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B/LOAD RESPONSE/DLR DATA STUDIES/ANALYSES

Turner-Fairbank Highway Research Center
TRUCK PAVEMENT INTERACTION GROUP

"Comparison and Quality Evaluation of LTPP DLR Data from Ohio and North Carolina"

Phase I Draft Final Report: "Quality Assurance and Quality Control Analysis"

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BACKGROUND

The Long Term Pavement Performance (LTPP) Team at the Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center (TFHRC) has been collecting pavement performance data across the United States and Canada since 1987. This effort includes more than 2400 asphalt concrete (AC) and portland cement concrete (PCC) test sections. These test sections are monitored for material property and performance changes over time. This data is collected and managed in the LTPP IMS database, and select data from that database was released with the DataPave 2.0 software as a resource to transportation industries internationally. Before data is included in the IMS database, it is processed and analyzed for quality assurance and physical merit. Two general categories of data are collected: General Pavement Studies (GPS) and Specific Pavement Studies (SPS). The GPS studies included prebuilt roads whereas the SPS studies included only new road construction.
As a part of the SPS studies, two states, Ohio and North Carolina, were selected to incorporate strain, deflection and stress instrumentation into selected SPS sections in their state, and to conduct controlled loading experiments. Raw data from the controlled loading tests have been reduced by PCS/LAW to key elements, enabling increased potential for user accessability. Raw dynamic load response (DLR) data collected from the SPS-2 sections in NC was processed and included in DataPave 2.0. Because some of the data obtained from the OH experiments was thought to be out of the anticipated range, none of this data was included in DataPave 2.0.

The Truck Pavement Interaction (TPI) group at TFHRC has been involved in performing controlled loading tests, and analyzing pavement response data since the mid 1980's. TPI uses this data to develop, validate and calibrate mechanistic pavement design models. With such experience in this area of work, TPI submitted a work proposal to LTPP, attached to this report as Appendix C, to examine a sample of the DLR data in question and provide and evaluation of the data in terms of quality and applicability to pavement modeling and design. The TPI group proposed three phases for a complete study, with work continuuing in phases II and III based on the outcomes and recommendations of phase I. This document competes phase I. It deals with the conduct of comparisons of the NC and OH data, as well as with the methods employed in their collection, processing and presentation, to identify differences, not only between the two sets of data, but also between data processing results obtained from PCS/LAW and TPI.

OBJECTIVE

Overall:

The main objective of this study is to determine those approaches and methodologies most appropriate for applications of measured stress, strain and deflection response obtained from in-service roads to theoretical (mechanistic) pavement analysis concepts and design processes.

Phase I – Quality Assurance and Quality Control Analysis.: Identify biases, procedural or processing errors, or physical irregularities, if any, that exist in the sample DLR data. Provide a scientific explanation for findings, as well as suggestions for future experimental and/or procedural modifications to ensure improvement of data quality.

Phase II – Statistical Analysis. – Perform correlations and regressions to provide correlation coefficients and linear/non-linear regression values to identify trends between experimental results and test variables.

Phase III – Mechanistic Analysis. - Verify that mechanistic models exist, or can be modified to predict pavement response given inputs similar to those test conditions found in the selected SPS sections.

EVALUATION OF AVAILABLE INFORMATION

Efforts to begin work on this project began with an overall review of documentation describing the LTPP experiments and the databases associated with these experiments. PCS/LAW established the format for DLR data tables to be included in the LTPP Information Management System (IMS) database. Revised specifications for DLR data to match IMS standards were made and documented by PCS/LAW to allow for additional elements in the OH dataset (1,2). Descriptions of tables and table elements within the IMS database are given for DLR data as well as off-line data storage specifications and a description of the DLRCheck computer program and its functions.

In April of 1994, PCS/LAW prepared a draft document to describe SPS-2 experiment instrumentation information common to both OH and NC data sources (3). This document gives detailed information on data acquisition systems, loading plans and locations, measurement parameters, instrumentation specifications, placement and installation procedures for SPS-2 experiments. This is good information to compare with the NC DOT open-house document (4). This NC DOT open-house document contains general background and motivation for all LTPP experiments as well as experimental design matrices, site maps, section layouts, mix designs and material sources for NC SPS-2 experiments. After examination of this NC DOT open-house document, it was discovered that specific spatial layout information for instruments was not included, but an instrument layout plan was later provided to TPI via fax by NC DOT (5). The faxed layout plan included gage lables and relative placement, but no spatial dimensions, which must be extracted from the IMS database through the DataPave version 2.0 software (6). This raised the question: "From what source did the spatial information included in the DataPave/IMS database originate, and why was it not provided to TPI?" The answer is at this point still unknown, but for further data analysis planned for phases II and III , it will need to be realized.

Some instrumentation in OH includes not only that set forth by the Strategic Highway Research Program (SHRP), but also instrumention placed for separate OH DOT and Ohio University (OU) experiments (7). For example, the LVDT's placed at the outermost positions of the test sections were not part of the SHRP protocol, and therefore data from those gages was not supplied as LTPP DLR data to PCS/LAW. The OH SPS instrumentation report (7) gives detailed information on instrumentation installation, calibration, data acquisition and work schedules for the SPS-1&2 sections in OH. Technical information required for completion of Phase I of this study is contained in the OH SPS instrumentation report (7) with the exception of instrument calibration factors, which had to be obtained directly from OU. Some spatial information for specific test sections and depth of OH LVDTs is not included, but this information was later obtained from OU via telephone conversation April 24, 2000. It was then discovered that all LVDT's used to measure entire pavement structure deflection (deep reference LVDT's in OH SPS sections) are anchored at a depth of 10 feet, and LVDT's used to measure only deflection of the base (shallow reference LVDT's) are anchored at the bottom of the base. Specific base depths vary with the test section and this information was obtained from the Ohio SHRP Test Road Open House booklet (8)

In addition to instrumentation details for both OH and NC data, for comparison purposes it was also essential to obtain information relating to data acquisition equipment and software which is contained in the MEGADAC technical manual (9). This document provides the information necessary for operation of the OPTIM Corporation's MEGADAC SERIES 3100 data acquisition system. This system also includes the Test Control Software (TCS) which is a database management package used to control how the MEGADAC data acquisition system will be used for testing applications. This may prove helpful in isolating possible causes of data collection errors.

INVESTIGATIVE PROCEDURE

A flow diagram of the process developed to achieve the objectives can be seen in Appedix A, figure 1.

Sample Data Examination

OH Data Examination

PCS/LAW provided representative OH AC DLR plots in hard copy form and raw DLR data from three OH AC sections, three OH PCC sections in electronic form on floppy disk. The hardcopies were plots of data traces as they appear when viewed with PCS/LAW's DLRCheck data processing software. OH files represented by these hardcopies include the following: j4a.001, j4a.008, j4e.001, j8a.001, j2e.012, j2e.010 and j8a.006. The file naming convention: first two digits represent site and site number, the next digit represents return visit to the site in alphabetical increments, and the numeric extension represents the run (repetition)number for that particular return visit to that particular site.

The compressed data files were copied from the floppy disks to hard drive and deflated using PKZip software. These compressed files contain at least two raw binary data files and several supporting MEGADAC (data acquisition equipment/ software) files. The raw files were opened and viewed using the PEAK software from OU. Plots of the raw data, from files that were a direct match with the hardcopies listed above, were printed to check that data trace forms matched. Some of the raw trace shapes that were produced did not appear to match their corresponding hardcopy traces at first glance, but it was later determined that peaks of interest had been "zoomed" using a feature in the DLRCheck software ("zoom" is not a feature included with Ohio's PEAK program).

Another observation is that the channel labels in the PEAK program are incremented one step ahead of the channel labels in the DLRCheck display. For example, channel 17 in PEAK corresponds to channel 16 in DLRCheck. DLRCheck begins labeling with channel zero (ch. 0) while PEAK begins labeling with channel one (ch. 1). This is not an important matter in terms of the data, but it should be noted for making comparisons between hardcopies of data traces provided in appendix B.
The MEGADAC system calibrates strains internally, therefore raw strain output from MEGADAC is in microstrain. PEAK can only read raw data with their supporting MEGADAC files, therefore Since all the DLRCheck output in hardcopy has been scaled using calibration factors, only peak strain channels could be directly compared with PEAK traces. Calibration factors can be applied using PEAK, however the results can be seen only at the PEAK output, and not on the trace display. PEAK outputs only the peak and valley values of the trace that it selects in ASCII form. Questions about the PEAK program were raised to OU pertaining to how the program algorithm identifies peaks and why expected peaks were not always being identified. An improved version of PEAK was suggested, which would allow the user to manually select peaks of interest in the event that the program does not automatically identify the expected peaks. This version of PEAK was to be supplied to TPI via e-mail, however it was never received. To check the validity of peak values supplied in the DLRCheck hardcopies, a combination of TCS and Microsoft Excel (XL) was chosen to manually extract peaks from the entire trace in ASCII form.

NC Data Examination

The same process was used to deflate and view the NC data, however there were no DLRCheck hardcopies to compare with PEAK output. NC file naming convention differs from OH in the following manner: for a file named t37201f.002, "t" represents truck (rather than an "f" for falling weight deflectometer), the next two digits indicate the SHRP State code, the next three digits indicate the last three digits of the SHRP ID for the test section, the last letter indicates the return visit (the sixth in this case), and the three digit extension represents the repetition number.

Data Processing

OH Data Processing

As stated previously, TCS, which comes with the MEGADAC system, was used to convert the entire raw data trace to ASCII format. Once this conversion was performed, XL was used to open the ASCII files, apply calibration factors to them and plot the results. Examples of these strain, LVDT, and pressure plots are included in Appendix A, figures 2-4. While specific calibration curves exist for each sensor at OU, they are not easily accessible, therefore general factores supplied to TPI by OU were applied. OU clarified that all LVDT calibrations (approximately 600 LVDTs) are linear and pass through the origin with slopes ranging from 19.5 – 20.5 Volts per inch. Therefore an average value of 20.0 V/in. was used for data processing. Dynatest strain gages were calibrated by OU using a MEGADAC data acquisition system in the ¼ Wheatstone Bridge setup, therefore no further conversion factors were needed in data processing for strain. A factor of 10 psi/volt is generally used for all pressure sensors, which are considered reliable to within ± 2%, according to OU.

NC Data Processing

NC displacement traces appeared smooth, as seen in appendix A, figures 4 and 5, while strain traces exhibit high noise levels as seen in figures 6 and 7. Raw displacement channel tags indicated that the data had already been calibrated to inches. NC was contacted via telephone to request information verifying that displacement calibration factors varied from 81 V/in to 83.8 V/in. and were input to the MEGADAC system and applied during data collection.

Data Processing using DLRCheck Software

A working copy of the DLRCheck software and a user manual was requested from PCS/LAW. Both of these items were supplied, however during program execution, multiple errors resulting in premature program termination. Initial attempts to overcome this problem were made by telephone conversation, and PCS/LAW suggested that a difference in the version of the Microsoft Visual Basic (MVB) compiler between TPI and PCS/LAW might be the cause of the problem. To address this problem, TPI upgraded to MVB, Version 6.0, and scheduled an onsite appointment with PCS/LAW to recompile and run DLRCheck on the TPI notebook computer. It was later discovered that the problem had to do with the DLRCheck software, and not the compiler, as described below.

During a meeting with PCS/LAW the DLRCheck program was recompiled with MVB 6.0 and executed on the notebook computer. Unfortunately the same problems with the program were encountered as before. One problem with the program recognizing data file names was identified and attempts were made to correct it, but it was concluded that it would require significantly more time to correct the problem than was available at the meeting because of the complexity of the program.

The DLRCheck program was designed to read raw data files, supporting MEGADAC files with calibration factors, check raw data file channels for possible problems, identify problem channels with flags, read satisfactory channels and apply filtering, extract peak values and load those values into a Microsoft Access database. Problems encountered when running DLRCheck were believed to be due to variations of numbers of channels between OH AC and PCC test sections, as well as OH and NC PCC test sections. As a result, it is necessary to modify the code of the DLRCheck program to read data from specific OH and NC sections, based on the number of channels present in the raw data files. TPI believes the program has some difficulty reading necessary information between data sources because of format inconsistency or program inflexibility issues. Because of this, all necessary information that the program needs to correctly process, is hardcoded rather than relying on user input. This makes the code very long, and since there is no documentation within the code, it would be very difficult for someone unfamiliar with the program to identify where and how the calibration factors are applied.

TPI requested the source code, but permission for the TPI contact at PCS/LAW to provide it was unavailable at the time of the meeting. However, an offer was made to modify the program to read at least one NC and one OH data set for comparison purposes with raw MEGADAC data processed by TPI using TCS and XL.
Modified DLRCheck program(s) were e-mailed to TPI as an executable file(s) (no re-compilation needed), however similar problems were encountered upon execution of these modified versions. PCS/LAW was contacted concerning these problems, and it was suggested that TPI leave the TPI notebook computer with PCS/LAW until DLRCheck was executed successfully. That option was deemed unnecessary for the completion of this phase of the study since other problems with the DLRCheck program had been uncovered during the meeting. These problems alone may be reasonable explanation for differences in data processing results. All raw DLR data possessed by PCS/LAW was acquired by TPI at the meeting and loaded to the TPI notebook for application to Phases II and III of the study.

DATA ANALYSIS

Some data was included in a limited analysis involving VESYS5 and IlliSLAB flexible and rigid pavement response models respectively. Model output is included in appedix D. Both flexible and rigid pavement section from OH, and a rigid pavement section from NC were chosen to determine if results obtained from TPI raw data processing were within the range predicted by the models.
OH and NC PCC sections were chosen to have the same physical dimensions for both the pavment and base material. While specific material property values were unavailable with the material provided to TPI from LTPP, the analysis was performed unsing general values for Poisson's ratio and Young's modulus for "ballpark" comparison purposes.

RESULTS, COMPARISONS AND DISCUSSION

OH AC Data Processing Results

Data traces, corresponding to DLRCheck output hardcopies supplied by PCS/LAW, were processed and plotted using TCS/XL and PEAK for comparison with DLRCheck. When the initial values (baseline's, or offsets) were subtracted from the signals, TCS/XL results were nearly identical to those obtained with PEAK, however, both PEAK and TCS/XL results were significantly less than those produced with DLRCheck. Direct comparison plots of all corresponding traces from DLRCheck, PEAK and XL are given in appendix B. Calibration factors were applied in XL and peak values corresponding to those shown on the DLRCheck hardcopies were extracted manually. Appendix A table 1 shows the percent difference in peak values between the three processing methods. On average, differences in results from TPI processing and those supplied from PCS/LAW ranged from –50 percent for strain to –1799 percent for pressure, which is believed to be caused by misapplication of gage calibration factors. These results are contained in Table 2, appendix A.

NC PCC Data Processing Results

Strain data channels from NC exhibit low signal-to-noise ratios, indicating the need for filtering in some cases to complete re-instrumentation in others. Displacement data from NC appears to be in good shape. Three strain gages and two LVDT's were chosen to perform a comparison between maximum peak and valley entries contained in the IMS database (obtained through DataPave 2.0) to those obtained through TPI processing. In order to do an accurate comparison, the same number of data points applied in the moving average filter used by DLRCheck (according to what is reported in the DataPave/IMS) was also used by TPI. These results are given in Table 3, appendix A.

The most obvious findings illustrated in table 3 are the strong match between results for displacement as opposed to the weak match for strain. Displacement values between DataPave/IMS entries and TPI results differ on average by only 0.25 percent, whileDataPave/IMS strain value entries are on average 16 percent of that found by TPI. The reason for the large difference in strain is puzzling considering the strong between displacement values. The signal processing problem causing this discrepancy may lie in the weak strain signal (in comparison with the high noise level in the channel), as mentioned earlier.

Low NC strain readings in the DataPave/IMS database have been consistent throughout this study, and the following observations should be discussed. The original strain devices planned for NC were embedded Dynatest gages, like those used at OH, but the gages soon failed after road construction. These gages were replaced with surface-mounted gages as an alternative to the Dynatest gages. Surface mounted gages are trouble-prone in this application for a number of reasons. First of all they are exposed to the rigors of the environment. Secondly there are a number of controversial issues pertaining to quality of strain data from gages mounted to a material, such as concrete, which has at least two materials (aggregate and matrix) with different strain responses to a given load. Thirdly, the surface-mounted strain gages were directly exposed to the truck tires which provided the load for each experiment. This alone will cause different readings as the gage is deformed to direct load application, for which they were never designed.

In addition to the problems associated with the surface mounted gages, wheel path offset was never recorded for NC DLR files. Wheel path offset plays a very important role in how a gage will respond to a passing load. Therefore, it is recommended that any data from these gages should be used in analysis for general trends, and not actual strain experience by the material.

DataPave 2.0 / IMS Application Results - NC

Some problems were encoutered while using DataPave 2.0/IMS. These problems were identified and reported in the "LTPP Data Analysis/Operations Feedback Report", which was supplied to TPI by SAIC. This report is included in appendix D.

Truck geometry values were not available due to what was likely an error in the program. When the truck geometry tables were requested, the software offered the following error message: "Error: 3061 Too few parameters. Expected 1." Perhaps this bug can be easily corrected by the software developer, but without the truck geometry values, the data would be useless for continuation to phases II and III of this study.

It appeared that axle loads were represented by values that were too low. This was probably a English to SI unit conversion error, because when the values were multiplied by 4.45^2 , the proper values were obtained in kiloNewtons. Also values of units for time corresponding to strain and displacement peaks and valleys were improperly labled as microseconds, rather than milliseconds.

Pavmement temperature was not included as data within the DataPave/IMS for DLR sections included in the DataPave 2.0 software. This information would be very important for further application to data analysis proposed in phases II and III of this study. Air temperature was available in a separate table from automatic weather stations. While air temperature may be used to estimate pavement temperature, it is not reliable to any accurate degree due to the lag in changes in pavement temperature with respect to relatively fast changes in air temperature. Furthermore, not only was air temperature for DLR runs not included with DLR data, air temperature data was not available for all test runs examined in the sample data set.

Data Analysis Results

Results of the analysis performed using VESYS5 and IlliSLAB are given in appendix A, table 4. Generally, the values predicted by the models match closely with that obtained from TPI processing. When compared to values provided in the DataPave/IMS database, deflection values match closely but IMS strain values remain low. This is consistent with results mention above.

CONCLUSIONS

OH Data Conclusions

Initial processing results indicate that DLRCheck results are considerably higher than those obtained by TPI. Differences in results from TPI processing methods and those supplied from PCS/LAW ranged from –50% to –1799%, which is believed to be caused by misapplication of gage calibration factors.

The condition of the OH data appears very good for AC data. The physical validity of the data was verified through analysis with the VESYS5 mechanistic flexible pavement response model. Anyone wishing to conduct further analysis of this data will require information regarding site-specific material properties, truck geometry, axle loads, wheel path offset, tire inflation pressure, speed and pavement temperature data.

The PCC data does contain some moderate noise, which can be smoothed through filtering without losing significant signal amplitude. The physical validity of the data was verified through analysis with the IlliSLAB mechanistic rigid pavement response model. Further analysis of the data will require information regarding site-specific material properties, truck geometry, axle loads, wheel path offset, tire inflation pressure, speed and pavement temperature data.

NC Data Conclusions

Strain data sets provided from NC exhibit considerable amounts of noise, indicating the need for filtering in some cases to re-instrumentation in others. DLRCheck-processed strain results which were entered into DataPave/IMS are low compared to the results of TPI processing. This discrepancy is believed to be a combination of the DLRCheck software failing to select the proper peaks (in the low amplitude/high noise signals) and the surface mounted strain gages which are known to be trouble-prone in this type of application. If this strain information is included in the DataPave/IMS database, a warning of the limitations of the DLRCheck software or strain gages, or both, in addition to a lack of wheelpath offset, and pavement temperature data should be included. This strain data may be useful in identifying general trends, but may not reflect actual strain associated with the specific loading or material characteristics. However, the displacement data appears to be in good condition. On average, maximum peak values of strain found in the IMS database were 16 percent of results obtained by TPI in contrast to a small difference with displacement of 0.25 percent.

DLRCheck Software Conclusions

More work needs to be done with DLRCheck to ensure the software has the flexibility to identify and read all types of data files from DLR sites. The software does not have the ability to allow the user to input calibration factors for instrumentation, nor can the hard-coded calibration factors be easily verified. Low signal to noise ratios seem to present a problem for DLRCheck as illustrated by the DataPave/IMS NC strain data. There exists a need for more work to be done to ensure proper extrusion of peaks and application of calibration factors, as well as database building.

DataPave 2.0/IMS

Some problems with the IMS database were identified and reported in appendix D. In order for these problems to be identified and corrected, someone knowledgeable about the history and present state of DLR pavement instrumentation and testing, as well as the mechanics of these materials, needs to be responsible for database content.

RECOMMENDATIONS

OH Data Recommendations

This data should be included in the DataPave/IMS database provided that all necessary supporting information is available, including: site-specific material properties; site-specific geometries; spatial instrumentation information; truck geometry; axle loads, configurations and load balance; wheel path offset, tire inflation pressure, tire type and dimensions; vehicle speed and pavement temperature data, etc. All this information should be available from OU.

NC Data Recommendations

NC strain data already included in DataPave/IMS should be either re-processed, ensuring that DLRCheck is extracting the proper peaks/valleys, or it should not be included at all.
NC displacement data already in place in DataPave/IMS seems to be in good condition, however for analysis applications all necessary supporting information needs to be made available, including: site-specific material properties; site-specific geometries; spatial instrumentation

information; truck geometry; axle loads, configurations and load balance; wheel path offset, tire inflation pressure, tire type and dimensions; vehicle speed and pavement temperature data, etc. If pavement temperature instrumentation is not present, this should be stated, along with a suggestion for converting air temperature to pavement temperature. All this information should be available from NC DOT.

DLRCheck Software

This software should be improved to allow input of raw data from any DLR site regardless of the number or order of data channels. Specific attention should also be placed on ability of the program to accept user input of calibration factors. It may be possible to adjust DLRCheck to more efficiently extract peaks/valleys in high noise signals, or perhaps the noise/signal ratio cutoff level needs to be re-established to identify junk signals. Attention should be focused on why DLRCheck rejects some signals and accepts others with similar noise content. .

DataPave 2.0/IMS

Problems identified in the report in appendix D, "LTPP Data Analysis/Operations Feedback Report" need to be addressed. In addition to the information already included with DLR tables, the following tables should also be made available for analysis purposes:
Pavement temperatures, or air temperature corresponding to those runs in the DLR tables;
Site-specific material properties; site-specific instrumentation spatial information, as well as calibration factors; tire dimensions.

In Addition

As part of National Pooled Fund Study SP&R 2(203), with OH serving as lead State, both TPI and OU will thoroughly process data taken from additional OH test sections. This data was originally paid for by FHWA and collected as part of a truck size and weight (TS&W) study. Parameters of interest included axle and load configuration, tire type and tire inflation pressure, effects of hot weather on vertical pavement shear, measured using innovative methods of pavement instrumentation. TPI has ensured this data to be well documented with all supporting information available for analysis purposes with the intention of calibrating pavement response models.

It is recommended that LTPP support TPI's effort in processing and analyzing the TS&W data for application to mechanistic pavement models, as outlined for phases II and III for the continuation of this study. The completion of phases I and II, will provide LTPP with an excellent addition of well documented DLR data for use in Data Pave. It will also provide LTPP with a methodology for validating and calibrating both a FEM and a layer system model (VESYS and one of Illislab, Islab 2002 or JSlab).

LIST OF REFERENCES

1. FHWA LTPP file: "Pavement Instrumentation/Load-Response/DLR IMS Issues – Revised IMS Specifications for Dynamic Load Response (DLR) PCC Data to Include OH PCC Data."

2. FHWA LTPP file: "Pavement Instrumentation/Load-Response/DLR IMS Issues – Revised IMS Specifications for Dynamic Load Response (DLR) AC Data."

3. PCS/LAW file: "Pavement Instrumentation Program for SPS-2 Experiments – Instrumentation Details"
4. NC DOT file: "SPS-2 Seasonal and Load Response Instrumentation North Carolina D.O.T. Open House – Overview of the LTPP Program"

5. NC DOT file: NC SPS-2 Instrument Layout Plan – facsimile

6. FHWA LTPP product: "Data Pave 2.0" software.

7. FHWA LTPP file: "Development of an Instrumentation Plan for the Ohio SPS Test Pavement"

8. OH DOT file: "Ohio Test Road Strategic Highway Research Program Open House"

9. "Technical Manual for the MEGADAC SERIES 3100"

APPENDIX A

Figures and Tables

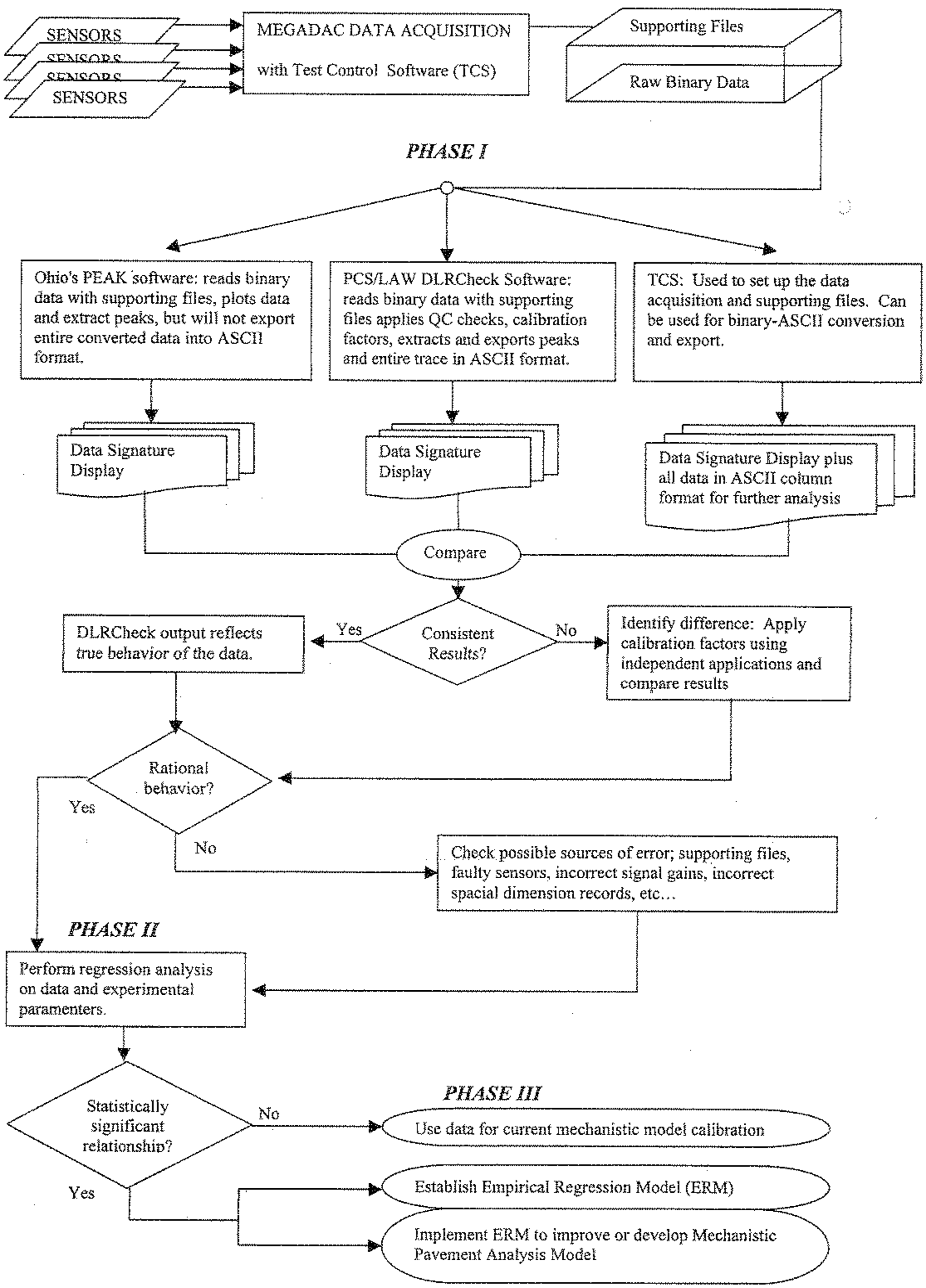


Figure 1: Process of DLR data collection, processing and comparison.

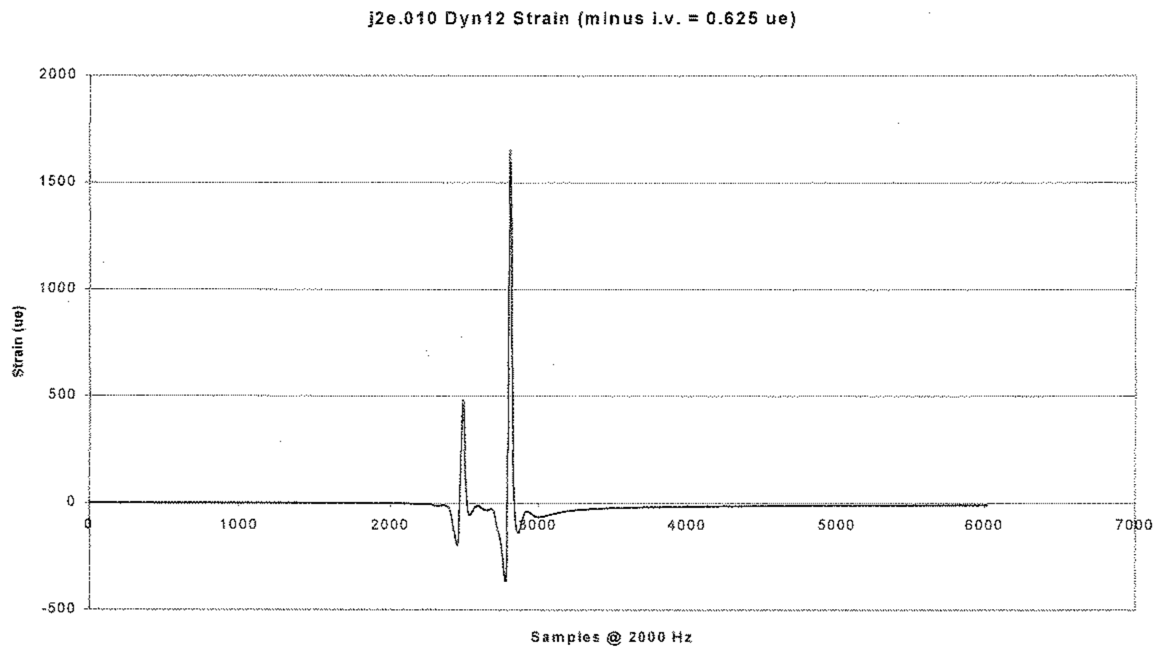


Figure 2: Typical Ohio AC strain trace created with XL.

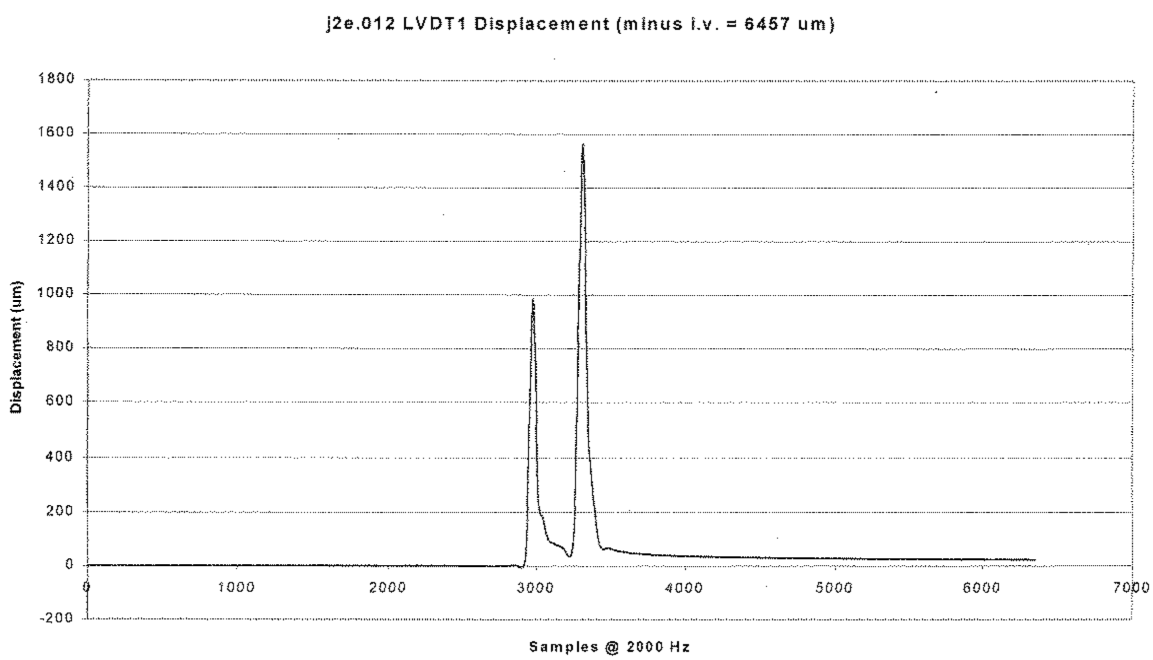


Figure 3: Typical Ohio AC displacement trace created with XL.

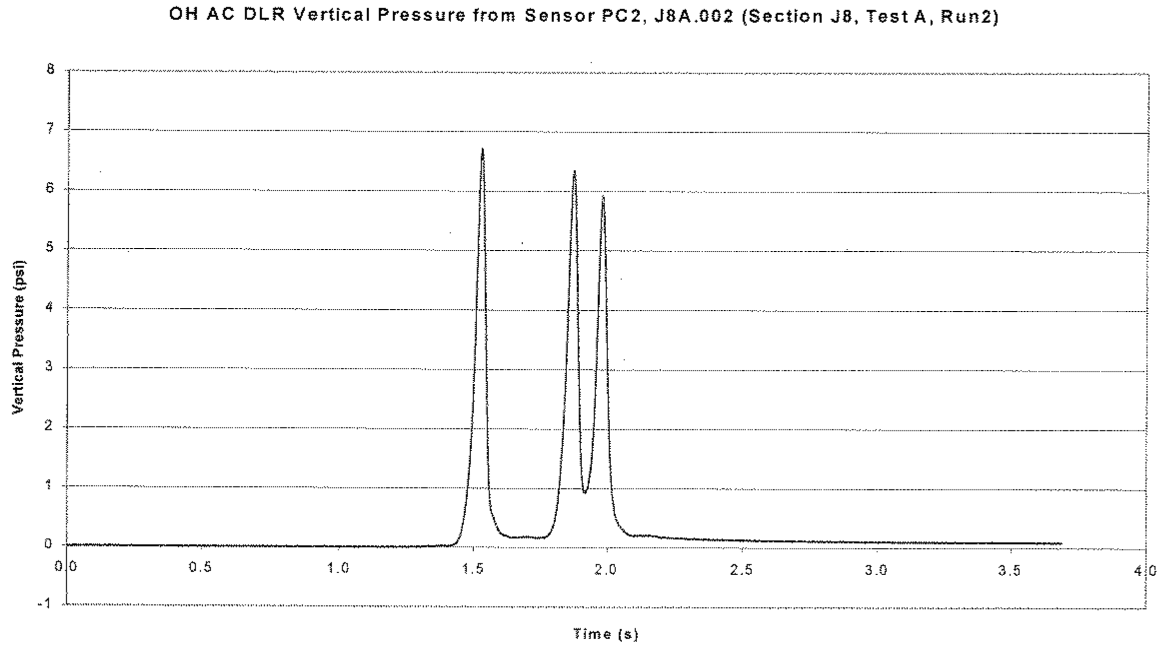


Figure 4: Typical Ohio AC pressure trace created with XL.

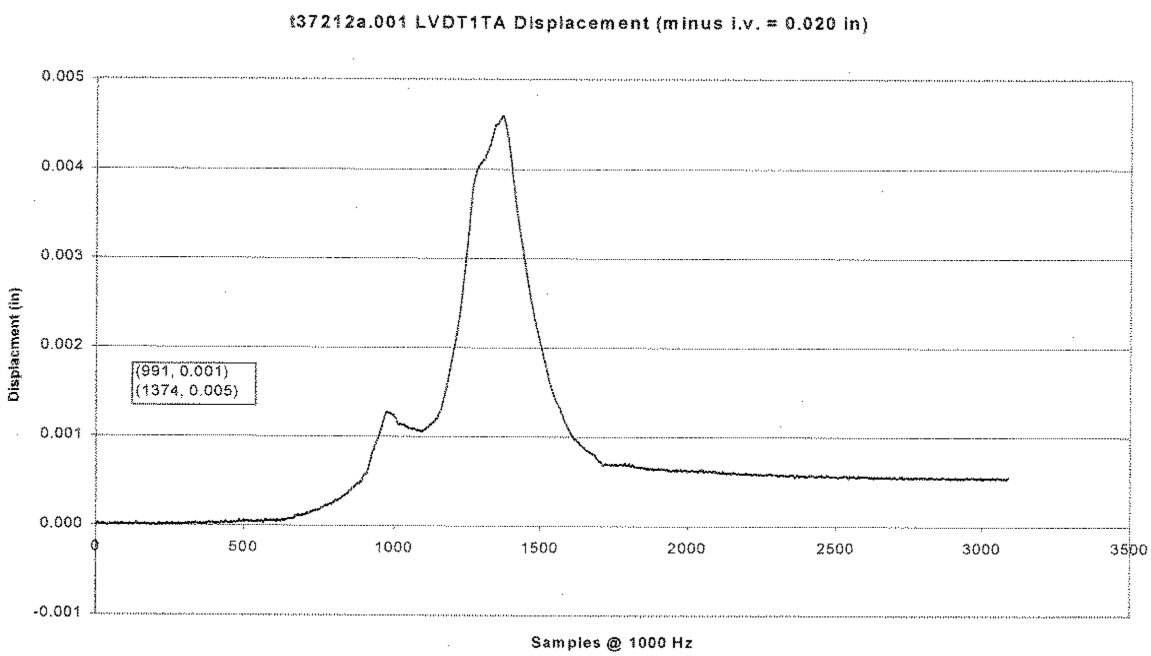


Figure 5: North Carolina PCC displacement trace created with XL.

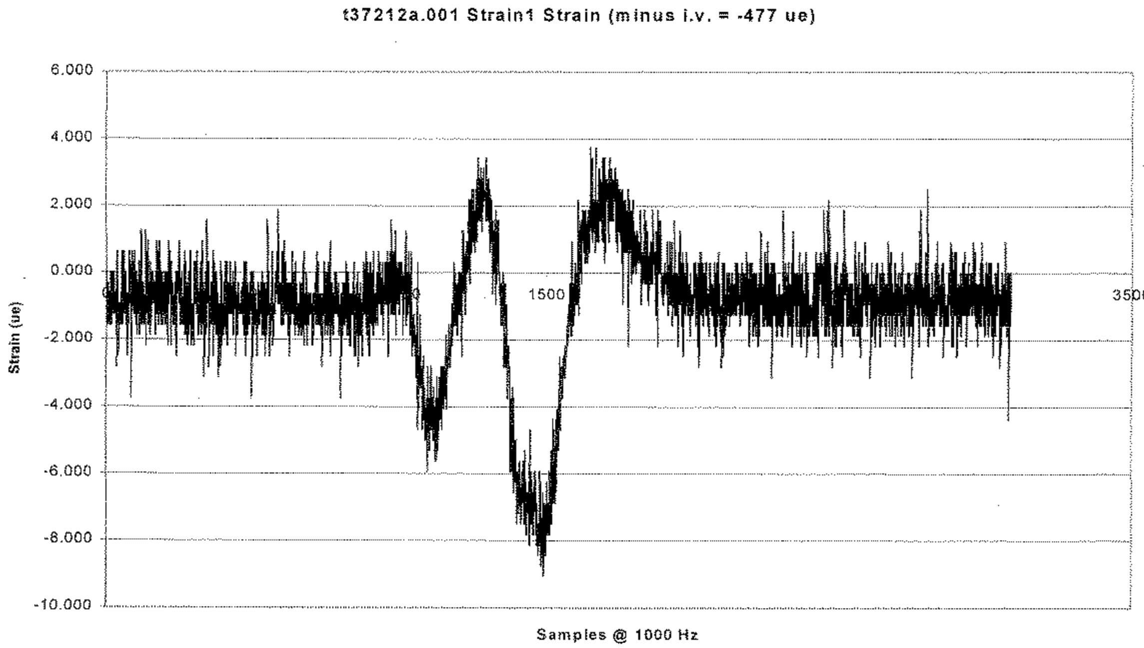


Figure 6: Example of a decent North Carolina PCC surface strain gage trace created with XL.

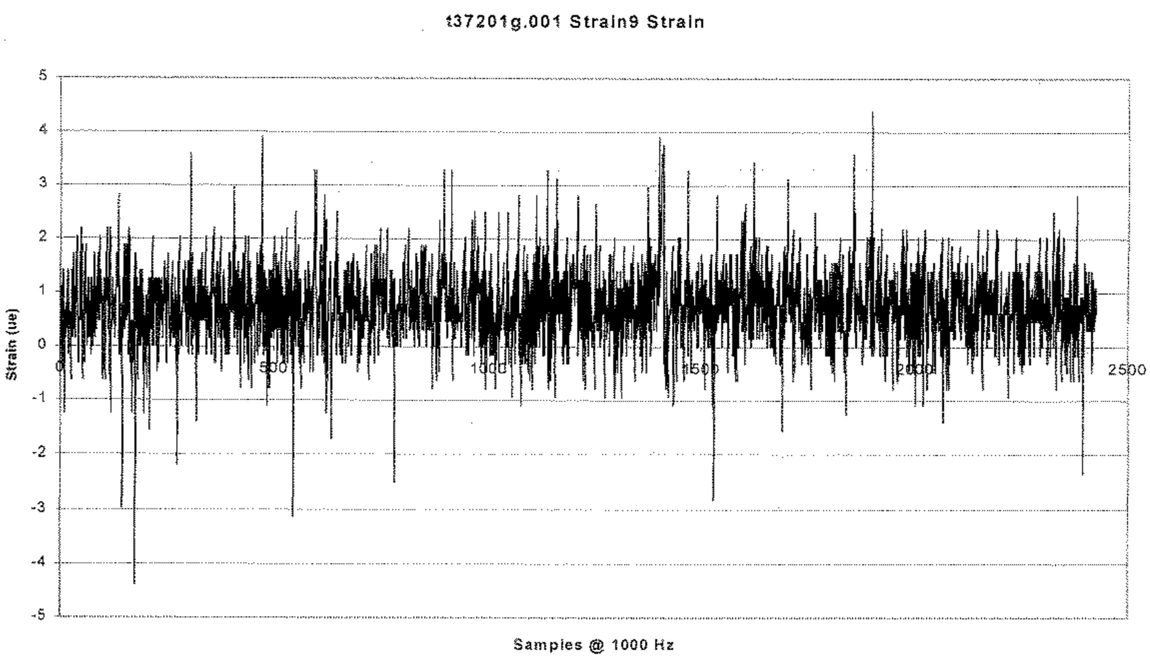


Figure 7: Example of a poor North Carolina PCC surface strain gage trace created with XL.

Table 1: Hardcopy peak value comparisons between DLRCheck, PEAK and XL.

Ohio AC Sections - Trailing axle peaks

*lead axle
**2nd axle

Calibration factors:
Displacement (20in/V)
Pressure: 10psi/V

filename	chan. Tag	sensor	DLRCheck	PEAK (apprx.)	TCS/XL (minus I.v.)	Initial value	Difference PEAK & DLRChk (%)	Difference XL & DLRChk (%)
j2e.010	dyn12	strain (ue)	2253	1650	1651	0.625	-37	-36
j2e.012	lvdt1	disp. (um)	4052	1568	1558	6457	-158	-160
j4a.001	lvdt1	disp. (um)	837	320	332	3442	-162	-152
j4a.008	dyn17	strain (ue)	85	56	55	0	-52	-55
j4a.008	pc2	press. (kPa)	-1375	-30	-30	-4.89	-4483	-4483
j4e.001	dyn16	strain (ue)	149	95	95	0.625	-57	-57
j4e.001	lvdt1	disp. (um)	909	343	349	4001	-165	-160
j4e.001	pc1	press. (kPa)	2028	44	44	10	-4509	-4509
j8a.001	dyn10*	strain (ue)	286	182	183	22	-57	-56
j8a.001	dyn13*	strain (ue)	228	150	150	9	-52	-52
j8a.001	dyn11*	strain (ue)	193	128	128	13	-51	-51
j8a.001	dyn15*	strain (ue)	255	166	164	6	-54	-55
j8a.001	lvdt1*	disp. (um)	535	208	204	-3589	-157	-162
j8a.001	lvdt2**	disp. (um)	1340	515	509	8222	-160	-163
j8a.001	lvdt4	disp. (um)	533	202	203	8821	-164	-163
j8a.006	dyn11**	strain (ue)	187	125	126	0.625	-50	-48
j8a.006	dyn13**	strain (ue)	176	120	126	0	-47	-40
j8a.006	dyn15	strain (ue)	246	165	164	0	-49	-50
j8a.006	pc1*	press. (kPa)	2513	55	54	5	-4469	-4554
j8a.006	lvdt3	disp. (um)	520	202	198	2690	-157	-163
j8a.006	pc2**	press. (kPa)	2479	54	54	5	-4491	-4491

Table 2: Average difference in TPI and DLRCheck results from OH AC data (hardcopies)

Sensor	Average % Difference	Number of Samples	Coefficient of Variation (%)
Strain	-50	10	-12
Displacement	-112	7	-2
Pressure	-1799	4	-1

Table 3: NC Smoothed Maximum Peak or Valley Strain and Displacement from IMS Entries vs. TPI Processing Results. ('p' indicates peak, and 'v' indicates valley)

		Strain (ue)						Displacement (um)			
		Strain 4		Strain 5		Strain 6		LVDT 2T		LVDT 2B	
Section.visit.rep	Date	IMS	TPI	IMS	TPI	IMS	TPI	IMS	TPI	IMS	TPI
t37201g.001	3/17/97	na	3.0p	na	1.6p	na	4.0p	313.2p	311.2p	-161.7v	-161.2v
t37201g.002	3/17/97	na	all noise	na	all noise	na	all noise	340.4p	340.2p	-221.3v	-221.3v
t37201g.003	3/17/97	na	2.6p	na	1.9p	na	2.5p	257.2p	256.3p	-136.6v	-136.5v
t37208e.105	5/15/96	-1.9v	-11.8v	-1.6v	-9.6v	-1.4v	-8.5v	na	na/flat	-231.6v	-231.4v
t37208e.106	5/15/96	-1.6v	-10.3v	-1.6v	-10.4v	-1.3v	-8.4v	na	na/flat	-378.3v	-377.4v
t37208e.107	5/15/96	-1.6v	-10.0v	-1.4v	-8.5v	-1.1v	7.4p	na	na/flat	-367.9v	-367.2v
t37208e.108	5/15/96	-1.5v	-9.0v	na	-8.6v	-1.3v	-7.8v	na	na/flat	-192.3v	-192.2v
t37212a.001	10/11/94	-1.9v	-11.8v	na	-10.2v	-2.9v	-17.9v	109.4p	109.1p	-65.7v	-65.5v
t37212a.002	10/11/94	-2.0v	-12.3v	na	-9.0v	-4.6v	-28.2v	74.5p	74.4p	-49.5v	-49.4v
t37212a.003	10/11/94	-1.1v	-8.8v	na	16.8p	-4.1v	-25.4v	111.9p	111.7p	-72.8v	-72.5v
t37212a.004	10/11/94	-2.4v	-15.1v	na	-16.3v	-2.5v	-15.4v	79.9p	79.6p	-52.5v	-51.6v

Entries not found in IMS for unknown reasons.

Entries not found in IMS for reasons consistent with TPI results.

Peaks not matching in either magnitude space or sign.

Table 4: Comparison of VESYS5 and IlliSLAB results with maximum values of TPI raw data processing results and maximum value entries found in IMS database.

