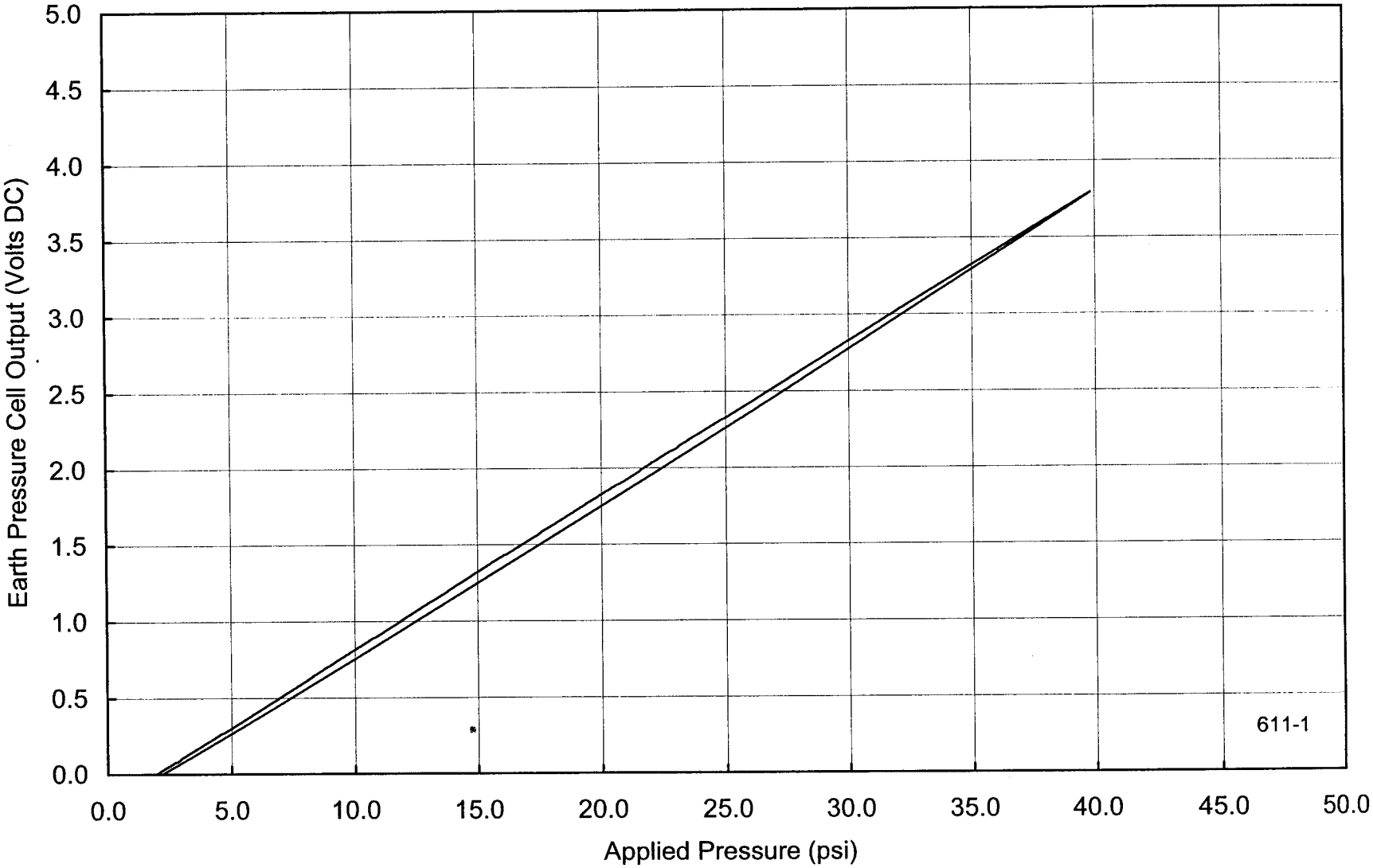

Figure A-73) Calibration record for the first calibration of earth pressure cell number 611 for the ODOT SHRP Test Road, Section 390111

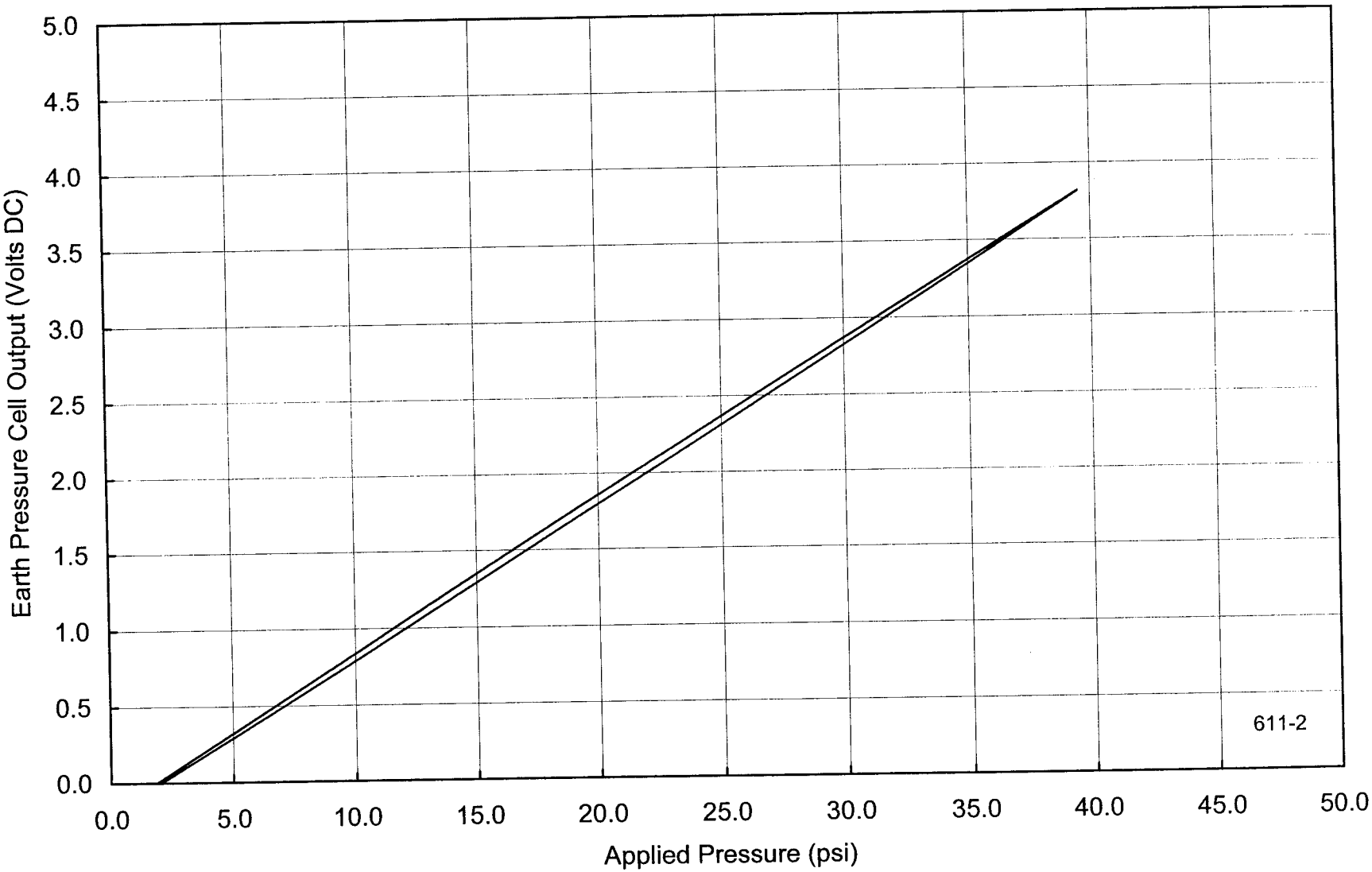

Figure A-74) Calibration record for the second calibration of earth pressure cell number 611 for the ODOT SHRP Test Road, Section 390111

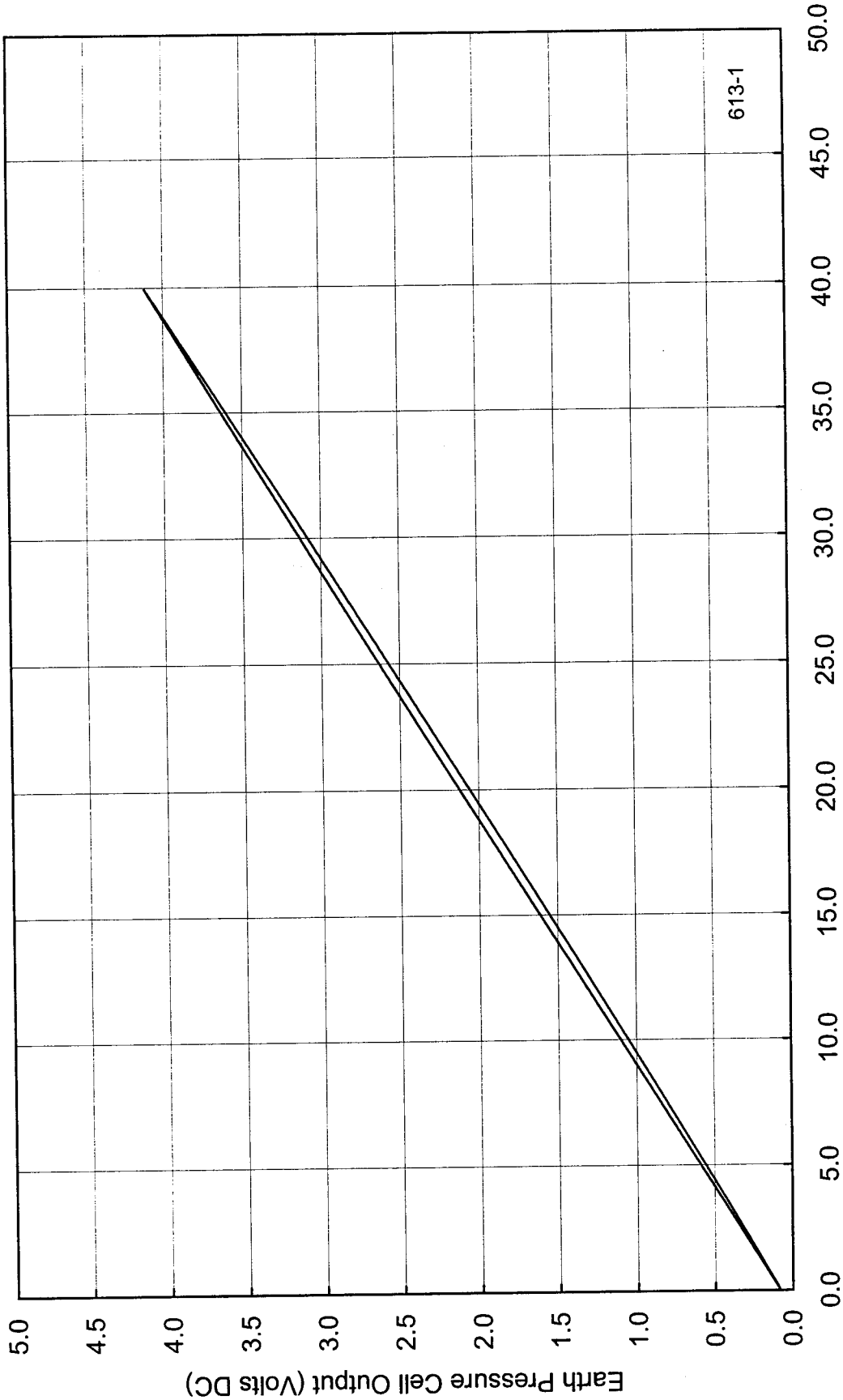

Figure A-75) Calibration record for the first calibration of earth pressure cell number 613 for the ODOT SHRP Test Road, Section 390108

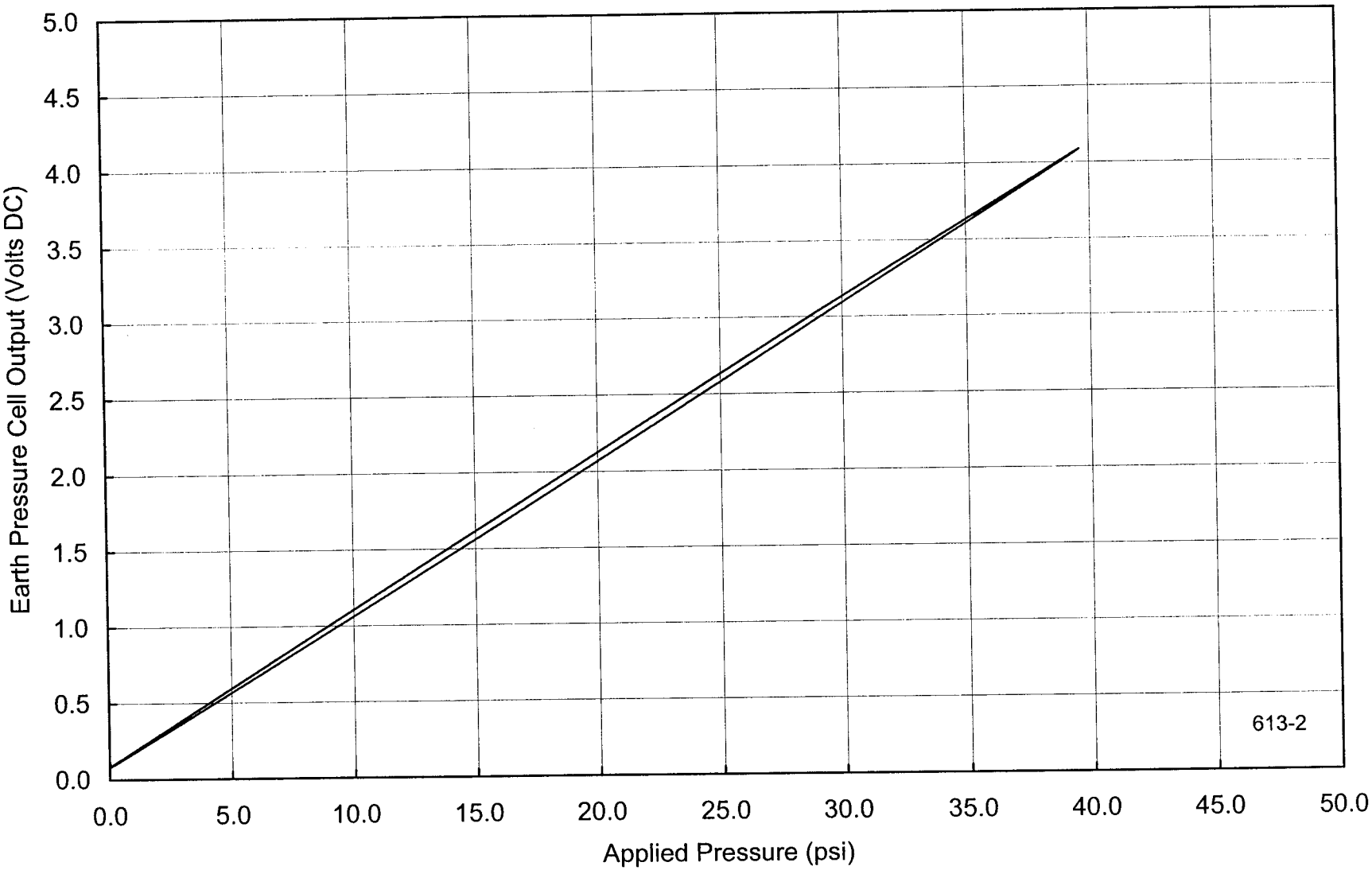

Figure A-76) Calibration record for the second calibration of earth pressure cell number 613 for the ODOT SHRP Test Road, Section 390108

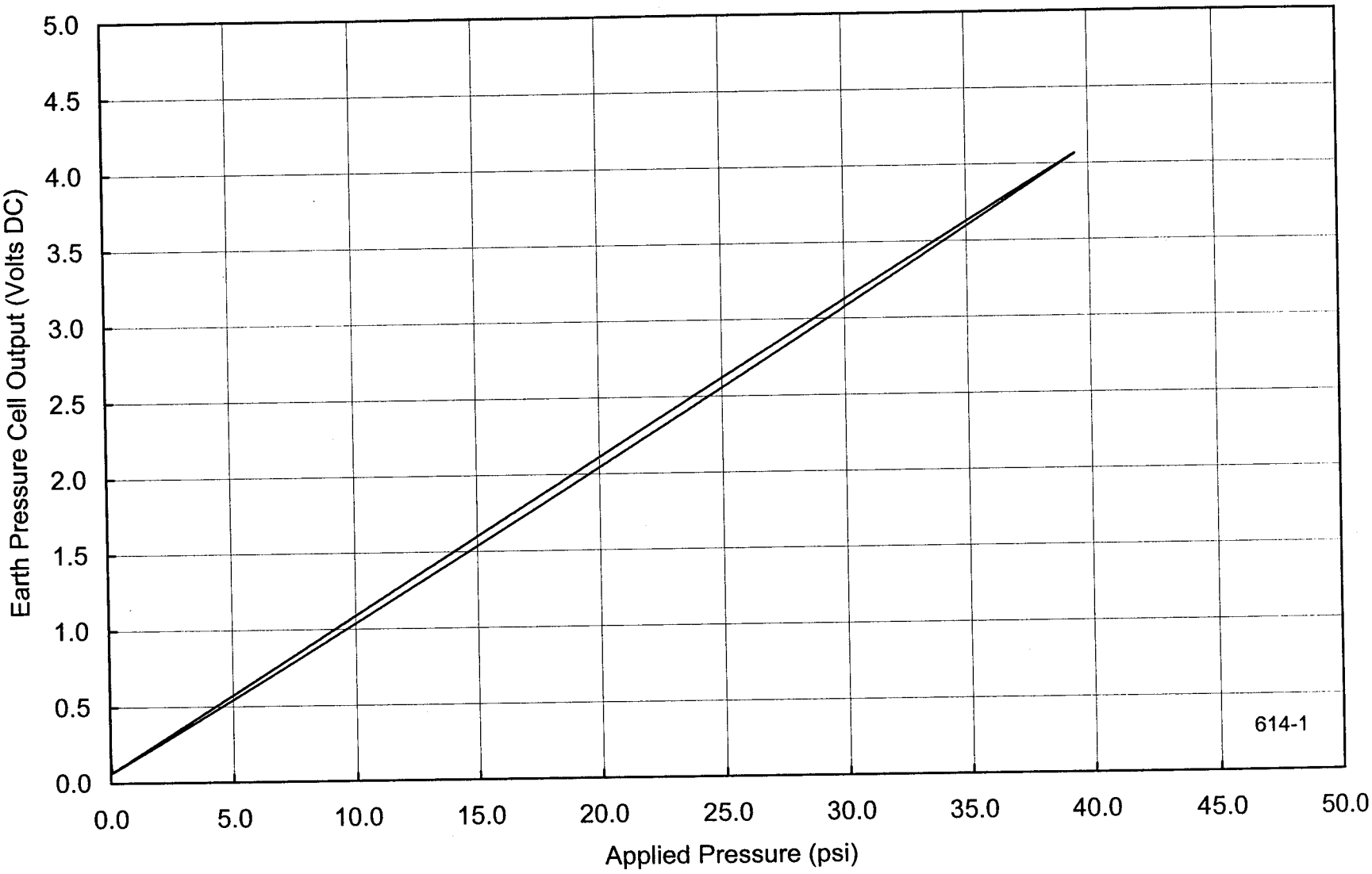

Figure A-77) Calibration record for the first calibration of earth pressure cell number 614 for the ODOT SHRP Test Road, Section 390104

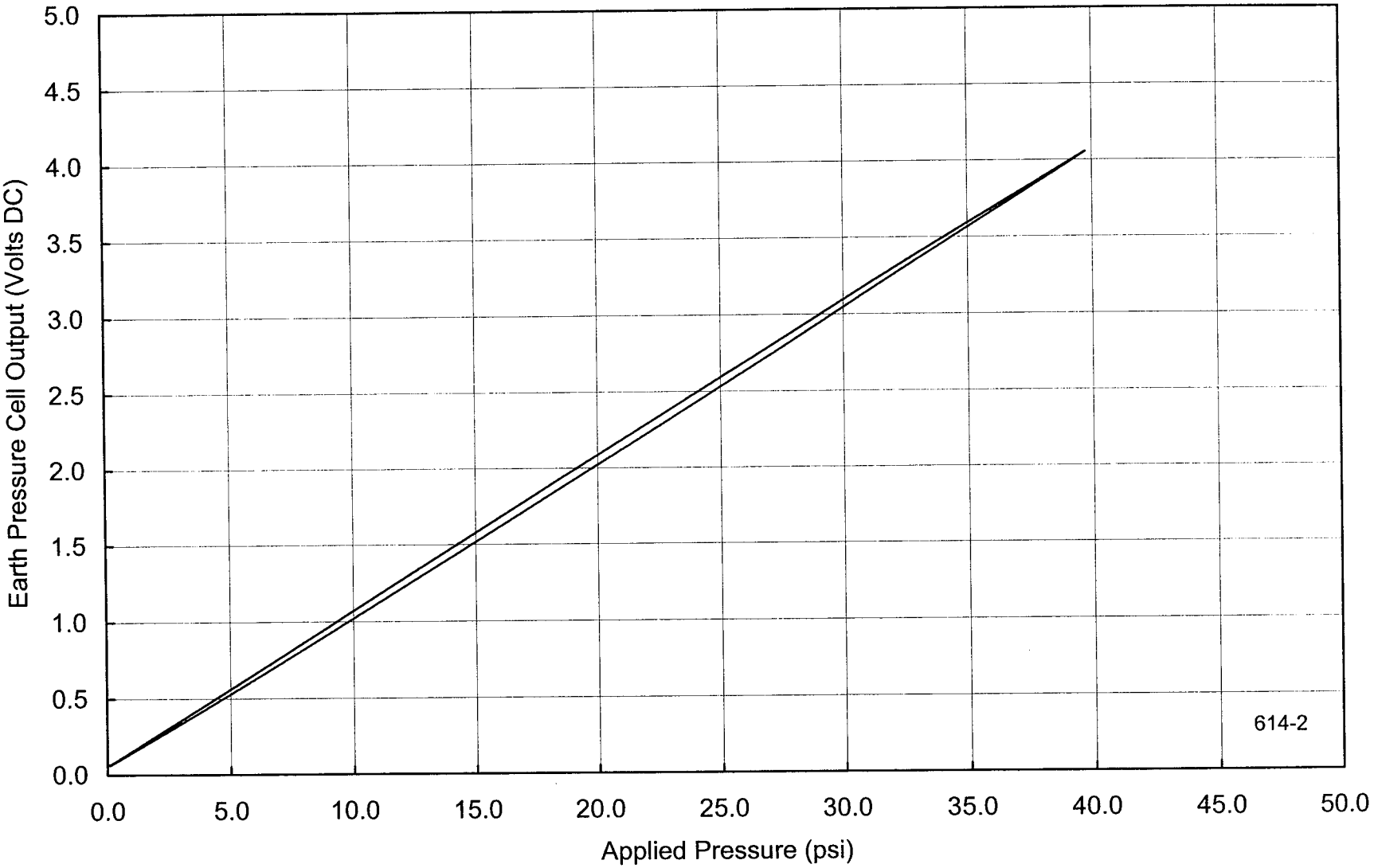

Figure A-78) Calibration record for the second calibration of earth pressure cell number 614 for the ODOT SHRP Test Road, Section 390104

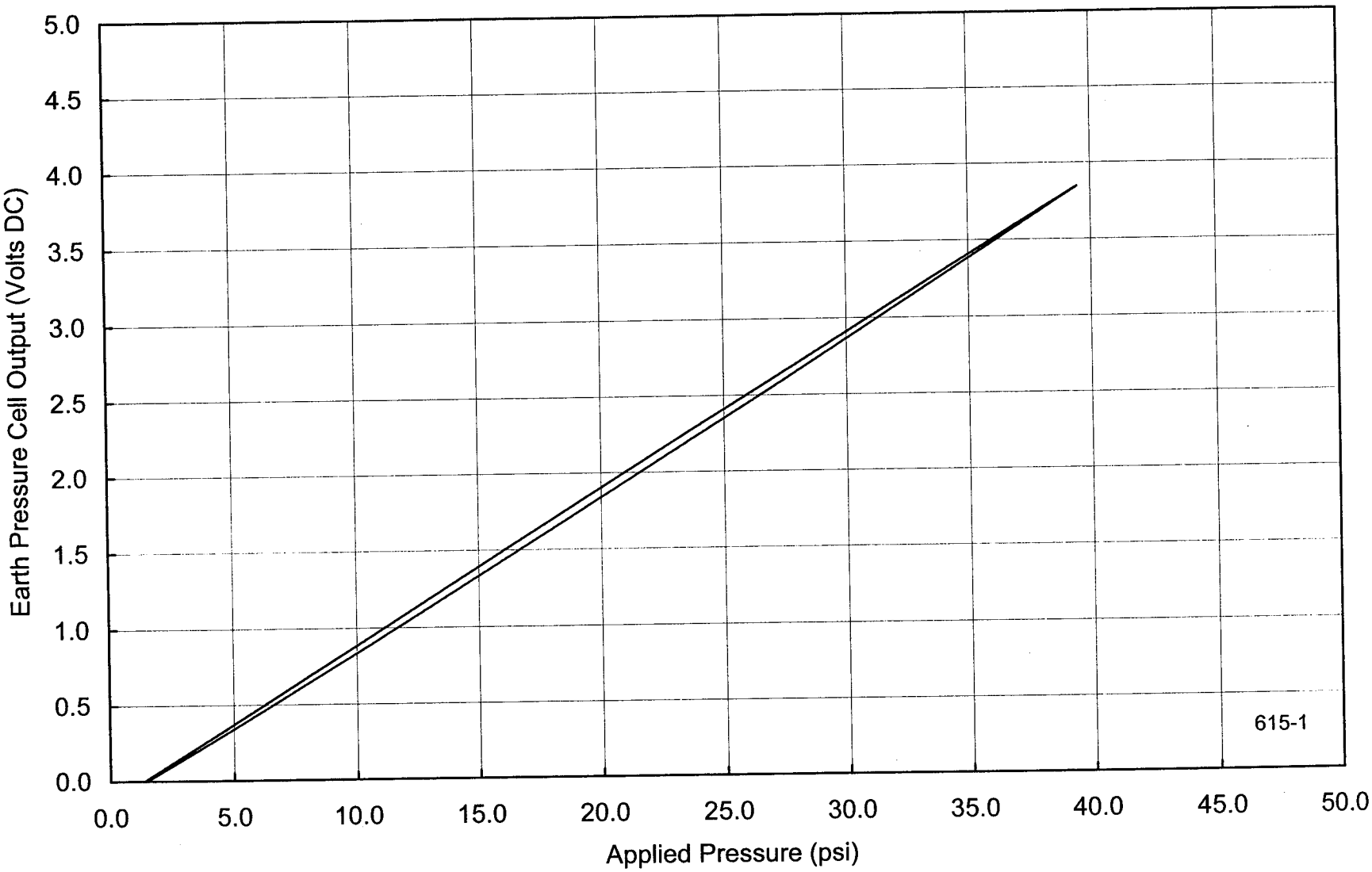

Figure A-79) Calibration record for the first calibration of earth pressure cell number 615 for the ODOT SHRP Test Road, Section 390104

