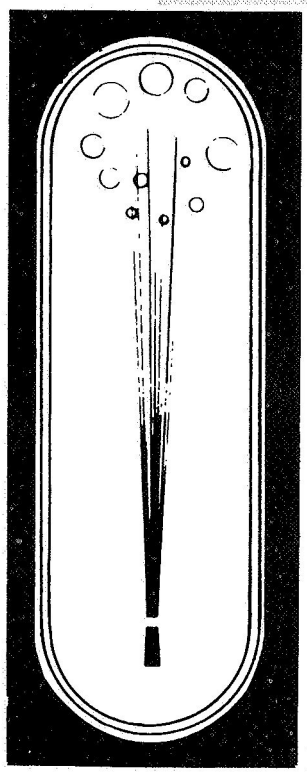

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A STUDY OF CRYOGENIC PROPELLANT MIXING TECHNIQUES

Final Report

(July 1967 - September 1968)

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Volume II - Experimental Data

GENERAL DYNAMICS
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FINAL REPORT

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Volume II: Experimental Data

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Prepared for the
George C. Marchall Space Flight Center
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Huntsville, Alabama

under

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F O R E W O R D

This document is Volume II of the annual report on NASA Contract NAS8-20330, "A Study of Cryogenic Propellant Stratification Reduction Techniques." The study was performed by the Fort Worth Division of General Dynamics Corporation for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The program was conducted under the technical direction of Mr. T. W. Winstead of the MSFC Propulsion and Vehicle Engineering Laboratory. His assistance in the performance of this study is gratefully acknowledged.

The final report consists of two volumes:

Volume I. Mixer Design and Experimental Investigations

Volume II. Experimental Data

Volume I contains a presentation of the experimental and mixer design investigations, together with a summary of the important findings of the study. Volume II contains a presentation of the experimental data utilized in the study.

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NOMENCLATURE

Symbol	Description	Units
A	Heated area	ft^2
c_p	Constant pressure specific heat	$Btu/lb_m\text{-}^oF$
D_o	Nozzle diameter	in
D_t	Tank diameter	in
G_o	Volume flow rate	gpm
g	Acceleration	ft/sec^2
I_m	Energy integral, $I_m = 1 - \frac{T_s - T_m}{T_s - T_b}$	———
k	Thermal conductivity	$Btu/ft\text{-}hr\text{-}^oF$
M_ℓ	Mass of water in tank	lb_m
m_o	Mass flow rate	lb_m/sec
N_i^*	Initial Grashof number divided by the square of the Reynolds number	———
Nu_{mi}	Initial Nusselt number, $Nu_{mi} = Q_m D_t / 2A(T_s - T_m)_i k$	———
N_{Pr}	Prandtl number	———
N_{Re}	Reynolds number	———
P	Tank pressure	psia
P_m	Saturation pressure of water at T_m	psia
P_{NC_f}	Difference between P and P_m for mixed conditions at end of test	psia
Q_b	Bottom heater power input	Btu/sec

N O M E N C L A T U R E (Cont'd)

Symbol	Description	Units
Q_m	Total heat absorbed by water based on difference between final and initial T_m	Btu/sec
Q_{sw}	Sidewall heater power input	Btu/sec
Q_t	Top heater power input	Btu/sec
T	Temperature	^oF
T_b	Average temperature at nozzle exit	^oF
T_m	Mean water temperature	^oF
T_s	Average surface temperature	^oF
V_o	Nozzle exit velocity	ft/sec
V_t	Volume of water	ft^3
Z	Axial distance above nozzle exit	in
Z_b	Axial distance from nozzle exit to liquid/vapor interface	in
β	Thermal coefficient of expansion	$1/^oF$
ΔP	$P - P_{NCf} - P_m$	psia
ΔP_i	$P_i - P_{NCf} - P_{mi}$	psia
ΔT	$T_s - T_m$ or $T_s - T_b$	^oF
ΔT_i	$(T_s - T_m)_i$ or $(T_s - T_b)_i$	^oF
θ	Time after heater or pump turned on	sec
θ_1	Time after pump turned on when T_s or P begins to decrease or when stratified dye layer begins to move	sec

N O M E N C L A T U R E (Cont'd)

Symbol	Description	Units
θ_j	Time associated with the axial jet moving up through the fluid	sec
λ_i	Initial performance paramter $\lambda_i = Q_m/(T_s-T_b)_i \dot{m}_o c_p$	———
λ_{mi}	Initial performance parameter $\lambda_{mi} = Q_m/(T_s-T_m)_i \dot{m}_o c_p$	———
ν	Kinematic viscosity	ft^2/sec

SECTION 1

INTRODUCTION

This volume of the final report contains the data utilized from the open-and closed-tank tests conducted during this study. The purpose of documenting these data is to (1) provide the detailed test data from which the correlations in Volume I were obtained, and (2) furnish data for further analyses as required.

The data presented are in the form of tabular summaries of test conditions and graphical representations of the test results in both basic and dimensionless form. The data are divided into two sections. The first section presents the results of 58 open-tank tests (non-pressurized). The second section contains the results of 20 closed-tank tests (pressurized).

Data for the open tank tests consist of jet-motion and jet-mixing data. The jet motion data resulted from visual measurements of the jet position in the tank as revealed by blue dye in the jet. These measurements were made from motion pictures of the various tests. The jet mixing data consists of dye position and temperature measurements. The jet mixing dye measurements were also obtained from motion pictures made during the tests. The dye data are presented as a

function of time versus dye level in the tank and in dimensionless form as a ratio of the dye level to the water level above the nozzle. Open tank temperature data presented consists of the surface and bottom temperatures as a function of time and the temperature difference between the surface temperature and the mean temperature and the difference between the mean temperature and the mean initial temperature versus time. In addition, temperature distributions in the tank with time as a parameter are also shown for some tests. Dimensionless temperature ratios, $(T_s-T_b)/(T_s-T_b)_i$ and $(T_s-T_m)/(T_s-T_m)_i$, are shown as a function of $V_o\ D_o\ \theta_1/\ D_t^2$. The energy integral, I_m , is shown as a function of $V_oD_o\theta/D_t^2$.

Closed tank temperature data is presented in much the same manner. There is no dye data for the closed tank tests. In addition to the temperature data, pressure histories during closed tank tests are shown as pressure versus time and as a dimensionless pressure ratio $\Delta P/\Delta P_i$ versus $V_oD_o\theta_1/D_t^2$.

Each figure is identified by a test and run number. These are shown for the convenience of the program personnel in order to allow convenient reference to the original strip charts and computer printouts from which the data shown in this volume were taken. The test number refers to the number assigned to the particular test conditions in the original matrix. The run number refers to the sequence in which the

tests were actually run. The discrepancies between the total number of runs and run and test numbers are due to (1) deletion of some tests of marginal interest in the test matrix because of previous work, (2) elimination of runs intended for system checkout purpose and (3) elimination of runs in which the data was of limited usefulness due to test procedural difficulties or data acquisition problems.

The methods of correlation are discussed in Section 2 of Volume I of the annual report. The notations used in the figures and tables are generally self-explanatory or easily identified in the nomenclature. Most of the dimensionless data shown in the figure are given in terms of an initial temperature, pressure, or dye level condition. This information plus values of temperature, pressure, and dye level given as a function of time will allow ready calculation of the dimensionless values for other than initial conditions.

SECTION 2

OPEN TANK TEST DATA

Table 2.0-1

SUMMARY OF OPEN TANK TESTS

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
1		Concave	8.7	0	0	1752	0.250	0	0
2		Concave	8.7	0	0	820	0.250	0	0
3	102	Concave	8.7	0	0	85	0.250	0	0
4	147	Concave	17.7	0	0	826	0.250	0	0
5	138	Concave	17.7	0	0	0	0.032	0.06	0
6	151	Concave	17.7	942	0	0	0.032	0.06	0
7	101	Concave	17.7	0	0	0	0.032	0.036	0
8	130	Concave	17.7	0	0	0	0.25	0.022 0.06 0.10	0
9	162	Concave	17.7	891	0	551	0.032	0.1	0
10	144	Concave	17.7	904	0	0	0.032	0.1	4.7

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
11	144	Concave	17.7	894	0	0	0.032	0.1	11.0
12	146	Concave	17.7	894	0	0	0.032	0.1	11.0
13	153	Concave	17.7	0	0	826	0.032	0.065	11.0
14	153	Concave	17.7	0	0	826	0.032	0.065	11.0
15	152	Concave	17.7	0	0	89	0.032	0	11.0
16	154	Concave	17.7	0	0	89	0.032	0.065	11.0
17	154	Concave	17.7	0	0	89	0.032	0.065	11.0
18	154	Concave	17.7	0	0	89	0.032	0.064	11.0
19	155	Concave	17.7	0	0	843	0.032	0	11.0
20	156	Concave	17.7	0	0	89	0.032	0	11.0
21	146	Concave	17.7	980	0	0	0.032	0.065	11.0

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
22	144	Concave	17.7	938	0	0	0.032	0	11.0
23	148	Concave	17.7	0	0	830	0.032	0	11.0
24	111	Concave	17.7	94	0	89	0.032	0.061	0
25	112	Concave	17.7	94	0	830	0.032	0.065	0
26	120	Concave	17.7	969	0	89	0.032	0.072	0
27	121	Concave	17.7	975	0	802	0.032	0.06	0
28	161	Concave	17.7	94	0	826	0.032	0	0
29	161	Concave	17.7	100.7	0	826.7	0.032	0	0
30	163	Concave	17.7	94.5	0	89.4	0.032	0	0
31	164	Concave	17.7	100.7	0	826.7	0.032	0	0
32	165	Concave	17.7	1043.4	0	793	0.032	0.065	0

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
33	166	Concave	17.7	0	0	806.4	0.032	0	11.0
34	146B	Concave	17.7	0	0	89.4	0.032	0	11.0
35	167	Concave	17.7	0	0	826.7	0.032	0.1	11.0
36	157	Concave	17.7	96.6	0	0	0.032	0.11	0
37	137	Concave	17.7	0	0	0	0.032	0.11	0
38	137	Concave	17.7	0	0	0	0.032	0.11	0
39	135	Concave	17.7	0	0	0	0.25	0.47	0
40	158	Concave	17.7	92.5	0	0	0.25	0.683	0
41	158	Concave	17.7	98.6	0	0	0.25	0.683	0
42	158	Concave	17.7	90.4	0	0	0.25	0.683	0
43	133	Concave	17.7	0	0	0	0.083	0.36	0

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
44	134	Concave	17.7	0	0	0	0.125	0.36	0
45	136	Concave	17.7	0	0	0	60°	0.5	0
46	136	Concave	17.7	0	0	0	60°	0.5	0
47	131	Concave	17.7	0	0	0	60°	0.22 0.5	0
	10	Convex	23.8	0	0	1670		0	0
	11	Convex	23.8	0	0	1670		0	11.0
	12	Convex	23.8	0	0	1660		0	11.0
	13	Convex	23.8	0	0	1660		0	0
JP-1		Convex	14.8 23.8	0	0	0	0.032	0.018 0.01 0.07	0 0

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
JP-1		Convex	23.8	0	0	0	0.032	0.085 0.080 0.082	0 0 0
JP-2		Convex	23.8	0	0	0	0.032	0.082	0
JP-3		Convex	23.8	0	0	0	0.032	0.082	0
47	2	Convex	23.8	0	0	1640	0.032	0	0
48	1	Convex	23.8	0	0	0	0.032	0.036	0
49	3	Convex	23.8	0	0	82.4	0.032	0.065	0
50	5	Convex	23.8	89	0	0	0.032	0.08	0
51	6	Convex	23.8	90.5	0	95.3	0.032	0.061	0
53	4	Convex	23.8	0	0	830	0.032	0.065	0
54	8	Convex	23.8	907.5	0	830	0.032	0.065	0

Table 2.0-1 (Cont'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
55	9	Convex	23.8	940	0	81.1	0.032	0.065	0
56	14	Convex	23.8	940	0	0	0.032	0.08	0
57	15	Convex	23.8	0	0	0	0.032	0.02	0
58	16	Convex	23.8	0	0	121.7	0.032	0.02	0
59	17	Convex	23.8	0	0	1275	0.032	0.02	0
60	18	Convex	23.8	91.8	0	0	0.032	0.038	0
61	19	Convex	23.8	98.9	0	128.8	0.032	0.038	0
62	20	Convex	23.8	89.6	0	1265	0.032	0.038	0
63	22	Convex	23.8	940	0	128	0.032	0.038	0
64	23	Convex	23.8	864	0	1265	0.032	0.038 0.085	0
65	28	Convex	23.8	0	0	0	0.032	0.038	0

Table 2.0-1 (Cont'd.)

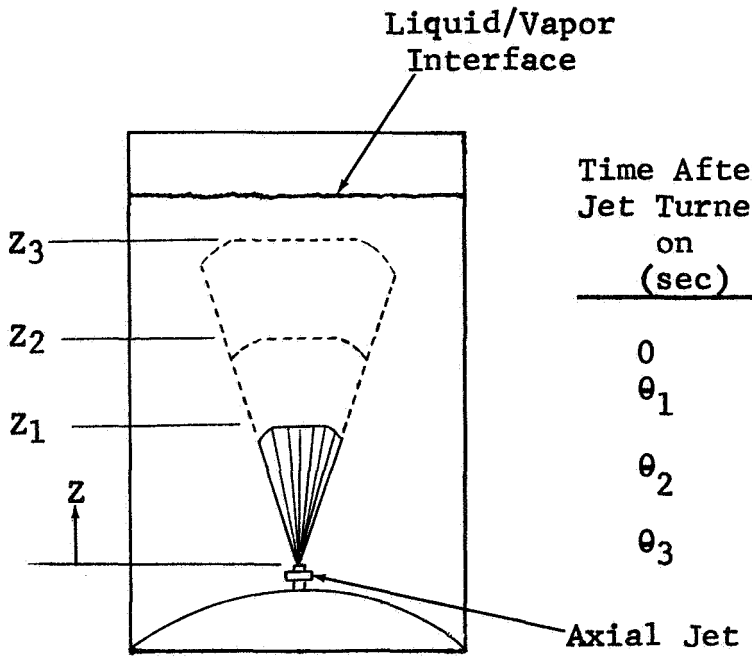
Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
66	29	Convex	14.8	0	0	0	0.032	0.038	0
67	31	Convex	14.8	0	0	0	0.032	0.072	0
68	30	Convex	6.7	0	0	0	0.032	0.038	0
69	32	Convex	6.7	0	0	0	0.032	0.02	0
70	33	Convex	23.8	0	0	0	0.032	0.10	0
71	24	Convex	23.8	0	0	0	0.25	0.50	0
72	24	Convex	23.8	0	0	0	0.25	0.50	0
73	26	Convex	23.8	0	0	1365	0.25	0.50	0
74	27	Convex	23.8	94.6	0	0	0.25	0.75	0
75	35	Convex	23.8	97	0	1265	0.25	0.75	0
76	35	Convex	23.8	94.6	0	1265	0.25	0.75	0

Table 2.0-1 (Concl'd.)

Run	Test	Bulkhead	Z_b (in.)	Q_t	Q_s (watts)	Q_b	D_o (in.)	G_o (gpm)	Drain Rate (gpm)
77	36	Convex	23.8	940	0	0	0.25	1.00	0
78	40	Convex	23.8	0	6827.8	0	0.032	0	0
79	39	Convex	23.8	0	6873.6	1200	0.032	0	0
80	42	Convex	23.8	0	6906.6	0	0.032	0.038 0.076	0

2.1 JET MOTION DATA

The following jet motion data was obtained visually from film data of an axial jet moving up to the liquid/vapor interface as shown in the sketch below.



Time After Jet Turned on (sec)	Axial Distance Above Nozzle (in.)
0	0
θ_1	Z_1
θ_2	Z_2
θ_3	Z_3

A correlation of the data shown in the following figures yields the time required for the jet to reach the liquid surface for various Z_b/D_t ratios.

Table 2.1-1

CONCAVE TANK BOTTOM JET MOTION DATA

Run	Test	Nozzle Diameter (in.)	Liquid Height Above Nozzle (in.)	Z_b/D_o	D_t (in.)	Volume Flow Rate (gpm)	V_oD_o (ft^2/sec)	Q_{Top} (watts)	Q_{Bottom} (watts)
39	135	0.250	17.7	70.8	11.719	0.470	0.0639	0.0	0.0
37	137	0.032	17.7	553	11.719	0.110	0.1169	0.0	0.0
38	137	0.032	17.7	553	11.719	0.110	0.1169	0.0	0.0
36	157	0.032	17.7	553	11.719	0.110	0.1169	94.2	0.0
40	158	0.250	17.7	70.8	11.719	0.683	0.0928	94.0	0.0
41	158	0.250	17.7	70.8	11.719	0.683	0.0928	96.6	0.0
42	158	0.250	17.7	70.8	11.719	0.683	0.0928	98.6	0.0

Table 2.1-2

CONVEX TANK BOTTOM JET MOTION DATA

Run	Test	Nozzle Diameter (in.)	Liquid Height Above Nozzle (in.)	Z_b/D_o	D_t (in.)	Volume Flow Rate (gpm)	V_oD_o (ft^2/sec)	Q_{Top} (watts)	Q_{Bottom} (watts)
54	8	0.032	23.8	744	11.719	0.065	0.0689	940	830
JP	1	0.032	23.8	744	11.719	0.082	0.0869	0	0
JP	2	0.032	23.8	744	11.719	0.082	0.0869	0	0

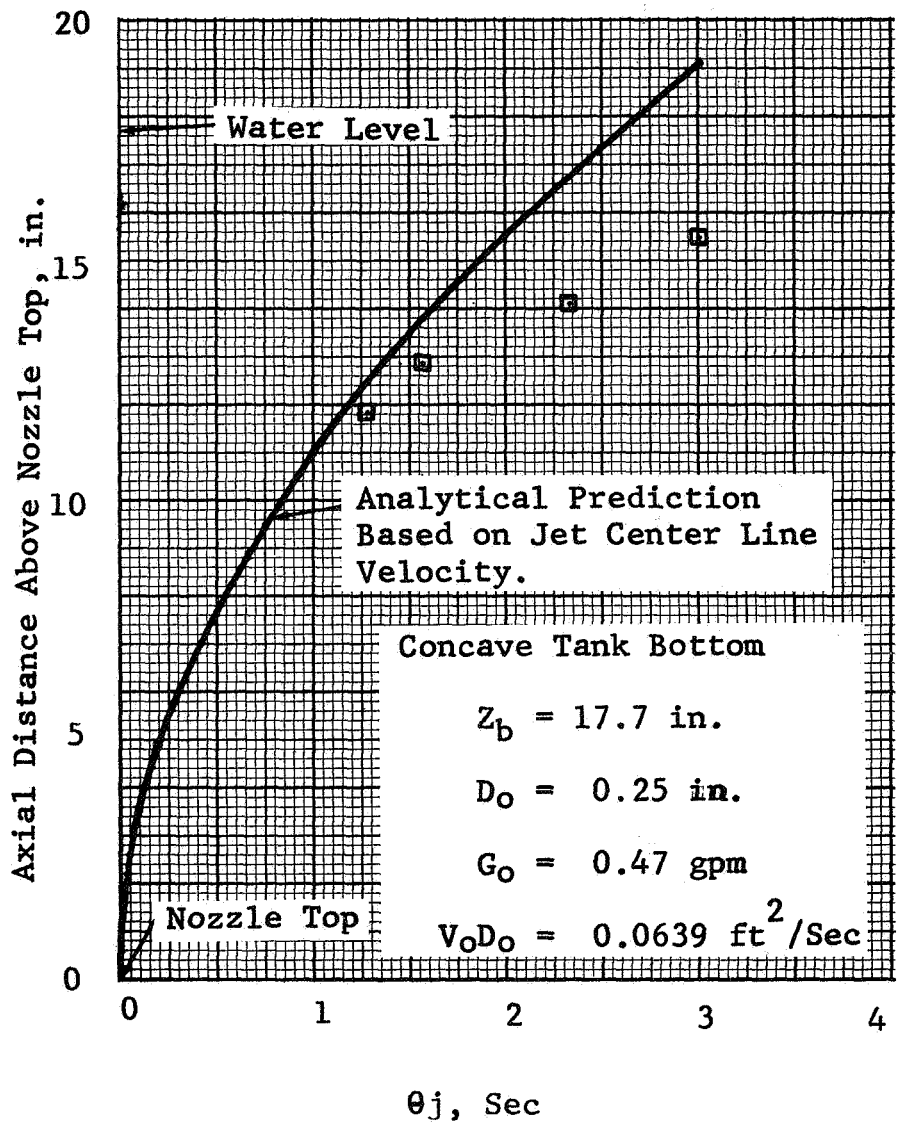


Figure 2.1-1 Axial Jet Motion After Pump Turned On: Test 135, Run 39

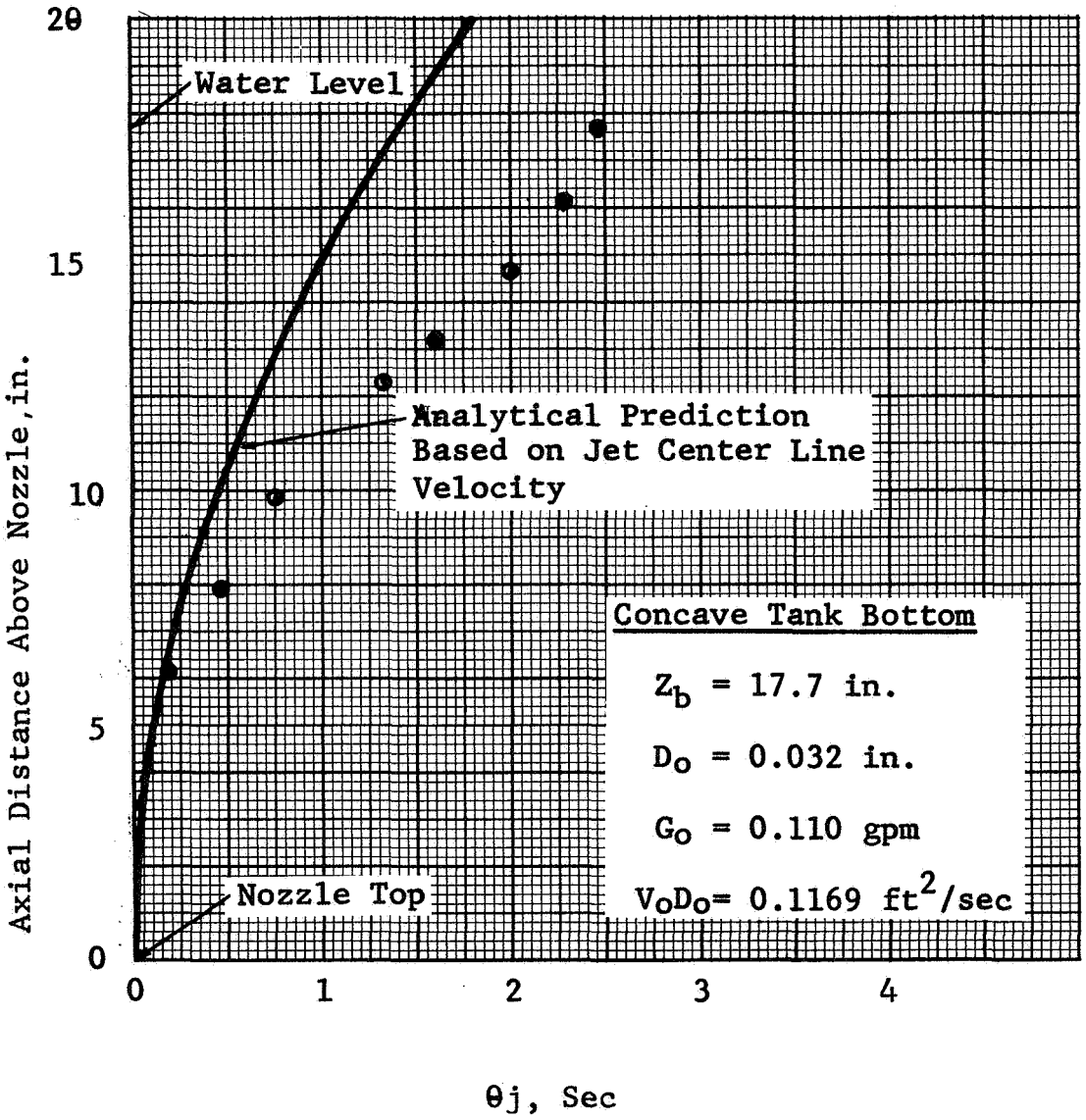


Figure 2.1-2 Axial Jet Motion After Pump Turned On: Test 137, Run 37

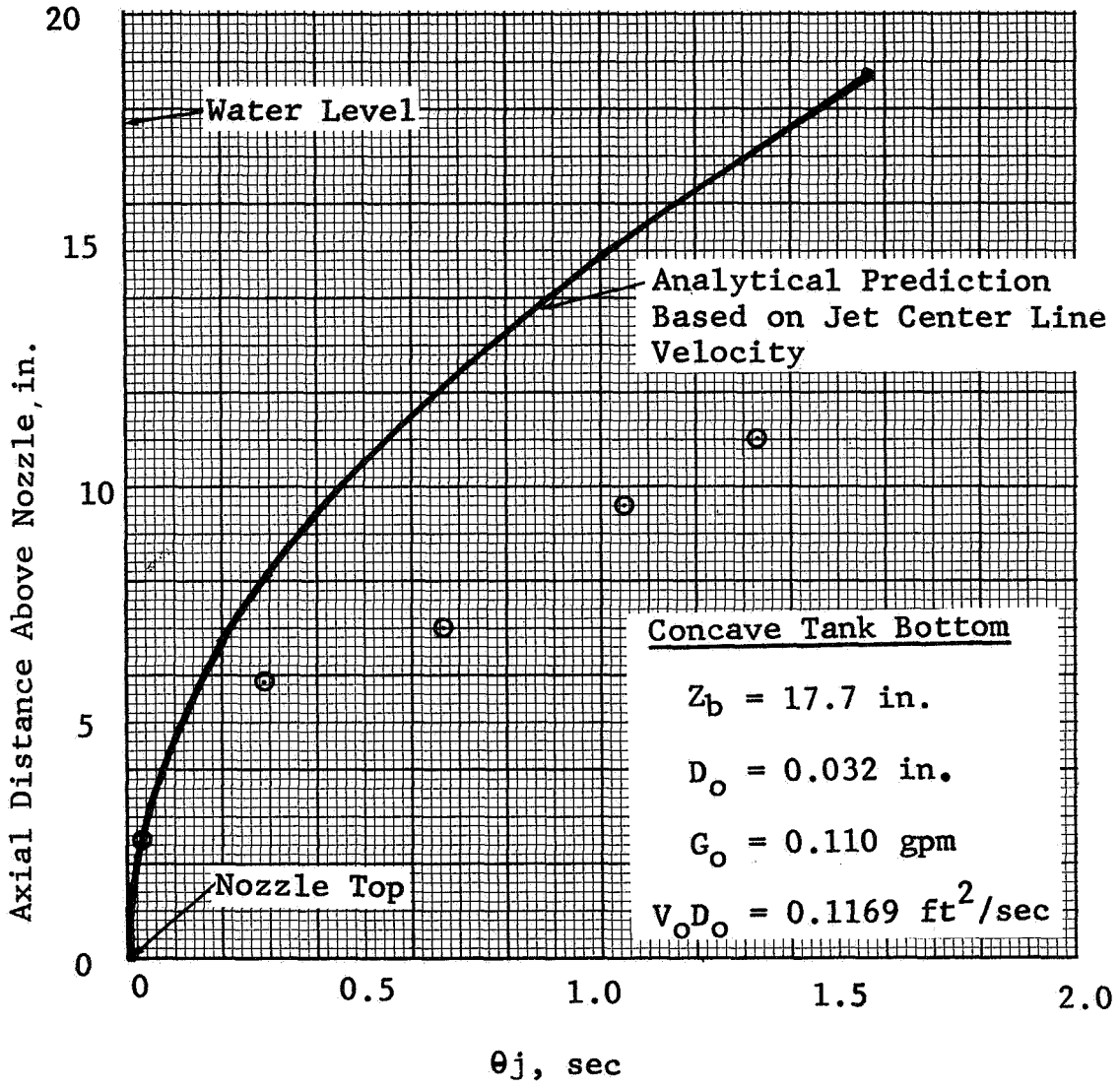


Figure 2.1-3 Axial Jet Motion After Pump Turned On: Test 137, Run 38

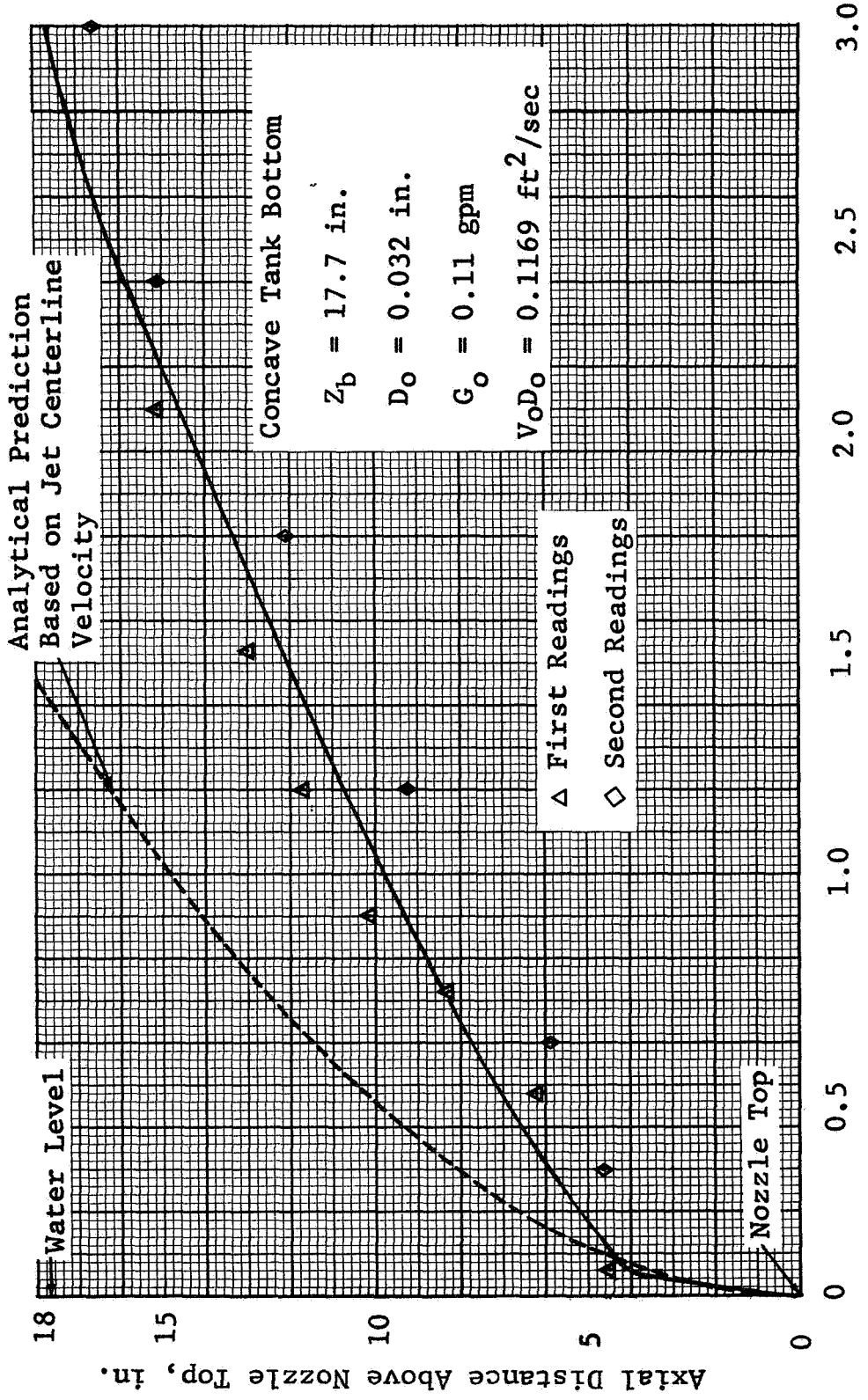


Figure 2.1-4 Axial Jet Motion After Pump Turned On: Test 157 , Run 36

Concave Tank Bottom

Z_b = 17.7 in.

D_o = 0.25 in.

G_o = 0.683 gpm

V_oD_o = 0.2832

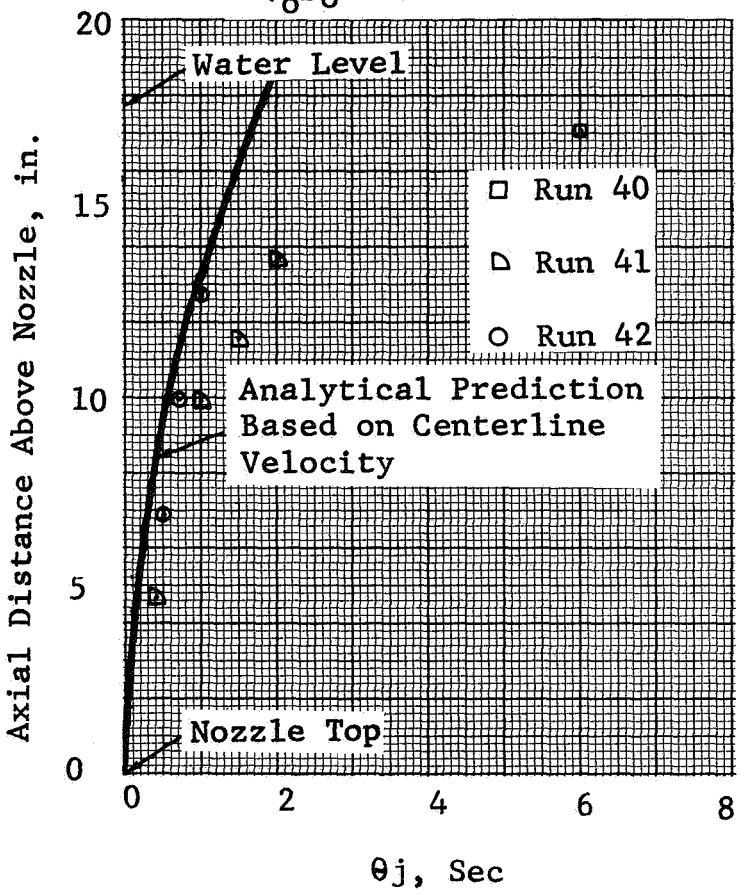


Figure 2.1-5 Axial Jet Motion After Pump Turned On: Test 158

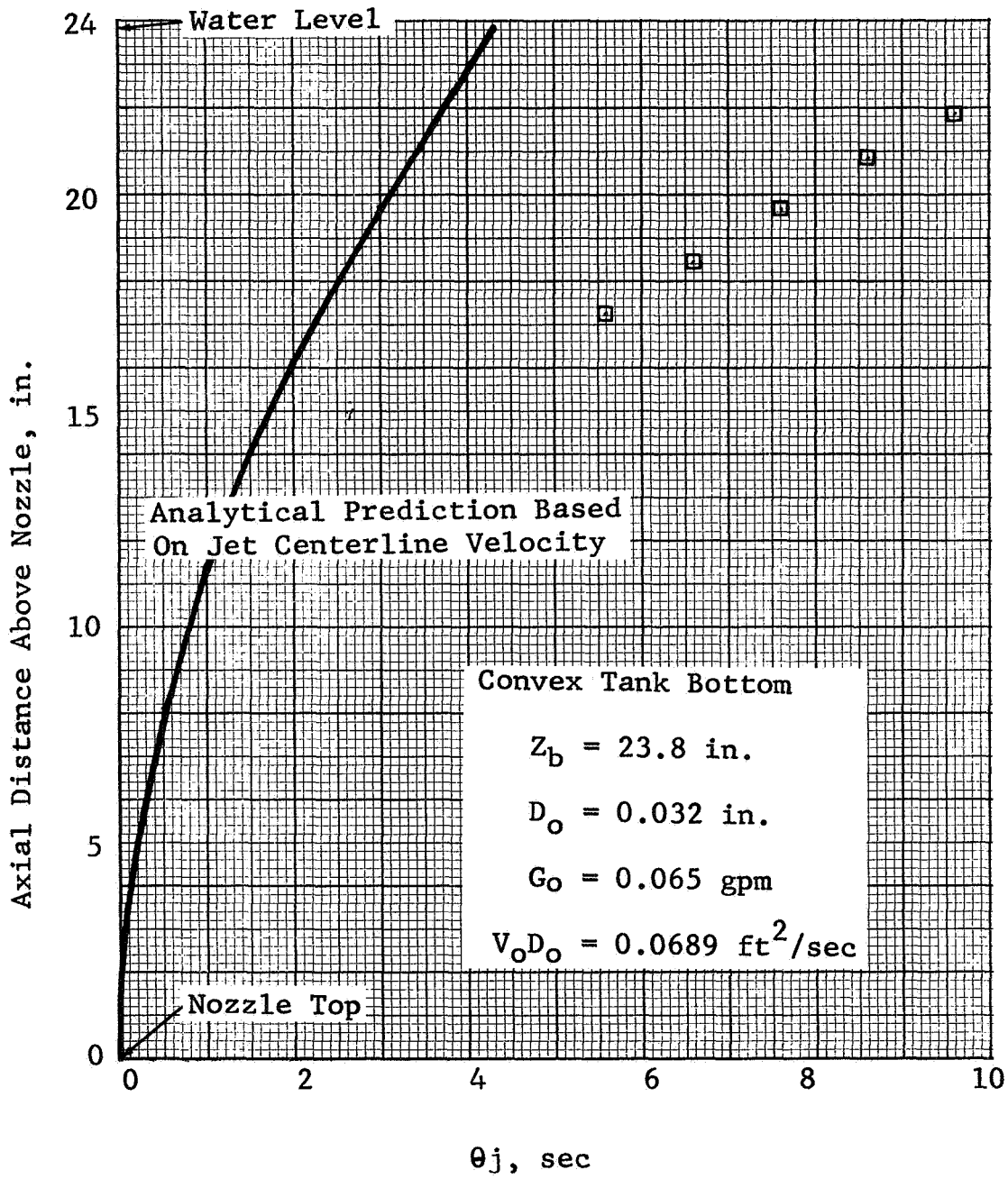


Figure 2.1-6 Axial Jet Motion After Pump Turned On: Test 8, Run 54

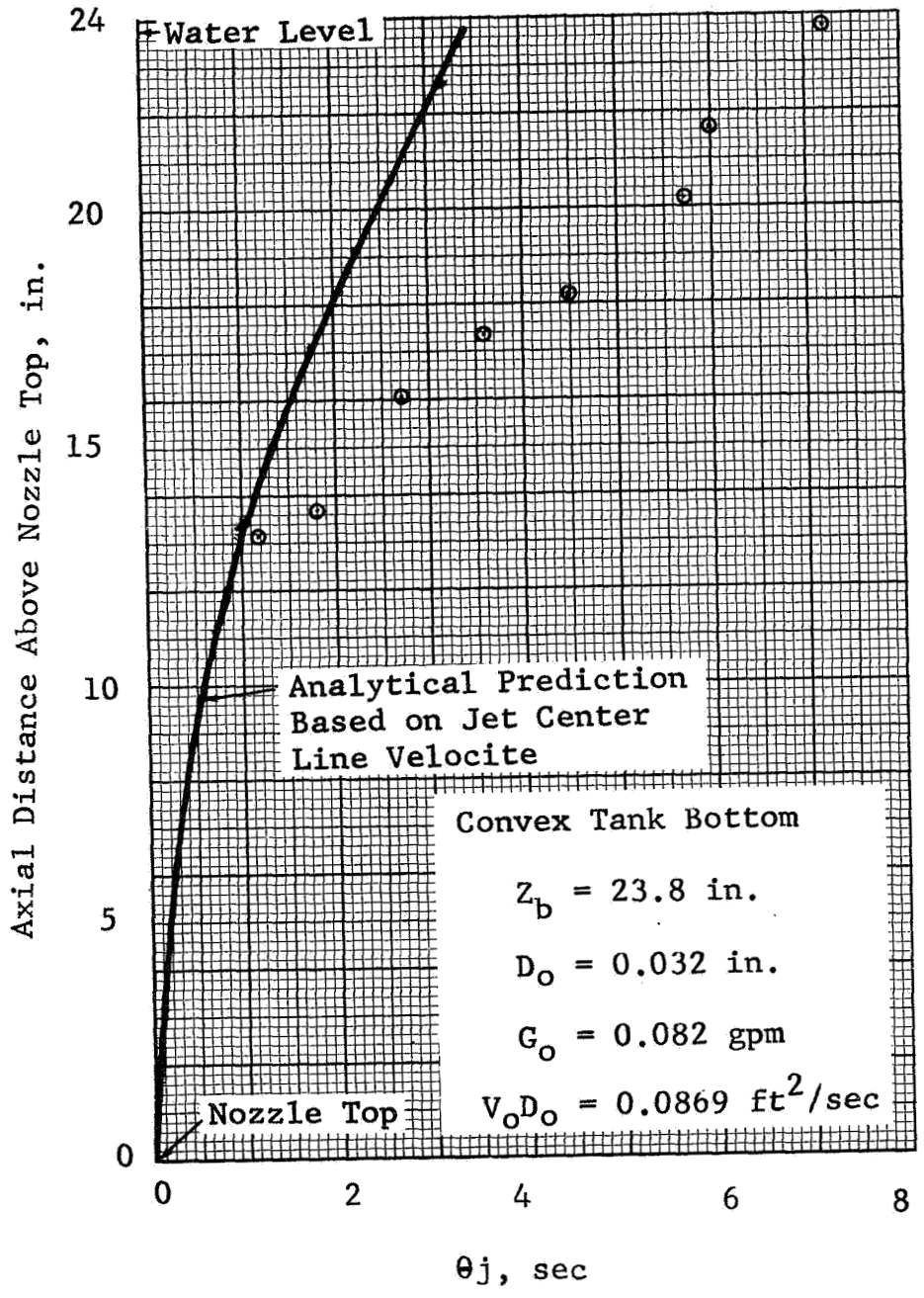


Figure 2.1-7 Axial Jet Motion After Pump Turned On: JP1

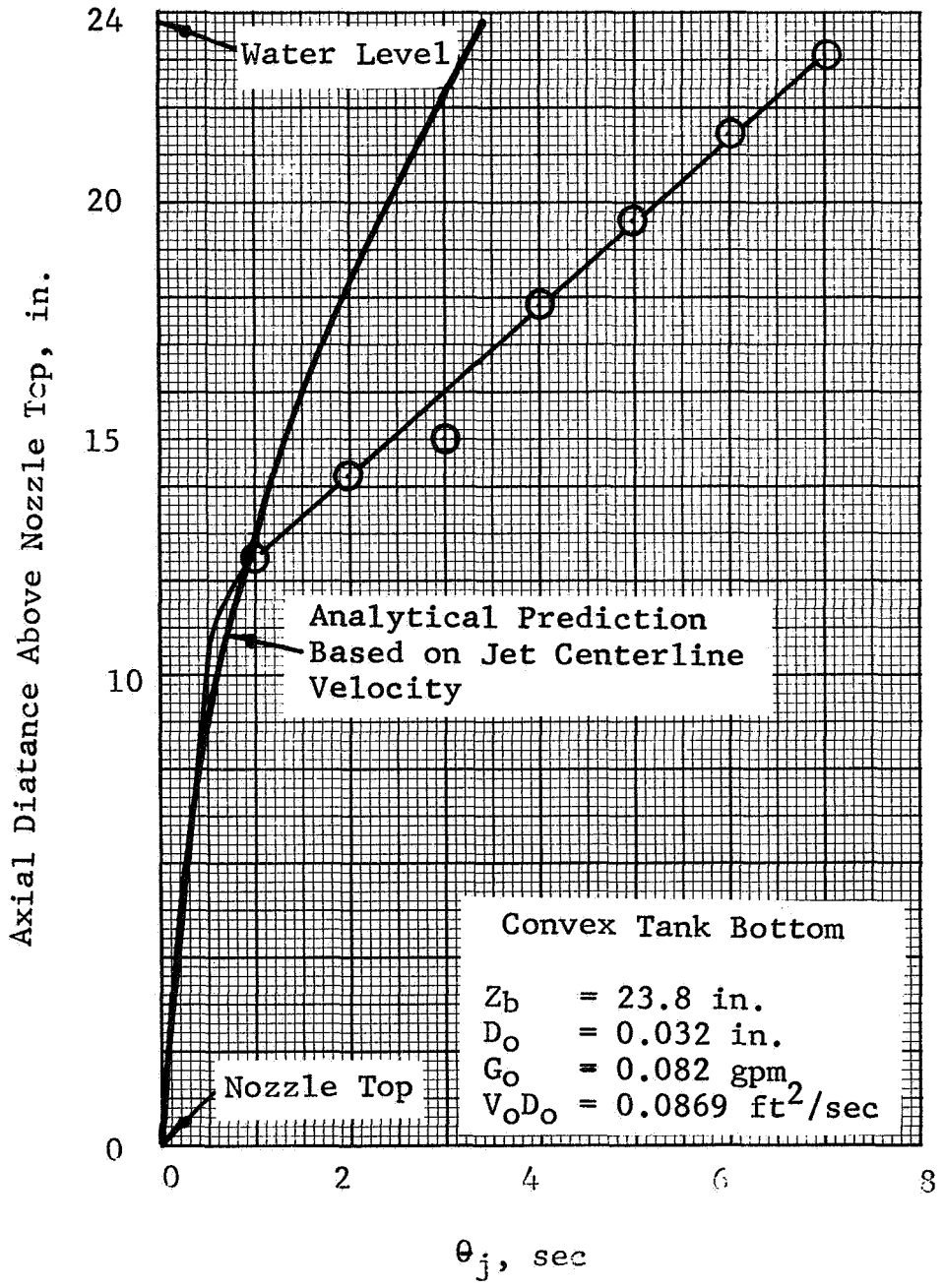


Figure 2.1-8 Axial Jet Motion After Pump Turned On: Test JP 2

2.2 JET MIXING DATA

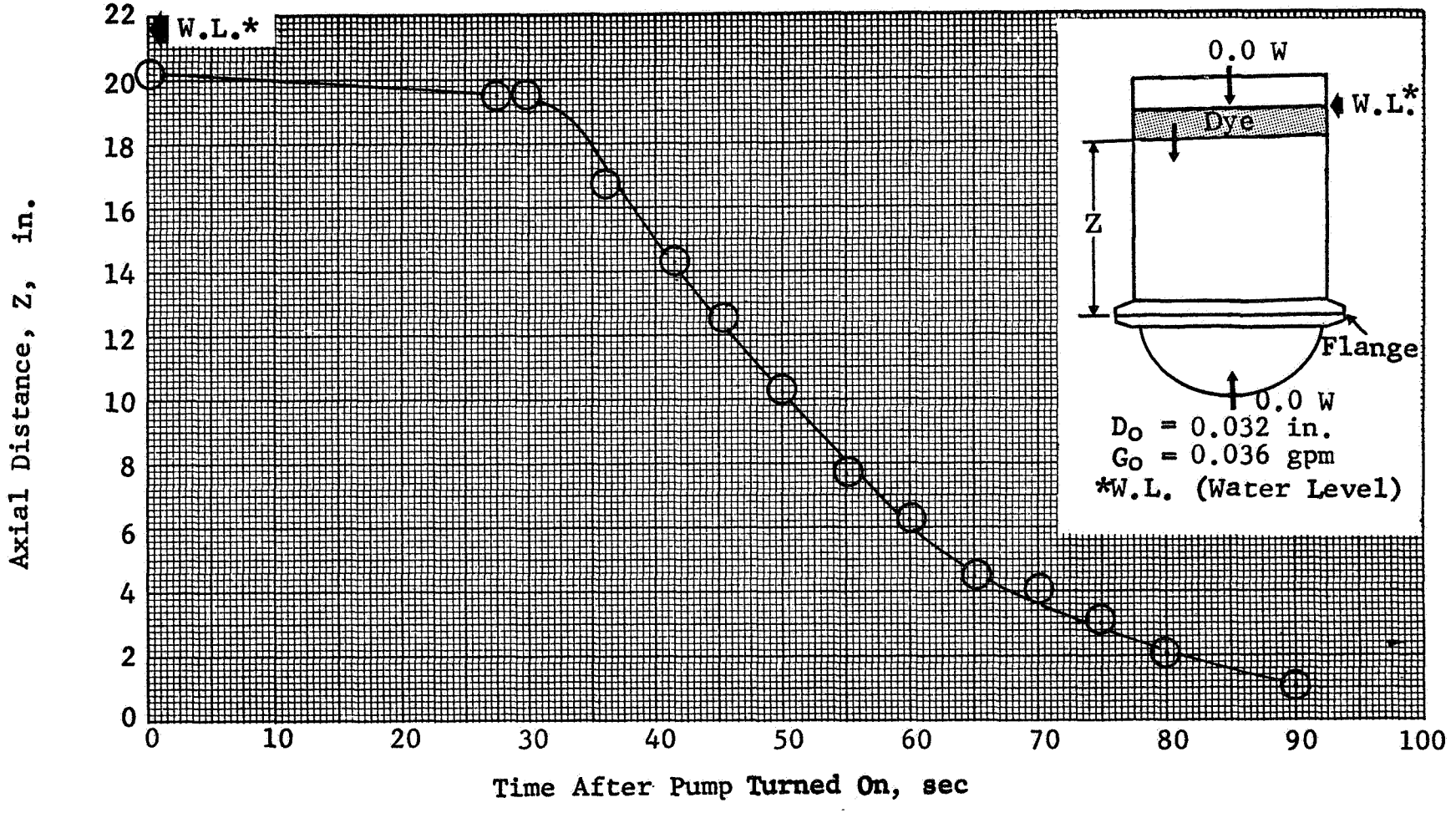


Figure 2.2-1 Axial Jet Dye Layer Motion: Test 1, Run 48

GENERAL DYNAMICS
Fort Worth Division

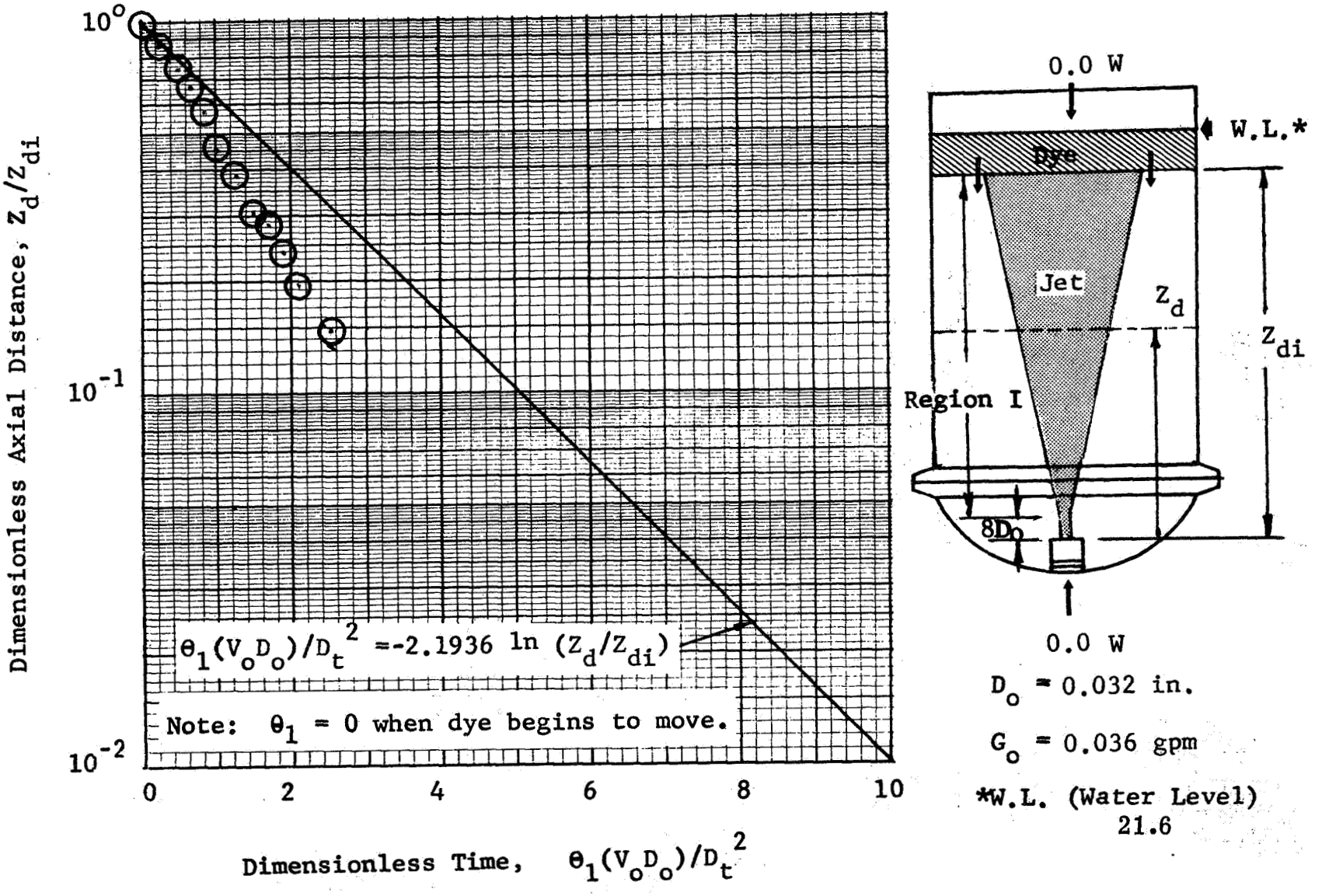


Figure 2.2-2 Correlation of Axial Jet Dye Layer Motion for Region I: Test 1, Run 48