	Longitudinal Strain (ue)	Total Displacement (in)	Pressure (psi)
OH AC			
J8a.002	AC bottom		Base Bottom
VESYS5	118	0.05	2.96
TPI RAW	120	0.0196	6.33
OH PCC			
J8a.002	PCC surface		
IlliSlab*	18.72	0.018	
TPI RAW	14.72	0.0093	
NC PCC			
t37208e.004	PCC Surface		
IlliSlab*	12.95	0.01025	
TPI RAW	17	0.0158	
IMS	2.5	0.0165	

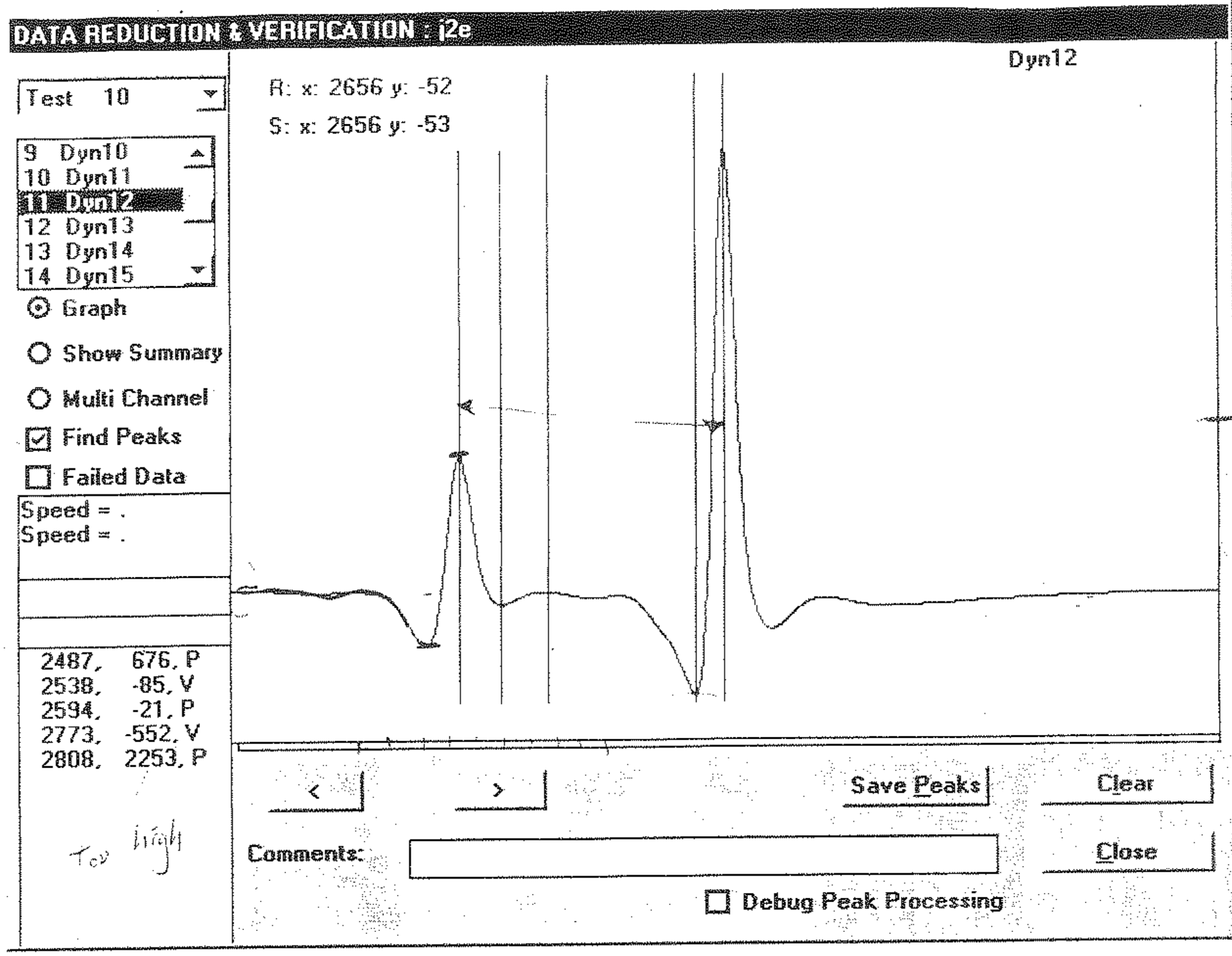
*averages of two nearest node deflections

APPENDIX B

Corresponding DLRCheck, PEAK and XL Plots

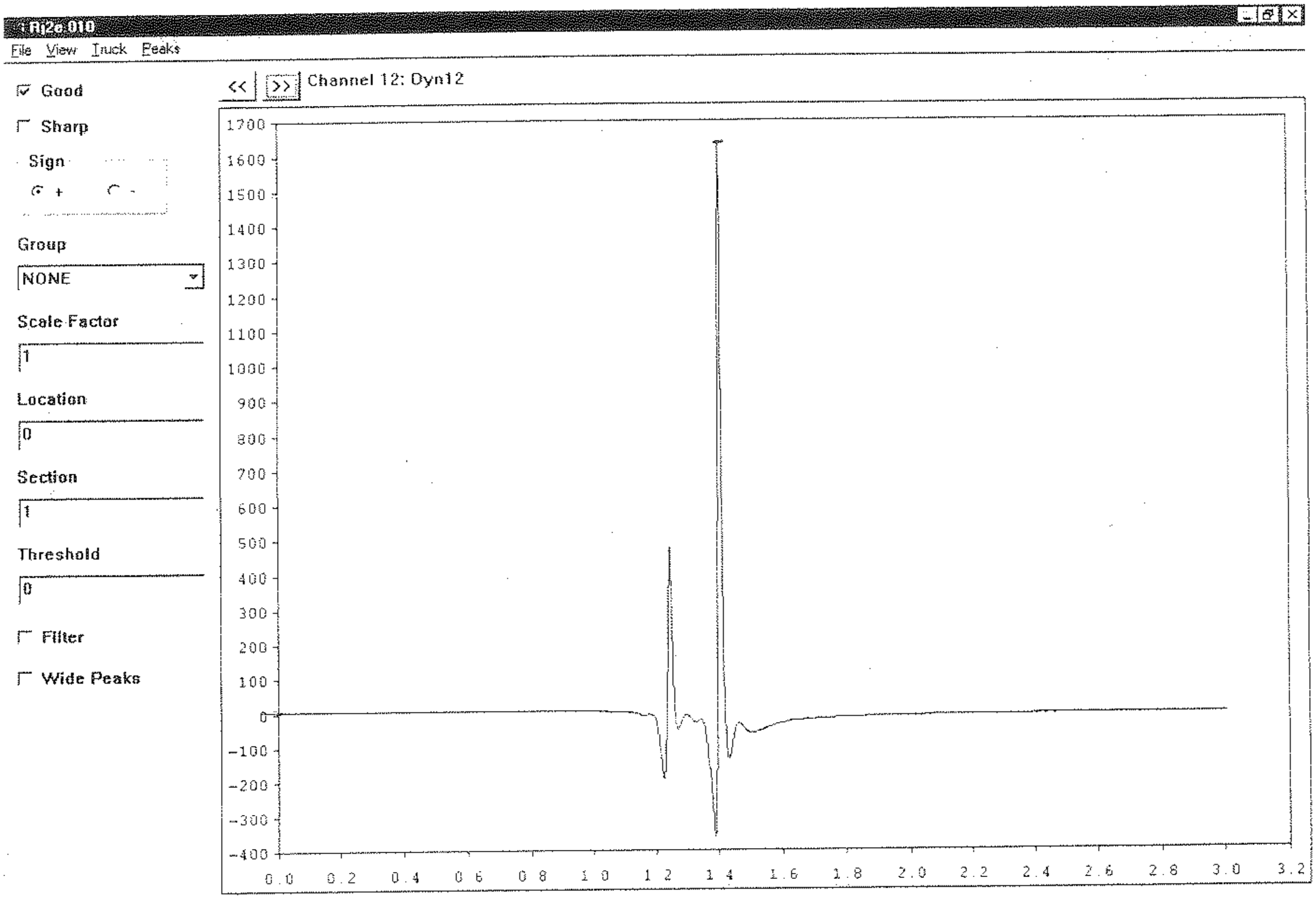
LAW/PCS-Supplied Hardcopy Data Trace Summary

Trace Plot	Sensor	Page #
J2e.010	dyn12	1
J23.012	lvdt1	4
J4a.001	lvdt1	7
J4a.008	dyn17	10
J4a.008	pc2	13
J4e.001	dyn16	16
J4e.001	lvdt1	19
J4e.001	pc1	22
J8a.001	dyn10	25
J8a.001	dyn13	28
J8a.001	dyn11	31
J8a.001	dyn15	34
J8a.001	lvdt1	37
J8a.001	lvdt2	40
J8a.001	lvdt4	43
J8a.006	dyn11	46
J8a.006	dyn13	49
J8a.006	dyn15	52
J8a.006	pc1	55
J8a.006	lvdt3	58
J8a.006	pc2	61

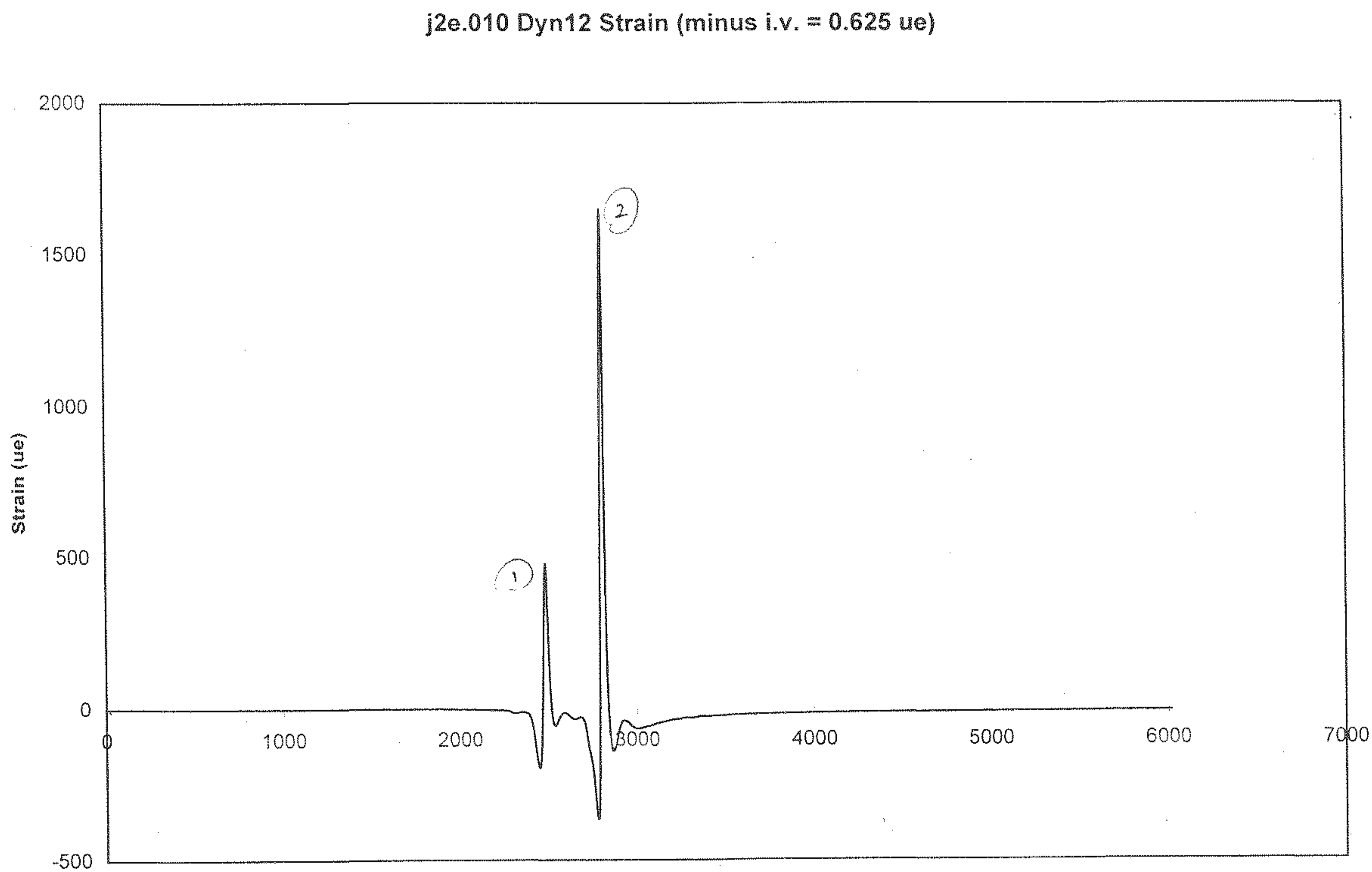


100pk

DLK check



Rj2e.010
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
<<
>>
Channel 12: Dyn12
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
−100
−200
−300
−400
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2

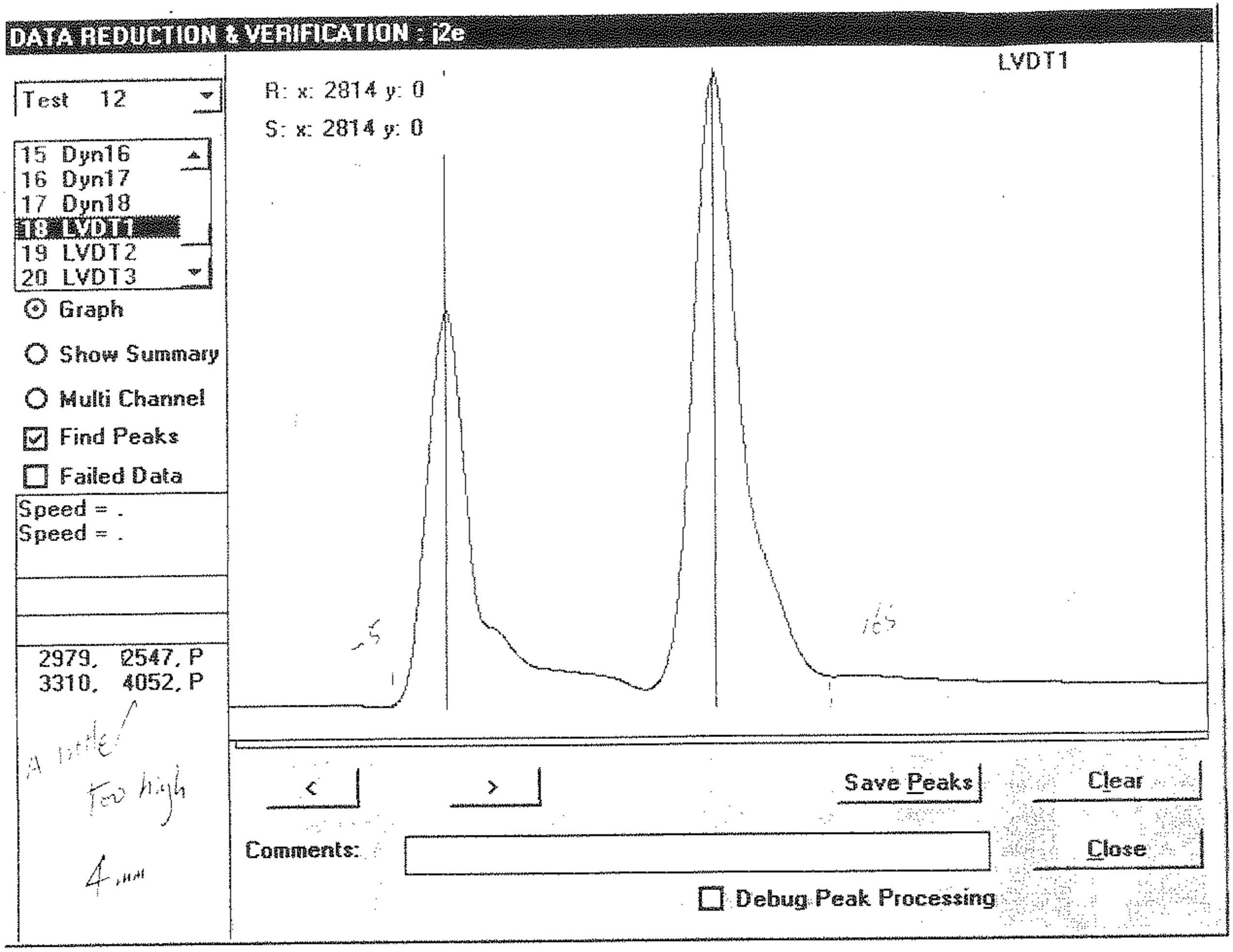


Microsoft Excel

1.) 2488, 477 $\mu\epsilon$ $\frac{199}{576.5} = 34.5\%$

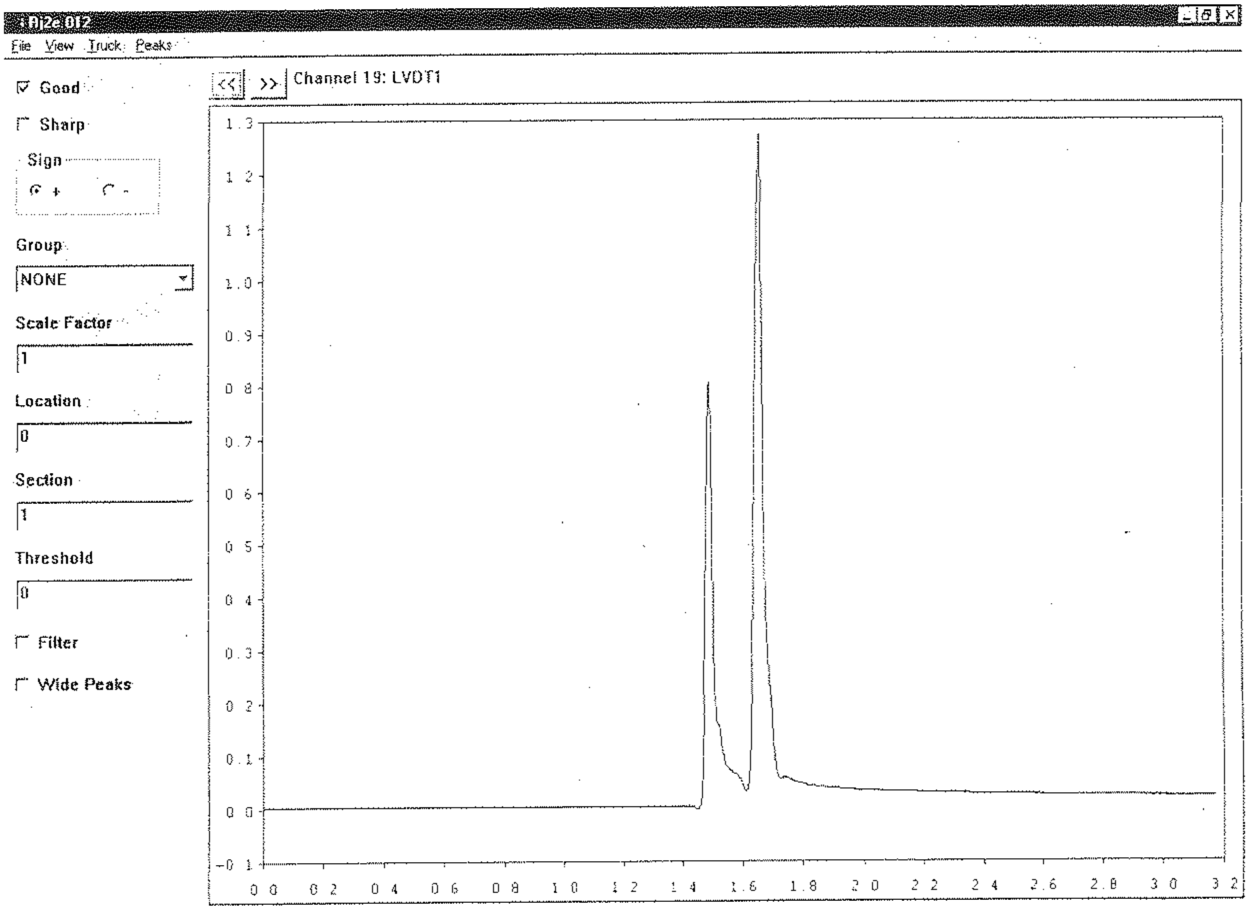
2.) 2808, 1651 $\mu\epsilon$ $\frac{602}{1952} = 30.8\%$

DLRV ✓

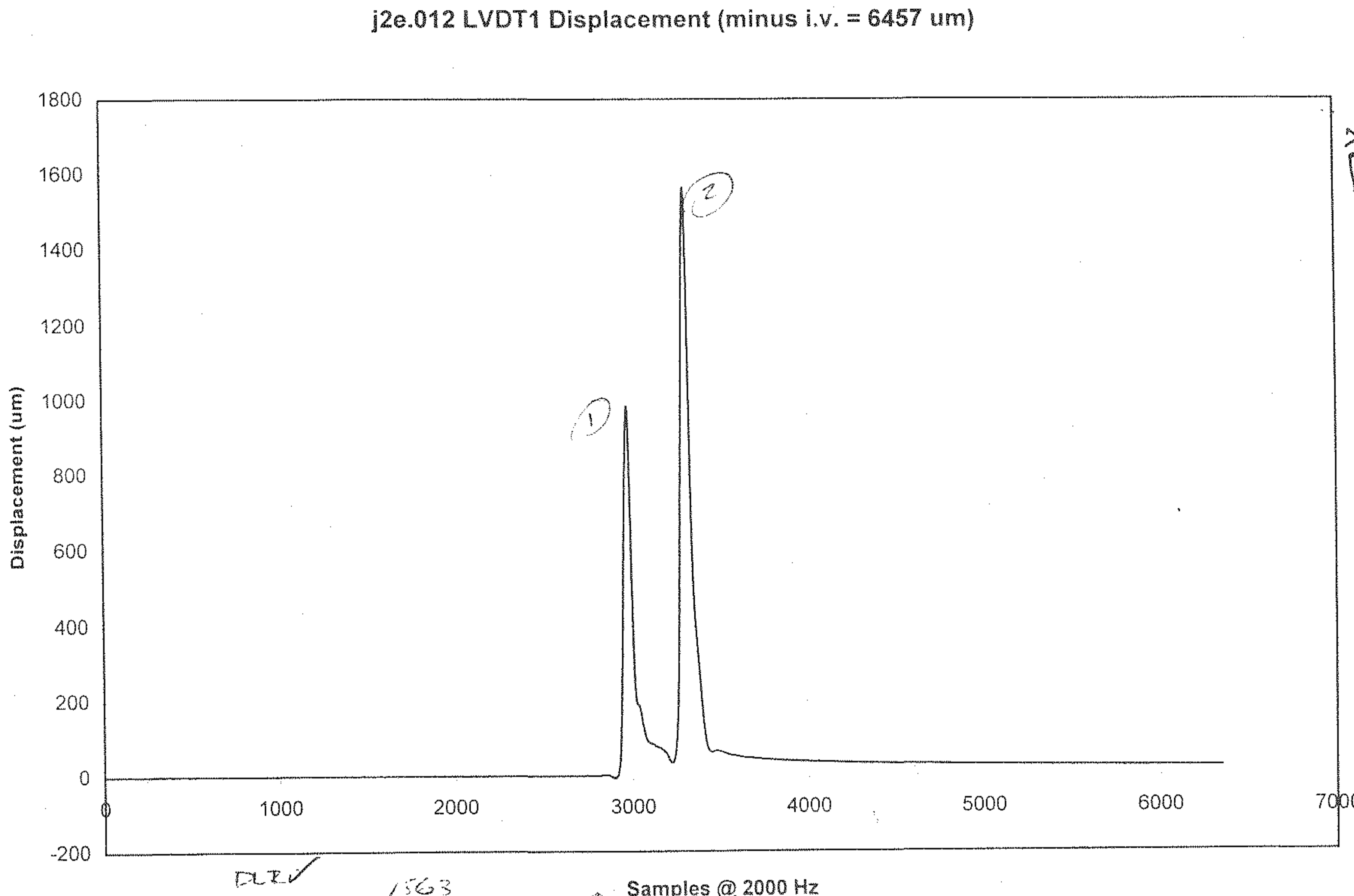


DATA REDUCTION & VERIFICATION : i2e
LVDT1
Test 12
R: x: 2814 y: 0
S: x: 2814 y: 0
15 Dyn16
16 Dyn17
17 Dyn18
18 LVDT1
19 LVDT2
20 LVDT3
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
2979, 2547, P
3310, 4052, P
A little Too high
4 mm
-5
165
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK


File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 19: LVDT1
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2

XL



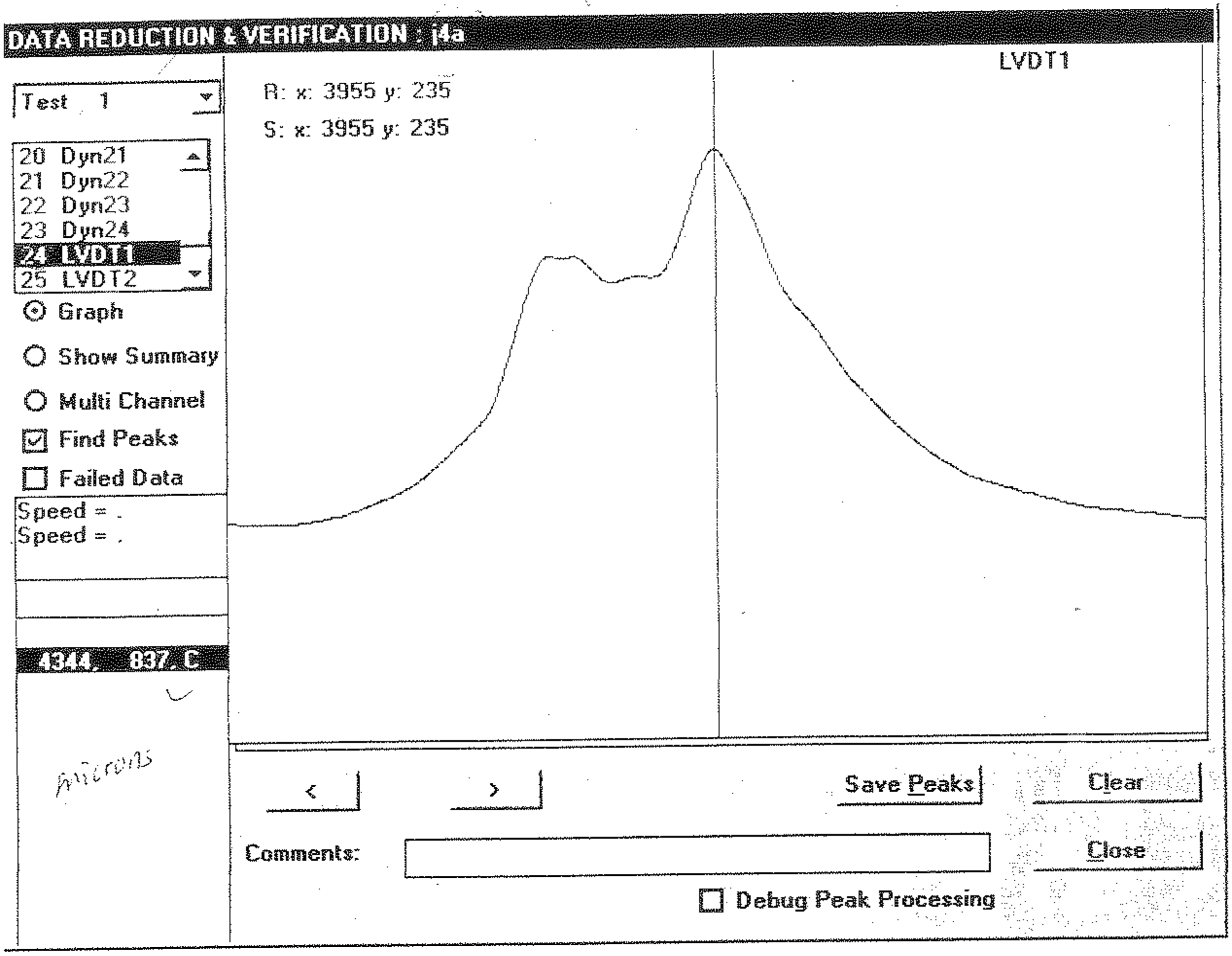
DLR ✓

1) 2981, 984 µm 2547 $\frac{1563}{1765.5} = 88.5\%$

2) 3313, 1558 µm 4052 $\frac{2494}{2805} = 88.9\%$

6

DLR


DATA REDUCTION & VERIFICATION : j4a
Test 1
20 Dyn21
21 Dyn22
22 Dyn23
23 Dyn24
24 LVDT1
25 LVDT2
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
4344, 837. C
microns
LVDT1
R: x: 3955 y: 235
S: x: 3955 y: 235
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK

RpHa 801

File View Truck Peaks

☑ Good

☐ Sharp

Sign

◉ + ○ -

Group

NONE

Scale Factor

1

Location

0

Section

1

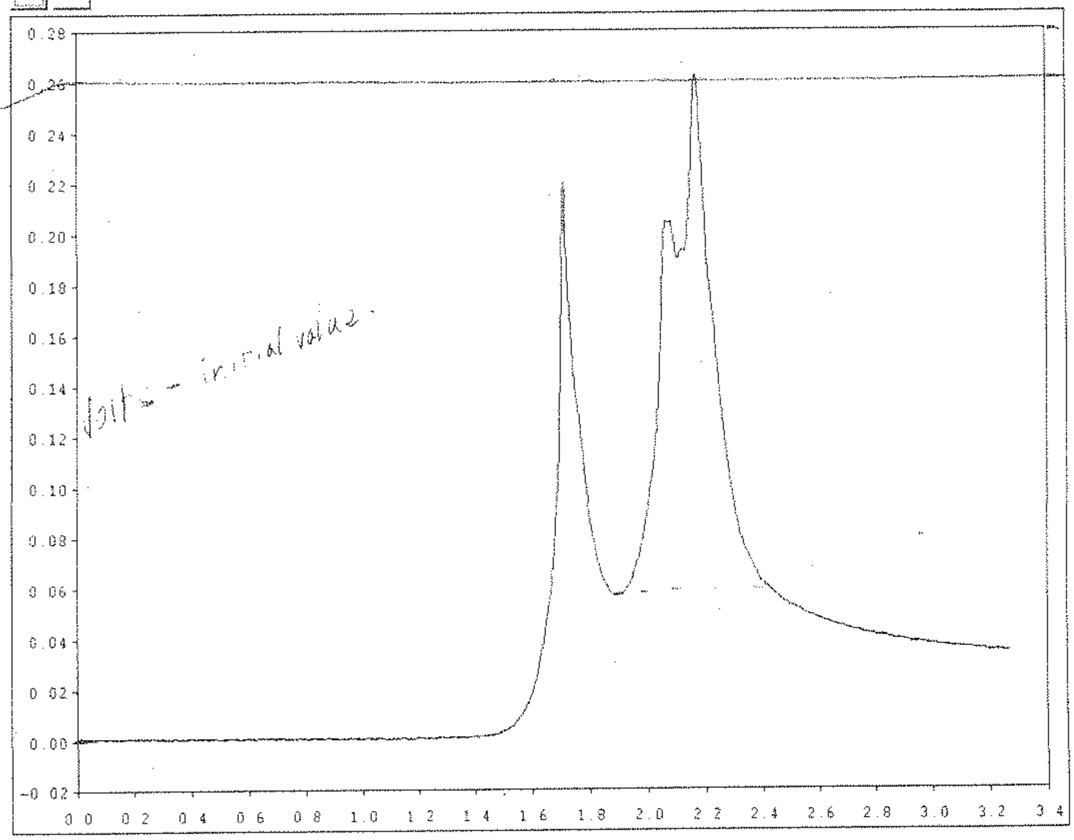
Threshold

0

☐ Filter

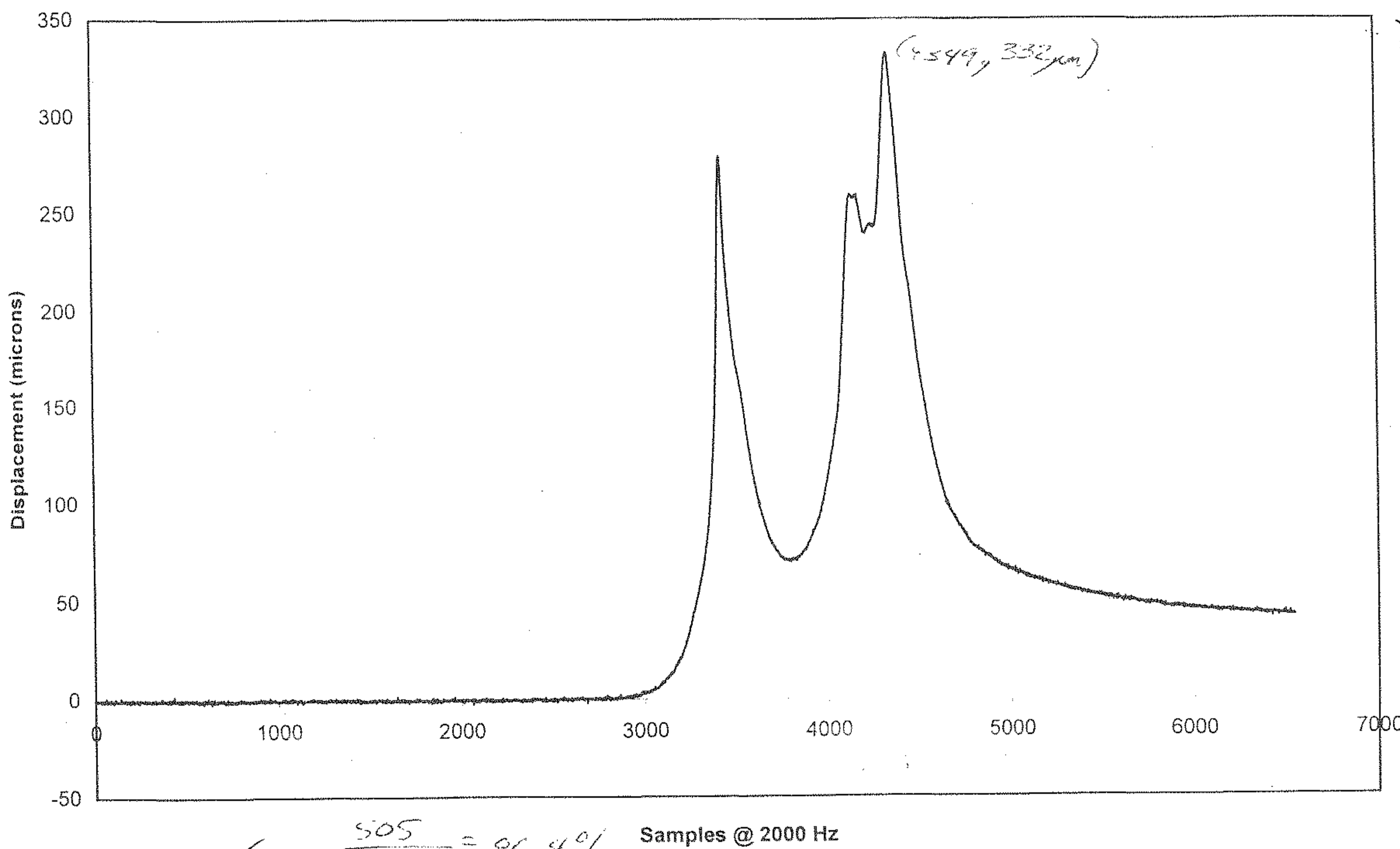
☐ Wide Peaks

<< >> Channel 25: LVDT1



3442 μm

j4a.001 LVDT1 Displacement (minus initial value = 2.81 V)



XL

$\frac{505}{584.5} = 86.4\%$

DLR ✓

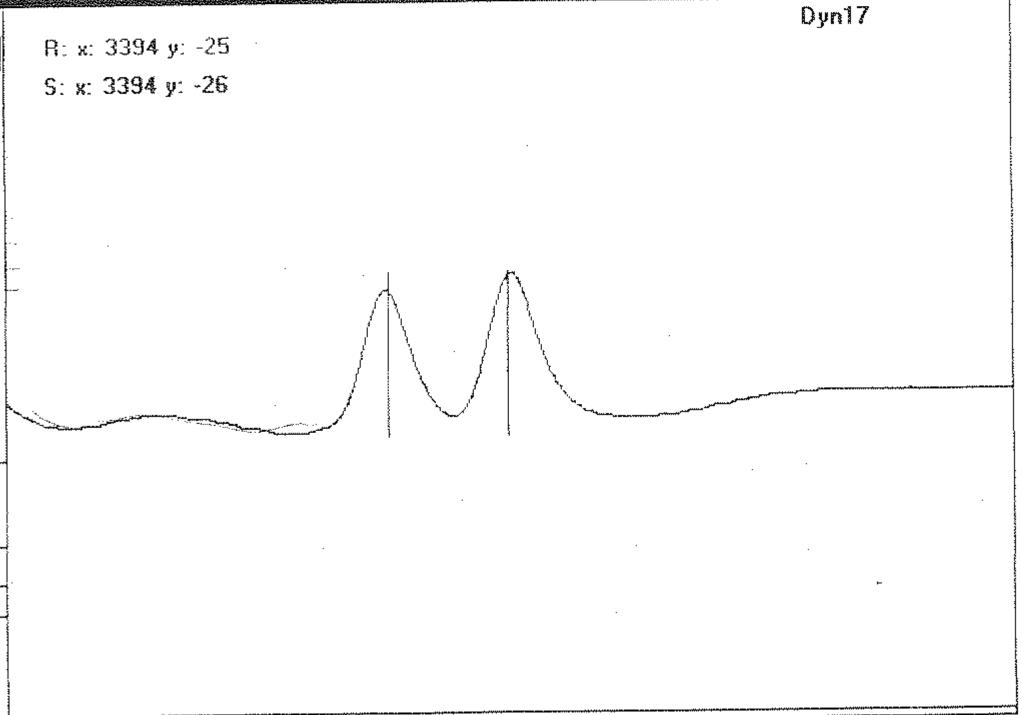
332 μm 837

DLR ✓

DATA REDUCTION & VERIFICATION : j4a

Test 8

11 Dyn12
12 Dyn13
13 Dyn14
14 Dyn15
15 Dyn16
16 Dyn17



- ⊙ Graph
- ○ Show Summary
- ○ Multi Channel
- ☑ Find Peaks
- ☐ Failed Data

Speed = .
Speed = .

3533, 74, P
3677, 85, P

microstrain

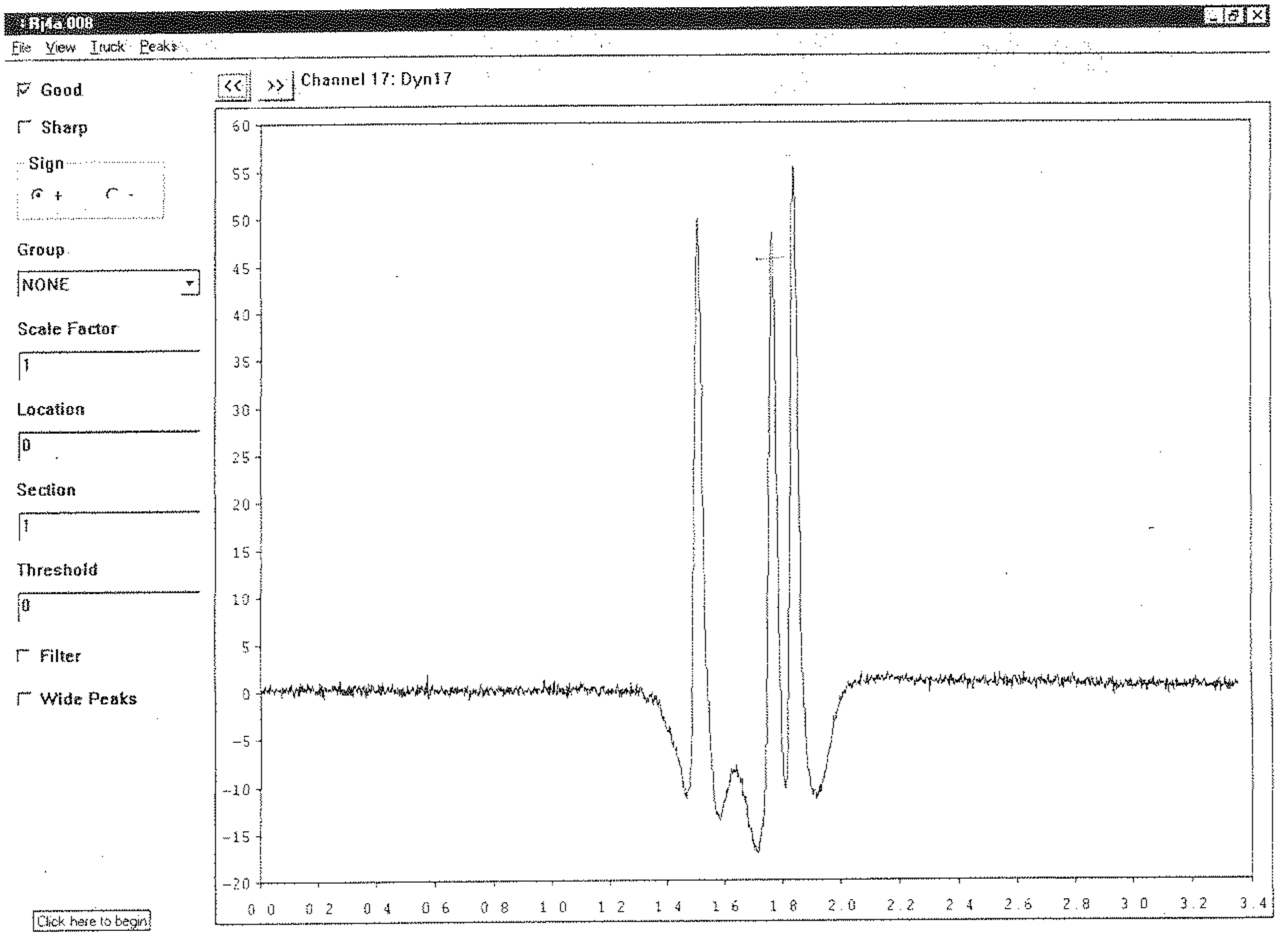
< >

Save Peaks | Clear | Close

Comments:

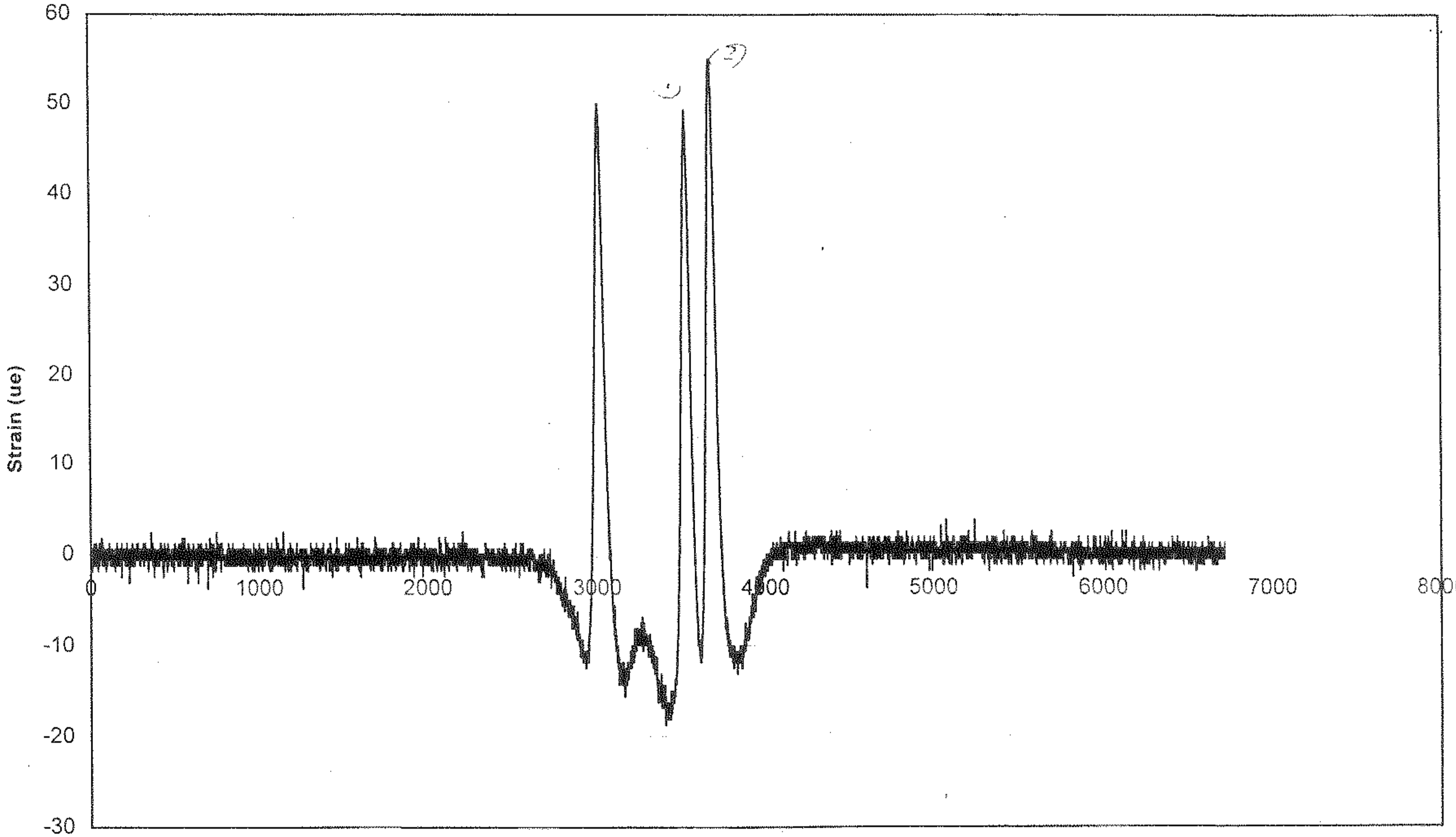
☐ Debug Peak Processing

BEAK :


Bj4a.008
File View Truck Peaks
Good
Sharp
Sign
+ -
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Click here to begin
<< >> Channel 17: Dyn17
60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4

XL

j4a.008 dyn17 Strain



DLR ✓

① 3531, 49.4 $\mu\epsilon$ 74 $\frac{24.6}{61.7}$ = 39.9%

② 3682, 55 $\mu\epsilon$ 85 $\frac{30}{70}$% = 42.9%

DLR

DATA REDUCTION & VERIFICATION : j4a

Test 8

24 LVDT1
25 LVDT2
26 LVDT3
27 LVDT4
28 PC1
29 PC2

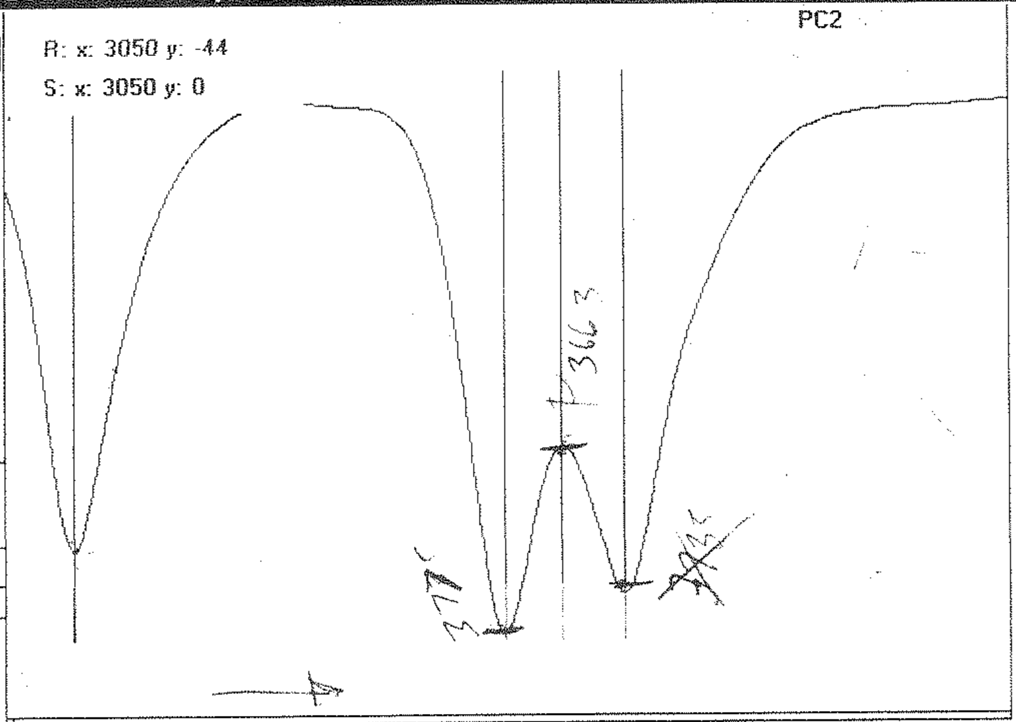
- (•) Graph
- ( ) Show Summary
- ( ) Multi Channel
- [x] Find Peaks
- [ ] Failed Data

Speed = .
Speed = .