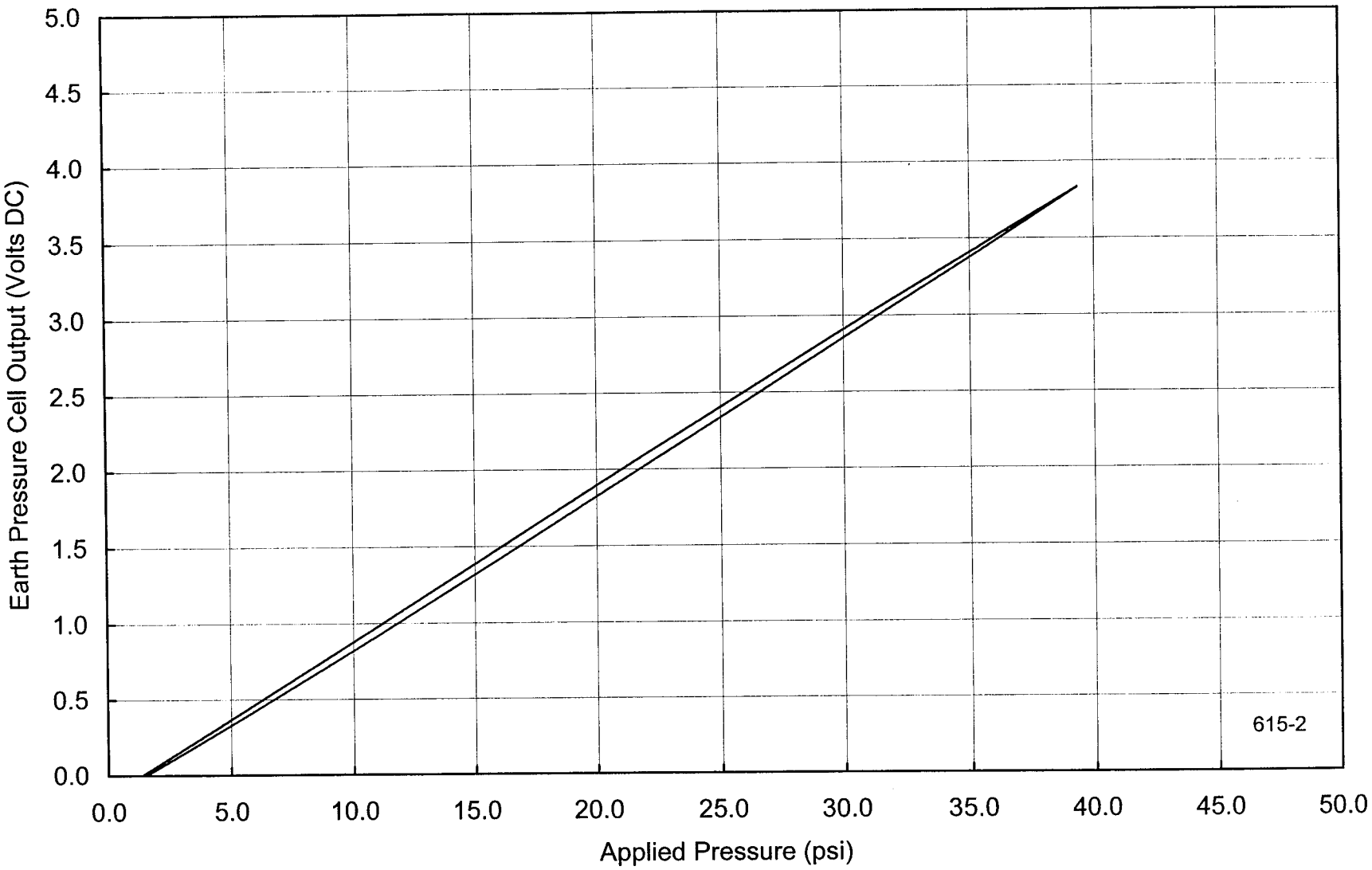

Figure A-80) Calibration record for the second calibration of earth pressure cell number 615 for the ODOT SHRP Test Road, Section 390104

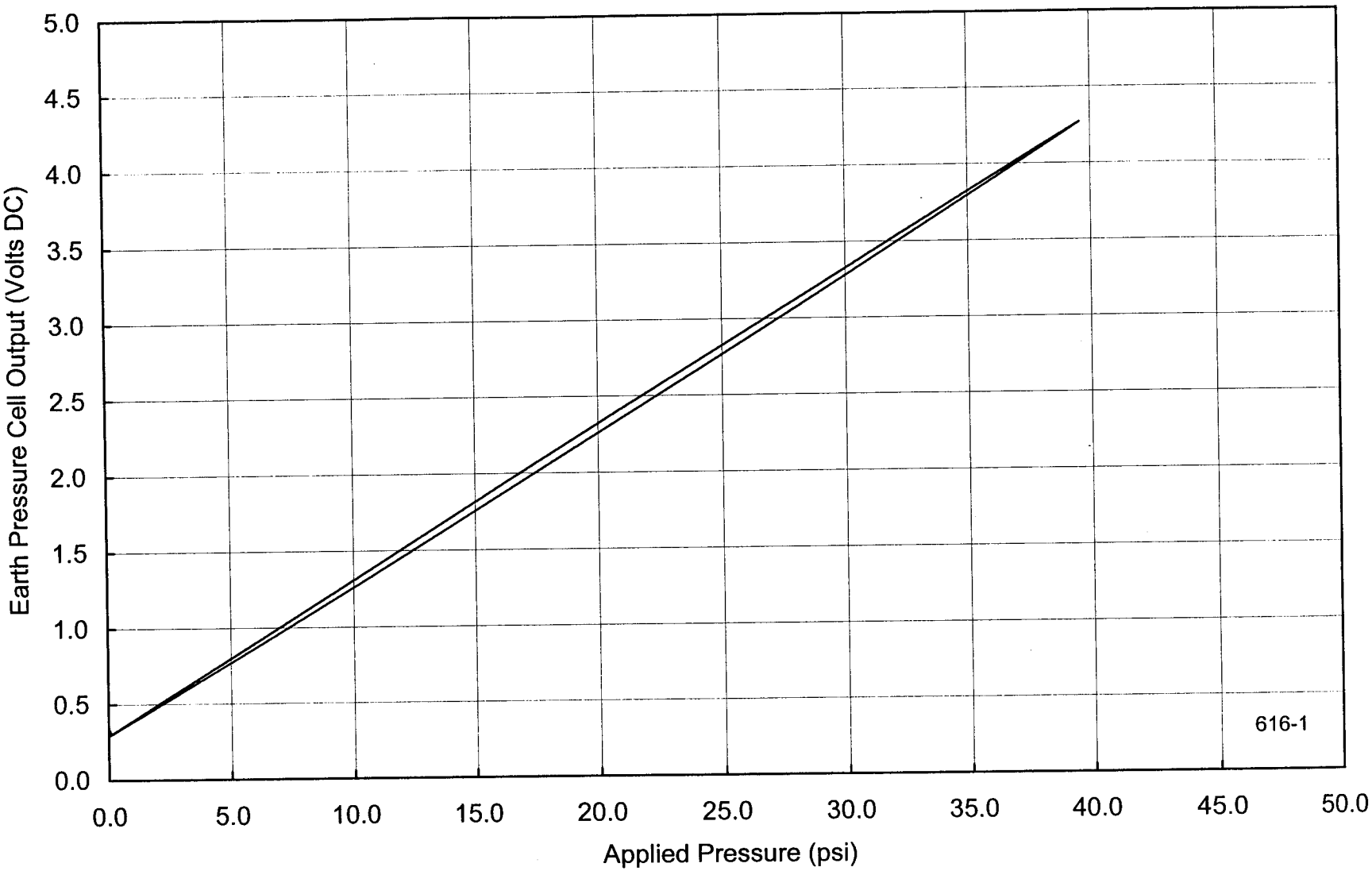

Figure A-81) Calibration record for the first calibration of earth pressure cell number 616 for the ODOT SHRP Test Road, Section 390101

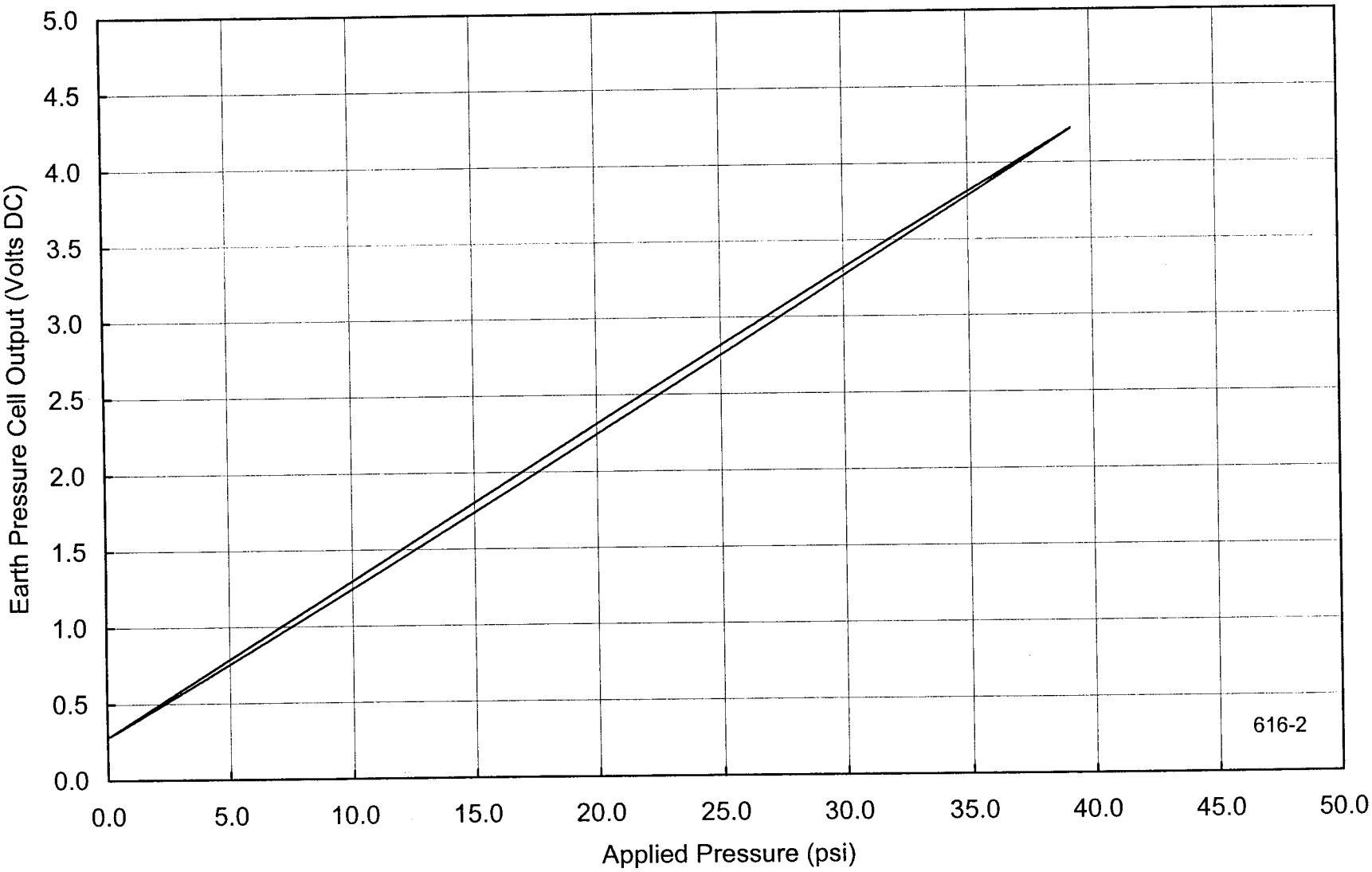

Figure A-82) Calibration record for the second calibration of earth pressure cell number 616 for the ODOT SHRP Test Road, Section 390101

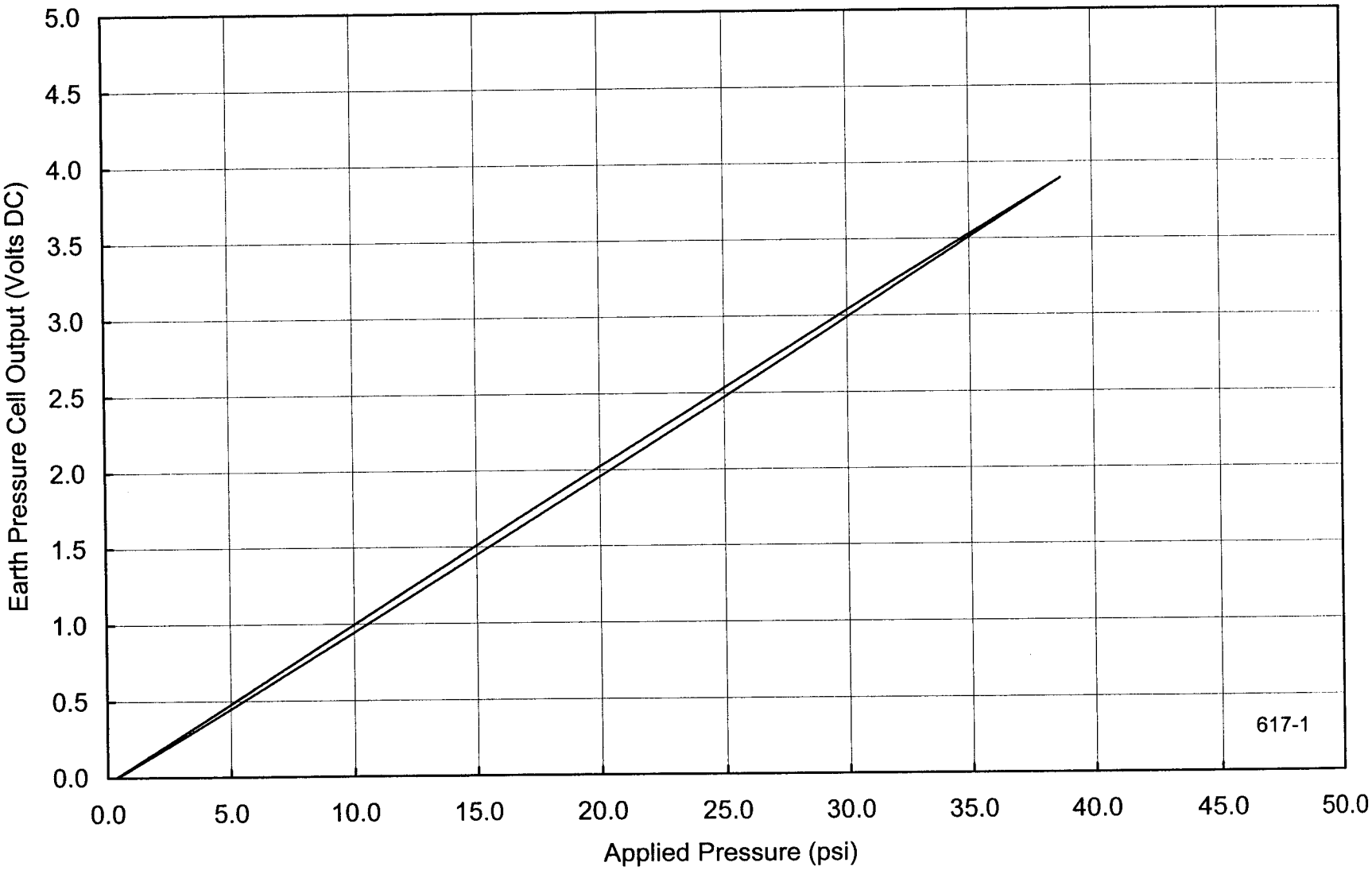

Figure A-83) Calibration record for the first calibration of earth pressure cell number 617 for the ODOT SHRP Test Road, Section 390101

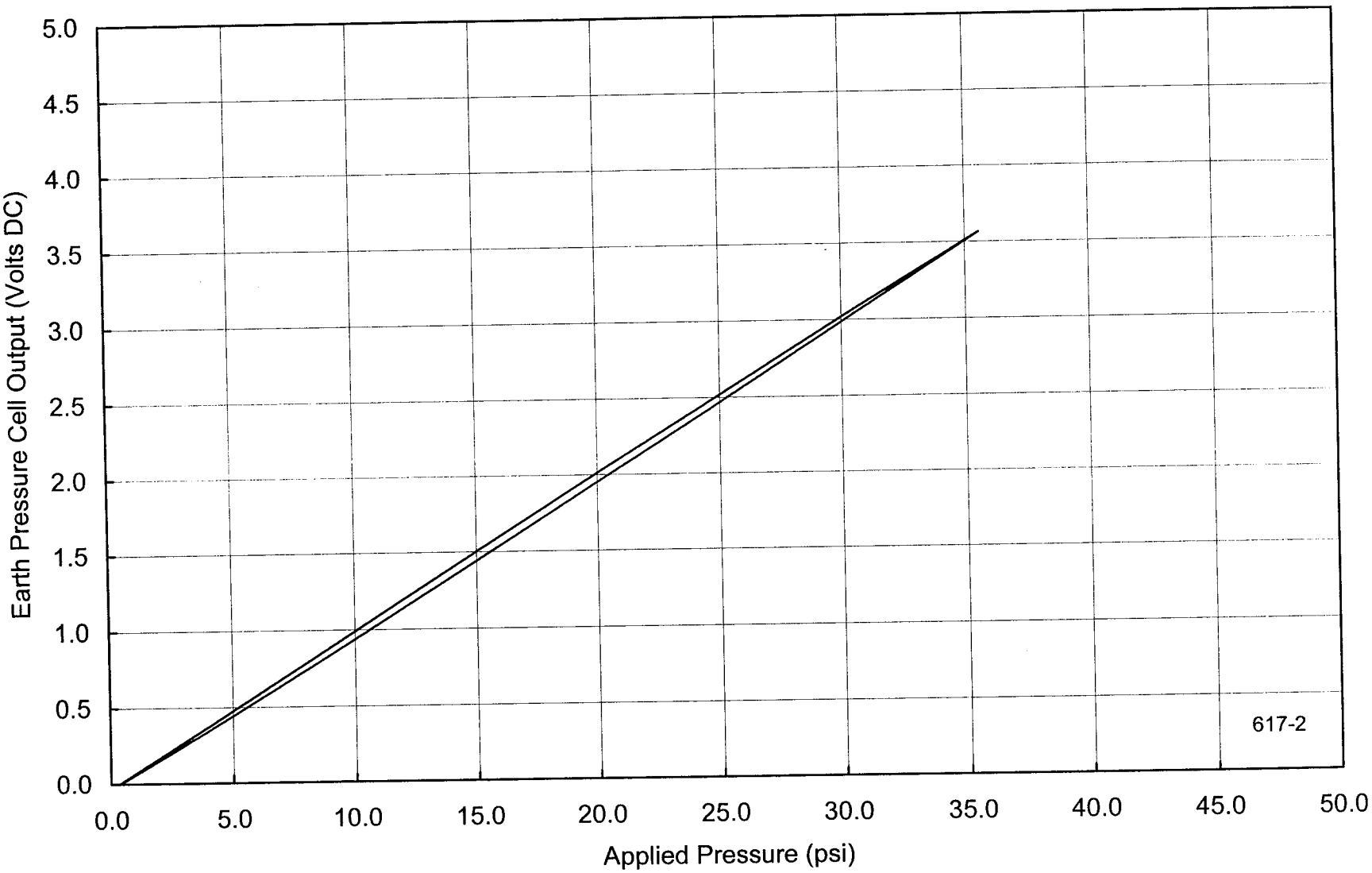

Figure A-84) Calibration record for the second calibration of earth pressure cell number 617 for the ODOT SHRP Test Road, Section 390101

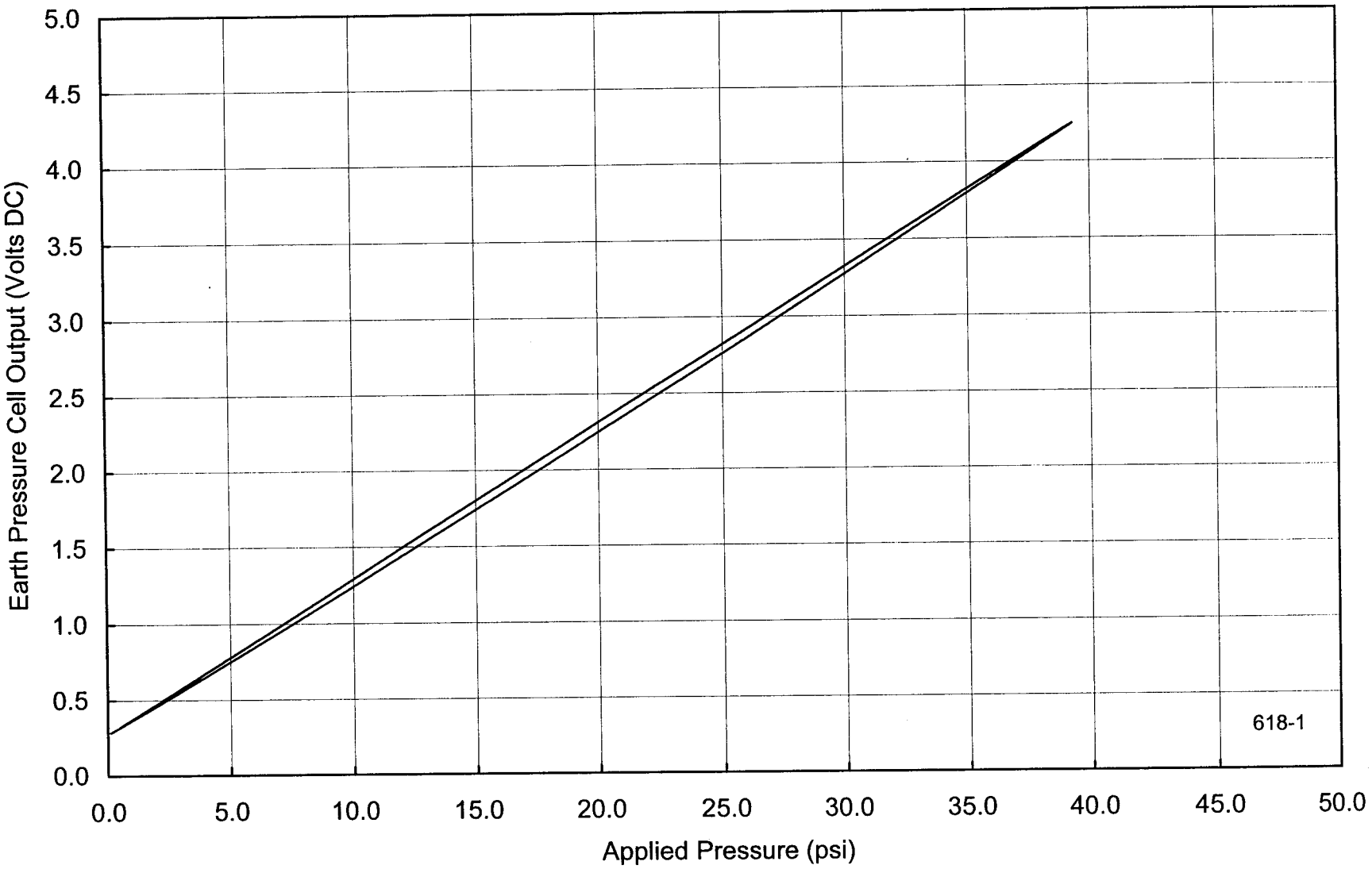

Figure A-85) Calibration record for the first calibration of earth pressure cell number 618 for the ODOT SHRP Test Road, Section 390107