GENERAL DYNAMICS
Fort Worth Division

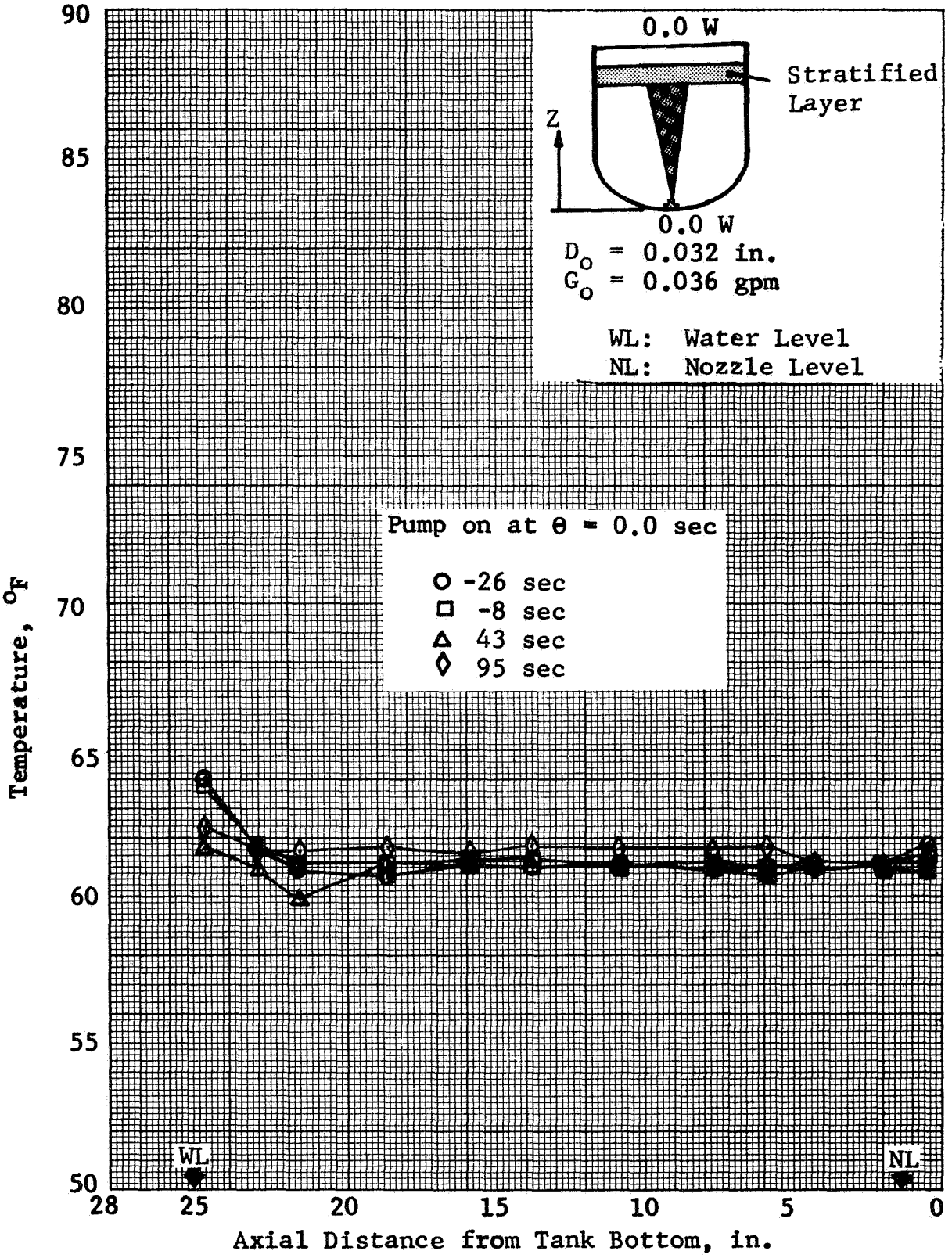


Figure 2.2-3 Temperature Distribution for Axial Jet Flow: Test 1, Run 48

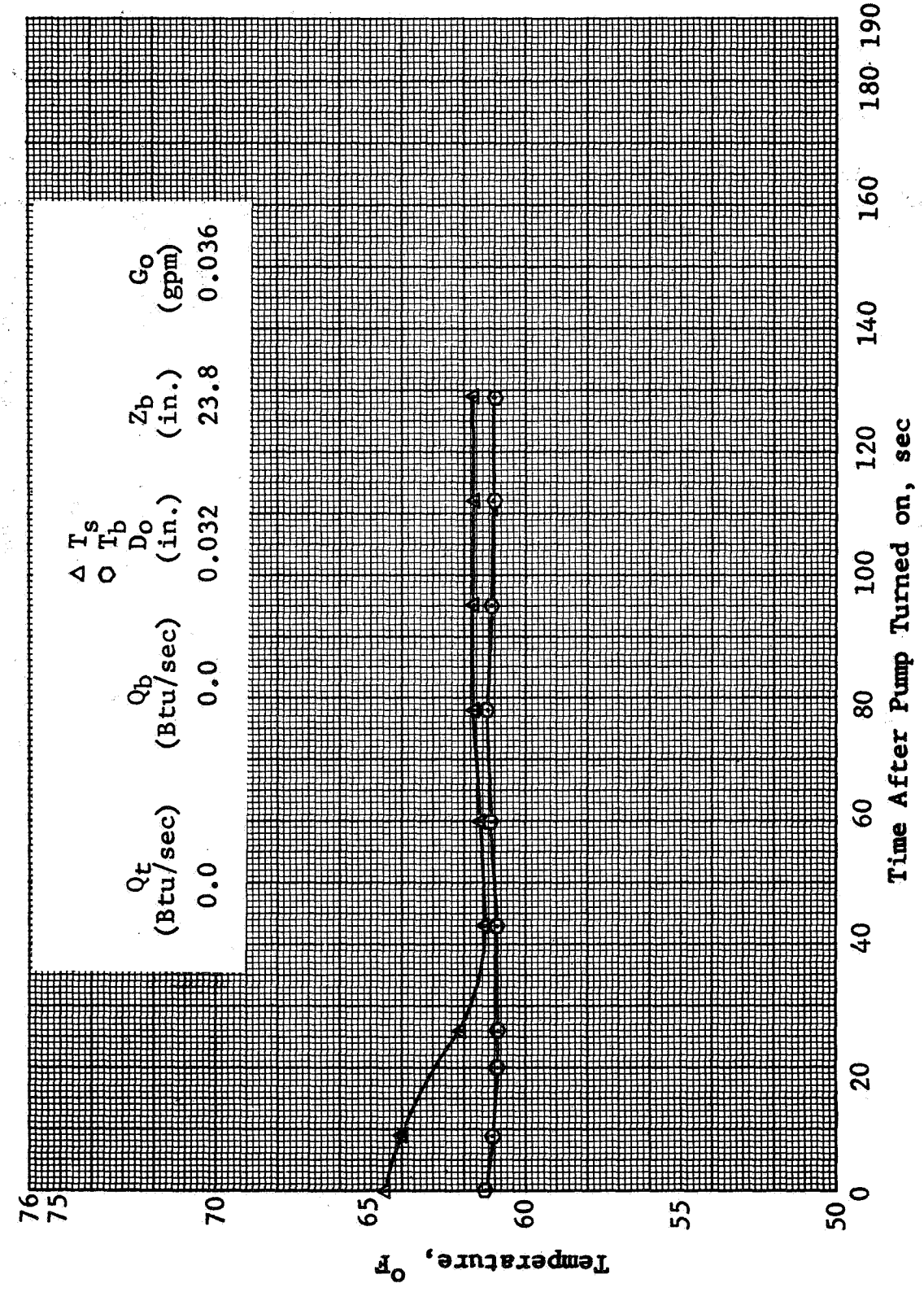


Figure 2.2-4 Transient Temperature Destratification: Test 1, Run 48

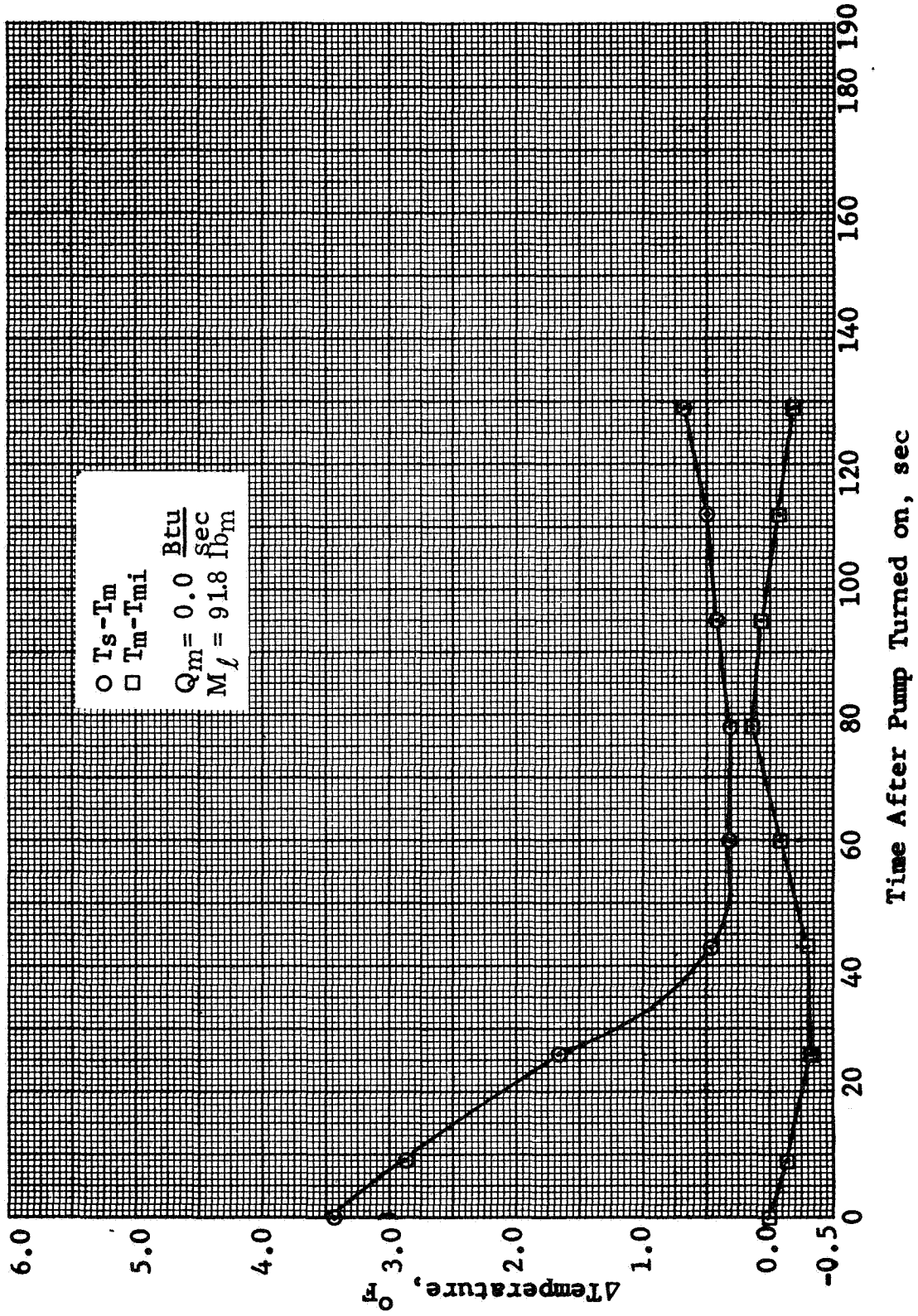


Figure 2.2-5 Transient ΔTemperature Destratification: Test 1, Run 48

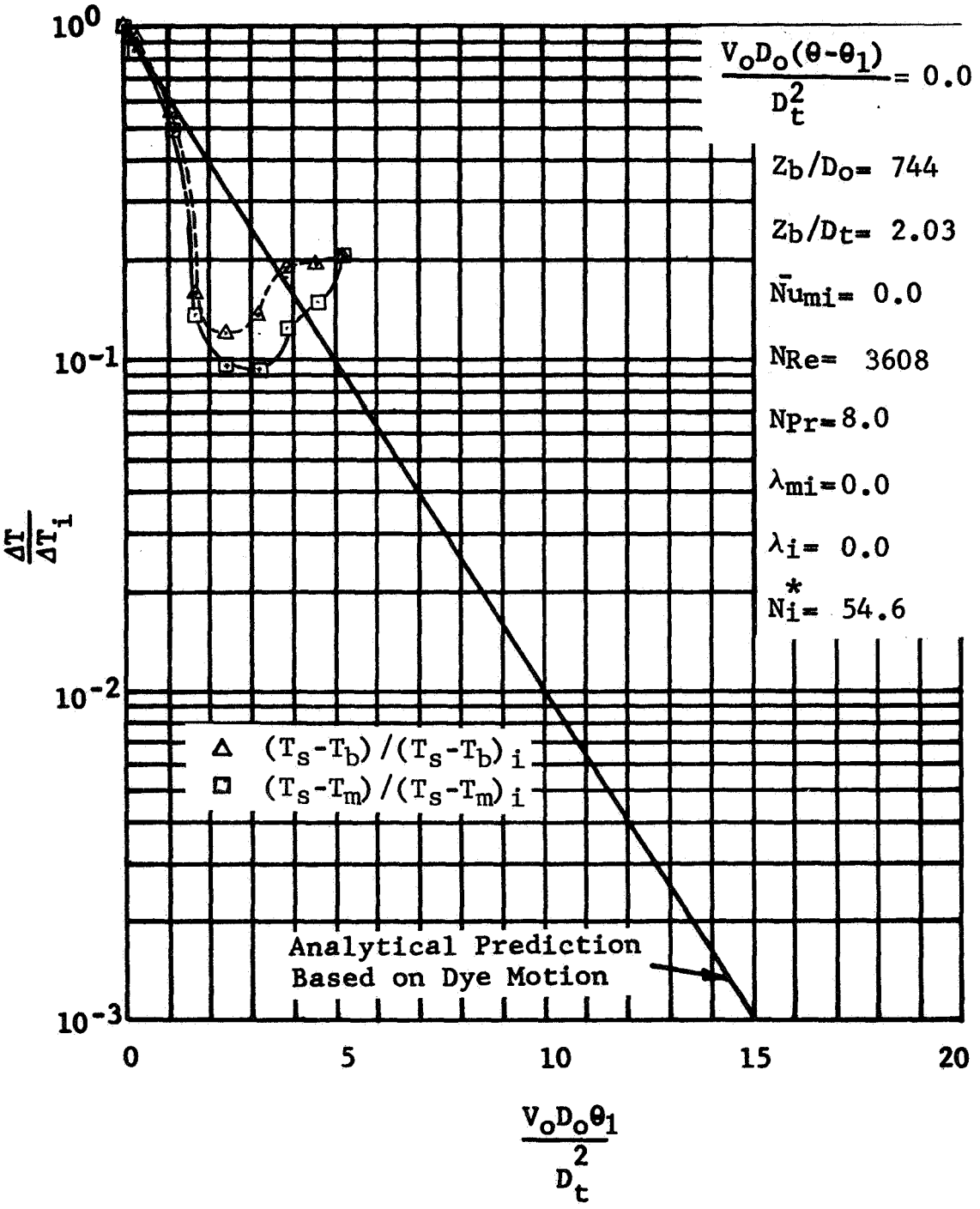


Figure 2.2-6 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 1, Run 48

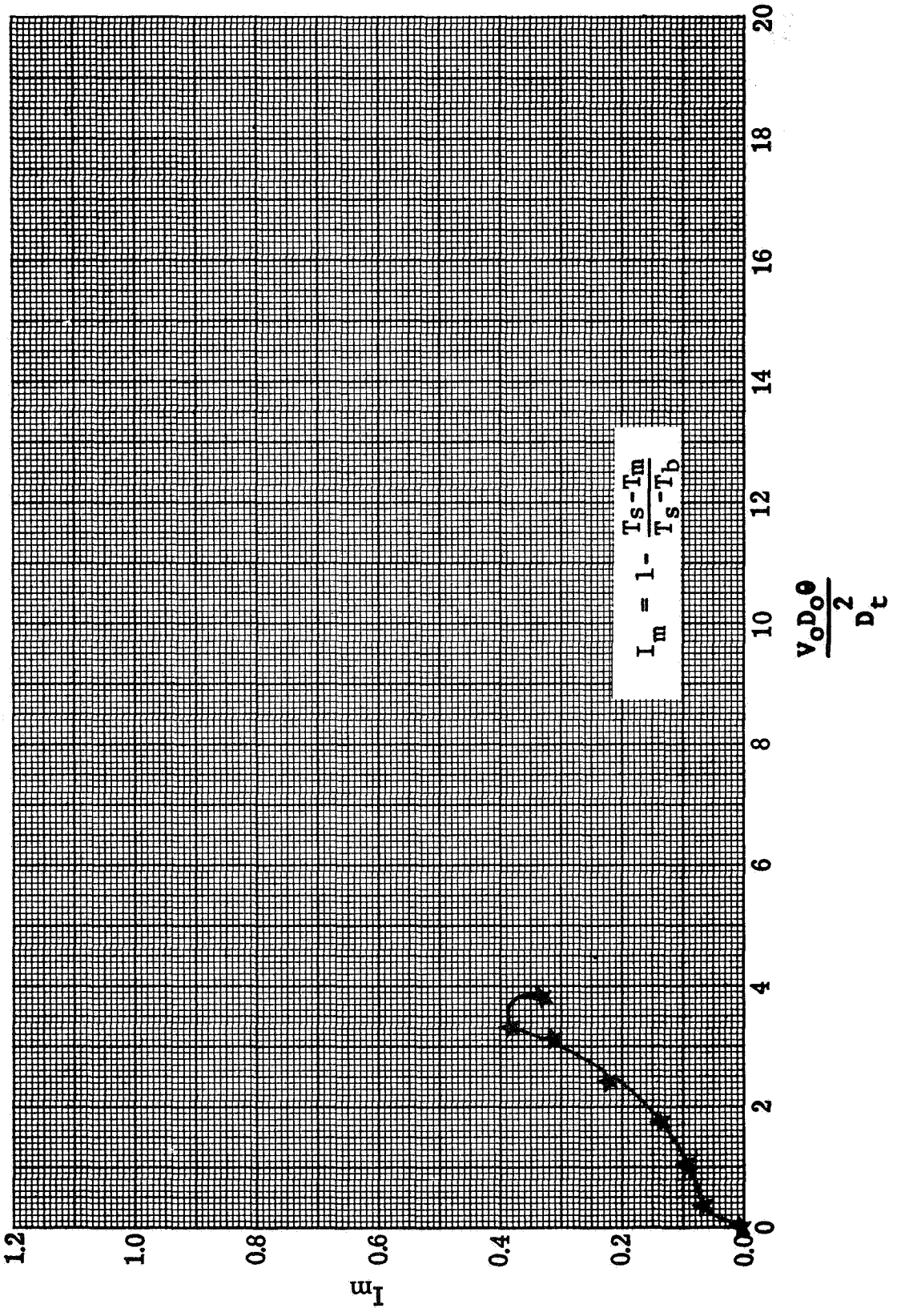


Figure 2.2-7 Transient Energy Integral: Test 1, Run 48

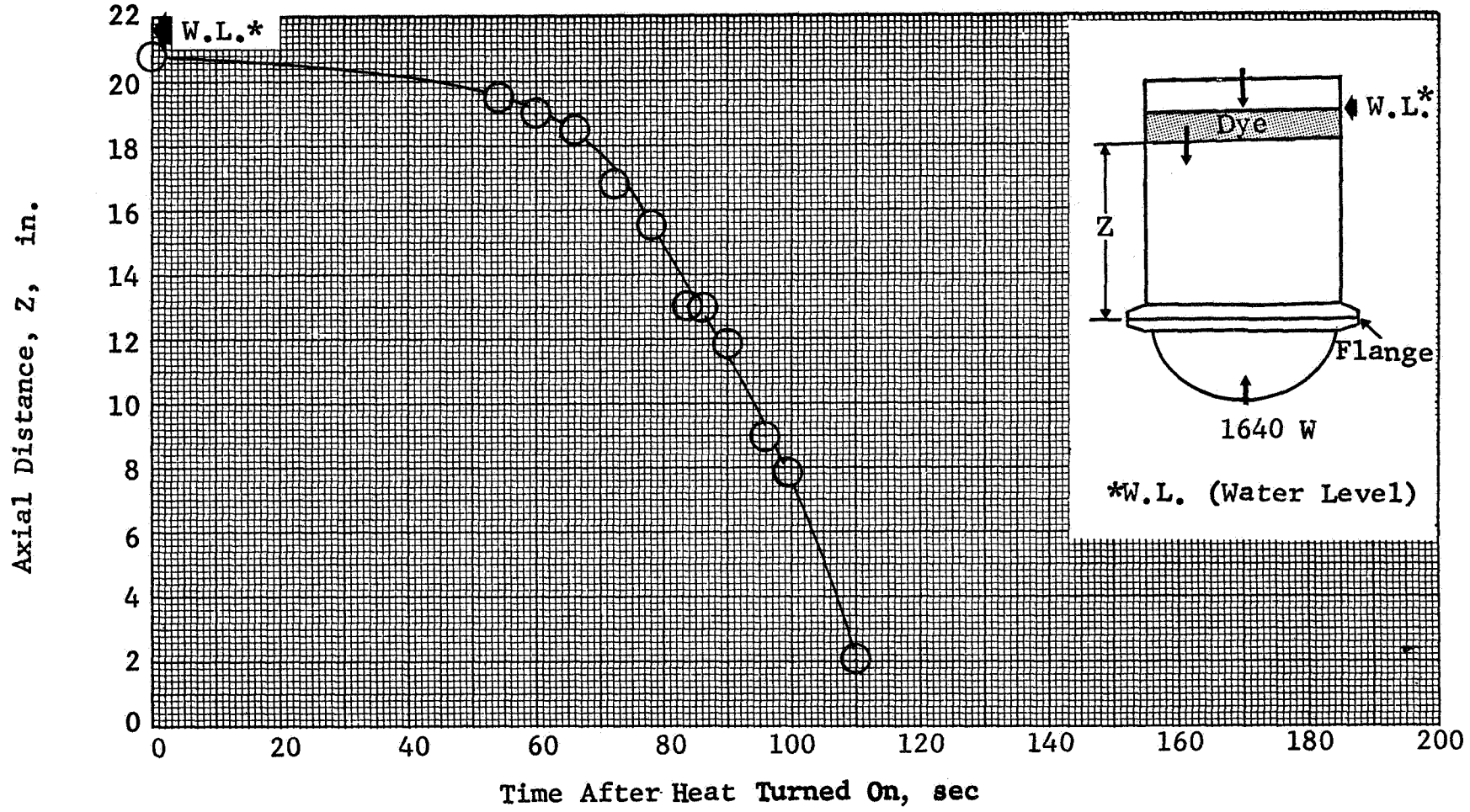


Figure 2.2-8 Axial Jet Dye Layer Motion: Test 2, Run 47

GENERAL DYNAMICS
Fort Worth Division

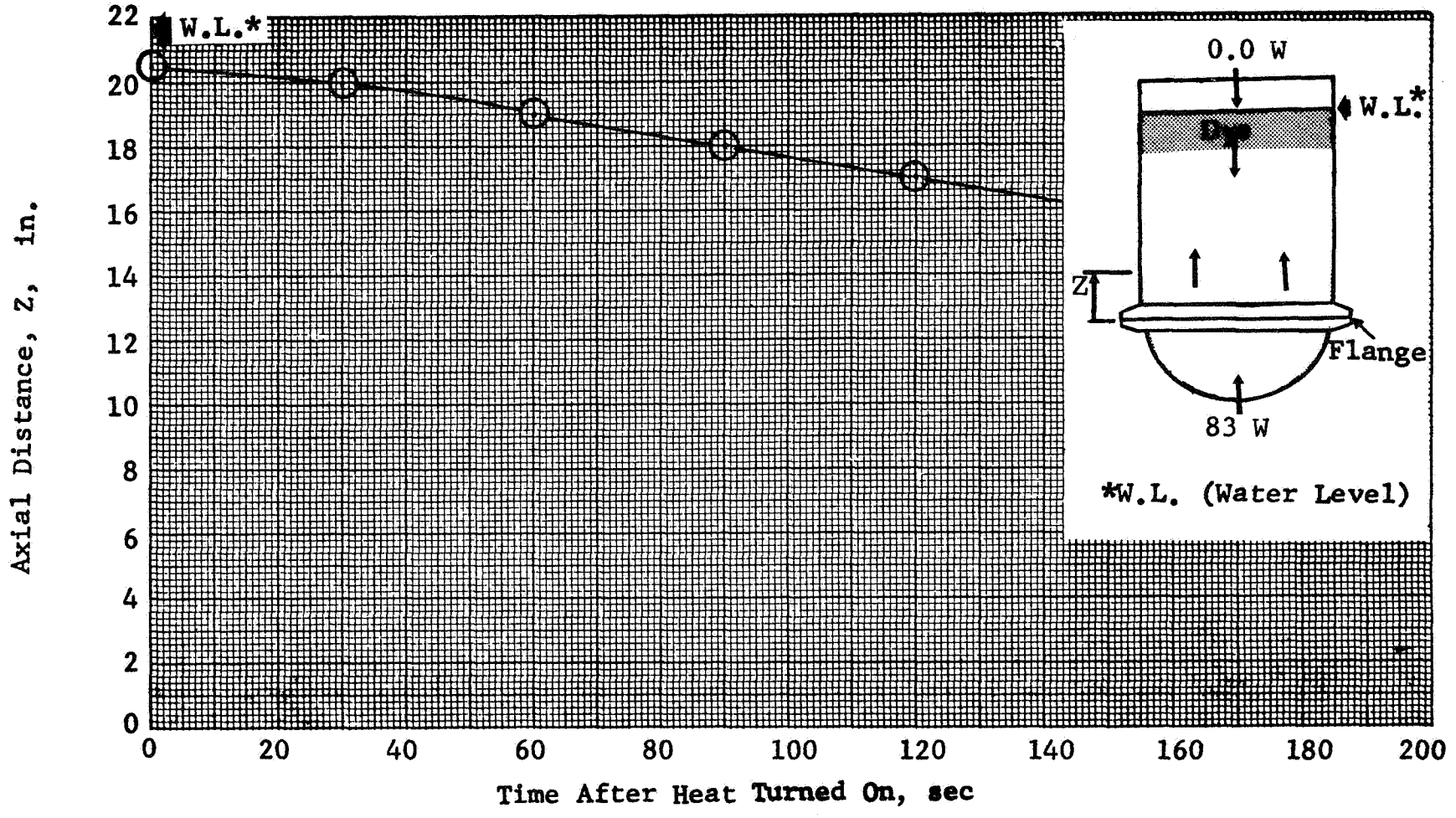


Figure 2.2-9 Axial Dye Layer Motion: Test 3, Run 49

GENERAL DYNAMICS
Fort Worth Division

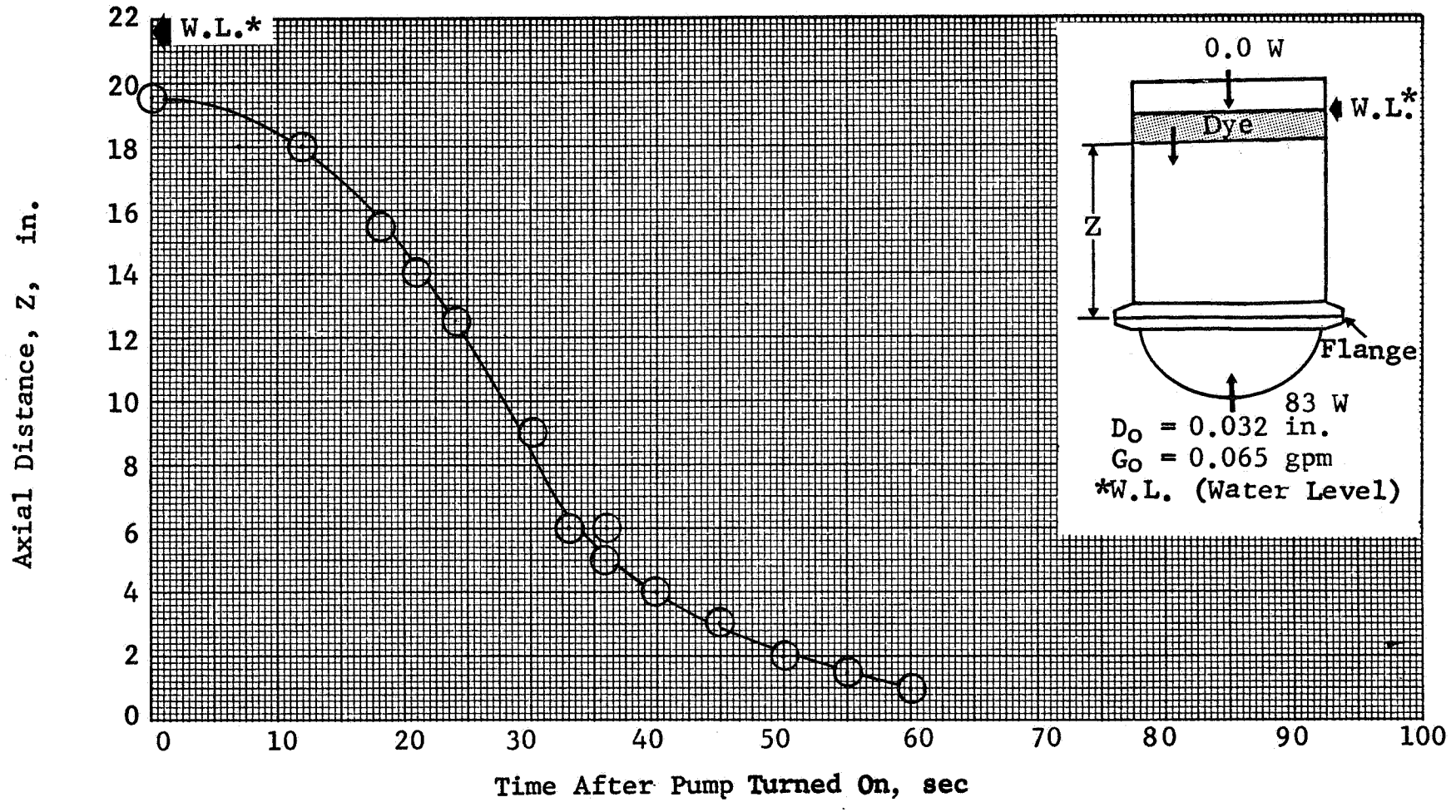


Figure 2.2-10 Axial Jet Dye Layer Motion: Test 3, Run 49

GENERAL DYNAMICS
Fort Worth Division

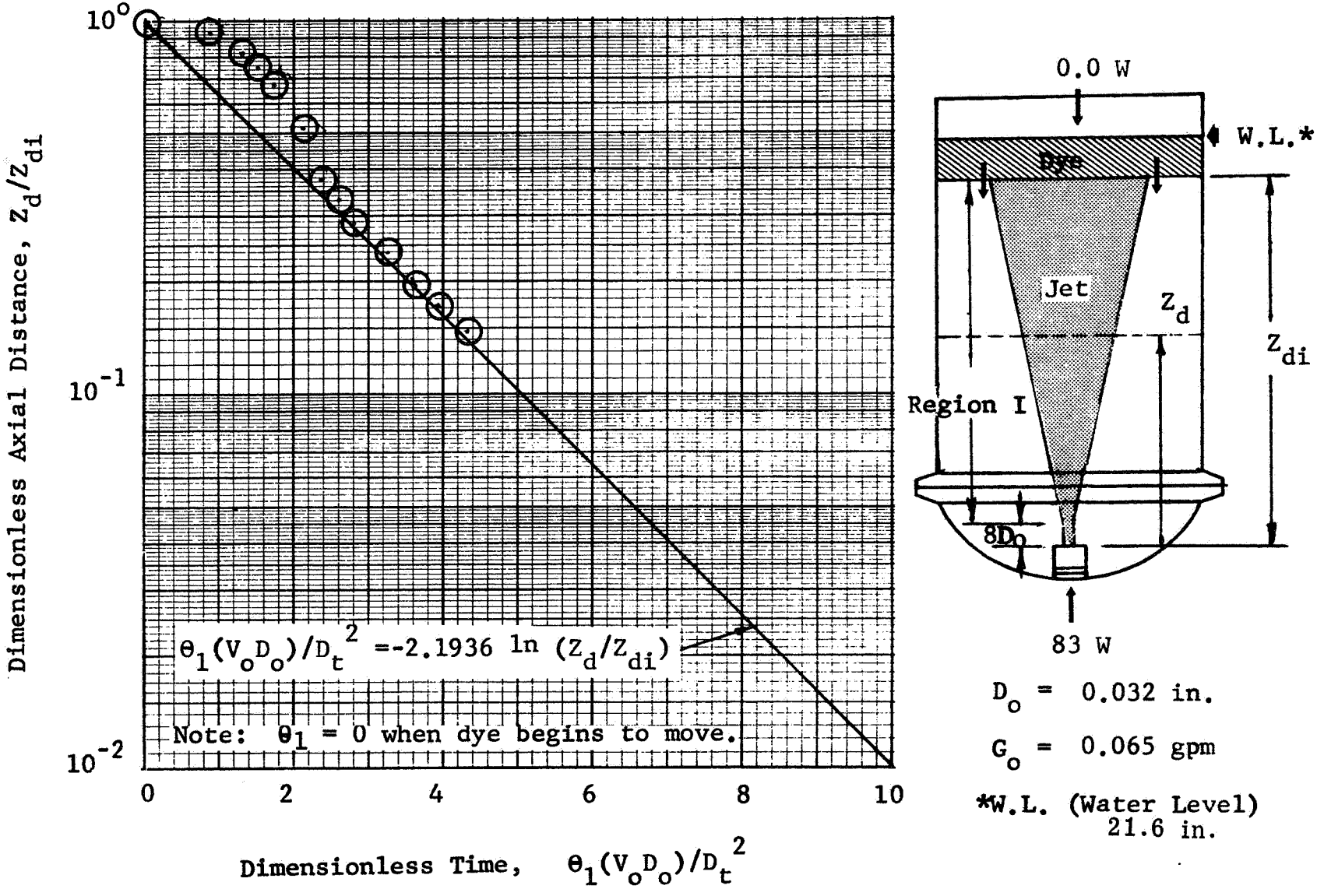


Figure 2.2-11 Correlation of Axial Jet Dye Layer Motion for Region I: Test 3, Run 49

GENERAL DYNAMICS
Fort Worth Division

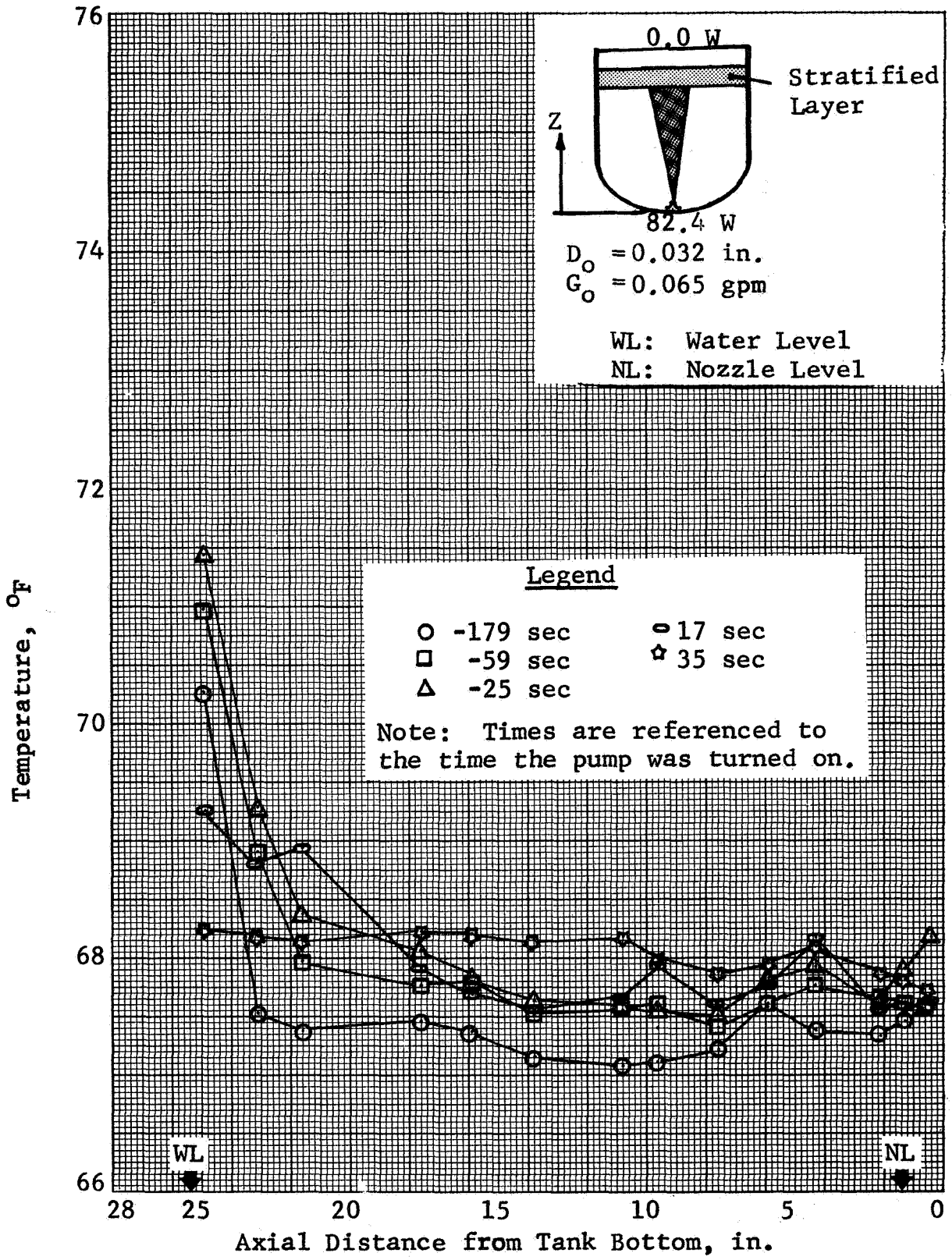


Figure 2.2-12 Temperature Distribution for Axial Jet Flow: Test 3, Run 49

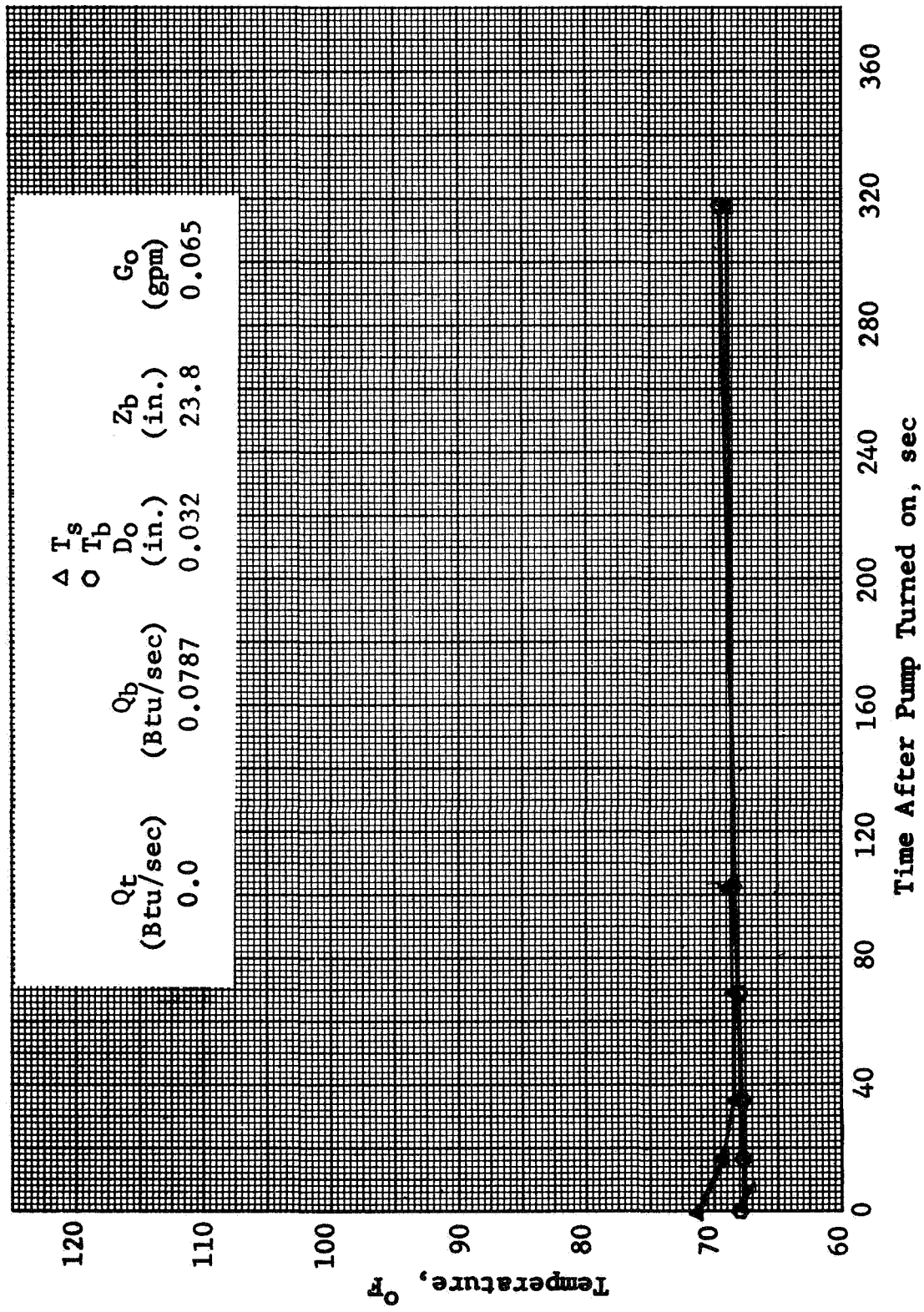


Figure 2.2-13 Transient Temperature Destratification: Test 3, Run 49

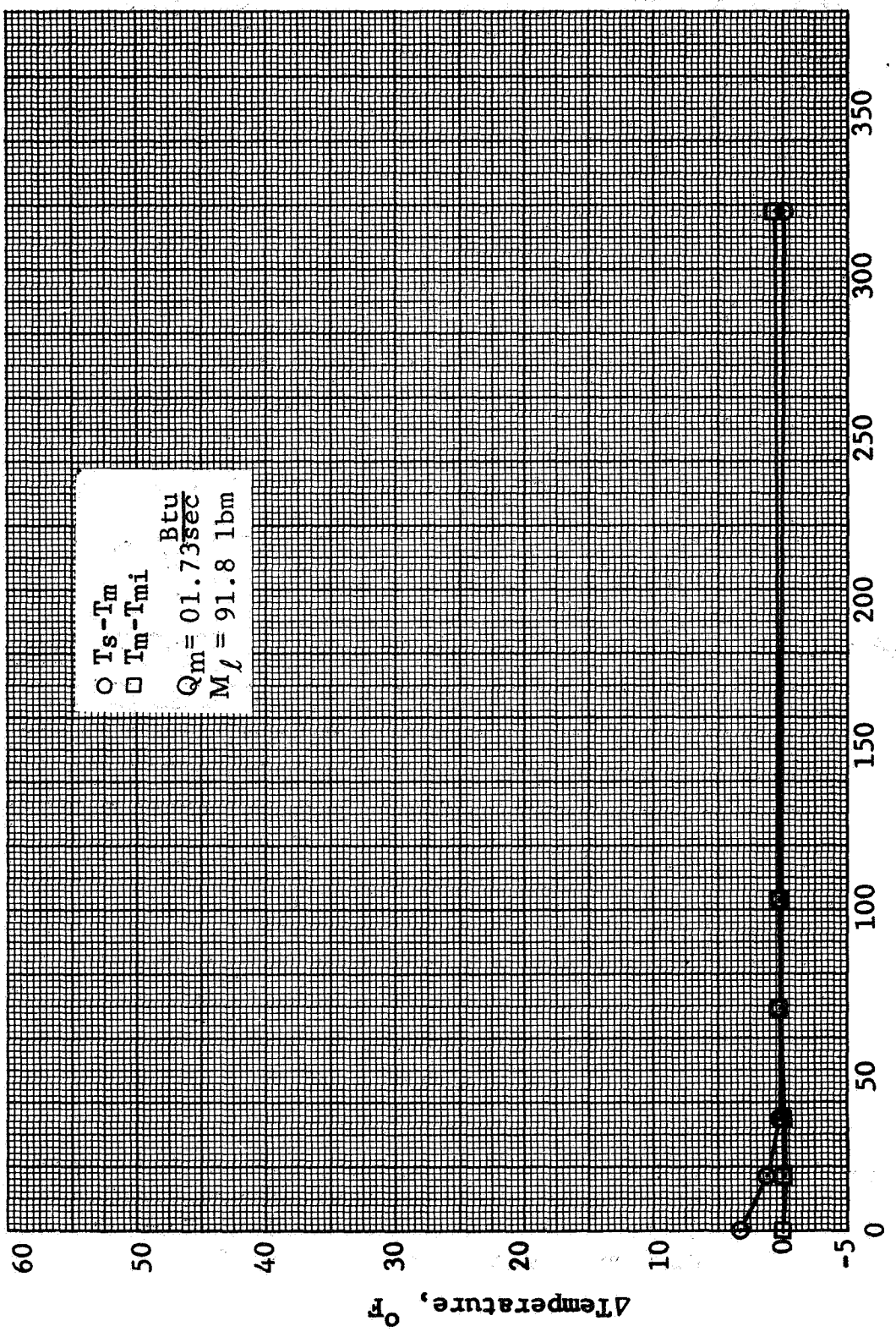


Figure 2.2-14 Transient ΔTemperature Destratification: Test 3, Run 49

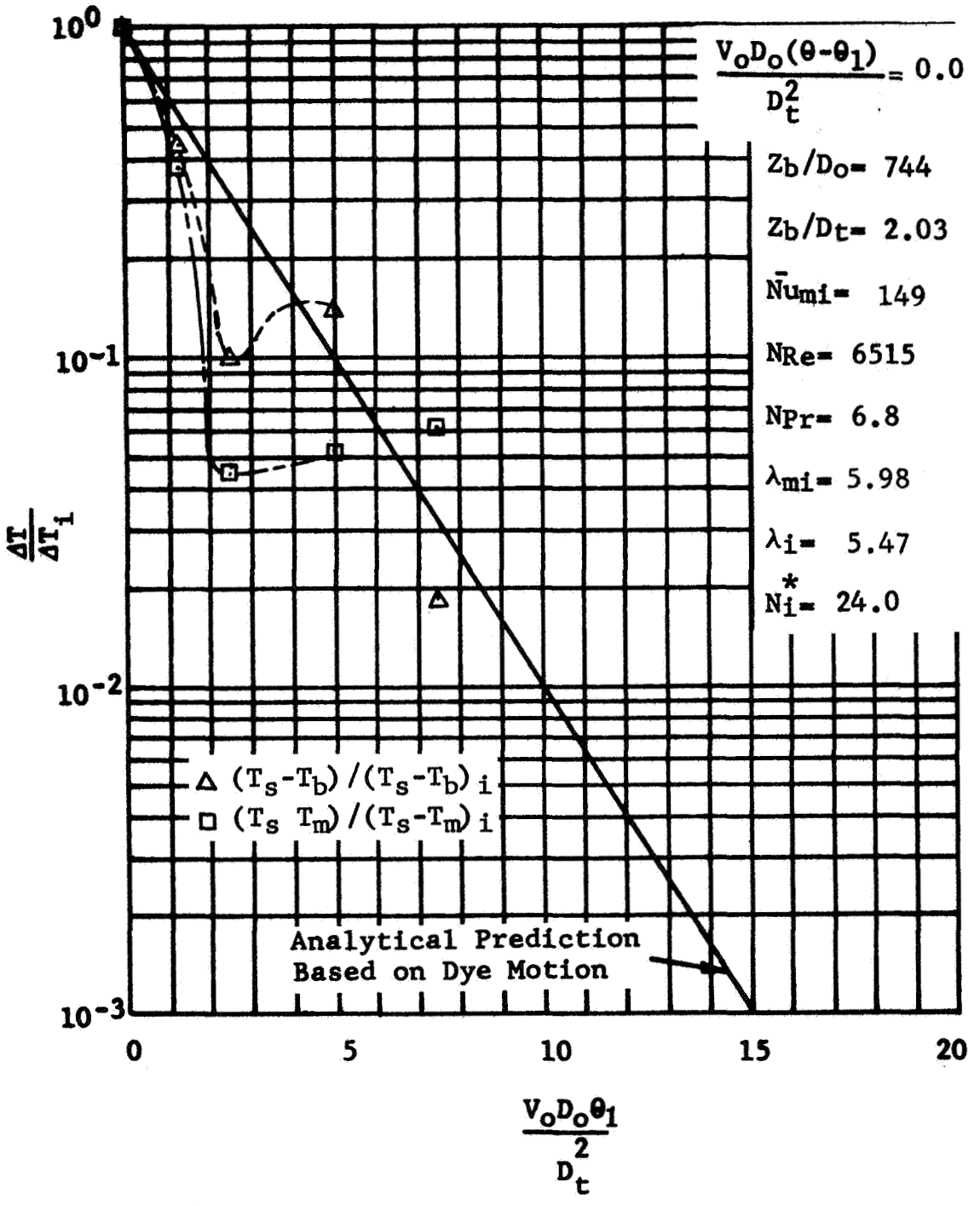


Figure 2.2-15 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 3, Run 49

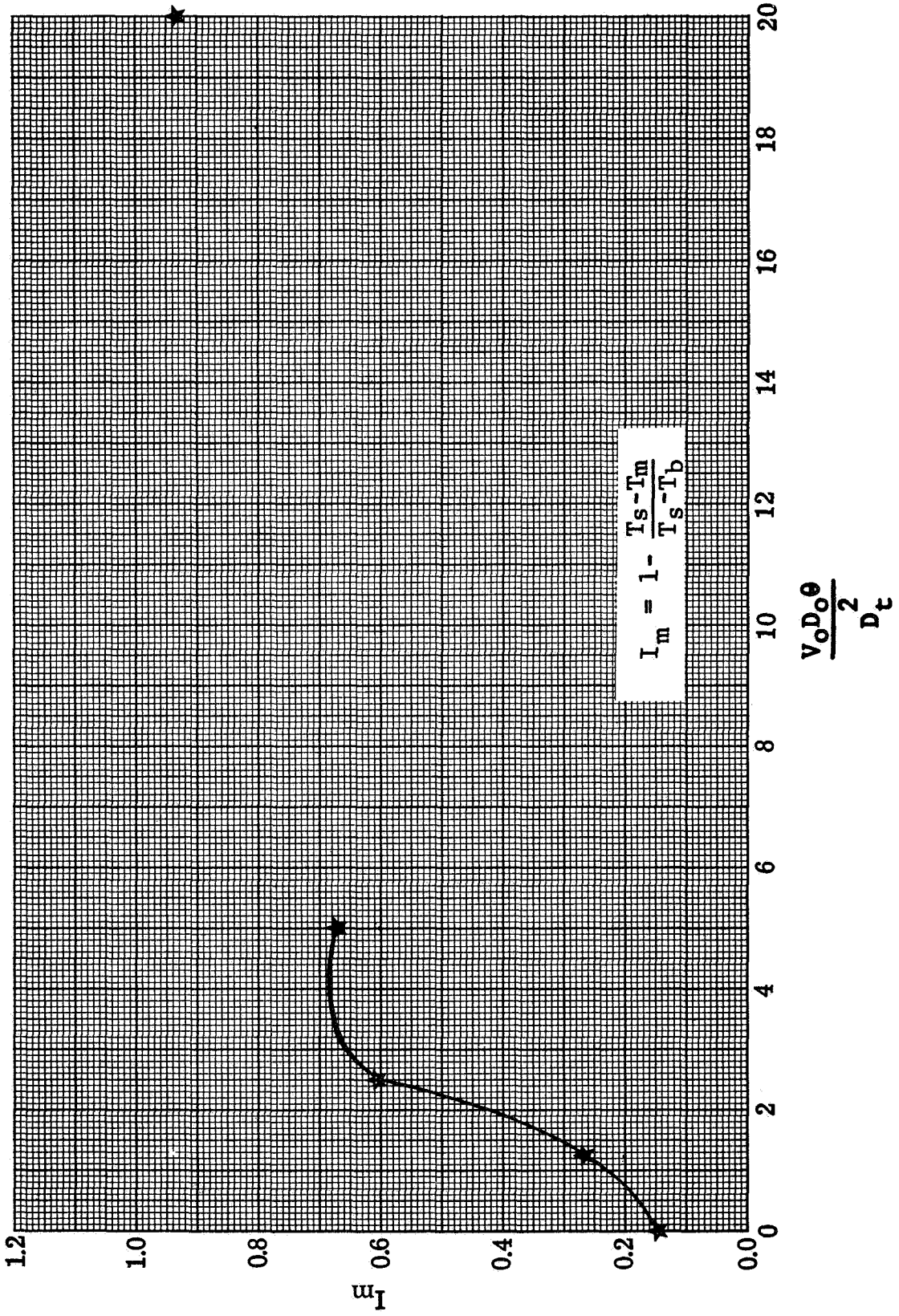


Figure 2.2-16 Transient Energy Integral: Test 3, Run 49

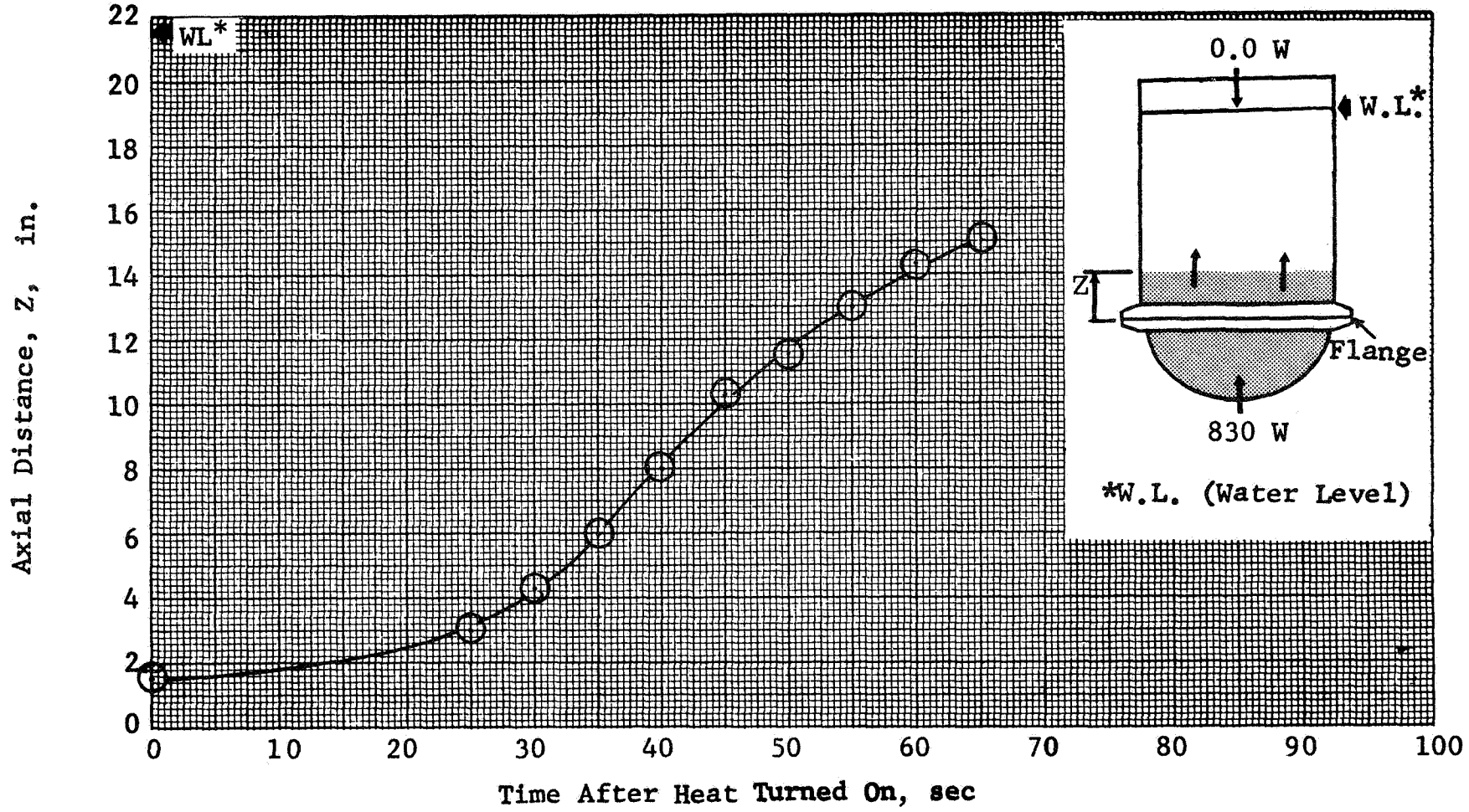


Figure 2.2-17 Axial Dye Layer Motion: Test 4, Run 53

GENERAL DYNAMICS
Fort Worth Division

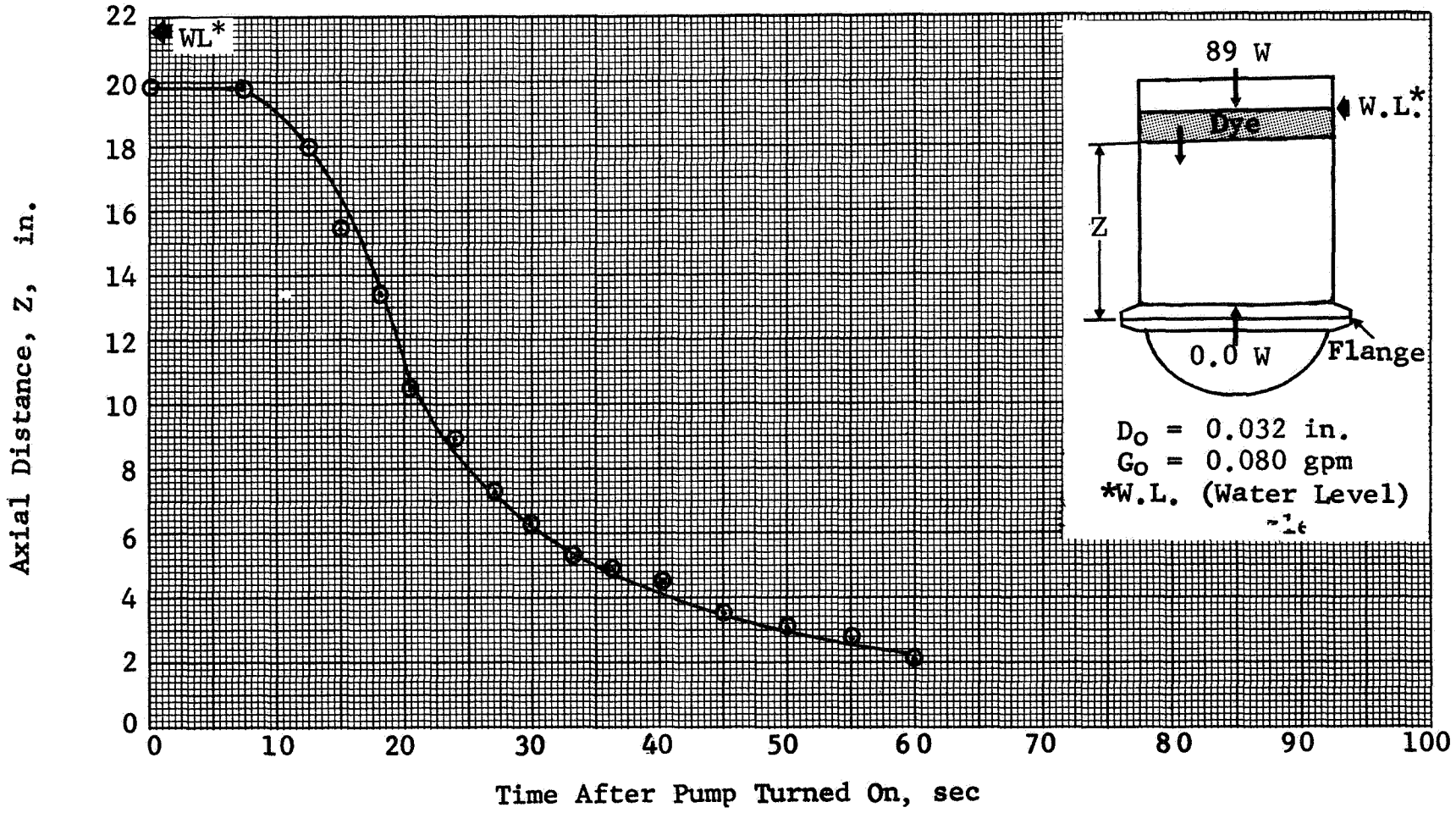


Figure 2.2-18 Axial Jet Dye Layer Motion: Test 5, Run 50

GENERAL DYNAMICS
Fort Worth Division

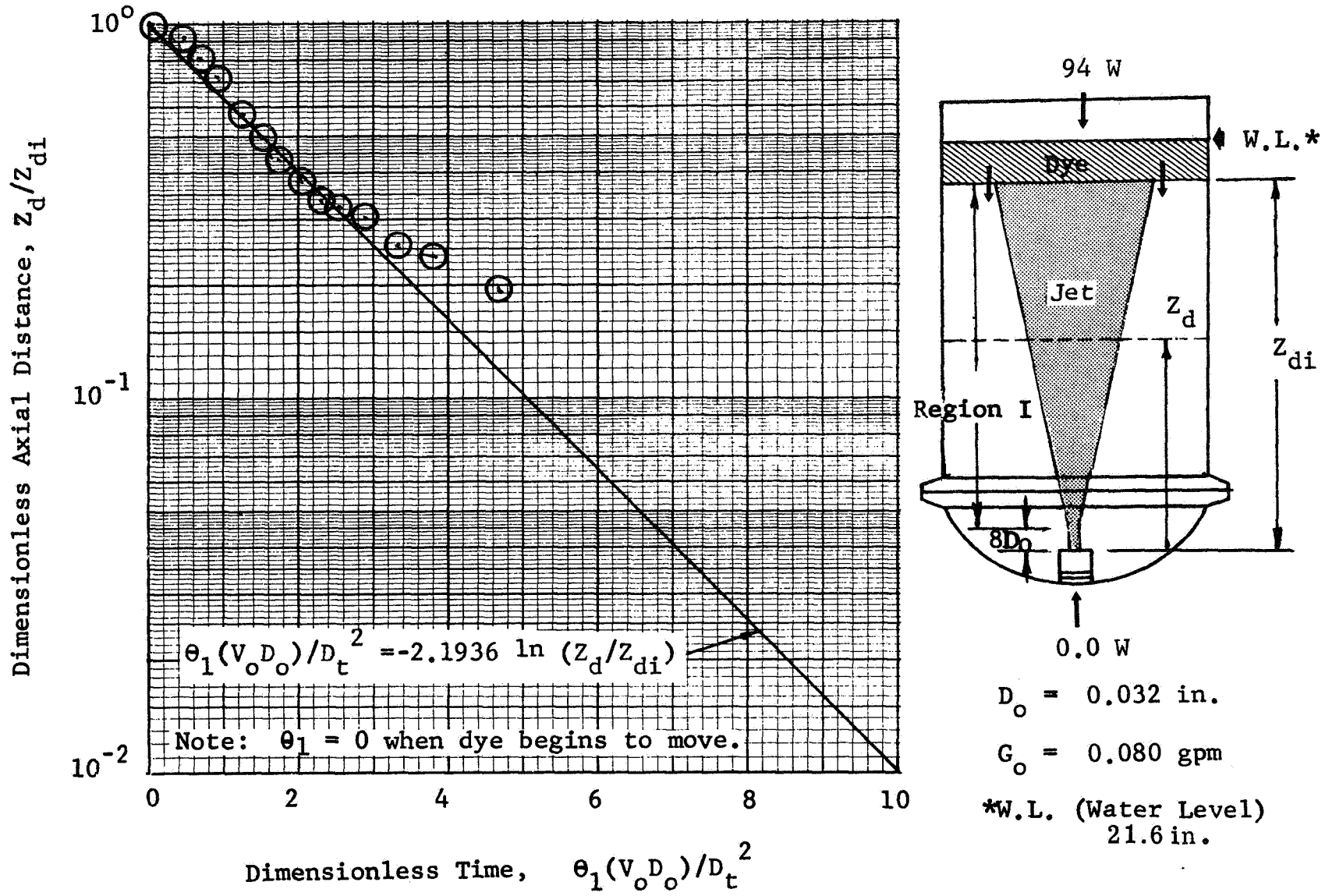


Figure 2.2-19 Correlation of Axial Jet Dye Layer Motion for Region I: Test 5, Run 50

