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TEXACO
E&P TECHNOLOGY DIVISION

VACUUM FIELD WATERFLOW PROBLEM: 1987 YEAR-END SUMMARY REPORT ANALYSIS OF WATER INJECTION WELL FALL-OFF TESTS

PREPARED BY: G. P. KOKOLIS

APPROVED BY: J. E. VARNON

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EXECUTIVE SUMMARY

This report contains results of pressure fall-off test analyses performed in 1987 by Texaco's E&P Technology Division in support of the work of the Vacuum Field Waterflow Problem Technical Committee.

Forty-nine tests on thirty-two separate wells were examined. Three wells show anomalously high wellbore storage volumes, four wells show medium storage volumes, and twenty wells show either insignificant or low storage volumes. Tests on five wells are inconclusive due to bad data.

INTRODUCTION

Water has been encountered under high pressure in the salt zone of the Vacuum field since around the mid-1970's. Various operators in the Vacuum field have been working accordingly in a joint effort to identify and correct the source of this problem.

Phillips Petroleum Company recommended that, as a part of this effort, pressure fall-off tests on water injection wells be examined for abnormally high wellbore storage volumes which could be indicative of communication with the salt section.[1]

CONCLUSIONS

1. The use of water injection well fall-off tests as a tool to identify wells contributing to the Vacuum Field Waterflow Problem remains unconfirmed. Fall-off test results should be considered a screening aid to identify wells for further testing techniques (logs, etc.) rather than a conclusive indicator of problem wells.

2. Three wells have been identified which have anomalously high wellbore storage volumes: VGSAU 49, CVU 81, and CVU 141.

   Of these, Well VGSAU 49 shows the highest wellbore storage (~100,000 bbl), which is as yet unexplained. The storage volume calculated for VGSAU 49 was repeated on subsequent fall-off tests with more accurate early time data capabilities. No confirmation of water injection out-of-zone has been obtained by other techniques. No further fall-off tests for VGSAU 49 are planned, but continued tests of VGSAU 49 using other techniques (logs, interference tests, etc.) are either underway or planned.

   The high storage behavior of Wells CVU 81 and CVU 141 is significantly less than that observed in well VGSAU49 (~23,000 bbl for CVU 81, ~11,000 bbl for CVU 141). The high storage volumes for these two wells is as of yet unconfirmed. Repeat fall-off tests of these two wells to confirm the high storage volumes are planned.

3. Four wells have been identified which have medium storage volumes: CVU 58, CVU 60, CVU 72, and CVU 73.

   The storage volume of CVU 58 has been confirmed by repeat testing. Repeat tests for the other wells are planned.

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[1] Pollin, A. G.: "Phillips Petroleum Company Engineering Report: Vacuum Field Waterflow Problem - Analysis of Water Injection Falloff Tests," December 1986.

4. Twenty wells have been identified which have either insignificant or low storage. No further testing of any type is planned for any of these wells.

5. Testing and analysis procedures have been refined over the last year. Recommended procedures for future tests are documented in this report.

RECOMMENDATIONS

1. No further testing should be required for water injection wells which have been identified to have insignificant or low wellbore storage volumes.

2. Wells classified as having medium or high storage should have repeat fall-off tests conducted and analyzed according to the procedures described in this report. If the behavior of these wells is confirmed by the repeat fall-off tests, then other testing techniques should be used to further examine those wells as possible contributors to the waterflow problem.

   Priority should be given to testing high storage injection wells over medium storage volume wells.

3. Future fall-off tests to investigate the Waterflow Problem should follow the procedures described in this report.

DISCUSSION

Analysis of fall-off tests performed to the present time has resulted in a four tier classification system for describing the wellbore storage volume determined from fall-off testing. The four classifications, which are described in more detail later in this report, are: INSIGNIFICANT STORAGE, LOW STORAGE, MEDIUM STORAGE, and HIGH STORAGE.

Further investigation should center on those wells receiving a HIGH STORAGE rating. No further testing should be required of wells falling in the INSIGNIFICANT STORAGE or LOW STORAGE categories. Moderate further testing (a minimum of repeat fall-off testing) should be performed on MEDIUM STORAGE wells.

Procedures are outlined in this report which should be followed when conducting and analyzing future fall-off tests. An emphasis is placed on obtaining very early time data. Amerada gauge data is generally not sufficient for use towards this end. Electronic surface pressure recording gauges are felt to provide the best performance at a reasonable cost for future fall-off tests. Field tests have been conducted at the Vacuum field where electronic surface gauges were used concurrently with dual (short and long clock) downhole Amerada gauges. The procedures in this report reflect and are a direct result of the experience gained in those tests.

Tables of well parameters, calculations, and conclusions from the analysis of the Vacuum Field fall-off tests are provided in this report. Figures 1 through 6 show copies of type-curves used to analyze the data. Figures 7 through 82 provide copies of the log-log plots used to analyze each test. Copies of other plots (linear, square root, quarter root, Horner, MDH), or the raw data are available upon request.

Texaco Summary of Wellbore Storage Analysis Results

Falloff tests have been performed and analyzed on thirty-two Texaco operated water injection wells.

These wells have been categorized below according to the wellbore storage volumes calculated from the falloff tests:

INSIGNIFICANT STORAGE		LOW STORAGE		MEDIUM STORAGE		HIGH STORAGE		BAD TEST	
<1000 bbl		>1000 bbl & <5000 bbl		>5000 bbl & <10000 bbl		>10000 bbl			
CVU	15	CVU	41	CVU	58*	VGSAU	49*	CVU	82
CVU	25	CVU	113	CVU	60	CVU	81	CVU	122
CVU	31	CVU	120	CVU	72	CVU	141	VGSAU	33
CVU	57	CVU	134	CVU	73			WVU	23
CVU	100	CVU	135					WVU	48
VGSAU	17	CVU	138						
		CVU	140						
		CVU	144						
		CVU	145						
		CVU	156						
		CVU	157						
		NVAWU	17						
		VGSAU	15						
		VGSAU	35						
	6		14		4		3		5

NOTES: * after well number indicates that MEDIUM or HIGH storage volume has been confirmed on these wells by repeat testing using high accuracy/high sample rate electronic surface pressure gauges.

Injection rates and storage volumes for wells with indicated high wellbore storage are:

VGSAU	49	2,100 BPD water injection	~100,000 bbl storage
CVU	81	1,280 BPD water injection	~ 23,000 bbl storage
CVU	141	1,127 BPD water injection	~ 11,000 bbl storage

Classification Categories for Water Injection Wells
<u>Based on Wellbore Storage Volume Calculated from Fall-Off Tests</u>

INSIGNIFICANT STORAGE	Wellbore storage <1,000 bbl. Wells in this category are felt to have virtually no chance of being in communication with salt caverns, and therefore should be considered exonerated as possible contributors to the waterflow problem. No further testing should be required of injection wells in this category.
LOW STORAGE	Wellbore storage >1,000 bbl., but <5,000 bbl. Wells in this category are considered extremely unlikely waterflow problem culprits. No further testing required.
MEDIUM STORAGE	Wellbore storage >5,000 bbl., but <10,000 bbl. Wells in this category have a moderately high level of storage, but storage is still an order of magnitude less than the most suspect wells identified by fall-off testing. Wells in this category are most likely not waterflow culprits, but further testing should be done on wells in this category. At a minimum, fall-off tests should be rerun and temperature surveys should be run.
HIGH STORAGE	Wellbore storage >10,000 bbl. Extremely high wellbore storage indicates anomalous behavior of some type for wells falling in this category. These wells could possibly be in communication with caverns in the salt zone, resulting in high apparent wellbore storage volumes. Wells in this category should be considered likely culprits unless they can be exonerated by further testing, or unless alternative testing fails to identify water channeling out of the injection interval.

Recommended Procedures for Fall-Off Testing

1. Any wells which have been tested to date and can be classified as "Insignificant Storage" or "Low Storage can be considered exonerated and no further testing of those wells is required.

2. Any wells tested to date and classified as "Medium Storage," "High Storage," or "Bad Test" should be repeat tested using electronic surface electronic memory gauges.

3. Any new fall-off tests to be performed should use electronic surface memory gauges using the following procedure:

   A. Monitor injection rate and make certain that well is injecting at a stable rate for at least a one-week period prior to the test.

   B. Program electronic memory gauge to obtain data at fastest possible capture rate.

   C. Connect electronic memory gauge to well and capture approximately 15 minutes of flowing pressure data. The tubing connecting the electronic memory gauge to the wellhead should be completely filled with a light oil such as silicone oil or automatic transmission fluid. The electronic memory gauge should be placed in an insulated container, and the tubing from the wellhead to the gauge should be insulated so as to minimize ambient temperature effects.

   D. Shut in well and capture approximately one hour of fall-off data. If well goes on vacuum prior to one hour after shut-in, the electronic memory gauge can be removed at that point.

4. Data from the electronic surface memory gauge should be analyzed as follows:

   A. Prepare log-log plot of Delta P and Derivative vs. Delta T.

   B. Inspect curve for any data which may fall in pressure oscillation period immediately after shut-in. Delta P curve should monotonically increase with Delta T. If a decrease of Delta P with Delta T is seen in the early time data, then pressure oscillation data may be present. Delete all points in pressure oscillation period and replot log-log plot of Delta P and Derivative.

   C. Inspect Derivative curve for a distinct unit slope region in early data points. If unit slope is observed, then storage can be calculated from the following formula:

   $$\text{STORAGE} = Q * (\text{Delta T}) / (24 * (\text{Delta P}) * C_{wbf})$$

Where: STORAGE = wellbore storage (bbl)

Delta T = Delta T point read off any point on unit slope line (hours)

Delta P = Delta P point read off same point on unit slope line (psi)

C_{wbf} = compressibility of wellbore fluid (bbl/psi)

The storage calculated from the above formula can be used to classify the well as "Insignificant Storage," "Low Storage," "Medium Storage," or "High Storage" according to the accepted classification criteria.

D. If a unit slope is not observed on the early portion of the Derivative curve, then a maximum storage value can be calculated using the equation in step 4.C. above, the only difference being Delta P and Delta T should be read from the first point of the Derivative curve.** The calculated storage volume should be preceded by a "less than" ($<$) sign when reported so as to indicate the reported value is a maximum and that no unit slope data was observed. If the well can be classified as "Low Storage" or "Unlikely" from the maximum calculated storage, then no further testing is required of that well.

If the calculated maximum storage value is greater than the criteria required for "Low Storage," then the well should be classified as "Medium Storage." The "High Storage" classification should not be issued to any well on the basis of calculated maximum storage alone (no unit slope observed).

5. Any wells classified as "Medium Storage" or "High Storage" as a result of surface pressure fall-off testing as described in steps 3 and 4 above will require more detailed fall-off testing utilizing downhole data in conjunction with surface data. The following procedure should be used:

A. Monitor injection rate and make certain that well is injecting at a stable rate for at least a one-week period prior to the test.

** This assumes the technique used to calculate the derivative curve does not use the shut-in point in the calculation of the derivative at any time. If the shut-in point is used, then the first derivative point which is independent of the shut-in pressure should be used to calculate the maximum storage value.

B. Program electronic memory gauge to obtain at least ten hours of data, with the first hour taken at the fastest possible capture rate.

C. Run Amerada-type gauge down hole. Clock in Amerada gauge should be chosen so as to be of sufficient duration to obtain data in the semi-log radial flow region (120 hours is usually sufficient). If well must be shut in to run in Amerada gauge, then resume injection and inject for at least 24 hours before shutting in to start the fall-off test.***

D. Connect electronic memory gauge to well and capture approximately 15 minutes of flowing pressure data. The tubing connecting the electronic memory gauge to the wellhead should be completely filled with a light oil such as silicone oil or automatic transmission fluid. The electronic memory gauge should be placed in an insulated container, and the tubing from the wellhead to the gauge should be insulated so as to minimize ambient temperature effects.

E. Shut in well and capture at least ten hours of data on surface electronic memory gauge. Gauge can be removed sooner if well goes on vacuum.

6. Data from the electronic memory gauge and concurrent Amerada data should be analyzed as follows:

A. Prepare log-log plots of Delta P and Derivative for surface data. Inspect for data in oscillation period and replot as may be necessary.

B. Prepare log-log plots of Delta P and Derivative for Amerada data.

*** Prior fall-off test procedure called for a flow period of at least four times the shut-in period required to run in tools (resulting in a flow period of only a few hours at most). Prior procedure necessitated a minimal flow period after running in tools because a 12 hour clock Amerada gauge was being used to obtain early time data. Results of some tests indicated that the prior recommended flow period was not sufficient to reach a stabilized injection pressure. Since now we are using surface gauges to obtain the early time data, the constraints of the clock on the 12 hour Amerada gauge no longer apply; a longer flow period can be used to assure stabilized injection pressure prior to the fall-off.

C. Overlay surface and Amerada plots. Derivative curves should overlay, with possible exceptions in early time Amerada data where low data density and inaccuracies in Amerada data may cause discrepancies. If Derivative curves do not agree, then there is a problem with the data, and the test must be rerun.

D. Note the constant pressure correction required to make the surface Delta P data overlay the Amerada Delta P data.

E. Adjust shut-in pressure used to plot surface data log-log plot as indicated in step 6-D above. Replot surface data and repeat steps 6-C, 6-D, and 6-E until the surface Delta P curve overlays the Amerada Delta P curve, with possible exceptions in the early Amerada data.

F. Inspect the final surface pressure log-log plot resulting from step 6-E for evidence of a unit slope region in the early Delta P data. If such a unit slope is evident, an overlaying unit slope should also be seen on the Derivative curve. If a unit slope is observed, calculate a storage value from the equation in step 4-C. If a unit slope is observed on the Delta P curve and none is observed on the Derivative curve, then the shut-in pressure adjustment is incorrect. Steps 6-C, 6-D, 6-E, and 6-F should be repeated accordingly.

If the well can now be characterized as "Insignificant Storage" or "Low Storage," no further testing or analysis for that well is required.

G. If a unit slope is not observed in the early time Delta P data, calculate a maximum slope value based on the Delta T and Delta P read from the first point of the Delta P plot (rather than from the first point of the Derivative plot as in step 4-D). Storage values calculated when a unit slope is not evident in the Delta P data should be preceded by a "less-than" symbol (<) when reported.

If the well can now be characterized as "Insignificant Storage" or "Low Storage," no further testing or analysis for that well is required.

If the calculated maximum storage value is greater than the criteria required for "Low Storage," then the well should be classified as "Medium Storage." The "High Storage" classification should not be issued to any well on the basis of maximum storage alone (no unit slope observed).

7. If, based on the analysis performed in step 6, the well falls in the "Medium Storage" category, then the following analysis should be performed:

   A. A composite log-log plot should be constructed using the early-time surface data and late-time Amerada data from step 6).

   B. The composite log-log plot should be used with appropriate type curves to attempt to determine a storage value.

   C. The storage volume which is felt to best describe the well should be assigned based on the results of the type curve analysis.

   If the well can now be characterized as "Insignificant Storage" or "Low Storage,, no further testing or analysis for that well is required.

8. Any wells which fall in the category of "High Storage" should be repeat tested using steps 5, 6, and 7 at least once.

APPENDIX

A. Vacuum Field Waterflow Problem
Fall-Off Tests
Parameters and Calculations

B. Vacuum Field Waterflood Problem
Fall-Off Tests
Summary of Test Analysis

C. Figures 1-6: Type Curves

D. Figures 7-82: Log-Log Plots of Fall-Off Test Data

VACUUM FIELD WATERFLOW PROBLEM

FALL-OFF TESTS

PARAMETERS AND CALCULATIONS

11/19/87

WELL	TEST DATE	GAUGE TYPE	Cum Inj. (Bbls)	Inj. Rate (BPD)	Inj. Time (hrs)	Por-osity (%)	Net Pay (ft)	Hole Dia. (in)	Tubing Size (in)	Tubing I.D. (in)	Datum Depth (ft)	Temp (F)	Grad-ient (lb/ft)	Form. Visc-osit (cp)	Vol. Fact. (rbbl sbbl)	Total Comp. (1/psi)	Pattern Size (ac)	Bias (psi)	Hydro Static Press (psi_)	Fall Liq Lev (Y/N)	Time Vac (hrs)
CVU 15	870320	S&L AM	942988	109	207630	8.6	36	7.875	2.375	2.041	4425	135	0.454	0.85	1.00	3.0e-06	40	0.0	2009	Y	109.00
CVU 25	861026	AMERADA	323755	887	8760	13.1	170	7.875	2.375	2.041	4599	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2120	Y	8.00
CVU 25	870917	S AM/SMP	3159020	174	435727	13.1	170	7.875	2.375	2.041	4599		0.458	0.85	1.00	3.0e-06	40	0.0	2106		
CVU 31	870309	S&L AM	1788708	600	71548	11.0	83	7.875	2.375	2.041	4606	137	0.459	0.85	1.00	3.0e-06	40	90.0	2024	N	-
CVU 41	870315	S&L AM	2719100	763	85529	11.0	98	7.875	2.375	2.041	4545	136	0.456	0.85	1.00	3.0e-06	40	87.0	1986	Y	45.00
CVU 41	870917	S AM/SMP	2891470	940	73825	11.0	98	7.875	2.375	2.041	4599		0.458	0.85	1.00	3.0e-06	40	0.0	2106		
CVU 57	861020	AMERADA	278860	764	8760	10.3	162	7.875	2.375	2.041	4382	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2020	Y	1.75
CVU 57	870921	S&L AM	3580639	966	88960	10.3	162	7.875	2.375	2.041	4382		0.458	0.85	1.00	3.0e-06	40	0.0	2007		
CVU 58	861020	AMERADA	330325	905	8760	11.4	185	7.875	2.375	2.041	4389	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2023	Y	18.00
CVU 58	870917	S&L/SMP	3670512	861	102314	11.4	185	7.875	2.375	2.041	4389		0.458	0.85	1.00	3.0e-06	40	0.0	2010		
CVU 60	870314	S&L AM	2170323	997	52244	10.0	54	7.785	2.375	2.041	4551	140	0.455	0.85	1.00	3.0e-06	40	0.0	2071	Y	11.50
CVU 72	861020	AMERADA	390915	1071	8760	11.2	202	7.875	2.375	2.041	4373	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2016	Y	0.75
CVU 72	870906	S&L AM	4043931	654	148401	11.2	202	7.875	2.375	2.041	4373		0.458	0.85	1.00	3.0e-06	40	0.0	2003		
CVU 73	861020	AMERADA	3525568	1340	63145	12.6	130	7.875	2.375	2.041	4381	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2020		
CVU 73	870902	S&L AM	3856456	1296	71416	12.6	130	7.875	2.375	2.041	4381		0.458	0.85	1.00	3.0e-06	40	0.0	2006		
CVU 81	861110	PANEX	3689603	1280	69180	11.0	134	6.125	2.375	2.041	4300	90	0.458	0.85	1.00	3.0e-06	40	0.0	1969		
CVU 82	861121	AMERADA	3911746	1373	68377	10.0	121	6.125	2.375	2.041	5000		0.458	0.85	1.00	3.0e-06	40	0.0	2290		
CVU 100	861008	AMERADA	1077115	454	56940	12.0	120	7.875	2.375	2.041	4550	102	0.458	0.85	1.00	3.0e-06	40	-13.2	2097	N	-
CVU 113	861023	AMERADA	7665	21	8760	10.5	140	7.875	2.375	2.041	4580	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2111	N	-
CVU 113	870917	SMP	331136	21	378441	10.5	140	7.875	2.375	2.041	4580		0.458	0.85	1.00	3.0e-06	40	0.0	2098		
CVU 113	870922	S&L AM	331136	21	378441	10.5	140	7.875	2.375	2.041	4580		0.458	0.85	1.00	3.0e-06	40	0.0	2098		
CVU 120	861023	AMERADA	225196	48	112598	16.8	76	7.875	2.375	2.041	4570	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2106	N	-
CVU 120	870325	S&L AM	242596	183	31816	9.9	76	7.875	2.375	2.041	4657	137	0.452	0.85	1.00	3.0e-06	40	0.0	2105	N	-
CVU 120	870916	S&L/SMP	265570	86	74113	9.9	76	7.875	2.375	2.041	4657		0.458	0.85	1.00	3.0e-06	40	0.0	2133		
CVU 122	870325	S&L AM	250016	19	315810	13.0	22	7.875	2.375	2.041	4720	136	0.455	0.85	1.00	3.0e-06	40	0.0	2148	N	-
CVU 134	861023	AMERADA	35405	97	8760	18.8	65	7.875	2.375	2.041	4579	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2110	N	-
CVU 134	870903	S&L AM	1025763	524	46982	18.8	65	7.875	2.375	2.041	4579		0.458	0.85	1.00	3.0e-06	40	0.0	2097		
CVU 135	861023	AMERADA	37595	103	8760	11.4	175	7.875	2.375	2.041	4581	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2111	N	-
CVU 135	870907	S&L AM	1074730	339	76087	11.4	175	7.875	2.375	2.041	4581		0.458	0.85	1.00	3.0e-06	40	0.0	2098		
CVU 138	861009	AMERADA	2538575	1070	56940	14.0	202	7.875	2.375	2.041	4550	102	0.458	0.85	1.00	3.0e-06	40	-13.2	2097	Y	8.00
CVU 140	861119	PANEX	3568520	1127	75993	12.0	116	6.125	2.375	2.041	4300	90	0.458	0.85	1.00	3.0e-06	40	0.0	1969		
CVU 141	861110	PANEX	3118868	1127	66418	9.0	92	6.125	2.375	2.041	4300	90	0.458	0.85	1.00	3.0e-06	40	0.0	1969		
CVU 144	870320	S&L AM	884461	277	76632	10.5	125	7.875	2.375	2.041	4550	136	0.462	0.85	1.00	3.0e-06	40	0.0	2102	N	-
CVU 145	861009	AMERADA	113463	1029	2646	11.0	118	7.875	2.375	2.041	4550	102	0.458	0.85	1.00	3.0e-06	40	-13.2	2097	Y	32.00
CVU 156	861026	AMERADA	1158416	523	53159	8.1	54	7.875	2.375	2.041	4606	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2123		
CVU 156	870902	S&L AM	1317555	418	75649	8.1	54	7.875	2.375	2.041	4606		0.458	0.85	1.00	3.0e-06	40	0.0	2110		
CVU 156	860916	SMP	1317555	418	75649	8.1	54	7.875	2.375	2.041	4606		0.458	0.85	1.00	3.0e-06	40	0.0	2110		
CVU 157	861026	AMERADA	1019675	714	34275	12.6	94	7.875	2.375	2.041	4599	101	0.458	0.85	1.00	3.0e-06	40	-13.2	2120		
CVU 157	860907	S&L AM	1203498	553	52231	12.6	94	7.875	2.375	2.041	4599		0.458	0.85	1.00	3.0e-06	40	0.0	2106		
NVAWU 17	870324	S&L AM	217646	195	26787	10.8	79	7.875	2.375	2.041	8724	176	0.431	1.47	1.00	7.0e-06	160	0.0	3760	N	-
VGSAU 15	870309	S&L AM	225780	194	27932	11.0	91	7.875	2.375	2.041	4493	141	0.463	1.47	1.00	3.0e-06	40	0.0	2080	N	-
VGSAU 17	870320	S&L AM	7188075	537	321255	12.7	156	7.875	2.375	2.041	4394	137	0.466	1.47	1.00	3.0e-06	40	0.0	2048	N	-
VGSAU 33	870315	S&L AM	6301182	1507	100351	12.0	84	7.875	2.375	2.041	4578	139	0.462	1.47	1.00	3.0e-06	40	0.0	2115	N	-
VGSAU 35	861008	AMERADA	2385705	718	79745	11.0	150	7.875	2.375	2.041	4550	102	0.458	1.47	1.00	3.0e-06	40	-13.2	2097	N	-
VGSAU 49	861008	AMERADA	9128194	2116	103533	11.0	150	7.875	2.375	2.041	4550	102	0.458	1.47	1.00	3.0e-06	40	-13.2	2097	Y	63.00
VGSAU 49	870309	S&L AM	9440869	2053	110366	11.0	150	7.875	2.375	2.041	4507	140	0.440	1.47	1.00	3.0e-06	40	0.0	1983	Y	92.00
VGSAU 49	870916	SMP	9784724	1318	178174	11.0	150	7.875	2.375	2.041	4507	140	0.440	1.47	1.00	3.0e-06	40	0.0	1983		
WVU 23	870402	S&L AM	2418499	189	307111	10.3	154	4.750	open	4.750	4472	135	0.460	0.85	1.00	3.0e-06	160	0.0	2057	N	-
WVU 48	870319	S&L AM	1178527	220	128567	10.0	90	4.750	open	4.750	4550	142	0.462	0.85	1.00	3.0e-06	160	0.0	2102	N	-

11/19/87 WELL	Wellbore Volume Vwb (bbl)	Wellbore Fluid Comp. (1/psi)	Wellbore Compress Storage (bbl/psi)	Del P @ Del T = .01, WCS	Fall Liq Level Storage (bbl/psi)	Del P @ Del T = .01, FLLS	10000 BBL Compress Storage (bbl/psi)	Del P @ Del T = .01, 10K	Del P @ Del T = .01,100K	Unit Slope Status	Unit Slope Vwb (bbl)	Unit Slope Storage (bbl/psi)
CVU 15	17.91	3.00e-06	5.37e-05	845.4	8.91e-03	5.10	3.00e-02	1.51	0.15	<	520	1.56e-03
CVU 25	18.61	3.00e-06	5.58e-05	6619.6	8.83e-03	41.83	3.00e-02	12.32	1.23	<	7130	2.13e-02
CVU 25	18.61	3.00e-06	5.58e-05	1298.6	8.83e-03	8.21	3.00e-02	2.42	0.24	<	200	6.00e-04
CVU 31	18.64	3.00e-06	5.59e-05	4471.0	8.81e-03	28.36	3.00e-02	8.33	0.83	<	5680	1.70e-02
CVU 41	18.39	3.00e-06	5.51e-05	5761.9	8.87e-03	35.82	3.00e-02	10.60	1.06	M	3450	1.03e-02
CVU 41	18.61	3.00e-06	5.58e-05	7015.2	8.83e-03	44.33	3.00e-02	13.06	1.31	<	3130	9.39e-03
CVU 57	17.73	3.00e-06	5.31e-05	5984.0	8.83e-03	36.03	3.00e-02	10.61	1.06	<	6130	1.83e-02
CVU 57	17.73	3.00e-06	5.31e-05	7566.2	8.83e-03	45.56	3.00e-02	13.42	1.34	<	3980	1.19e-02
CVU 58	17.76	3.00e-06	5.32e-05	7077.1	8.83e-03	42.68	3.00e-02	12.57	1.26	M	15500	4.65e-02
CVU 58	17.76	3.00e-06	5.32e-05	6733.0	8.83e-03	40.60	3.00e-02	11.96	1.20	Y	6500	1.95e-02
CVU 60	18.42	3.00e-06	5.52e-05	7519.0	8.89e-03	46.71	3.00e-02	13.85	1.38	Y	6610	1.98e-02
CVU 72	17.70	3.00e-06	5.30e-05	8405.9	8.83e-03	50.51	3.00e-02	14.88	1.49	<	15750	4.72e-02
CVU 72	17.70	3.00e-06	5.30e-05	5133.0	8.83e-03	30.84	3.00e-02	9.08	0.91			??
CVU 73	17.73	3.00e-06	5.31e-05	10497.9	8.83e-03	63.19	3.00e-02	18.61	1.86	<	19840	5.95e-02
CVU 73	17.73	3.00e-06	5.31e-05	10153.2	8.83e-03	61.12	3.00e-02	18.00	1.80	Y	7120	2.13e-02
CVU 81	17.40	3.00e-06	5.22e-05	10216.8	8.83e-03	60.36	3.00e-02	17.78	1.78	Y	22960	6.88e-02
CVU 82	20.23	3.00e-06	6.06e-05	9424.8	8.83e-03	64.75	3.00e-02	19.07	1.91			0.00
CVU 100	18.41	3.00e-06	5.52e-05	3424.7	8.83e-03	21.41	3.00e-02	6.31	0.63	<	11630	3.48e-02
CVU 113	18.53	3.00e-06	5.56e-05	157.4	8.83e-03	0.99	3.00e-02	0.29	0.03	Y	30000	9.00e-02
CVU 113	18.53	3.00e-06	5.56e-05	157.4	8.83e-03	0.99	3.00e-02	0.29	0.03			??
CVU 113	18.53	3.00e-06	5.56e-05	157.4	8.83e-03	0.99	3.00e-02	0.29	0.03	Y	1330	3.99e-03
CVU 120	18.49	3.00e-06	5.54e-05	360.5	8.83e-03	2.26	3.00e-02	0.67	0.07	Y	57700	1.73e-01
CVU 120	18.85	3.00e-06	5.65e-05	1348.7	8.95e-03	8.52	3.00e-02	2.54	0.25	??	1000000	3.00e+00
CVU 120	18.85	3.00e-06	5.65e-05	633.8	8.83e-03	4.06	3.00e-02	1.19	0.12	<	3400	1.02e-02
CVU 122	19.10	3.00e-06	5.73e-05	138.2	8.89e-03	0.89	3.00e-02	0.26	0.03	??	100000	3.00e-01
CVU 134	18.53	3.00e-06	5.55e-05	727.1	8.83e-03	4.57	3.00e-02	1.35	0.13	<	5270	1.58e-02
CVU 134	18.53	3.00e-06	5.55e-05	3927.7	8.83e-03	24.71	3.00e-02	7.28	0.73			??
CVU 135	18.54	3.00e-06	5.56e-05	771.7	8.83e-03	4.86	3.00e-02	1.43	0.14	<	3960	1.18e-02
CVU 135	18.54	3.00e-06	5.56e-05	2539.9	8.83e-03	15.99	3.00e-02	4.71	0.47			??
CVU 138	18.41	3.00e-06	5.52e-05	8071.3	8.83e-03	50.46	3.00e-02	14.86	1.49	<	18300	5.49e-02
CVU 140	17.40	3.00e-06	5.22e-05	8995.6	8.83e-03	53.15	3.00e-02	15.65	1.57	<	1377	4.13e-03
CVU 141	17.40	3.00e-06	5.22e-05	8995.6	8.83e-03	53.15	3.00e-02	15.65	1.57	<	10664	3.19e-02
CVU 144	18.41	3.00e-06	5.52e-05	2089.5	8.75e-03	13.18	3.00e-02	3.85	0.38	Y	3100	9.30e-03
CVU 145	18.41	3.00e-06	5.52e-05	7762.1	8.83e-03	48.53	3.00e-02	14.29	1.43	<	10000	3.00e-02
CVU 156	18.64	3.00e-06	5.59e-05	3897.2	8.83e-03	24.66	3.00e-02	7.26	0.73	<	4200	1.26e-02
CVU 156	18.64	3.00e-06	5.59e-05	3114.8	8.83e-03	19.71	3.00e-02	5.81	0.58	Y	1100	3.30e-03
CVU 156	18.64	3.00e-06	5.59e-05	3114.8	8.83e-03	19.71	3.00e-02	5.81	0.58	Y	1987	5.96e-03
CVU 157	18.61	3.00e-06	5.58e-05	5328.5	8.83e-03	33.67	3.00e-02	9.92	0.99	Y	20700	6.21e-02
CVU 157	18.61	3.00e-06	5.58e-05	4127.0	8.83e-03	26.08	3.00e-02	7.68	0.77	<	3137	9.41e-03
NVAWU 17	35.30	3.00e-06	1.05e-04	767.2	9.38e-03	8.65	3.00e-02	2.71	0.27	Y	4400	1.32e-02
VGSAU 15	18.18	3.00e-06	5.45e-05	1482.0	8.74e-03	9.25	3.00e-02	2.69	0.27	??	3670	1.10e-02
VGSAU 17	17.78	3.00e-06	5.33e-05	4194.6	8.68e-03	25.77	3.00e-02	7.46	0.75	<	4810	1.44e-02
VGSAU 33	18.53	3.00e-06	5.55e-05	11298.2	8.75e-03	71.69	3.00e-02	20.93	2.09	??	577000	1.73e+00
VGSAU 35	18.41	3.00e-06	5.52e-05	5416.1	8.83e-03	33.86	3.00e-02	9.97	1.00	<	20700	6.21e-02
VGSAU 49	18.41	3.00e-06	5.52e-05	15961.6	8.83e-03	99.79	3.00e-02	29.39	2.94	Y	114600	3.43e-01
VGSAU 49	18.24	3.00e-06	5.47e-05	15634.2	9.19e-03	93.01	3.00e-02	28.51	2.85	Y	135300	4.05e-01
VGSAU 49	18.24	3.00e-06	5.47e-05	10036.9	9.19e-03	59.71	3.00e-02	18.31	1.83	Y	95800	2.87e-01
WVU 23	98.02	3.00e-06	2.94e-04	267.8	4.76e-02	1.65	3.00e-02	2.63	0.26	<	2200	6.60e-03
WVU 48	99.73	3.00e-06	2.99e-04	306.4	4.74e-02	1.93	3.00e-02	3.06	0.31	??	1353000	4.05e+00

11/19/87	HORNER												MILLER-DYES-HUTCHINSON								
WELL	Pwf(t=0) (psi_)	P1hr (psi_	m (psi/ cyc)	P* (psi_	k (md)	S	Xf (ft)	TpDA	PDMBH	Pavg MBH (psi_)	tss 5 sp inj (hr)	tp/tss	P1hr (psi_	m (psi/ cyc)	P* (psi_	k (md)	S	Xf (ft)	del tDA @ 1hr	PDMDH con P sq bd	Pe MDH (psi_
CVU 15	2787.6	2730	345	910	1.21	-4.97	94	347.61	7.77	2074	149.33	1390	2760	355	872	1.18	-5.06	103	1.62e-03	2.19	2085
CVU 25	2876.2	2380	280	1275	2.58	-3.29	18	20.44	4.83	1862	107.13	82	2400	310	1178	2.33	-3.51	22	2.10e-03	2.06	1845
CVU 25					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 31	3206.3	3220	510	735	1.96	-5.31	133	151.25	6.93	2270	118.26	605	3220	510	744	1.96	-5.31	133	2.11e-03	2.06	2307
CVU 41	2922.9	2580	365	770	2.95	-4.40	54	272.09	7.52	1962	78.58	1088	2580	370	755	2.91	-4.41	54	3.13e-03	1.86	1982
CVU 41					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 57	2548.2	2050	190	1300	3.43	-2.57	9	34.63	5.45	1750	63.24	139	2055	195	1286	3.34	-2.67	9	3.85e-03	1.75	1759
CVU 57					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 58	2519.2	2317	242	1366	2.79	-4.48	58	25.48	5.15	1907	85.94	102	2330	247	1356	2.74	-4.55	62	2.85e-03	1.90	1922
CVU 58					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 60	3114.1	2605	415	675	6.15	-4.50	58	381.32	7.87	2093	34.25	1525	2680	460	510	5.55	-4.77	77	6.58e-03	1.50	2081
CVU 72	2308.2	1975	275	890	2.66	-4.03	37	24.74	5.12	1502	88.52	99	1980	280	876	2.62	-4.06	38	2.77e-03	1.91	1515
CVU 72					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 73	2364.2				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 73					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 81	2532.4				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 82	1658.0				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 100	3069.2	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 113	2868.2	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 113					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 113					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 120	3034.2	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 120	3074.8	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 120					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 122	2584.9	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 134	2936.2	2980	228	2084	0.90	-4.85	83	5.00	3.52	2433	437.71	20	2980	228	2081	0.90	-4.85	83	5.71e-04	2.71	2443
CVU 134					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 135	2882.2	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 135					??	??		0.00		??	??	??			??	??	??		0.00		??
CVU 138	2683.2	2400	368	648	1.99	-4.28	47	96.04	6.48	1684	148.21	384	2405	370	645	1.98	-4.30	48	1.67e-03	2.18	1704
CVU 140	2521.8				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 141	2589.6				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 144	2789.5	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 145	3266.2	2850	427	1566	2.82	-4.34	50	8.06	3.87	2284	82.08	32	2850	427	1388	2.82	-4.34	50	3.04e-03	1.87	2156
CVU 156	2940.2				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 156	2940.2				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 156	2940.2				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 157	3037.2				??	??		0.00		0	??	??			0	??	??		0.00		0
CVU 157	2940.2				??	??		0.00		0	??	??			0	??	??		0.00		0
NVAWU 17	6792.6	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
VGSAU 15	3528.0	3630	635	795	0.80	-4.74	75	13.99	4.55	2050	499.29	56	3590	615	856	0.83	-4.69	71	5.16e-04	2.76	2116
VGSAU 17	3649.6	3835	687	719	1.20	-5.00	97	207.94	7.28	2891	386.24	832	3800	675	83	1.22	-4.95	93	6.58e-04	2.63	2258
VGSAU 33	3605.6	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
VGSAU 35	3435.2	3280	103	2770	11.11	-4.14	41	552.71	8.24	3139	36.07	2211	3280	108	2751	10.59	-4.19	43	6.61e-03	1.50	3139
VGSAU 49	3305.2	3620	830	-565	4.06	-5.81	218	262.44	7.48	2131	98.63	1050	3670	830	-493	4.06	-5.87	234	2.53e-03	1.97	2250
VGSAU 49	3374.8	3780	875	-615	3.74	-5.86	230	257.47	7.47	2224	107.16	1030	3825	880	-613	3.72	-5.91	243	2.31e-03	2.03	2273
VGSAU 49					??	??		0.00		??	??	??			??	??	??		0.00		??
WVU 23	3852.9	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0
WVU 48	2892.5	NO SEMILOG			??	??		0.00		0	??	??			0	??	??		0.00		0

11/19/87	LINEAR FLOW		BILINEAR FLOW	
WELL	m (psi/ hr**1/2)	Xf (ft)	m (psi/ hr**1/4)	kf*bf (md ft)
CVU 15	100	205	200	30
CVU 25		??	320	??
CVU 25		??		??
CVU 31	192	176		??
CVU 41		??	448	??
CVU 41		??		??
CVU 57		??	470	??
CVU 57		??		??
CVU 58		??	330	??
CVU 58		??		??
CVU 60		??	635	??
CVU 72		??	428	??
CVU 72		??		??
CVU 73		??		??
CVU 73		??		??
CVU 81		??		??
CVU 82		??		??
CVU 100	130	??		??
CVU 113		??		??
CVU 113		??		??
CVU 113		??		??
CVU 120		??		??
CVU 120		??		??
CVU 120		??		??
CVU 122		??		??
CVU 134	52	151		??
CVU 134		??		??
CVU 135	75	??	100	??
CVU 135		??		??
CVU 138		??	500	??
CVU 140		??		??
CVU 141		??		??
CVU 144		??	252	??
CVU 145		??	580	??
CVU 156		??		??
CVU 156		??		??
CVU 156		??		??
CVU 157		??		??
CVU 157		??		??
NVAWU 17	252	??		??
VGSAU 15	160	127	166	56
VGSAU 17	242	103		??
VGSAU 33		??		??
VGSAU 35		??		??
VGSAU 49	200	301		??
VGSAU 49	187	326		??
VGSAU 49		??		??
WVU 23	54	??	58	??
WVU 48		??		??

VACUUM FIELD WATERFLOW PROBLEM

FALL-OFF TESTS

11/19/87

SUMMARY OF TEST ANALYSIS

CVU 15 DATE: 870320 TYPE: S&L AMERADA Q = 109 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 7, 8

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.56e-03									8.21e-04
Vwb (bbl)	< 520									274
k (md)		1.21	1.18						0.81	
s		-4.98	-5.07						-5.54	
Pavg (psi)		2074	2085							
Xf (ft)		95	104	205					246	
kfbf (md-ft)					5.70e+02				6.22e+02	
Delta T (match)									6.1	0.311
Delta P (match)									14.37	1.72
Type Curve X (match)									1.0	100
Type Curve Y (match)									0.1	0.1
Type Curve Z (match)									3.1416	0.5

CVU 25 DATE: 861026 TYPE: AMERADA Q = 887 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 9

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 2.13e-02					6.04e-04				1.61e-03
Vwb (bbl)	< 7130					201				538
k (md)		2.58	2.33			2.56			2.35	
s		-3.29	-3.51			-3.31			-3.40	
Pavg (psi)		1862	1845							
Xf (ft)		18	22			18			38	
kfbf (md-ft)					YES				1.39e+02	
Delta T (match)						0.40			3.13	2
Delta P (match)						24.5			17	4.58
Type Curve X (match)						100			10	1000
Type Curve Y (match)						0.1			0.1	0.1
Type Curve Z (match)						0.1			3.1416/2	0

CVU 25A DATE: 870917 TYPE: S AM/SMP Q = 174 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 10, 11

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 6.00e-03					6.04e-04				
Vwb (bbl)	<200					201				
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

11/19/87

CVU 31 DATE: 870309 TYPE: S&L AMERADA Q = 600 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 12, 13

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.70e-02						5.44e-04			
Vwb (bbl)	< 5680						182			
k (md)		1.96	1.96				1.89		1.87	
s		-5.31	-5.31				-5.31		-5.37	
Pavg (psi)		2270	2307							
Xf (ft)		133	133	176			133		148	
kfbf (md-ft)									8.69e+04	
Delta T (match)							0.10		1.27	
Delta P (match)							4.6		14.8	
Type Curve X (match)							0.01		10000	
Type Curve Y (match)							0.01		10	
Type Curve Z (match)							0.001		100*3.1416	

CVU 41 DATE: 870315 TYPE: S&L AMERADA Q = 763 BPD CONCLUSION: LOW STORAGE

FIG 14, 15

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	M 1.03e-02									4.08e-02
Vwb (bbl)	M 3450									2426
k (md)		2.95	2.91						3.50	
s		-4.42	-4.43						-4.41	
Pavg (psi)		1962	1982							
Xf (ft)		55	55						57	
kfbf (md-ft)					YES				6.26e+04	
Delta T (match)									10	8.7
Delta P (match)									10.04	3.8
Type Curve X (match)									1000000	1000
Type Curve Y (match)									10	0.1
Type Curve Z (match)									100*3.1416	5

CVU 41A DATE: 870917 TYPE: SMP Q = 940 BPD CONCLUSION: LOW STORAGE

FIG 16

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 9.39e-03									
Vwb (bbl)	< 3130									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

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CVU 57 DATE: 861020 TYPE: AMERADA Q = 764 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 17

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.83e-02					2.55e-03				
Vwb (bbl)	< 6130					849				
k (md)		3.43	3.34			3.77			3.34	
s		-2.57	-2.67			-2.48			-2.72	
Pavg (psi)		1750	1759							
Xf (ft)		9	9			8			10	
kfbf (md-ft)					YES				2.17e+03	
Delta T (match)						1.2			81	
Delta P (match)						15			27	
Type Curve X (match)						100			1.00e+07	
Type Curve Y (match)						0.1			10	
Type Curve Z (match)						3			20*3.1416	

CVU 57A DATE: 870921 TYPE: S&L AMERADA Q = 966 BPD CONCLUSION: LOW STORAGE

FIG 18, 19

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.19e-02									
Vwb (bbl)	< 3980									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 58 DATE: 861020 TYPE: AMERADA Q = 905 BPD CONCLUSION: MEDIUM STORAGE

FIG 20

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	M 4.65e-02									2.82e-02
Vwb (bbl)	M 15500									9410
k (md)		2.79	2.74				2.47		2.49	
s		-4.48	-4.55				-4.44		-4.64	
Pavg (psi)		1907	1922							
Xf (ft)		58	62				56		68	
kfbf (md-ft)					YES				5.28e+04	
Delta T (match)							13.8		20.5	0.265
Delta P (match)							2.38		7.5	3.54
Type Curve X (match)							10		1000000	10
Type Curve Y (match)							0.01		10	0.1
Type Curve Z (match)							0.05		100*3.1416	2.5

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CVU 58A DATE: 870917 TYPE: S&L AM/SMP Q = 861 BPD CONCLUSION: MEDIUM STORAGE

FIG 21, 22, 23

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	1.95e-02									
Vwb (bbl)	6500									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 60 DATE: 870314 TYPE: S&L AMERADA Q = 997 BPD CONCLUSION: MEDIUM STORAGE

FIG 24, 25

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	1.98e-02									1.39e-02
Vwb (bbl)	6610									4645
k (md)		6.15	5.55						3.77	
s		-4.49	-4.76						-5.21	
Pavg (psi)		2093	2081							
Xf (ft)		58	76						120	
kfbf (md-ft)					YES				1.42e+05	
Delta T (match)									37.5	0.265
Delta P (match)									1.87	7.9
Type Curve X (match)									1.0e+06	10
Type Curve Y (match)									1	0.1
Type Curve Z (match)									100*3.1416	0

CVU 72 DATE: 861020 TYPE: AMERADA Q = 1071 BP CONCLUSION: MEDIUM STORAGE

FIG 26

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 4.72E-02									
Vwb (bbl)	< 15750									
k (md)		2.66	2.62				2.87		2.25	
s		-4.03	-4.06				-4.12		-4.26	
Pavg (psi)		1502	1515							
Xf (ft)		37	38				40		46	
kfbf (md-ft)					YES				3.28e+04	
Delta T (match)							6.1		1.05	
Delta P (match)							2.22		9	
Type Curve X (match)							10		1.0e+05	
Type Curve Y (match)							0.01		10	
Type Curve Z (match)									100*3.1416	

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CVU 72A DATE: 870906 TYPE: S&L AMERADA Q = 654 BPD CONCLUSION: BAD TEST

FIG 27, 28

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)										
k (md)										
S										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 73 DATE: 861020 TYPE: AMERADA Q = 1340 BP CONCLUSION: LOW STORAGE

FIG 29

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 5.95e-02					6.98e-03				
Vwb (bbl)	<19840					2328				
k (md)										
S										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)						0.306				
Delta P (match)						26.95				
Type Curve X (match)						10				
Type Curve Y (match)						0.1				
Type Curve Z (match)						0.1				

CVU 73A DATE: 870902 TYPE: S&L AMERADA Q = 1296 BP CONCLUSION: MEDIUM STORAGE

FIG 30, 31

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	2.13e-02									
Vwb (bbl)	7120									
k (md)										
S										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

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CVU 81 DATE: 861110 TYPE: PANEX Q = 1280 BP CONCLUSION: HIGH STORAGE

FIG 32

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	6.88e-02									
Vwb (bbl)	22960									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 82 DATE: 861121 TYPE: AMERADA Q = 1373 BP CONCLUSION: BAD TEST

FIG 33

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)										
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 100 DATE: 861008 TYPE: AMERADA Q = 454 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 34

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 3.48E-02						0.00			
Vwb (bbl)	< 11630						0			
k (md)							0.66		0.97	
s							-5.43		-5.71	
Pavg (psi)										
Xf (ft)				YES			151		206	
kfbf (md-ft)									2.20e+04	
Delta T (match)							40		0.42	
Delta P (match)							6.9		4.25	
Type Curve X (match)							1		100	
Type Curve Y (match)							0.01		1	
Type Curve Z (match)							0		35*3.1416	

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	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS

CVU 113 DATE: 861023 TYPE: AMERADA Q = 21 BPD CONCLUSION: HIGH STORAGE

FIG 35

C (bbl/psi)	9.00e-02
Vwb (bbl)	30000
k (md)	
S	
Pavg (psi)	
Xf (ft)	
kfbf (md-ft)	
Delta T (match)	
Delta P (match)	
Type Curve X (match)	
Type Curve Y (match)	
Type Curve Z (match)	

CVU 113A DATE: 870917 TYPE: SMP Q = 21 BPD CONCLUSION: BAD TEST

FIG 36

C (bbl/psi)	
Vwb (bbl)	
k (md)	
S	
Pavg (psi)	
Xf (ft)	
kfbf (md-ft)	
Delta T (match)	
Delta P (match)	
Type Curve X (match)	
Type Curve Y (match)	
Type Curve Z (match)	

CVU 113B DATE: 870922 TYPE: S&L AMERADA Q = 21 BPD CONCLUSION: LOW STORAGE

FIG 37, 38

C (bbl/psi)	3.99e-03
Vwb (bbl)	1330
k (md)	
S	
Pavg (psi)	
Xf (ft)	
kfbf (md-ft)	
Delta T (match)	
Delta P (match)	
Type Curve X (match)	
Type Curve Y (match)	
Type Curve Z (match)	

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	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS

CVU 120 DATE: 861023 TYPE: AMERADA Q = 48 BPD CONCLUSION: HIGH STORAGE

FIG 39

C	(bbl/psi)	1.73e-01
Vwb	(bbl)	57700
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T	(match)	
Delta P	(match)	
Type Curve X	(match)	
Type Curve Y	(match)	
Type Curve Z	(match)	

CVU 120A DATE: 870325 TYPE: S&L AMERADA Q = 183 BPD CONCLUSION: BAD TEST

FIG 40, 41

C	(bbl/psi)	?? 3.00E00
Vwb	(bbl)	?? 1000000
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T	(match)	
Delta P	(match)	
Type Curve X	(match)	
Type Curve Y	(match)	
Type Curve Z	(match)	

CVU 120B DATE: 870916 TYPE: S&L AM/SMP Q = 86 BPD CONCLUSION: LOW STORAGE

FIG 42, 43, 44

C	(bbl/psi)	< 1.02e-02
Vwb	(bbl)	< 3400
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T	(match)	
Delta P	(match)	
Type Curve X	(match)	
Type Curve Y	(match)	
Type Curve Z	(match)	

CVU 122 DATE: 870325 TYPE: S&L AMERADA Q = 19 BPD CONCLUSION: BAD TEST

FIG 45, 46

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)										
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 134 DATE: 861023 TYPE: AMERADA Q = 97 BPD CONCLUSION: LOW STORAGE

FIG 47

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.58E-02						< 1.27E-02			
Vwb (bbl)	< 5270						< 4233			
k (md)		0.90	0.90				0.95		0.89	
s		-4.85	-4.85				-4.79		-4.91	
Pavg (psi)		2433	2443							
Xf (ft)		83	83	151			79		91	
kfbf (md-ft)									1.26e+04	
Delta T (match)							11.8		6.8	
Delta P (match)							1.88		1.28	
Type Curve X (match)							1		1.0e+04	
Type Curve Y (match)							0.01		1	
Type Curve Z (match)							>0.05		50*3.1416	

CVU 134A DATE: 870903 TYPE: S&L AMERADA Q = 524 BPD CONCLUSION: BAD TEST

FIG 48, 49

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)										
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

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CVU 135 DATE: 861023 TYPE: AMERADA Q = 103 BPD CONCLUSION: LOW STORAGE

FIG 50

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.18E-02									
Vwb (bbl)	<3960									
k (md)									0.24	
s									-3.11	
Pavg (psi)										
Xf (ft)				YES					15	
kfbf (md-ft)					YES				1.11e+03	
Delta T (match)									22.8	
Delta P (match)									9.3	
Type Curve X (match)									1.0e+05	
Type Curve Y (match)									10	
Type Curve Z (match)									100*3.1416	

CVU 135A DATE: 870907 TYPE: S&L AMERADA Q = 339 BPD CONCLUSION: BAD TEST

FIG 51, 52

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)										
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 138 DATE: 861009 TYPE: AMERADA Q = 1070 BP CONCLUSION: LOW STORAGE

FIG 53

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 5.49e-02						3.04e-03			
Vwb (bbl)	< 18300						1015			
k (md)		1.99	1.98				1.45		1.23	
s		-4.28	-4.30				-4.46		-4.77	
Pavg (psi)		1684	1704							
Xf (ft)		47	48				57		77	
kfbf (md-ft)					YES				2.97e+04	
Delta T (match)							0.3		6.6	
Delta P (match)							4.4		1.65	
Type Curve X (match)							0.1		1.0e+05	
Type Curve Y (match)							0.01		1	
Type Curve Z (match)							0.01		100*3.1416	

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CVU 140 DATE: 861119 TYPE: PANEX Q = 1127 BP CONCLUSION: LOW STORAGE

FIG 54

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 4.13e-03									
Vwb (bbl)	< 1377									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 141 DATE: 861110 TYPE: PANEX Q = 1127 BP CONCLUSION: HIGH STORAGE

FIG 55

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	3.19e-02									
Vwb (bbl)	10664									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 144 DATE: 870320 TYPE: S&L AMERADA Q = 277 BPD CONCLUSION: LOW STORAGE

FIG 56, 57

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	9.30e-03						< 2.24e-04			2.56e-03
Vwb (bbl)	3100						< 75			855
k (md)							1.72		1.51	
s							-3.88		-4.21	
Pavg (psi)										
Xf (ft)							32		44	
kfbf (md-ft)					YES				2.10e+04	
Delta T (match)							0.6		12.6	0.05
Delta P (match)							1.55		5.6	2.25
Type Curve X (match)							1		1.0e+06	10
Type Curve Y (match)							0.01		10	.1
Type Curve Z (match)							<0.005		100*3.1416	0

CVU 145 DATE: 861009 TYPE: AMERADA Q = 1029 BP CONCLUSION: LOW STORAGE

FIG 58

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 3.00e-02						< 1.22e-03			
Vwb (bbl)	< 10000						< 409			
k (md)		2.82	2.82				2.65		2.22	
s		-4.34	-4.34				-4.39		-4.64	
Pavg (psi)		2284	2156							
Xf (ft)		50	50	270			53		68	
kfbf (md-ft)					1.89e+03				4.75e+04	
Delta T (match)							0.113		0.225	
Delta P (match)							3.95		1.5	
Type Curve X (match)							0.1		1.0e+04	
Type Curve Y (match)							0.01		1	
Type Curve Z (match)							<0.01		100*3.1416	

CVU 156 DATE: 861026 TYPE: AMERADA Q = 1029 BP CONCLUSION: LOW STORAGE

FIG 59

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.26e-02									
Vwb (bbl)	< 4200									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

CVU 156A DATE: 870902 TYPE: S&L AMERADA Q = 418 BPD CONCLUSION: LOW STORAGE

FIG 60, 61

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	3.30e-03									
Vwb (bbl)	1100									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS

CVU 156B DATE: 860916 TYPE: SMP Q = 418 BPD CONCLUSION: LOW STORAGE

FIG 62

C	(bbl/psi)	5.96e-03
Vwb	(bbl)	1987
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T (match)		
Delta P (match)		
Type Curve X (match)		
Type Curve Y (match)		
Type Curve Z (match)		

CVU 157 DATE: 861026 TYPE: AMERADA Q = 714 BPD CONCLUSION: HIGH STORAGE

FIG 63

C	(bbl/psi)	6.21e-02
Vwb	(bbl)	20700
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T (match)		
Delta P (match)		
Type Curve X (match)		
Type Curve Y (match)		
Type Curve Z (match)		

CVU 157A DATE: 860907 TYPE: S&L AMERADA Q = 553 BPD CONCLUSION: LOW STORAGE

FIG 64, 65

C	(bbl/psi)	< 9.41e-03
Vwb	(bbl)	< 3137
k	(md)	
S		
Pavg	(psi)	
Xf	(ft)	
kfbf	(md-ft)	
Delta T (match)		
Delta P (match)		
Type Curve X (match)		
Type Curve Y (match)		
Type Curve Z (match)		

11/19/87

NVAWU 17 DATE: 870324 TYPE: S&L AMERADA Q = 195 BPD CONCLUSION: LOW STORAGE

FIG 66, 67

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	1.32e-02						3.34e-03			
Vwb (bbl)	4400						1114			
k (md)							0.23			
s							-5.03			
Pavg (psi)										
Xf (ft)				YES			100			
kfbf (md-ft)										
Delta T (match)							18.3			
Delta P (match)							22			
Type Curve X (match)							0.1			
Type Curve Y (match)							0.01			
Type Curve Z (match)							0.005			

VGSAU 15 DATE: 870309 TYPE: S&L AMERADA Q = 194 BPD CONCLUSION: LOW STORAGE

FIG 68, 69

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	1.10e-02						1.03e-02			
Vwb (bbl)	3670						3425			
k (md)		0.80	0.83				0.73			
s		-4.74	-4.69				-4.78			
Pavg (psi)		2050	2116							
Xf (ft)		75	71	127			78			
kfbf (md-ft)					YES					
Delta T (match)							1.55			
Delta P (match)							6.1			
Type Curve X (match)							0.1			
Type Curve Y (match)							0.01			
Type Curve Z (match)							0.05			

VGSAU 17 DATE: 870320 TYPE: S&L AMERADA Q = 537 BPD CONCLUSION: INSIGNIFICANT STORAGE

FIG 70, 71

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 1.44e-02						0.00			
Vwb (bbl)	< 4810						0			
k (md)		1.20	1.22				1.10			
s		-4.98	-4.94				-5.08			
Pavg (psi)		2891	2258							
Xf (ft)		96	92	103			105			
kfbf (md-ft)										
Delta T (match)							2.13			
Delta P (match)							6.5			
Type Curve X (match)							0.1			
Type Curve Y (match)							0.01			
Type Curve Z (match)							0			

11/19/87

VGSAU 33 DATE: 870315 TYPE: S&L AMERADA Q = 1507 BP CONCLUSION: BAD TEST

FIG 72, 73

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)										
Vwb (bbl)	?? 577000									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

VGSAU 35 DATE: 861008 TYPE: AMERADA Q = 718 BPD CONCLUSION: LOW STORAGE

FIG 74

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 6.21e-02						7.45e-03			
Vwb (bbl)	< 20700						2485			
k (md)		11.10	10.59				9.46		9.04	
s		-4.14	-4.19				-4.67		-4.41	
Pavg (psi)		3169	3139							
Xf (ft)		41	43				70		54	
kfbf (md-ft)									1.53e+05	
Delta T (match)							0.46		6.7	
Delta P (match)							10.5		3.5	
Type Curve X (match)							1		1.0e+06	
Type Curve Y (match)							0.10		10	
Type Curve Z (match)							<0.025		100*3.1416	

VGSAU 49 DATE: 861008 TYPE: AMERADA Q = 2116 BP CONCLUSION: HIGH STORAGE

FIG 75

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	3.43e-01						2.52e-01			
Vwb (bbl)	114600						84305			
k (md)		4.06	4.06				3.29			
s		-5.81	-5.87				-5.93			
Pavg (psi)		2131	2250							
Xf (ft)		218	234	301			247			
kfbf (md-ft)										
Delta T (match)							3.4			
Delta P (match)							8.9			
Type Curve X (match)							0.1			
Type Curve Y (match)							0.01			
Type Curve Z (match)							0.075			

VGSAU 49A DATE: 870309 TYPE: S&L AMERADA Q = 2053 BP CONCLUSION: HIGH STORAGE

FIG 76, 77

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	4.05e+00						3.31e-01			
Vwb (bbl)	135300						110582			
k (md)		3.74	3.72				3.12			
s		-5.85	-5.91				-6.07			
Pavg (psi)		2224	2273							
Xf (ft)		229	241	326			283			
kfbf (md-ft)										
Delta T (match)							4.7			
Delta P (match)							9.1			
Type Curve X (match)							0.1			
Type Curve Y (match)							0.01			
Type Curve Z (match)							0.075			

VGSAU 49B DATE: 870916 TYPE: SMP Q = 1318 BP CONCLUSION: HIGH STORAGE

FIG 78

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	2.87e-01									
Vwb (bbl)	95800									
k (md)										
s										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

WVU 23 DATE: 870402 TYPE: S&L AMERADA Q = 189 BPD CONCLUSION: BAD TEST

FIG 79, 80

	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	< 6.60e-03									
Vwb (bbl)	< 2200									
k (md)									0.02	
s									-7.32	
Pavg (psi)										
Xf (ft)				YES					986	
kfbf (md-ft)					YES				6.50e+03	
Delta T (match)									4.6	
Delta P (match)									2.2	
Type Curve X (match)									10	
Type Curve Y (match)									0.1	
Type Curve Z (match)									100*3.1416	

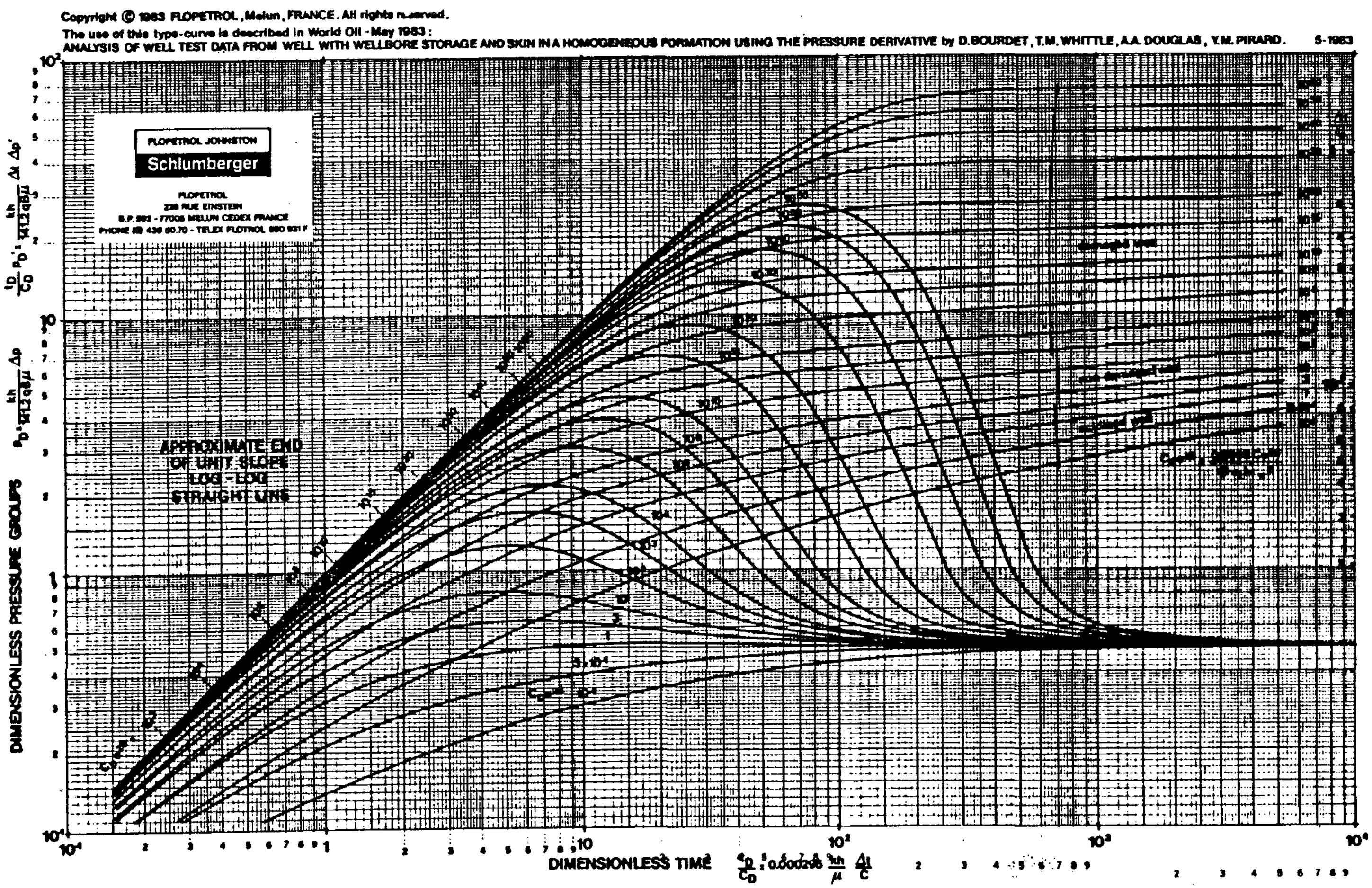
11/19/87

WVU 48 DATE: 870319 TYPE: S&L AMERADA Q = 220 BPD CONCLUSION: BAD TEST

FIG 81, 82

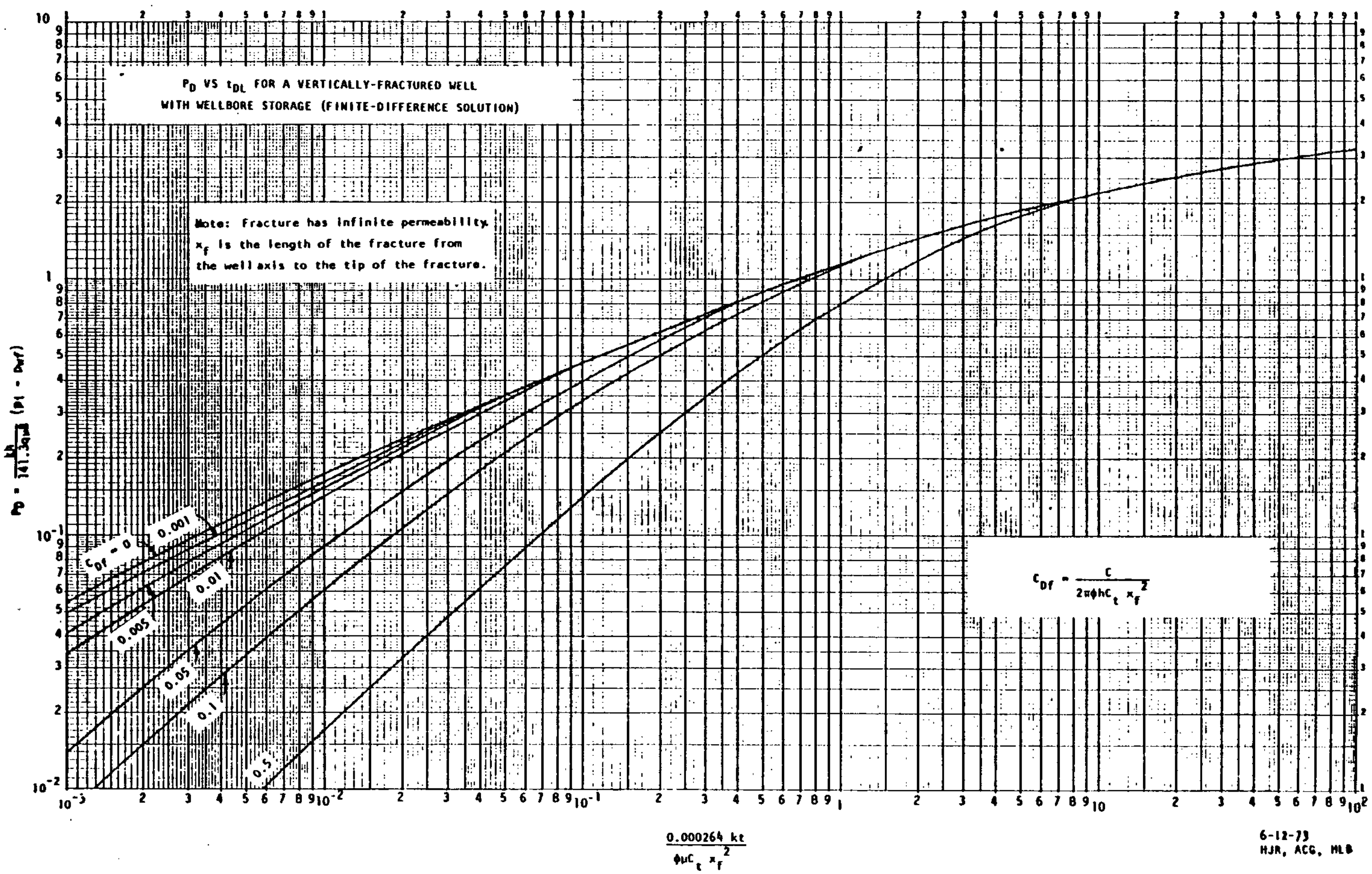
	Unit Slope	Horner	MDH	Sq Root	1/4 Root	WSS	VFWS(IP)	VFWS(UF)	FCVFWD	FCVFWSS
C (bbl/psi)	?? 4.05e00									
Vwb (bbl)	?? 135300									
k (md)										
S										
Pavg (psi)										
Xf (ft)										
kfbf (md-ft)										
Delta T (match)										
Delta P (match)										
Type Curve X (match)										
Type Curve Y (match)										
Type Curve Z (match)										