3087, -1259, V
3595, -1482, V
3663, -992, P
3735, -1375, V

KPa

Too high

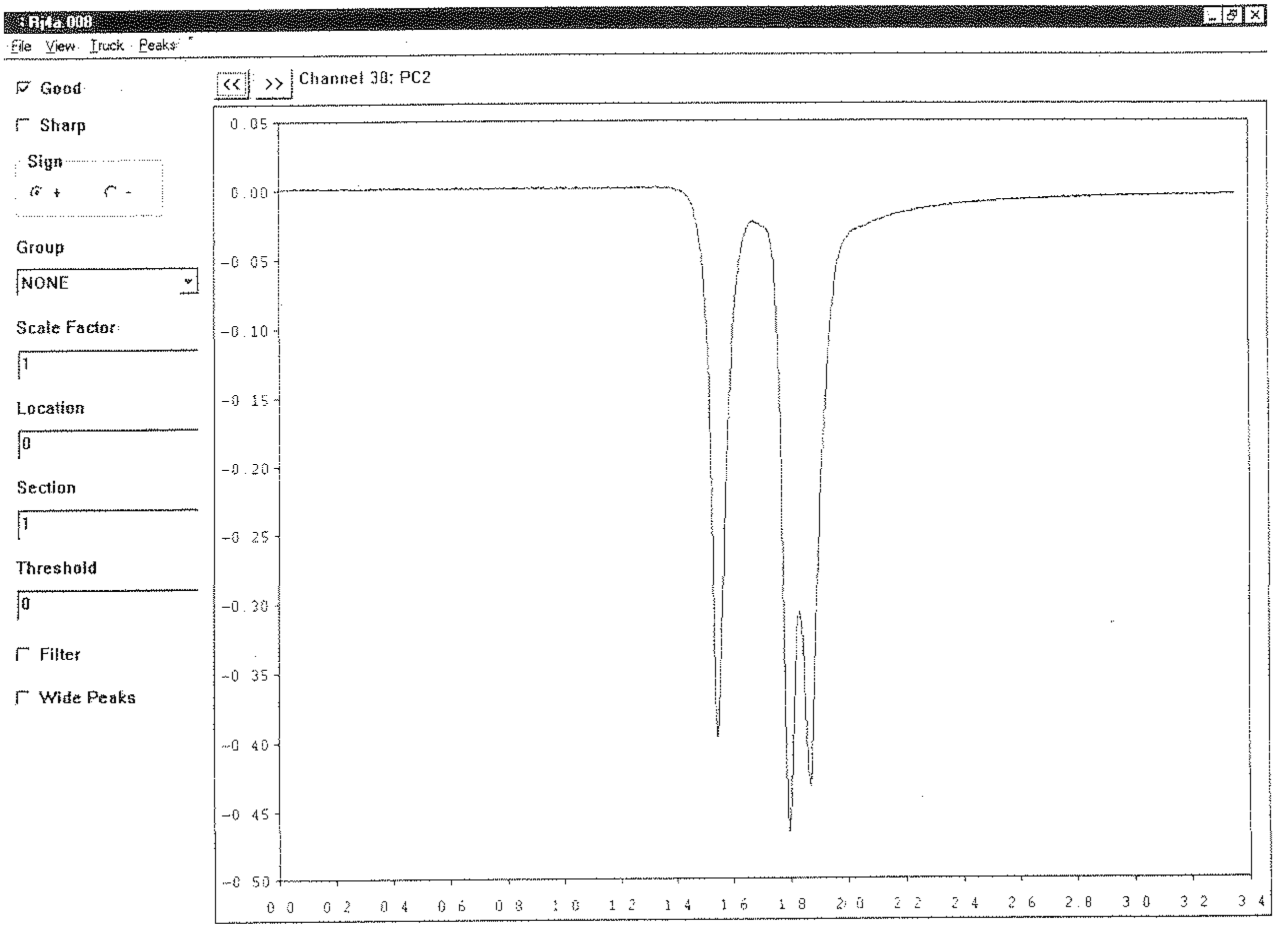


< | > | Save Peaks | Clear

Comments: | Close

- [ ] Debug Peak Processing

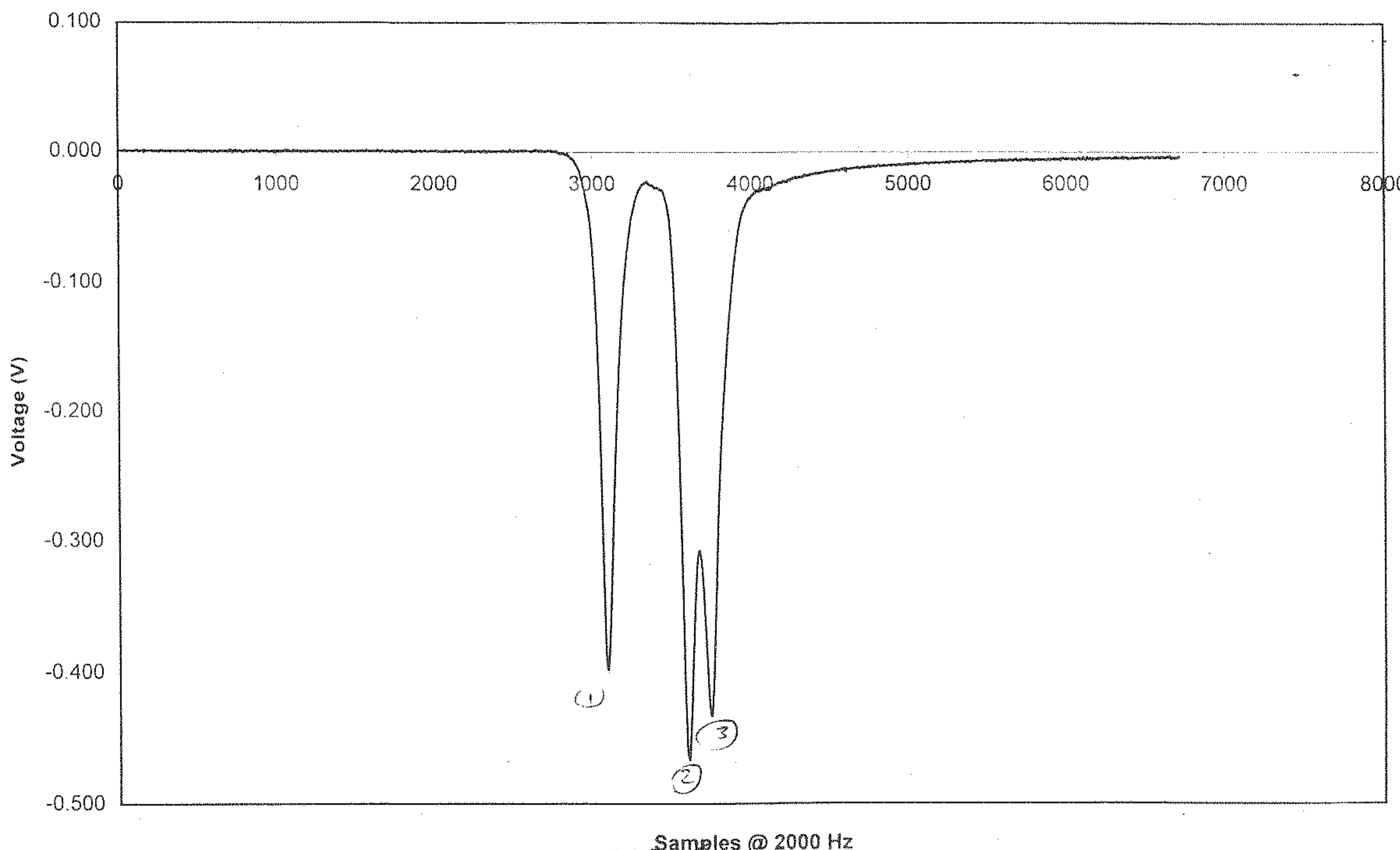
PEAK


Rj4a.008
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 38: PC2
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4

$-0.071\ V = -4.89\ kPa$

j4a.008 PC2 Voltage (minus initial value)

XL

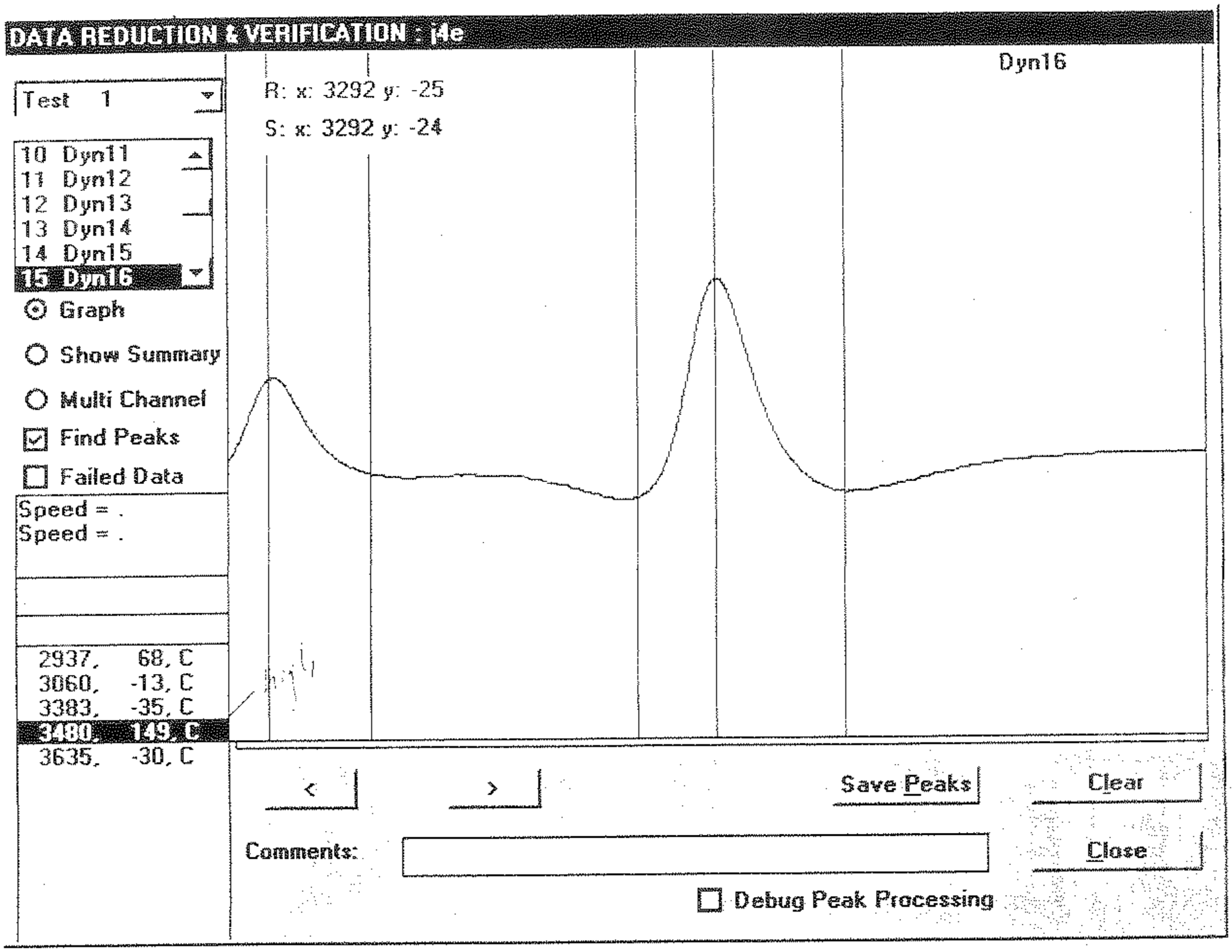


1. 3094, -0.392 V or 27 kPa
2. 3600, -0.466 V or 32 kPa
3. 3741, -0.431 V = 30 kPa

DLE 1359 kPa

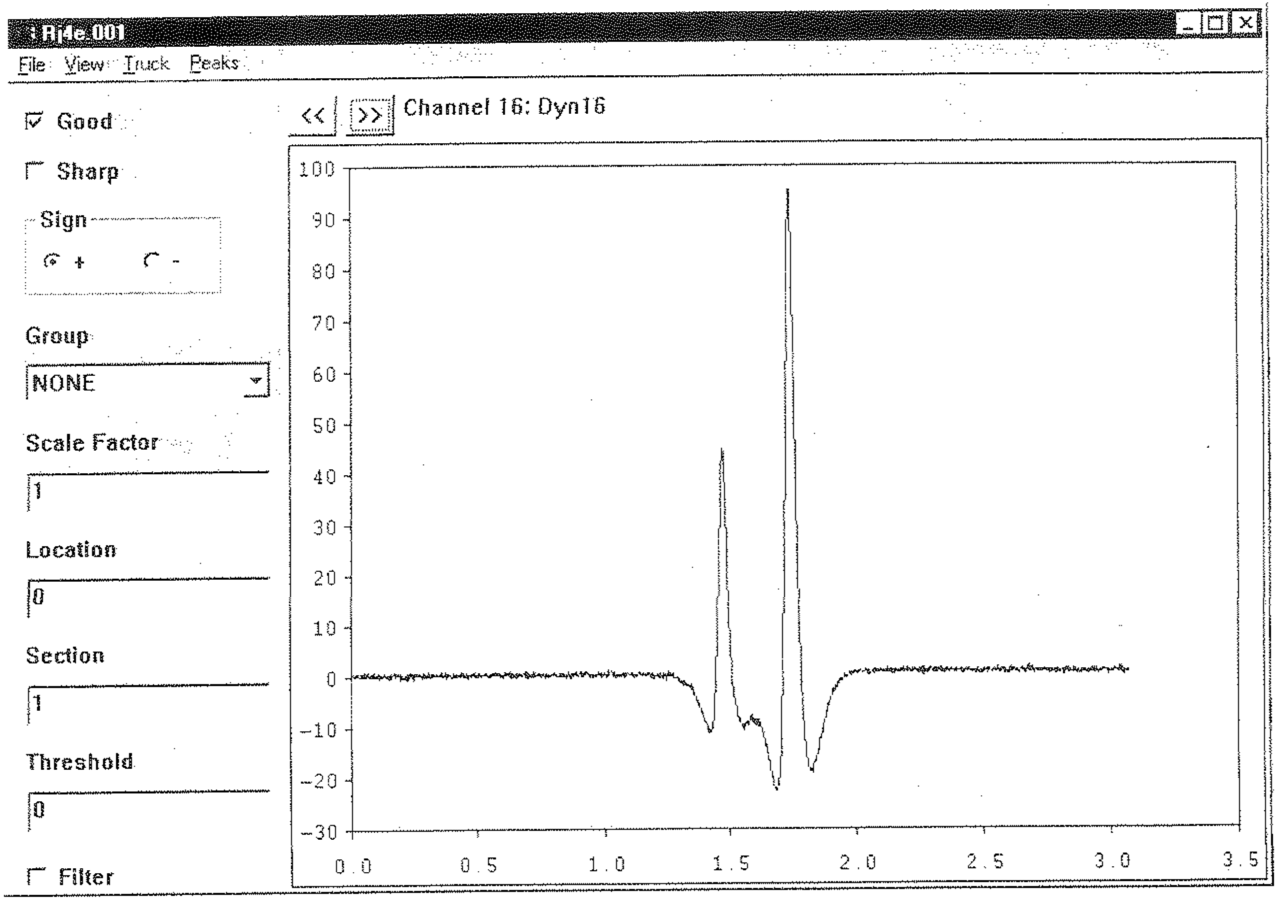
$\frac{1232}{643} = 191.6\%$

DLR ✓


DATA REDUCTION & VERIFICATION : j4e
Test 1
10 Dyn11
11 Dyn12
12 Dyn13
13 Dyn14
14 Dyn15
15 Dyn16
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
2937, 68, C
3060, -13, C
3383, -35, C
3480, 149, C
3635, -30, C
R: x: 3292 y: -25
S: x: 3292 y: -24
Dyn16
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

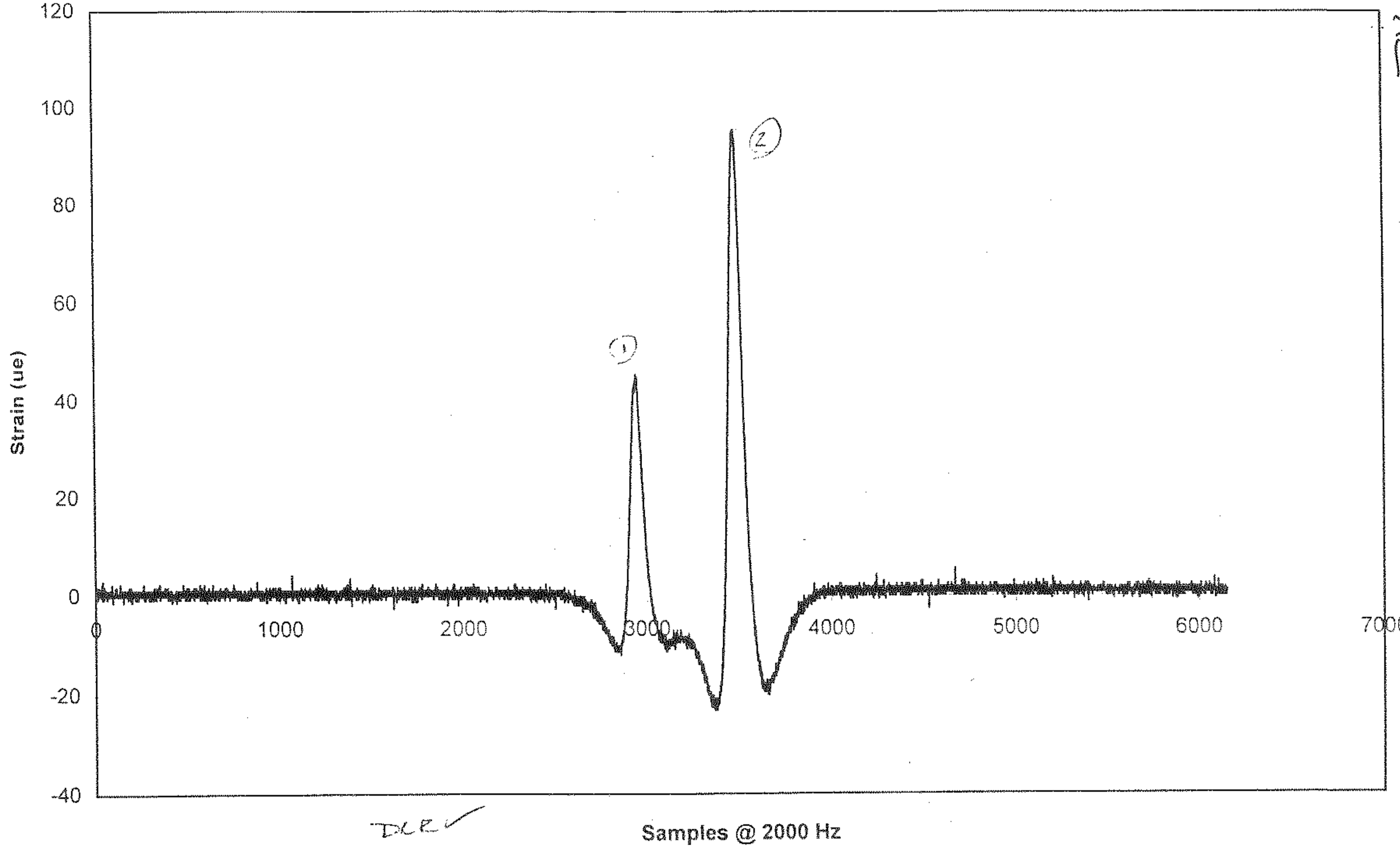
46

PEAK


Rj4e.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
<<
>>
Channel 16: Dyn16
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

XL

j4e.001 Dyn16 Strain (minus i.v. = 0.625)

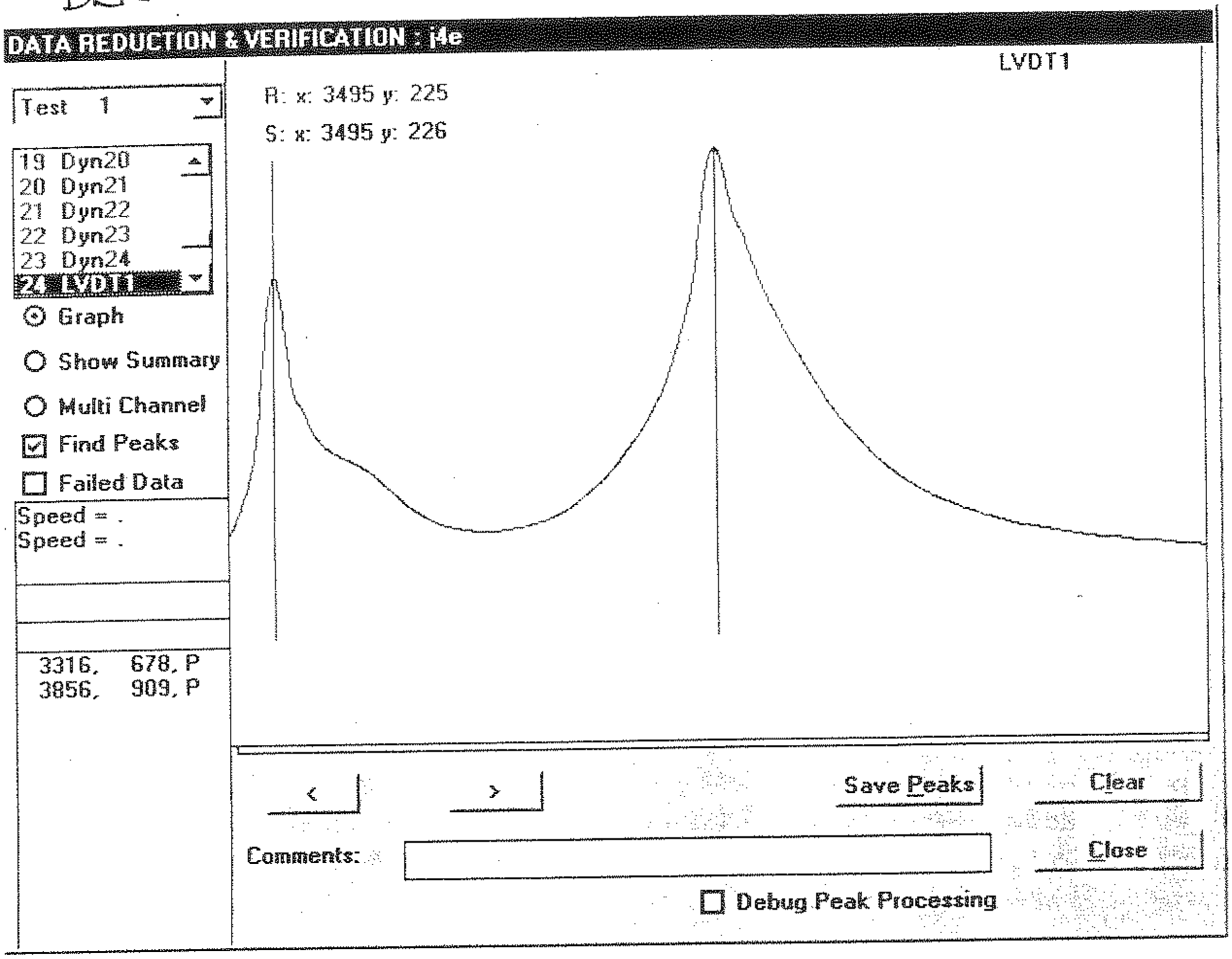


DLR ✓

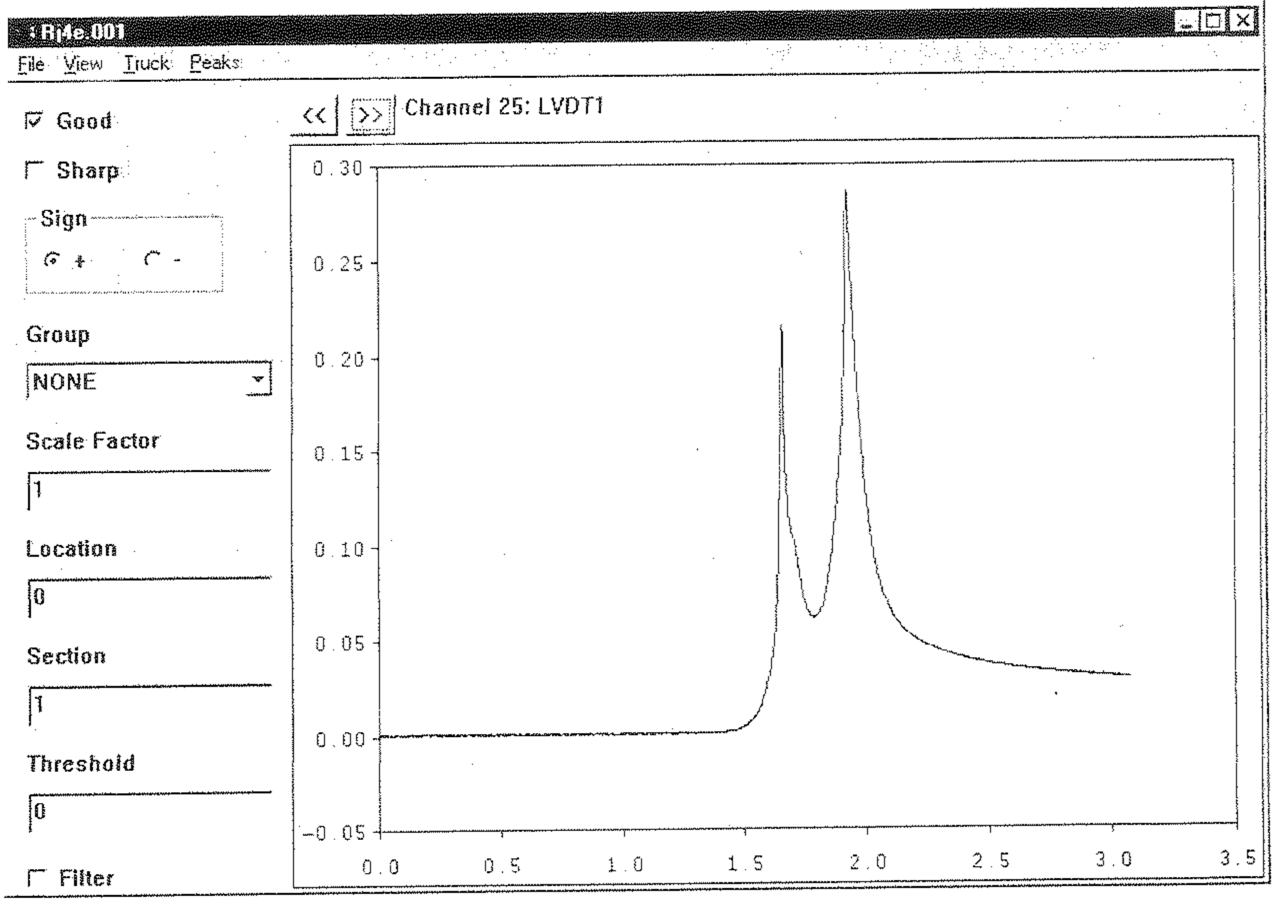
① 2945, 45.6 $\mu\epsilon$

② 3497, 95 $\mu\epsilon$ .49 $\mu\epsilon$ $\frac{54}{122}$ = 44.3%

DLR ✓


DATA REDUCTION & VERIFICATION : j4e
LVDT1
R: x: 3495 y: 225
S: x: 3495 y: 226
Test 1
19 Dyn20
20 Dyn21
21 Dyn22
22 Dyn23
23 Dyn24
24 LVDT1
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
3316, 678, P
3856, 909, P
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

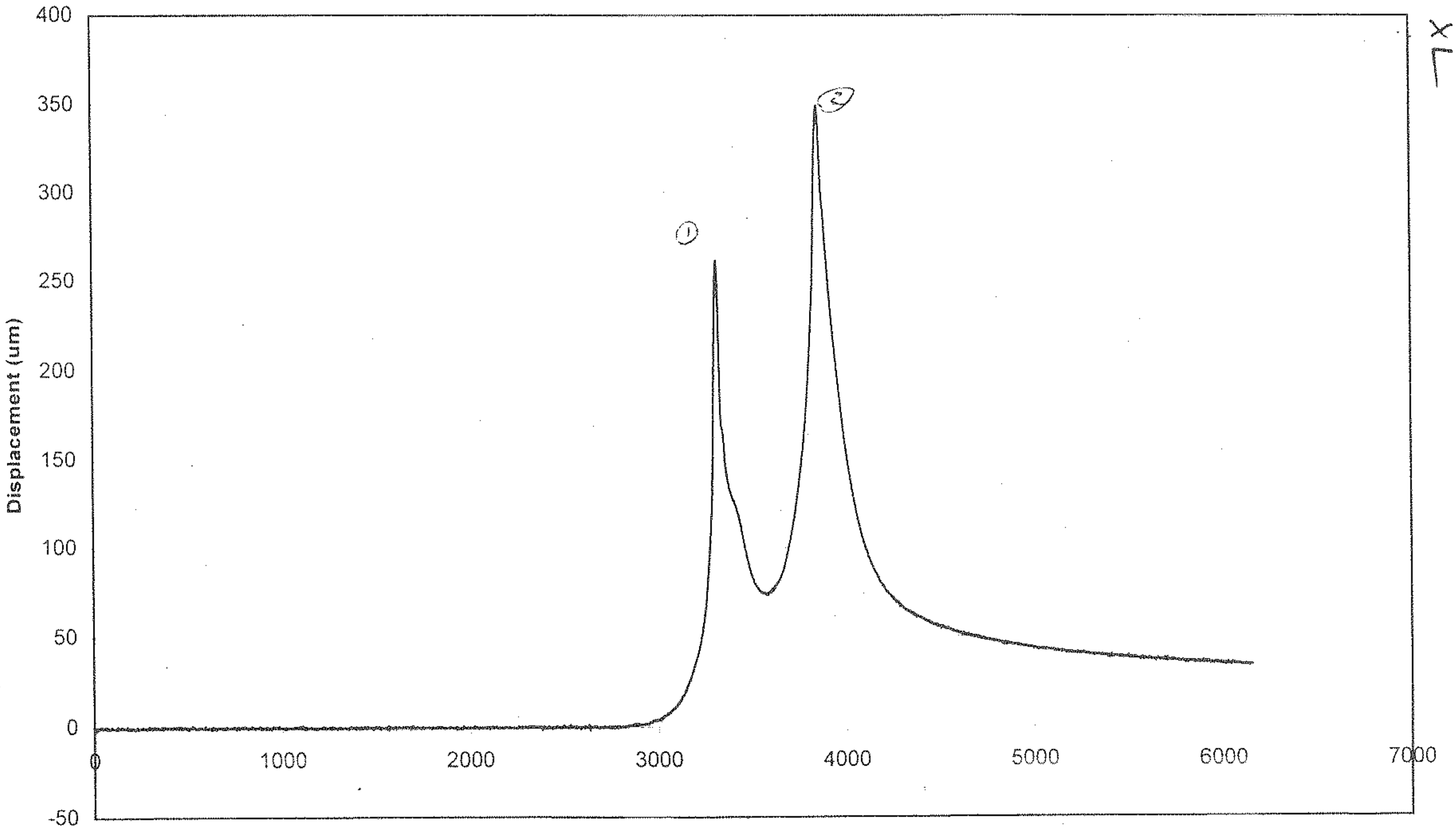
PEAK



Rj4e.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Channel 25: LVDT1
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

XL

j4e.001 LVDT1 Displacement (minus i.v. = 4001 um)



Samples @ 2000 Hz

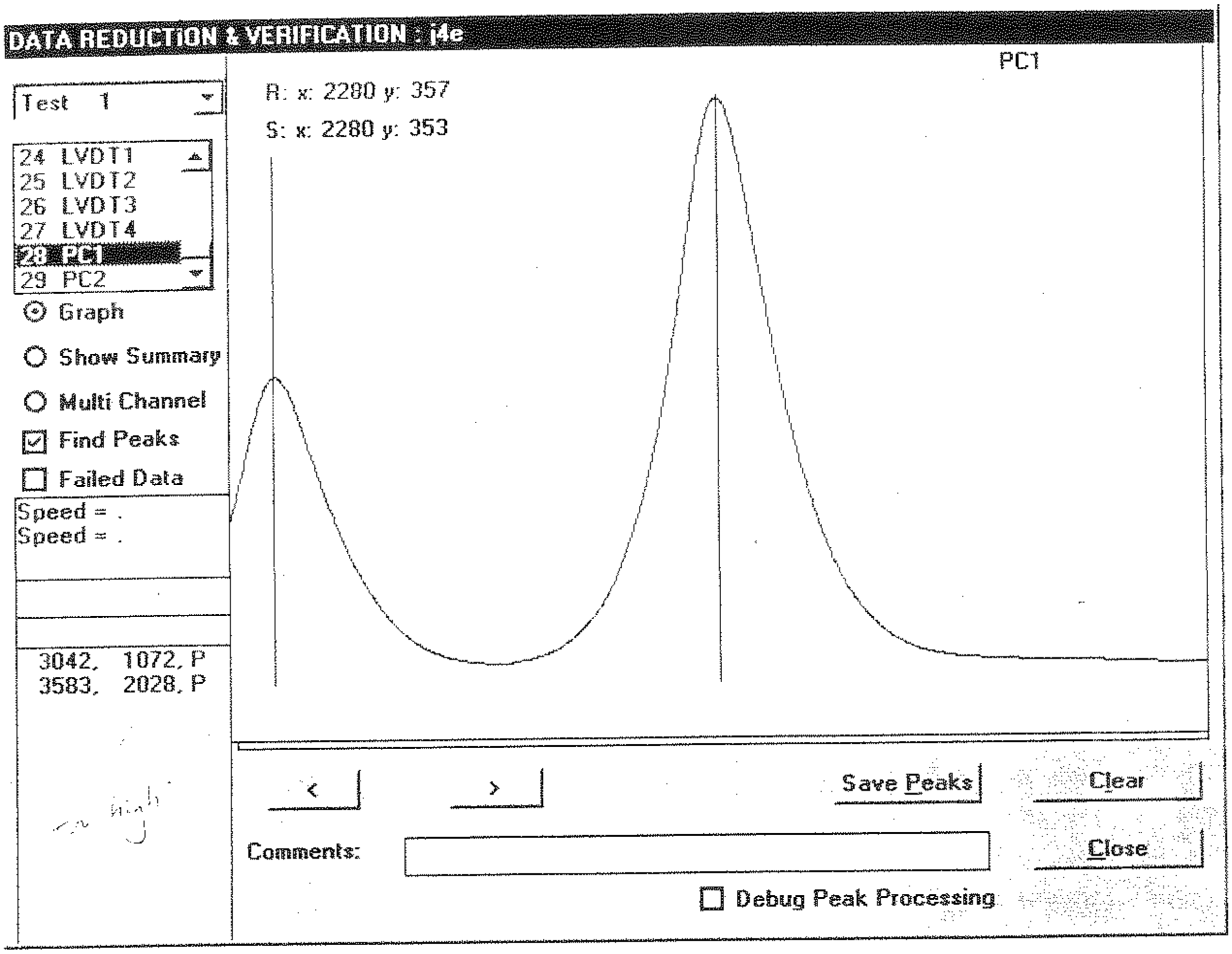
DCR ✓

① 3316, 262 µm   678 µm   416/470 = 88.5%

② 3858, 349 µm   709 µm   360/3[illegible] = 89.0%

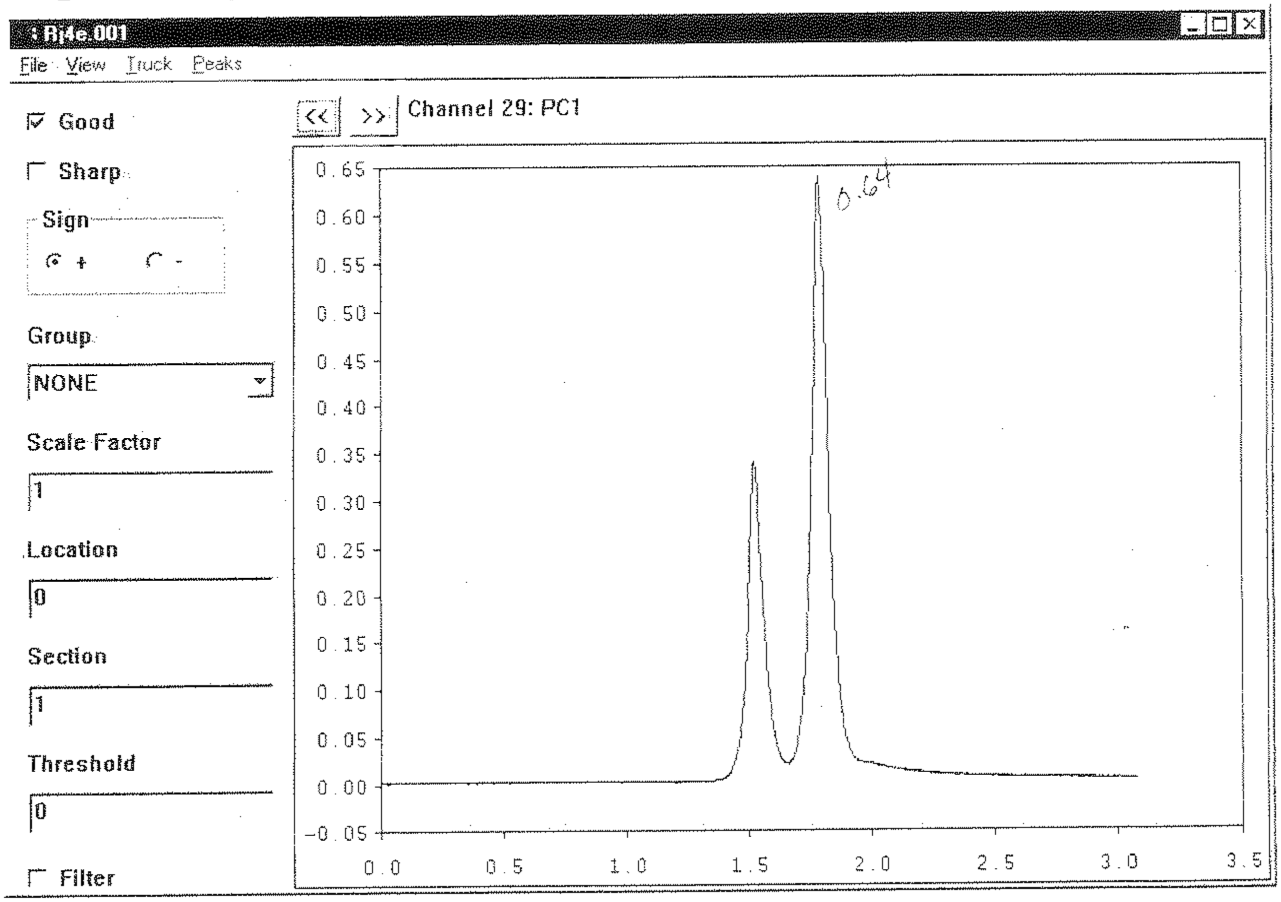
21

DLRV



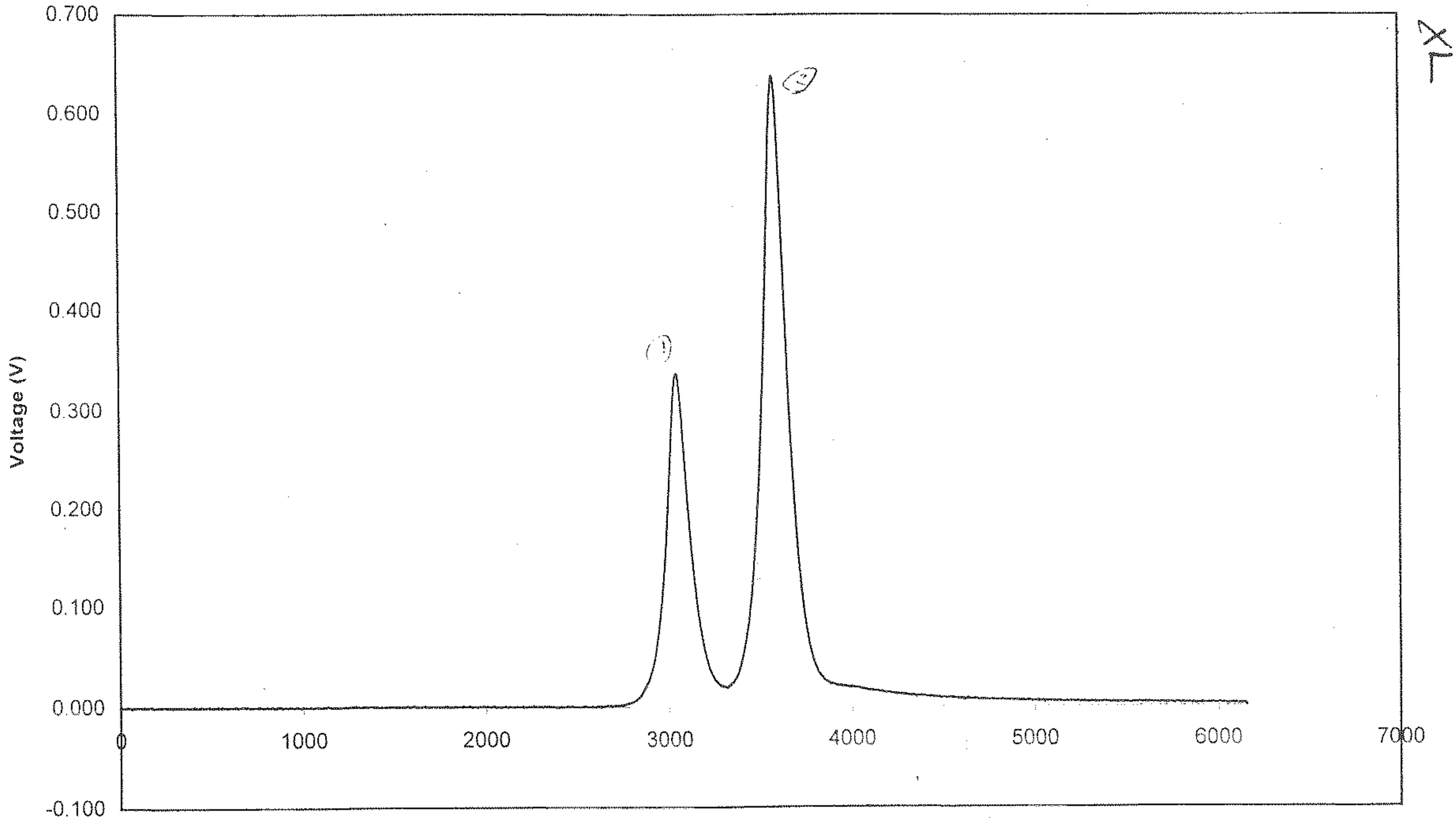
DATA REDUCTION & VERIFICATION : j4e
PC1
Test 1
R: x: 2280 y: 357
S: x: 2280 y: 353
24 LVDT1
25 LVDT2
26 LVDT3
27 LVDT4
28 PC1
29 PC2
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
3042, 1072, P
3583, 2028, P
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

~~[illegible]~~ PEAK


Rj4e.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
<<
>>
Channel 29: PC1
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.64

10 kPa

j4e.001 PC1 Voltage (minus i.v. = 0.147 V)



(1) 3017, 0.337 v (23.2 kPa) TLE✓ 1072 kPa

(2) 3586, 0.637 v (43.9 kPa) 2028✓ 10psi/V

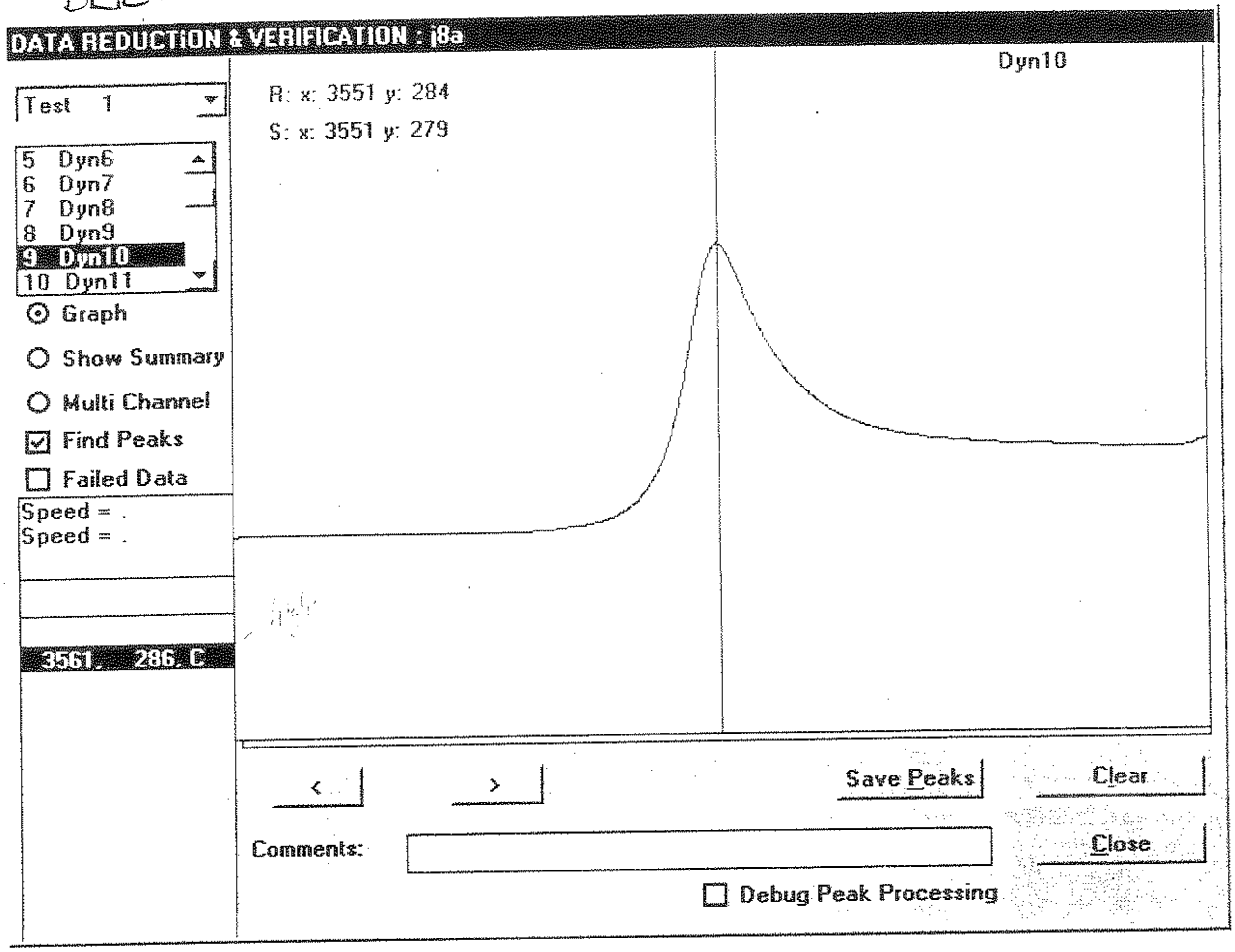
psi * 6.89 = kPa

1048.8 / 547.6 = 191.5%

1984.1 / 1036 = 191.5

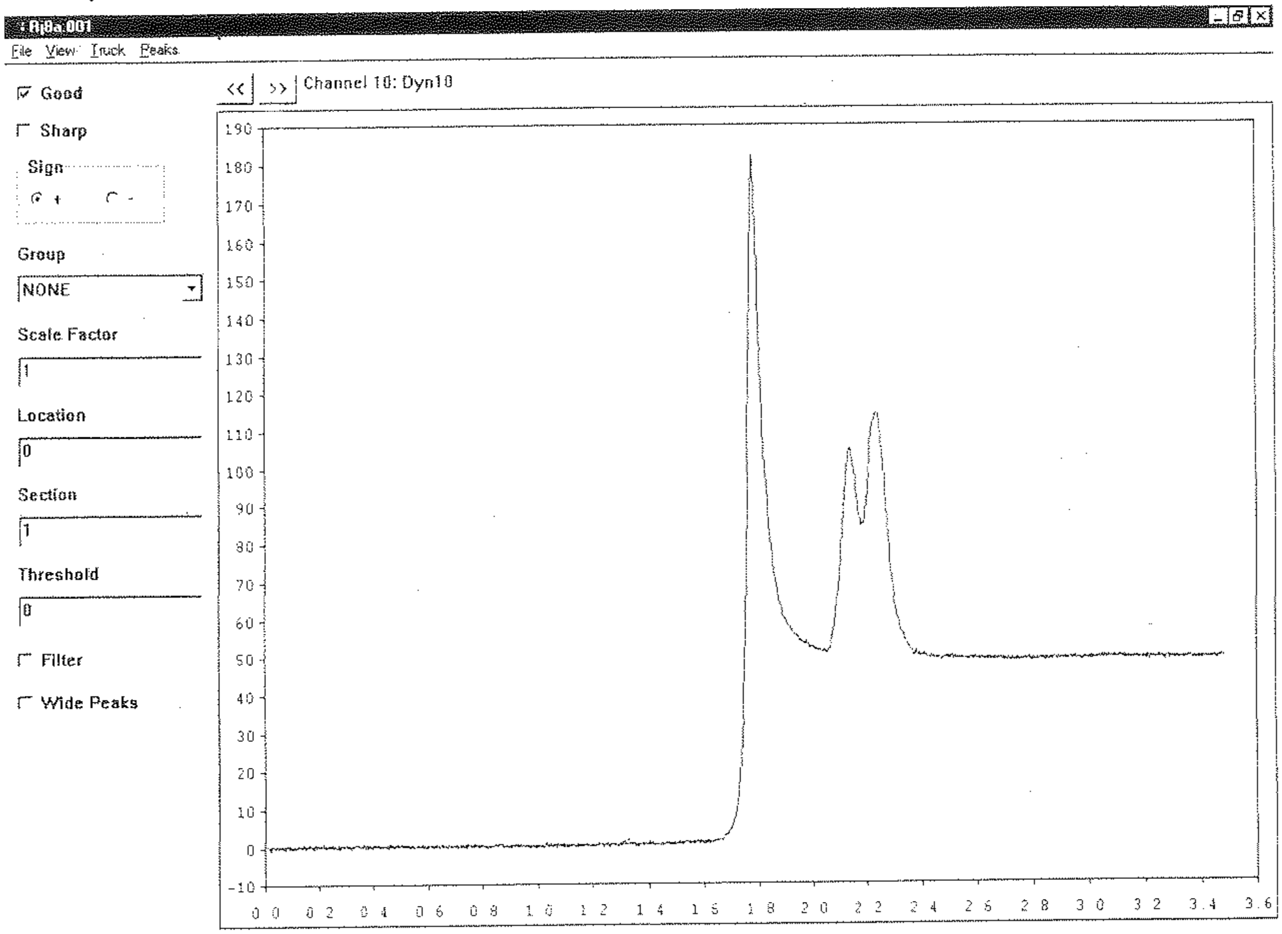
24

DLR ✓



DATA REDUCTION & VERIFICATION : j8a
Test 1
5 Dyn6
6 Dyn7
7 Dyn8
8 Dyn9
9 Dyn10
10 Dyn11
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
3561, 286, C
Dyn10
R: x: 3551 y: 284
S: x: 3551 y: 279
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