GENERAL DYNAMICS
Fort Worth Division

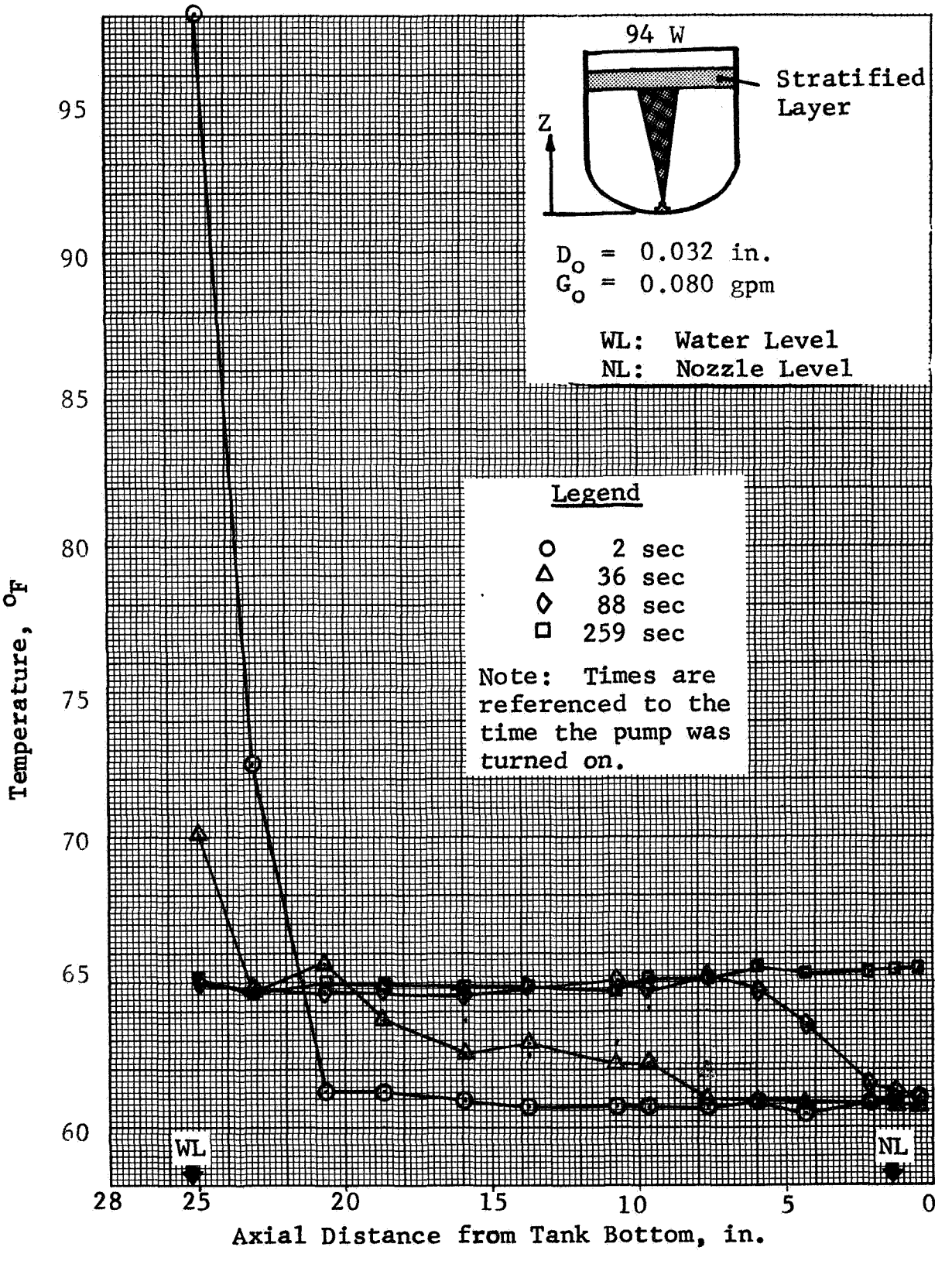


Figure 2.2-20 Temperature Distribution for Axial Jet Flow: Test 5, Run 50

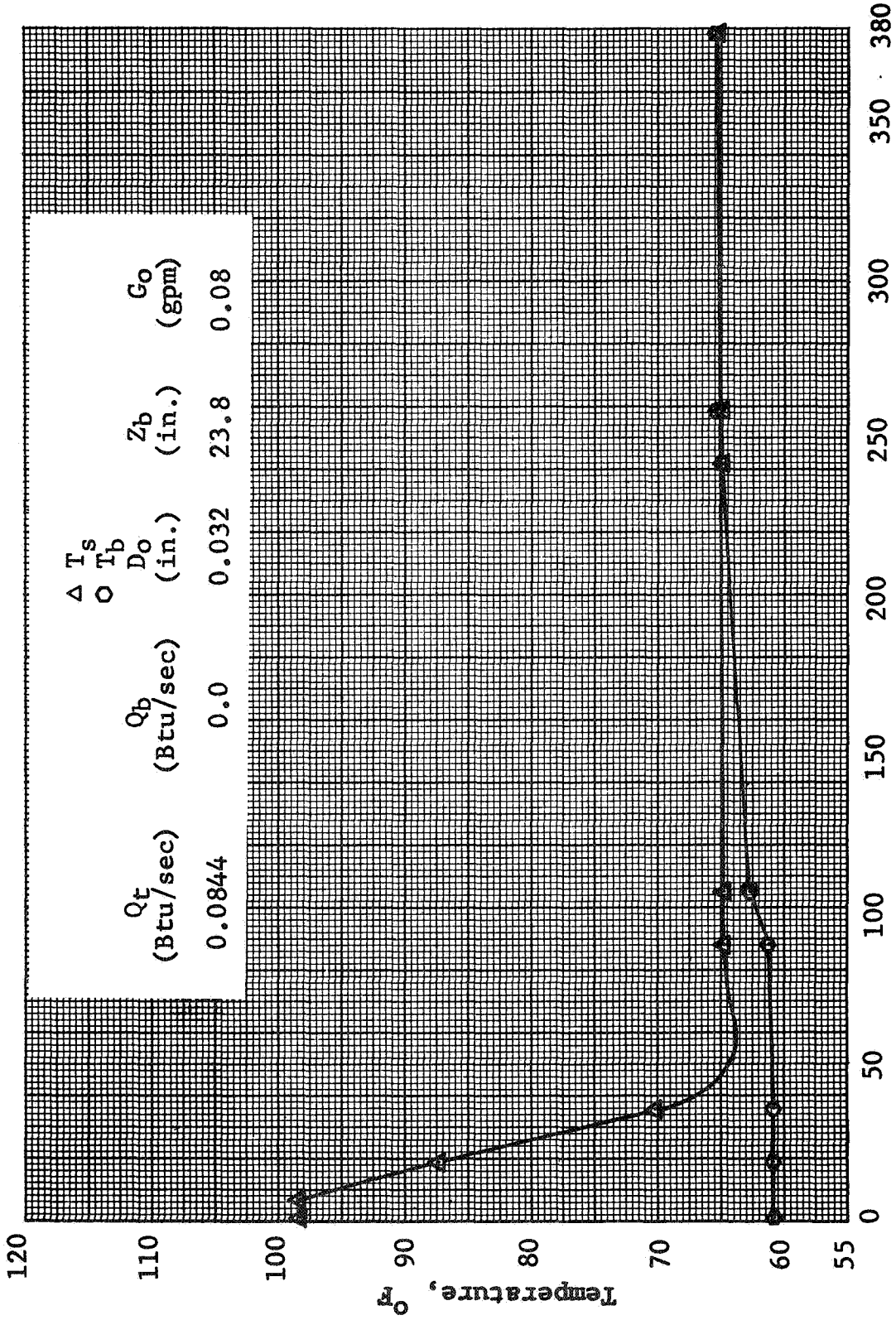


Figure 2.2-21 Transient Temperature Destratification: Test 5, Run 50

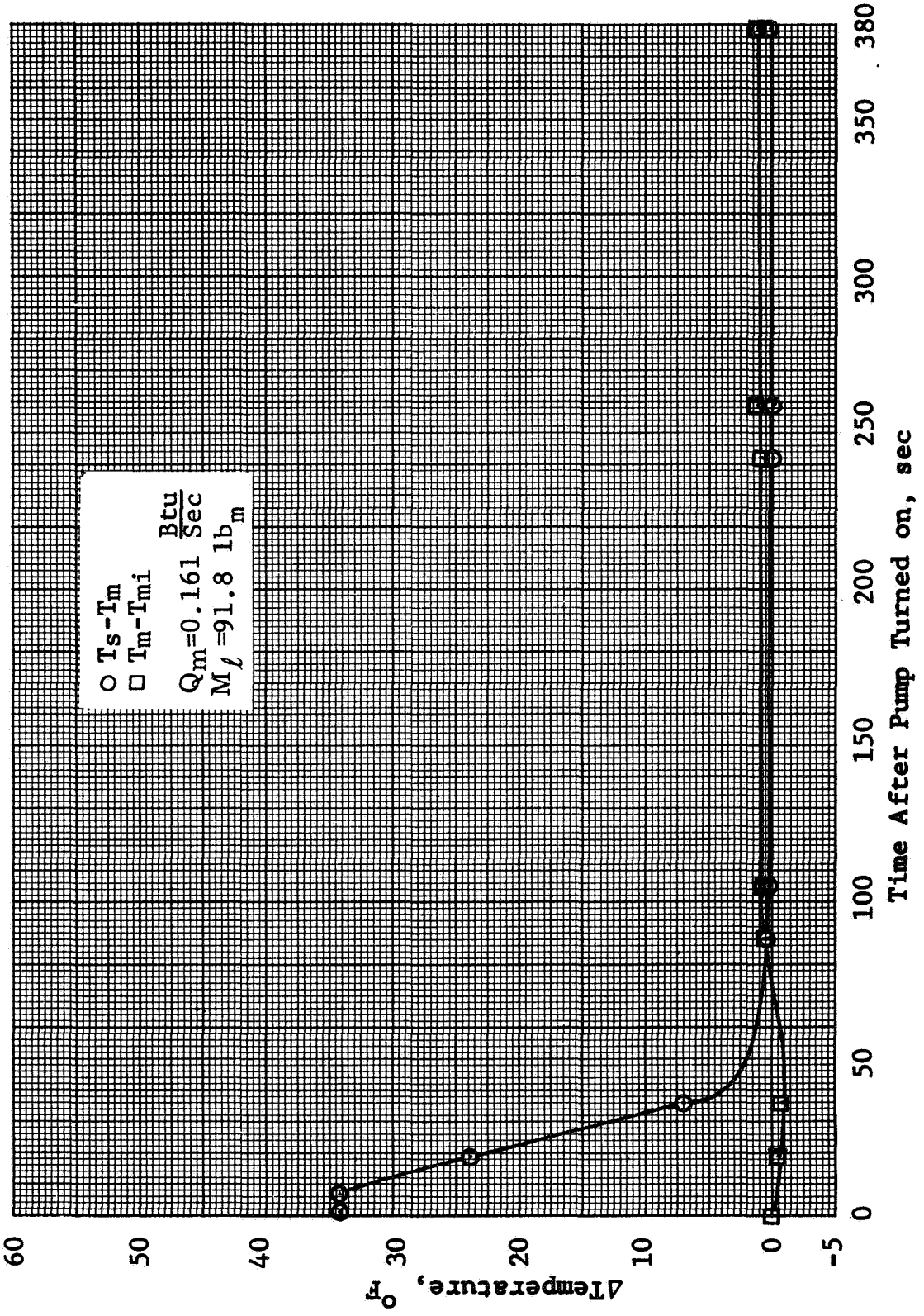


Figure 2.2-22 Transient ΔTemperature Destratification: Test 5, Run 50

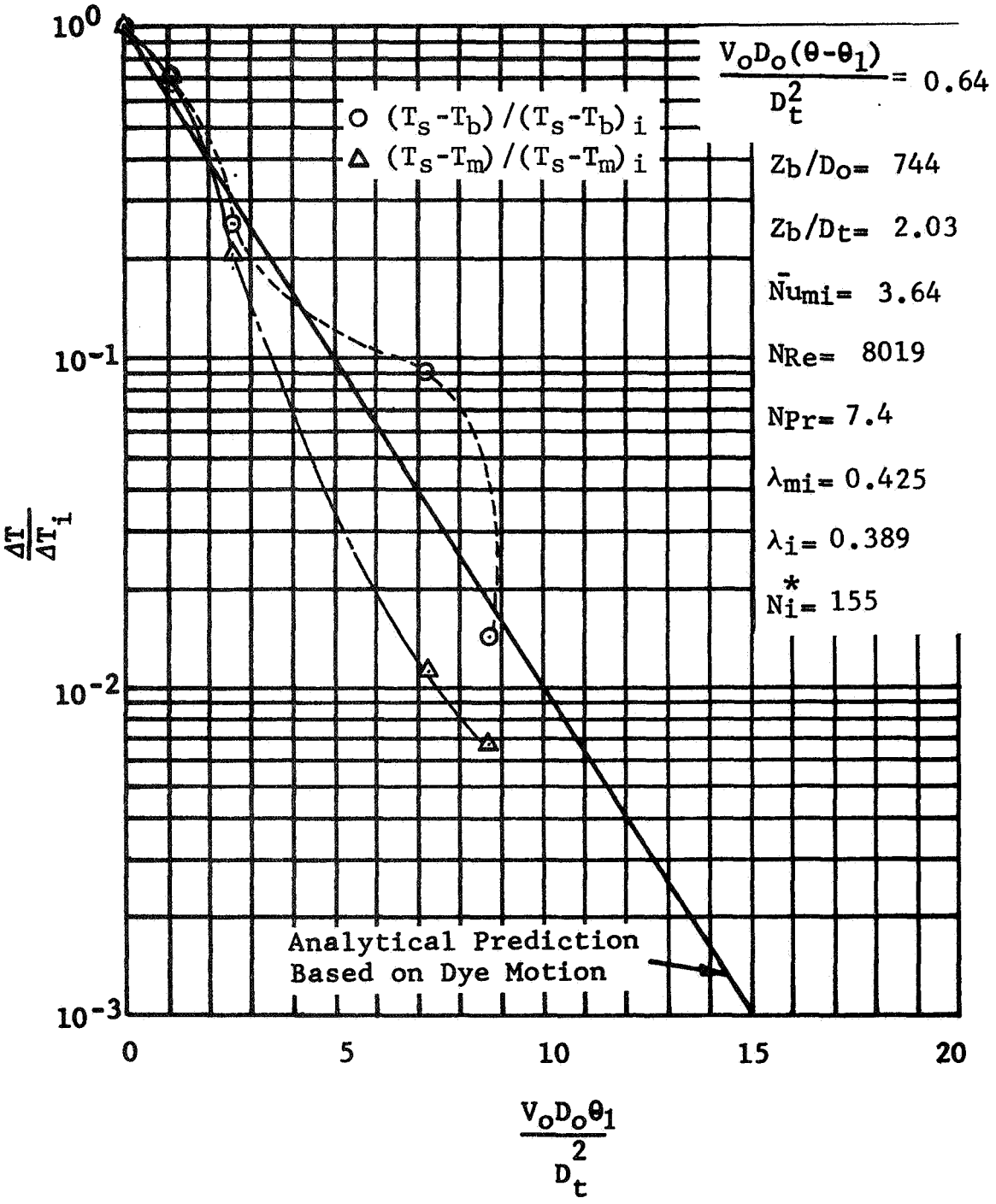


Figure 2.2-23 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 5, Run 50

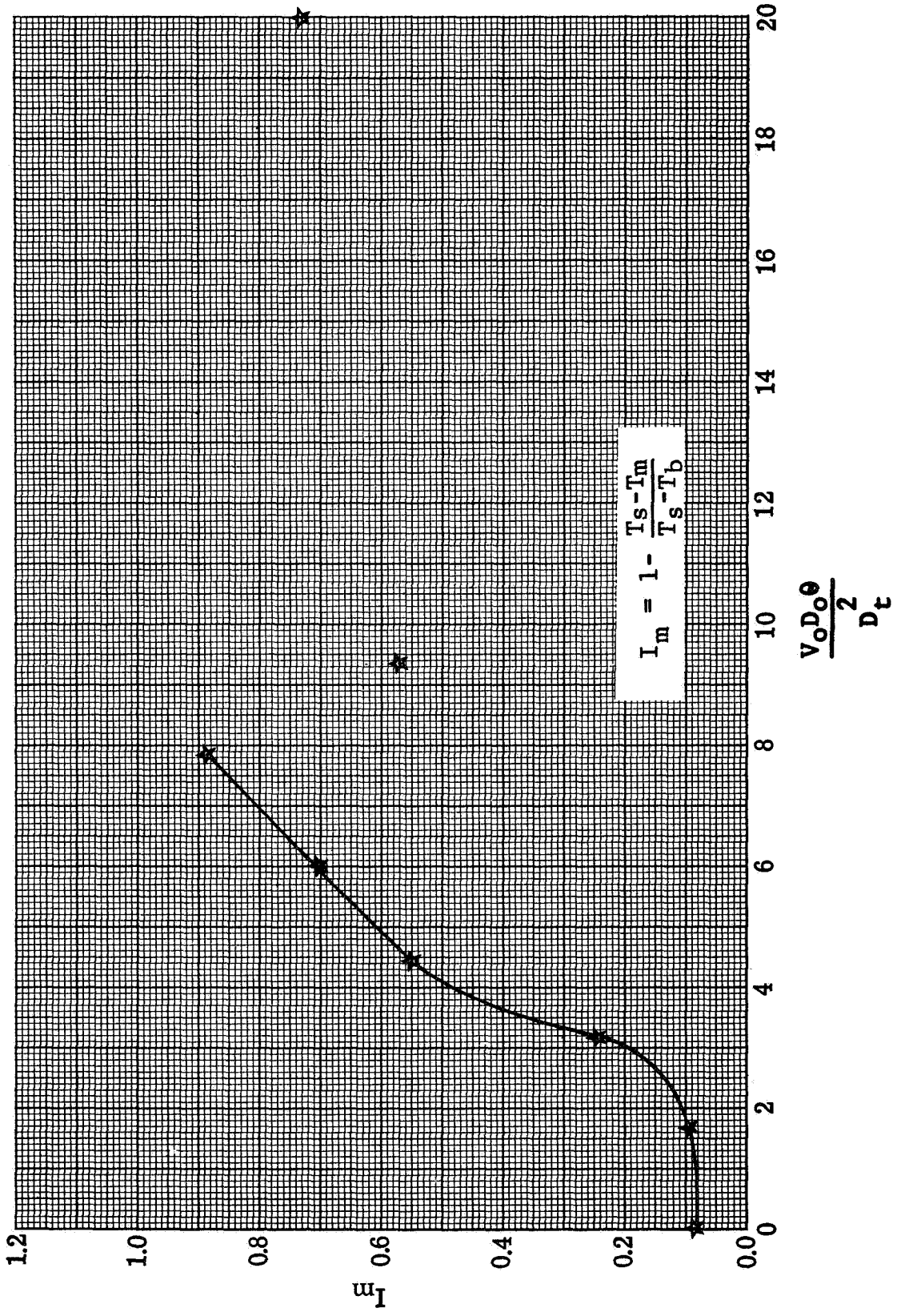


Figure 2.2-24 Transient Energy Integral: Test 5, Run 50

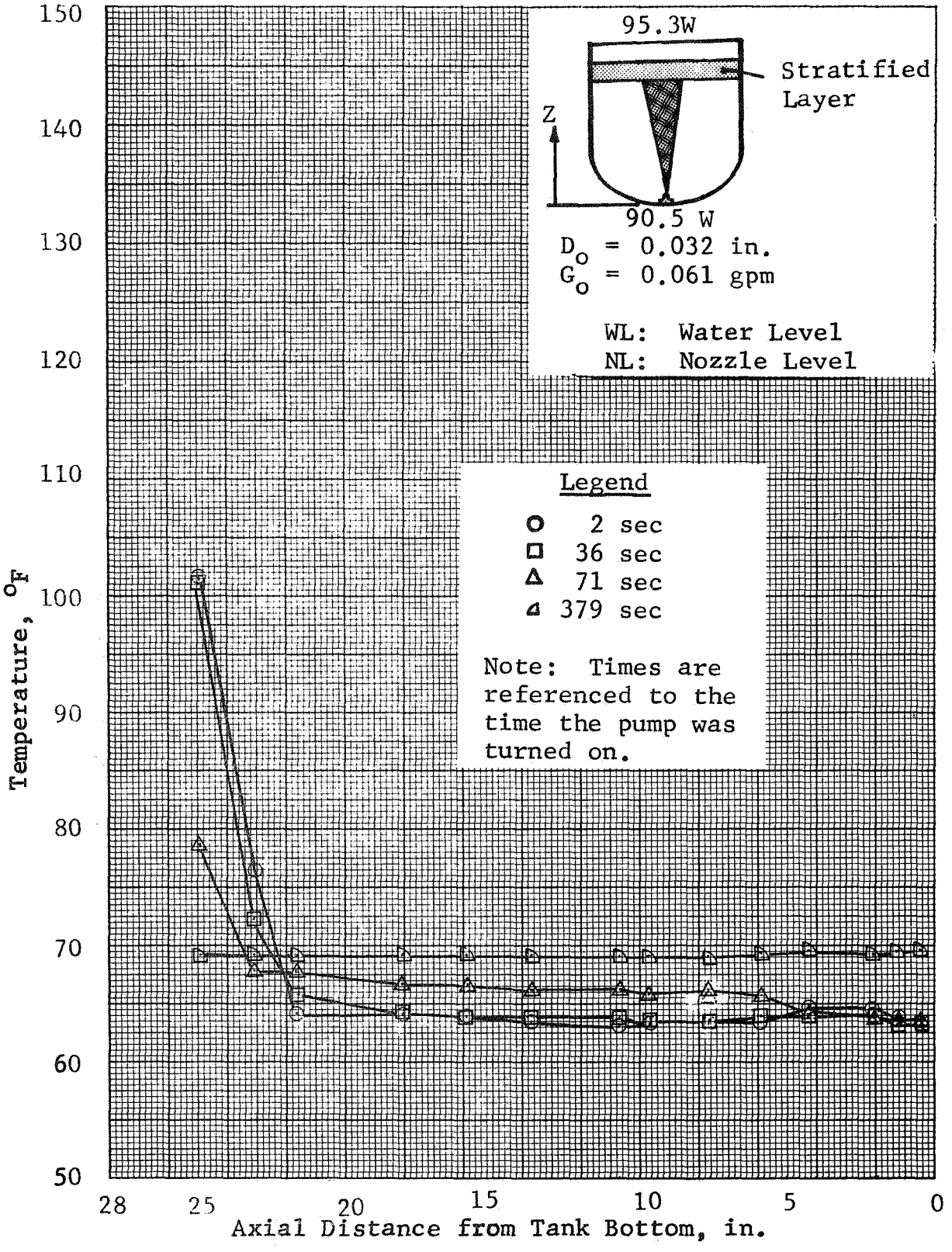


Figure 2.2-25 Temperature Distribution for Axial Jet Flow Test 6, Run 51

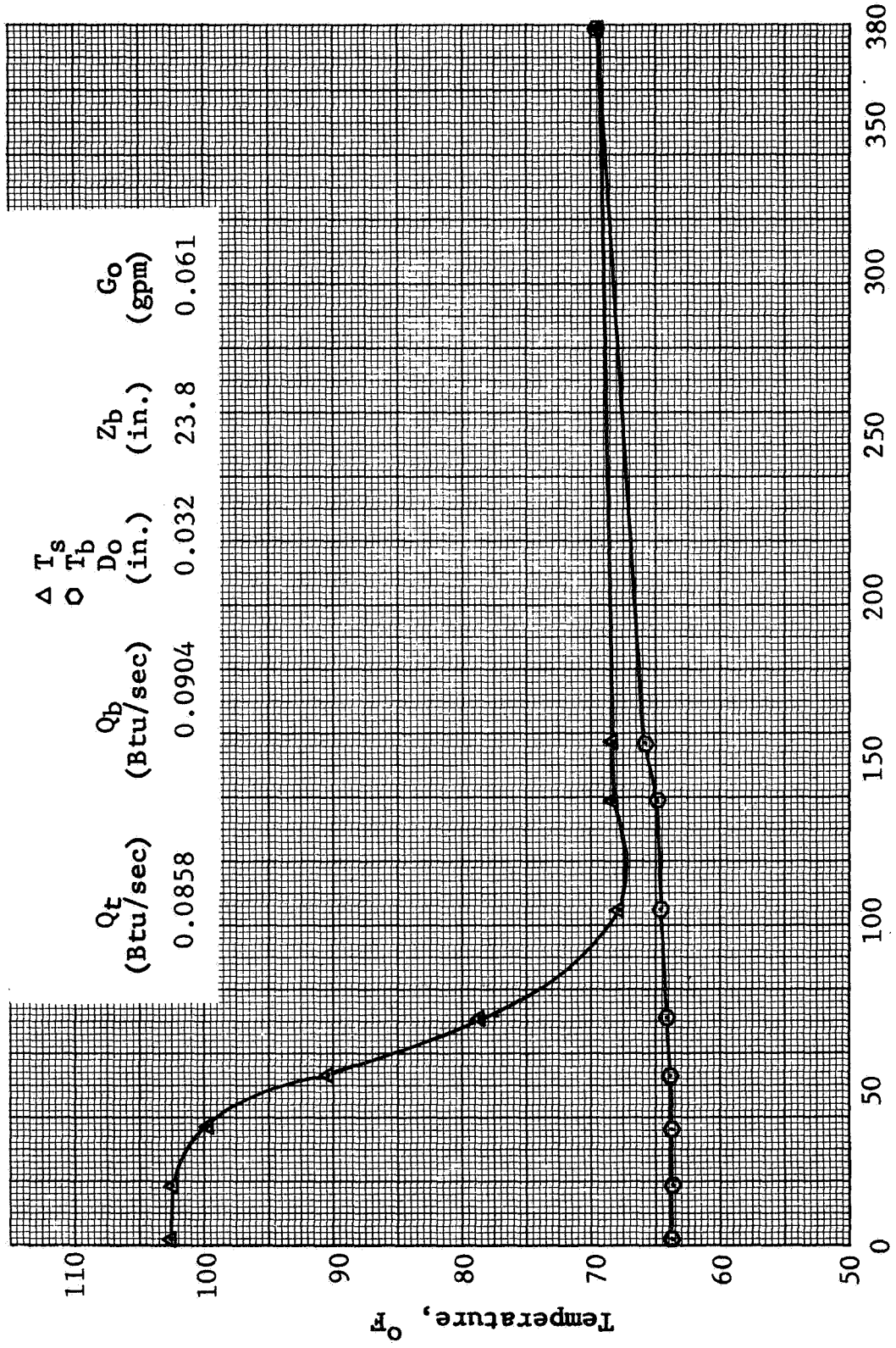


Figure 2.2-26 Transient Temperature Destratification: Test 6, Run 51

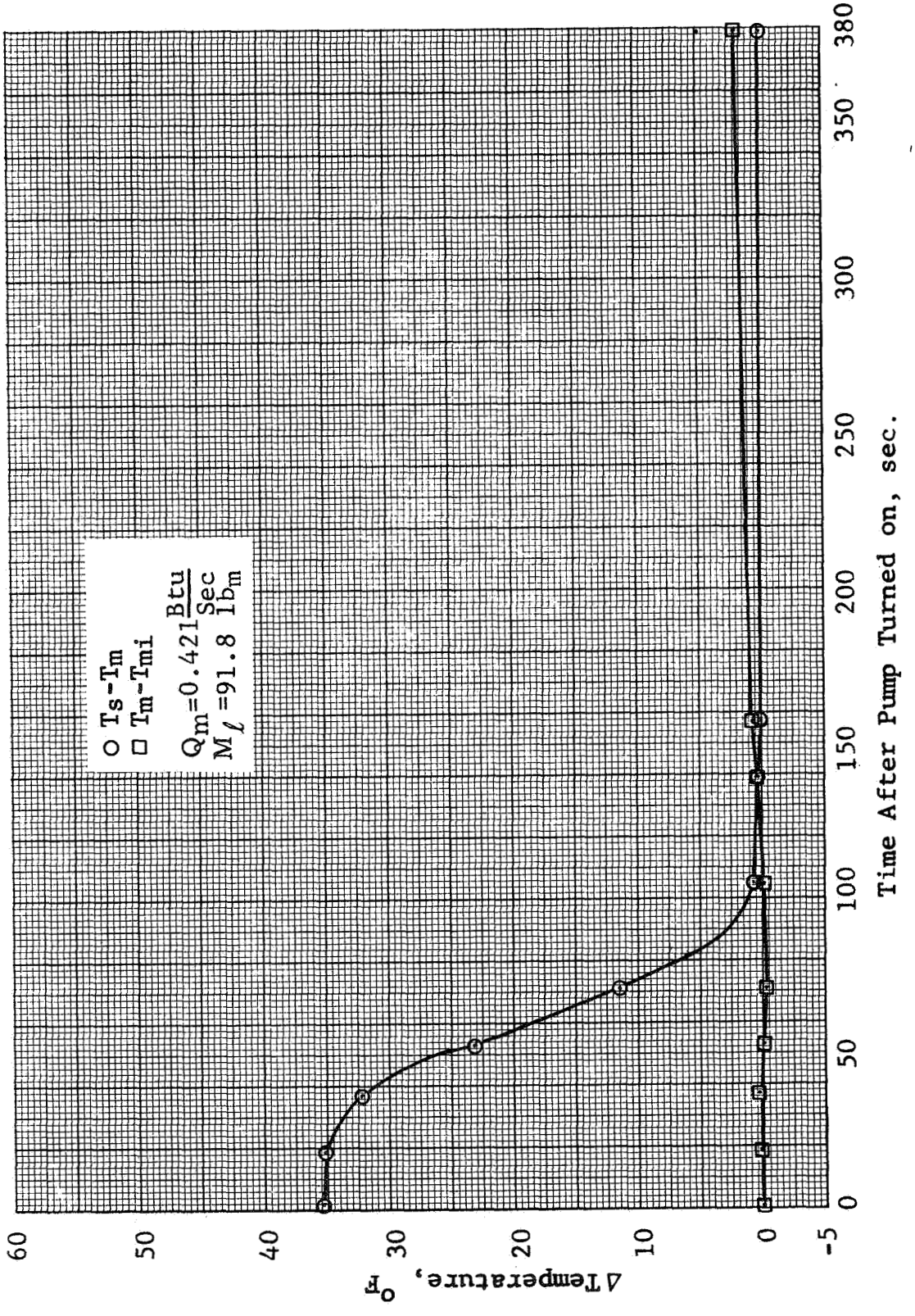


Figure 2.2-27 Transient ΔTemperature Destratification: Test 6, Run 51

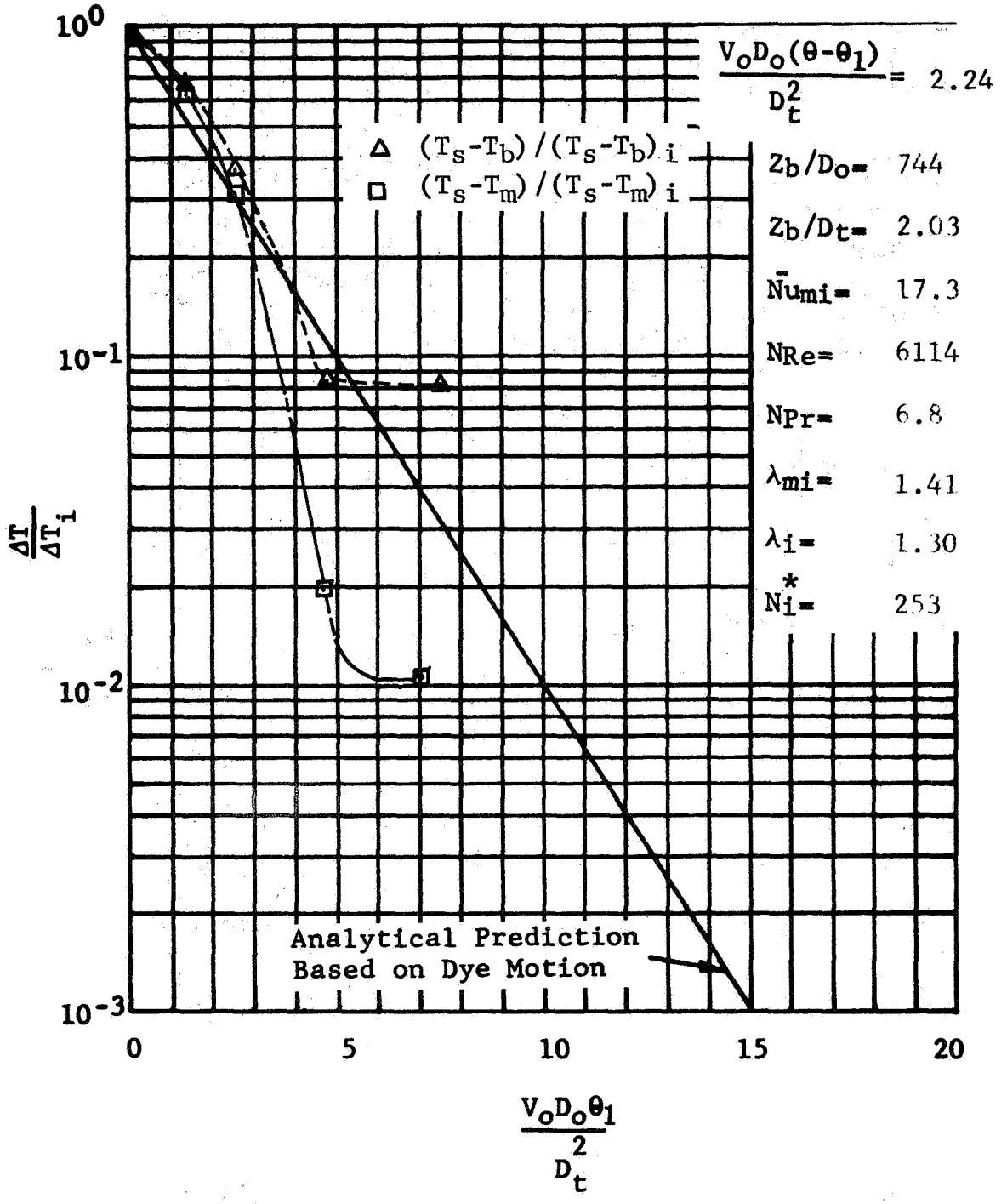


Figure 2.2-28 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 6, Run 51

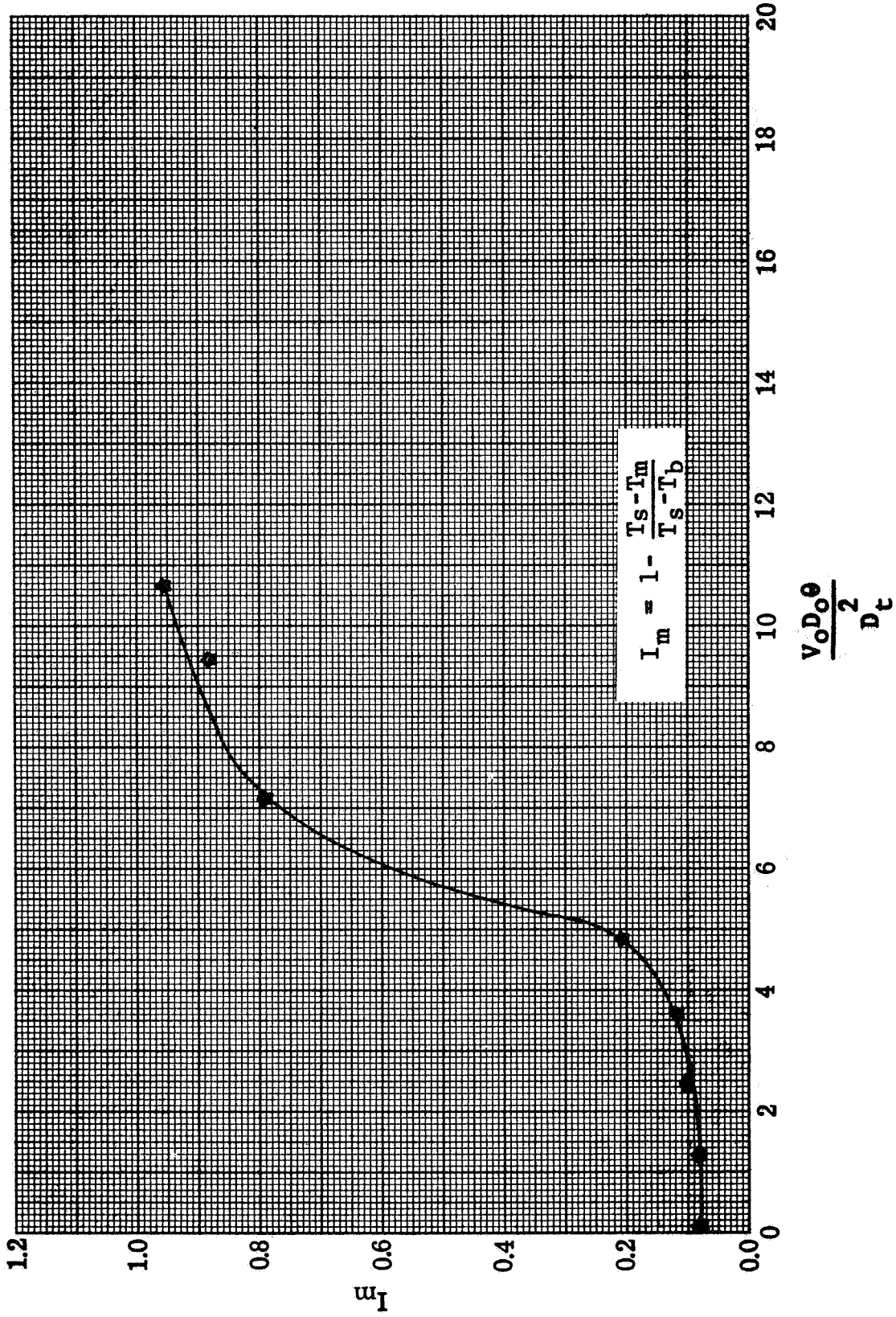


Figure 2.2-29 Transient Energy Integral: Test 6, Run 51

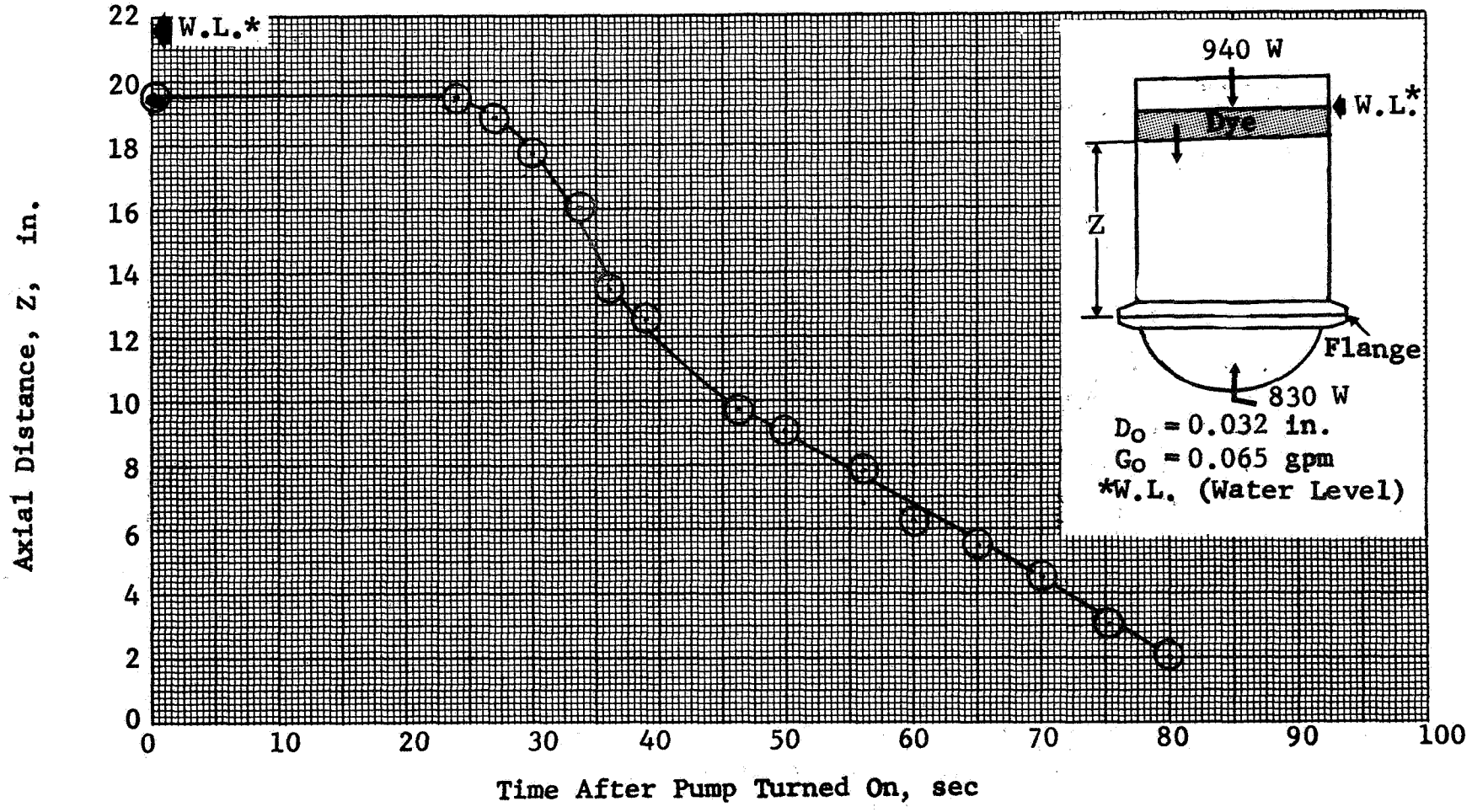


Figure 2.2-30 Axial Jet Dye Layer Motion: Test 8, Run 54

GENERAL DYNAMICS
Fort Worth Division

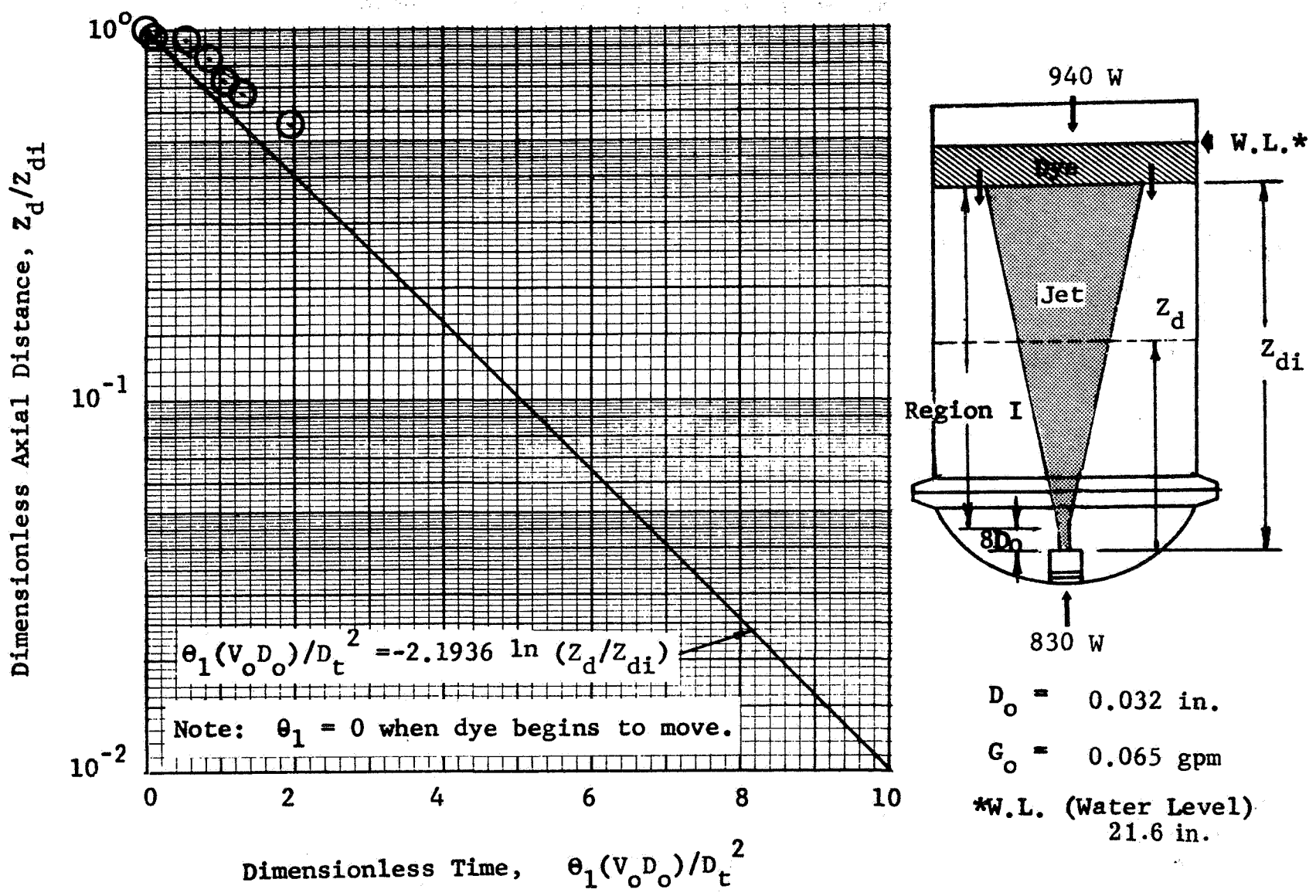


Figure 2.2-31 Correlation of Axial Jet Dye Layer Motion for Region I: Test 8, Run 54

GENERAL DYNAMICS
Fort Worth Division

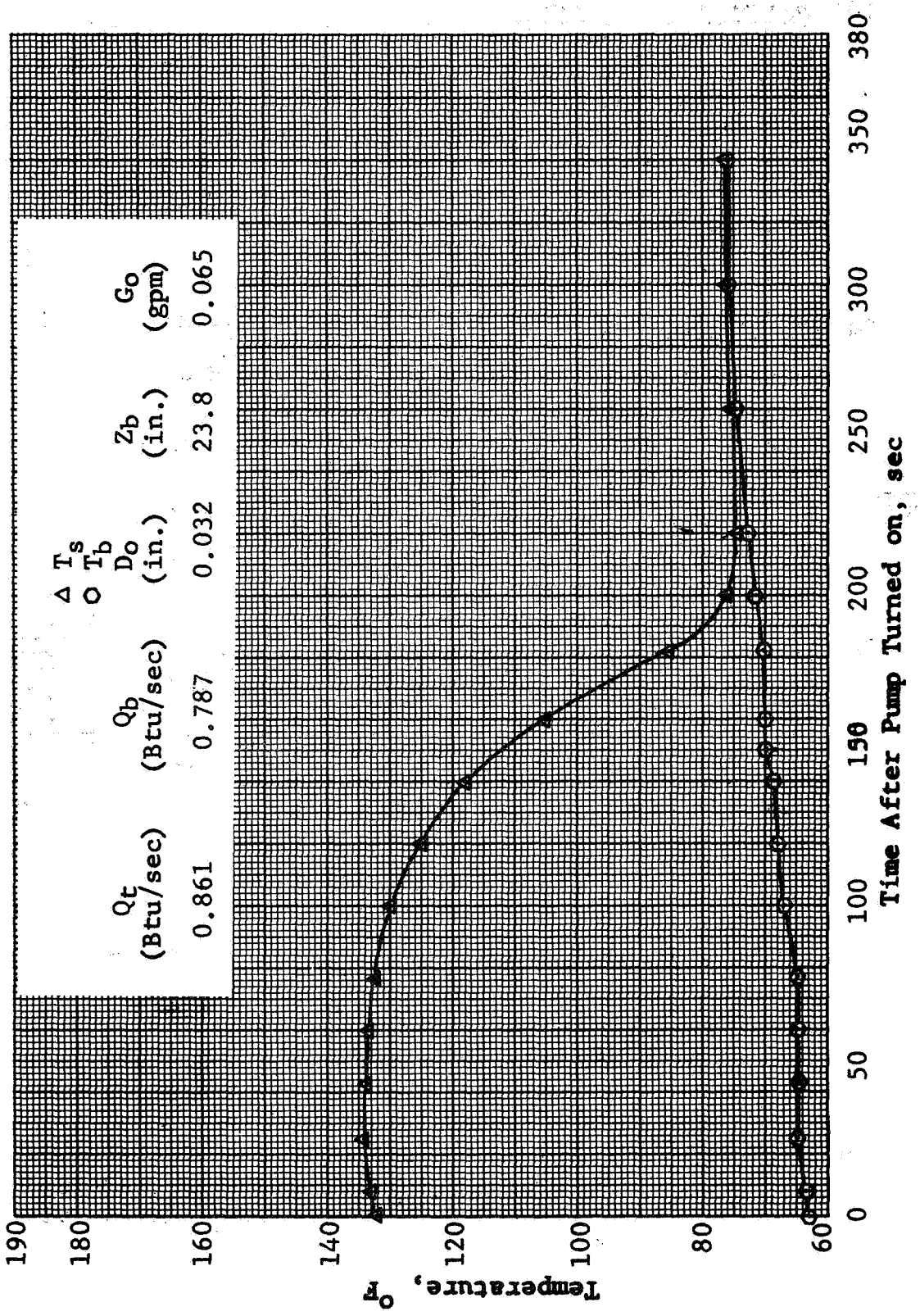


Figure 2.2-32 Transient Temperature Destratification: Test 8, Run 54

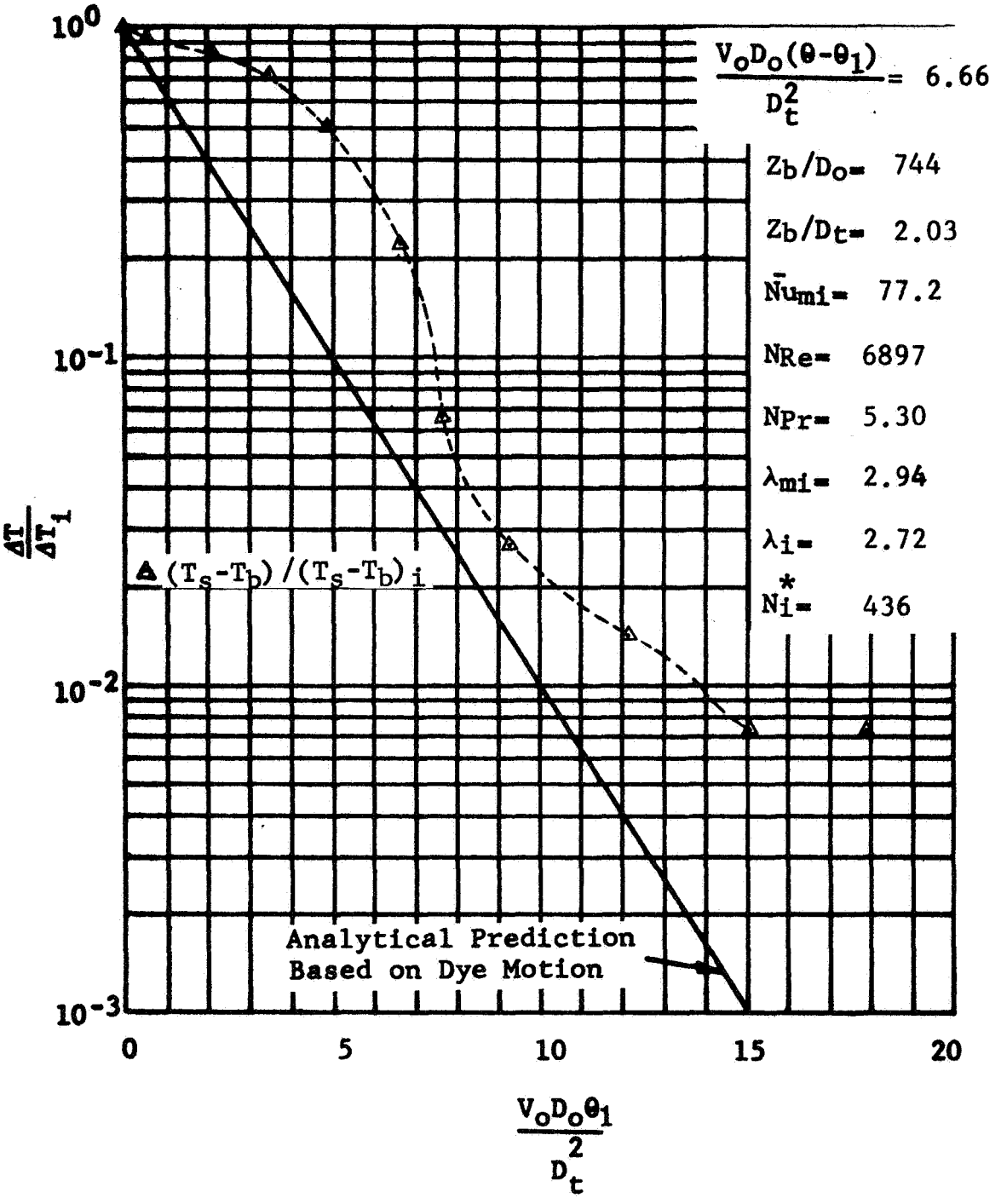


Figure 2.2-33 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 8, Run 54

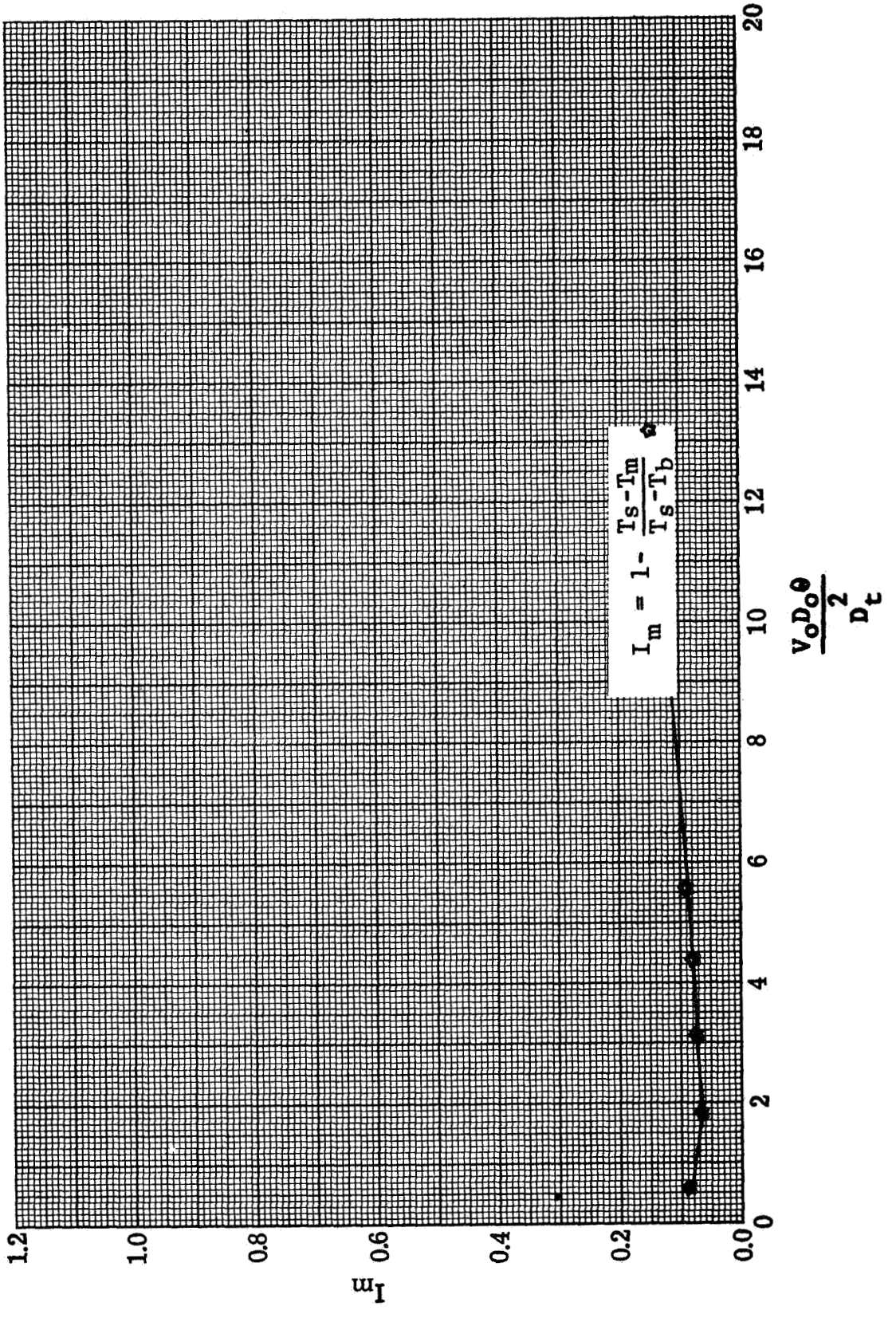


Figure 2.2-34 Transient Energy Integral: Test 8, Run 54

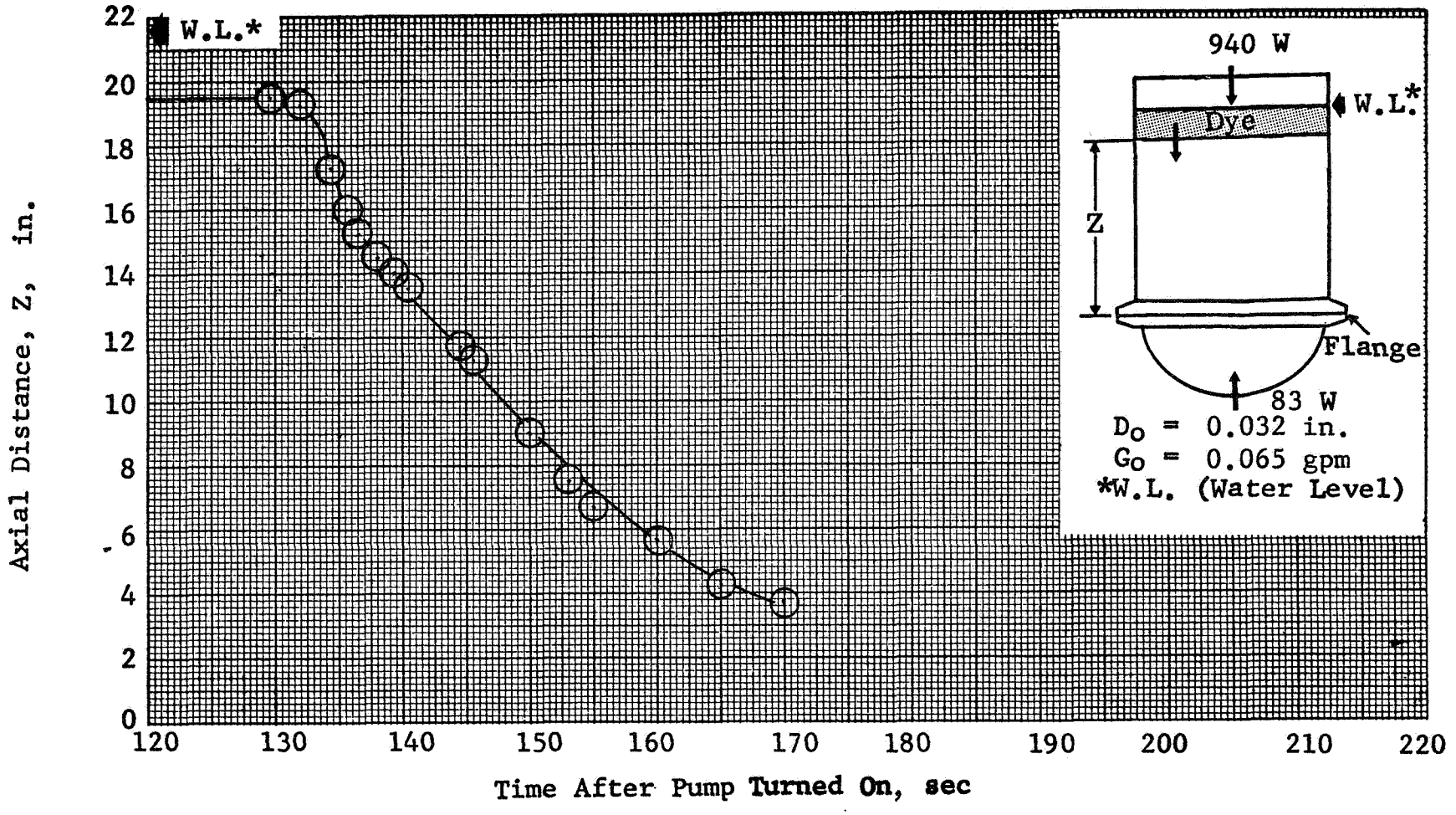


Figure 2.2-35 Axial Jet Dye Layer Motion: Test 9, Run 55

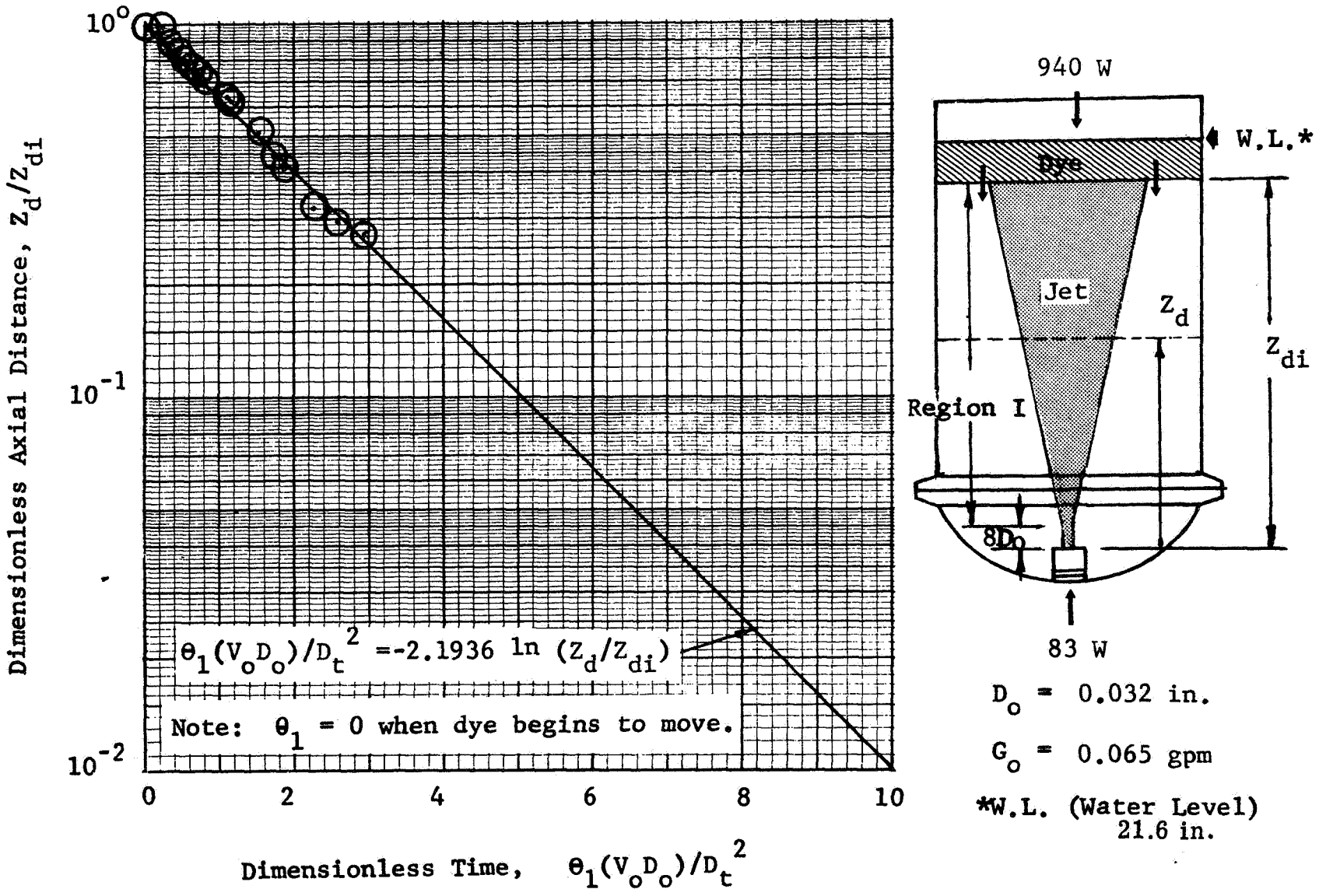


Figure 2.2-36 Correlation of Axial Jet Dye Layer Motion for Region I: Test 9, Run 55

