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SYSTEMS ANALYSIS·EXPERIMENT SPECIFICATION

BWR POOL SWELL MODEL EVALUATION FOR MARK III PSTF TEST DATA

By

J. I. MILLS
(Consultant)

ENERGY SAFETY ENVIRONMENT

IDAHO NATIONAL ENGINEERING LABORATORY

Aerojet Nuclear Company

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

This report describes the results and analysis of a comparison of data derived from the General Electric Companys' PSTF Test Series 5806[1] with results predicted by a one-dimensional analytical model[2] developed to analyze the pool swell occurring early in the pressure suppression transient associated with a BWR loss-of-coolant accident (LOCA).

Although other geometries have been investigated, the pool swell model was developed primarily to analyze pool swell and allied transients resulting from air blowdown through horizontal vent (Mark III) geometries. Because test series 5806 involved a total of 12 air blowdowns in the one third scale PSTF operating with a horizontal vent geometry, these data provide an ideal test for the pool swell model.

The results of the comparison between the PSTF data and model prediction for pool surface displacement, slug thickness, and pool surface velocity, all as a function of time, are presented and analyzed in this report. For pool surface displacement, two comparisons between data and model prediction are made. Initially, the data are compared to the predicted values of surface displacement as a function of time while making no adjustments to the model input. Secondly, the critical parameter of the pool surface area assumed to be involved in the blowdown transient is adjusted until generally excellent agreement between theory and experiment has been achieved. Finally, development of a correlation to determine the appropriate adjustment factor to maximize the effectiveness of the model as a predictive tool is suggested for future inclusion in the one-dimensional pool swell model.

II. MODEL EVALUATION

The data from the 12 air blowdowns performed on the one third scale PSTF were used for model evaluation. The data for each run included:

1) Drywell temperatures vs time
2) Vent mass flow vs time
3) Air/water and water/air interface vs time
4) Surface velocity vs time
5) Slug length vs time

The first two data items included in the above information were used, along with PSTF geometrical parameters, as input for the one-dimensional pool swell model. Items 3, 4 and 5 above were compared to the corresponding prediction made by the model.

Table I represents a test matrix defining the major differences in the experimental test parameter for each of the twelve runs. Parameters other than venturi size and vent submergence were maintained at fairly constant values for each test. Since test runs 8 and 9 were repeats of runs 1 and 2, they were not included in the data chosen for model evaluation.

The procedure for the evaluation was to determine from the data the input required for each run, to obtain the calculated result, and to then compare the experimental and calculated results. C rtain simplifying assumptions introduced into the model lead to time scale variation between the data and the model. A method must be chosen to normalize these time scales so that the time histories of the predicted results match the time histories of the experimental data analyzed. The assumptions, resulting difficulties, and solution will be discussed before the results are presented.

RUN	VENTURI DATA (in.)	TOP VENT SUBMERGENCE (ft.)
1	3.000	5.0
2	3.000	7.5
3	3.000	6.0
4	2.500	5.0
5	3.625	5.0
6	3.625	7.5
7	3.625	6.0
8	REPEAT OF 1	
9	REPEAT OF 2	
10	4.25	5.0
11	3.00	2.5
12	4.25	7.5

Table I: Air Blowdown (Test Series 5806) Test Matrix

The experimental results display a time lag between initiation of blowdown, complete clearing of vents, and the beginning of the pool swell transient. Therefore, although the blowdown begins at time zero, the pool swell transient does not begin until a short period later. The one-dimensional pool swell model does not presently have the capability of following the blowdown from initiation through vent clearing, and thus the calculations are begun only after vent clearing is completed. The task when constructing model input, therefore, is to determine the experimental time corresponding to the completion of vent clearing and to use this time as time zero for the purposes of calculation.

The method used to determine the appropriate starting time was based upon an examination of the data involving vent mass flow as a function of time. For example, Figure 1 illustrates mass flow rate vs time for Test 5806/Run 1. It is noted that an apparently random and noisy signal exists for approximately 0.8 seconds before the mass flow rate becomes well defined and consistent. It is postulated that this initial signal originates from the vent clearing transient and, furthermore, that the cessation of these random signals is indicative of the completion of vent clearing. Therefore, the method used to approximate time zero for purposes of model calculations and data comparison was to select a point corresponding to the transition from "noise" to a well defined and consistent mass flow rate and to construct at this point a tangent to the curve of mass flow rate vs time. The intersection of this tangent with the abscissa is taken to be time zero. All data input determination as well as comparisons of predicted to theoretical results were initiated at this time. In Figure 1 a dotted line represents the tangent, and it is seen that time zero for this example corresponds to an experimental time of approximately 0.75 seconds. This method produces good and consistent results and has

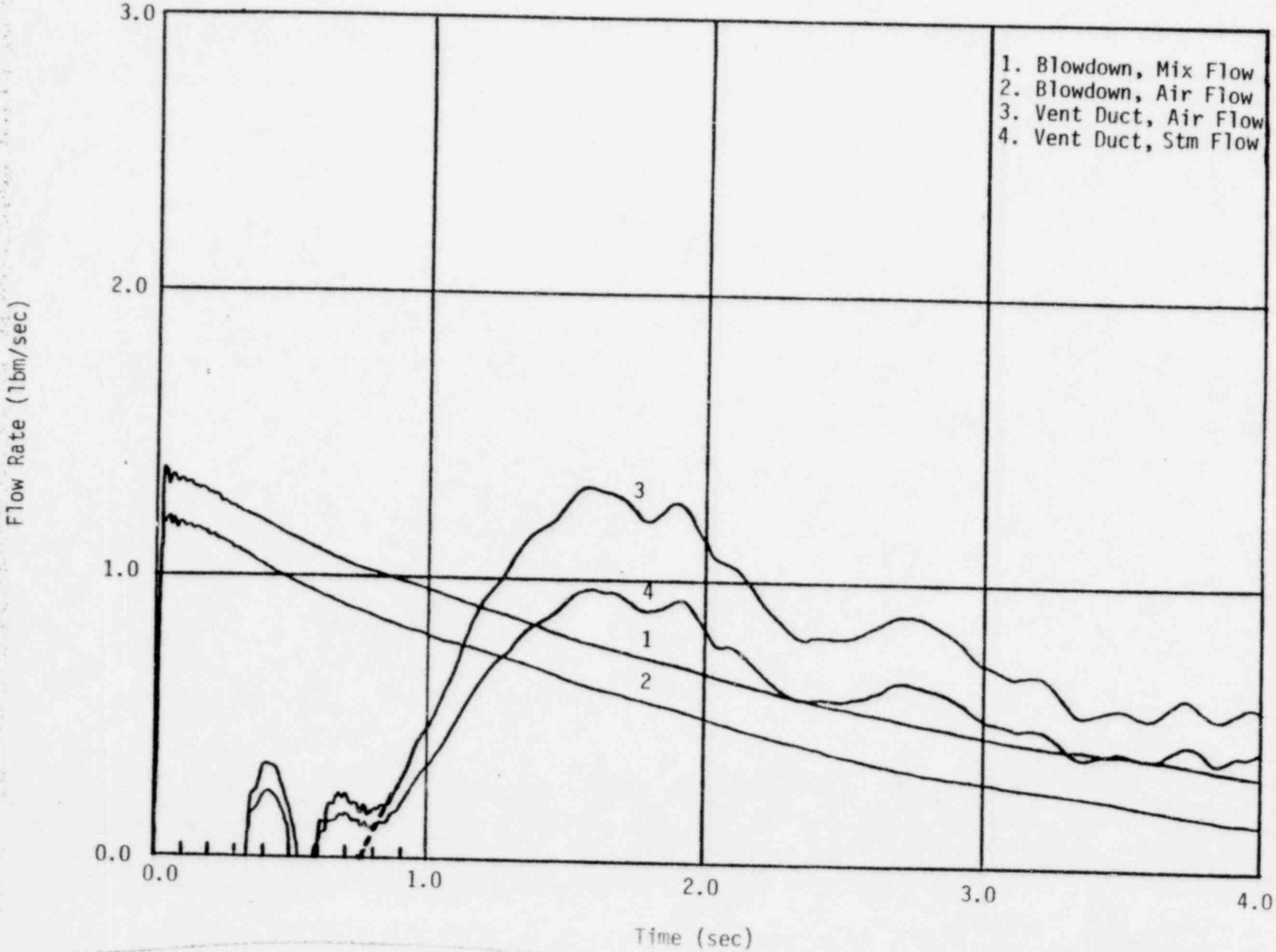

Figure 1: Test 580[illegible]

been used exclusively throughout this evaluation.

Figures 2 through 31 illustrate the comparisons of theoretical results to data. Data points, rather than solid lines, are used to represent the theoretical predictions. Two sets of theoretical predictions for pool surface displacement are presented for each test run, except for Test 7. Initially, the theoretical calculations are based upon the assumption that upon vent clearing an air bubble, or "pancake", is established that covers the entire area of the test pool. This assumption results in the largest possible volume of water involved in the pool swell transient and thus leads to the smallest possible values for predicted pool surface displacement and pool surface velocities. Realistically, it is expected that the forming air bubble involves a pool volume corresponding only to some fraction of the total pool surface and therefore a smaller working volume of the pool would be involved in the transient. As expected, the initial assumption of full pool bubble expansion results in predictions that are generally smaller in magnitude than the corresponding experimental values; this is clearly seen for each run. Therefore, a second model calculation was made based upon a modified value of the input parameter determining the pool volume involved in the traisnet. The pool volume may be modified until the desired agreement with experimental results has been obtained. The graphs presented of pool surface velocity vs time are based upon this second calculation, while the predictions of slug thickness vs time do not depend on the area of the pool involved in the transient and are therefore generally valid.

Examination of the results shows that the one-dimensional pool swell model is capable of producing very good agreement with experimental results when the input parameter determining the working pool volume is suitably modified. It is noted that the largest discrepancy between data

and theory occurs near the beginning and end of each transient. It is postulated that this disagreement can be explained by examining these two extremes in some detail. Initially, there is some finite time interval involved in bubble formation and horizontal expansion. The pool swell model, however, assumes formation and expansion to occur instantaneously, and it is felt that this assumption explains the initial discrepancies. At the end of the transient, the experimental uncertainties introduced as a result of frothing and other phenomena associated with breakthrough make comparisons with theory more difficult. Likewise, for comparisons of slug thickness vs time, experimental difficulties due to frothing and turbulence make accurate bubble-pool and pool-air interface determinations difficult, and comparisons between experiment and theory become correspondingly more difficult and uncertain. Even with these difficulties, the results of the comparison of experiment to theory for slug thickness vs time indicate generally conservative predictions for slug thickness and the results are considered encouraging.

It should be noted that an attempt was made, when adjusting the pool surface area input parameter, to obtain close agreement between experiment and theory. More conservative theoretical predictions leading to greater magnitudes for pool surface displacement and pool surface velocity may be obtained by a correspondingly conservative pool area input.

Finally, in Appendix I, a sample output for Test 5806/Run 1 is presented.

III. CONCLUSIONS AND RECOMMENDATIONS

The results presented in this report indicate that the one-dimensional pool swell model is capable of accurate predictions of pool surface displacement, pool surface velocity, and slug thickness vs time when care

is taken to normalize the time scale of theory and experiment, and when the input parameter determining the working volume of the pool is appropriately adjusted.

In order to facilitate accurate predictions of the appropriate pool volume input parameters, it should be possible to develop a correlation, based upon pool surface area, vent diameter, mass flow rate and other appropriate parameters, that would be capable of determining the desired input for any given PSTF or full scale system. Such a correlation would represent a worthwhile addition to the predictive capability of the one-dimensional pool swell model.

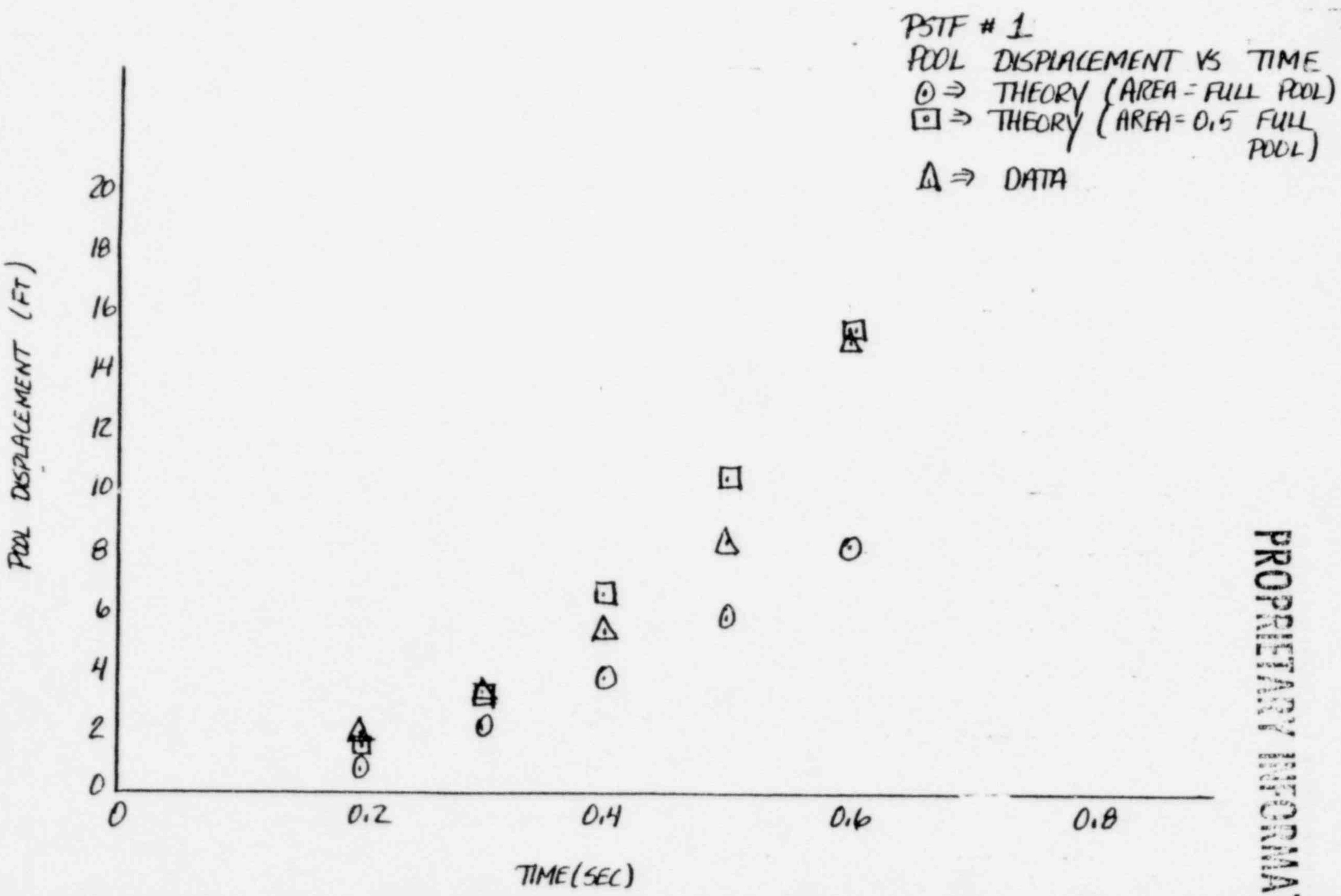

Figure 2: Run 1, Pool Displacement

PROPRIETARY INFORMATION

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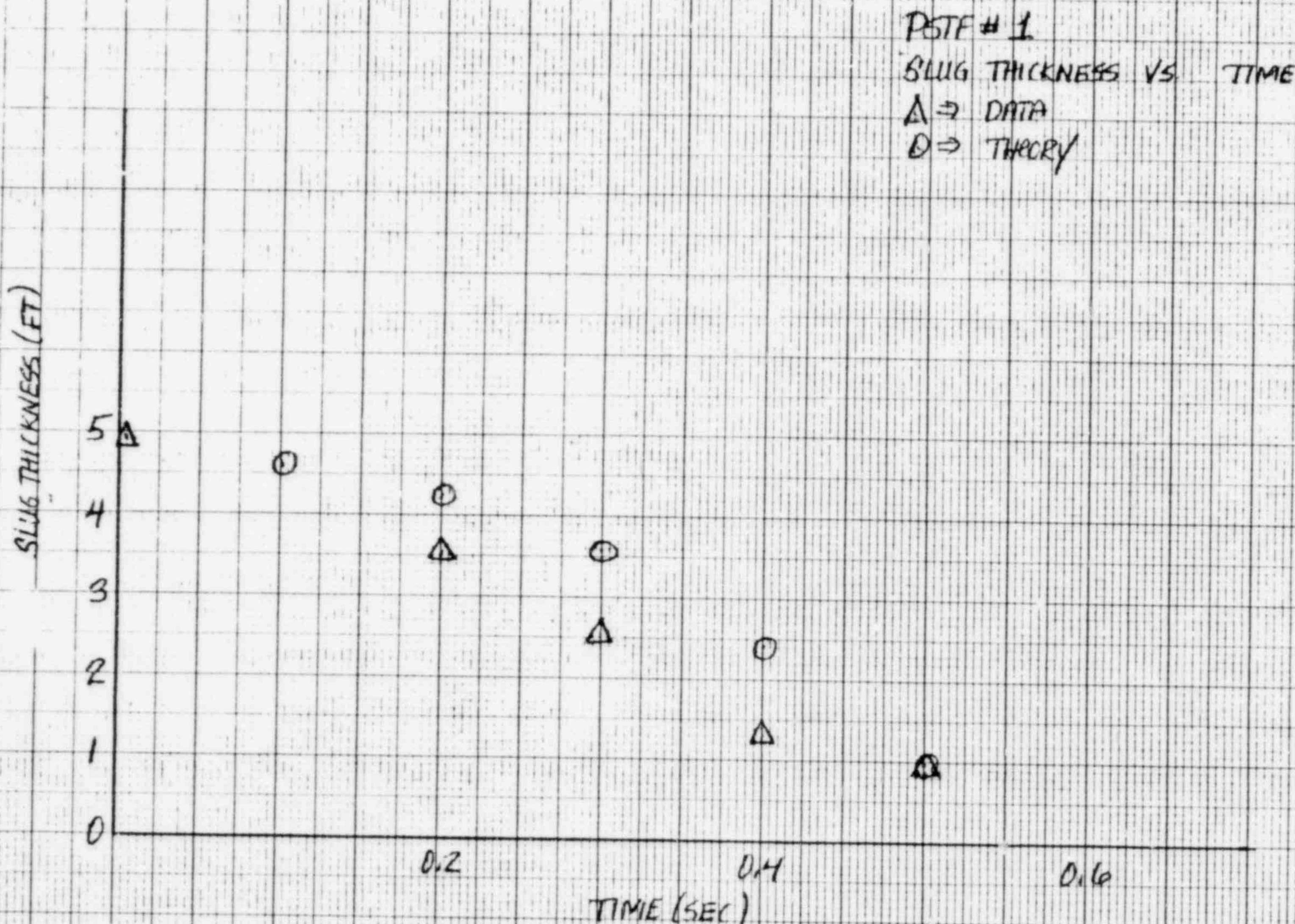