FIGURE 1



TYPE-CURVE FOR A WELL WITH WELLBORE STORAGE AND SKIN. RESERVOIR WITH HOMOGENEOUS BEHAVIOR
IN TERMS OF DIMENSIONLESS PRESSURE AND DIMENSIONLESS PRESSURE DERIVATIVE

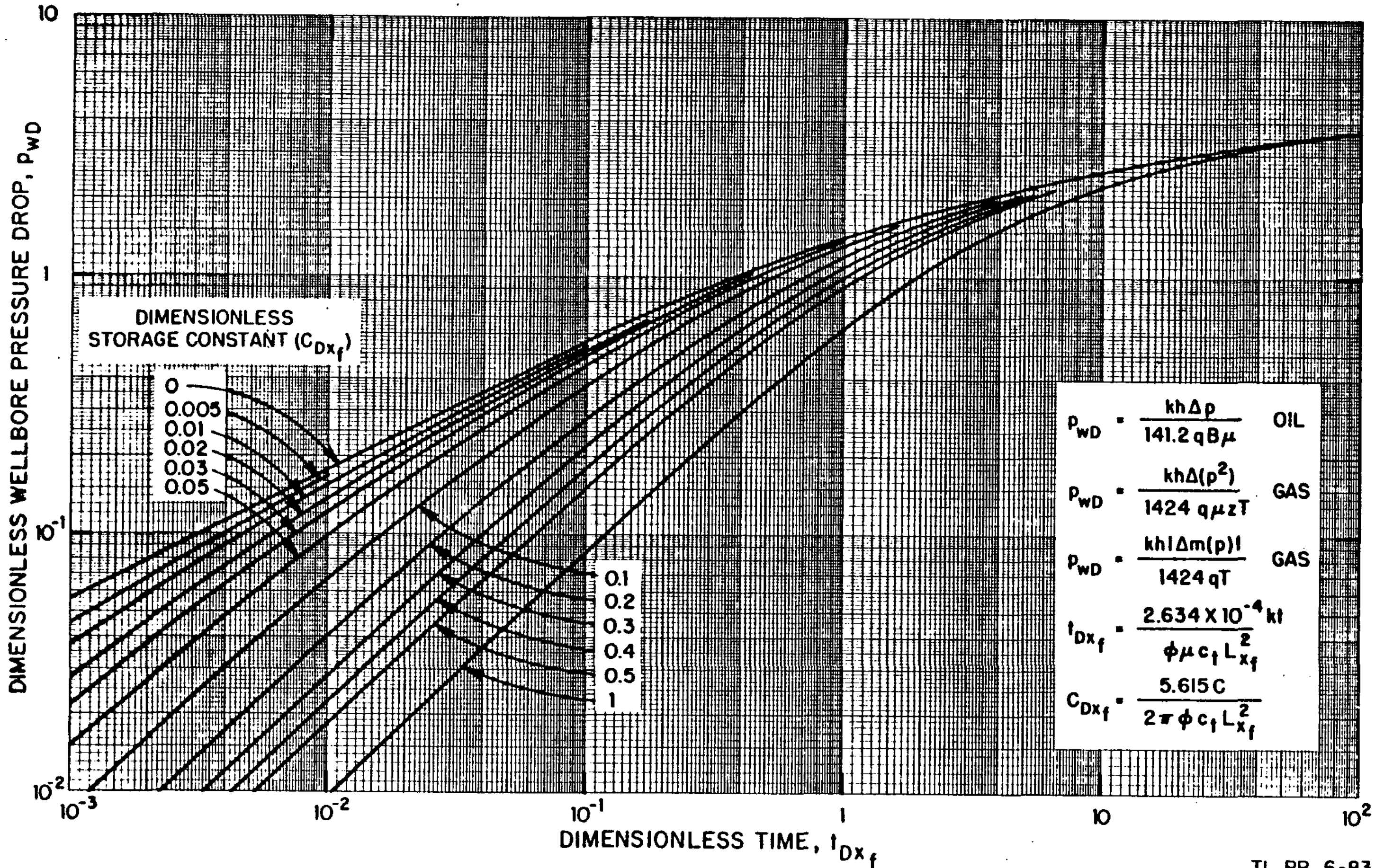
FIGURE 2



P_D VS t_{DL} FOR A VERTICALLY-FRACTURED WELL
WITH WELLBORE STORAGE (FINITE-DIFFERENCE SOLUTION)
Note: Fracture has infinite permeability.
x_f is the length of the fracture from
the well axis to the tip of the fracture.
$C_{Df} = \frac{C}{2\pi\phi h c_t x_f^2}$
$C_{Df} = 0$
0.001
0.005
0.01
0.05
0.1
0.5
$P_D = \frac{kh}{141.2 q \mu B}(p_i - p_{wf})$
$\frac{0.000264\ kt}{\phi \mu c_t x_f^2}$
6-12-73
HJR, ACG, MLB

FIGURE 3

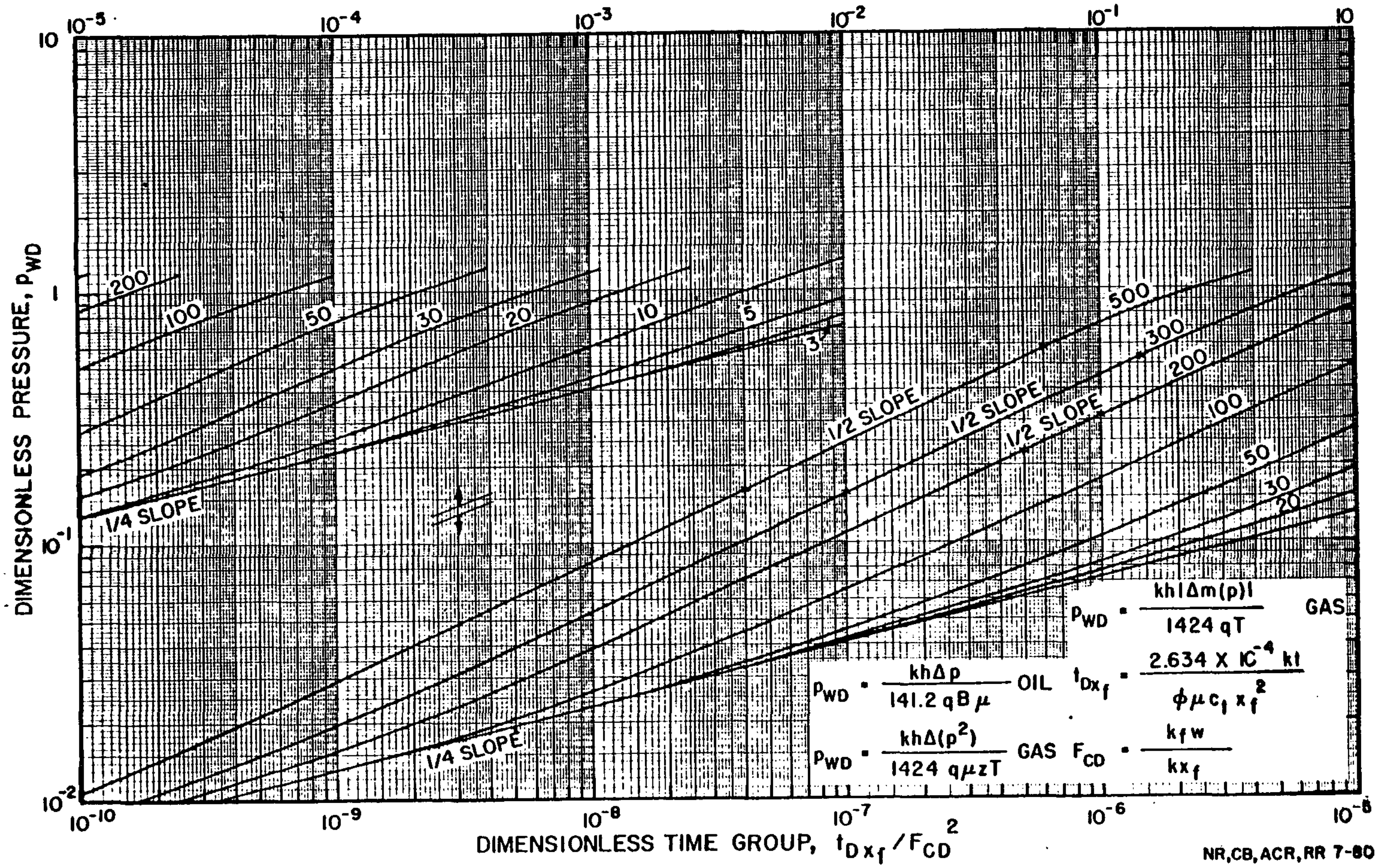
VERTICAL FRACTURE WITH STORAGE (UNIFORM-FLUX)



TL,RR, 6-83

FIGURE 4

FINITE CAPACITY VERTICAL FRACTURES - CONSTANT RATE



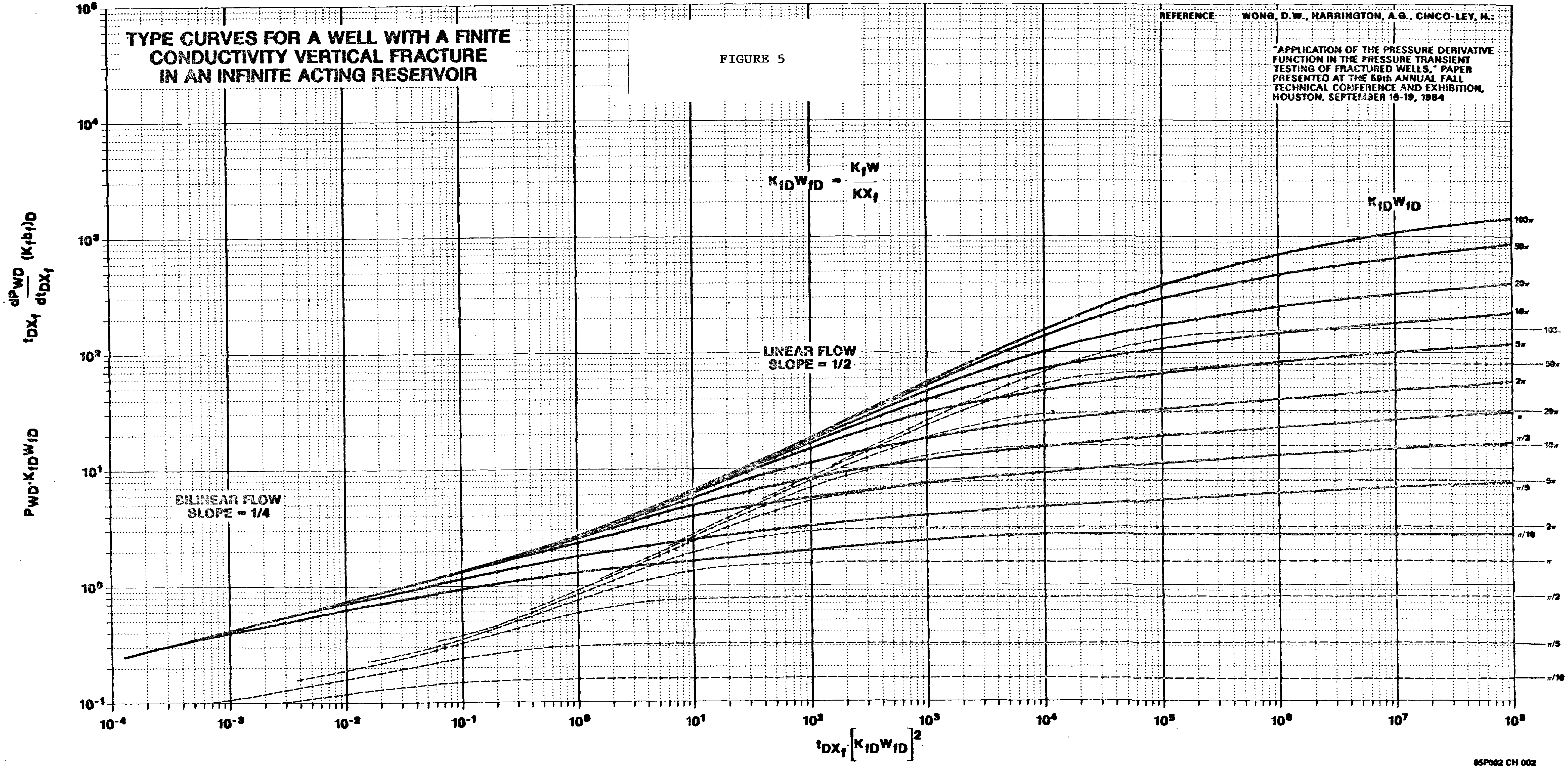
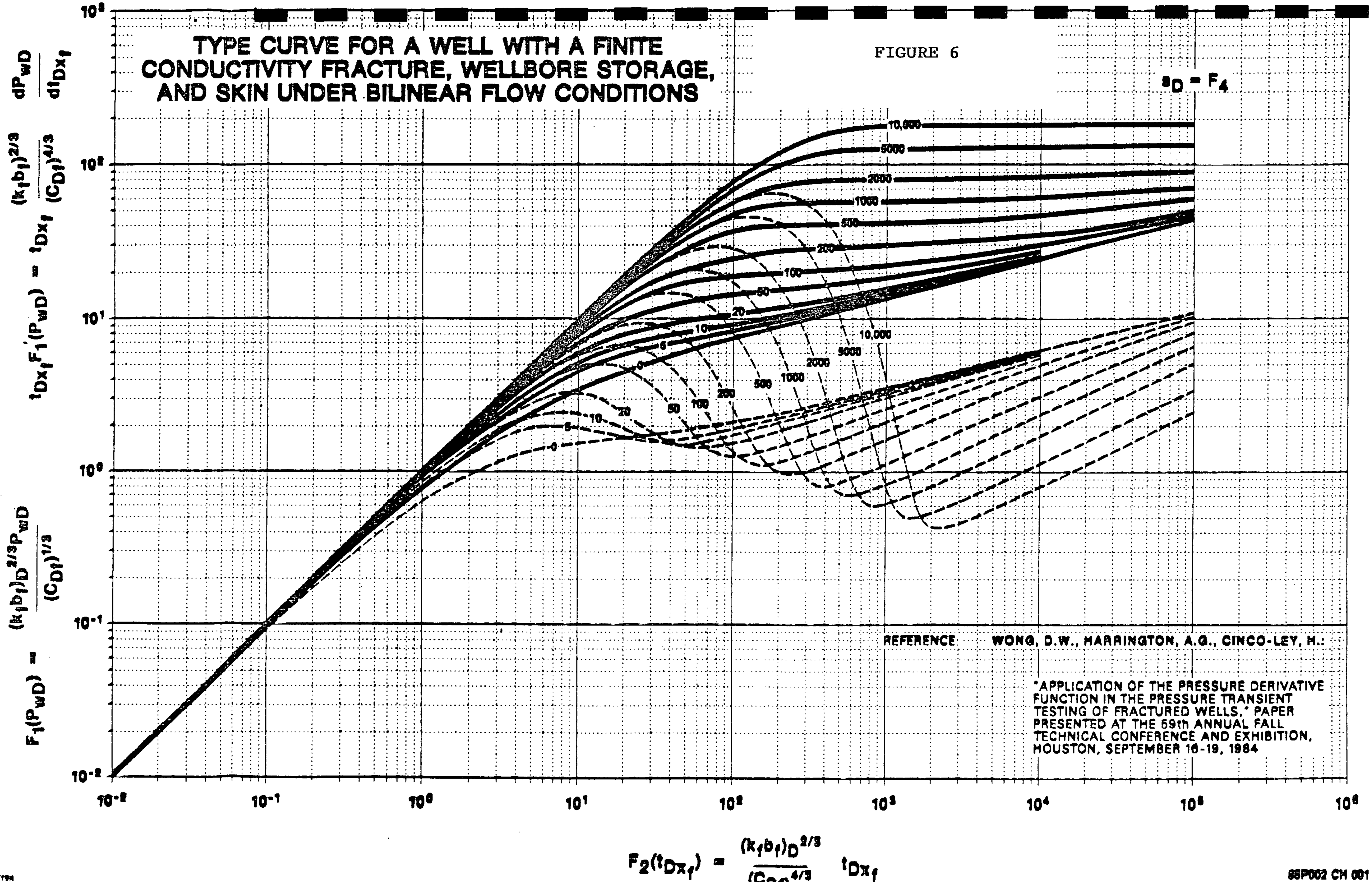

TYPE CURVES FOR A WELL WITH A FINITE CONDUCTIVITY VERTICAL FRACTURE IN AN INFINITE ACTING RESERVOIR
REFERENCE: WONG, D.W., HARRINGTON, A.G., CINCO-LEY, H.:
"APPLICATION OF THE PRESSURE DERIVATIVE FUNCTION IN THE PRESSURE TRANSIENT TESTING OF FRACTURED WELLS," PAPER PRESENTED AT THE 59th ANNUAL FALL TECHNICAL CONFERENCE AND EXHIBITION, HOUSTON, SEPTEMBER 16-19, 1984
$K_{fD}W_{fD} = \frac{K_fW}{KX_f}$
$K_{fD}W_{fD}$
LINEAR FLOW
SLOPE = 1/2
BILINEAR FLOW
SLOPE = 1/4
$t_{DX_f} \frac{dP_{WD}}{dt_{DX_f}} (K_fb_f)_D$
$P_{WD} \cdot K_{fD}W_{fD}$
$t_{DX_f} \cdot [K_{fD}W_{fD}]^2$
85P082 CH 002

FIGURE 5

FIGURE 6



TYPE CURVE FOR A WELL WITH A FINITE CONDUCTIVITY FRACTURE, WELLBORE STORAGE, AND SKIN UNDER BILINEAR FLOW CONDITIONS
$s_D = F_4$
$\frac{dP_{wD}}{dt_{Dx_f}}$
$t_{Dx_f} F_1'(P_{wD}) = t_{Dx_f} \frac{(k_f b_f)^{2/3}}{(C_{Df})^{4/3}}$
$F_1(P_{wD}) = \frac{(k_f b_f)_D^{2/3} P_{wD}}{(C_{Df})^{1/3}}$
$F_2(t_{Dx_f}) = \frac{(k_f b_f)_D^{2/3}}{(C_{Df})^{4/3}} t_{Dx_f}$
10,000
5000
2000
1000
500
200
100
50
20
10
5
0
REFERENCE WONG, D.W., HARRINGTON, A.G., CINCO-LEY, H.:
"APPLICATION OF THE PRESSURE DERIVATIVE FUNCTION IN THE PRESSURE TRANSIENT TESTING OF FRACTURED WELLS," PAPER PRESENTED AT THE 59th ANNUAL FALL TECHNICAL CONFERENCE AND EXHIBITION, HOUSTON, SEPTEMBER 16-19, 1984
88P002 CH 001

FIGURE 7

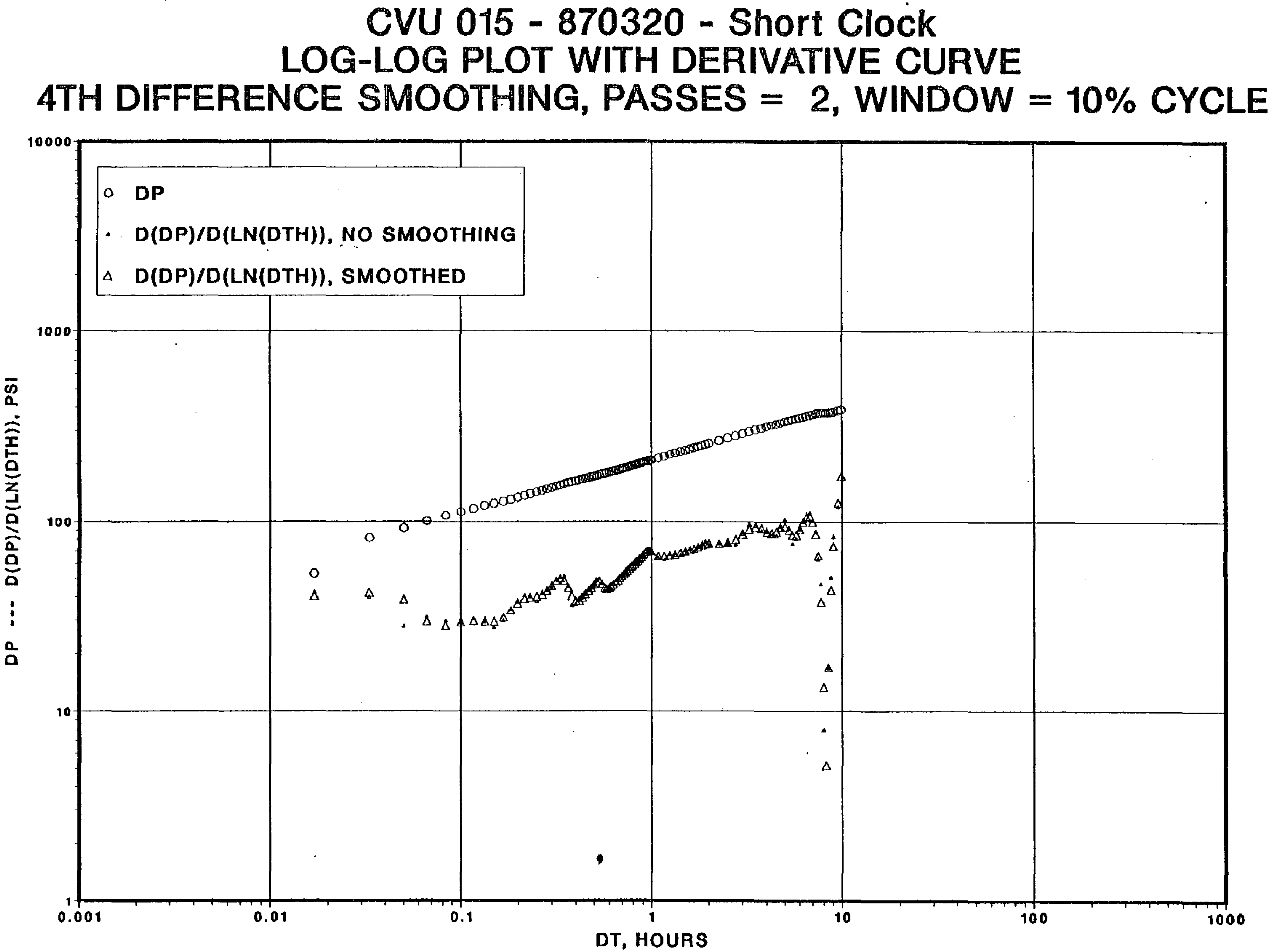

CVU 015 - 870320 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

FIGURE 8

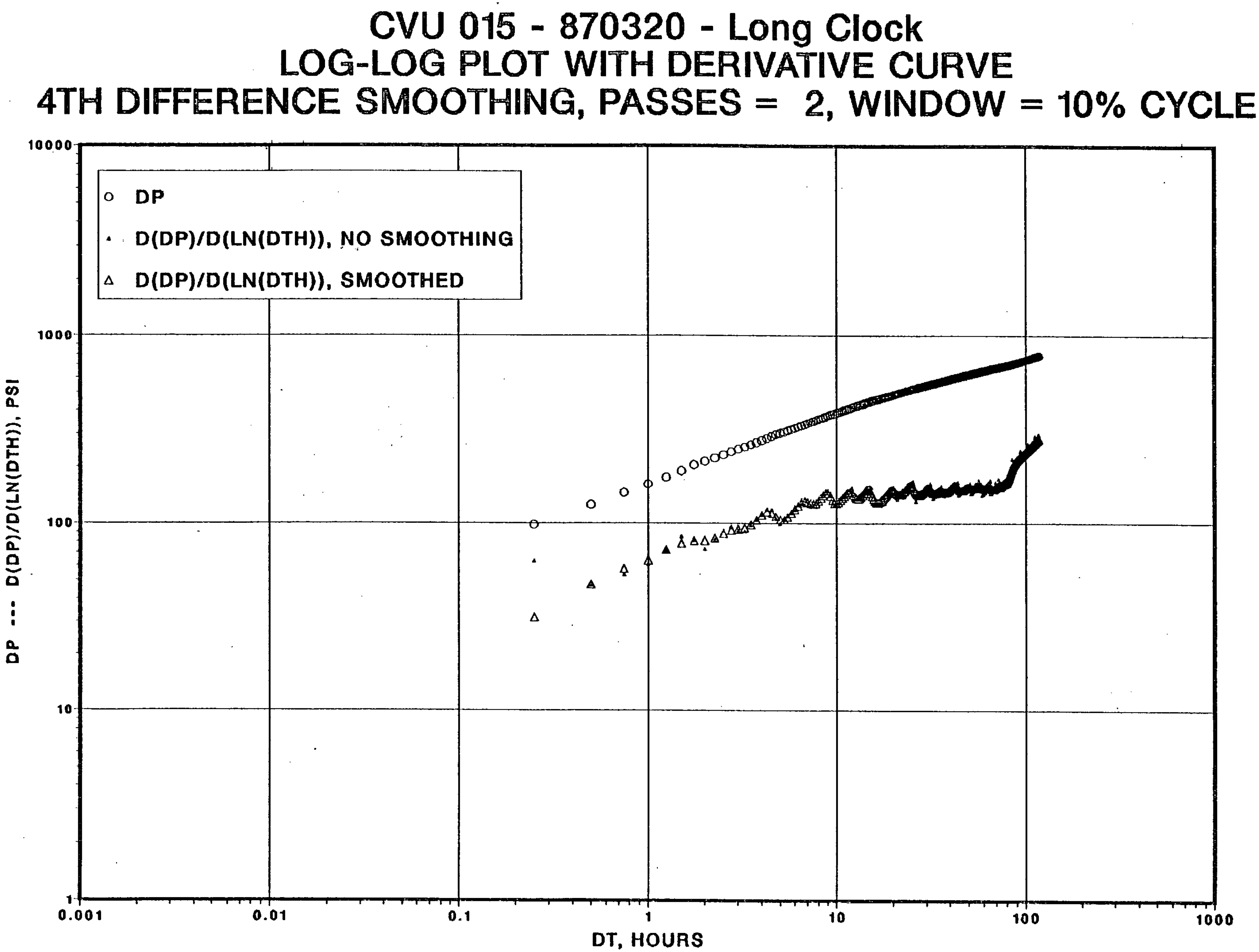

CVU 015 - 870320 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS
DP --- D(DP)/D(LN(DTH)), PSI

FIGURE 9

CVU 025 - 861026
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

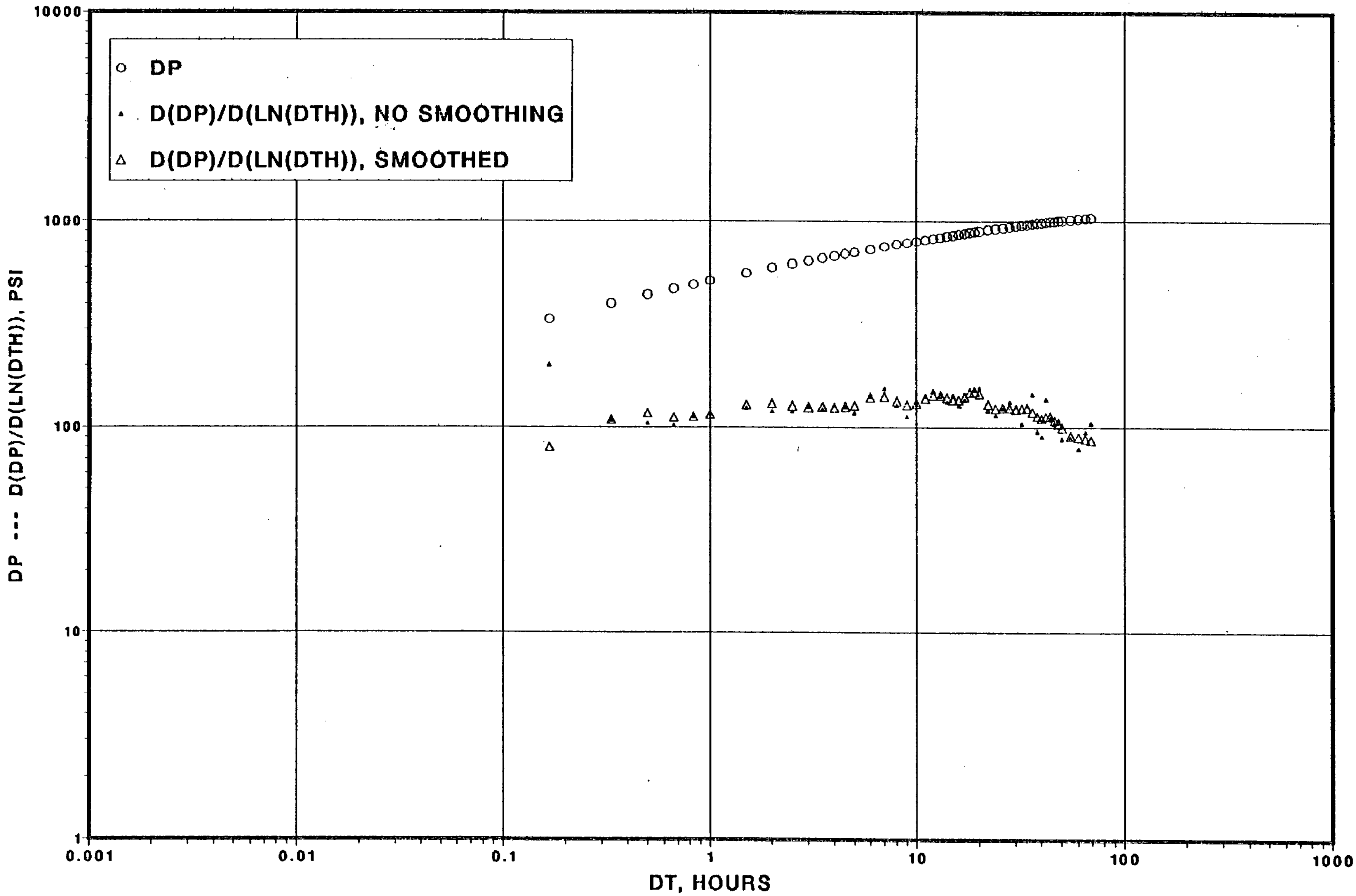
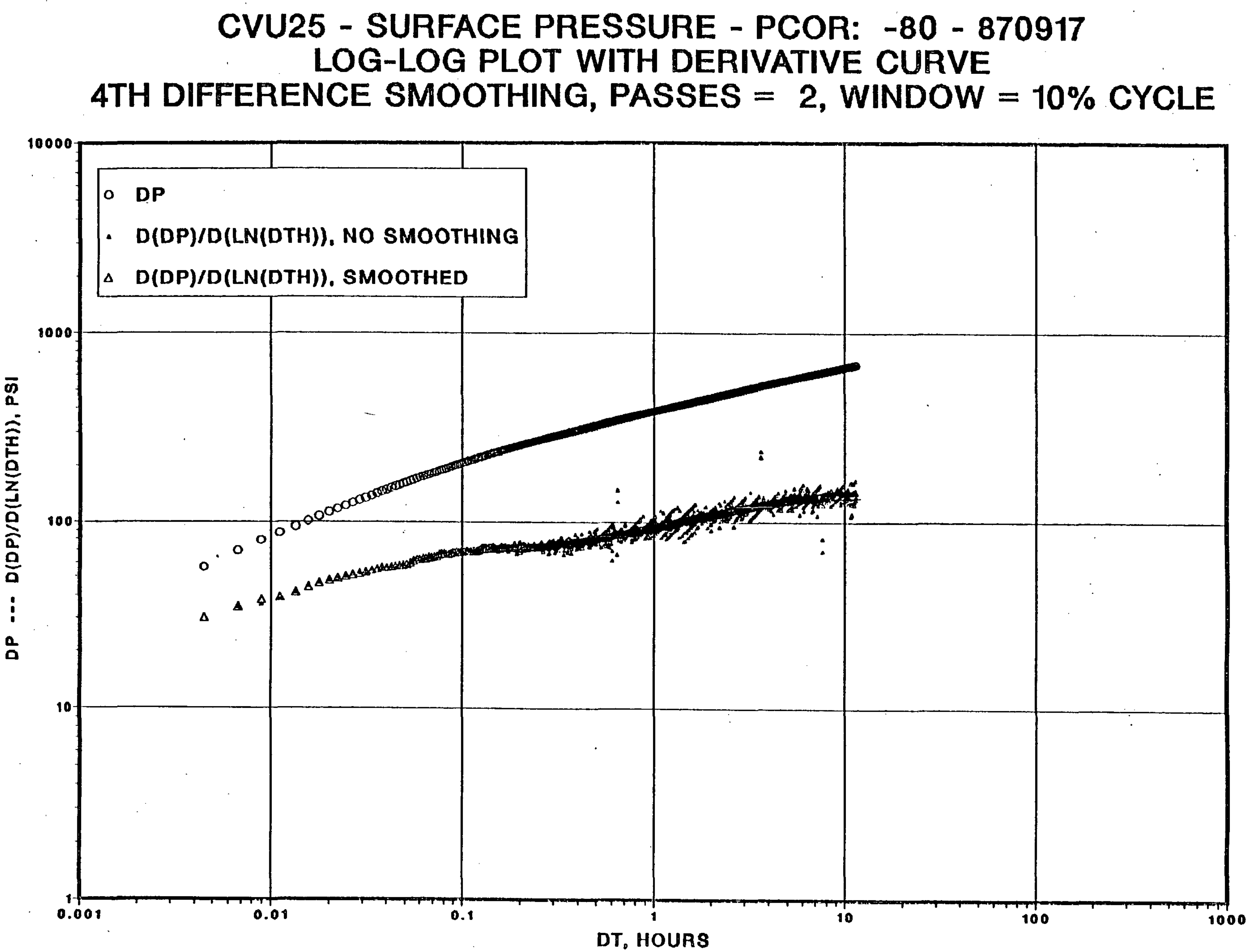


FIGURE 10



CVU25 - SURFACE PRESSURE - PCOR: -80 - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

FIGURE 11

CVU 025 - Short Clock - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

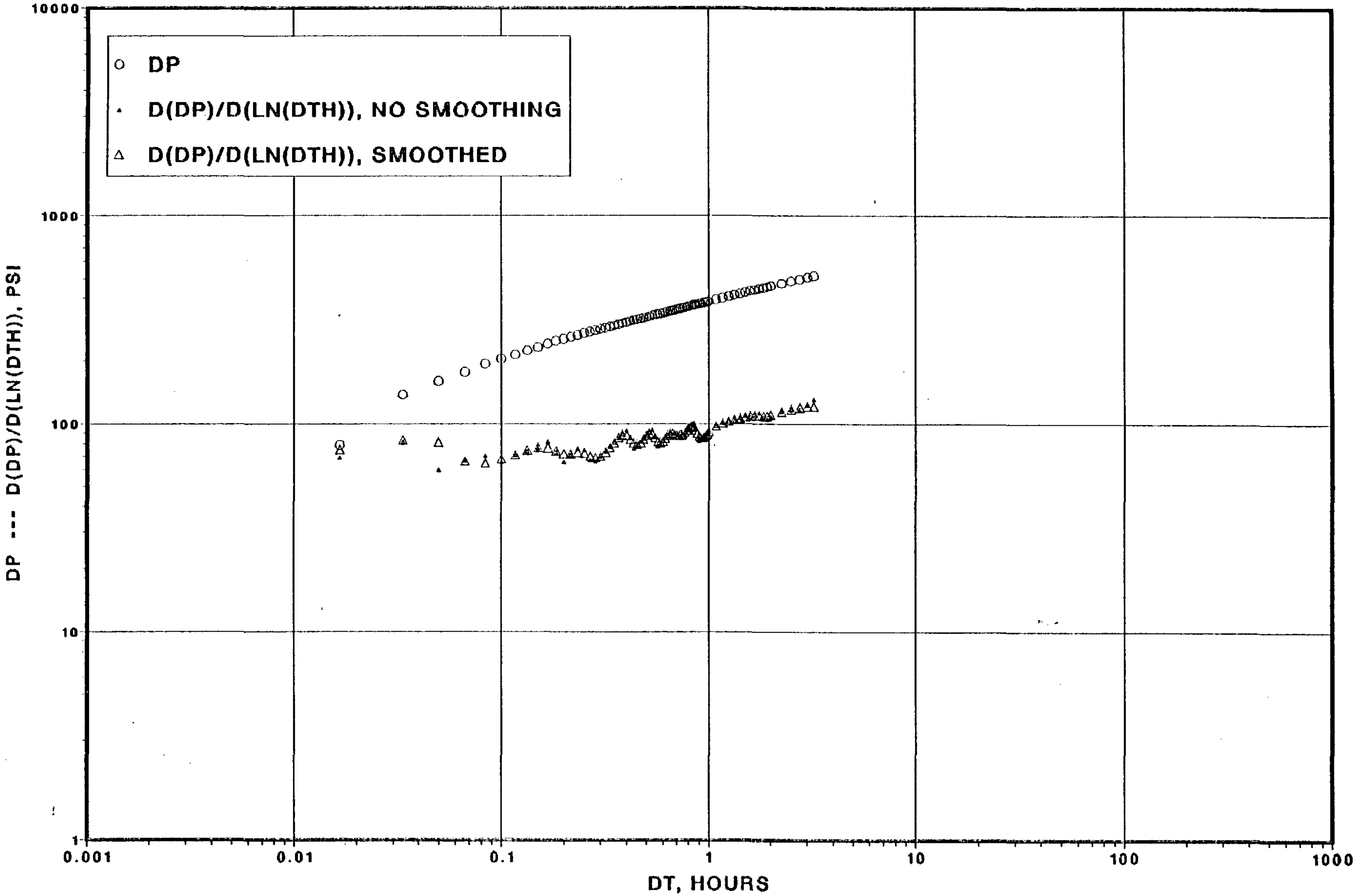


FIGURE 12

CVU 031 - 870320 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

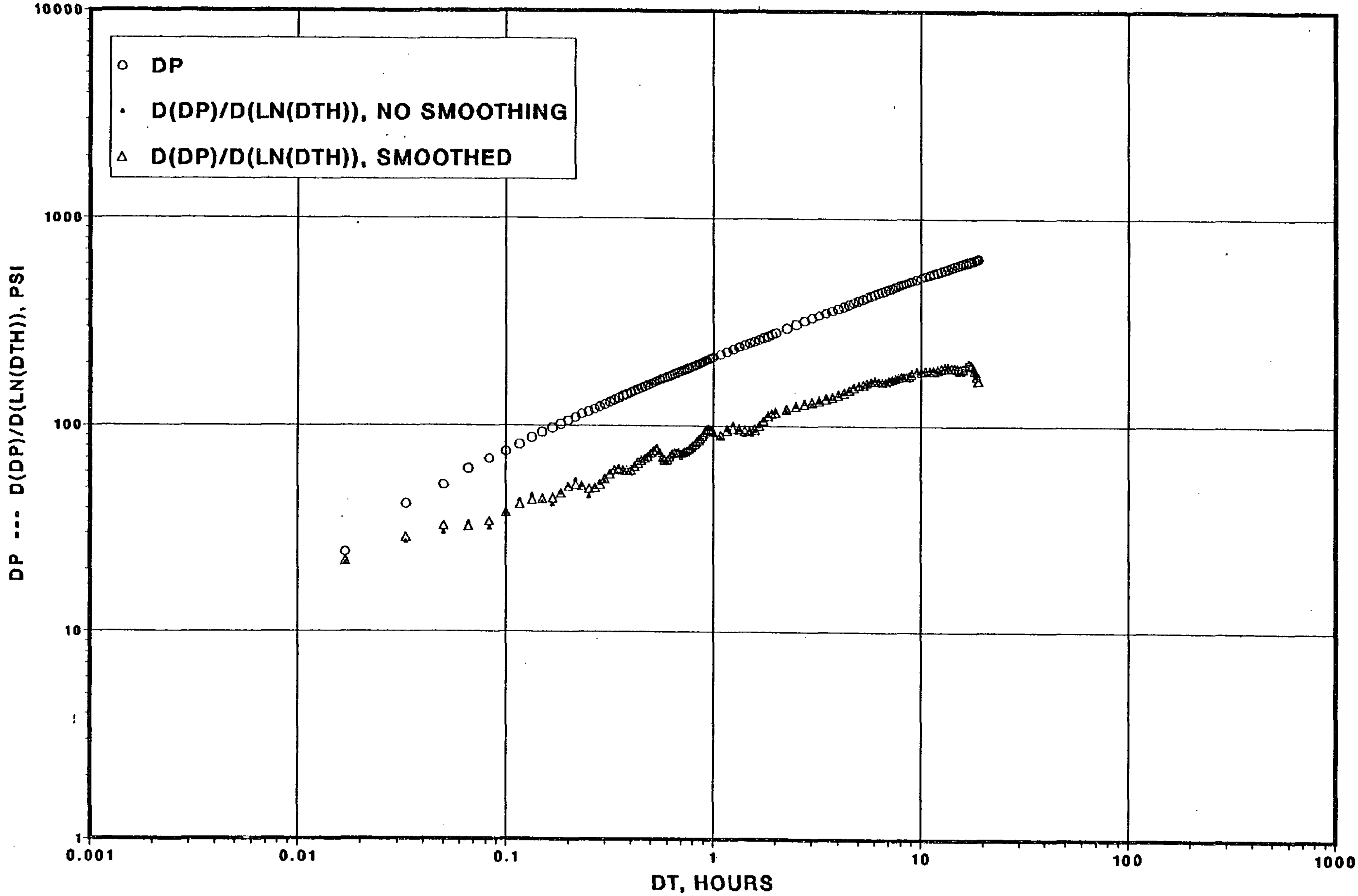


FIGURE 13

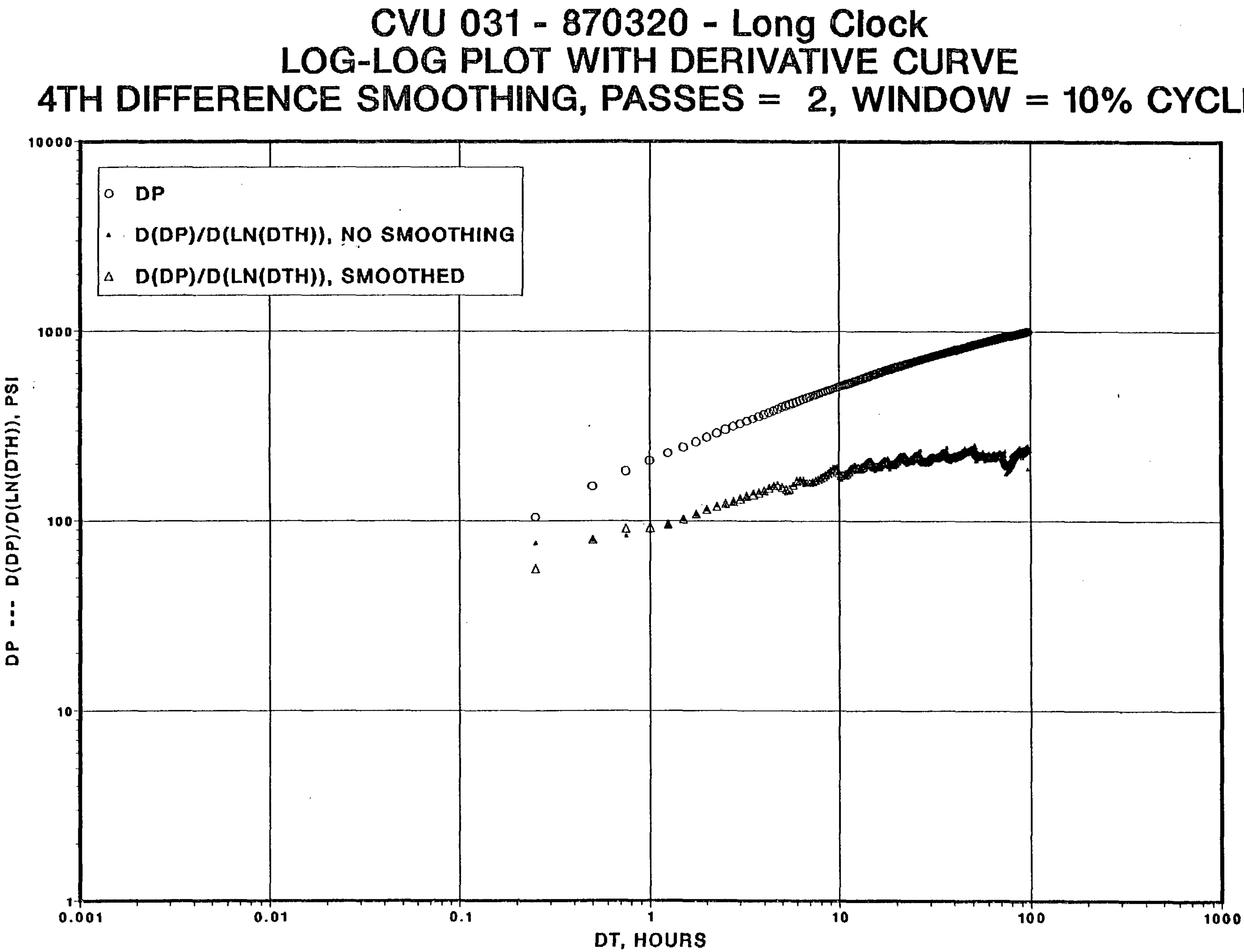

CVU 031 - 870320 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS
DP --- D(DP)/D(LN(DTH)), PSI

FIGURE 14

CVU 041 - 870320 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

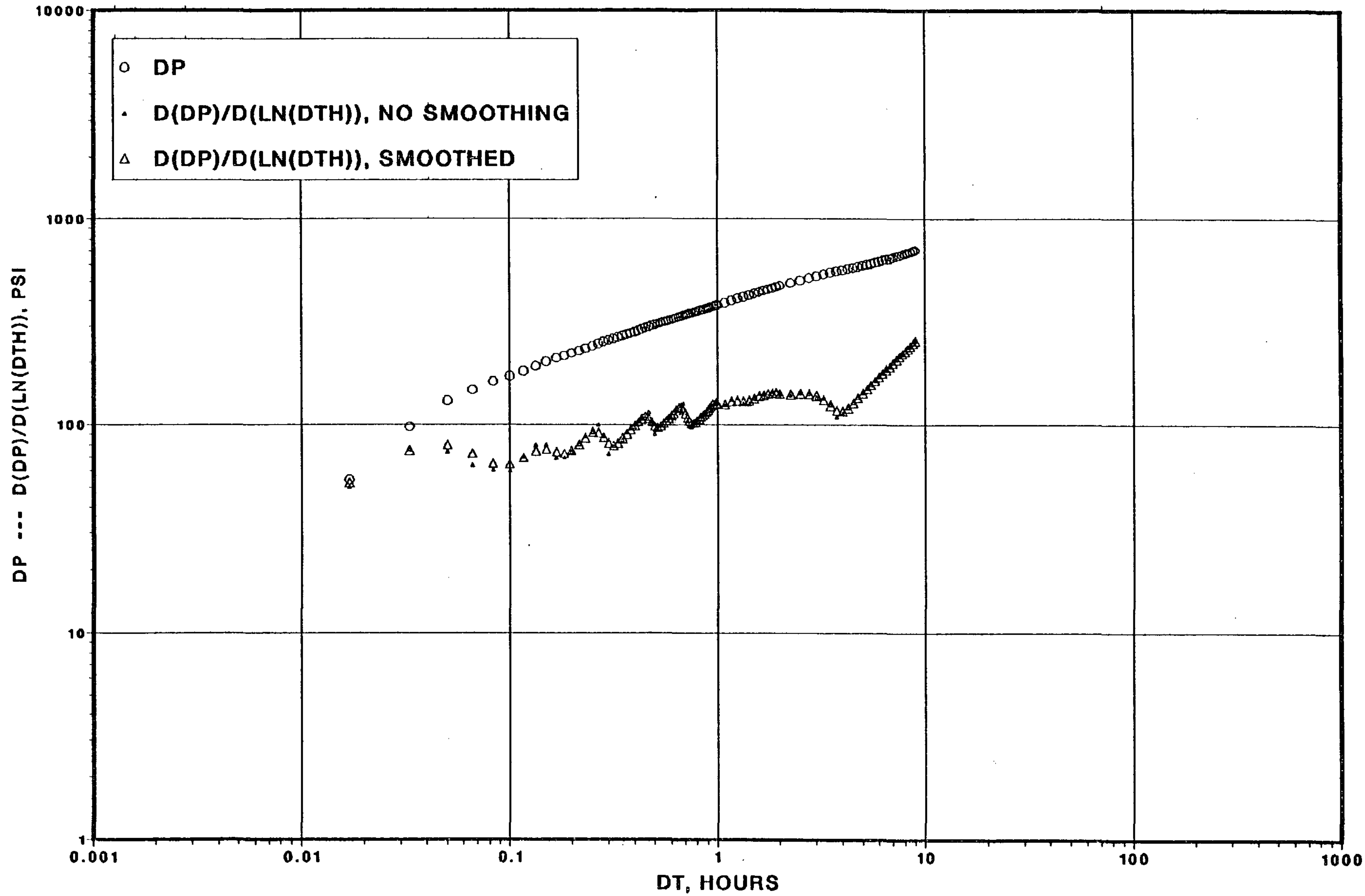


FIGURE 15

CVU 041 - 870315 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

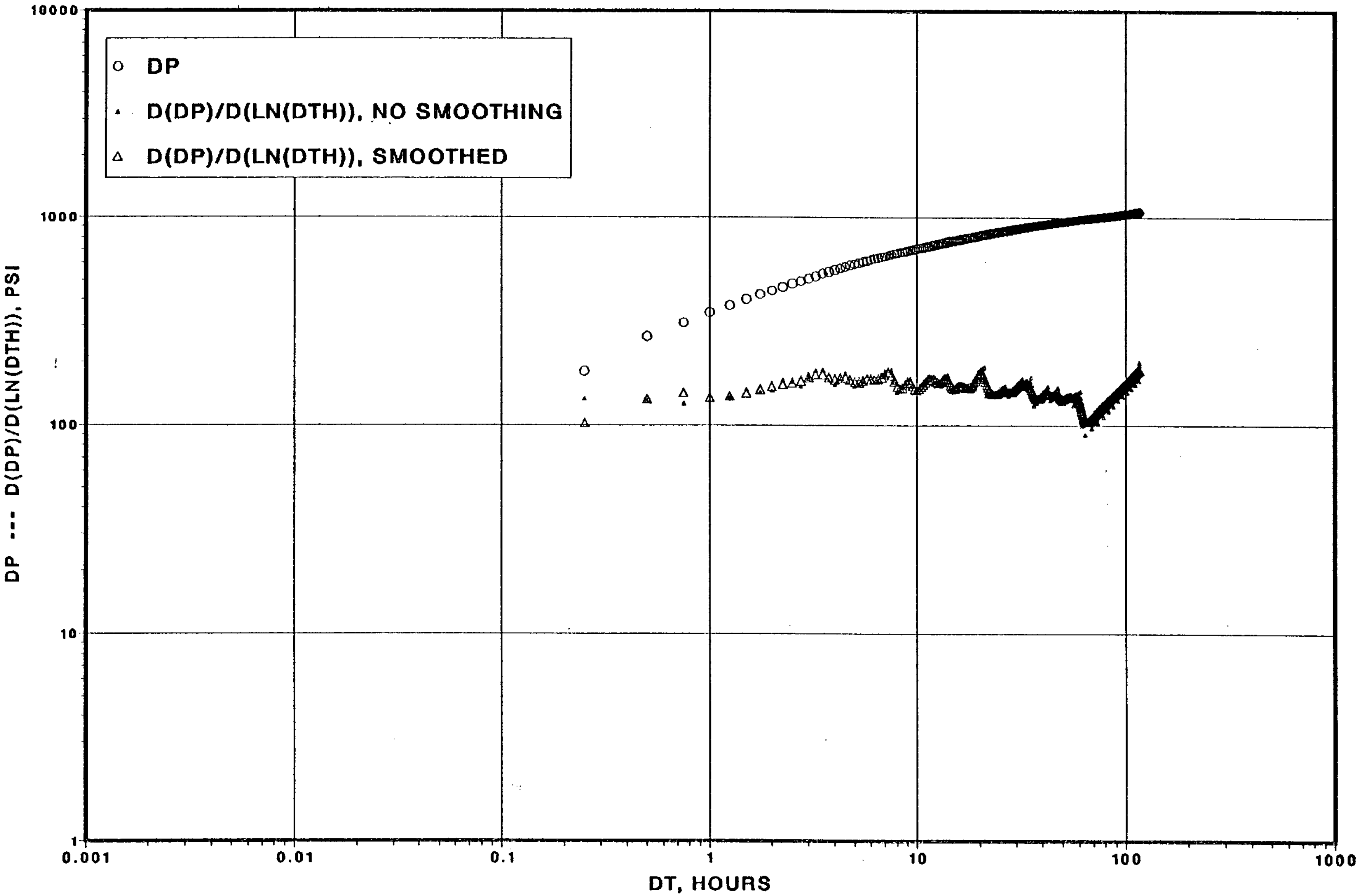


FIGURE 16

CVU41 - SURFACE PRESSURES - 2 HR TEST - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

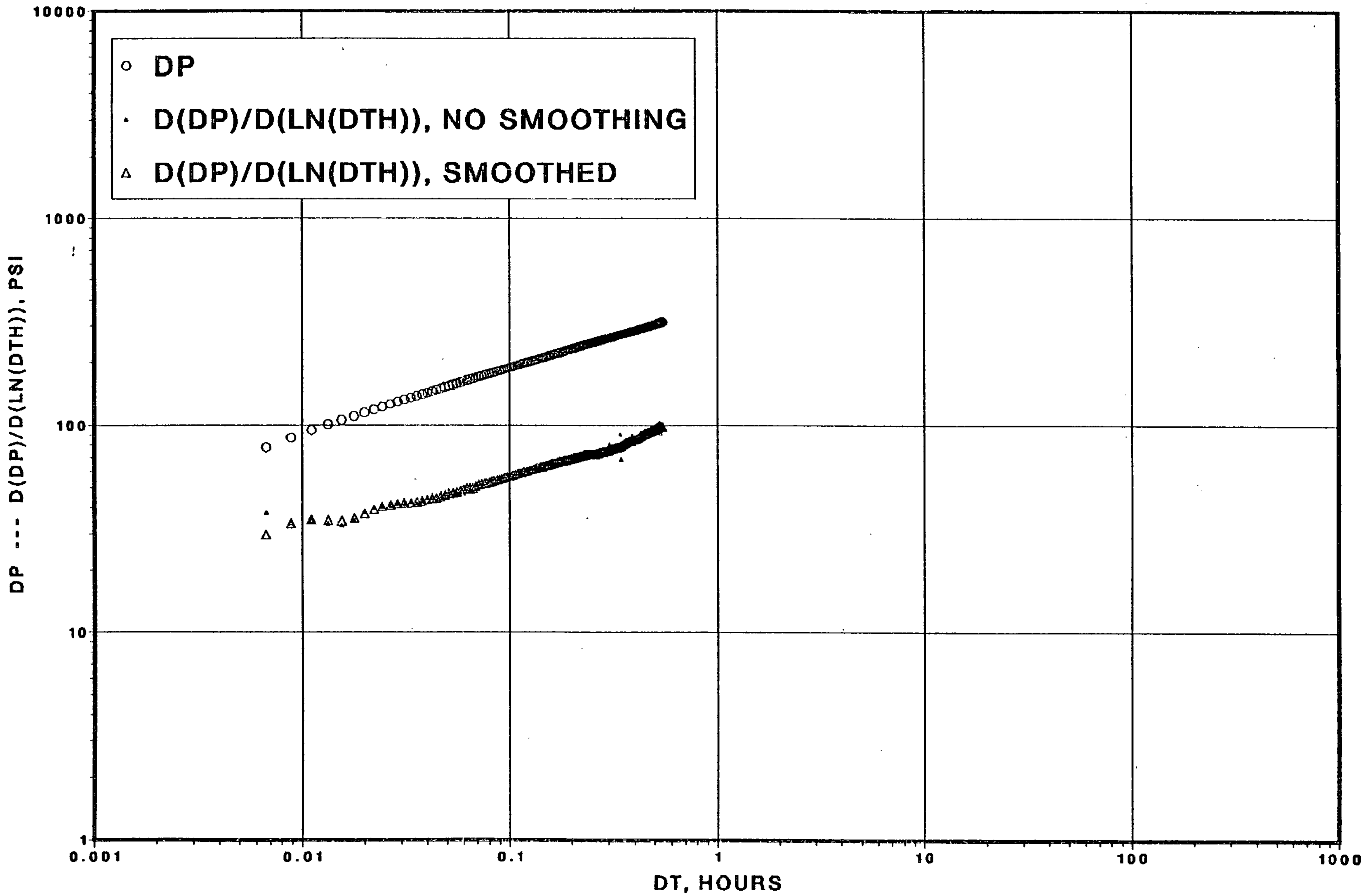


FIGURE 17

CVU 057 - 861020
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

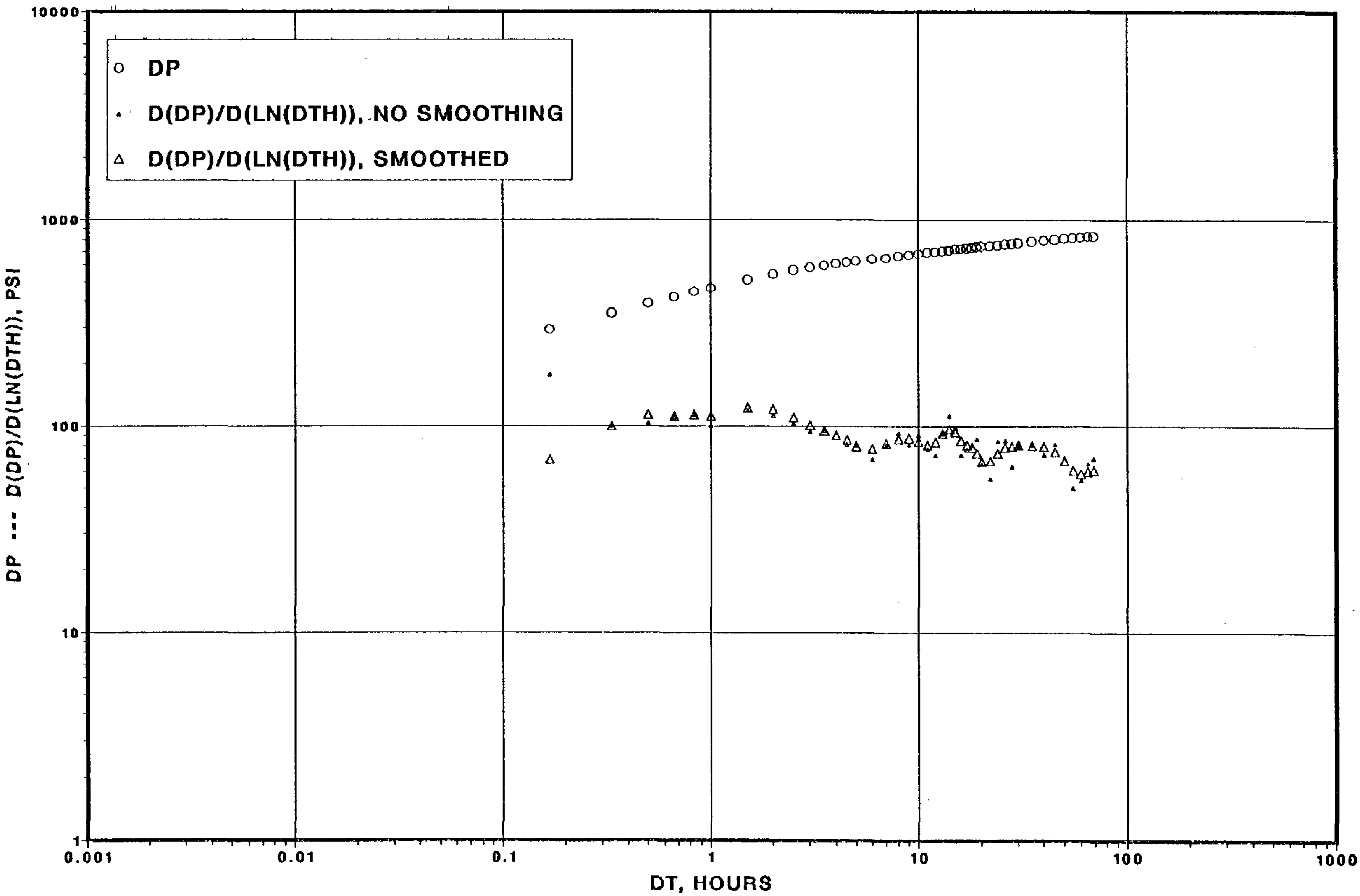


FIGURE 18

CVU 057 - Short Clock - 870921
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