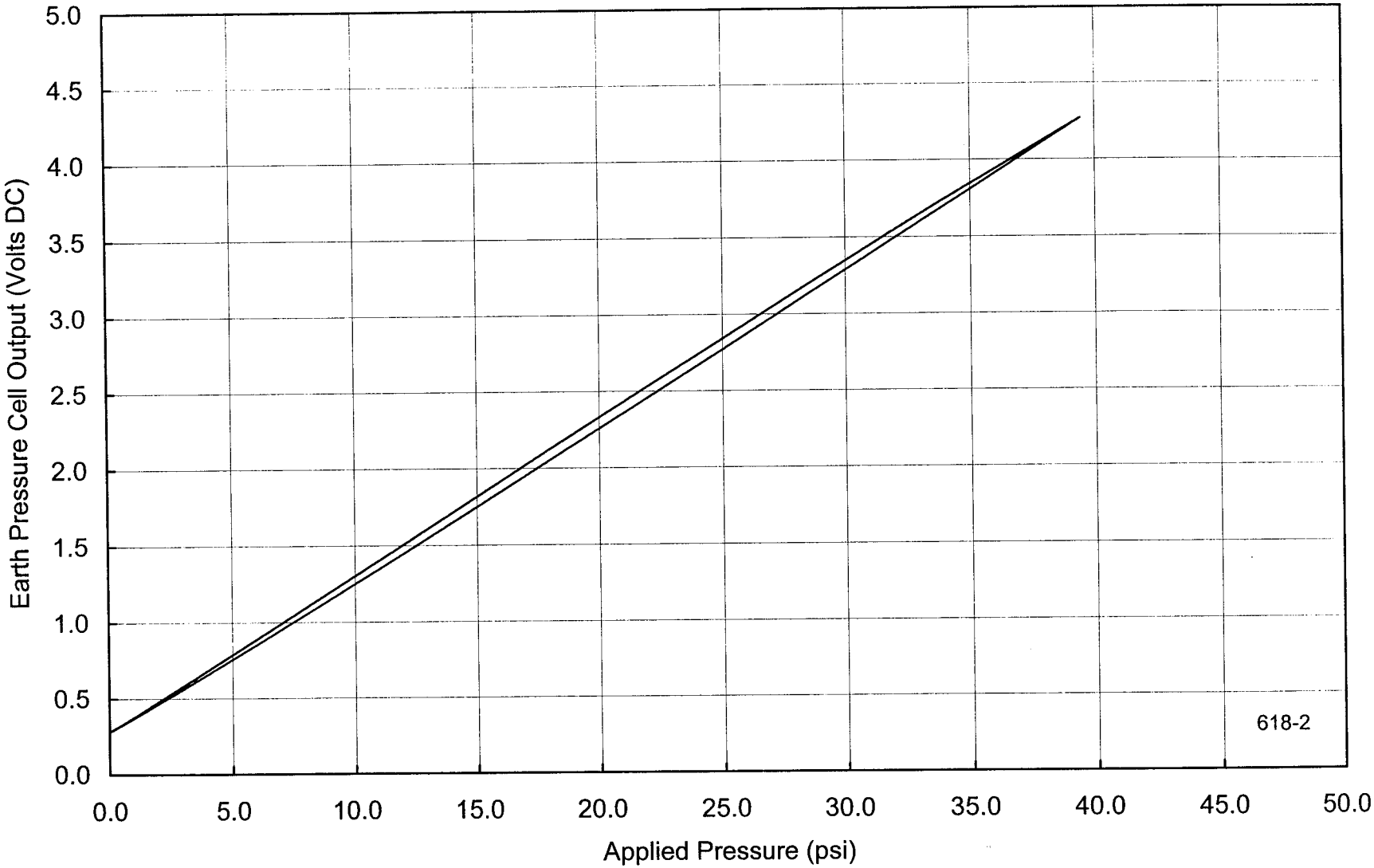

Figure A-86) Calibration record for the second calibration of earth pressure cell number 618 for the ODOT SHRP Test Road, Section 390107

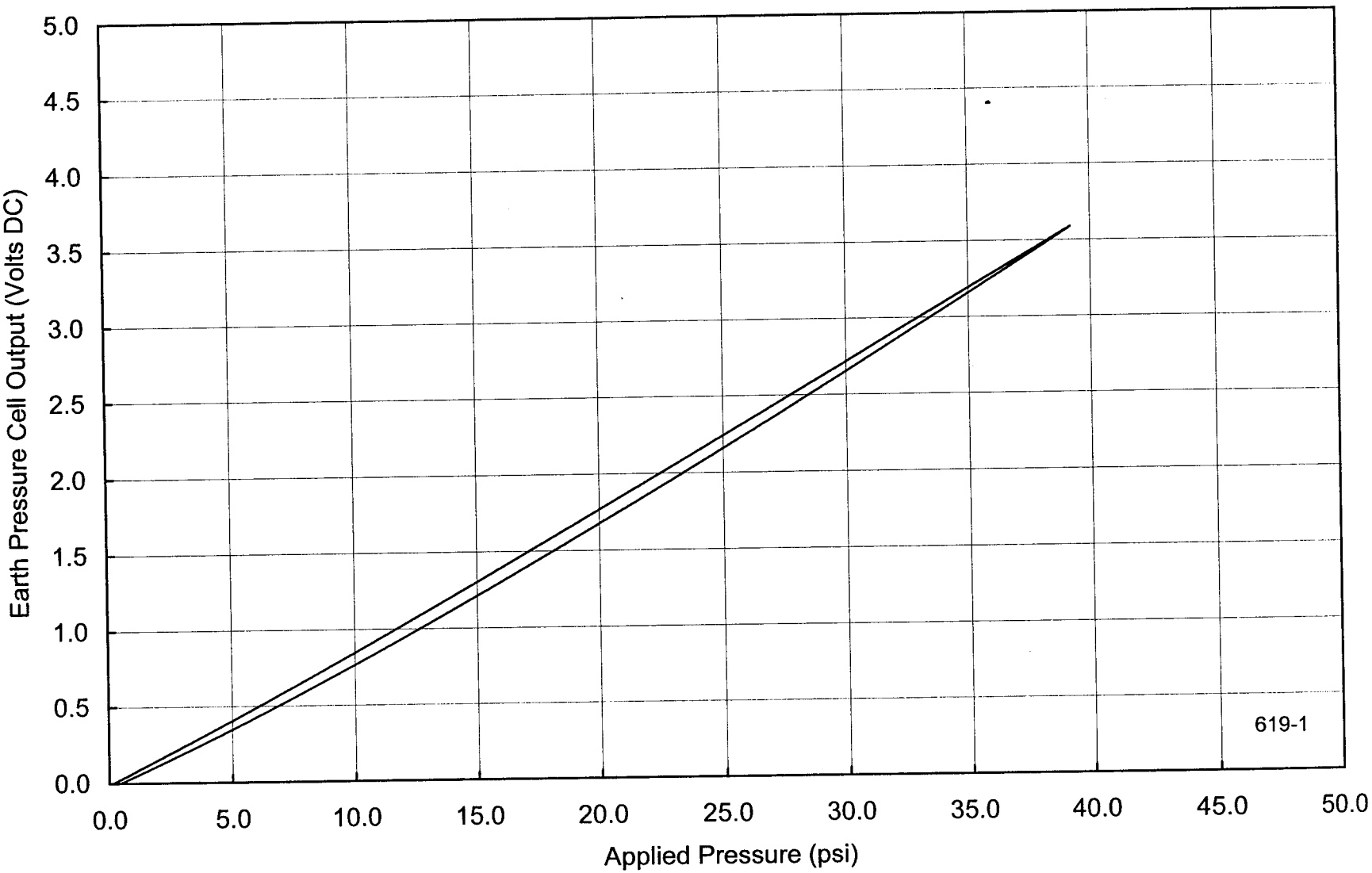

Figure A-87) Calibration record for the first calibration of earth pressure cell number 619 for the ODOT SHRP Test Road, Section 390107

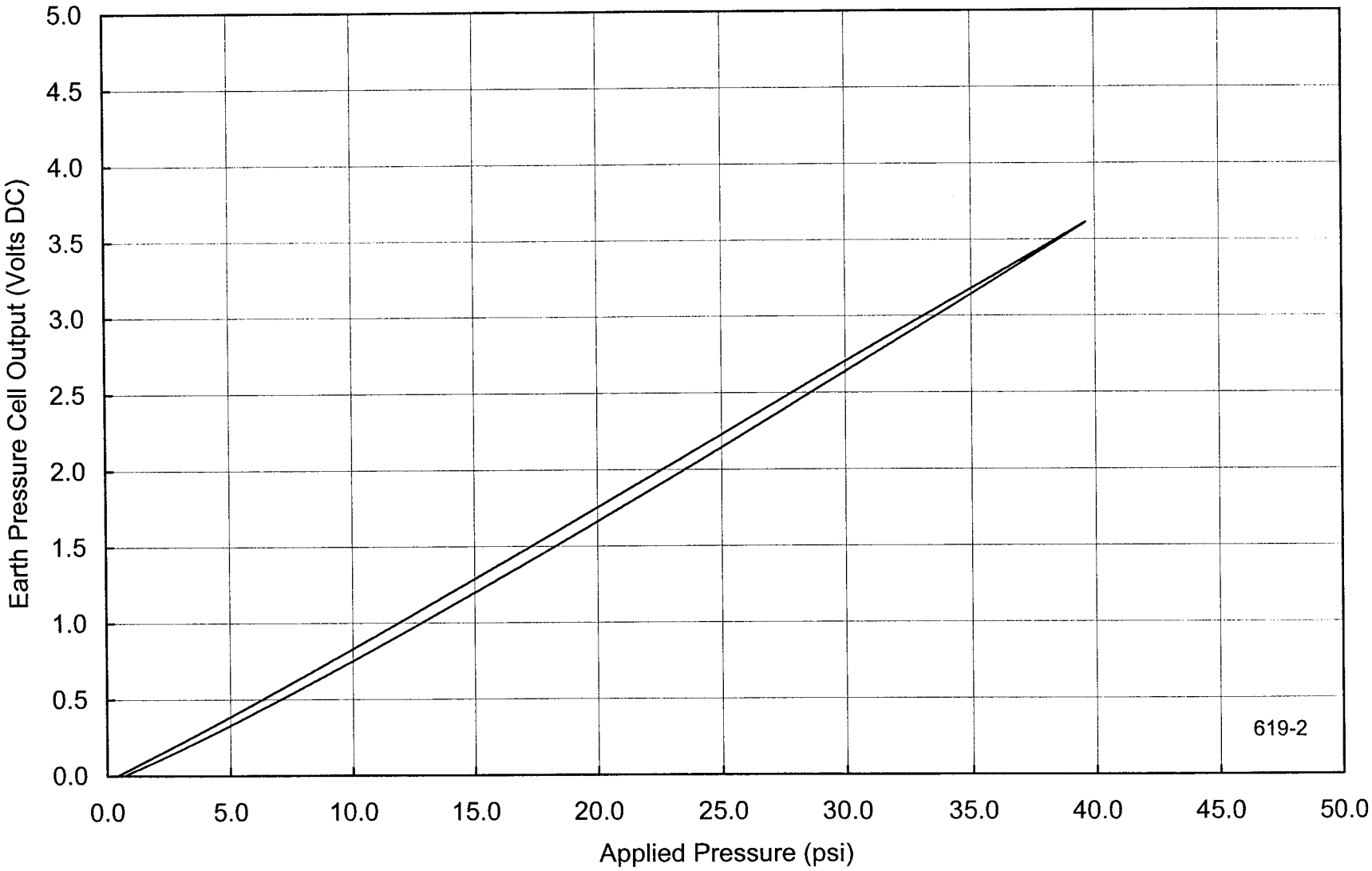

Figure A-88) Calibration record for the second calibration of earth pressure cell number 619 for the ODOT SHRP Test Road, Section 390107

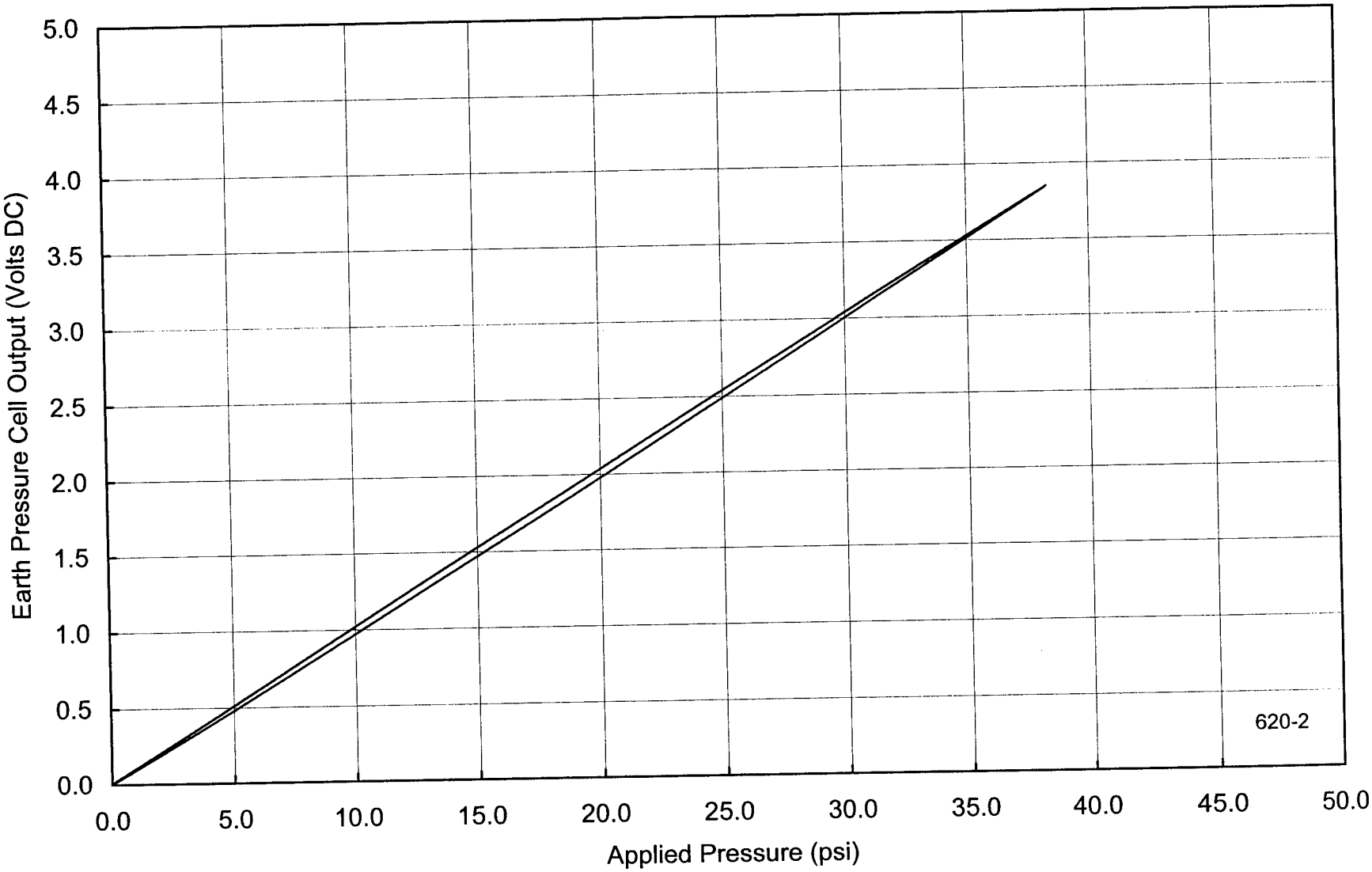

Figure A-89) Calibration record for the first calibration of earth pressure cell number 620 for the ODOT SHRP Test Road, Section 390102

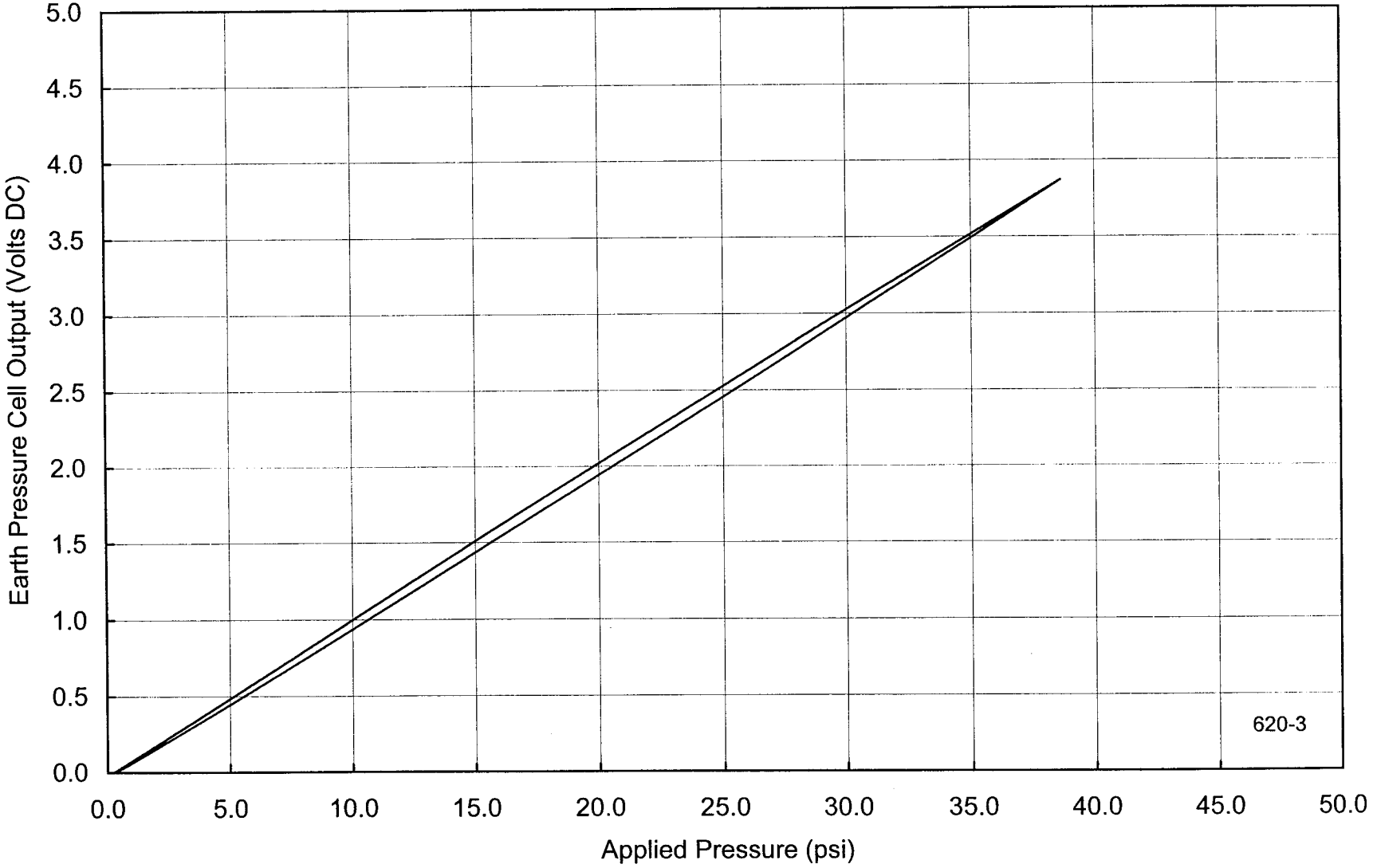

Figure A-90) Calibration record for the second calibration of earth pressure cell number 620 for the ODOT SHRP Test Road, Section 390102

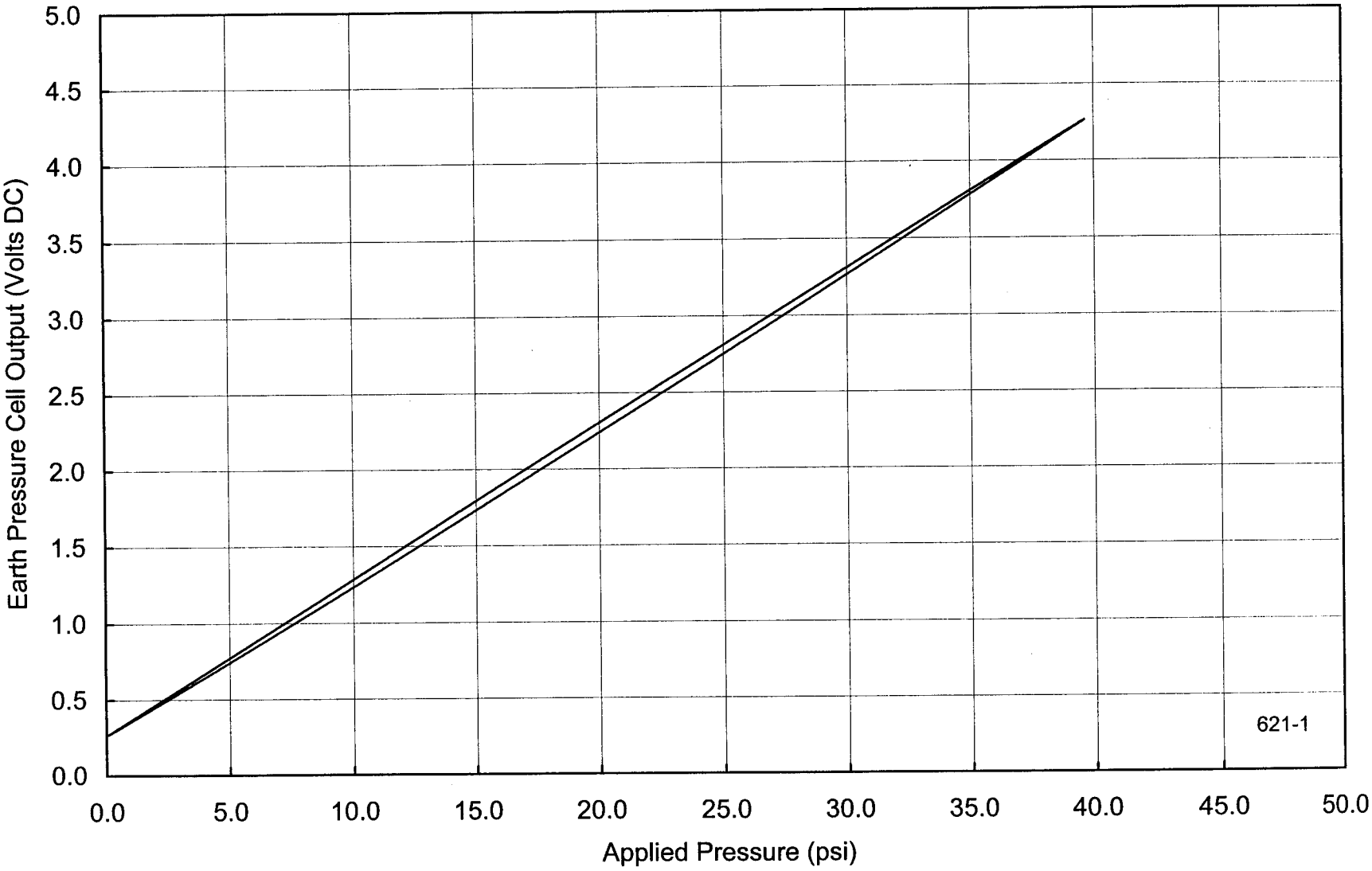

Figure A-91) Calibration record for the first calibration of earth pressure cell number 621 for the ODOT SHRP Test Road, Section 390102

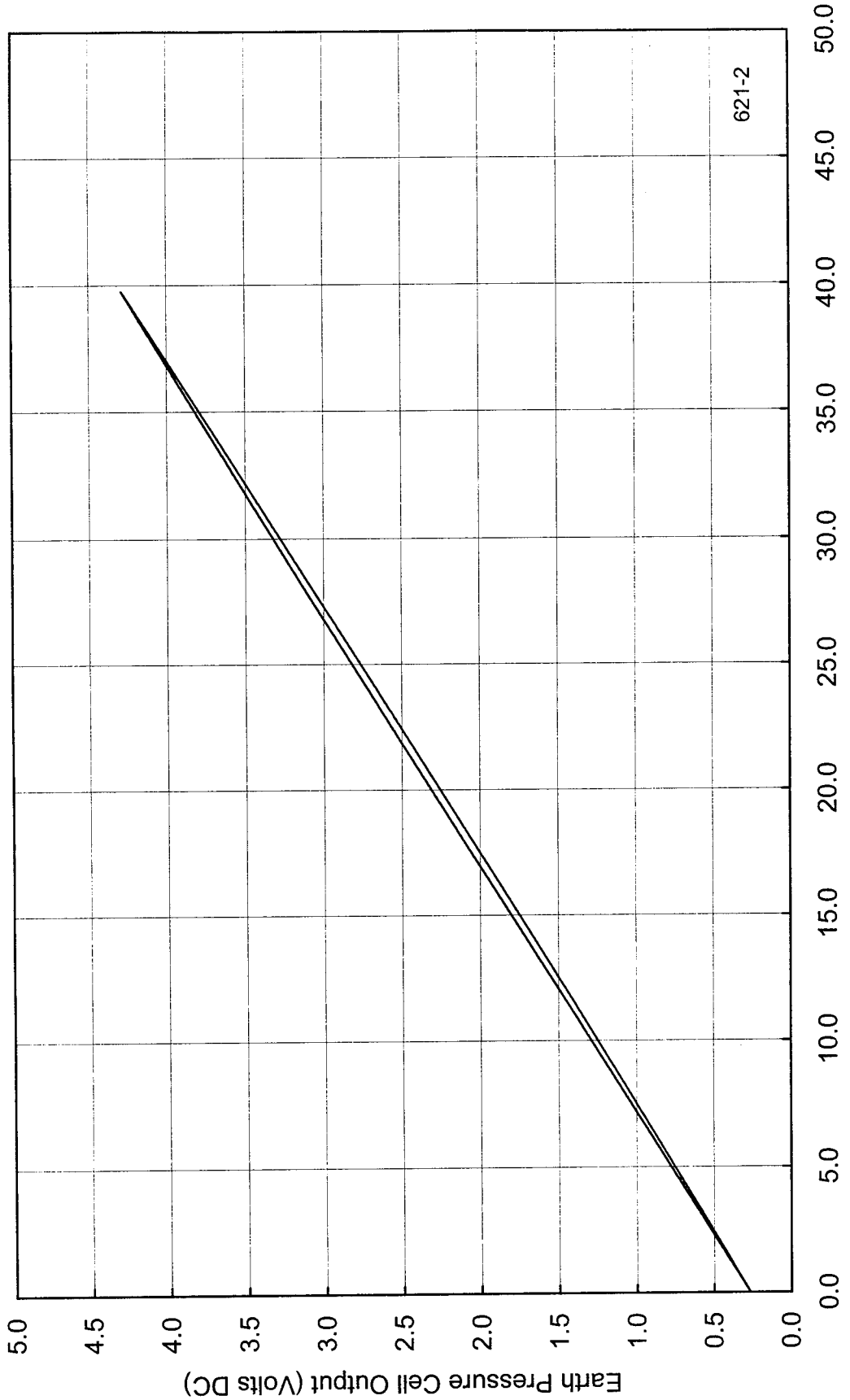

Figure A-92) Calibration record for the second calibration of earth pressure cell number 621 for the ODOT SHRP Test Road, Section 390102