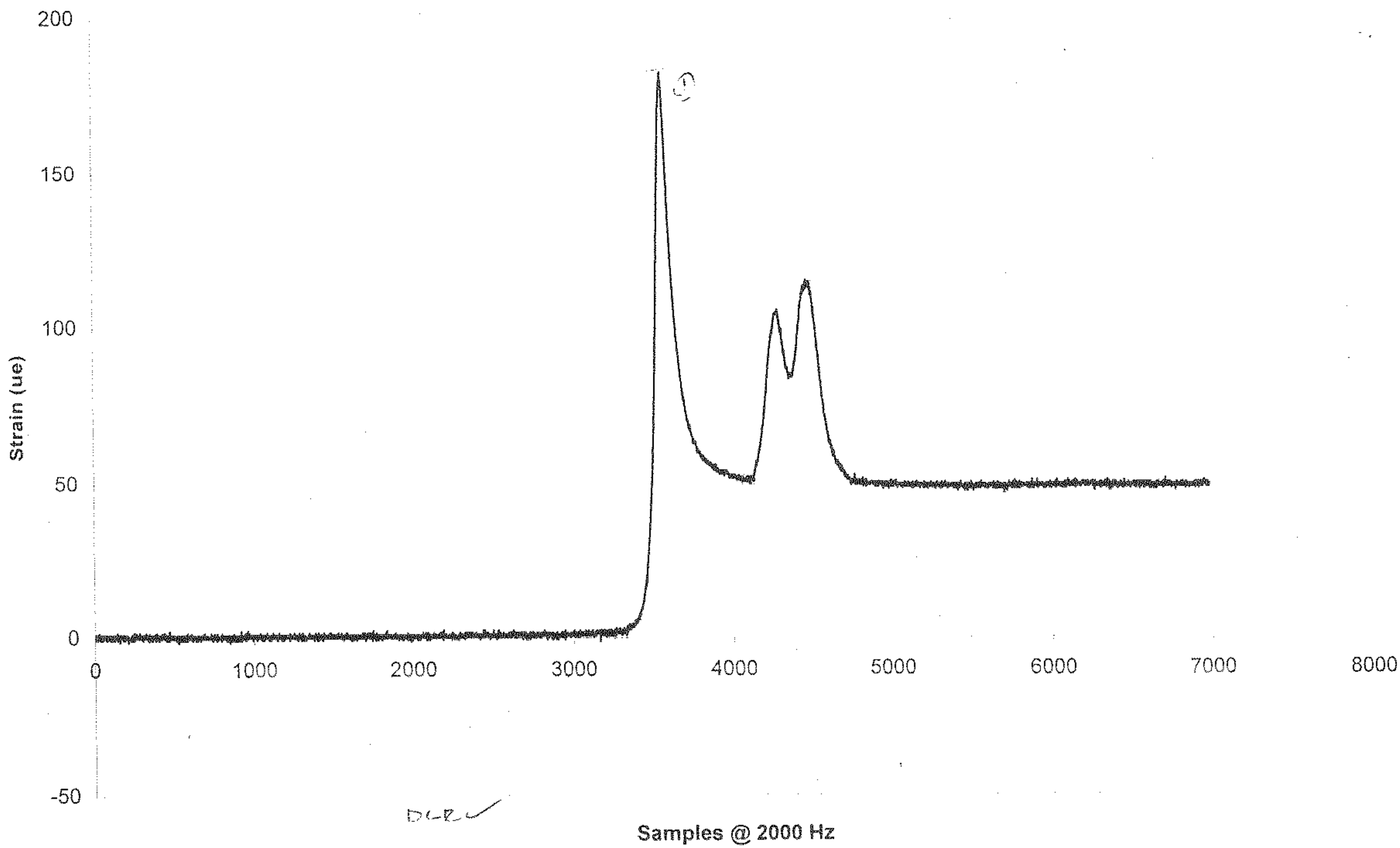
PEAK


RjBa.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 10: Dyn10
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6

XF

j8a.001 Dyn10 Strain (minus initial value)

22 µ+

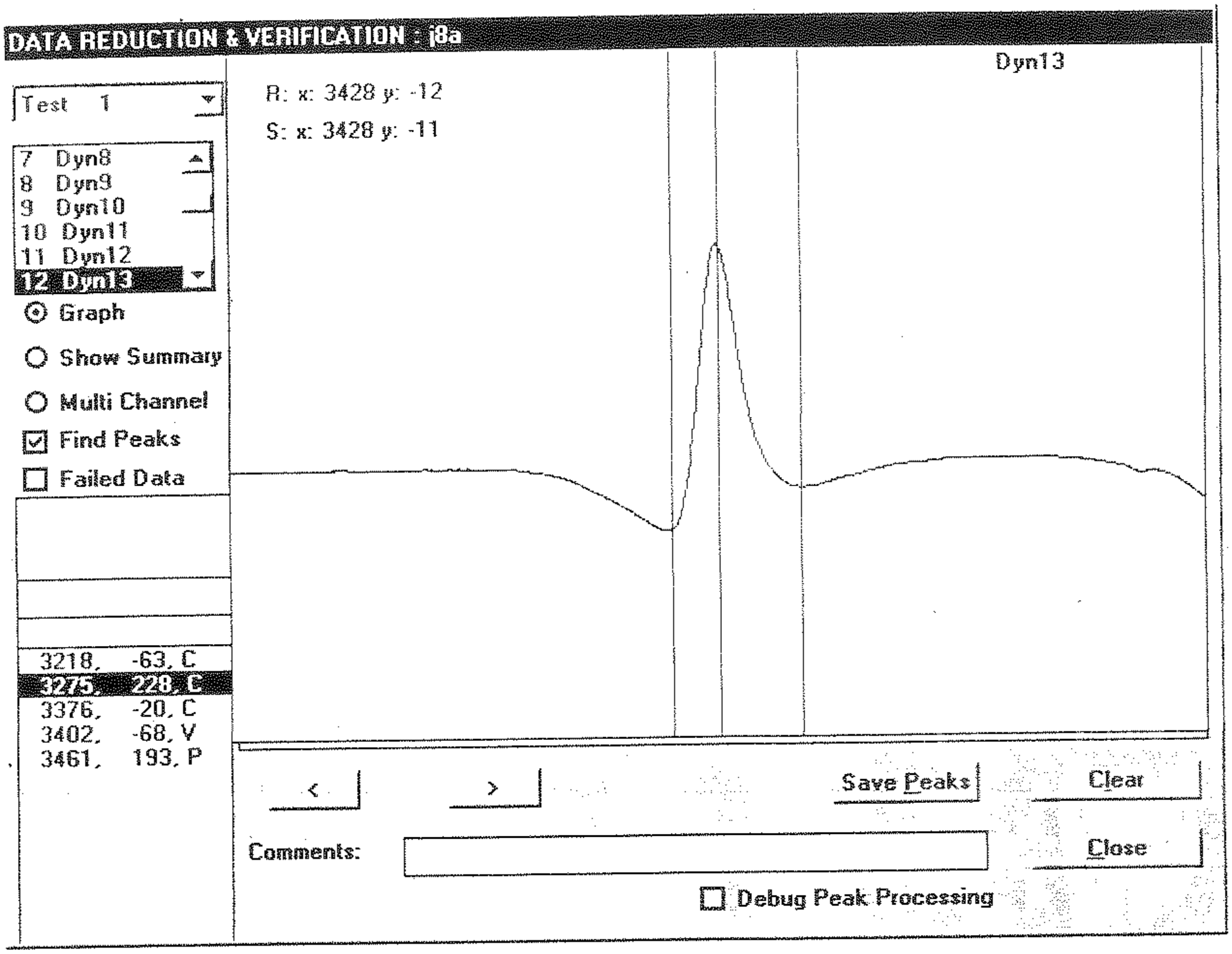


DLR ✓

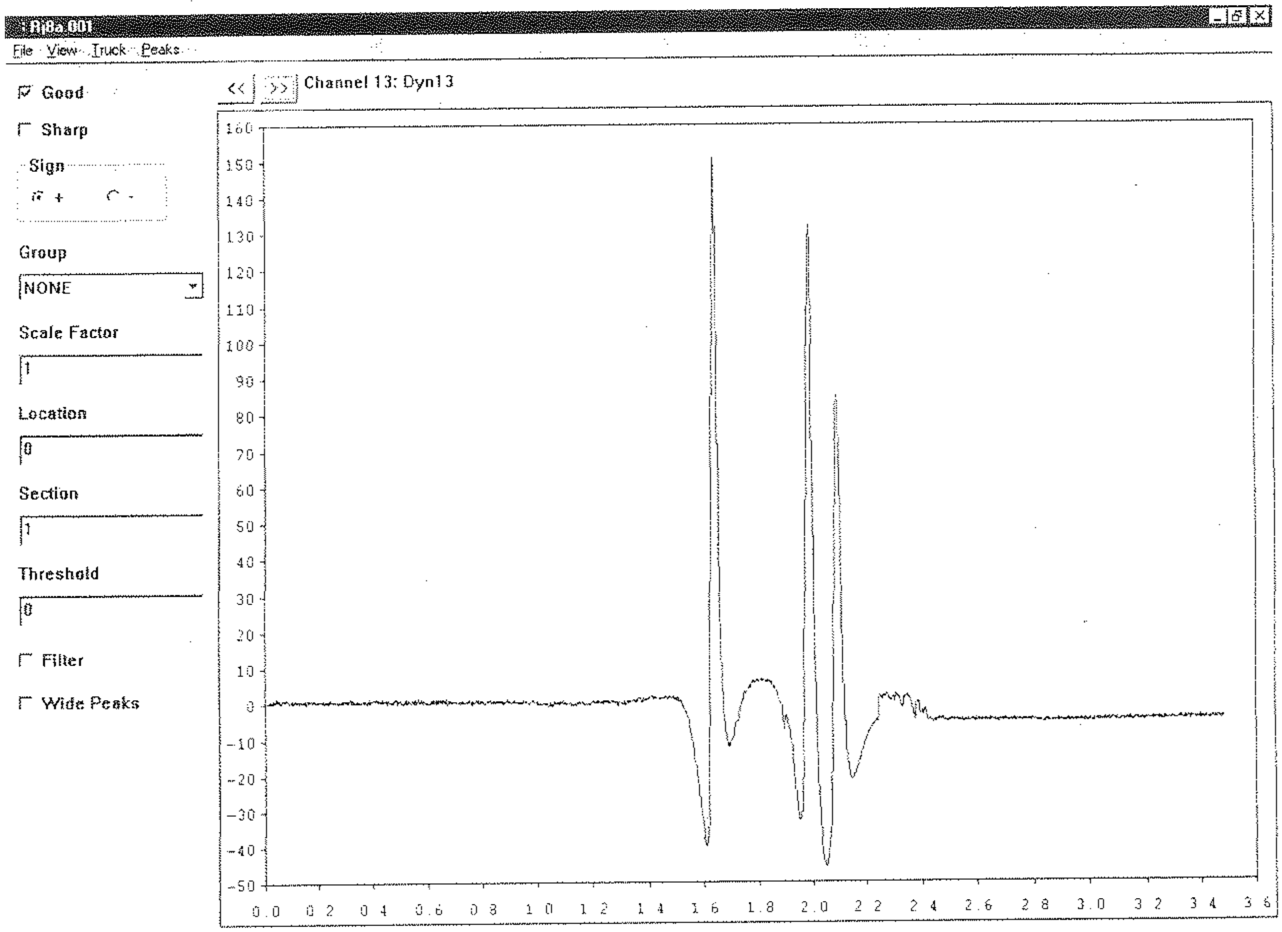
① 3501, 183 µε   286 µε $\frac{103}{234.5} = 43.9\%$

27

DLR ✓


DATA REDUCTION & VERIFICATION : j8a
Test 1
7 Dyn8
8 Dyn9
9 Dyn10
10 Dyn11
11 Dyn12
12 Dyn13
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
3218, -63, C
3275, 228, C
3376, -20, C
3402, -68, V
3461, 193, P
R: x: 3428 y: -12
S: x: 3428 y: -11
Dyn13
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

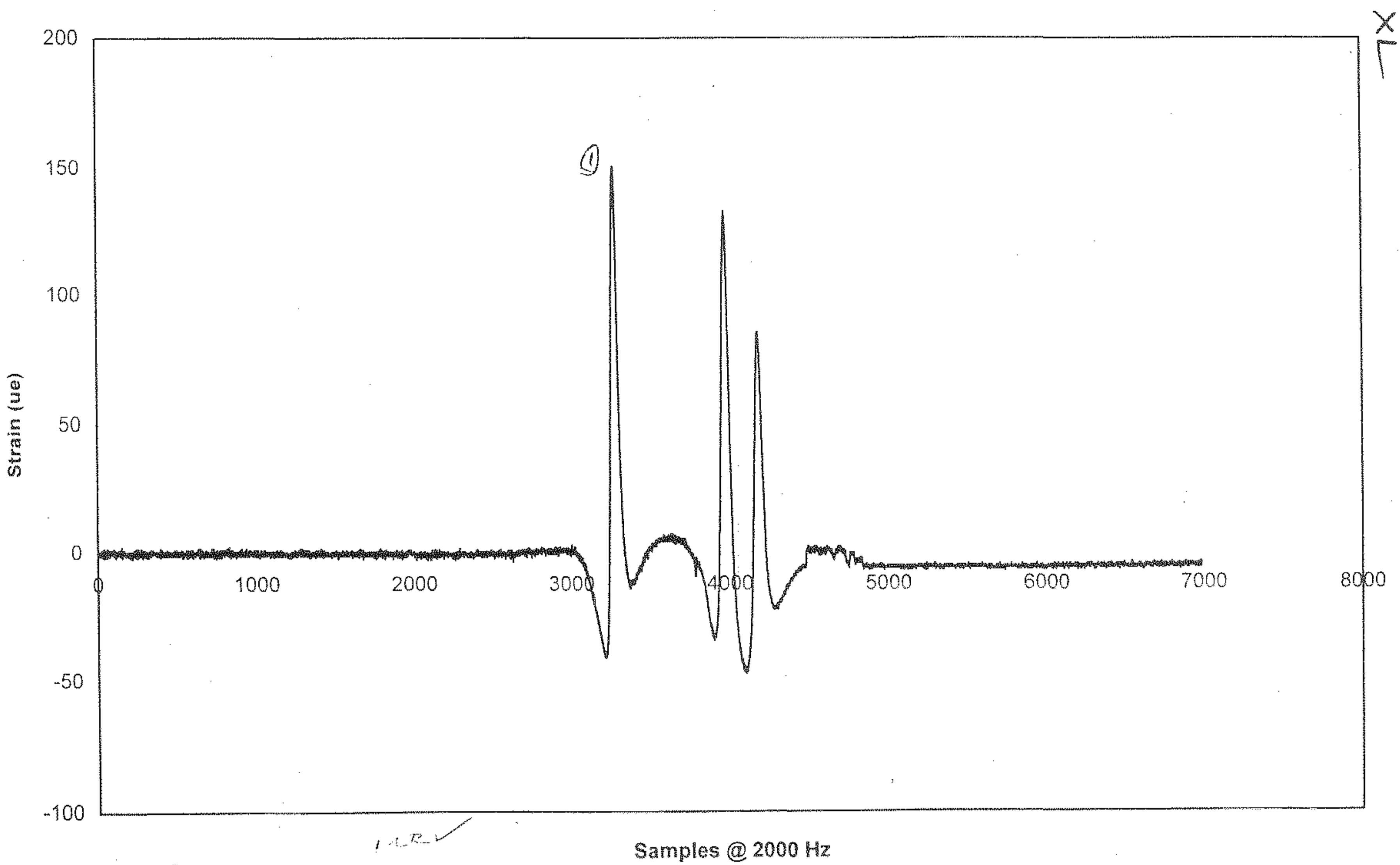
PEAK



Ri8a.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 13: Dyn13
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6

9.57 µε

j8a.001 Dyn13 Strain (minus initial value)

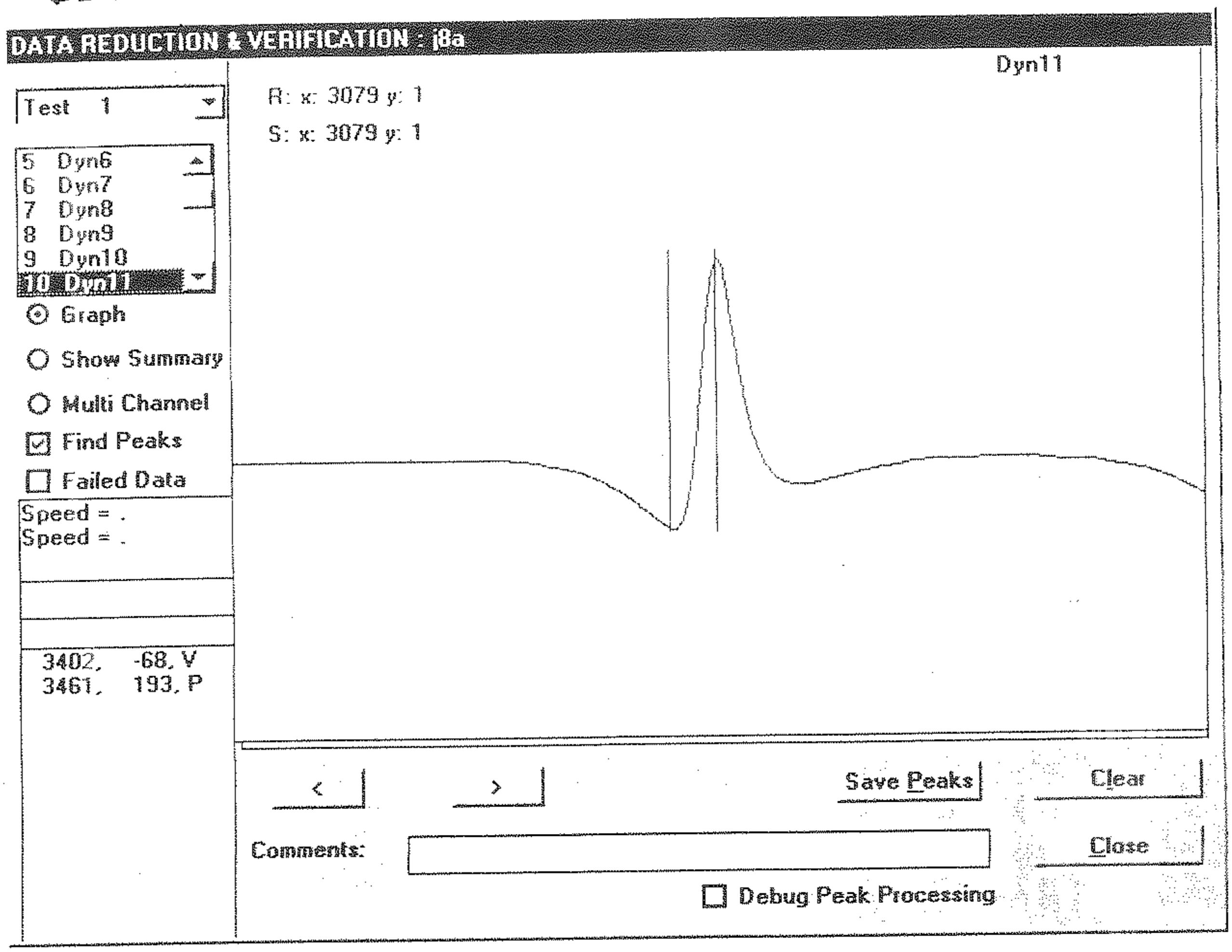


MR

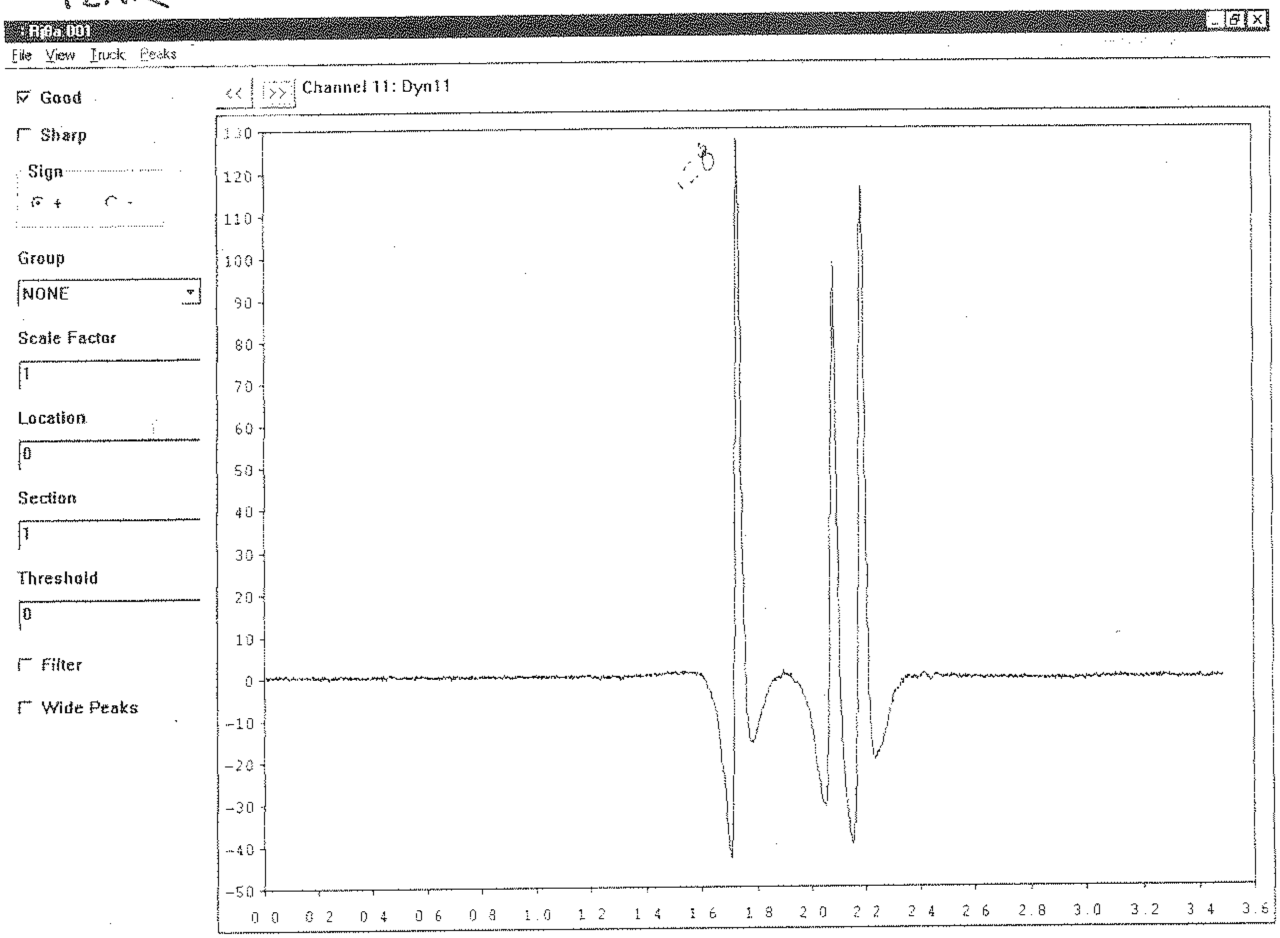
① 3275, 150 µε   228 µε

$\frac{78}{189} = 41.3\%$

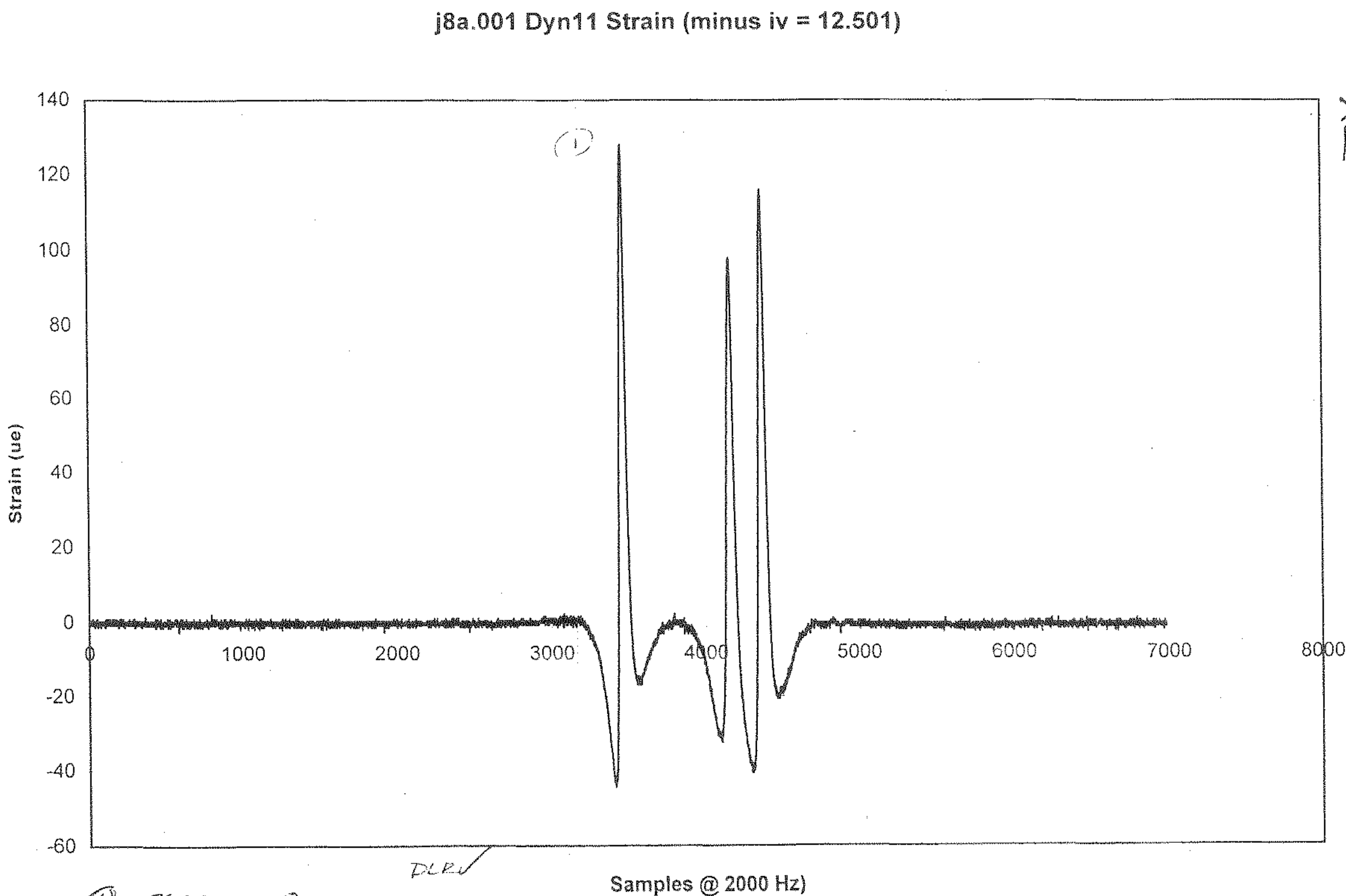
DLR ✓


DATA REDUCTION & VERIFICATION : j8a
Dyn11
Test 1
R: x: 3079 y: 1
S: x: 3079 y: 1
5 Dyn6
6 Dyn7
7 Dyn8
8 Dyn9
9 Dyn10
10 Dyn11
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
3402, -68, V
3461, 193, P
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK


Rjba.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 11: Dyn11
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6

XL



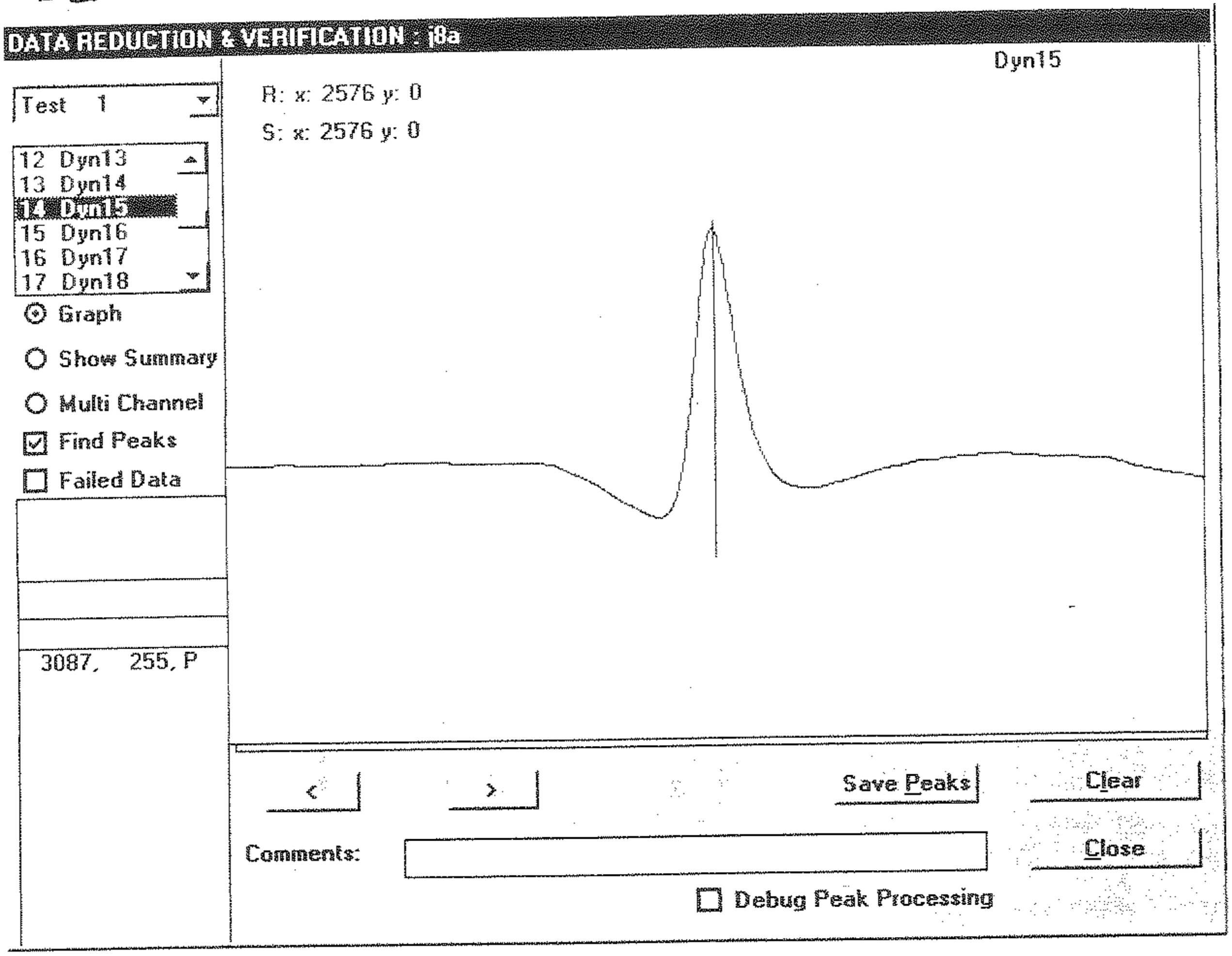
(1) 3462, 128με

DLR✓

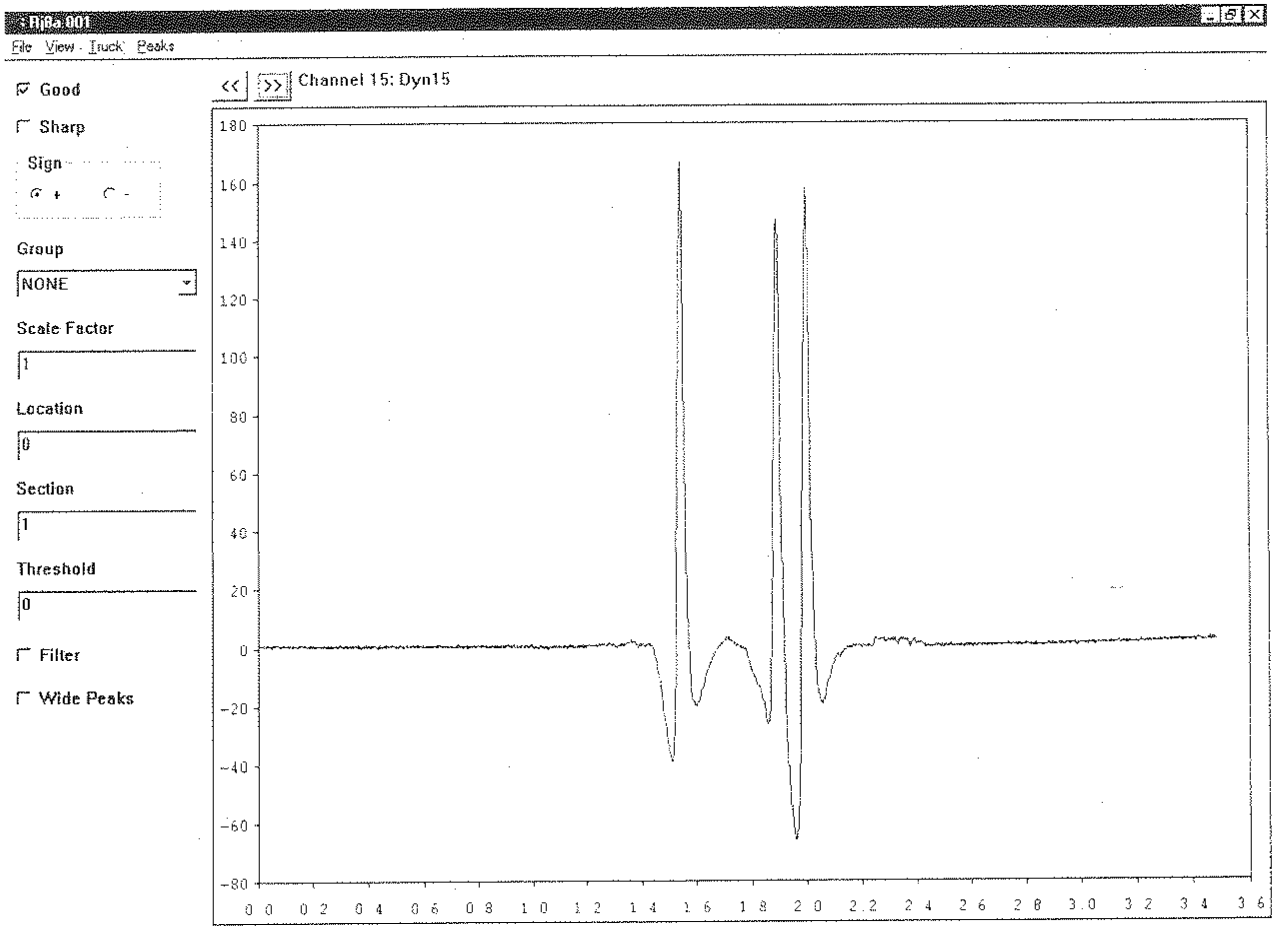
193με

$\frac{65}{160.5} = 40.5\%$

DLR ✓

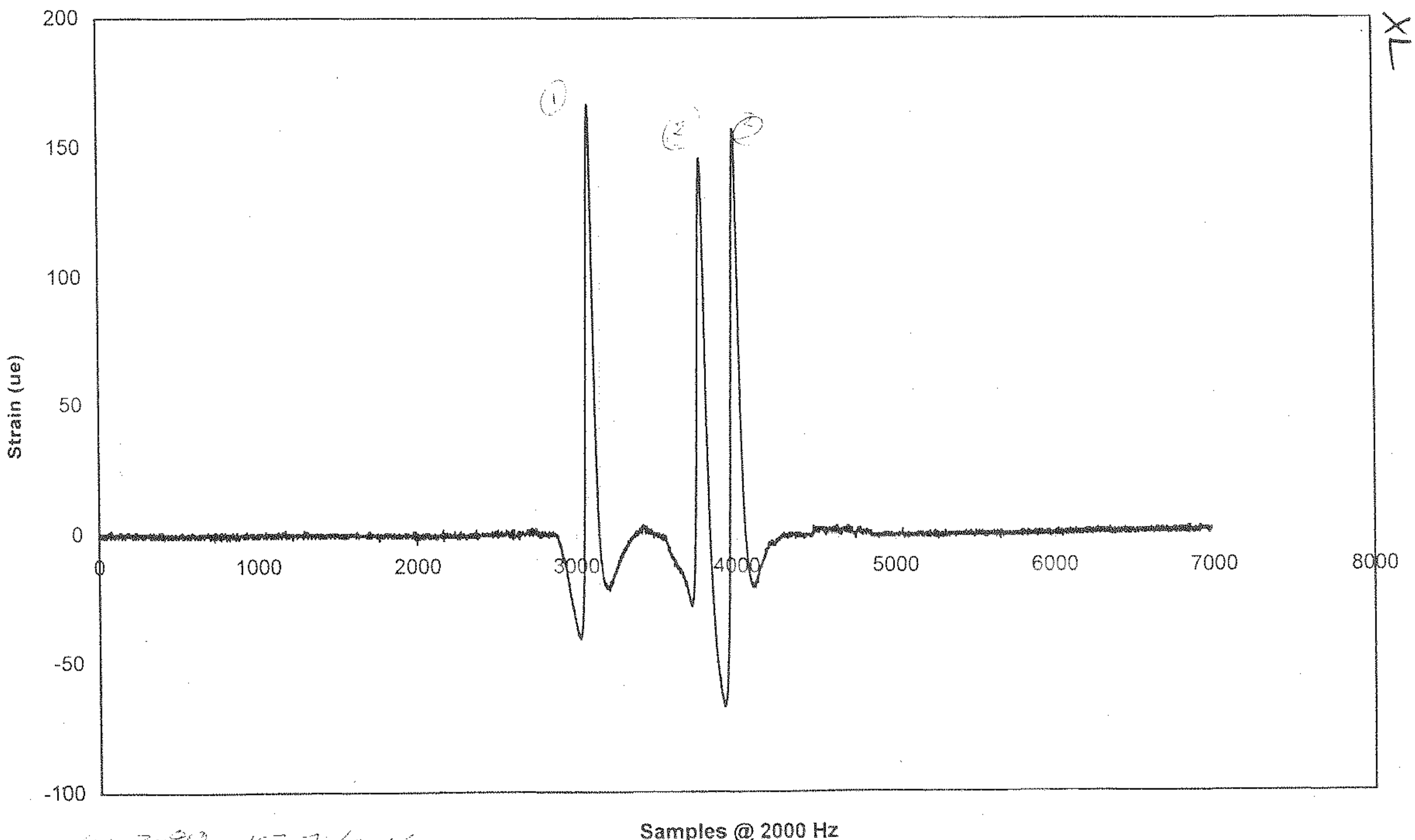

DATA REDUCTION & VERIFICATION : j8a
Dyn15
Test 1
R: x: 2576 y: 0
S: x: 2576 y: 0
12 Dyn13
13 Dyn14
14 Dyn15
15 Dyn16
16 Dyn17
17 Dyn18
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
3087, 255, P
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK.



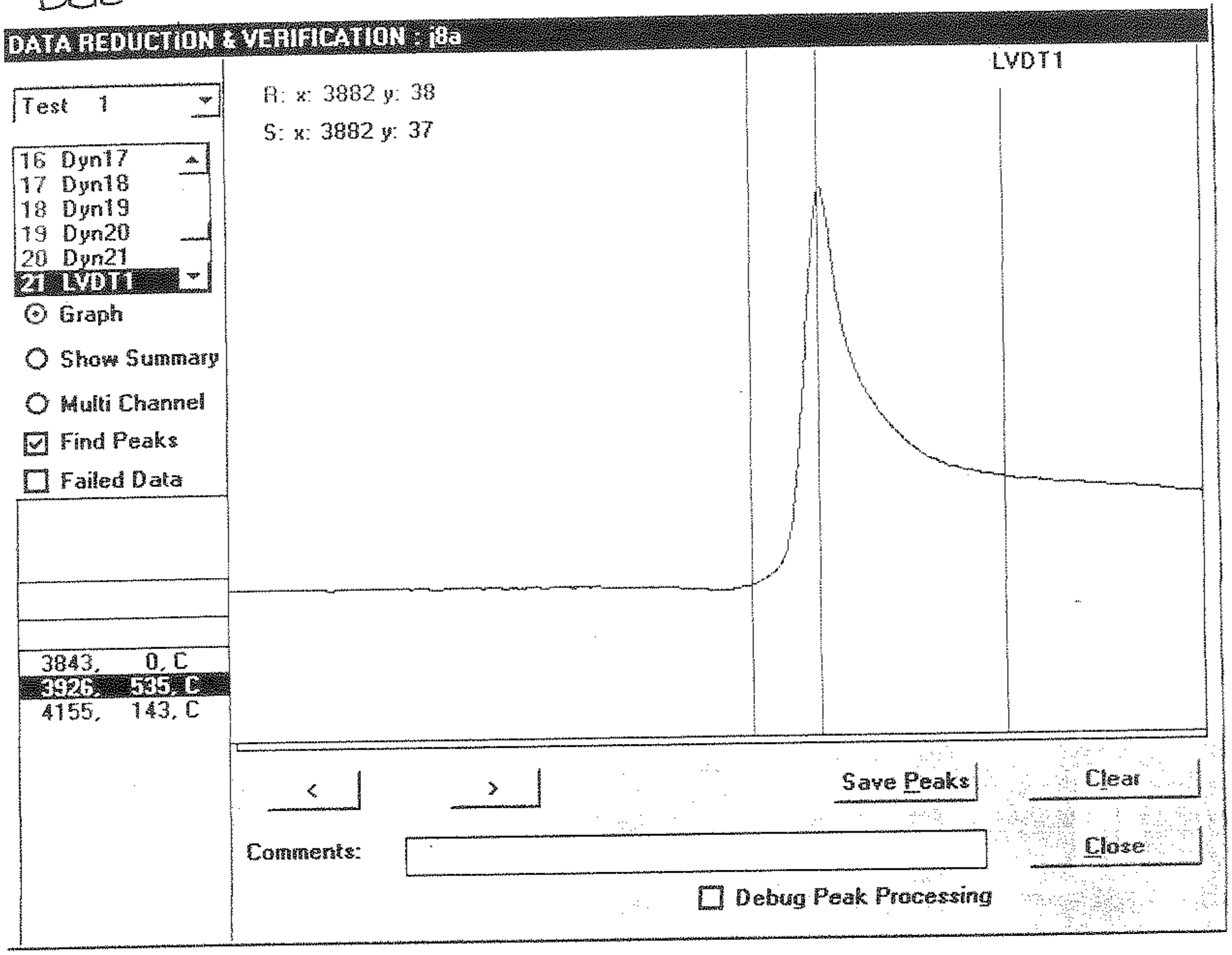
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 15: Dyn15
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6

j8a.001 Dyn15 Strain (minus i.v. = 6.251 ue)

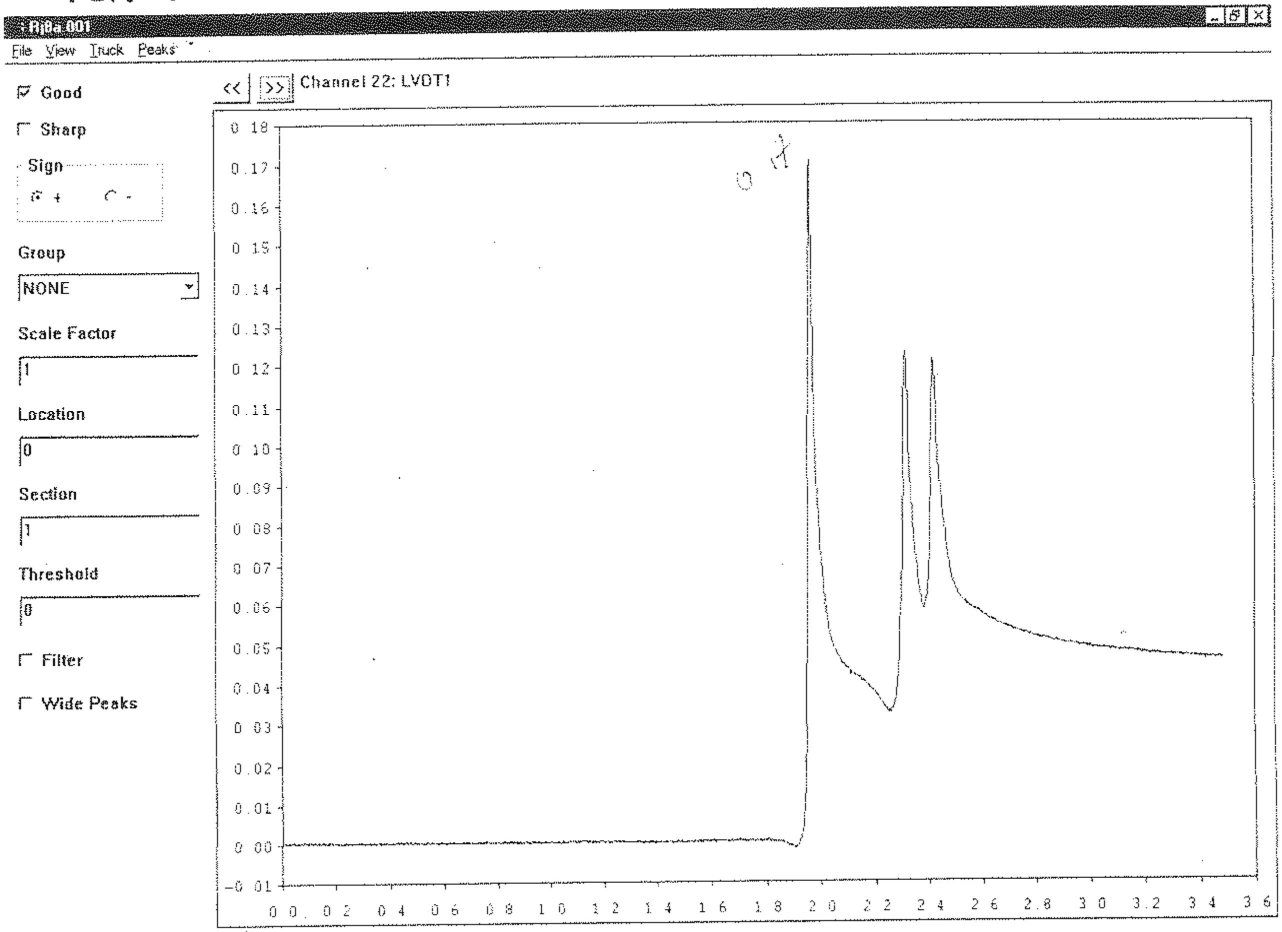


(1) 3089, 16[illegible] µε
(2) 3731, 14[illegible].5 µε
(3) 3995, 155.0 µε

DCR

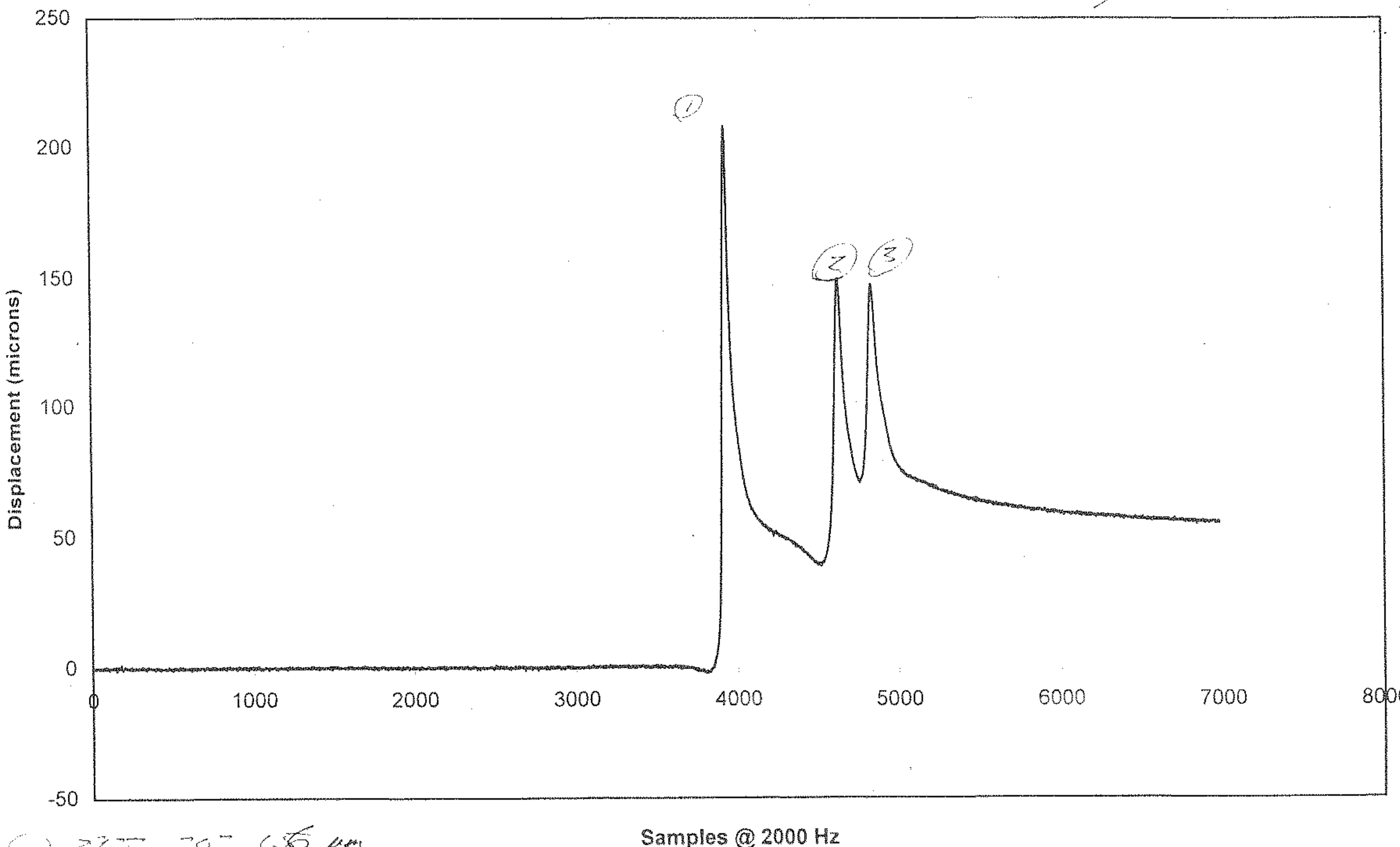

DATA REDUCTION & VERIFICATION : j8a
Test 1
16 Dyn17
17 Dyn18
18 Dyn19
19 Dyn20
20 Dyn21
21 LVDT1
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
3843, 0, C
3926, 535, C
4155, 143, C
R: x: 3882 y: 38
S: x: 3882 y: 37
LVDT1
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK


Rj8a.001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 22: LVDT1
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6

j8a.001 LVDT1 Displacement (minus I.v.)