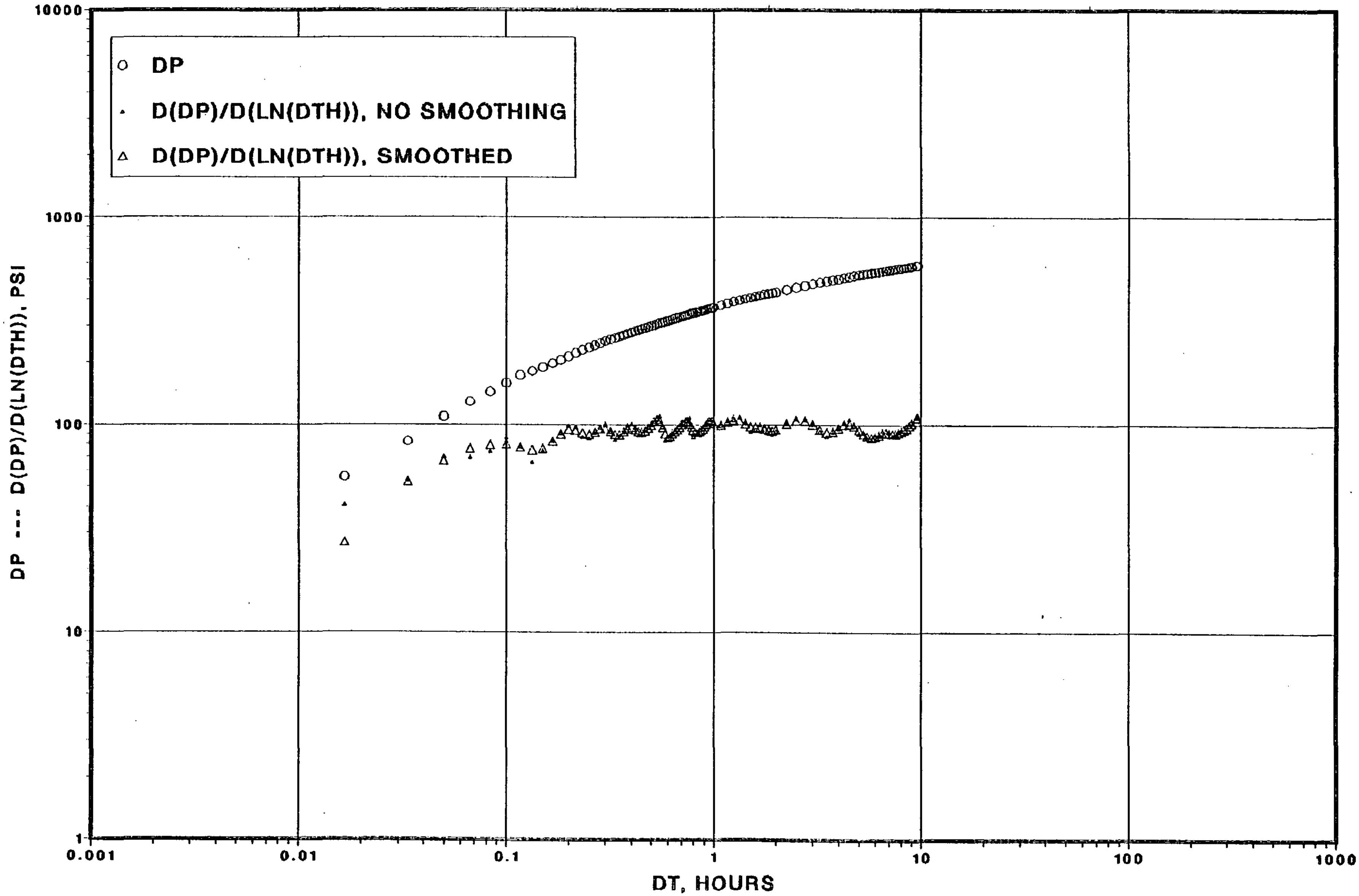


FIGURE 19

CVU 057 - Long Clock - 870921
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

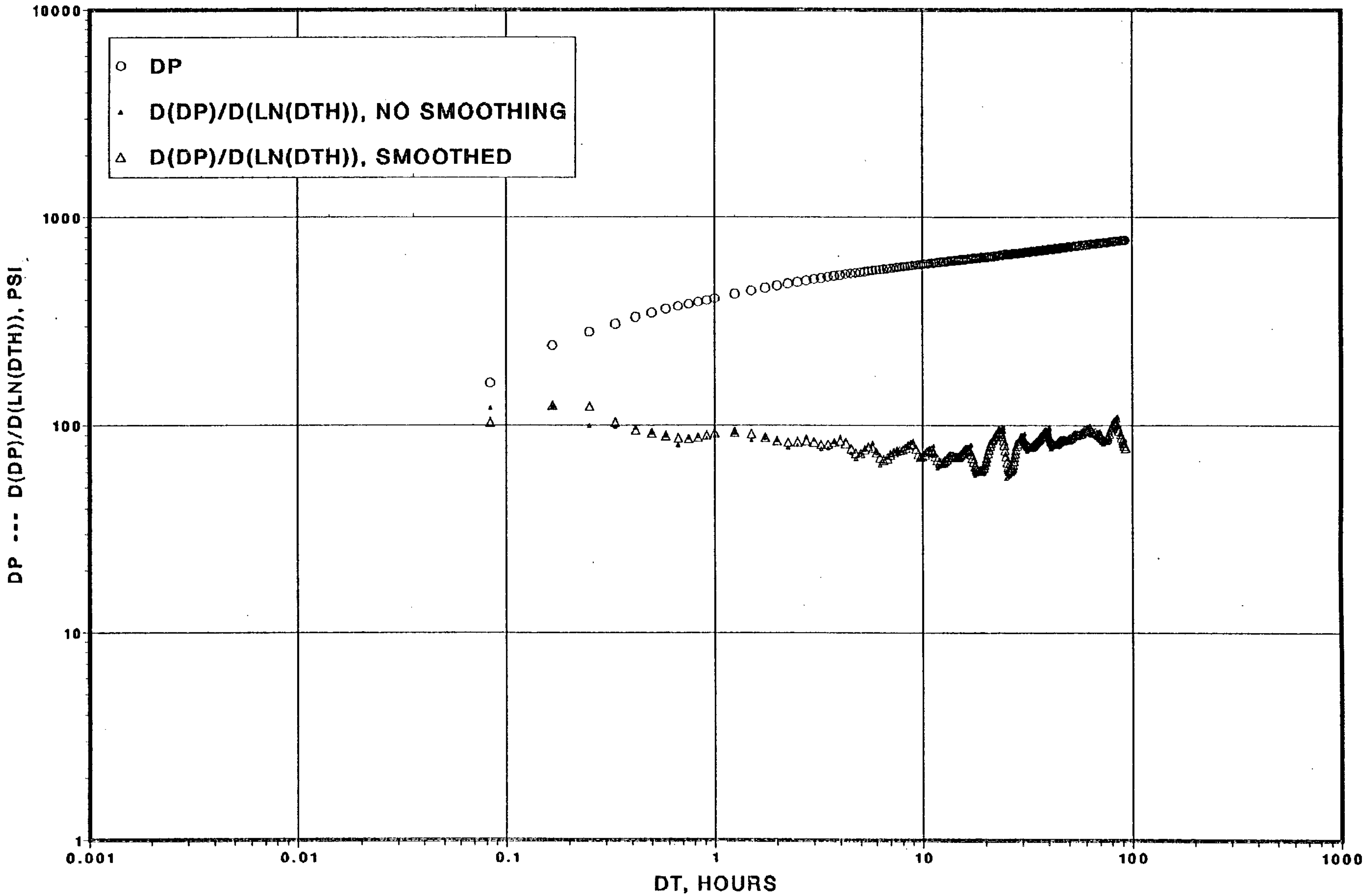


FIGURE 20

CVU 058 - 861020
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

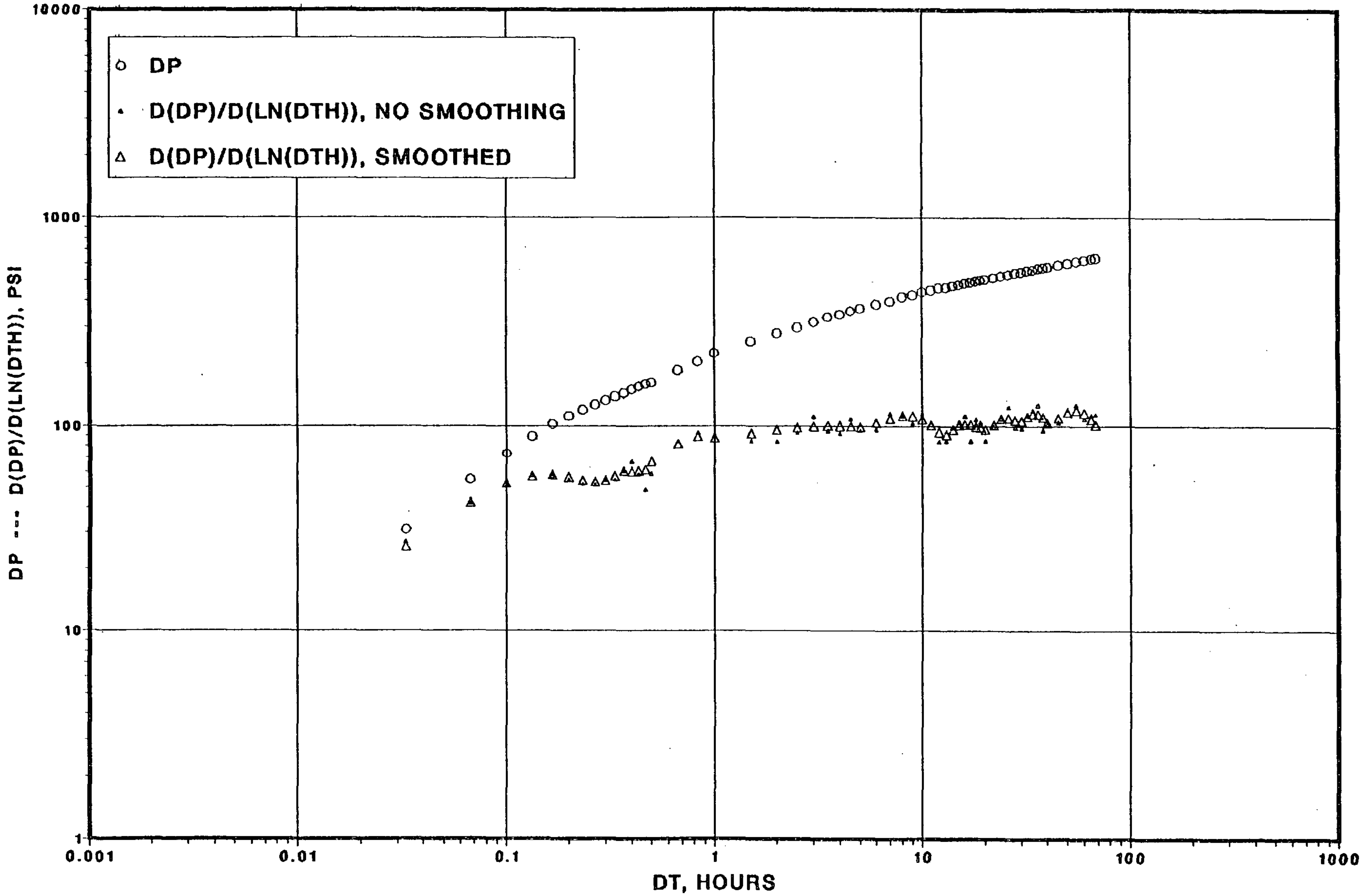


FIGURE 21

CVU 058 - Short Clock - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

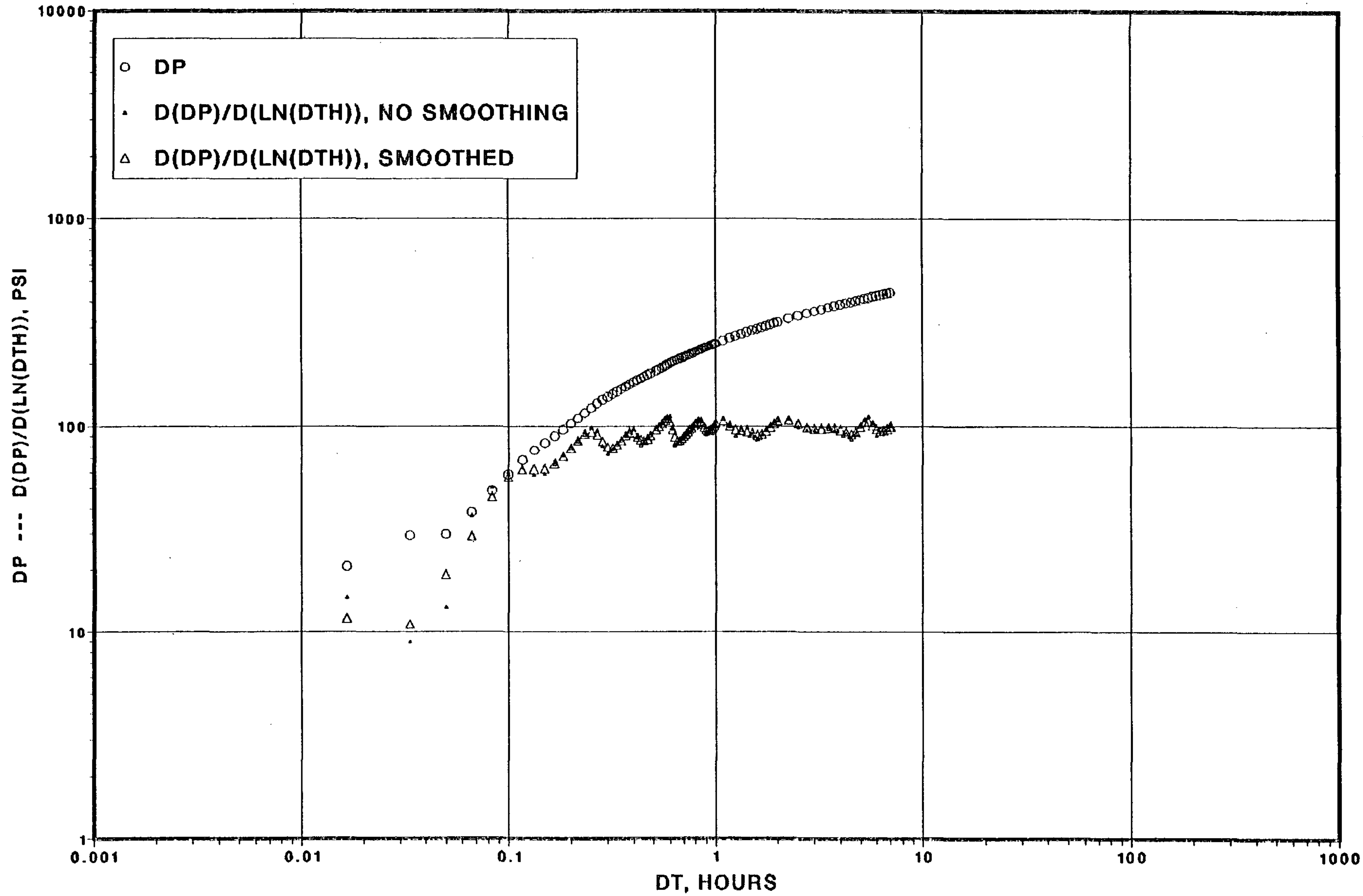


FIGURE 22

CVU 058 - Long Clock - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

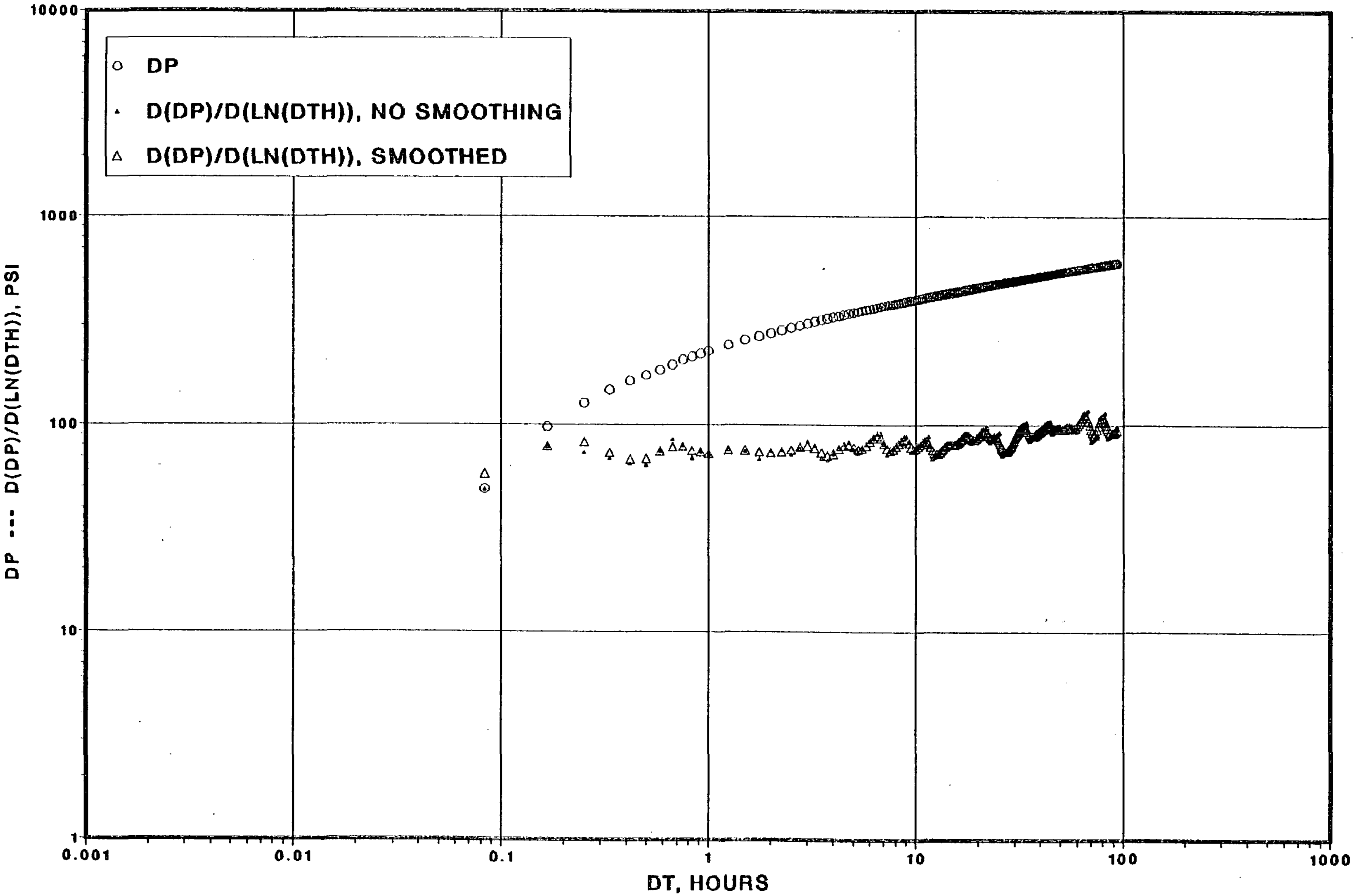
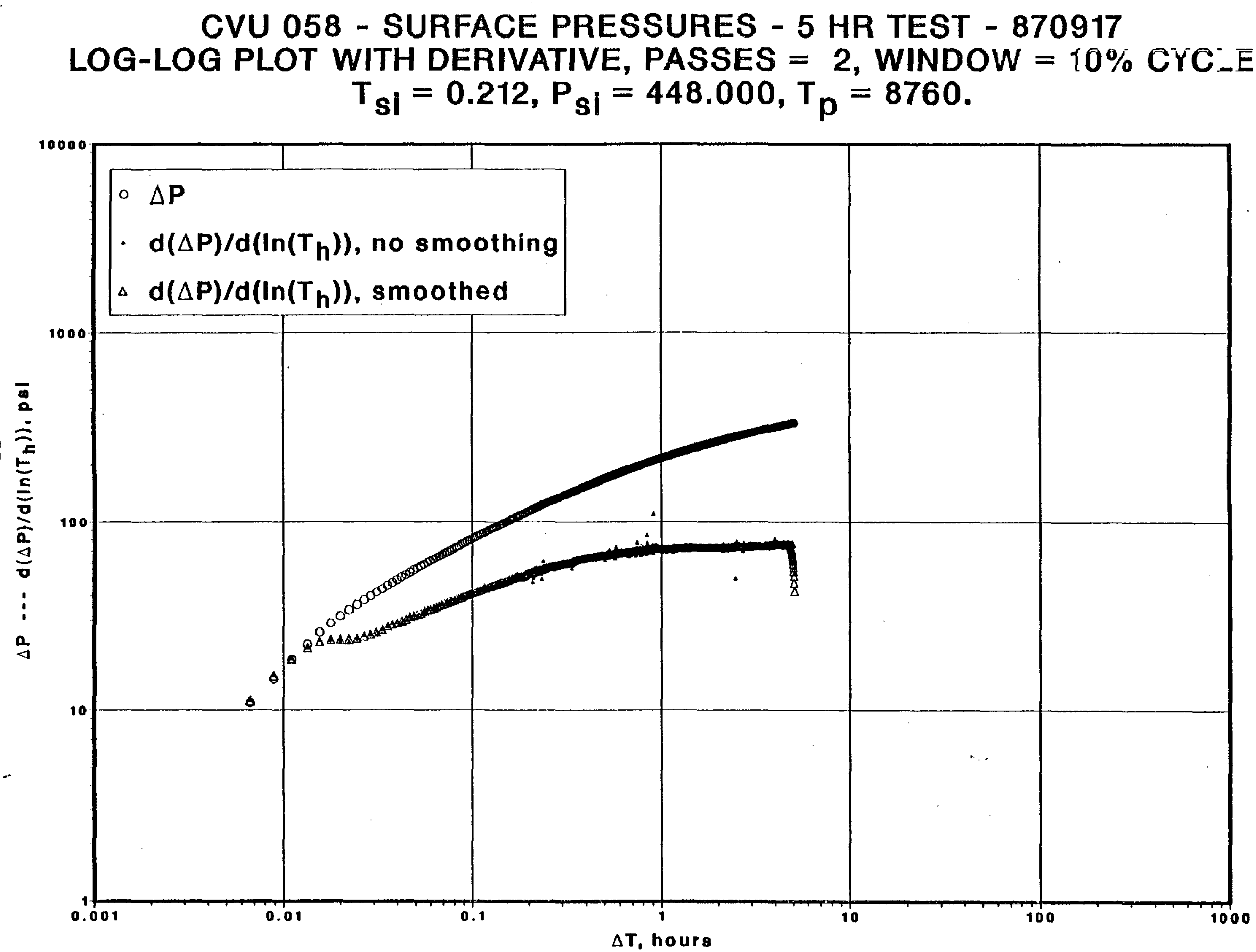
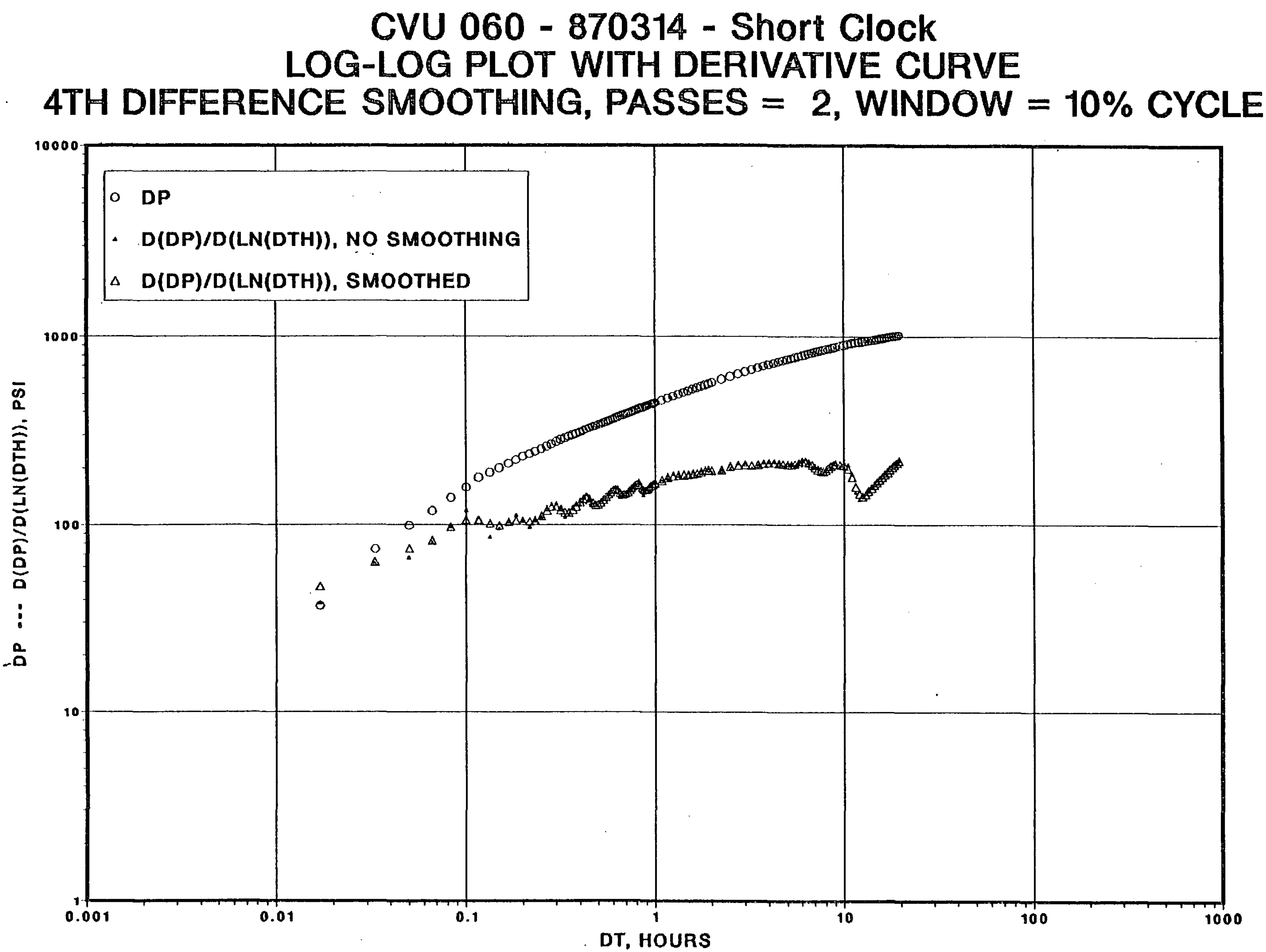


FIGURE 23



CVU 058 - SURFACE PRESSURES - 5 HR TEST - 870917
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 0.212, P_{si} = 448.000, T_p = 8760.
ΔP
d(ΔP)/d(ln(T_h)), no smoothing
d(ΔP)/d(ln(T_h)), smoothed
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
ΔP --- d(ΔP)/d(ln(T_h)), psi
ΔT, hours

FIGURE 24



CVU 060 - 870314 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

FIGURE 25

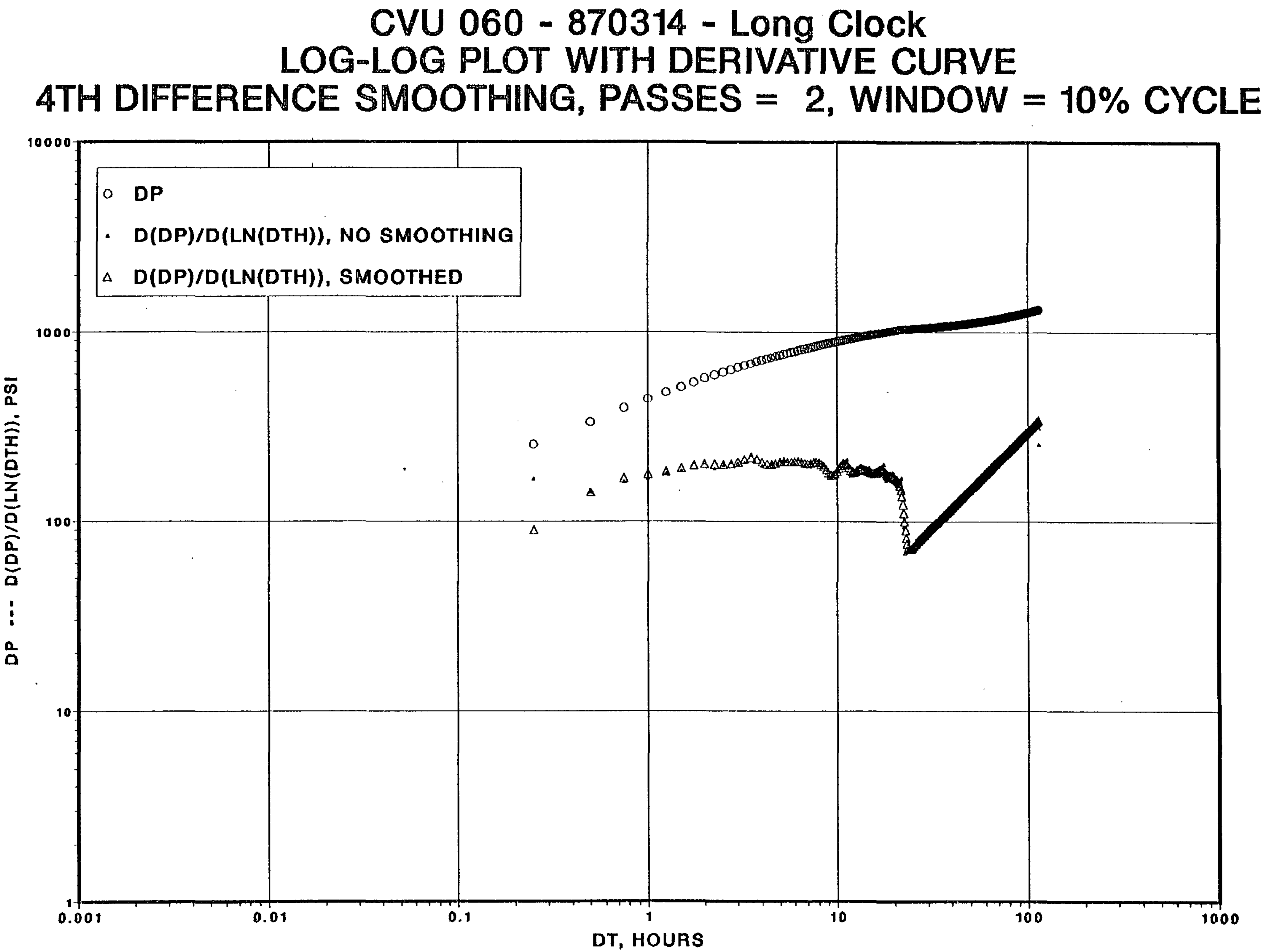

CVU 060 - 870314 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS
DP --- D(DP)/D(LN(DTH)), PSI

FIGURE 26

CVU 072 - 861020
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

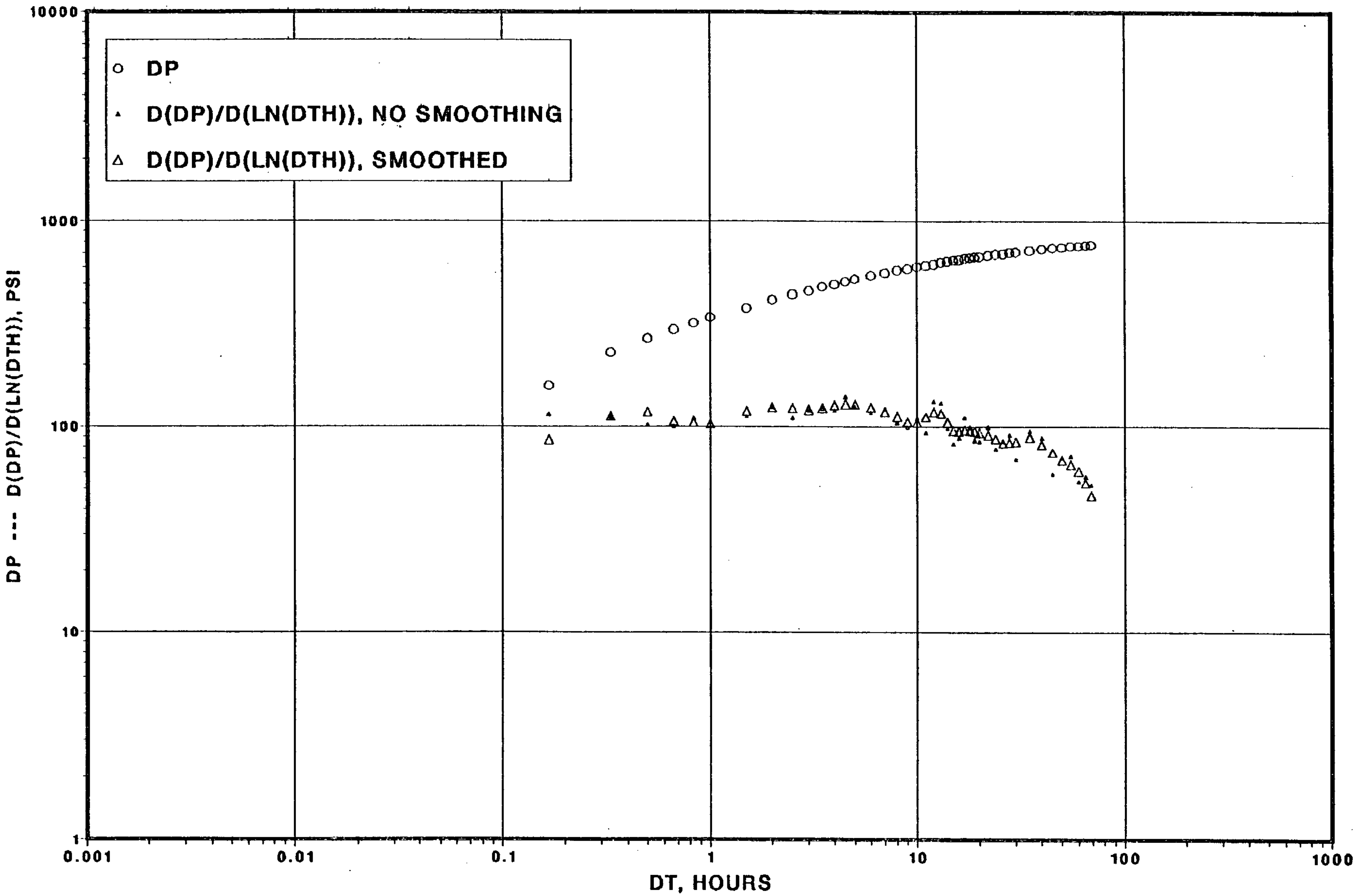


FIGURE 27

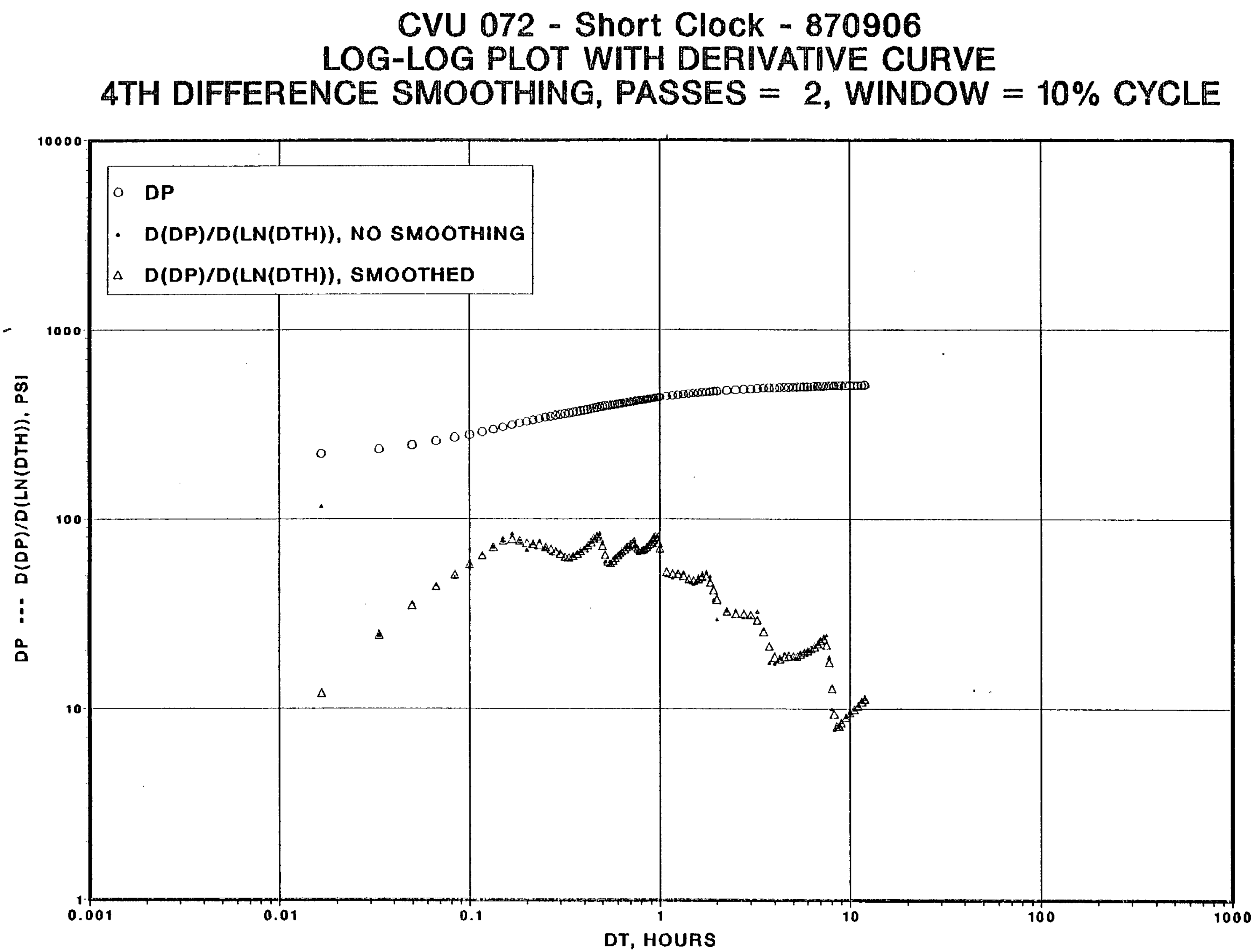
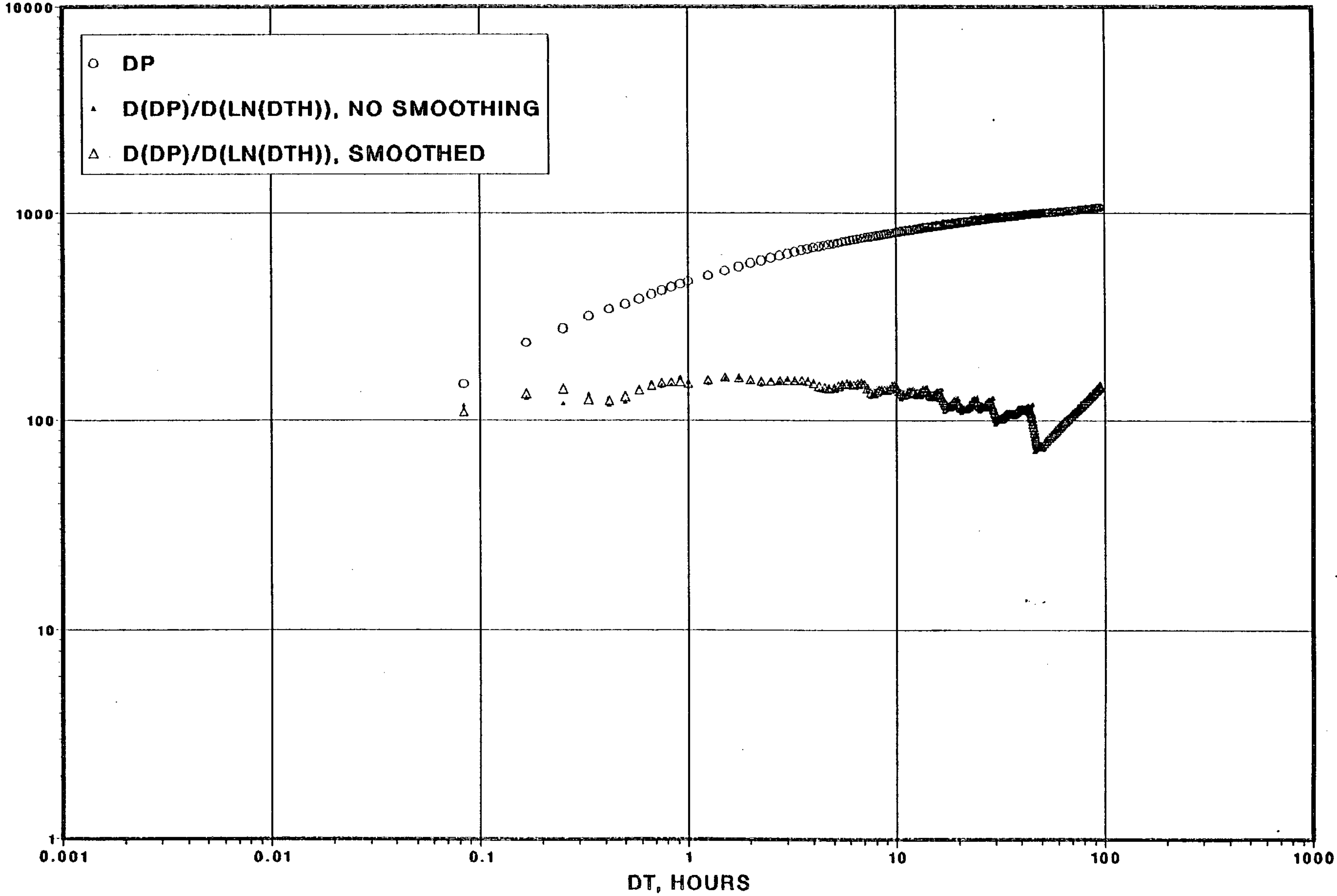

CVU 072 - Short Clock - 870906
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
DT, HOURS
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000

FIGURE 28



CVU 072 - Long Clock - 870906
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

FIGURE 29

CVU 73 - 1340 BPD - AMERADA GAUGE - 861020
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 0.000, P_{si} = 2364.200, T_p = 8760.

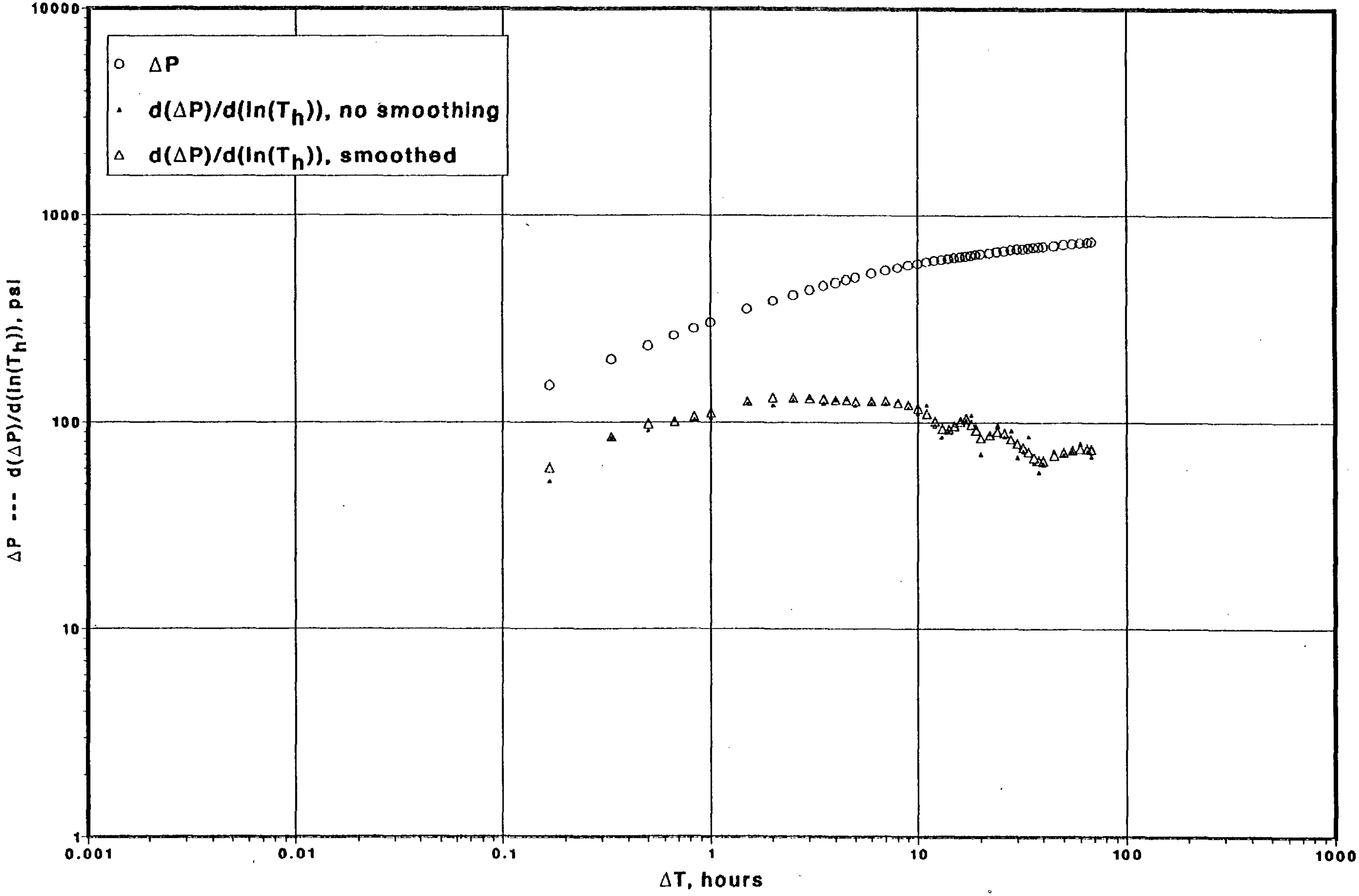


FIGURE 30

CVU 073 - Short Clock - 870902
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

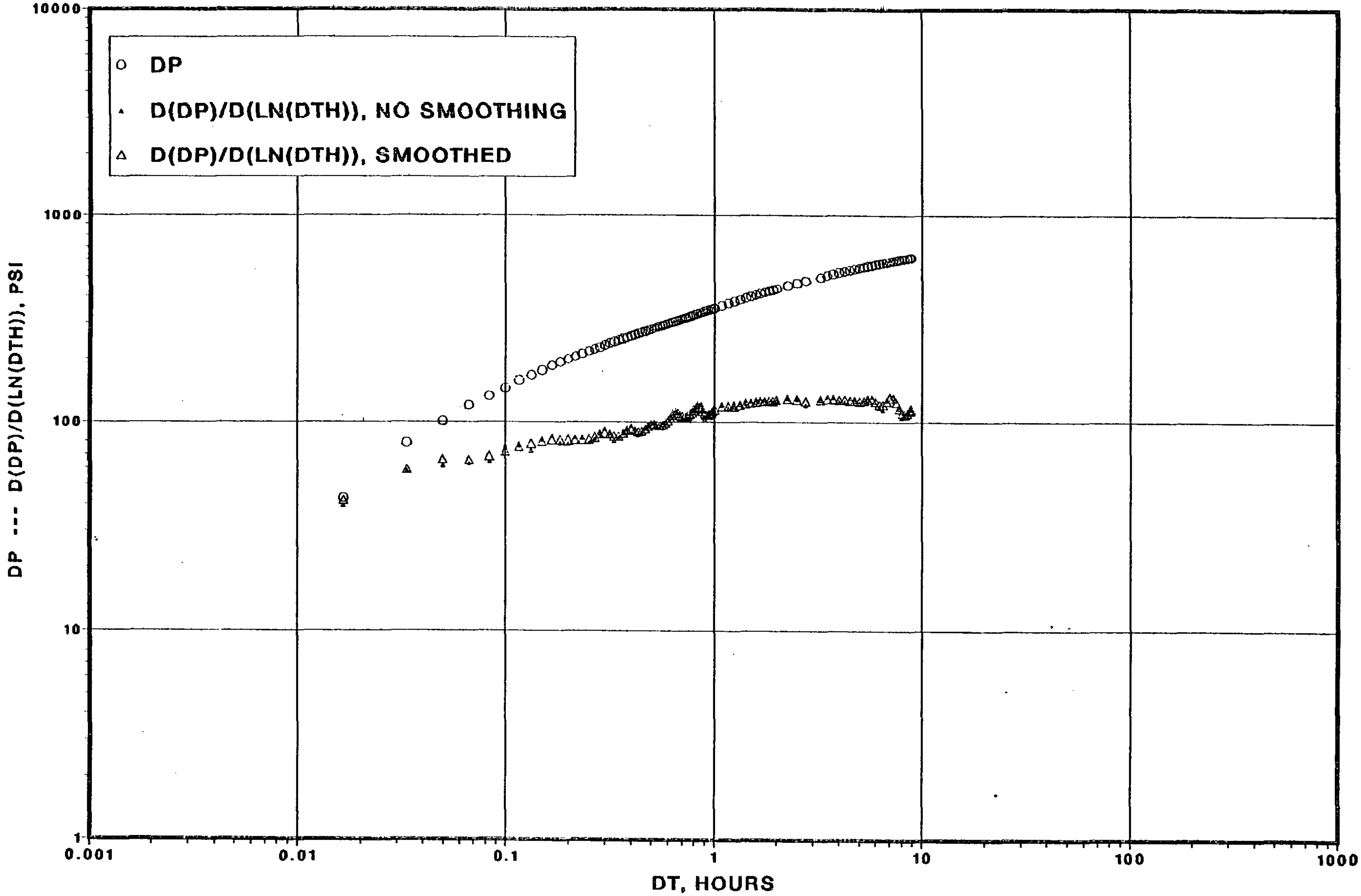


FIGURE 31

CVU 073 - Long Clock - 870902
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

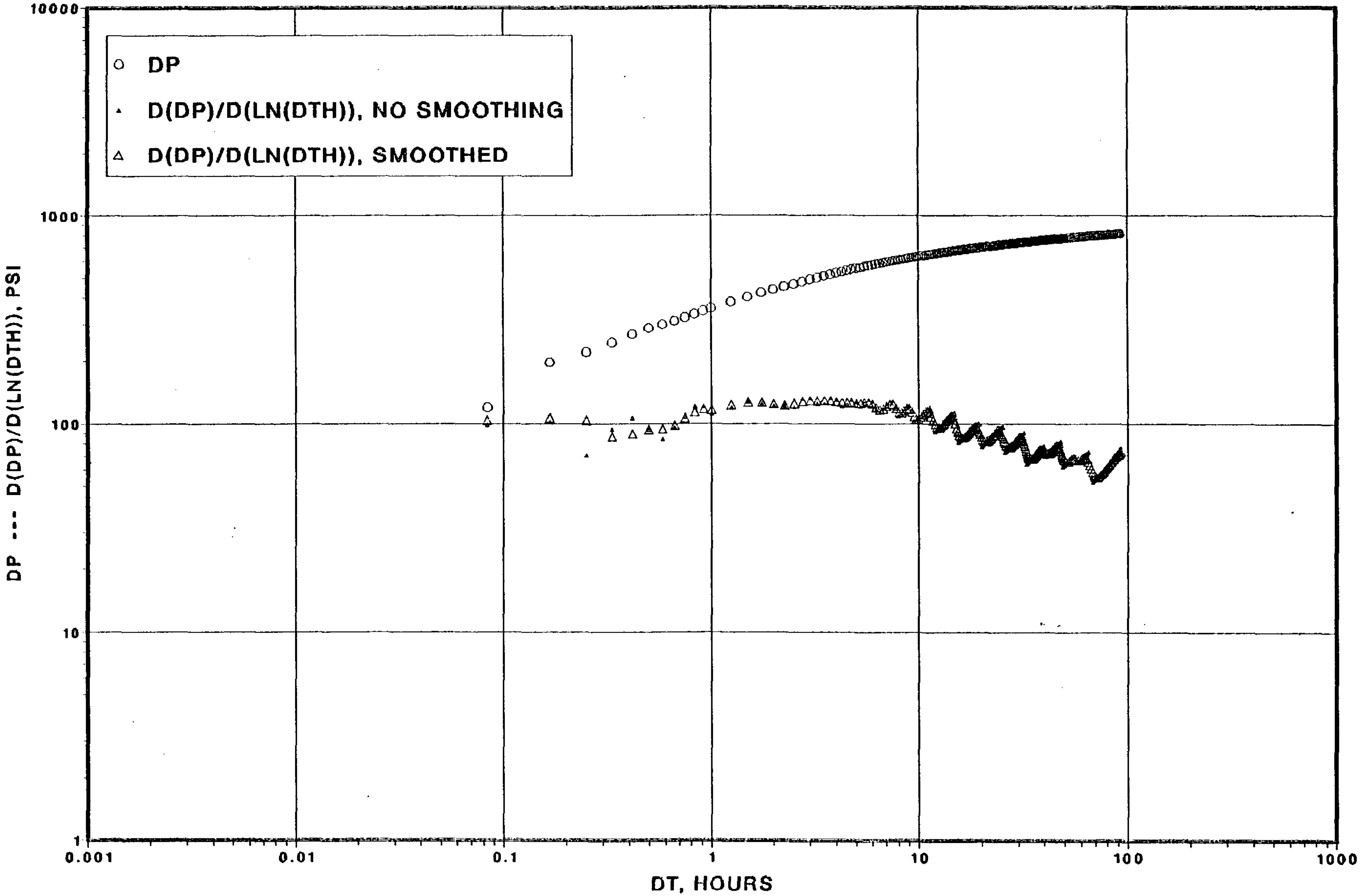


FIGURE 32

CVU 81 - 1280 BPD - PANEX GAUGE - 861110
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 2.750, P_{si} = 2536.000, T_p = 8760.

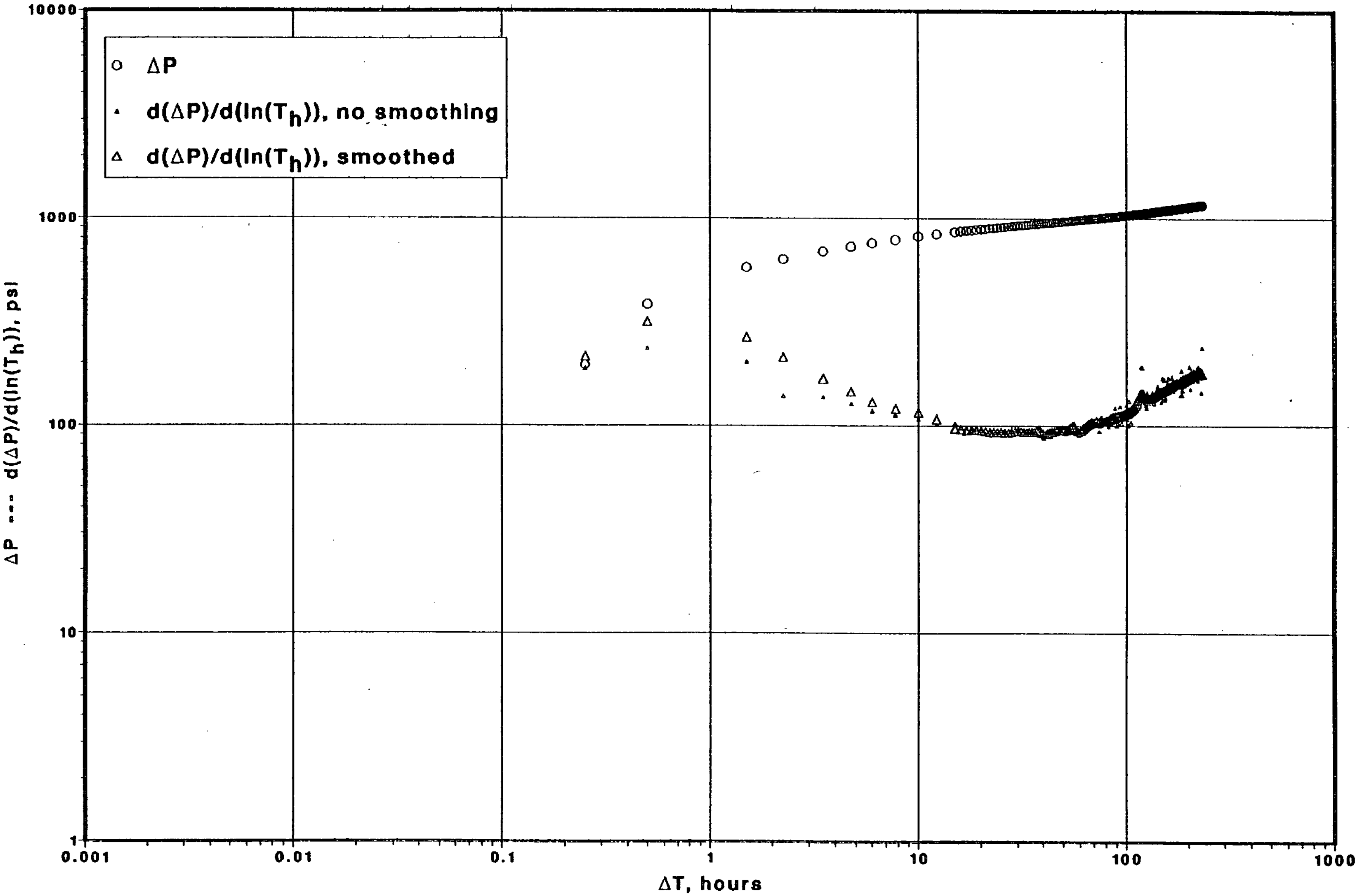


FIGURE 33

CVU 82 - 1373 BPD - AMERADA GAUGE - 861121
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 50% CYCLE
T_{si} = 0.000, P_{si} = 1658.000, T_p = 8760.