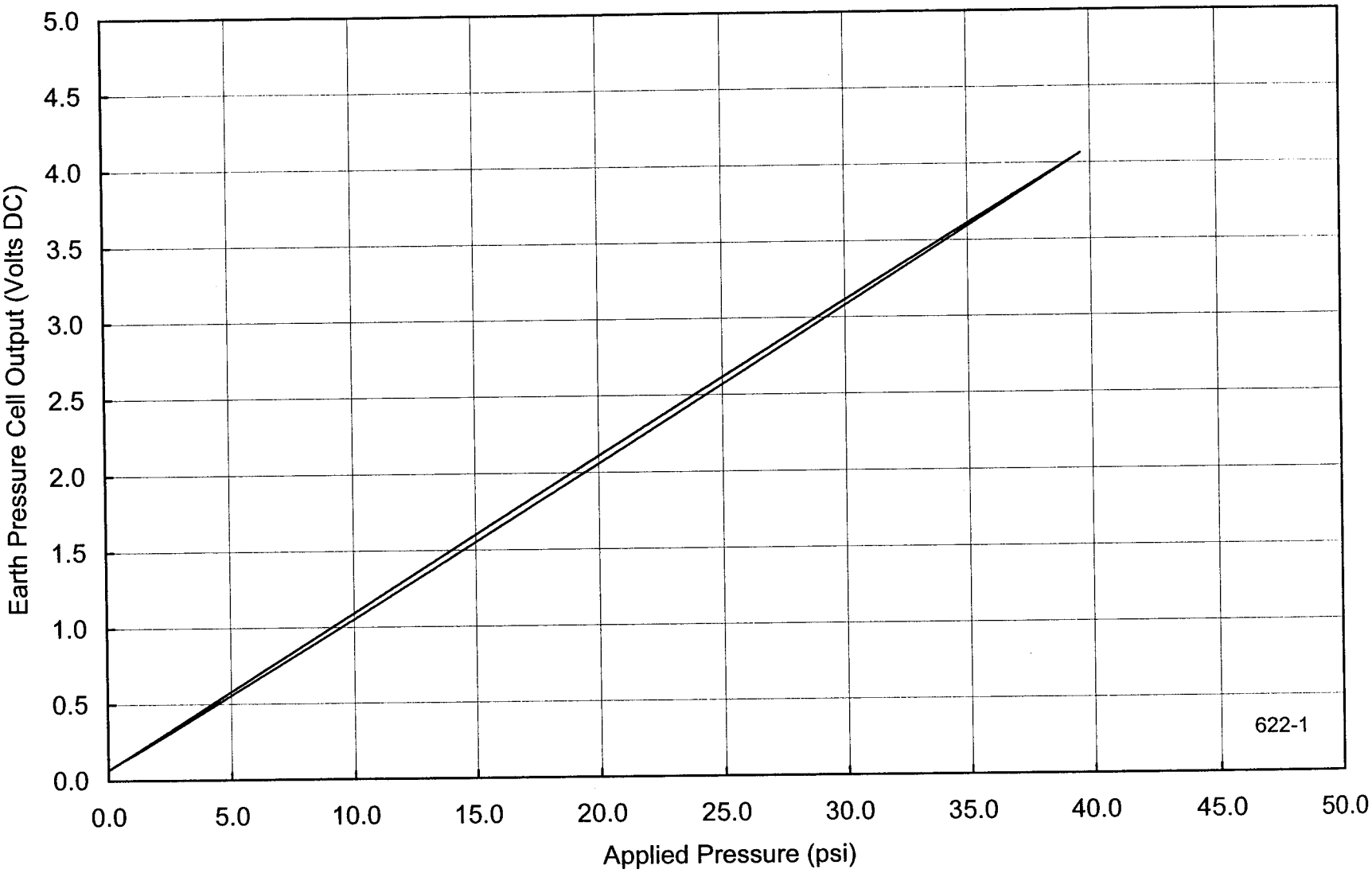

Figure A-93) Calibration record for the first calibration of earth pressure cell number 622 for the ODOT SHRP Test Road, Section 390160

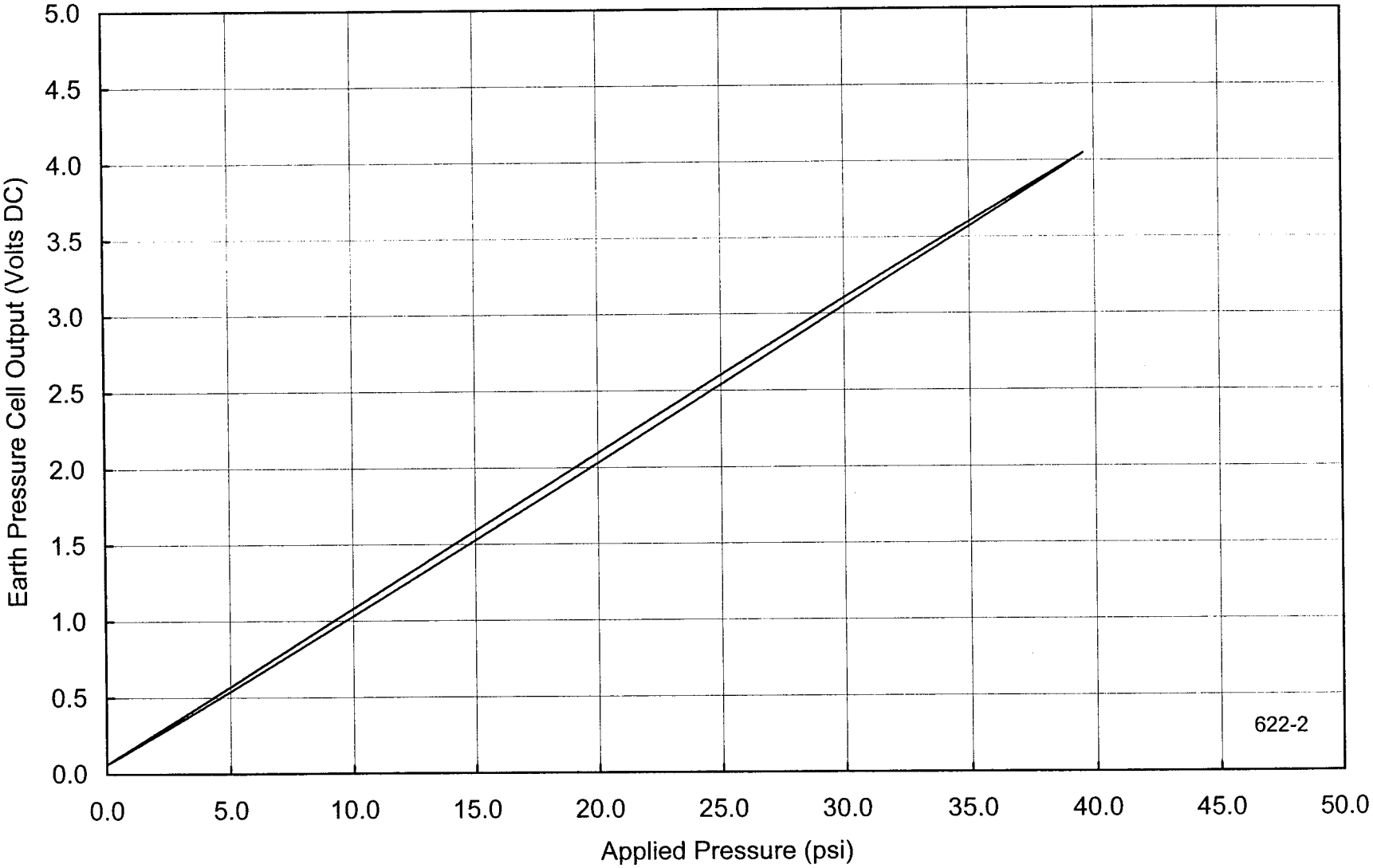

Figure A-94) Calibration record for the second calibration of earth pressure cell number 622 for the ODOT SHRP Test Road, Section 390160

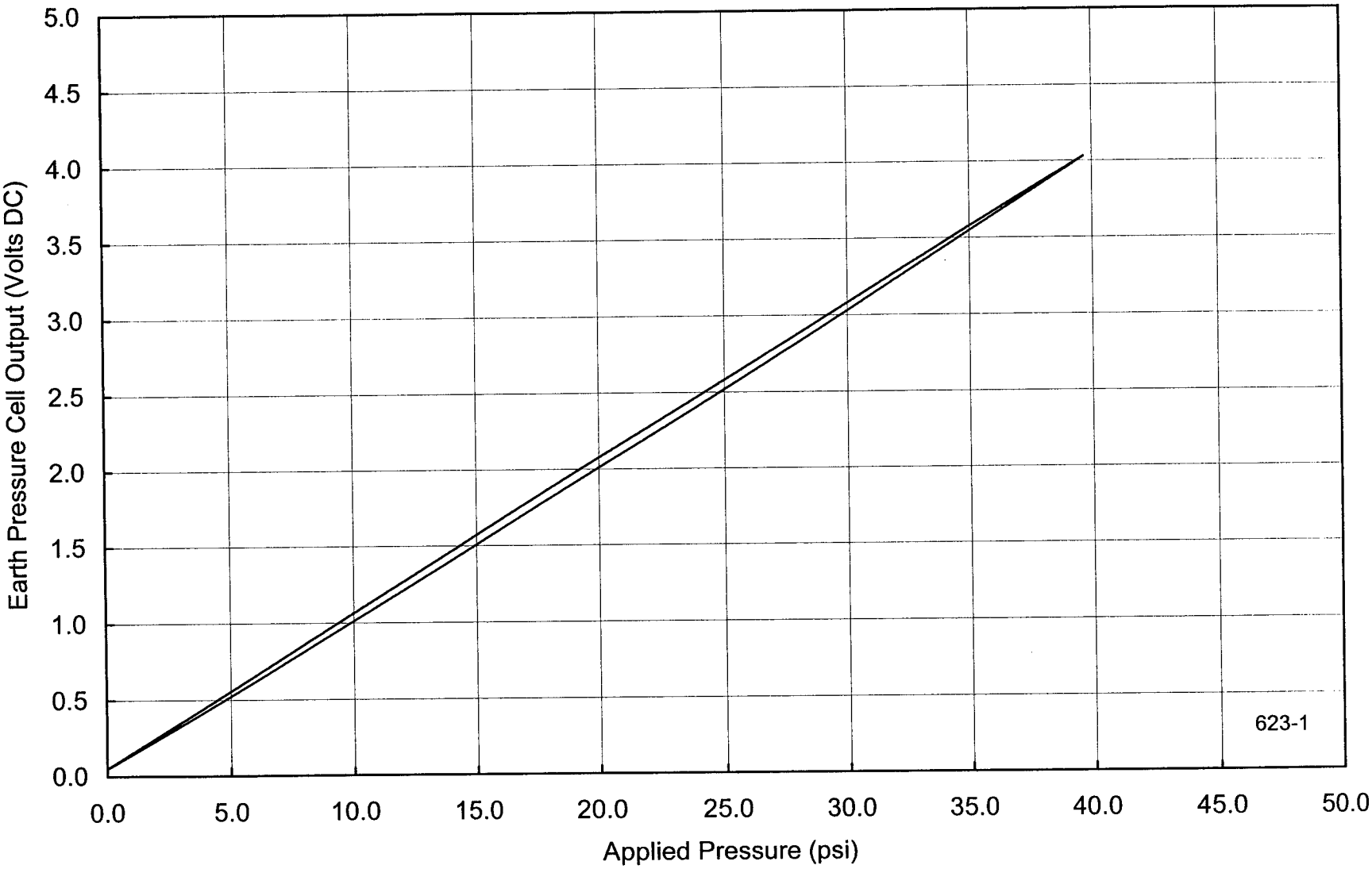

Figure A-95) Calibration record for the first calibration of earth pressure cell number 623 for the ODOT SHRP Test Road, Section 390160

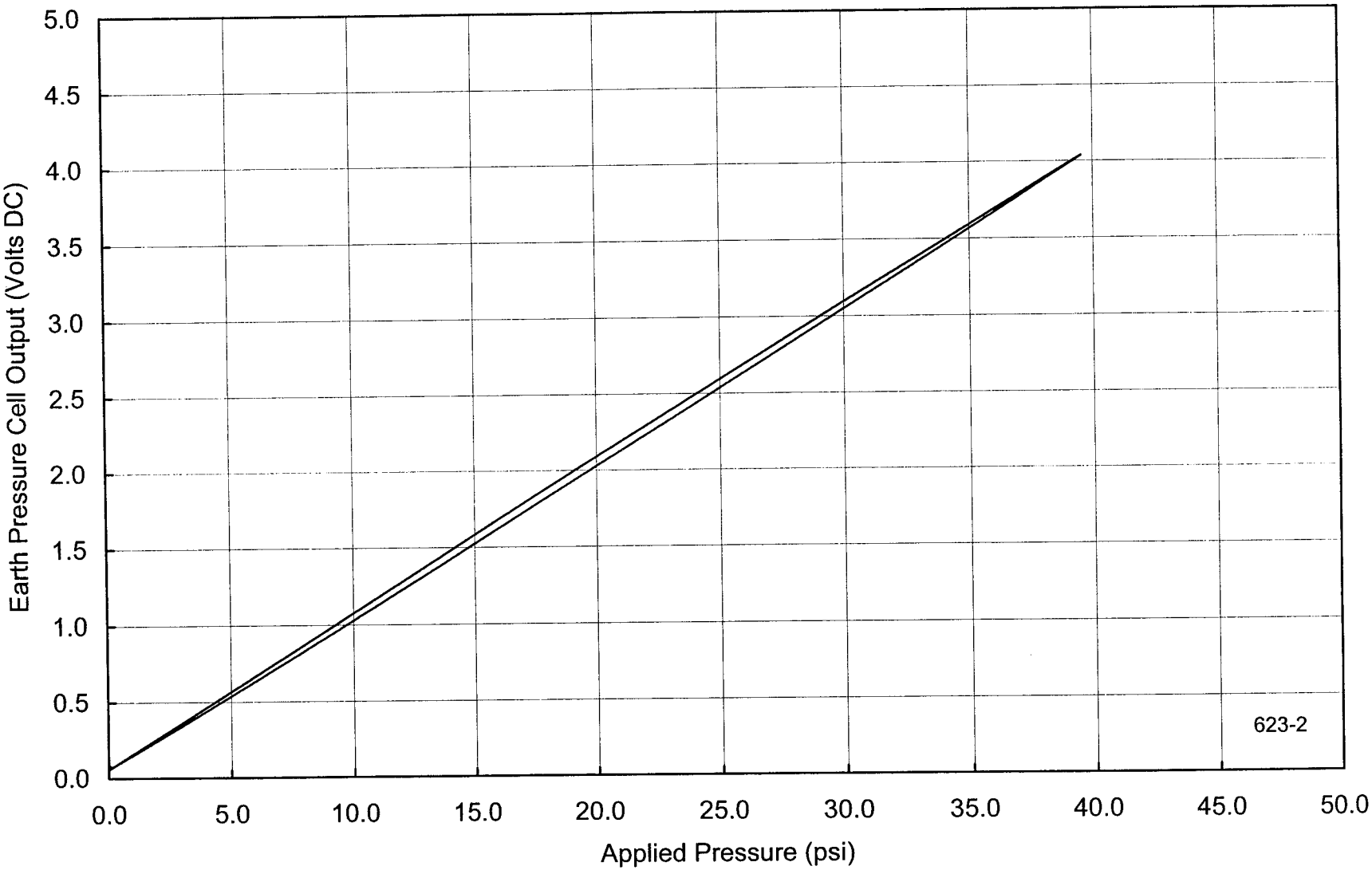

Figure A-96) Calibration record for the second calibration of earth pressure cell number 623 for the ODOT SHRP Test Road, Section 390160

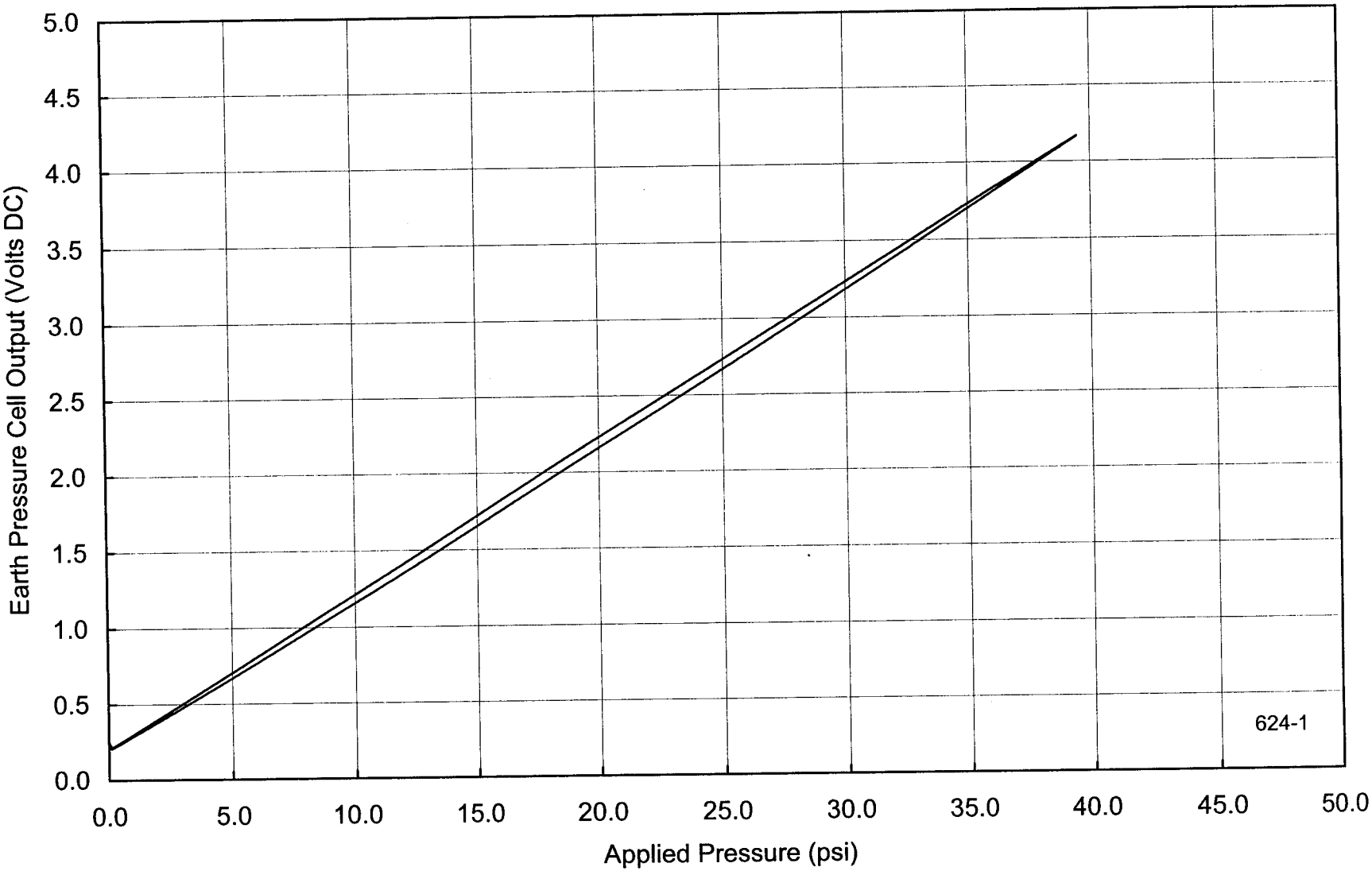

Figure A-97) Calibration record for the first calibration of earth pressure cell number 624 for the ODOT SHRP Test Road, (not installed)

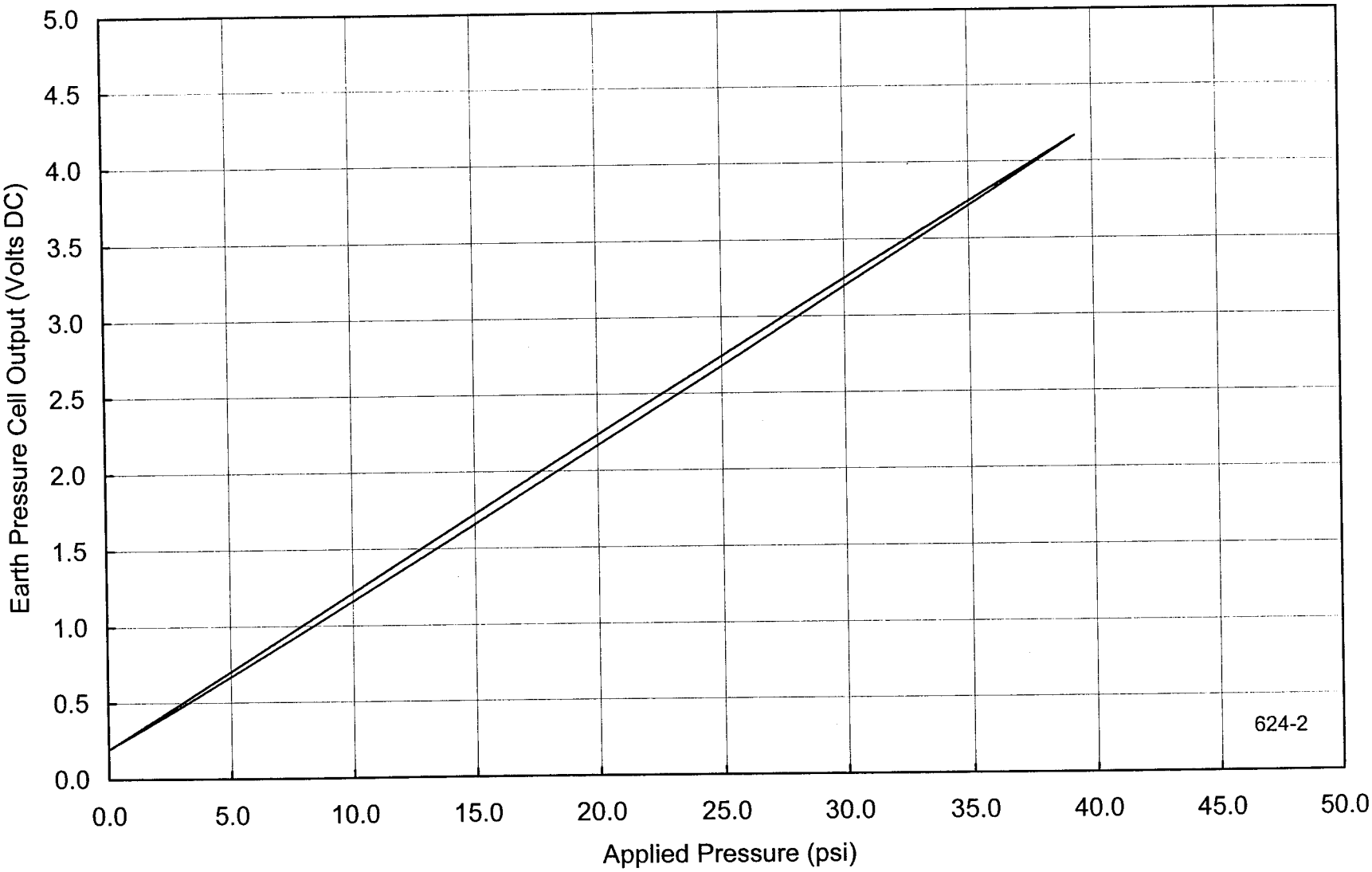

Figure A-98) Calibration record for the second calibration of earth pressure cell number 624 for the ODOT SHRP Test Road, (not installed)