GENERAL DYNAMICS
Fort Worth Division

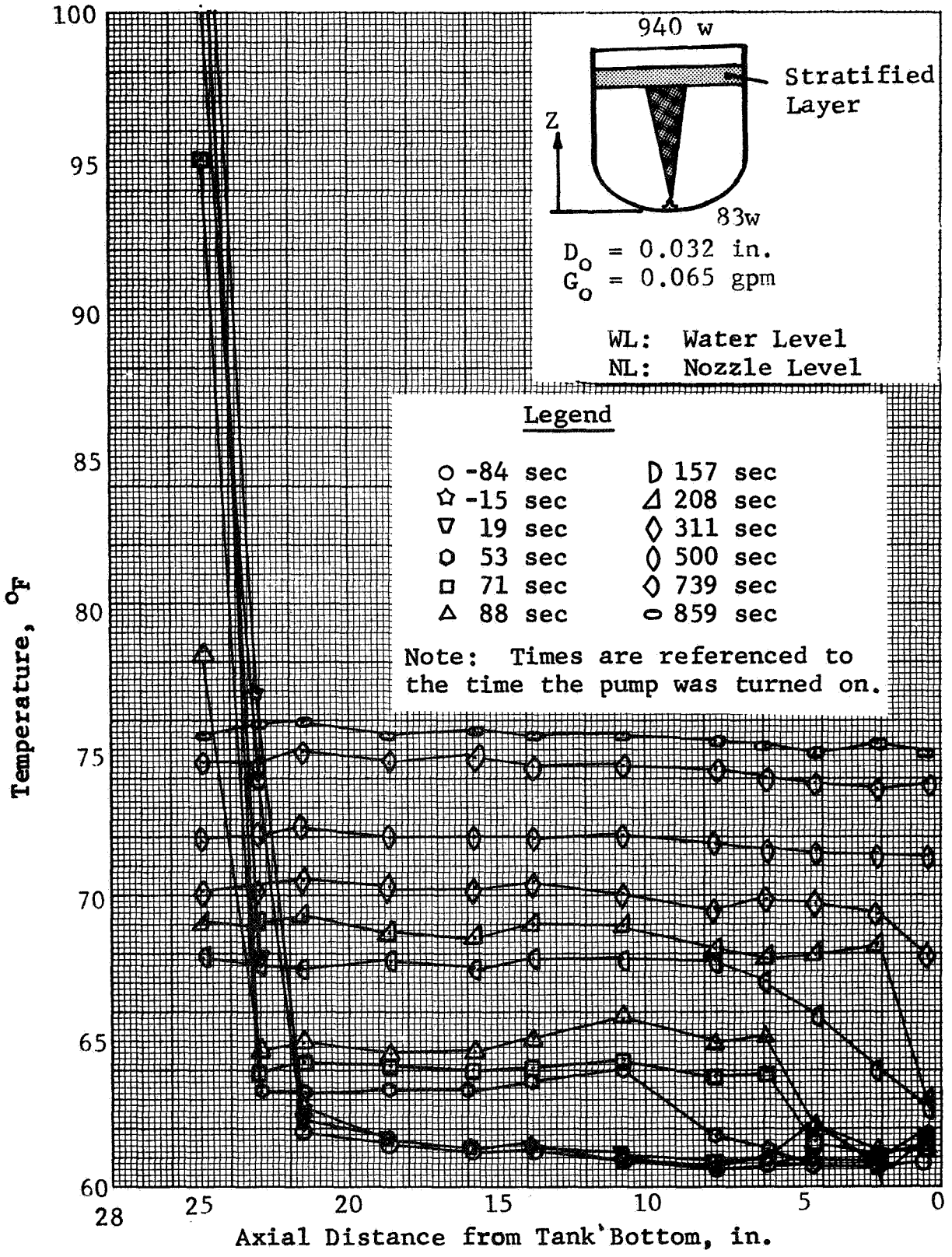


Figure 2.2-37 Temperature Distribution for Axial Jet Flow: Test 9, Run 55

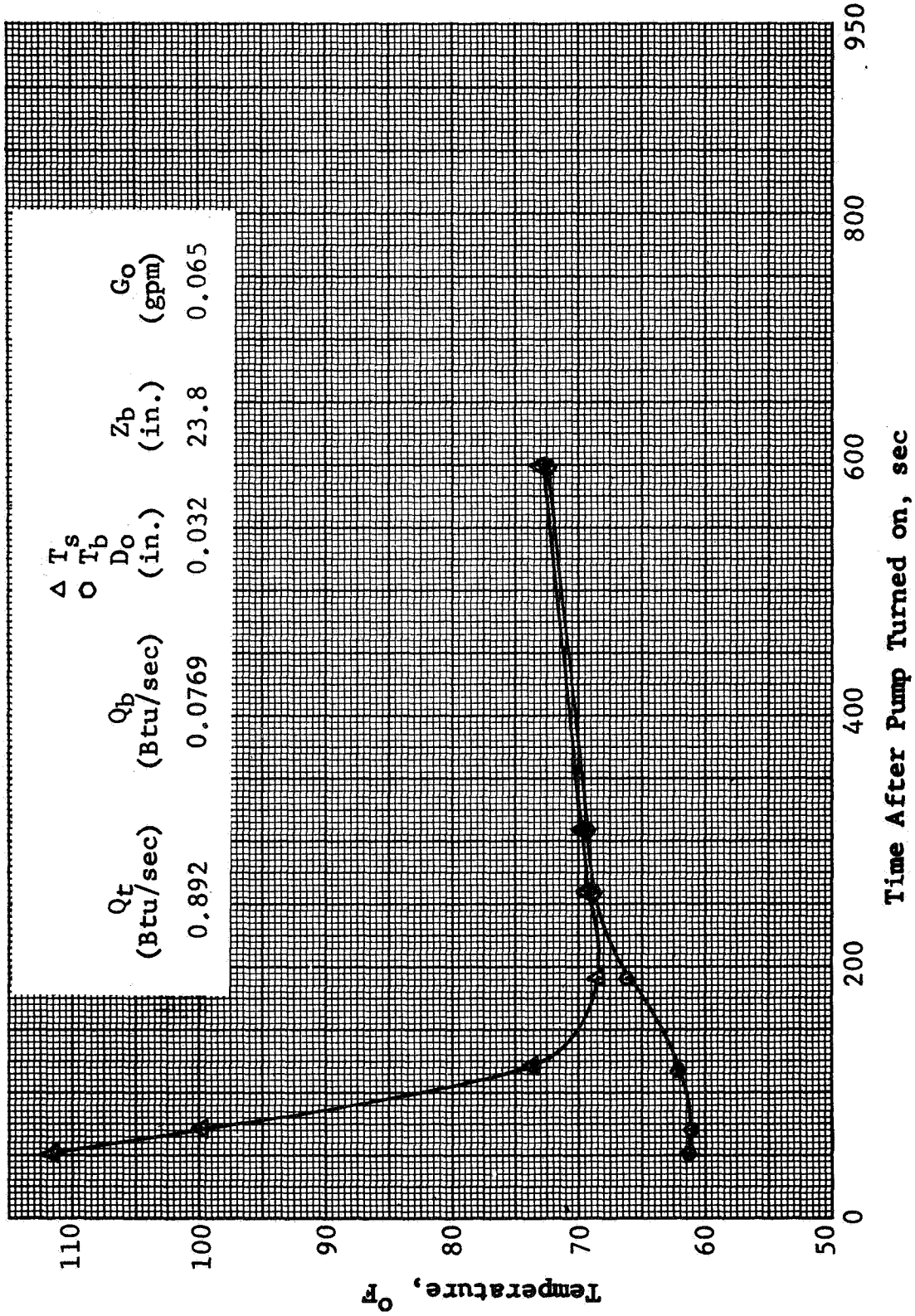


Figure 2.2-38 Transient Temperature Destratification: Test 9, Run 55

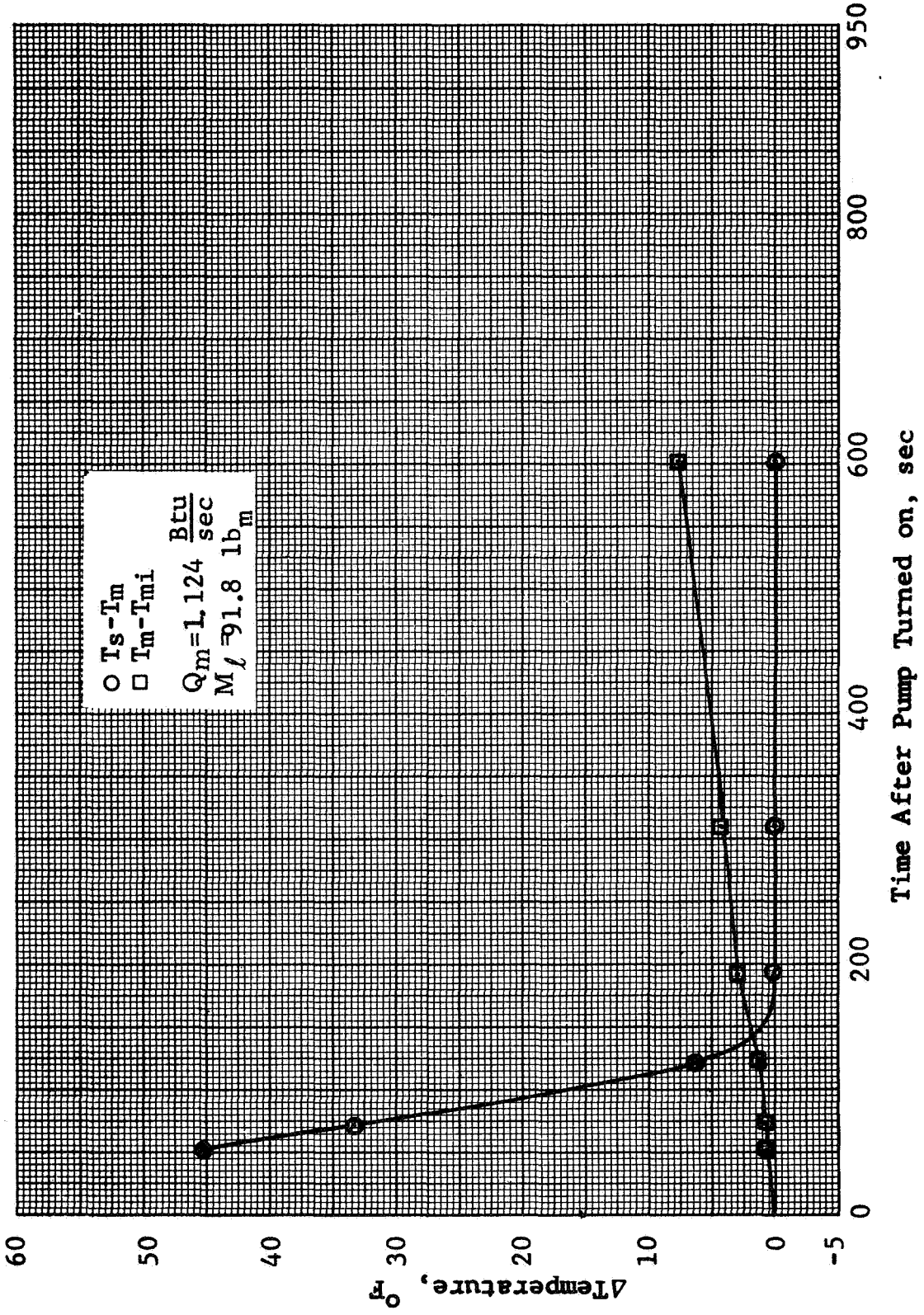


Figure 2.2-39 Transient ΔTemperature Destratification: Test 9, Run 55

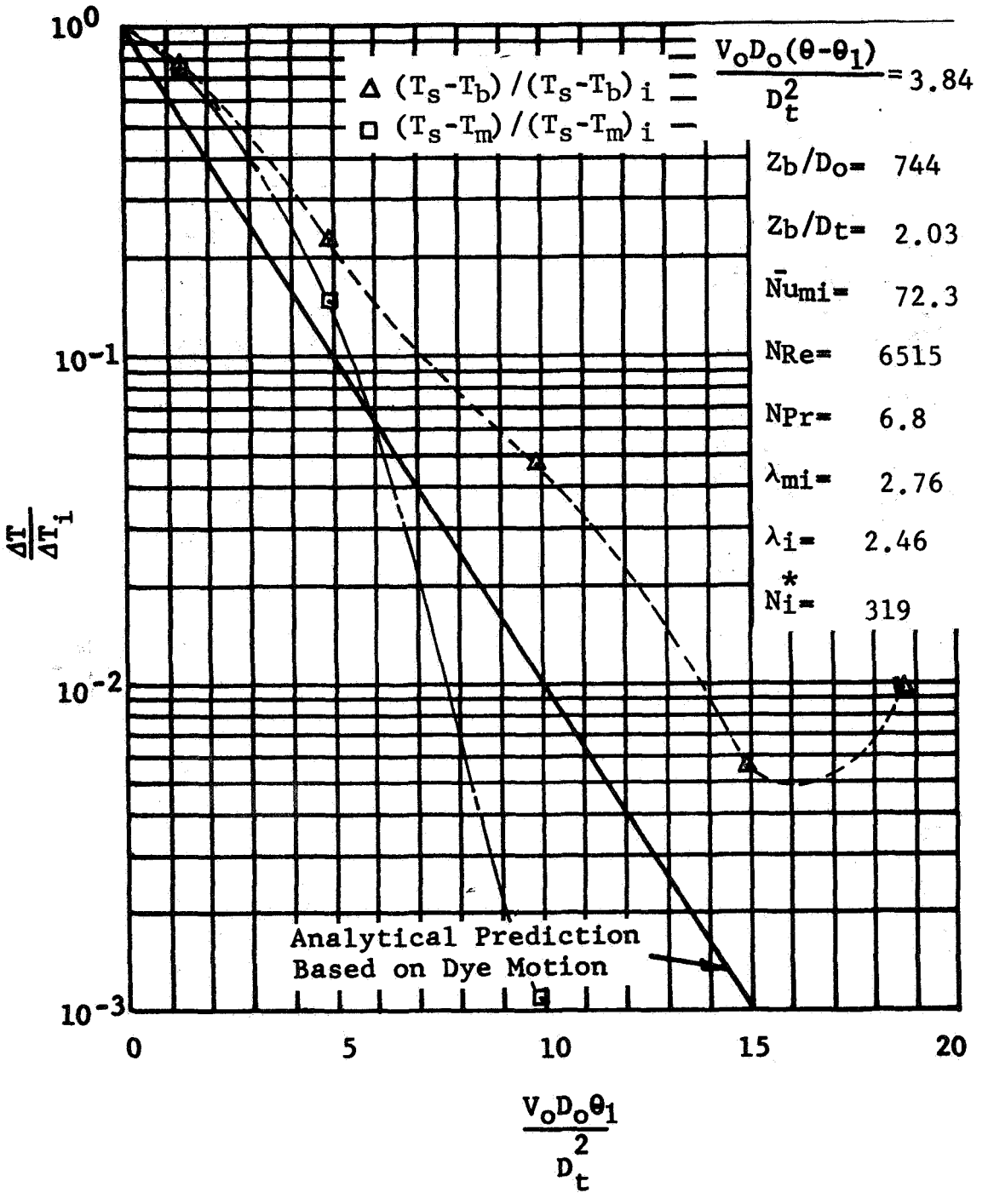


Figure 2.2-40 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 9, Run 55

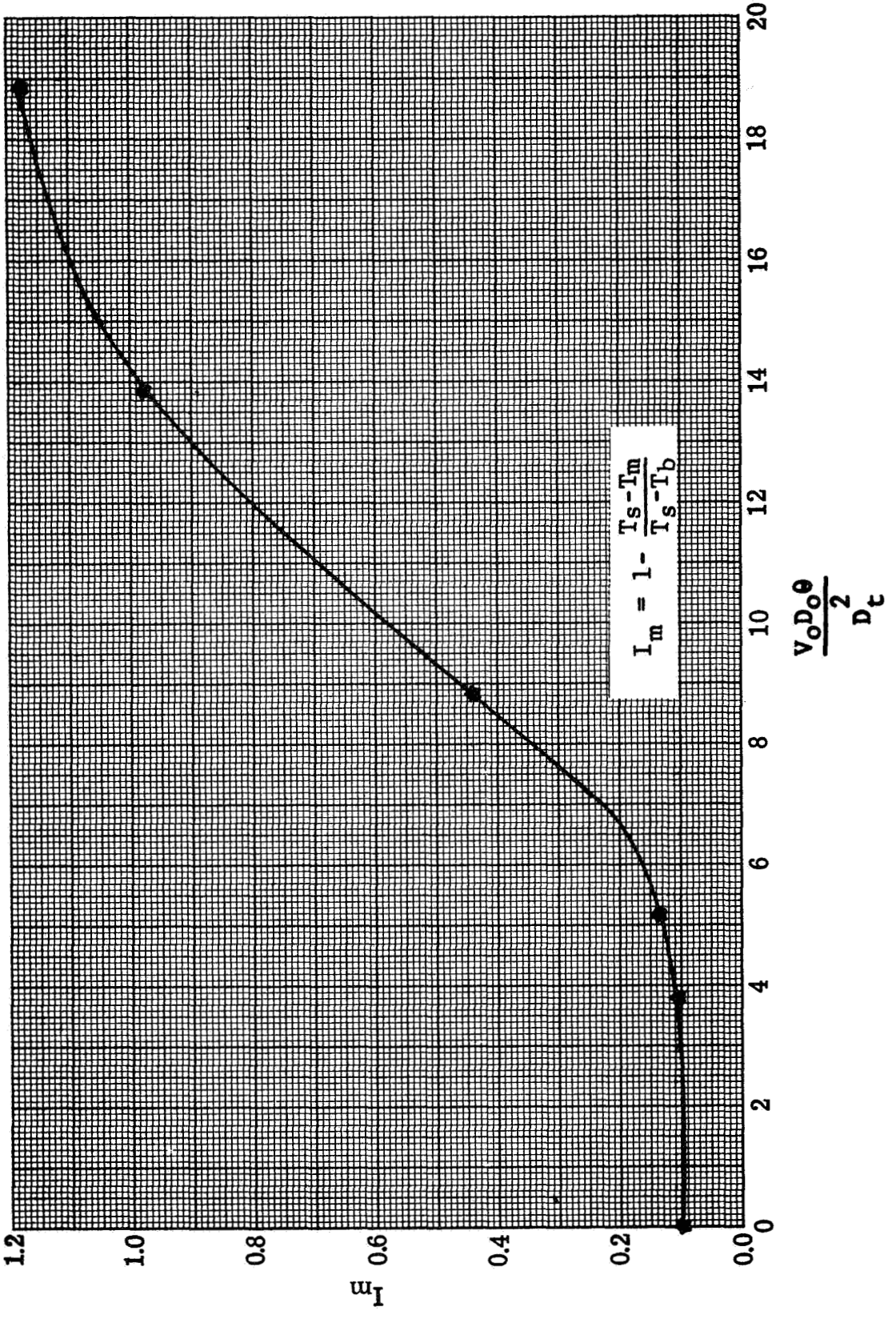


Figure 2.2-41 Transient Energy Integral: Test 9, Run 55

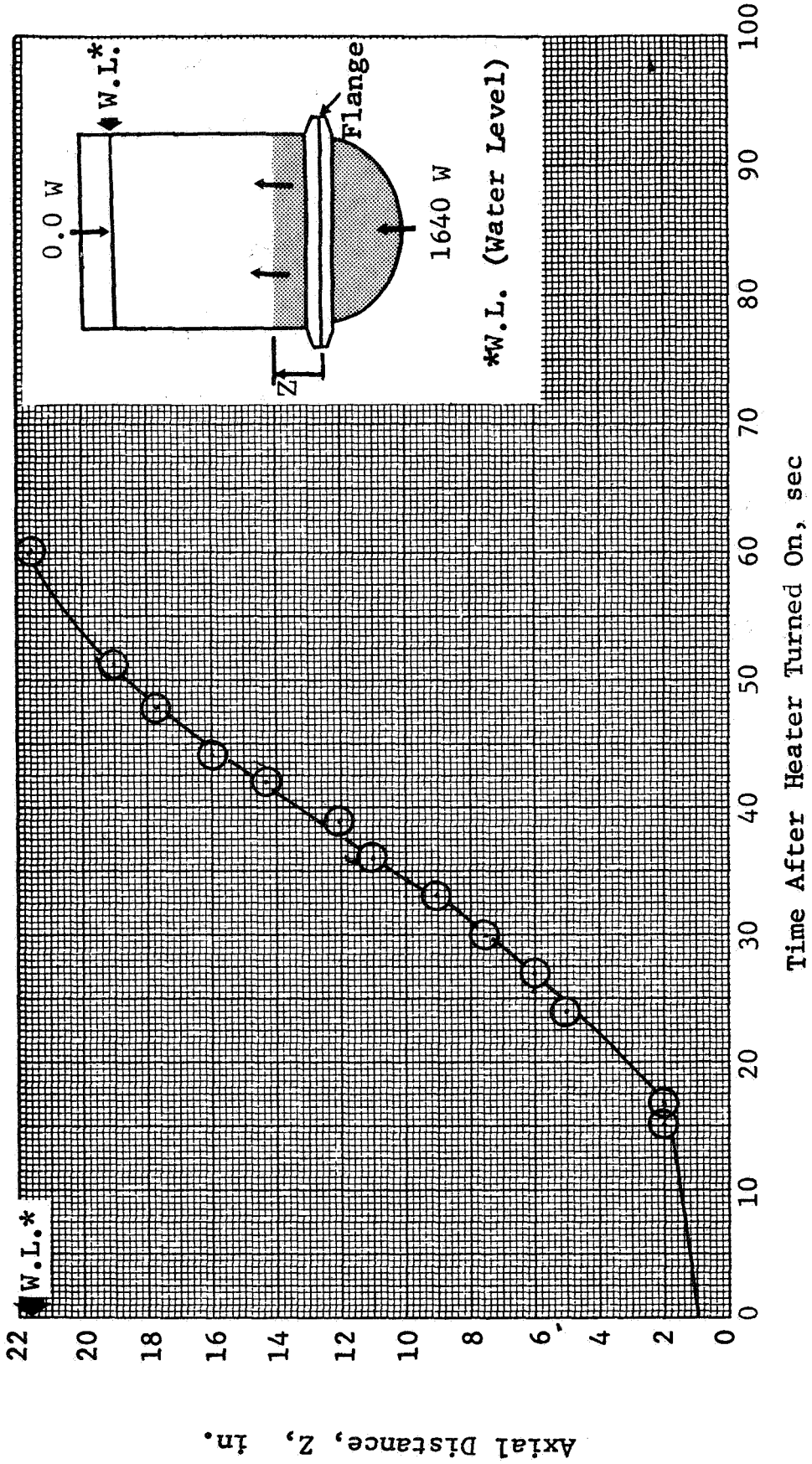


Figure 2.2-42 Axial Dye Layer Motion: Test 10

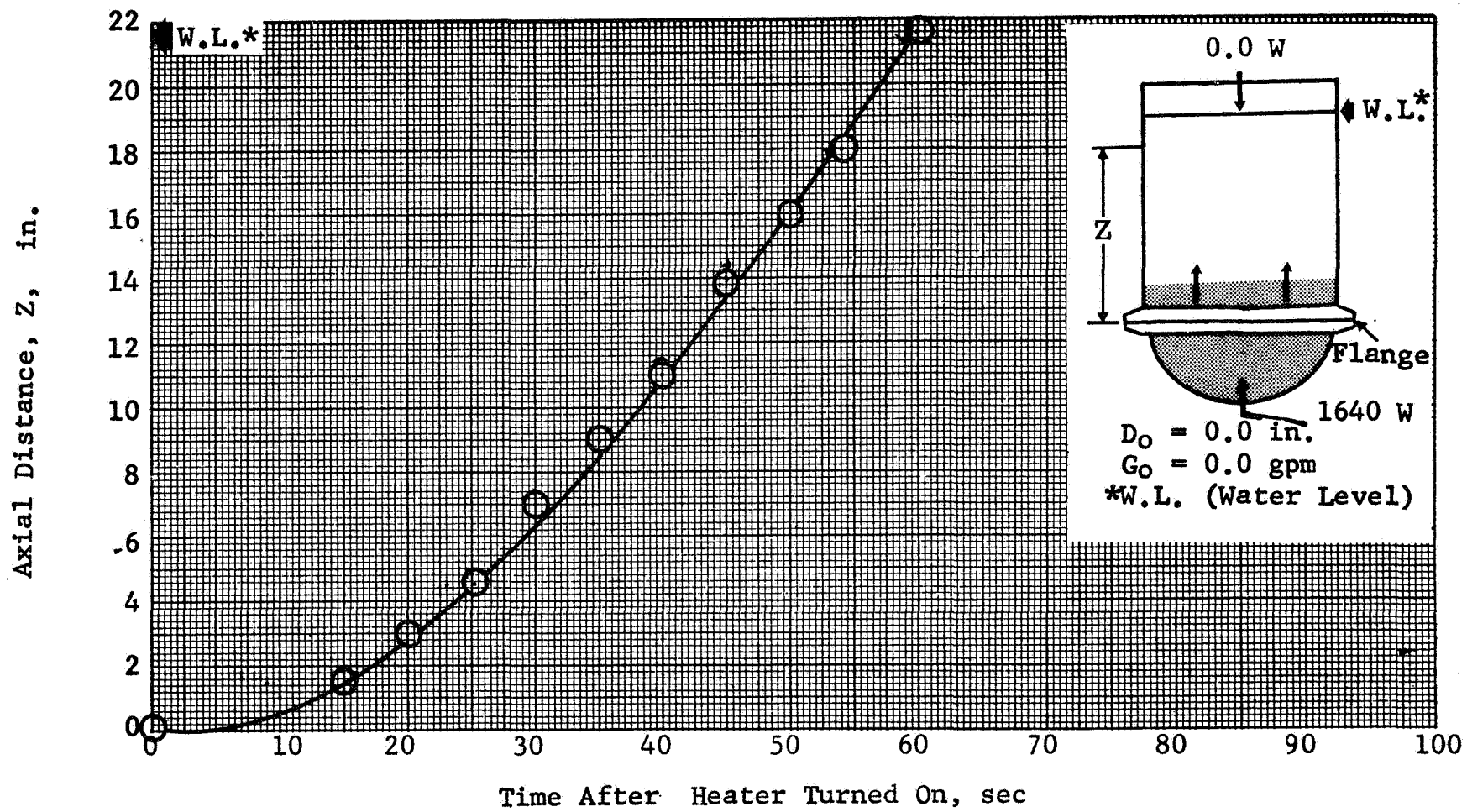


Figure 2.2-43 Axial Dye Layer Motion: Test 11

GENERAL DYNAMICS
Fort Worth Division

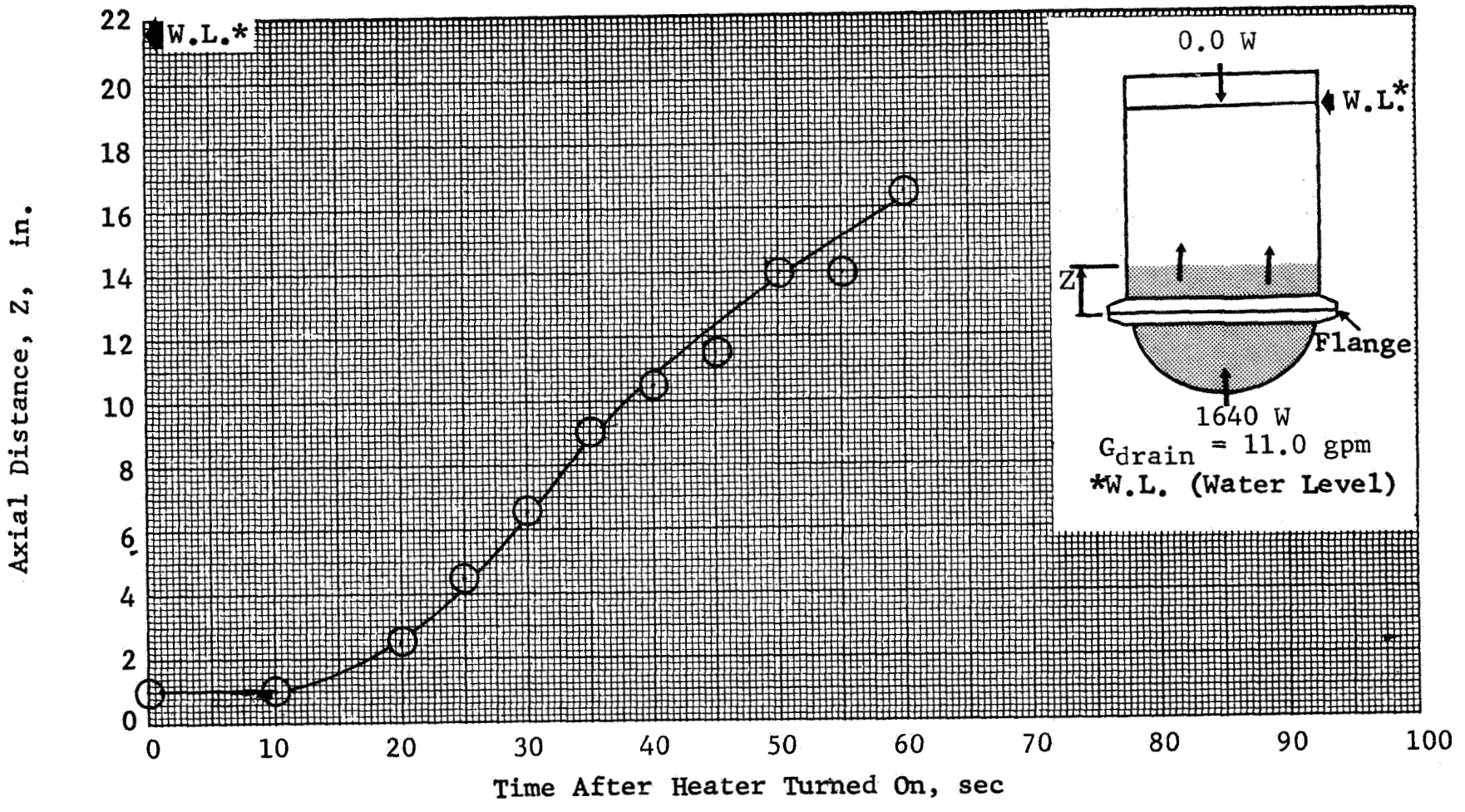


Figure 2.2-44 Axial Dye Layer Motion: Test 12

GENERAL DYNAMICS
Fort Worth Division

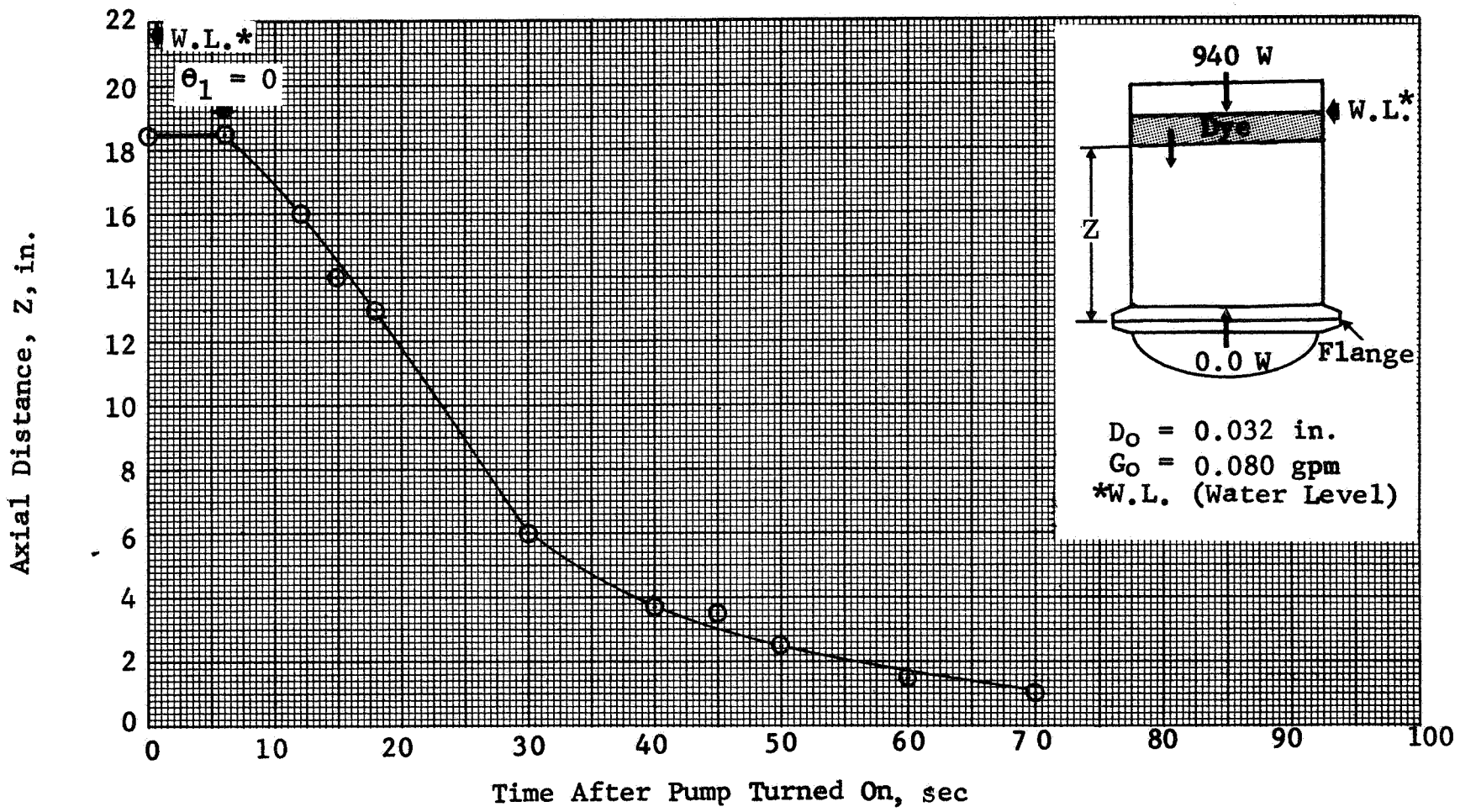


Figure 2.2-45 Axial Jet Dye Layer Motion: Test 14, Run 56

GENERAL DYNAMICS
Fort Worth Division

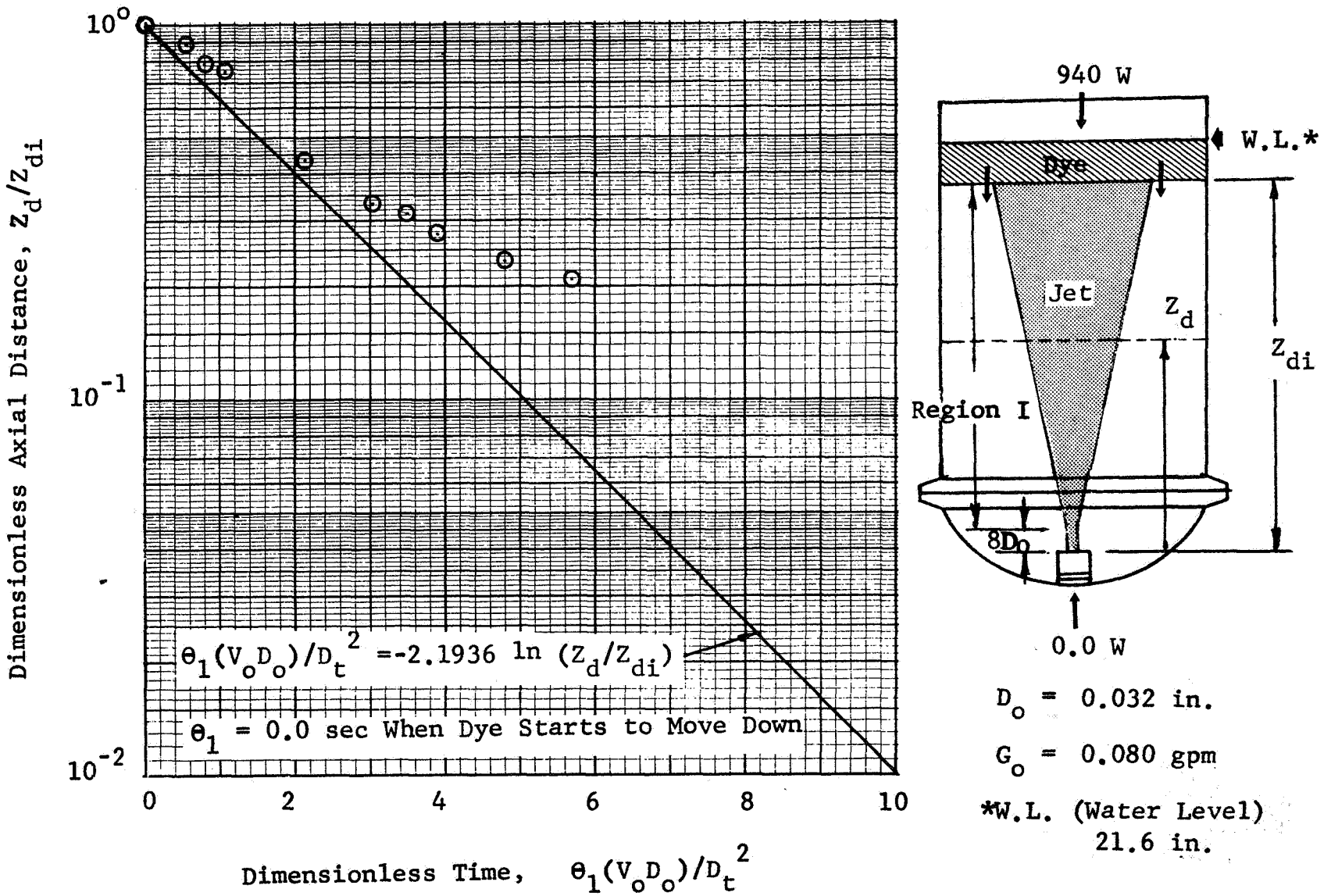


Figure 2.2-46 Correlation of Axial Jet Dye Layer Motion for Region I: Test 14, Run 56

GENERAL DYNAMICS
Fort Worth Division

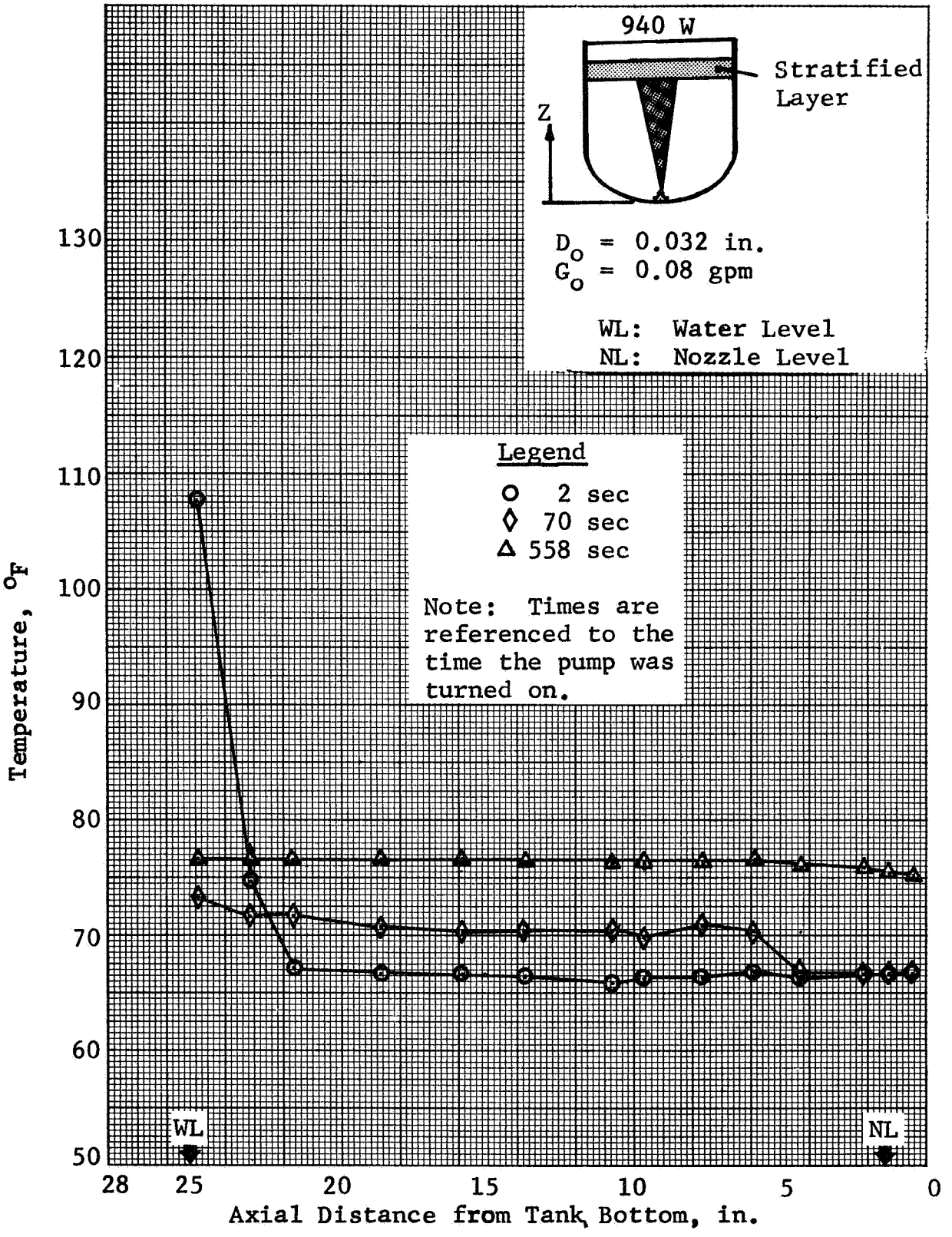


Figure 2.2-47 Temperature Distribution for Axial Jet Flow: Test 14, Run 56

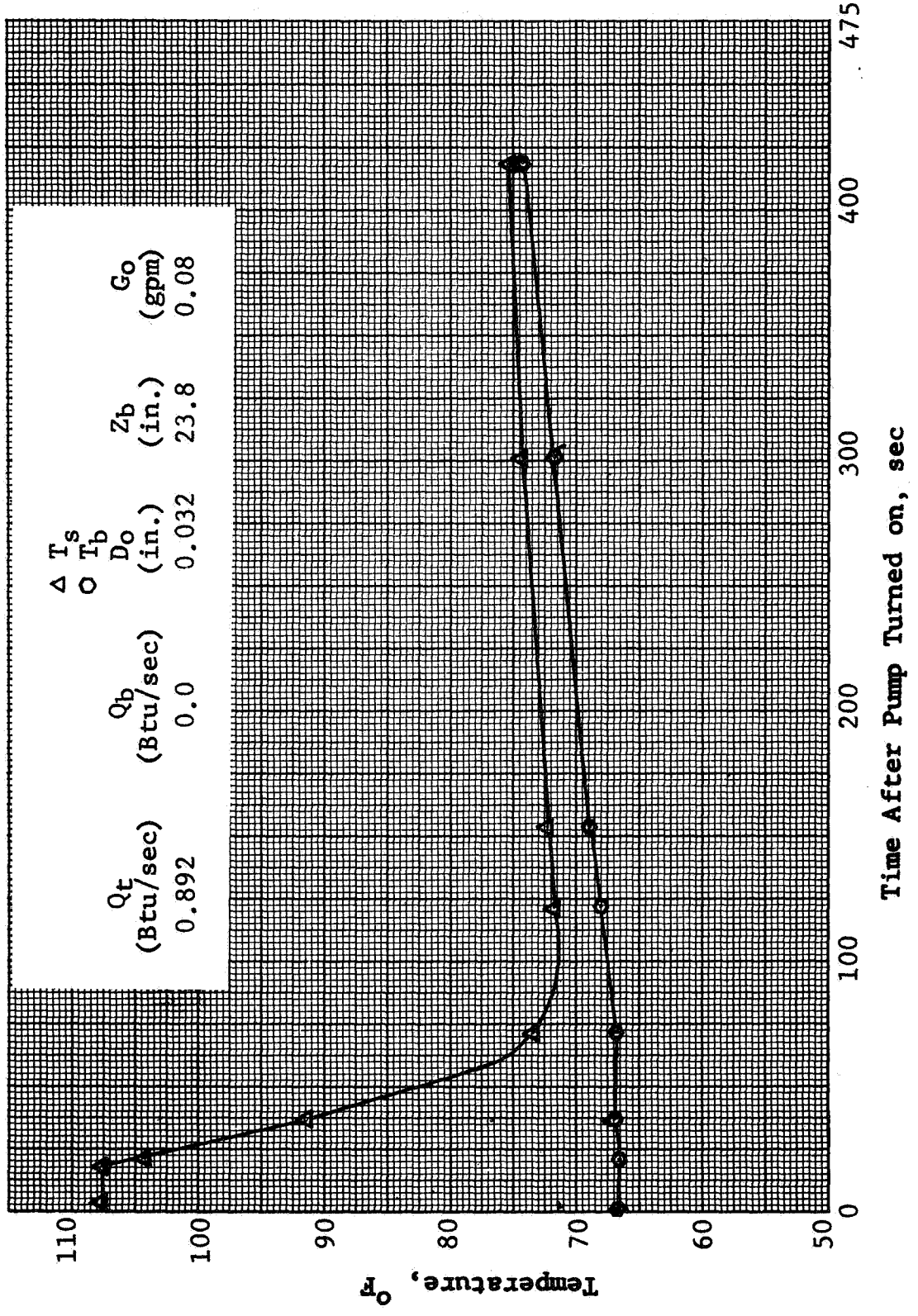


Figure 2.2-48 **Transient Temperature Destratification:** Test 14, Run 56

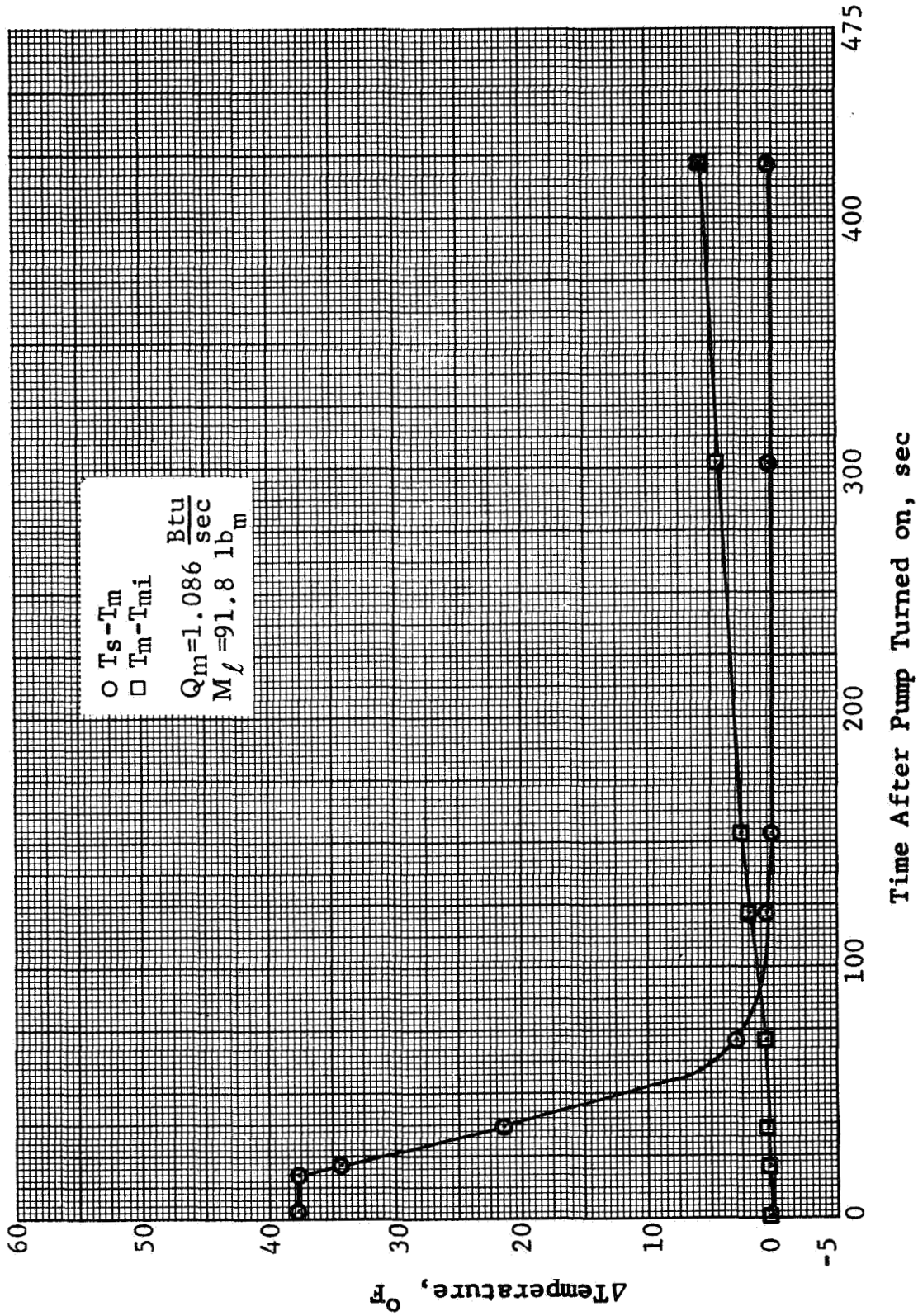


Figure 2.2-49 Transient ΔTemperature Destratification: Test 14, Run 56

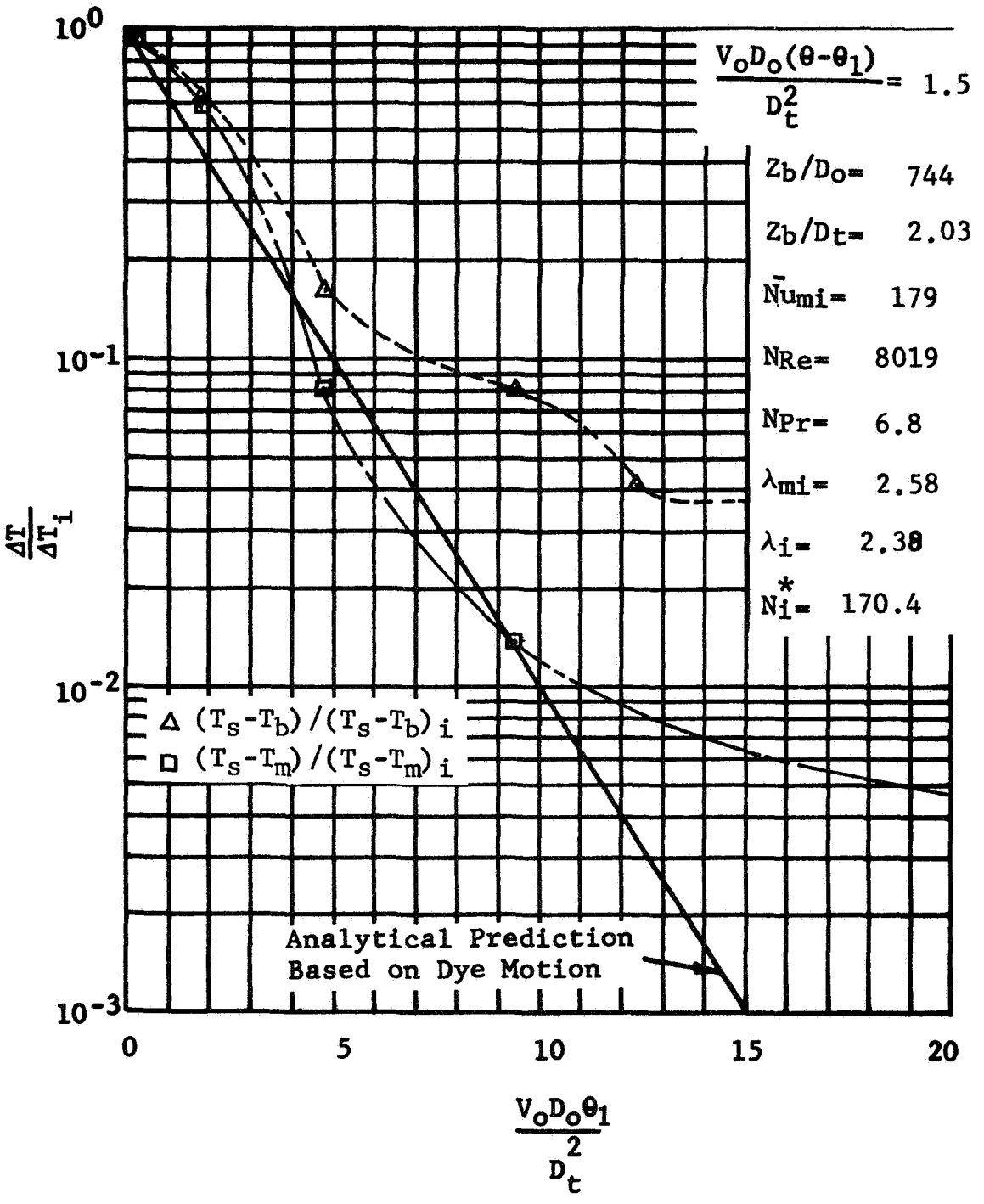


Figure 2.2-50 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 14, Run 56

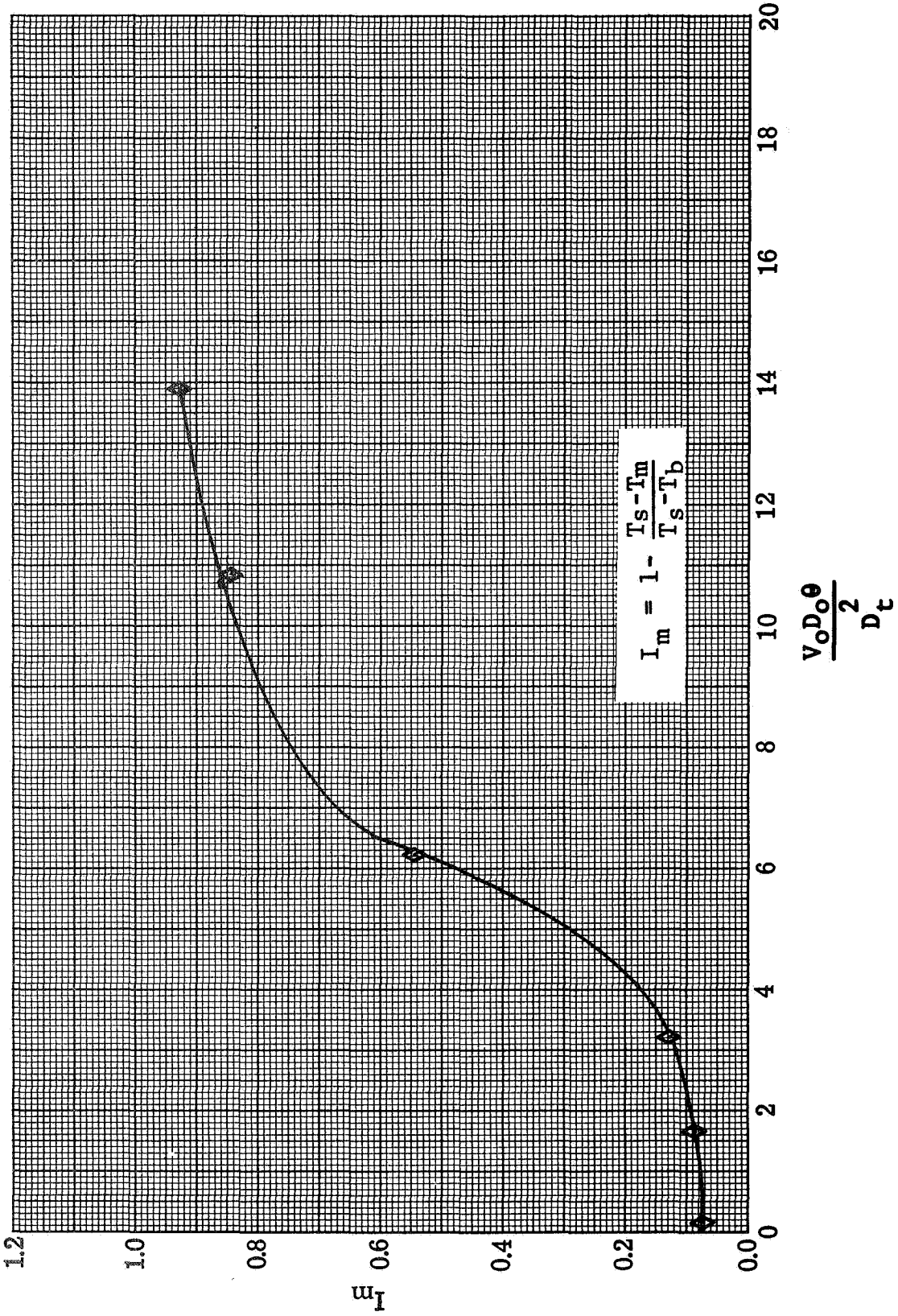


Figure 2.2-51 Transient Energy Integral: Test 14, Run 56

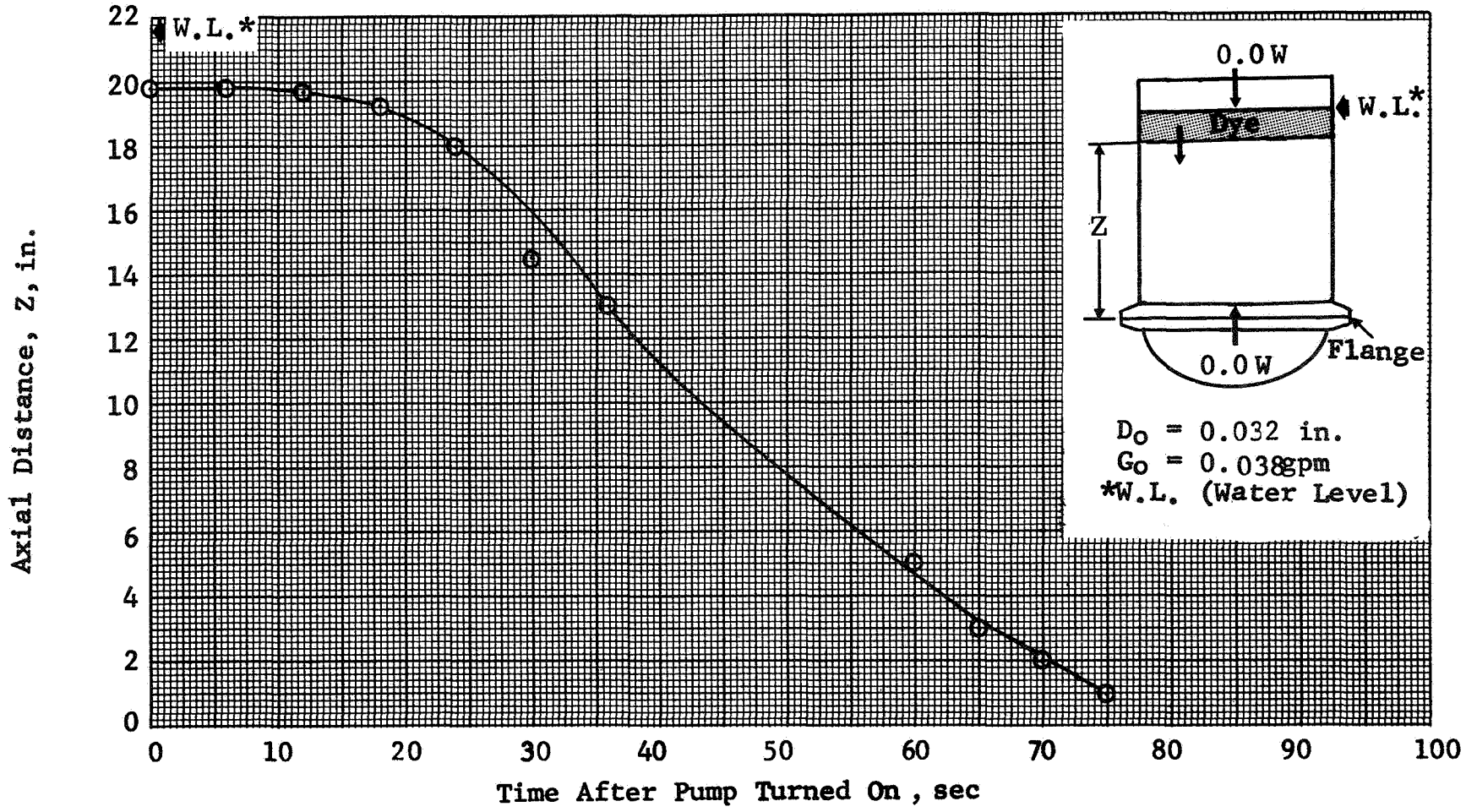


Figure 2.2-52 Axial Jet Dye Layer Motion: Test 15, Run 57

GENERAL DYNAMICS
Fort Worth Division

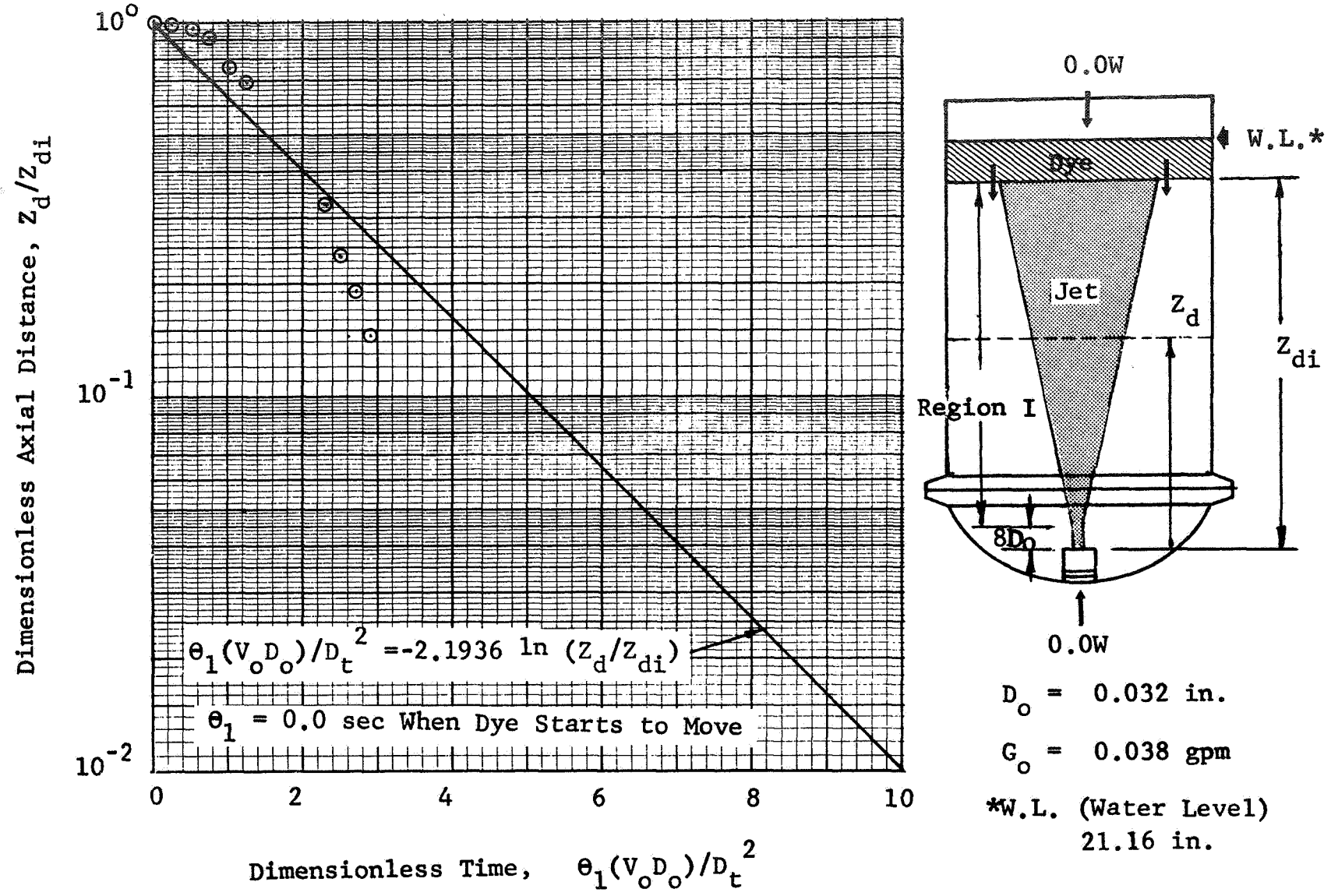


Figure 2.2-53 Correlation of Axial Jet Dye Layer Motion for Region I: Test 15, Run 57