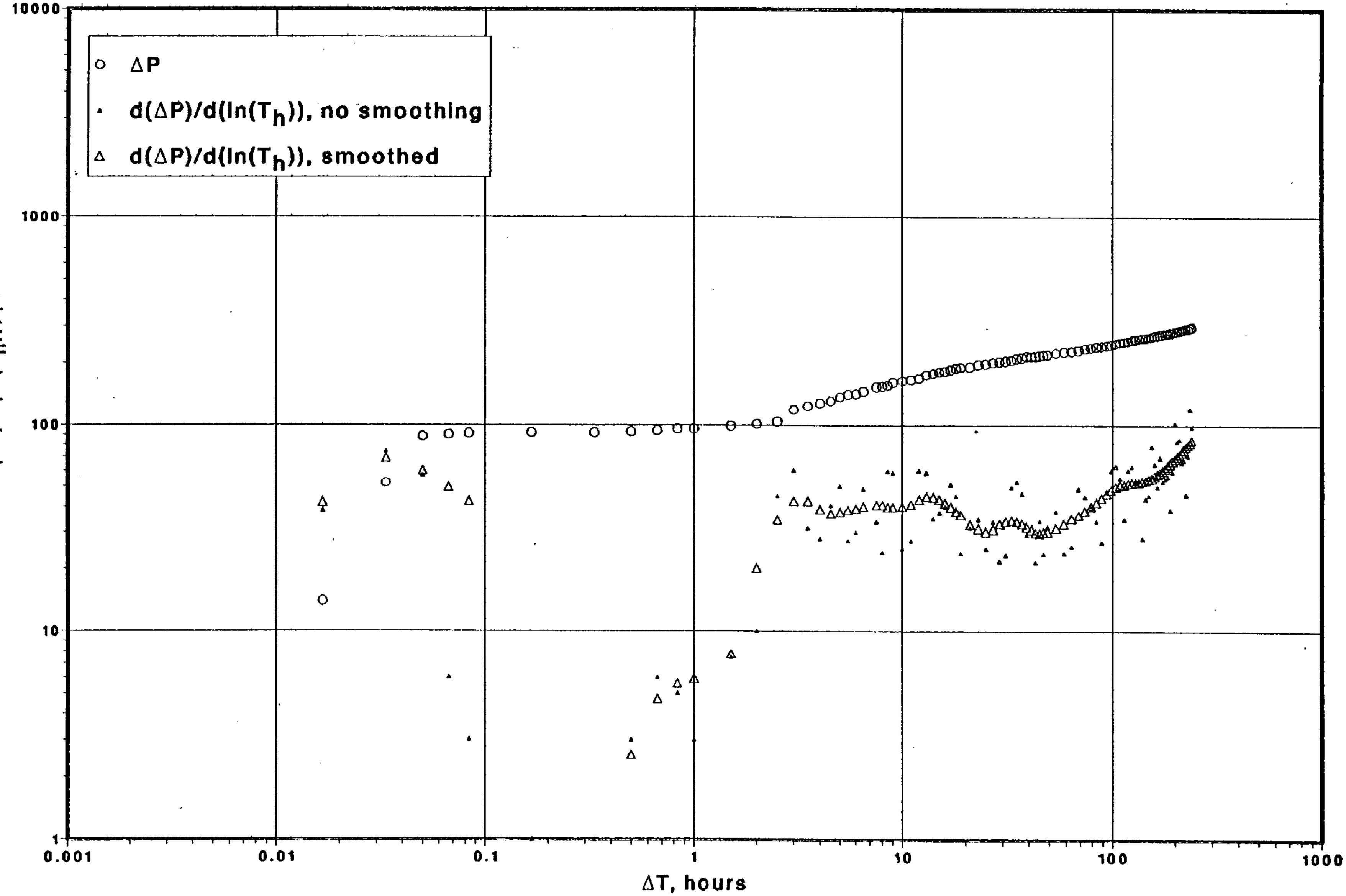


FIGURE 34

CVU 100 - 861008
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

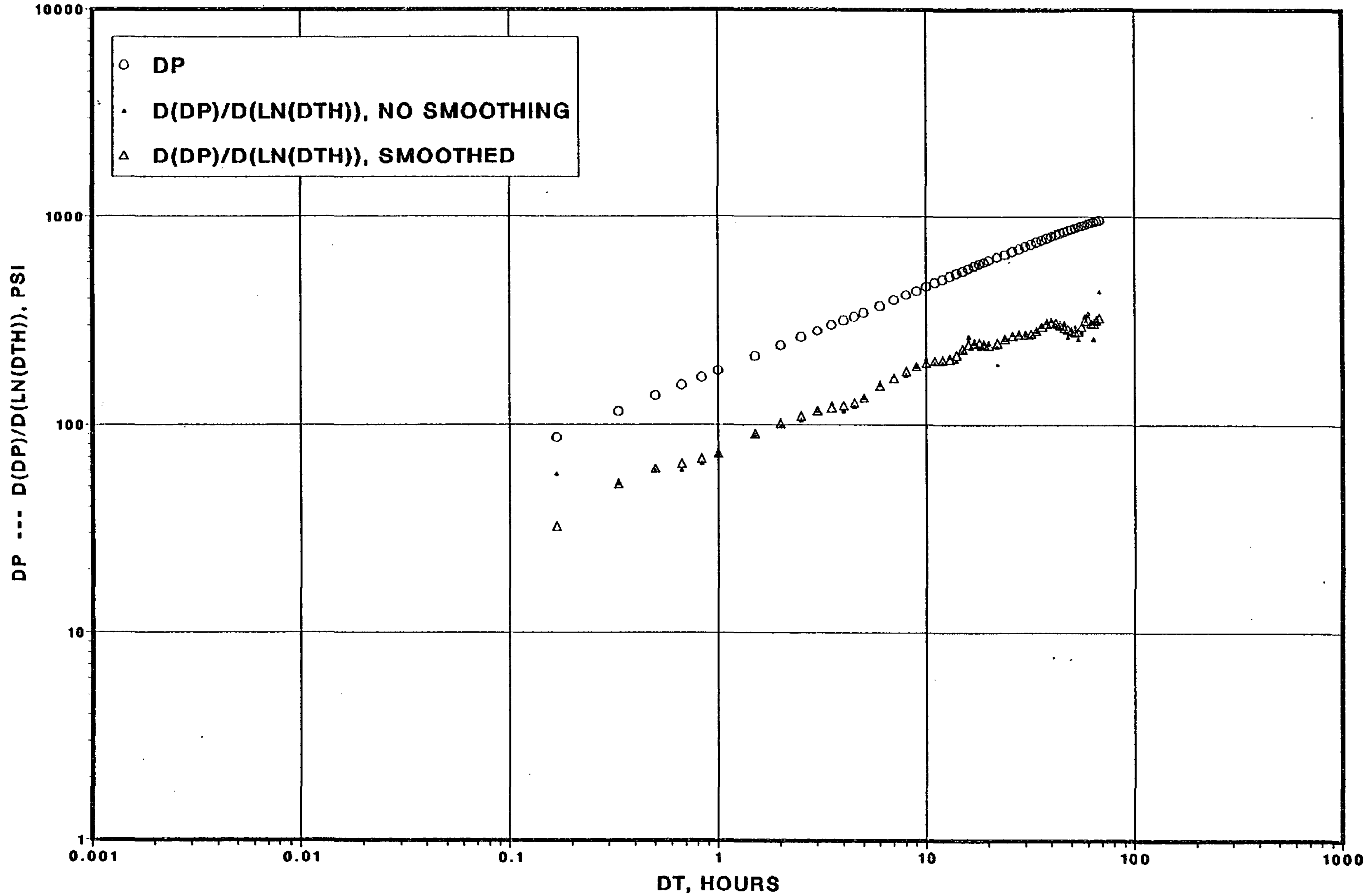


FIGURE 35

CVU 113 - 861023
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

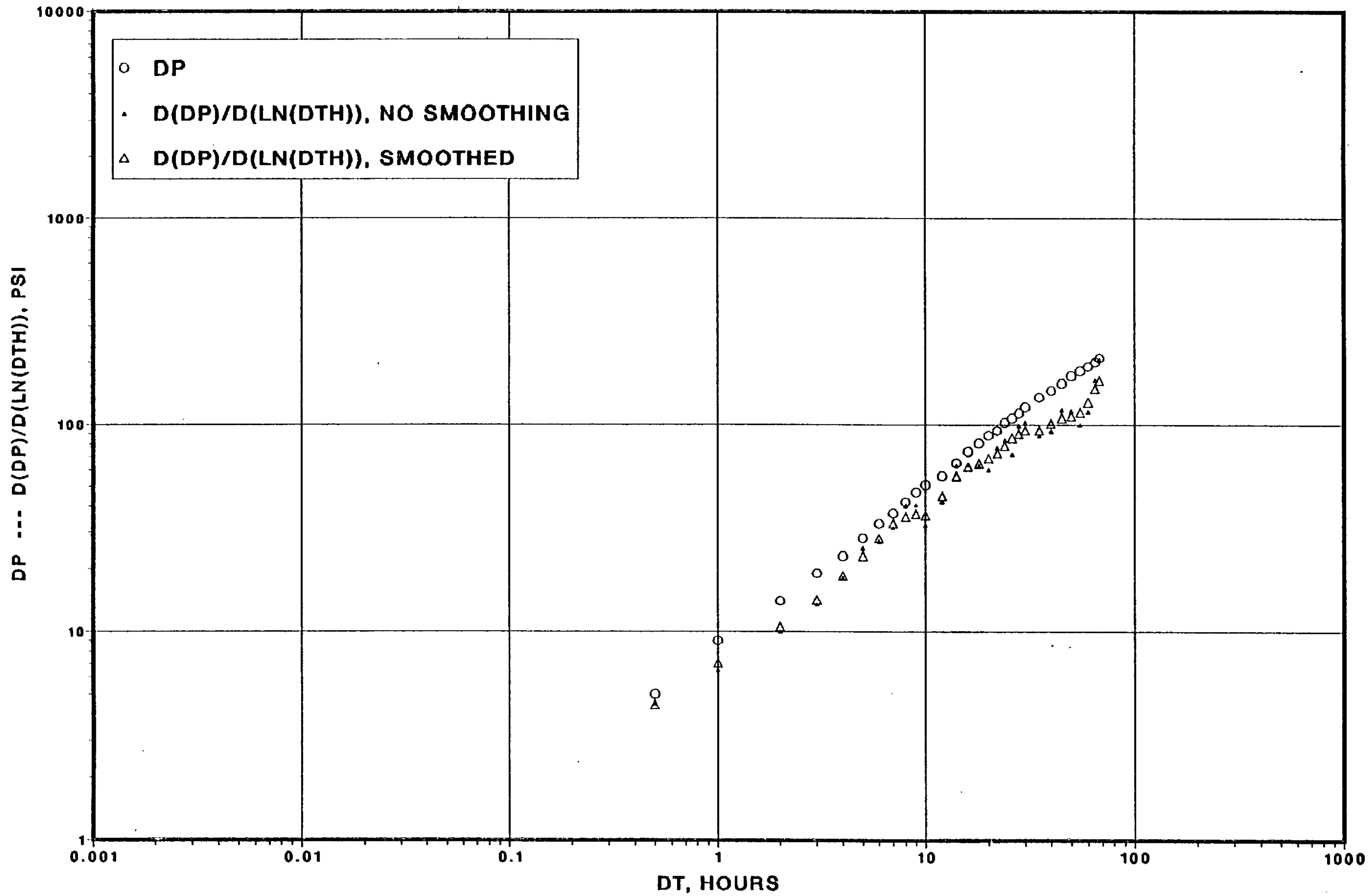


FIGURE 36

CVU113 - MINI TEST - 870917
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 2/10 INCHES

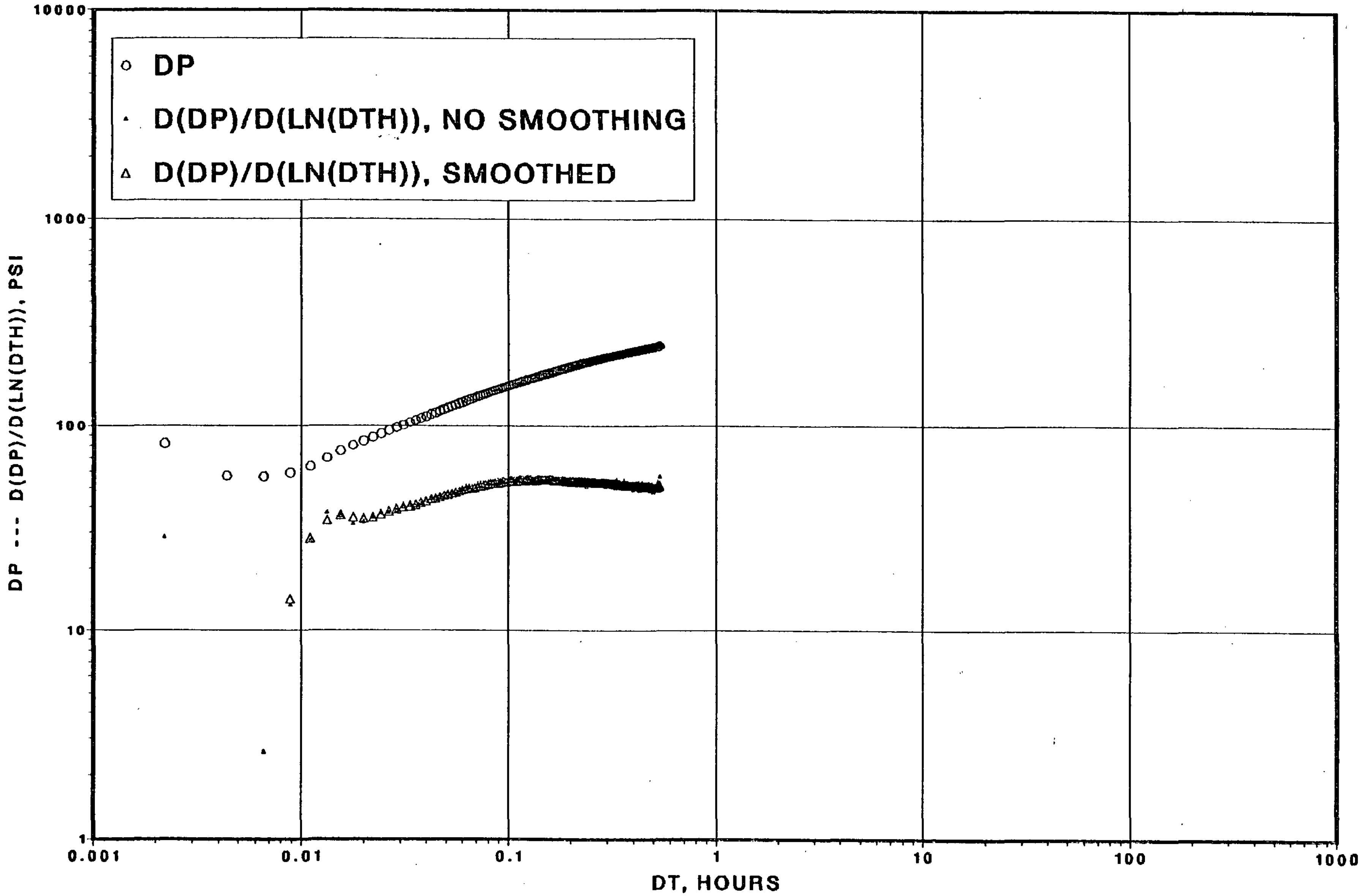


FIGURE 37

CVU 113 - Short Clock - 870922
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

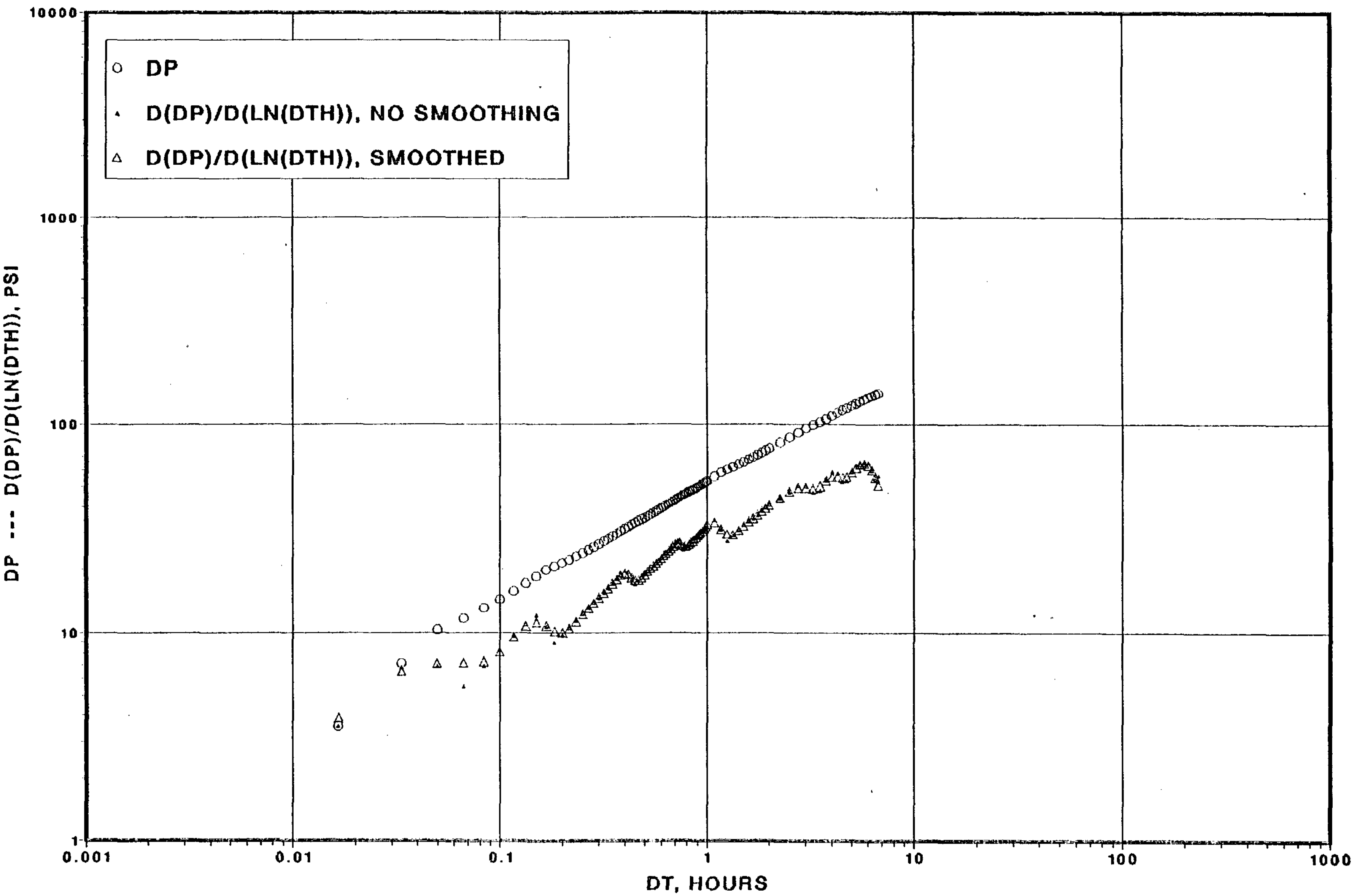


FIGURE 38

CVU 113 - Long Clock - 870922
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

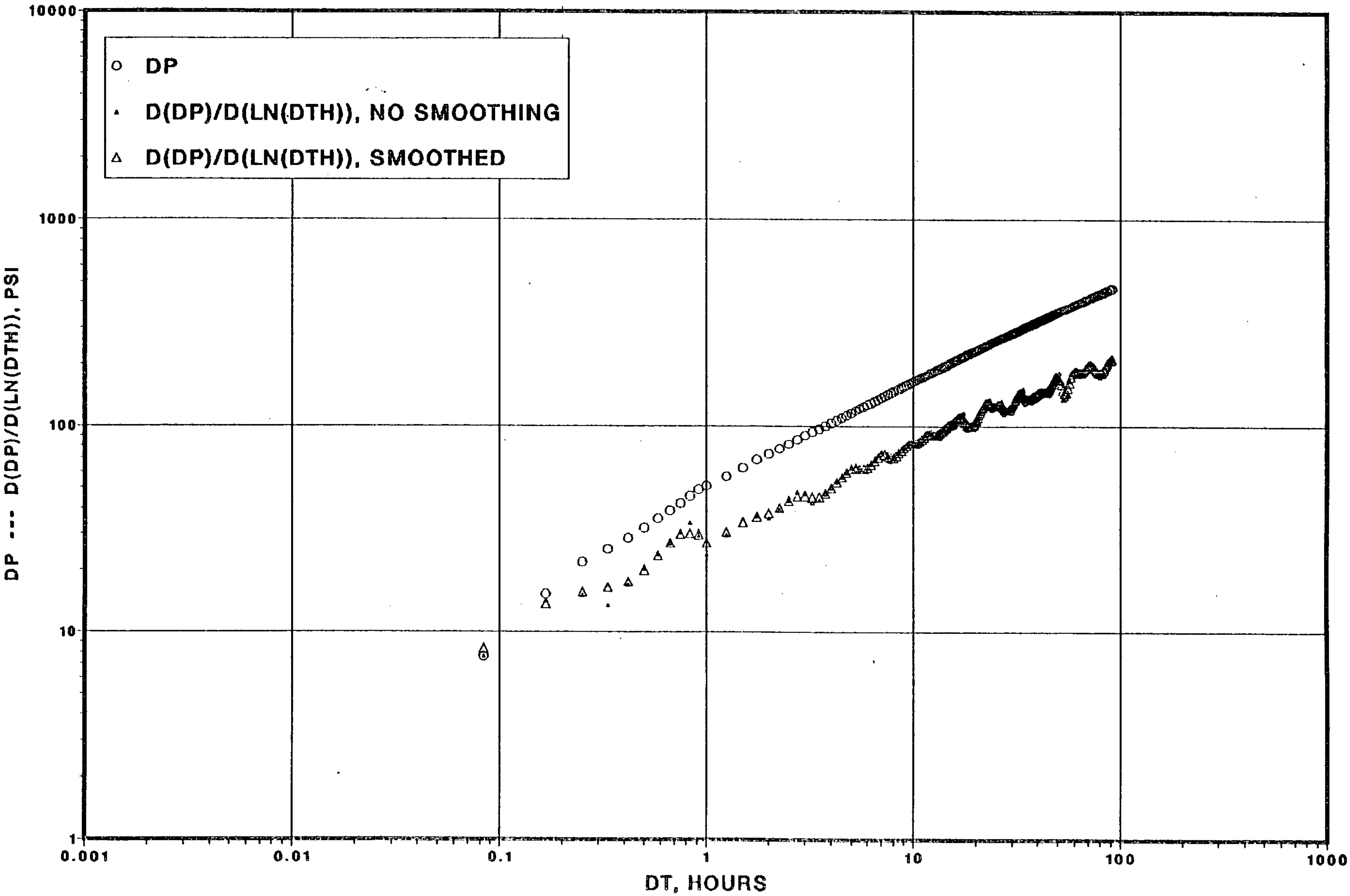


FIGURE 39

CVU 120 - 861023
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

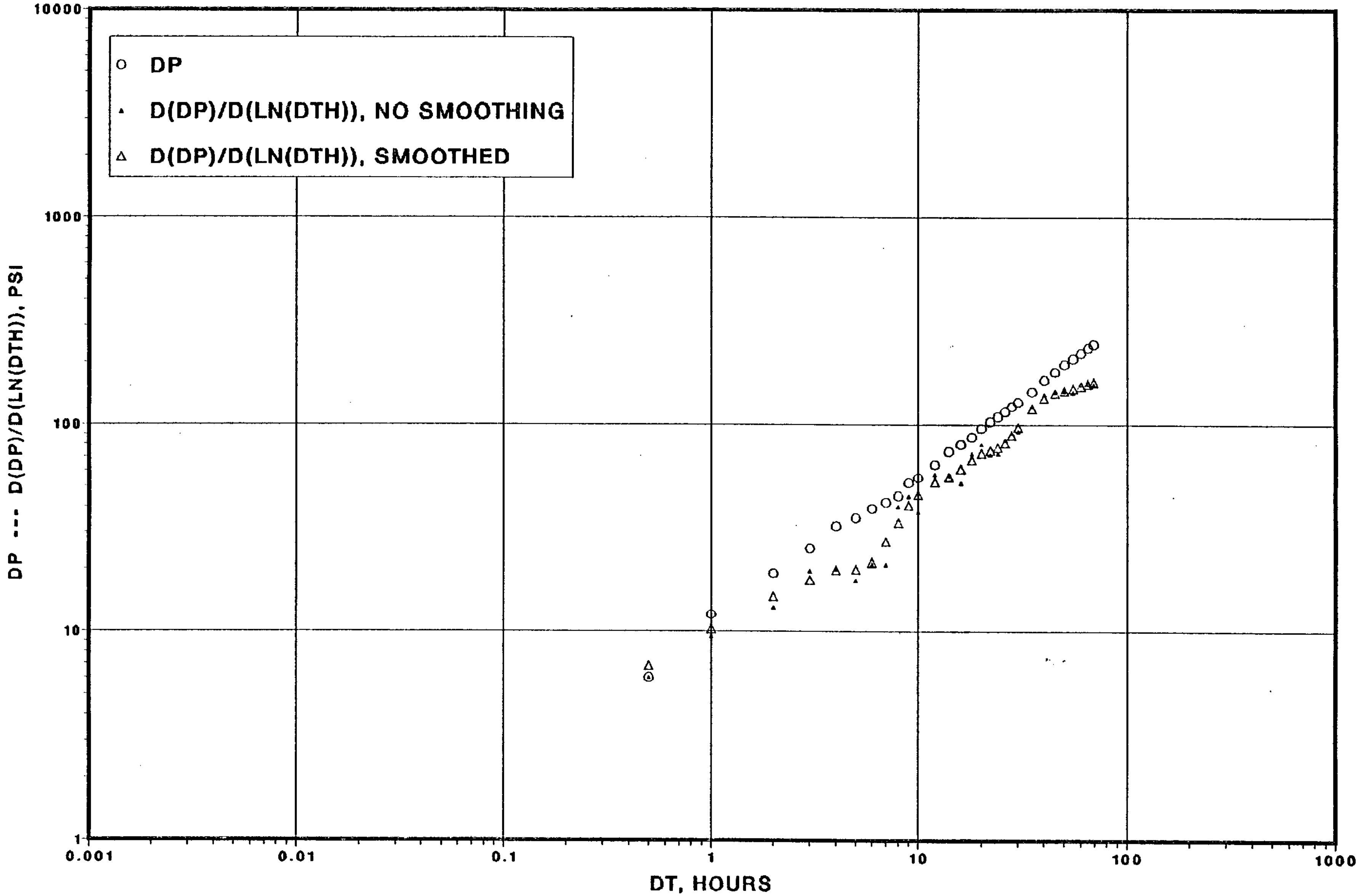


FIGURE 40

CVU 120 A X - 870325 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

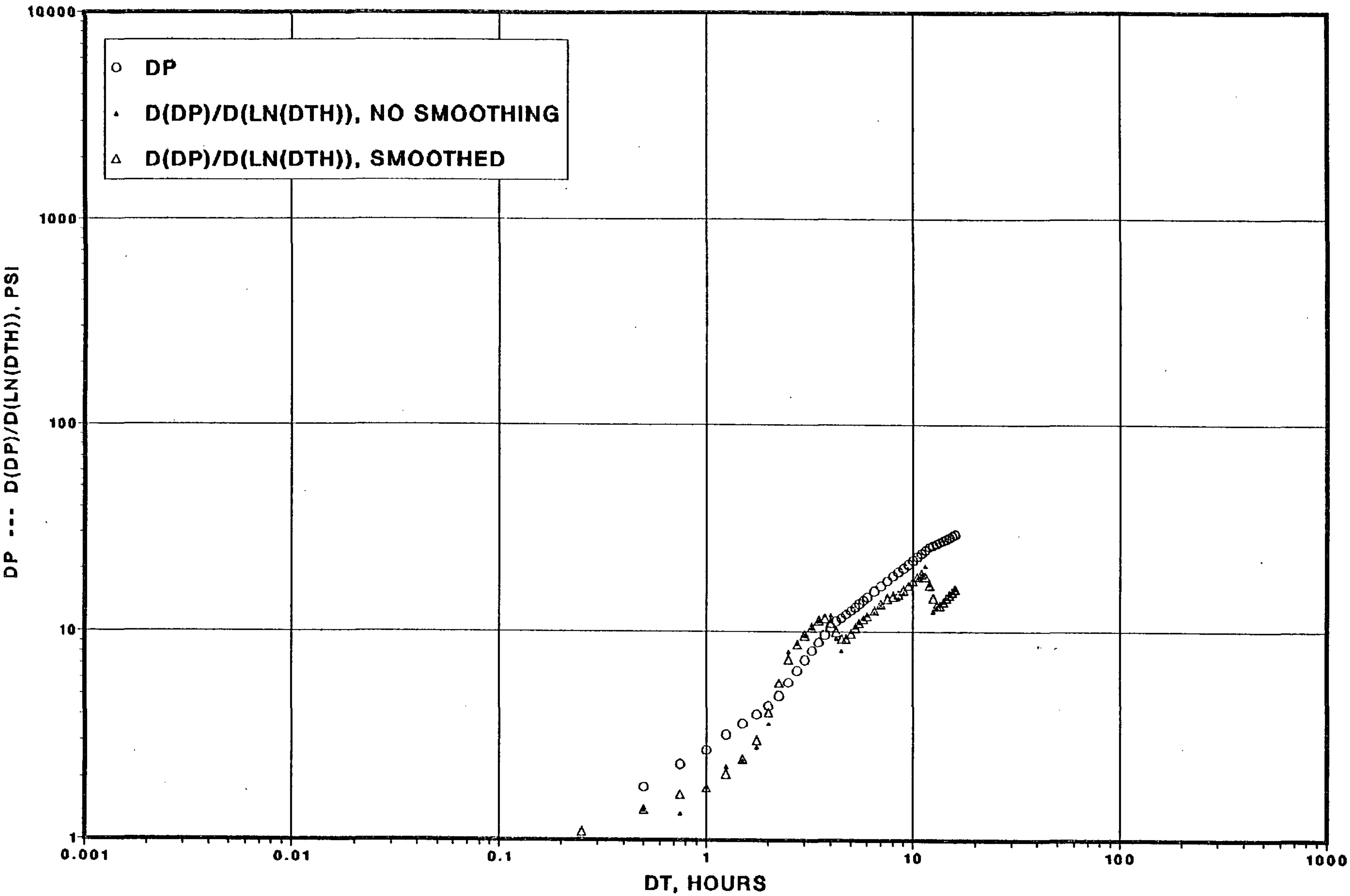


FIGURE 41

CVU 120 A - 870325 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

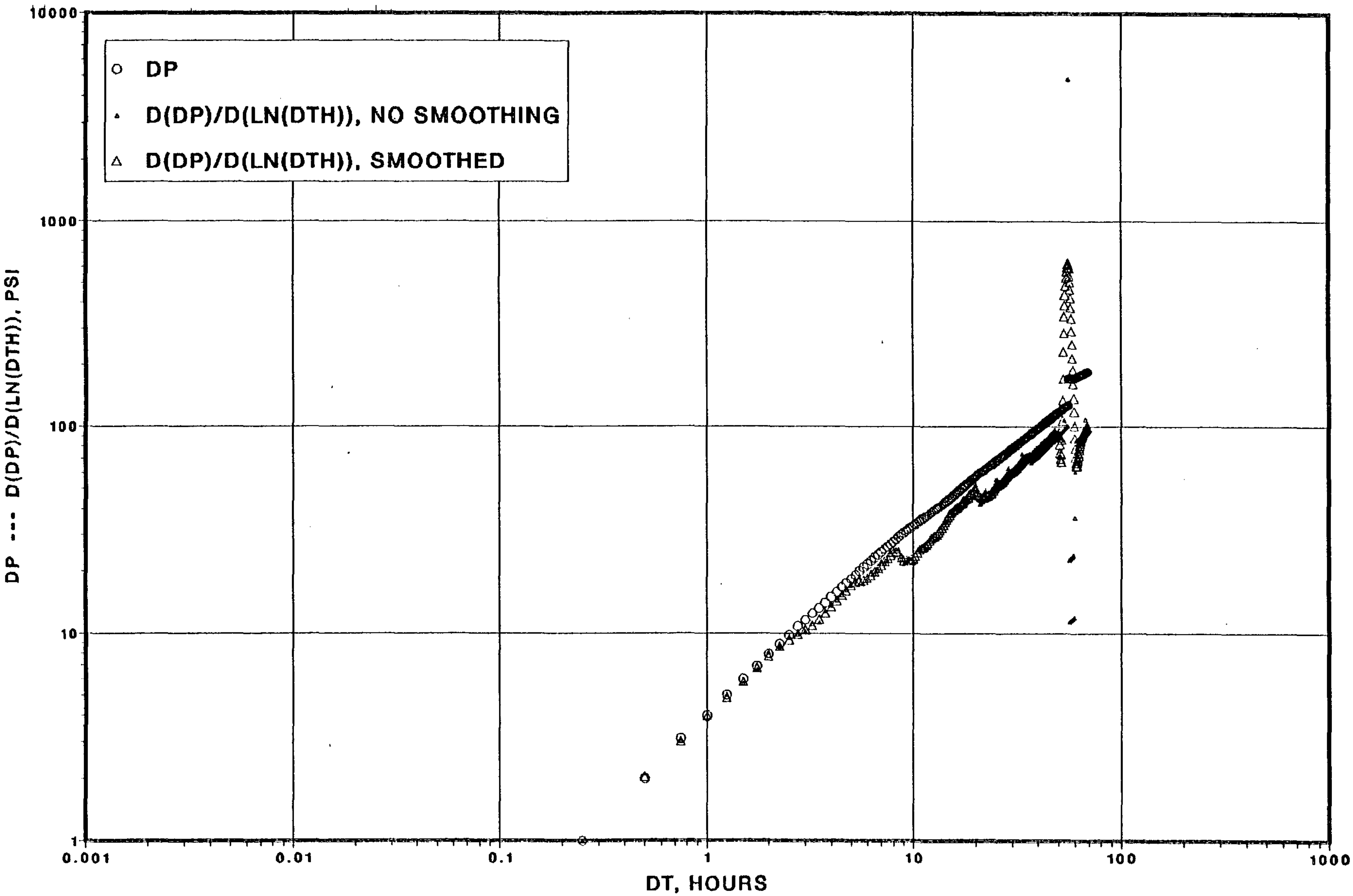


FIGURE 42

CVU 120 - Short Clock - 870916
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

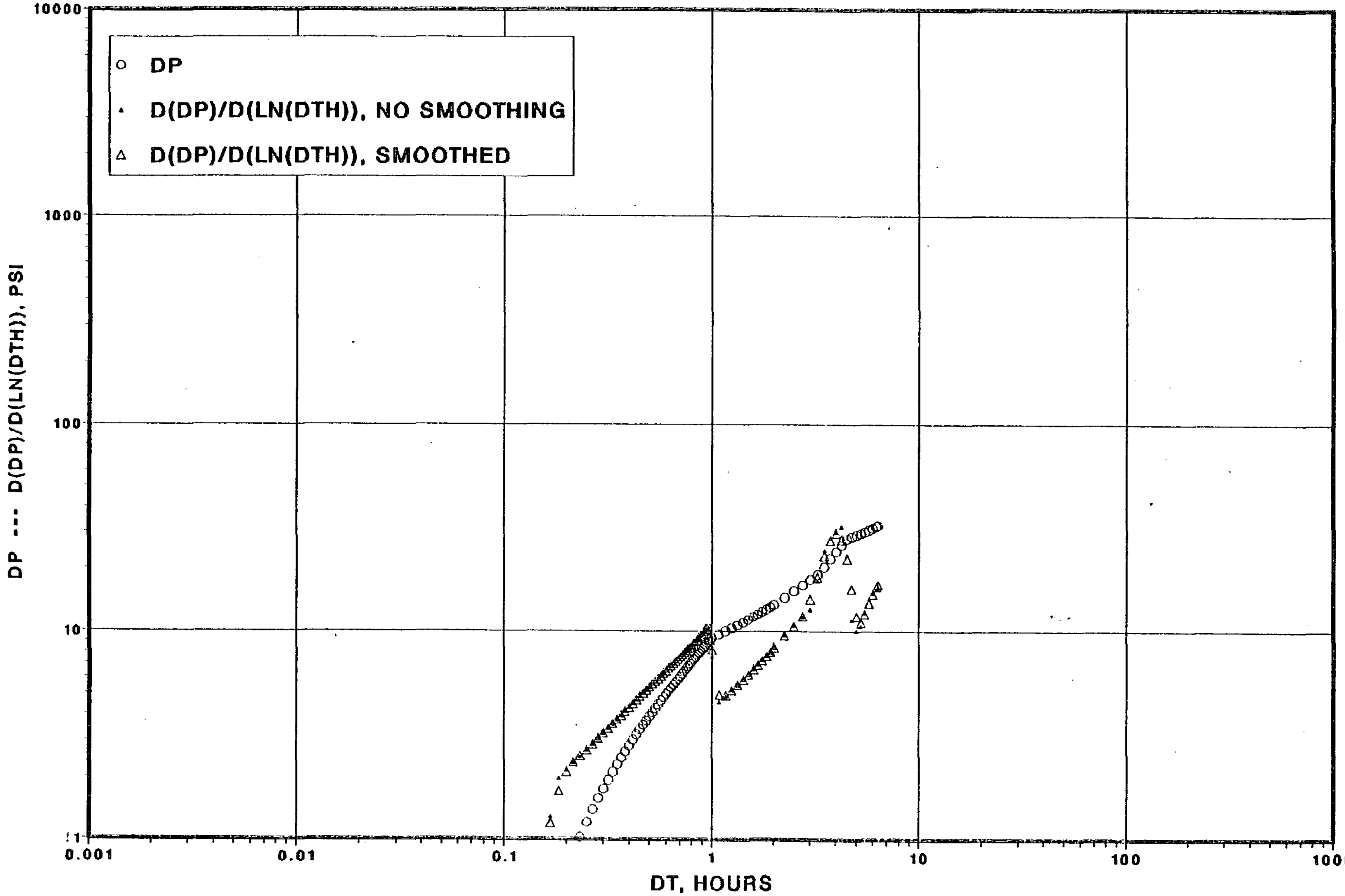


FIGURE 43

CVU 120 - Long Clock - 870916
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

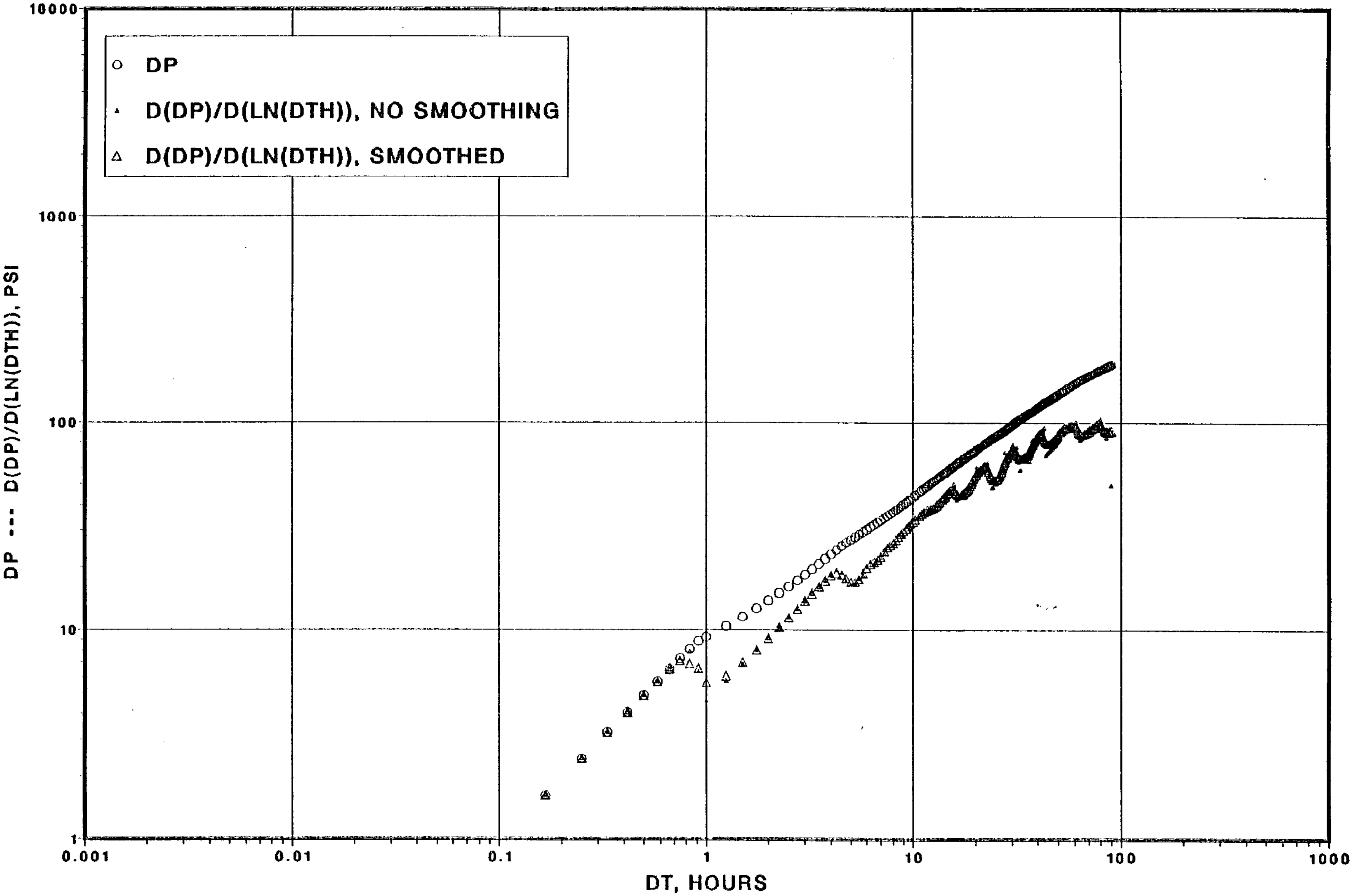


FIGURE 44

CVU120 - OVERNIGHT TEST - 870916
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 5, WINDOW = 5/10 INCHES

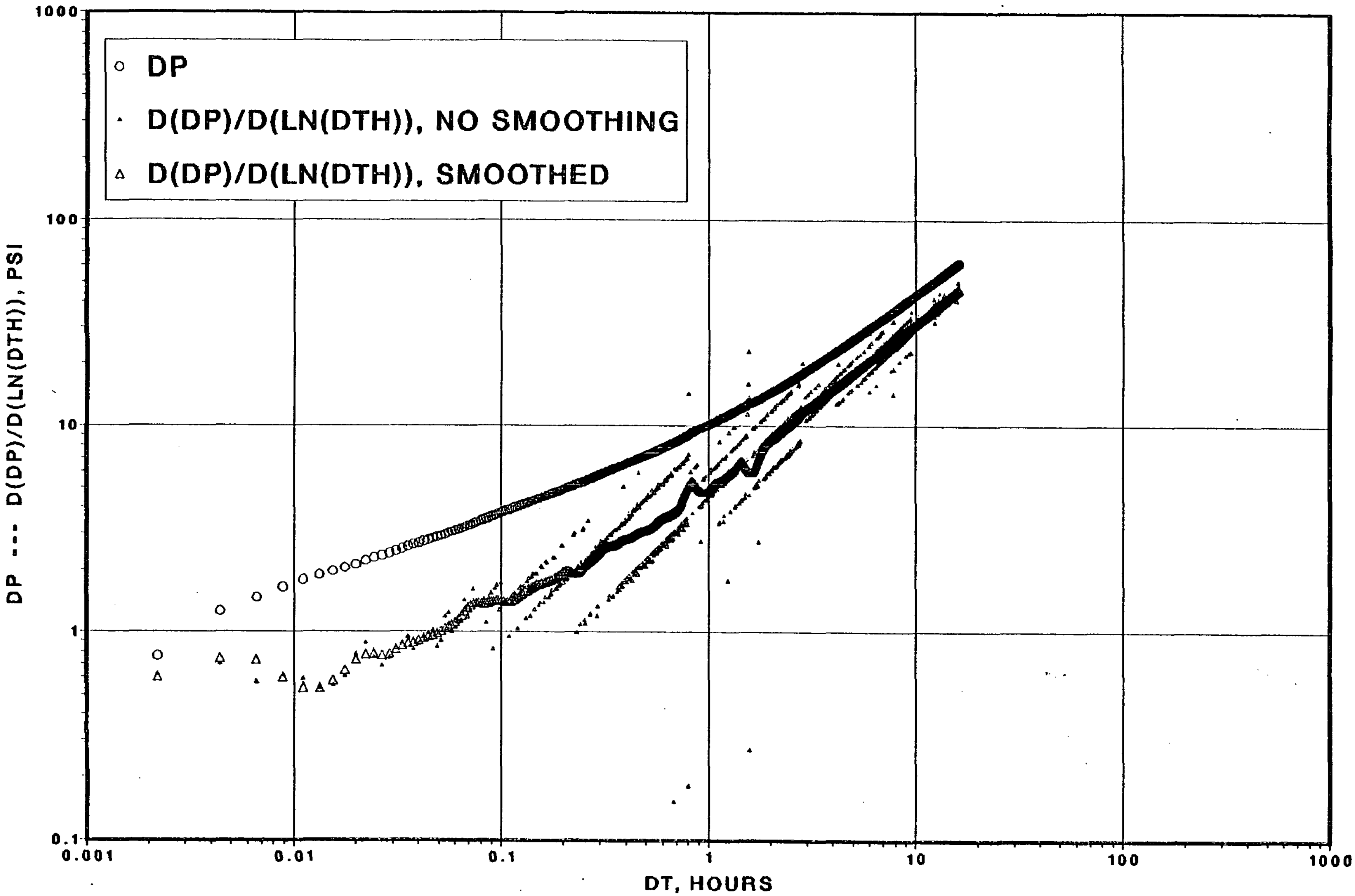


FIGURE 45

CVU 122 - 870325 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

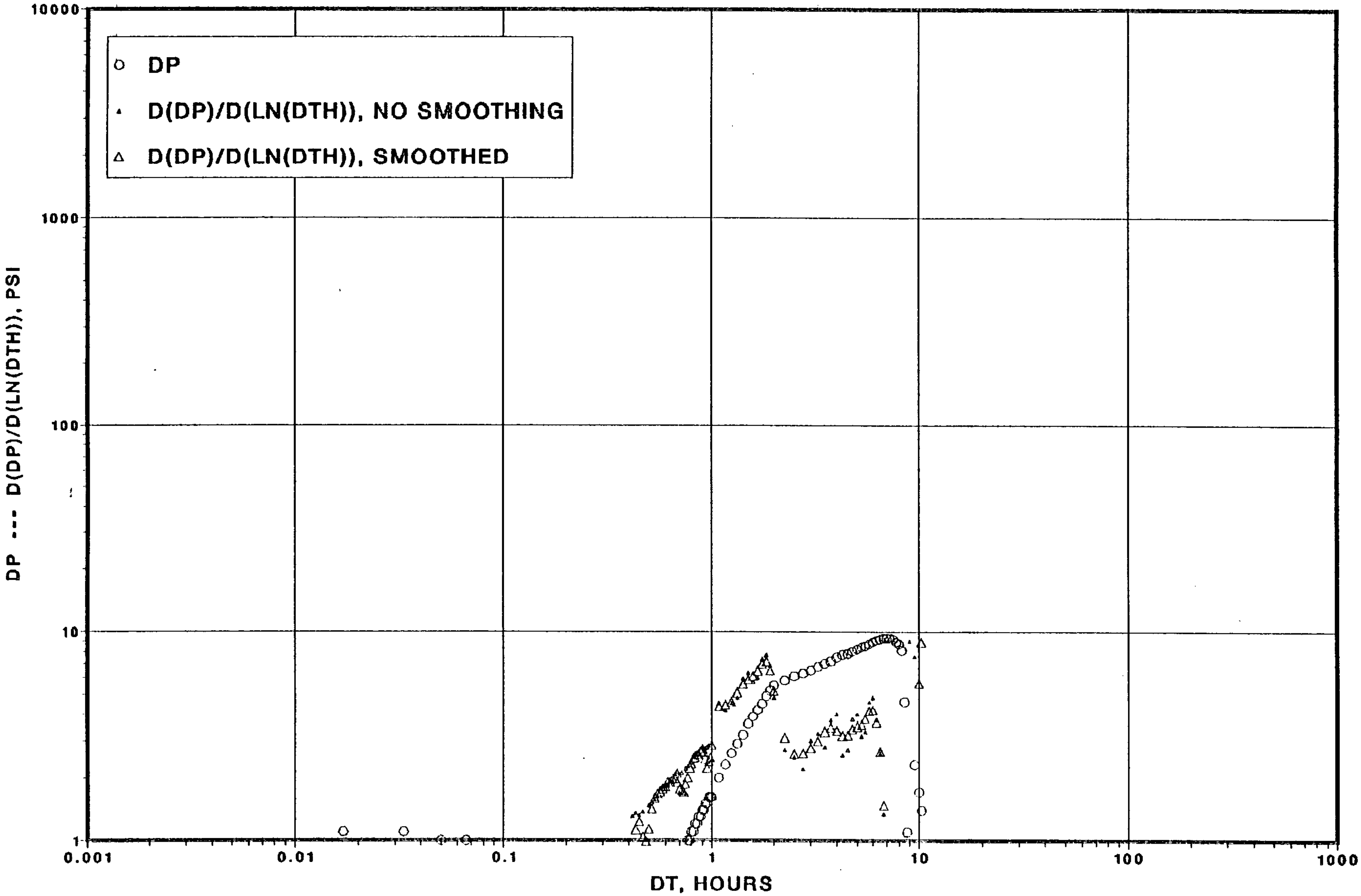


FIGURE 46

CVU 122 - 870325 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

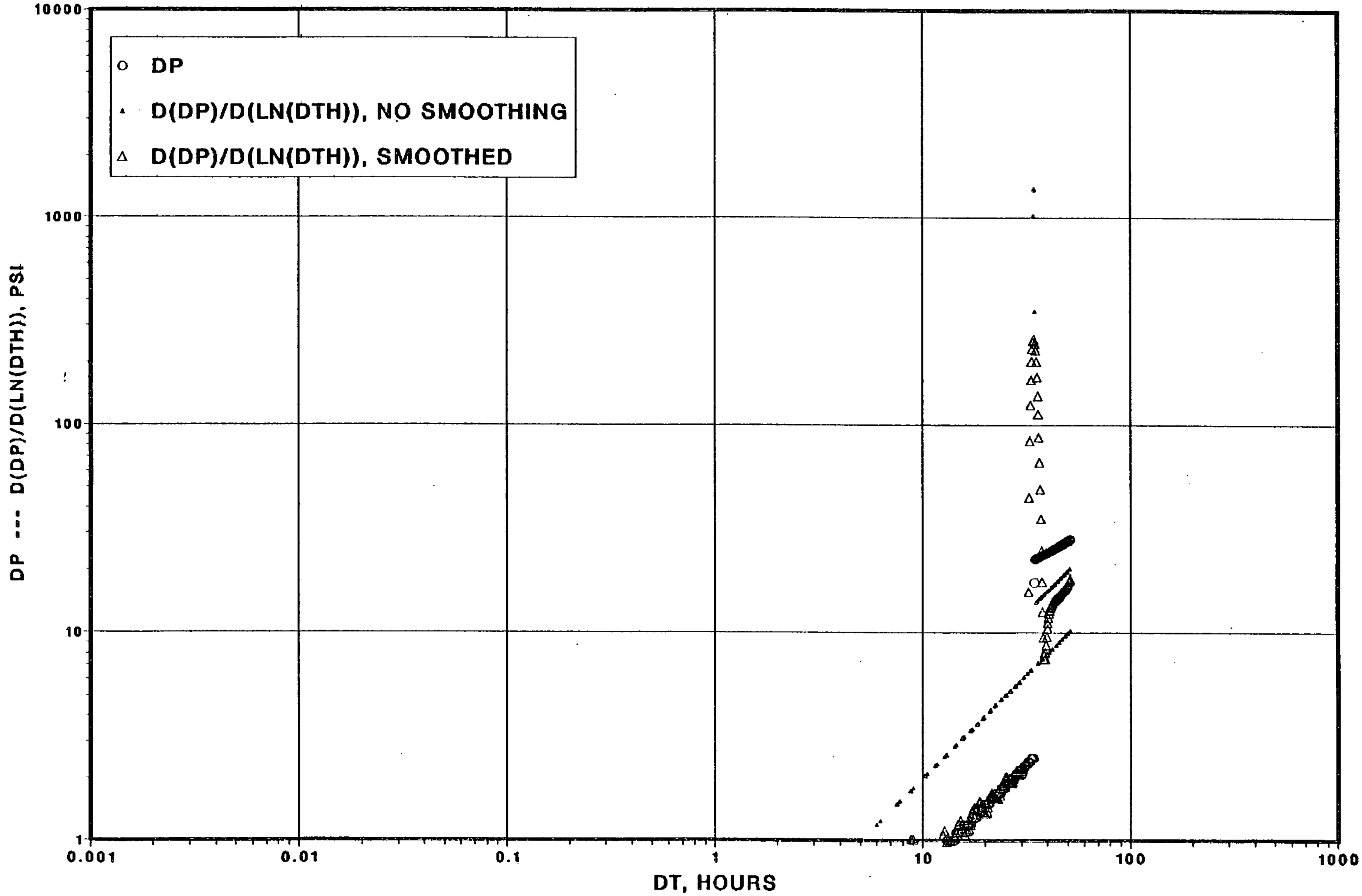


FIGURE 47

CVU 134 - 861023
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

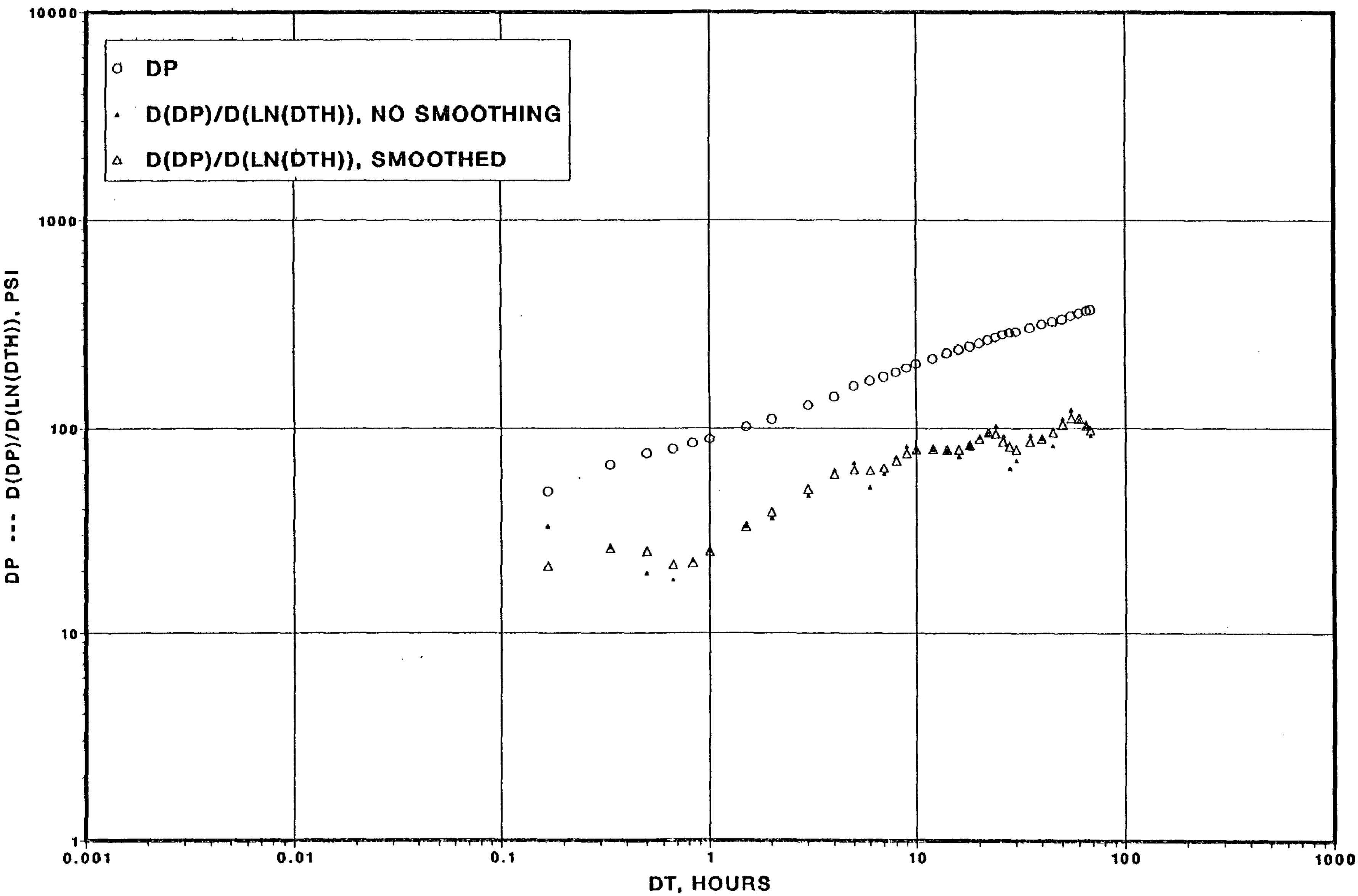


FIGURE 48

CVU 134 - Short Clock - 870903
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

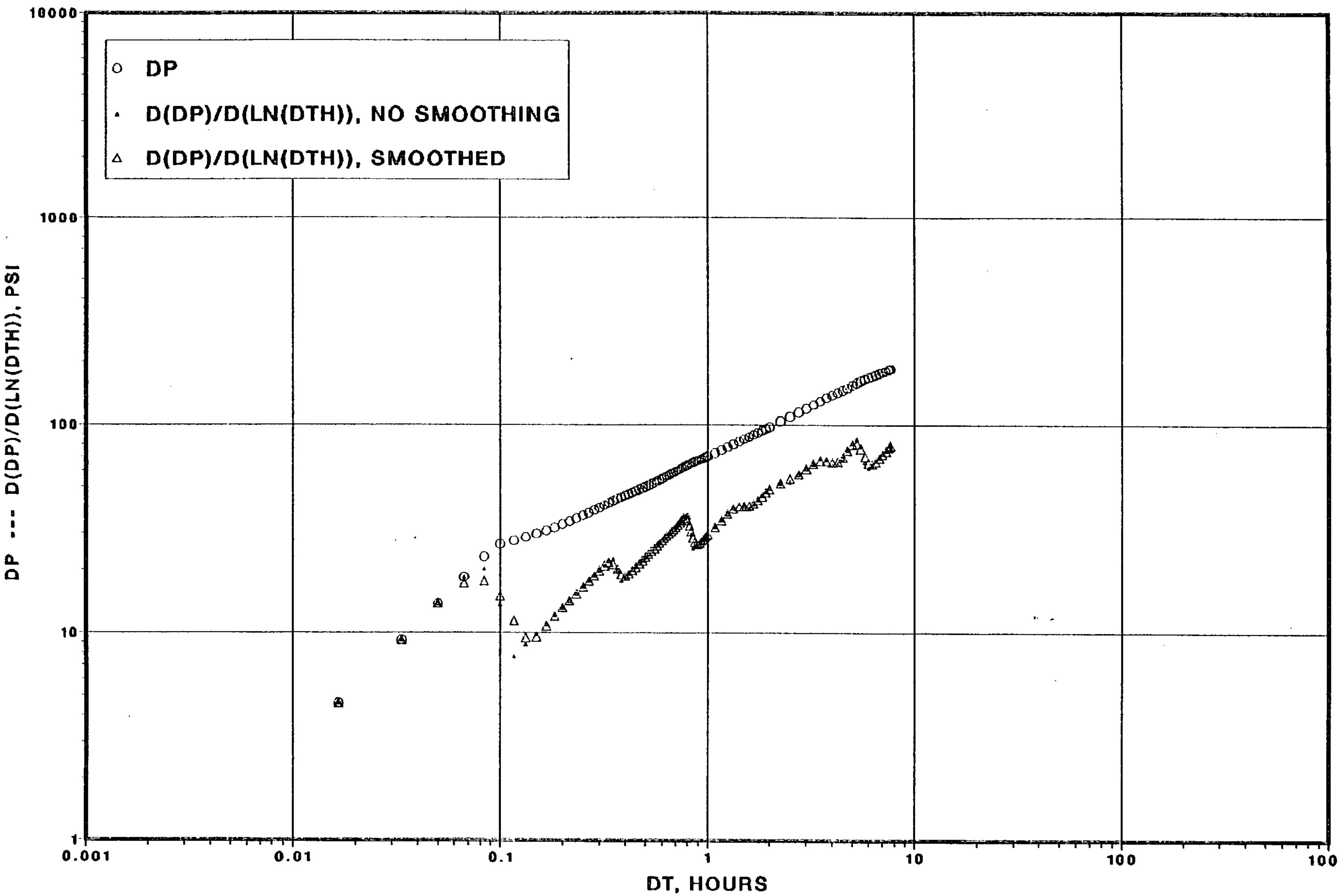


FIGURE 49

CVU 134 - Long Clock - 870903
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

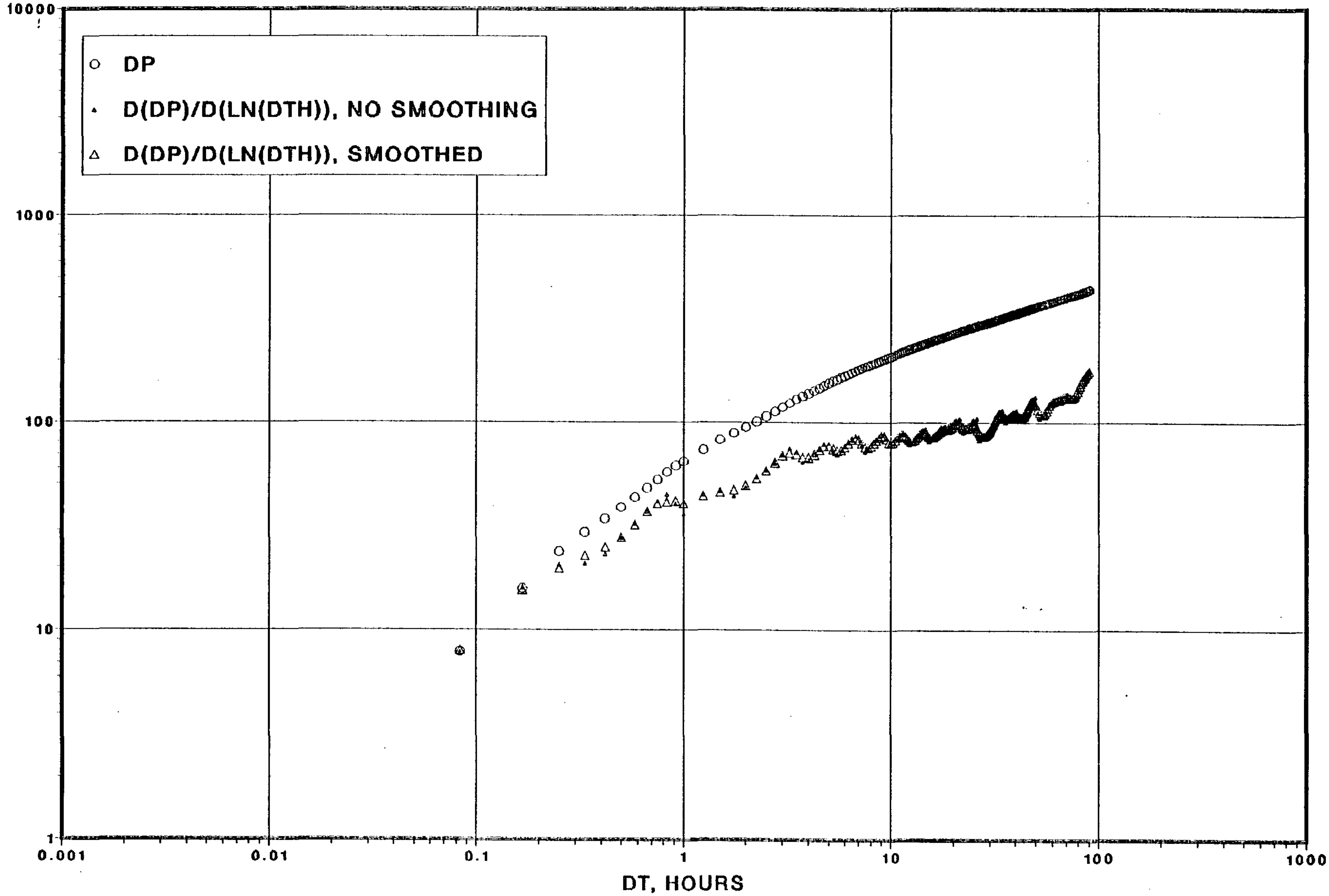


FIGURE 50

CVU 135 - 861023
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

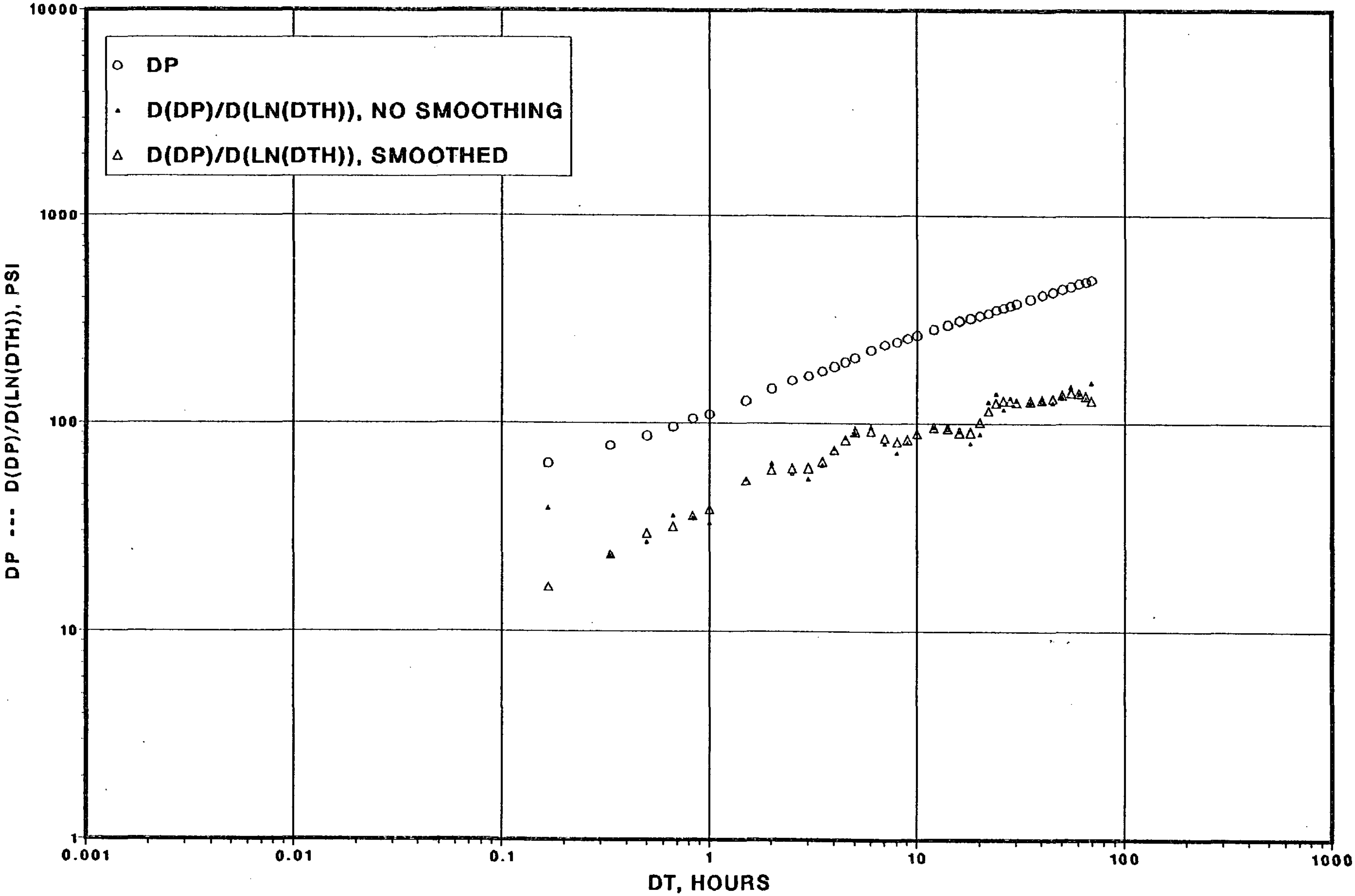


FIGURE 51

CVU 135 - Short Clock - 870907
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

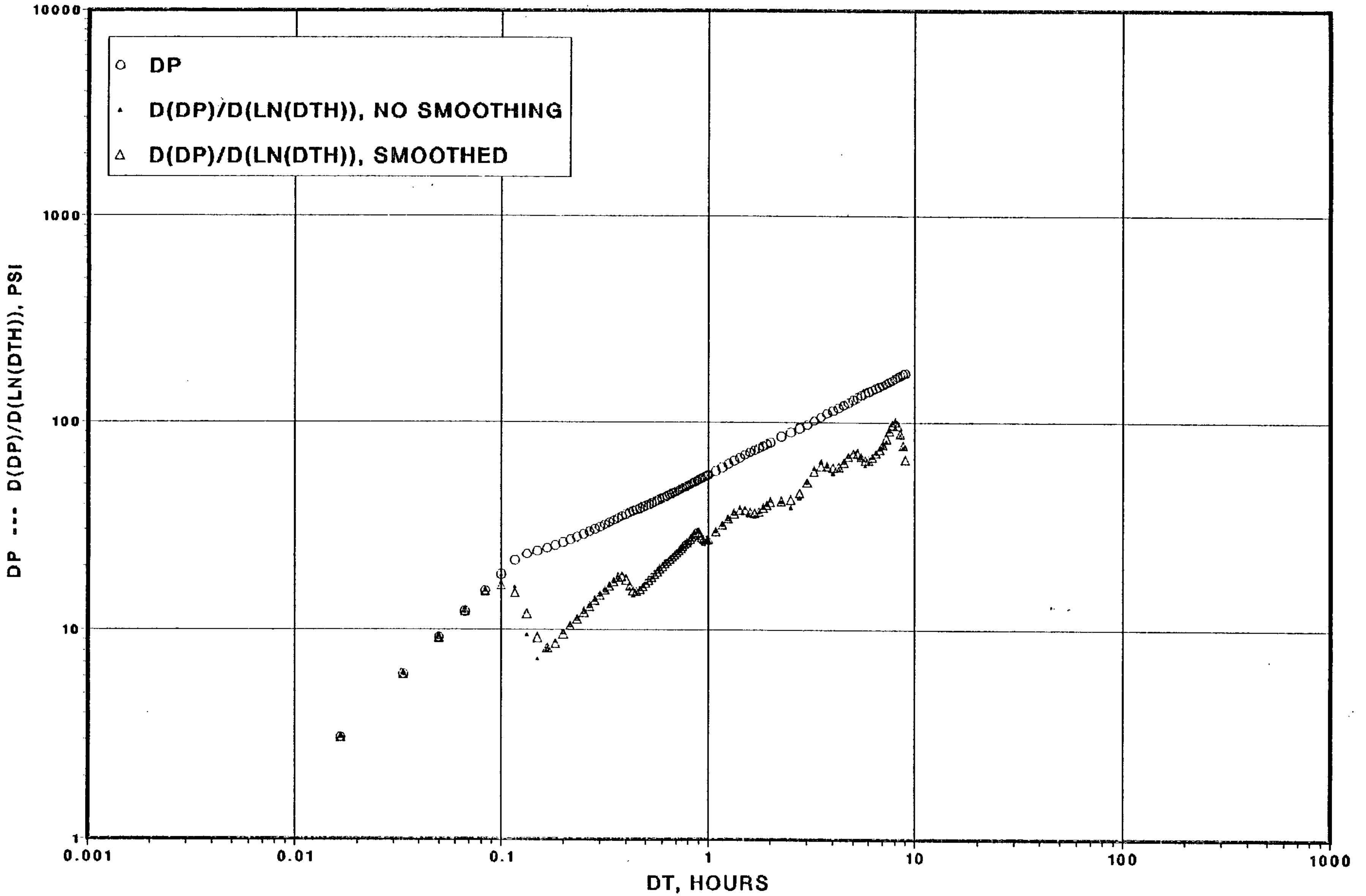


FIGURE 52

CVU 135 - Long Clock - 870907
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

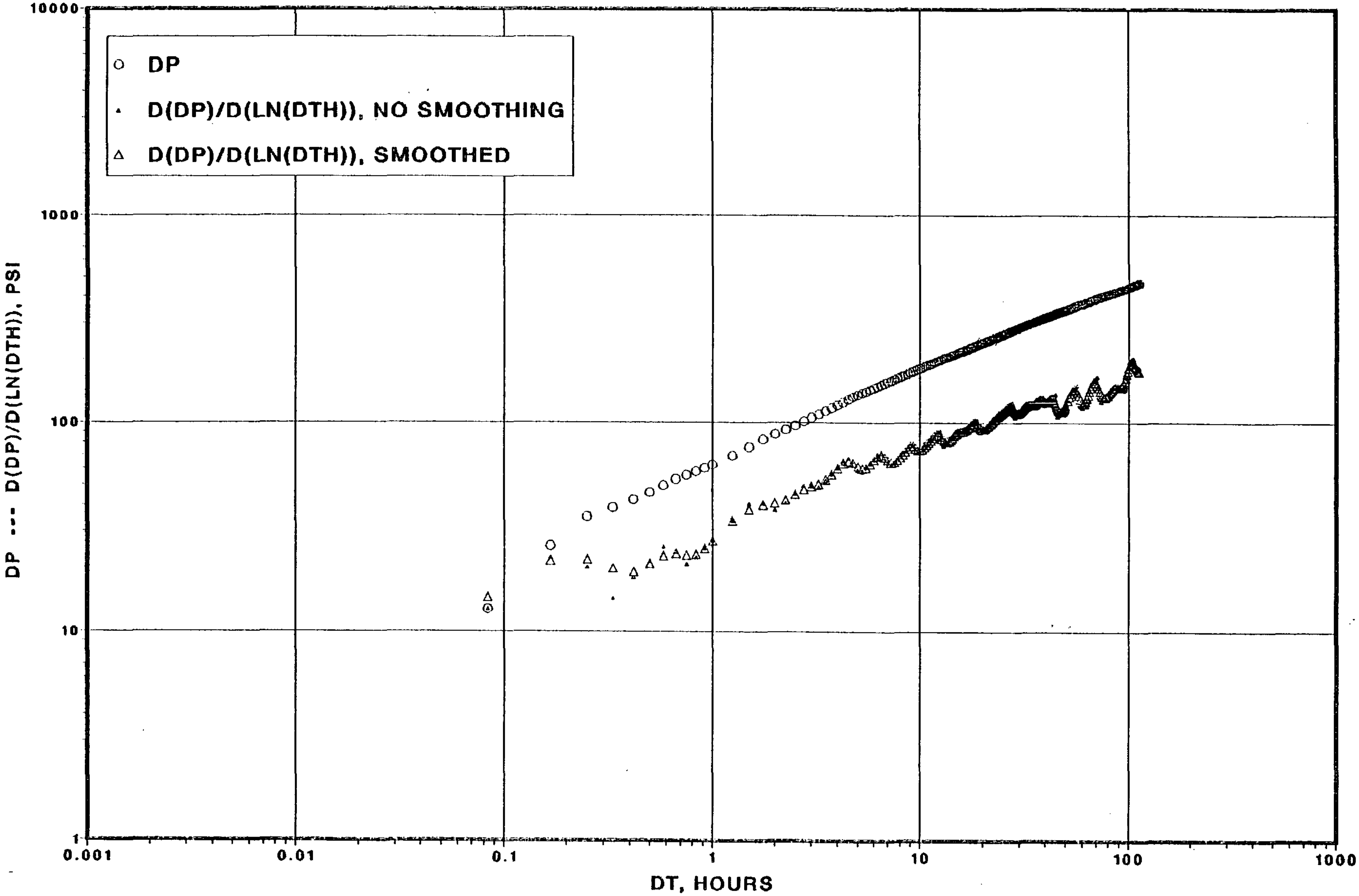


FIGURE 53

CVU 138 - 861009
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

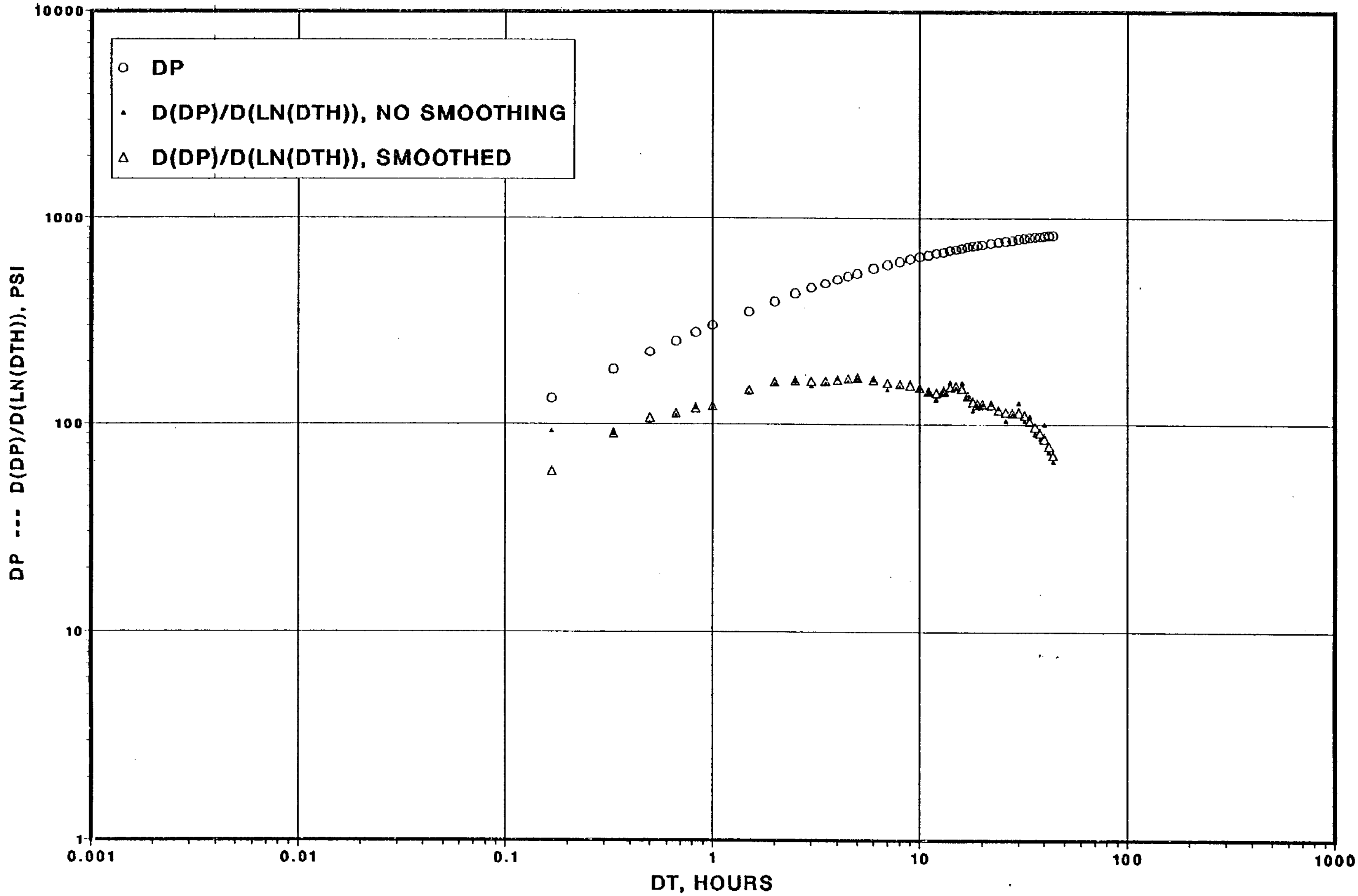


FIGURE 54

CVU 140 - 1127 BPD - PANEX GAUGE - 861119
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 3.244, P_{si} = 2521.780, T_p = 8760.