Figure 3: Run 1, Slug Thickness

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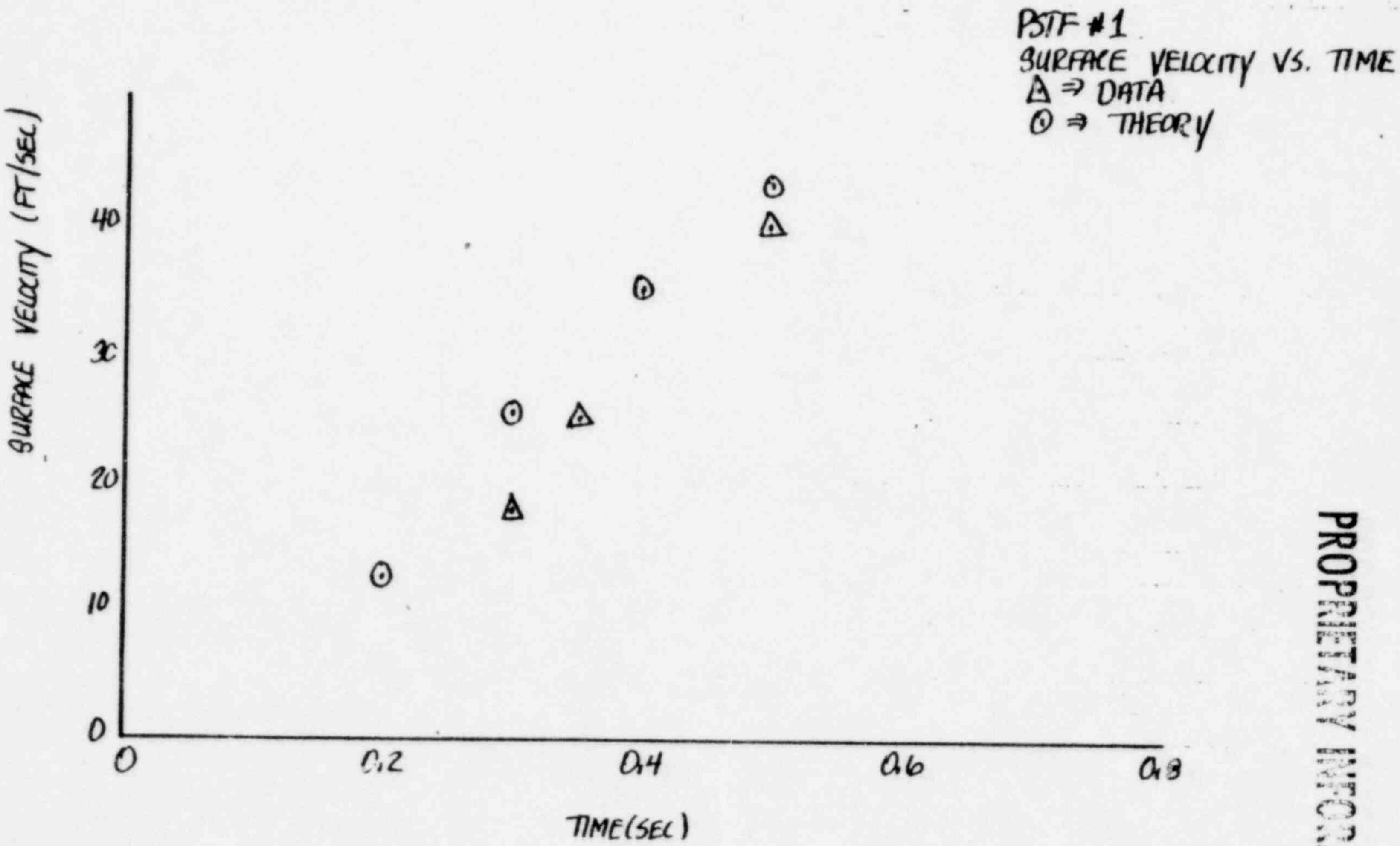