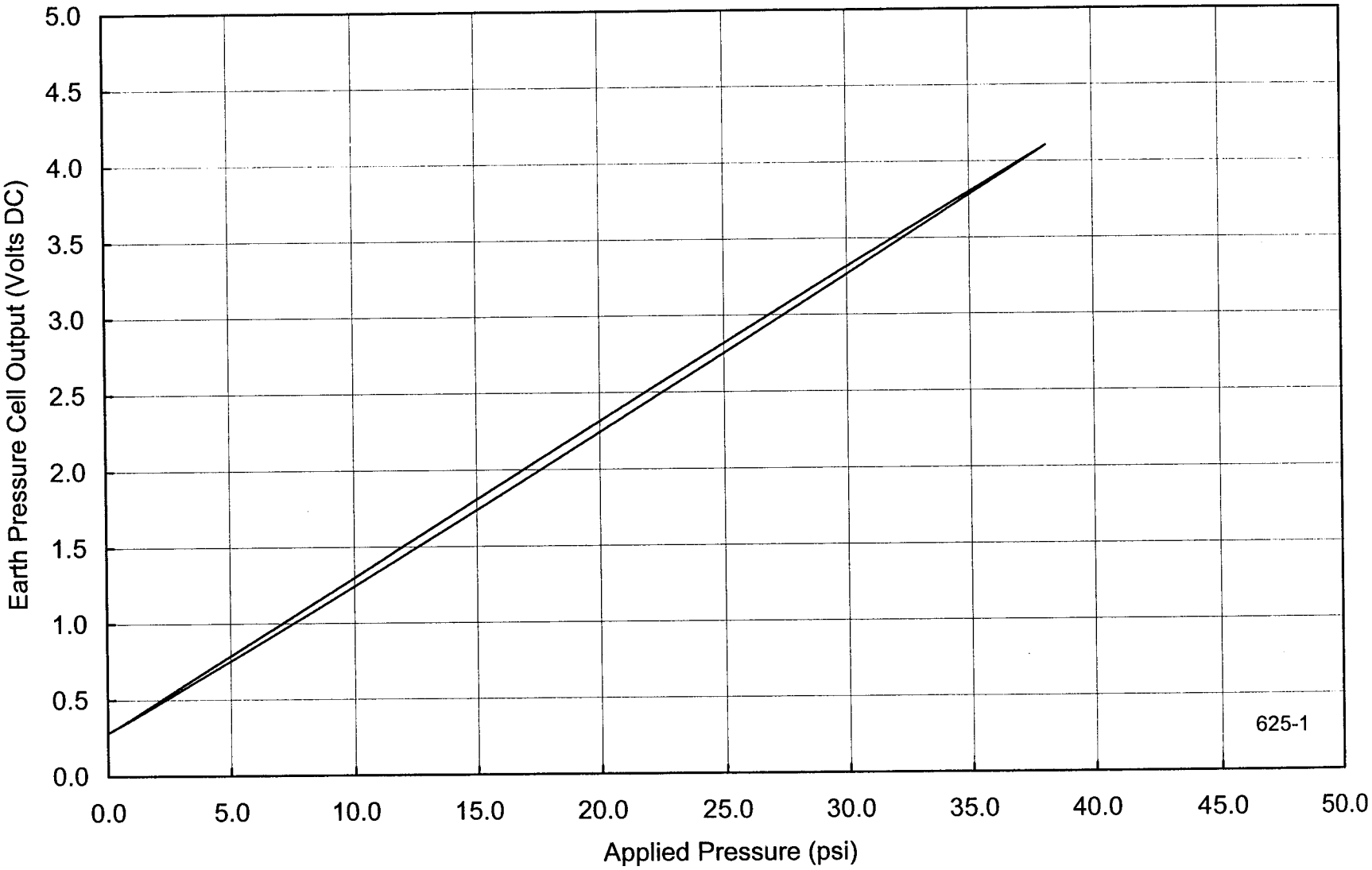

Figure A-99) Calibration record for the first calibration of earth pressure cell number 625 for the ODOT SHRP Test Road, (not installed)

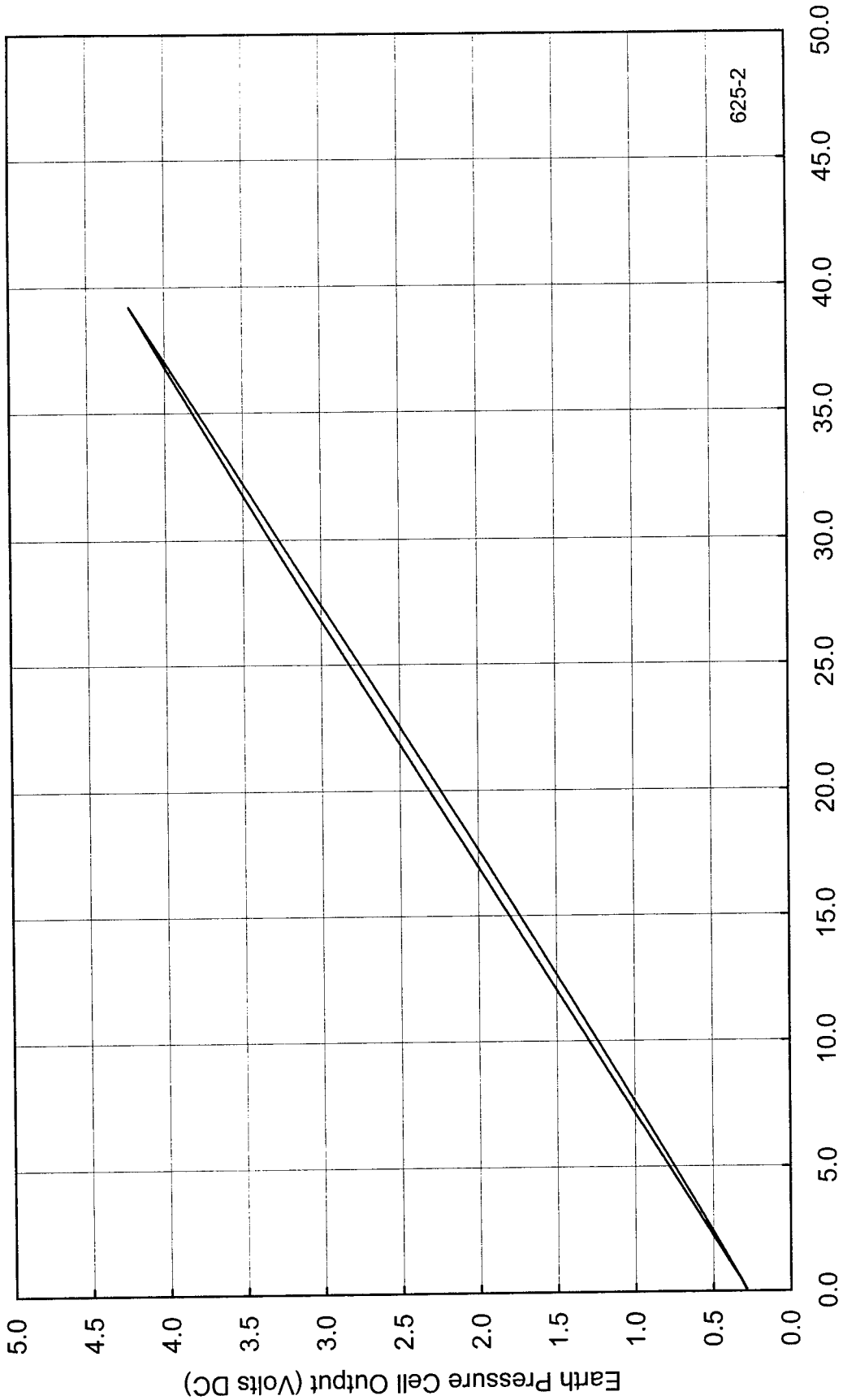

Figure A-100) Calibration record for the second calibration of earth pressure cell number 625 for the ODOT SHRP Test Road, (not installed)

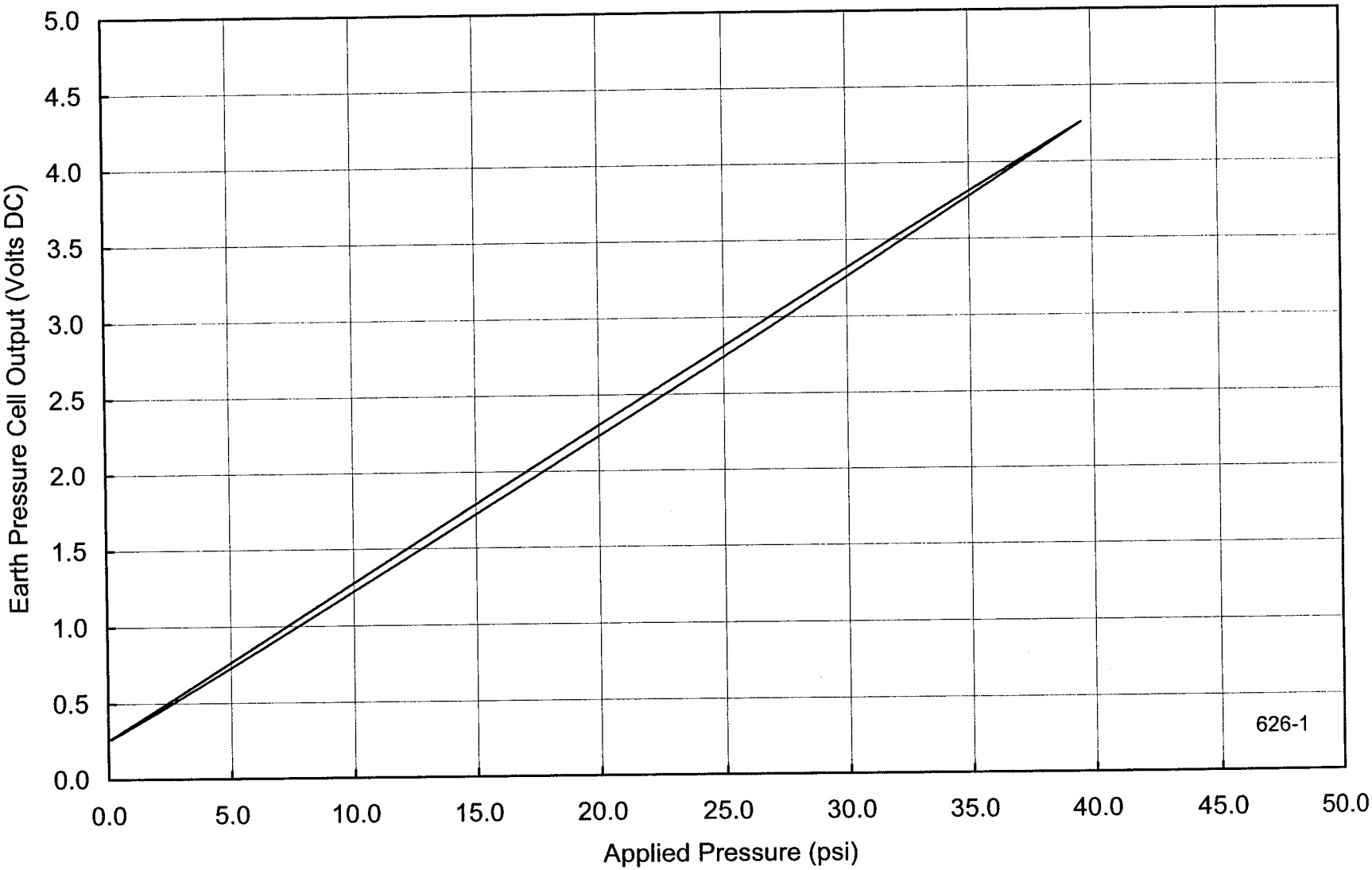

Figure A-101) Calibration record for the first calibration of earth pressure cell number 626 for the ODOT SHRP Test Road, Section 390109

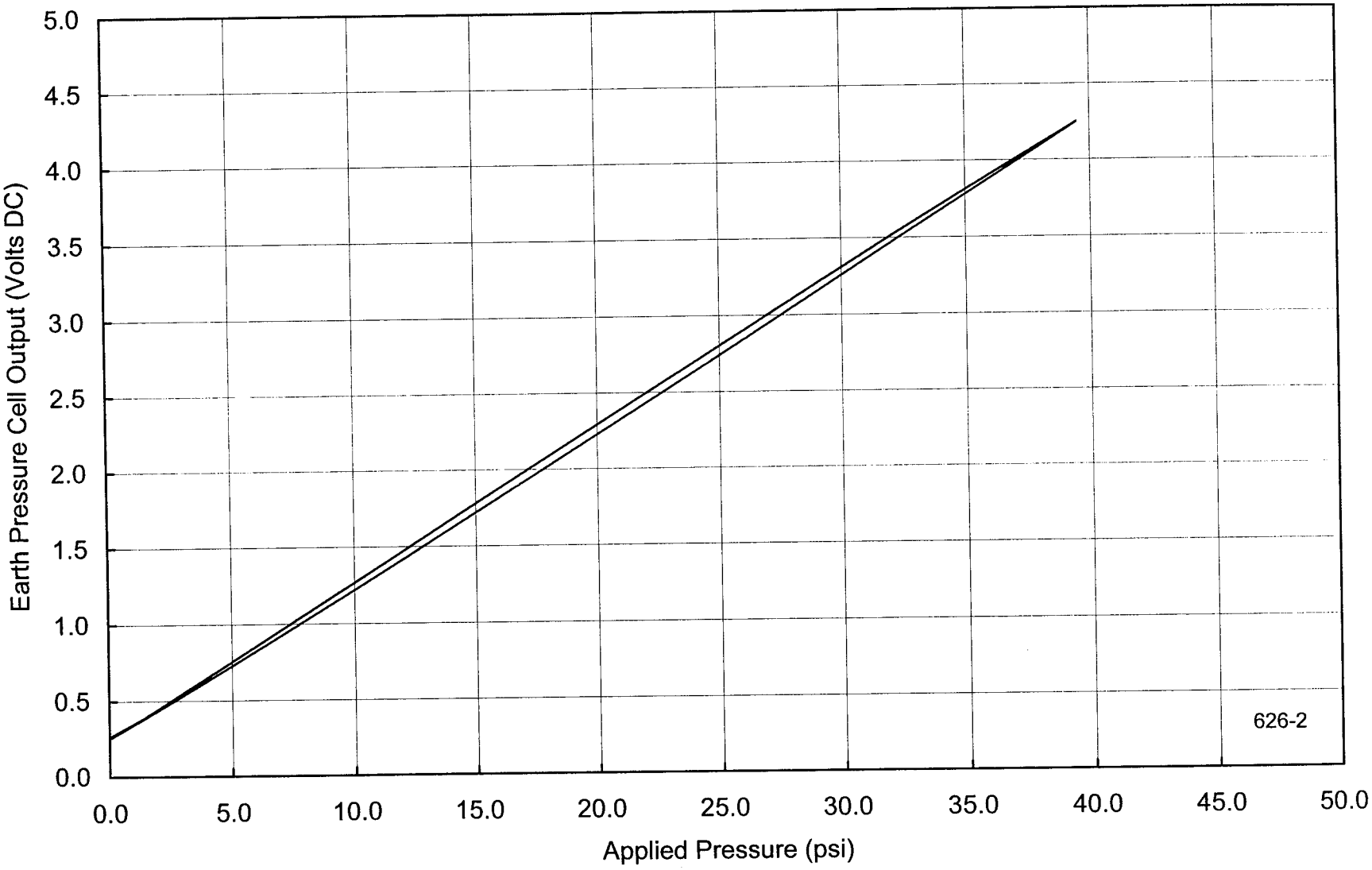

Figure A-102) Calibration record for the second calibration of earth pressure cell number 626 for the ODOT SHRP Test Road, Section 390109

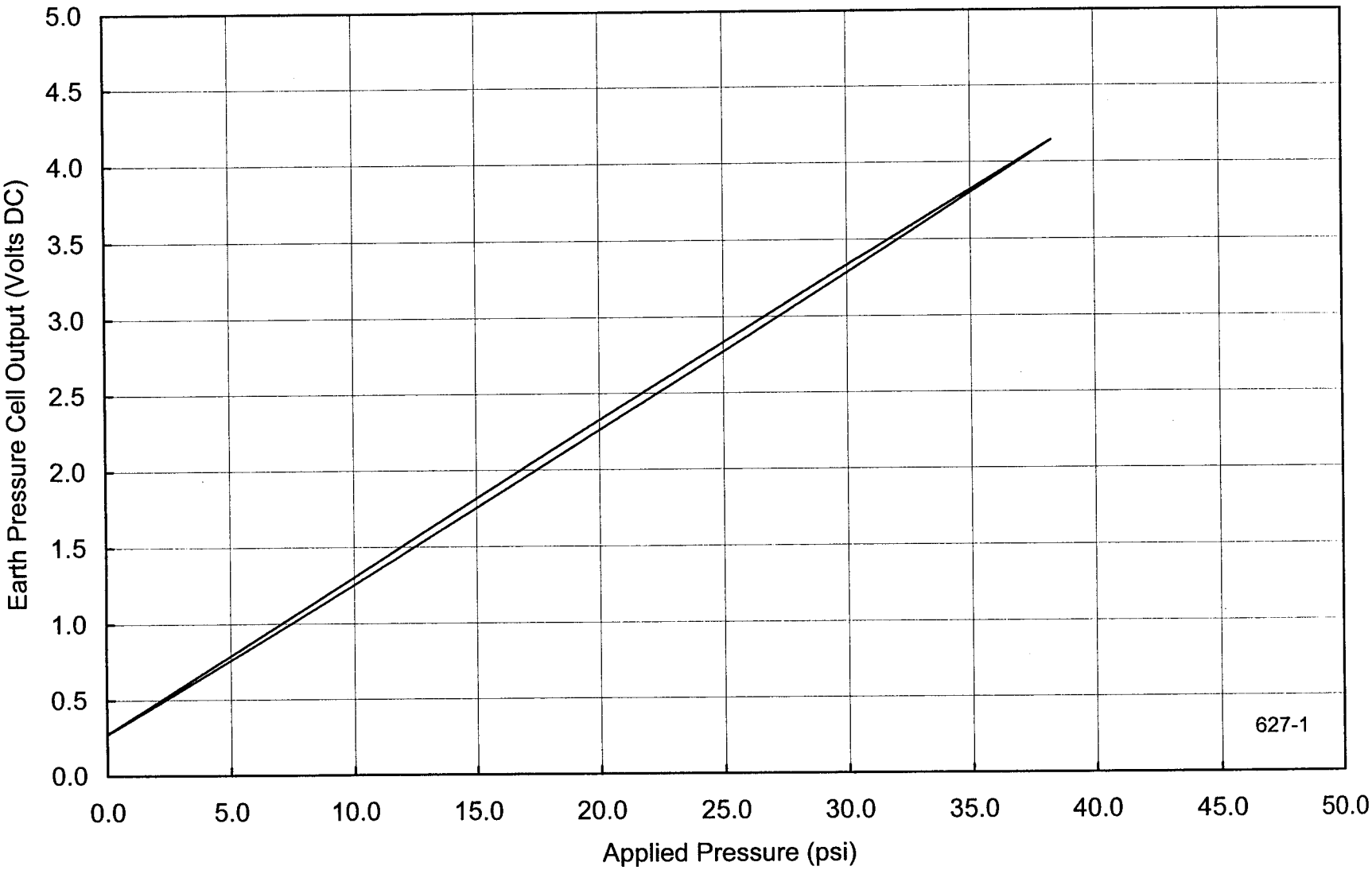

Figure A-103) Calibration record for the first calibration of earth pressure cell number 627 for the ODOT SHRP Test Road, Section 390109

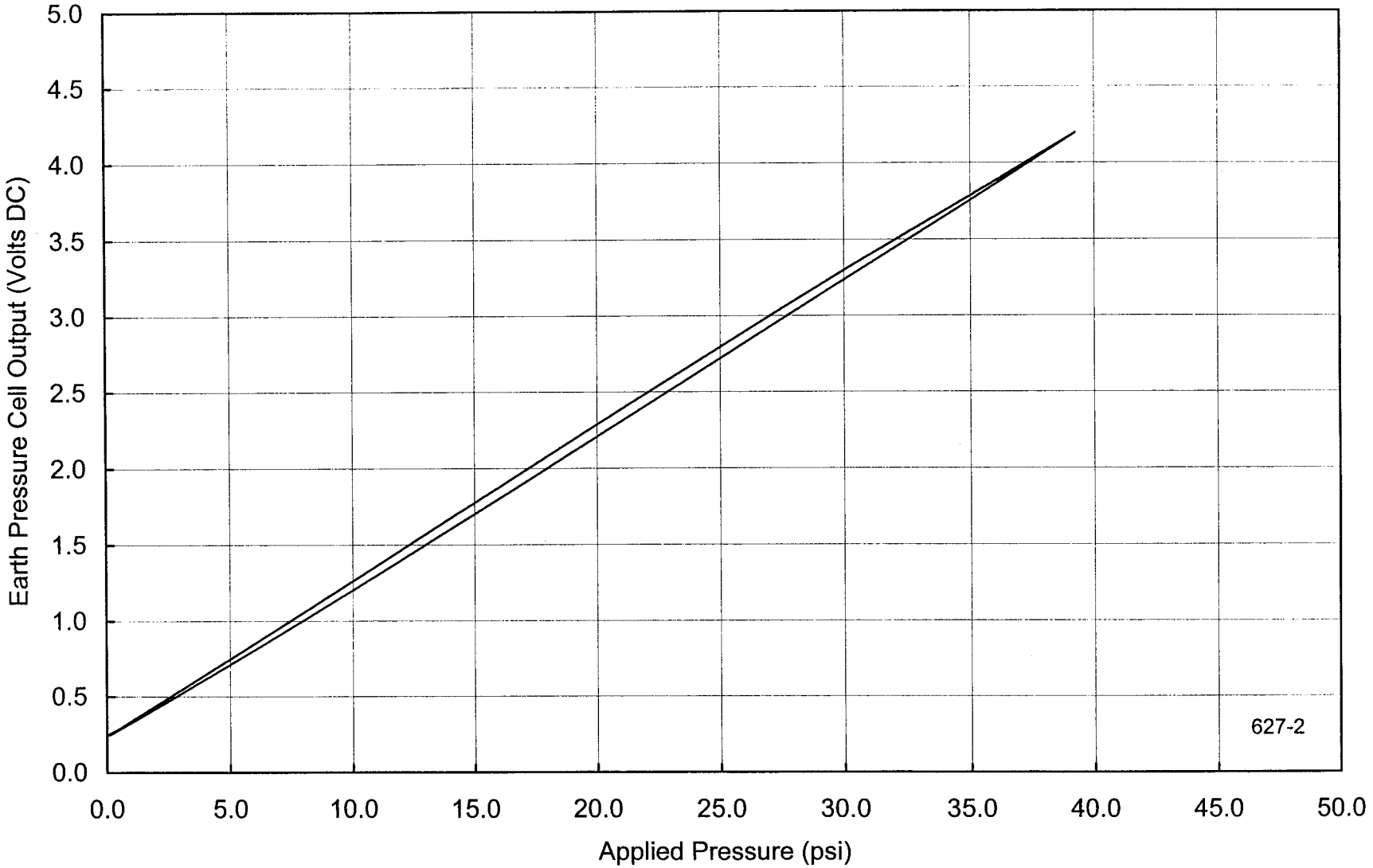

Figure A-104) Calibration record for the second calibration of earth pressure cell number 627 for the ODOT SHRP Test Road, Section 390109

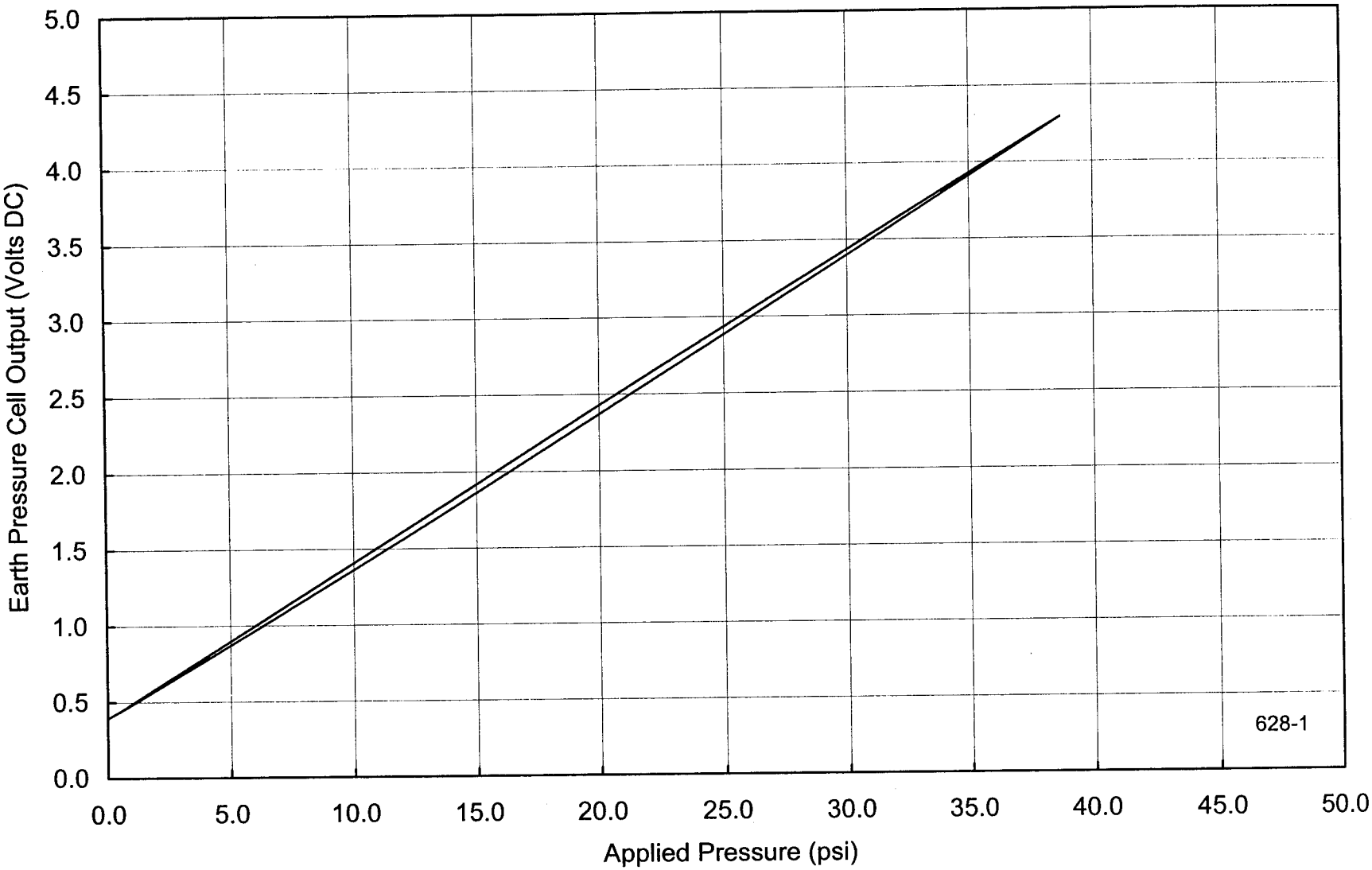

Figure A-105) Calibration record for the first calibration of earth pressure cell number 628 for the ODOT SHRP Test Road, Section 390110