-2.73V = -3589.25 µm

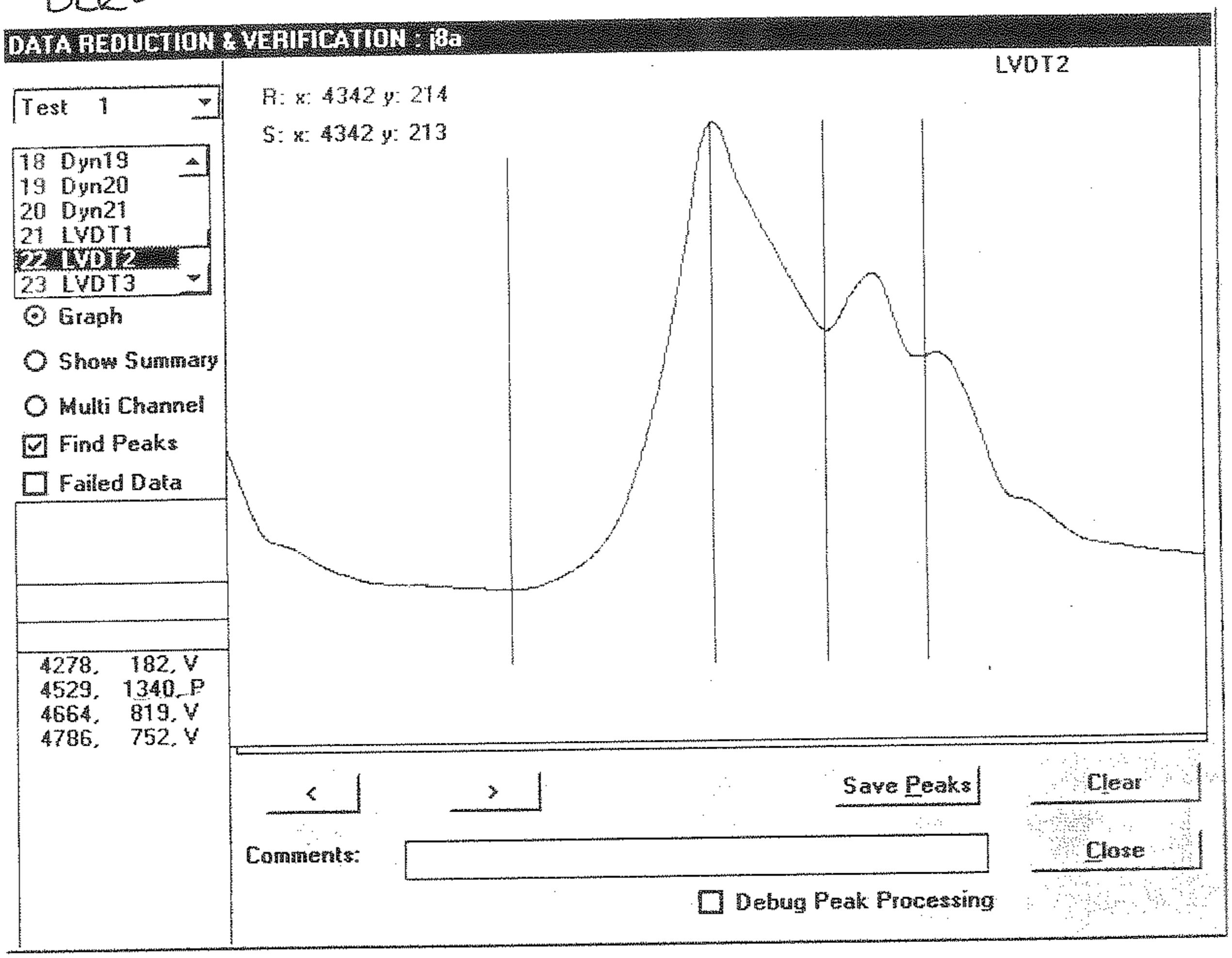


1 3755, 207.66 µm

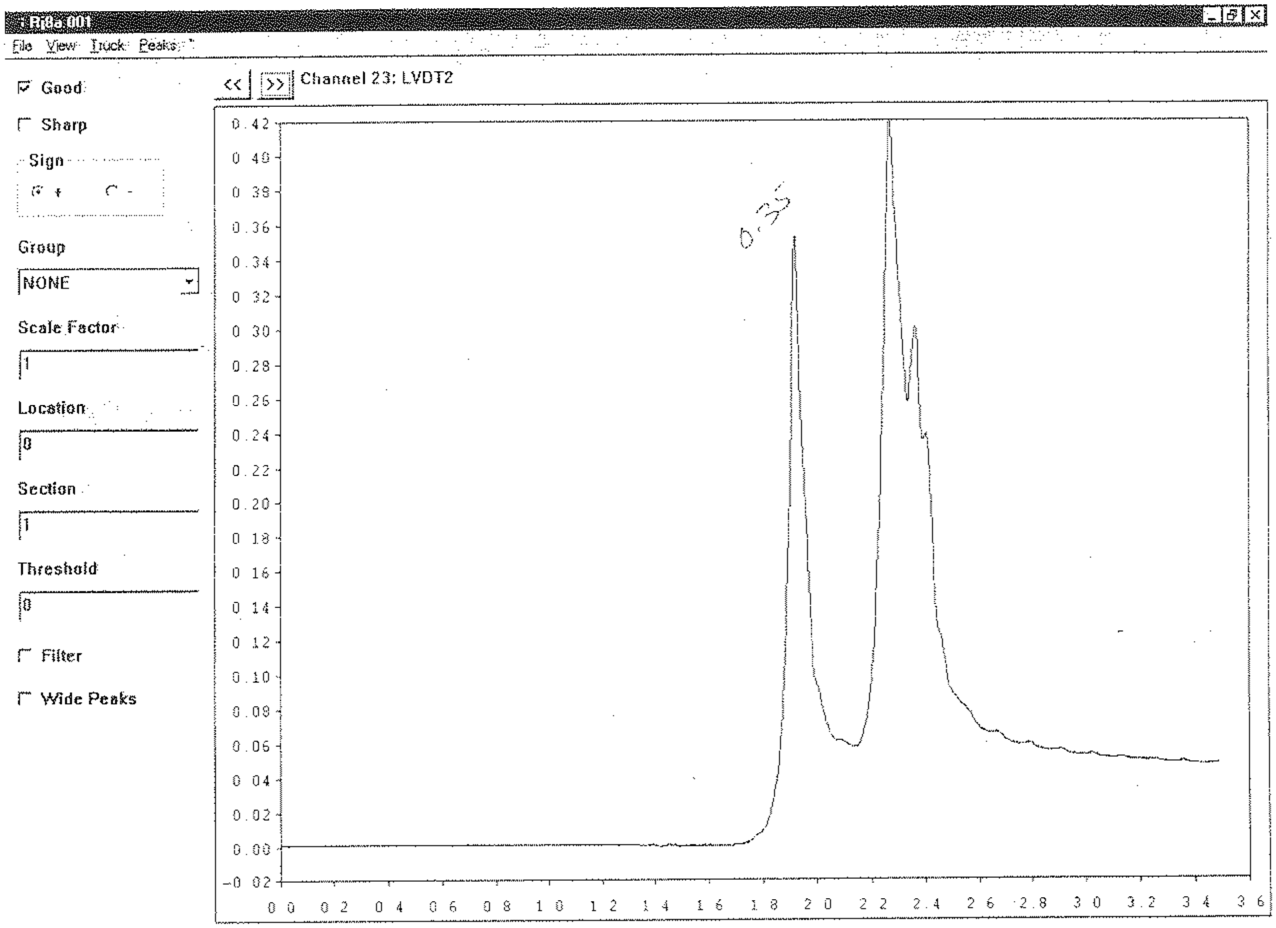
2 4638, 145.09 µm

3 4893, 145.09 µm

DLR ✓

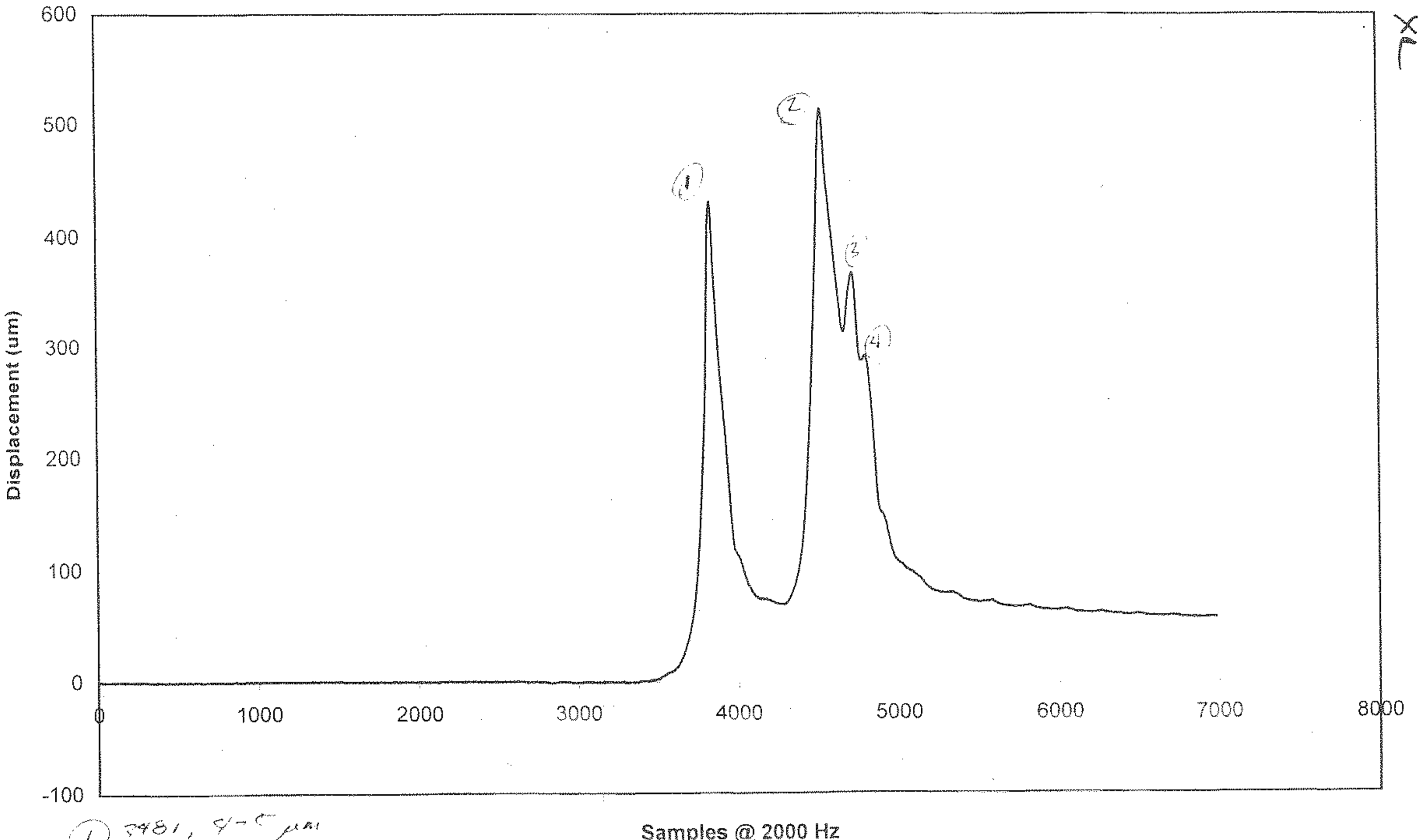

DATA REDUCTION & VERIFICATION : j8a
LVDT2
Test 1
R: x: 4342 y: 214
S: x: 4342 y: 213
18 Dyn19
19 Dyn20
20 Dyn21
21 LVDT1
22 LVDT2
23 LVDT3
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
4278, 182, V
4529, 1340, P
4664, 819, V
4786, 752, V
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK


File View Truck Peaks
Channel 23: LVDT2
Good
Sharp
Sign
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
0.35

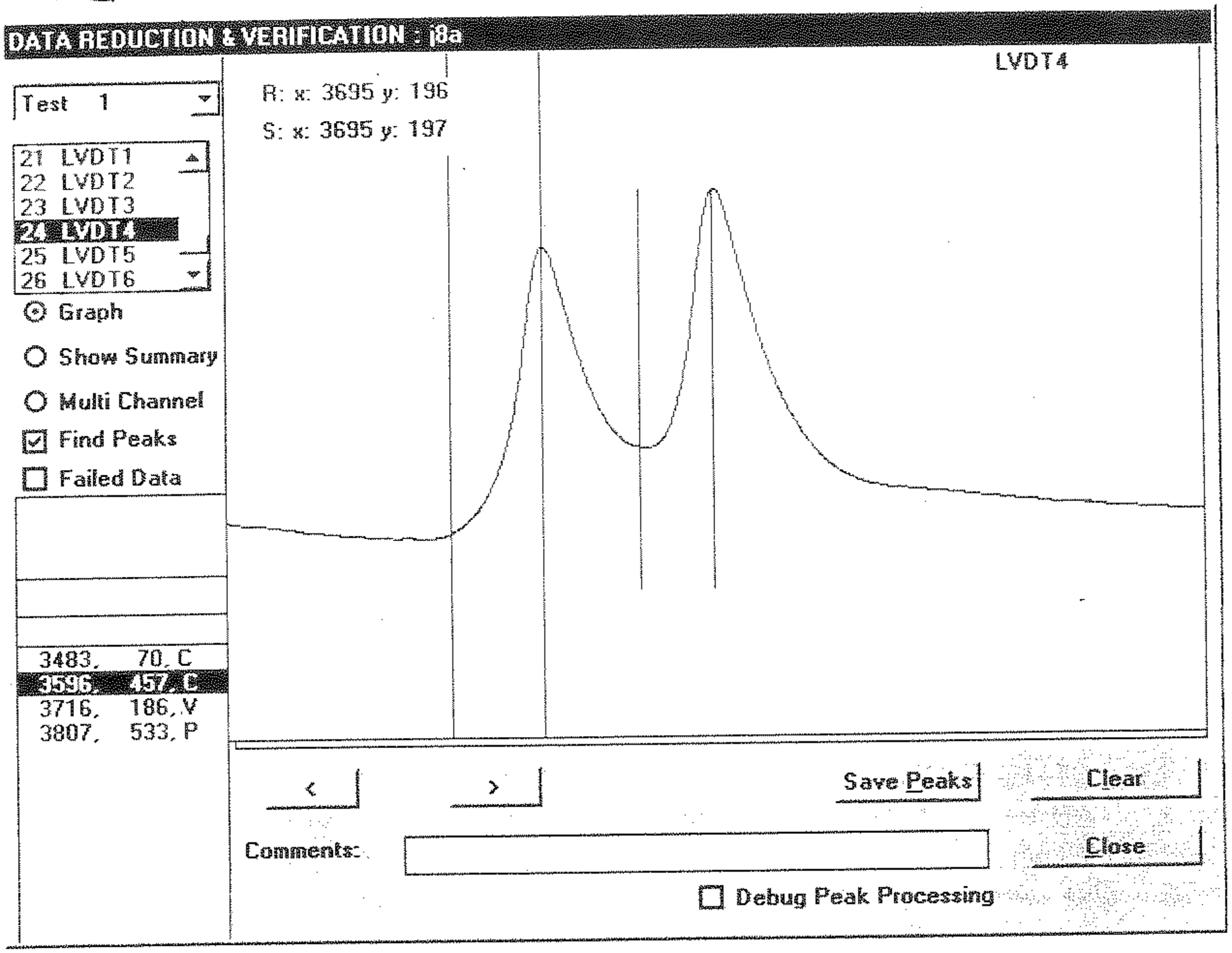
XL

j8a.001 LVDT2 Displacement (minus i.v. = 8222 um)

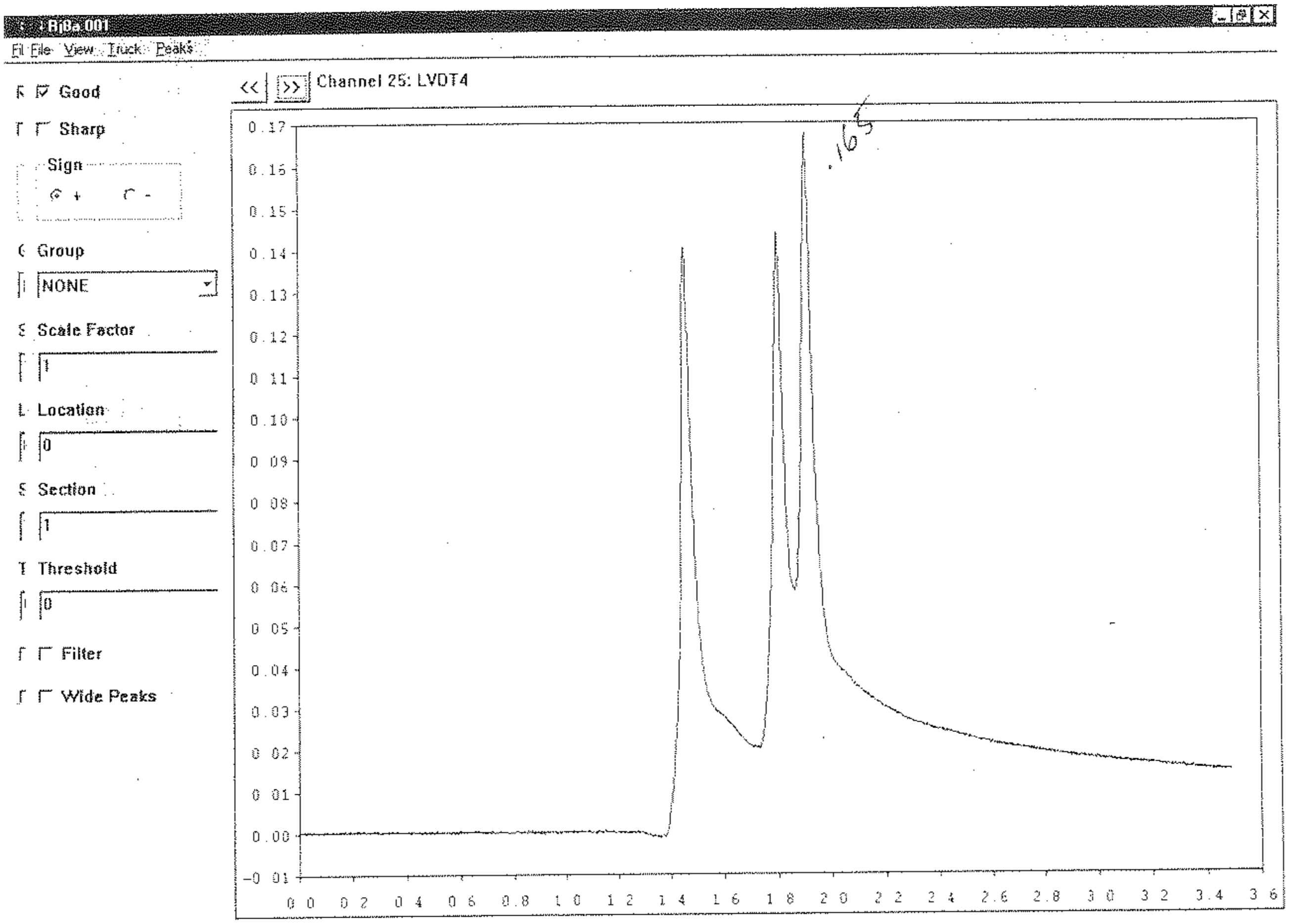


① 3781, 4[illegible] μm
② 4539, 509 μm
③ 4733, 362 μm
④ 4815, 286 μm

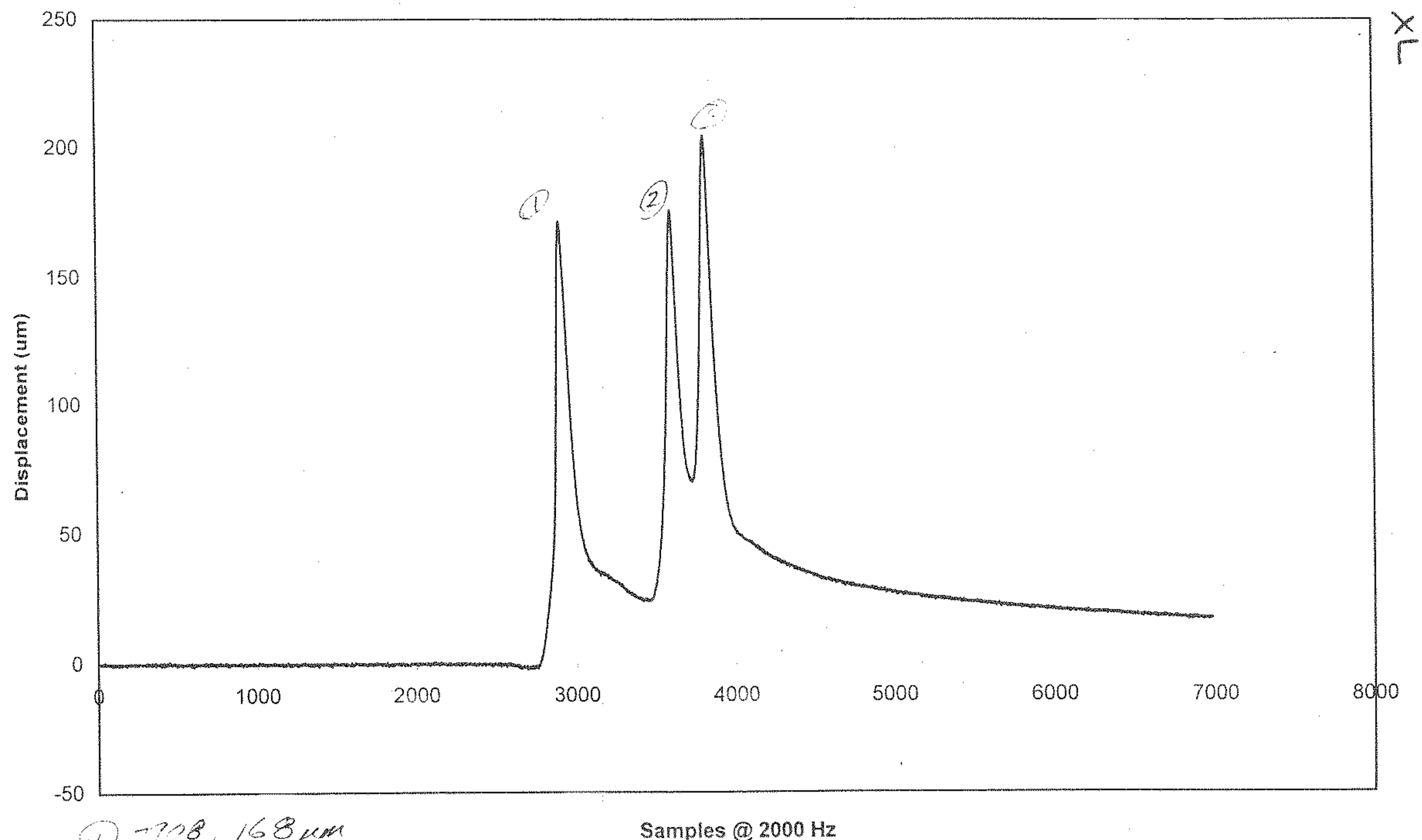
DLR ✓


DATA REDUCTION & VERIFICATION : j8a
LVDT4
Test 1
R: x: 3695 y: 196
S: x: 3695 y: 197
21 LVDT1
22 LVDT2
23 LVDT3
24 LVDT4
25 LVDT5
26 LVDT6
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
3483, 70, C
3596, 457, C
3716, 186, V
3807, 533, P
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK

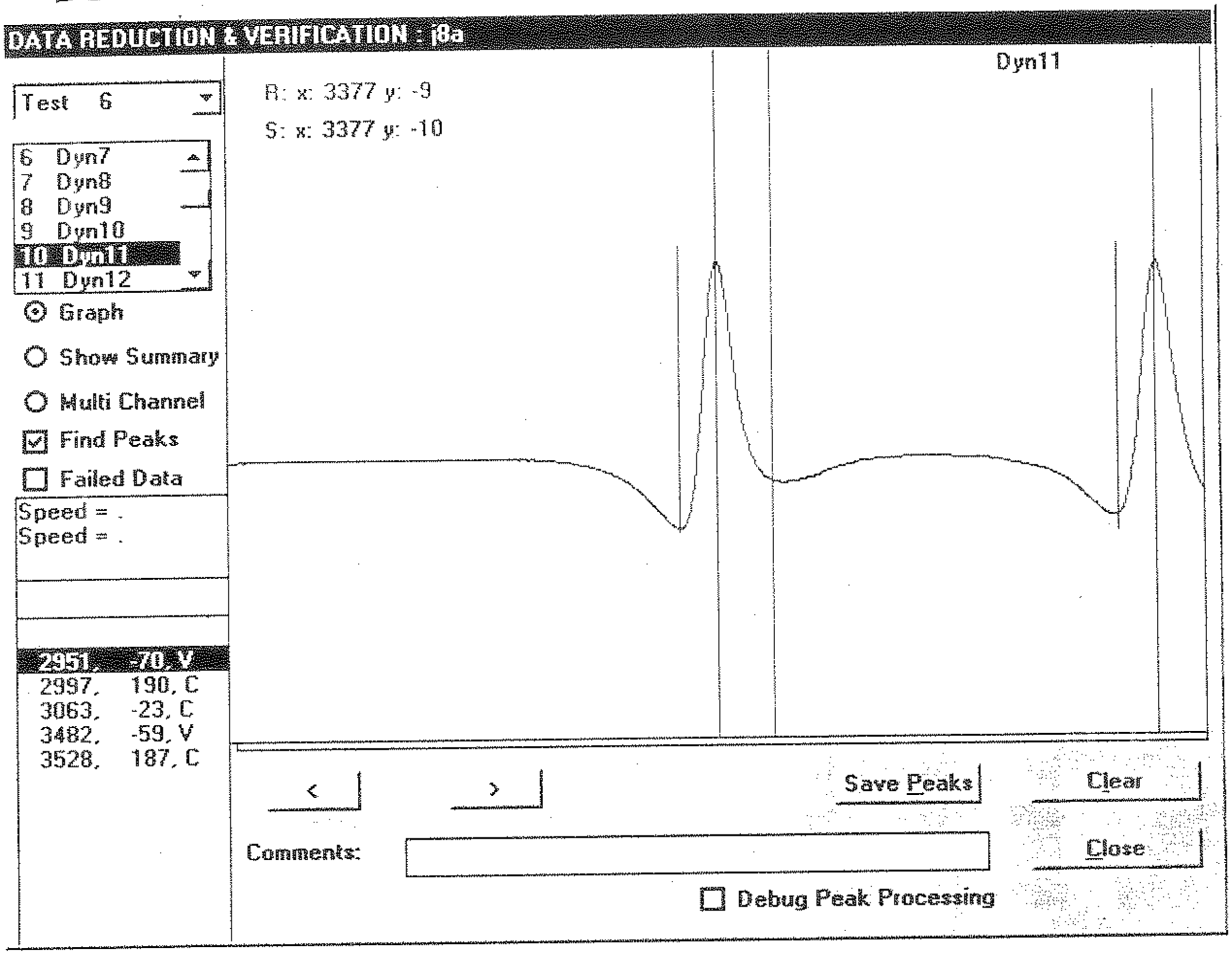

RjBa 001
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 25: LVDT4
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6
.165

j8a.001 LVDT4 Displacement (minus i.v. = 8821 um)

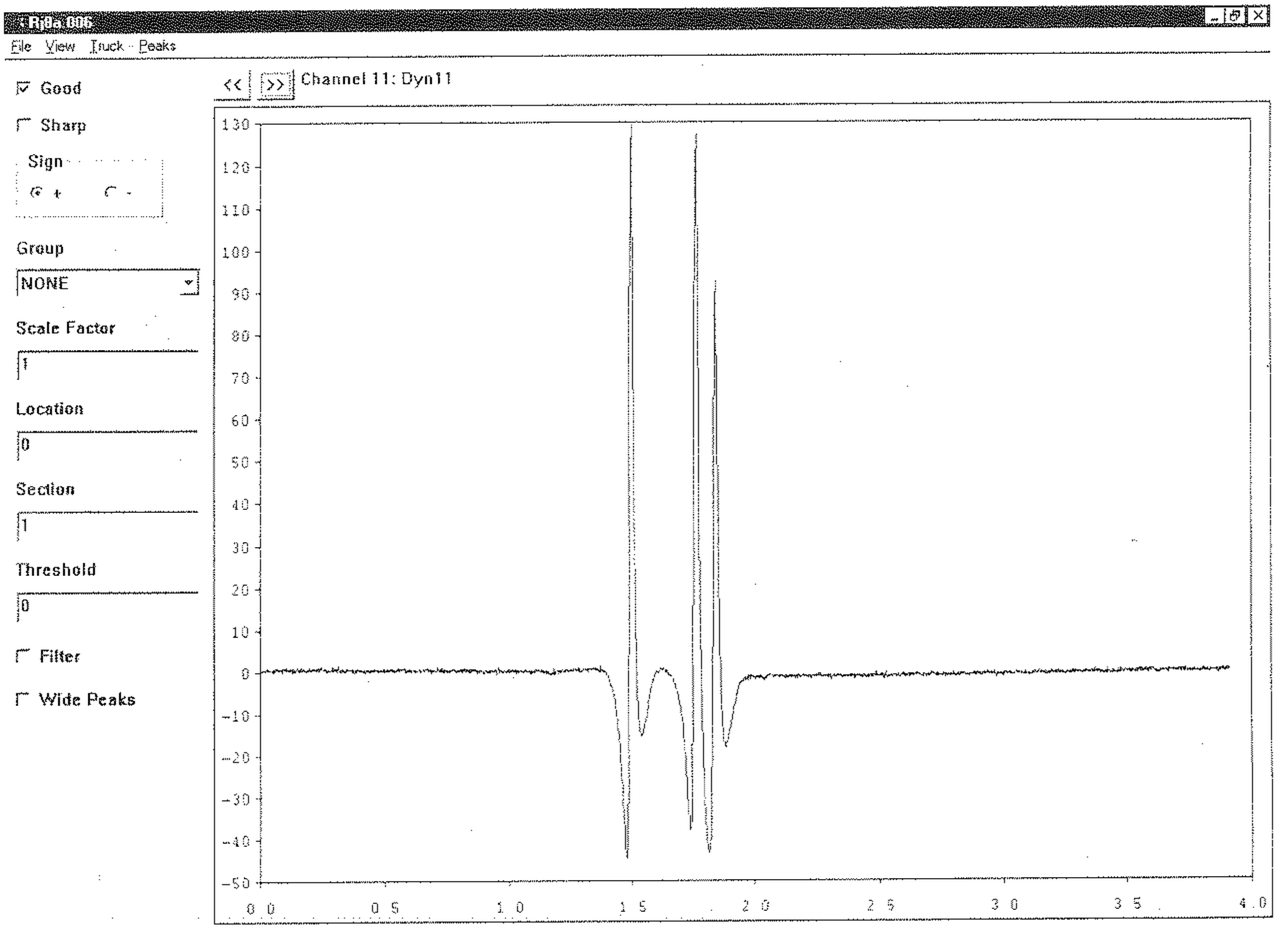


1) 2908, 168 μm
2) 3602, 174 μm
3) 3814, 203 μm

DLR ✓


DATA REDUCTION & VERIFICATION : j8a
Test 6
6 Dyn7
7 Dyn8
8 Dyn9
9 Dyn10
10 Dyn11
11 Dyn12
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
2951, -70, V
2997, 190, C
3063, -23, C
3482, -59, V
3528, 187, C
R: x: 3377 y: -9
S: x: 3377 y: -10
Dyn11
<
>
Save Peaks
Clear
Close
Comments:
Debug Peak Processing

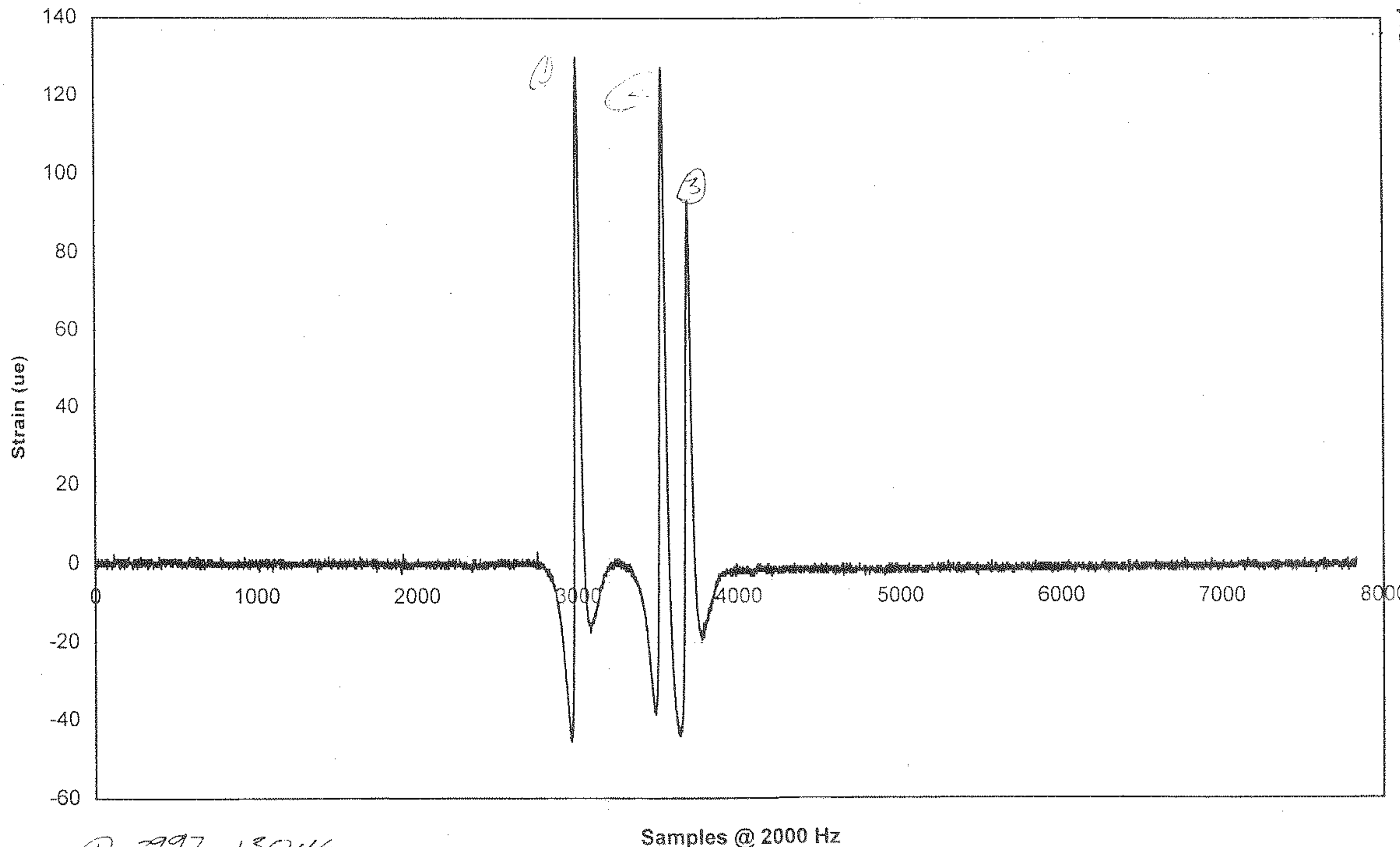
PEAK



Rj9a.006
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 11: Dyn11
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

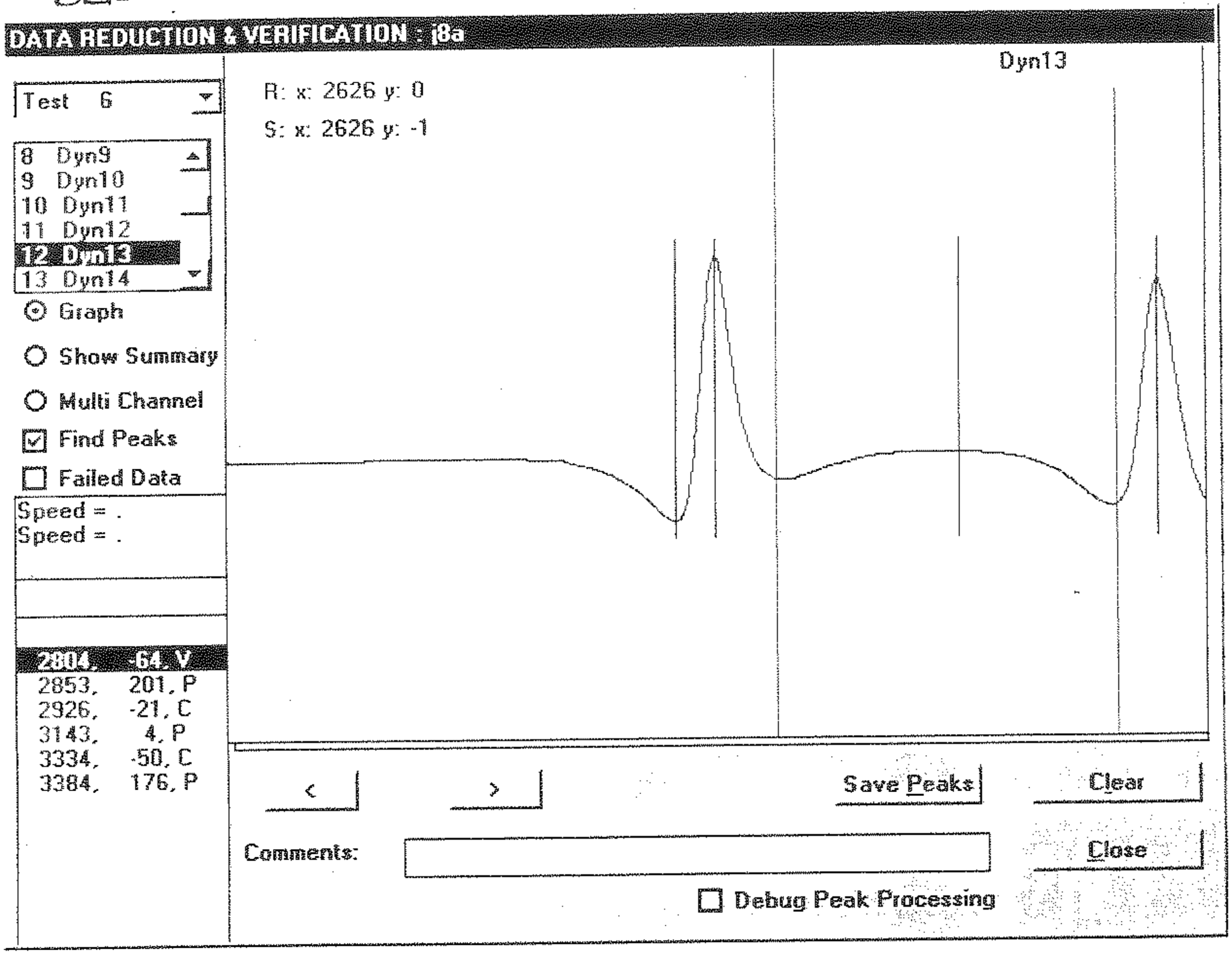
XL

j8a.006 Dyn11 Strain (minus i.v. = 0.625 ue)

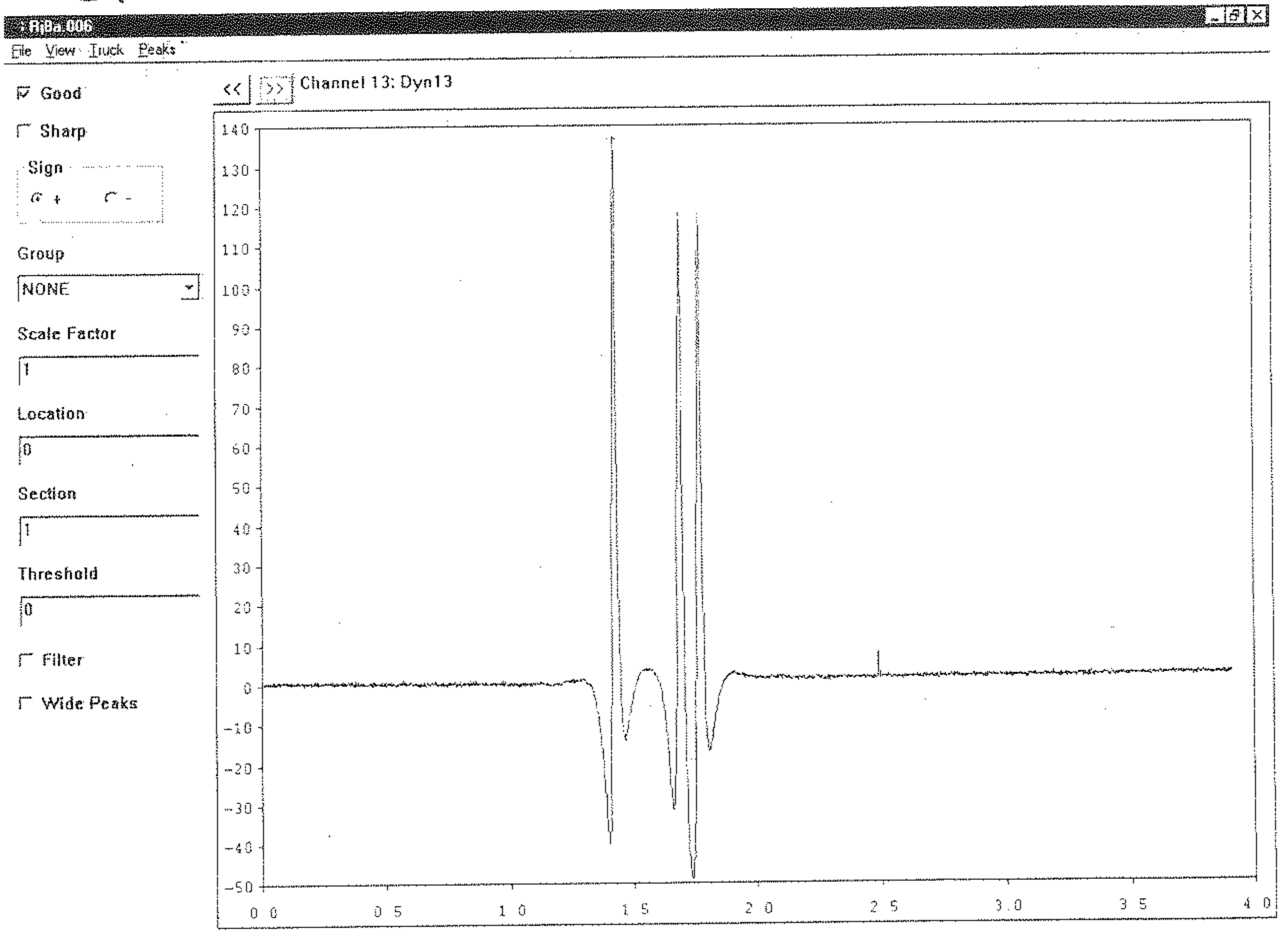


① 2997, 130 με
② 3532, 126 με
③ 3691, 92 με

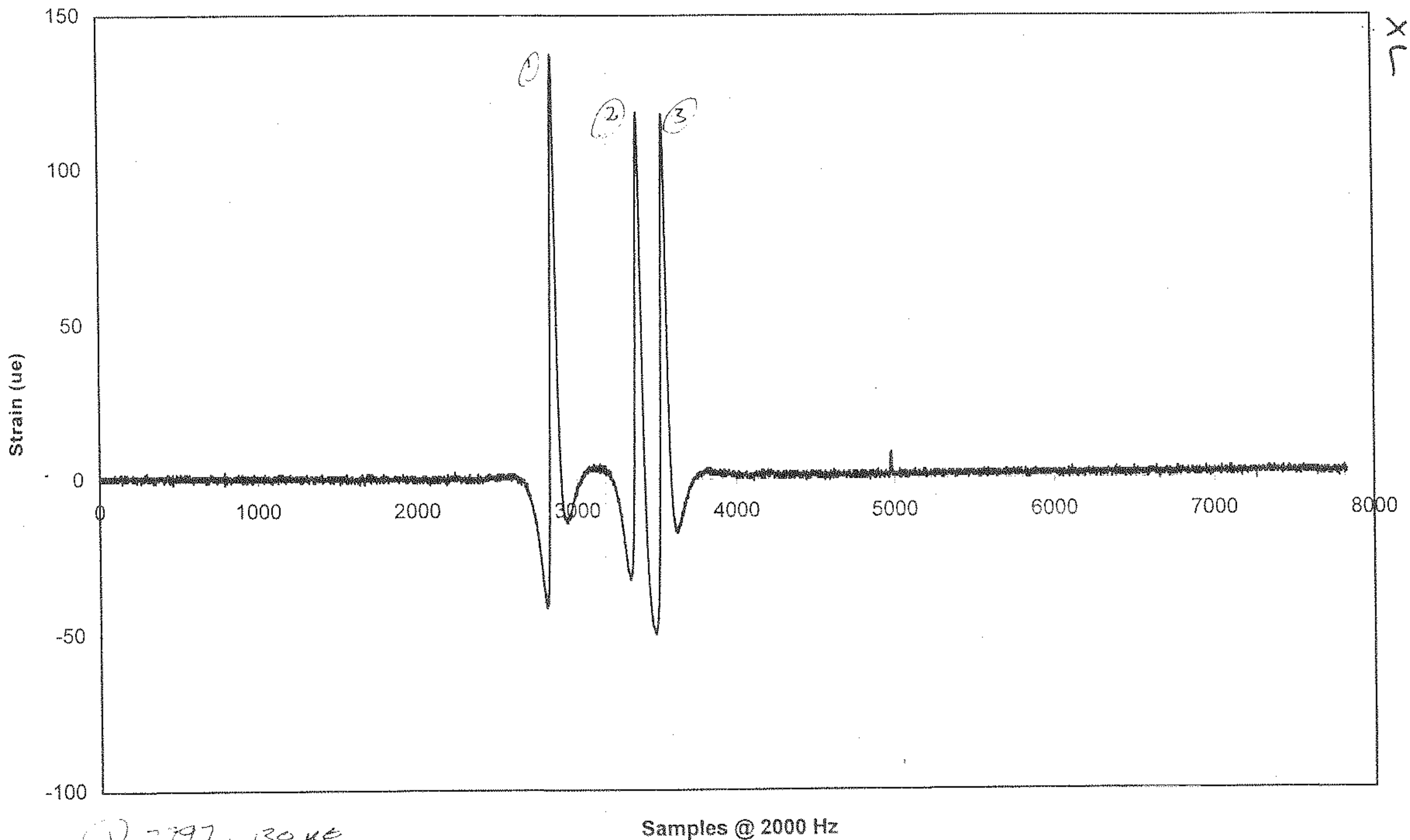
DLR


DATA REDUCTION & VERIFICATION : j8a
Test 6
8 Dyn9
9 Dyn10
10 Dyn11
11 Dyn12
12 Dyn13
13 Dyn14
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
Speed = .
Speed = .
2804, -64, V
2853, 201, P
2926, -21, C
3143, 4, P
3334, -50, C
3384, 176, P
Dyn13
R: x: 2626 y: 0
S: x: 2626 y: -1
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PENK


RjBa.006
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 13: Dyn13
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

j8a.006 Dyn13 Strain



(1) 2797, 130 με
(2) 3532, 126 με
(3) 3671, 92 με

DLR

DATA REDUCTION & VERIFICATION : i8a

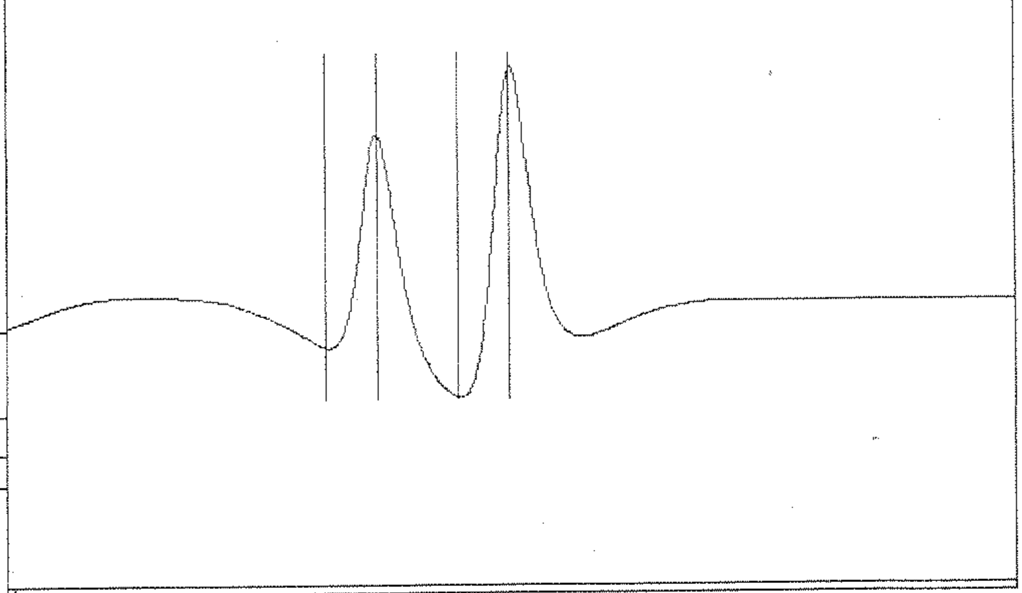
Dyn15

Test 6

R: x: 3056 y: -5

S: x: 3056 y: -4

13 Dyn14
14 Dyn15
15 Dyn16
16 Dyn17
17 Dyn18
18 Dyn19



- Graph
- Show Summary
- Multi Channel
- Find Peaks
- Failed Data

Speed = .
Speed = .