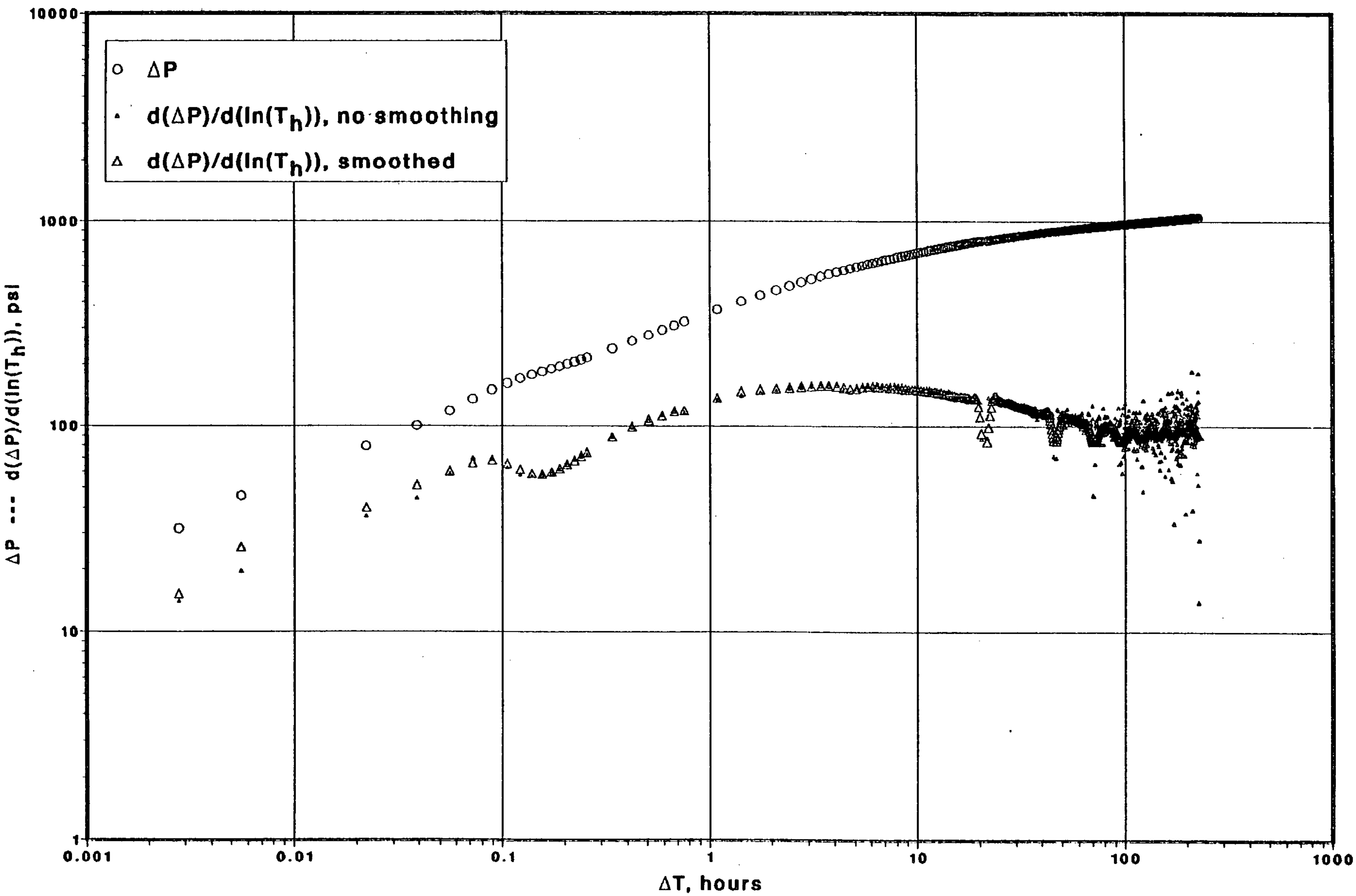


FIGURE 55

CVU 141 - 1127 BPD - PANEX GAUGE A - 861110
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 3.250, P_{si} = 2589.550, T_p = 8760.

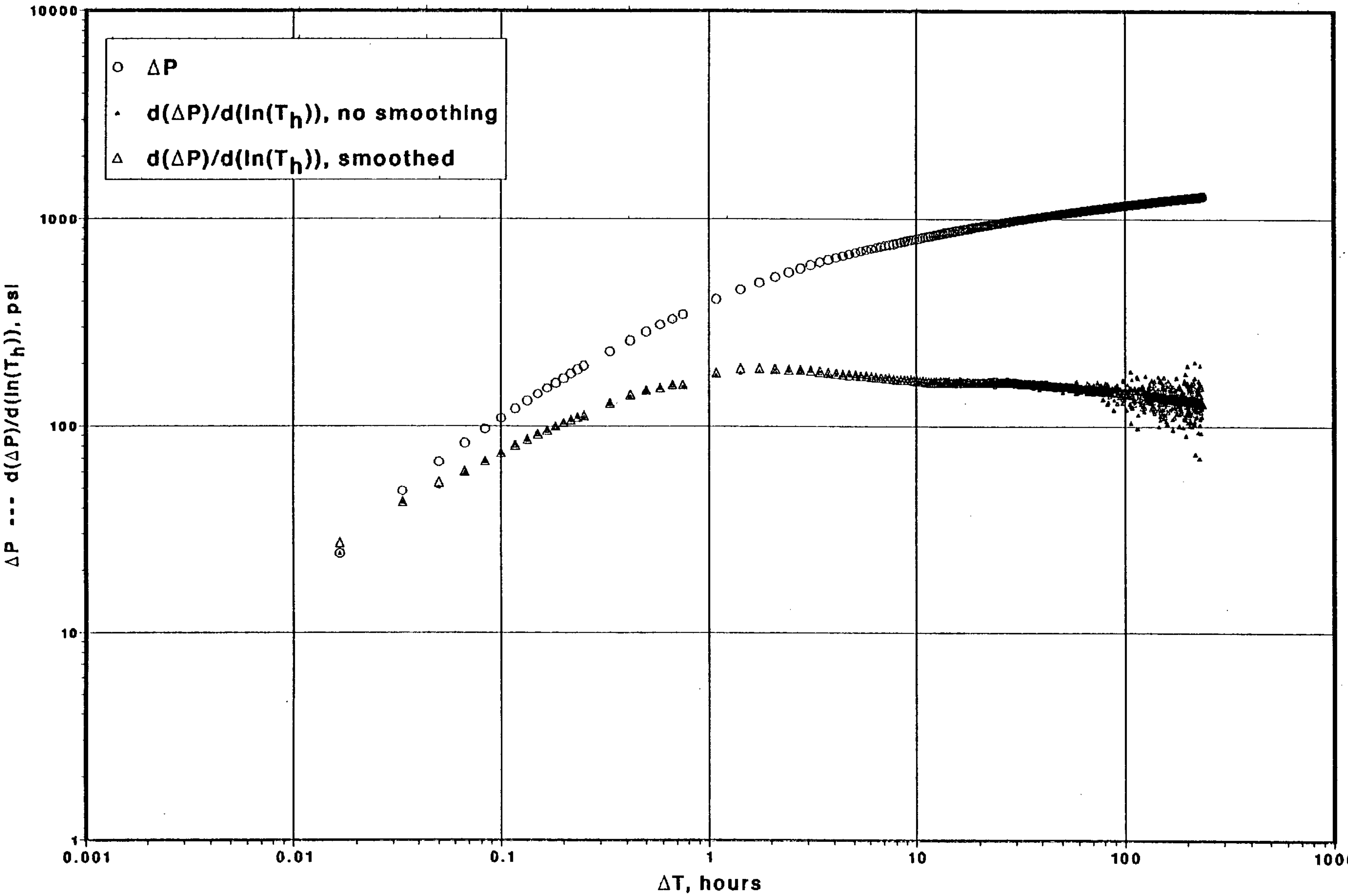


FIGURE 56

CVU 144 - 870320 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

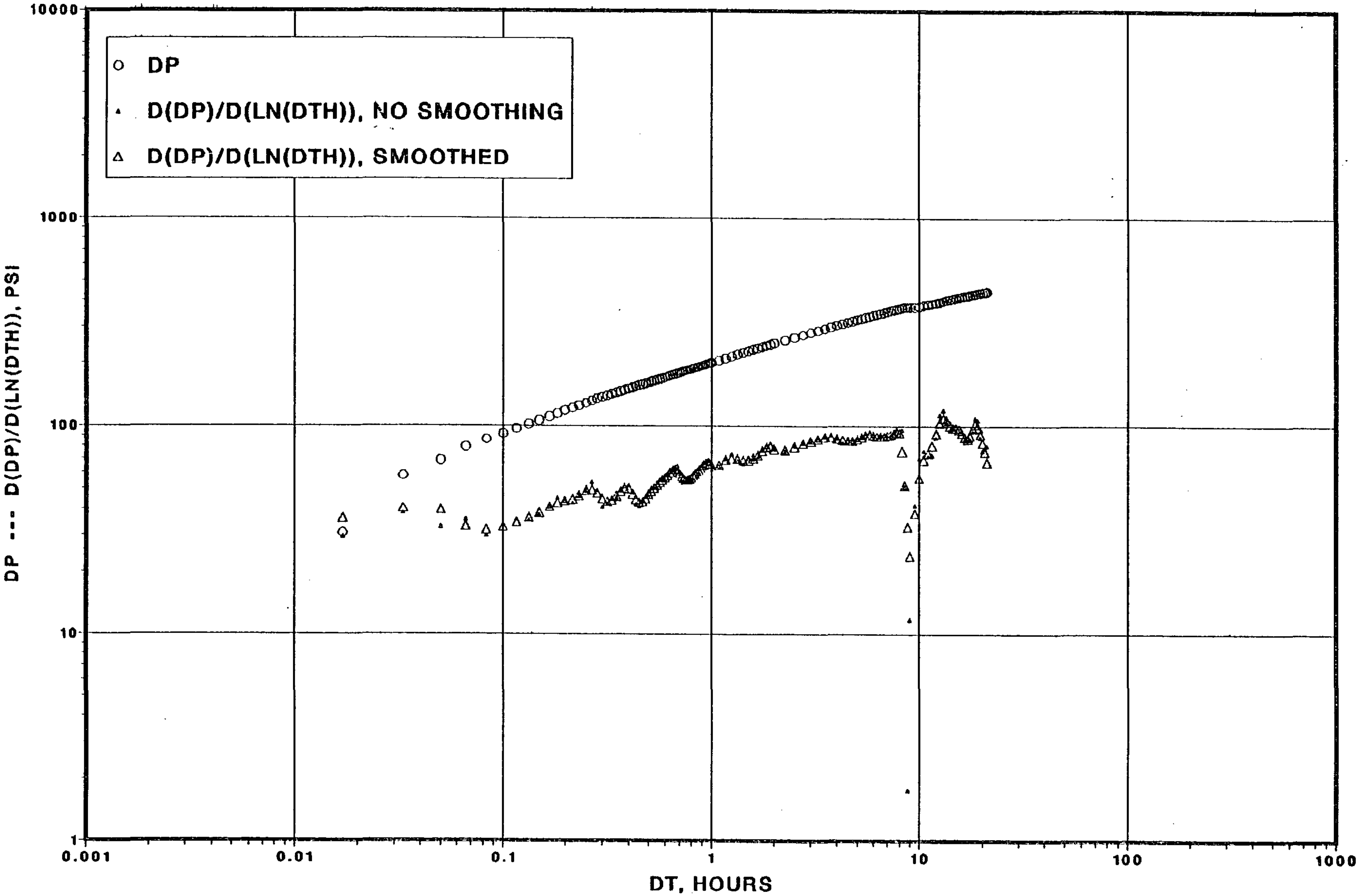


FIGURE 57

CVU 144 - 870320 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

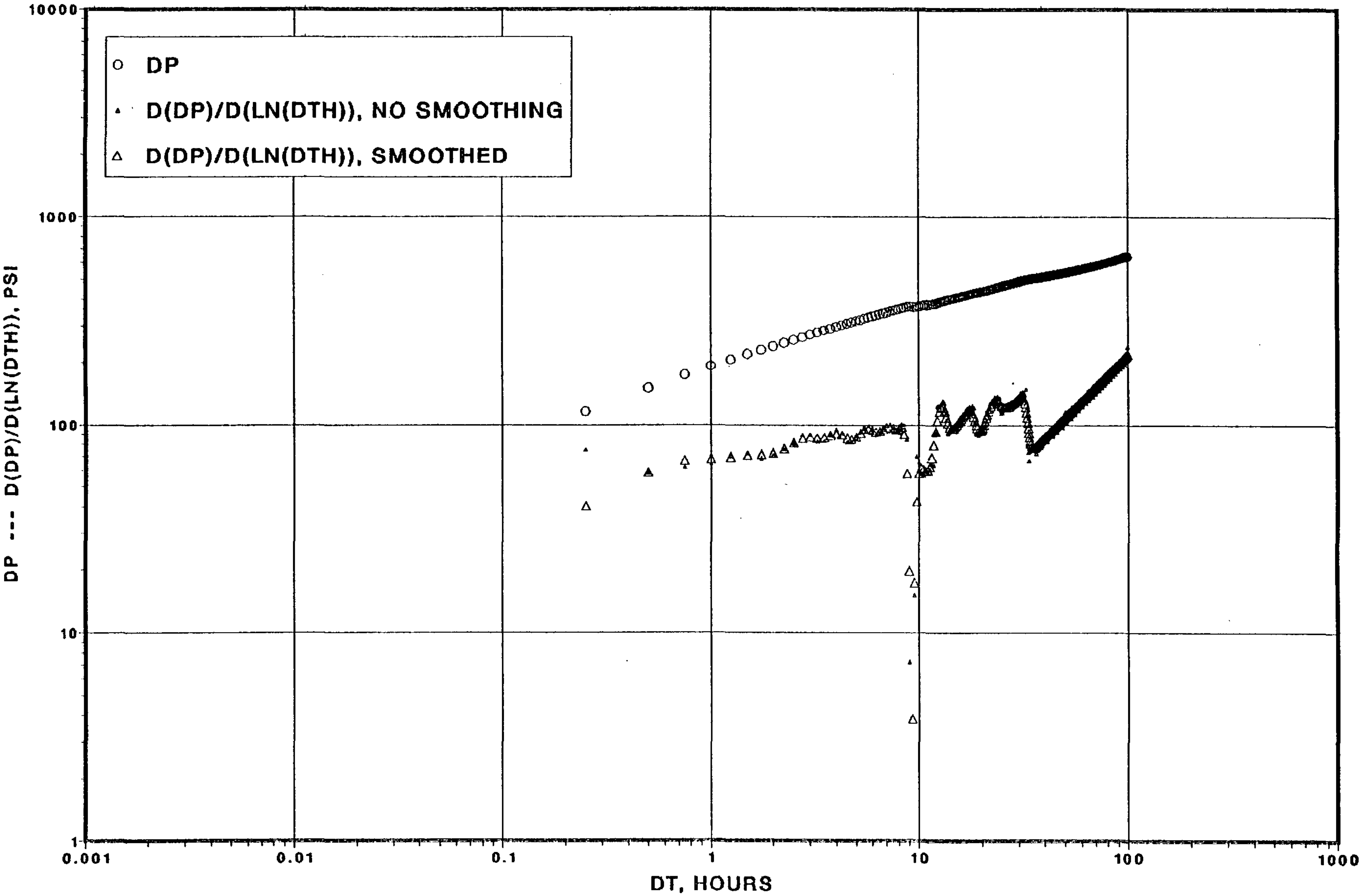


FIGURE 58

CVU 145 - 861009
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

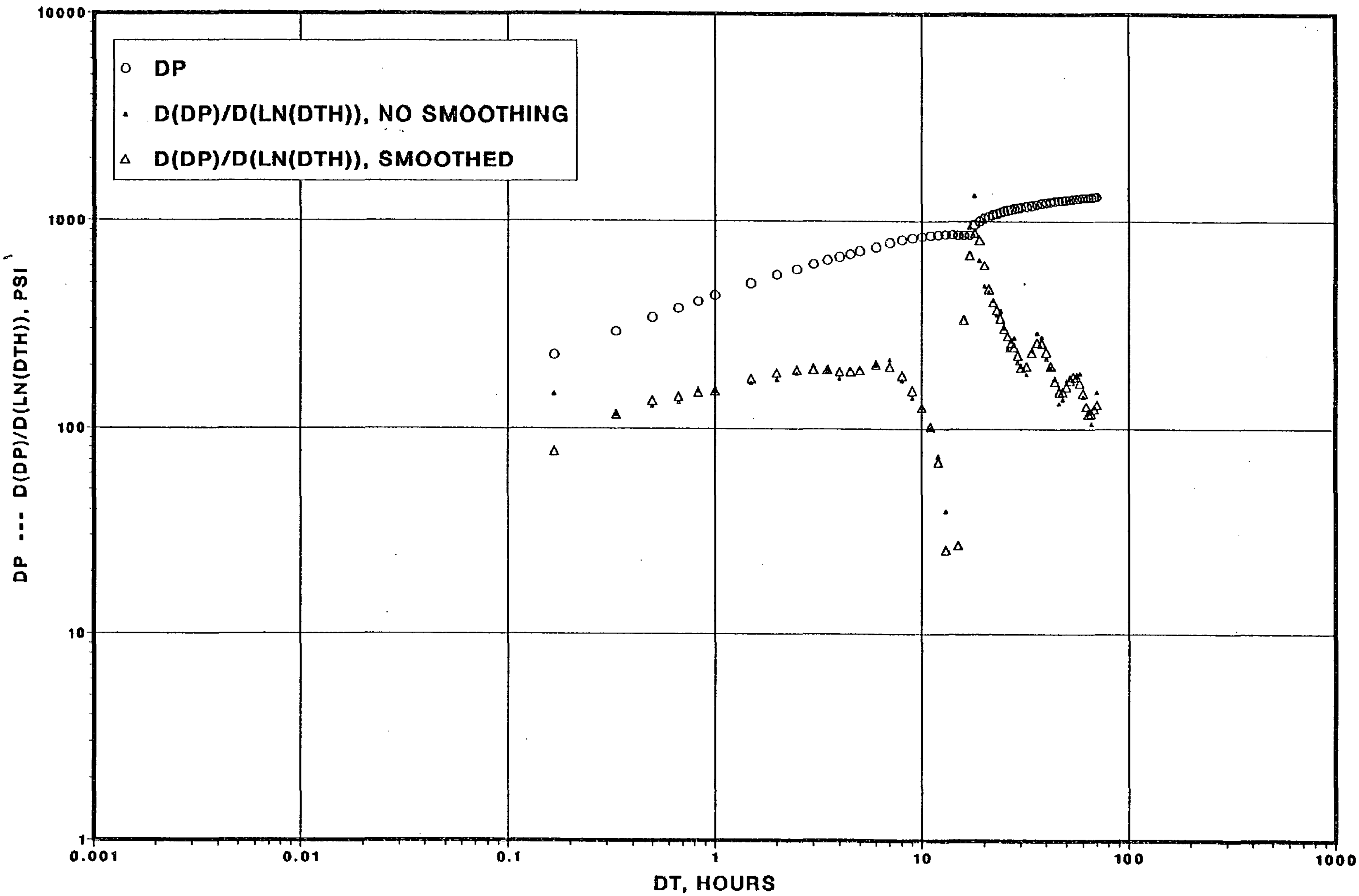


FIGURE 59

CVU 156 - 523 BPD - AMERADA GAUGE - 861026
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 0.000, P_{si} = 2940.200, T_p = 8760.

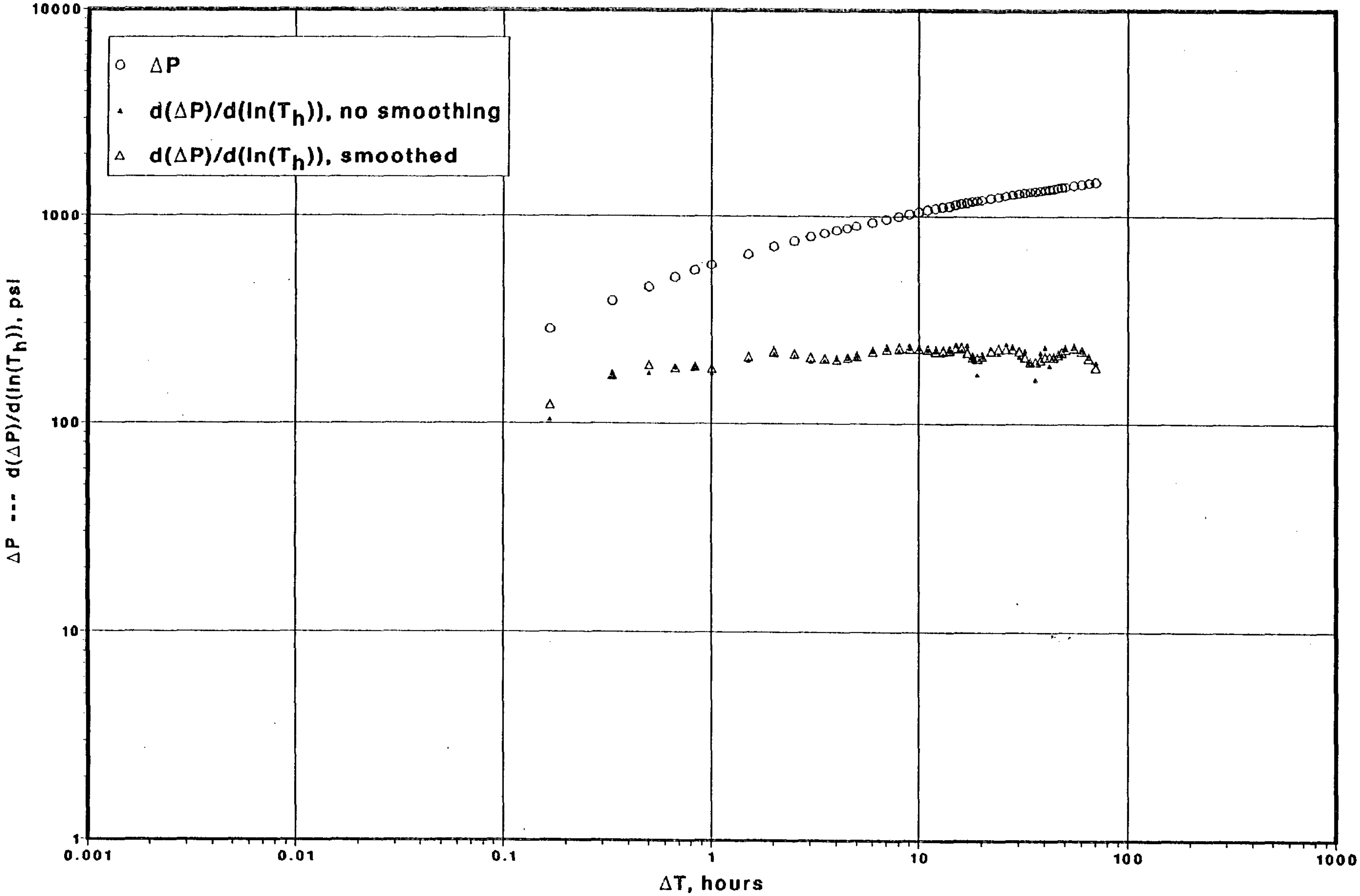


FIGURE 60

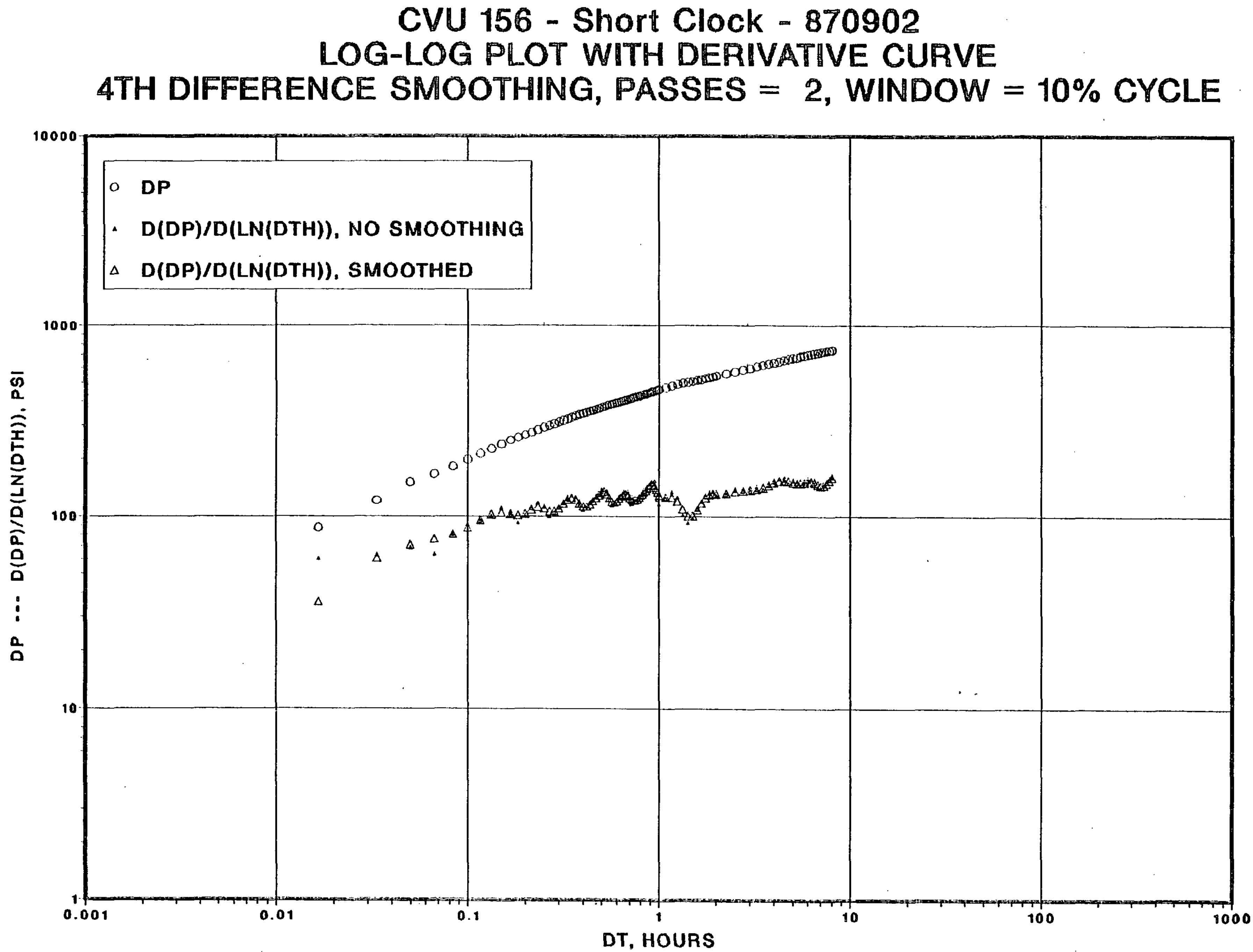

CVU 156 - Short Clock - 870902
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

FIGURE 61

CVU 156 - Long Clock - 870902
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

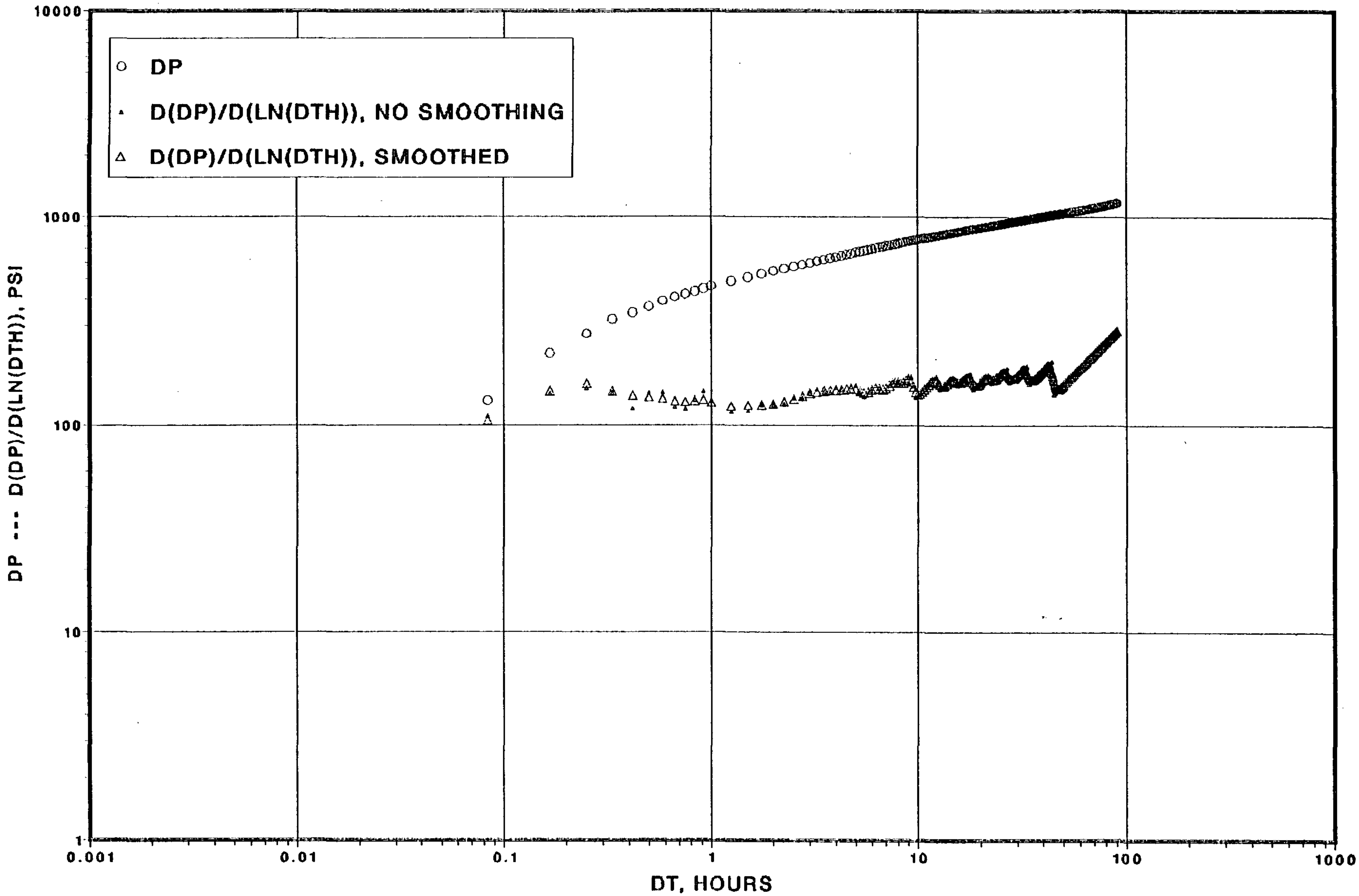


FIGURE 62

CVU 156 - MINI TEST - 870916
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 2/10 INCHES

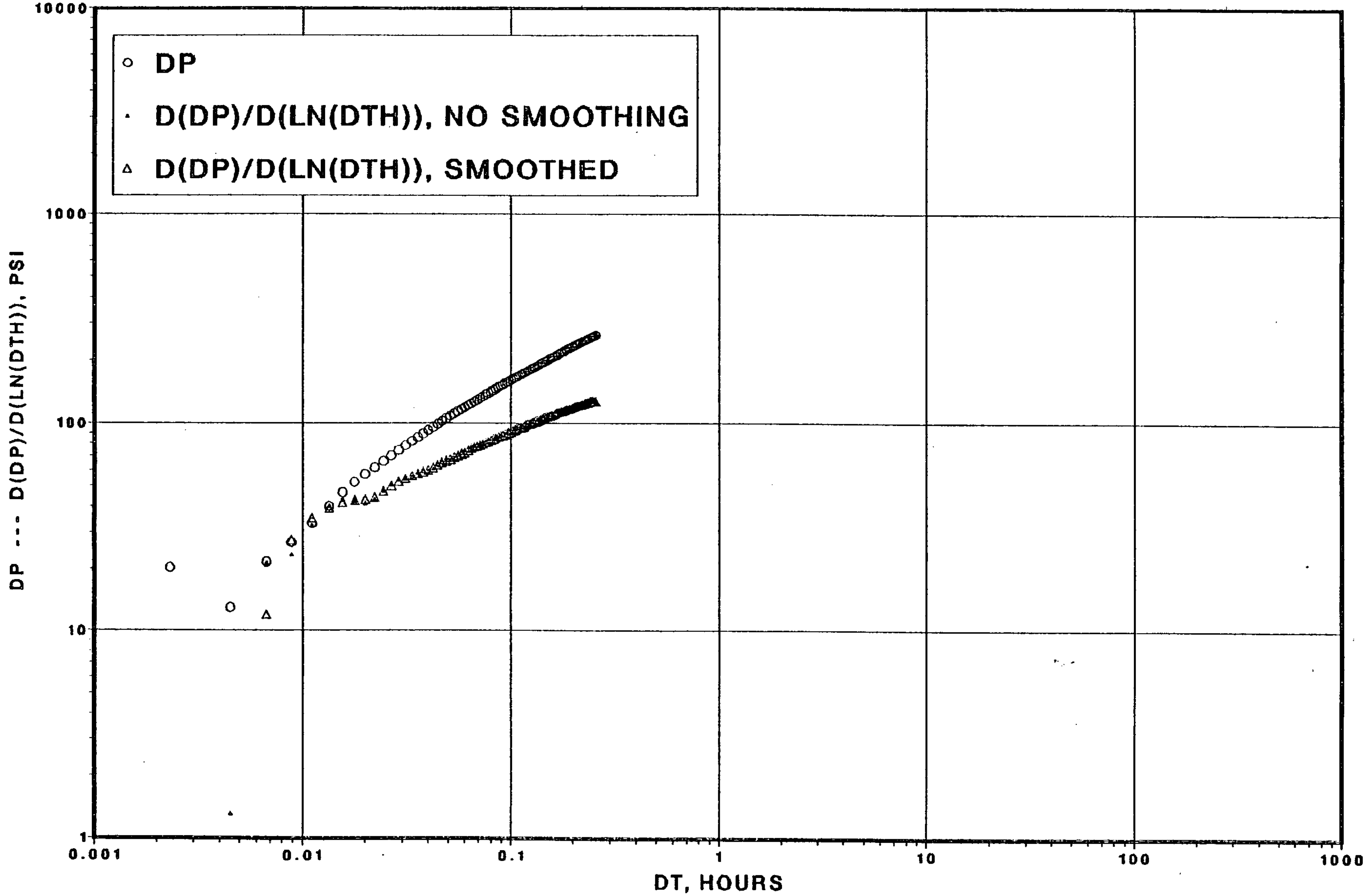


FIGURE 63

CVU 157 - 714 BPD - AMERADA GAUGE - 861026
LOG-LOG PLOT WITH DERIVATIVE, PASSES = 2, WINDOW = 10% CYCLE
T_{si} = 0.000, P_{si} = 2896.200, T_p = 8760.

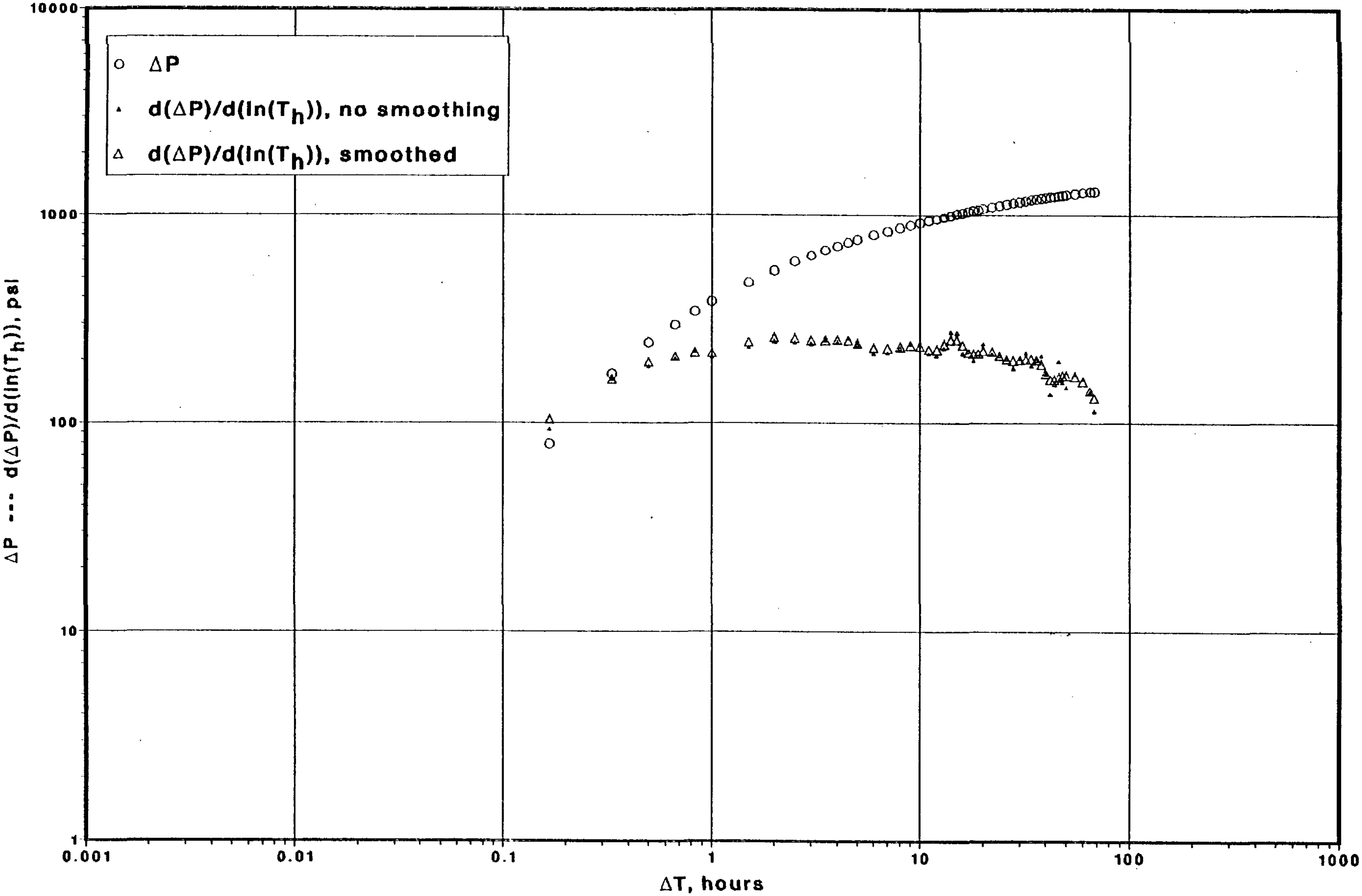


FIGURE 64

CVU 157 - Short Clock - 870907
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

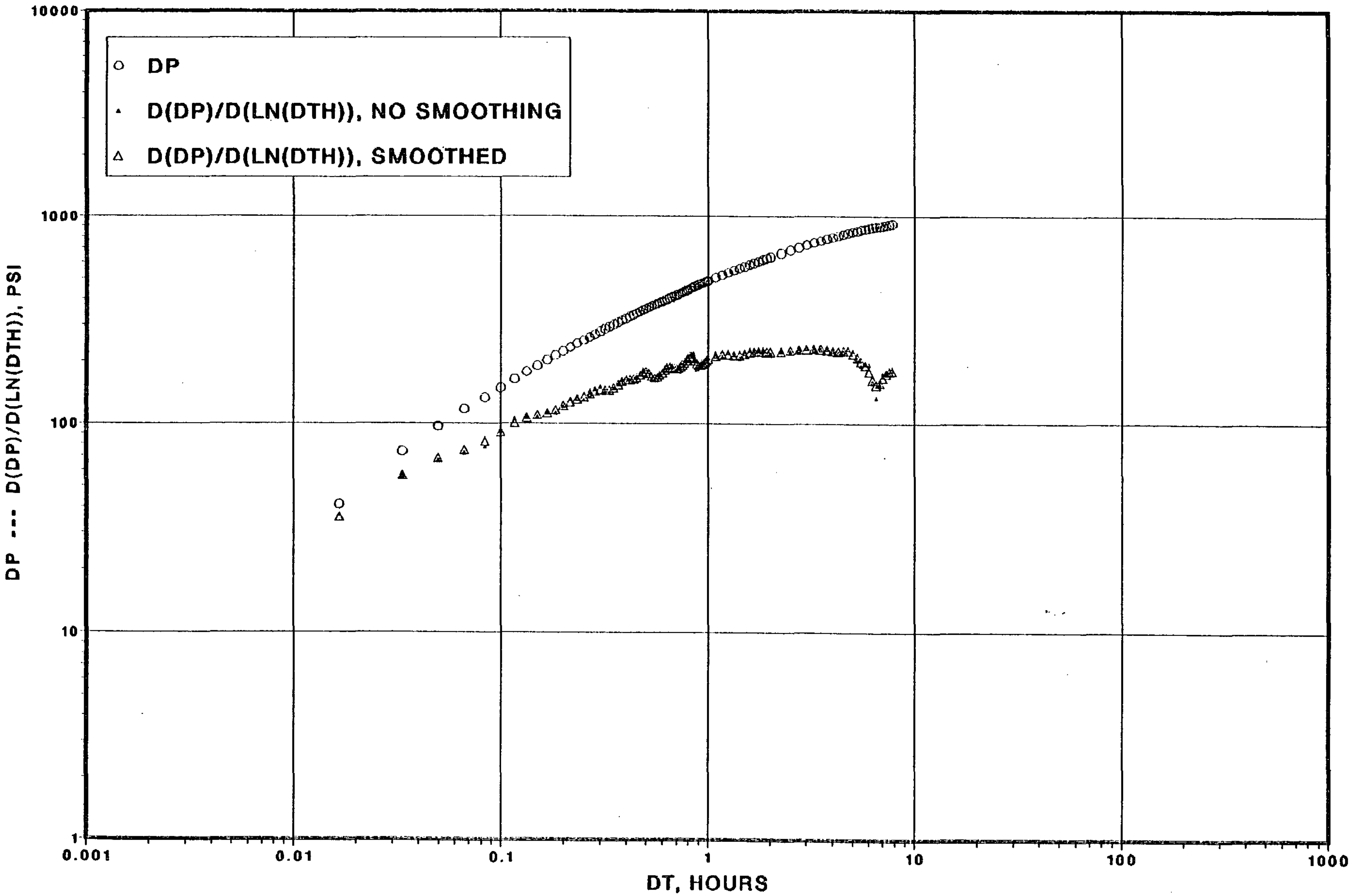


FIGURE 65

CVU 157 - Long Clock - 870907
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

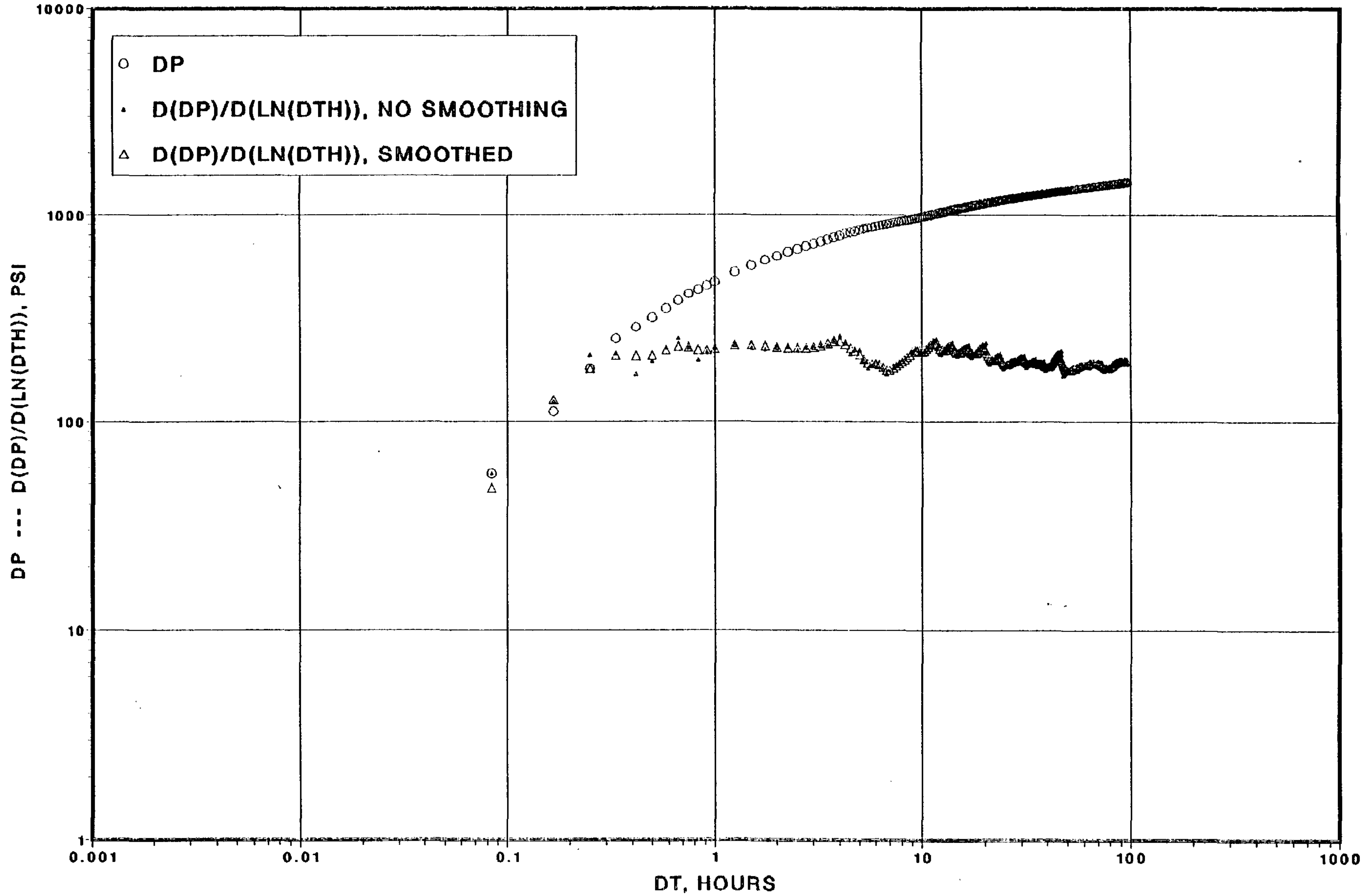


FIGURE 66

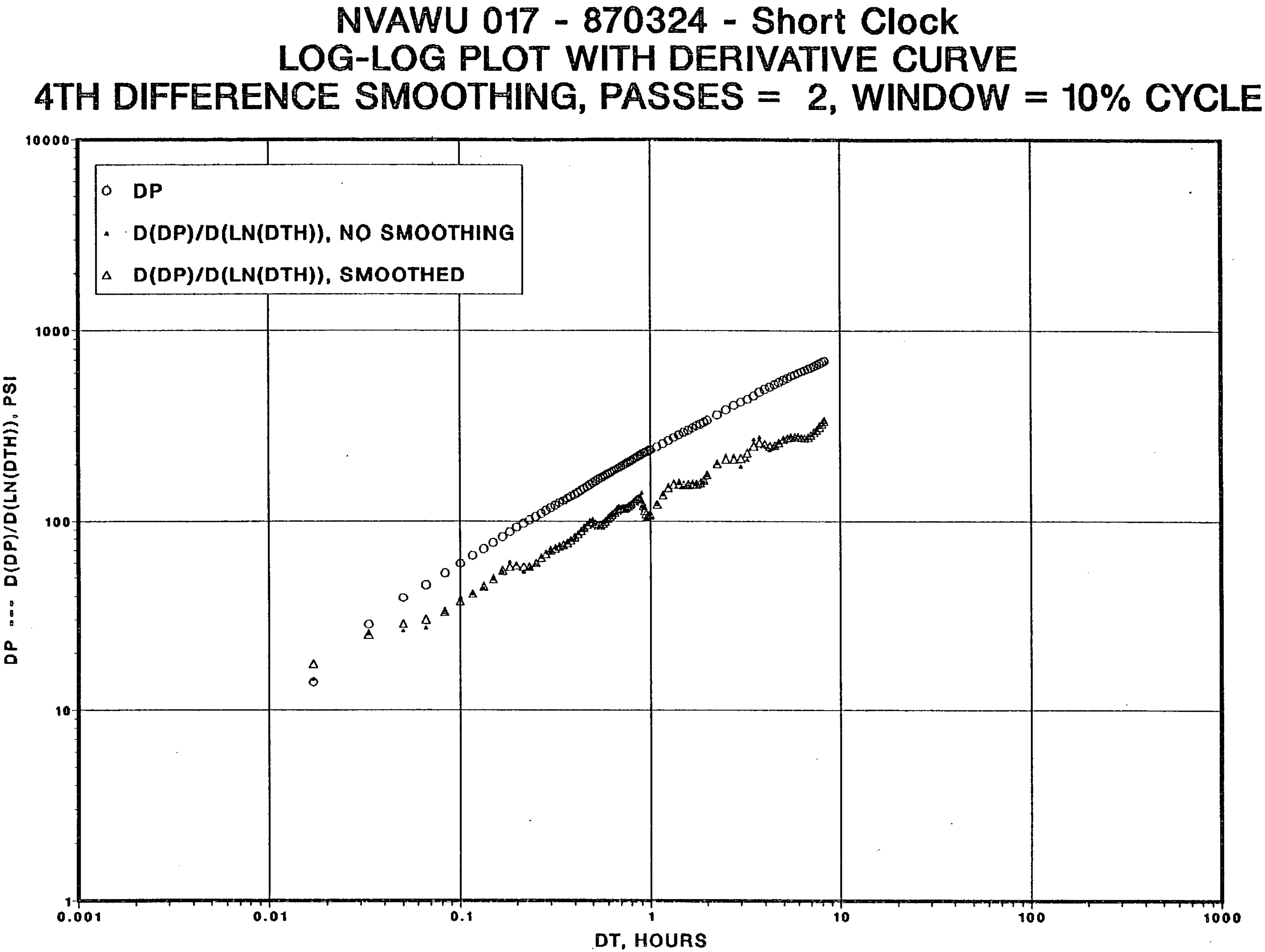

NVAWU 017 - 870324 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS
DP --- D(DP)/D(LN(DTH)), PSI