GENERAL DYNAMICS
Fort Worth Division

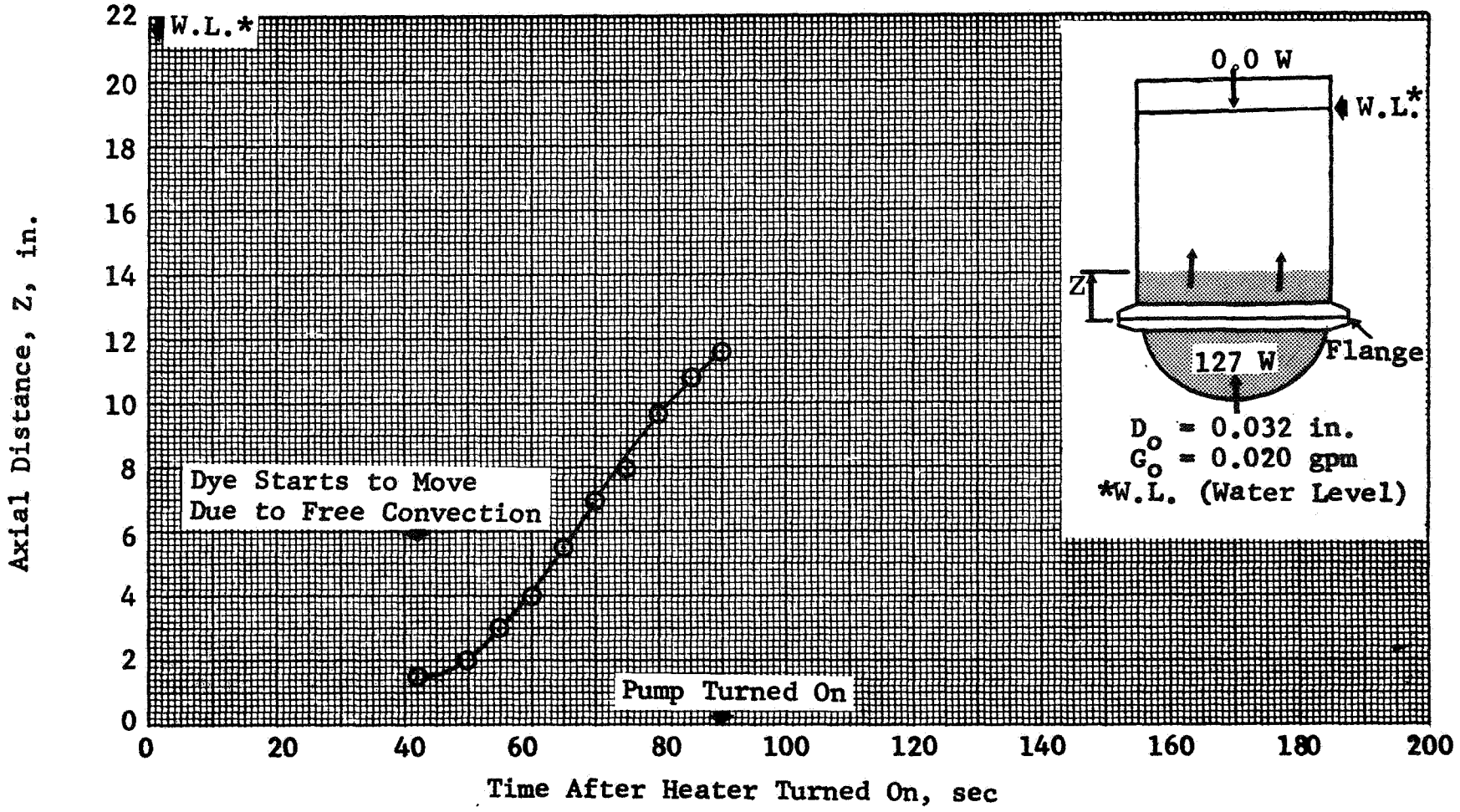


Figure 2.2-54 Axial Dye Layer Motion: Test 16, Run 58

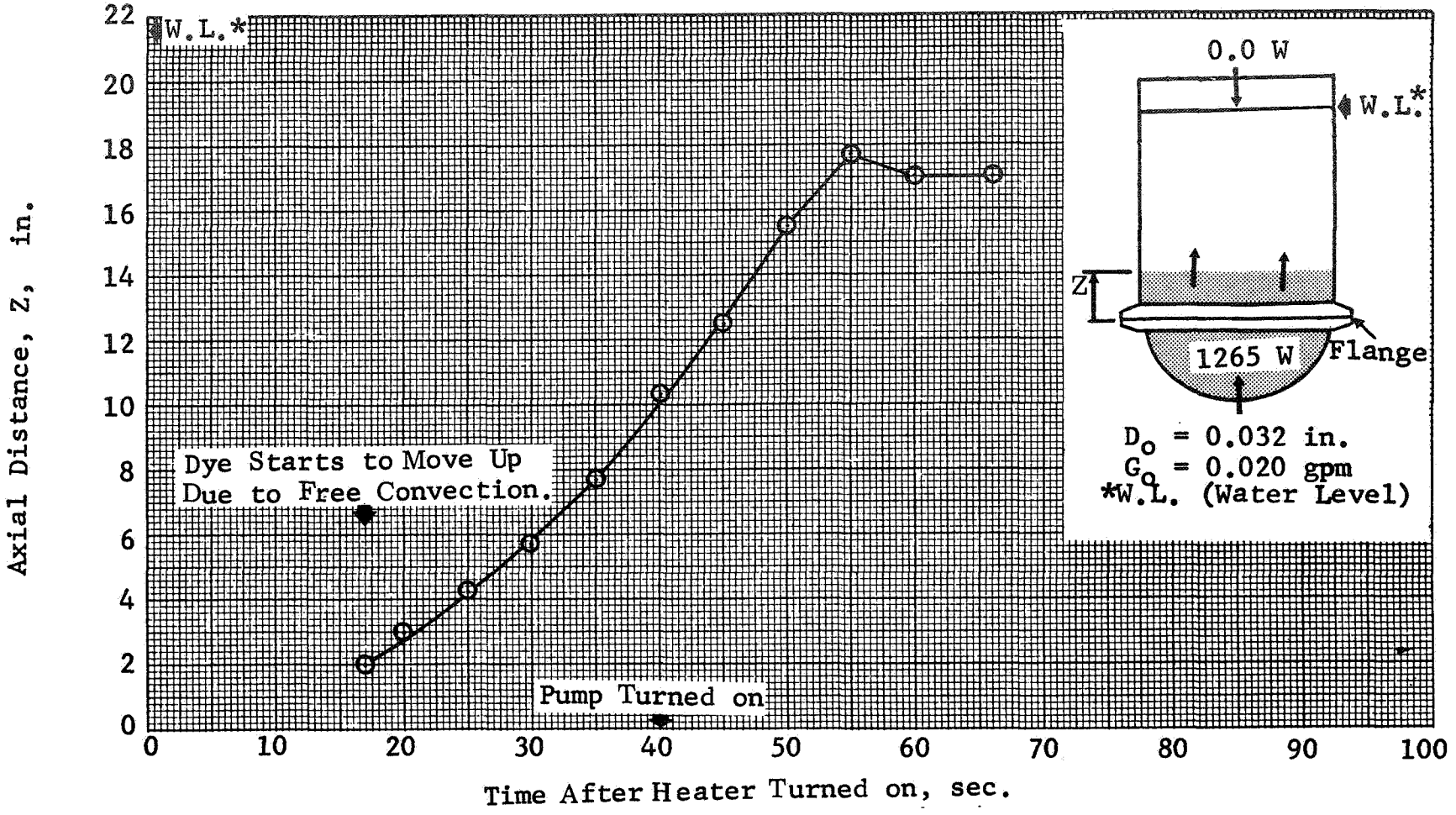


Figure 2.2-55 Axial Dye Layer Motion: Test 17, Run 59

GENERAL DYNAMICS
Fort Worth Division

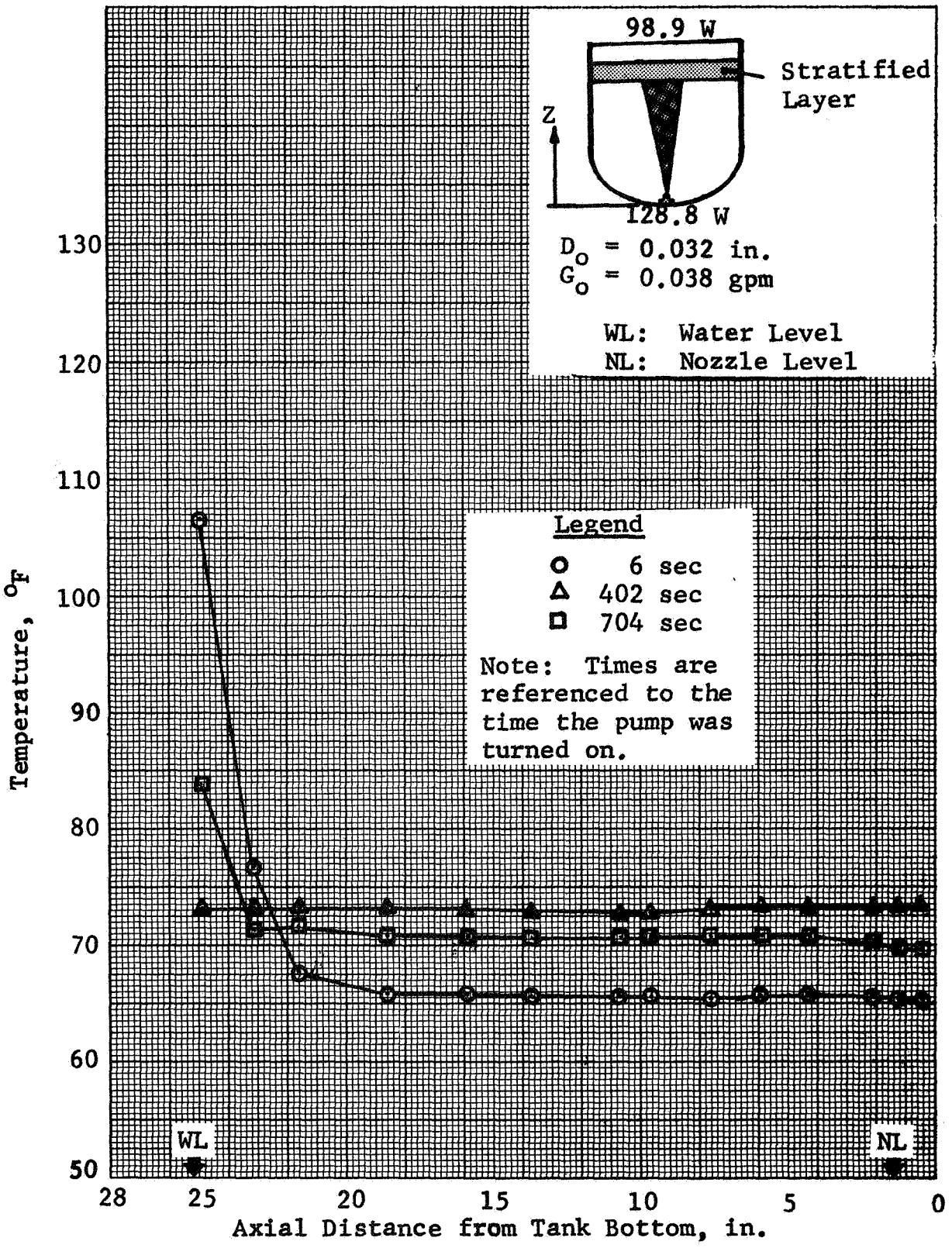


Figure 2.2-56 Temperature Distribution for Axial Jet Flow: Test 19, Run 61

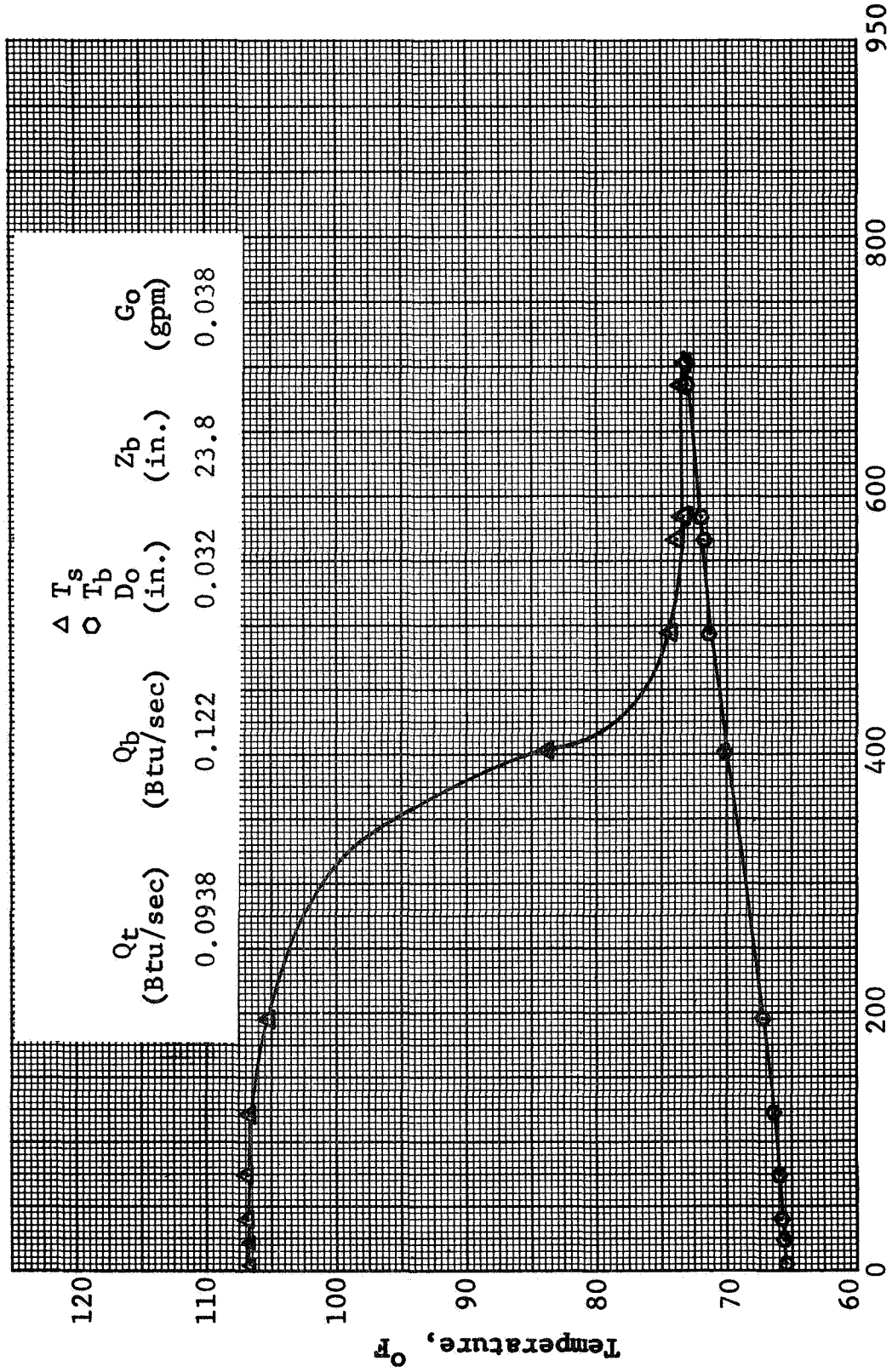


Figure 2.2-57 **Transient Temperature Destratification:** Test 19, Run 61

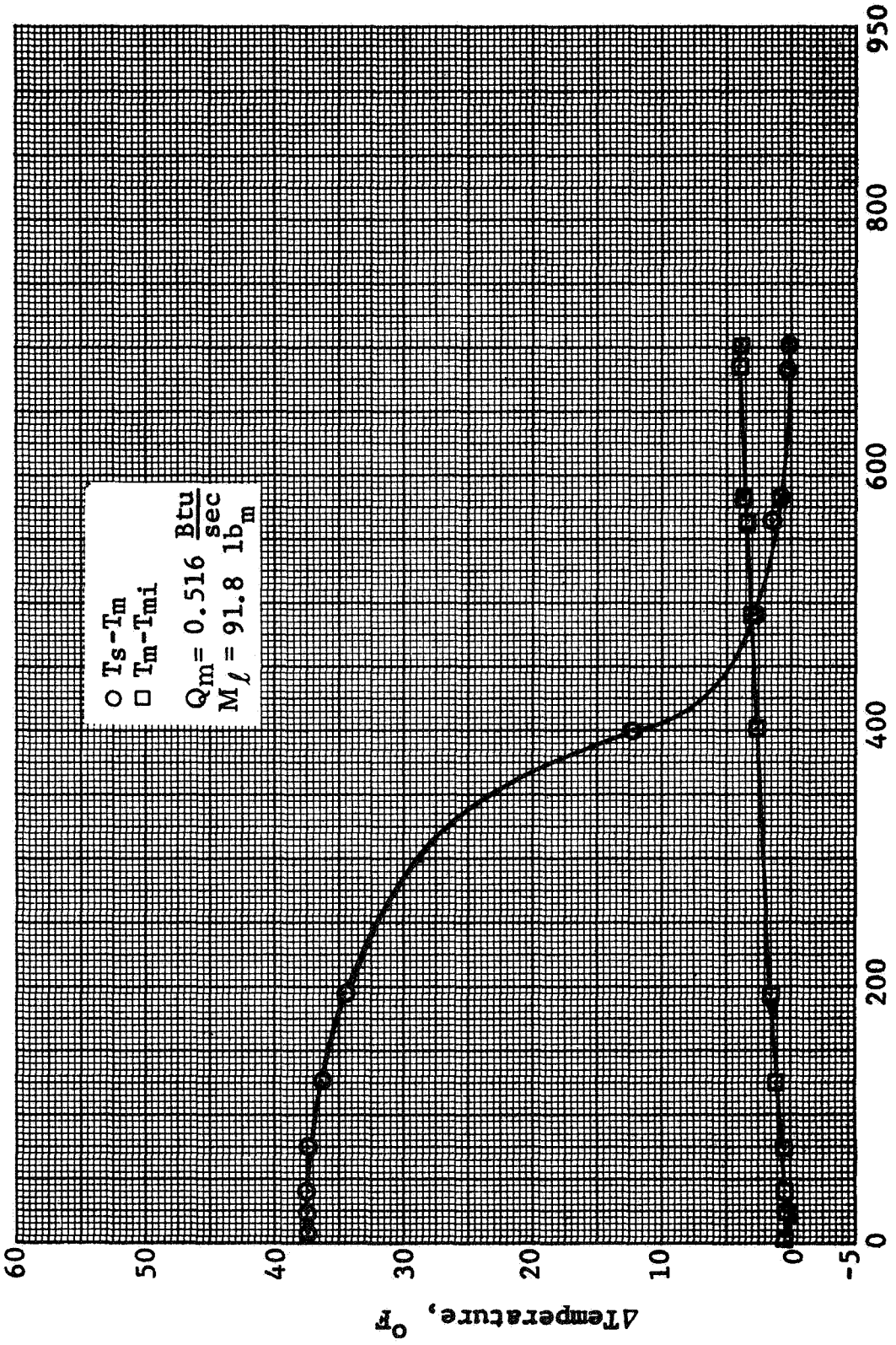


Figure 2.2-58 Transient ΔTemperature Destratification: Test 19, Run 61

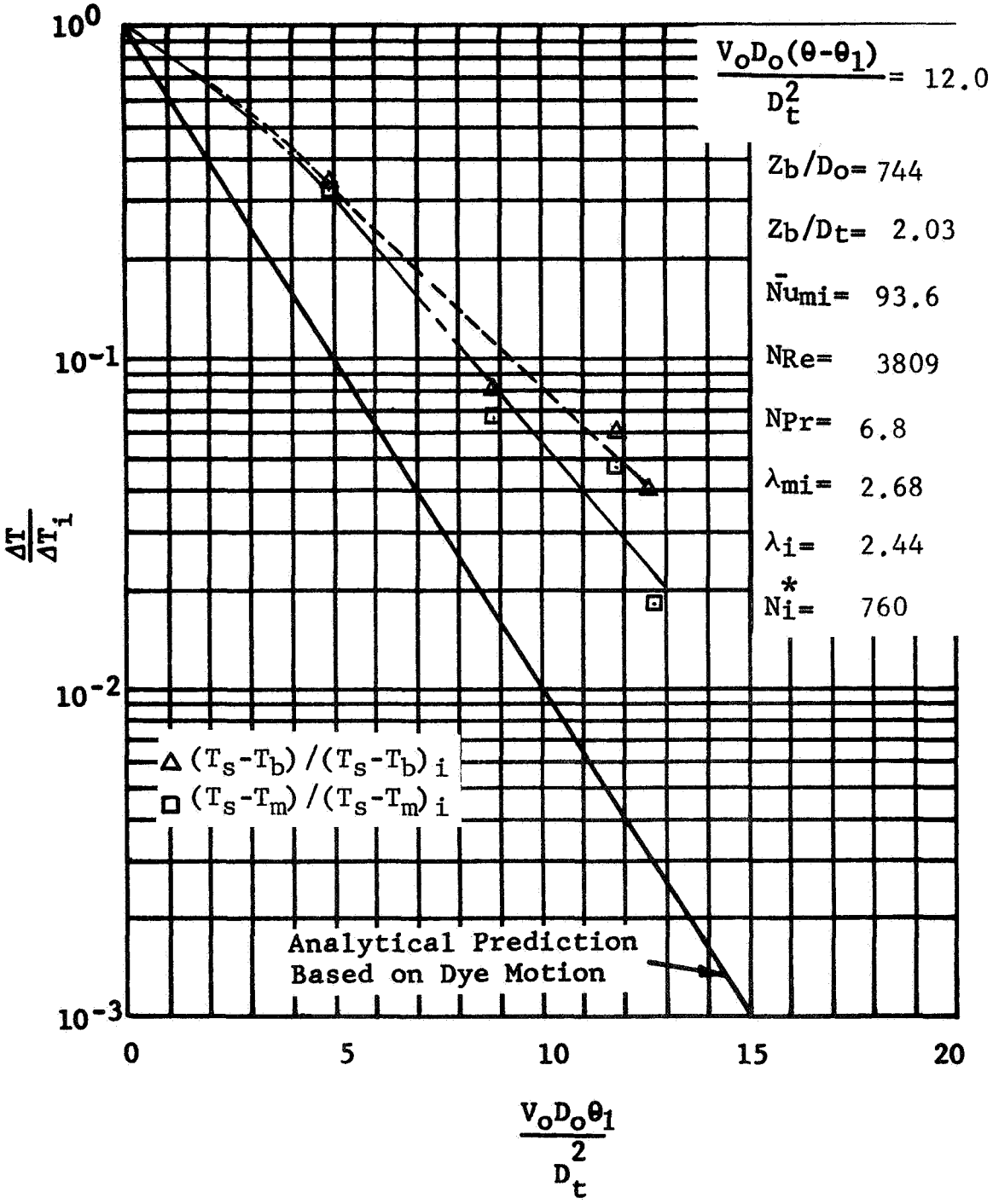


Figure 2.2-59 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 19, Run 61

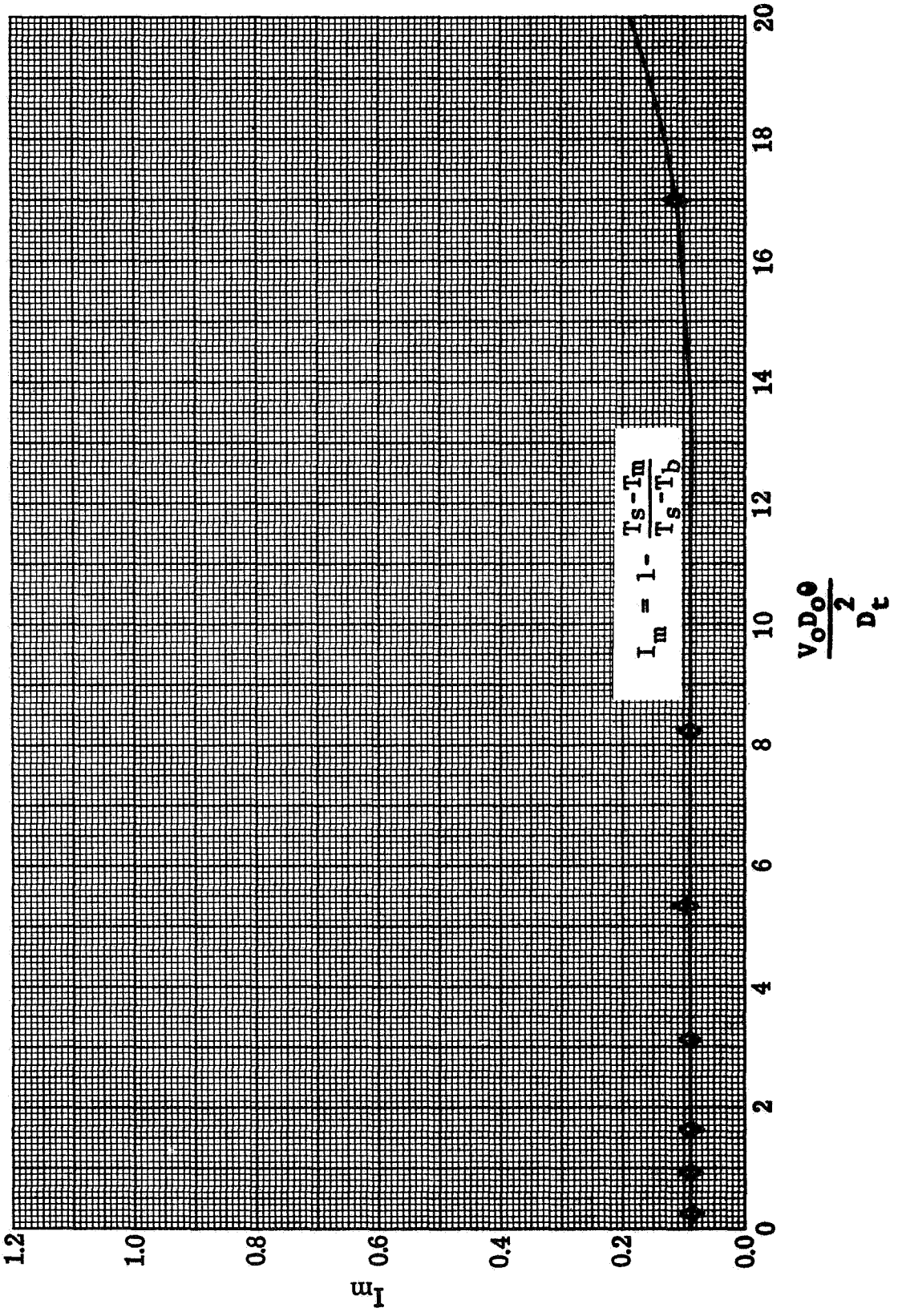


Figure 2.2-60 Transient Energy Integral: Test 19, Run 61

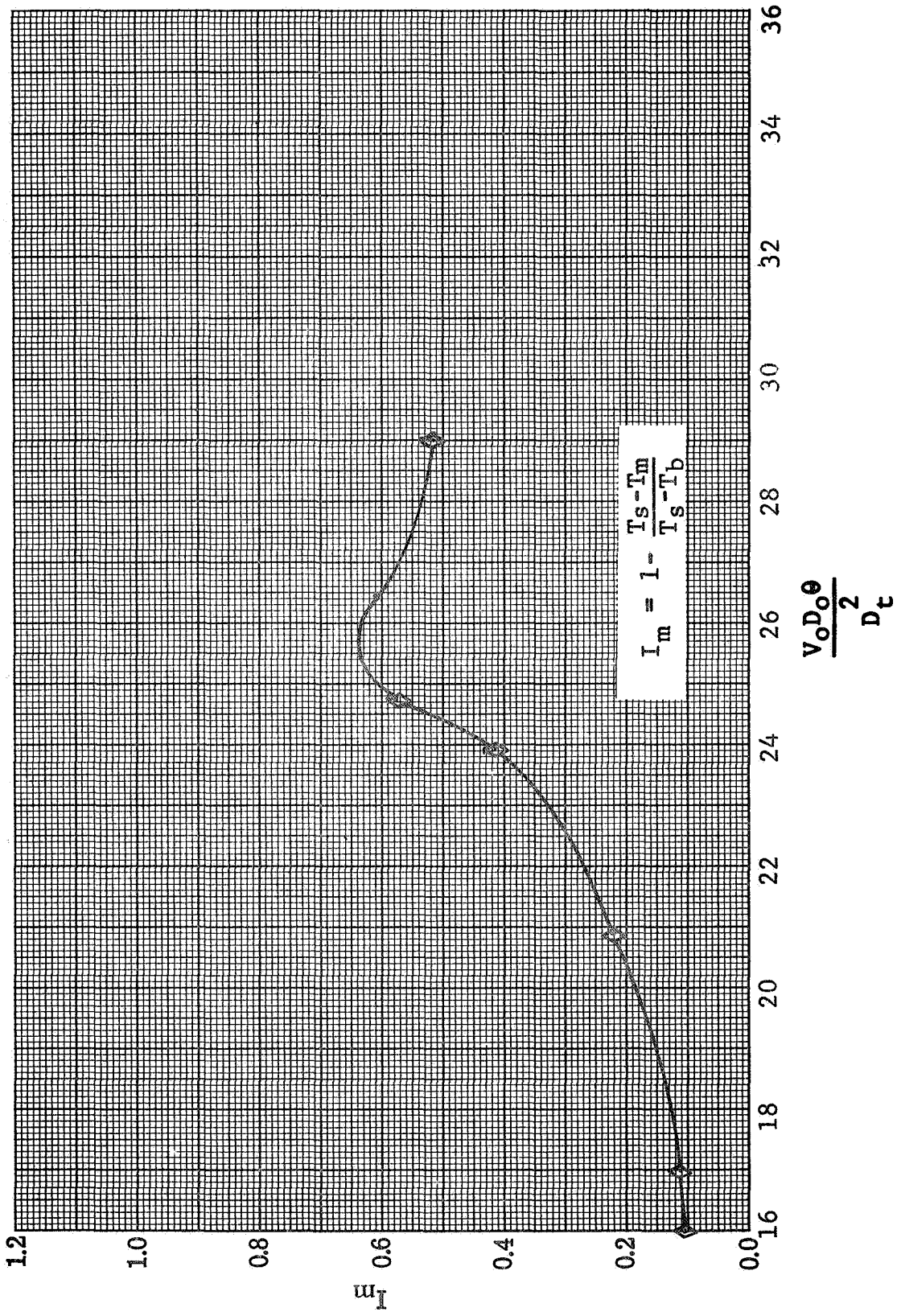


Figure 2.2-61 Transient Energy Integral: Test 19, Run 61

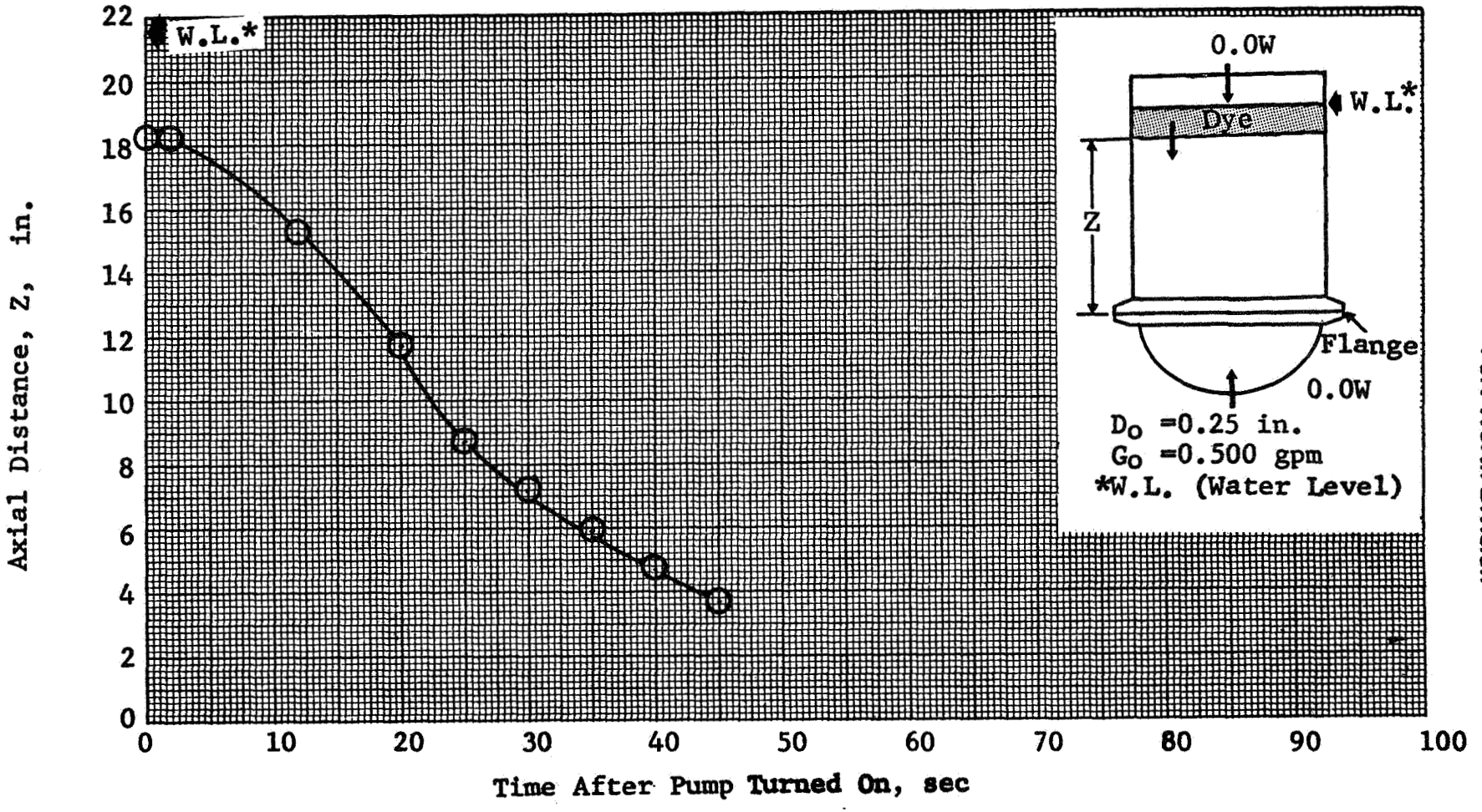


Figure 2.2-62 Axial Jet Dye Layer Motion: Test 24, Run 71

GENERAL DYNAMICS
Fort Worth Division

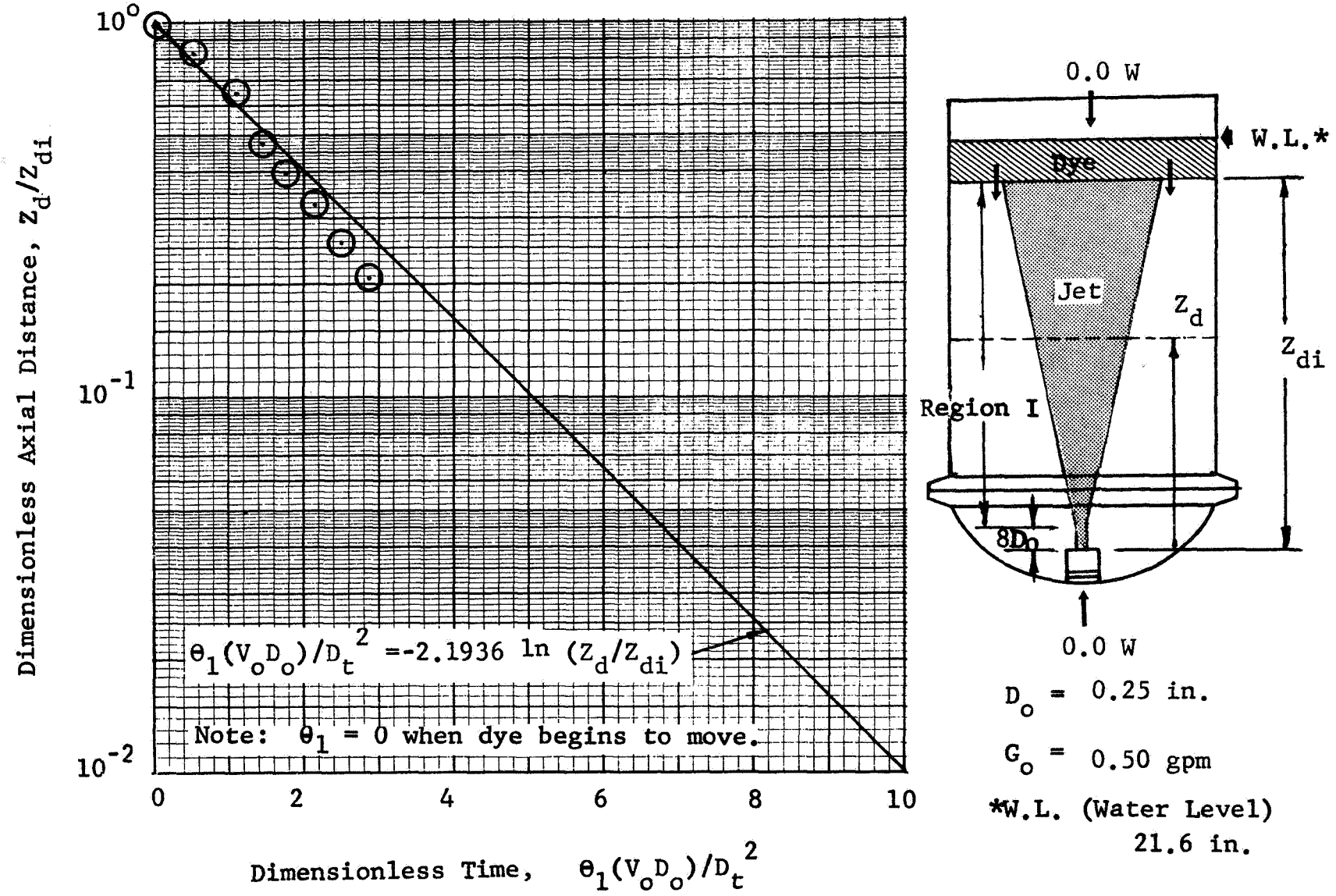


Figure 2.2-63 Correlation of Axial Jet Dye Layer Motion for Region I: Test 24, Run 71

GENERAL DYNAMICS
Fort Worth Division

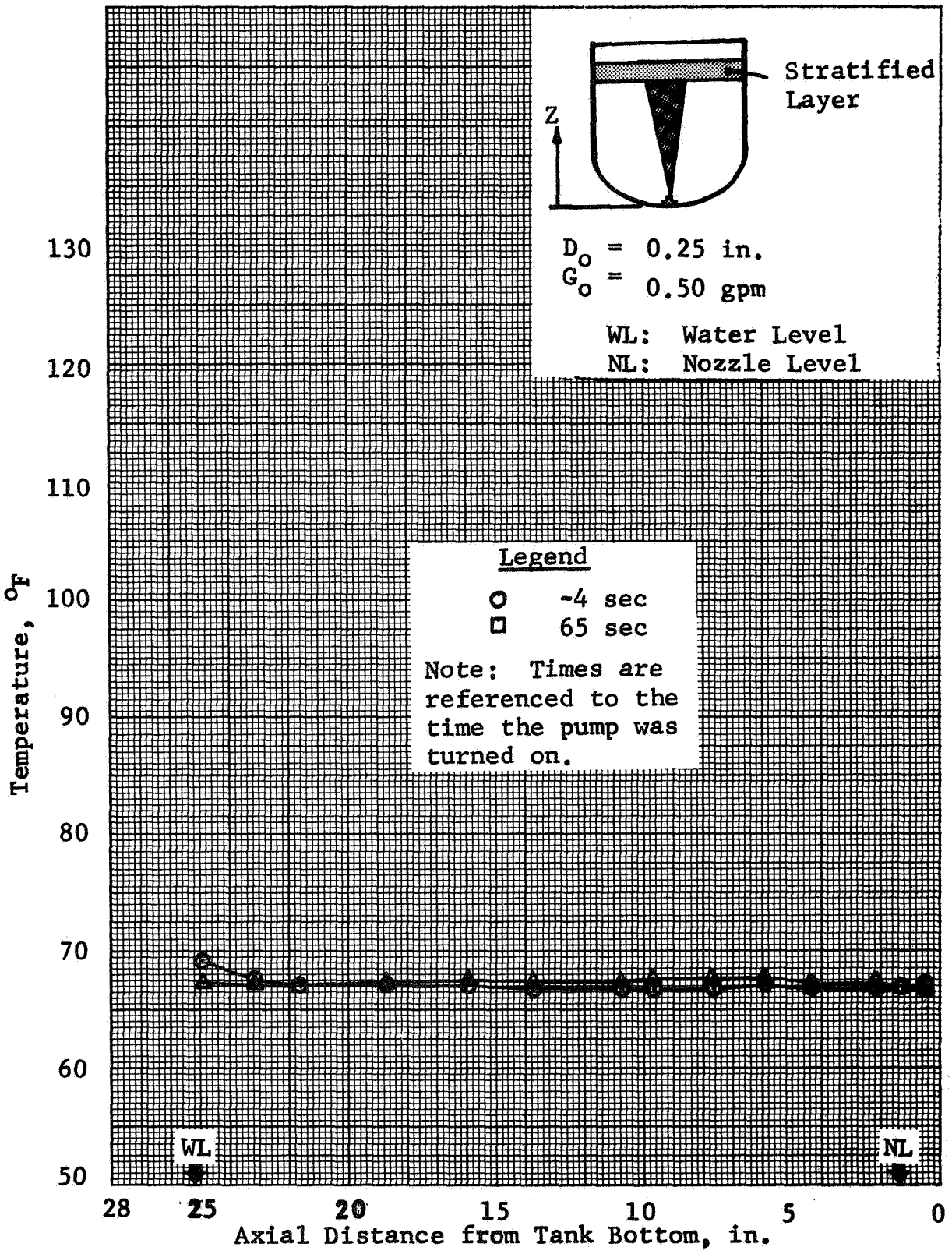


Figure 2.2-64 Temperature Distribution for Axial Jet Flow: Test 24, Run 71

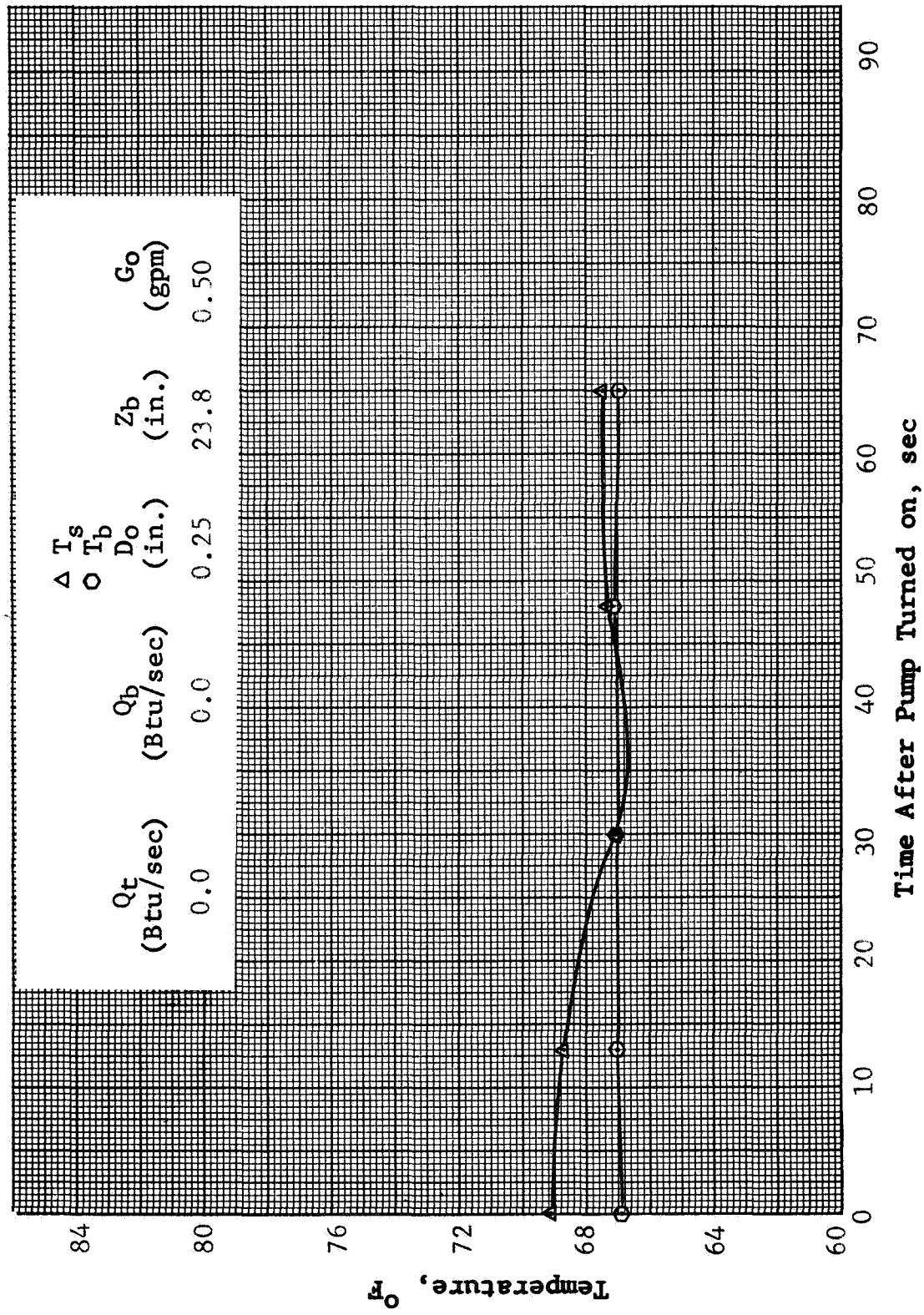


Figure 2.2-65 Transient Temperature Destratification: Test 24, Run 71

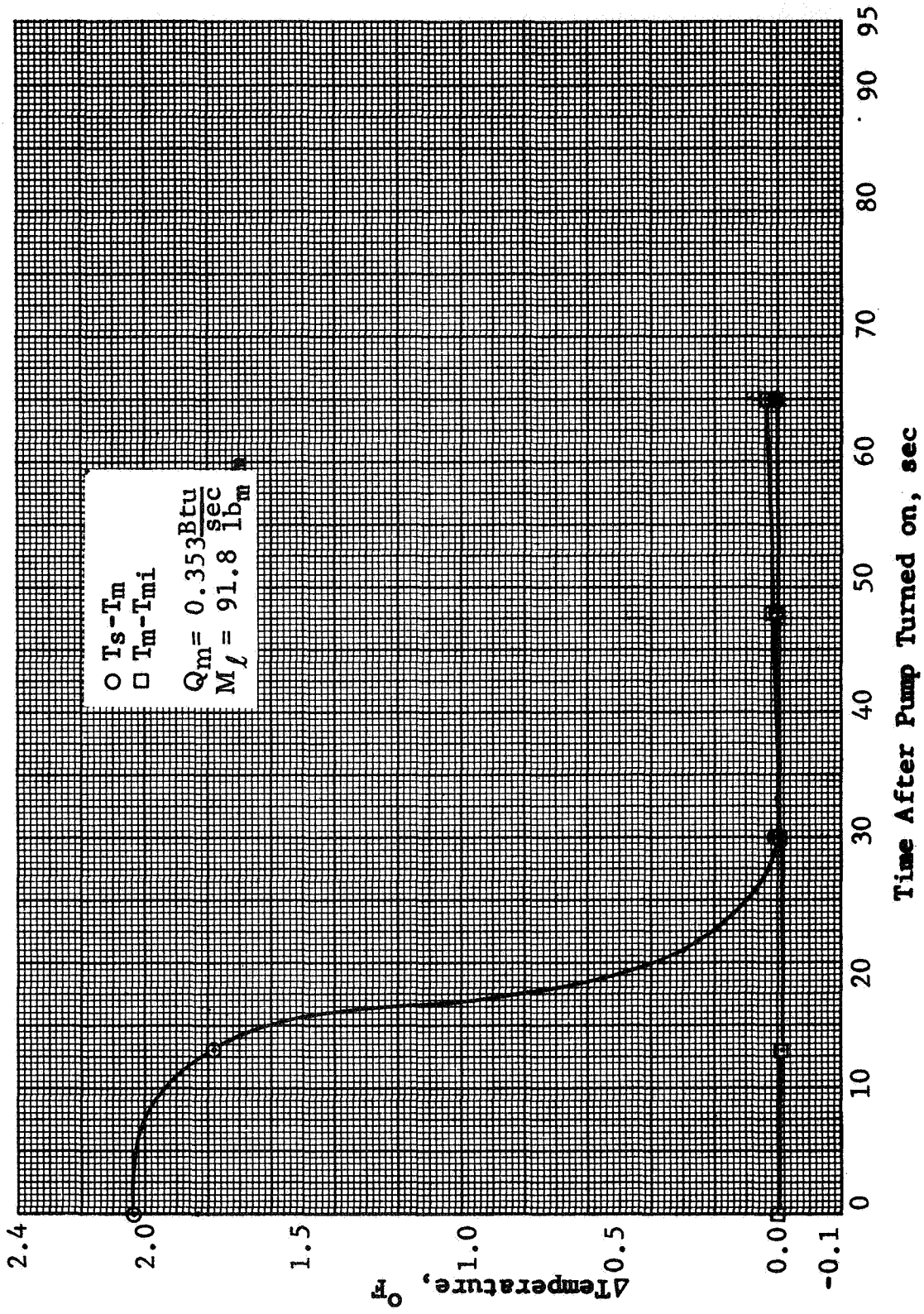


Figure 2.2-66 Transient ΔTemperature Destratification: Test 24, Run 71

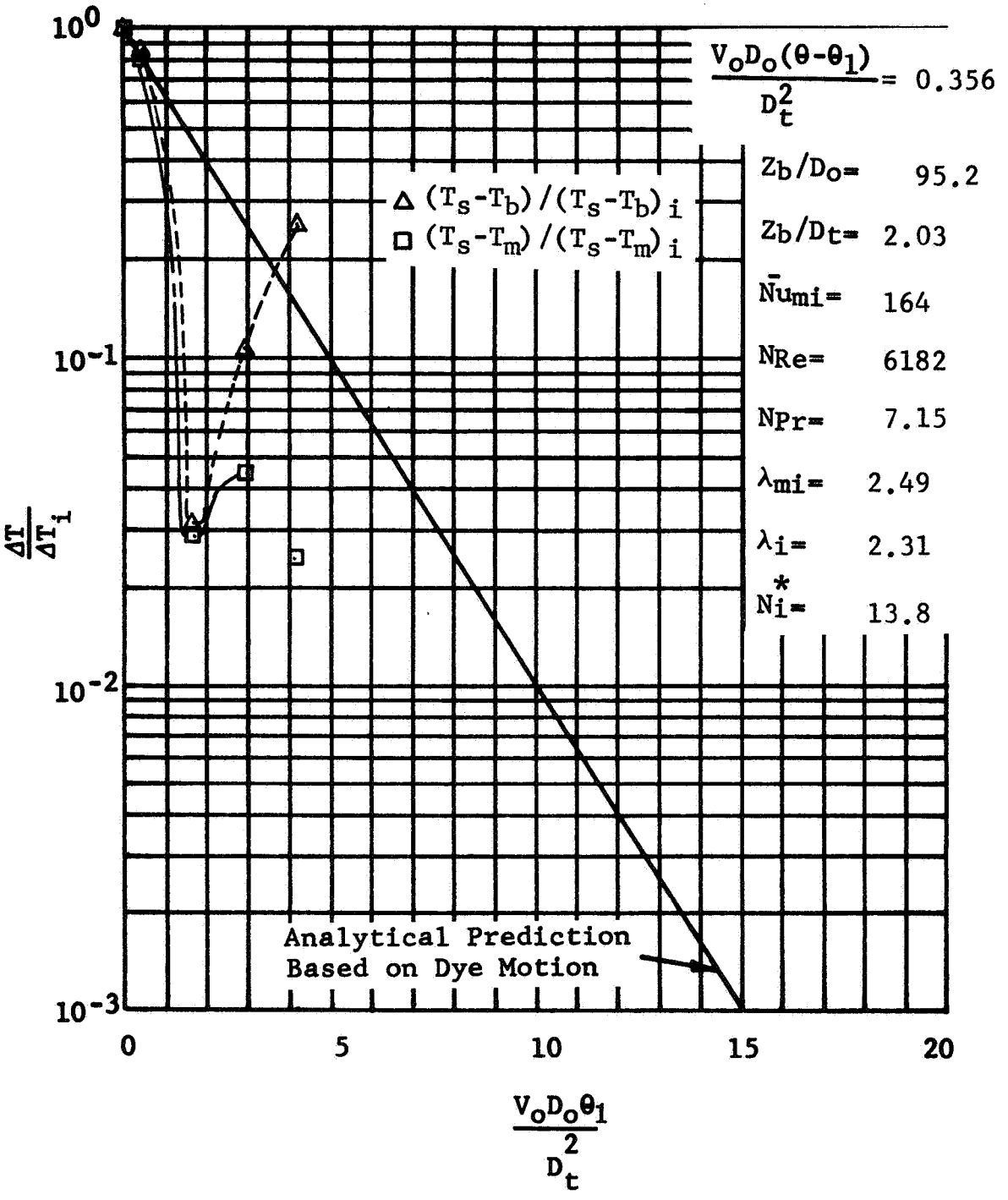


Figure 2.2-67 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 24, Run 71

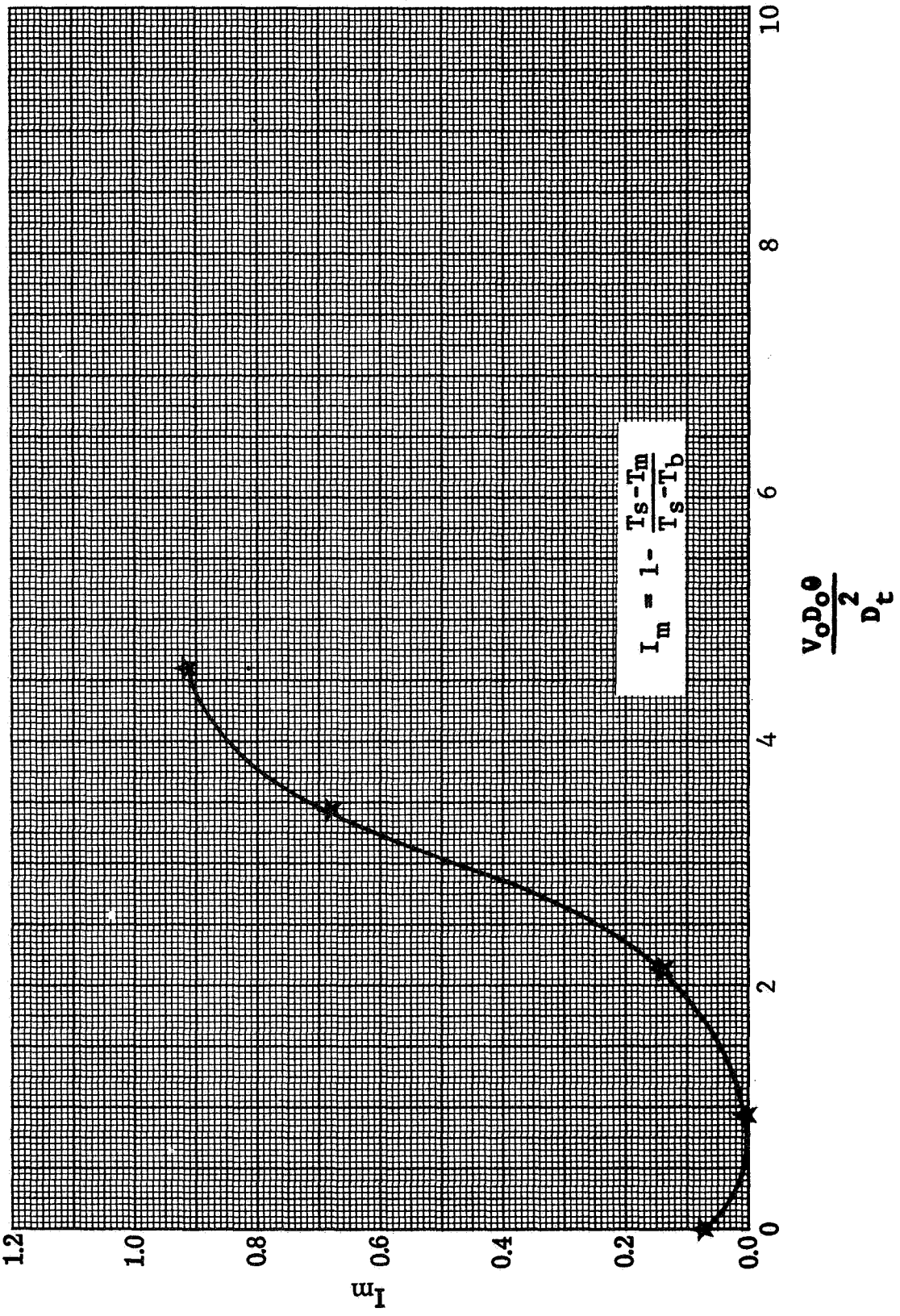


Figure 2.2-68 Transient Energy Integral: Test 24, Run 71

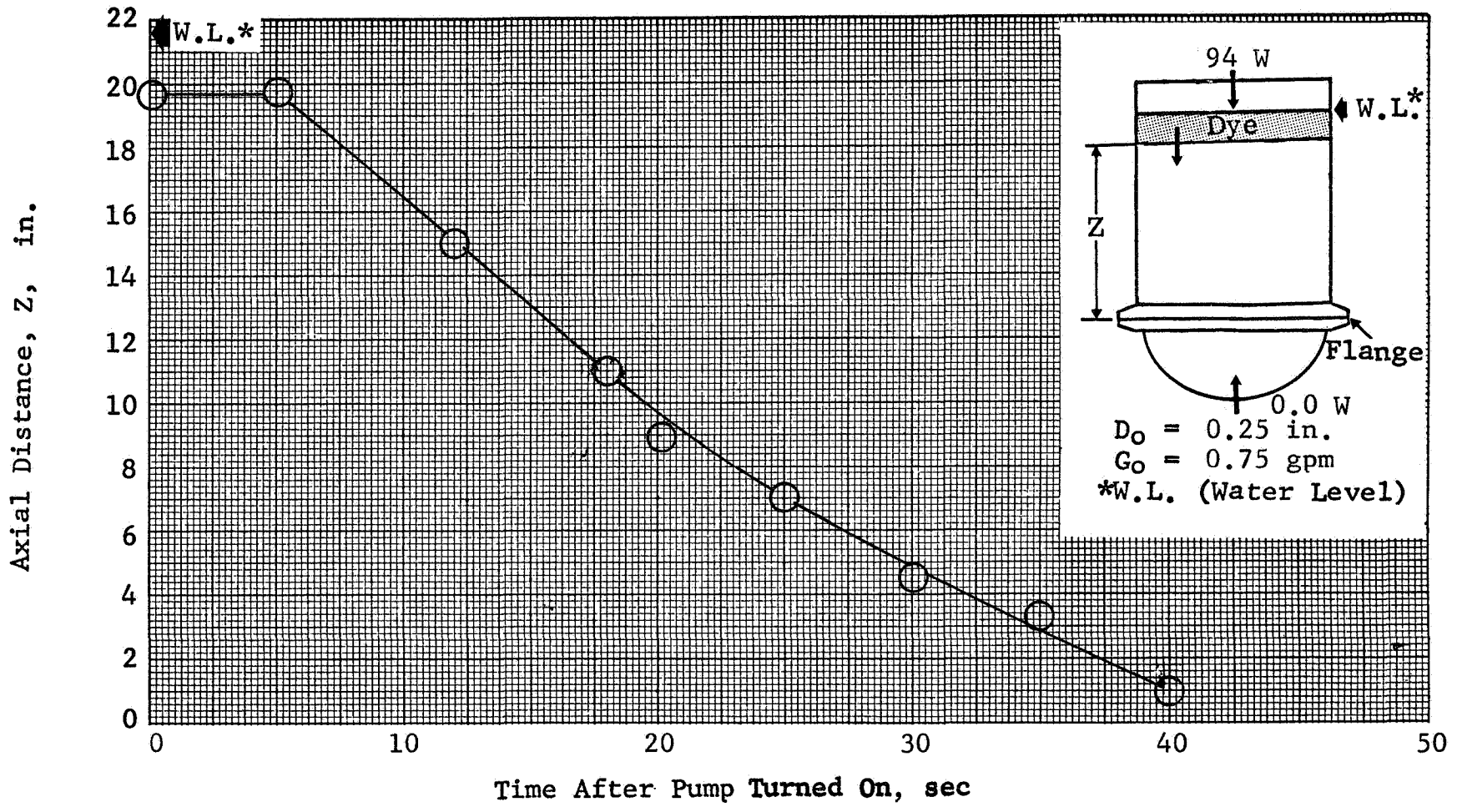


Figure 2.2-69 **Axial Jet Dye Layer Motion:** Test 27, Run 74

GENERAL DYNAMICS
Fort Worth Division

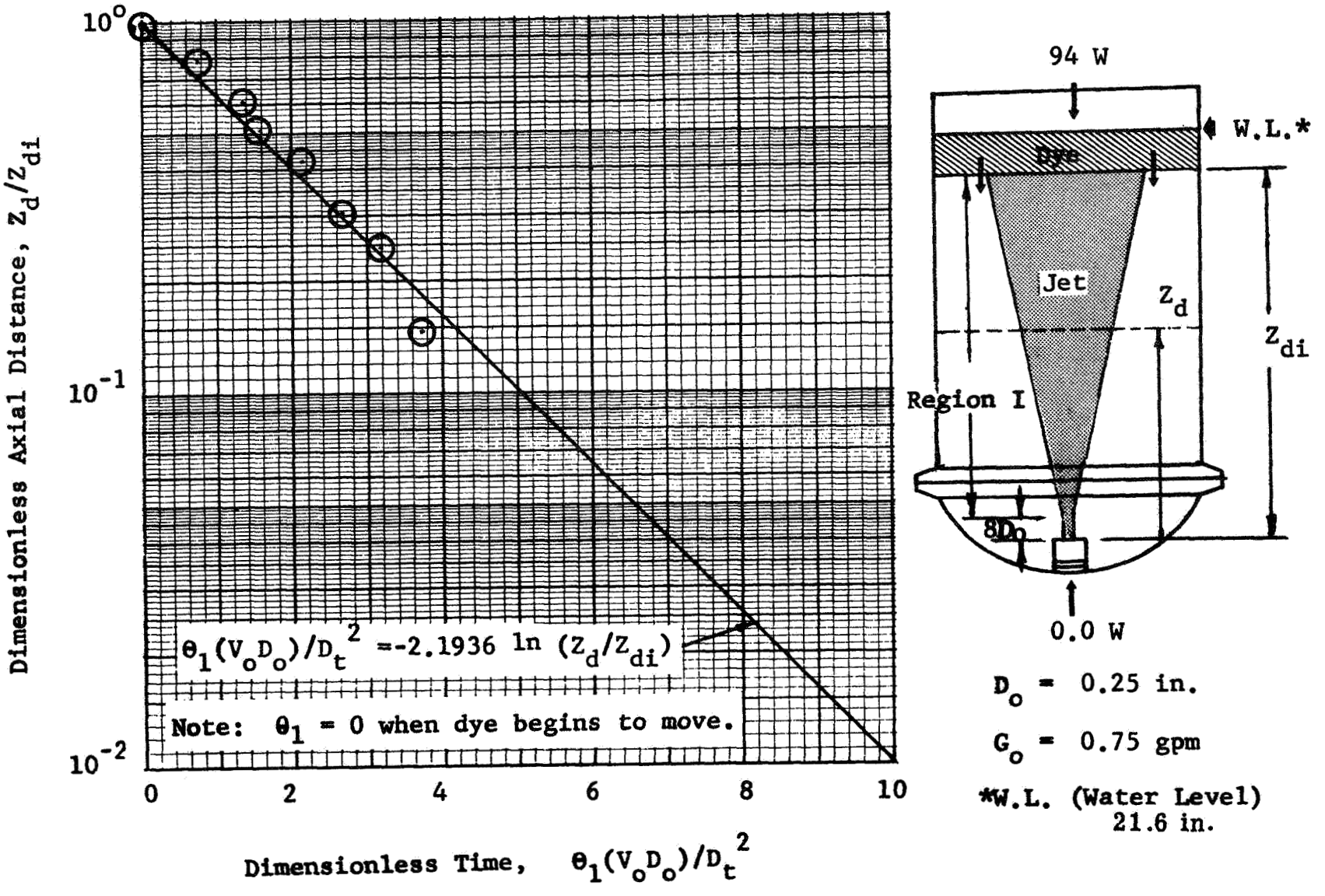


Figure 2.2-70 Correlation of Axial Jet Dye Layer Motion for Region I: Test 27, Run 74