Figure 4: Run 1, Surface Velocity

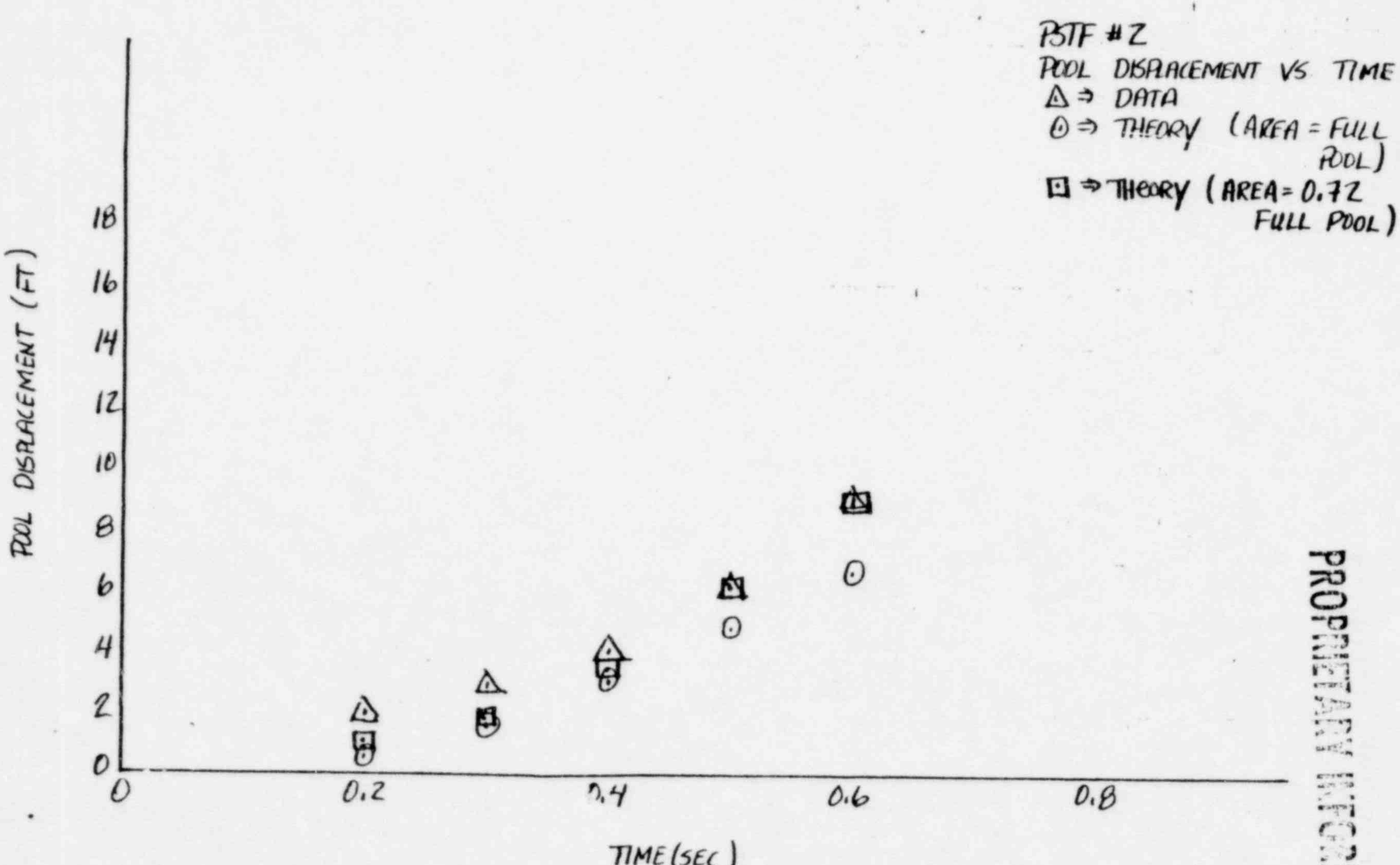

Figure 5: Run 2, Pool Displacement

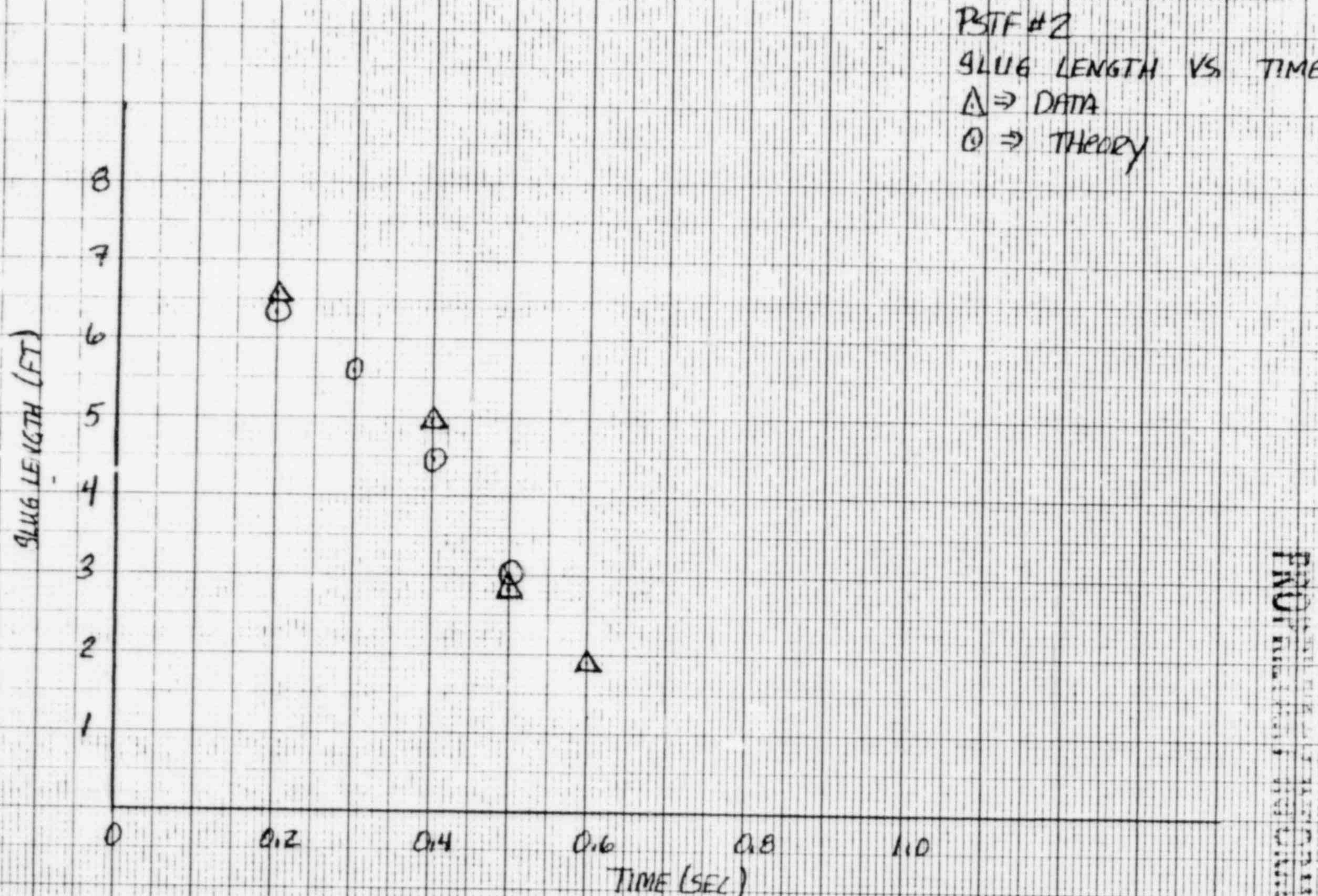

Figure 6: Run 2, Slug Thickness

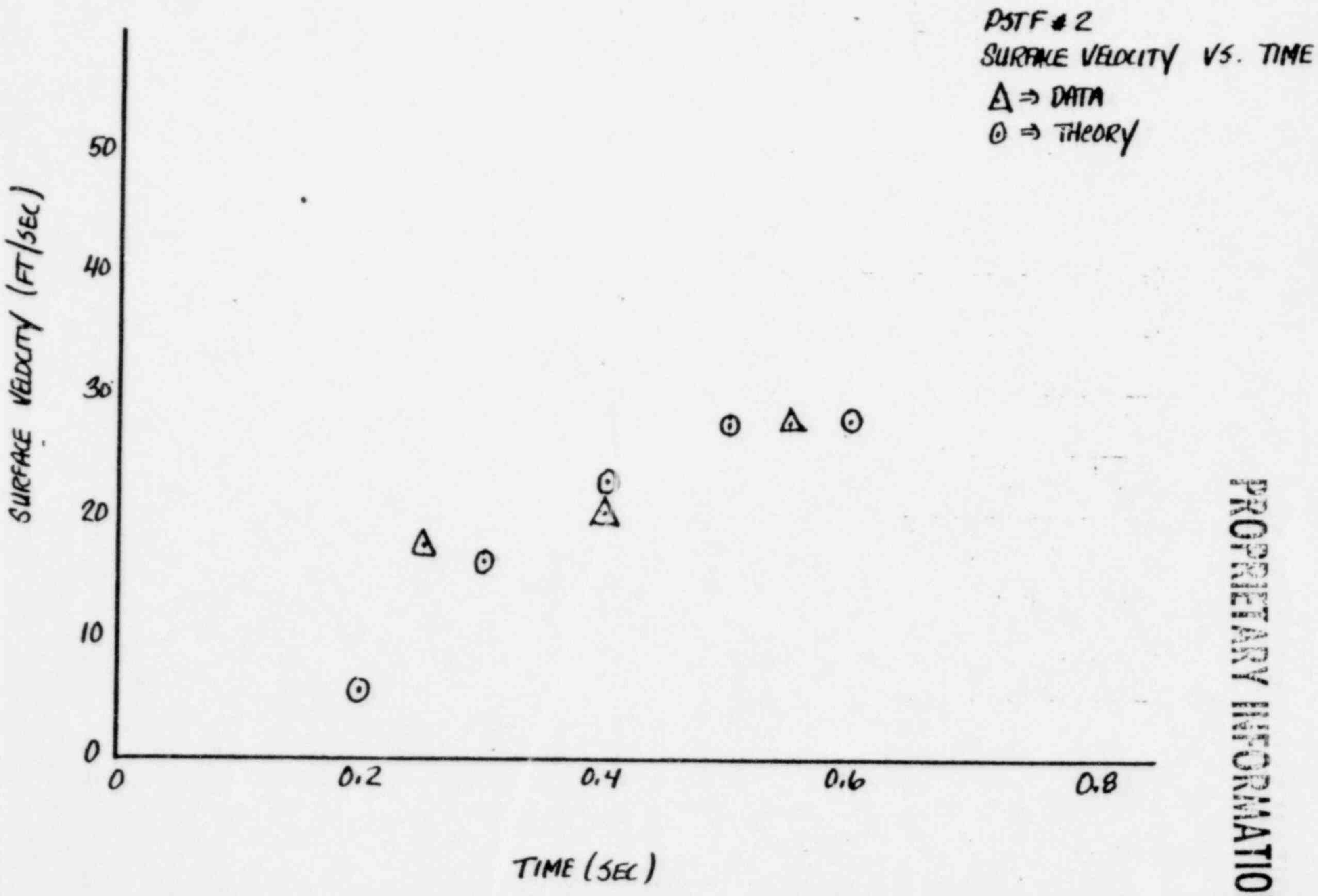

Figure 7: Run 2, Surface Velocity

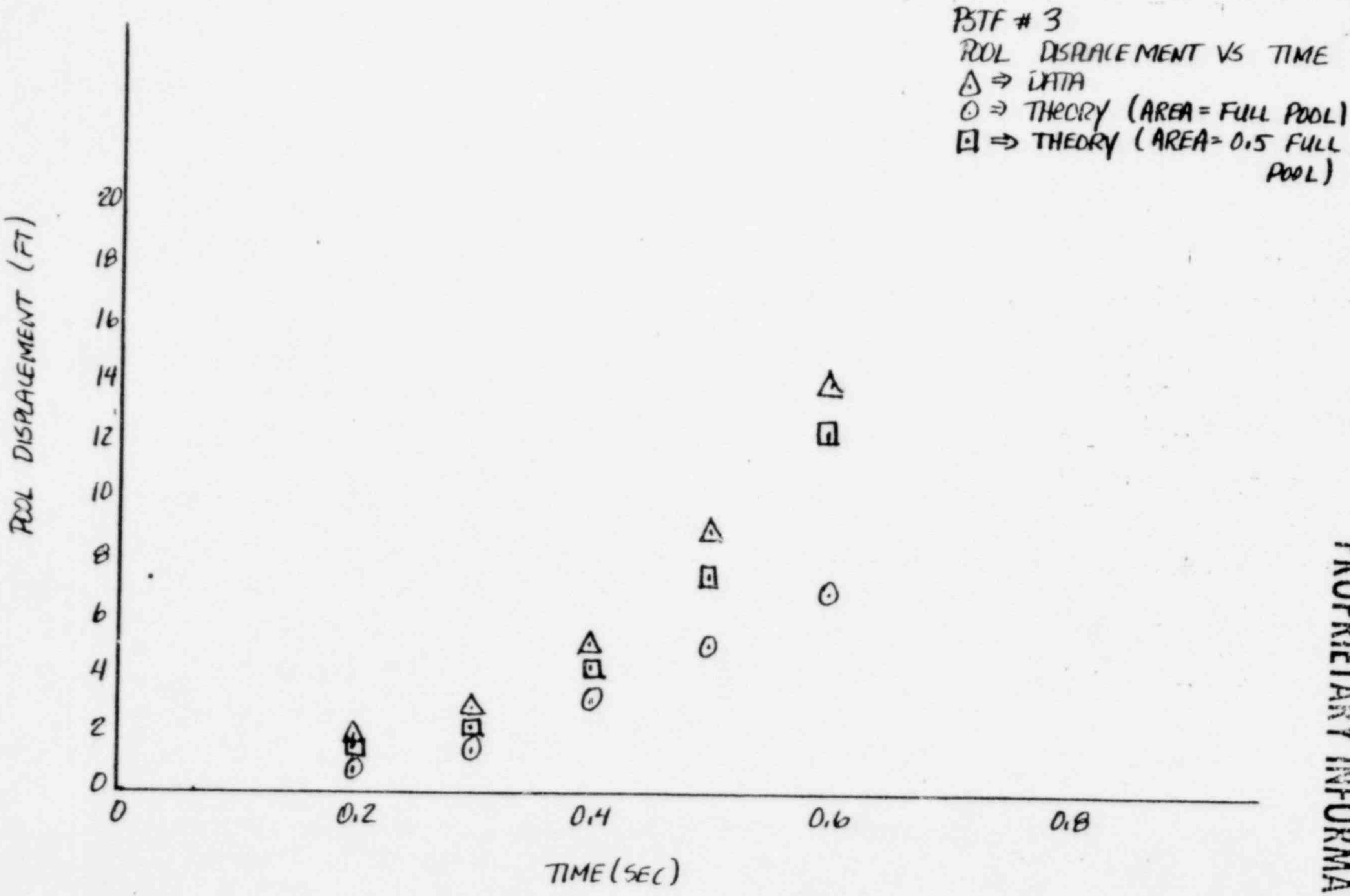

Figure 8: Run 3, Pool Displacement

PROPRIETARY INFORMATION

PROPRIETARY INFORMATION

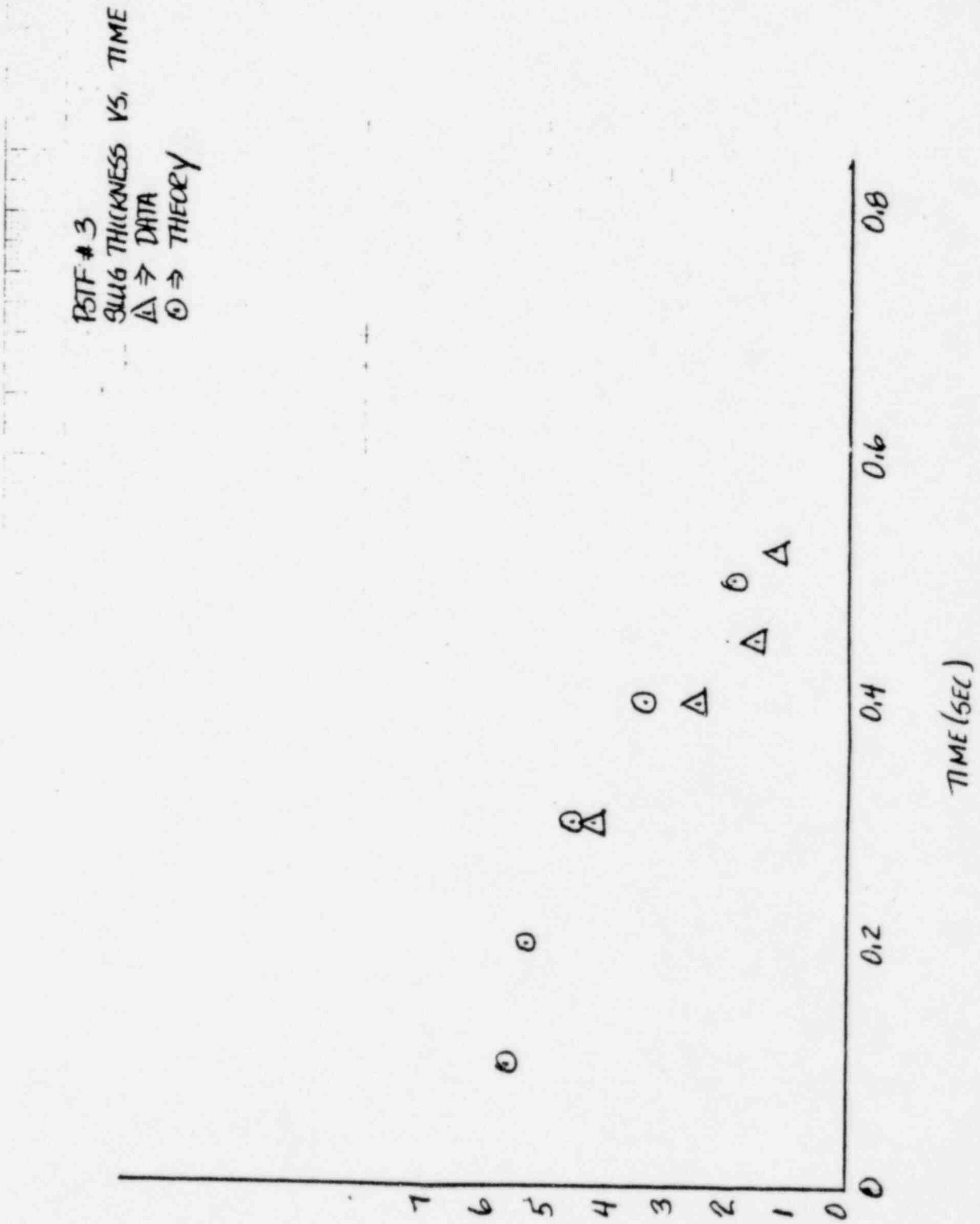

Figure 9: Run 3, Slug Thickness

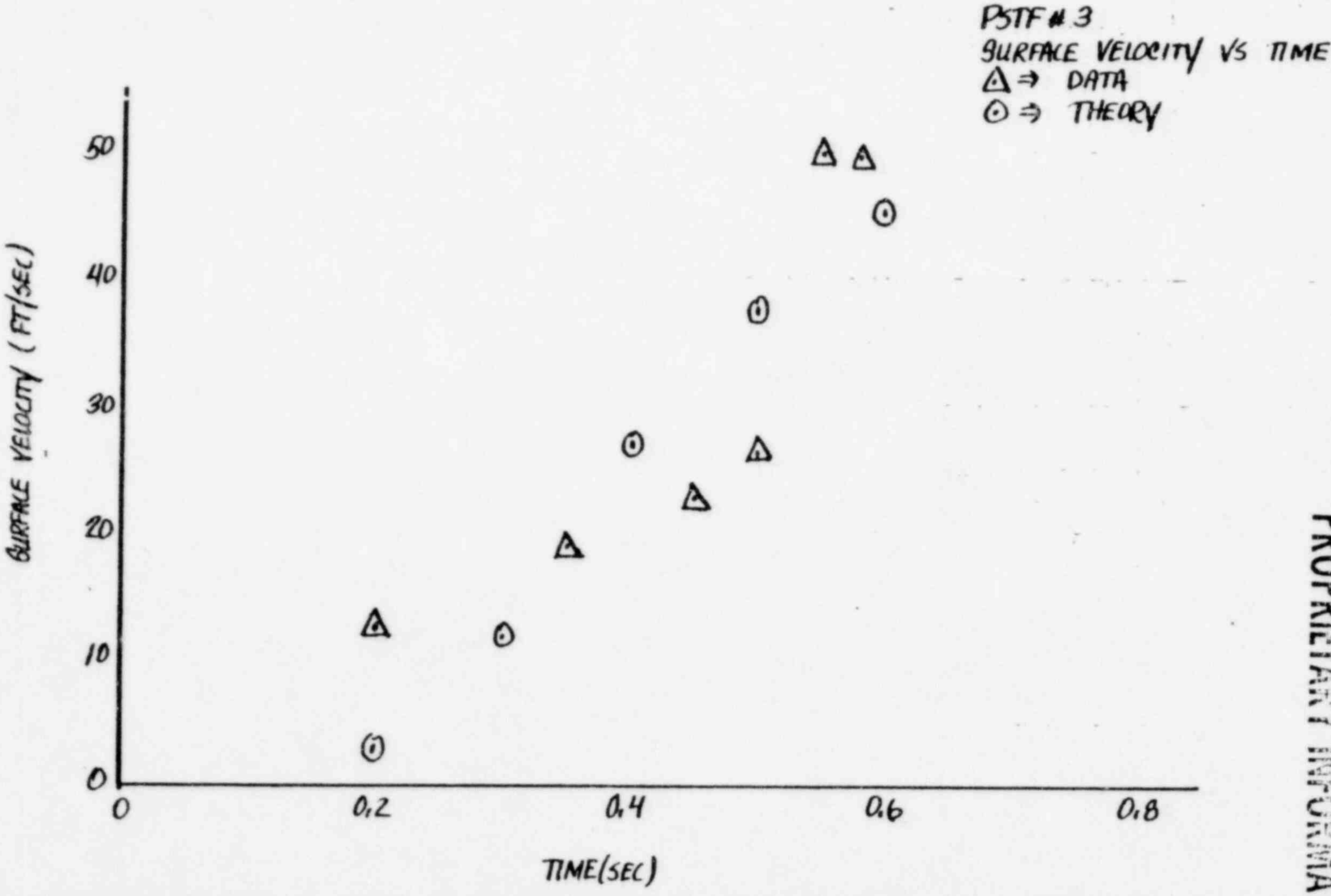

Figure 10: Run 3, Surface Velocity

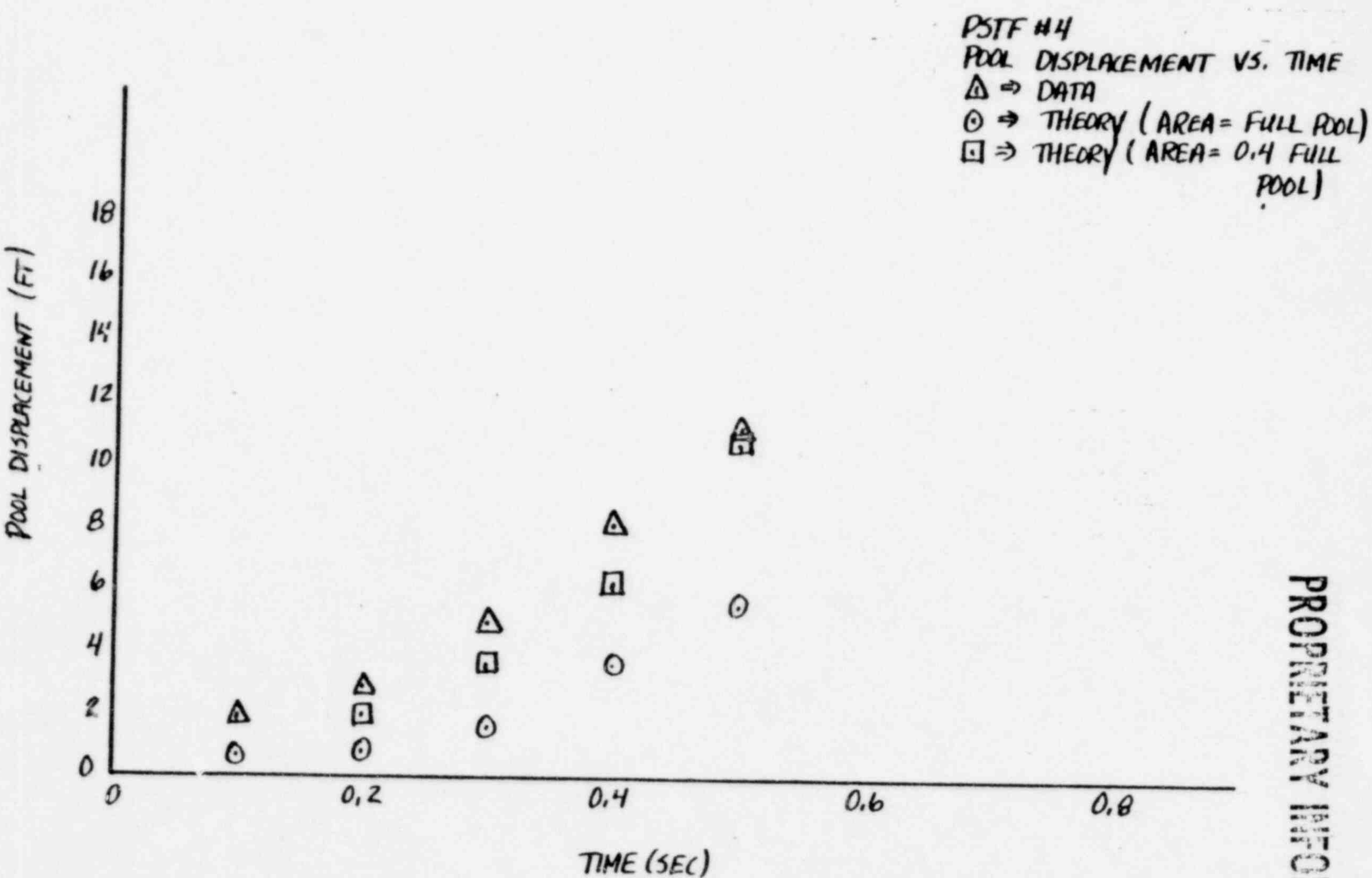