FIGURE 67

NVAWU 017 - 870324 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

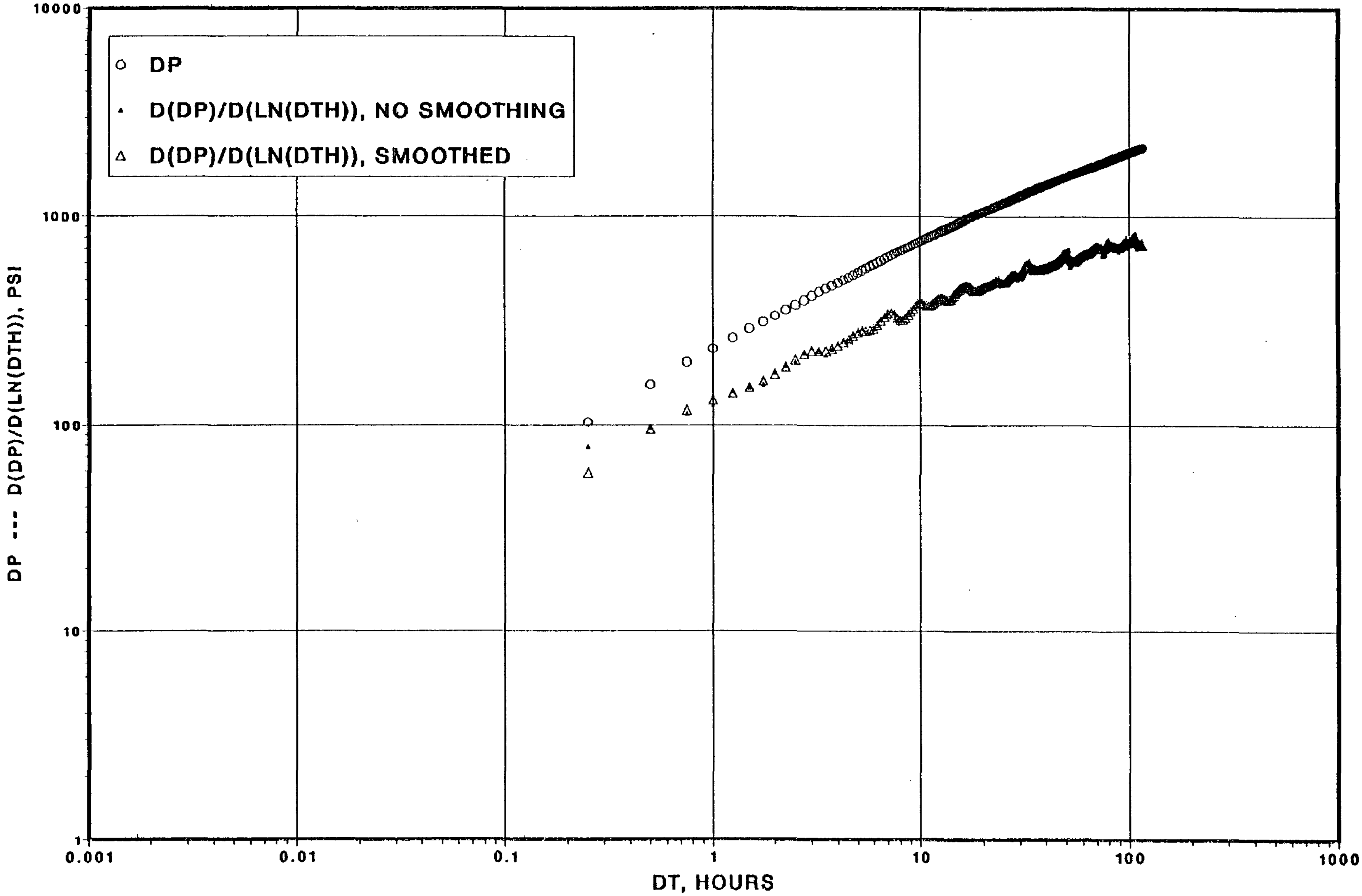


FIGURE 68

VGSAU 015 X - 870309 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

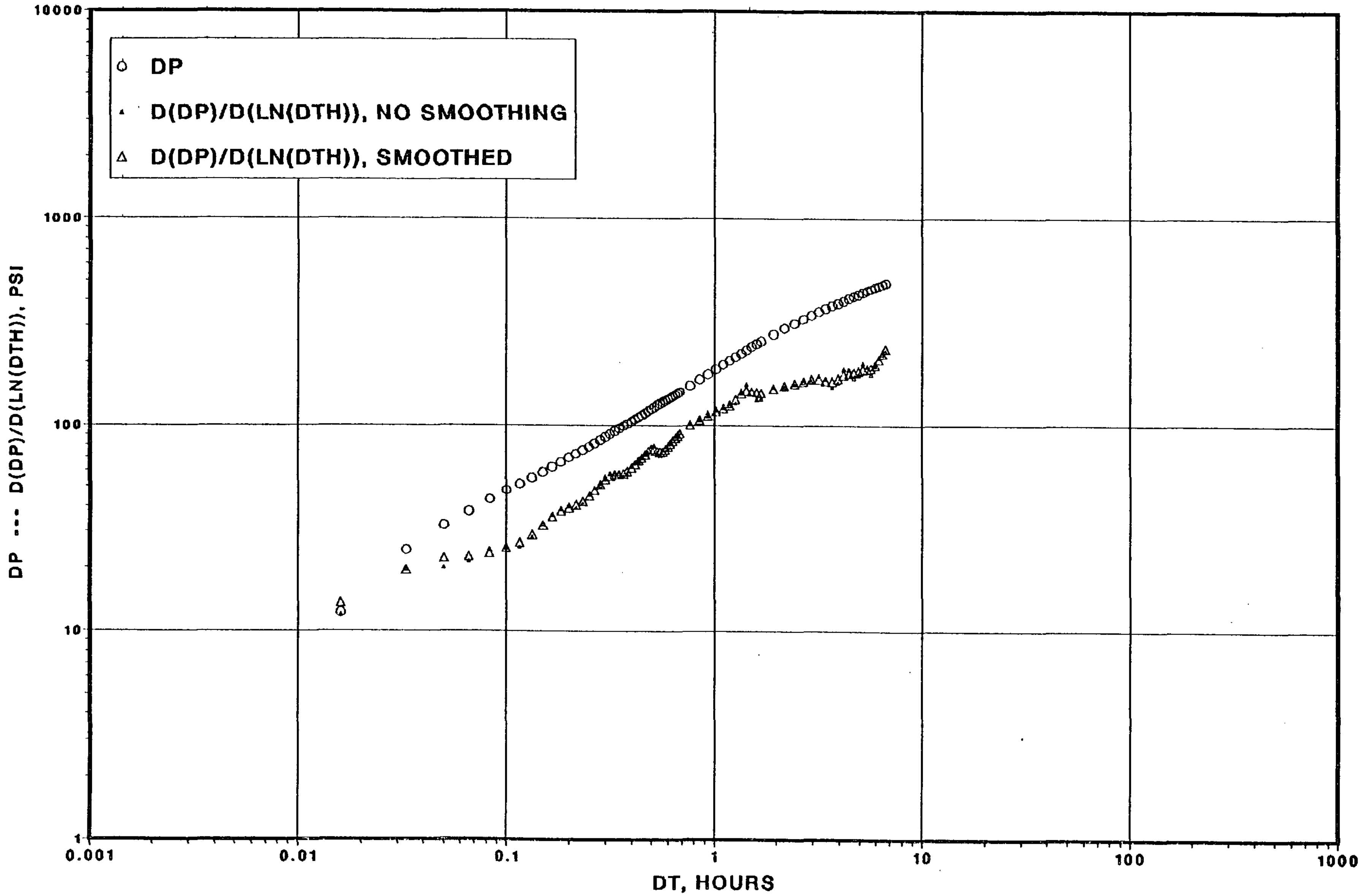


FIGURE 69

VGSAU 015 - 870309 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

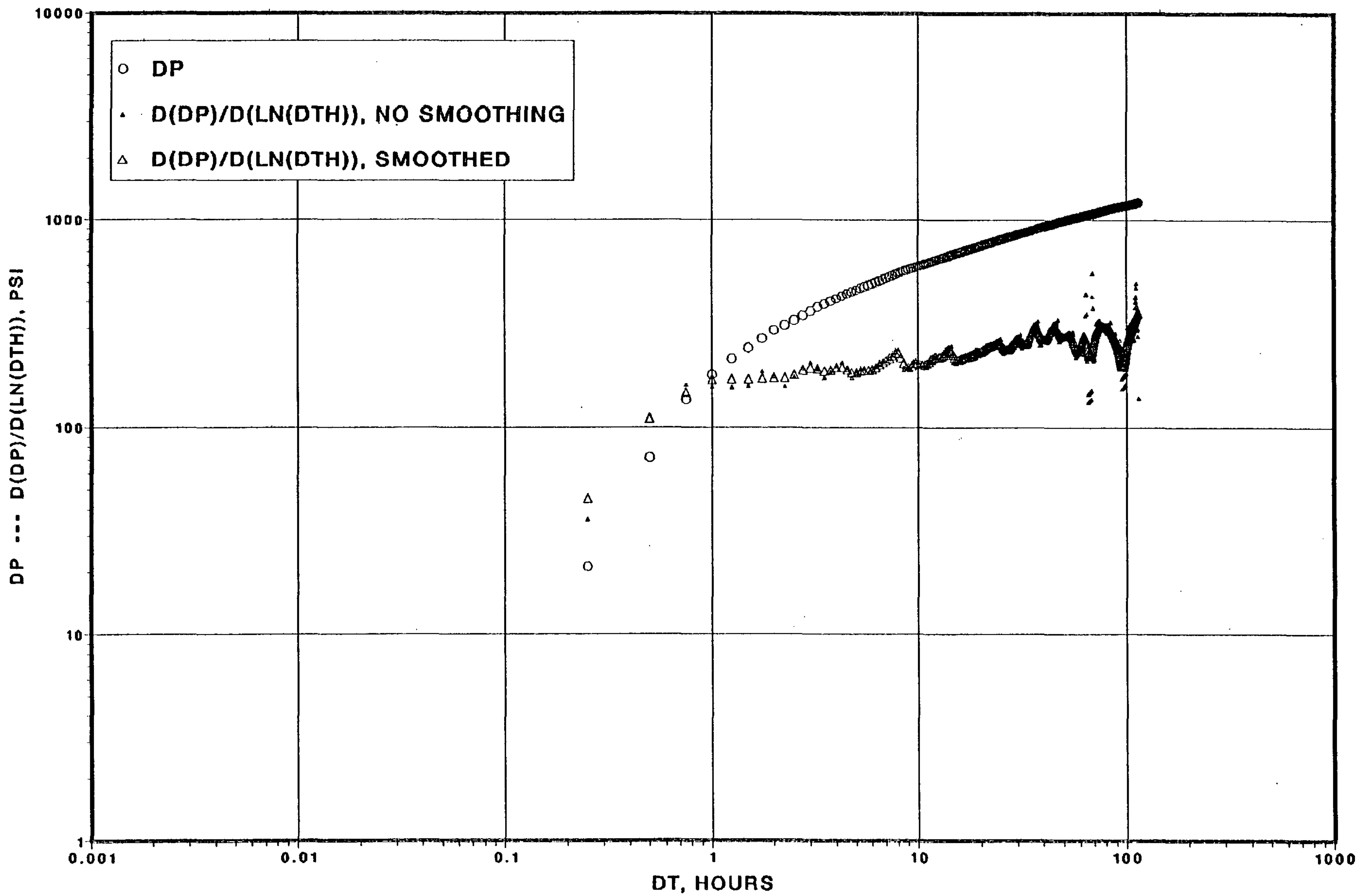


FIGURE 70

VGSAU 017 - 870320 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

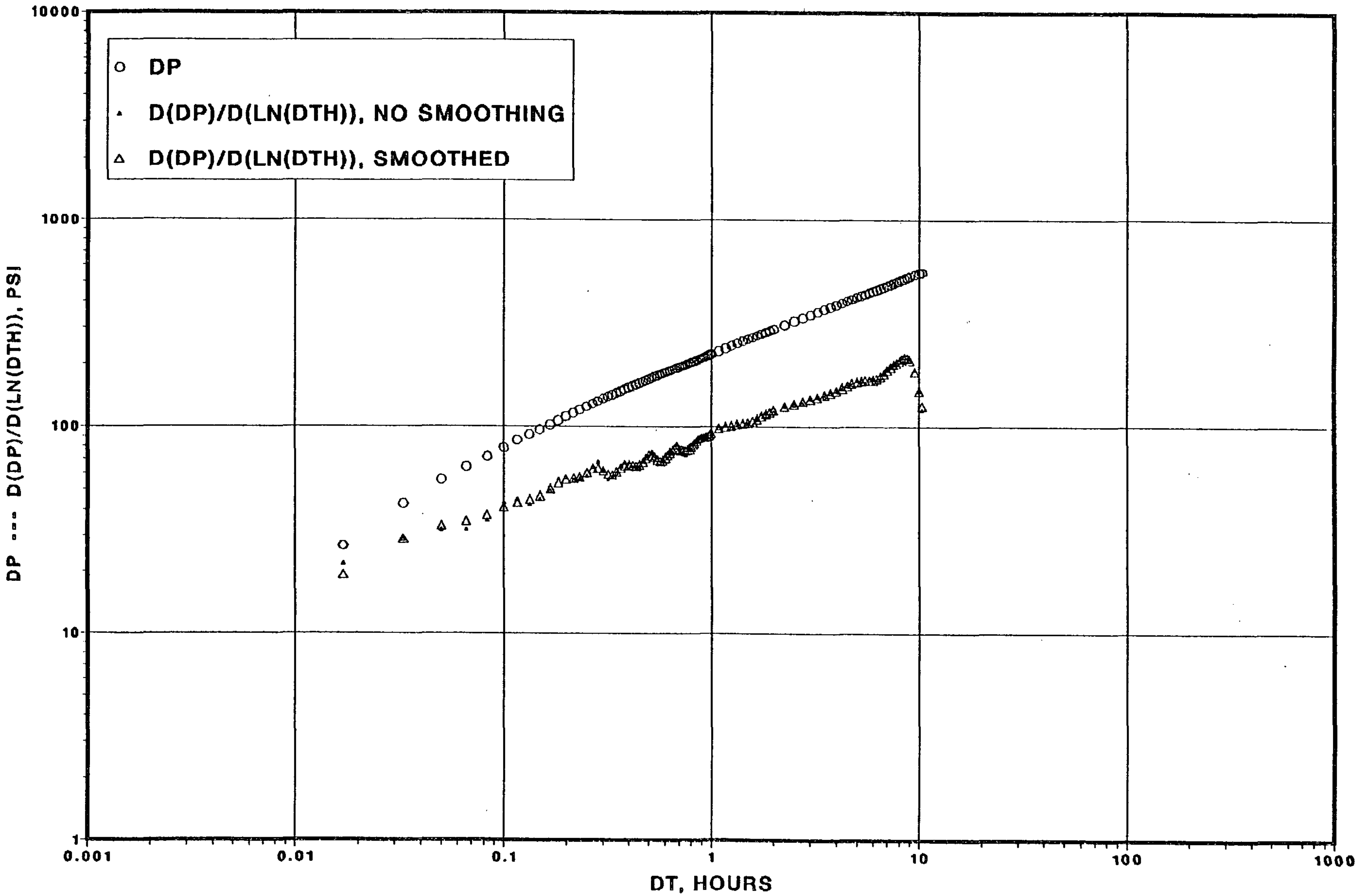


FIGURE 71

VGSAU 017 - 870320 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

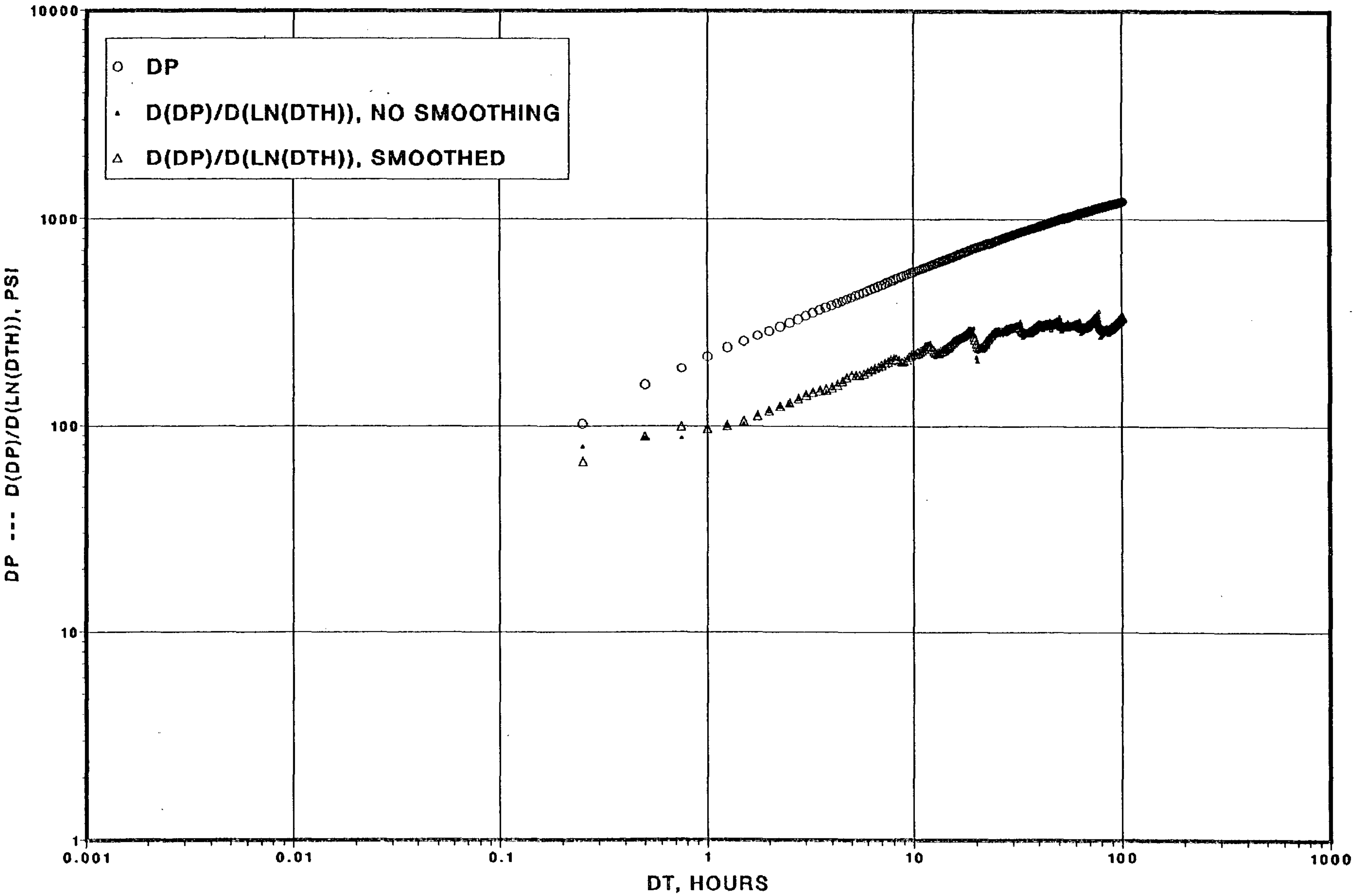


FIGURE 72

VGSAU 033 - 870315 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

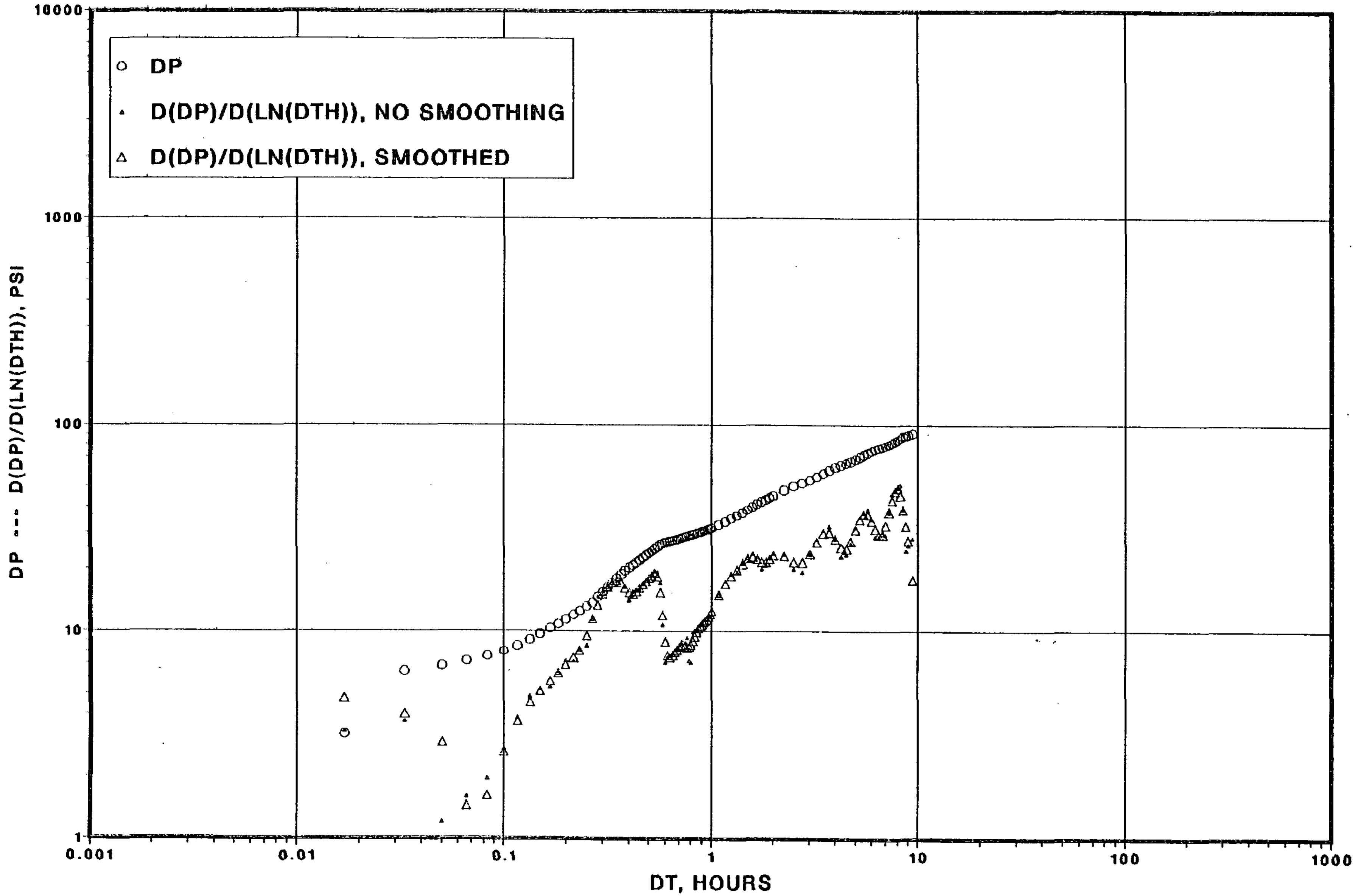


FIGURE 73

VGSAU 033 - 870315 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

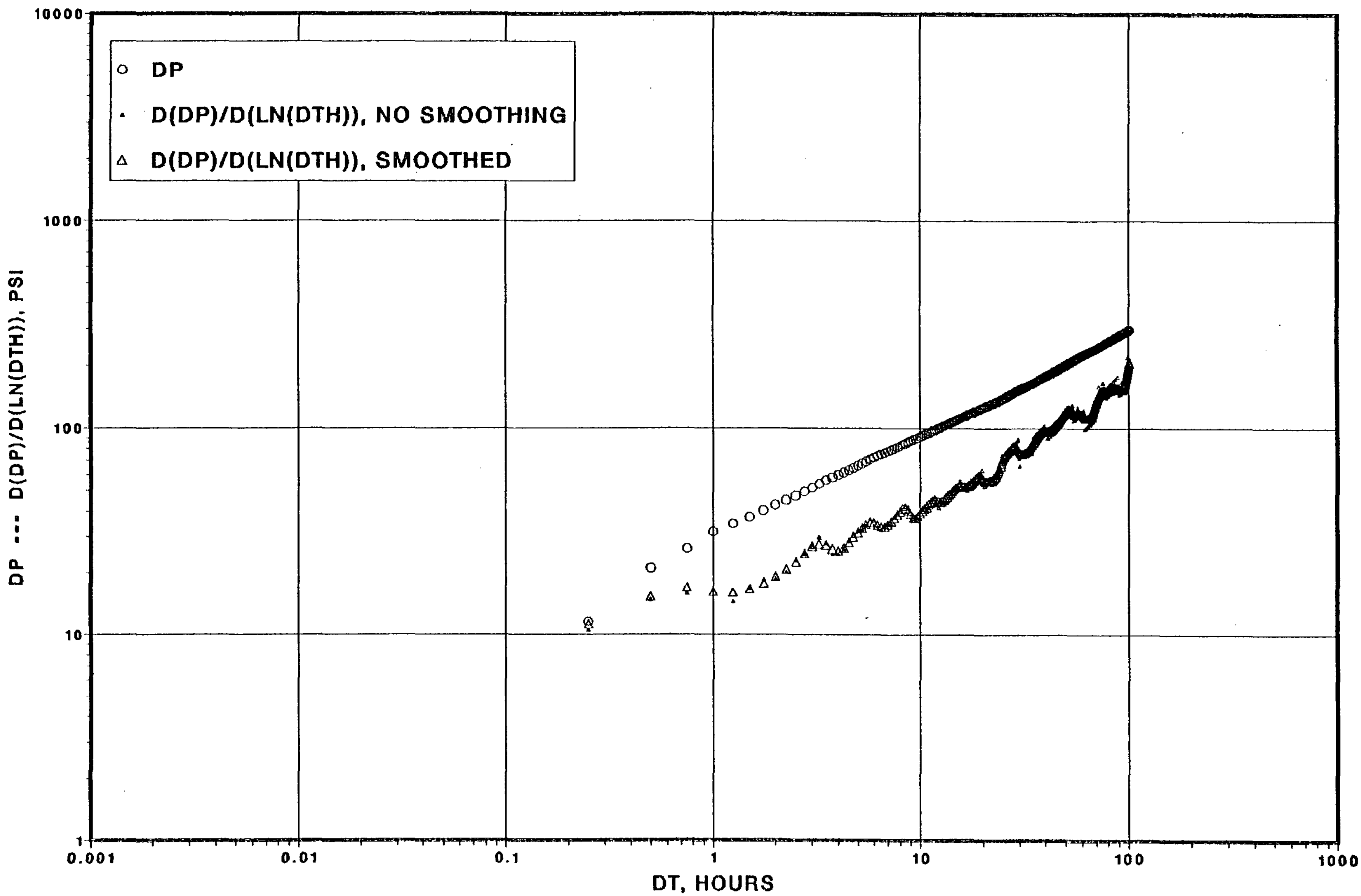


FIGURE 74

VGSAU 035 - 861008
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

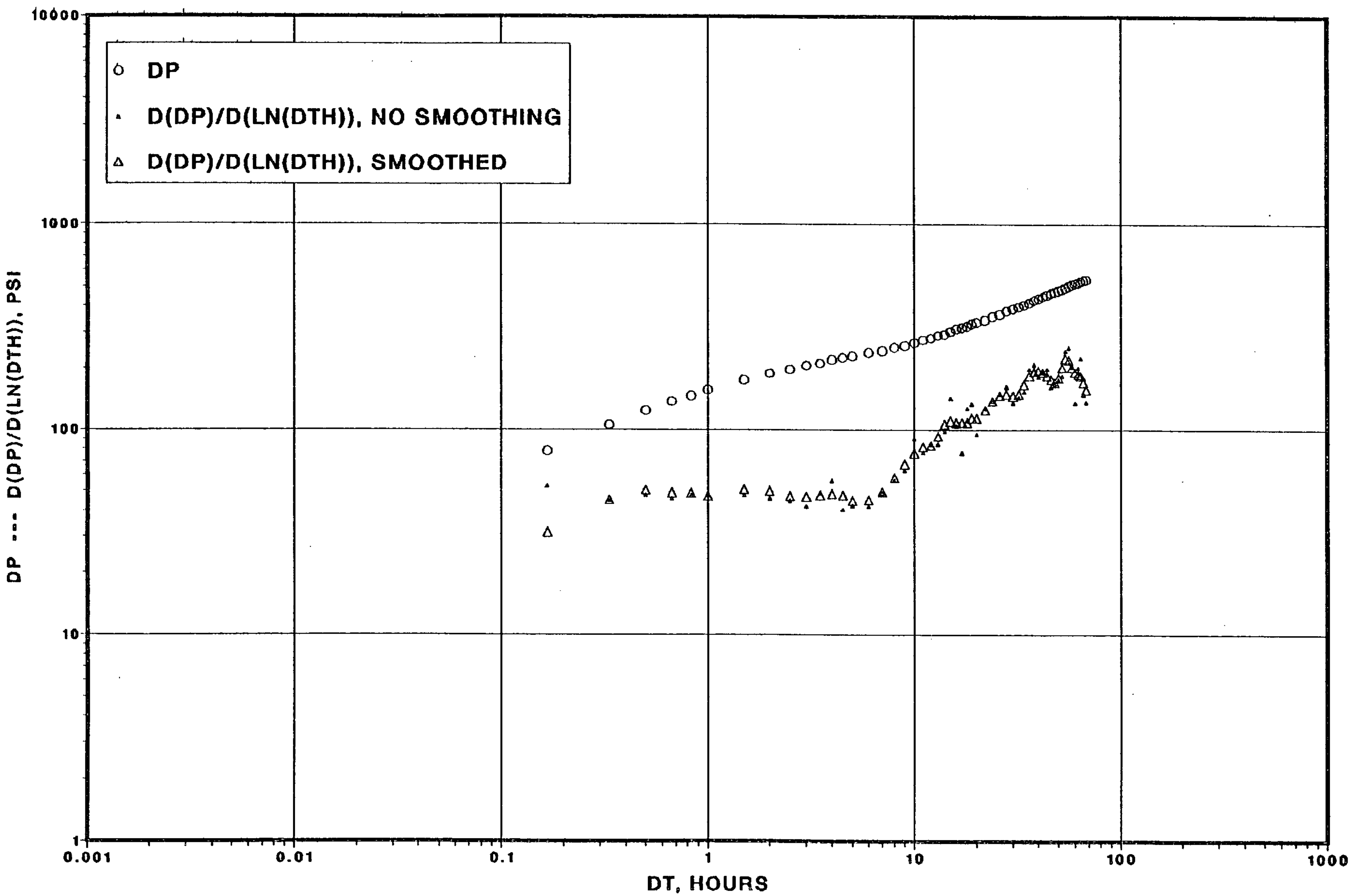


FIGURE 75

VGSAU 049 - 861008
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

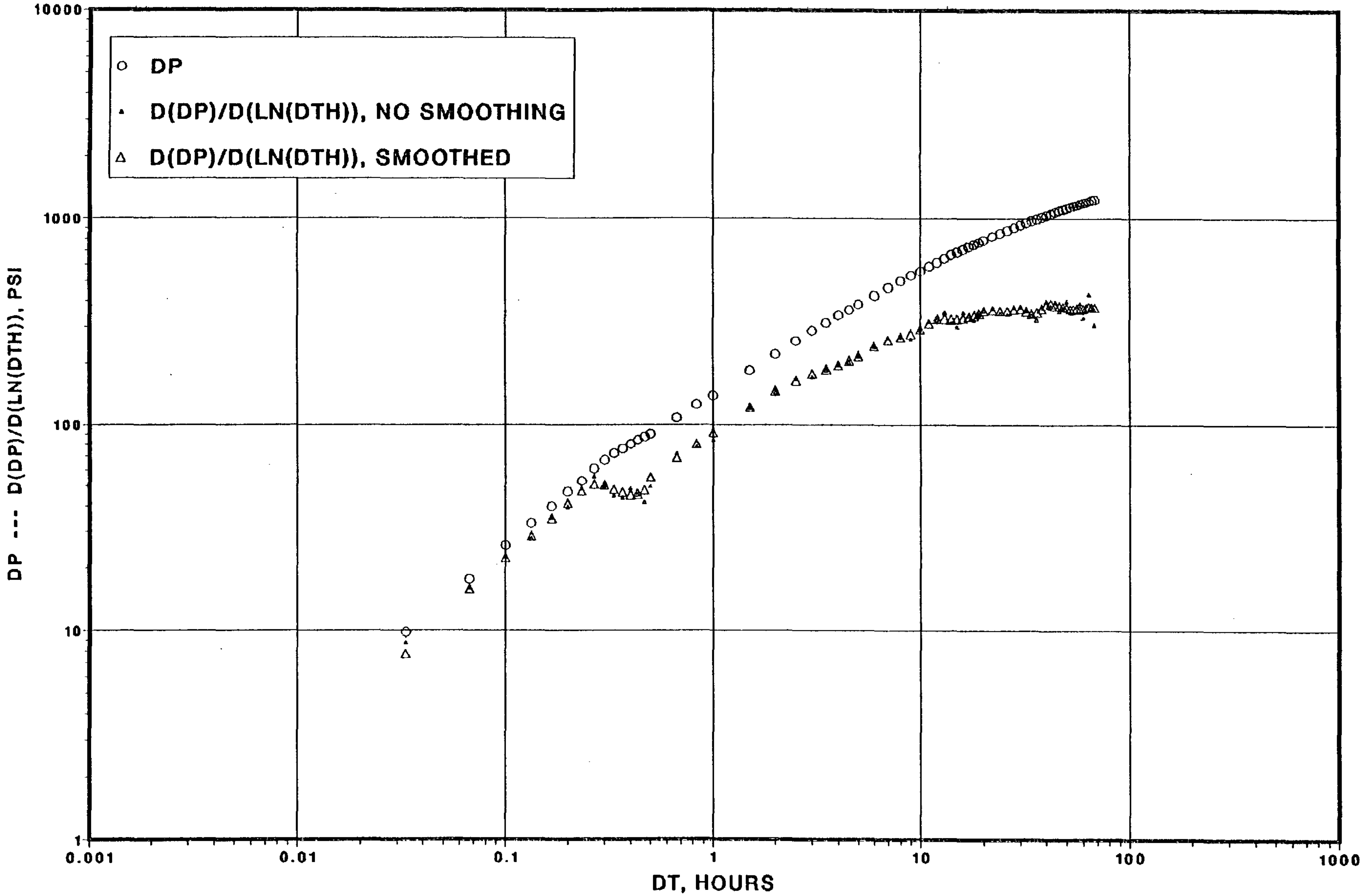


FIGURE 76

VGSAU 049 A - 870309 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

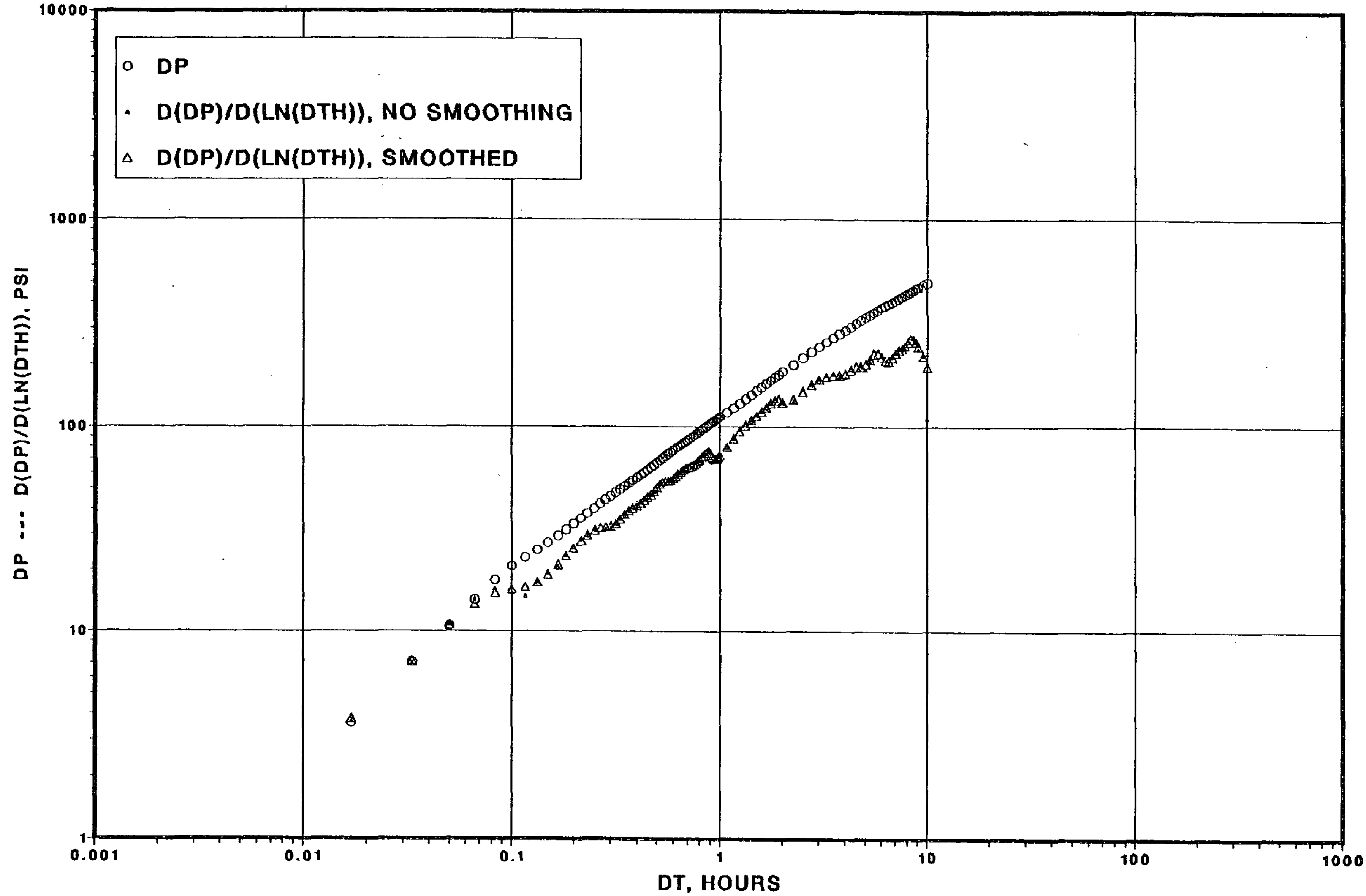


FIGURE 77

VGSAU 049 A - 870309 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

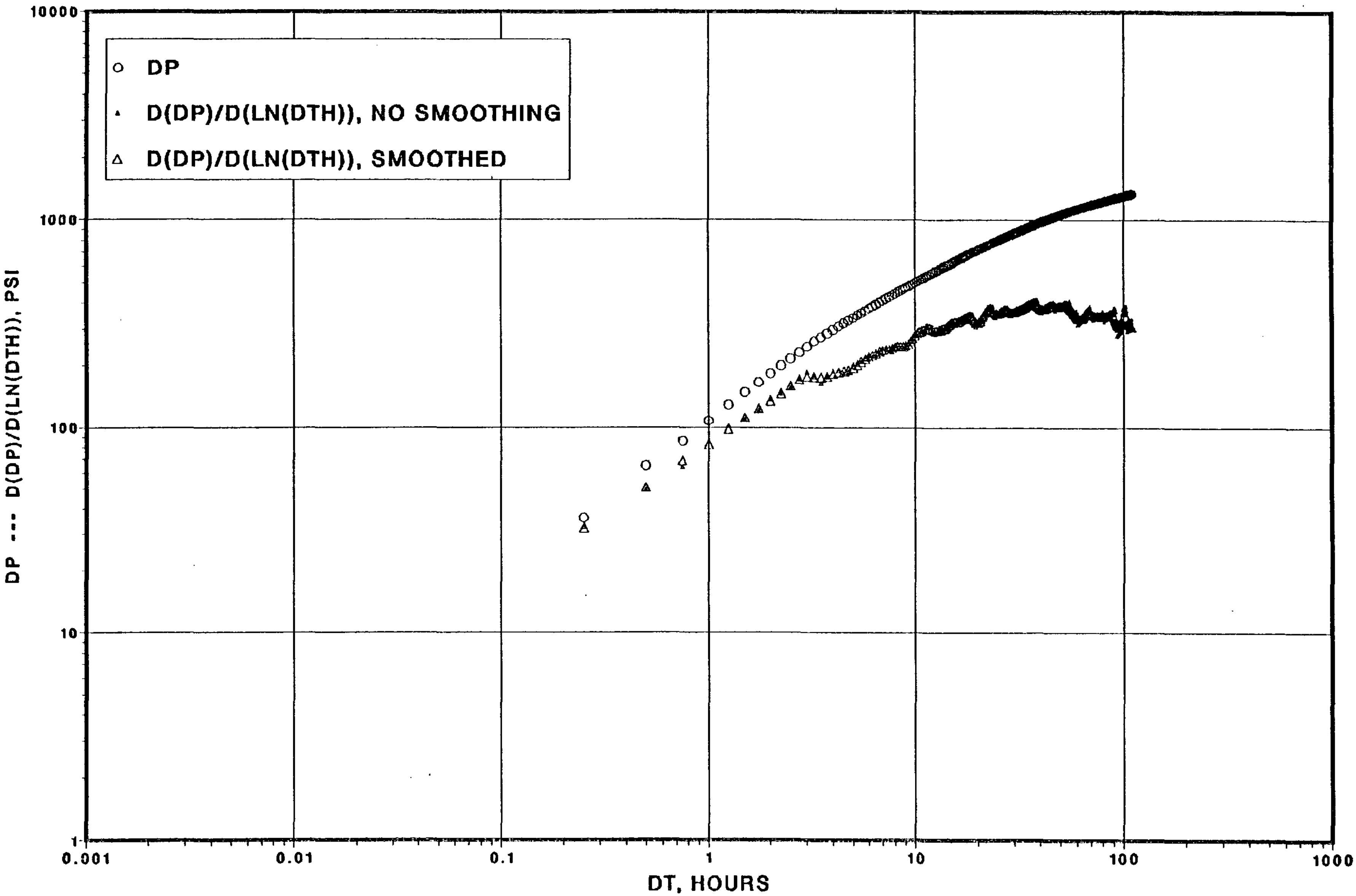
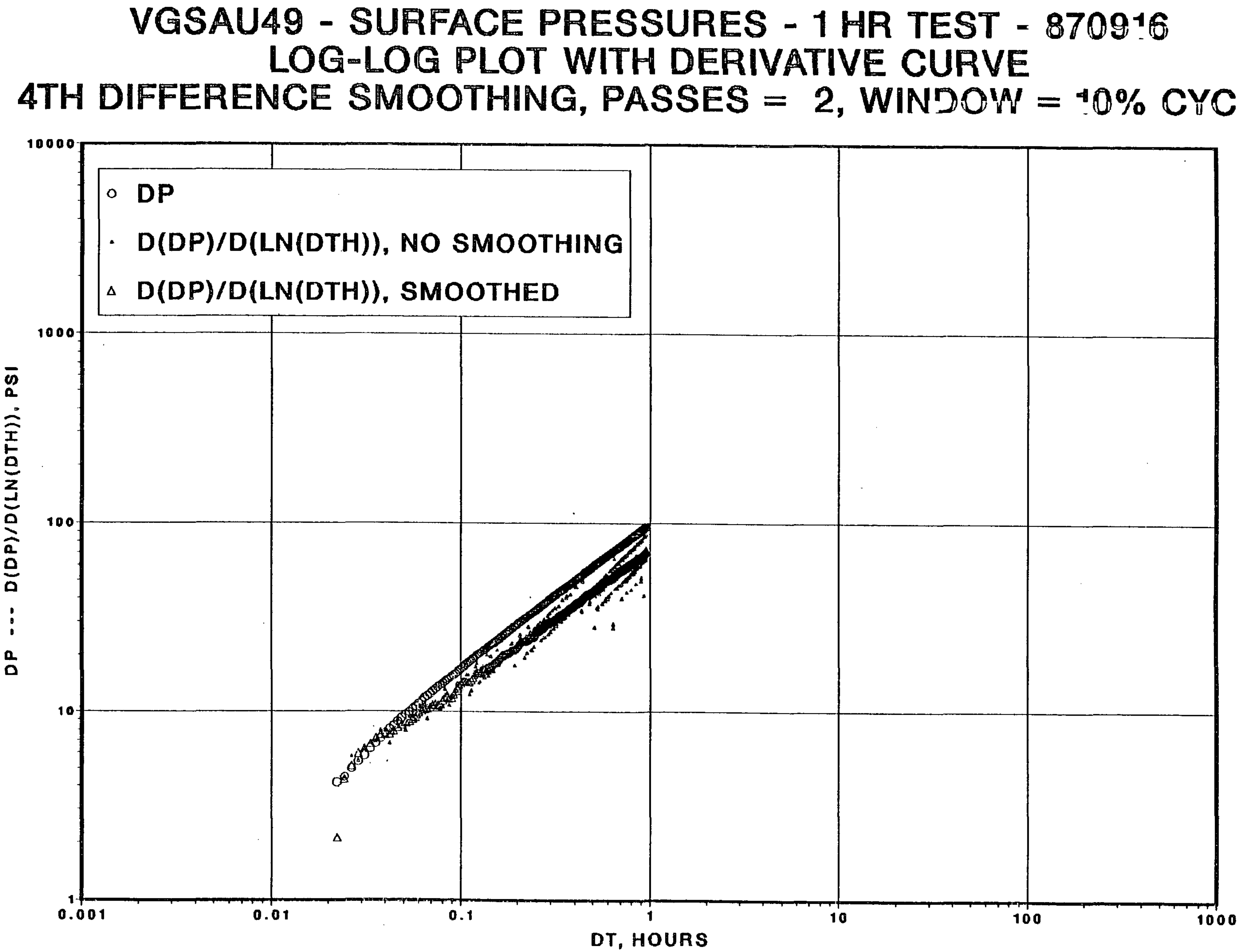


FIGURE 78



VGSAU49 - SURFACE PRESSURES - 1 HR TEST - 870916
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS
DP --- D(DP)/D(LN(DTH)), PSI

FIGURE 79

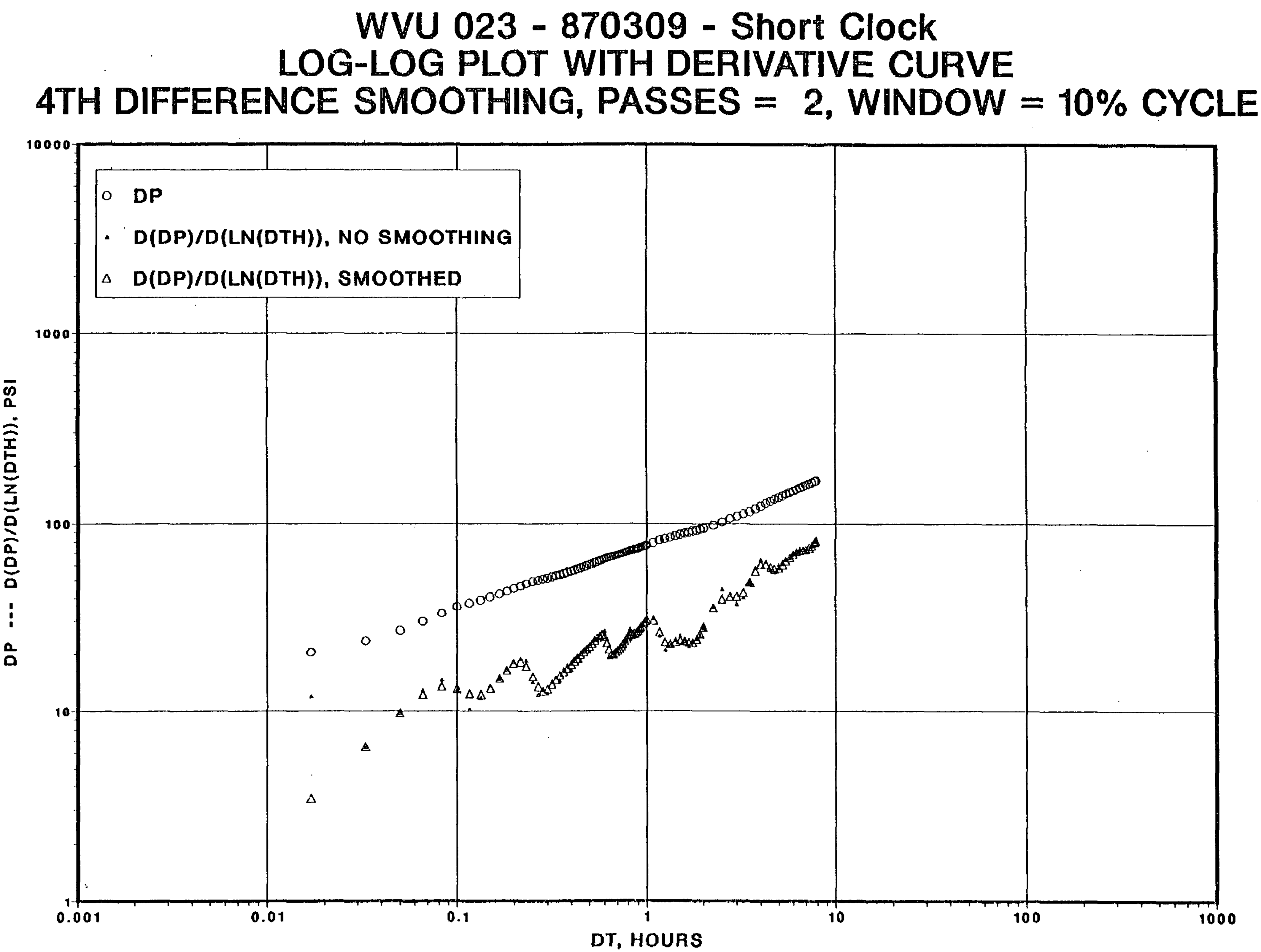

WVU 023 - 870309 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
DP --- D(DP)/D(LN(DTH)), PSI
10000
1000
100
10
1
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

FIGURE 80

WVU 023 - 870309 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

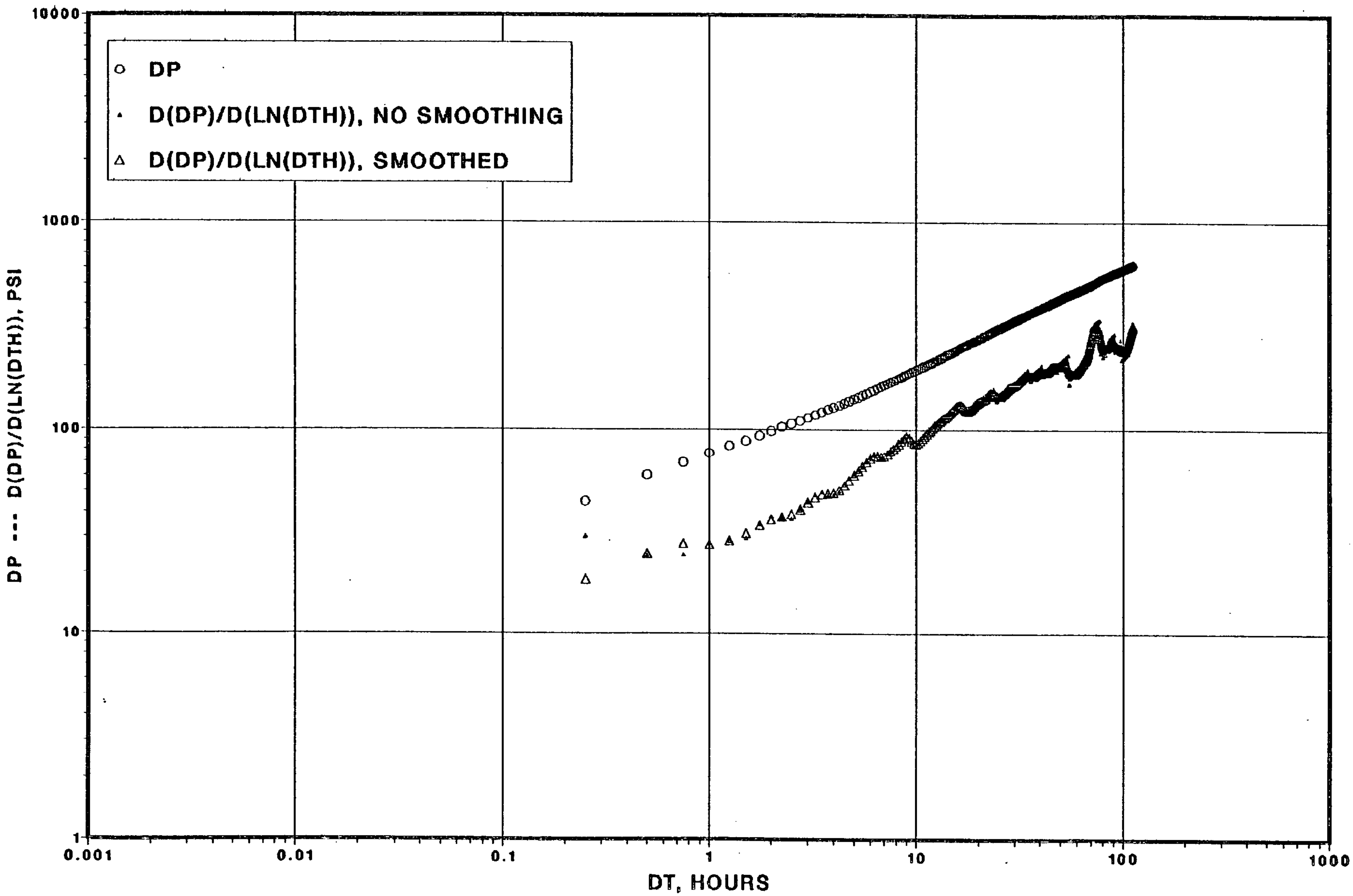


FIGURE 81

WVU 048 - 870319 - Short Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE

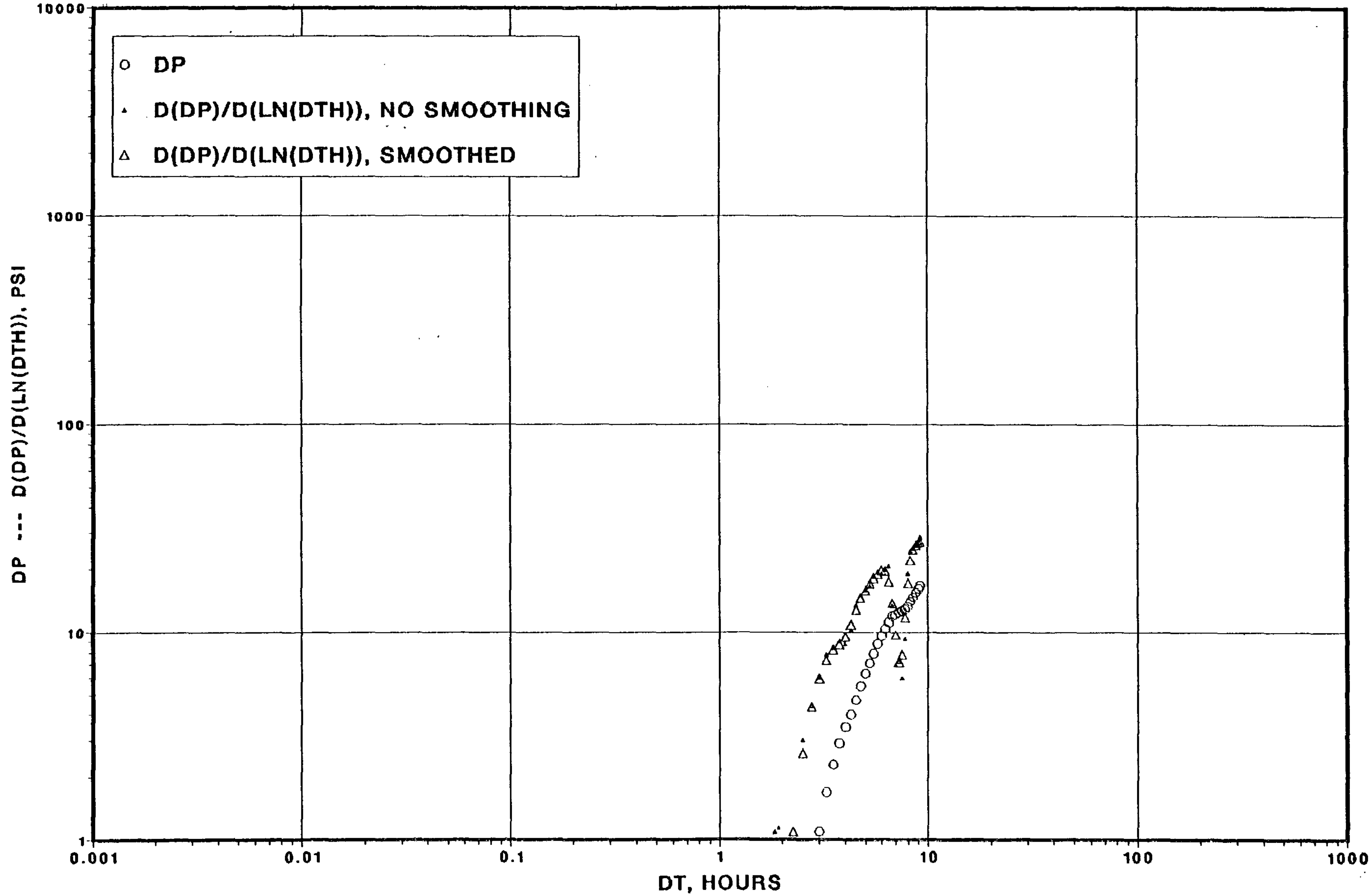
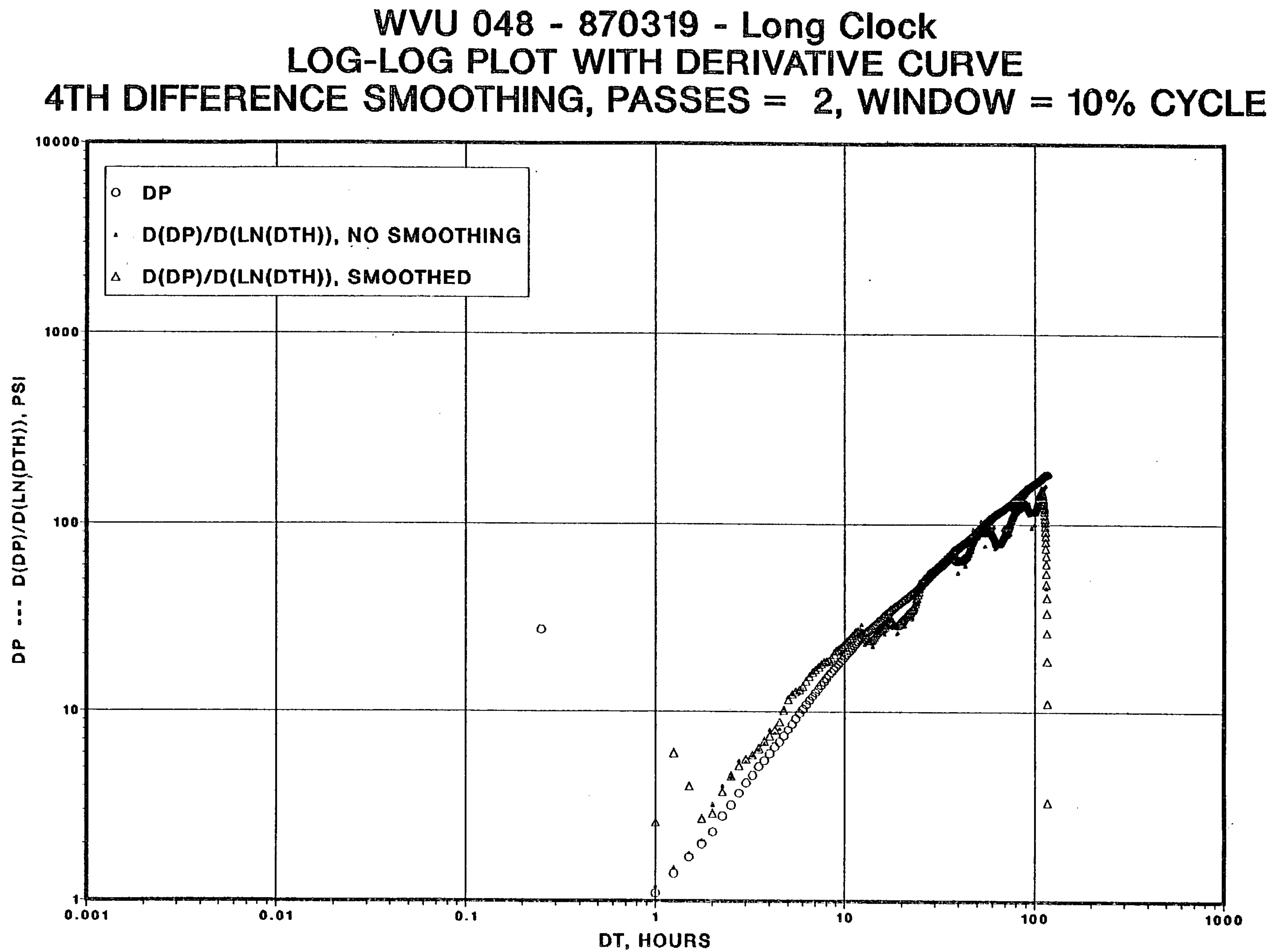


FIGURE 82



WVU 048 - 870319 - Long Clock
LOG-LOG PLOT WITH DERIVATIVE CURVE
4TH DIFFERENCE SMOOTHING, PASSES = 2, WINDOW = 10% CYCLE
DP
D(DP)/D(LN(DTH)), NO SMOOTHING
D(DP)/D(LN(DTH)), SMOOTHED
10000
1000
100
10
1
DP --- D(DP)/D(LN(DTH)), PSI
0.001
0.01
0.1
1
10
100
1000
DT, HOURS

DISTRIBUTION

TR 87-243

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D. C. Cain (10 copies)	District Reservoir Engineer, Hobbs District,Midland Operations Division
D. M. Demel	Area Engineer, Buckeye Area Office, Hobbs District, Midland Operations Division

Jamie

STATUS REPORT

August 18, 1986

The schedule presented during the December, 1985 meeting called for the implementation of a tracer program during the second quarter of 1986. This schedule was based on obtaining pressure transient analysis between infill drilling locations in Texaco's Central Vacuum Unit and the monitor well during the first quarter of 1986. Due to the falling crude price, the wells became economically unfeasible to drill.

The pressure transient work was needed to establish communication through the salt and define characteristics of flow through salt. Although isotope-18 analysis indicates water from the monitor well originating from ogallala, it is not conclusive. Fresh water must be continuously pumped into the monitor well to keep it flowing and could possibly have contaminated samples.

With the uncertainty of the availability of pressure transient information, design of the tracer program was initiated. As originally envisioned, an optimum tracer program would be designed to test selected injection systems with different materials giving a definite solution to the source. Two categories of tracer candidates were proposed, radioactive and non-radioactive. Attention was focused on the latter due to the negative safety and environmental aspects of radioactive substances. Five components were identified as tracer candidates. A field-wide tracer program, coupled with only one monitor well, would be a lengthy, and expensive, and inconclusive test.

Estimates as to wellbore (reservoir) storage have been calculated by two methods. Pressure build-up analysis indicates a volume of 600,000 barrels. Cumulative salt water production from the monitor well is 2.1 MM barrels. This equates to 350,000 barrels of pure salt produced. This second calculation is on the conservative end. Injected fresh water has been subtracted out of the total fluid produced from the monitor well. This injected fresh water has dissolved an incalculable amount of free salt. Assuming a 10 percent leak at the source to the salt, approximately $600,000 worth of tracer would be required per waterflood unit. A flowrate of 500 barrels per day from the monitor well would yield a time factor as high as 3 years to detect tracer at the monitor well.

The tracer program was delayed after considering costs, time requirements, unavailability of pressure transient analysis, and lack of further evidence to establish direct communication between the San Andres waterfloods and the salt section. Another major concern is that of subsidence. Any major tracer program will require flowing the monitor well for an extended period of time.

Texaco recently lost a well on the Central Vacuum Unit due to a casing leak in the salt section. Analysis of water samples taken from this well should help pinpoint the source since it has not been contaminated with fresh water. Plans are to redrill this well which may possibly create an opportunity to run pressure transients.

Water samples on the monitor well have been analyzed for foreign elements. Polymer has been used in three of the Vacuum Grayburg-San Andres floods for tertiary processes. Tests for polymer have been negative. Carbon dioxide, which is being injected in one flood, is being checked presently.

Recommendations:

1.) Shut-in monitor well until all alternatives have been evaluated and final recommendation is approved.

2.) Continue evaluation of tracer program:

    a) Radioactive materials

    b) Subsidence

3.) Identify and evaluate possible alternative methods including but not limited to the following:

    a) Behind pipe movement logs. (This will necessitate involving all operators in the Vacuum field, not just waterflood operators, since there is still primary production.)

    b) Seismic

4.) Design a pressure transient test for Texaco redrill. Included in this would be catching water sample for isotope-18 and a foreign element analysis.

MINUTES OF MEETING NO. 7

VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE

January 21, 1986

The seventh meeting of the Vacuum Field Waterflow Technical Committee was held at 1:00 PM on Tuesday, January 21, 1986. The location for the meeting was the office of Phillips Petroleum Company in Odessa, Texas. The following representatives were in attendance:

Attendee	Company	Location
Mike Brownlee	Phillips	Odessa, Texas
Ulrich Kiesow	Phillips	Bartlesville, OK
Steve Guillot	Texaco	Hobbs, New Mexico
John Currie	Phillips	Odessa, Texas
Charles Lord	Phillips	Bartlesville, OK
Glenn Bankson	Mobil	Midland, Texas
David Douglas	ARCO	Midland, Texas

The meeting opened with a presentation by John Currie on waterflows encountered while Phillips was drilling wells on their "Lea" and "Leamex" leases on the western edge of the Vacuum Field. These waterflows were apparently coming from the Queen formation, and Phillips had difficulty in their primary cementing jobs due to them. It was agreed that this problem was secondary in importance to the problem in the vicinity of the Central Vacuum Unit Monitor Well No. 1 due to the relatively limited potential for both erosion of the salt section and oil production. Nevertheless, it was agreed that any water samples pertinent to this new problem be analyzed.

Water sampling elsewhere in the field was then discussed and a list of water samples that should be obtained was drawn up. This list included virtually every different source of water for injection, including a sample of injection water from the EK Queen Unit. This unit is operated by Murphy Baxter, who is not represented on the Technical Committee. Steve Guillot agreed to contact Baxter and, if necessary, the NMOCD for their assistance in this matter.

The next topic discussed was the planned interference test between the Central Vacuum Unit Monitor Well No. 1 and the planned infill wells in Section 6. It was reaffirmed that the procedure used would be that recommended as "Option 1", (with the monitor well shut-in prior to drilling into the salt section) as per Ulrich Kiesow's letter dated November 6, 1985. Kiesow mentioned that an accuracy of ±10 psi was necessary and not ±50 psi as stated in his letter. The much slower buildup noted in the most recent pressure test indicated the need for greater accuracy. He also stressed the need for a continuous recording of pressure. Guillot then assured the committee that the necessary equipment would be available for this test.

Different types of tracers that could be injected were then discussed, and some prices were quoted. Mike Brownlee suggested the possibility that some chemicals used in field operations could be used as a tracer. It was agreed that each company should generate a list of chemicals used on their respective units.

The meeting was adjourned at 2:30 PM.

MINUTES OF MEETING NO. 8
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
APRIL 3, 1986

The eighth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:30 P.M. on Thursday, April 3, 1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

NAME	COMPANY	LOCATION	PHONE NO.
Mike Brownlee	Phillips	Odessa, TX	915-367-1413
David Douglas	ARCO	Midland, TX	915-688-5563
Antoinette Green	ARCO	Midland, TX	915-894-3118
Brian Horanoff	Conoco	Hobbs, NM	505-392-2702
Robert Gudramovics	Mobil	Midland, TX	915-688-2042
Charley Lord	Phillips	Bartlesville, OK	918-661-9734
David Cain	Texaco	Hobbs, NM	505-393-7191
Steve Guillot	Texaco	Hobbs, NM	806-894-3118

The meeting opened with a discussion on chairing of the technical committee. Steve Guillot is being replaced by David Cain as Texaco's representative on the committee. Steve has been promoted to Area Engineer at Levelland, Texas and will no longer be assigned to this project. It was agreed Texaco would continue chairing the technical committee.