3182,	-55,	V
3243,	176,	P
3341,	-108,	V
3401,	246,	P

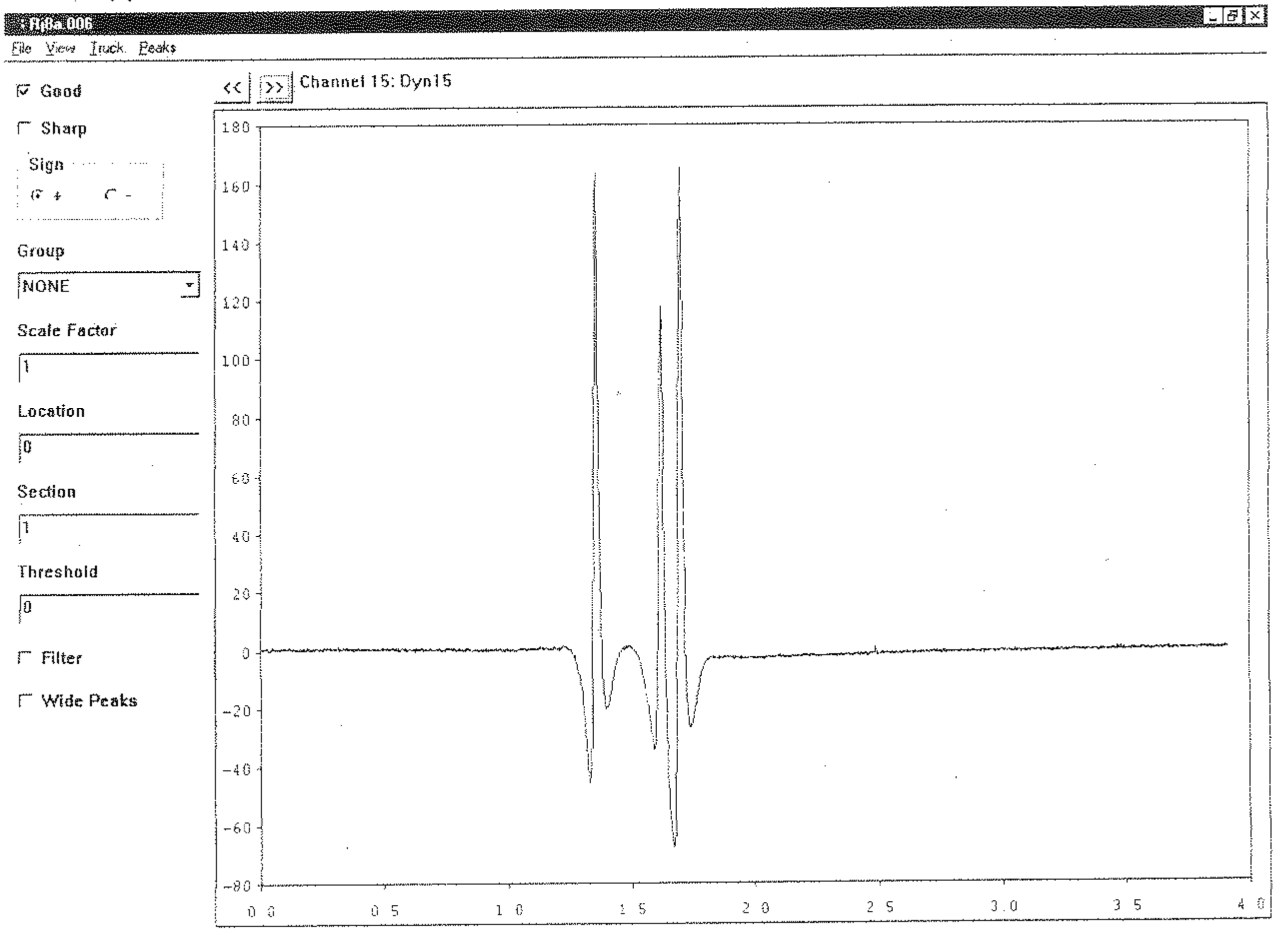
<   >   Save Peaks   Clear

Comments:

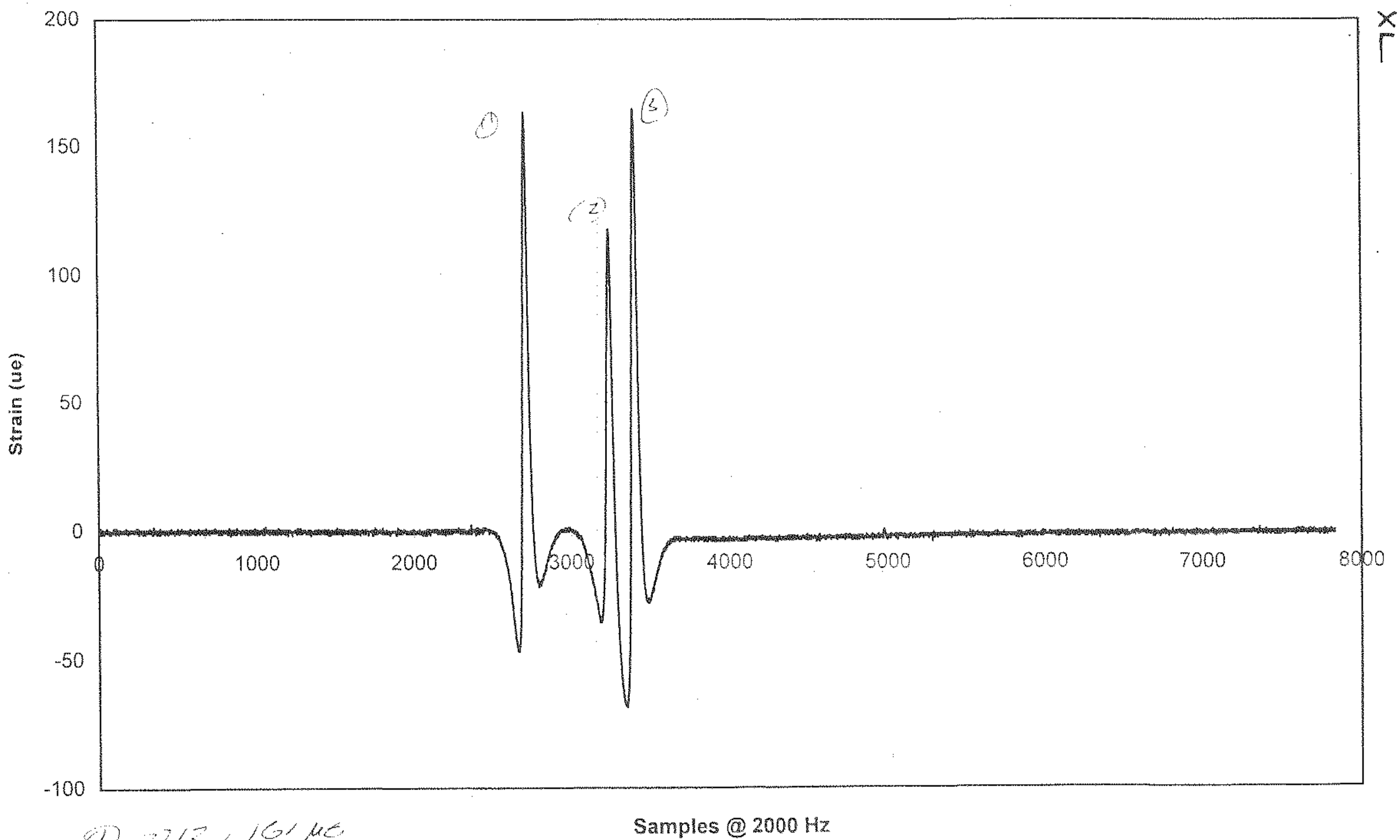
Close

Debug Peak Processing

PEAK


File View Truck Peaks
Good
Sharp
Sign
+ -
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
<< >> Channel 15: Dyn15
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

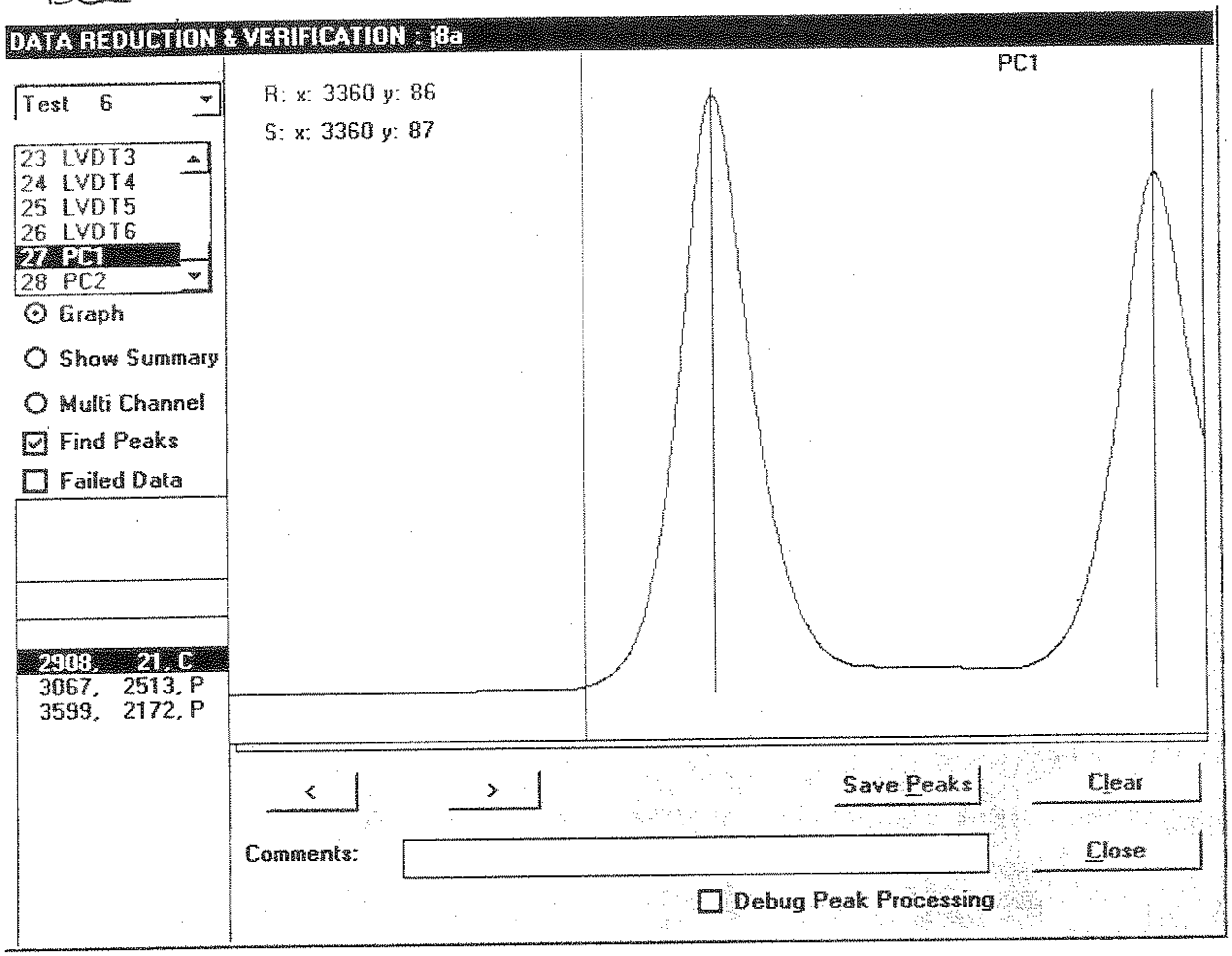
j8a.006 Dyn15 Strain



① 2713, 161 με
② 3240, 116 με
③ 3403, 164 με

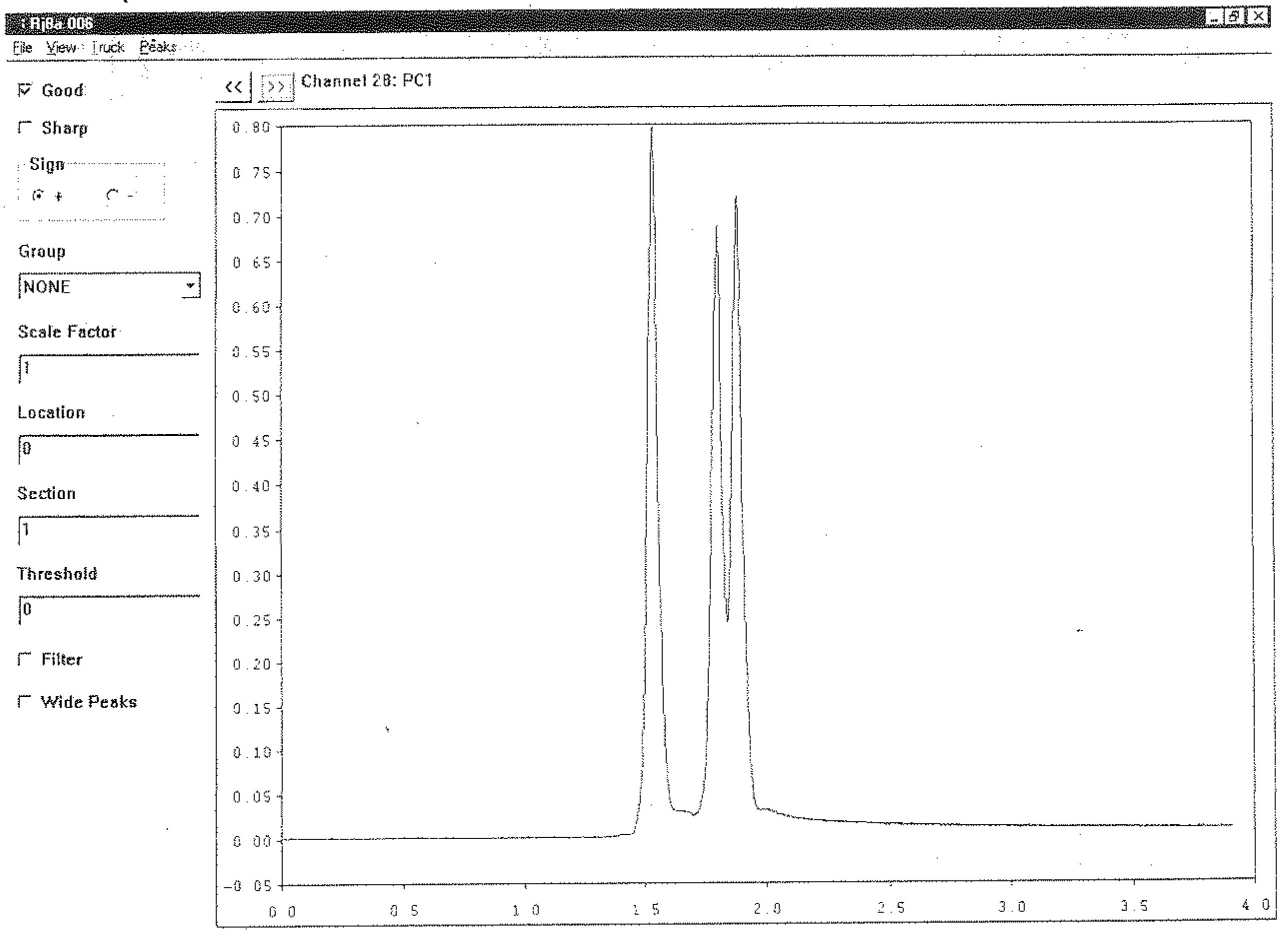
54

DLR ✓


DATA REDUCTION & VERIFICATION : j8a
Test 6
23 LVDT3
24 LVDT4
25 LVDT5
26 LVDT6
27 PC1
28 PC2
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
2908, 21, C
3067, 2513, P
3599, 2172, P
R: x: 3360 y: 86
S: x: 3360 y: 87
PC1
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

55

PEAK

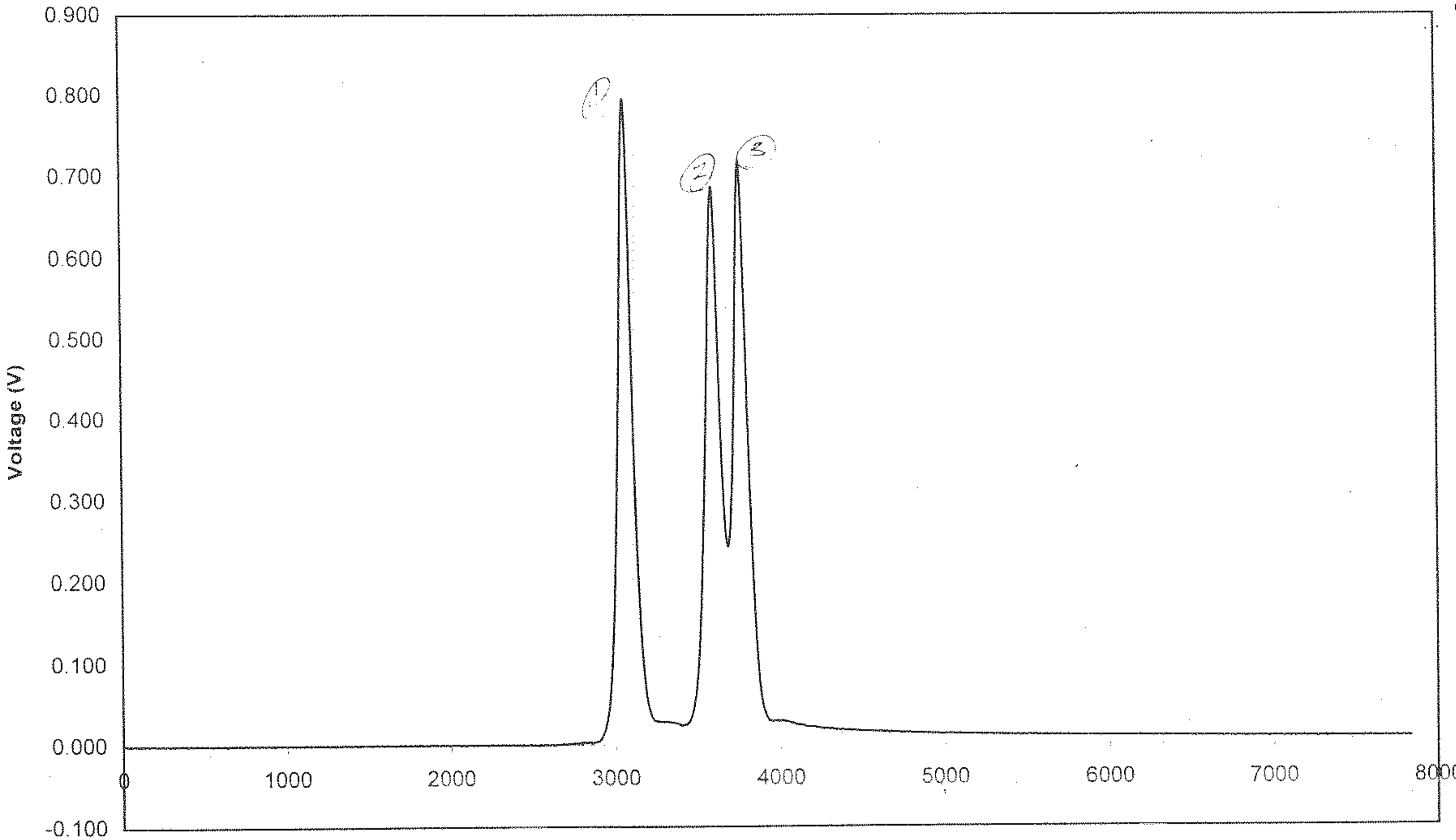


RjBa 006
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
Channel 28: PC1
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

XL

j8a.006 PC1 Voltage (minus i.v. = 0.069 V)

4.75 kPa



1 3023, 0.789 V; 54.36 kPa
2 3566, 0.680 V; 46.85 kPa
3 3769, 0.713 V; 49.17 kPa

DLR ✓

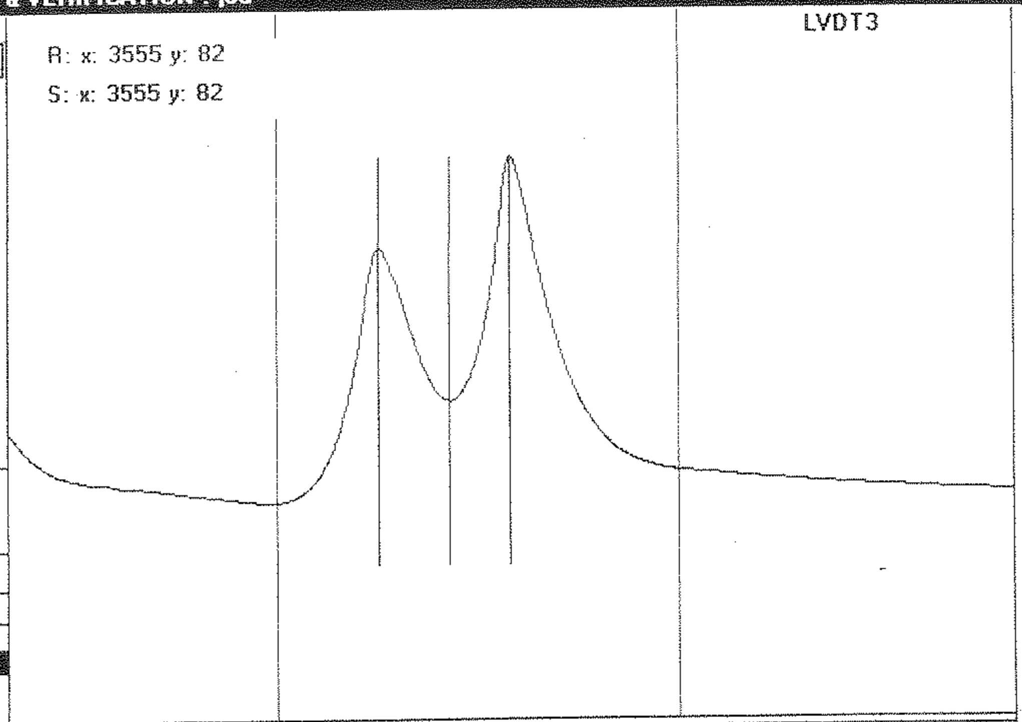
DATA REDUCTION & VERIFICATION : i8a

Test 6

18 Dyn19
19 Dyn20
20 Dyn21
21 LVDT1
22 LVDT2
23 LVDT3

Graph
Show Summary
Multi Channel
Find Peaks
Failed Data

3624,	76, C
3747,	405, P
3832,	206, V
3904,	520, P
4100,	116, C



< >

Save Peaks

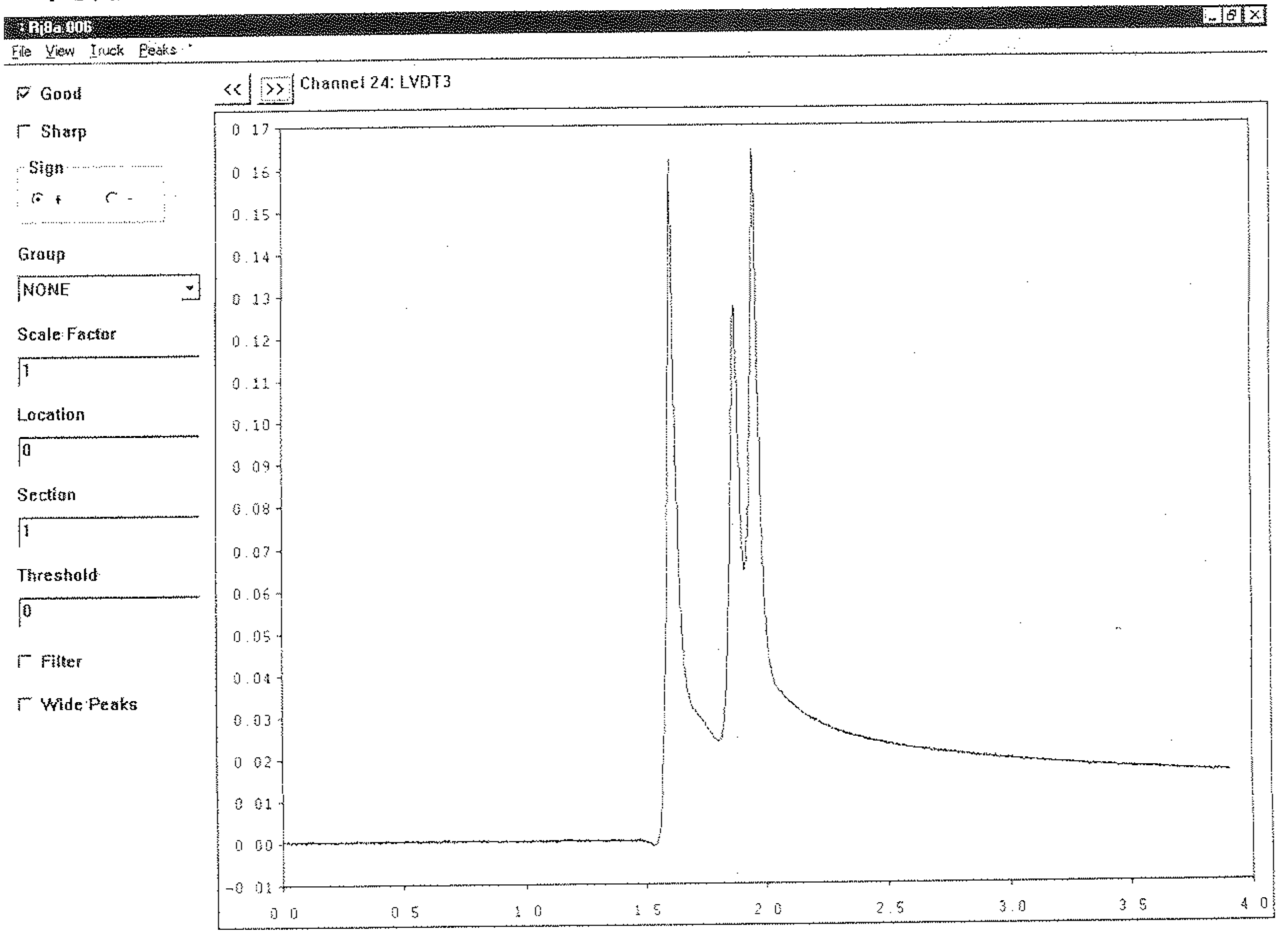
Clear

Comments:

Close

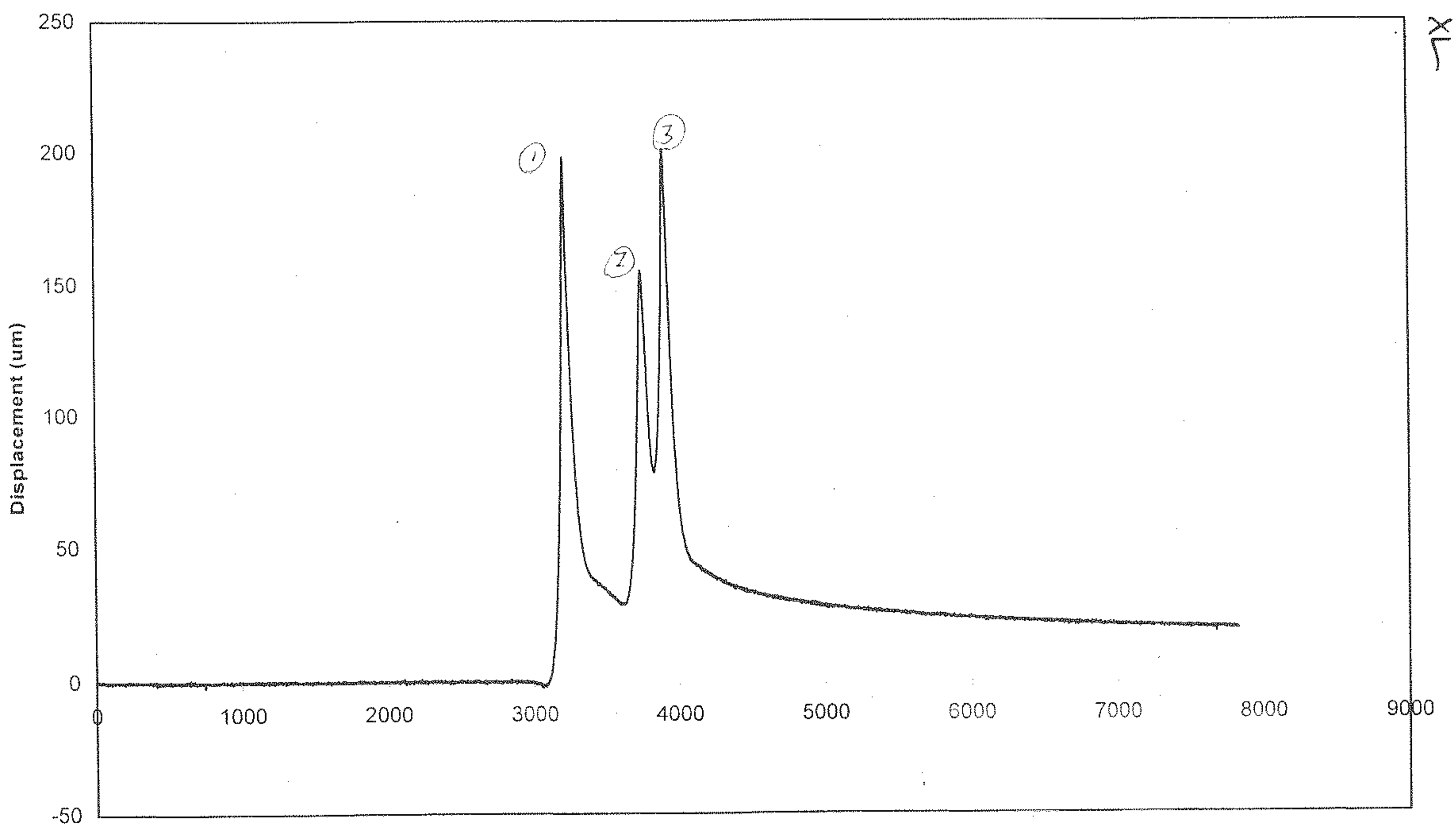
Debug Peak Processing

PEAK



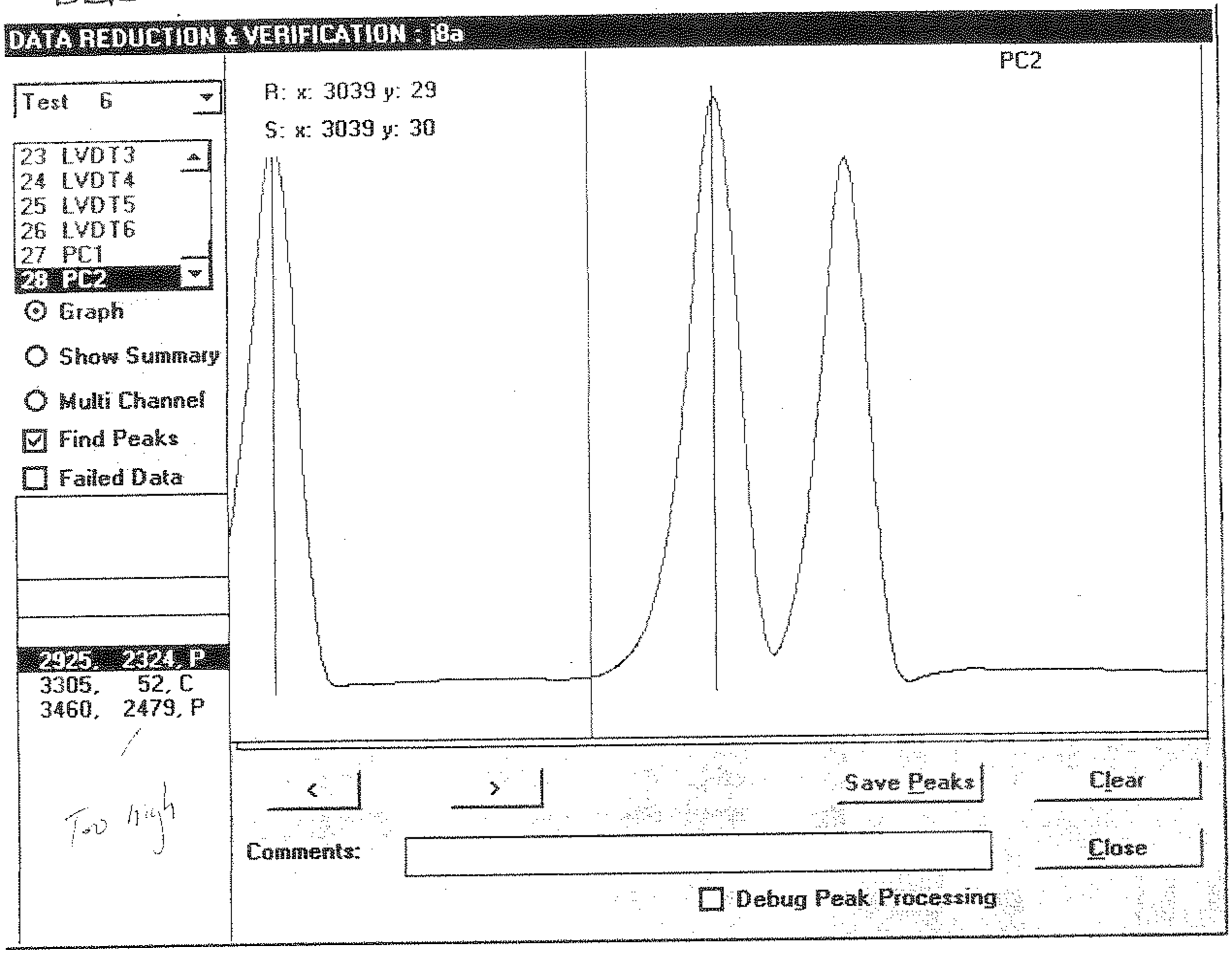
Rj8a.006
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
<<
>>
Channel 24: LVDT3
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

j8a.006 LVDT3 Displacement (minus i.v. = 2690 um)

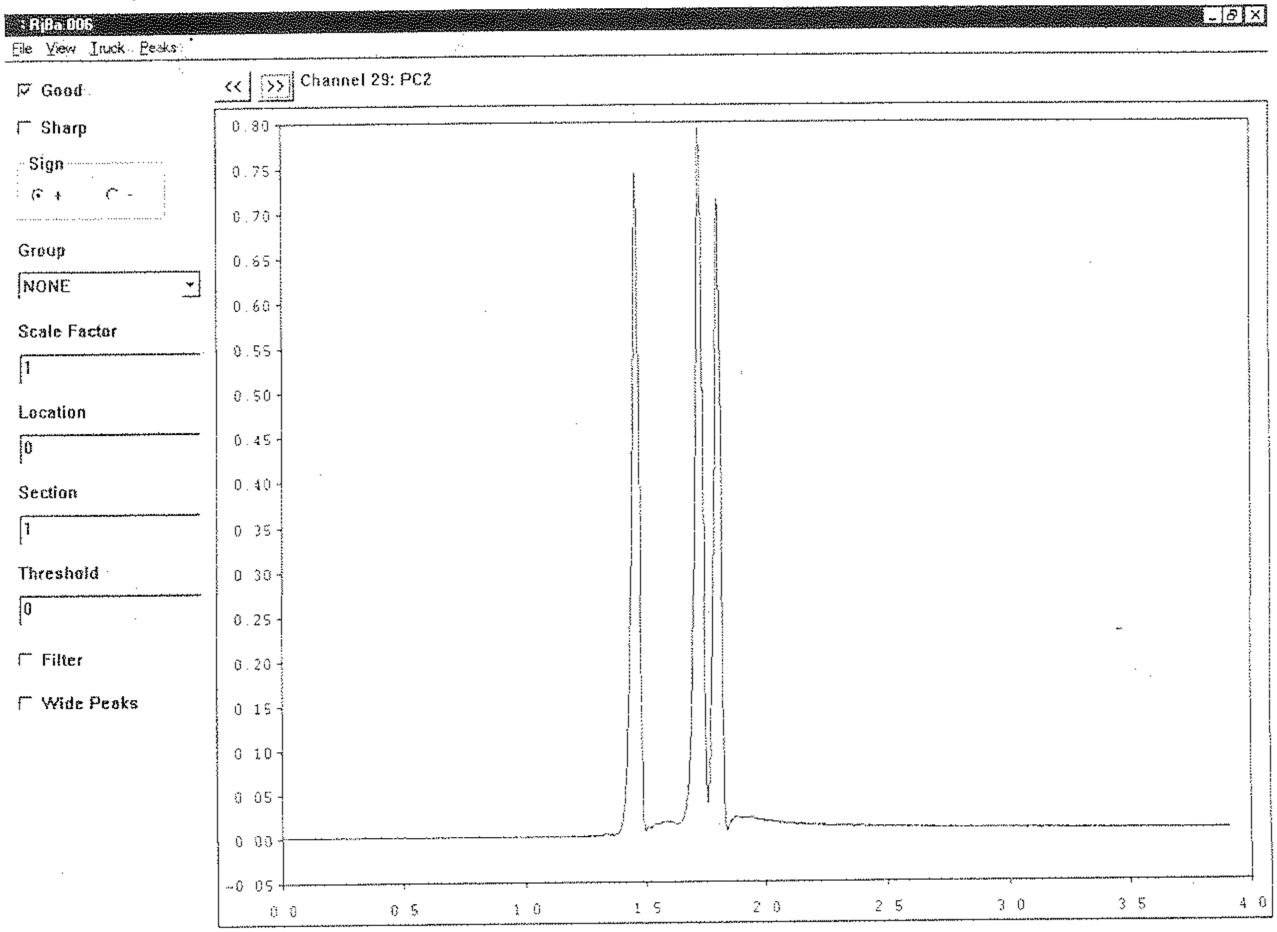


1 ~~3075~~, 3216, 197 μm
2 3754, 153 μm
3 3909, 198 μm

DLR ✓


DATA REDUCTION & VERIFICATION : j8a
Test 6
23 LVDT3
24 LVDT4
25 LVDT5
26 LVDT6
27 PC1
28 PC2
Graph
Show Summary
Multi Channel
Find Peaks
Failed Data
2925, 2324, P
3305, 52, C
3460, 2479, P
Too high
R: x: 3039 y: 29
S: x: 3039 y: 30
PC2
<
>
Save Peaks
Clear
Comments:
Close
Debug Peak Processing

PEAK

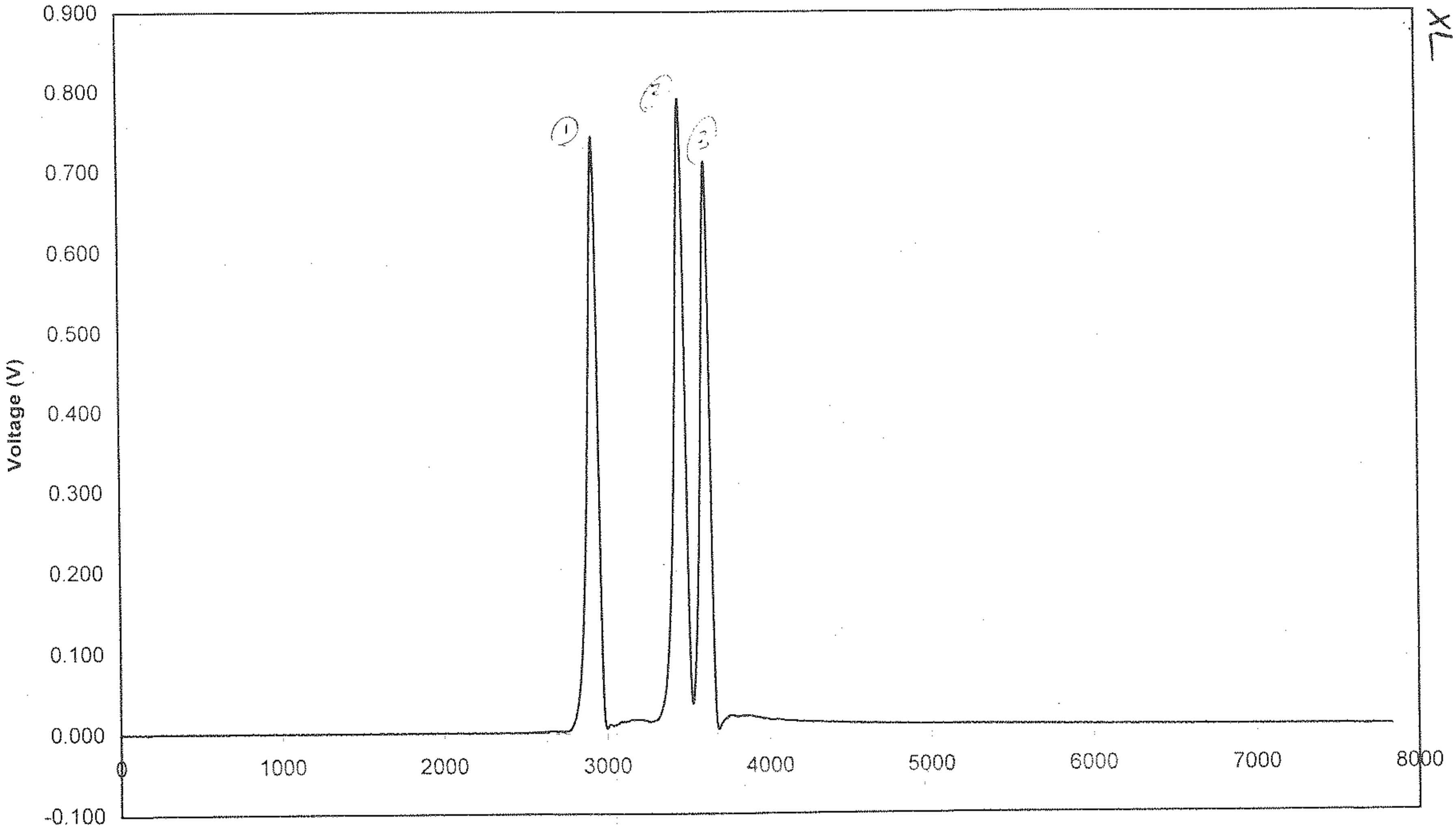

RjBa 006
File View Truck Peaks
Good
Sharp
Sign
+
-
Group
NONE
Scale Factor
1
Location
0
Section
1
Threshold
0
Filter
Wide Peaks
<<
>>
Channel 29: PC2
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

62

j8a.006 PC2 Voltage (minus i.v. = 0.071 V)

1.89 kPa

XL



(1) ~~3216~~, ~~197~~ 2930, 6.737; 51 kPa

(2) 3440, 0.785 V; 59 kPa

(3) 3571, 0.709 V; 49 kPa

APPENDIX C

Original Work Proposal

Turner-Fairbank Highway Research Center
TRUCK PAVEMENT INTERACTION GROUP

Work Proposal:
"Comparison and Quality Evaluation of LTPP DLR Data from Ohio and North Carolina"

11/15/1999

Background

The Long Term Pavement Performance (LTPP) Team at the Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center (TFHRC) has been collecting pavement performance data across the United States and Canada since 1987. This effort includes more than 2400 asphalt and portland cement concrete test sections. These test sections are monitored for material property and performance changes over time. This data is collected and managed in the LTPP IMS database, and select data from that database was released with the DataPave 2.0 software as a resource to transportation industries internationally. Before data is included in the IMS database, it is processed and analyzed for quality assurance and physical merit. Two general categories of data are collected: General Pavement Studies (GPS) and Specific Pavement Studies (SPS). The GPS studies included prebuilt roads whereas the SPS studies included only new road construction. As a part of the SPS studies, two states, Ohio and North Carolina, were selected to incorporate strain, deflection and stress instrumentation into selected SPS sections in their state, and to conduct controlled loading experiments. Raw data collected from the SPS-1 (rigid pavement sections) and SPS-2 (flexible pavement sections) have been reduced by PCS/LAW to key elements, enabling increased potential for user accessability. Raw data collected from the SPS-1 sections in NC was processed and included in DataPave 2.0. Because some of the data obtained from the OH experiments was thought to be out of the anticipated range, none of this data was included in DataPave 2.0. No further analysis of either the NC or OH data, in terms of quality, trend identification or applicability to mechanistic pavement design has been performed to date.

Objective

The main objective of this study is to determine those approaches and methodologies most appropriate for applications of measured stress, strain and deflection response obtained from in-service roads to theoretical (mechanistic) pavement analysis concepts and design processes.

Approach

Work for this study will be divided into three phases:

Phase I – Quality Assurance and Quality Control Analysis. - Identify biases, procedural or processing errors, or physical irregularities, if any, that exist in the sample DLR data. Provide a scientific explanation for findings, as well as suggestions for future experimental and/or procedural modifications to ensure improvement of data quality. Work will be initiated by reviewing all the supporting material to become familiar with all information sources and to decide what data processing software will be appropriate for TPI use.

Phase II – Statistical Analysis. – Perform correlations and regressions to provide correlation coefficients and linear/non-linear regression values to identify trends between experimental results and test variables.

Phase III – Mechanistic Analysis. - Verify that mechanistic models exist, or can be modified to predict pavement response given inputs similar to those test conditions found in the selected SPS sections.