Figure 11: Run 4, Pool Displacement

PROPRIETARY INFORMATION

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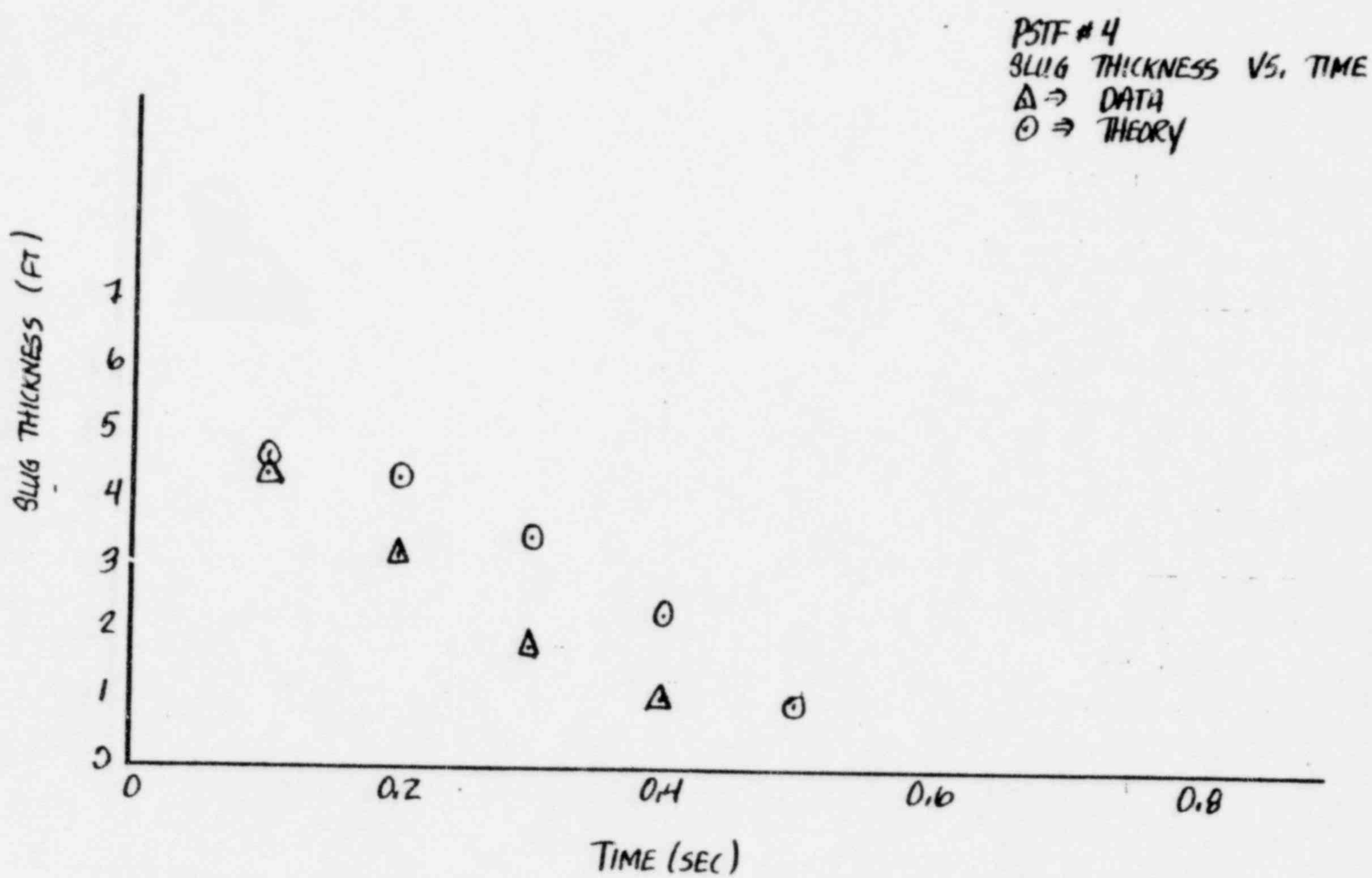

Figure 12: Run 4, Slug Thickness

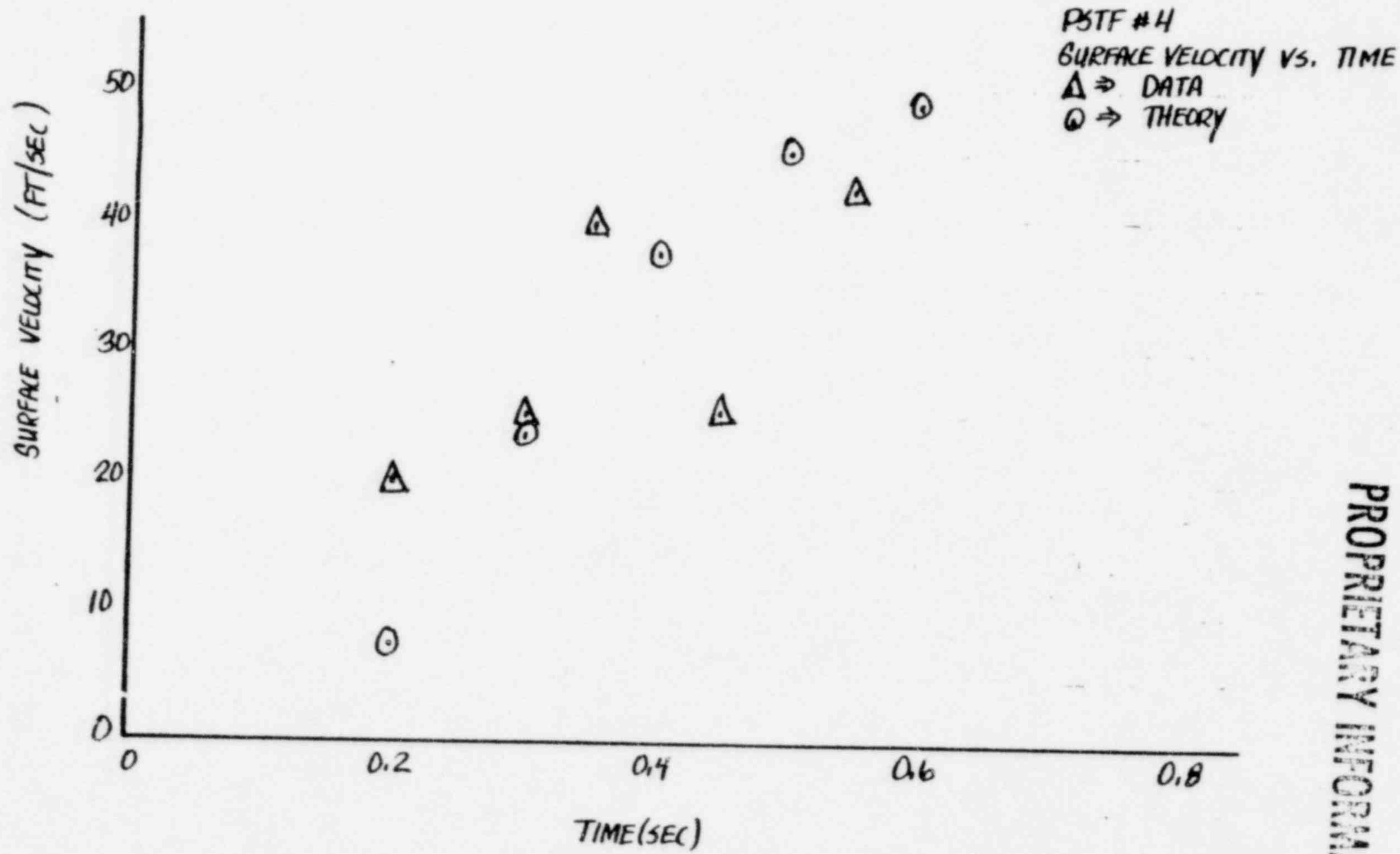

Figure 13: Run 4, Surface Velocity

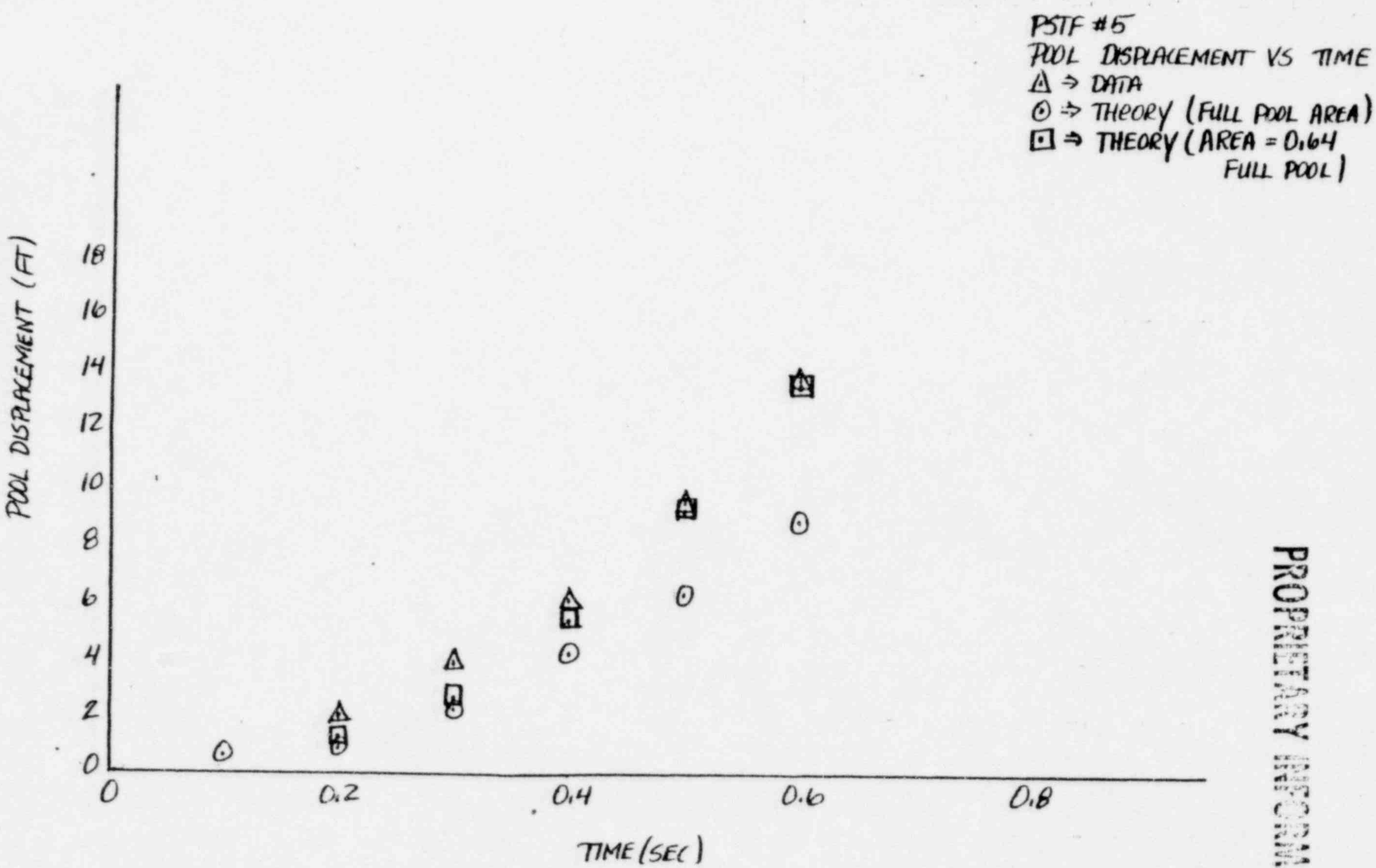

Figure 14: Run 5, Pool Displacement

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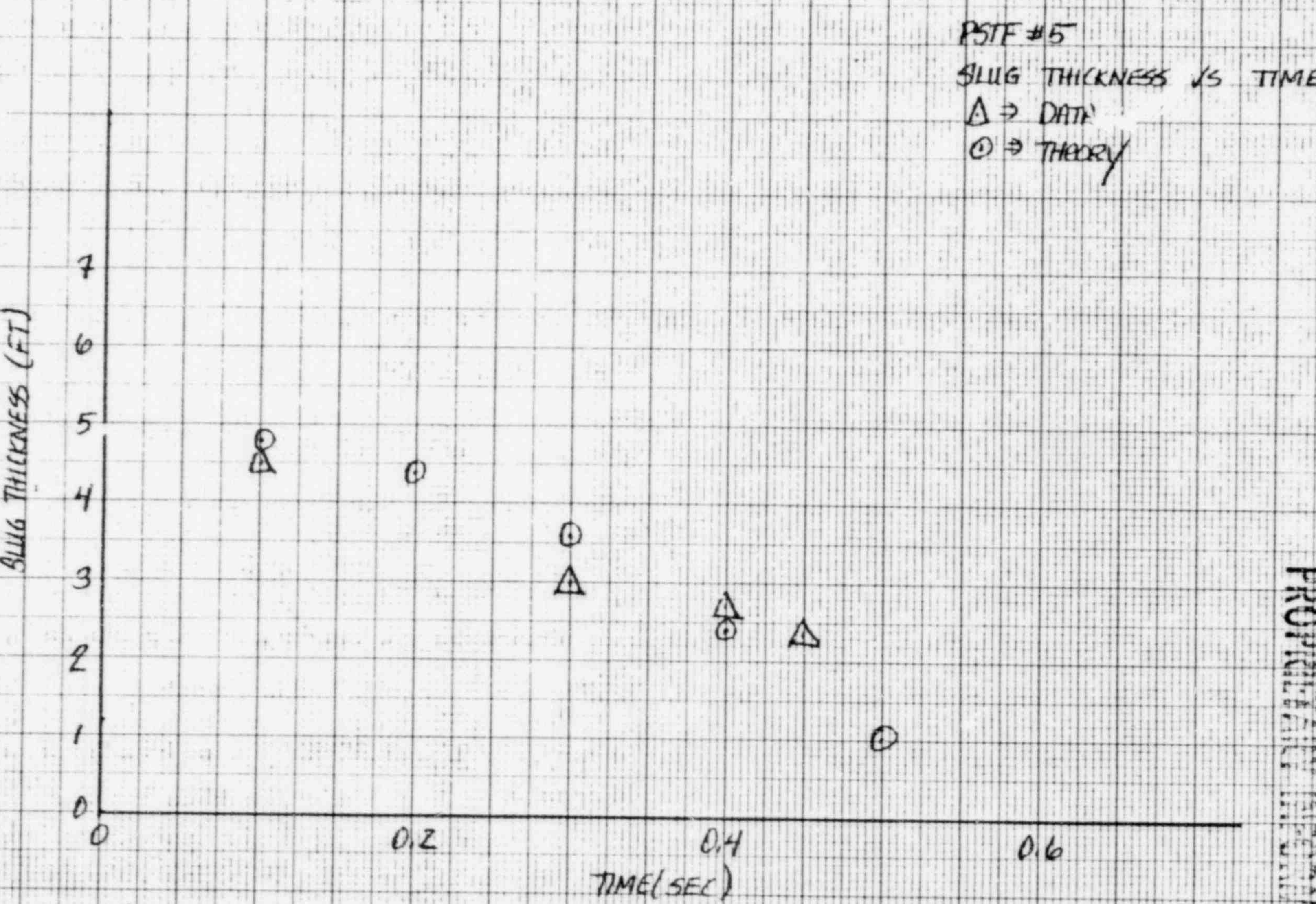

Figure 15: Run 5, Slug Thickness

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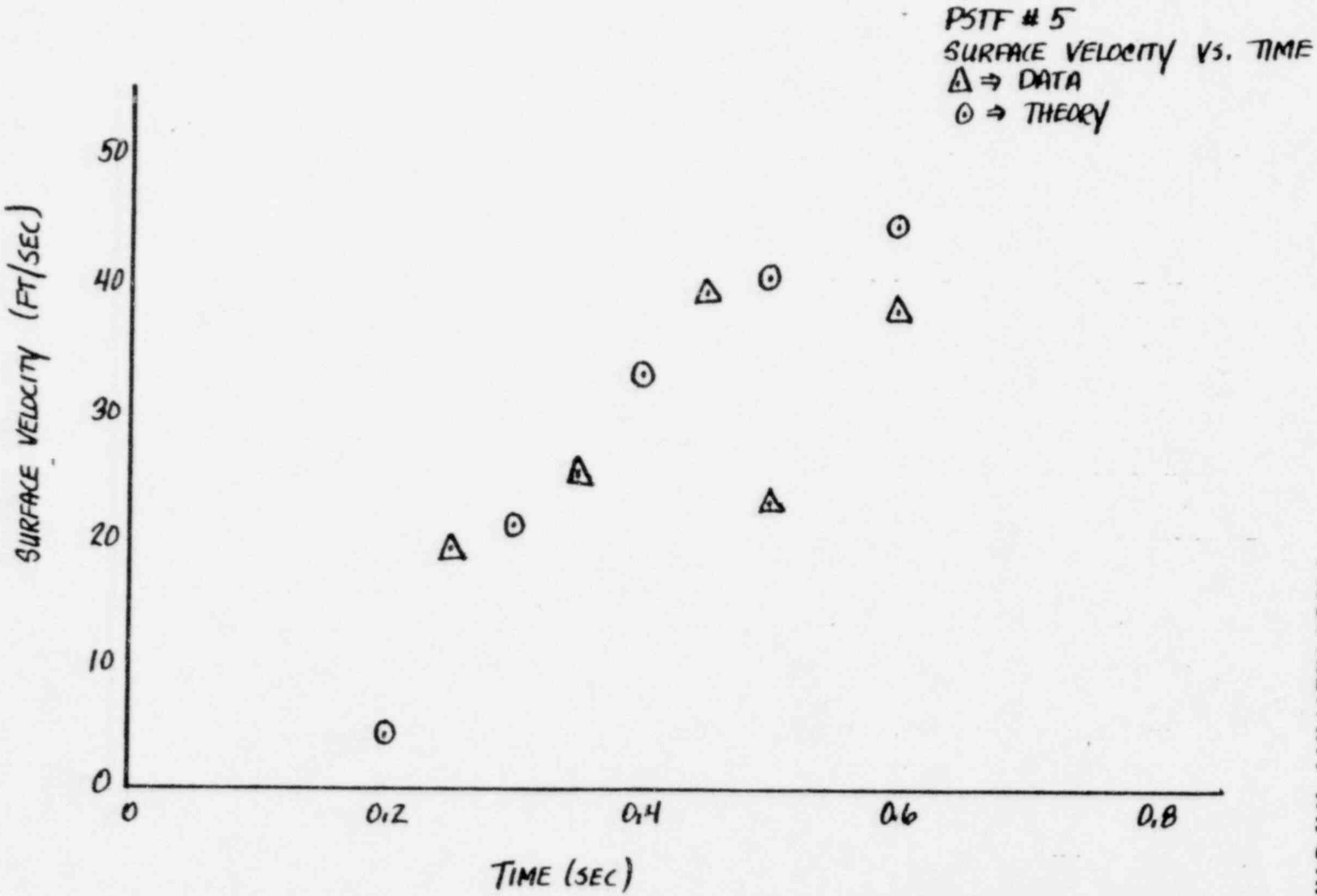