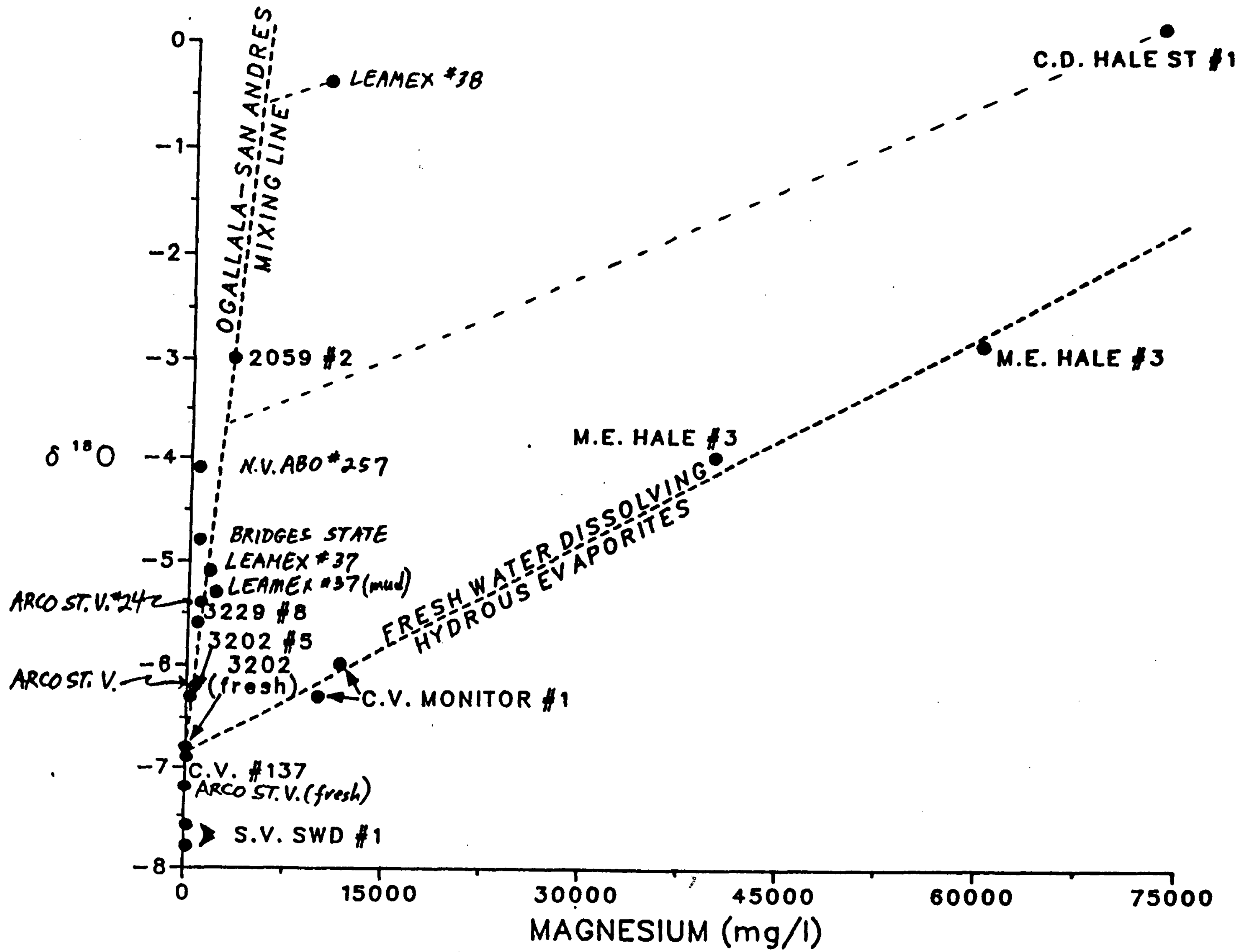
Charley Lord presented additional information on work with Oxygen 18 isotope tests (attached). His major observation precluded Arco's "State Vacuum" Well No. 1 (salt water disposal) as a source for the flow in the salt as previously expounded. Also stressed was the labeling of samples. Specifically, some of the samples submitted were unclear as to origin such as production, injection or disposal waters, etc.

Mike Brownlee recommended the technical committee begin taking preliminary steps on work with tracers. Due to the current economic climate, Texaco's infill drilling program on the Central Vacuum Unit has been postponed indefinitely. The December, 1985 meeting with the NMOCD resulted in a timetable for activities. Interference tests between Texaco's monitor well and proposed drilling wells on the Central Vacuum Unit were scheduled for the first quarter of 1986 with tracer evaluations set for the second quarter. Since it is impossible to forecast when these wells will be drilled, the technical committee decided to begin researching tracers and evaluating costs. A discussion ensued as to the different methods for tracing the flow. The general consensus was the method adopted depended mainly on the number of tracers available. Charley Lord volunteered to work on researching possible traces. Also on the timetable was a progress report scheduled for July, 1986 with the NMOCD. Bancker Cade, Texaco's representative on the management committee met with Jerry Sexton of the NMOCD discussing the current status of the waterflow committee. Sexton concurred that due to the uncertain economic conditions, a delay in the July meeting might be warranted. Sexton agreed to discuss the matter with R. L. Stamets, Director of the NMOCD, and get back in touch.

The meeting was adjourned at 3:30 P.M. with the next meeting tentatively scheduled after the list of possible traces has been formulated.

4 – 03 – 86

WATER MIXING DIAGRAM



MINUTES OF MEETING NO. 9
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
JULY 30, 1986

The ninth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:00 p.m. on Thursday, July 30,1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

Name	Company	Location	Phone No.
Mike Brownlee	Phillips	Odessa	915-367-1413
Bill Hermance	Mobil	Midland	915-688-2191
Ron Rogers	ARCO	Midland	915-688-5579
David Douglas	ARCO	Midland	915-688-5562
David Cain	Texaco	Hobbs	505-393-7191
Ulrich Kiesow	Phillips	Bartlesville	918-661-3931
Charley Lord	Phillips	Bartlesville	918-661-3418

The meeting opened informing those present of the upcoming project status report meeting called by R. L. Stamets, Director of the NMOCD, August 19,1986 at 10:00 a.m. MDLST in the Phillips office building, 1625 W. Marland, Hobbs, New Mexico. A joint meeting between the management and technical committees is scheduled for August 12, 1986 at 1:00 p.m. CDLST in the 4th floor conference room of the Phillips Building, 4001 Penbrook, Odessa, Texas.

Charley Lord presented the attached list of preliminary tracer recommendations adding Sodium Perchlorate as an additional possible candidate. Concern for possible environmental and health risks were raised about all those listed and Charley agreed to investigate. Charley is working on an updated graph of Oxygen-18 isotope tests which should be ready for the August status report.

Ulrich Kiesow presented the attached pressure build-up information on the Texaco monitor well. Preliminary modeling indicates reservoir storage in the neighborhood of 350,000 barrels.

A discussion ensued concerning the use of interference testing in a future Texaco redrill of a producing well some one half mile west of the monitor well to evaluate response time in the salt section. This interference testing would be helpful in determining the volume in the salt section. Drilling of this well is not likely to begin prior to the August meeting with the NMOCC. Conversion of a nearby producer to use for interference tests was discussed but deemed unfeasible.

Concern was voiced to have a tentative schedule ready should the NMOCC require tracer injection begin immediately. With the available information, tracer slug volumes were calculated with estimates starting at 50,000 barrels and larger depending on the distance from the flood to the monitor well. The question was brought up as to the availability of other well bores for potential use as additional monitor wells. Except for the Texaco well being redrilled, none were available. After putting some cost estimates to these slug volumes, the motion was made to investigate the use of radioactive tracers which had been ruled out in the past due to possible safety risks. Charley Lord is going to evaluate and attempt to have some cost comparisons available by the next meeting. The point was brought out that there is more than likely more than one source for the pressure in the salt section and that tracer testing may be limited by the number of tracers available.

Questions concerning alternative methods of detecting the pressure sources were discussed such as injection volumes, injection-withdrawal ratios, injection pressures, and possible pulse testing between the various floods and the monitor well. All of these methods have been investigated previously and ruled out for various reasons.

The meeting was adjourned at 4:00 p.m. with another meeting scheduled for 1:00 p.m., Thursday August 7, 1986 at the Phillips Petroleum Building, 4001 Penbrook, Odessa, Texas.

June 24, 1986

INTER-OFFICE CORRESPONDENCE / SUBJECT:
BARTLESVILLE, OKLAHOMA

Vacuum Field Unit, Lea County, N.M., Preliminary Tracer Recommendations for Waterflood Injectors

CJL-1-86

M. H. Brownlee
Odessa Office

A consensus based on the oxygen isotope data is that the most probable sources of salt section waterflows are the Vacuum Field water injection projects. A tracer program is being designed to identify which of the waterflood projects are involved in the problem. Some preliminary design specifications are given below.

Ideally, a different tracer would be used for each of the waterfloods. At the present time, five non-radioactive tracers have been selected for use in the Vacuum Field injection wells. The following table summarizes the costs for these tracers.

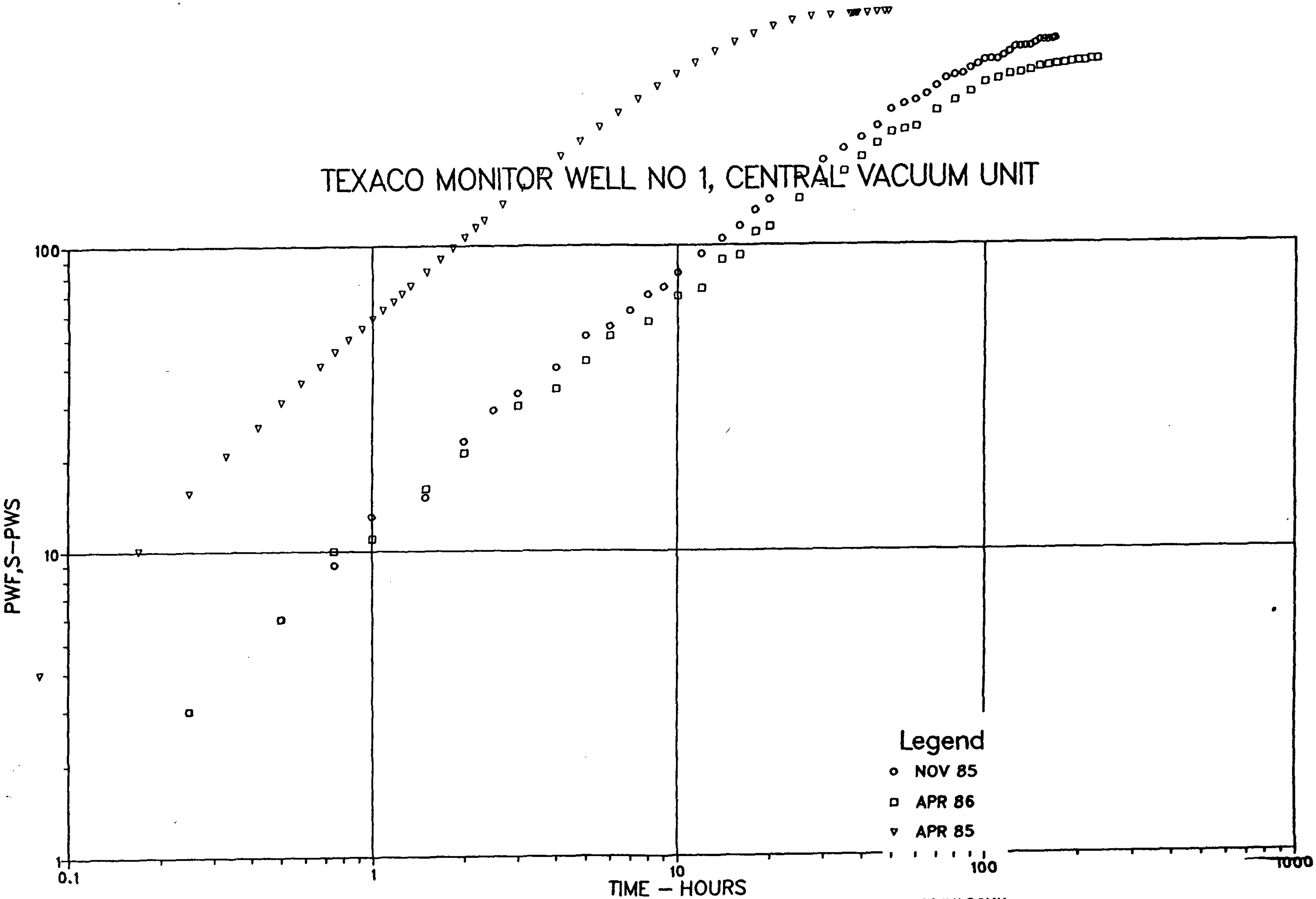
TRACER COMPONENT	LB/GAL		COST/LB		COST/GAL
Lithium chloride	0.62	X	$ 8.50	=	$ 5.27
Sodium thiocyanate	0.53	X	$ 4.50	=	$ 2.39
Sodium nitrate	0.71	X	$ 2.85	=	$ 2.02
Potassium iodide	0.33	X	$13.40	=	$ 4.42
Ammonium chloride	0.75	X	$ 2.36	=	$ 1.77

The volume of each tracer solution to inject has not yet been calculated but will depend on the estimated volume of water which is presently contained within the salt section. After the tracers have been injected, two samples will be collected daily from the Central Vacuum Monitor Well #1. These water samples will then be sent to the Phillips Research Center for analysis. The results will be reported to all members of the Vacuum Field Waterflow Committee in the form of tracer breakthrough curves.

Charley Lord
C. J. Lord
233A PL, Ext. 3418

cc: J. R. Paxson (r) R&D Records (RC)
D. W. Hausler (r) TVI, JHR
W. J. Mueller
J. F. Griggs (r) M. J. Fetkovich
U. G. Kiesow
W. D. Byrd (r) DWD

TEXACO MONITOR WELL NO 1, CENTRAL VACUUM UNIT



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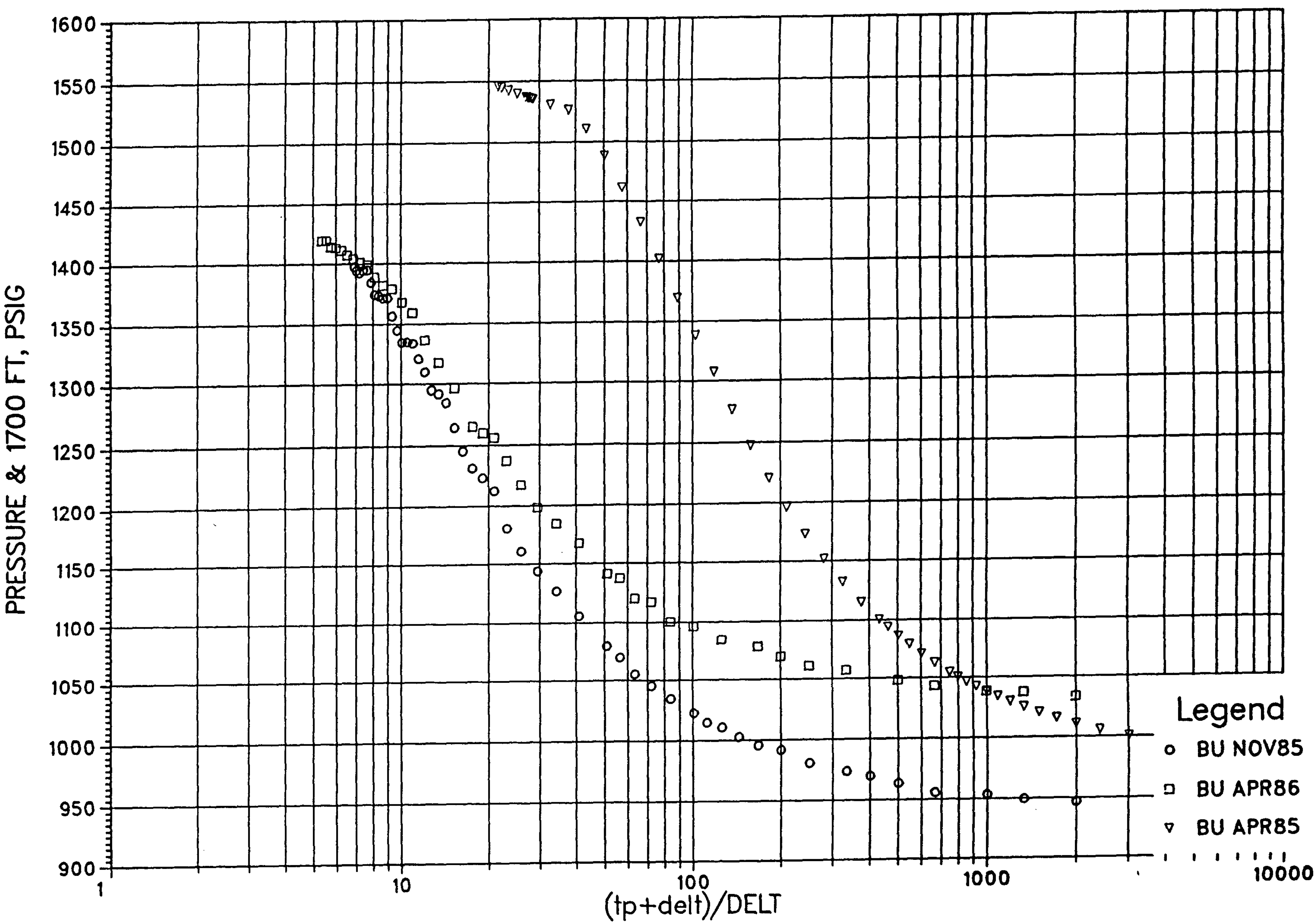
TEXACO MONITOR WELL; BUILDUPS 0485,1185,0486; TP=1000HRS



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MINUTES OF MEETING NO. 10
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
AUGUST 7, 1986

The tenth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:00 p.m. on Thursday, August 7,1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

Name	Company	Location
Mike Brownlee	Phillips	Odessa
Glenn Bankson	Mobil	Midland
Ron Rogers	ARCO	Midland
David Douglas	ARCO	Midland
Don Steinnerd	Texaco	Hobbs
Ulrich Kiesow	Phillips	Bartlesville
Charley Lord	Phillips	Bartlesville

The agenda for the meeting included the upcoming meeting with the NMOCD, updates on water analysis, build-up analysis, and tracer injection plans.

Non-radioactive (sodium thiocyanate) tracer costs for a field wide tracer program were presented by Phillips for two cases. Costs for assumptions of 1% and 10% injected out of zone are $30,000,000 and $3,000,000 respectively. It was also estimated radioactive tracers would cost up to $10,000 per 100 millicuries depending on the type of tracer. Phillips estimated approximately 100 millicuries would be needed to tag a single flood. Radioactive tracers would be preferred due to the lower cost and greater number of tracers available if safety concerns are acceptable.

An updated build-up analysis on Texaco's monitor well by Phillips indicated a well storage of approximately 600,000 barrels. The previous estimate was 336,000 barrels. Texaco disagreed with the validity of the estimate. Texaco contends pressure build-up analysis for porous media is not applicable in this situation. The pressure build-up curve shape is more dependent upon the rate at which the salt is being deformed by overburden pressure. There was no further discussion on build-up analysis. A copy of Phillips tracer cost estimates and build-up analysis is attached.

Preliminary water analysis results for the latest sample from the monitor well indicates the "origin" is shifting upward. This indicates the latest sample is more of a mix between San Andres and Ogallala. Phillips will complete the analysis prior to the meeting with the NMOCD.

An alternative to the field wide tracer program was presented by Texaco. There was considerable disagreement between the four companies present over either Phillip's or Texaco's proposals.

The Phillip's proposal is to inject tracer in every flood and test only at Texaco's monitor well. Radioactive tracers would be preferred if safety concerns are resolved. However, non-radioactive tracers are still recommended if radioactive tracers cannot be used, even though costs would be significant. Texaco's proposal is to use tracers in the "hot" spots (water flows and/or bradenhead flows). Texaco would begin with their injection wells offsetting the monitor well. Additional monitor wells would be needed to conduct tracer surveys in other "hot" spot areas. Comments were noted for those companies present as follows:

Texaco	-	Opposes Phillip's field-wide tracer program. They prefer their proposed alternative.
Phillips	-	Opposes Texaco's limited tracer program. They prefer their proposed alternative.
Mobil	-	They see problems with both alternatives and are not in favor of either Texaco's or Phillip's proposal.
ARCO	-	Opposes drilling of additional monitor wells. They do support field-wide tracers in offsetting floods, only if radioactive tracers can be used.

The committee was not able to reach an agreement on recommending a specific tracer program.

Some additional comments and/or requests were made prior to adjourning the meeting. Texaco stated the replacement well for Central Vacuum Unit No. 91 would not be available for pressure transient testing unless water flows are of sufficient magnitude to require drilling be temporarily suspended. However, a pressure recorder would be installed on the monitor well and the well will be shut-in prior to spudding the new well. Texaco also stated they are preparing cost estimates for converting the existing Central Vacuum Unit No. 91 as a monitor well. Phillips requested the CO_2 content of the monitor well produced water be analyzed for future reference. Texaco stated they would have it done. Phillips also requested the cumulative water produced from the monitor wells as of the dates of the pressure build-ups. Texaco would provide them. Texaco recommended their monitor well be shut-in except for testing purposes. All companies present concurred.

The meeting was adjourned at 4:00 p.m. with the next meeting scheduled for August 12 at 1:00 p.m.; a joint meeting with the management.

Tracer Cost *

August 6, 1986 ak

Monitor Well Storage Vol. ≈ 600,000 BBL (Apr. 86)
Dilution factor: 1/1000
Need Tracer Vol. 600,000 BBL/1000 = 600 BBL
Injector assumed to leak at 1% or 10%
Needed volume to be injected:

@ Leak:	1%	10%
Vol:	600/.01 = 60,000 BBL	600/.1 = 6,000 BBL
Tracer Cost:	60,000 BBL x 100 $/BBL	6000 BBL x 100 $/BBL
	$6,000,000	$600,000

x5 satellites where injection to take place at same time

	$30,000,000	$3,000,000

LBS of tracer

$$60{,}000\ \text{BBL} \left(42\ \frac{\text{GAL}}{\text{BBL}}\right)\ .53\ \frac{\text{lb}}{\text{GAL}}$$

= 1,335,600 lbs   133,560 lbs

* Assumes tracer cost of $100/BBL and 0.53 lb/gal (sodium thiocyanate)

June 24, 1986

INTER-OFFICE CORRESPONDENCE / SUBJECT:
BARTLESVILLE, OKLAHOMA

Vacuum Field Unit, Lea County, N.M.,
Preliminary Tracer Recommendations
for Waterflood Injectors

CJL-1-86

M. H. Brownlee
Odessa Office

A consensus based on the oxygen isotope data is that the most probable sources of salt section waterflows are the Vacuum Field water injection projects. A tracer program is being designed to identify which of the waterflood projects are involved in the problem. Some preliminary design specifications are given below.

Ideally, a different tracer would be used for each of the waterfloods. At the present time, five non-radioactive tracers have been selected for use in the Vacuum Field injection wells. The following table summarizes the costs for these tracers.

@ 1 tonne *42 GAL/BBL

TRACER COMPONENT	LB/GAL		COST/LB		COST/GAL	COST/BBL*
Lithium chloride	0.62	X	$ 8.50	=	$ 5.27	221
Sodium thiocyanate	0.53	X	$ 4.50	=	$ 2.39	100
Sodium nitrate	0.71	X	$ 2.85	=	$ 2.02	85
Potassium iodide	0.33	X	$13.40	=	$ 4.42	186
Ammonium chloride	0.75	X	$ 2.36	=	$ 1.77	74

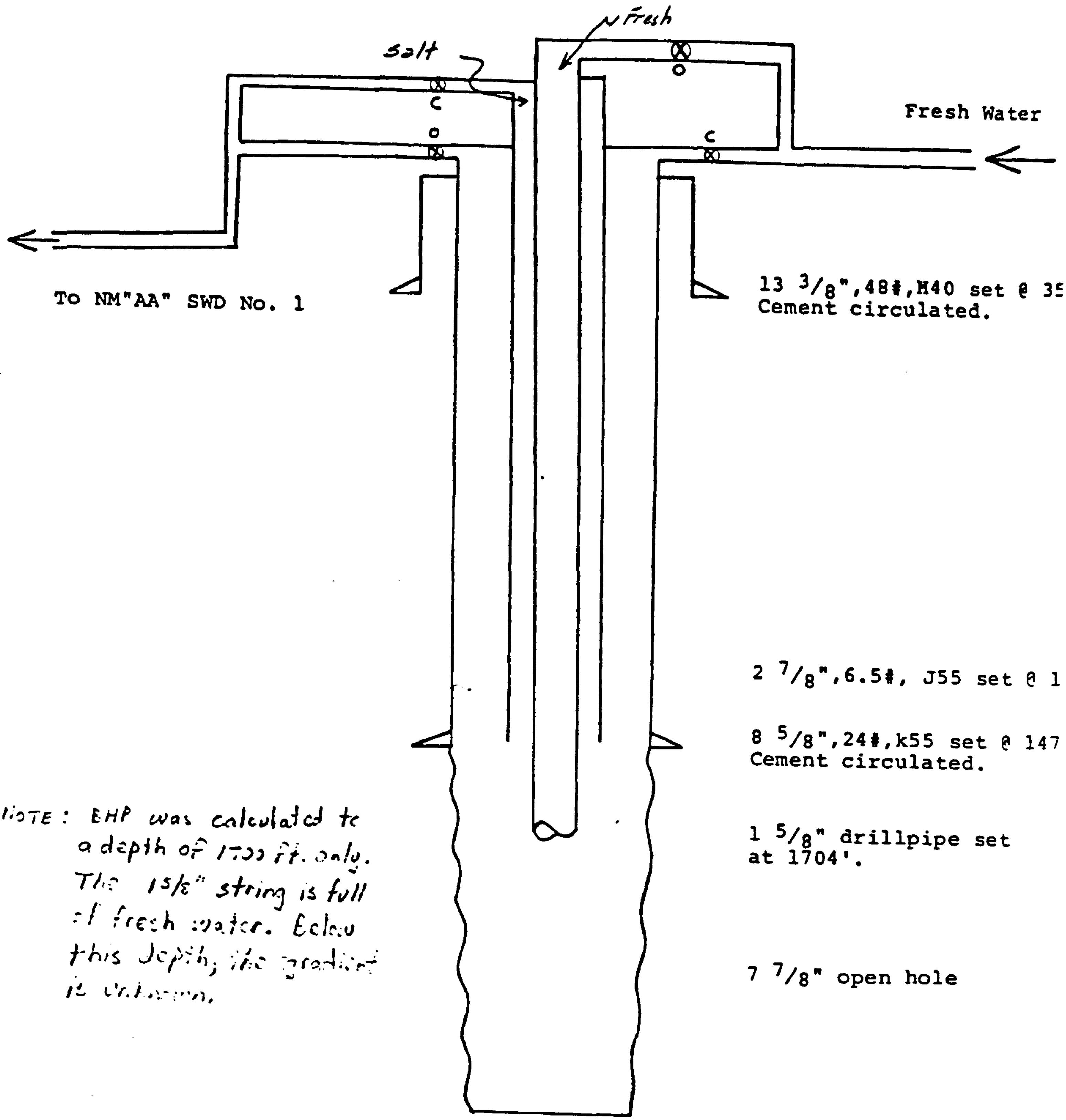
Sodium perchlorate

The volume of each tracer solution to inject has not yet been calculated but will depend on the estimated volume of water which is presently contained within the salt section. After the tracers have been injected, two samples will be collected daily from the Central Vacuum Monitor Well #1. These water samples will then be sent to the Phillips Research Center for analysis. The results will be reported to all members of the Vacuum Field Waterflow Committee in the form of tracer breakthrough curves.

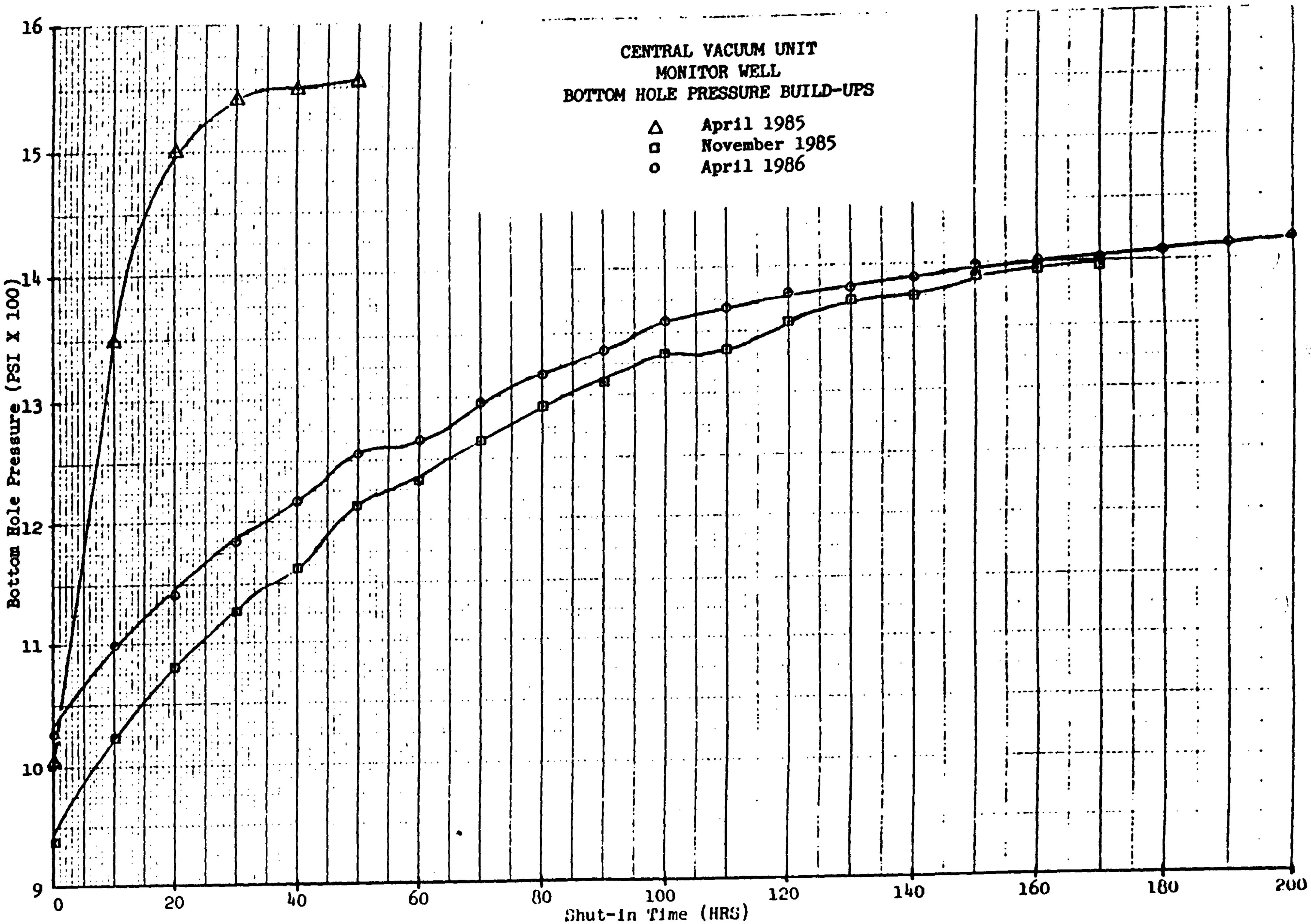
Charley Lord
C. J. Lord
233A PL, Ext. 3418

cc: J. R. Paxson (r) R&D Records (RC)
D. W. Hausler (r) TVI, JHR
W. J. Mueller
J. F. Griggs (r) M. J. Fetkovich
U. G. Kiesow
W. D. Byrd (r) DWD

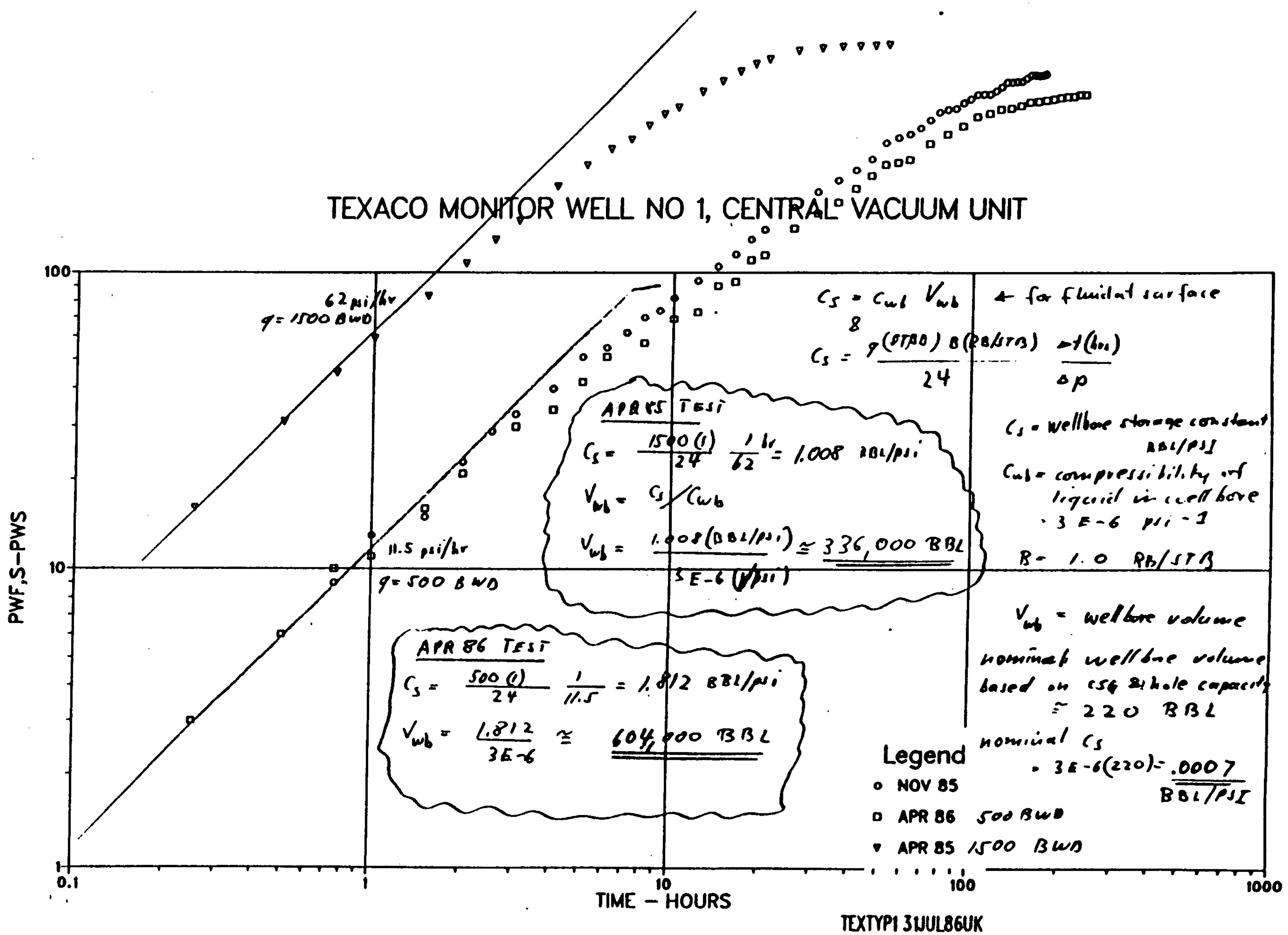
CENTRAL VACUUM UNIT
SALTWATER MONITOR WELL



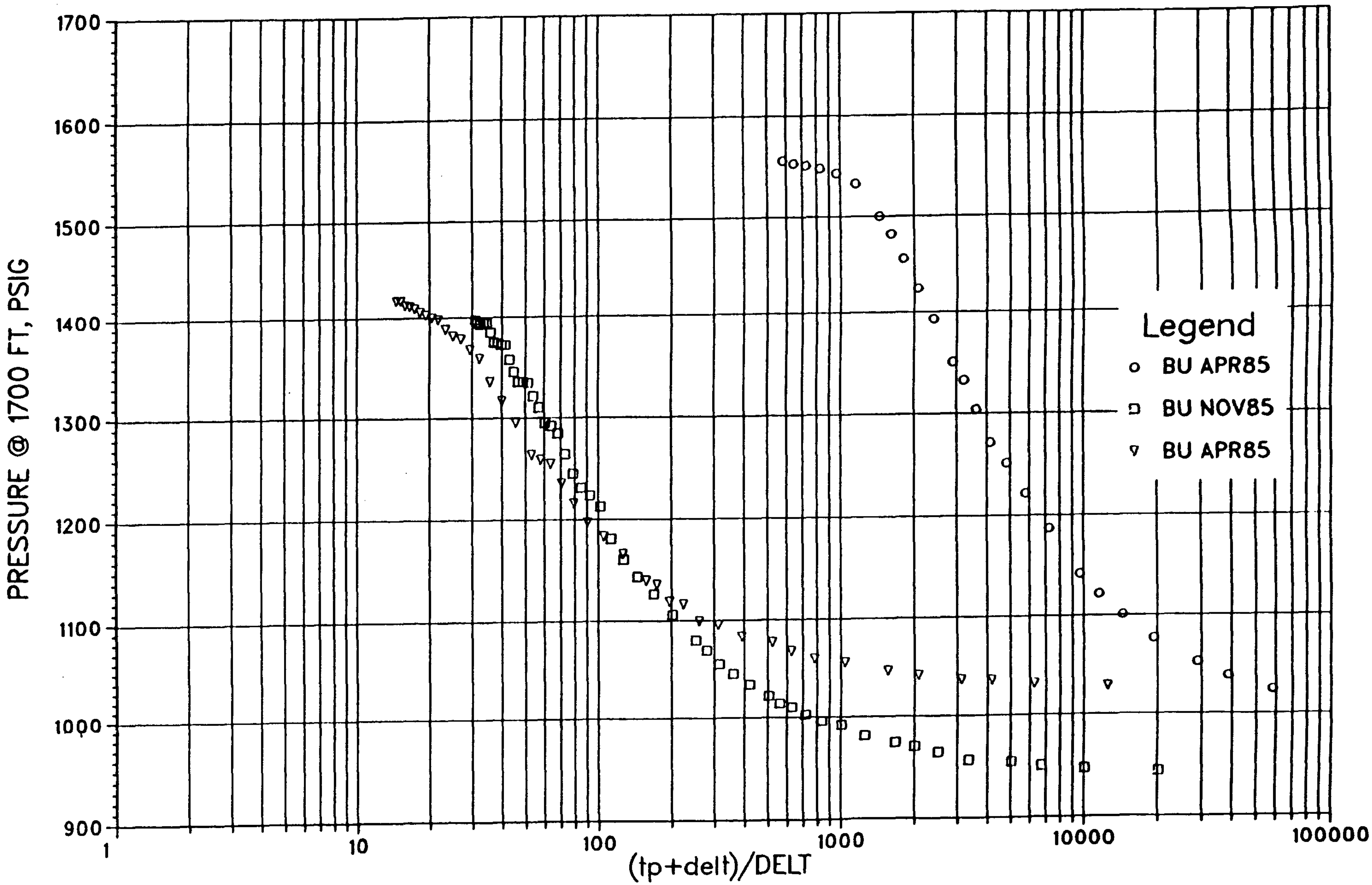
NOTE: BHP was calculated to a depth of 1700 ft. only. The 1 5/8" string is full of fresh water. Below this depth, the gradient is unknown.


CENTRAL VACUUM UNIT
MONITOR WELL
BOTTOM HOLE PRESSURE BUILD-UPS
April 1985
November 1985
April 1986
Bottom Hole Pressure (PSI X 100)
16
15
14
13
12
11
10
9
0
20
40
60
80
100
120
140
160
180
200
Shut-in Time (HRS)

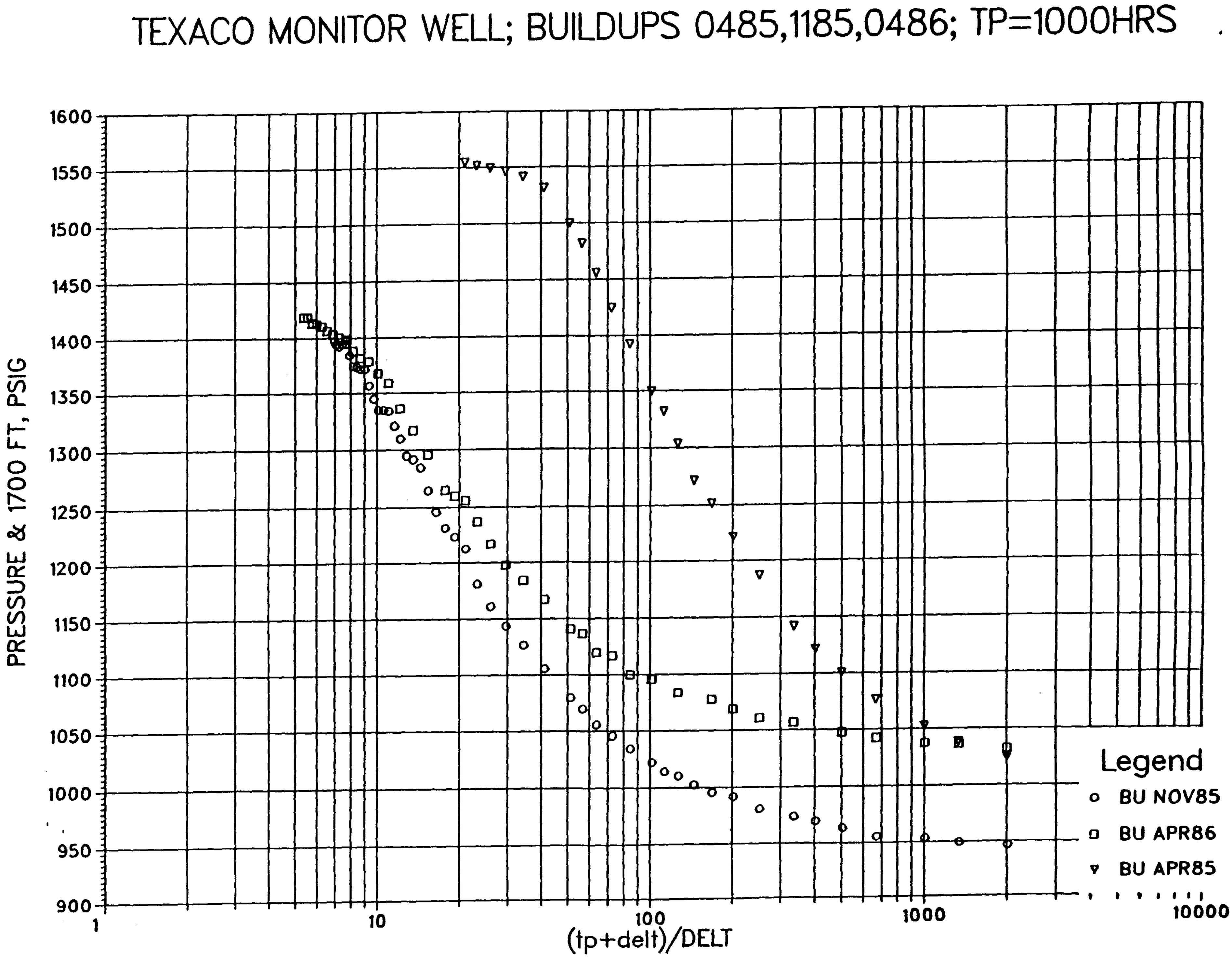
TEXACO MONITOR WELL NO 1, CENTRAL VACUUM UNIT



TEXACO MONITOR WELL, CENTRAL VACUUM FLD; BUILDUPS
APR85:TP=28800HRS;NOV85:TP=5016; APR86:TP=3096



EXH2 05AUG86UK



EXH1 31JUL86UK

CENTRAL VACUUM UNIT

MONITOR WELL PRESSURE BUILD-UPS

Prod. time prior to shut-in (hrs)	28,800	5016	3096
Shut-in time (hrs)	Bottom Hole Pressure at 1700' 4-20-85	11-15-85	3-31-86
0.0	991	937	1028
0.25	1010	944	1030
0.50	1025	947	1033
0.75	1039	950	1037
1.0	1053	954	1038
1.5	1077	956	1043
2.0	1101	964	1048
2.5	1122	970	-
3.0	1142	974	1057
4.0	1187	981	1061
5.0	1222	992	1069
6.0	1252	996	1078
7.0	1272	1003	-
8.0	1304	1011	1084
9.0	1332	1015	-
10.0	1350	1023	1096
12.0	1393	1035	1100
14.0	1426	1046	1117
16.0	1456	1056	1120
18.0	1482	1070	1137
20.0	1500	1080	1141
25.0	1532	1106	1167
30.0	1542	1127	1184
35.0	1547	1144	1198
40.0	1550	1161	1217
45.0	1552	1181	1237
50.0	1555	1213	1256
55.0	End of	1224	1260
60.0	build-up	1232	1265
65.0		1246	-
70.0		1265	1296
75.0		1285	-
80.0		1292	1317
85.0		1295	-
90.0		1310	1336
95.0		1321	-
100.0		1334	1359

Shut-in time (hrs)	4-20-85	11-15-85	3-31-86
110.0		1335	1368
115.0		1345	-
120.0		1357	1379
125.0		1372	-
130.0		1372	1382
135.0		1374	-
140.0		1375	1389
145.0		1385	-
150.0		1395	1399
155.0		1395	-
160.0		1393	1401
165.0		1395	-
170.0		End of build-up	1404
180.0			1407
190.0			1411
200.0			1413
210.0			1414
220.0			1419
230.0			1419
239.0			1438

STATUS REPORT

August 18, 1986

The schedule presented during the December, 1985 meeting called for the implementation of a tracer program during the second quarter of 1986. This schedule was based on obtaining pressure transient analysis between infill drilling locations in Texaco's Central Vacuum Unit and the monitor well during the first quarter of 1986. Due to the falling crude price, the wells became economically unfeasible to drill.

The pressure transient work was needed to establish communication through the salt and define characteristics of flow through salt. Although isotope-18 analysis indicates water from the monitor well originating from ogallala, it is not conclusive. Fresh water must be continuously pumped into the monitor well to keep it flowing and could possibly have contaminated samples.

With the uncertainty of the availability of pressure transient information, design of the tracer program was initiated. As originally envisioned, an optimum tracer program would be designed to test selected injection systems with different materials giving a definite solution to the source. Two categories of tracer candidates were proposed, radioactive and non-radioactive. Attention was focused on the latter due to the negative safety and environmental aspects of radioactive substances. Five components were identified as tracer candidates. A field-wide tracer program, coupled with only one monitor well, would be a lengthy, and expensive, and inconclusive test.

Estimates as to wellbore (reservoir) storage have been calculated by two methods. Pressure build-up analysis indicates a volume of 600,000 barrels. Cumulative salt water production from the monitor well is 2.1 MM barrels. This equates to 350,000 barrels of pure salt produced. This second calculation is on the conservative end. Injected fresh water has been subtracted out of the total fluid produced from the monitor well. This injected fresh water has dissolved an incalculable amount of free salt. Assuming a 10 percent leak at the source to the salt, approximately $600,000 worth of tracer would be required per waterflood unit. A flowrate of 500 barrels per day from the monitor well would yield a time factor as high as 3 years to detect tracer at the monitor well.

The tracer program was delayed after considering costs, time requirements, unavailability of pressure transient analysis, and lack of further evidence to establish direct communication between the San Andres waterfloods and the salt section. Another major concern is that of subsidence. Any major tracer program will require flowing the monitor well for an extended period of time.

Texaco recently lost a well on the Central Vacuum Unit due to a casing leak in the salt section. Analysis of water samples taken from this well should help pinpoint the source since it has not been contaminated with fresh water. Plans are to redrill this well which may possibly create an opportunity to run pressure transients.

Water samples on the monitor well have been analyzed for foreign elements. Polymer has been used in three of the Vacuum Grayburg-San Andres floods for tertiary processes. Tests for polymer have been negative. Carbon dioxide, which is being injected in one flood, is being checked presently.

Recommendations:

1.) Shut-in monitor well until all alternatives have been evaluated and final recommendation is approved.
2.) Continue evaluation of tracer program:
    a) Radioactive materials
    b) Subsidence
3.) Identify and evaluate possible alternative methods including but not limited to the following:
    a) Behind pipe movement logs. (This will necessitate involving all operators in the Vacuum field, not just waterflood operators, since there is still primary production.)
    b) Seismic

4.) Design a pressure transient test for Texaco redrill. Included in this would be catching water sample for isotope-18 and a foreign element analysis.

MINUTES OF MEETING NO. 7

VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE

January 21, 1986

The seventh meeting of the Vacuum Field Waterflow Technical Committee was held at 1:00 PM on Tuesday, January 21, 1986. The location for the meeting was the office of Phillips Petroleum Company in Odessa, Texas. The following representatives were in attendance:

Attendee	Company	Location
Mike Brownlee	Phillips	Odessa, Texas
Ulrich Kiesow	Phillips	Bartlesville, OK
Steve Guillot	Texaco	Hobbs, New Mexico
John Currie	Phillips	Odessa, Texas
Charles Lord	Phillips	Bartlesville, OK
Glenn Bankson	Mobil	Midland, Texas
David Douglas	ARCO	Midland, Texas

The meeting opened with a presentation by John Currie on waterflows encountered while Phillips was drilling wells on their "Lea" and "Leamex" leases on the western edge of the Vacuum Field. These waterflows were apparently coming from the Queen formation, and Phillips had difficulty in their primary cementing jobs due to them. It was agreed that this problem was secondary in importance to the problem in the vicinity of the Central Vacuum Unit Monitor Well No. 1 due to the relatively limited potential for both erosion of the salt section and oil production. Nevertheless, it was agreed that any water samples pertinent to this new problem be analyzed.

Water sampling elsewhere in the field was then discussed and a list of water samples that should be obtained was drawn up. This list included virtually every different source of water for injection, including a sample of injection water from the EK Queen Unit. This unit is operated by Murphy Baxter, who is not represented on the Technical Committee. Steve Guillot agreed to contact Baxter and, if necessary, the NMOCD for their assistance in this matter.

The next topic discussed was the planned interference test between the Central Vacuum Unit Monitor Well No. 1 and the planned infill wells in Section 6. It was reaffirmed that the procedure used would be that recommended as "Option 1", (with the monitor well shut-in prior to drilling into the salt section) as per Ulrich Kiesow's letter dated November 6, 1985. Kiesow mentioned that an accuracy of ±10 psi was necessary and not ±50 psi as stated in his letter. The much slower buildup noted in the most recent pressure test indicated the need for greater accuracy. He also stressed the need for a continuous recording of pressure. Guillot then assured the committee that the necessary equipment would be available for this test.

Different types of tracers that could be injected were then discussed, and some prices were quoted. Mike Brownlee suggested the possibility that some chemicals used in field operations could be used as a tracer. It was agreed that each company should generate a list of chemicals used on their respective units.

The meeting was adjourned at 2:30 PM.

MINUTES OF MEETING NO. 8
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
APRIL 3, 1986

The eighth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:30 P.M. on Thursday, April 3, 1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

NAME	COMPANY	LOCATION	PHONE NO.
Mike Brownlee	Phillips	Odessa, TX	915-367-1413
David Douglas	ARCO	Midland, TX	915-688-5563
Antoinette Green	ARCO	Midland, TX	915-894-3118
Brian Horanoff	Conoco	Hobbs, NM	505-392-2702
Robert Gudramovics	Mobil	Midland, TX	915-688-2042
Charley Lord	Phillips	Bartlesville, OK	918-661-9734
David Cain	Texaco	Hobbs, NM	505-393-7191
Steve Guillot	Texaco	Hobbs, NM	806-894-3118

The meeting opened with a discussion on chairing of the technical committee. Steve Guillot is being replaced by David Cain as Texaco's representative on the committee. Steve has been promoted to Area Engineer at Levelland, Texas and will no longer be assigned to this project. It was agreed Texaco would continue chairing the technical committee.

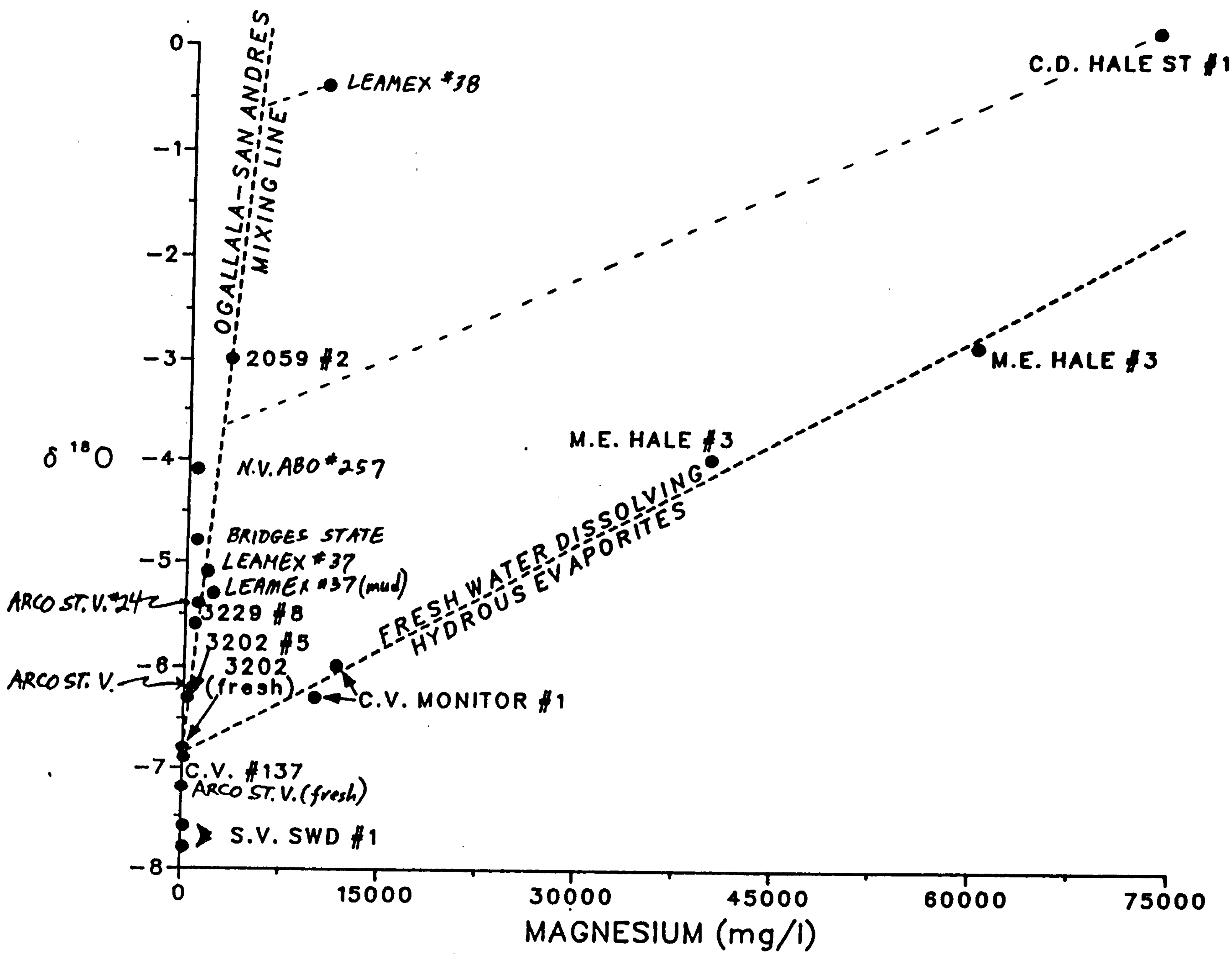
Charley Lord presented additional information on work with Oxygen 18 isotope tests (attached). His major observation precluded Arco's "State Vacuum" Well No. 1 (salt water disposal) as a source for the flow in the salt as previously expounded. Also stressed was the labeling of samples. Specifically, some of the samples submitted were unclear as to origin such as production, injection or disposal waters, etc.

Mike Brownlee recommended the technical committee begin taking preliminary steps on work with tracers. Due to the current economic climate, Texaco's infill drilling program on the Central Vacuum Unit has been postponed indefinitely. The December, 1985 meeting with the NMOCD resulted in a timetable for activities. Interference tests between Texaco's monitor well and proposed drilling wells on the Central Vacuum Unit were scheduled for the first quarter of 1986 with tracer evaluations set for the second quarter. Since it is impossible to forecast when these wells will be drilled, the technical committee decided to begin researching tracers and evaluating costs. A discussion ensued as to the different methods for tracing the flow. The general consensus was the method adopted depended mainly on the number of tracers available. Charley Lord volunteered to work on researching possible traces. Also on the timetable was a progress report scheduled for July, 1986 with the NMOCD. Bancker Cade, Texaco's representative on the management committee met with Jerry Sexton of the NMOCD discussing the current status of the waterflow committee. Sexton concurred that due to the uncertain economic conditions, a delay in the July meeting might be warranted. Sexton agreed to discuss the matter with R. L. Stamets, Director of the NMOCD, and get back in touch.

The meeting was adjourned at 3:30 P.M. with the next meeting tentatively scheduled after the list of possible traces has been formulated.

4 — 03 — 86

WATER MIXING DIAGRAM



MINUTES OF MEETING NO. 9
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
JULY 30, 1986

The ninth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:00 p.m. on Thursday, July 30,1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

Name	Company	Location	Phone No.
Mike Brownlee	Phillips	Odessa	915-367-1413
Bill Hermance	Mobil	Midland	915-688-2191
Ron Rogers	ARCO	Midland	915-688-5579
David Douglas	ARCO	Midland	915-688-5562
David Cain	Texaco	Hobbs	505-393-7191
Ulrich Kiesow	Phillips	Bartlesville	918-661-3931
Charley Lord	Phillips	Bartlesville	918-661-3418

The meeting opened informing those present of the upcoming project status report meeting called by R. L. Stamets, Director of the NMOCD, August 19,1986 at 10:00 a.m. MDLST in the Phillips office building, 1625 W. Marland, Hobbs, New Mexico. A joint meeting between the management and technical committees is scheduled for August 12, 1986 at 1:00 p.m. CDLST in the 4th floor conference room of the Phillips Building, 4001 Penbrook, Odessa, Texas.

Charley Lord presented the attached list of preliminary tracer recommendations adding Sodium Perchlorate as an additional possible candidate. Concern for possible environmental and health risks were raised about all those listed and Charley agreed to investigate. Charley is working on an updated graph of Oxygen-18 isotope tests which should be ready for the August status report.

Ulrich Kiesow presented the attached pressure build-up information on the Texaco monitor well. Preliminary modeling indicates reservoir storage in the neighborhood of 350,000 barrels.

A discussion ensued concerning the use of interference testing in a future Texaco redrill of a producing well some one half mile west of the monitor well to evaluate response time in the salt section. This interference testing would be helpful in determining the volume in the salt section. Drilling of this well is not likely to begin prior to the August meeting with the NMOCC. Conversion of a nearby producer to use for interference tests was discussed but deemed unfeasible.

Concern was voiced to have a tentative schedule ready should the NMOCC require tracer injection begin immediately. With the available information, tracer slug volumes were calculated with estimates starting at 50,000 barrels and larger depending on the distance from the flood to the monitor well. The question was brought up as to the availability of other well bores for potential use as additional monitor wells. Except for the Texaco well being redrilled, none were available. After putting some cost estimates to these slug volumes, the motion was made to investigate the use of radioactive tracers which had been ruled out in the past due to possible safety risks. Charley Lord is going to evaluate and attempt to have some cost comparisons available by the next meeting. The point was brought out that there is more than likely more than one source for the pressure in the salt section and that tracer testing may be limited by the number of tracers available.

Questions concerning alternative methods of detecting the pressure sources were discussed such as injection volumes, injection-withdrawal ratios, injection pressures, and possible pulse testing between the various floods and the monitor well. All of these methods have been investigated previously and ruled out for various reasons.

The meeting was adjourned at 4:00 p.m. with another meeting scheduled for 1:00 p.m., Thursday August 7, 1986 at the Phillips Petroleum Building, 4001 Penbrook, Odessa, Texas.

June 24, 1986

INTER-OFFICE CORRESPONDENCE / SUBJECT:
BARTLESVILLE, OKLAHOMA

Vacuum Field Unit, Lea County, N.M.,
Preliminary Tracer Recommendations
for Waterflood Injectors

CJL-1-86

M. H. Brownlee
Odessa Office

A consensus based on the oxygen isotope data is that the most probable sources of salt section waterflows are the Vacuum Field water injection projects. A tracer program is being designed to identify which of the waterflood projects are involved in the problem. Some preliminary design specifications are given below.

Ideally, a different tracer would be used for each of the waterfloods. At the present time, five non-radioactive tracers have been selected for use in the Vacuum Field injection wells. The following table summarizes the costs for these tracers.

TRACER COMPONENT	LB/GAL		COST/LB		COST/GAL
Lithium chloride	0.62	X	$ 8.50	=	$ 5.27
Sodium thiocyanate	0.53	X	$ 4.50	=	$ 2.39
Sodium nitrate	0.71	X	$ 2.85	=	$ 2.02
Potassium iodide	0.33	X	$13.40	=	$ 4.42
Ammonium chloride	0.75	X	$ 2.36	=	$ 1.77

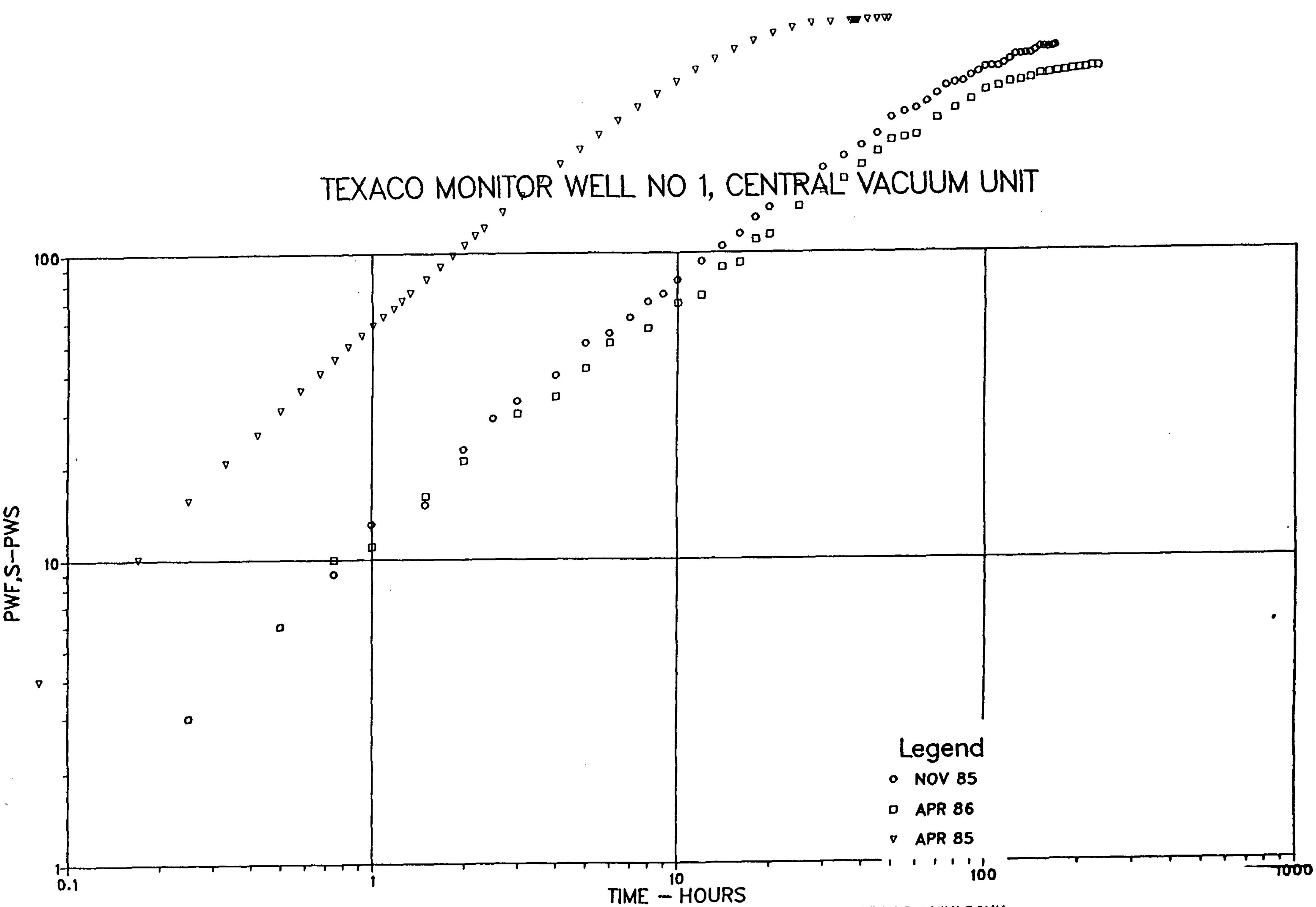
The volume of each tracer solution to inject has not yet been calculated but will depend on the estimated volume of water which is presently contained within the salt section. After the tracers have been injected, two samples will be collected daily from the Central Vacuum Monitor Well #1. These water samples will then be sent to the Phillips Research Center for analysis. The results will be reported to all members of the Vacuum Field Waterflow Committee in the form of tracer breakthrough curves.