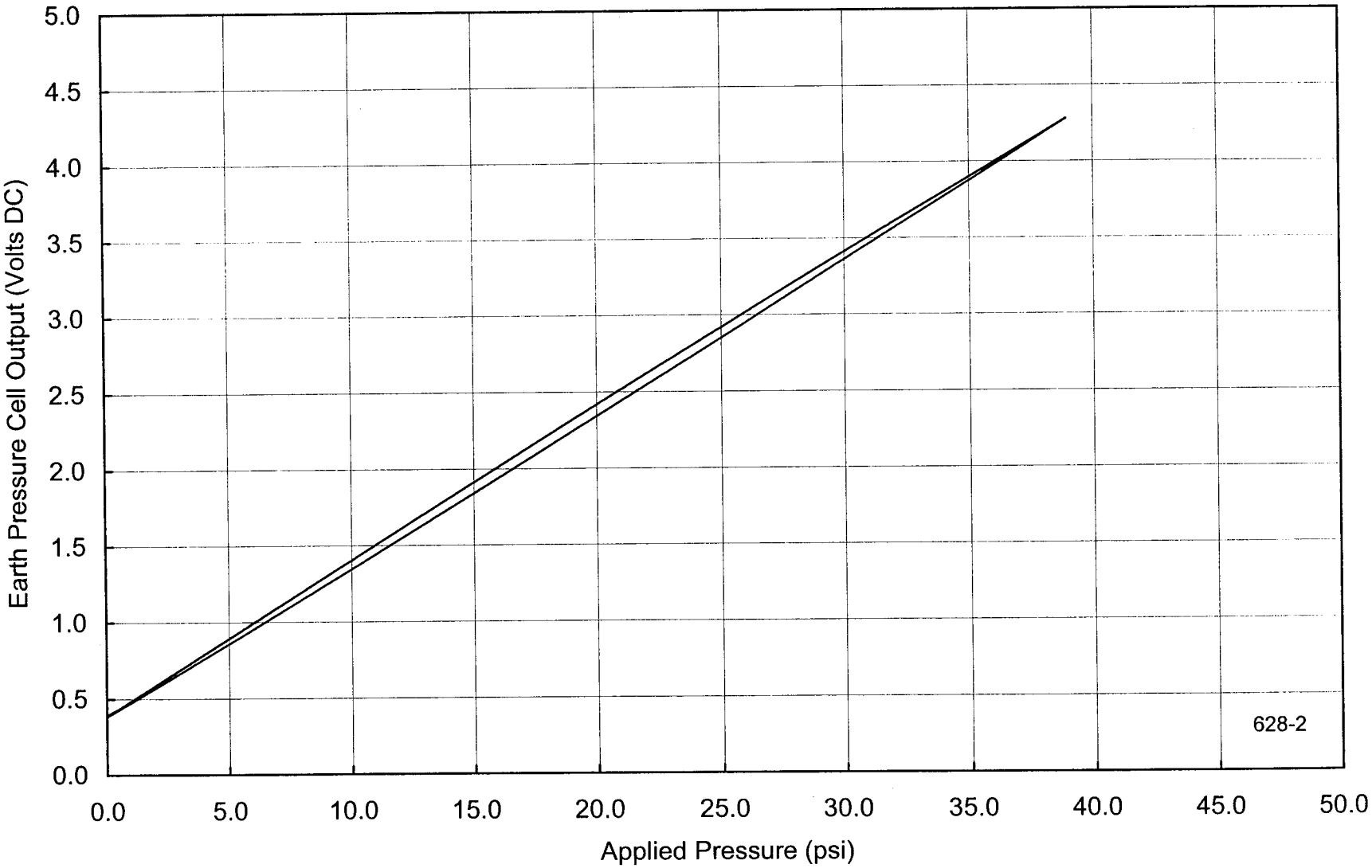

Figure A-106) Calibration record for the second calibration of earth pressure cell number 628 for the ODOT SHRP Test Road, Section 390110

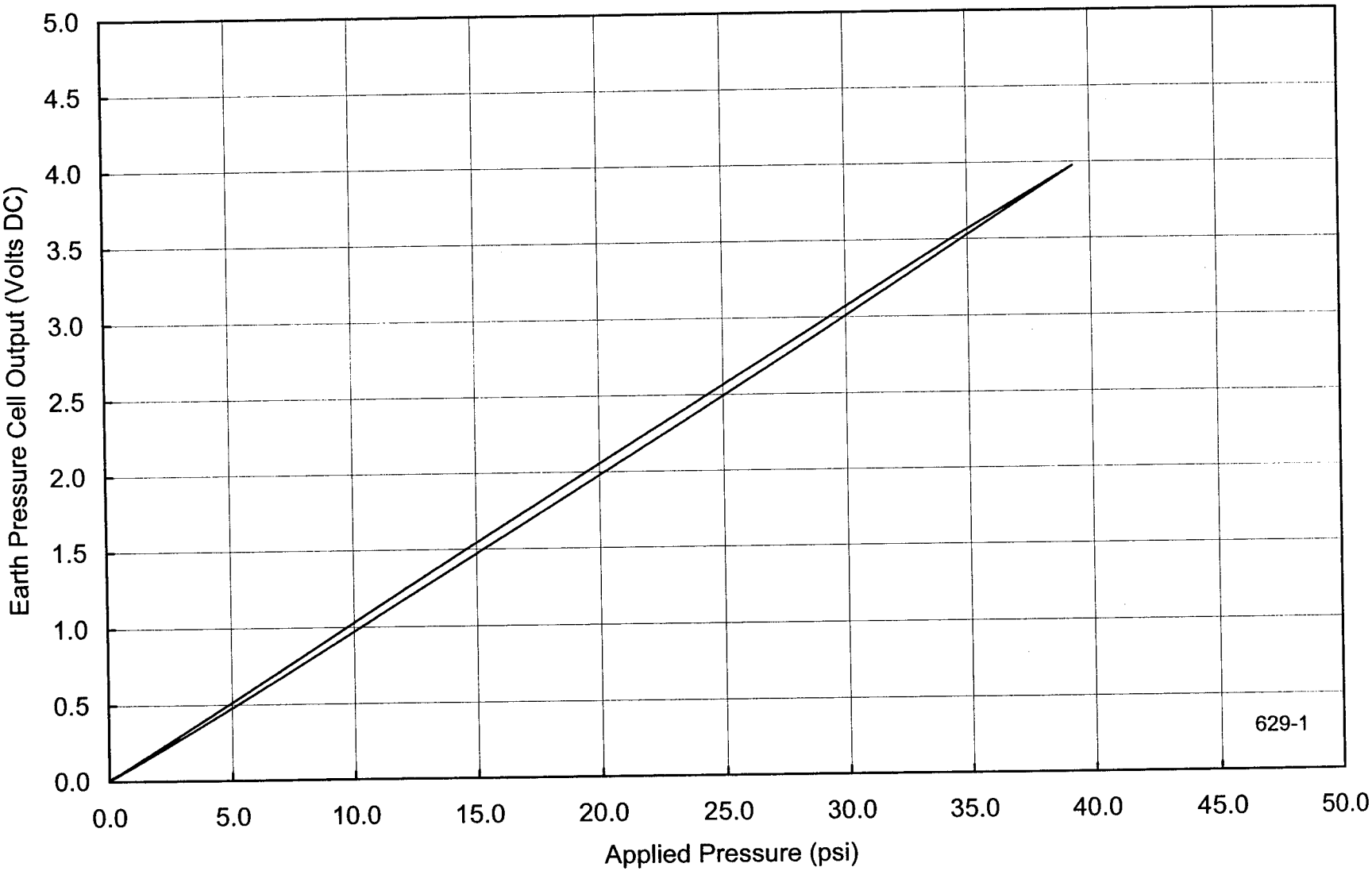

Figure A-107) Calibration record for the first calibration of earth pressure cell number 629 for the ODOT SHRP Test Road, Section 390110

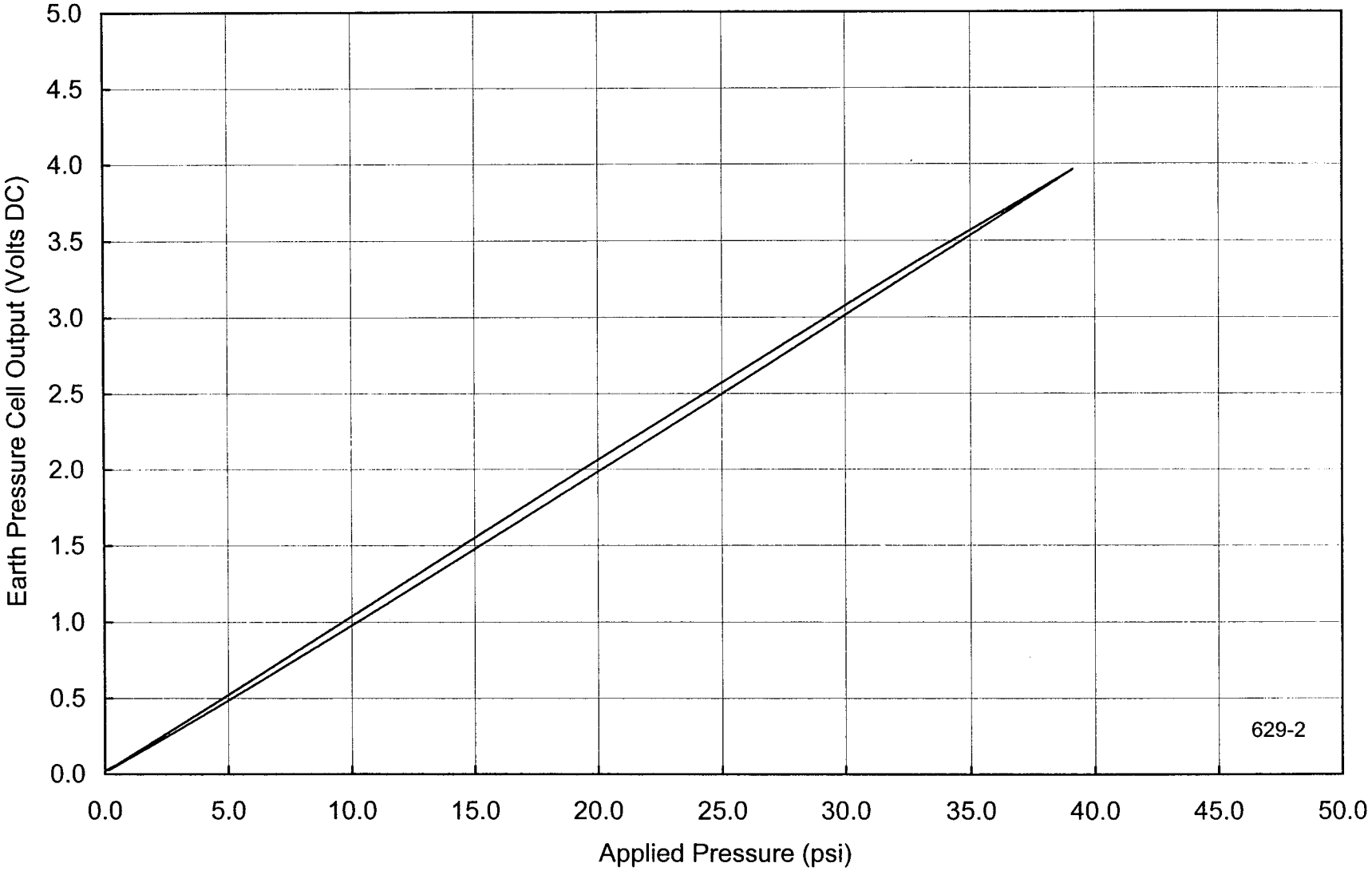

Figure A-108) Calibration record for the second calibration of earth pressure cell number 629 for the ODOT SHRP Test Road, Section 390110

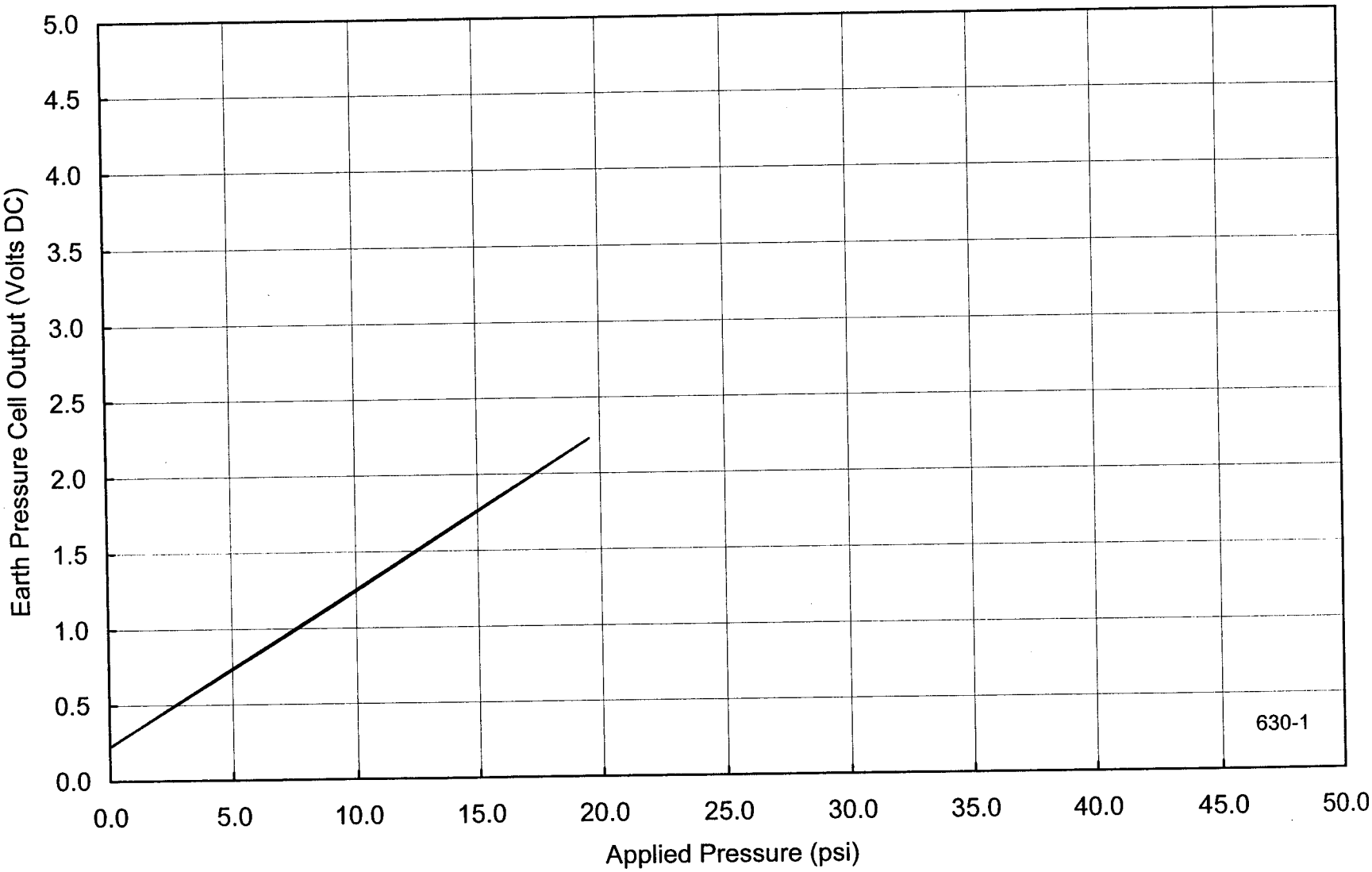

Figure A-109) Calibration record for the first calibration of earth pressure cell number 630 for the ODOT SHRP Test Road, Section 390263

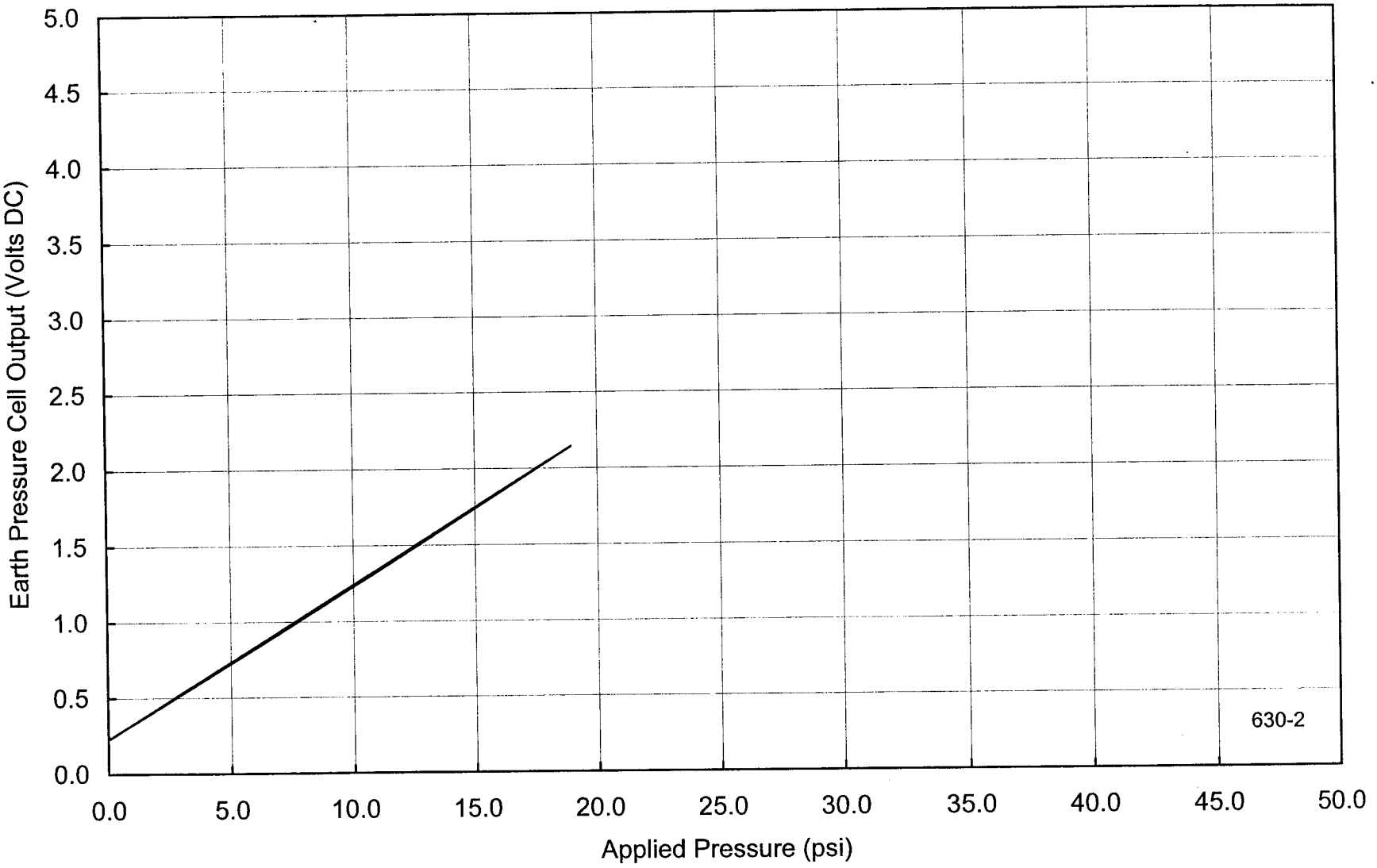

Figure A-110) Calibration record for the second calibration of earth pressure cell number 630 for the ODOT SHRP Test Road, Section 390263

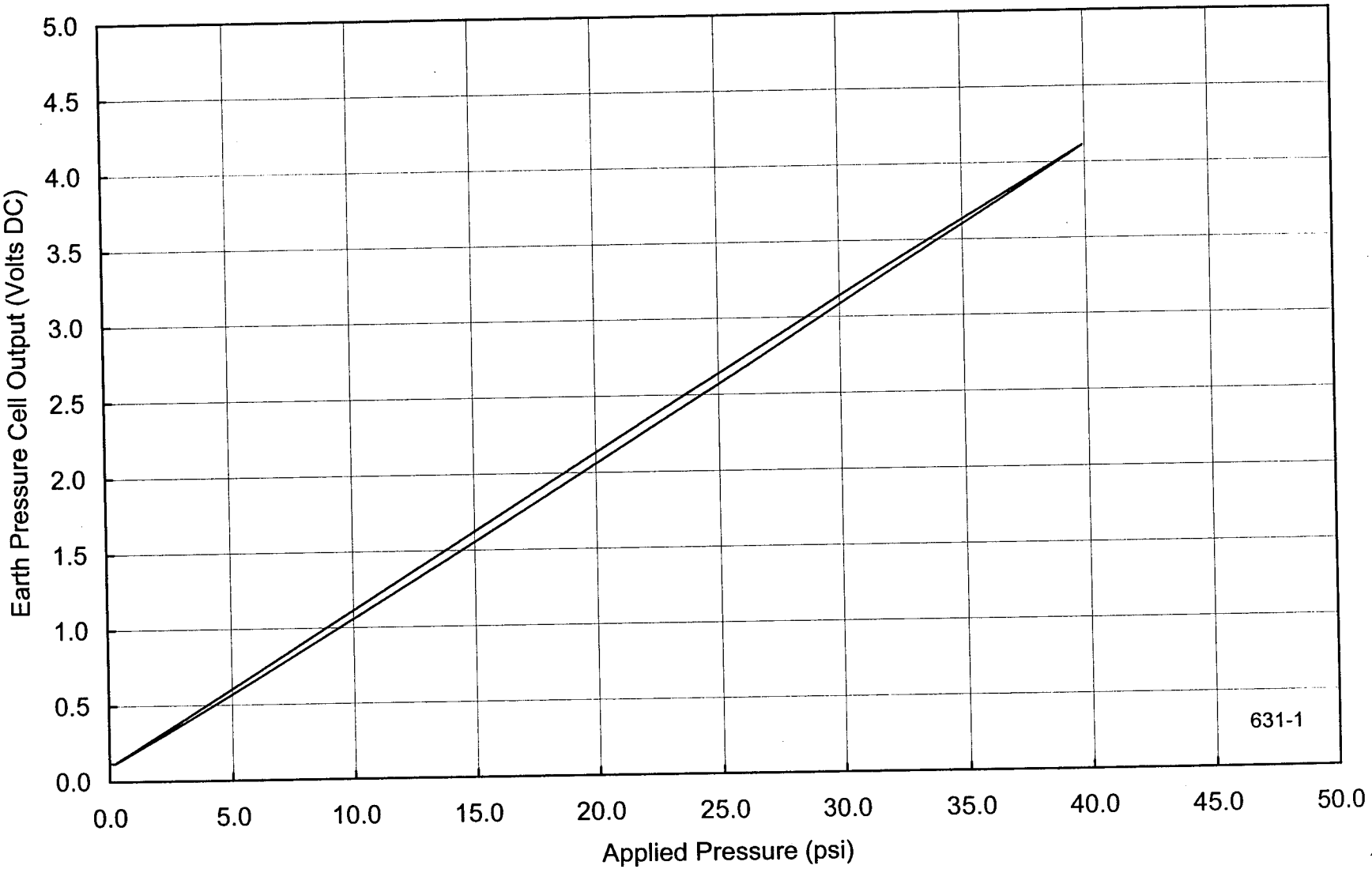

Figure A-111) Calibration record for the first calibration of earth pressure cell number 631 for the ODOT SHRP Test Road, Section 390103