Figure 16: Run 5, Surface Velocity

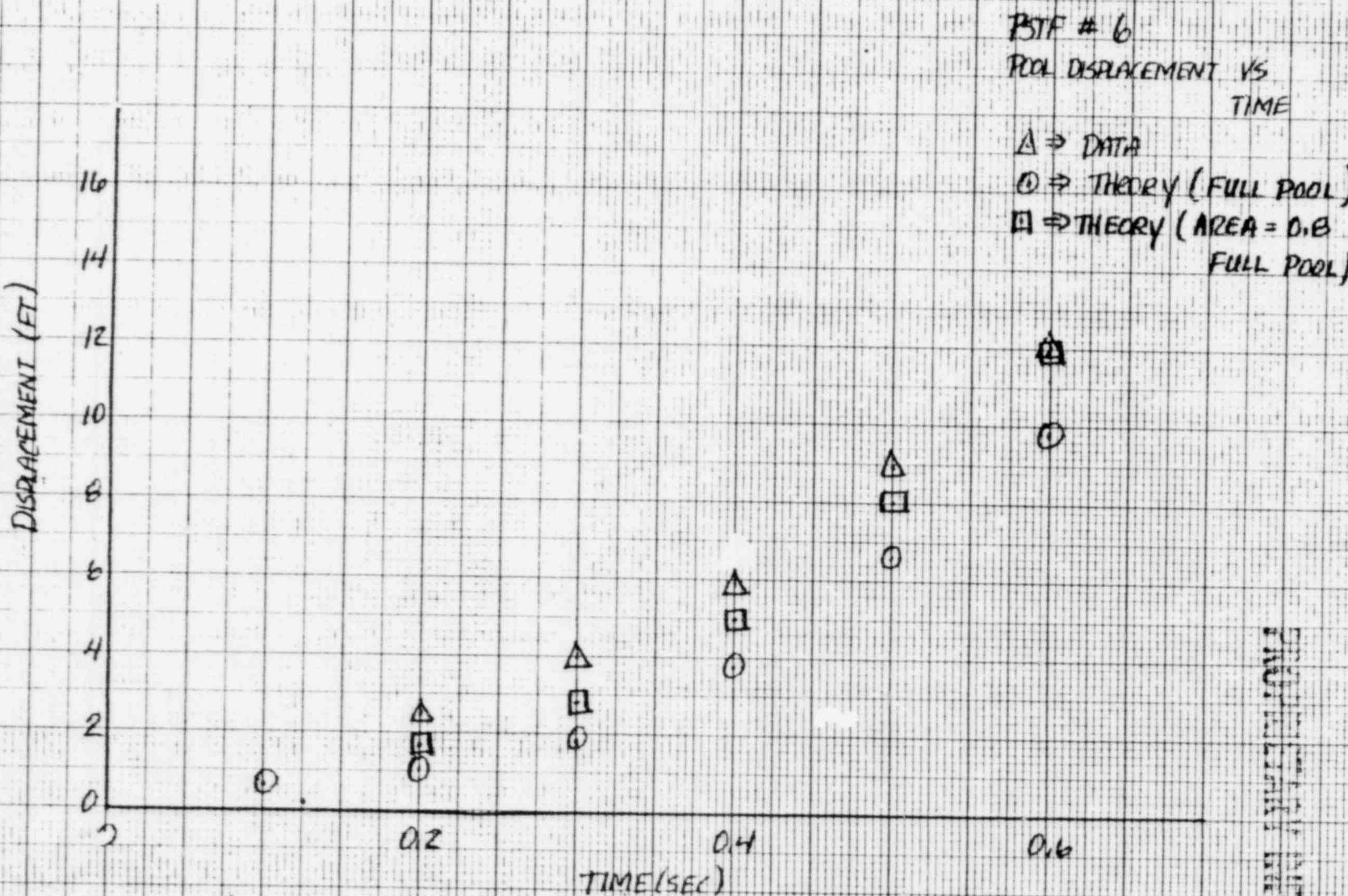

Figure 17: Run 6, Pool Displacement

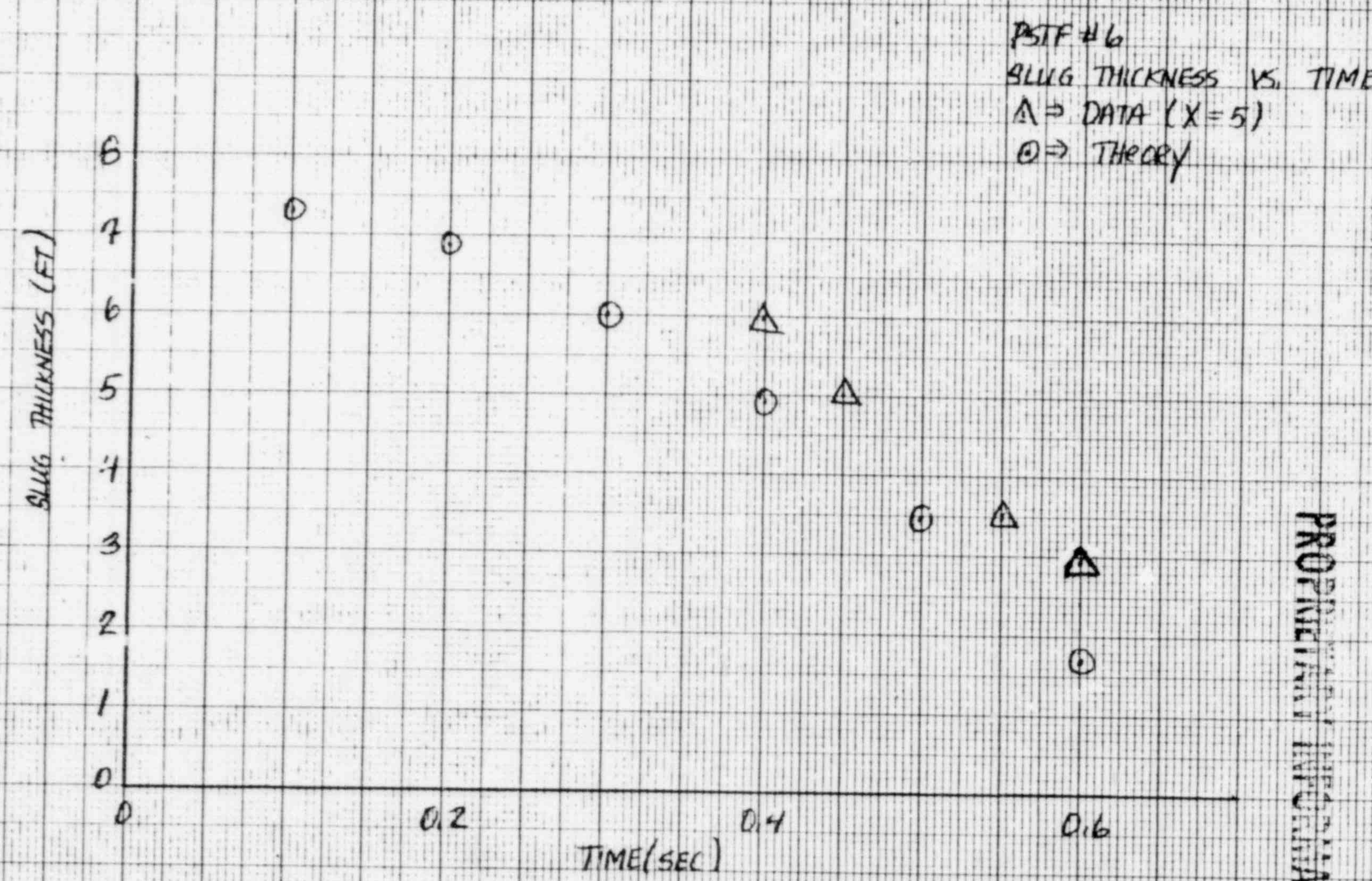

Figure 18: Run 6, Slug Thickness

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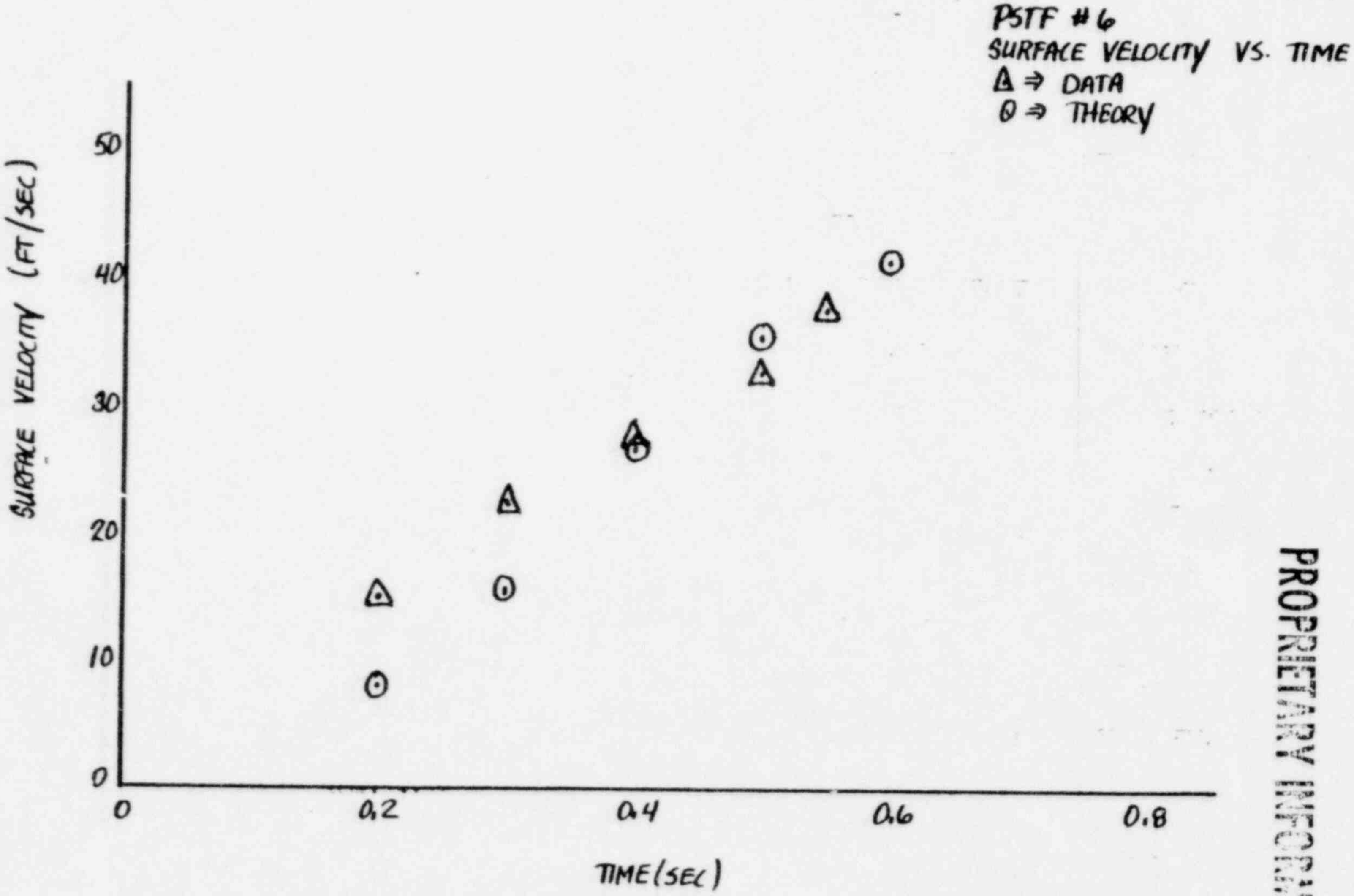