Work Tasks

Phase I - Quality Assurance and Quality Control Analysis - TPI-selected data processing software will be used to convert binary raw data to ASCII format. Then a comparison of gage, loading, and site-specific factors will be performed to identify any obvious data input errors, which would affect processing. Once the input data match is confirmed, initial processing will be performed by TPI and then compared to that data processed by PCS/LAW. If differences in results are identified at this point, focus will be applied to differences between processing software algorithms. If results match at this point, a further investigation of the OH test setup and instrumentation will be implemented to ensure that proper experimental data was supplied to PCS/LAW. Specific gages may have to be tested to confirm operational integrity, or perhaps a miscommunication in data transfer occurred and can be rectified. TPI will require a package of available material from PCS/LAW including:

- information on experimental design;
- test section physical and environmental description data;
- data collection instrumentation, software and supporting literature;
- data processing software and its supporting literature;
- representative set of "suspicious" and "good" data with file naming conventions. The representative data set should included the data in its raw and processed form.
- additional raw data if needed for Phases II and III.
- all processed data from NC and OH
- all software used to process the raw data in a form suitable for input to DataPave 2.0

Task A. Familiarization of LTPP Data Collection and Processing

A.1. Review supporting literary material:
"Pavement Instrumentation/Load-Response/DLR IMS Issues";
"Development of an Instrumentation Plan for the Ohio SPS Test Pavement";

"SPS-2 Seasonal and Load Response Instrumentation North Carolina D.O.T. Open house - Overview of the LTPP Program";
"Pavement Instrumentation Program for SPS-2 Experiments - Instrumentation Details";
"Technical Manual for the MEGADAC SERIES 3100";
"Climatic Data for SPS Test Sites"
"Minnesota Road Research Project: Load Response Instrumentation and Testing Procedures"

A.2. Review DLRCheck software and supporting literature.

A.3. Choose appropriate software for TPI data processing.

Task B. Data Examination and Processing

B.1. Examine each of the data files provided in their as-received form to identify any discrepancies, trends or physical irregularities.

B.2 Perform detailed comparison of experimental procedures between data sources to identify biases or errors due to data acquisition/instrumentation processing software input data influences. i.e. gage calibration factors and spatial placement. loading data, etc.

B.3 Process sample data sets using DLRCheck and TPI-selected software.
B.4. Compare processed data to identify any biases or errors introduced by processing.

Task C. Identify problem areas and seek solutions to fill in missing or erroneous entries to the data. This effort may require travel to NC or OH to identify specific records for gage sites, test questionable gages still in service, etc.

Task D. Prepare and submit Phase I report documenting all work performed, findings, discussions and conclusions.

Phase II - Statistical Analysis. - Correlation and regression analyses of data will be performed to determine repeatability between runs, identify dominant trends in the data, identify degree of linearity of results with respect to test variables and identify environmental and/or loading variables most influential to these trends.

Task E. Process and group data into suitable sets for correlation and regression analyses purposes. Perform auto and cross correlation analyses on processed data to determine repeatability between runs, identify the importance of each variables involved in the data.

Task F. Perform linear and non-linear multivariable regression analyses on the processed data to identify dominant trends in the data, degree of linearity of results with respect to test variables and environmental and/or loading variables most influential to these trends.

Task G. Prepare and submit Phase II report documenting all work performed, findings, discussions and conclusions.

Phase III – Mechanistic Analysis. - Two readily available mechanistic model sets will be selected: one for rigid pavements and the other for flexible pavements. These models will be employed using input data, which identifies as close as possible with the climatic, loading, geometric and material properties associated with the selected SPS test sections. Simulation results obtained by the models will be compared to experimental results. Model validity will be assessed based on model and experiment results comparison. If in the event the models do not demonstrate sensitivity to influential variables identified in Phase II, adjustments to the model may be implemented.

Task H. Select mechanistic models for rigid pavements and flexible pavements. The selection criteria will be model mechanistic basis, validity, reliability and availability. The mechanistic models developed at TPI group will be first examined. Test selected models using input data, which identifies as close as possible with the climatic, loading, geometric and material properties associated with the selected SPS test sections. Simulation results obtained by the models will be compared to experimental results.

Task I. Validate selected models based on simulation results and filed data comparison. If discrepancy exists, the model parameters will be calibrated using typical field measurement and more simulations will be performed to further validate the models. If in the event the models do not demonstrate sensitivity to influential variables identified in Phase II, adjustment or improvements to the model will be performed. The results from regression analyses conducted in Phase II will be used for model improvement.

Task J. If needed, develop software to implement the selected mechanistic models. The software will be a user-friendly, windows based computer program.

Task K. Prepare and submit Phase III progress report that documents all work performed, findings, discussions, conclusions and suggestions for the DLR study overall.

At the end of each Phase, an interim report outlining procedure of the investigation and findings for that Phase, will be submitted.

ESTIMATED COST:

Labor Costs - One (1) research engineer and one (1) mechanical engineer, and possibly input from OH and/or NC personnel, are needed to complete the work. A computer programmer may be needed if computer software to be developed

Phase I - Quality Assurance and Quality Control Analysis (staff labor hours)

Task A.	**40**	
Task B.	**220**	
Task C.	**220**	
Task D.	**70**	
Subtotal	**550 @$90/hr. =**	**$49,500**

Phase II - Statistical Analysis (staff labor hours)

Task E.	**150**	
Task F.	**150**	
Task G.	**100**	
Subtotal	**400 @$90/hr. =**	**$36,000**

Phase III – Mechanistic Analysis (staff labor hours)

Task H.	**40**	
Task I.	**160**	
Task J.	**240**	
Task K.	**100**	
Subtotal	**540 @$90/hr. =**	**$48,600**

Total Staff Labor	**1455 @$90/hr. =**	**$134,100**

Other Costs

Outside Consultant Support hours	**150 @$65/hr. =**	**$9,750**
Equipment		**$2500**
Travel		**$5000**
TOTAL COST:		**$151,350**

APPENDIX D

"LTPP Data Analysis/Operations Feedback Report"

LTPP Data Analysis/Operations Feedback Report: Objective and Instructions

LTPP has made every effort to insure that quality data is provided to users. However, it is not possible to review every item of data or perform every comparative evaluation between items. As a result, users may encounter instances where data does not conform to expectations and an apparent systematic problem exists. LTPP encourages users to report such instances for further investigation when they are unable to satisfactorily explain them for themselves.

In order to facilitate reporting data which suggest or demonstrate the need for corrective actions or further investigation of the data, and/ or data collection and processing procedures, LTPP has developed the Long Term Pavement Performance Data Analysis/Operations Feedback Report. This form is applicable(but is not limited) to the following circumstances:

- the absence of critical data for specific test sections;
- data which appear to be incorrect, contradictory, or otherwise suspect;
- data which are not currently collected but which are needed to fill voids identified in the analysis;
- recommendations arising from the analysis as to how data collection procedures might be improved.

Instructions for completion of the report are as follows.

Report No.: A unique, sequential number is to be entered, by the originator of the feedback report, in the block labeled **Report No.**. The number is to consist of a 3-8 character identifier for the source of the report, followed by an Arabic numeral (e.g., XYZ-1, XYZ-2, etc.). The character identifiers may be derived from company names, or the names of individuals.

Submitted by: Enter the name of the individual submitting the report along with a phone number or e-mail address.

Subject: Enter a BRIEF (1-line), but meaningful synopsis of the feedback topic.

Situation: Describe, as fully as possible, the data or situation in question. Attach additional pages as necessary. Where insufficient information is provided to describe the issue, the submittal will be returned for further clarification before any action is taken.

Recommended Action: Clearly outline the specific action(s) you believe necessary to resolve the situation identified. Attach additional pages as necessary.

The completed form should be sent to the FHWA LTPP Team at the address or facsimile number listed on the Feedback Report. An electronic copy of the form (provided in WordPerfect) can be sent to ltppinfo@fhwa.dot.gov. Otherwise, the .pdf file can be printed and the hard copy returned to the address or facsimile number on the Feedback Report. The LTPP Team will keep the user informed of any action taken on the report and/or its resolution.

TO: **Long Term Pavement Performance Program**
HRDI-13
6300 Georgetown Pike
McLean, VA 22101-2296
Facsimile: (202) 493-3161
Email: *LTPPINFO@fhwa.dot.gov*

LTPP Data Analysis/Operations Feedback Report	**Report No.: EJW-1** **Date: 8/14/2000**

Submitted by: Eric Weaver

Subject: Problems encountered with IMS database entries while accessing them through DataPave 2.0

Situation: (1.) Improper values for axle loads: values need to be multiplied by 4.45^2 to get kN. (2.) Improper units for time: units are milliseconds, rather than microseconds as indicated. (3.) Some dates do not match, even for data entries within the same run. (4.) Truck geometry tables are not available: software indicates an error. "Error: 3061 Too few parameters. Expected 1."
(5.) Pavement temperature is not available at all, and air temperature is not available for all runs.

Recommended Action: (1.) Correct conversion factor applied to arrive at SI units. (2.) Change the unit label to milliseconds (ms). (3.) Ensure that dates supplied with database input files match, and if not, verify proper date with data supplier. (4.) Bring to attention of software developer. (5.) Add pavement (or air) temperature to DLR tables and provide and air-pavement temperature conversion factor.

Distribution			**Urgency** (check one) Resolution needed by: ❑ ______________ (Date) ❑ Next upload of affected data
Referred to:	**Assigned to:**	**Information Copies to:**	
			Comments

Action to be taken: As recommended______ As outlined below	**Date assigned:**
	Date due:

Findings/Actions Taken	
	Date completed:

Attach additional pages as necessary to describe situation, recommended action, and actions taken.

APPENDIX E

VESYS and JSLAB Output

CH [illegible] LTPP 39..22

DATE: 8/12/1993

TIME: 3 : 34 pm

AXLE LOAD: 32 Kip

AXLE: TANDEM

SPEED: 30 mph

WHEEL PATH OFFSET: 8"

REAR AXLE WIDTH = 5.94'

AXLE 2 WHEELBASE: 19.9'

AXLE 3 WHEELBASE: 19.4'

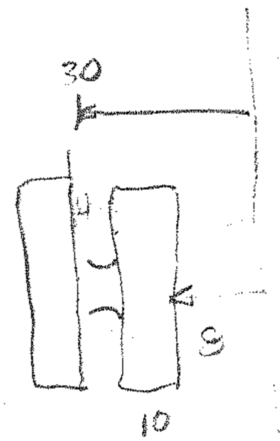
TIRE TYPE: 10.00R22

TIRE PRESSURE: 105 psi

MEAN HOURLY AIR TEMPERATURE: 72.32°F

σ_{ft} = 700psi Flexural Strength

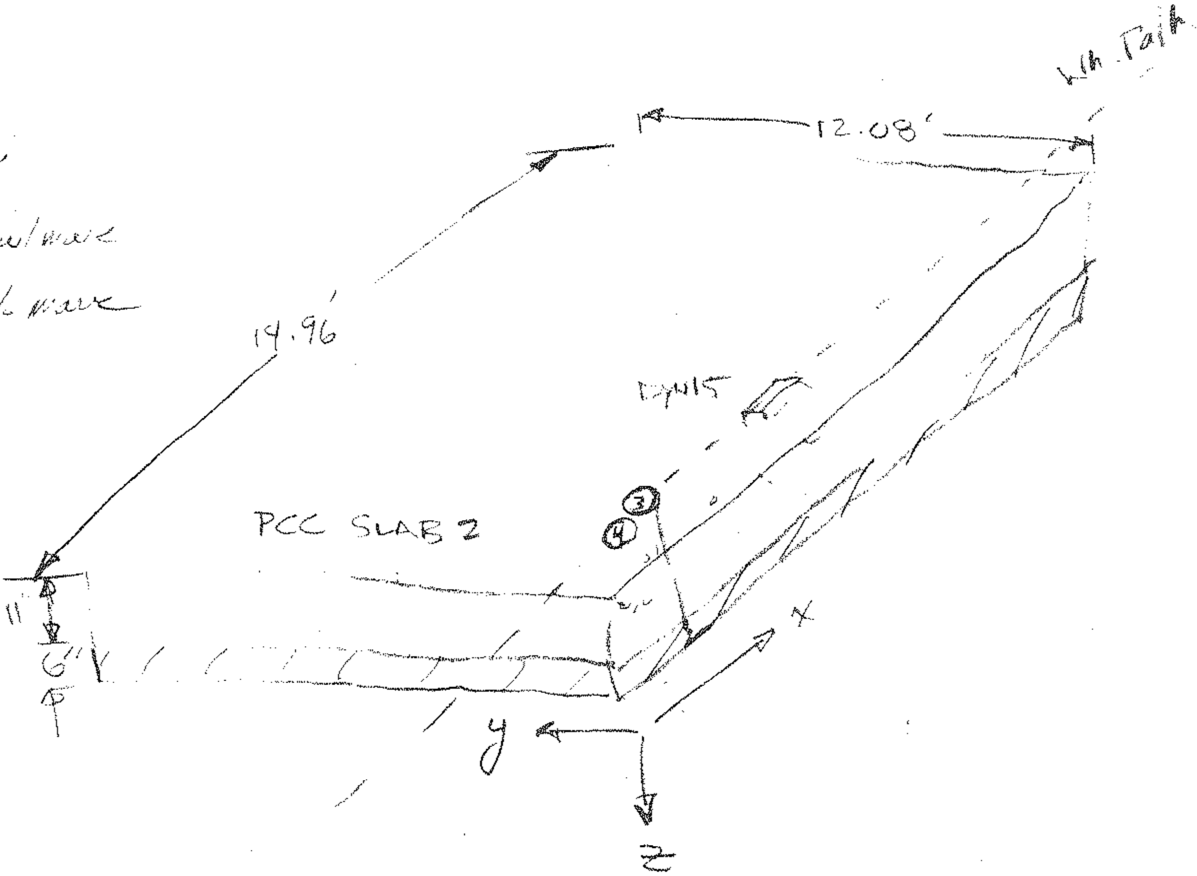
LOCATION	X	Y	Z
STRAIN	60"	30"	0"
LVDT 3	30"	30"	17"
LVDT 4	42"	30"	144"

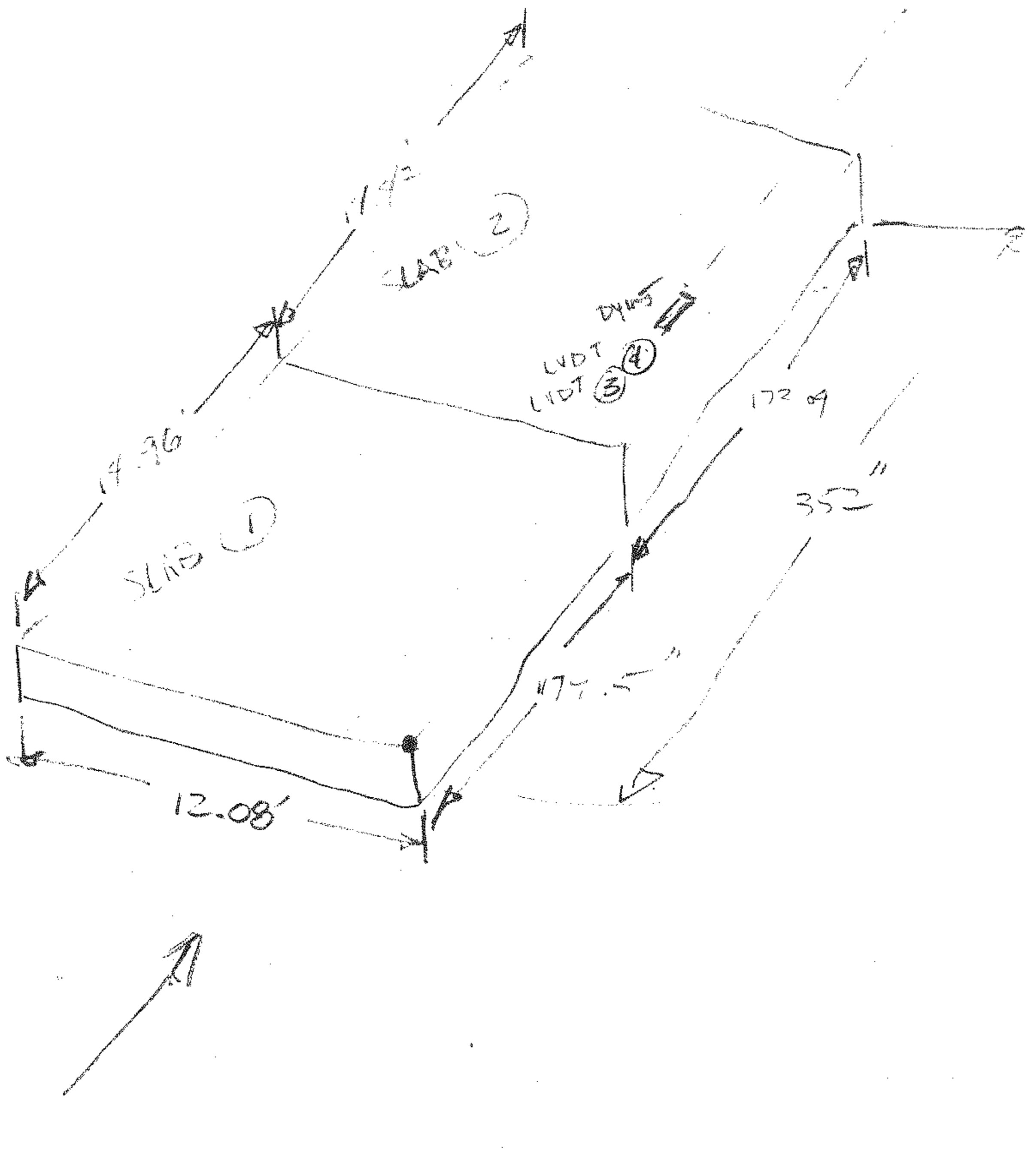


LVDT4: 0.0074"

DYN5 = 11.82 w/mark

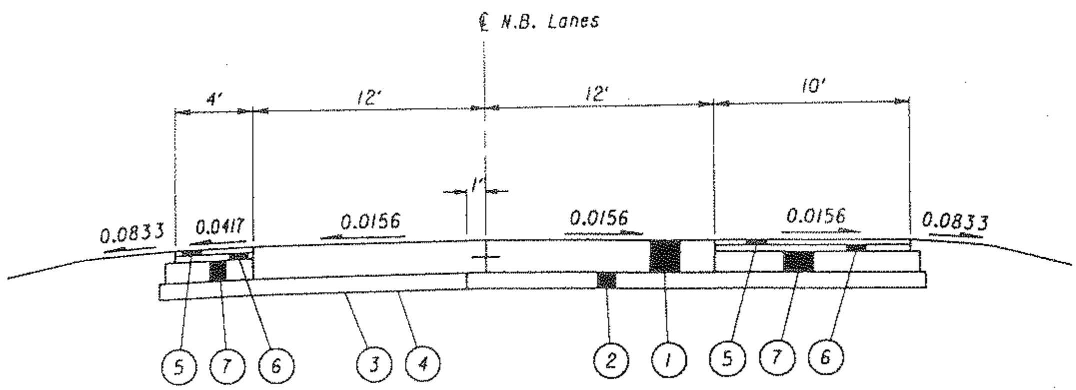
= 14.72 w/o mark




SLAB 2
SLAB 1
14.96'
12.08'
LVDT 4
LVDT 3
172.09
352"
174.5"

SPS-2

SHRP J1
SHRP J5
SHRP J8



LEGEND

1. 8" Plain Concrete Pavement (J1 and J5)
   f_t = 550 psi
   11" Plain Concrete Pavement (J8)
   f_t = 900 psi
2. 6" Lean Concrete Base (J5 and J8)
   6" Aggregate Base (J1)
3. Subgrade Compaction
4. Proof Rolling
5. 1¼" Asphalt Concrete Surface Course
6. 1¾" Asphalt Concrete Intermediate Course
7. 5" Bituminous Aggregate Base (J1 and J5)
   8" Bituminous Aggregate Base (J8)

[illegible] OUTPUT CALCULATIONS FOR CH [illegible]80.002

1) @ x = 60": y = [illegible]

$\delta_v = 0.01532$ $\sigma_x =$ [illegible] psi

$\sigma_y =$ [illegible] psi

$\epsilon_x = (\sigma_x - \nu\sigma_z)/E$

$= [80 - (0.2)(51)] / 0.332 \times 10^7 = 18.27\,\mu\epsilon$

2) @ x = 30", y = 30"

$\delta_v = 0.020541$

$\sigma_x = 85.511$ psi , $\sigma_y = 51.372$ psi

$\epsilon_x = [85 - 0.2(51)] / 0.332 \times 10^7 = 19.16\,\mu\epsilon$

$\Big\}\ 18.72\,\mu\epsilon$

$\bar{\delta}_v = 0.0179$

$E\epsilon_y + \nu(\sigma_x + \sigma_y) = \sigma_z$

$0.332 \times 10^7 ($ [illegible] $) + 0.2(\sigma_x + \sigma_y) = \sigma_{z_1}$

Run 3: Tandem, D tire, 2-layer, spring sub, 42 kips edge, Load at x=60"

ILLISLAB OUTPUT FOR
CH J8a.002

TOTAL MEMORY SPACES FOR THE FINITE ELEMENT MESH= 74837
(SHOULD BE LESS THAN 900000)

NO. OF NODES IN SLABS ALONG X-AXIS = 17 0 0 0 0 0 0 0 0 0

NO. OF NODES IN SLABS ALONG Y-AXIS = 13 0 0 0 0 0 0 0 0 0

X-COORDINATES ARE:

0.000	12.000	24.000	30.000	36.000	42.000	48.000	54.000	60.000	66.000
78.000	90.000	114.000	138.000	180.000	222.000	264.000			

Y-COORDINATES ARE:

0.000	12.000	24.000	30.000	36.000	42.000	54.000	66.000	78.000	90.000
108.000	126.000	144.000							

COORDINATES OF EACH NODE:

NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y
1	0	0	2	0	12	3	0	24	4	0	30	5	0	36	6	0	42	7	0	54	8	0	66	9	0	78	10	0	90
11	0	108	12	0	126	13	0	144	14	12	0	15	12	12	16	12	24	17	12	30	18	12	36	19	12	42	20	12	54
21	12	66	22	12	78	23	12	90	24	12	108	25	12	126	26	12	144	27	24	0	28	24	12	29	24	24	30	24	30
31	24	36	32	24	42	33	24	54	34	24	66	35	24	78	36	24	90	37	24	108	38	24	126	39	24	144	40	30	0
41	30	12	42	30	24	43	30	30	44	30	36	45	30	42	46	30	54	47	30	66	48	30	78	49	30	90	50	30	108
51	30	126	52	30	144	53	36	0	54	36	12	55	36	24	56	36	30	57	36	36	58	36	42	59	36	54	60	36	66
61	36	78	62	36	90	63	36	108	64	36	126	65	36	144	66	42	0	67	42	12	68	42	24	69	42	30	70	42	36
71	42	42	72	42	54	73	42	66	74	42	78	75	42	90	76	42	108	77	42	126	78	42	144	79	48	0	80	48	12
81	48	24	82	48	30	83	48	36	84	48	42	85	48	54	86	48	66	87	48	78	88	48	90	89	48	108	90	48	126
91	48	144	92	54	0	93	54	12	94	54	24	95	54	30	96	54	36	97	54	42	98	54	54	99	54	66	100	54	78
101	54	90	102	54	108	103	54	126	104	54	144	105	60	0	106	60	12	107	60	24	108	60	30	109	60	36	110	60	42
111	60	54	112	60	66	113	60	78	114	60	90	115	60	108	116	60	126	117	60	144	118	66	0	119	66	12	120	66	24
121	66	30	122	66	36	123	66	42	124	66	54	125	66	66	126	66	78	127	66	90	128	66	108	129	66	126	130	66	144
131	78	0	132	78	12	133	78	24	134	78	30	135	78	36	136	78	42	137	78	54	138	78	66	139	78	78	140	78	90
141	78	108	142	78	126	143	78	144	144	90	0	145	90	12	146	90	24	147	90	30	148	90	36	149	90	42	150	90	54
151	90	66	152	90	78	153	90	90	154	90	108	155	90	126	156	90	144	157	114	0	158	114	12	159	114	24	160	114	30
161	114	36	162	114	42	163	114	54	164	114	66	165	114	78	166	114	90	167	114	108	168	114	126	169	114	144	170	138	0
171	138	12	172	138	24	173	138	30	174	138	36	175	138	42	176	138	54	177	138	66	178	138	78	179	138	90	180	138	108
181	138	126	182	138	144	183	180	0	184	180	12	185	180	24	186	180	30	187	180	36	188	180	42	189	180	54	190	180	66
191	180	78	192	180	90	193	180	108	194	180	126	195	180	144	196	222	0	197	222	12	198	222	24	199	222	30	200	222	36
201	222	42	202	222	54	203	222	66	204	222	78	205	222	90	206	222	108	207	222	126	208	222	144	209	264	0	210	264	12
211	264	24	212	264	30	213	264	36	214	264	42	215	264	54	216	264	66	217	264	78	218	264	90	219	264	108	220	264	126
221	264	144																											

NO. OF SLABS = 1
NO. OF LAYERS= 2
SYMMETRY INDEX = 3
COMP. ACTION = 1

PROPERTIES OF THE TOP LAYER:

POISSON RATIO OF TOP LAYER= 0.200
THICKNESS OF TOP LAYER = 11.000
MODULUS OF TOP LAYER = 0.382E+07

PROPERTIES OF THE BOTTOM LAYER :

POISSON RATIO OF BOTTOM LAYER= 0.300
THICKNESS OF BOTTOM LAYER = 6.000
MODULUS OF BOTTOM LAYER = 0.800E+06

MODULUS OF SUBGRADE REACTION = 155.000

LOADED AREAS AS SPECIFIED WITH RESPECT TO GLOBAL COORDINATE SYSTEM:

PRESSURE	X1-COOR.	X2-COOR.	Y1-COOR.	Y2-COOR.
82.031	56.000	64.000	8.000	16.000
82.031	56.000	64.000	21.000	29.000
82.031	56.000	64.000	85.000	93.000
82.031	56.000	64.000	98.000	106.000
82.031	104.000	112.000	8.000	16.000
82.031	104.000	112.000	21.000	29.000
82.031	104.000	112.000	85.000	93.000
82.031	104.000	112.000	98.000	106.000

TOTAL APPLIED LOAD IS 41999.872

SUBGRADE TYPE = 6

NODE	DEFLECTION	X-ROTATION	Y-ROTATION	SUBGRADE STRESS	SUBGRADE FORCE
1	0.013653	0.000000	0.000000	2.116	76.238
2	0.013567	0.000014	0.000000	2.103	151.517
3	0.013318	0.000027	0.000000	2.064	111.982
4	0.013139	0.000032	0.000000	2.037	73.412
5	0.012930	0.000037	0.000000	2.004	72.240
6	0.012694	0.000041	0.000000	1.968	105.731
7	0.012158	0.000048	0.000000	1.884	135.811
8	0.011555	0.000053	0.000000	1.791	129.082
9	0.010892	0.000058	0.000000	1.688	121.676
10	0.010162	0.000064	0.000000	1.575	140.260
90	0.008713	0.000090	0.000033	1.351	145.839
91	0.007112	0.000088	0.000030	1.102	63.519
92	0.015937	0.000000	0.000046	2.470	88.816
93	0.015820	0.000021	0.000047	2.452	176.284
94	0.015432	0.000043	0.000044	2.392	129.673
95	0.015145	0.000052	0.000041	2.347	84.468
96	0.014818	0.000056	0.000038	2.297	82.657
97	0.014475	0.000058	0.000035	2.244	120.259
98	0.013790	0.000056	0.000032	2.137	153.894
99	0.013144	0.000052	0.000031	2.037	146.679
100	0.012528	0.000052	0.000033	1.942	139.746
101	0.011863	0.000062	0.000037	1.839	163.539
102	0.010518	0.000086	0.000034	1.630	175.687
103	0.008895	0.000091	0.000028	1.379	148.909
104	0.007284	0.000086	0.000027	1.129	64.960
105	0.016170	0.000000	0.000031	2.506	90.116
106	0.016056	0.000021	0.000030	2.489	178.873
107	0.015654	0.000045	0.000029	2.426	131.527
108	0.015352	0.000055	0.000027	2.380	85.615
109	0.015011	0.000059	0.000026	2.327	83.726
110	0.014656	0.000059	0.000025	2.272	121.744
111	0.013956	0.000057	0.000023	2.163	155.743
112	0.013306	0.000052	0.000022	2.062	148.481
113	0.012696	0.000050	0.000023	1.968	141.616
114	0.012045	0.000061	0.000023	1.867	166.042
115	0.010689	0.000089	0.000023	1.657	178.518
116	0.009044	0.000092	0.000022	1.402	151.409
117	0.007432	0.000087	0.000022	1.152	66.177
118	0.016308	0.000000	0.000015	2.528	136.418
119	0.016183	0.000022	0.000012	2.508	270.634
120	0.015772	0.000046	0.000011	2.445	198.918
121	0.015469	0.000054	0.000012	2.398	129.497
122	0.015127	0.000059	0.000013	2.345	126.664
123	0.014770	0.000060	0.000013	2.289	184.190
124	0.014063	0.000057	0.000012	2.180	235.629
125	0.013410	0.000052	0.000012	2.079	224.671
126	0.012798	0.000051	0.000011	1.984	214.284
127	0.012137	0.000062	0.000008	1.881	251.161

NODE	DEPTH	X-STRESS	Y-STRESS	XY-STRESS	MAJ.PRINC.STRESS	MIN.PRINC.STRESS
1	0.000	-50.234077	14.640816	0.000000	14.640816	-50.234077
	11.000	36.840641	-14.215725	0.000000	36.840641	-14.215725
	11.000	7.715317	-2.977115	0.000000	7.715317	-2.977115
	17.000	17.549461	-5.114823	0.000000	17.549461	-5.114823
2	0.000	-49.626578	13.110527	0.000000	13.110527	-49.626578
	11.000	36.292711	-13.081222	0.000000	36.292711	-13.081222
	11.000	7.600568	-2.739523	0.000000	7.600568	-2.739523
	17.000	17.337229	-4.580211	0.000000	17.337229	-4.580211
3	0.000	-47.865309	9.302559	0.000000	9.302559	-47.865309
	11.000	34.751717	-10.239241	0.000000	34.751717	-10.239241
	11.000	7.277847	-2.144344	0.000000	7.277847	-2.144344
	17.000	16.721923	-3.249883	0.000000	16.721923	-3.249883
4	0.000	-46.668156	7.003904	0.000000	7.003904	-46.668156
	11.000	33.726208	-8.513559	0.000000	33.726208	-8.513559
	11.000	7.063080	-1.782944	0.000000	7.063080	-1.782944
	17.000	16.303694	-2.446840	0.000000	16.303694	-2.446840
5	0.000	-45.462705	4.422711	0.000000	4.422711	-45.462705
	11.000	32.673414	-6.586274	0.000000	32.673414	-6.586274
	11.000	6.842600	-1.379324	0.000000	6.842600	-1.379324
	17.000	15.882565	-1.545091	0.000000	15.882565	-1.545091
6	0.000	-44.380595	1.691378	0.000000	1.691378	-44.380595
	11.000	31.696995	-4.561523	0.000000	31.696995	-4.561523
	11.000	6.638114	-0.955293	0.000000	6.638114	-0.955293
	17.000	15.504526	-0.590889	0.000000	15.504526	-0.590889
7	0.000	-42.472781	-1.932836	0.000000	-1.932836	-42.472781
	11.000	30.065666	-1.839161	0.000000	30.065666	-1.839161
	11.000	6.296475	-0.385165	0.000000	6.296475	-0.385165
	17.000	14.838024	0.675244	0.000000	14.838024	0.675244
8	0.000	-41.176014	-2.525099	0.000000	-2.525099	-41.176014
	11.000	29.098426	-1.319740	0.000000	29.098426	-1.319740
	11.000	6.093911	-0.276385	0.000000	6.093911	-0.276385
	17.000	14.384993	0.882153	0.000000	14.384993	0.882153
9	0.000	-40.370532	-0.992620	0.000000	-0.992620	-40.370532
	11.000	28.641433	-2.348877	0.000000	28.641433	-2.348877
	11.000	5.998206	-0.491911	0.000000	5.998206	-0.491911
	17.000	14.103595	0.346775	0.000000	14.103595	0.346775
10	0.000	-39.522590	0.677026	0.000000	0.677026	-39.522590
	11.000	28.164619	-3.472371	0.000000	28.164619	-3.472371
	11.000	5.898349	-0.727198	0.000000	5.898349	-0.727198
	17.000	13.807364	-0.236522	0.000000	13.807364	-0.236522
11	0.000	-37.059612	0.925320	0.000000	0.925320	-37.059612
	11.000	26.431431	-3.462608	0.000000	26.431431	-3.462608
	11.000	5.535378	-0.725154	0.000000	5.535378	-0.725154
	17.000	12.946913	-0.323264	0.000000	12.946913	-0.323264
100	0.000	41.326343	18.084301	5.483903	42.555276	16.855367
	11.000	-28.027950	-9.736525	-4.315817	-8.769358	-28.995117
	11.000	-5.869728	-2.039063	-0.903836	-1.836515	-6.072276
	17.000	-14.437512	-6.317818	-1.915822	-5.888485	-14.866844
101	0.000	56.107490	53.581257	4.197648	59.227946	50.460801
	11.000	-35.855987	-33.867849	-3.303537	-31.412058	-38.311778
	11.000	-7.509107	-7.092743	-0.691840	-6.578441	-8.023409

	17.000	-19.601360	-18.718811	-1.466464	-17.628668	-20.691503
102	0.000	46.577952	36.964594	-10.149739	53.001650	30.540896
	11.000	-30.334823	-22.769136	7.987817	-17.713703	-35.390256
	11.000	-6.352843	-4.768405	1.672841	-3.709676	-7.411572
	17.000	-16.272181	-12.913718	3.545849	-10.669576	-18.516323
103	0.000	23.850145	2.662165	-3.685851	24.473023	2.039287
	11.000	-16.763739	-0.088856	2.900755	0.401348	-17.253942
	11.000	-3.510731	-0.018609	0.607488	0.084052	-3.613391
	17.000	-8.332137	-0.930037	1.287666	-0.712433	-8.549741
104	0.000	16.867886	0.000000	0.000000	16.867886	0.000000
	11.000	-11.965727	0.000000	0.000000	0.000000	-11.965727
	11.000	-2.505911	0.000000	0.000000	0.000000	-2.505911
	17.000	-5.892859	0.000000	0.000000	0.000000	-5.892859
105	0.000	84.406647	56.330437	0.000000	84.406647	56.330437
	11.000	-55.777832	-33.681930	0.000000	-33.681930	-55.777832
	11.000	-11.681221	-7.053807	0.000000	-7.053807	-11.681221
	17.000	-29.487776	-19.679247	0.000000	-19.679247	-29.487776
106	0.000	105.930351	85.442479	-2.191757	106.162197	85.210633
	11.000	-68.885179	-52.761280	1.724907	-52.578817	-69.067642
	11.000	-14.426216	-11.049483	0.361237	-11.011271	-14.464428
	17.000	-37.007162	-29.849648	0.765698	-29.768651	-37.088158
107	0.000	98.892546	74.747343	-3.642842	99.430179	74.209710
	11.000	-64.688348	-45.686138	2.866907	-45.263022	-65.111463
	11.000	-13.547298	-9.567778	0.600399	-9.479167	-13.635908
	17.000	-34.548478	-26.113262	1.272641	-25.925438	-34.736302
108	0.000	80.114804	51.094693	-3.931142	80.637898	50.571599
	11.000	-53.121143	-30.282394	3.093798	-29.870720	-53.532816
	11.000	-11.124847	-6.341863	0.647916	-6.255648	-11.211061
	17.000	-27.988404	-17.850121	1.373359	-17.667376	-28.171149
109	0.000	60.825543	26.368491	-3.932143	61.268572	25.925462
	11.000	-41.271320	-14.153713	3.094586	-13.805050	-41.619983
	11.000	-8.643208	-2.964128	0.648081	-2.891110	-8.716227
	17.000	-21.249629	-9.211930	1.373709	-9.057156	-21.404403
110	0.000	50.382709	13.905677	-3.543611	50.723769	13.564617
	11.000	-34.786173	-6.078847	2.788813	-5.810434	-35.054586
	11.000	-7.285062	-1.273057	0.584045	-1.216845	-7.341275
	17.000	-17.601387	-4.858000	1.237974	-4.738849	-17.720537

MAXIMUM OR MINIMUM VALUES OF (COMPRESSION IS POSITIVE):

DEFLECTION = 0.016308 AT NODE 118
AND -0.003859 AT NODE 221

SUBGRADE STRESS = 2.528 AT NODE 118

RANGE OF X-STRESS AT BOTTOM OF LAYER 1: FROM -68.885 AT NODE 106 TO 36.841 AT NODE 1
RANGE OF Y-STRESS AT BOTTOM OF LAYER 1: FROM -52.761 AT NODE 106 TO 1.635 AT NODE 111
RANGE OF MINOR PRINC. STRESS BOT. LAYER 1: FROM -69.068 AT NODE 106 TO 0.000 AT NODE 0
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 1: FROM -52.579 AT NODE 106 TO 36.841 AT NODE 1
RANGE OF X-STRESS AT BOTTOM OF LAYER 2: FROM -37.007 AT NODE 106 TO 17.549 AT NODE 1
RANGE OF Y-STRESS AT BOTTOM OF LAYER 2: FROM -29.850 AT NODE 106 TO 0.882 AT NODE 8
RANGE OF MINOR PRINC. STRESS BOT. LAYER 2: FROM -37.088 AT NODE 106 TO 0.882 AT NODE 8
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 2: FROM -29.769 AT NODE 106 TO 17.549 AT NODE 1

SUM OF REACTION FORCES = 41999.87

Run 2: Tandem, D tire, 2-layer, spring sub, 42 kips Loading at x=30"

ILLISLAB OUTPUT FOR
OH J8a.002

TOTAL MEMORY SPACES FOR THE FINITE ELEMENT MESH= 74837
(SHOULD BE LESS THAN 900000)

NO. OF NODES IN SLABS ALONG X-AXIS = 17 0 0 0 0 0 0 0 0 0

NO. OF NODES IN SLABS ALONG Y-AXIS = 13 0 0 0 0 0 0 0 0 0

X-COORDINATES ARE:

0.000 12.000 24.000 30.000 36.000 42.000 48.000 54.000 60.000 66.000
78.000 90.000 114.000 138.000 180.000 222.000 264.000

Y-COORDINATES ARE:

0.000 12.000 24.000 30.000 36.000 42.000 54.000 66.000 78.000 90.000
108.000 126.000 144.000

1

COORDINATES OF EACH NODE:

NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y	NODE	X	Y
1	0	0	2	0	12	3	0	24	4	0	30	5	0	36	6	0	42	7	0	54	8	0	66	9	0	78	10	0	90
11	0	108	12	0	126	13	0	144	14	12	0	15	12	12	16	12	24	17	12	30	18	12	36	19	12	42	20	12	54
21	12	66	22	12	78	23	12	90	24	12	108	25	12	126	26	12	144	27	24	0	28	24	12	29	24	24	30	24	30
31	24	36	32	24	42	33	24	54	34	24	66	35	24	78	36	24	90	37	24	108	38	24	126	39	24	144	40	30	0
41	30	12	42	30	24	43	30	30	44	30	36	45	30	42	46	30	54	47	30	66	48	30	78	49	30	90	50	30	108
51	30	126	52	30	144	53	36	0	54	36	12	55	36	24	56	36	30	57	36	36	58	36	42	59	36	54	60	36	66
61	36	78	62	36	90	63	36	108	64	36	126	65	36	144	66	42	0	67	42	12	68	42	24	69	42	30	70	42	36
71	42	42	72	42	54	73	42	66	74	42	78	75	42	90	76	42	108	77	42	126	78	42	144	79	48	0	80	48	12
81	48	24	82	48	30	83	48	36	84	48	42	85	48	54	86	48	66	87	48	78	88	48	90	89	48	108	90	48	126
91	48	144	92	54	0	93	54	12	94	54	24	95	54	30	96	54	36	97	54	42	98	54	54	99	54	66	100	54	78
101	54	90	102	54	108	103	54	126	104	54	144	105	60	0	106	60	12	107	60	24	108	60	30	109	60	36	110	60	42
111	60	54	112	60	66	113	60	78	114	60	90	115	60	108	116	60	126	117	60	144	118	66	0	119	66	12	120	66	24
121	66	30	122	66	36	123	66	42	124	66	54	125	66	66	126	66	78	127	66	90	128	66	108	129	66	126	130	66	144
131	78	0	132	78	12	133	78	24	134	78	30	135	78	36	136	78	42	137	78	54	138	78	66	139	78	78	140	78	90
141	78	108	142	78	126	143	78	144	144	90	0	145	90	12	146	90	24	147	90	30	148	90	36	149	90	42	150	90	54
151	90	66	152	90	78	153	90	90	154	90	108	155	90	126	156	90	144	157	114	0	158	114	12	159	114	24	160	114	30
161	114	36	162	114	42	163	114	54	164	114	66	165	114	78	166	114	90	167	114	108	168	114	126	169	114	144	170	138	0
171	138	12	172	138	24	173	138	30	174	138	36	175	138	42	176	138	54	177	138	66	178	138	78	179	138	90	180	138	108
181	138	126	182	138	144	183	180	0	184	180	12	185	180	24	186	180	30	187	180	36	188	180	42	189	180	54	190	180	66
191	180	78	192	180	90	193	180	108	194	180	126	195	180	144	196	222	0	197	222	12	198	222	24	199	222	30	200	222	36
201	222	42	202	222	54	203	222	66	204	222	78	205	222	90	206	222	108	207	222	126	208	222	144	209	264	0	210	264	12
211	264	24	212	264	30	213	264	36	214	264	42	215	264	54	216	264	66	217	264	78	218	264	90	219	264	108	220	264	126
221	264	144																											

NO. OF SLABS = 1

NO. OF LAYERS= 2

SYMMETRY INDEX = 3

COMP. ACTION = 1

PROPERTIES OF THE TOP LAYER:

POISSON RATIO OF TOP LAYER= 0.200
THICKNESS OF TOP LAYER = 11.000
MODULUS OF TOP LAYER = 0.382E+07

PROPERTIES OF THE BOTTOM LAYER :
POISSON RATIO OF BOTTOM LAYER= 0.300

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THICKNESS OF BOTTOM LAYER     =     6.000
MODULUS OF BOTTOM LAYER       = 0.800E+06

MODULUS OF SUBGRADE REACTION =   155.000

LOADED AREAS AS SPECIFIED WITH RESPECT TO GLOBAL COORDINATE SYSTEM:
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PRESSURE	X1-COOR.	X2-COOR.	Y1-COOR.	Y2-COOR.
82.031	26.000	34.000	8.000	16.000
82.031	26.000	34.000	21.000	29.000
82.031	26.000	34.000	85.000	93.000
82.031	26.000	34.000	98.000	106.000
82.031	74.000	82.000	8.000	16.000
82.031	74.000	82.000	21.000	29.000
82.031	74.000	82.000	85.000	93.000
82.031	74.000	82.000	98.000	106.000

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TOTAL APPLIED LOAD IS 41999.872

SUBGRADE TYPE =     6   ********************************
                        *                              *
                        * I T E R A T I O N   N O.  1  *
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NODE	DEFLECTION	X-ROTATION	Y-ROTATION	SUBGRADE STRESS	SUBGRADE FORCE
1	0.022050	0.000000	0.000000	3.418	122.878
2	0.021884	0.000027	0.000000	3.392	243.923
3	0.021410	0.000051	0.000000	3.319	179.802
4	0.021078	0.000060	0.000000	3.267	117.553
5	0.020699	0.000066	0.000000	3.208	115.437
6	0.020289	0.000070	0.000000	3.145	168.641
7	0.019425	0.000073	0.000000	3.011	216.647
8	0.018554	0.000072	0.000000	2.876	206.941
9	0.017672	0.000076	0.000000	2.739	197.071
39	0.010865	0.000106	-0.000024	1.684	144.142
40	0.021545	0.000000	-0.000046	3.339	120.081
41	0.021399	0.000026	-0.000046	3.317	238.455
42	0.020907	0.000055	-0.000046	3.241	175.618
43	0.020541	0.000066	-0.000046	3.184	114.567
44	0.020127	0.000071	-0.000046	3.120	112.269
45	0.019691	0.000073	-0.000045	3.052	163.663
46	0.018813	0.000072	-0.000044	2.916	209.943
47	0.017975	0.000068	-0.000043	2.786	200.586
48	0.017171	0.000067	-0.000040	2.662	191.546
49	0.016316	0.000078	-0.000038	2.529	225.157

NODE	DEPTH	X-STRESS	Y-STRESS	XY-STRESS	MAJ.PRINC.STRESS	MIN.PRINC.STRESS
1	0.000	33.738035	67.498570	0.000000	67.498570	33.738035
	11.000	-18.890883	-45.460334	0.000000	-18.890883	-45.460334
	11.000	-3.956206	-9.520489	0.000000	-3.956206	-9.520489
	17.000	-11.786508	-23.580876	0.000000	-11.786508	-23.580876
2	0.000	33.153846	63.468514	0.000000	63.468514	33.153846
	11.000	-18.780301	-42.637863	0.000000	-18.780301	-42.637863
	11.000	-3.933047	-8.929395	0.000000	-3.933047	-8.929395
	17.000	-11.582419	-22.172961	0.000000	-11.582419	-22.172961
3	0.000	32.192025	50.768506	0.000000	50.768506	32.192025
	11.000	-19.057180	-33.676821	0.000000	-19.057180	-33.676821
	11.000	-3.991032	-7.052737	0.000000	-3.991032	-7.052737
	17.000	-11.246403	-17.736166	0.000000	-11.246403	-17.736166

4	0.000	32.173126	41.518146	0.000000	41.518146	32.173126
	11.000	-19.743737	-27.098243	0.000000	-19.743737	-27.098243
	11.000	-4.134814	-5.675025	0.000000	-4.134814	-5.675025
	17.000	-11.239801	-14.504518	0.000000	-11.239801	-14.504518
5	0.000	32.311165	31.233739	0.000000	32.311165	31.233739
	11.000	-20.620178	-19.772247	0.000000	-19.772247	-20.620178
	11.000	-4.318362	-4.140785	0.000000	-4.140785	-4.318362
	17.000	-11.288026	-10.911623	0.000000	-10.911623	-11.288026
14	0.000	46.701619	70.123439	0.000000	70.123439	46.701619
	11.000	-27.913567	-46.346476	0.000000	-27.913567	-46.346476
	11.000	-5.845773	-9.706068	0.000000	-5.845773	-9.706068
	17.000	-16.315384	-24.497884	0.000000	-16.315384	-24.497884
15	0.000	43.947141	68.342479	0.232166	68.344688	43.944932
	11.000	-26.089010	-45.288075	-0.182714	-26.087271	-45.289814
	11.000	-5.463667	-9.484414	-0.038265	-5.463303	-9.484778
	17.000	-15.353097	-23.875699	-0.081108	-15.352325	-23.876471
16	0.000	41.112513	55.905460	-3.356747	56.631521	40.386452
	11.000	-25.013813	-36.655823	2.641751	-24.442405	-37.227231
	11.000	-5.238495	-7.676612	0.553246	-5.118828	-7.796279
	17.000	-14.362809	-19.530780	1.172692	-14.109157	-19.784432
17	0.000	40.510085	44.816263	-4.733839	47.863657	37.462690
	11.000	-25.424442	-28.813393	3.725519	-23.026151	-31.211684
	11.000	-5.324491	-6.034218	0.780213	-4.822231	-6.536478
	17.000	-14.152349	-15.656728	1.653784	-13.087730	-16.721347
27	0.000	80.538583	71.037455	0.000000	80.538583	71.037455
	11.000	-51.913462	-44.436100	0.000000	-44.436100	-51.913462
	11.000	-10.871929	-9.305989	0.000000	-9.305989	-10.871929
	17.000	-28.136453	-24.817199	0.000000	-24.817199	-28.136453
28	0.000	83.328840	86.225313	1.631339	86.958512	82.595642
	11.000	-52.748932	-55.028449	-1.283860	-52.171907	-55.605474
	11.000	-11.046897	-11.524282	-0.268871	-10.926054	-11.645125
	17.000	-29.111240	-30.123134	-0.569915	-28.855094	-30.379279
29	0.000	77.348035	74.622771	-3.570120	79.806728	72.164078
	11.000	-49.372636	-47.227860	2.809675	-45.292876	-51.307621
	11.000	-10.339819	-9.890651	0.588414	-9.485419	-10.745051
	17.000	-27.021823	-26.069742	1.247235	-25.210789	-27.880777
30	0.000	68.992747	54.385559	-5.696332	70.951479	52.426827
	11.000	-44.960722	-33.464905	4.482998	-31.923388	-46.502239
	11.000	-9.415858	-7.008357	0.938848	-6.685526	-9.738689
	17.000	-24.102872	-18.999797	1.990035	-18.315507	-24.787163
40	0.000	88.804796	68.500906	0.000000	88.804796	68.500906
	11.000	-57.985370	-42.006263	0.000000	-42.006263	-57.985370
	11.000	-12.143533	-8.797123	0.000000	-8.797123	-12.143533
	17.000	-31.024286	-23.931046	0.000000	-23.931046	-31.024286
41	0.000	110.449279	96.925833	0.141842	110.450767	96.924346
	11.000	-71.230626	-60.587711	-0.111630	-60.586540	-71.231797
	11.000	-14.917409	-12.688526	-0.023378	-12.688281	-14.917654
	17.000	-38.585866	-33.861400	-0.049553	-33.860880	-38.586386
42	0.000	103.816404	84.305877	0.318176	103.821592	84.300690
	11.000	-67.467487	-52.112755	-0.250403	-52.108673	-67.471570
	11.000	-14.129317	-10.913666	-0.052441	-10.912811	-14.130172
	17.000	-36.268647	-29.452571	-0.111156	-29.450759	-36.270459