GENERAL DYNAMICS
Fort Worth Division

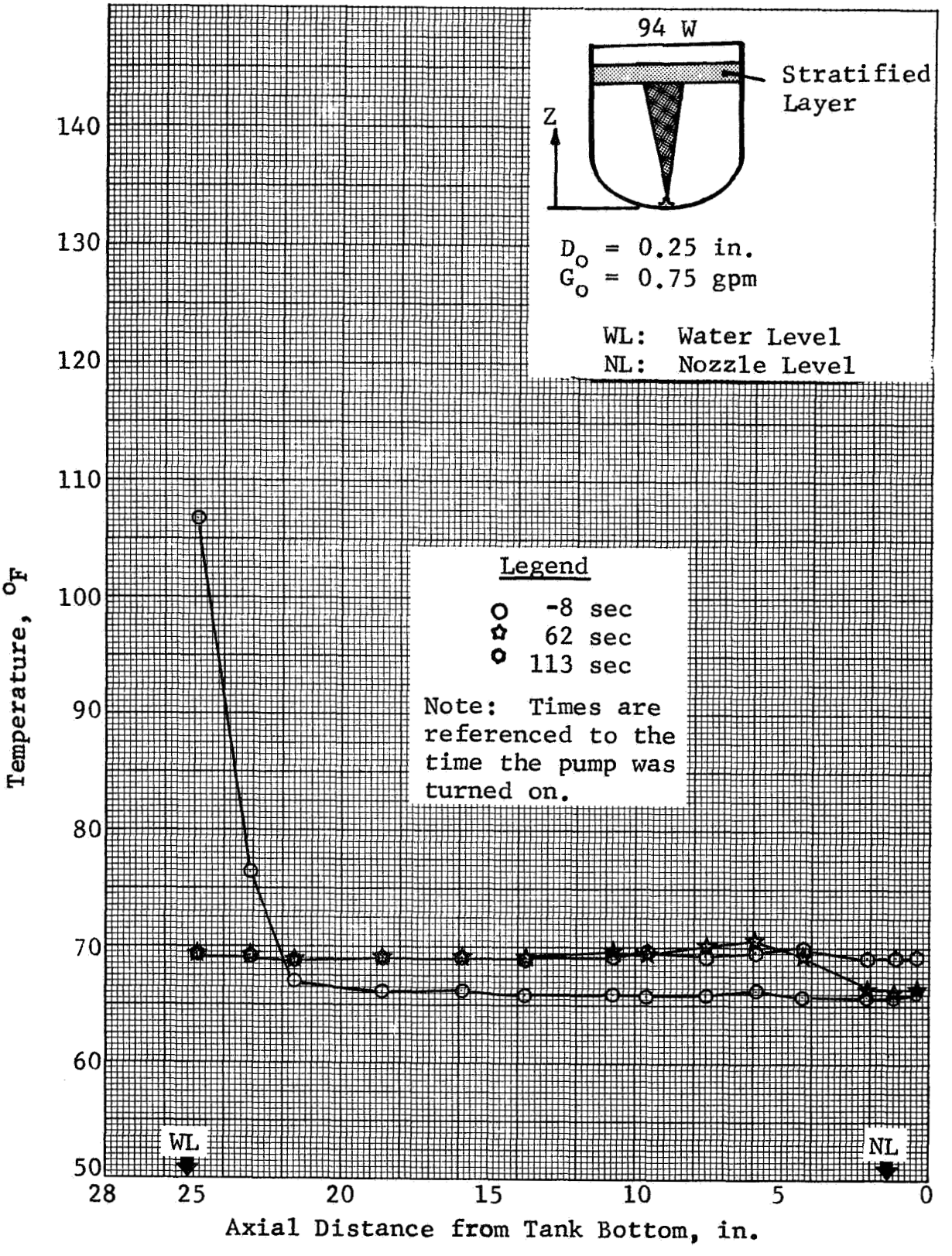


Figure 2.2-71 Temperature Distribution for Axial Jet Flow: Test 27, Run 74

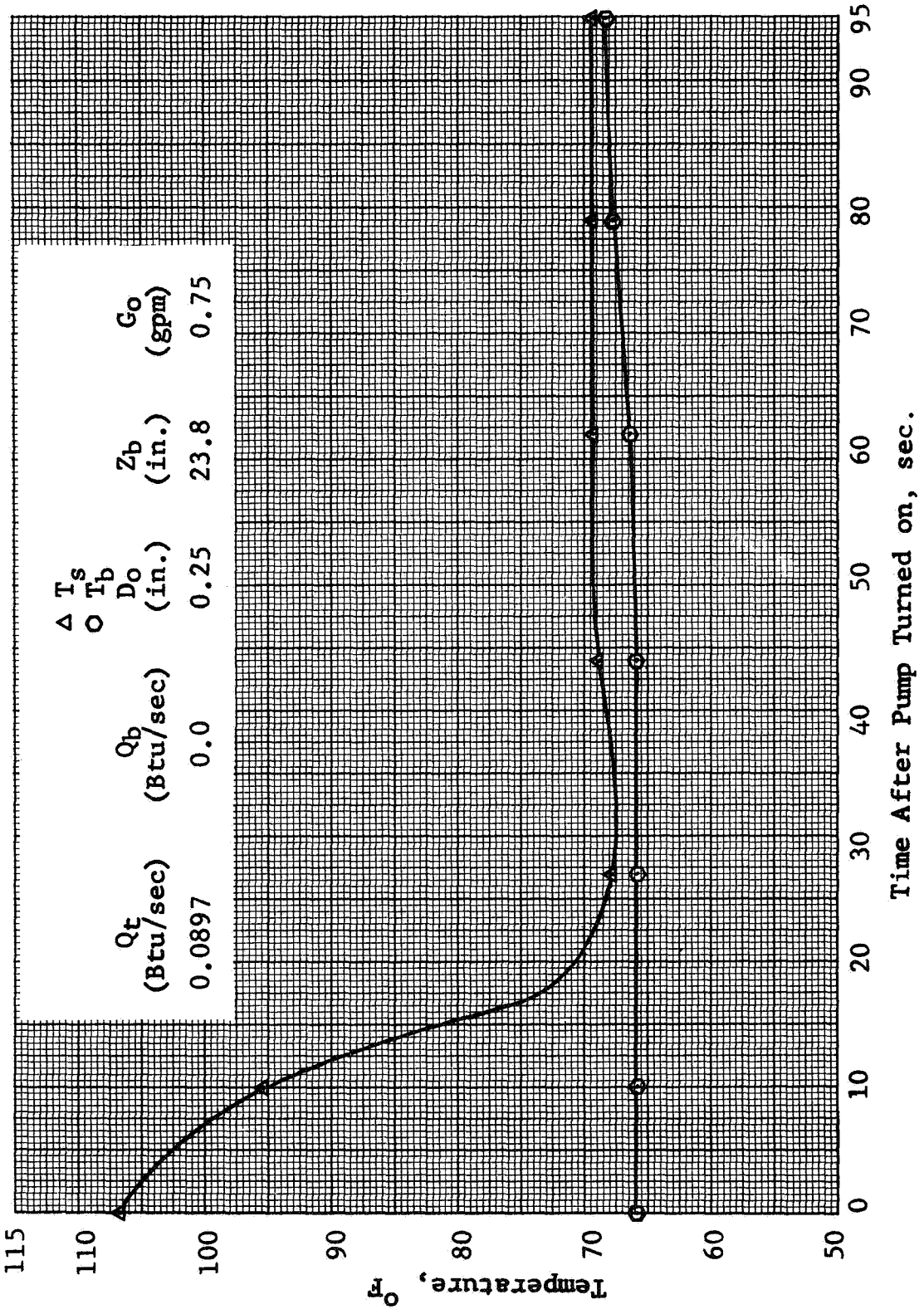


Figure 2.2-72 Transient Temperature Destratification: Test 27, Run 74

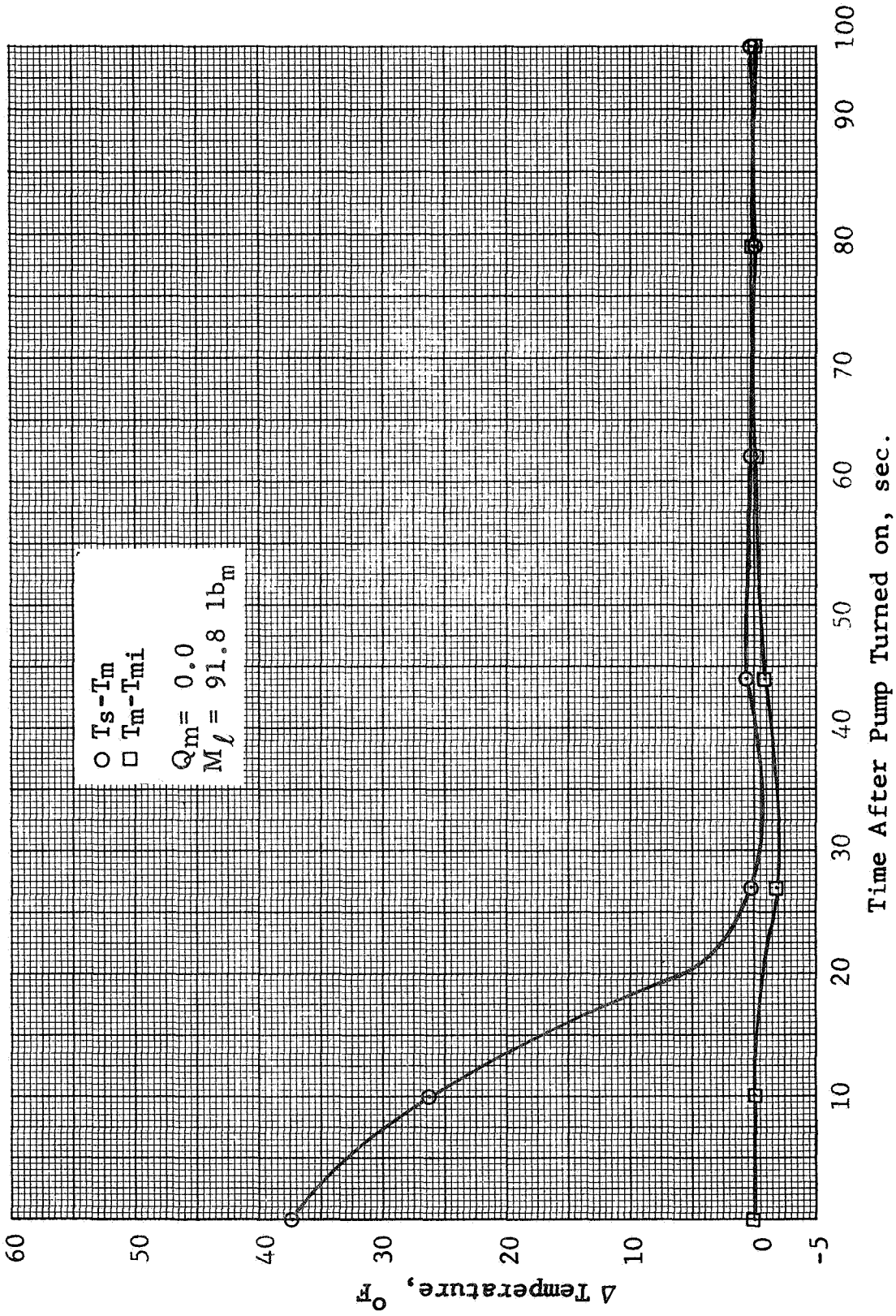


Figure 2.2-73 Transient ΔTemperature Destratification: Test 27, Run 74

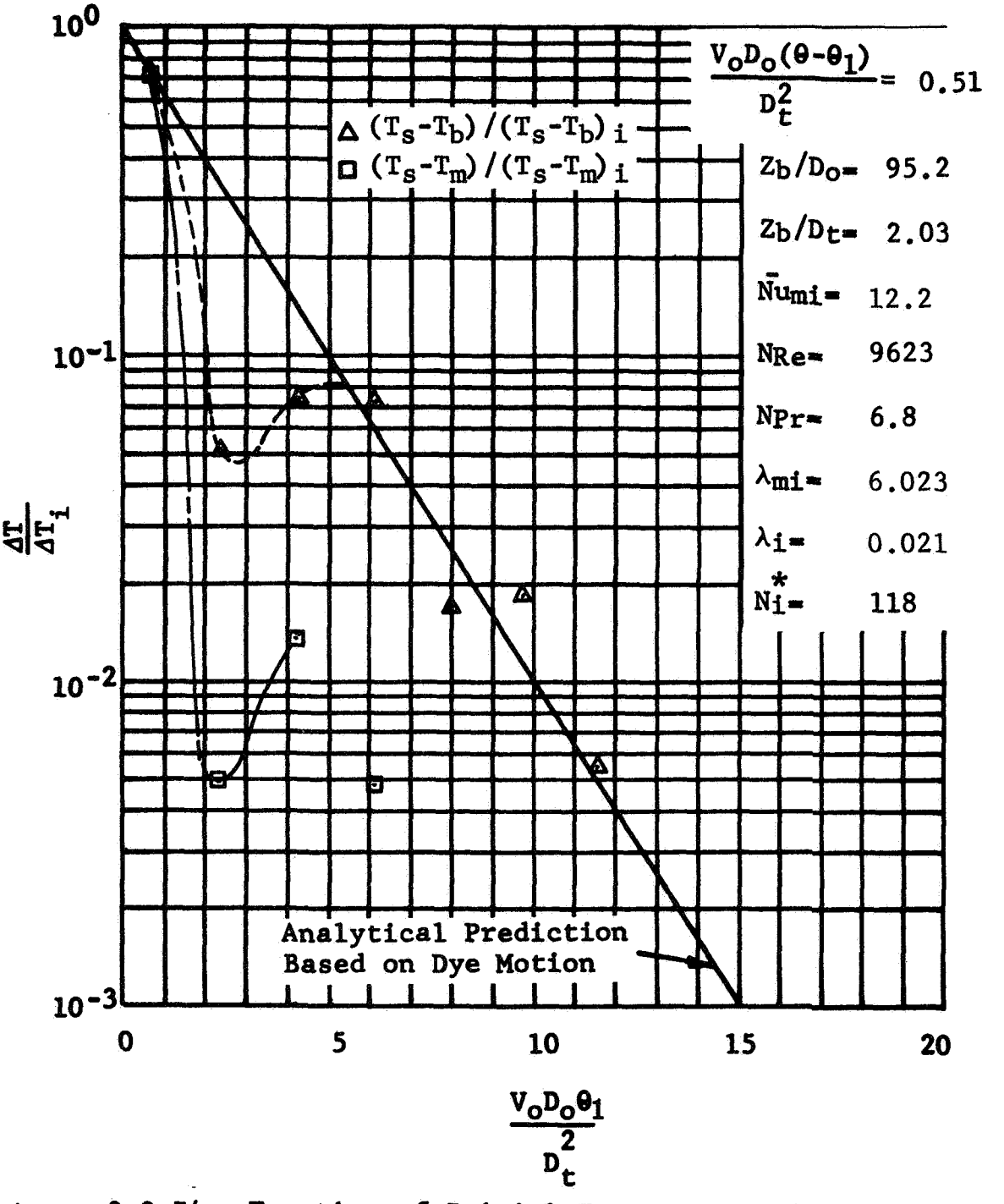


Figure 2.2-74 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 27, Run 74

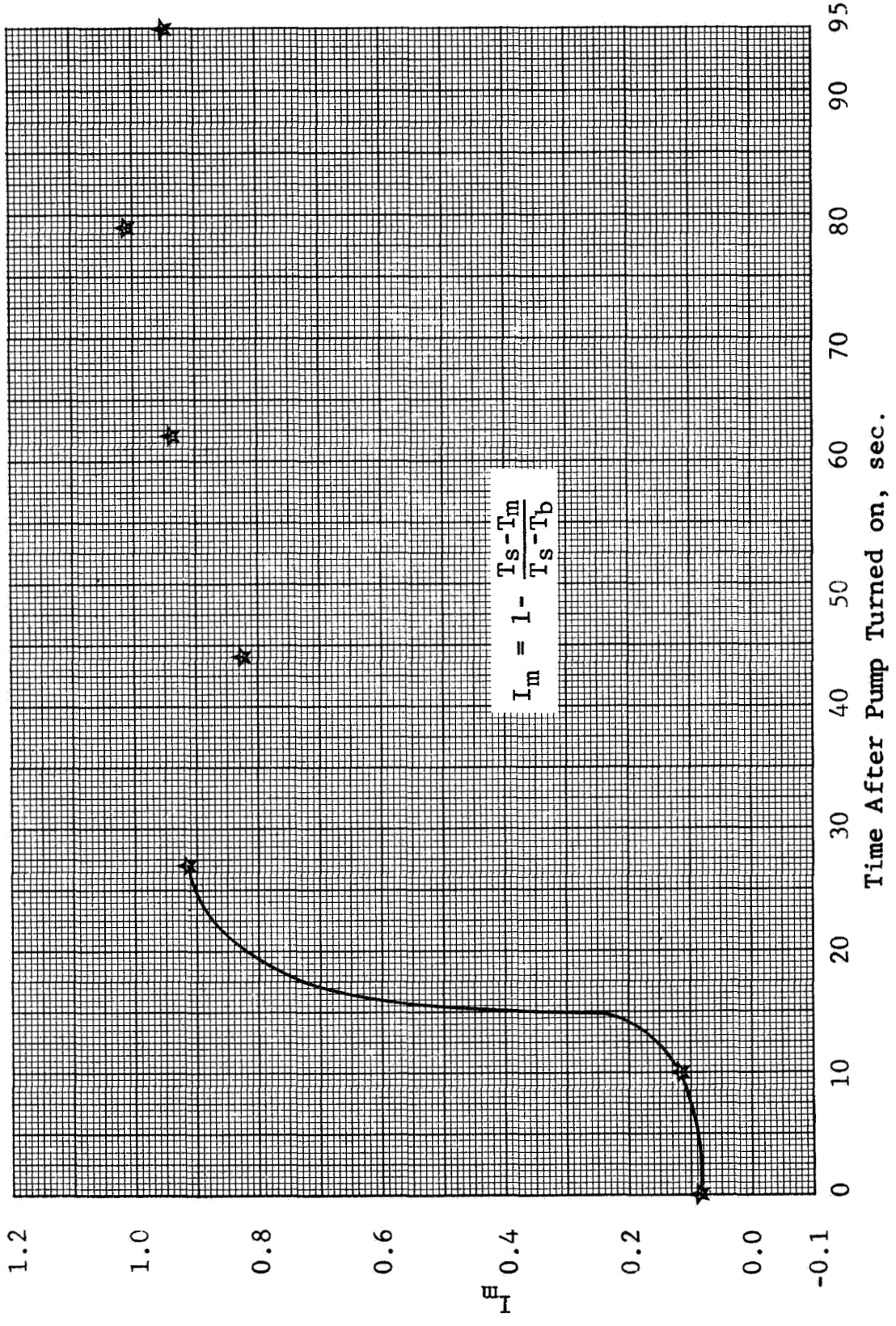


Figure 2.2-75 Transient Energy Integral: Test 27, Run 74

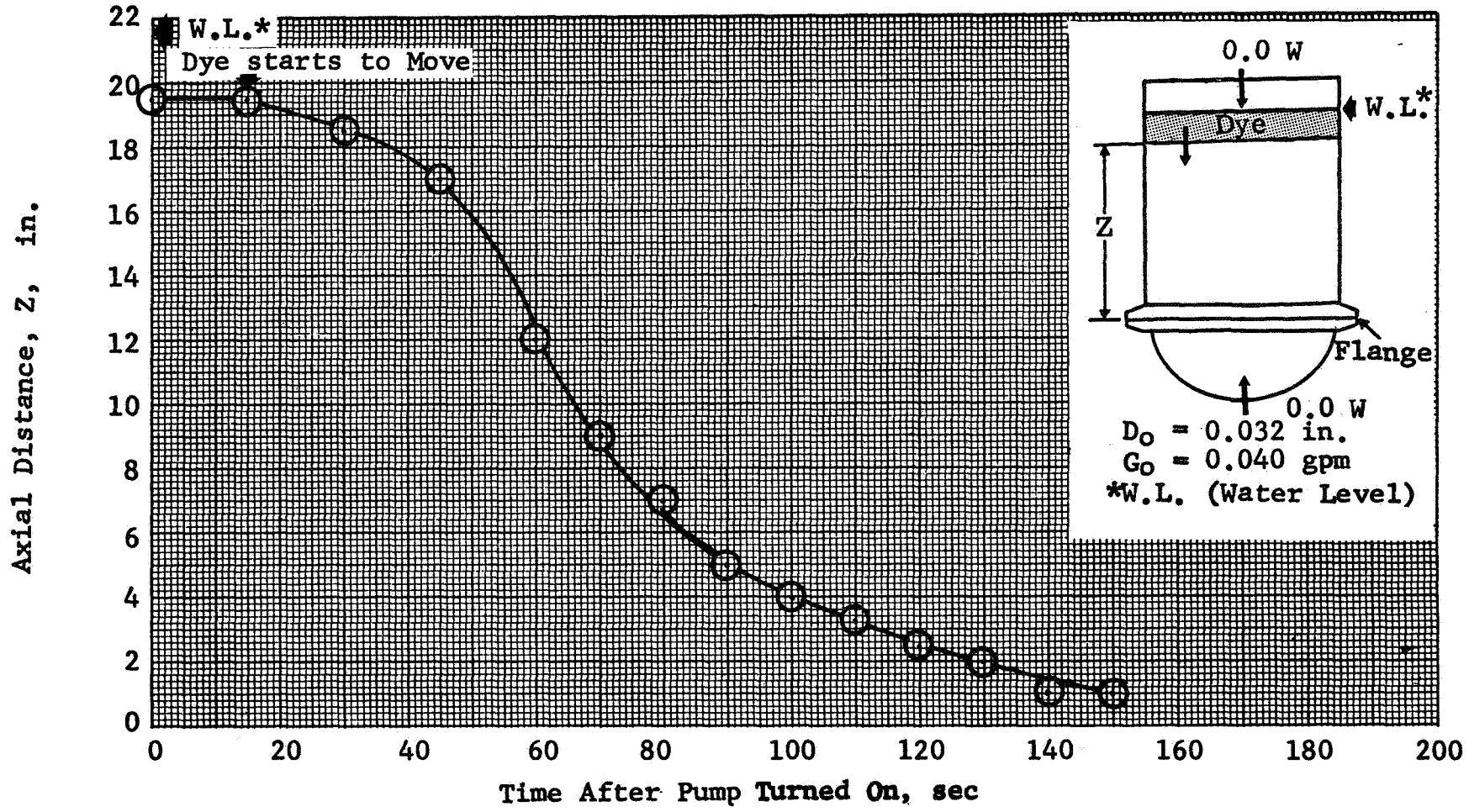


Figure 2.2-76 Axial Jet Dye Layer Motion: Test 28, Run 65

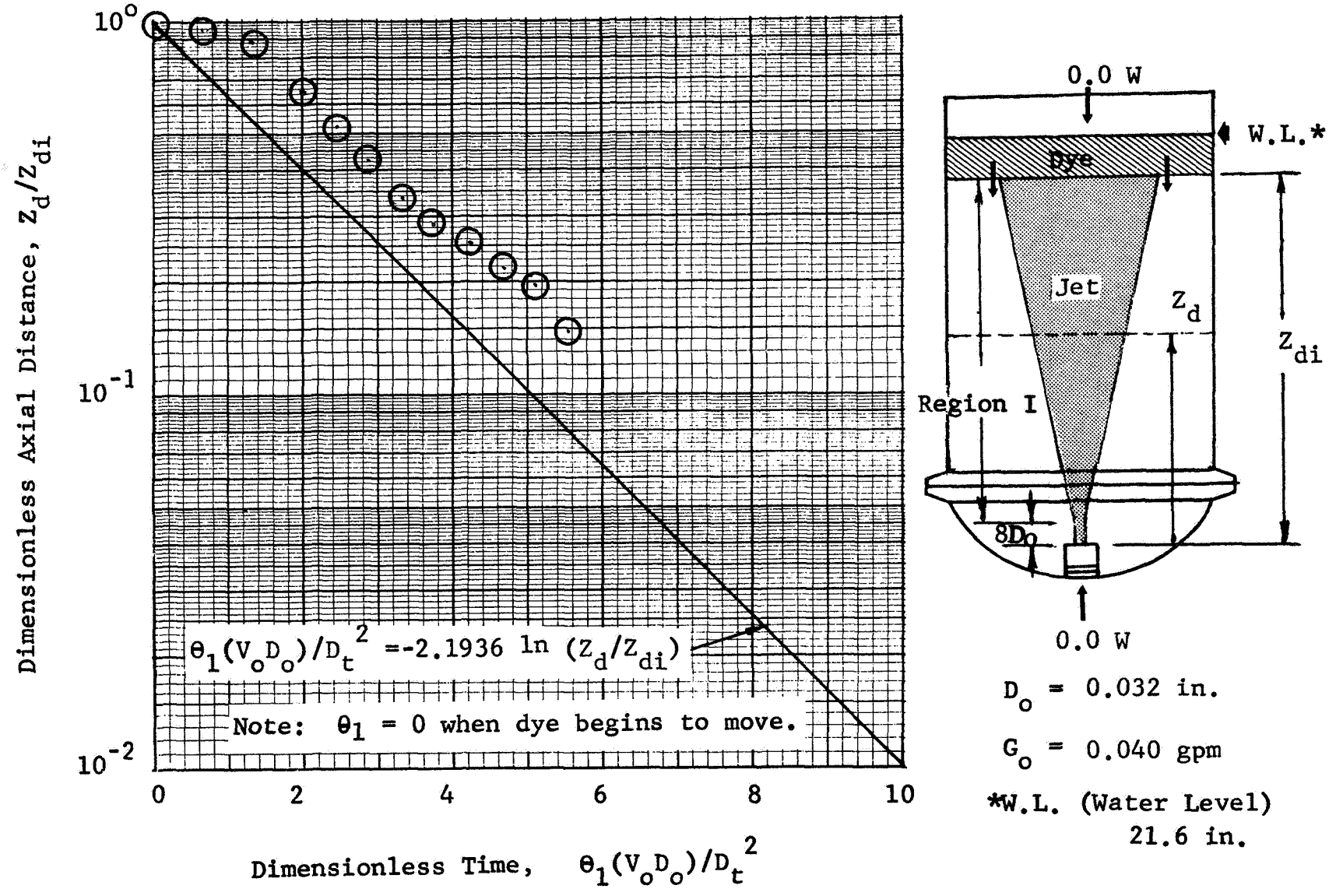


Figure 2.2-77 Correlation of Axial Jet Dye Layer Motion for Region I: Test 28, Run 65

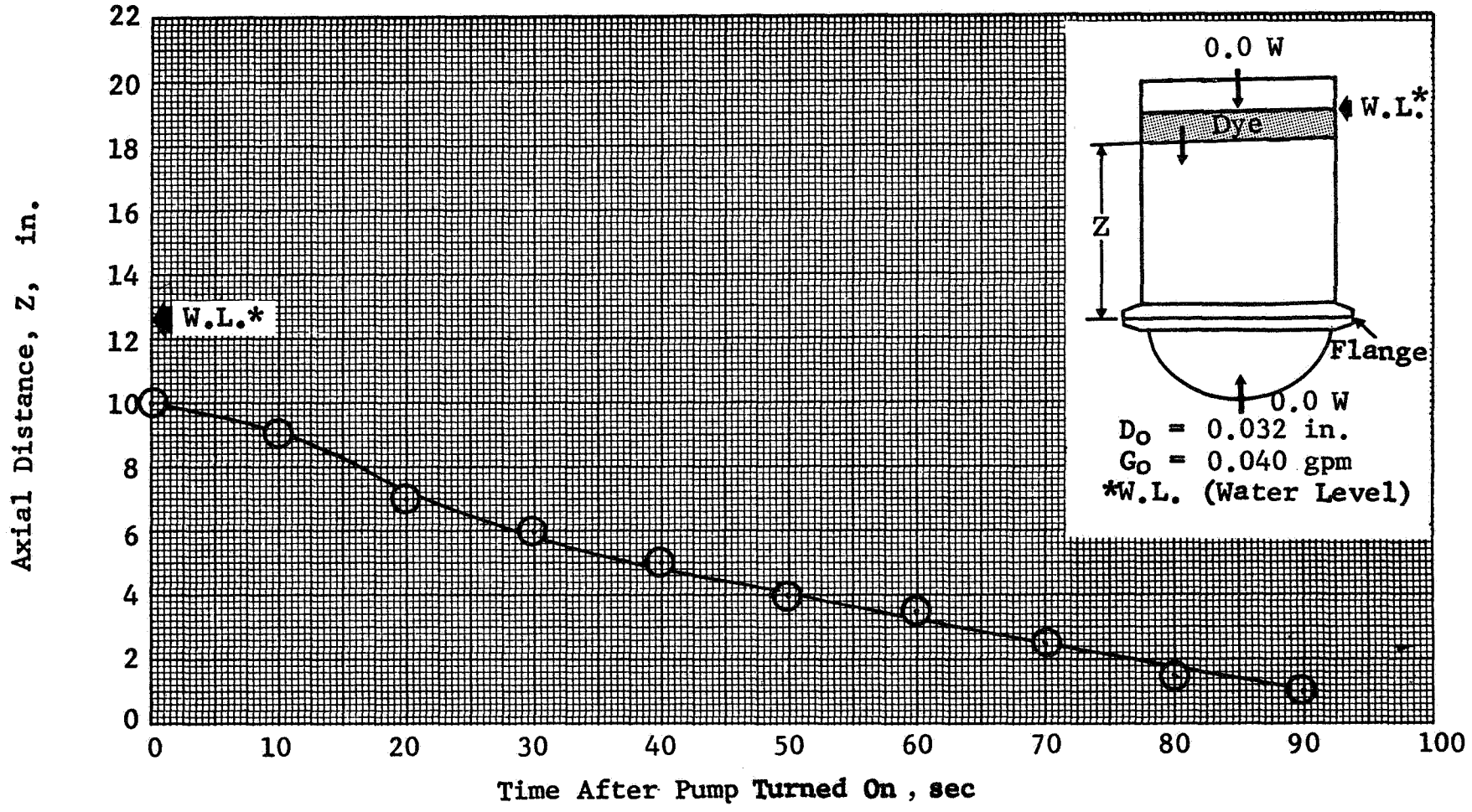


Figure 2.2-78 Axial Jet Dye Layer Motion: Test 29, Run 66

GENERAL DYNAMICS
Fort Worth Division

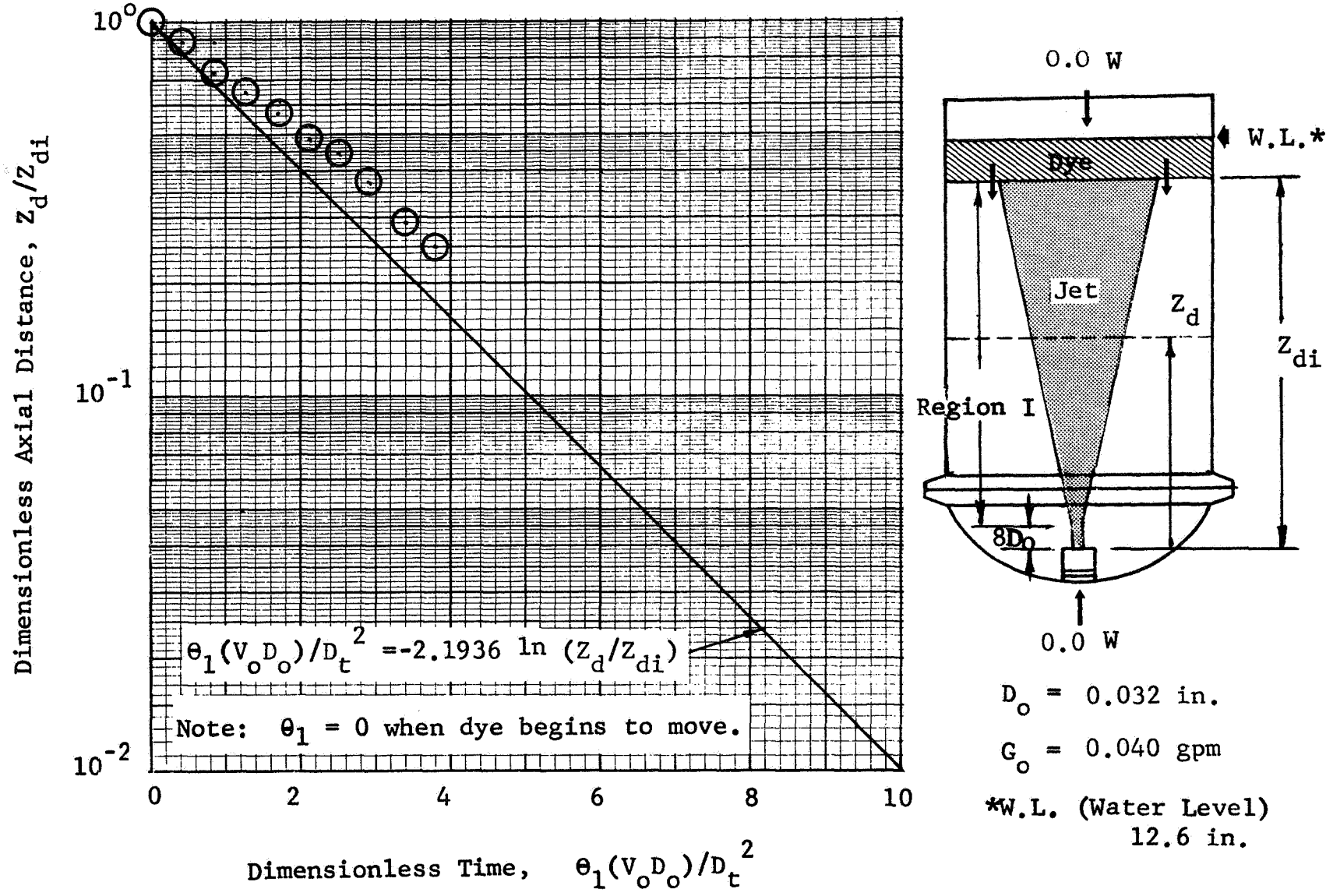


Figure 2.2-79 Correlation of Axial Jet Dye Layer Motion for Region I: Test 29, Run 66

GENERAL DYNAMICS
Fort Worth Division

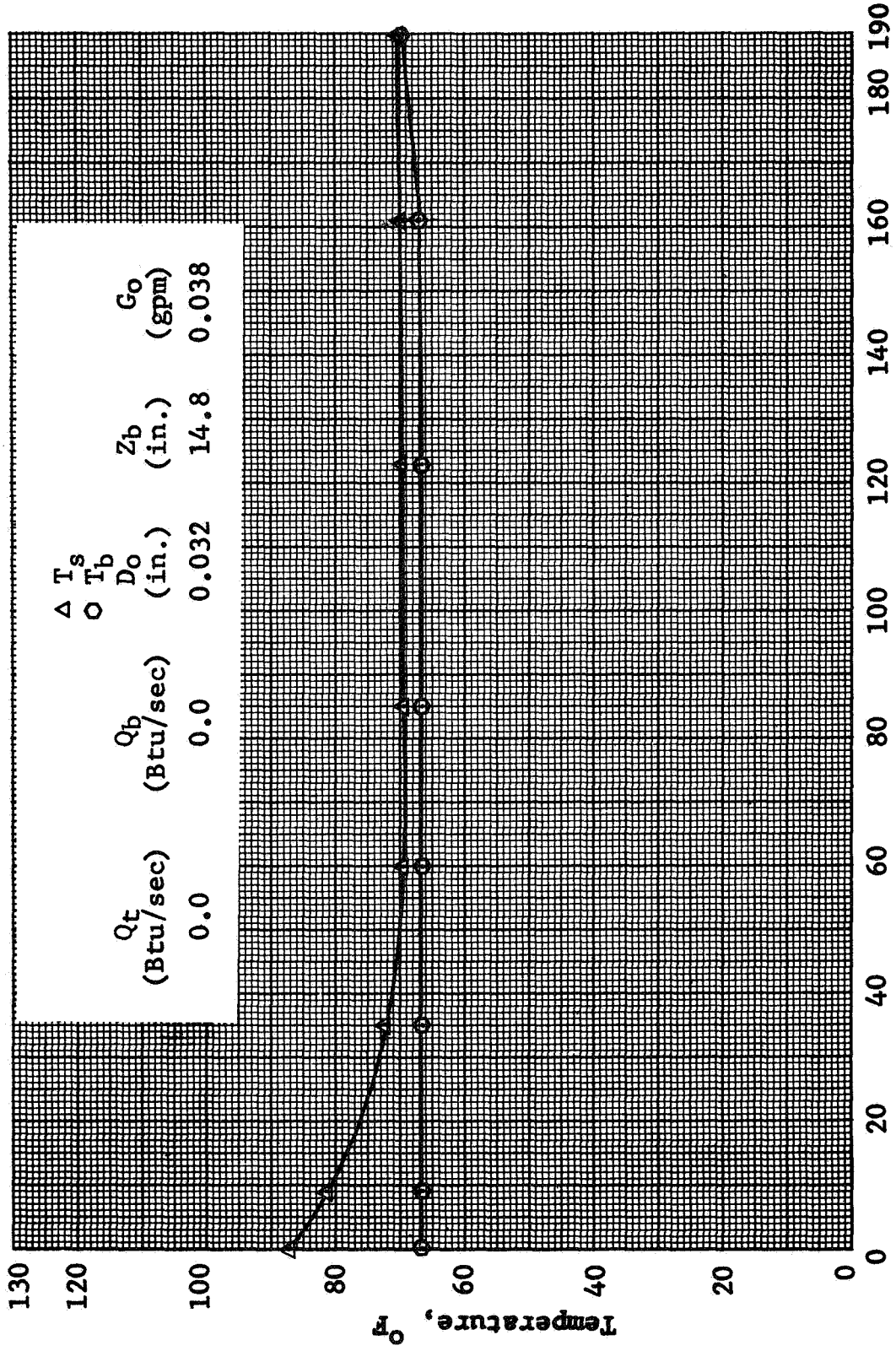


Figure 2.2-80 Transient Temperature Destratification: Test 29, Run 66

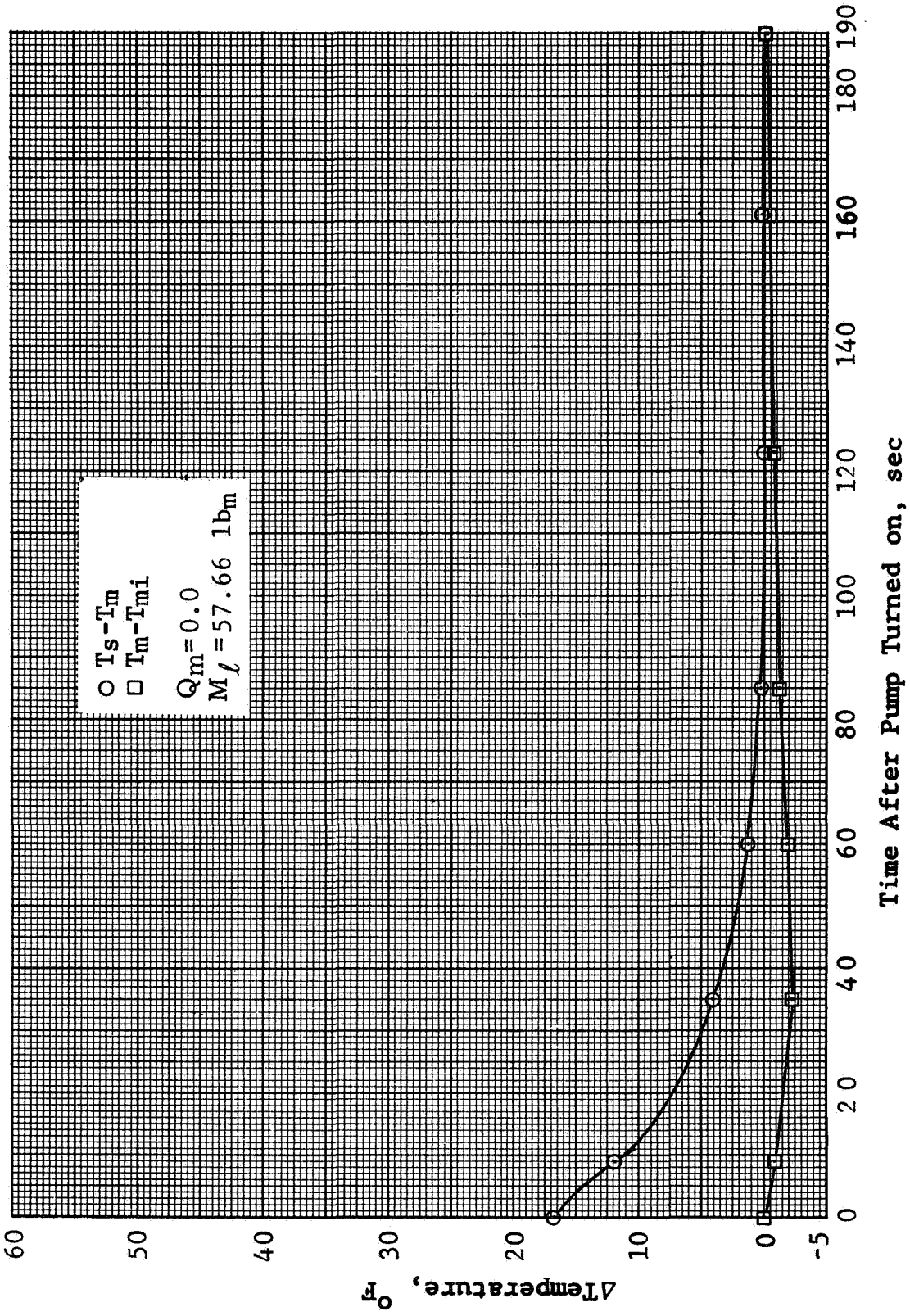


Figure 2.2-81 Transient **ΔTemperature Destratification:** Test 29, Run 66

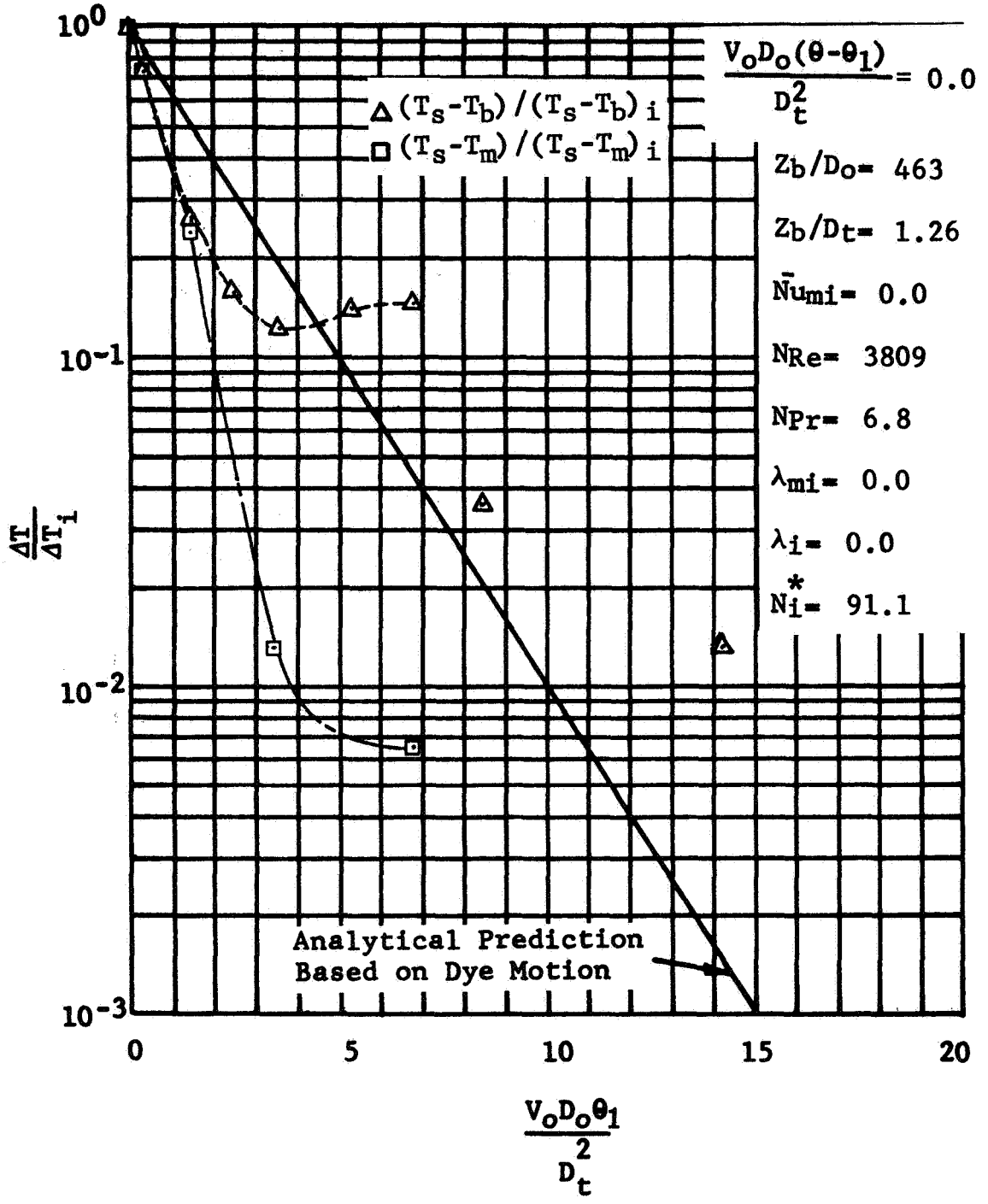


Figure 2.2-82 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 29, Run 66

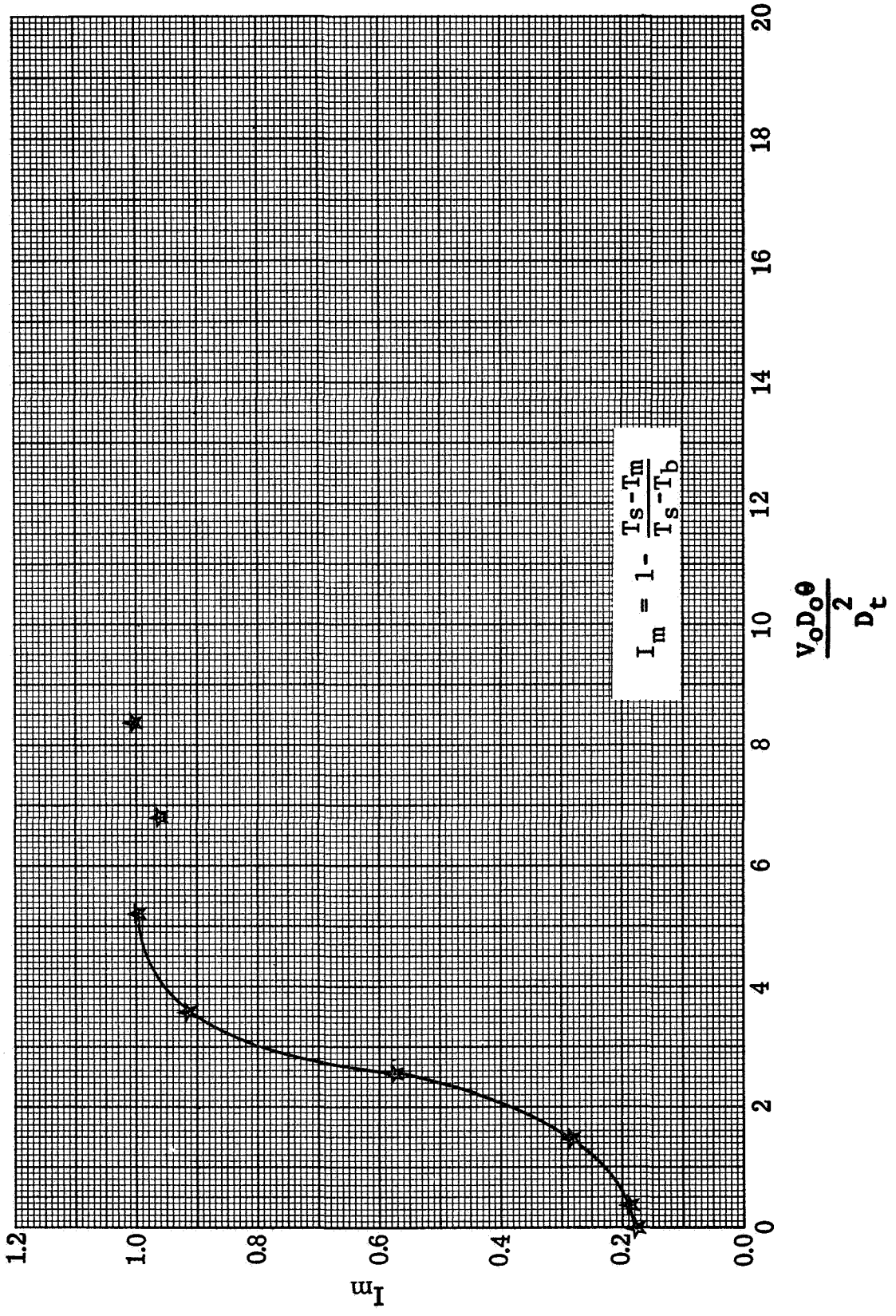


Figure 2.2-83 Transient Energy Integral: Test 29, Run 66

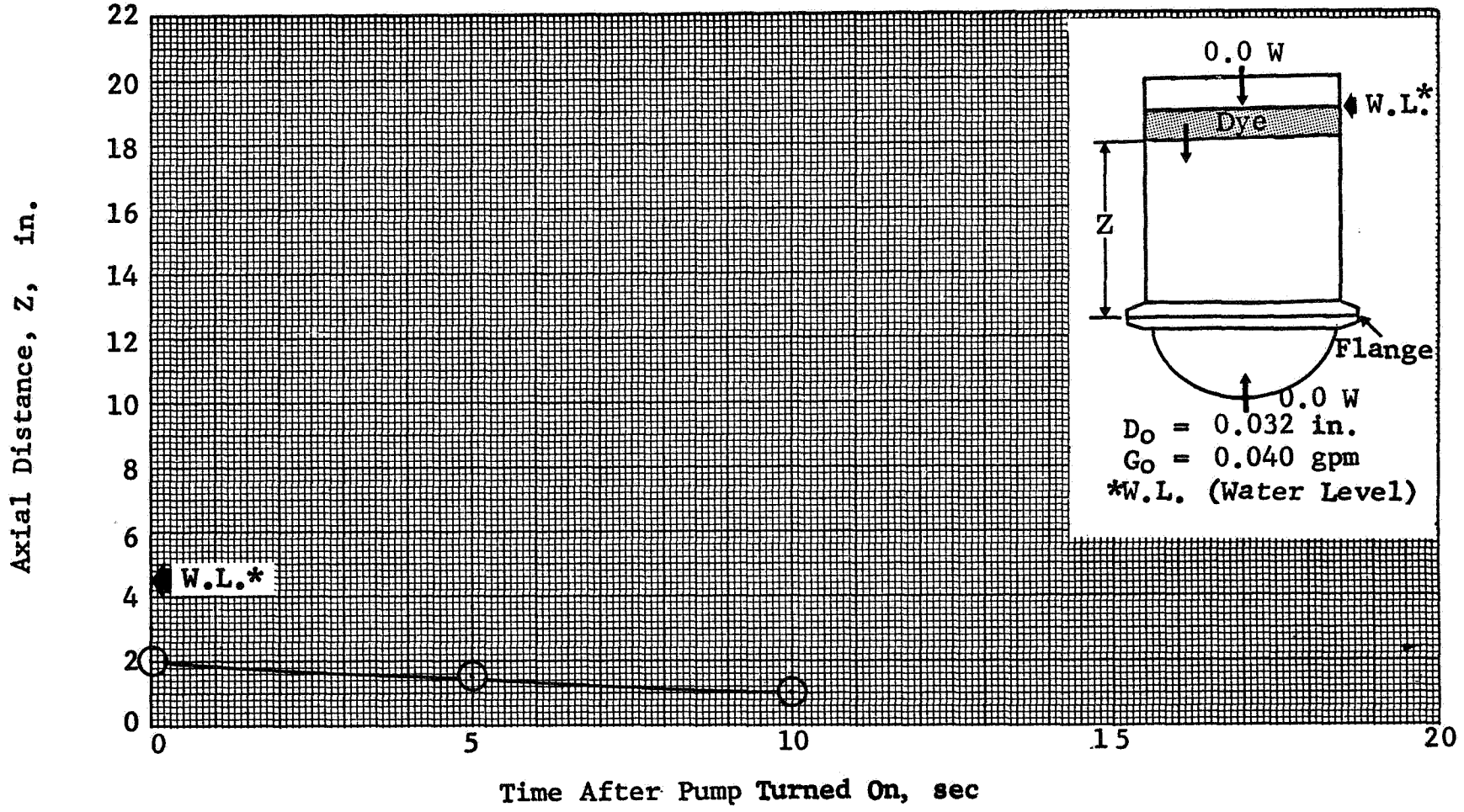


Figure 2.2-84 Axial Jet Dye Layer Motion: Test 30, Run 68

GENERAL DYNAMICS
Fort Worth Division

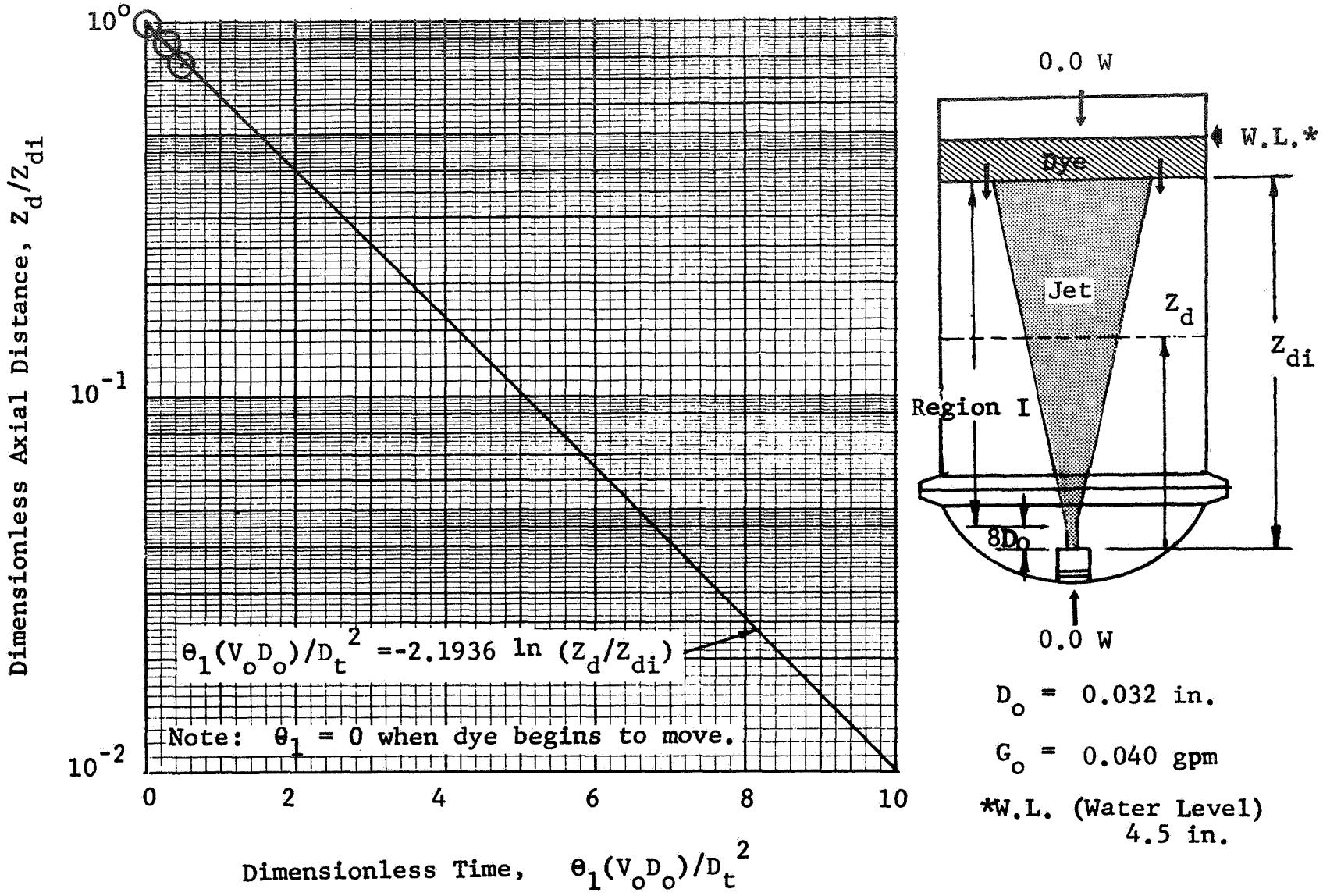


Figure 2.2-85 Correlation of Axial Jet Dye Layer Motion for Region I: Test 30, Run 68

GENERAL DYNAMICS
Fort Worth Division

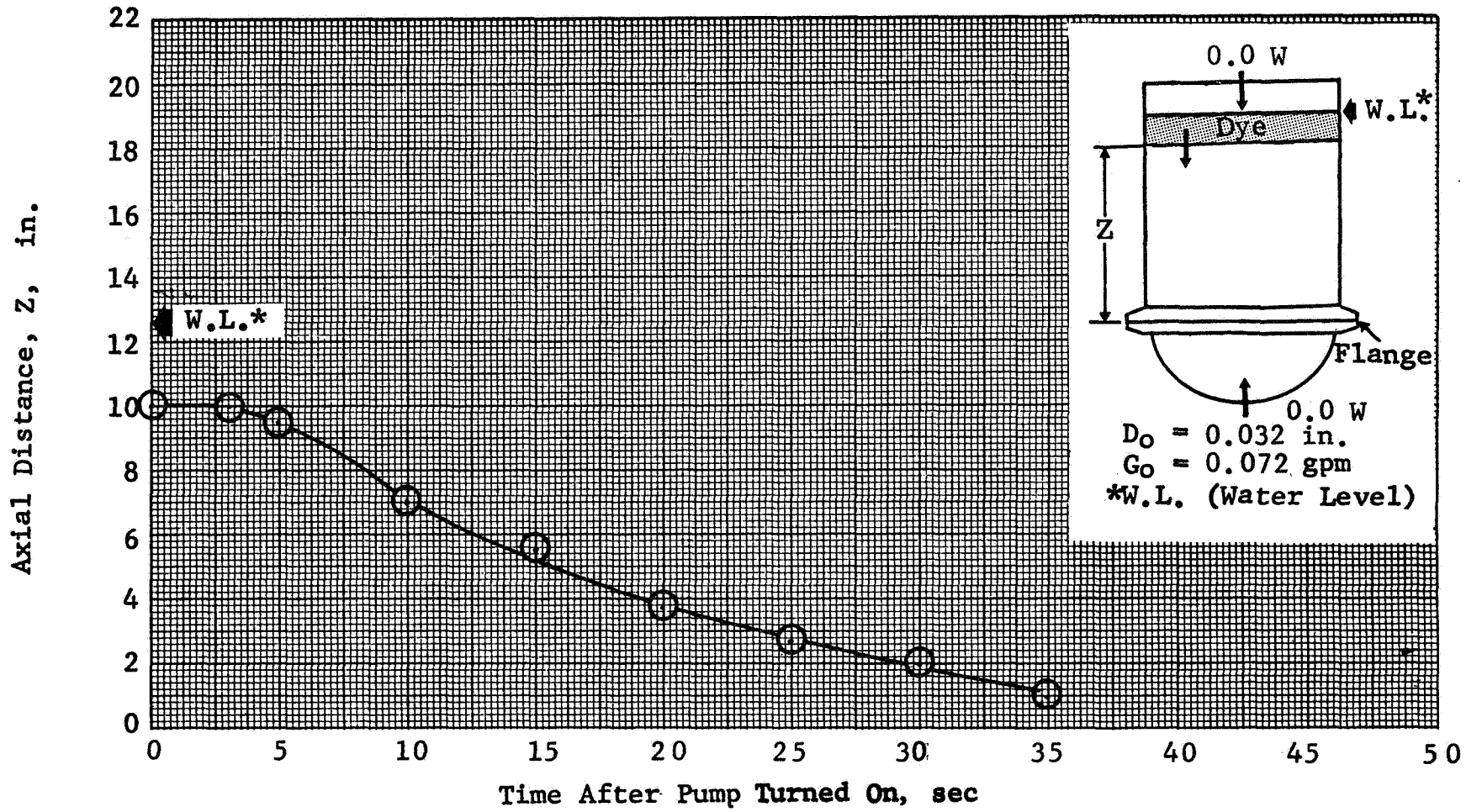


Figure 2.2-86 Axial Jet Dye Layer Motion: Test 31, Run 67

GENERAL DYNAMICS
Fort Worth Division

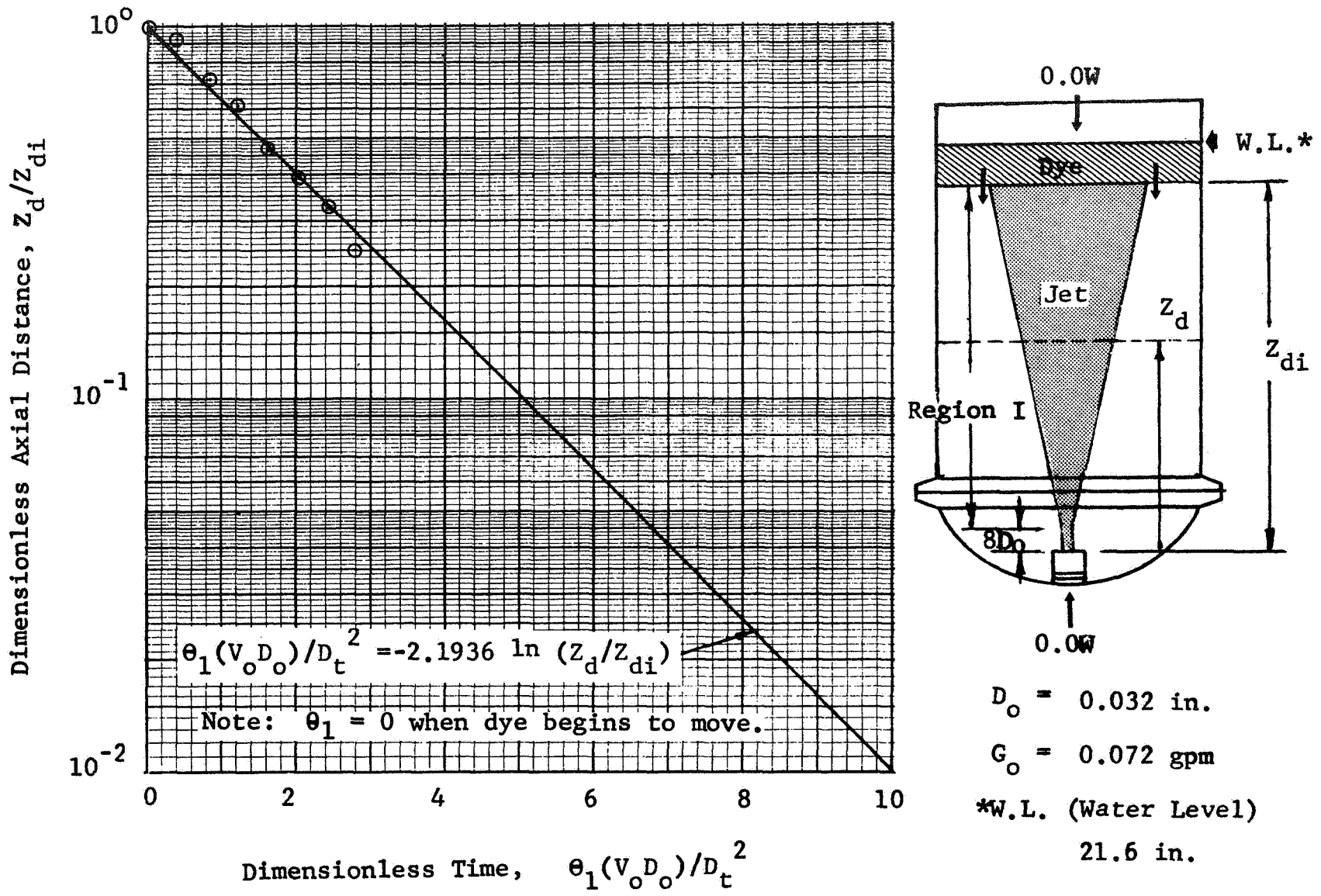


Figure 2.2-87 Correlation of Axial Jet Dye Layer Motion for Region I: Test 31, Run 67