Figure 19: Run 6, Surface Velocity

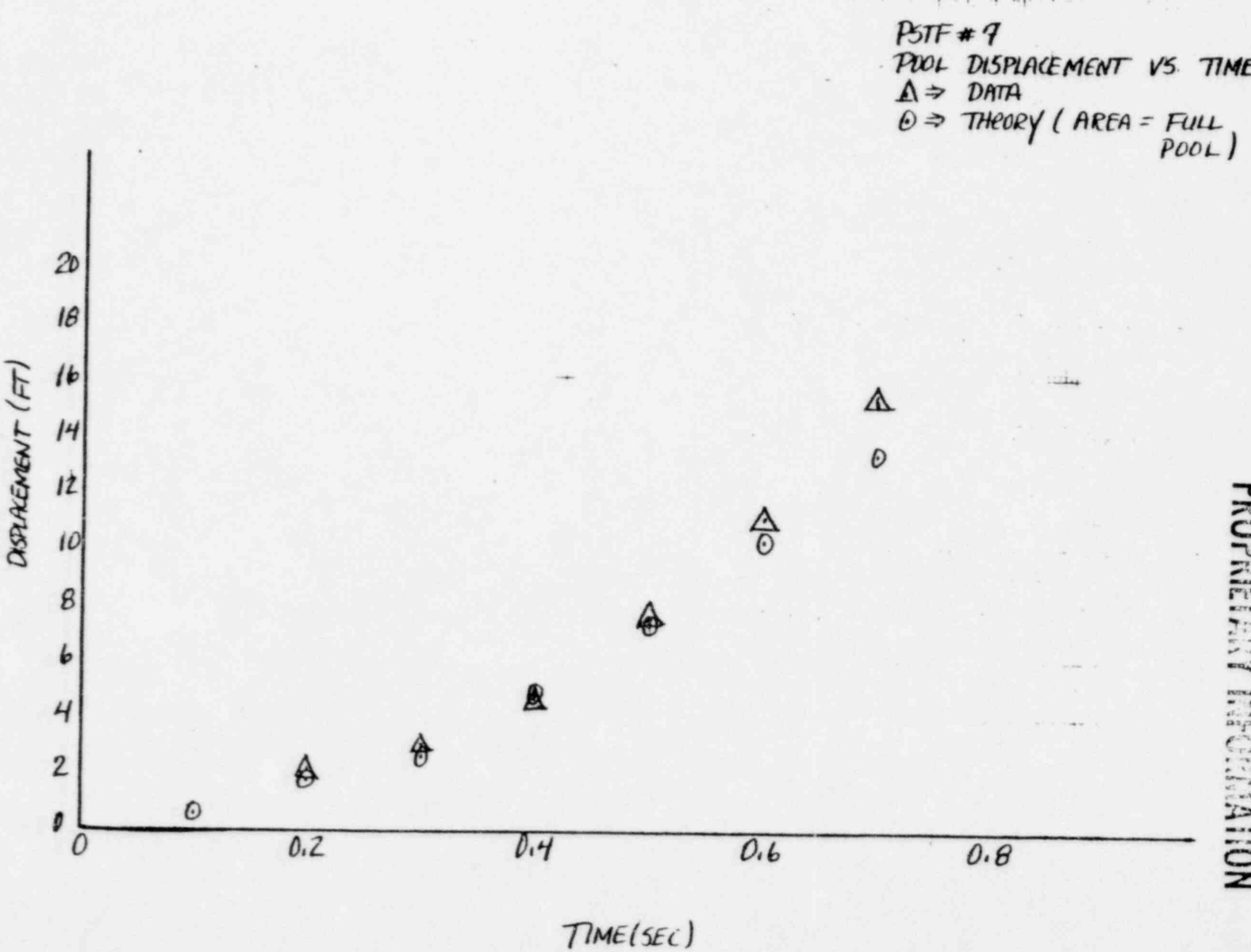


Figure 20: Run 7, Pool Displacement

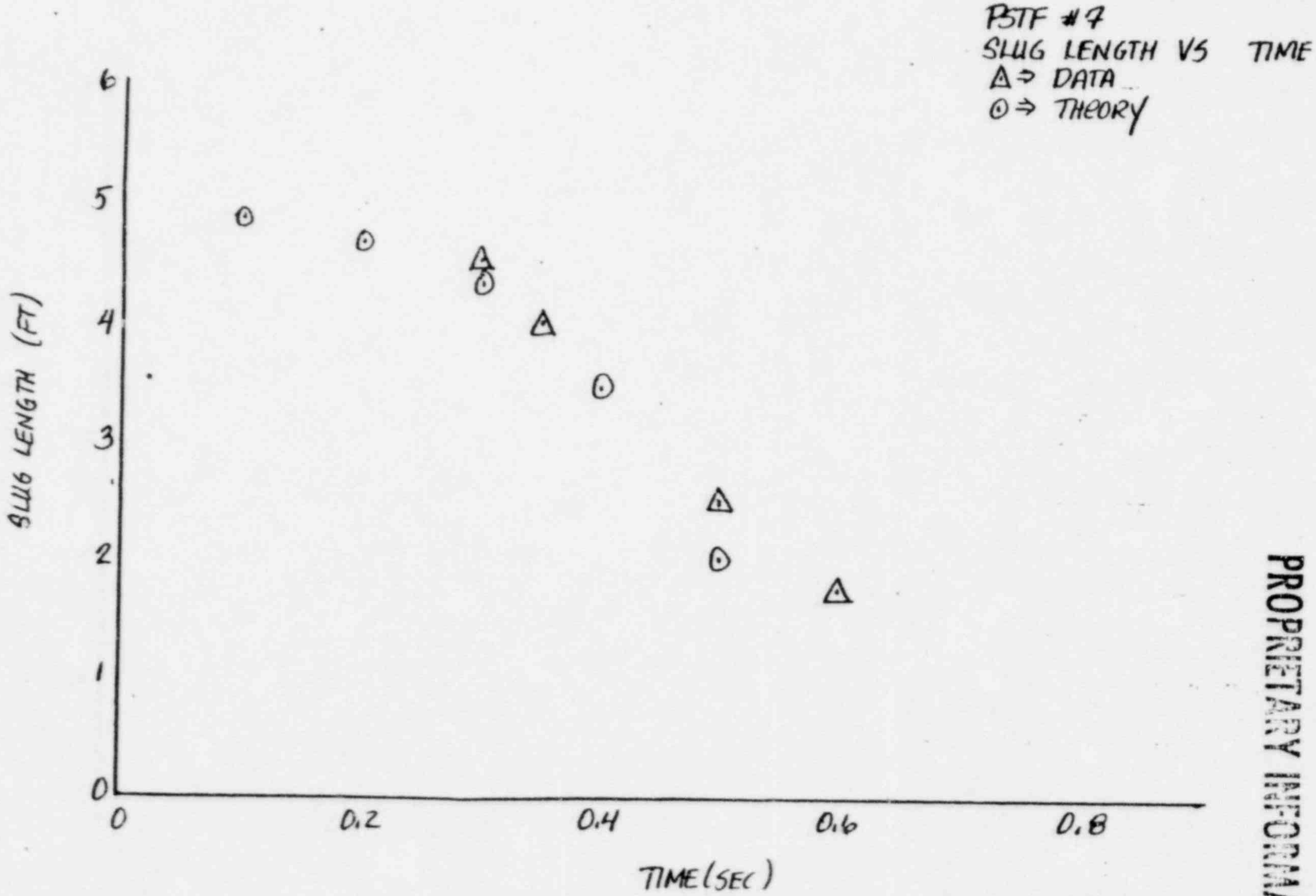
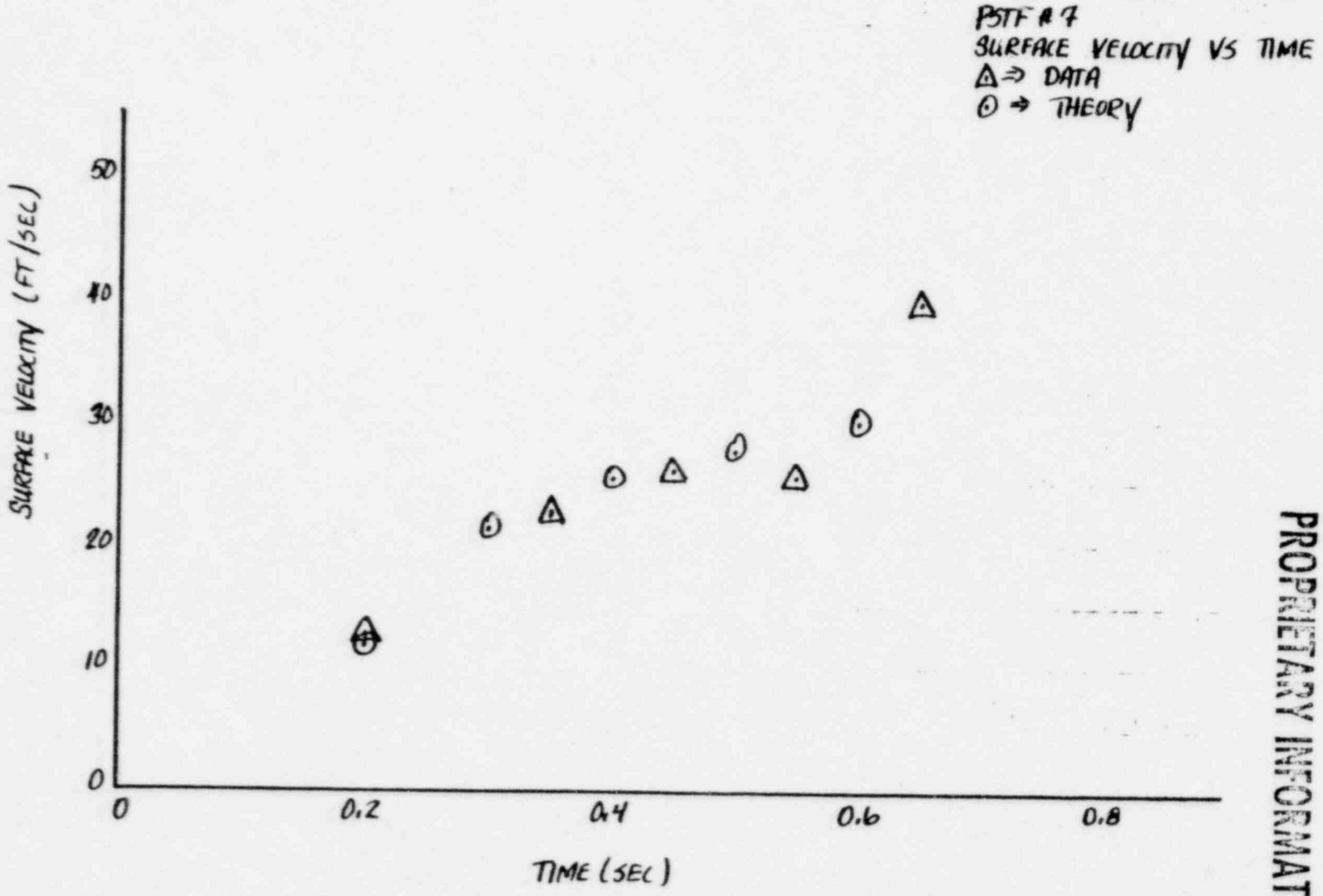