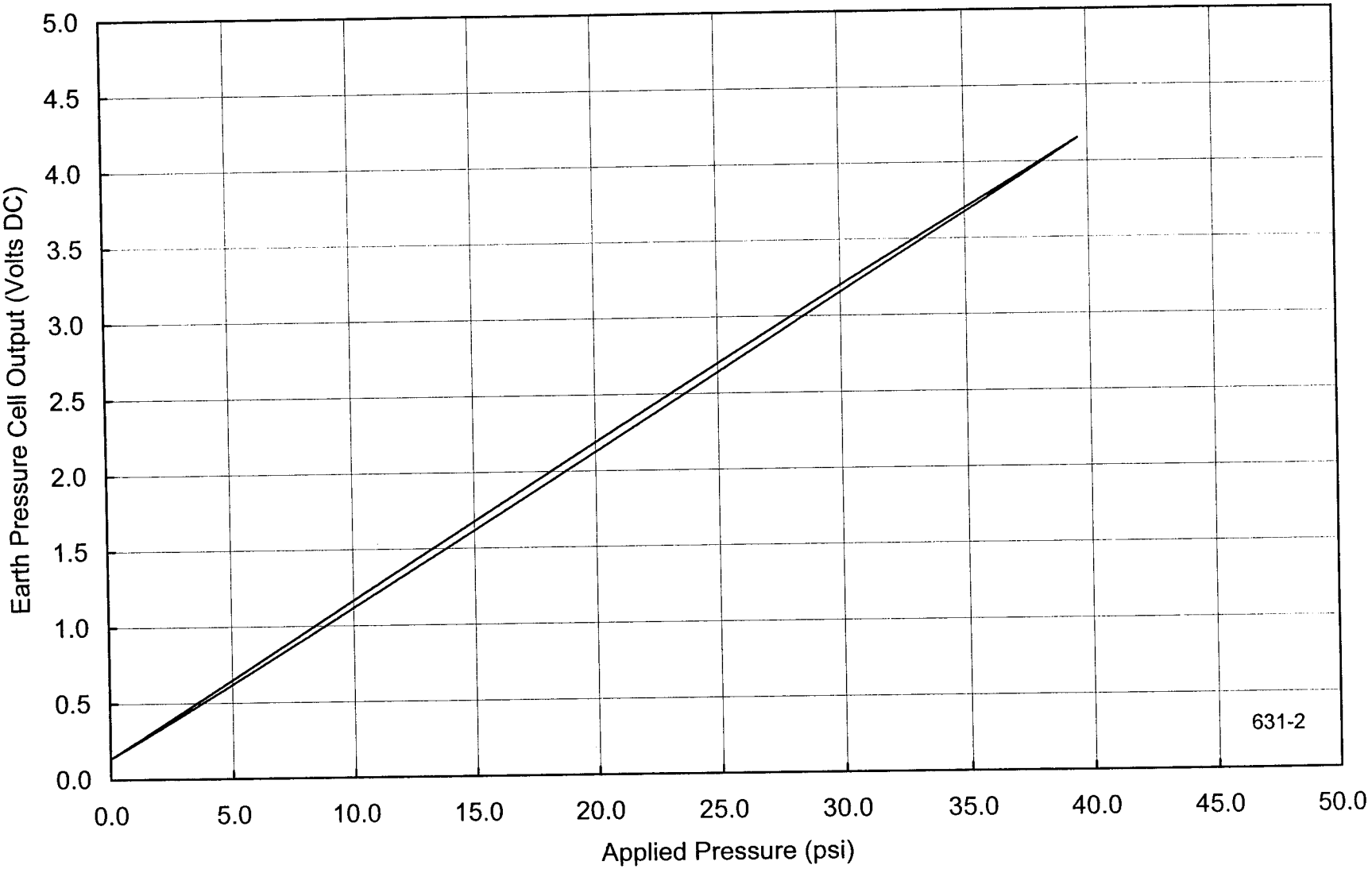

Figure A-112) Calibration record for the second calibration of earth pressure cell number 631 for the ODOT SHRP Test Road, Section 390103

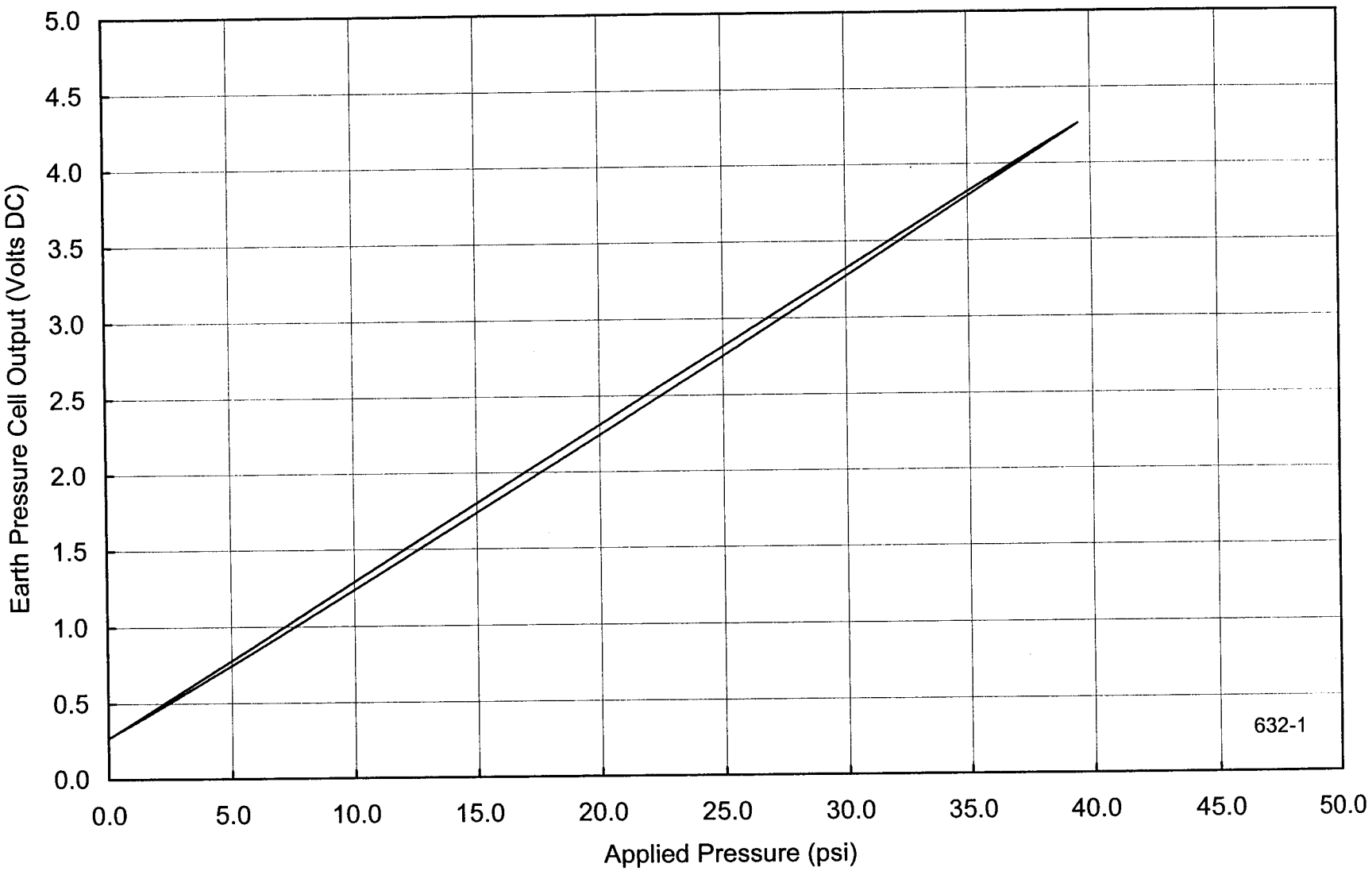

Figure A-113) Calibration record for the first calibration of earth pressure cell number 632 for the ODOT SHRP Test Road, Section 390103

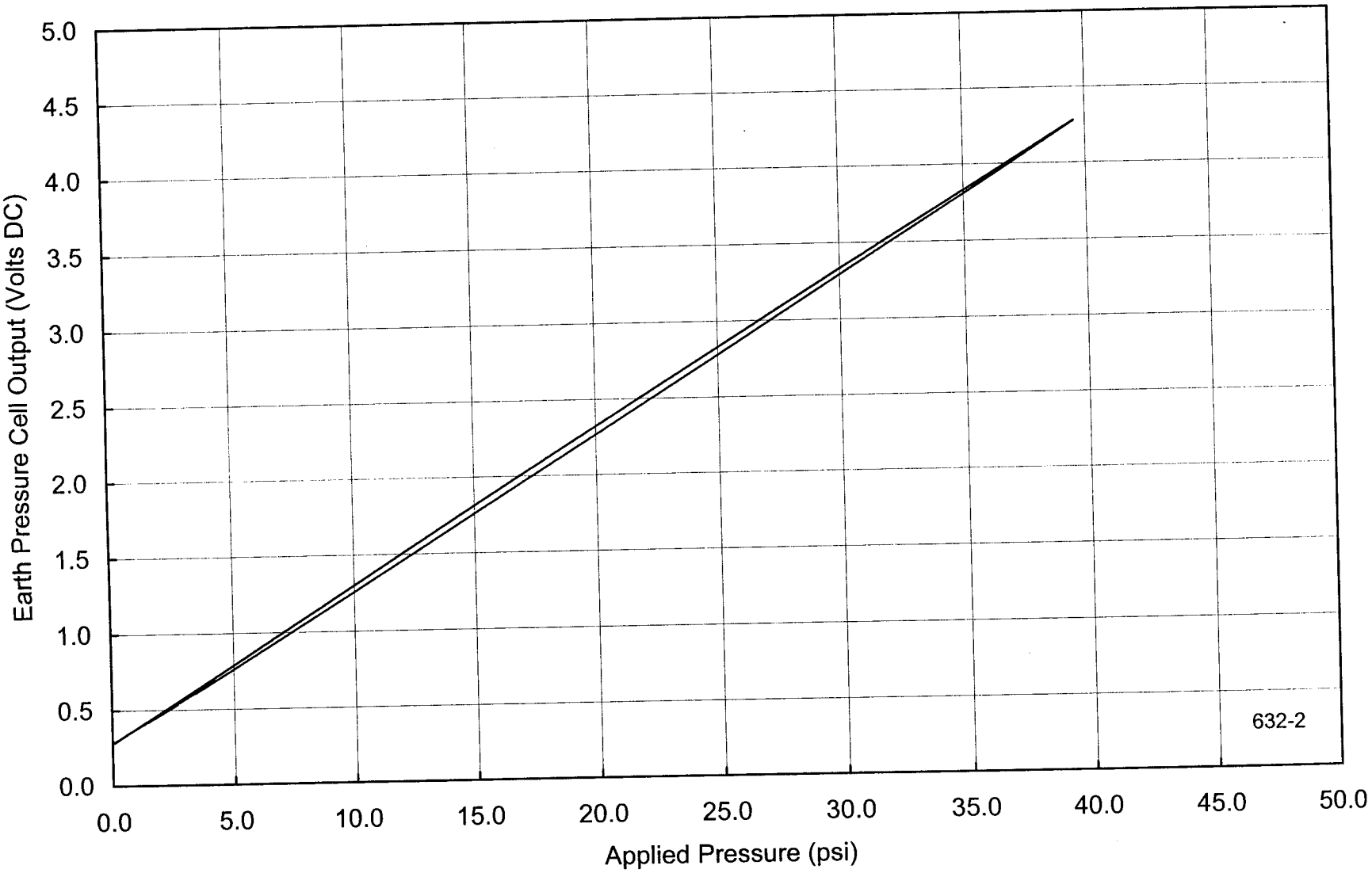

Figure A-114) Calibration record for the second calibration of earth pressure cell number 632 for the ODOT SHRP Test Road, Section 390103

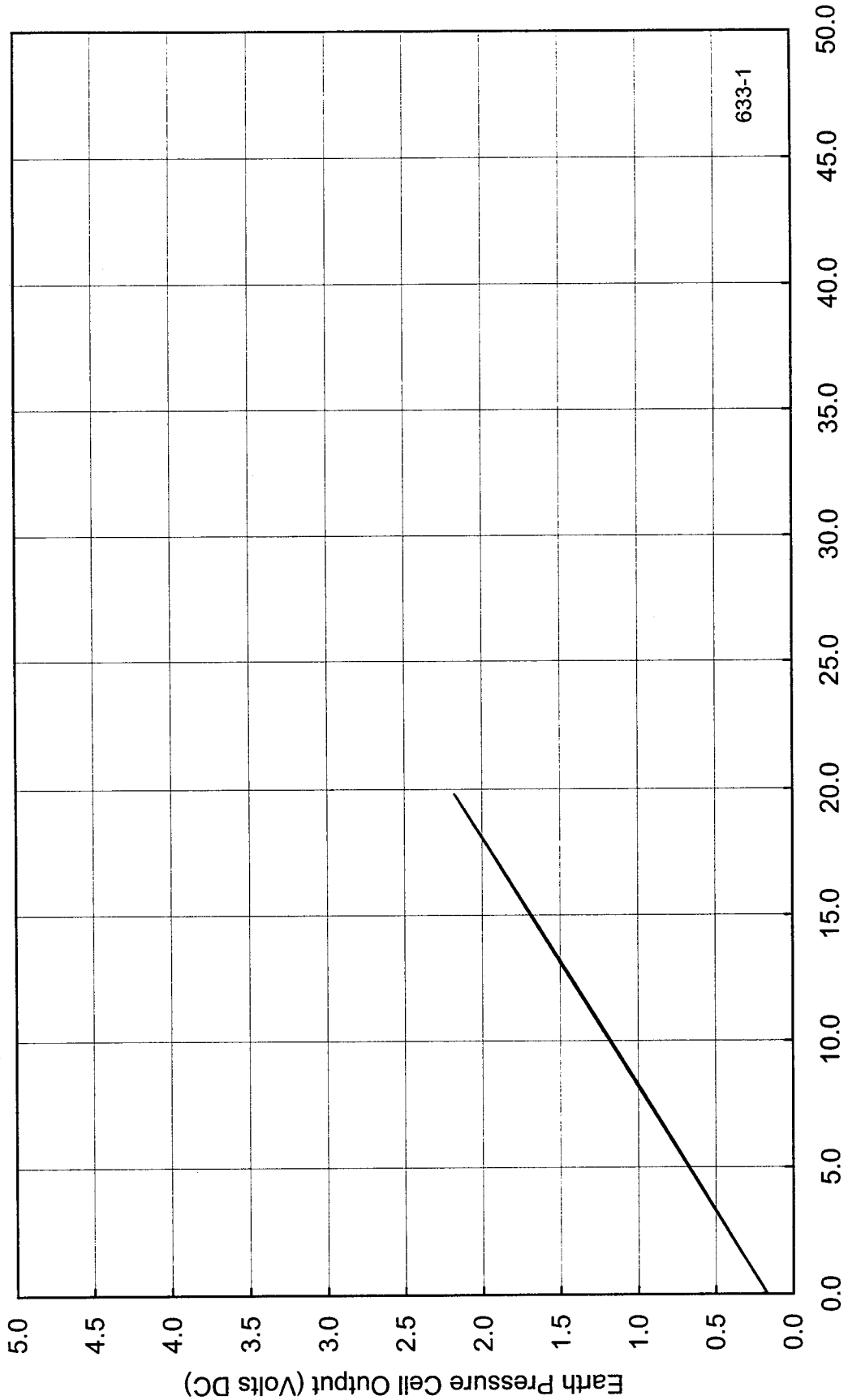

Figure A-115) Calibration record for the first calibration of earth pressure cell number 633 for the ODOT SHRP Test Road, Section 390209

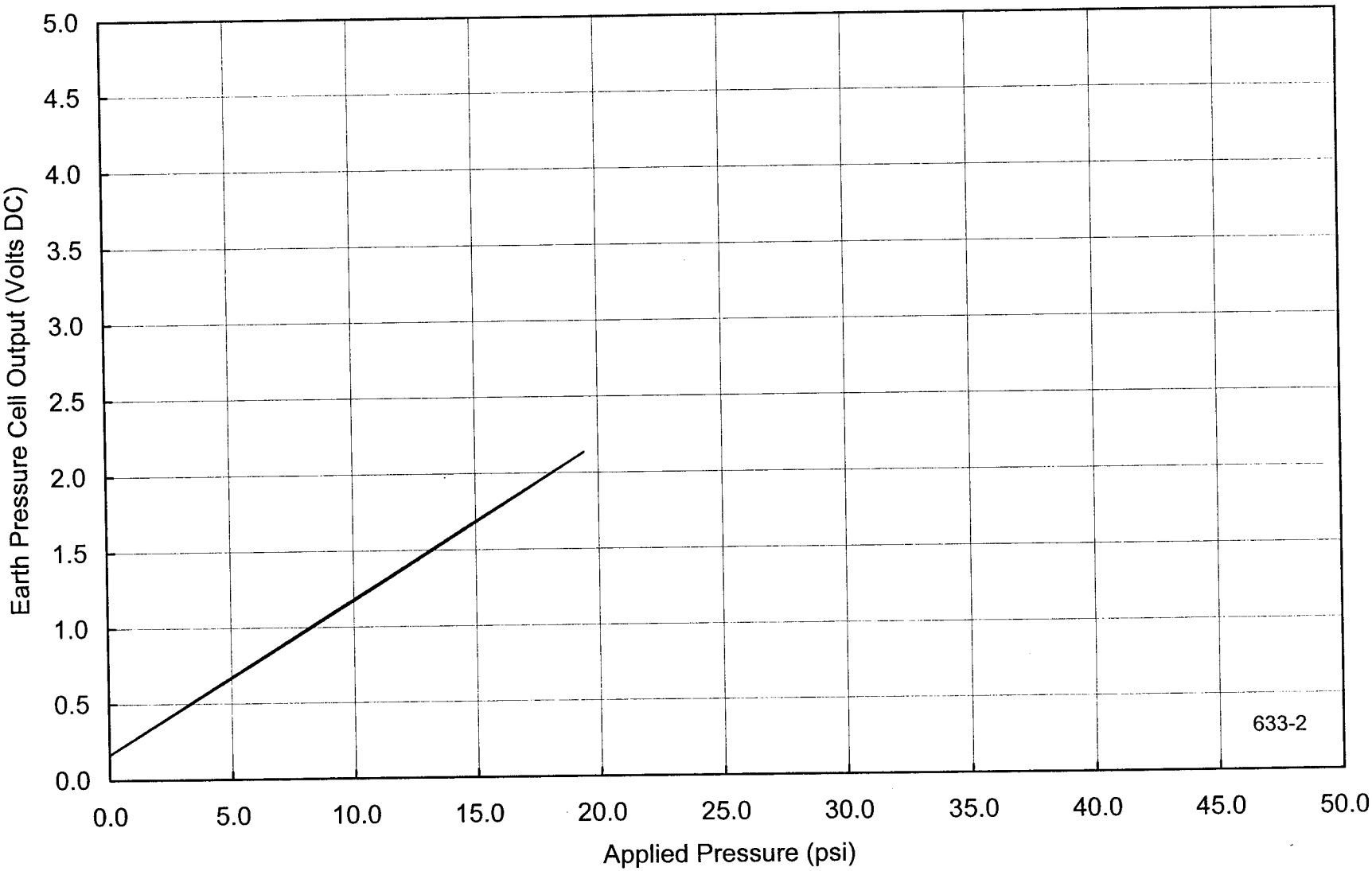

Figure A-116) Calibration record for the second calibration of earth pressure cell number 633 for the ODOT SHRP Test Road, Section 390209

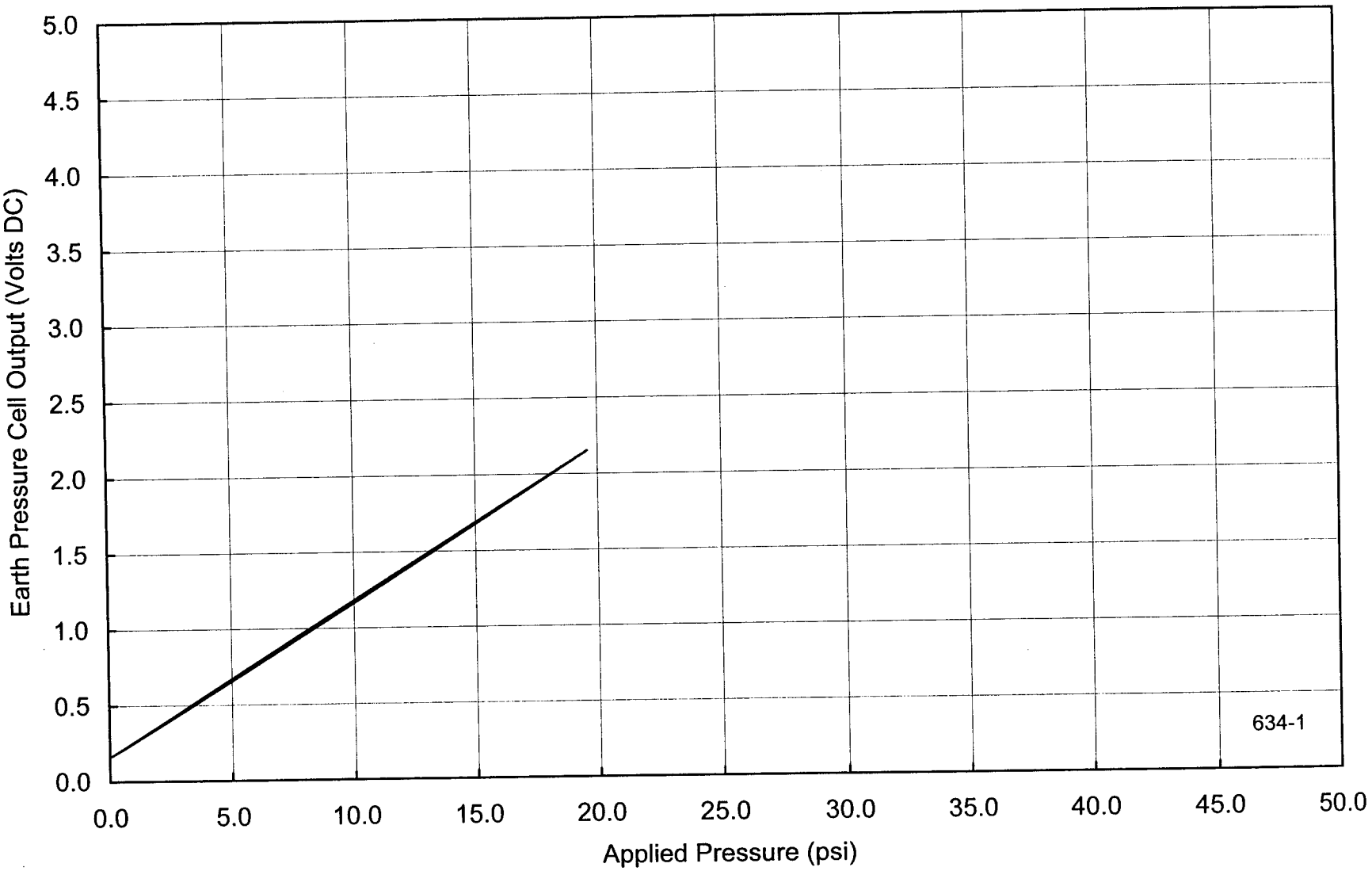

Figure A-117) Calibration record for the first calibration of earth pressure cell number 634 for the ODOT SHRP Test Road, Section 390209

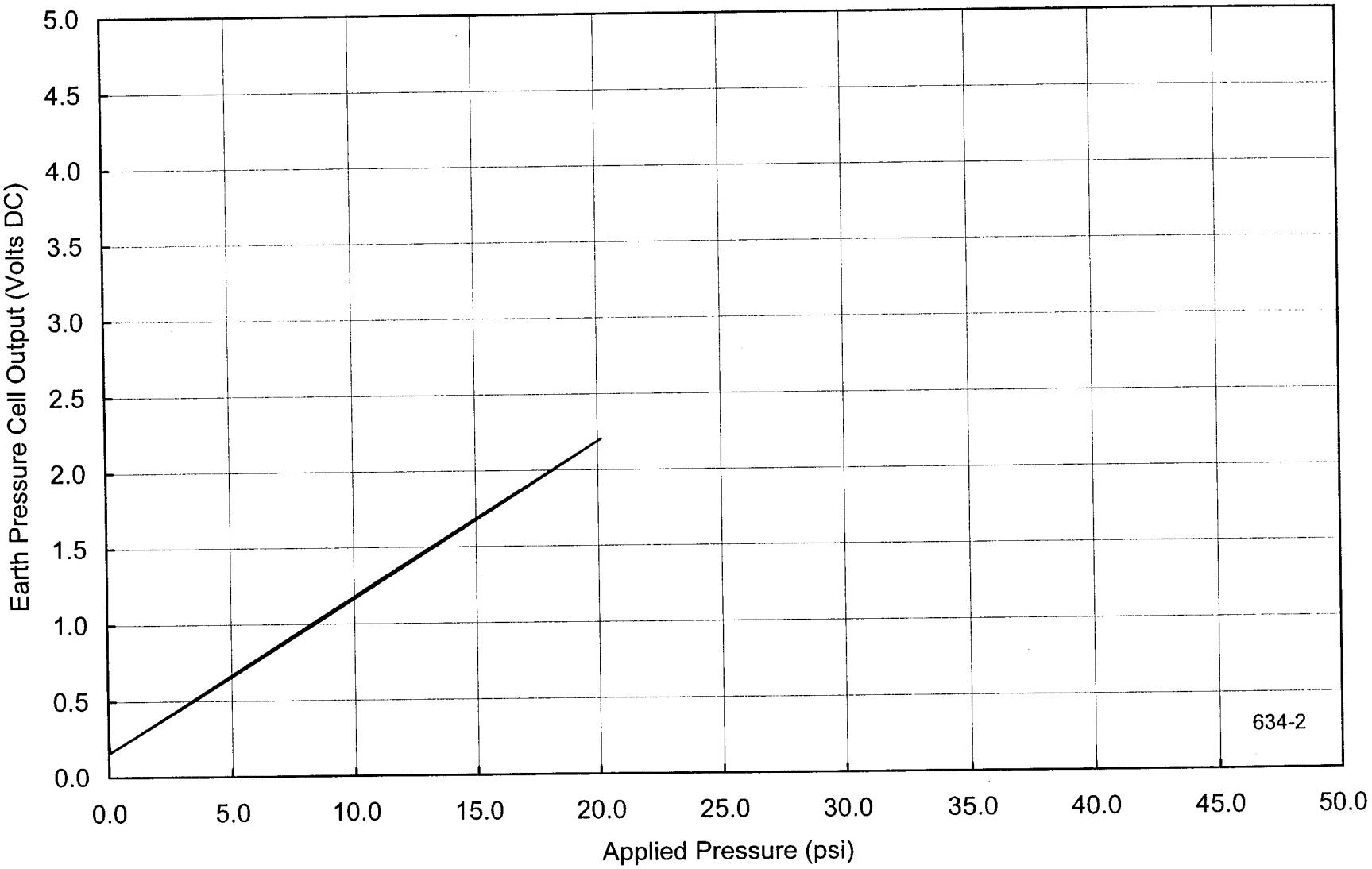

Figure A-118) Calibration record for the second calibration of earth pressure cell number 634 for the ODOT SHRP Test Road, Section 390209