GENERAL DYNAMICS
Fort Worth Division

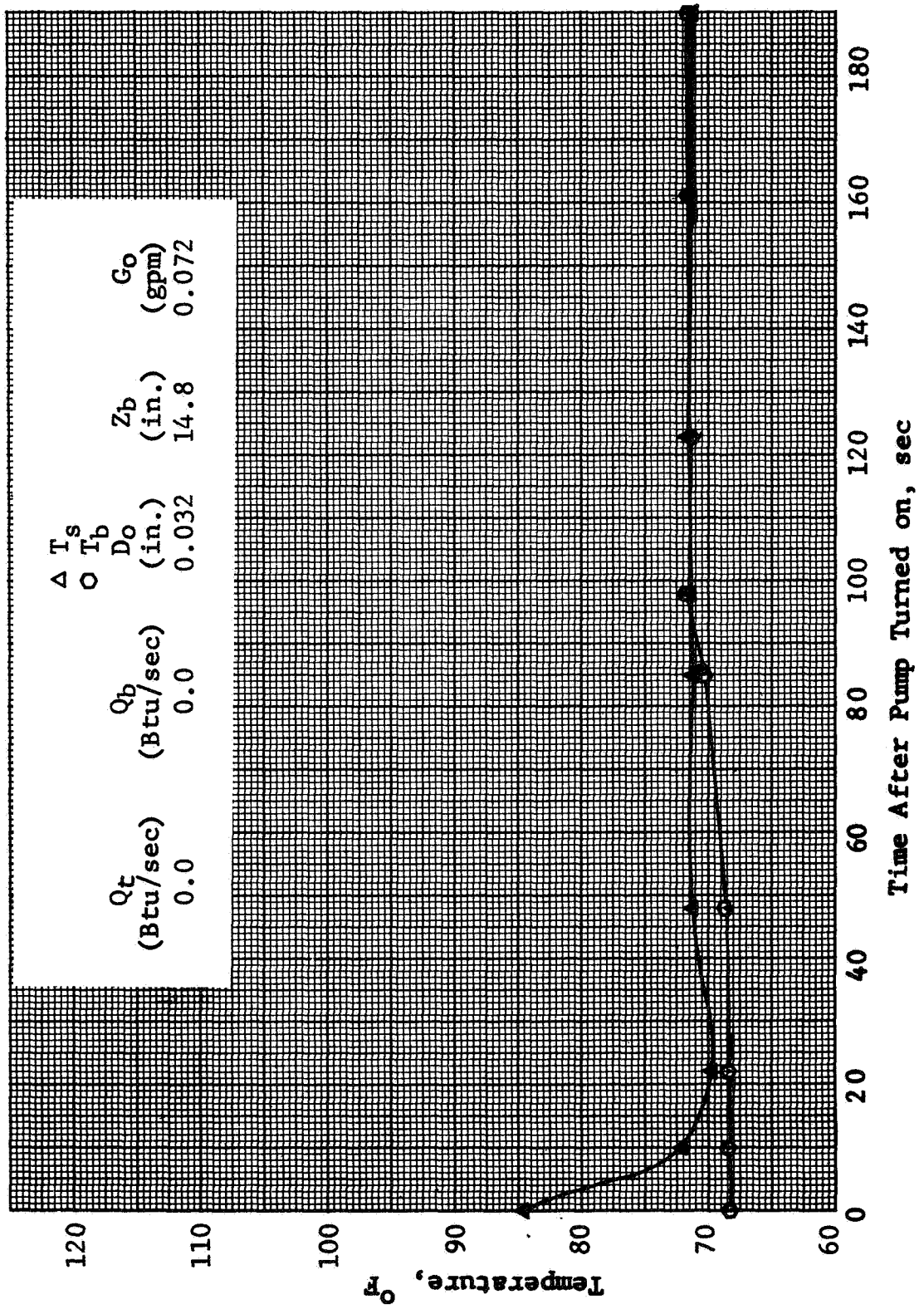


Figure 2.2-88 Transient Temperature Destratification: Test 31, Run 67

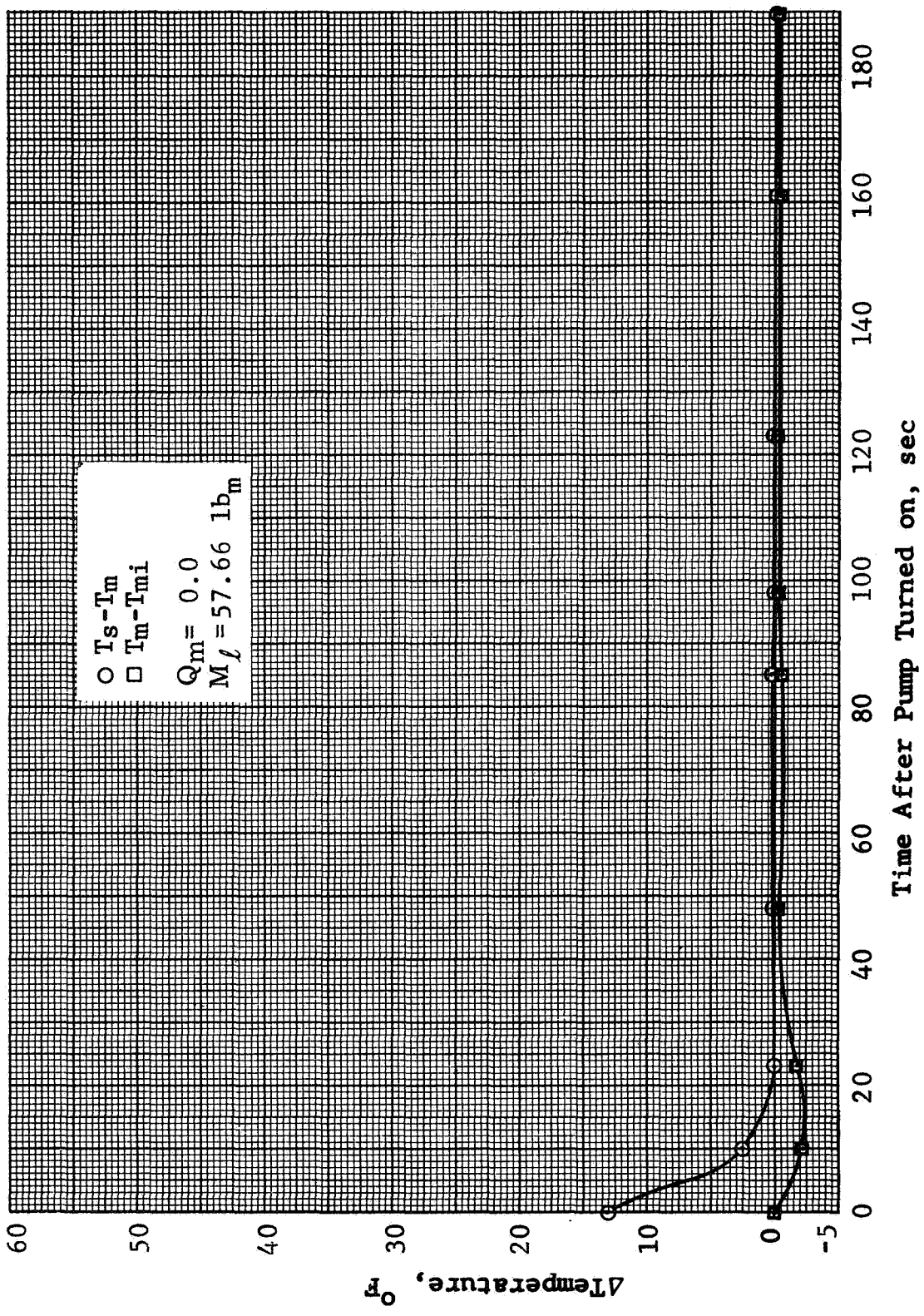


Figure 2.2-89 Transient ΔTemperature Destratification: Test 31, Run 67

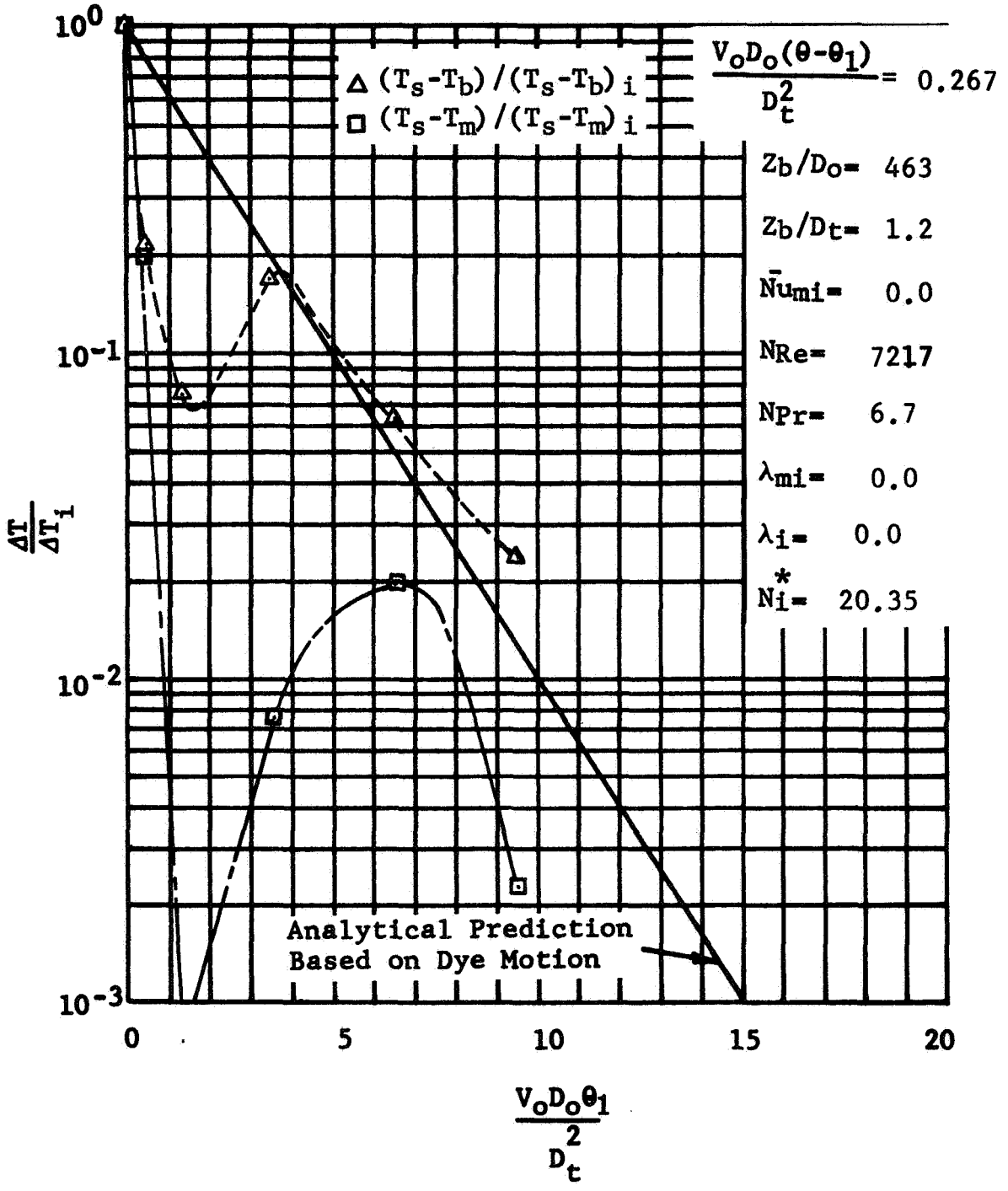


Figure 2.2-90 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 31, Run 67

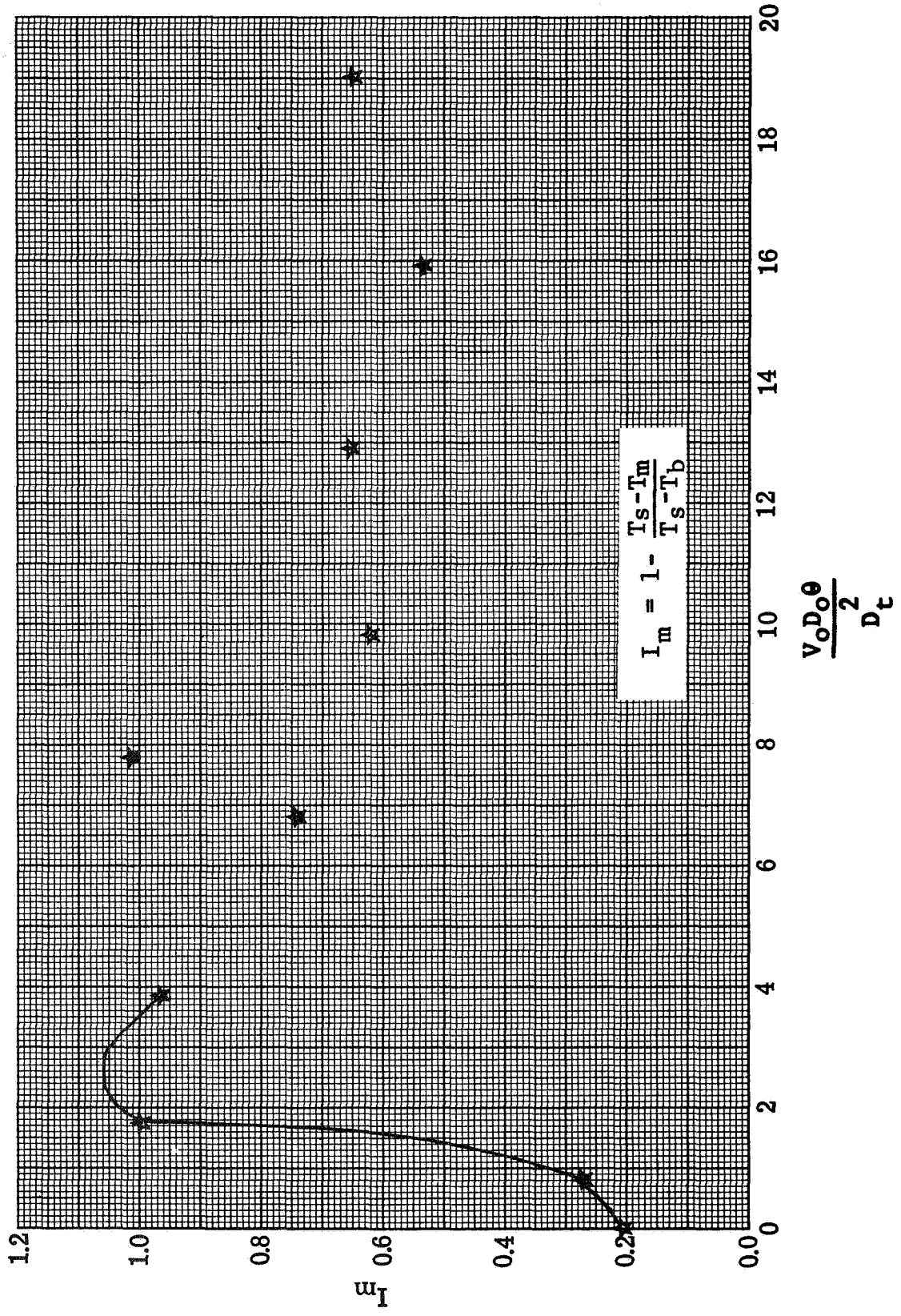


Figure 2.2-91 Transient Energy Integral: Test 31, Run 67

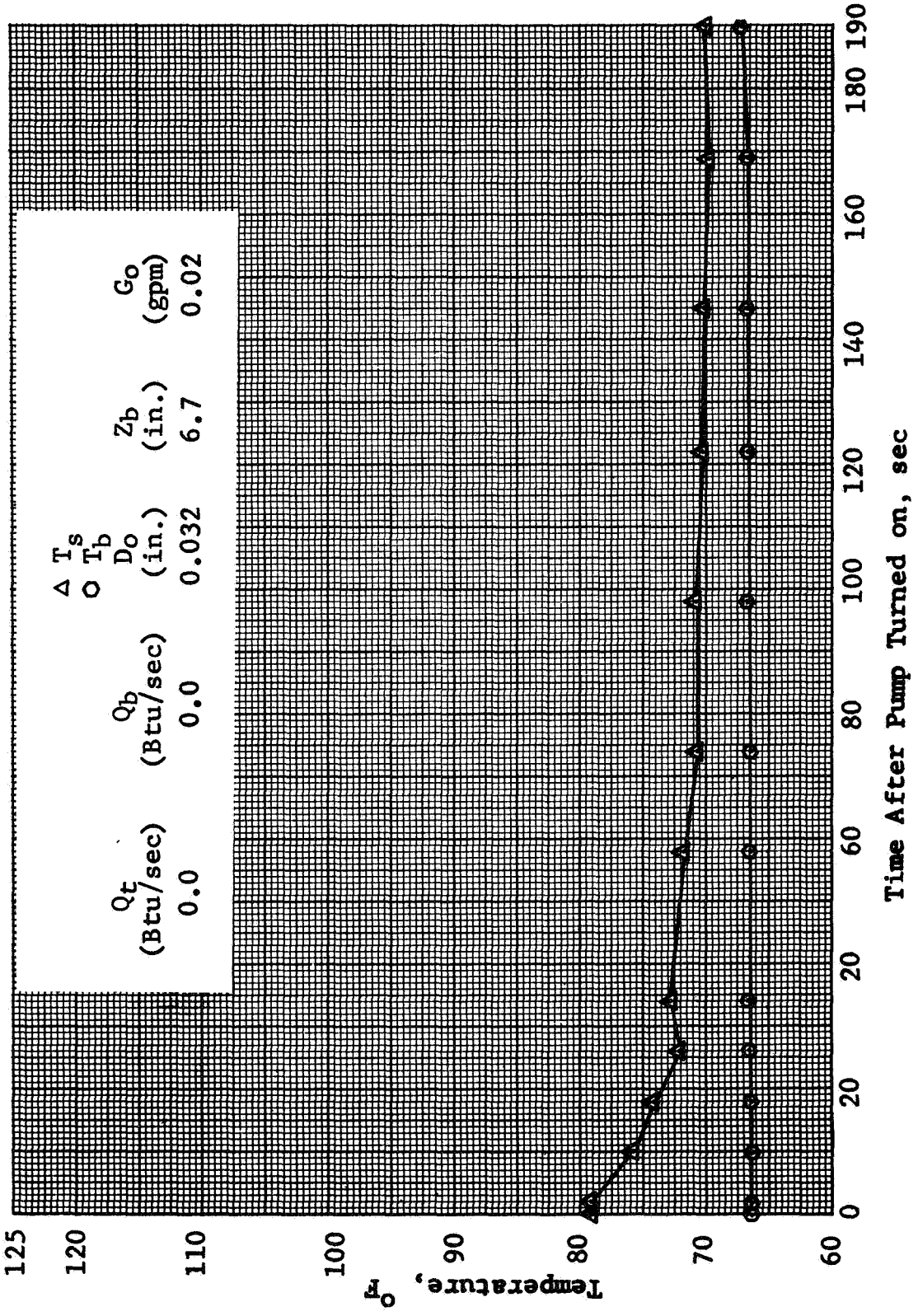


Figure 2.2-92 Transient Temperature Destratification: Test 32, Run 69

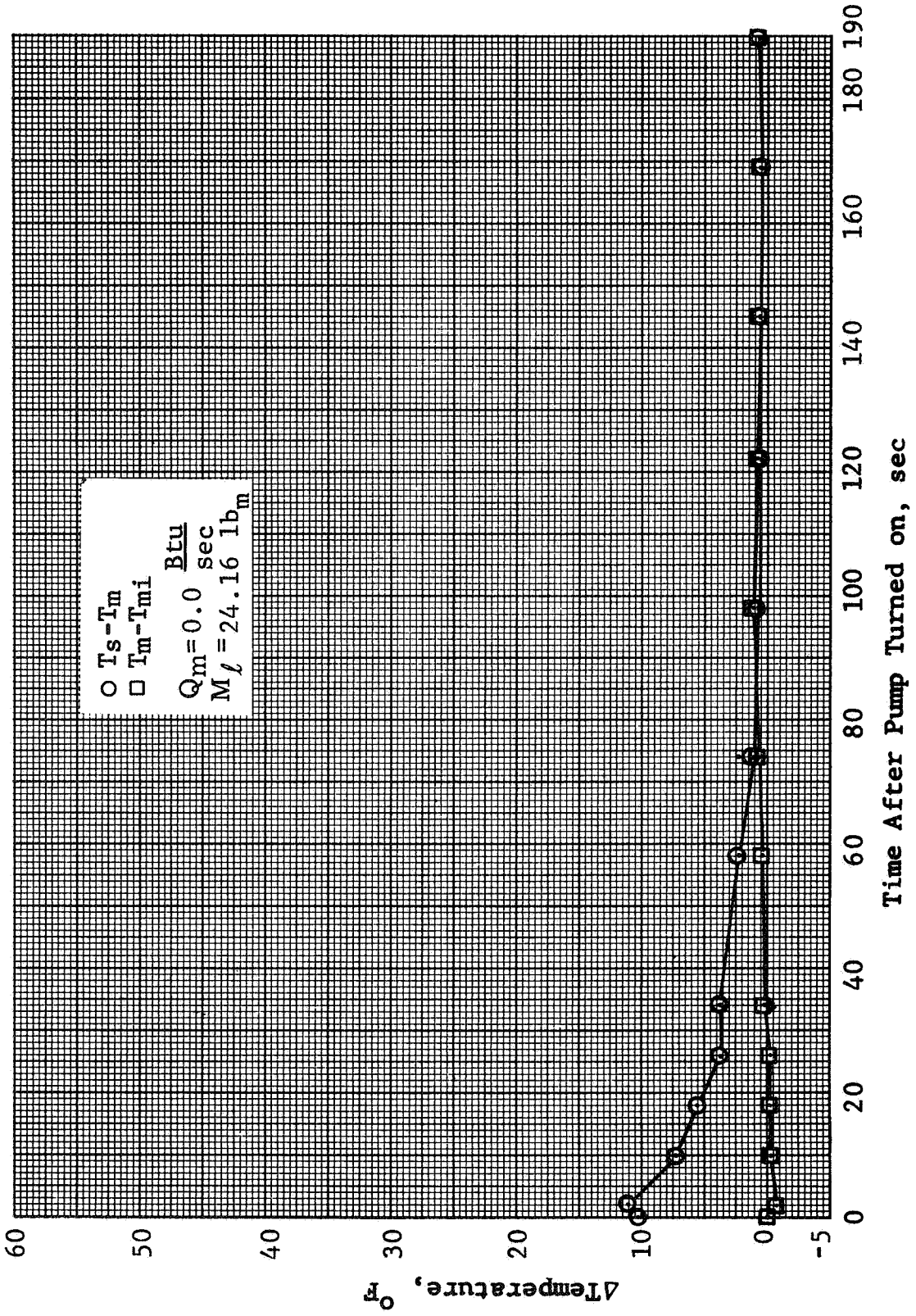


Figure 2.2-93 Transient ΔTemperature Destratification: Test 32, Run 69

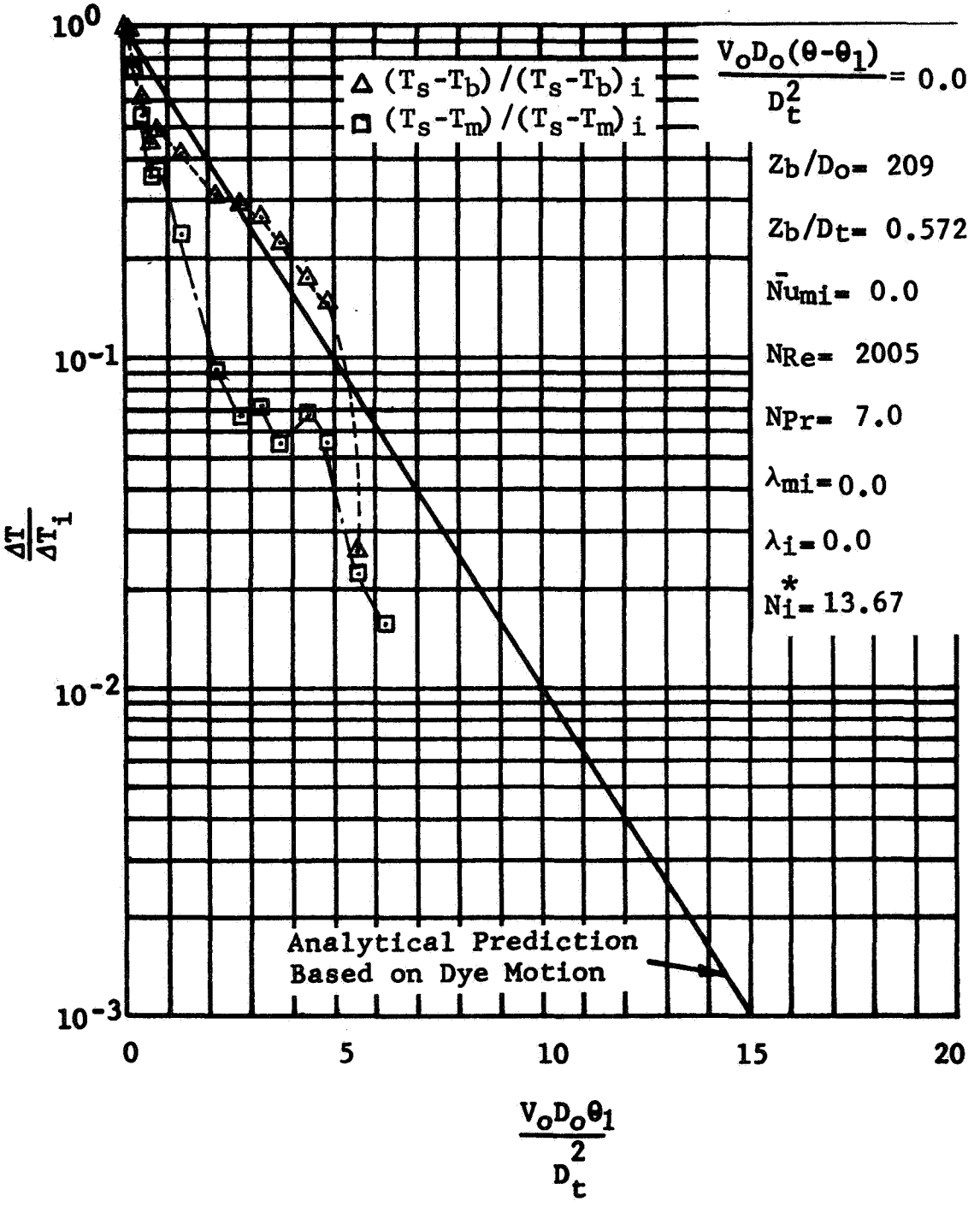


Figure 2.2-94 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 32, Run 69

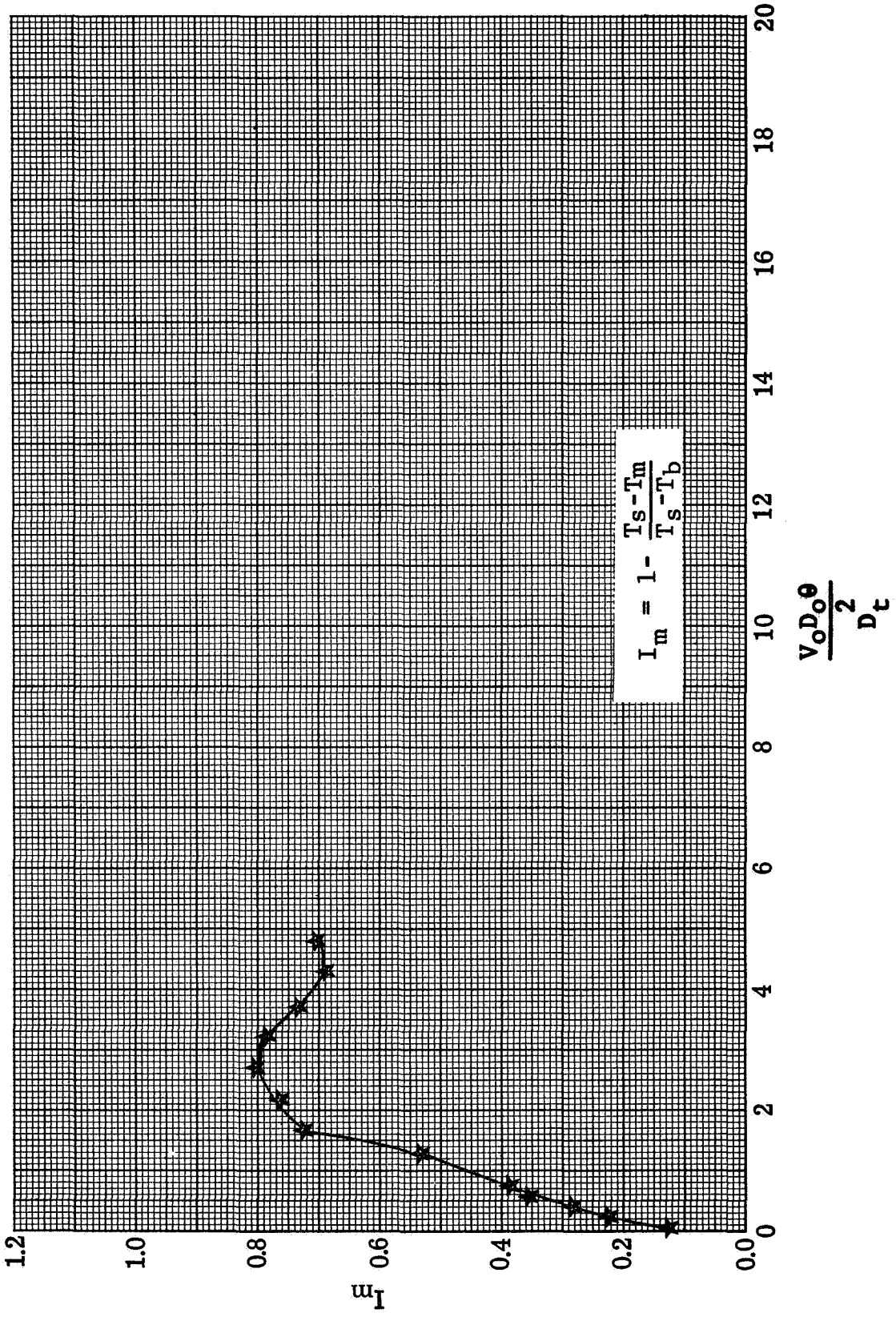


Figure 2.2-95 Transient Energy Integral: Test 32, Run 69

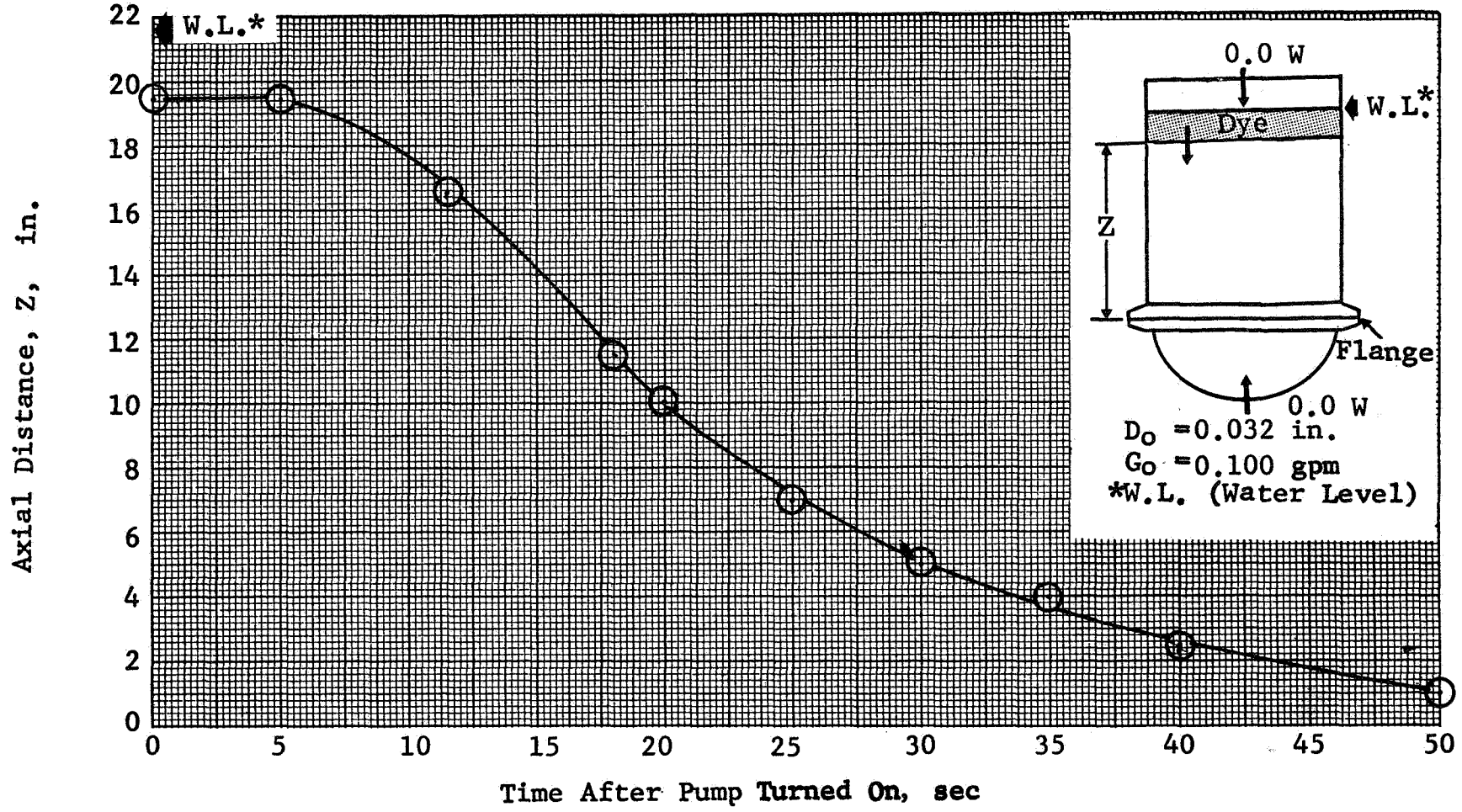


Figure 2.2-96 Axial Jet Dye Layer Motion: Test 33, Run 70

GENERAL DYNAMICS
Fort Worth Division

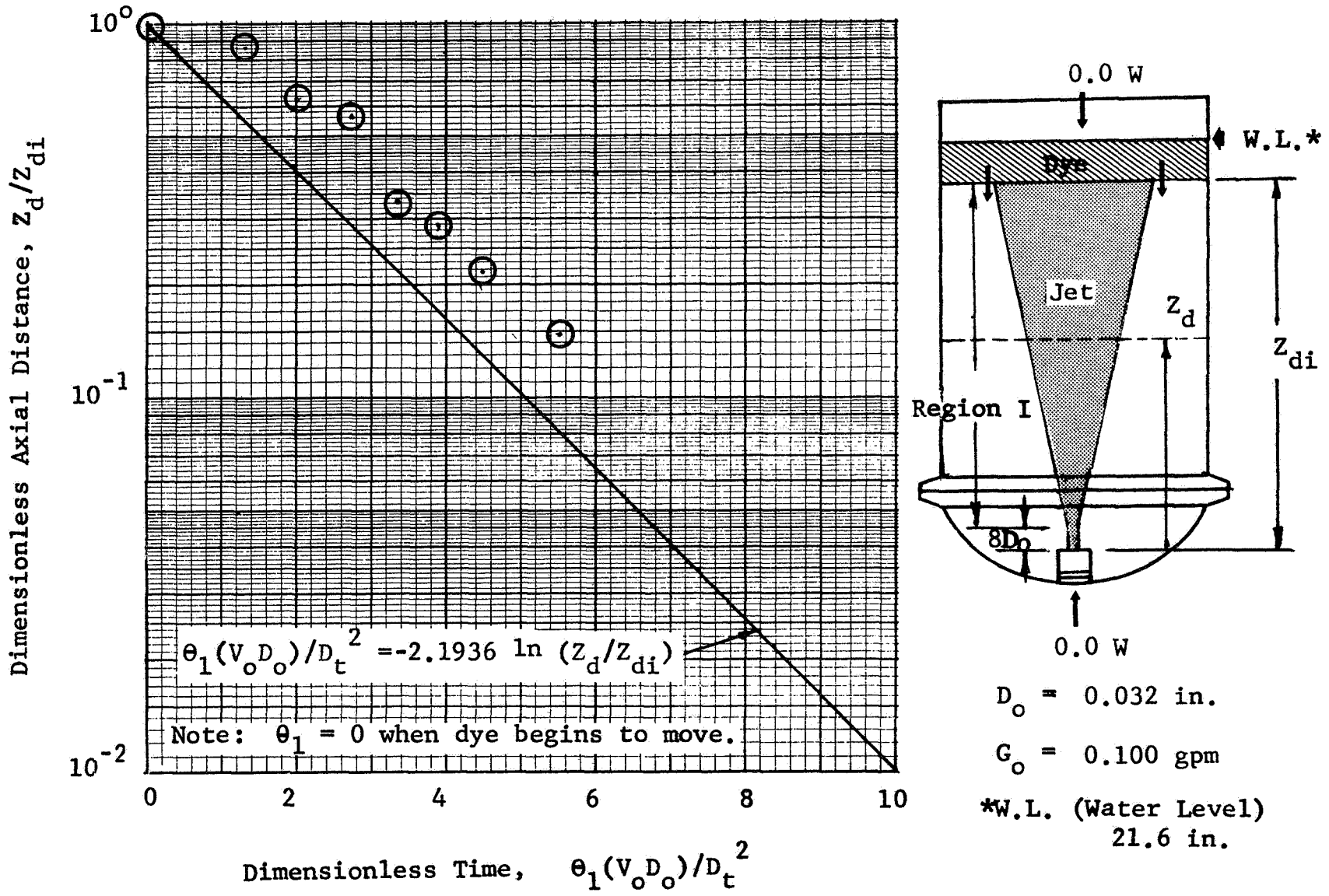


Figure 2.2-97 Correlation of Axial Jet Dye Layer Motion for Region I: Test 33, Run 70