Charley Lord

C. J. Lord
233A PL, Ext. 3418

cc: J. R. Paxson (r) R&D Records (RC)
D. W. Hausler (r) TVI, JHR
W. J. Mueller
J. F. Griggs (r) M. J. Fetkovich
U. G. Kiesow
W. D. Byrd (r) DWD

TEXACO MONITOR WELL NO 1, CENTRAL VACUUM UNIT



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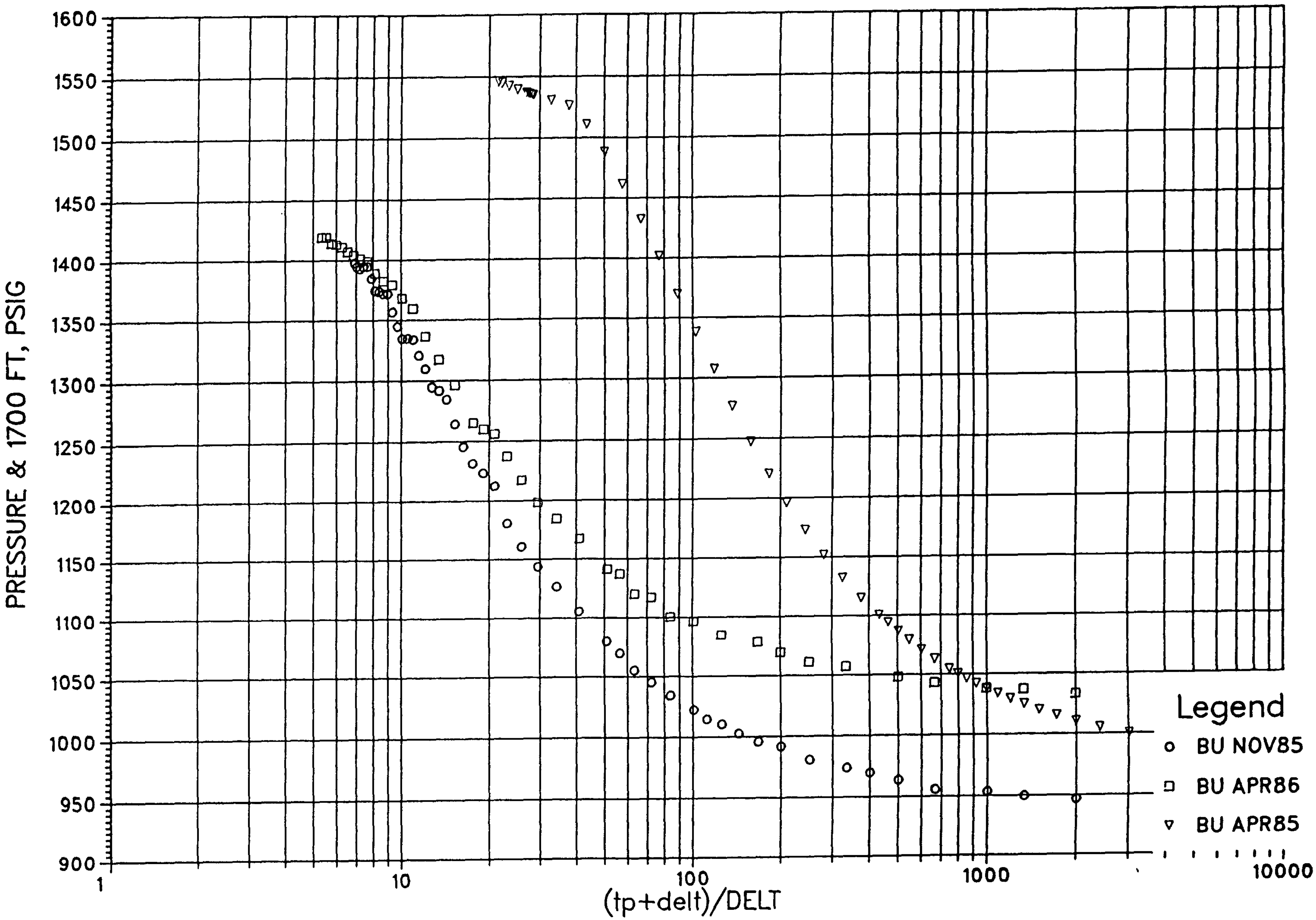

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MINUTES OF MEETING NO. 10
VACUUM FIELD WATERFLOW TECHNICAL COMMITTEE
AUGUST 7, 1986

The tenth meeting of the Vacuum Field Waterflow Technical Committee convened at 1:00 p.m. on Thursday, August 7,1986. The meeting was held at Phillips Petroleum Company's office in Odessa, Texas. The following representatives attended:

Name	Company	Location
Mike Brownlee	Phillips	Odessa
Glenn Bankson	Mobil	Midland
Ron Rogers	ARCO	Midland
David Douglas	ARCO	Midland
Don Steinnerd	Texaco	Hobbs
Ulrich Kiesow	Phillips	Bartlesville
Charley Lord	Phillips	Bartlesville

The agenda for the meeting included the upcoming meeting with the NMOCD, updates on water analysis, build-up analysis, and tracer injection plans.

Non-radioactive (sodium thiocyanate) tracer costs for a field wide tracer program were presented by Phillips for two cases. Costs for assumptions of 1% and 10% injected out of zone are $30,000,000 and $3,000,000 respectively. It was also estimated radioactive tracers would cost up to $10,000 per 100 millicuries depending on the type of tracer. Phillips estimated approximately 100 millicuries would be needed to tag a single flood. Radioactive tracers would be preferred due to the lower cost and greater number of tracers available if safety concerns are acceptable.

An updated build-up analysis on Texaco's monitor well by Phillips indicated a well storage of approximately 600,000 barrels. The previous estimate was 336,000 barrels. Texaco disagreed with the validity of the estimate. Texaco contends pressure build-up analysis for porous media is not applicable in this situation. The pressure build-up curve shape is more dependent upon the rate at which the salt is being deformed by overburden pressure. There was no further discussion on build-up analysis. A copy of Phillips tracer cost estimates and build-up analysis is attached.

Preliminary water analysis results for the latest sample from the monitor well indicates the "origin" is shifting upward. This indicates the latest sample is more of a mix between San Andres and Ogallala. Phillips will complete the analysis prior to the meeting with the NMOCD.

An alternative to the field wide tracer program was presented by Texaco. There was considerable disagreement between the four companies present over either Phillip's or Texaco's proposals.

The Phillip's proposal is to inject tracer in every flood and test only at Texaco's monitor well. Radioactive tracers would be preferred if safety concerns are resolved. However, non-radioactive tracers are still recommended if radioactive tracers cannot be used, even though costs would be significant. Texaco's proposal is to use tracers in the "hot" spots (water flows and/or bradenhead flows). Texaco would begin with their injection wells offsetting the monitor well. Additional monitor wells would be needed to conduct tracer surveys in other "hot" spot areas. Comments were noted for those companies present as follows:

Texaco	-	Opposes Phillip's field-wide tracer program. They prefer their proposed alternative.
Phillips	-	Opposes Texaco's limited tracer program. They prefer their proposed alternative.
Mobil	-	They see problems with both alternatives and are not in favor of either Texaco's or Phillip's proposal.
ARCO	-	Opposes drilling of additional monitor wells. They do support field-wide tracers in offsetting floods, only if radioactive tracers can be used.

The committee was not able to reach an agreement on recommending a specific tracer program.

Some additional comments and/or requests were made prior to adjourning the meeting. Texaco stated the replacement well for Central Vacuum Unit No. 91 would not be available for pressure transient testing unless water flows are of sufficient magnitude to require drilling be temporarily suspended. However, a pressure recorder would be installed on the monitor well and the well will be shut-in prior to spudding the new well. Texaco also stated they are preparing cost estimates for converting the existing Central Vacuum Unit No. 91 as a monitor well. Phillips requested the CO_2 content of the monitor well produced water be analyzed for future reference. Texaco stated they would have it done. Phillips also requested the cumulative water produced from the monitor wells as of the dates of the pressure build-ups. Texaco would provide them. Texaco recommended their monitor well be shut-in except for testing purposes. All companies present concurred.

The meeting was adjourned at 4:00 p.m. with the next meeting scheduled for August 12 at 1:00 p.m.; a joint meeting with the management.

Tracer Cost *

August 6, 1986 aK

Monitor Well Storage Vol. ≈ 600,000 BBL (Apr. 86)
Dilution factor: 1/1000
Need Tracer Vol. 600,000 BBL/1000 = 600 BBL
Injector assumed to leak at 1% or 10%
Needed volume to be injected:

@ Leak:	1%	10%
Vol:	600/.01 = 60,000 BBL	600/.1 = 6,000 BBL
Tracer Cost:	60,000 BBL x 100 $/BBL	6000 BBL x 100 $/BBL
	$6,000,000	$600,000

x5 satellites where injection to take place at same time

	$30,000,000	$3,000,000

LBS of tracer

$$60{,}000 \text{ BBL} \left(42 \frac{\text{GAL}}{\text{BBL}}\right) .53 \frac{\text{lb}}{\text{GAL}}$$

= 1,335,600 lbs | 133,560 lbs

* Assumes tracer cost of $100/BBL and 0.53 lb/gal (sodium thiocyanate)

June 24, 1986

INTER-OFFICE CORRESPONDENCE / SUBJECT:
BARTLESVILLE, OKLAHOMA

Vacuum Field Unit, Lea County, N.M.,
Preliminary Tracer Recommendations
for Waterflood Injectors

CJL-1-86

M. H. Brownlee
Odessa Office

A consensus based on the oxygen isotope data is that the most probable sources of salt section waterflows are the Vacuum Field water injection projects. A tracer program is being designed to identify which of the waterflood projects are involved in the problem. Some preliminary design specifications are given below.

Ideally, a different tracer would be used for each of the waterfloods. At the present time, five non-radioactive tracers have been selected for use in the Vacuum Field injection wells. The following table summarizes the costs for these tracers.

TRACER COMPONENT	LB/GAL		COST/LB (@ 1 tonne)		COST/GAL	COST/BBL* (*42 GAL/BBL)
Lithium chloride	0.62	X	$ 8.50	=	$ 5.27	221
Sodium thiocyanate	0.53	X	$ 4.50	=	$ 2.39	100
Sodium nitrate	0.71	X	$ 2.85	=	$ 2.02	85
Potassium iodide	0.33	X	$13.40	=	$ 4.42	186
Ammonium chloride	0.75	X	$ 2.36	=	$ 1.77	74

Sodium perchlorate

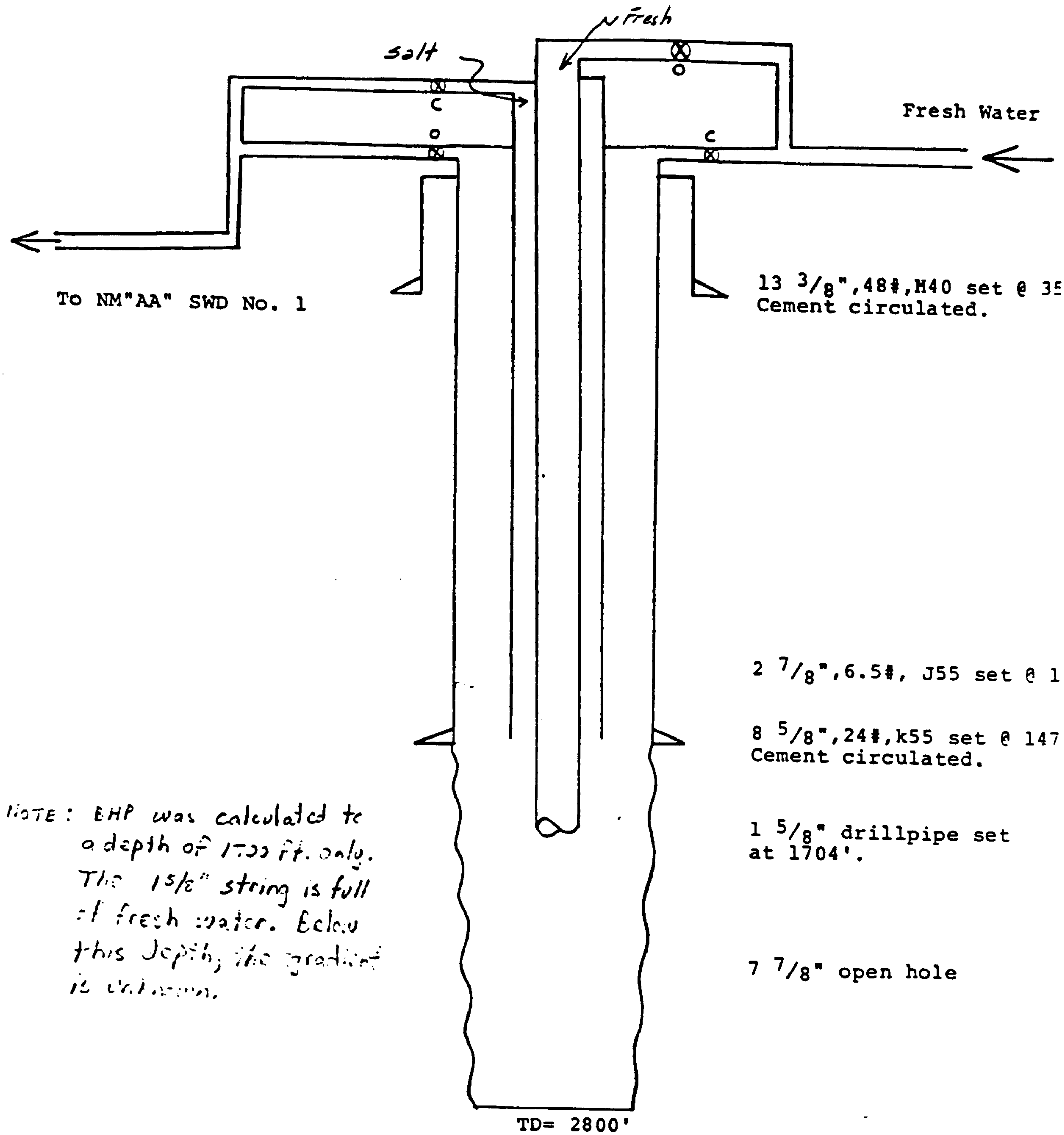
The volume of each tracer solution to inject has not yet been calculated but will depend on the estimated volume of water which is presently contained within the salt section. After the tracers have been injected, two samples will be collected daily from the Central Vacuum Monitor Well #1. These water samples will then be sent to the Phillips Research Center for analysis. The results will be reported to all members of the Vacuum Field Waterflow Committee in the form of tracer breakthrough curves.

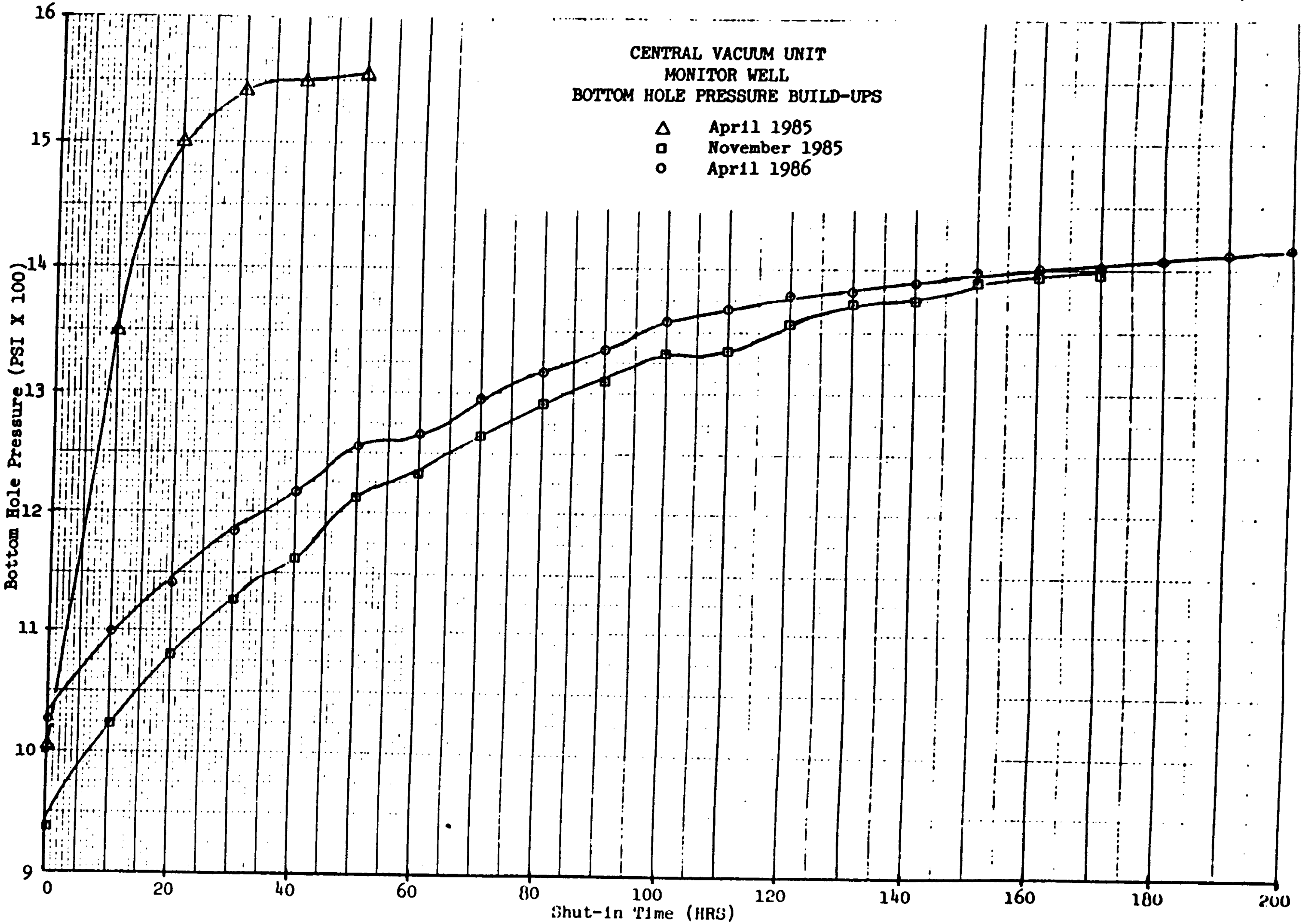
Charley Lord
C. J. Lord
233A PL, Ext. 3418

cc: J. R. Paxson (r) R&D Records (RC)
D. W. Hausler (r) TVI, JHR
W. J. Mueller
J. F. Griggs (r) M. J. Fetkovich
U. G. Kiesow
W. D. Byrd (r) DWD

CENTRAL VACUUM UNIT

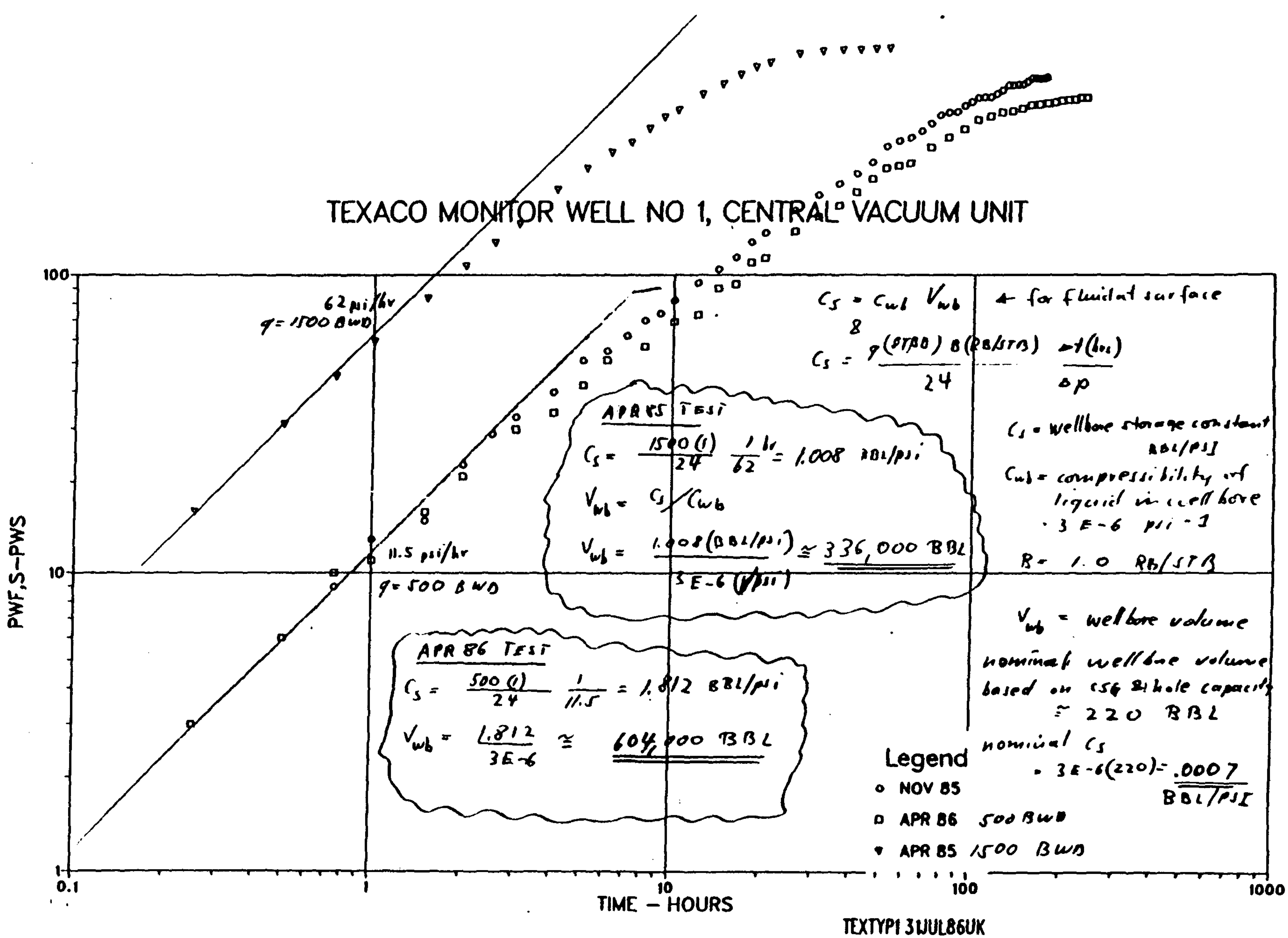
SALTWATER MONITOR WELL



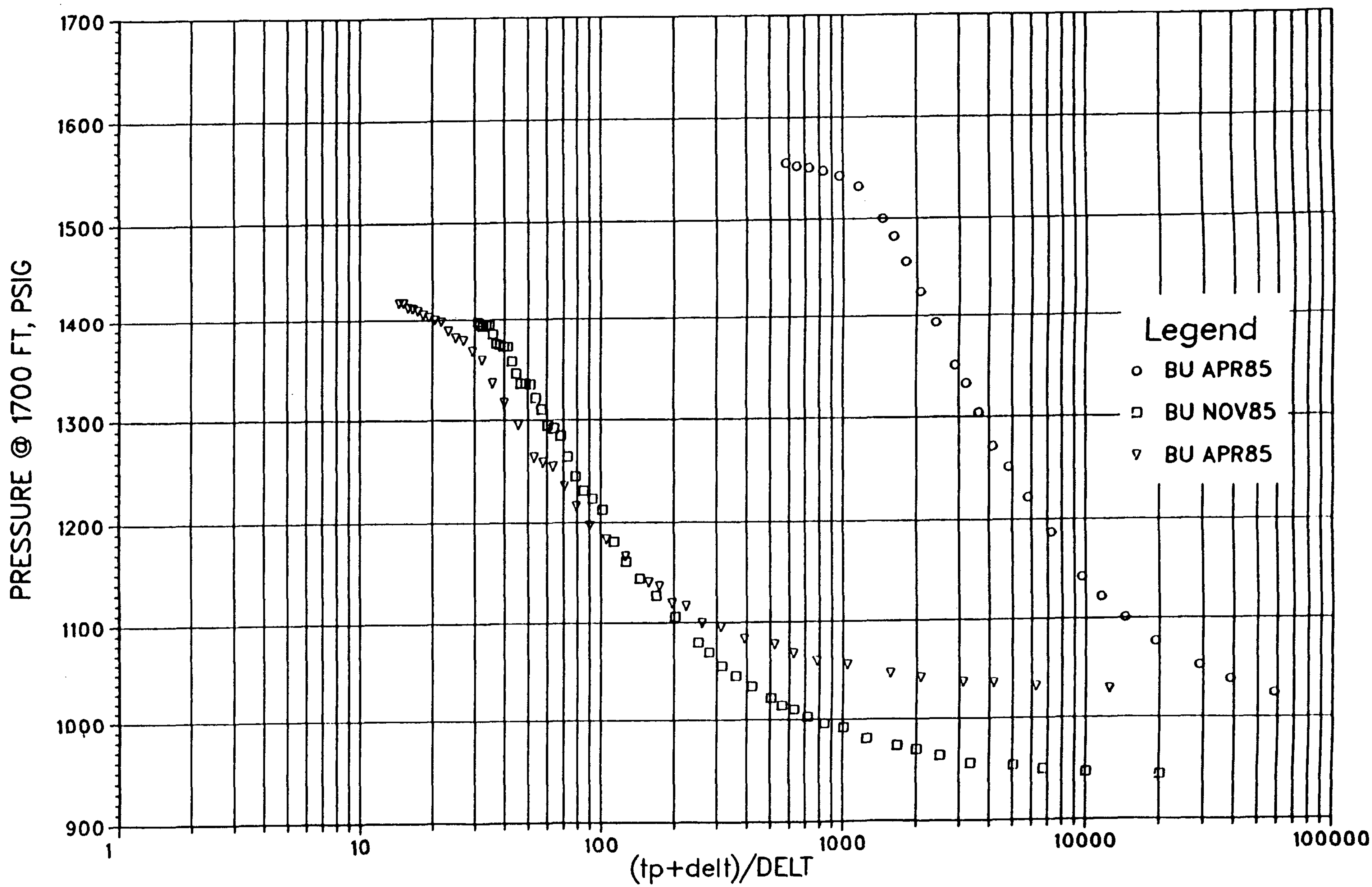


CENTRAL VACUUM UNIT
MONITOR WELL
BOTTOM HOLE PRESSURE BUILD-UPS
△ April 1985
□ November 1985
○ April 1986
Bottom Hole Pressure (PSI X 100)
16
15
14
13
12
11
10
9
0
20
40
60
80
100
120
140
160
180
200
Shut-in Time (HRS)

TEXACO MONITOR WELL NO 1, CENTRAL VACUUM UNIT

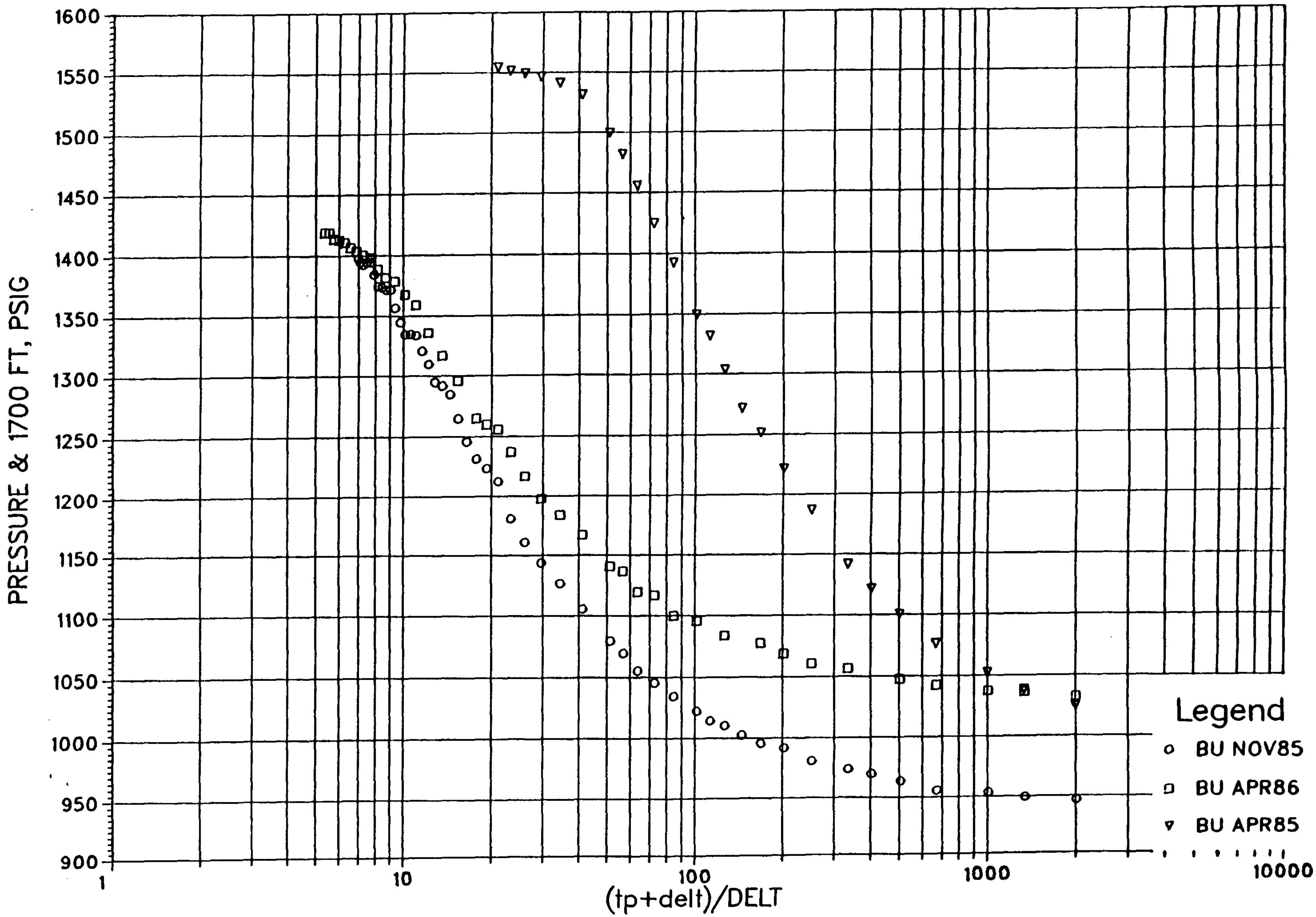


TEXACO MONITOR WELL, CENTRAL VACUUM FLD; BUILDUPS
APR85:TP=28800HRS;NOV85:TP=5016; APR86:TP=3096



EXH2 05AUG86UK

TEXACO MONITOR WELL; BUILDUPS 0485,1185,0486; TP=1000HRS



EXH1 31JUL86UK

CENTRAL VACUUM UNIT

MONITOR WELL PRESSURE BUILD-UPS

Prod. time prior to shut-in (hrs)	28,800	5016	3096
Shut-in time (hrs)	Bottom Hole Pressure at 1700' 4-20-85	11-15-85	3-31-86
0.0	991	937	1028
0.25	1010	944	1030
0.50	1025	947	1033
0.75	1039	950	1037
1.0	1053	954	1038
1.5	1077	956	1043
2.0	1101	964	1048
2.5	1122	970	-
3.0	1142	974	1057
4.0	1187	981	1061
5.0	1222	992	1069
6.0	1252	996	1078
7.0	1272	1003	-
8.0	1304	1011	1084
9.0	1332	1015	-
10.0	1350	1023	1096
12.0	1393	1035	1100
14.0	1426	1046	1117
16.0	1456	1056	1120
18.0	1482	1070	1137
20.0	1500	1080	1141
25.0	1532	1106	1167
30.0	1542	1127	1184
35.0	1547	1144	1198
40.0	1550	1161	1217
45.0	1552	1181	1237
50.0	1555	1213	1256
55.0	End of build-up	1224	1260
60.0		1232	1265
65.0		1246	-
70.0		1265	1296
75.0		1285	-
80.0		1292	1317
85.0		1295	-
90.0		1310	1336
95.0		1321	-
100.0		1334	1359

Shut-in time (hrs)	4-20-85	11-15-85	3-31-86
110.0		1335	1368
115.0		1345	-
120.0		1357	1379
125.0		1372	-
130.0		1372	1382
135.0		1374	-
140.0		1375	1389
145.0		1385	-
150.0		1395	1399
155.0		1395	-
160.0		1393	1401
165.0		1395	-
170.0		End of	1404
180.0		build-up	1407
190.0			1411
200.0			1413
210.0			1414
220.0			1419
230.0			1419
239.0			1438

PHILLIPS PETROLEUM COMPANY
BARTLESVILLE, OKLAHOMA 74004 918 661-6600

Origin of Vacuum Field Waterflow Brines: Status Report

Conclusions

1. The Vacuum Field salt section waterflow brines from the two wells sampled are not naturally occurring connate waters formed by the evaporation of Permian seawater.

2. The waters presently found in the Salado, San Andres, and Devonian formations have fresh water (meteoric) origins.

3. Waterflow brines can be correlated with specific injection or disposal waters based on their isotopic composition.

4. The dissolved salts in the waterflow brines are determined by the dissolution of evaporite minerals from the Salado Formation and are not related to the original components in the source water.

Project History

A major objective of the Vacuum Field Waterflow Technical Committee is to identify the source of high pressure water which is currently flowing from the salt section (Salado Formation) in the south-central portion of the Vacuum Field Unit. In response to R. L. Stamets' letter of February 7, 1985 a novel approach using state of the art technology is being applied to the problem. This approach is based on a detailed geochemical examination of produced, injection, and disposal water samples from various locations around the field.

During the initial phase of this project a series of waterflow samples was collected and analyzed in a routine manner by either Martin Water Laboratories or Unichem International. In these analyses all of the major dissolved salts were measured except for sodium and potassium which were calculated by balancing the positive and negative ion charges. The calculated "sodium and/or potassium" values were then reported as sodium equivalents. These data were examined along with several previous analyses of waterflow brines. The compositions of all the salt section waterflow samples were found to be similar to each other but very different from produced San Andres waters. The most striking characteristics of the salt section waters were their high magnesium and sulfate concentrations accompanied by a very high magnesium to calcium ratio. The composition of these brines was in fact quite similar to that of solutions formed during the last stages of seawater evaporation. In addition, preliminary calculations suggested that the waterflow brines were supersaturated salt solutions. This supersaturation was most obvious with respect to sodium chloride.

The significance of a supersaturated condition lies in the fact that it can only be attained through an evaporative process and not through a process of salt dissolution. Based on these observations it seemed reasonable at that time to conclude that the waterflow brines were naturally occurring connate waters produced by evaporation of Permian seawater. The source of this water was believed to be the upper zone of the salt section.

Because of the complex nature of concentrated salt solutions, it is difficult to accurately evaluate the state of saturation without the aid of sophisticated computer programs. It was suggested that a consultant be contracted to perform the necessary computer calculations (geochemical modeling). If the waterflow brines were in fact supersaturated then this would support the hypothesis that these waters were naturally occurring. If, however, the brines were not supersaturated then no information concerning their origin could be obtained from the data.

In order to more clearly resolve the question of brine origin, a second phase of the project was initiated in April, 1985. This work involved the complete characterization of water samples including all of the major and several minor dissolved salts as well as an isotopic analysis of the water molecules themselves. The sodium and potassium concentrations were specifically measured in these samples rather than using the calculated "sodium and/or potassium" method discussed earlier. By combining the isotopic and compositional data it became possible to accurately determine the sources of various brines from the Vacuum Field area. This new data led the Technical Committee to revise its preliminary position concerning the origin of waterflow brines.

Analytical Data

The results of the chemical analyses are given in Tables 2, 3, and 4. The data for the waterflow brines and injection water collected during the initial phase of the project are shown in Tables 2-A through 2-G. In these tables the sodium values represent the combined sodium and potassium concentrations. The data for samples collected during the second phase of the project are given in Tables 3-A through 3-I. These samples consist of three waterflow brines (Tables 3-A, 3-B, and 3-I), four produced waters from the San Andres Formation (Tables 3-C, 3-D, 3-E, and 3-F), one fresh water from the Ogallala Formation (Table 3-G), and one disposal brine from the Devonian section (Table 3-H). The isotopic data are compiled in Table 4 and plotted on Figures 1 and 2. In all of the tables a blank means that the measurement was not made and a zero means that the measurement was performed but the concentration was less than 0.5 mg/l.

Discussion and Conclusions

The following discussion refers to Figure 1 and illustrates the use of geochemical measurements to identify the origin of produced waters. A brine which formed by the evaporation of seawater will have undergone predictable compositional changes and would plot within the field designated as "Evaporating Marine Brine". For example, a late stage evaporite solution with a total dissolved solids (TDS) content of 300,000 to 400,000 mg/l would have a $\delta^{18}O$ value of about +6. On the other hand, fresh water such as found in the Ogallala Formation (3202-fresh) has a very low TDS and a $\delta^{18}O$ value of -6.8. If this fresh water flowed through and dissolved a salt deposit, the resulting brines would be characterized by higher TDS contents and somewhat less negative $\delta^{18}O$ values. As can be seen in Figure 1, the data are consistent with this salt dissolution model and none of the water samples plot in or near the "Evaporating Marine Brine" field.

$$\delta^{18}O = \frac{\left({}^{18}O/{}^{16}O_{sample} - {}^{18}O/{}^{16}O_{std} \right)}{{}^{18}O/{}^{16}O_{std}} \times 1000$$

Perhaps the most obvious conclusion to be drawn from Figure 1 is that the waters presently found in the Salado, San Andres, and Devonian formations have fresh water origins. The salt section waterflow brines, therefore, are not naturally occurring connate waters produced by the evaporation of Permian seawater. Rather, the high salt content of the brines is caused by dissolution of evaporite minerals from the rock and not by an evaporative process. This is the Technical Committee's current belief and is contrary to the preliminary theory proposed for the origin of the water in the salt section.

A second conclusion based on the data in Figure 2 is that waters which share a common origin can be clearly identified. This is because mixtures of waters from two different sources will plot along a straight line on Figure 2. For example, the C.V. #137, 3202 (fresh), 3202 #5, 3229 #8, and 2059 #2 samples represent various mixtures of Ogallala injection water and naturally occurring San Andres water. The 2059 #2 brine from the northern edge of the East Vacuum Unit contains the greatest percentage of San Andres water. This is probably a result of the fact that the San Andres Formation is tighter in this area and has not been effectively flushed by the waterflood operations.

The waterflow brines sampled from the C.V. Monitor #1 and the M.E. Hale #3 plot along the line in Figure 2 labeled "Fresh Water Dissolving Hydrous Evaporites". This line represents the mixing of Ogallala water with mineral-bound water from the Salado Formation. Many evaporite minerals contain structural water within their salt crystals as shown in Table 1. These water-bearing salts are referred to as hydrous evaporites. When these minerals dissolve, they release their structural water into solution which results in a mixture of two different water sources. Based on analyses of waterflow brines, the most abundant hydrous evaporites appear to be carnallite ($KMgCl_3 \cdot 6H_2O$) and bischofite ($MgCl_2 \cdot 6H_2O$). Both of these salts have a water to magnesium ratio of 6:1. Therefore, the magnesium concentration is directly proportional to the amount of structural water released during dissolution. For this reason, magnesium concentration is plotted against $\delta^{18}O$ in Figure 2.

The S.V. SWD #1 sample, a disposal brine from Arco's Devonian production, is distinctly different from the other waters sampled to date. The more negative $\delta^{18}O$ value suggests that the fresh water recharge for the Devonian section occurs in a colder or higher elevation environment as compared to the Ogallala waters. The net result of this analysis is that salt section waterflows caused by the disposal of Devonian brines should be distinguishable from those caused by Vacuum Field waterflood operations. In effect, the isotopic difference between these fresh water sources provides an in situ tracer for studying water movement across the field.

It was found through a detailed analysis of the dissolved salts that most salt section brines contain roughly equal amounts of potassium and sodium. When the actual sodium concentration is considered rather than a calculated "sodium and/or potassium" value, it becomes apparent that the salt section waters are saturated with respect to sodium chloride but not supersaturated. The potassium and magnesium salts in these waters are all undersaturated. This lack of supersaturation is consistent with the concept that the salt section brines formed through the dissolution of evaporite minerals. The original belief that these were supersaturated solutions has been revised in light of these newer data.

The characteristic features of salt section brines would now be expanded to include high potassium, magnesium, and sulfate concentrations accompanied by a very high magnesium to calcium ratio. It is relatively easy to explain these observed features by examining the list of evaporite minerals given in Table 1. A quick look at Table 1 reveals a large number of very soluble potassium and magnesium chlorides and sulfates. This accounts for the high potassium and magnesium concentrations found in the salt section brines. The only insoluble mineral present is anhydrite ($CaSO_4$) and this fact directly controls the dissolved calcium concentration. This means that as the sulfate concentration in the brine increases through the dissolution of soluble magnesium and potassium sulfates, the concentration of calcium is forced to decrease by an equivalent amount. It is this process which explains the high sulfate and low calcium levels observed in the brines. Due to the overwhelming effect of evaporite mineral dissolution, the composition of water entering the salt section will have little effect on the final brine composition. The water will, however, retain its original isotopic signature.

Recommendations

The following are recommendations for future work to define the origin and movement of salt section waterflow brines.

1. Obtain and analyze samples of all injection waters, disposal waters, bradenhead flows, and salt section waterflows from the entire Vacuum Field area. The analyses should include isotopic measurements as well as detailed analyses of the dissolved salts. The purpose of this study would be to correlate the various waterflow brines with specific disposal or injection operations. This program, therefore, will help to identify both the potential sources and flow directions of the salt section brines. The total cost per sample would be about $450.

2. Use the detailed chemical analyses of waterflow brines to determine which salts have been dissolved from the Salado Formation. Due to the stratified nature of evaporite deposits, certain salts are concentrated in specific beds. By analyzing the salts dissolved in the water it may be possible to identify the beds (i.e. depths) through which the water has flowed. The location of potassium-rich salt beds, such as the McNutt potash zone in the Salado Formation, can be picked from gamma ray well logs, because all potassium salts contain the radioactive isotope ^{40}K which allows them to be detected by wireline gamma ray tools. Based on the high potassium concentrations found in waterflow brines, it is reasonable to conclude that the water flowed through or across a potassium-rich bed.

3. Perform a series of experiments in which Salado Formation core samples are reacted with waters of different compositions (Ogallala water, San Andres water, disposal brine, etc.) and determine the characteristics of the resulting solutions. These solutions can then be used to empirically evaluate the possible origins of the salt section waters. If the chemical and isotopic composition of an experimental solution matches that of the salt section water, then a probable mode of formation can be established.

4. Introduce a tracer into those injector and/or disposal wells that are suspected sources for the salt section waterflows. Monitor nearby wells for the appearance of the tracer by collecting and analyzing produced water samples. By studying the movement of the tracer solution over time, both flow directions and flow rates can be obtained.

Charles J. Lord, III

Charles J. Lord, III

(Doc: Vacfield)

FIGURE 1

BRINE EVOLUTION DIAGRAM

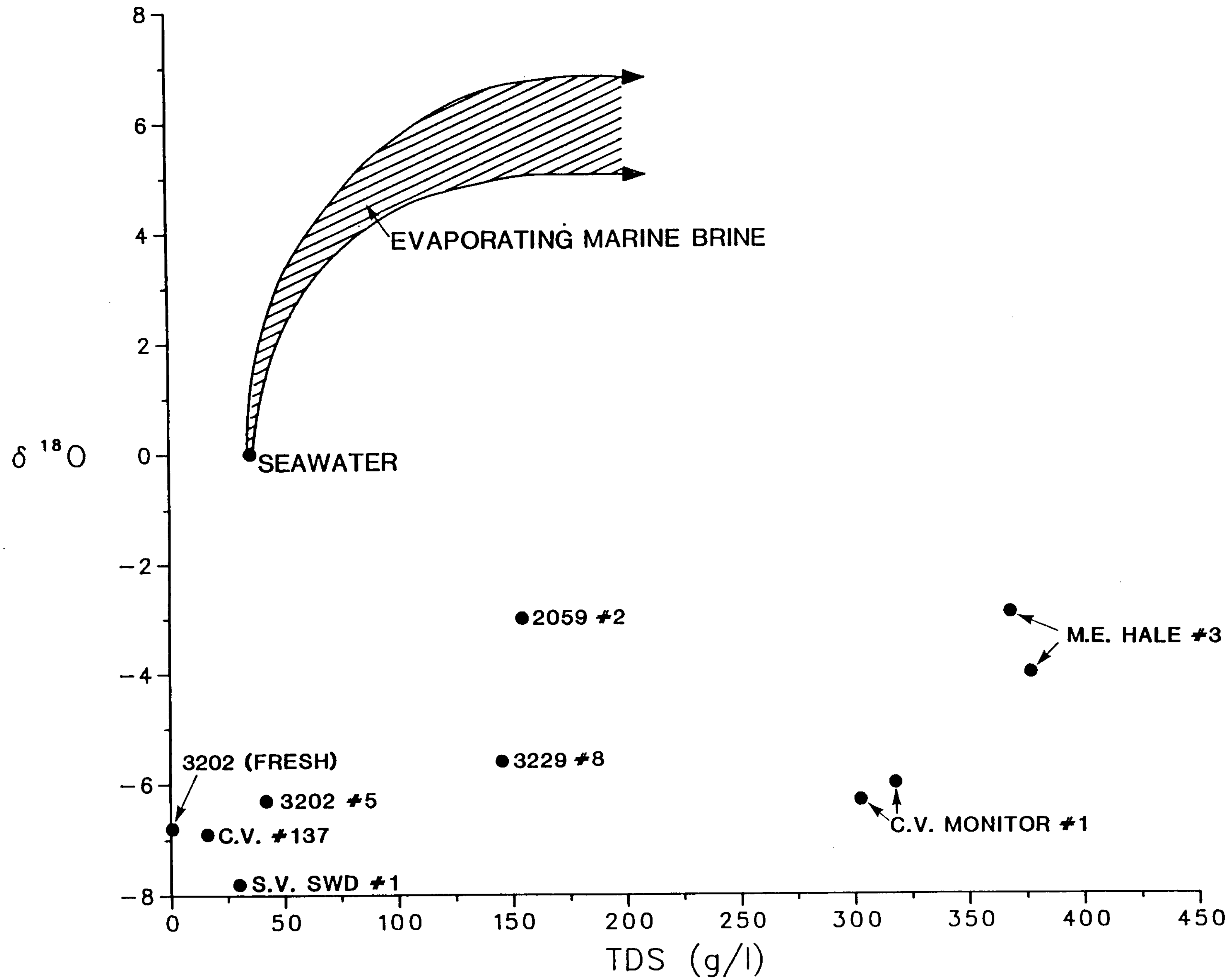


FIGURE 2

WATER MIXING DIAGRAM

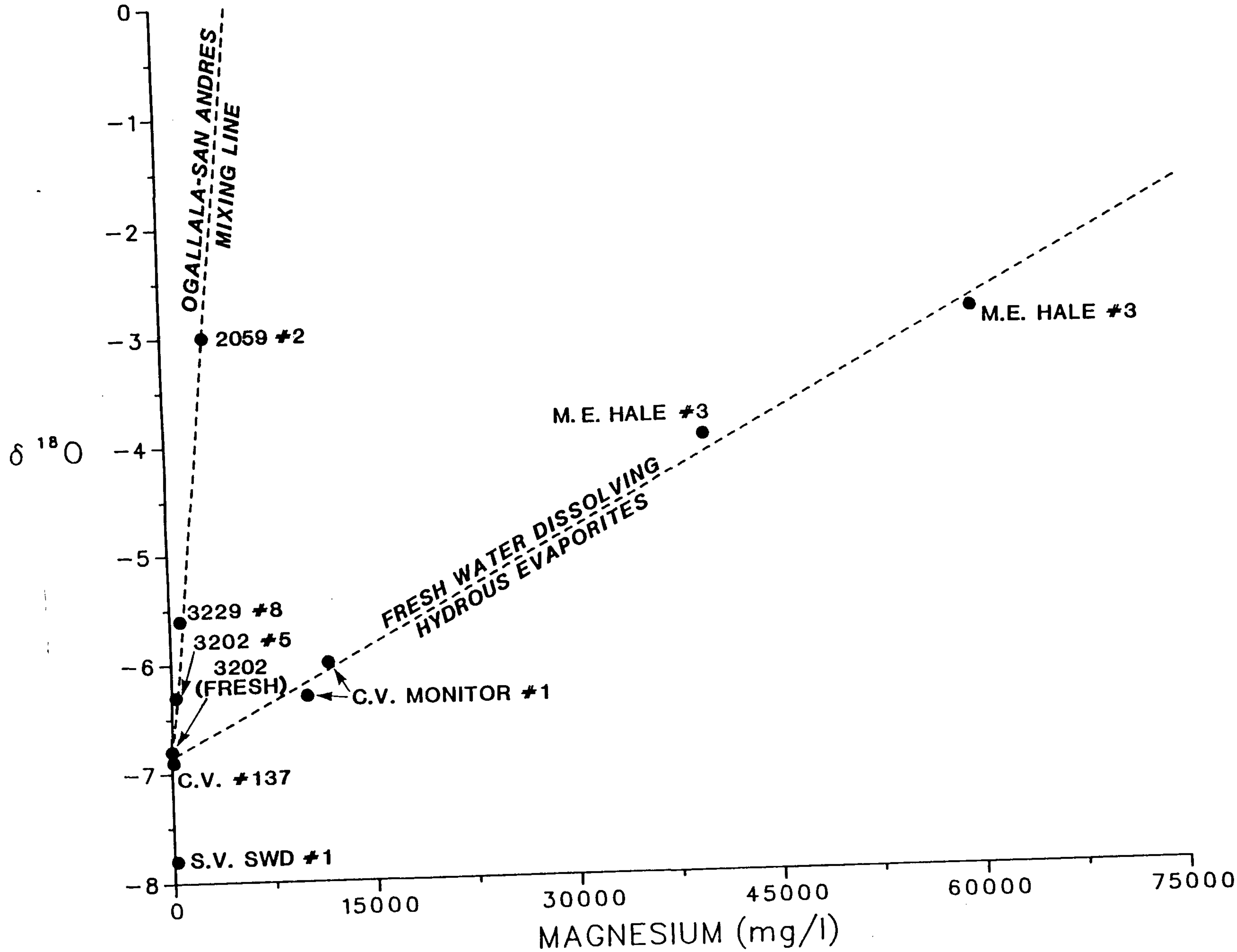


TABLE 1

COMMON EVAPORITE MINERALS

MINERAL	FORMULA
HALITE	$NaCl$
ANHYDRITE	$CaSO_4$
CARNALLITE	$KMgCl_3 \cdot 6H_2O$
KAINITE	$KMgClSO_4 \cdot 2\frac{3}{4}H_2O$
BISCHOFITE	$MgCl_2 \cdot 6H_2O$
SYLVITE	KCl
LANGBEINITE	$K_2Mg_2(SO_4)_3$
KIESERITE	$MgSO_4 \cdot H_2O$
BLOEDITE	$Na_2Mg(SO_4)_2 \cdot 4H_2O$
POLYHALITE	$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$
TACHYHYDRITE	$CaMg_2Cl_6 \cdot 12H_2O$
LEONITE	$K_2Mg(SO_4)_2 \cdot 4H_2O$

TABLE 2-A

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : C. VACUUM UNIT #162

SAMPLE : WATERFLOW BRINE : 6-15-83

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	92900	4040.9	CHLORIDE	172000	4851.5
MAGNESIUM	13800	1135.5	SULFATE	16600	345.6
CALCIUM	440	22.0	BICARBONATE	390	6.4
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 296130
SPECIFIC GRAVITY (60/60 F) = 1.1918
RESISTIVITY (OHM-M @ 77 F) = 0.046
PH = 6.49

OPERATOR : TEXACO
SAMPLING POINT : CASING
ANALYST : MARTIN WATER LABS

TABLE 2-B

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : C. VACUUM UNIT #162

SAMPLE : WATERFLOW BRINE : 6-15-83

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	113000	4915.2	CHLORIDE	195000	5500.2
MAGNESIUM	12400	1020.3	SULFATE	21700	451.8
CALCIUM	460	23.0	BICARBONATE	409	6.7
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 342969
SPECIFIC GRAVITY (60/60 F) = 1.2272
RESISTIVITY (OHM-M @ 77 F) = 0.042
PH = 6.25

OPERATOR : TEXACO
SAMPLING POINT : TUBING
ANALYST : MARTIN WATER LABS

TABLE 2-C

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : ARCO STATE #2

SAMPLE : WATERFLOW BRINE : 12-13-84

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	108000	4697.7	CHLORIDE	198000	5584.9
MAGNESIUM	15000	1234.3	SULFATE	18500	385.2
CALCIUM	772	38.5	BICARBONATE	244	4.0
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 340516
SPECIFIC GRAVITY (60/60 F) = 1.2300
RESISTIVITY (OHM-M @ 77 F) =
PH = 6.04

OPERATOR : BLANKS ENERGY
SAMPLING POINT :
ANALYST : UNICHEM INTERNATIONAL

TABLE 2-D

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : C. VACUUM UNIT MONITOR WELL #1

SAMPLE : WATERFLOW BRINE : 3-27-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	104000	4523.7	CHLORIDE	185000	5218.2
MAGNESIUM	11600	954.5	SULFATE	13200	274.8
CALCIUM	560	27.9	BICARBONATE	290	4.8
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 314650
SPECIFIC GRAVITY (60/60 F) = 1.2104
RESISTIVITY (OHM-M @ 77 F) = 0.045
PH = 6.80

OPERATOR : TEXACO
SAMPLING POINT :
ANALYST : MARTIN WATER LABS

TABLE 2-E

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : COLE DARDEN HALE STATE #1

SAMPLE : WATERFLOW BRINE : 3-22-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	77500	3371.1	CHLORIDE	196000	5528.4
MAGNESIUM	38700	3184.4	SULFATE	47600	991.0
CALCIUM	228	11.4	BICARBONATE	2990	49.0
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 363018
SPECIFIC GRAVITY (60/60 F) = 1.2598
RESISTIVITY (OHM-M @ 77 F) = 0.040
PH = 6.59

OPERATOR : ARCO
SAMPLING POINT : FLOWLINE
ANALYST : MARTIN WATER LABS

TABLE 2-F

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : COLE DARDEN HALE STATE #1

SAMPLE : WATERFLOW BRINE : 4-9-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	32600	1418.0	CHLORIDE	226000	6374.6
MAGNESIUM	77500	6377.0	SULFATE	67300	1401.2
CALCIUM	13	0.6	BICARBONATE	1590	26.1
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE		
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 405003
SPECIFIC GRAVITY (60/60 F) = 1.3018
RESISTIVITY (OHM-M @ 77 F) = 0.034
PH = 5.28

OPERATOR : ARCO
SAMPLING POINT : FLOWLINE
ANALYST : MARTIN WATER LABS

TABLE 2-G

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : C. VACUUM UNIT #137

SAMPLE : INJECTION WATER : 3-31-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	5480	238.4	CHLORIDE	8920	251.6
MAGNESIUM	104	8.6	SULFATE	751	15.6
CALCIUM	419	20.9	BICARBONATE	332	5.4
POTASSIUM			CARBONATE	0	0.0
STRONTIUM			BROMIDE	6	0.1
BARIUM			IODIDE		

TOTAL DISSOLVED SOLIDS (MG/L) = 16012
SPECIFIC GRAVITY (60/60 F) =
RESISTIVITY (OHM-M @ 77 F) =
PH = 7.30

OPERATOR : TEXACO
SAMPLING POINT :
ANALYST : TEXACO, INC.

TABLE 3-A

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : M.E.HALE #3

SAMPLE : WATERFLOW BRINE

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	50500	2196.6	CHLORIDE	215000	6064.4
MAGNESIUM	39800	3274.9	SULFATE	22600	470.5
CALCIUM	162	8.1	BICARBONATE	305	5.0
POTASSIUM	47800	1222.4	CARBONATE	0	0.0
STRONTIUM	1	0.0	BROMIDE	666	8.3
BARIUM	0	0.0	IODIDE	54	0.4

TOTAL DISSOLVED SOLIDS (MG/L) = 376888
SPECIFIC GRAVITY (60/60 F) = 1.2546
RESISTIVITY (OHM-M @ 77 F) = 0.057
PH = 5.87

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : SAMPLE #1
R & D SAMPLE CODE : GI-85-FW-4

TABLE 3-B

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : M.E.HALE #3

SAMPLE -: WATERFLOW BRINE

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	34500	1500.7	CHLORIDE	211000	5951.5
MAGNESIUM	59800	4920.6	SULFATE	39800	828.6
CALCIUM	176	8.8	BICARBONATE	305	5.0
POTASSIUM	21800	557.5	CARBONATE	0	0.0
STRONTIUM	1	0.0	BROMIDE	898	11.2
BARIUM	0	0.0	IODIDE	29	0.2

TOTAL DISSOLVED SOLIDS (MG/L) = 368309
SPECIFIC GRAVITY (60/60 F) = 1.2636
RESISTIVITY (OHM-M @ 77 F) = 0.071
PH = 5.54

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : SAMPLE #2
R & D SAMPLE CODE : GI-85-FW-5

TABLE 3-C

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : E. VACUUM G-SA UNIT 3202 #5

SAMPLE : PRODUCED WATER : 5-20-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	13800	600.3	CHLORIDE	22700	640.3
MAGNESIUM	284	23.4	SULFATE	2830	58.9
CALCIUM	1600	79.8	BICARBONATE	272	4.5
POTASSIUM	152	3.9	CARBONATE	48	1.6
STRONTIUM	29	0.7	BROMIDE	27	0.3
BARIUM	0	0.0	IODIDE	5	0.0

TOTAL DISSOLVED SOLIDS (MG/L) = 41747
SPECIFIC GRAVITY (60/60 F) = 1.0306
RESISTIVITY (OHM-M @ 77 F) = 0.174
PH = 8.01

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : 3202-005
R & D SAMPLE CODE : GI-85-FW-6

TABLE 3-D

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : E. VACUUM G-SA UNIT 3229 #8

SAMPLE : PRODUCED WATER : 5-20-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	53100	2309.7	CHLORIDE	84300	2377.8
MAGNESIUM	737	60.6	SULFATE	3640	75.8
CALCIUM	2680	133.7	BICARBONATE	207	3.4
POTASSIUM	483	12.4	CARBONATE	5	0.2
STRONTIUM	84	1.9	BROMIDE	90	1.1
BARIUM	0	0.0	IODIDE	12	0.1

TOTAL DISSOLVED SOLIDS (MG/L) = 145338
SPECIFIC GRAVITY (60/60 F) = 1.0999
RESISTIVITY (OHM-M @ 77 F) = 0.072
PH = 7.13

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : 3229-008
R & D SAMPLE CODE : GI-85-FW-7

TABLE 3-E

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : E. VACUUM G-SA UNIT 2059 #2

SAMPLE : PRODUCED WATER : 5-28-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	48700	2118.3	CHLORIDE	93700	2642.9
MAGNESIUM	3090	254.3	SULFATE	2130	44.3
CALCIUM	5220	260.5	BICARBONATE	50	0.8
POTASSIUM	1260	32.2	CARBONATE	0	0.0
STRONTIUM	156	3.6	BROMIDE	163	2.0
BARIUM	0	0.0	IODIDE	21	0.2

TOTAL DISSOLVED SOLIDS (MG/L) = 154490
SPECIFIC GRAVITY (60/60 F) = 1.1082
RESISTIVITY (OHM-M @ 77 F) = 0.070
PH = 3.71

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : 2059-002
R & D SAMPLE CODE : GI-85-FW-8

TABLE 3-F

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : E. VACUUM G-SA UNIT 2059 #2

SAMPLE : PRODUCED WATER : 6-3-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	48000	2087.9	CHLORIDE	92400	2606.3
MAGNESIUM	3050	251.0	SULFATE	2110	43.9
CALCIUM	5150	257.0	BICARBONATE	0	0.0
POTASSIUM	1260	32.2	CARBONATE	0	0.0
STRONTIUM	148	3.4	BROMIDE	157	2.0
BARIUM	0	0.0	IODIDE	15	0.1

TOTAL DISSOLVED SOLIDS (MG/L) = 152290
SPECIFIC GRAVITY (60/60 F) = 1.1092
RESISTIVITY (OHM-M @ 77 F) = 0.070
PH = 2.18

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : 2059-002-B
R & D SAMPLE CODE : GI-85-FW-10

TABLE 3-G

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : E. VACUUM G-SA UNIT 3202

SAMPLE : FRESH WATER

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	38	1.7	CHLORIDE	67	1.9
MAGNESIUM	12	1.0	SULFATE	44	0.9
CALCIUM	31	1.5	BICARBONATE	106	1.7
POTASSIUM	0	0.0	CARBONATE	4	0.1
STRONTIUM	0	0.0	BROMIDE	0	0.0
BARIUM	0	0.0	IODIDE	0	0.0

TOTAL DISSOLVED SOLIDS (MG/L) = 302
SPECIFIC GRAVITY (60/60 F) = 1.0002
RESISTIVITY (OHM-M @ 77 F) =12.600
PH = 8.72

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE : 3202-S07
R & D SAMPLE CODE : GI-85-FW-9

TABLE 3-H

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : SINCLAIR VACUUM SWD WELL #1

SAMPLE : DISPOSAL BRINE : 10-8-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	9540	415.0	CHLORIDE	16500	465.4
MAGNESIUM	193	15.9	SULFATE	1700	35.4
CALCIUM	1250	62.4	BICARBONATE	395	6.5
POTASSIUM	256	6.5	CARBONATE	8	0.3
STRONTIUM	36	0.8	BROMIDE	27	0.3
BARIUM	0	0.0	IODIDE	0	0.0

TOTAL DISSOLVED SOLIDS (MG/L) = 29905

SPECIFIC GRAVITY (60/60 F) = 1.0222

RESISTIVITY (OHM-M @ 77 F) =

PH = 7.50

PHILLIPS PETROLEUM COMPANY

FIELD SAMPLE CODE :

R & D SAMPLE CODE : GI-85-FW-12

TABLE 3-I

FORMATION WATER CHARACTERIZATION

LOCATION : LEA COUNTY, NEW MEXICO

WELL : C. VACUUM UNIT MONITOR WELL #1

SAMPLE : WATERFLOW BRINE : 10-17-85

CHEMICAL COMPOSITION

CATIONS	MG / L	MEQ / L	ANIONS	MG / L	MEQ / L
SODIUM	96700	4206.2	CHLORIDE	175000	4936.1
MAGNESIUM	10000	822.8	SULFATE	12400	258.2
CALCIUM	615	30.7	BICARBONATE	242	4.0
POTASSIUM	7240	185.2	CARBONATE	6	0.2
STRONTIUM	22	0.5	BROMIDE	180	2.3
BARIUM	0	0.0	IODIDE	8	0.1

TOTAL DISSOLVED SOLIDS (MG/L) = 302413
SPECIFIC GRAVITY (60/60 F) = 1.2022
RESISTIVITY (OHM-M @ 77 F) =
PH = 7.42

PHILLIPS PETROLEUM COMPANY
FIELD SAMPLE CODE :
R & D SAMPLE CODE : GI-85-FW-13

TABLE 4

VACUUM FIELD UNIT

FORMATION WATER COMPOSITIONS

WELL	LOCATION	FORMATION	TDS	0-18
M. E. HALE #3	T17S-R34E-S35	SALADO ?	376900	-4.0
M. E. HALE #3	T17S-R34E-S35	SALADO ?	368300	-2.9
E. VACUUM G-SA UNIT 3202 #5	T17S-R35E-S32	SAN ANDRES	41750	-6.3
E. VACUUM G-SA UNIT 3229 #8	T17S-R35E-S32	SAN ANDRES	145300	-5.6
E. VACUUM G-SA UNIT 2059 #2	T17S-R35E-S20	SAN ANDRES	154500	-3.0
E. VACUUM G-SA UNIT 3202	T17S-R35E-S32	OGALLALA	302	-6.8
SINCLAIR VACUUM SWD WELL #1	T18S-R35E-S16	DEVONIAN	29900	-7.8
C. VACUUM UNIT #137	T18S-R35E-S6	OGAL-S.ANDRES	16000	-6.9
C. VACUUM UNIT MONITOR WELL #1	T18S-R35E-S6	SALADO	317700	-6.0
C. VACUUM UNIT MONITOR WELL #1	T18S-R35E-S6	SALADO	302400	-6.3

NOTE : A - TDS VALUES ARE IN UNITS OF MG/L.
B - O-18 VALUES ARE IN UNITS OF PER MILL VERSUS THE SMOW ISOTOPIC STANDARD.

K·E 10 X 10 TO THE INCH 47 0780
10 X 15 INCHES
KEUFFEL & ESSER CO.

CENTRAL VACUUM UNIT MONITOR WELL

BHP @ 1700 ft. vs. Shut-in time