Figure 21: Run 7, Slug Thickness



PROPRIETARY INFORMATION

Figure 22: Run 7, Surface Velocity

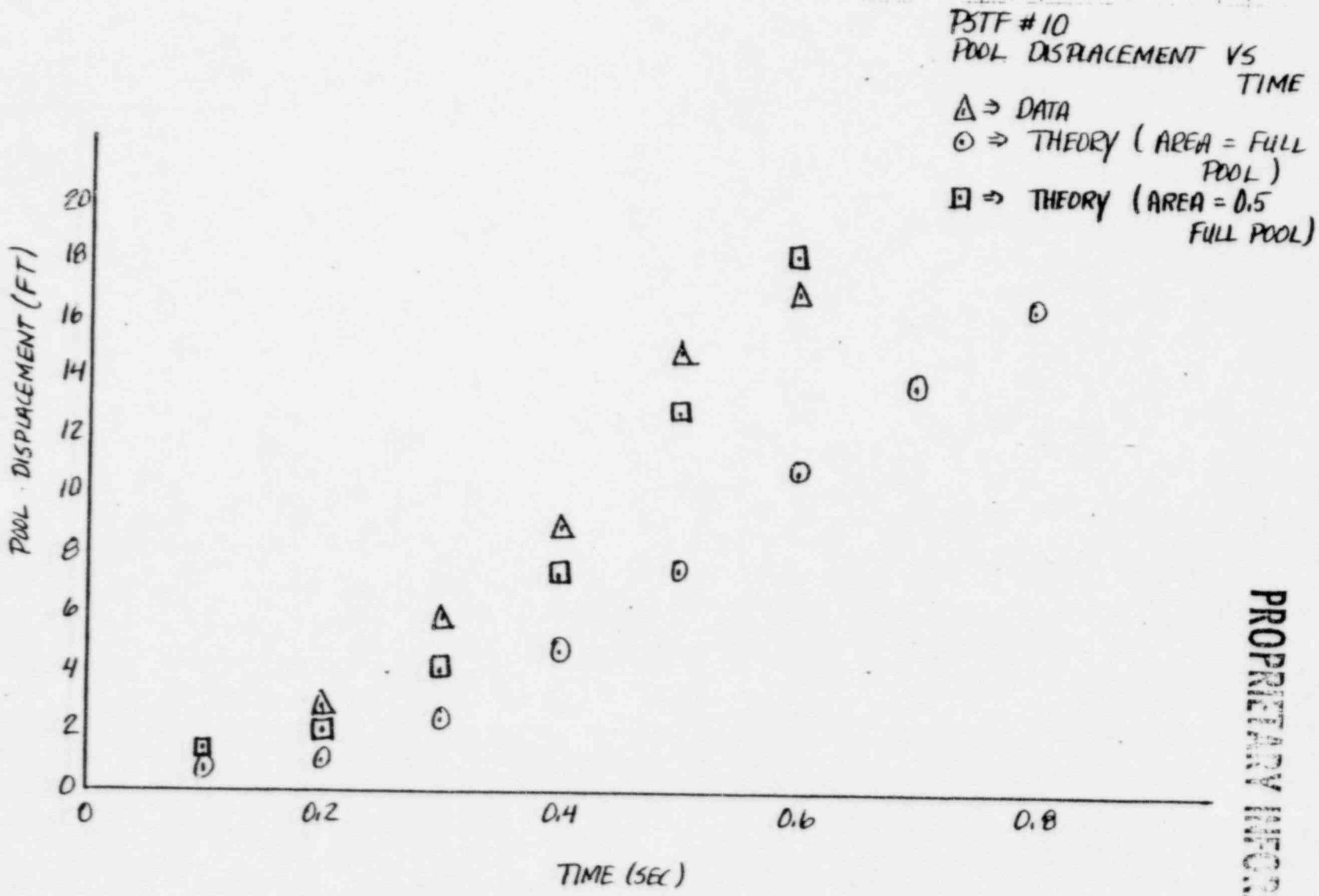


Figure 23: Run 10, Pool Displacement

PROPRIETARY INFORMATION

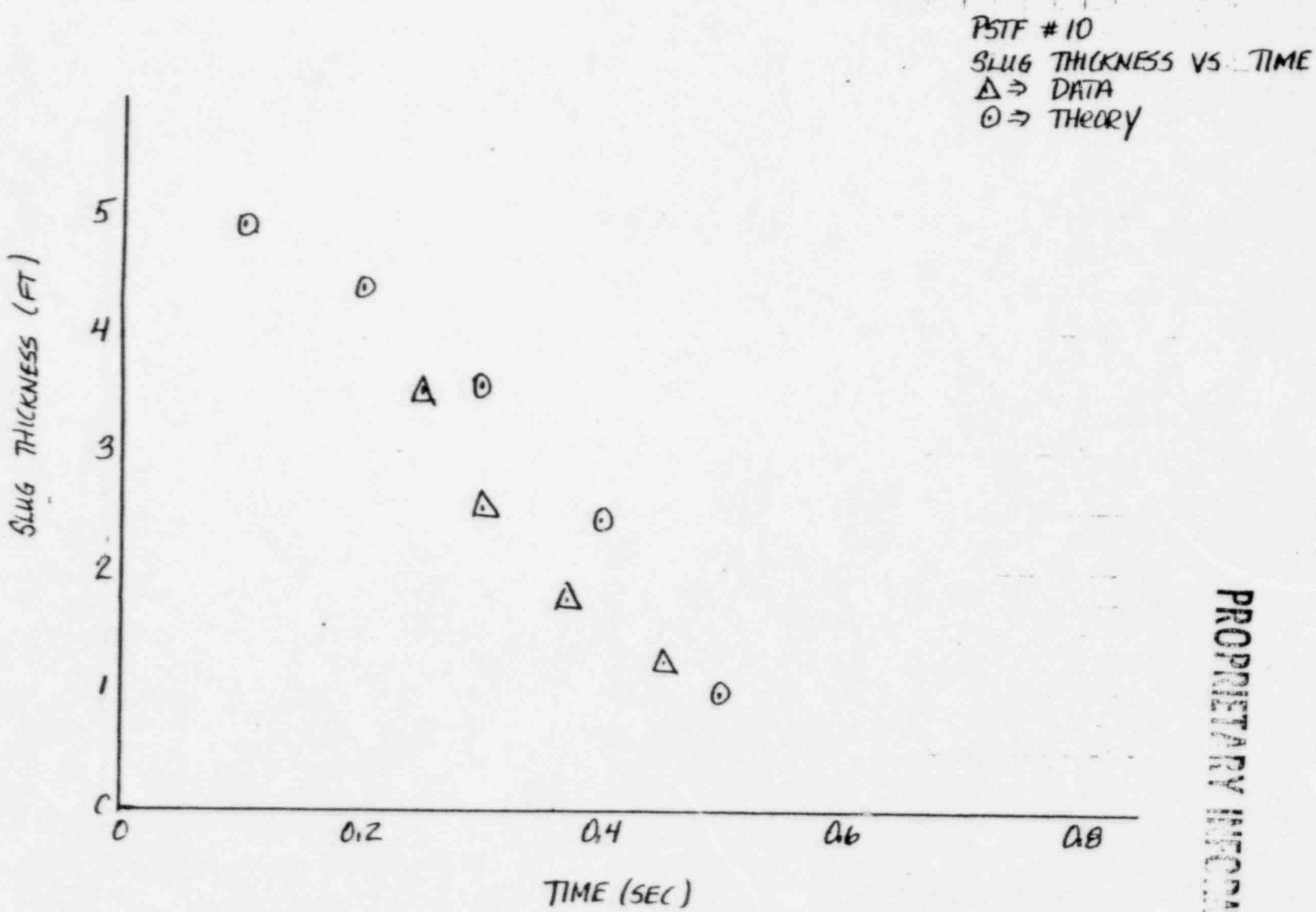


Figure 24: Run 10, Slug Thickness

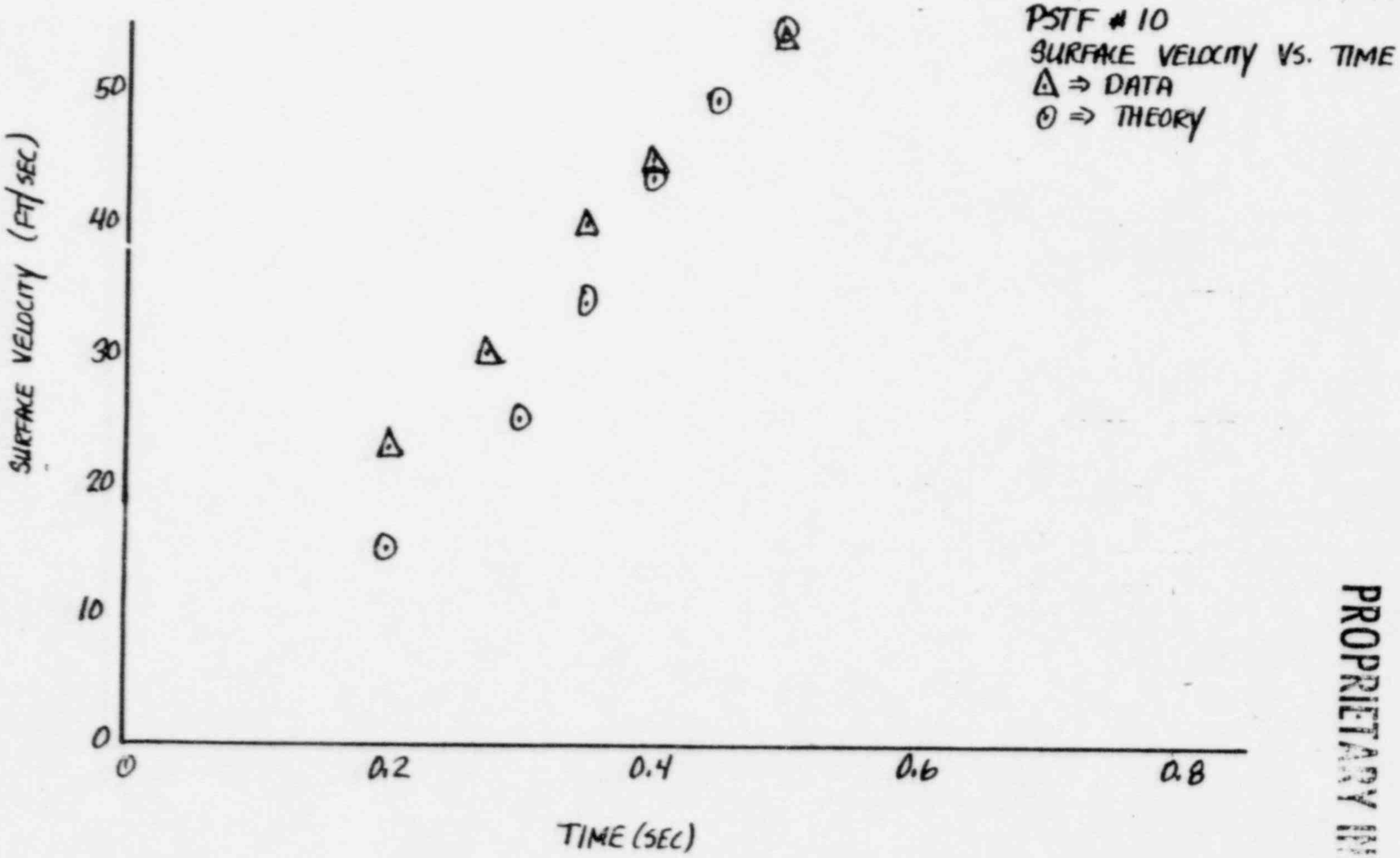


Figure 25: Run 10, Surface Velocity

PROPRIETARY INFORMATION

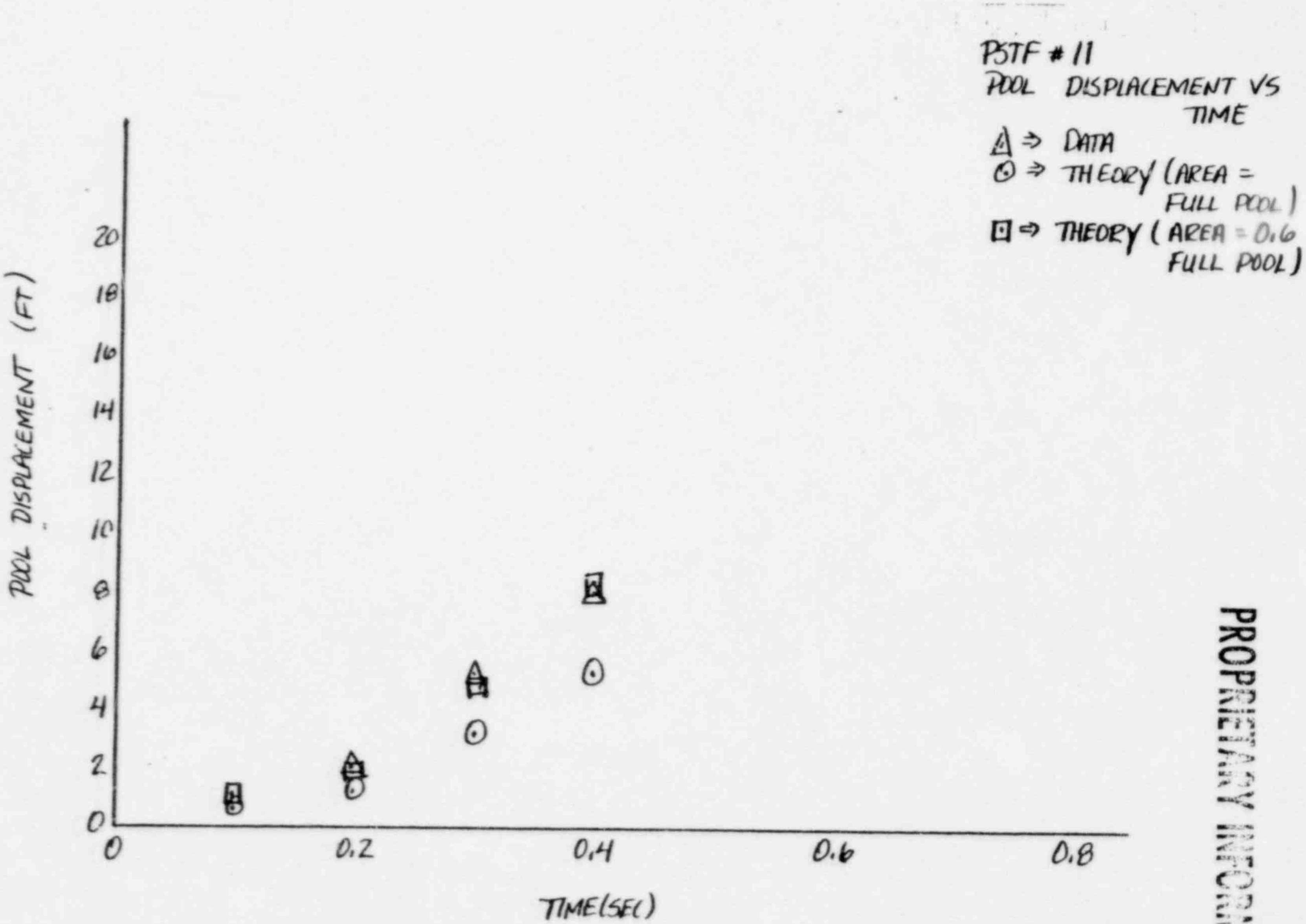


Figure 26: Run 11, Pool Displacement

PROPRIETARY INFORMATION

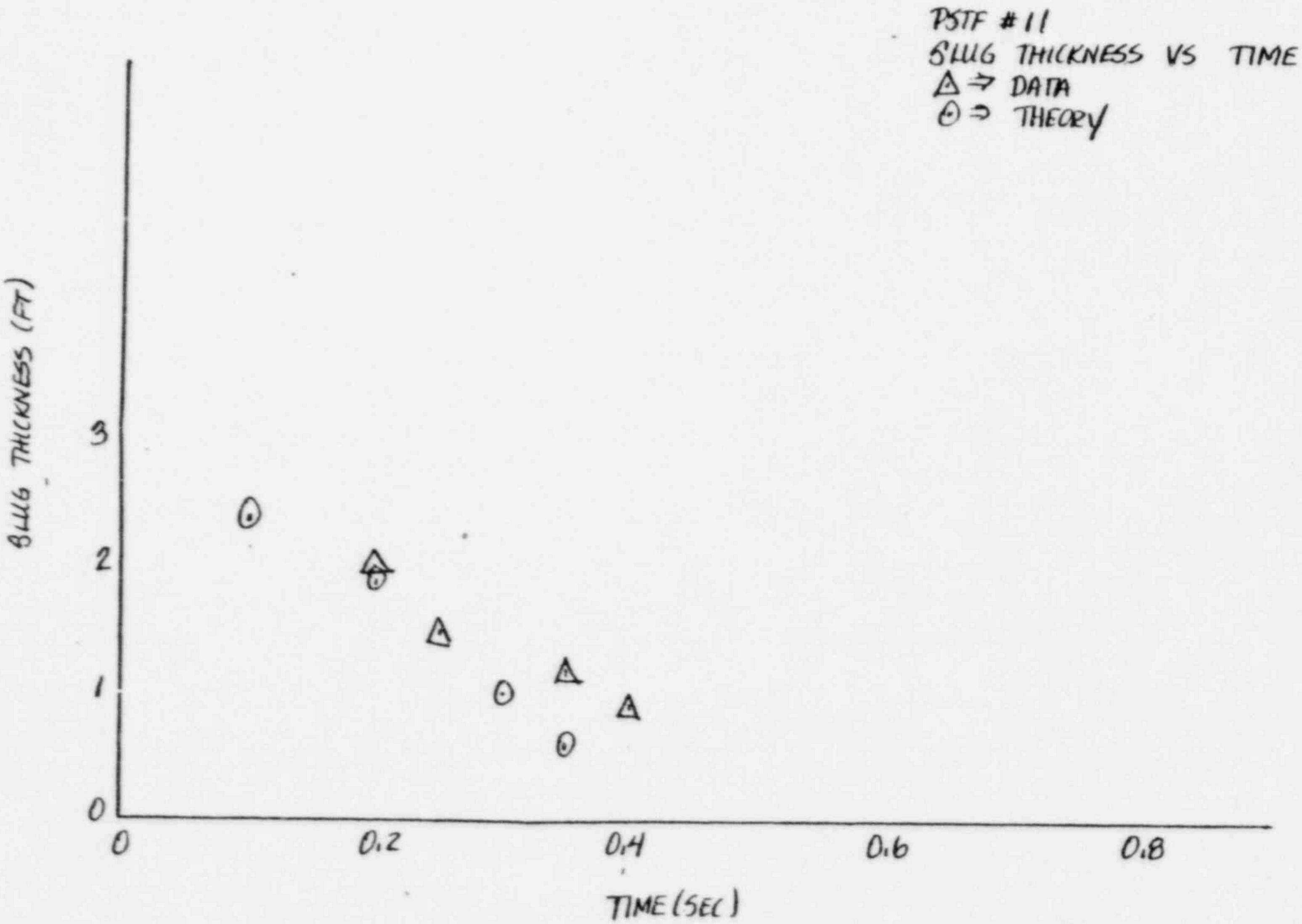


Figure 27: Run 11, Slug Thickness

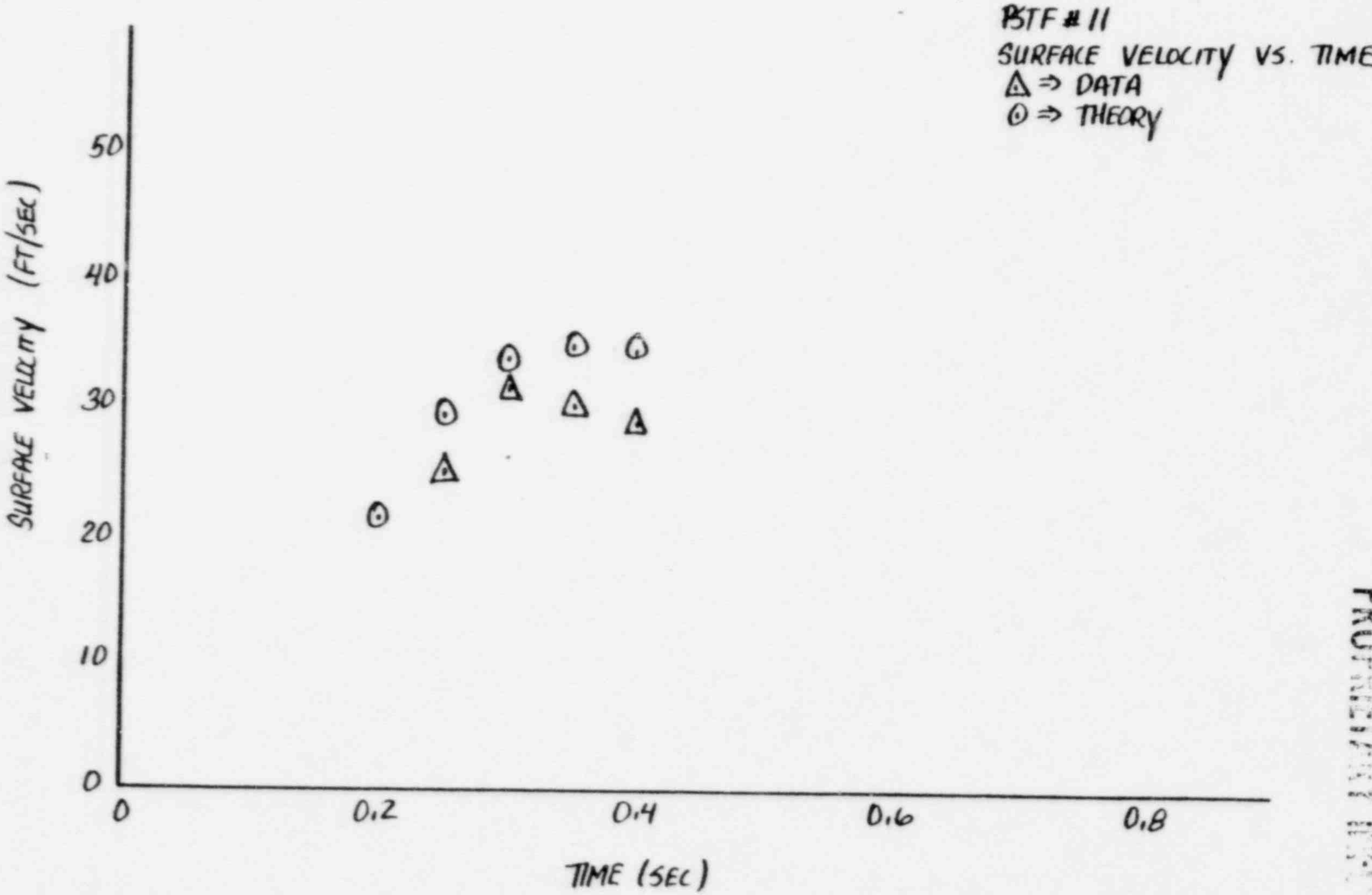


Figure 28: Run 11, Surface Velocity

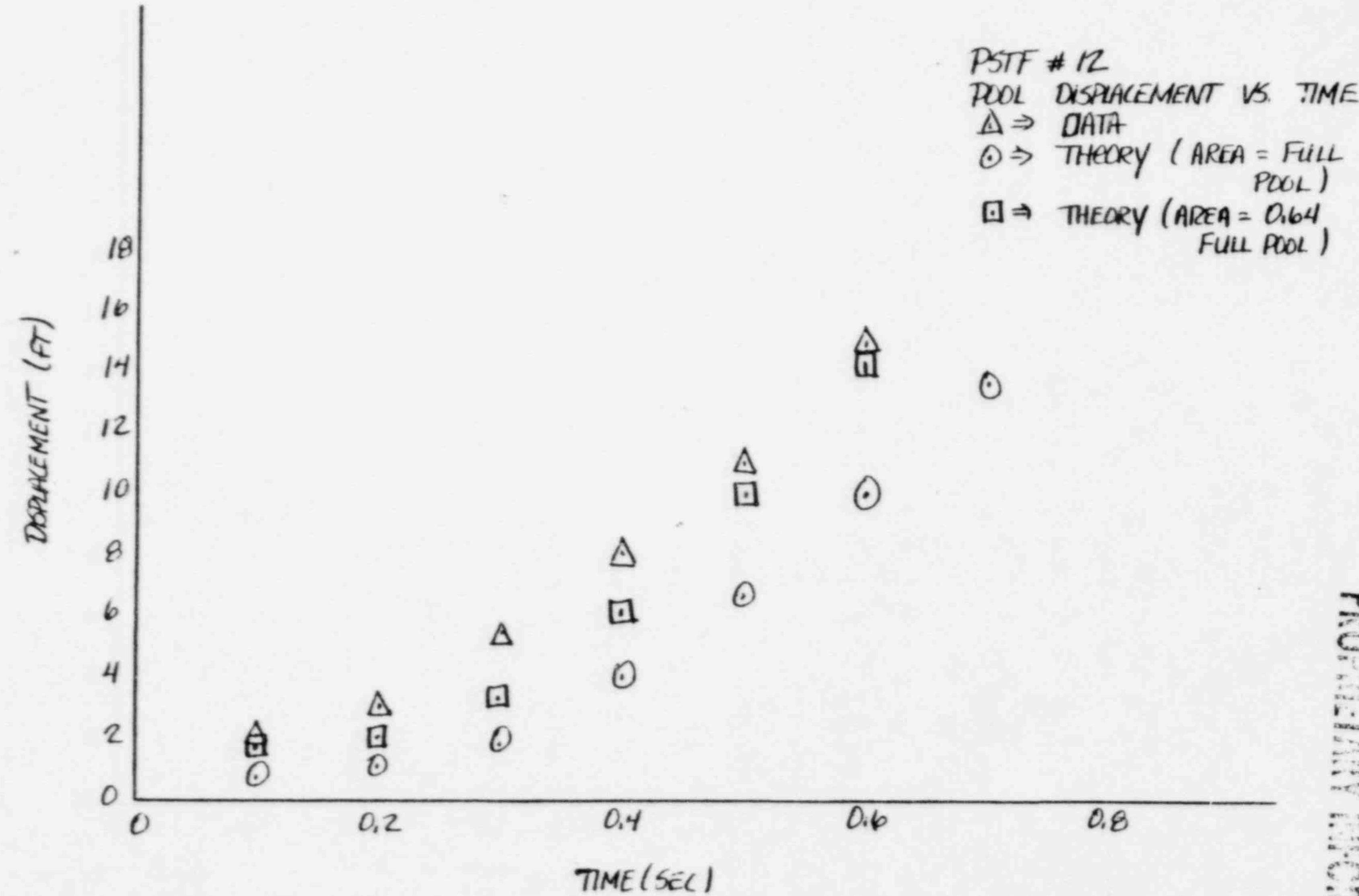


Figure 29: Run 12, Pool Displacement

PROPRIETARY INFORMATION

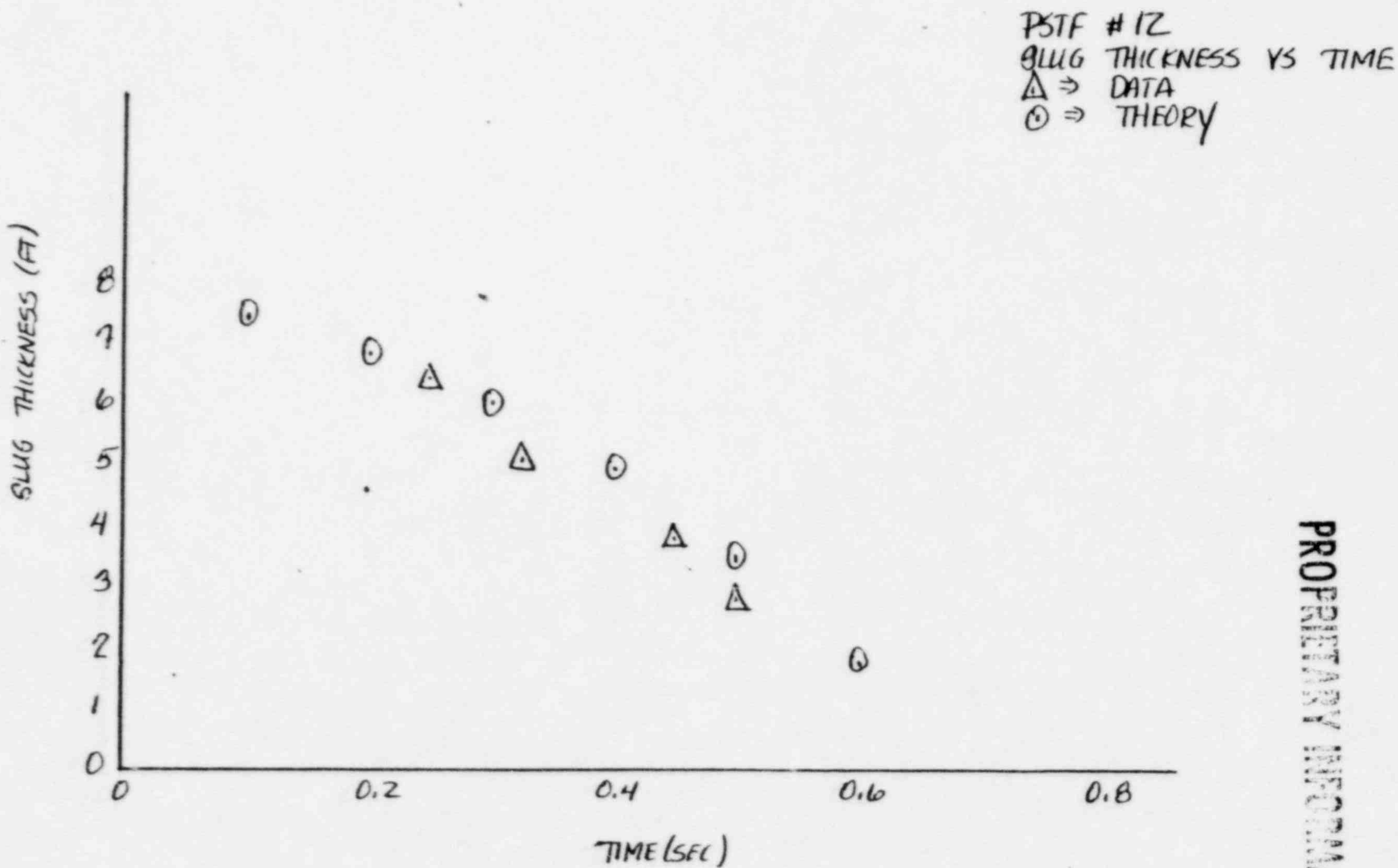


Figure 30: Run 12, Slug Thickness

PROPRIETARY INFORMATION

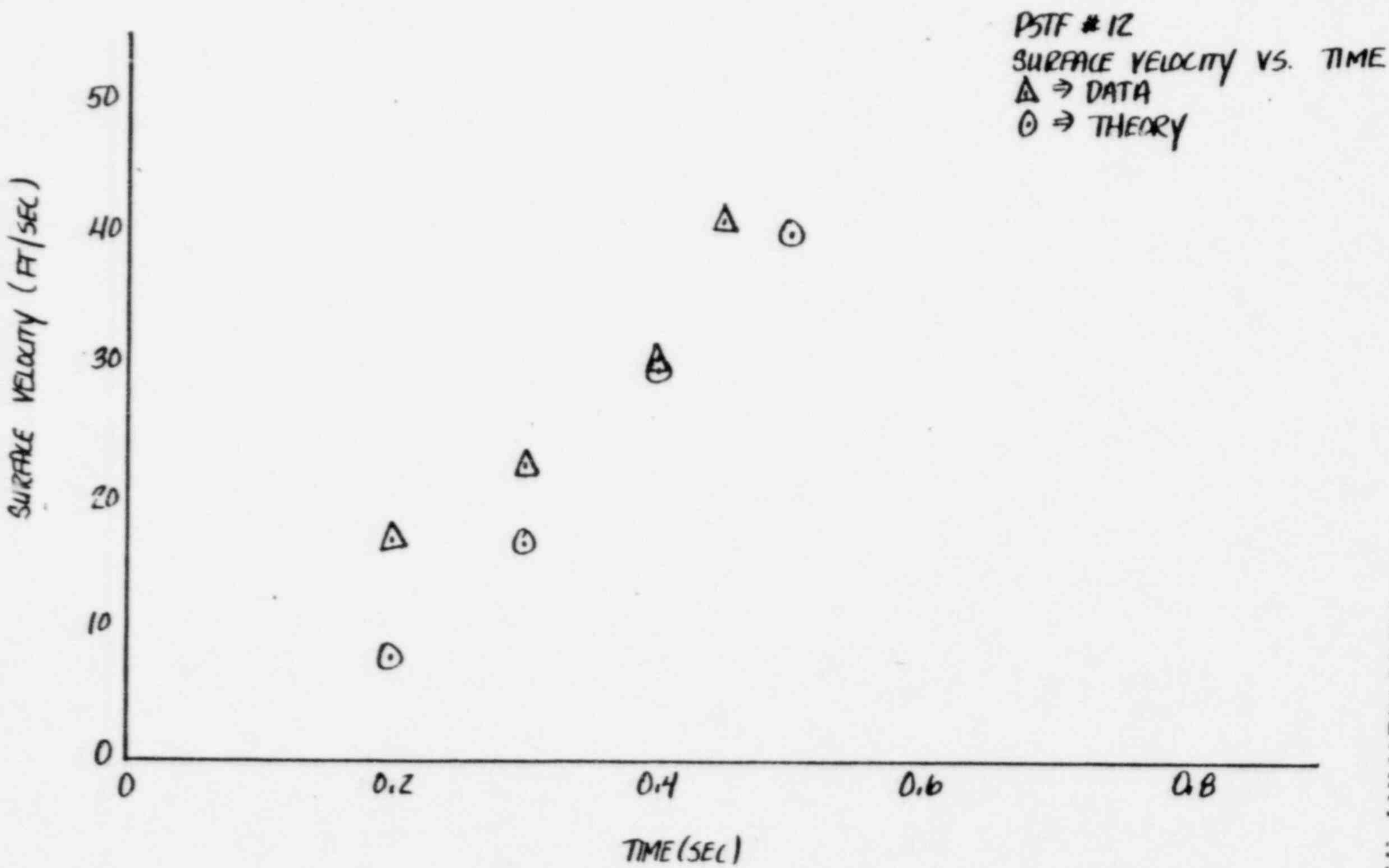


Figure 31: Run 12, Surface Velocity

PROPRIETARY INFORMATION

APPENDIX I.

SAMPLE OUTPUT/TEST 5806/RUN 1

POOL SWELL PROGRAM VERSION OF JUNE 6,1975

PROPRIETARY INFORMATION

TSTART = 0.0010 SEC
TSTOP = 1.0000 SEC
INITIAL BUBBLE DISPLACEMENT = 0.1000 FT.
INITIAL BUBBLE VELOCITY = 0.5000 FT/SEC.
GAS CONSTANT OF AIR = 53.3600 FT-LBF /LBM-DEG R
INITIAL WETWELL PRESSURE = 14.7000 PSIA
INITIAL THICKNESS OF WETWELL ATMOSPHERE = 10000.0000 FT
VENT SPACINGS ARE 0.0000 0.0000 0.0000 0.0000 FT. VENTS 2 THRU 5
VENT CLEARING TIMES ARE 0.0000 0.0000 0.0000 0.0000 SEC RESPECTIVELY
A,A2,A3,A4,A5 ARE... 23.3200 0.0000 0.0000 0.0000 0.0000SQ.FT. RESPECTIVELY
THE NUMBER OF POINTS IN TABLE = 8

	TIME	MASS(LB)	TEMP--DEG R	HEIGHT
1	0.0010	0.4000	540.0000	5.0000
2	0.1000	1.0000	540.0000	5.0000
3	0.2000	4.0000	550.0000	5.0000
4	0.3000	9.0000	555.0000	5.0000
5	0.4000	16.0000	560.0000	5.0000
6	0.5000	25.0000	565.0000	5.0000
7	0.6000	36.0000	565.0000	5.0000
8	1.0000	100.0000	570.0000	5.0000

BREAKTHROUGH TIME = 0.56 SEC

TIME(SEC)	DISPLACEMENT OF POOL(FT)	MASS OF BUBBLE(LB)	VOLUME OF BUBBLE(FT3)	BUBBLE PRESSURE(PSI)	WETWELL PRESSURE(PSI)	VELOCITY OF POOL(FT/SEC)
0.001000	0.100000	0.4000	2.3320	34.3224	14.7001	0.5000
0.002000	0.100630	0.4061	2.3467	34.6242	14.7001	0.7618
0.003000	0.101525	0.4121	2.3676	34.8315	14.7001	1.0273
0.004000	0.102686	0.4182	2.3946	34.9441	14.7001	1.2953
0.005000	0.104115	0.4242	2.4280	34.9637	14.7001	1.5642
0.006000	0.105814	0.4303	2.4676	34.8940	14.7002	1.8327
0.007000	0.107780	0.4364	2.5134	34.7399	14.7002	2.0996
0.008000	0.110012	0.4424	2.5655	34.5079	14.7002	2.3636
0.009000	0.112505	0.4485	2.6236	34.2052	14.7002	2.6236
0.010000	0.115257	0.4545	2.6878	33.8398	14.7002	2.8785
0.011000	0.118261	0.4606	2.7578	33.4201	14.7002	3.1278
0.012000	0.121510	0.4667	2.8336	32.9543	14.7002	3.3704
0.013000	0.124999	0.4727	2.9150	32.4506	14.7002	3.6058
0.014000	0.128719	0.4788	3.0017	31.9167	14.7002	3.8334
0.015000	0.132663	0.4848	3.0937	31.3599	14.7002	4.0530
0.016000	0.135822	0.4909	3.1907	30.7867	14.7002	4.2641
0.017000	0.141188	0.4970	3.2925	30.2030	14.7002	4.4667
0.018000	0.145752	0.5030	3.3989	29.6140	14.7002	4.6605
0.019000	0.150506	0.5091	3.5098	29.0242	14.7002	4.8455
0.020000	0.155440	0.5152	3.6249	28.4374	14.7002	5.0219
0.021000	0.160546	0.5212	3.7439	27.8568	14.7002	5.1895