43	0.000	85.310678	59.371816	0.495025	85.320122	59.362372
	11.000	-56.190742	-35.776927	-0.389584	-35.769495	-56.198174
	11.000	-11.767695	-7.492550	-0.081588	-7.490994	-11.769251
	17.000	-29.803602	-20.741765	-0.172939	-20.738465	-29.806902
131	0.000	85.198634	56.979396	0.000000	85.198634	56.979396
	11.000	-56.292083	-34.083619	0.000000	-34.083619	-56.292083
	11.000	-11.788918	-7.137931	0.000000	-7.137931	-11.788918
	17.000	-29.764459	-19.905964	0.000000	-19.905964	-29.764459
132	0.000	104.596604	86.648113	3.672731	105.319061	85.925656
	11.000	-67.845219	-53.719805	-2.890429	-53.151233	-68.413791
	11.000	-14.208423	-11.250221	-0.605325	-11.131148	-14.327495
	17.000	-36.541212	-30.270840	-1.283082	-30.018447	-36.793605
133	0.000	97.604031	76.253583	6.967590	99.676659	74.180955
	11.000	-63.657814	-46.855069	-5.483475	-45.223916	-65.288967
	11.000	-13.331479	-9.812580	-1.148372	-9.470977	-13.673082
	17.000	-34.098331	-26.639472	-2.434154	-25.915392	-34.822411
134	0.000	79.262275	51.719346	8.120757	81.478303	49.503318
	11.000	-52.467448	-30.791238	-6.391014	-29.047230	-54.211457
	11.000	-10.987947	-6.448427	-1.338432	-6.083189	-11.353185
	17.000	-27.690570	-18.068346	-2.837017	-17.294168	-28.464748
135	0.000	60.187536	26.528125	8.718954	62.311963	24.403698
	11.000	-40.805410	-14.315545	-6.861793	-12.643626	-42.477329
	11.000	-8.545636	-2.998020	-1.437025	-2.647880	-8.895776
	17.000	-21.026739	-9.267699	-3.045999	-8.525522	-21.768916
136	0.000	49.060497	13.899370	8.846375	51.160751	11.799116
	11.000	-33.846129	-6.174416	-6.962073	-4.521522	-35.499022
	11.000	-7.088194	-1.293071	-1.458026	-0.946916	-7.434350
	17.000	-17.139467	-4.855797	-3.090514	-4.122065	-17.873198
137	0.000	38.762066	1.936973	8.253495	40.527281	0.171759
	11.000	-27.425831	1.555418	-6.495478	2.944637	-28.815050
	11.000	-5.743629	0.325742	-1.360310	0.616678	-6.034565
	17.000	-13.541672	-0.676689	-2.883389	-0.060005	-14.158356
138	0.000	38.794620	3.560505	7.316109	40.253363	2.101762
	11.000	-27.326130	0.403024	-5.757758	1.551051	-28.474156
	11.000	-5.722750	0.084403	-1.205813	0.324827	-5.963174
	17.000	-13.553045	-1.243876	-2.555910	-0.734258	-14.062662
139	0.000	51.969335	19.312363	6.972842	53.395848	17.885851
	11.000	-35.505640	-9.804691	-5.487608	-8.682029	-36.628301
	11.000	-7.435736	-2.053338	-1.149237	-1.818226	-7.670848
	17.000	-18.155680	-6.746846	-2.435988	-6.248488	-18.654038
140	0.000	86.758117	66.024999	7.951196	89.456284	63.326832
	11.000	-56.716876	-40.399968	-6.257570	-38.276517	-58.840326
	11.000	-11.877880	-8.460726	-1.310486	-8.016025	-12.322581
	17.000	-30.309271	-23.066079	-2.777780	-22.123464	-31.251885
168	0.000	-10.453349	2.566370	13.995011	11.491490	-19.378469
	11.000	7.629928	-2.616556	-11.014036	14.653973	-9.640602
	11.000	1.597891	-0.547970	-2.306604	3.068895	-2.018974
	17.000	3.651916	-0.896571	-4.889209	6.769940	-4.014595
169	0.000	-9.110925	0.000000	0.000000	0.000000	-9.110925
	11.000	6.356156	0.000000	0.000000	6.356156	0.000000
	11.000	1.331132	0.000000	0.000000	1.331132	0.000000
	17.000	3.182935	0.000000	0.000000	3.182935	0.000000
170	0.000	-38.151332	4.754552	0.000000	4.754552	-38.151332

	11.000	27.497767	-6.269048	0.000000	27.497767	-6.269048
	11.000	5.758695	-1.312890	0.000000	5.758695	-1.312890
	17.000	13.328310	-1.661021	0.000000	13.328310	-1.661021
171	0.000	-37.483931	4.093005	3.274832	4.349368	-37.740294
	11.000	26.972967	-5.747969	-2.577284	27.174725	-5.949727
	11.000	5.648789	-1.203763	-0.539745	5.691042	-1.246016
	17.000	13.095151	-1.429906	-1.144075	13.184712	-1.519468

MAXIMUM OR MINIMUM VALUES OF (COMPRESSION IS POSITIVE):

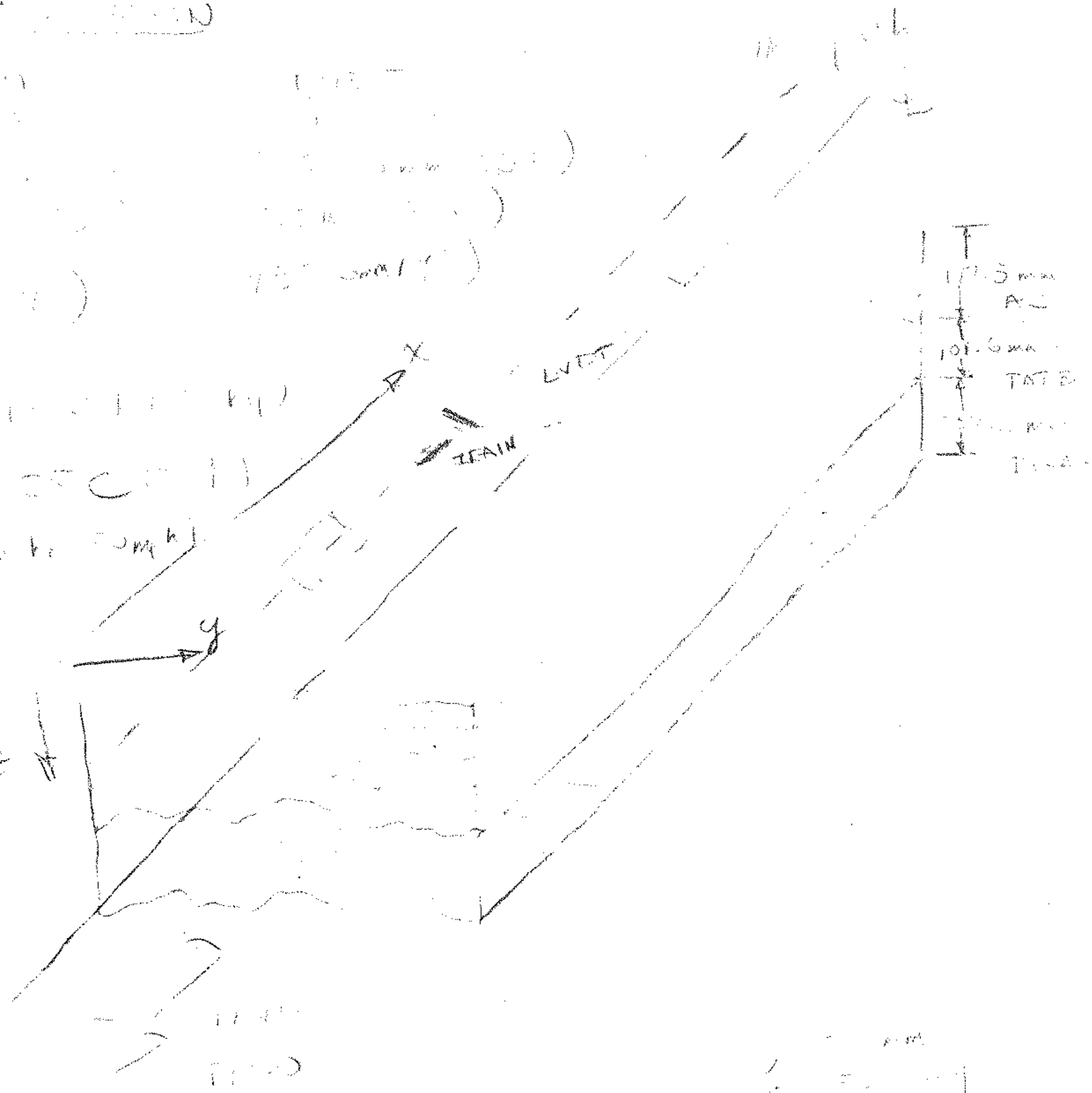
DEFLECTION = 0.022050 AT NODE 1
AND -0.003086 AT NODE 221

SUBGRADE STRESS = 3.418 AT NODE 1

RANGE OF X-STRESS AT BOTTOM OF LAYER 1: FROM	-71.231	AT NODE	41	TO	27.498	AT NODE	170
RANGE OF Y-STRESS AT BOTTOM OF LAYER 1: FROM	-60.588	AT NODE	41	TO	1.555	AT NODE	137
RANGE OF MINOR PRINC. STRESS BOT. LAYER 1: FROM	-71.232	AT NODE	41	TO	0.000	AT NODE	0
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 1: FROM	-60.587	AT NODE	41	TO	27.498	AT NODE	170
RANGE OF X-STRESS AT BOTTOM OF LAYER 2: FROM	-38.586	AT NODE	41	TO	13.328	AT NODE	170
RANGE OF Y-STRESS AT BOTTOM OF LAYER 2: FROM	-33.861	AT NODE	41	TO	1.107	AT NODE	183
RANGE OF MINOR PRINC. STRESS BOT. LAYER 2: FROM	-38.586	AT NODE	41	TO	1.107	AT NODE	183
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 2: FROM	-33.861	AT NODE	41	TO	13.328	AT NODE	170

SUM OF REACTION FORCES = 41999.87

AIR TEMP



[illegible] @ [illegible] $\mu\varepsilon$ [illegible]

T [illegible]

[illegible] @ [illegible] ε_r = 11[illegible] $\mu\varepsilon$ @ z = [illegible]

[illegible] δ_r = [illegible].3505" @ z = 1[illegible]

Stress @ [illegible] = σ_r = [illegible] psi [illegible] psi

<u>RAW</u>

[illegible] $\varepsilon_{r,peak}$ = 11[illegible].3 $\mu\varepsilon$ } ave = 1[illegible]

[illegible] 15 $\varepsilon_{r,p}$ = 1[illegible]

[illegible] 12 $\varepsilon_{r,p}$ = ~ No good

T [illegible] LVDT [illegible] = [illegible].0196" } ave = [illegible].0133"

LVDT 3 [illegible] = [illegible]9"

Stress PC2 $\sigma_{r,p}$ = [illegible] psi } ave = [illegible].53 psi

PC1 $\sigma_{r,p}$ = 8.[illegible] psi

```
                              F H W A
            P R E D I C T I V E   D E S I G N   P R O C E D U R E S
                            V E S Y S - 5
       A PROBABILISTIC PREDICTIVE MODEL FOR PAVEMENT AND AXLE DESIGN
                  LATEST REVISION: 12/01/87 BY MIT
==============================================================================
INPUT DATA VALUES FOR RUN    1
------------------------------------------------------------------------------
    >>>> TYPE               1
    >>>> TITLE       "LTPP Data Test Run 1 OH Pavement                          "
    >>>> NRPOINTS           3
    >>>> RPOINTS
           .0000E+00   .6000E+01   .1000E+02
    >>>> NZPOINTS           3
    >>>> ZPOINTS
           .0000E+00   .7000E+01   .1900E+02
    >>>> NLAYER             4
    >>>> THICK
           .7000E+01   .4000E+01   .8000E+01
    >>>> LOADING     .1050E+03
    >>>> RADIUS      .6965E+01
    >>>> ZCRACK      .7000E+01
    >>>> NTEMPS             1
    >>>> LAYER              2
           .2000E+06
    >>>> LAYER              3
           .3800E+05
    >>>> LAYER              4
           .3000E+04
    >>>> VARCOEF
           .1000E+00   .1500E+00   .1500E+00   .2000E+00
    >>>> POISSON
           .3300E+00   .3800E+00   .4000E+00   .4000E+00
    >>>> TEMPS              1
           .7700E+02
    >>>> GNU          LAYER  1
           .7000E-01
    >>>> ALPHA        LAYER  1
          ..7400E+00
    >>>> GNU          LAYER  2
           .5200E+00
   ********************     LTPP Data Test Run 1 OH Pavement                    ********************

    >>>> ALPHA        LAYER  2
           .7100E+00
    >>>> GNU          LAYER  3
           .2000E-01
    >>>> ALPHA        LAYER  3
           .7500E+00
    >>>> GNU          LAYER  4
           .4000E-01
    >>>> ALPHA        LAYER  4
```

```
      .7500E+00
>>>> NTSTATIC          11
>>>> TSTATIC
      .1000E-02  .3000E-02  .1000E-01  .3000E-01  .1000E+00  .3000E+00  .1000E+01  .3000E+01  .1000E+02  .3000E+02
      .1000E+03
>>>> CREEP              1
      .3700E-06  .5200E-06  .8600E-06  .1450E-05  .2500E-05  .4000E-05  .6200E-05  .8600E-05  .1200E-04  .1600E-04
      .1900E-04
>>>> BETA
      .1130E+00  .1130E+00  .1130E+00  .1130E+00
    REFTEMPC   .7000E+02
>>>> VSPEED     .3000E+02
    DURCOEF1
      .2000E+01  .2000E+01  .2000E+01  .2000E+01
    DURCOEF2
      .1000E+01  .1000E+01  .1000E+01  .1000E+01
>>>> LAYERRUT
===> COMPUTED DIRICHLET COEFFICIENTS -- LAYER 1
     -.5852E-06  .1309E-07 -.2169E-05 -.3761E-05 -.5544E-05 -.6658E-05  .1900E-04
===> COMPUTED CREEP COMPLIANCES      -- LAYER 1
      .3727E-06  .5112E-06  .8739E-06  .1441E-05  .2496E-05  .4038E-05  .6138E-05  .8620E-05  .1203E-04  .1602E-04
      .1867E-04
********************      LTPP Data Test Run 1 OH Pavement                                   ********************

SOLUTION NUMBER   1         CONTACT RADIUS      6.97        LAYER    MODULUS   POISSON   THICKNESS   VARCOEF
  SEASON NUMBER   1        CONTACT PRESSURE  105.00        -----    -------   -------   ---------   -------
 RADIUS NUMBER    1        TOTAL WHEEL LOAD16002.25                                                            1      209857.
.330       7.00        .100
                             VEHICLE SPEED   30.00                                                             2      200000.
.380       4.00        .150
                                                            3       38000.     .400       8.00        .150
                                                            4        3000.     .400     INFINITY      .200
```

S T R E S S E S

R	Z	VERTICAL MEAN	VERTICAL DEVIATION	TANGENTIAL MEAN	TANGENTIAL DEVIATION	RADIAL MEAN	RADIAL DEVIATION	SHEAR MEAN	SHEAR DEVIATION	KTG
.00	.00	-.10500E+03	.00000E+00	-.16300E+03	.77344E+01	-.16300E+03	.77344E+01	.00000E+00	.00000E+00	4
.00	7.00	-.47428E+02	.20652E+01	.13442E+02	.98756E+01	.13442E+02	.98756E+01	.00000E+00	.00000E+00	4
.00	11.00	-.14953E+02	.13894E+01	.85269E+02	.12692E+02	.85269E+02	.12692E+02	.00000E+00	.00000E+00	4
.00	19.01	-.29621E+01	.40390E+00	-.71623E-01	.41147E-01	-.71623E-01	.41147E-01	.00000E+00	.00000E+00	4

D I S P L A C E M E N T S / S T R A I N S

R	Z	DISPLACEMENTS VERTICAL MEAN	DISPLACEMENTS VERTICAL DEVIATION	DISPLACEMENTS RADIAL MEAN	DISPLACEMENTS RADIAL DEVIATION	STRAINS RADIAL MEAN	STRAINS RADIAL DEVIATION	STRAINS TANGENTIAL MEAN	STRAINS TANGENTIAL DEVIATION	KTG
.00	.00	.57137E-01	.73854E-02	.00000E+00	.00000E+00	-.35530E-03	.52618E-04	-.35530E-03	.52618E-04	4
.00	7.00	.55655E-01	.73983E-02	.00000E+00	.00000E+00	.11750E-03	.51032E-04	.11750E-03	.51032E-04	4
.00	11.00	.54409E-01	.73690E-02	.00000E+00	.00000E+00	.29274E-03	.80896E-04	.29274E-03	.80896E-04	4
.00	19.01	.50510E-01	.72366E-02	.00000E+00	.00000E+00	.38062E-03	.94410E-04	.38062E-03	.94410E-04	4

V A L U E S   O N   A X I S   O F   L O A D I N G , R = 0

DEFORMATION

LAYER	MEAN	DEVIATION
1	.148150E-02	.194216E-03
2	.124645E-02	.167254E-03
3	.389887E-02	.543325E-03
4	.505100E-01	.723660E-02

FATIGUE STRAIN

ZCRACK	MEAN	R-DEVIATION	T-DEVIATION
7.00	.117498E-03	.510321E-04	.510321E-04

MEAN VERTICAL COMPRESSIVE STRAIN ON TOP OF SUBGRADE = .968260E-03

******************** LTPP Data Test Run 1 OH Pavement ********************

SOLUTION NUMBER 1
SEASON NUMBER 1
RADIUS NUMBER 1

RADIAL INFULENCE FUNCTION VALUES

		AXIAL-VALUE	.0	3.0	6.0	12.0	24.0	48.0	96.0
DEFORMATION:	LAYER 1	.14815E-02	1.0000	.9777	.5002	.0000	.0000	.0000	.0000
	LAYER 2	.12465E-02	1.0000	.9214	.7128	.3069	.0620	.0000	.0000
	LAYER 3	.38989E-02	1.0000	.9579	.8471	.5882	.2565	.0309	.0000
	LAYER 4	.50510E-01	1.0000	.9758	.9095	.7406	.4154	.1185	.0000
CRACKING:	DEPTH 7.00	.11750E-03	1.0000	.9500	.8010	.4161	.1302	.0241	.0000

******************** LTPP Data Test Run 1 OH Pavement ********************

SOLUTION NUMBER 1
SEASON NUMBER 1
RADIUS NUMBER 1

CONTACT RADIUS 6.97
CONTACT PRESSURE 105.00
TOTAL WHEEL LOAD16002.25
VEHICLE SPEED 30.00

LAYER	MODULUS	POISSON	THICKNESS	VARCOEF
1	209857.	.330	7.00	.100
2	200000.	.380	4.00	.150
3	38000.	.400	8.00	.150
4	3000.	.400	INFINITY	.200

S T R E S S E S

		VERTICAL		TANGENTIAL		RADIAL		SHEAR		
R	Z	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	KTG
6.00	.00	-.77314E+02	.00000E+00	-.13734E+03	.65433E+01	-.12426E+03	.58411E+01	.00000E+00	.00000E+00	4
6.00	7.00	-.28432E+02	.10921E+01	.12004E+02	.73141E+01	.49538E+01	.60118E+01	-.27030E+02	.12611E+01	4
6.00	19.00	-.27492E+01	.36346E+00	.20241E+02	.29145E+01	.19169E+02	.27792E+01	-.43583E+00	.77446E-01	4

D I S P L A C E M E N T S / S T R A I N S

		DISPLACEMENTS VERTICAL		DISPLACEMENTS RADIAL		STRAINS RADIAL		STRAINS TANGENTIAL		
R	Z	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	KTG
6.00	.00	.54564E-01	.73248E-02	-.20247E-02	.14083E-03	-.25458E-03	.39099E-04	-.33745E-03	.46854E-04	4
6.00	7.00	.53823E-01	.73467E-02	.56472E-03	.11623E-03	.49438E-04	.31310E-04	.94120E-04	.37358E-04	4
6.00	19.00	.49641E-01	.71990E-02	.21588E-02	.16746E-03	.32032E-03	.92808E-04	.35981E-03	.98316E-04	4

******************** LTPP Data Test Run 1 OH Pavement ********************

SOLUTION NUMBER 1
SEASON NUMBER 1
RADIUS NUMBER 1

CONTACT RADIUS 6.97
CONTACT PRESSURE 105.00
TOTAL WHEEL LOAD16002.25
VEHICLE SPEED 30.00

LAYER	MODULUS	POISSON	THICKNESS	VARCOEF
1	209857.	.330	7.00	.100
2	200000.	.380	4.00	.150
3	38000.	.400	8.00	.150
4	3000.	.400	INFINITY	.200

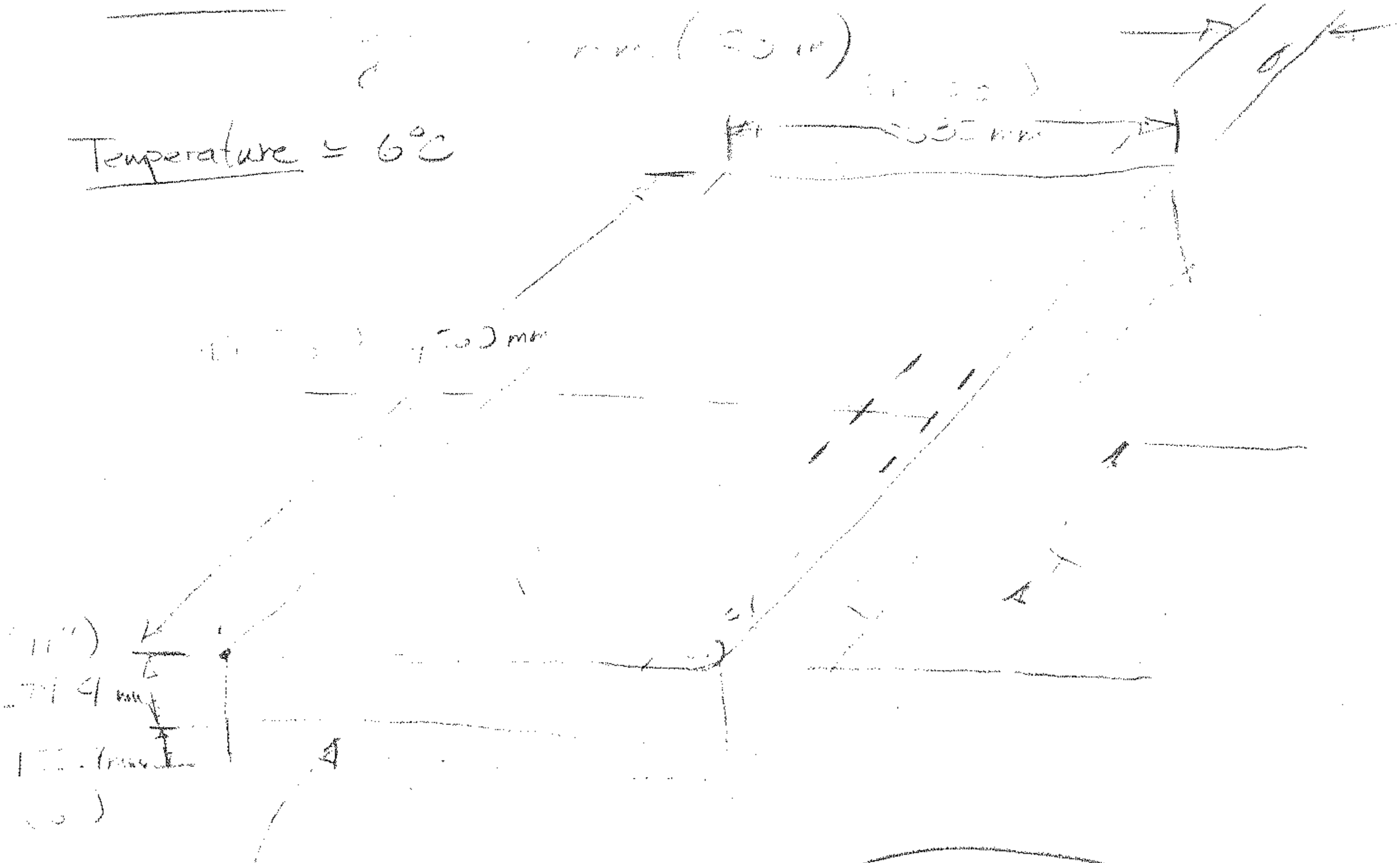
S T R E S S E S

		VERTICAL		TANGENTIAL		RADIAL		SHEAR		
R	Z	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	KTG
10.00	.00	-.46296E+01	.00000E+00	-.72484E+02	.54974E+01	-.46152E+02	.44401E+01	.00000E+00	.00000E+00	4
10.00	7.00	-.95065E+01	.40756E+00	.90281E+01	.45425E+01	-.25520E+01	.24950E+01	-.24815E+02	.10573E+01	4
10.00	19.00	-.25186E+01	.31102E+00	.17974E+02	.26903E+01	.15575E+02	.24032E+01	-.60894E+00	.10466E+00	4

		DISPLACEMENTS				STRAINS				
		VERTICAL		RADIAL		RADIAL		TANGENTIAL		
R	Z	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	MEAN	DEVIATION	KTG
10.00	.00	.50903E-01	.69544E-02	-.26554E-02	.19077E-03	-.98661E-04	.24894E-04	-.26554E-03	.37949E-04	4
10.00	7.00	.51310E-01	.69902E-02	.61982E-03	.14683E-03	-.11408E-04	.13932E-04	.61982E-04	.22864E-04	4
10.00	19.00	.48170E-01	.68326E-02	.33557E-02	.27585E-03	.24717E-03	.78657E-04	.33557E-03	.90535E-04	4

Stop - Program terminated.

Temperature ≃ 6°C



t37208e.004

$$\varepsilon_x = \frac{(55.56 - 0.2 \times 26.47)}{0.382 \times 10^7} = 12.1\,\mu\varepsilon$$

$$\varepsilon_x = \frac{(55.56 - 0.2 \times 17.31)}{0.[illegible] \times 10^7} = 13.8\,\mu\varepsilon$$

ans

$\varepsilon_x =$ [illegible]

[illegible] TFI [illegible] max [illegible] $\mu\varepsilon$

[illegible] $= $ [illegible] $\mu\varepsilon$

[illegible] $= $ [illegible] $\mu\varepsilon$

ILLISLAB OUTPUT FOR
NC t37208e.004

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Run 1: Tandem, D tire, 2-layer, spring sub, 32 kips load on track

TOTAL MEMORY SPACES FOR THE FINITE ELEMENT MESH=   74837
(SHOULD BE LESS THAN            900000  )

NO. OF NODES IN SLABS ALONG X-AXIS      =  17    0    0    0    0    0    0    0    0    0

NO. OF NODES IN SLABS ALONG Y-AXIS      =  13    0    0    0    0    0    0    0    0    0

   X-COORDINATES ARE:

    0.000       24.000      48.000      60.000      66.000      72.000      80.000      86.000      92.000      98.000
  104.000      110.000     116.000     140.000     152.000     164.000     180.000

   Y-COORDINATES ARE:

    0.000       12.000      24.000      36.000      48.000      60.000      72.000      84.000      96.000     108.000
  120.000      132.000     144.000
1
          COORDINATES OF EACH NODE:

          NODE       X         Y

  1   0   0     2   0  12     3   0  24     4   0  36     5   0  48     6   0  60     7   0  72     8   0  84     9   0  96    10   0 108
 11   0 120    12   0 132    13   0 144    14  24   0    15  24  12    16  24  24    17  24  36    18  24  48    19  24  60    20  24  72
 21  24  84    22  24  96    23  24 108    24  24 120    25  24 132    26  24 144    27  48   0    28  48  12    29  48  24    30  48  36
 31  48  48    32  48  60    33  48  72    34  48  84    35  48  96    36  48 108    37  48 120    38  48 132    39  48 144    40  60   0
 41  60  12    42  60  24    43  60  36    44  60  48    45  60  60    46  60  72    47  60  84    48  60  96    49  60 108    50  60 120
 51  60 132    52  60 144    53  66   0    54  66  12    55  66  24    56  66  36    57  66  48    58  66  60    59  66  72    60  66  84
 61  66  96    62  66 108    63  66 120    64  66 132    65  66 144    66  72   0    67  72  12    68  72  24    69  72  36    70  72  48
 71  72  60    72  72  72    73  72  84    74  72  96    75  72 108    76  72 120    77  72 132    78  72 144    79  80   0    80  80  12
 81  80  24    82  80  36    83  80  48    84  80  60    85  80  72    86  80  84    87  80  96    88  80 108    89  80 120    90  80 132
 91  80 144    92  86   0    93  86  12    94  86  24    95  86  36    96  86  48    97  86  60    98  86  72    99  86  84   100  86  96
101  86 108   102  86 120   103  86 132   104  86 144   105  92   0   106  92  12   107  92  24   108  92  36   109  92  48   110  92  60
111  92  72   112  92  84   113  92  96   114  92 108   115  92 120   116  92 132   117  92 144   118  98   0   119  98  12   120  98  24
121  98  36   122  98  48   123  98  60   124  98  72   125  98  84   126  98  96   127  98 108   128  98 120   129  98 132   130  98 144
131 104   0   132 104  12   133 104  24   134 104  36   135 104  48   136 104  60   137 104  72   138 104  84   139 104  96   140 104 108
141 104 120   142 104 132   143 104 144   144 110   0   145 110  12   146 110  24   147 110  36   148 110  48   149 110  60   150 110  72
151 110  84   152 110  96   153 110 108   154 110 120   155 110 132   156 110 144   157 116   0   158 116  12   159 116  24   160 116  36
161 116  48   162 116  60   163 116  72   164 116  84   165 116  96   166 116 108   167 116 120   168 116 132   169 116 144   170 140   0
171 140  12   172 140  24   173 140  36   174 140  48   175 140  60   176 140  72   177 140  84   178 140  96   179 140 108   180 140 120
181 140 132   182 140 144   183 152   0   184 152  12   185 152  24   186 152  36   187 152  48   188 152  60   189 152  72   190 152  84
191 152  96   192 152 108   193 152 120   194 152 132   195 152 144   196 164   0   197 164  12   198 164  24   199 164  36   200 164  48
201 164  60   202 164  72   203 164  84   204 164  96   205 164 108   206 164 120   207 164 132   208 164 144   209 180   0   210 180  12
211 180  24   212 180  36   213 180  48   214 180  60   215 180  72   216 180  84   217 180  96   218 180 108   219 180 120   220 180 132
221 180 144
1
     NO. OF SLABS =     1

     NO. OF LAYERS=     2

   SYMMETRY INDEX =     3

     COMP. ACTION =     1

     PROPERTIES OF THE TOP LAYER:

     POISSON RATIO OF TOP LAYER=      0.200

     THICKNESS OF TOP LAYER     =    11.000

     MODULUS OF TOP LAYER       = 0.382E+07
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1

PROPERTIES OF THE BOTTOM LAYER :

POISSON RATIO OF BOTTOM LAYER= 0.300

THICKNESS OF BOTTOM LAYER = 6.000

MODULUS OF BOTTOM LAYER = 0.800E+06

MODULUS OF SUBGRADE REACTION = 155.000

1

LOADED AREAS AS SPECIFIED WITH RESPECT TO GLOBAL COORDINATE SYSTEM:

PRESSURE	X1-COOR.	X2-COOR.	Y1-COOR.	Y2-COOR.
66.667	85.500	93.000	14.000	22.000
66.667	85.500	93.000	27.000	35.000
66.667	85.500	93.000	91.000	99.000
66.667	85.500	93.000	104.000	112.000
66.667	133.500	141.000	14.000	22.000
66.667	133.500	141.000	27.000	35.000
66.667	133.500	141.000	91.000	99.000
66.667	133.500	141.000	104.000	112.000

TOTAL APPLIED LOAD IS 32000.160

1

+ SUBGRADE TYPE = 6

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*******************************
*                             *
* I T E R A T I O N   N O.  1 *
*                             *
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NODE	DEFLECTION	X-ROTATION	Y-ROTATION	SUBGRADE STRESS	SUBGRADE FORCE
90	0.006074	0.000050	0.000072	0.941	78.499
91	0.005476	0.000049	0.000070	0.849	36.520
92	0.010352	0.000000	0.000085	1.604	57.721
93	0.010320	0.000006	0.000086	1.600	115.034
94	0.010170	0.000019	0.000085	1.576	113.320
95	0.009859	0.000032	0.000082	1.528	109.919
96	0.009462	0.000033	0.000078	1.467	105.579
97	0.009083	0.000030	0.000075	1.408	101.380
98	0.008756	0.000025	0.000074	1.357	97.720
99	0.008468	0.000023	0.000074	1.313	94.460
100	0.008154	0.000031	0.000075	1.264	90.840

1

NODE	DEFLECTION	X-ROTATION	Y-ROTATION	SUBGRADE STRESS	SUBGRADE FORCE
101	0.007703	0.000044	0.000073	1.194	85.809
102	0.007115	0.000052	0.000069	1.103	79.351
103	0.006490	0.000052	0.000067	1.006	72.423
104	0.005883	0.000049	0.000065	0.912	33.820
105	0.010836	0.000000	0.000076	1.680	60.417
106	0.010801	0.000006	0.000074	1.674	120.400
107	0.010644	0.000020	0.000072	1.650	118.600
108	0.010320	0.000033	0.000071	1.600	115.055
109	0.009907	0.000034	0.000070	1.536	110.549
110	0.009516	0.000030	0.000069	1.475	106.206

196	0.012381	0.000000	-0.000021	1.919	160.764
197	0.012322	0.000010	-0.000021	1.910	319.999
198	0.012145	0.000020	-0.000020	1.882	315.421
199	0.011860	0.000027	-0.000018	1.838	308.109
200	0.011505	0.000031	-0.000015	1.783	298.982

1

201	0.011125	0.000032	-0.000014	1.724	289.193
202	0.010751	0.000031	-0.000014	1.666	279.433
203	0.010374	0.000032	-0.000015	1.608	269.558
204	0.009962	0.000037	-0.000016	1.544	258.777
205	0.009483	0.000043	-0.000016	1.470	246.320
206	0.008935	0.000048	-0.000014	1.385	232.125
207	0.008345	0.000050	-0.000011	1.294	216.864
208	0.007748	0.000049	-0.000010	1.201	102.995
209	0.012056	0.000000	-0.000019	1.869	90.349
210	0.011998	0.000010	-0.000019	1.860	179.833
211	0.011830	0.000018	-0.000019	1.834	177.310
212	0.011570	0.000025	-0.000018	1.793	173.373
213	0.011245	0.000029	-0.000016	1.743	168.463
214	0.010887	0.000031	-0.000015	1.687	163.078
215	0.010515	0.000032	-0.000015	1.630	157.521
216	0.010126	0.000033	-0.000015	1.570	151.756
217	0.009705	0.000037	-0.000016	1.504	145.489
218	0.009234	0.000042	-0.000015	1.431	138.439
219	0.008710	0.000046	-0.000014	1.350	130.567
220	0.008146	0.000048	-0.000013	1.263	122.113
221	0.007565	0.000049	-0.000012	1.173	58.017

THE SUM OF REACTION FORCES IS 32000.160

1

NODE	DEPTH	X-STRESS	Y-STRESS	XY-STRESS	MAJ.PRINC.STRESS	MIN.PRINC.STRESS
1	0.000	-54.274583	-8.165574	0.000000	-8.165574	-54.274583
	11.000	37.988928	1.701262	0.000000	37.988928	1.701262
	11.000	7.955797	0.356285	0.000000	7.955797	0.356285
	17.000	18.961027	2.852674	0.000000	18.961027	2.852674
2	0.000	-54.011269	-8.307888	0.000000	-8.307888	-54.011269
	11.000	37.790857	1.822419	0.000000	37.790857	1.822419
	11.000	7.914316	0.381659	0.000000	7.914316	0.381659
	17.000	18.869038	2.902392	0.000000	18.869038	2.902392
3	0.000	-53.284963	-8.651823	0.000000	-8.651823	-53.284963
	11.000	37.248191	2.122031	0.000000	37.248191	2.122031
	11.000	7.800668	0.444404	0.000000	7.800668	0.444404
	17.000	18.615300	3.022547	0.000000	18.615300	3.022547
4	0.000	-52.231862	-8.995032	0.000000	-8.995032	-52.231862
	11.000	36.473123	2.445854	0.000000	36.473123	2.445854
	11.000	7.638350	0.512221	0.000000	7.638350	0.512221
	17.000	18.247395	3.142448	0.000000	18.247395	3.142448
5	0.000	-50.984262	-9.115455	0.000000	-9.115455	-50.984262
	11.000	35.576562	2.625924	0.000000	35.576562	2.625924
	11.000	7.450589	0.549932	0.000000	7.450589	0.549932
	17.000	17.811541	3.184518	0.000000	17.811541	3.184518
92	0.000	42.613624	21.244606	0.000000	42.613624	21.244606
	11.000	-28.704475	-11.887116	0.000000	-11.887116	-28.704475
	11.000	-6.011408	-2.489448	0.000000	-2.489448	-6.011408
	17.000	-14.887228	-7.421882	0.000000	-7.421882	-14.887228
93	0.000	53.564218	36.470457	1.716934	53.734965	36.299710
	11.000	-35.341718	-21.888974	-1.351223	-21.754596	-35.476095
	11.000	-7.401407	-4.584078	-0.282979	-4.555936	-7.429549

	17.000	-18.712859	-12.741090	-0.599817	-12.681439	-18.772510
94	0.000	62.263947	47.512822	-3.083549	62.882583	46.894186
	11.000	-40.694442	-29.085345	2.426745	-28.598481	-41.181306
	11.000	-8.522396	-6.091172	0.508219	-5.989211	-8.624357
	17.000	-21.752141	-16.598781	1.077249	-16.382658	-21.968264
95	0.000	49.934031	31.312526	-7.553521	52.612682	28.633876
	11.000	-33.149792	-18.494718	5.944600	-16.386627	-35.257883
	11.000	-6.942365	-3.873239	1.244943	-3.431754	-7.383850
	17.000	-17.444639	-10.939147	2.638851	-10.003351	-18.380436
96	0.000	30.106154	3.994484	-5.404739	31.180642	2.919996
	11.000	-21.112971	-0.563157	4.253515	0.282462	-21.958590
	11.000	-4.421565	-0.117939	0.890788	0.059154	-4.598658
	17.000	-10.517697	-1.395488	1.888165	-1.020111	-10.893073
100	0.000	55.231852	43.555105	-0.479363	55.251498	43.535459
	11.000	-35.991831	-26.802263	0.377258	-26.786802	-36.007293
	11.000	-7.537556	-5.613039	0.079007	-5.609801	-7.540794
	17.000	-19.295453	-15.216138	0.167467	-15.209274	-19.302316
101	0.000	54.258550	43.760303	-4.354279	55.829473	42.189380
	11.000	-35.283970	-27.021878	3.426806	-25.785565	-36.520282
	11.000	-7.389313	-5.659032	0.717656	-5.400118	-7.648227
	17.000	-18.955426	-15.287824	1.521183	-14.739016	-19.504234
106	0.000	59.502575	39.203312	-4.135273	60.312665	38.393222
	11.000	-39.359014	-23.383548	3.254449	-22.746009	-39.996553
	11.000	-8.242725	-4.897078	0.681560	-4.763562	-8.376241
	17.000	-20.787446	-13.695823	1.444673	-13.412815	-21.070454
107	0.000	68.865900	50.192727	-2.499670	69.194726	49.863901
	11.000	-45.187776	-30.492039	1.967233	-30.233254	-45.446561
	11.000	-9.463409	-6.385767	0.411986	-6.331572	-9.517604
	17.000	-24.058558	-17.535016	0.873269	-17.420139	-24.173434
108	0.000	55.768717	33.501022	-0.321102	55.773346	33.496392
	11.000	-37.134537	-19.609921	0.252706	-19.606278	-37.138181
	11.000	-7.776866	-4.106790	0.052923	-4.106027	-7.777629
	17.000	-19.483008	-11.703706	0.112178	-11.702089	-19.484626
113	0.000	60.968369	45.942484	-2.703024	61.439826	45.471027
	11.000	-39.891696	-28.066366	2.127272	-27.695330	-40.262732
	11.000	-8.354282	-5.877773	0.445502	-5.800069	-8.431986
	17.000	-21.299526	-16.050178	0.944311	-15.885472	-21.464231
114	0.000	59.859575	46.163838	-0.765985	59.902282	46.121131
	11.000	-39.086234	-28.307726	0.602828	-28.274115	-39.119844
	11.000	-8.185599	-5.928320	0.126247	-5.921281	-8.192638
	17.000	-20.912165	-16.127508	0.267600	-16.112588	-20.927085
170	0.000	50.500576	24.825744	0.000000	50.500576	24.825744
	11.000	-34.043662	-13.837639	0.000000	-13.837639	-34.043662
	11.000	-7.129563	-2.897935	0.000000	-2.897935	-7.129563
	17.000	-17.642564	-8.672966	0.000000	-8.672966	-17.642564
171	0.000	61.050757	41.306559	-2.260075	61.306159	41.051157
	11.000	-40.301115	-24.762484	1.778673	-24.561483	-40.502116
	11.000	-8.440024	-5.185861	0.372497	-5.143766	-8.482118
	17.000	-21.328309	-14.430600	0.789566	-14.341374	-21.417535
172	0.000	69.640644	53.206055	1.114186	69.715836	53.130863
	11.000	-45.510843	-32.576866	-0.876861	-32.517690	-45.570019
	11.000	-9.531067	-6.822380	-0.183636	-6.809987	-9.543460
	17.000	-24.329218	-18.587733	-0.389245	-18.561464	-24.355486
173	0.000	56.899324	35.175992	4.808419	57.916070	34.159246

	11.000	-37.812016	-20.715812	-3.784213	-19.915636	-38.612192
	11.000	-7.918747	-4.338390	-0.792505	-4.170814	-8.086323
	17.000	-19.877990	-12.288863	-1.679839	-11.933659	-20.233194
178	0.000	61.741780	46.583498	-2.478611	62.136778	46.188501
	11.000	-40.393336	-28.463809	1.950660	-28.152946	-40.704198
	11.000	-8.459337	-5.961007	0.408515	-5.895905	-8.524439
	17.000	-21.569720	-16.274118	0.865912	-16.136124	-21.707714
179	0.000	60.641310	46.512630	2.857373	61.197304	45.956637
	11.000	-39.615907	-28.496674	-2.248745	-28.059109	-40.053473
	11.000	-8.296525	-5.967890	-0.470941	-5.876253	-8.388162
	17.000	-21.185267	-16.249360	-0.998234	-16.055122	-21.379505

MAXIMUM OR MINIMUM VALUES OF (COMPRESSION IS POSITIVE):

```
DEFLECTION                    =  0.012697    AT NODE  170
                            AND  0.000000    AT NODE    0

SUBGRADE STRESS               =     1.968    AT NODE  170

   RANGE OF X-STRESS AT BOTTOM OF LAYER 1: FROM   -45.511  AT NODE  172     TO    37.989  AT NODE    1
   RANGE OF Y-STRESS AT BOTTOM OF LAYER 1: FROM   -32.577  AT NODE  172     TO     3.615  AT NODE   97
RANGE OF MINOR PRINC. STRESS BOT. LAYER 1: FROM   -45.570  AT NODE  172     TO     2.626  AT NODE    5
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 1: FROM   -32.518  AT NODE  172     TO    37.989  AT NODE    1
   RANGE OF X-STRESS AT BOTTOM OF LAYER 2: FROM   -24.329  AT NODE  172     TO    18.961  AT NODE    1
   RANGE OF Y-STRESS AT BOTTOM OF LAYER 2: FROM   -18.588  AT NODE  172     TO     3.185  AT NODE    5
RANGE OF MINOR PRINC. STRESS BOT. LAYER 2: FROM   -24.355  AT NODE  172     TO     3.185  AT NODE    5
RANGE OF MAJOR PRINC. STRESS BOT. LAYER 2: FROM   -18.561  AT NODE  172     TO    18.961  AT NODE    1

SUM OF REACTION FORCES =  32000.16
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130	0.000001	0.000050	0.000054	1.023	37.841
131	0.011627	0.000000	0.000056	1.802	64.820
132	0.011573	0.000010	0.000055	1.794	129.015
133	0.011387	0.000022	0.000053	1.765	126.938
134	0.011060	0.000032	0.000053	1.714	123.334
135	0.010651	0.000035	0.000054	1.651	118.836
136	0.010248	0.000032	0.000053	1.588	114.367
137	0.009894	0.000027	0.000052	1.534	110.413
138	0.009575	0.000027	0.000050	1.484	106.794
139	0.009218	0.000034	0.000047	1.429	102.754
140	0.008747	0.000045	0.000046	1.356	97.502
141	0.008160	0.000052	0.000047	1.265	91.002
142	0.007524	0.000053	0.000047	1.166	83.955
143	0.006903	0.000050	0.000047	1.070	39.529
144	0.011939	0.000000	0.000048	1.851	66.559
145	0.011880	0.000010	0.000047	1.841	132.443
146	0.011687	0.000022	0.000047	1.811	130.288
147	0.011357	0.000032	0.000046	1.760	126.657
148	0.010948	0.000035	0.000045	1.697	122.150
149	0.010541	0.000032	0.000045	1.634	117.634
150	0.010161	0.000028	0.000044	1.578	113.605

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151	0.009851	0.000028	0.000043	1.527	109.880
152	0.009483	0.000035	0.000042	1.470	105.724
153	0.009008	0.000045	0.000041	1.396	100.419
154	0.008422	0.000052	0.000041	1.305	93.927
155	0.007786	0.000053	0.000040	1.207	86.875
156	0.007163	0.000050	0.000040	1.110	40.981
157	0.012200	0.000000	0.000039	1.891	172.406
158	0.012141	0.000010	0.000040	1.882	343.292
159	0.011947	0.000022	0.000040	1.852	338.019
160	0.011613	0.000032	0.000039	1.800	328.624
161	0.011197	0.000036	0.000037	1.735	316.849
162	0.010783	0.000033	0.000036	1.671	305.230
163	0.010418	0.000028	0.000036	1.615	294.993
164	0.010087	0.000028	0.000036	1.563	285.717
165	0.009717	0.000035	0.000037	1.506	275.480
166	0.009238	0.000045	0.000036	1.432	262.028
167	0.008646	0.000052	0.000034	1.340	245.293
168	0.008005	0.000053	0.000033	1.241	227.317
169	0.007379	0.000051	0.000032	1.144	107.454
170	0.012697	0.000000	0.000001	1.968	211.611
171	0.012660	0.000007	0.000000	1.962	421.735
172	0.012490	0.000022	-0.000001	1.936	415.812
173	0.012142	0.000035	0.000001	1.882	404.376
174	0.011697	0.000037	0.000004	1.813	389.844
175	0.011272	0.000033	0.000005	1.747	375.703
176	0.010902	0.000028	0.000005	1.690	363.325
177	0.010579	0.000026	0.000003	1.640	352.308
178	0.010232	0.000034	0.000000	1.586	340.301
179	0.009744	0.000047	0.000000	1.510	324.015
180	0.009117	0.000055	0.000004	1.413	303.425
181	0.008460	0.000054	0.000005	1.311	281.588
182	0.007829	0.000051	0.000006	1.213	133.322
183	0.012603	0.000000	-0.000015	1.954	140.482
184	0.012550	0.000009	-0.000016	1.945	279.751
185	0.012370	0.000021	-0.000016	1.917	275.741
186	0.012056	0.000031	-0.000013	1.869	268.802
187	0.011659	0.000034	-0.000009	1.807	260.061
188	0.011256	0.000033	-0.000007	1.745	251.108
189	0.010883	0.000030	-0.000007	1.687	242.771
190	0.010530	0.000030	-0.000010	1.632	234.826
191	0.010142	0.000036	-0.000013	1.572	226.102
192	0.009659	0.000045	-0.000012	1.497	215.303
193	0.009077	0.000051	-0.000009	1.407	202.390
194	0.008453	0.000052	-0.000006	1.310	188.538
195	0.007837	0.000050	-0.000004	1.215	89.429