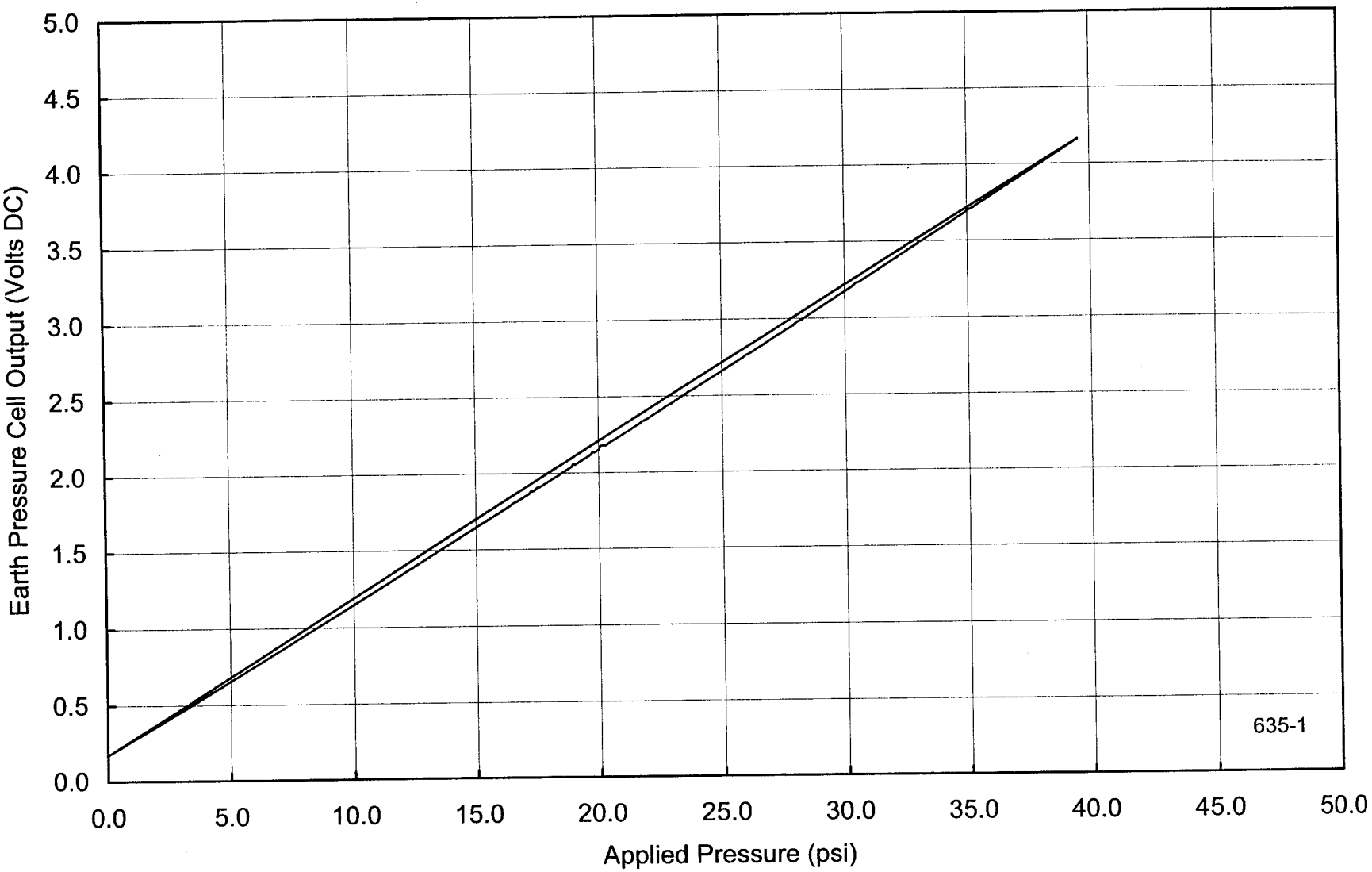

Figure A-119) Calibration record for the first calibration of earth pressure cell number 635 for the ODOT SHRP Test Road, Section 390106

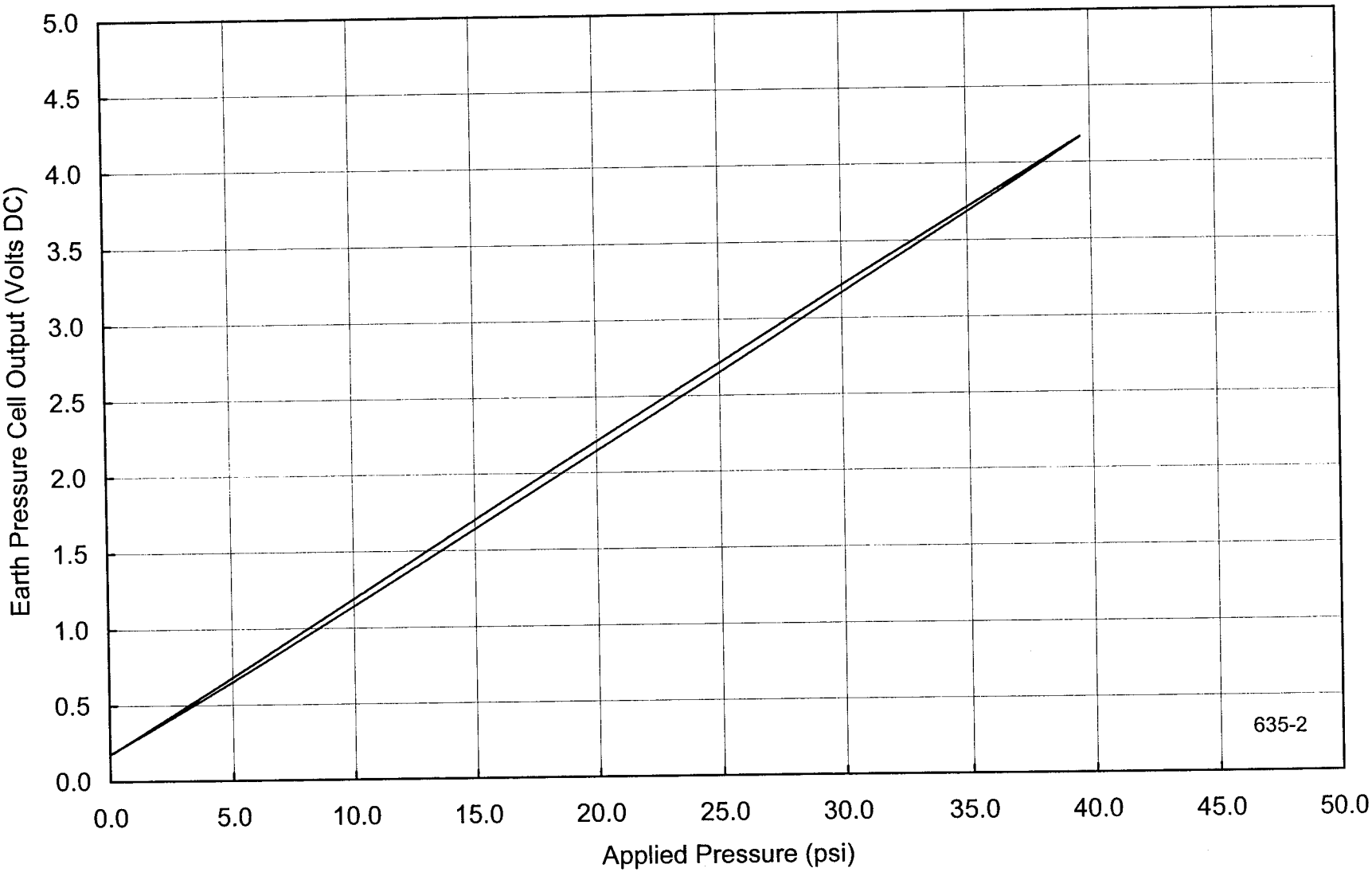

Figure A-120) Calibration record for the second calibration of earth pressure cell number 635 for the ODOT SHRP Test Road, Section 390106

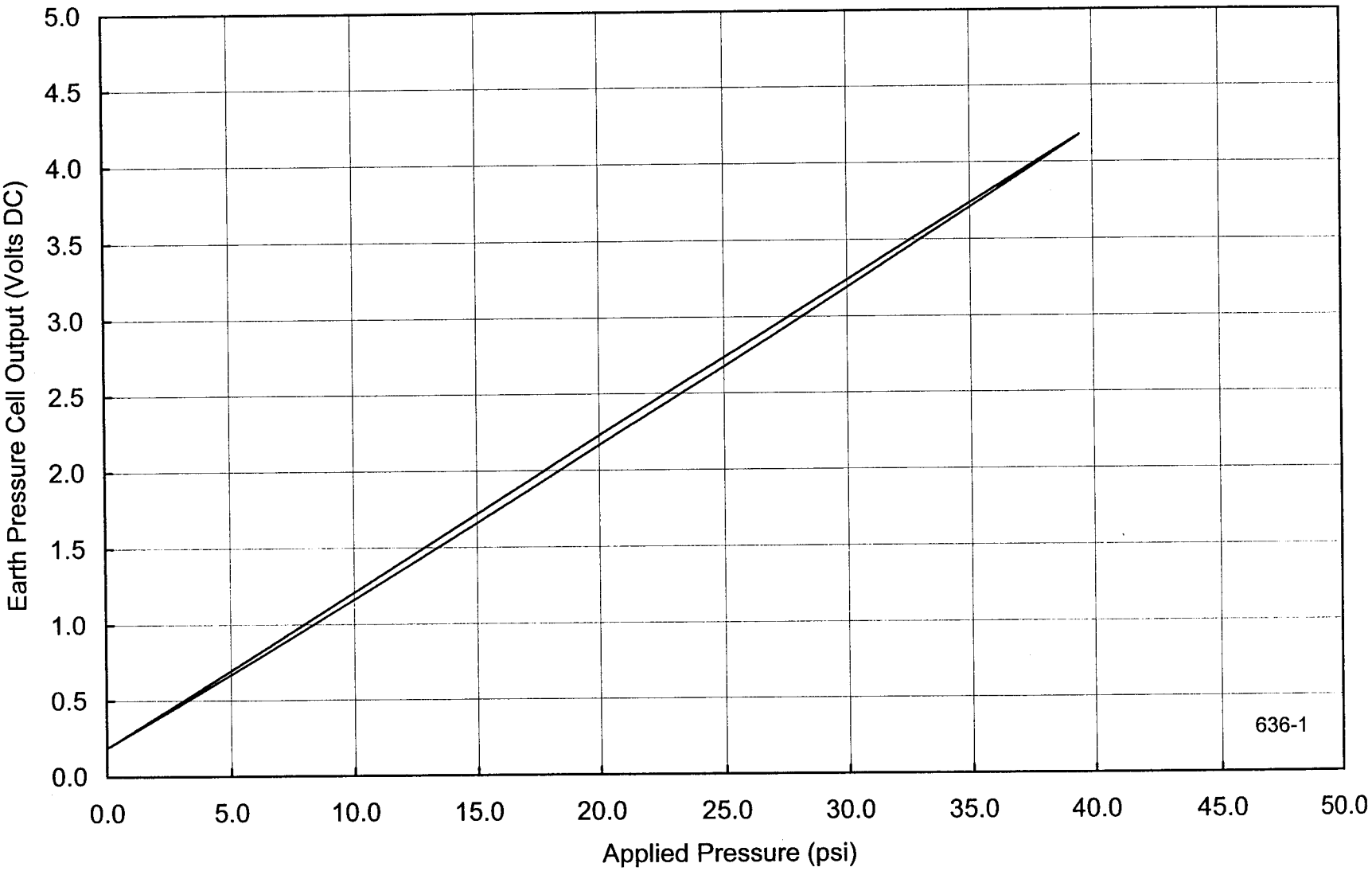

Figure A-121) Calibration record for the first calibration of earth pressure cell number 636 for the ODOT SHRP Test Road, Section 390106

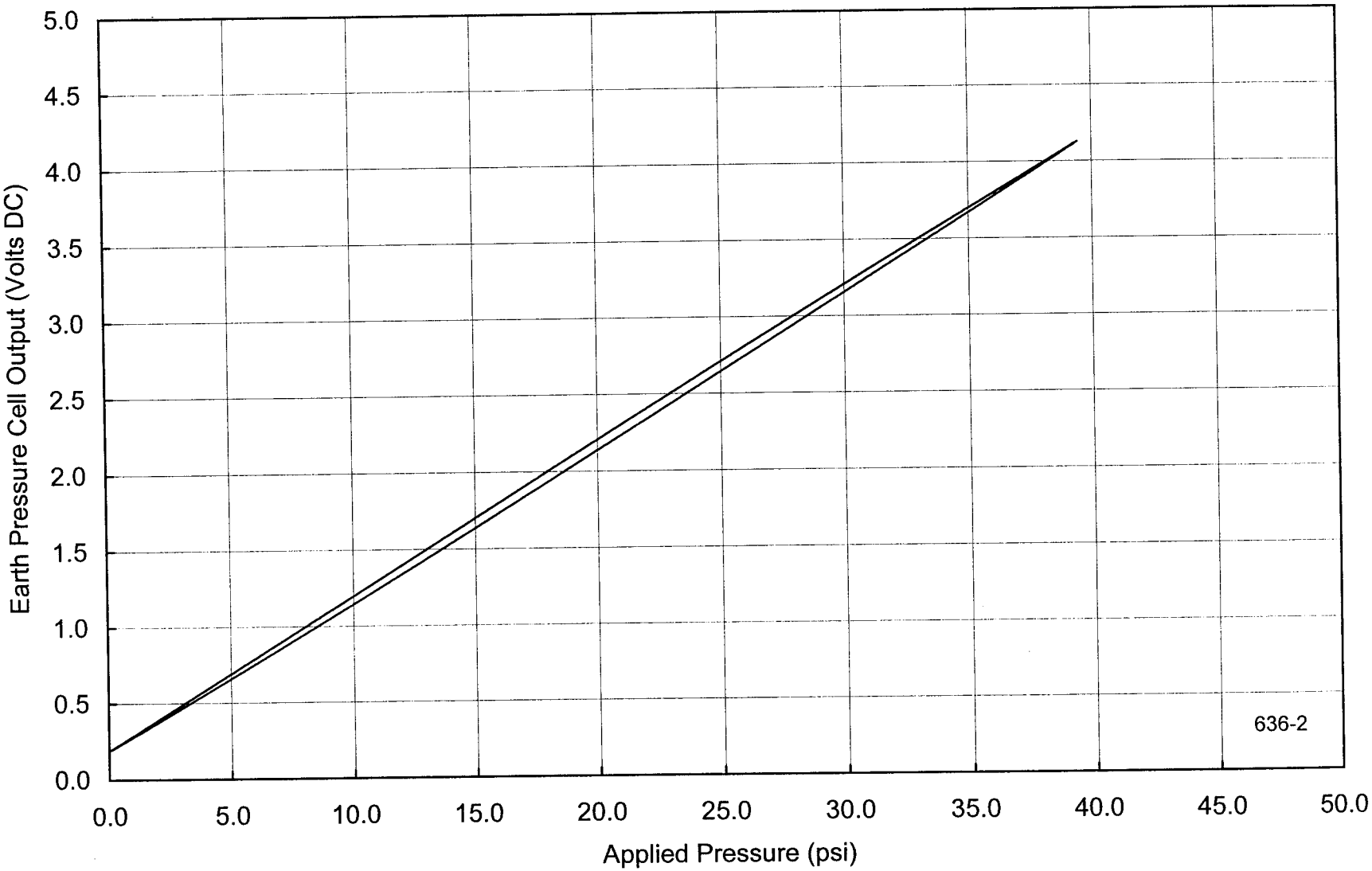

Figure A-122) Calibration record for the second calibration of earth pressure cell number 636 for the ODOT SHRP Test Road, Section 390106

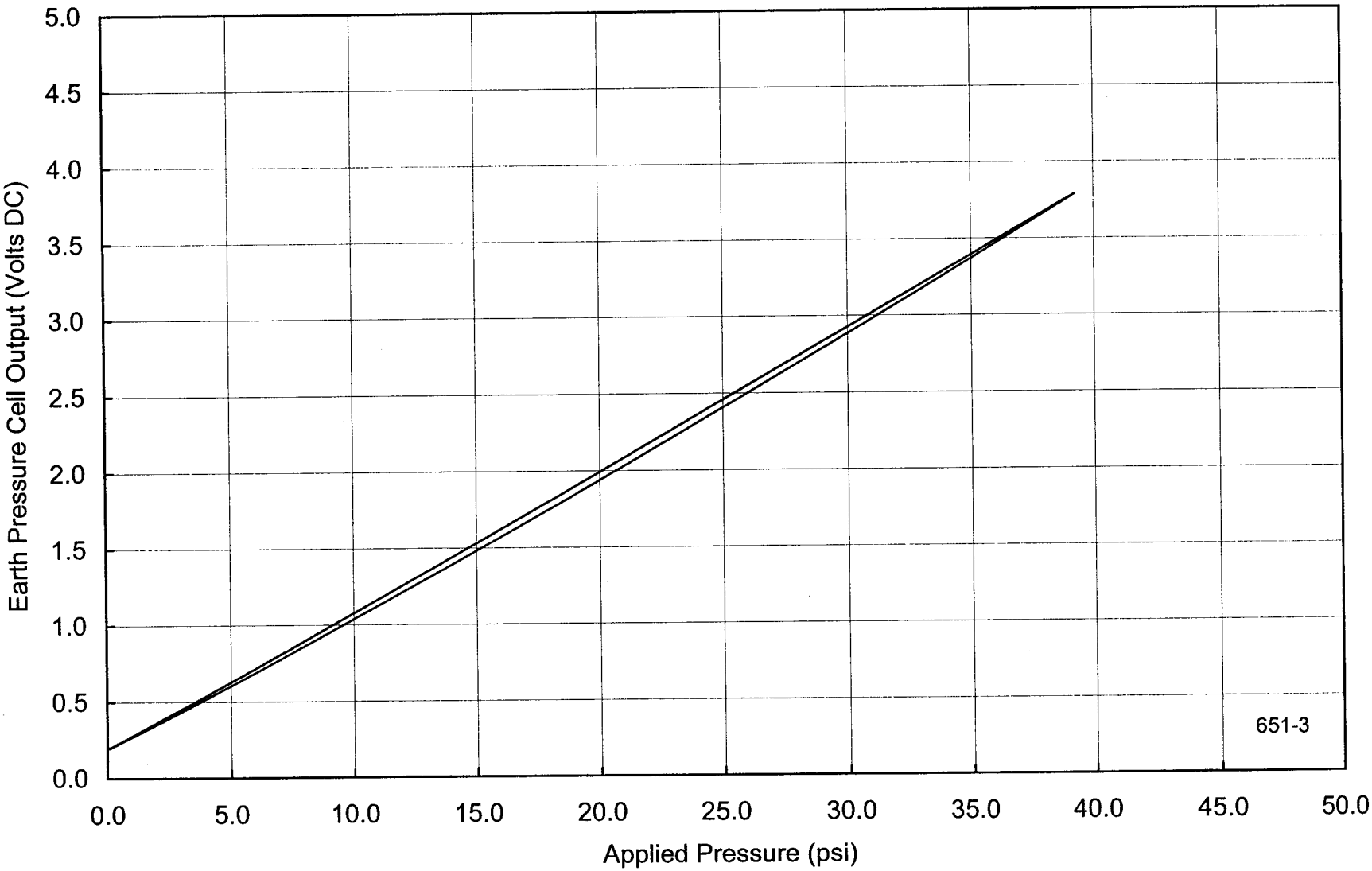

Figure A-123) Calibration record for the first calibration of earth pressure cell number 651 for the ODOT SHRP Test Road, Section 390108

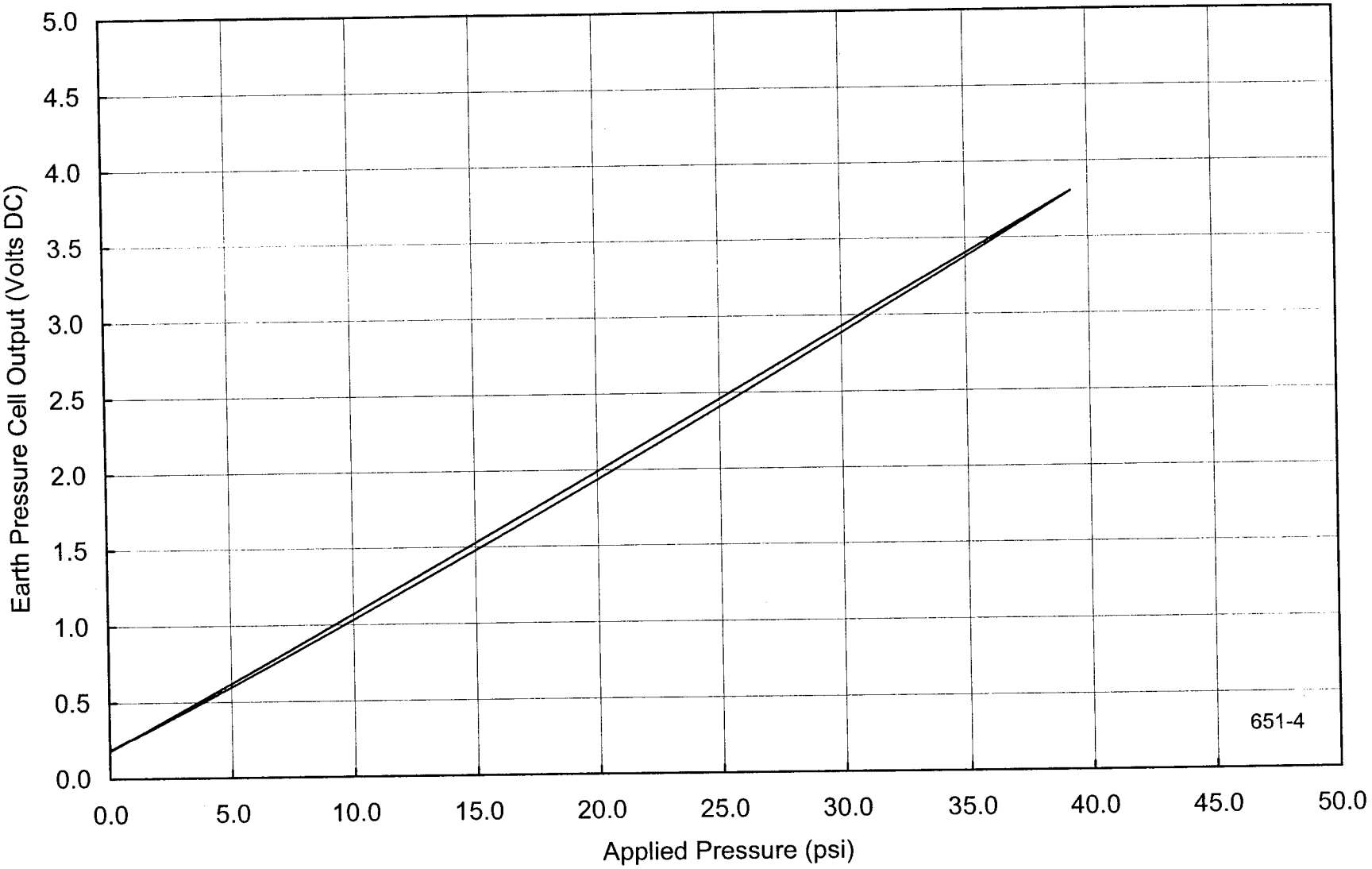

Figure A-124) Calibration record for the second calibration of earth pressure cell number 651 for the ODOT SHRP Test Road, Section 390108