0.022000	0.165816	0.5273	3.8668	27.2852	14.7002	5.3485
0.023000	0.171240	0.5333	3.9933	26.7245	14.7002	5.4992
0.024000	0.176811	0.5394	4.1232	26.1766	14.7003	5.6416
0.025000	0.182521	0.5455	4.2564	25.6427	14.7003	5.7760
0.025000	0.188360	0.5515	4.3926	25.1238	14.7003	5.9025
0.027000	0.194323	0.5576	4.5316	24.6205	14.7003	6.0215
0.028000	0.200401	0.5636	4.6733	24.1333	14.7003	6.1331
0.029000	0.206586	0.5697	4.8176	23.6625	14.7003	6.2375
0.030000	0.212873	0.5758	4.9642	23.2079	14.7003	6.3351
0.031000	0.219254	0.5818	5.1130	22.7697	14.7003	6.4261
0.032000	0.225723	0.5879	5.2639	22.3475	14.7003	6.5106
0.033000	0.232273	0.5939	5.4166	21.9412	14.7003	6.5890
0.034000	0.238899	0.6000	5.5711	21.5504	14.7003	6.6615
0.035000	0.245594	0.6061	5.7273	21.1746	14.7004	6.7283
0.036000	0.252353	0.6121	5.8849	20.8135	14.7004	6.7896
0.037000	0.259171	0.6182	6.0439	20.4666	14.7004	6.8457
0.038000	0.266043	0.6242	6.2041	20.1335	14.7004	6.8967
0.039000	0.272963	0.6303	6.3655	19.8136	14.7004	6.9428
0.040000	0.279927	0.6364	6.5279	19.5065	14.7004	6.9843
0.041000	0.286930	0.6424	6.6912	19.2116	14.7004	7.0214
0.042000	0.293968	0.6485	6.8553	18.9285	14.7004	7.0541
0.043000	0.301036	0.6545	7.0202	18.6568	14.7004	7.0827
0.044000	0.308131	0.6606	7.1856	18.3960	14.7004	7.1073
0.045000	0.315249	0.6667	7.3516	18.1456	14.7005	7.1282
0.046000	0.322386	0.6727	7.5181	17.9052	14.7005	7.1454
0.047000	0.329539	0.6788	7.6848	17.6744	14.7005	7.1591
0.048000	0.336703	0.6848	7.8519	17.4528	14.7005	7.1694
0.049000	0.343876	0.6909	8.0192	17.2399	14.7005	7.1765
0.050000	0.351055	0.6970	8.1866	17.0355	14.7005	7.1805
0.051000	0.358236	0.7030	8.3541	16.8392	14.7005	7.1816
0.052000	0.365417	0.7091	8.5215	16.6506	14.7005	7.1797

PROPRIETARY INFORMATION

TYPICAL OUTPUT PG. 1

TIME(SEC)	DISPLACEMENT OF POOL(FT)	MASS OF BUBBLE(LB)	VOLUME OF BUBBLE(FT3)	BUBBLE PRESSURE(PSI)	WETWELL PRESSURE(PSI)	VELOCITY OF POOL(FT/SEC)
0.986905	30.721780	31.3006	716.4321	9.2253	14.7453	23.6052
0.987904	30.745300	31.3006	716.9805	9.2185	14.7453	23.4908
0.988904	30.768700	31.3006	717.5264	9.2116	14.7454	23.3762
0.989904	30.791990	31.3006	718.0693	9.2049	14.7454	23.2616
0.990904	30.815170	31.3006	718.6099	9.1982	14.7454	23.1468
0.991904	30.838220	31.3006	719.1475	9.1915	14.7455	23.0319
0.992904	30.861170	31.3006	719.6826	9.1848	14.7455	22.9170
0.993904	30.884030	31.3006	720.2151	9.1783	14.7455	22.8019
0.994904	30.906720	31.3006	720.7449	9.1717	14.7456	22.6868
0.995904	30.929320	31.3006	721.2720	9.1652	14.7456	22.5715
0.996904	30.951790	31.3006	721.7961	9.1588	14.7456	22.4551
0.997903	30.974160	31.3006	722.3176	9.1523	14.7457	22.3407
0.998903	30.995420	31.3006	722.8369	9.1460	14.7457	22.2251
0.999452	31.008570	31.3006	723.1201	9.1425	14.7457	22.1617
1.000000	31.020690	31.3006	723.4026	9.1390	14.7457	22.0983

THERE ARE 1004 DATA POINTS.

CORE USAGE OBJECT CODE= 14352 BYTES,ARRAY AREA= 932 BYTES,TOTAL AREA AVAILABLE= 22624 BYTES

DIAGNOSTICS NUMBER OF ERRORS= 0, NUMBER OF WARNINGS= 1, NUMBER OF EXTENSIONS= 0

COMPILE TIME= 0.41 SEC,EXECUTION TIME= 6.30 SEC, WATFIV - JUL 1973 V1L4 22.09.55 MONDAY 31 MAY 76

S. W. O. R. C. C. WATFIV V1L4 DATE - 05/31/76 TIME - 22.09.55 RUN ON IBM SYSTEM/370 MODEL 168

PROPRIETARY INFORMATION

LAST PAGE