GENERAL DYNAMICS
Fort Worth Division

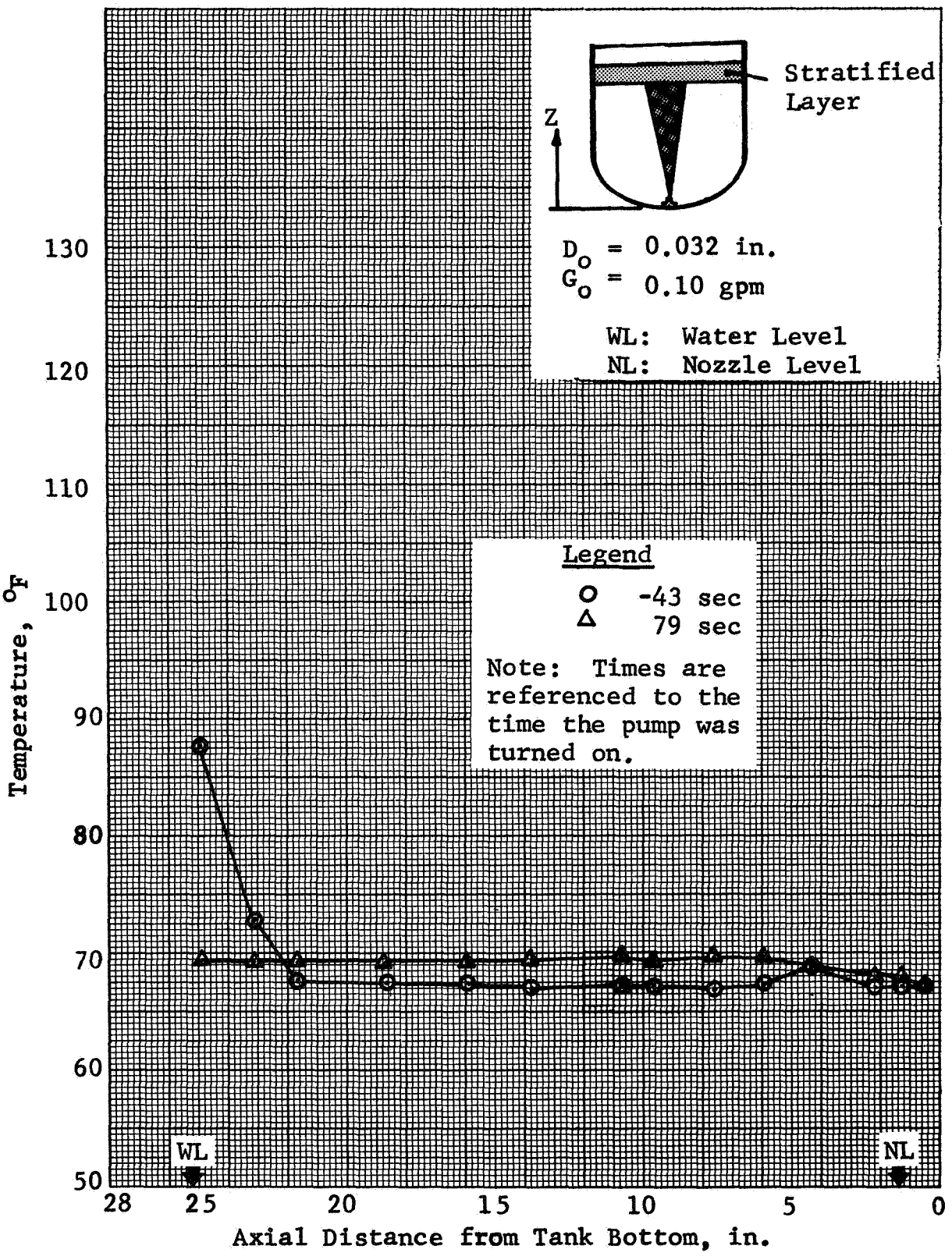


Figure 2.2-98 Temperature Distribution for Axial Jet Flow: Test 33, Run 70

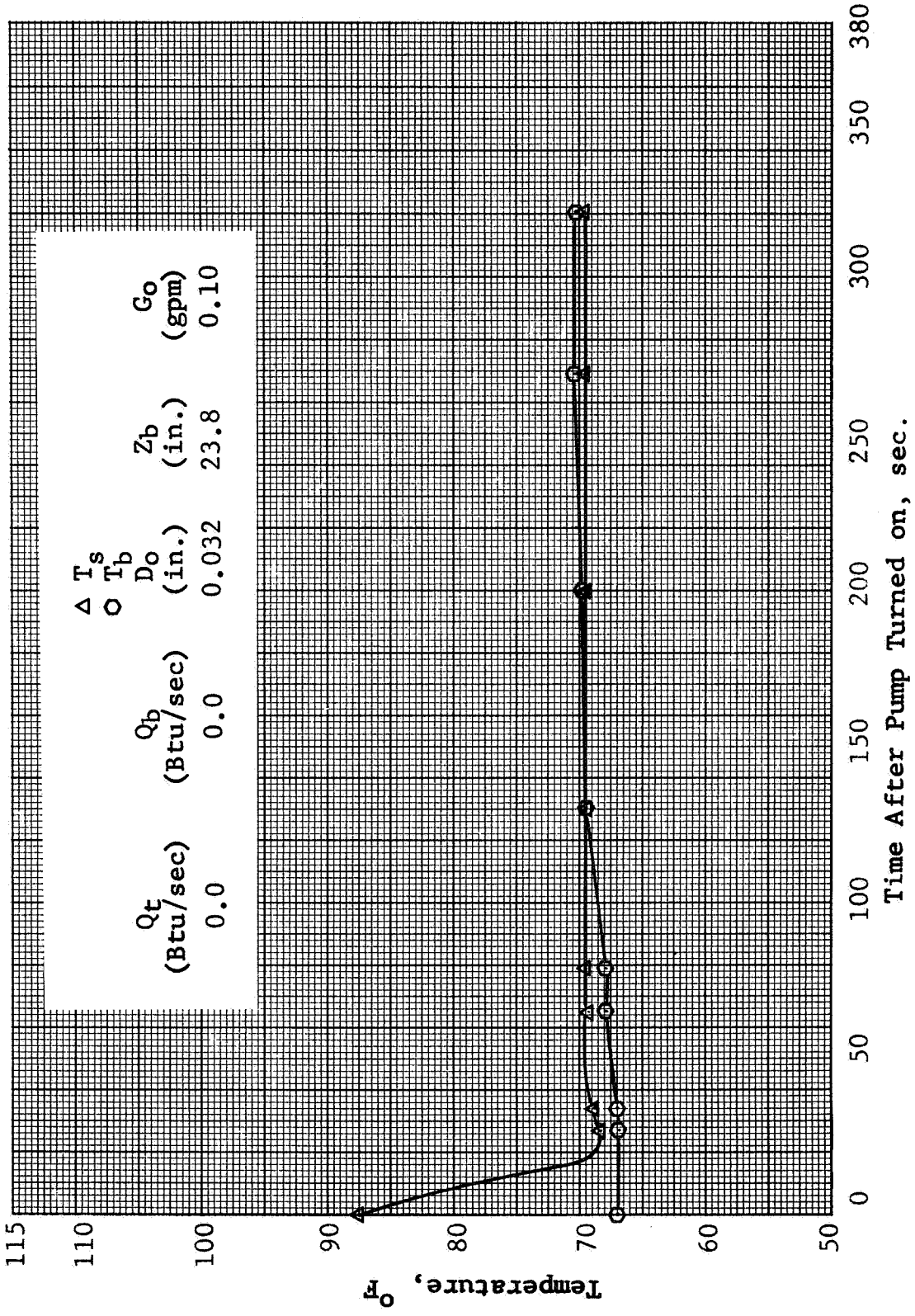


Figure 2.2-99 Transient Temperature Destratification: Test 33, Run 70

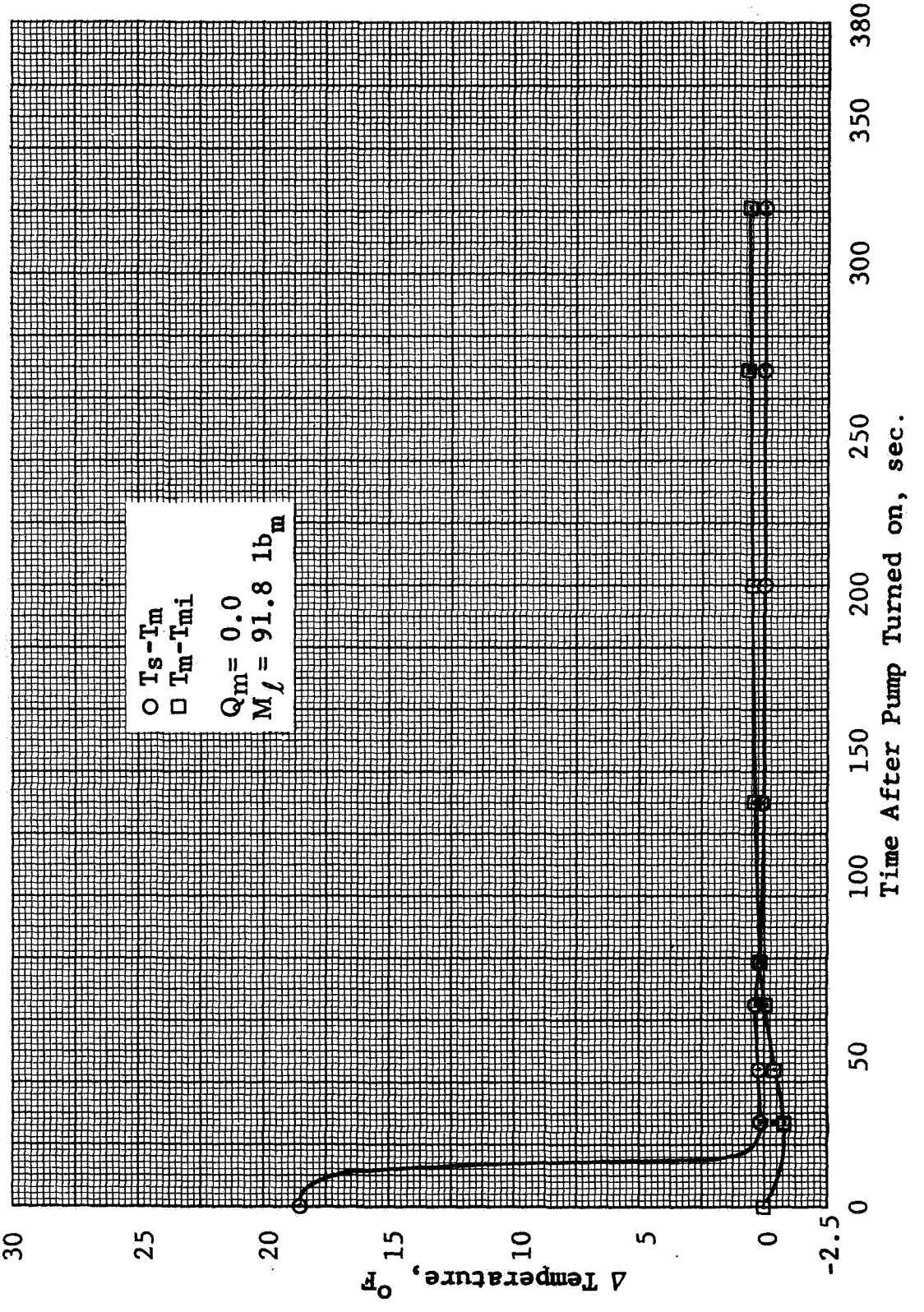


Figure 2.2-100 Transient ΔTemperature Destratification: Test 33, Run 70

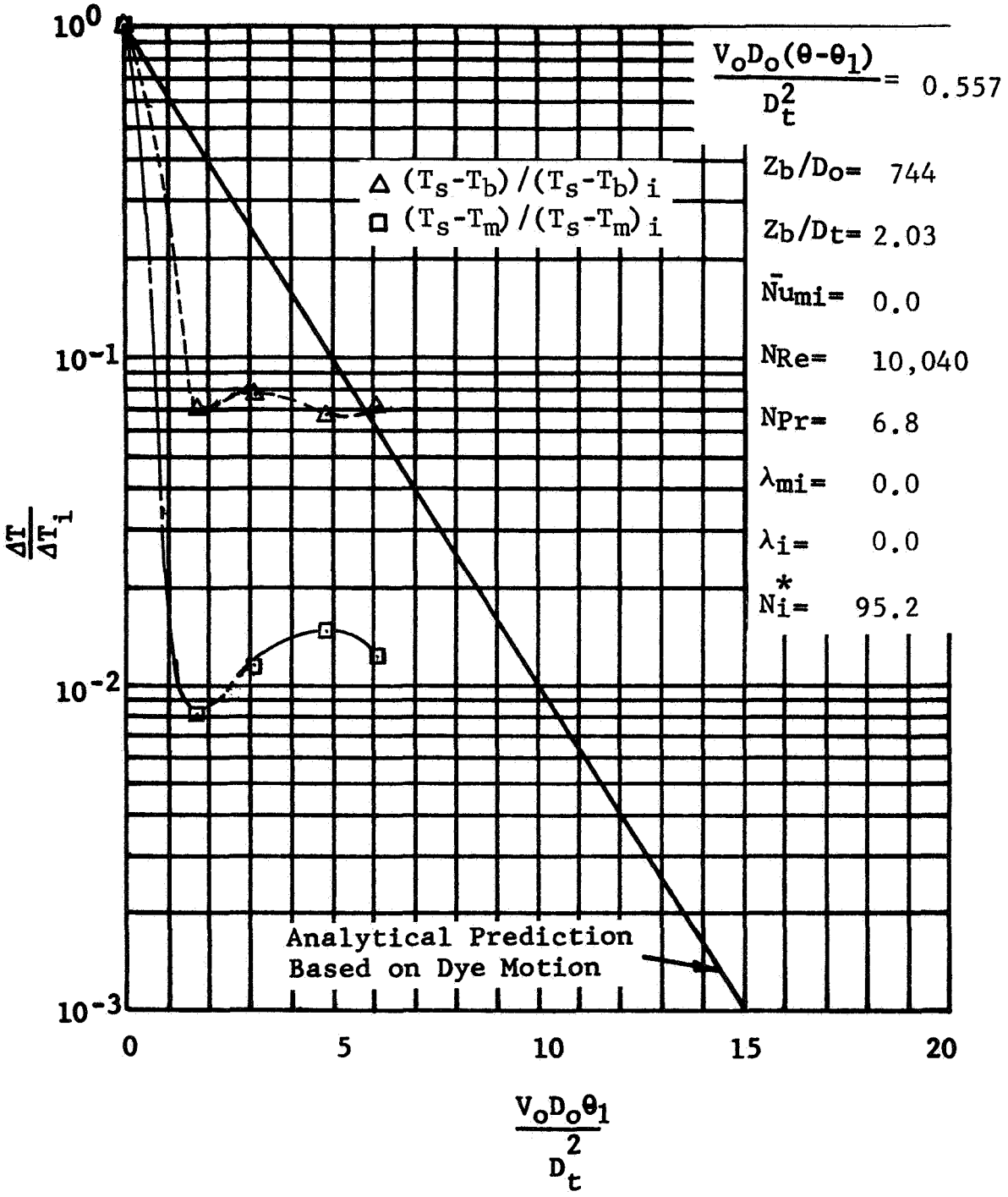


Figure 2.2-101 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 33, Run 70

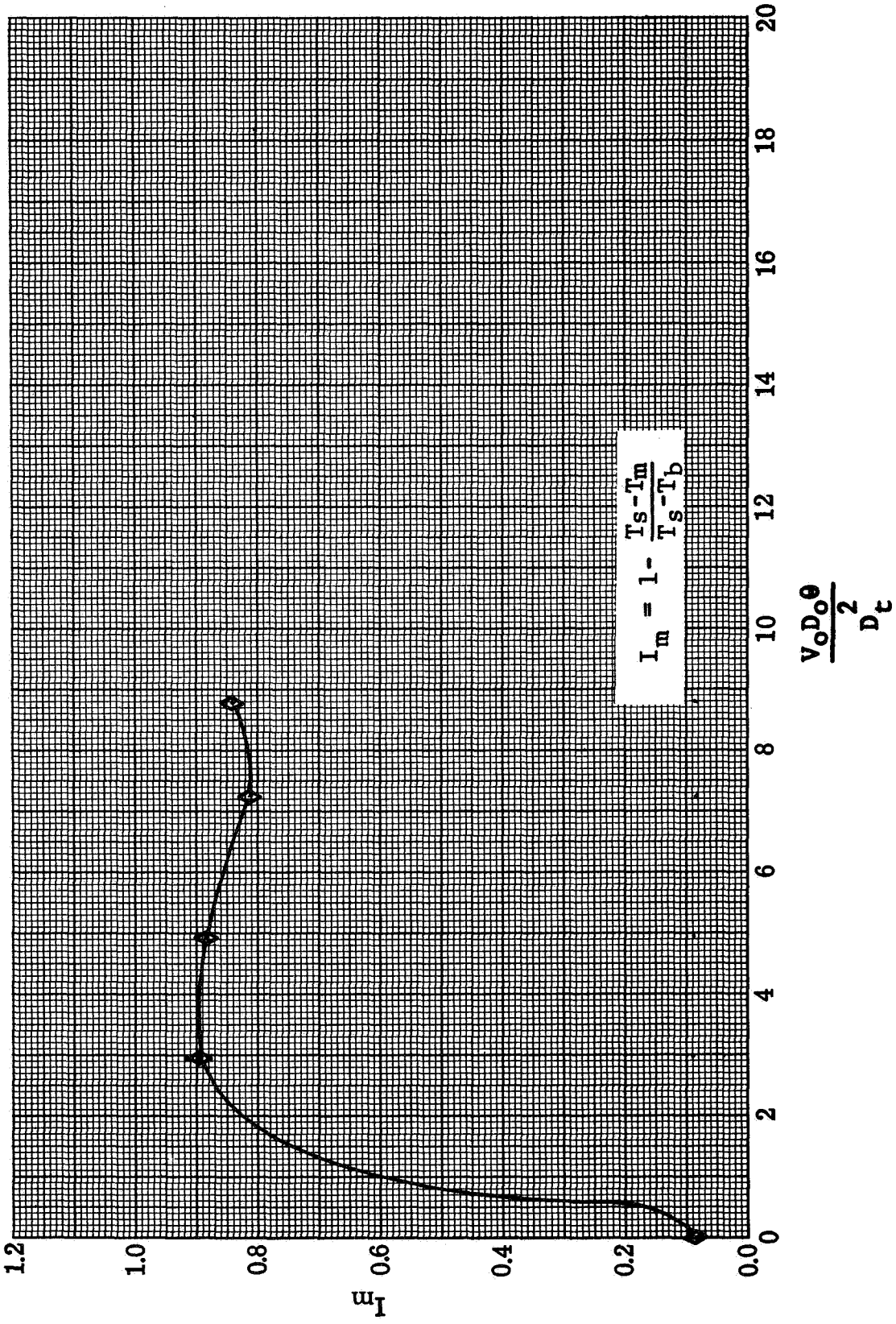


Figure 2.2-102 Transient Energy Integral: Test 33, Run 70

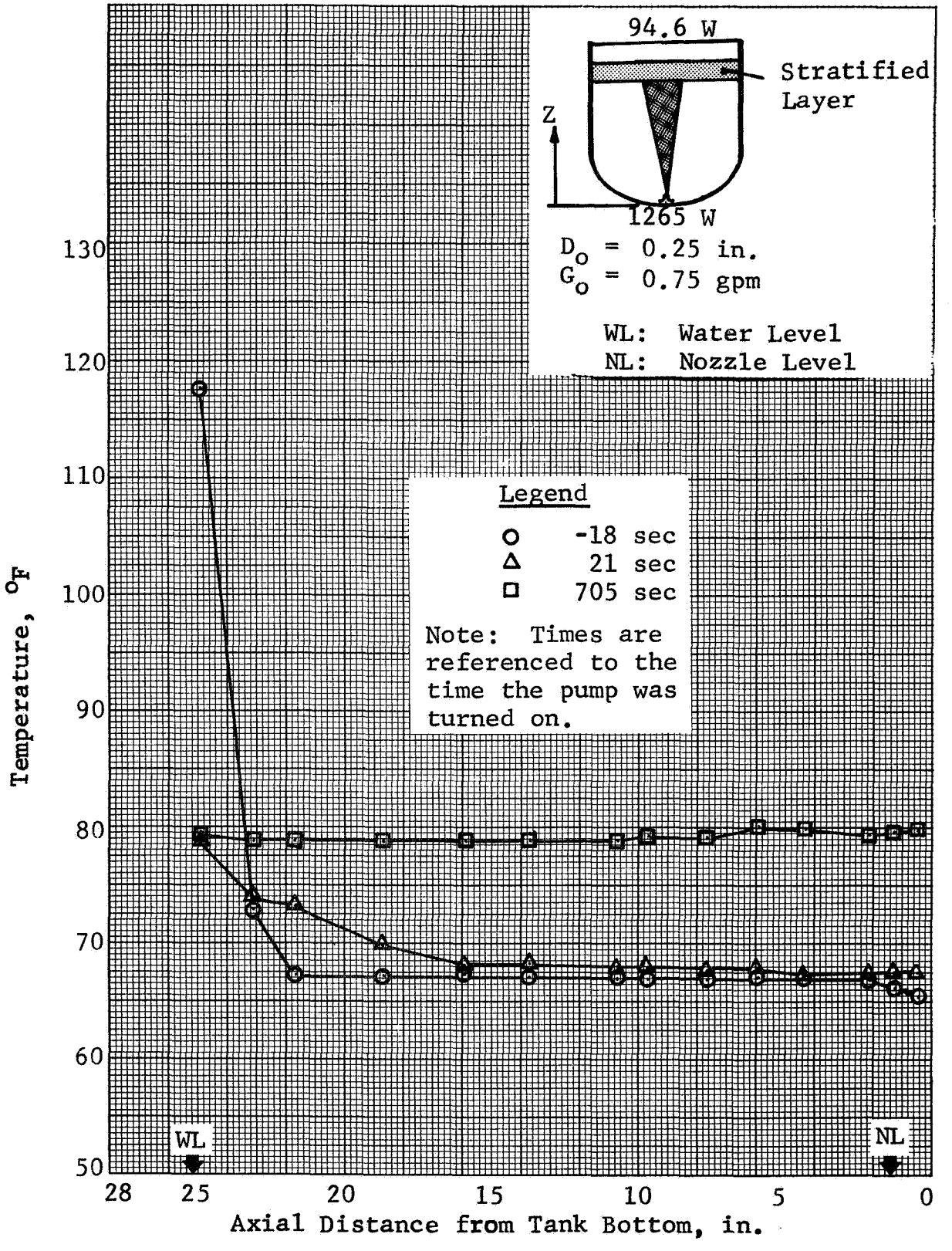


Figure 2.2-103 Temperature Distribution for Axial Jet Flow: Test 35, Run 76

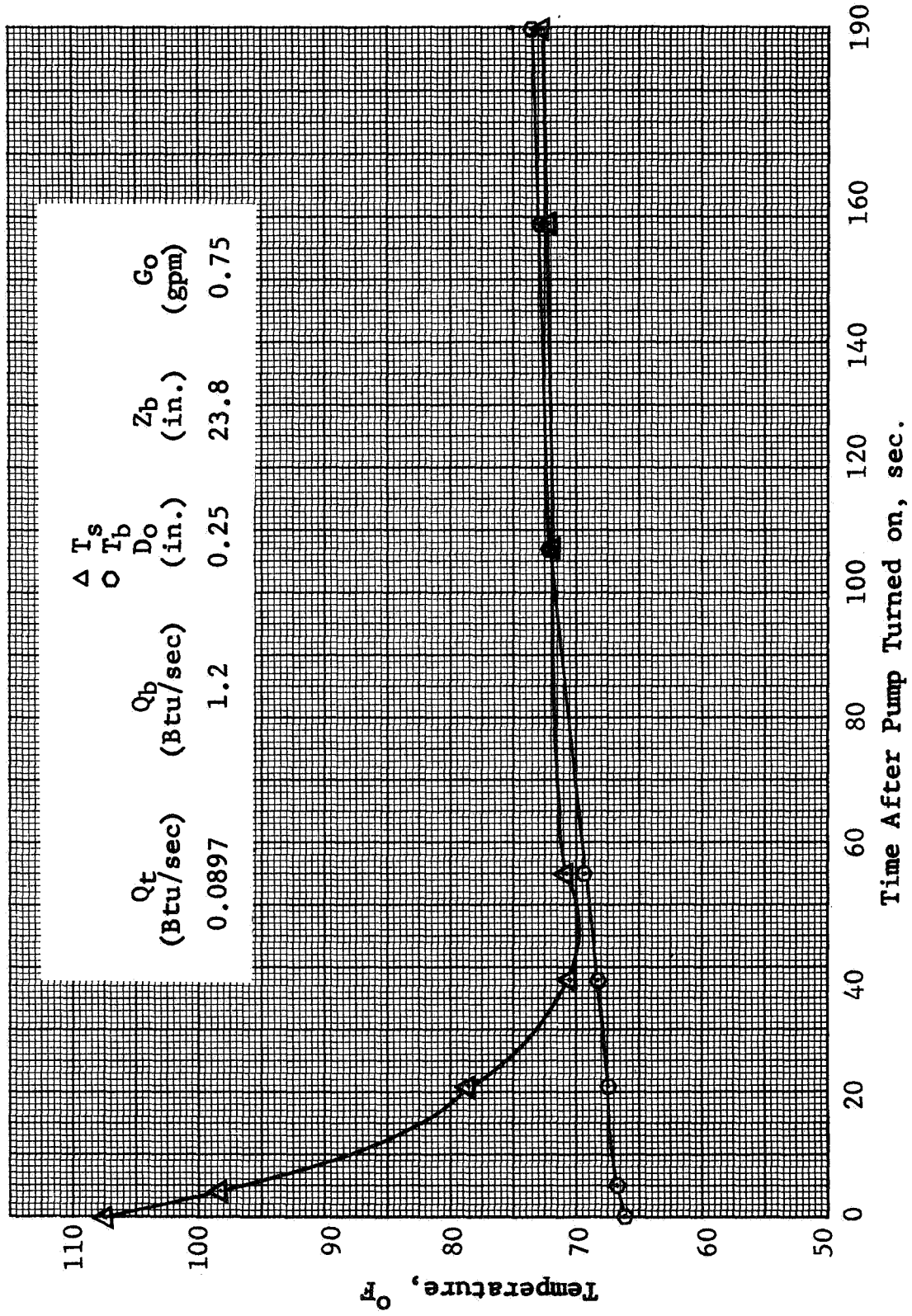


Figure 2.2-104 Transient Temperature Destratification: Test 35, Run 76

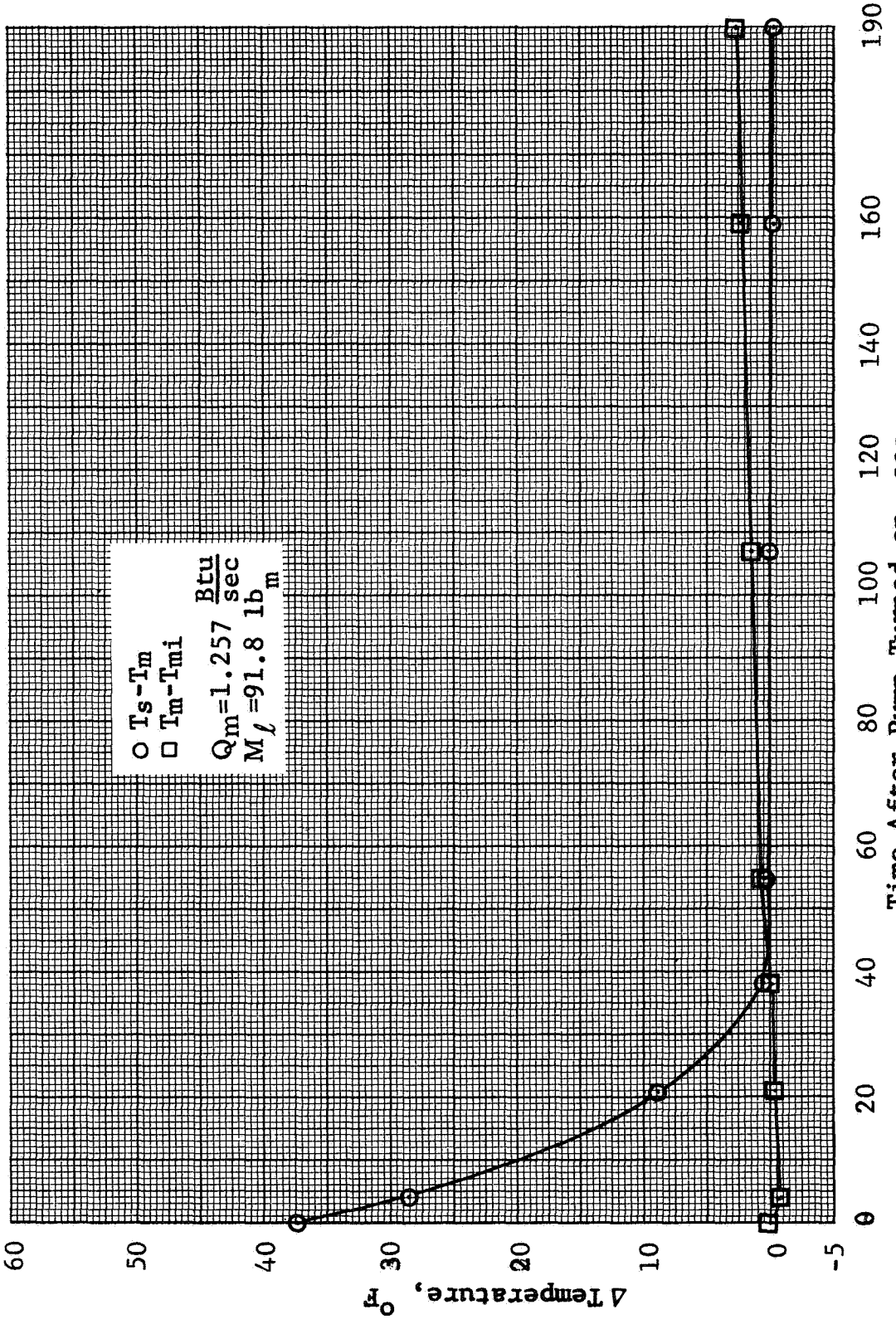


Figure 2.2-105 Transient ΔTemperature Destratification: Test 35, Run 76

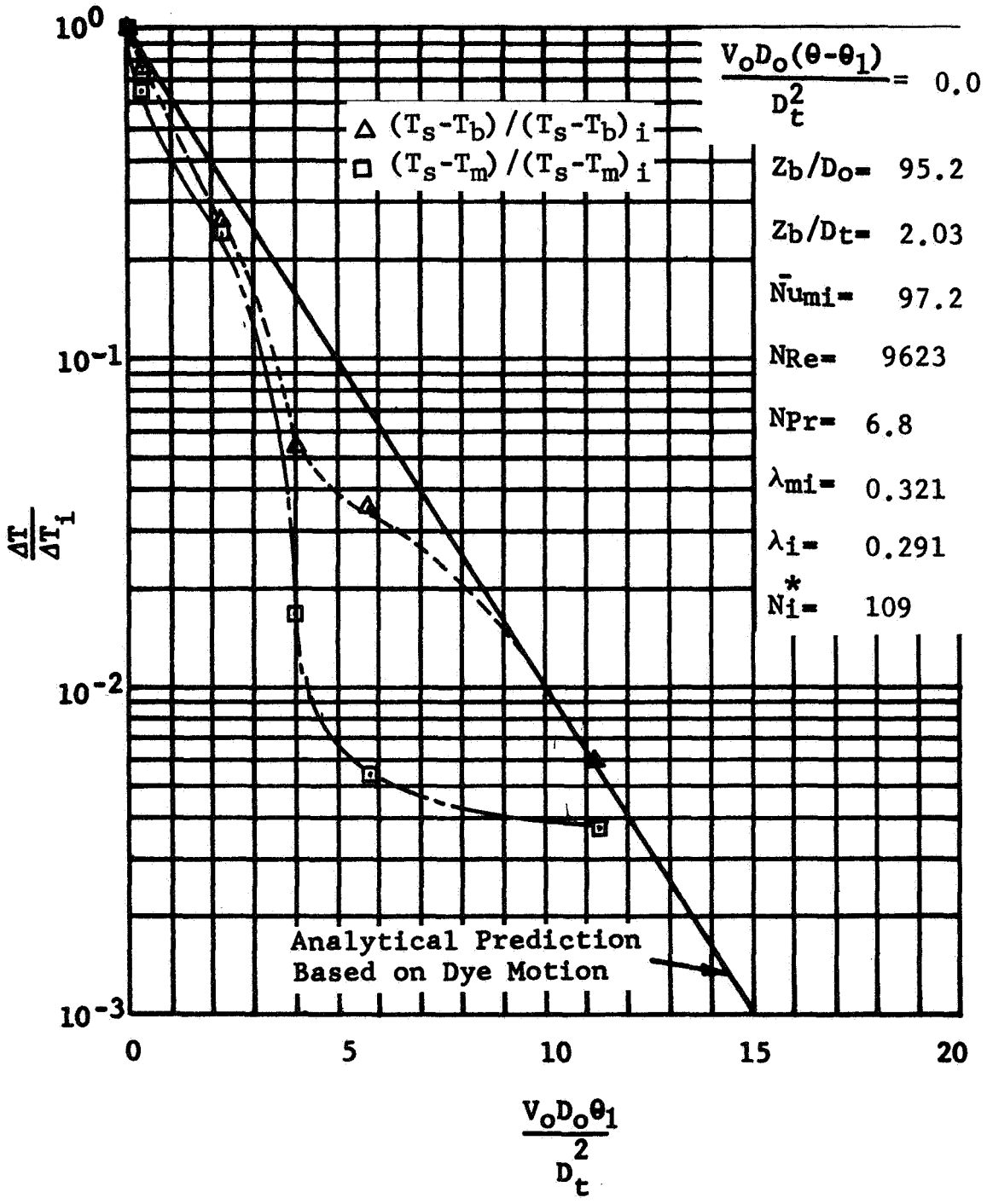


Figure 2.2-106 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 35, Run 76

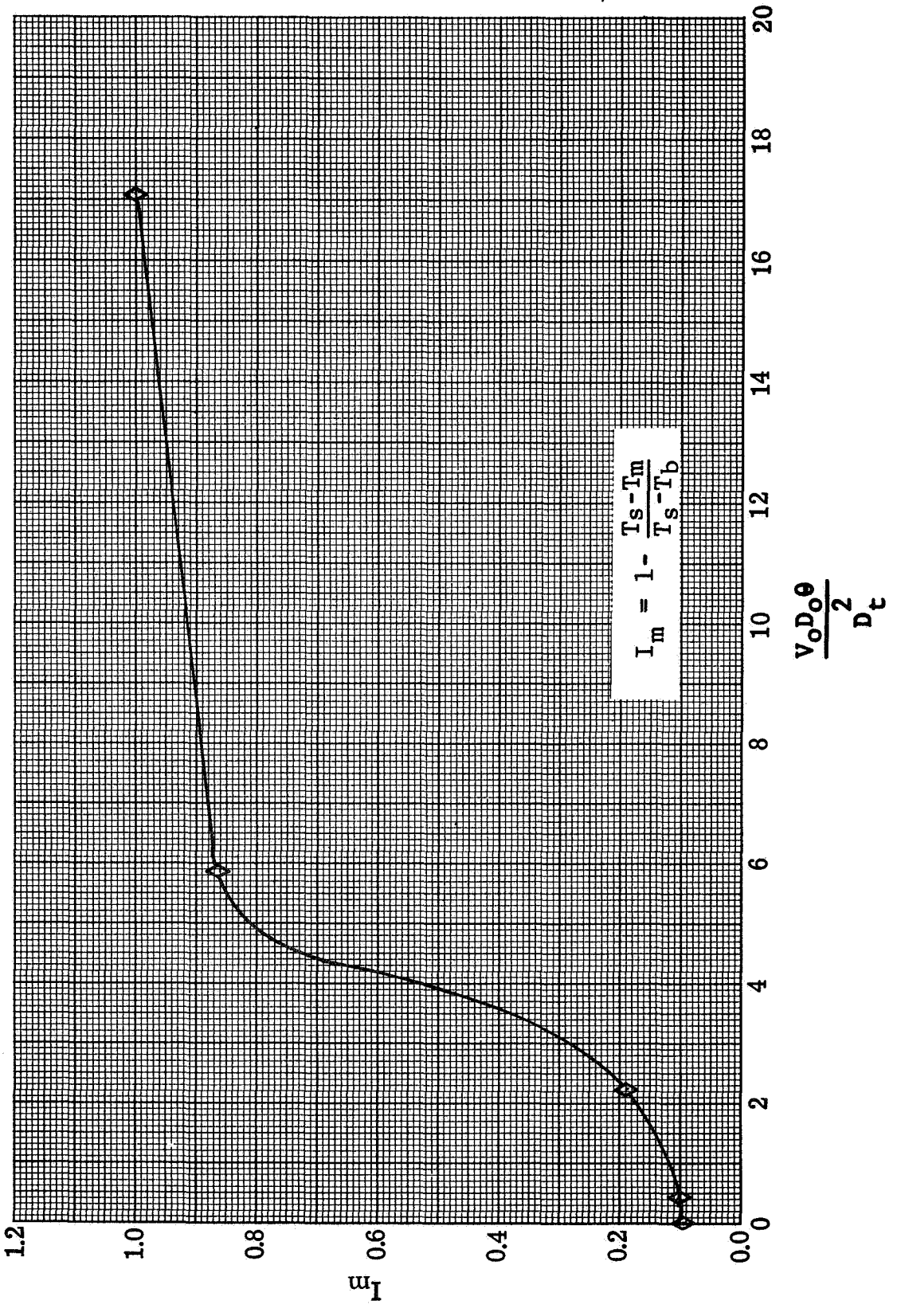


Figure 2.2-107 Transient Energy Integral: Test 35, Run 76

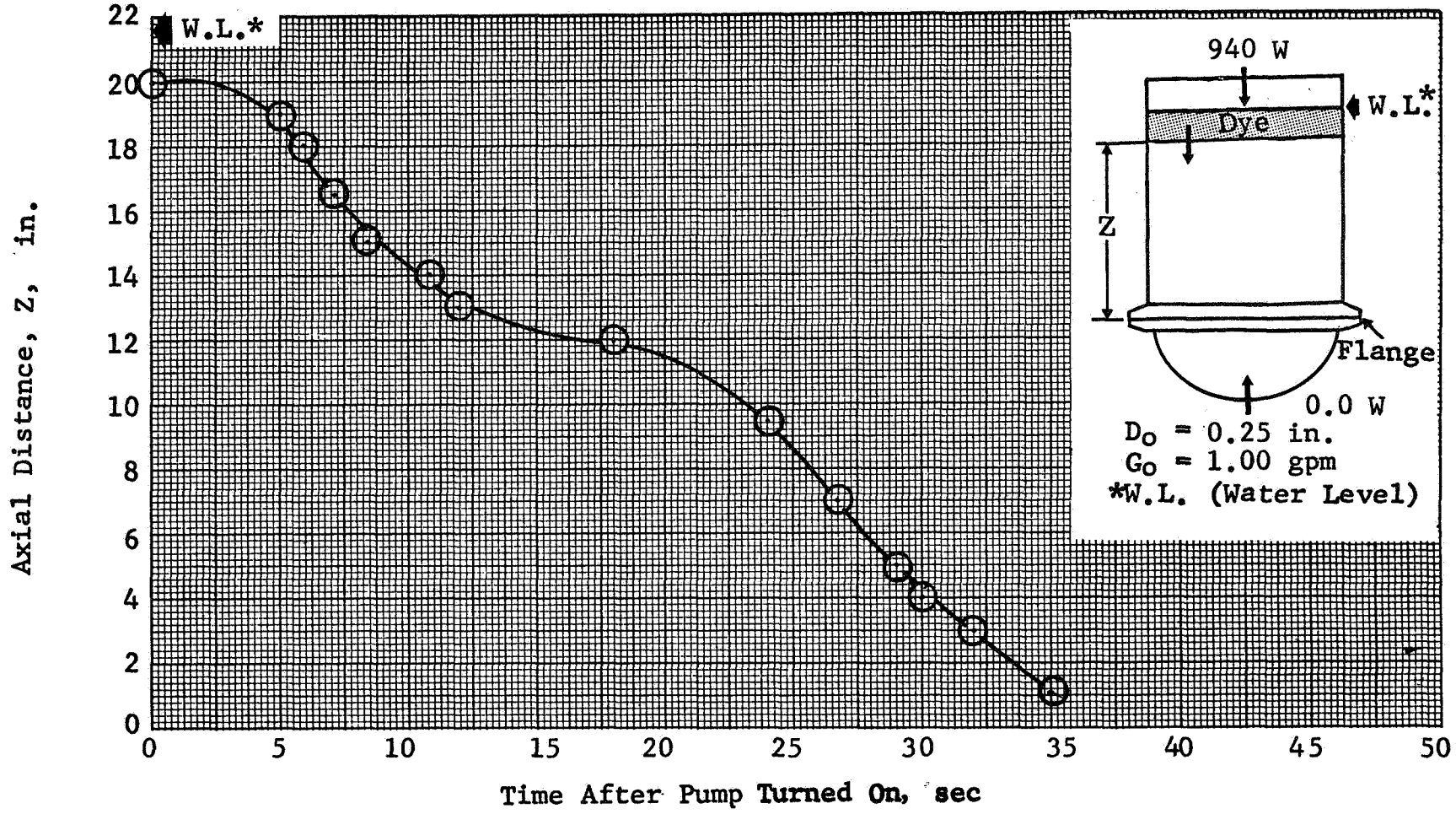


Figure 2.2-108 Axial Jet Dye Layer Motion: Test 36, Run 77

GENERAL DYNAMICS
Fort Worth Division

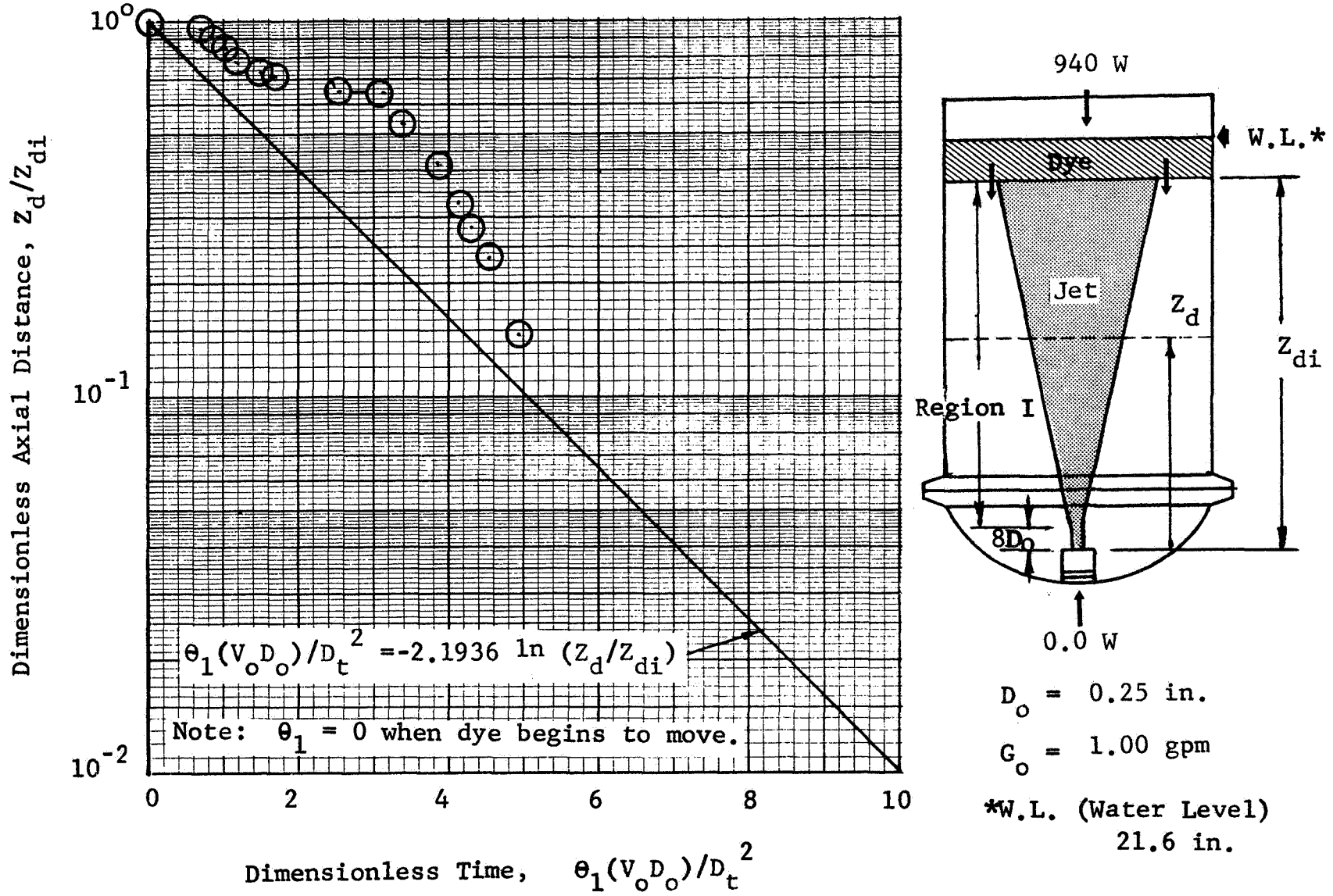


Figure 2.2-109 Correlation of Axial Jet Dye Layer Motion for Region I: Test 36, Run 77

GENERAL DYNAMICS
Fort Worth Division

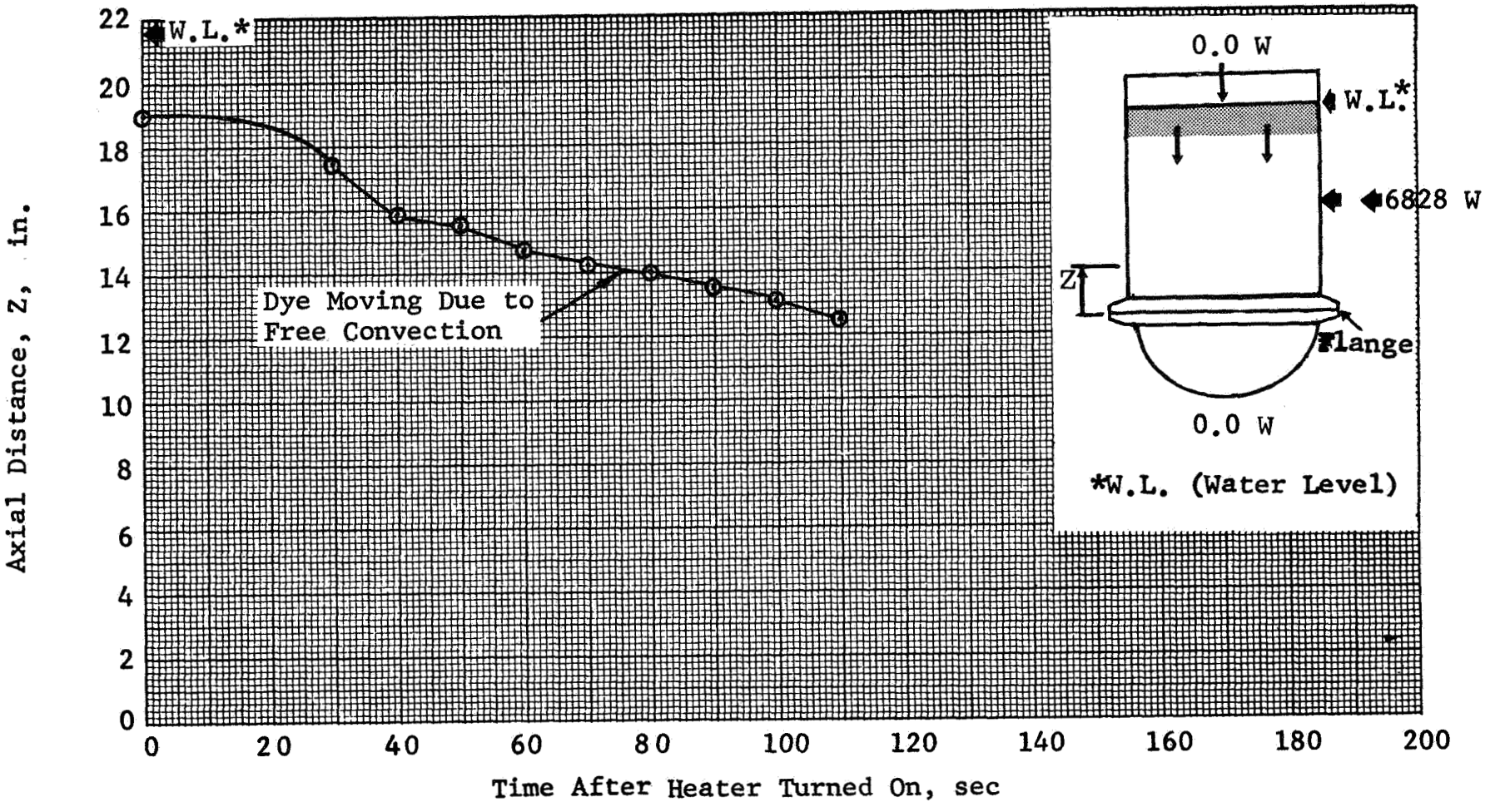


Figure 2.2-110 Axial Dye Layer Motion: Test 40, Run 78

GENERAL DYNAMICS
Fort Worth Division

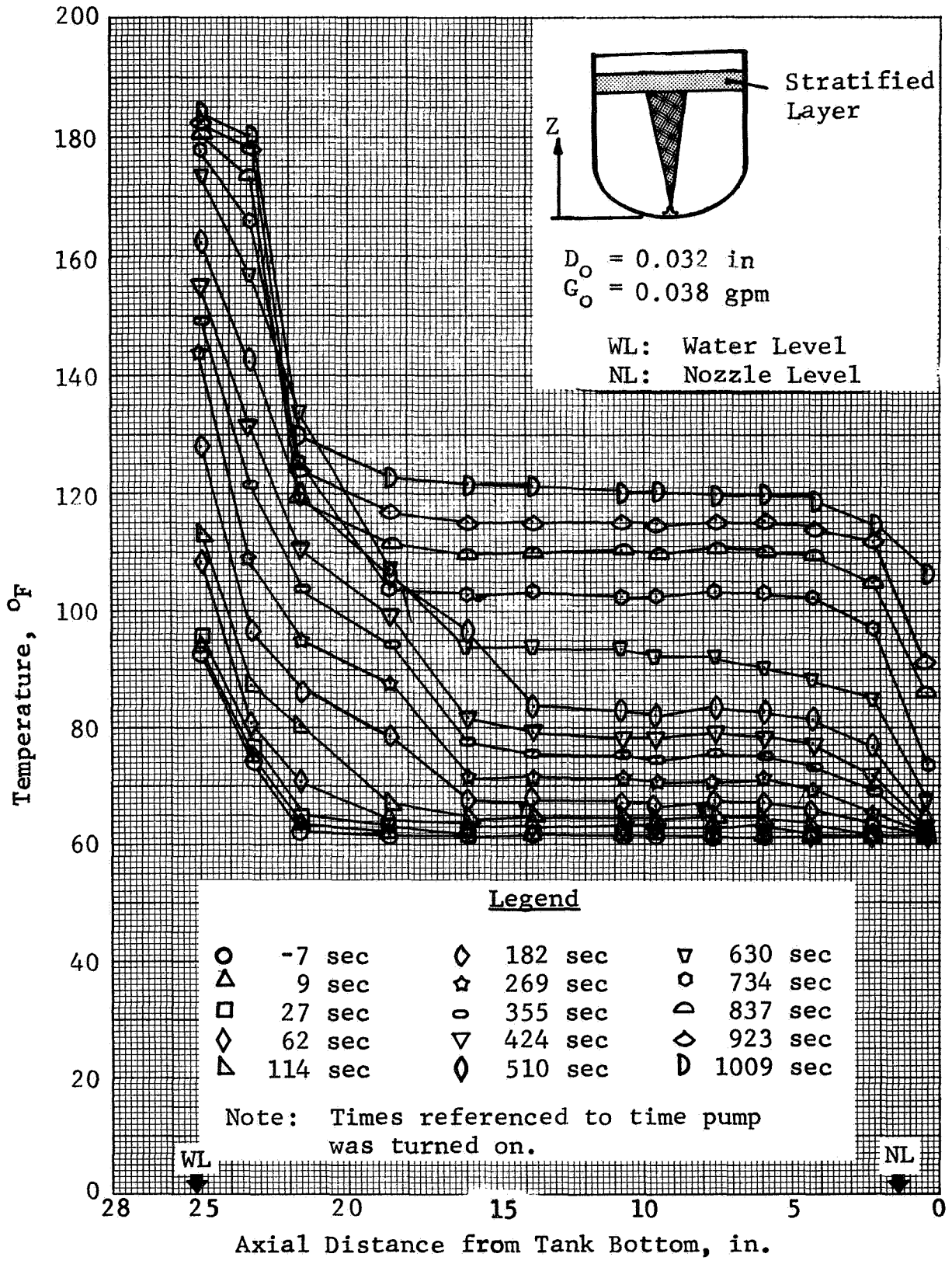


Figure 2.2-111 Temperature Distribution for Axial Jet Flow: Test 42, Run 80

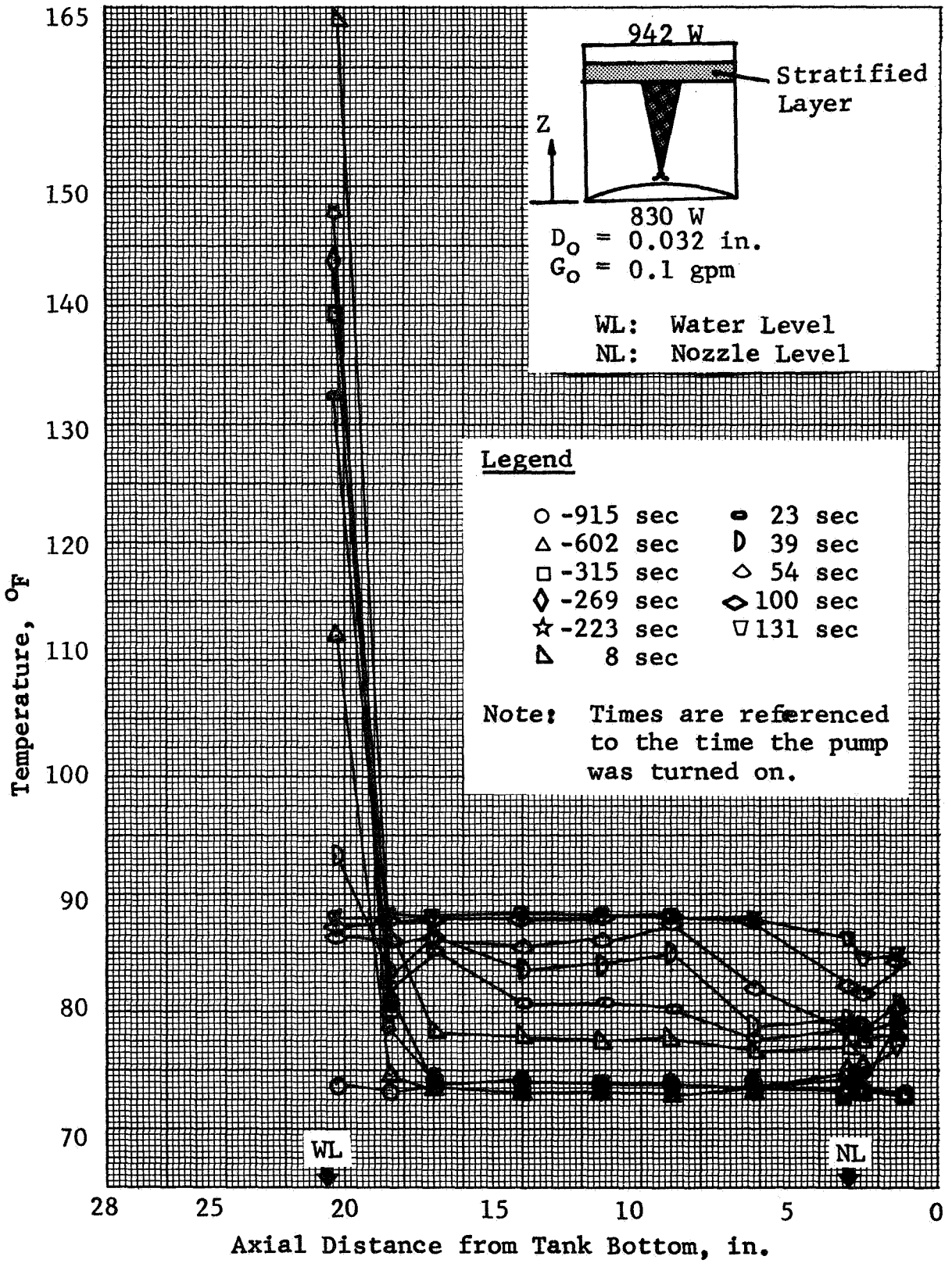


Figure 2.2-112 Temperature Distribution for Axial Jet Flow: Test 102, Run 9

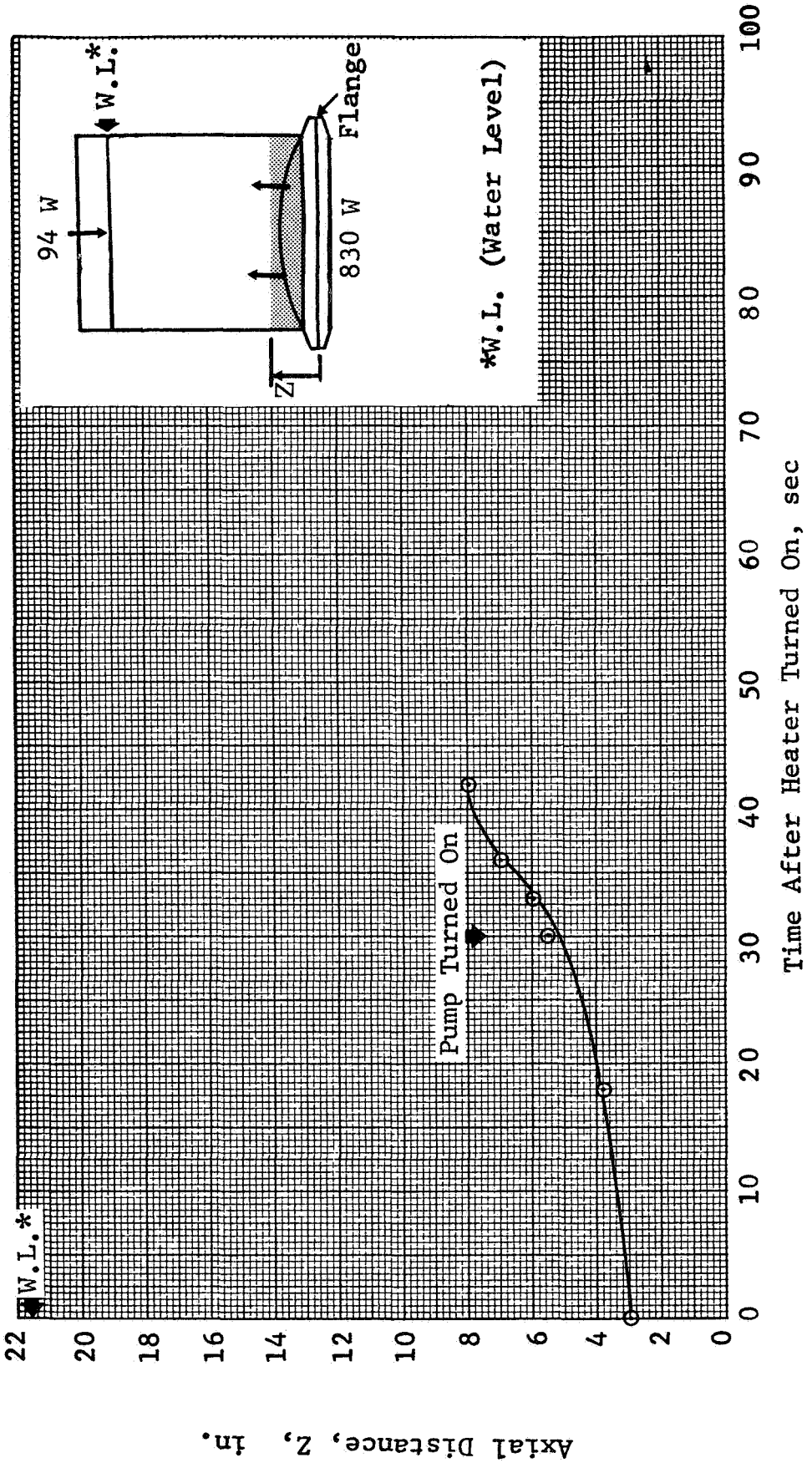


Figure 2.2-113 Axial Dye Layer Motion: Test 112, Run 25

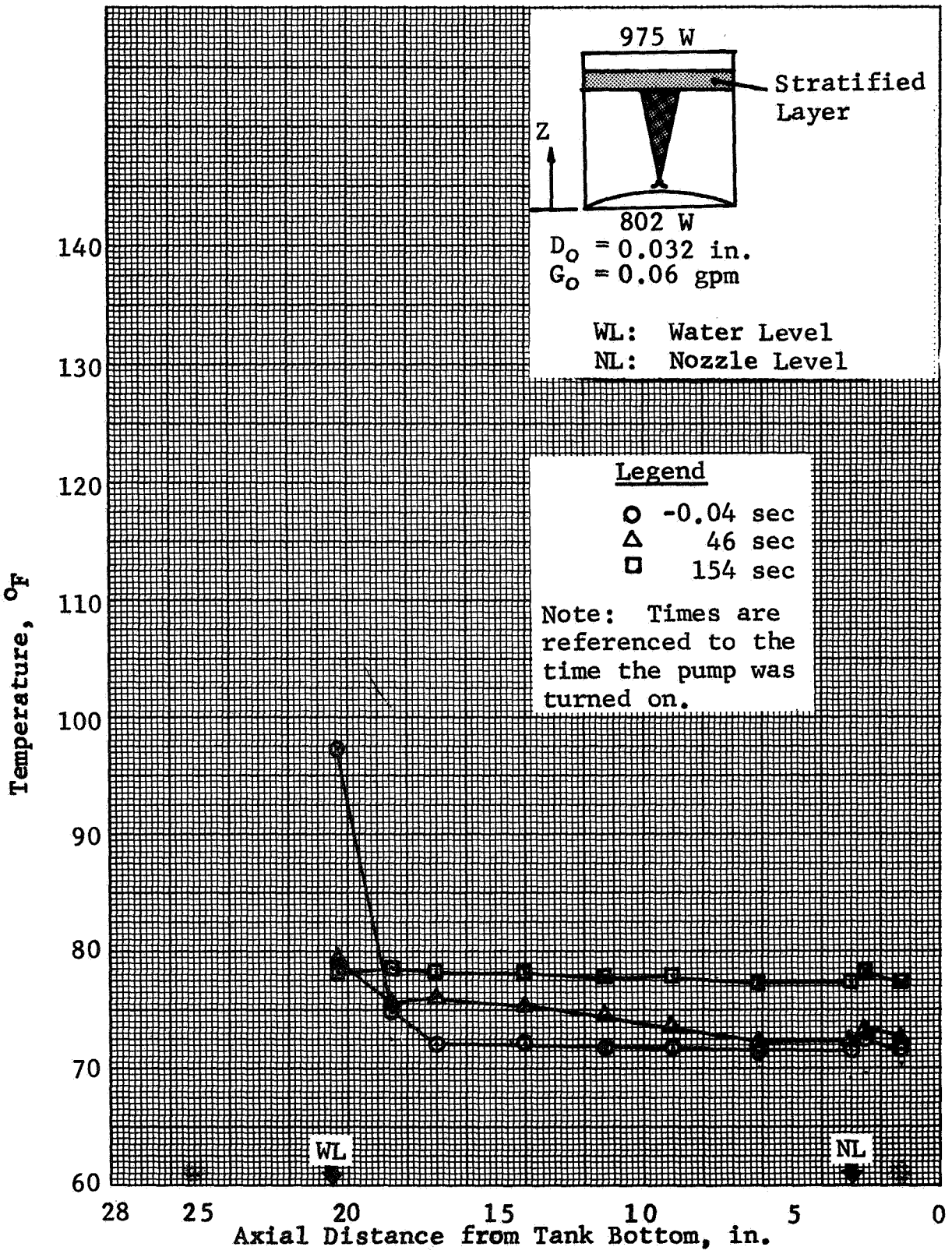


Figure 2.2-114 Temperature Distribution for Axial Jet Flow: Test 121, Run 27

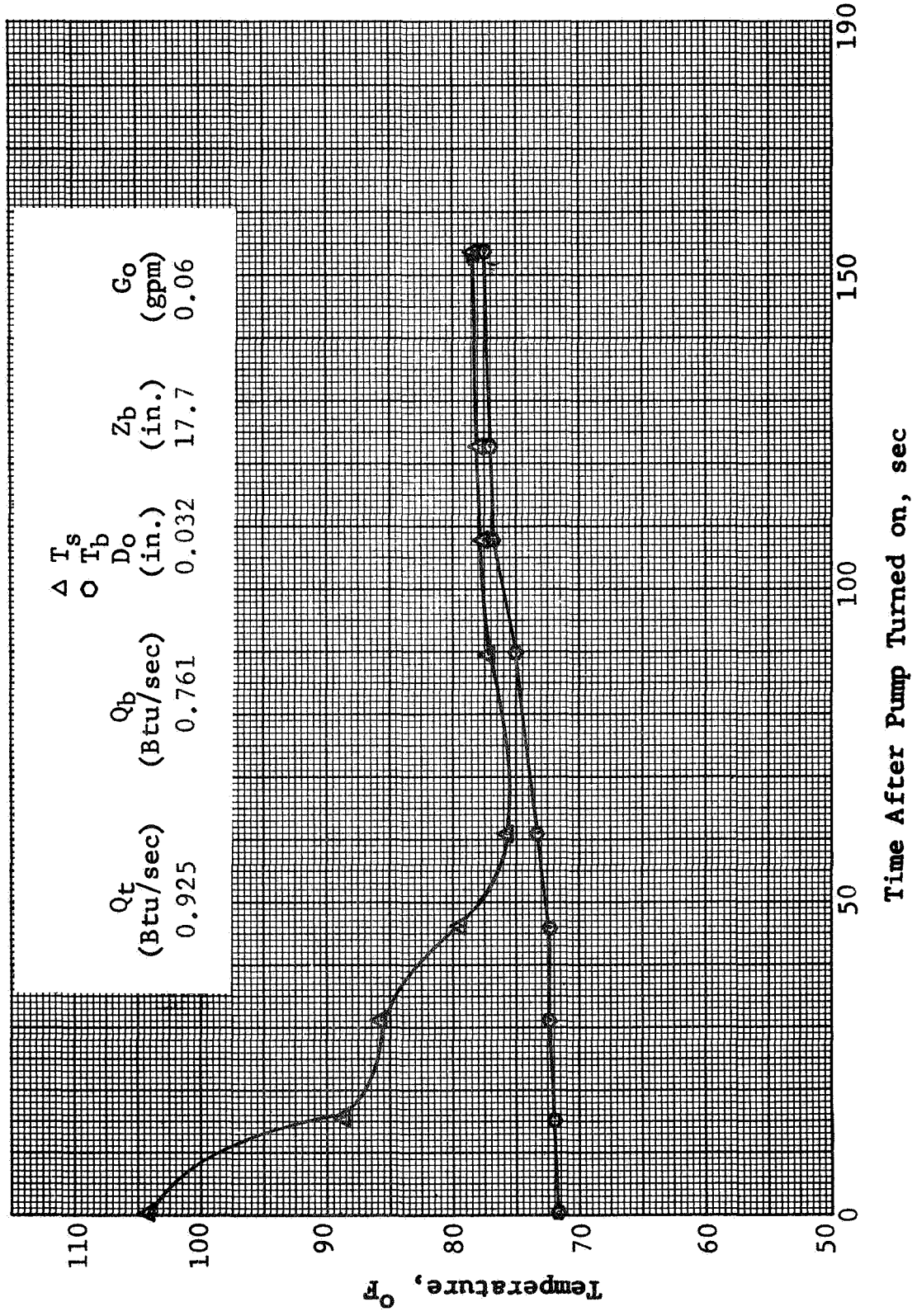


Figure 2.2-115 **Transient Temperature Destratification:** Test 121, Run 27

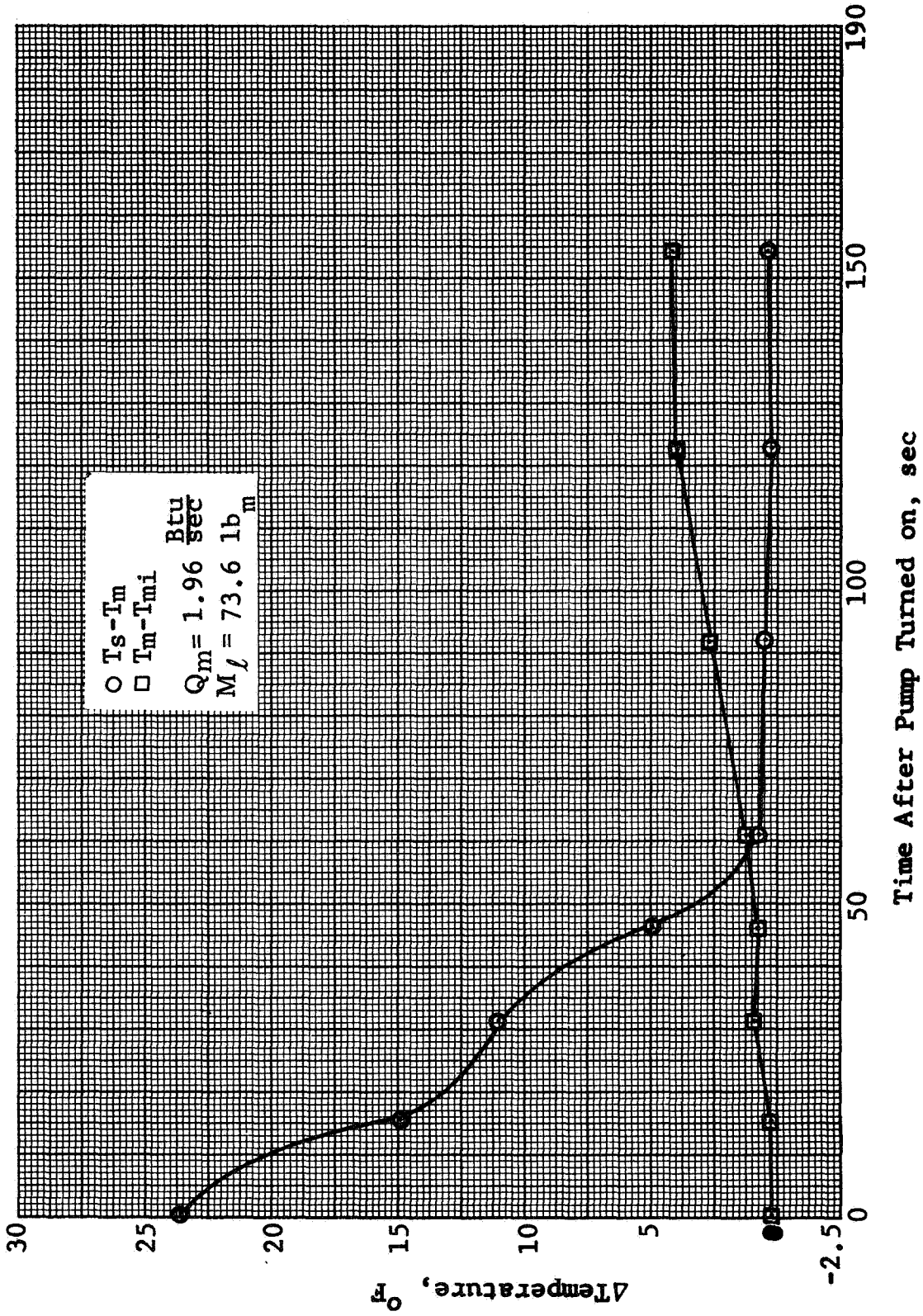


Figure 2.2-116 Transient ΔTemperature Destratification: Test 121, Run 27

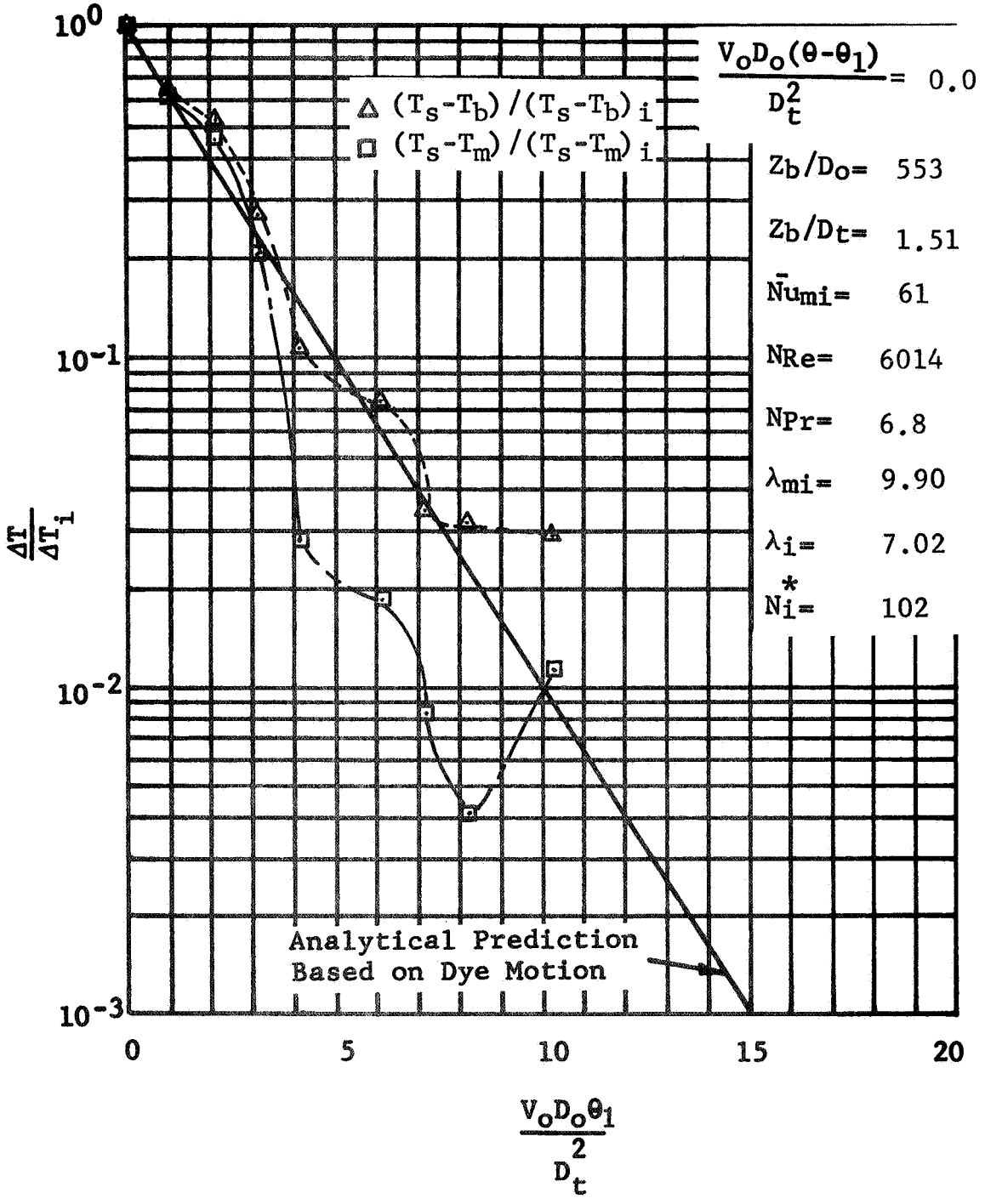


Figure 2.2-117 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 121, Run 27

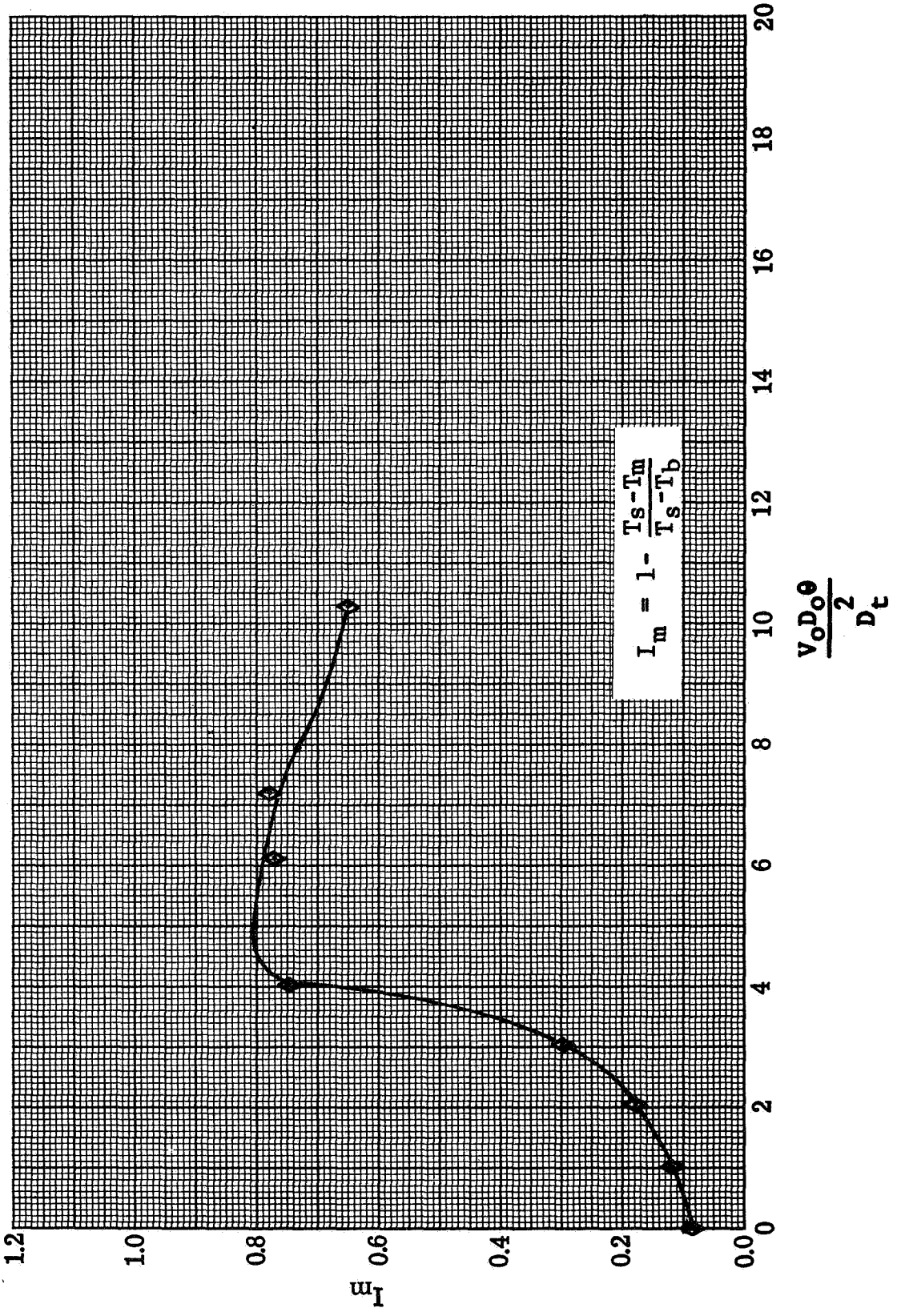


Figure 2.2-118 Transient Energy Integral: Test 121, Run 27

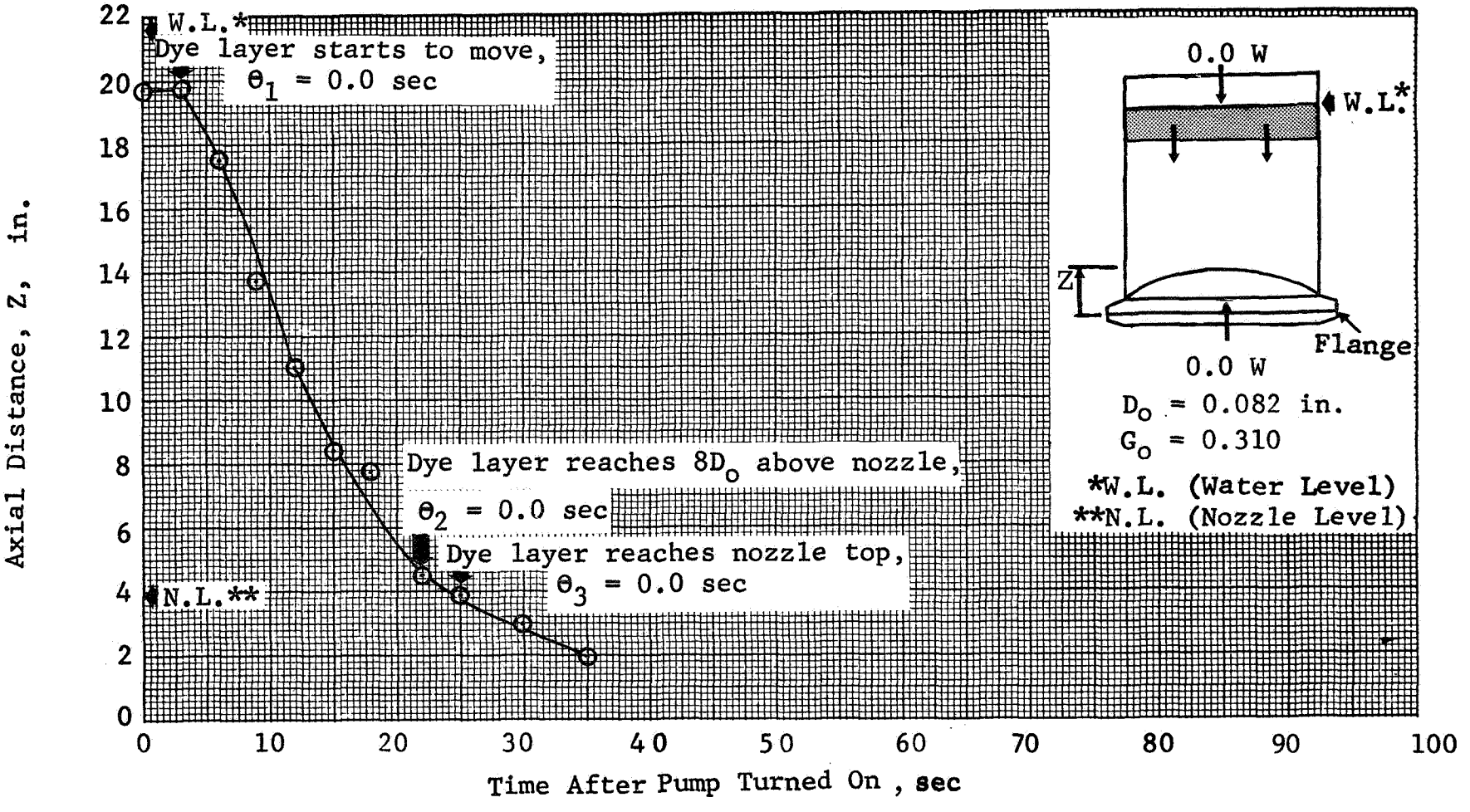


Figure 2.2-119 Axial Dye Layer Motion: Test 133, Run 43

GENERAL DYNAMICS
Fort Worth Division

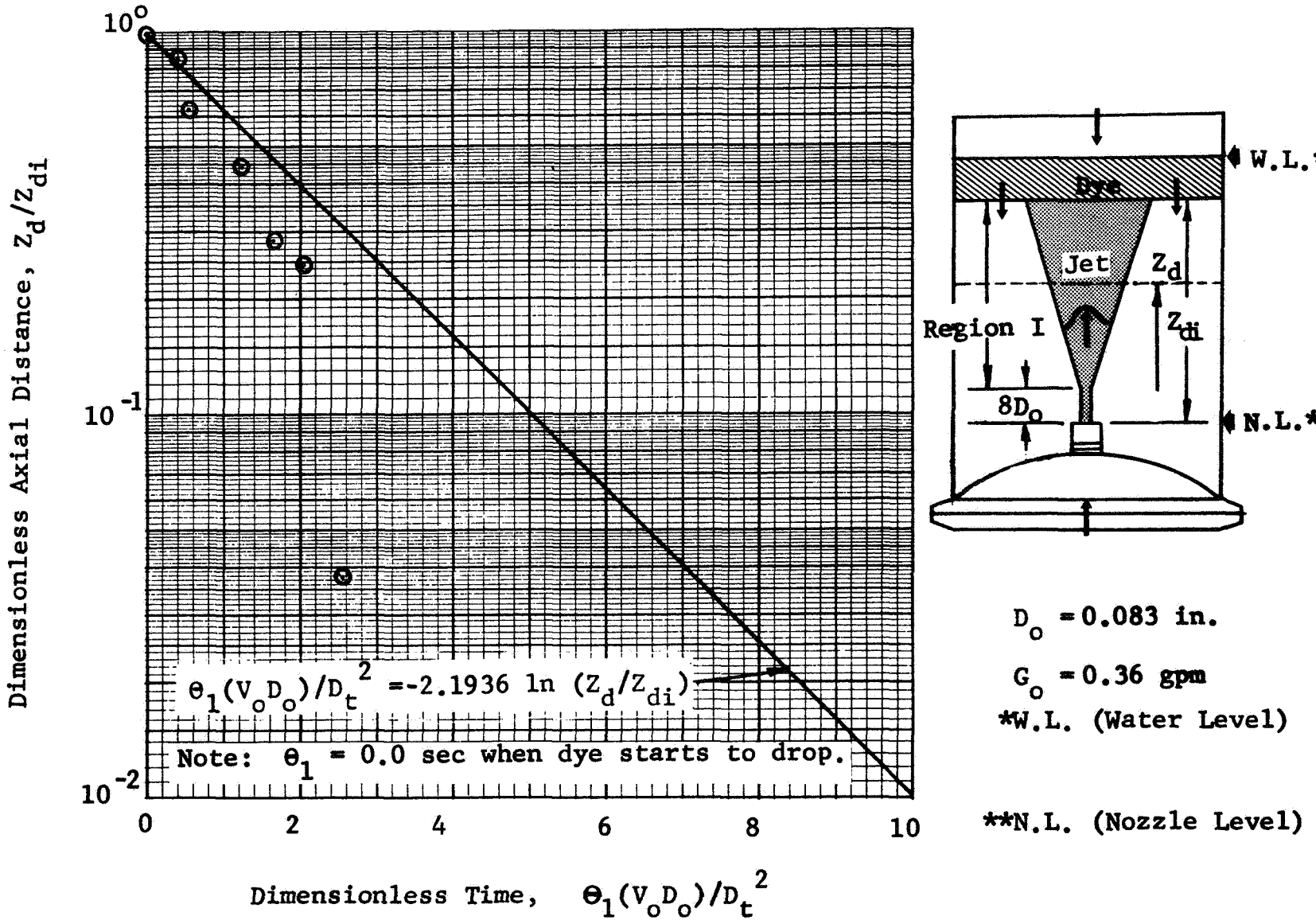


Figure 2.2-120 Correlation of Axial Jet Dye Layer Motion for Region I: Test 133, Run 43

GENERAL DYNAMICS
Fort Worth Division

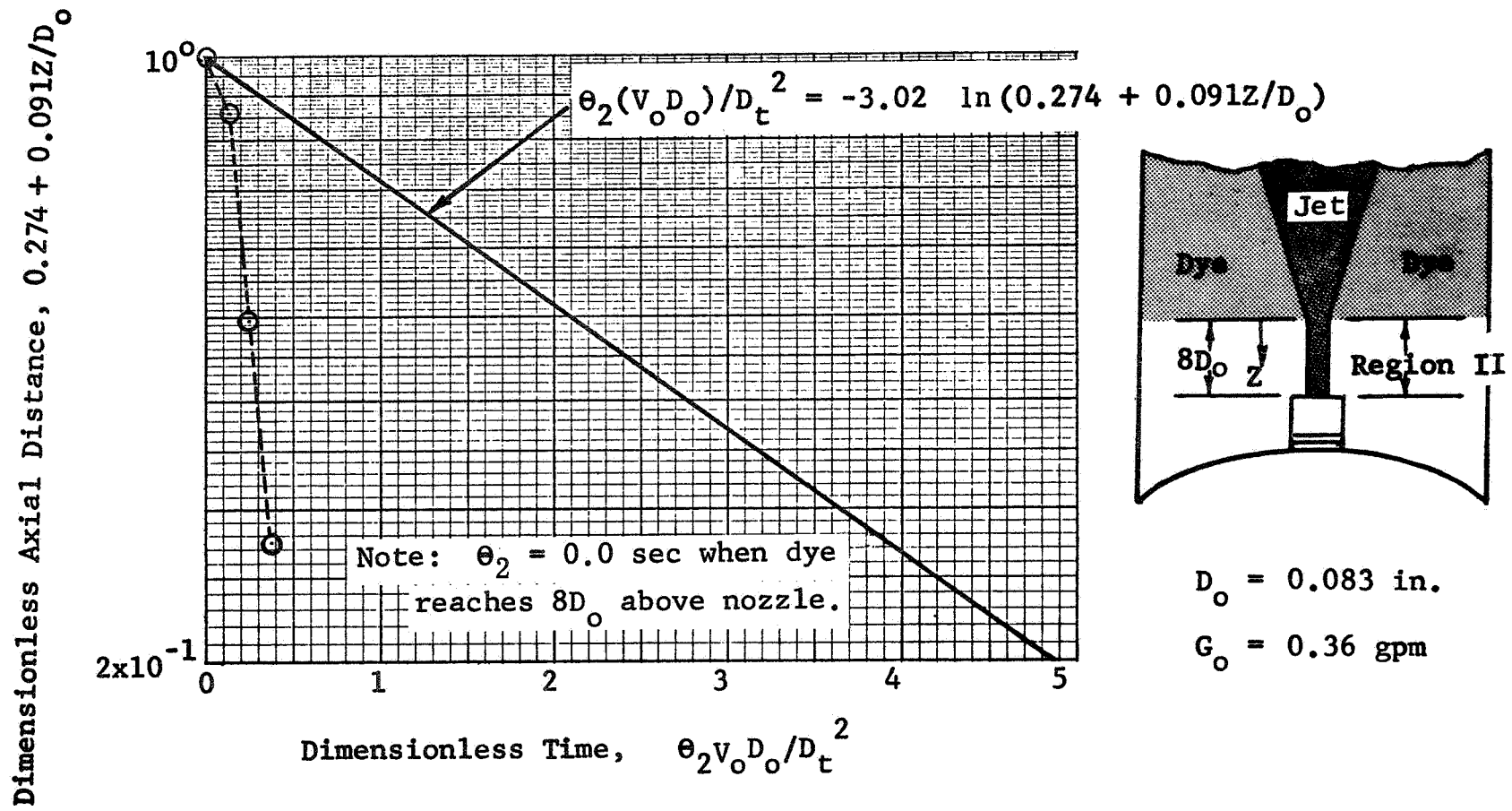
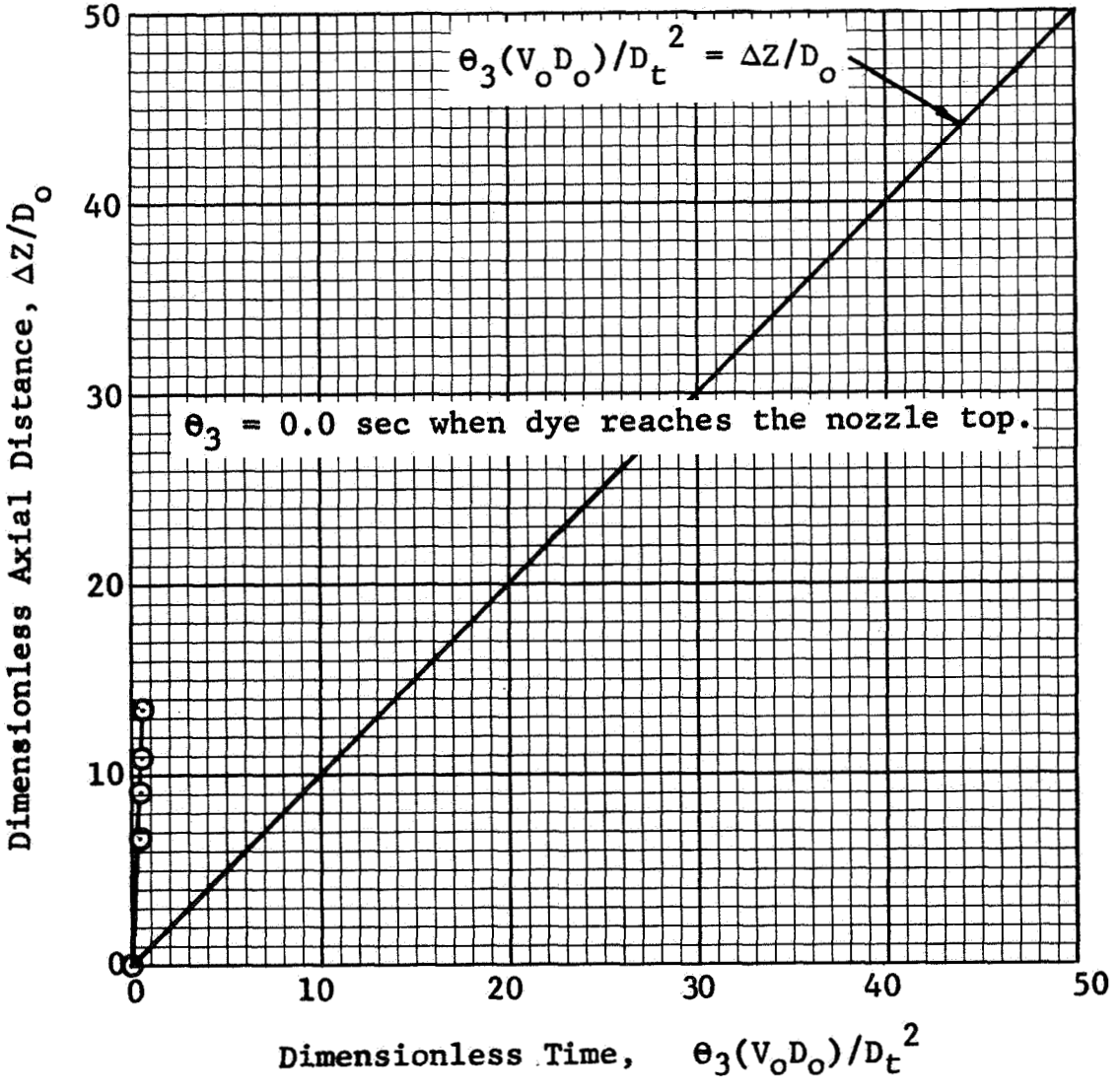
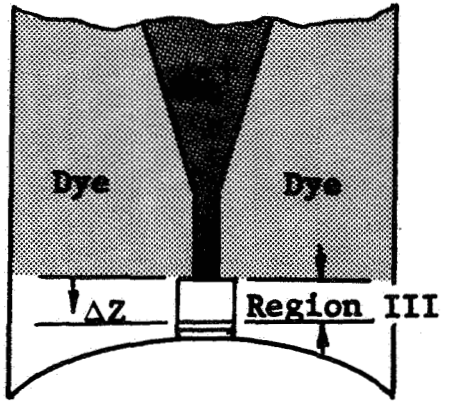


Figure 2.2-121 Correlation of Axial Jet Dye Layer Motion for Region II: Test 133, Run 43

GENERAL DYNAMICS
Fort Worth Division





D_o = 0.083 in.

G_o = 0.36 gpm

Figure 2.2-122 Correlation of Axial Jet Dye Layer Motion for Region III: Test 133, Run 43

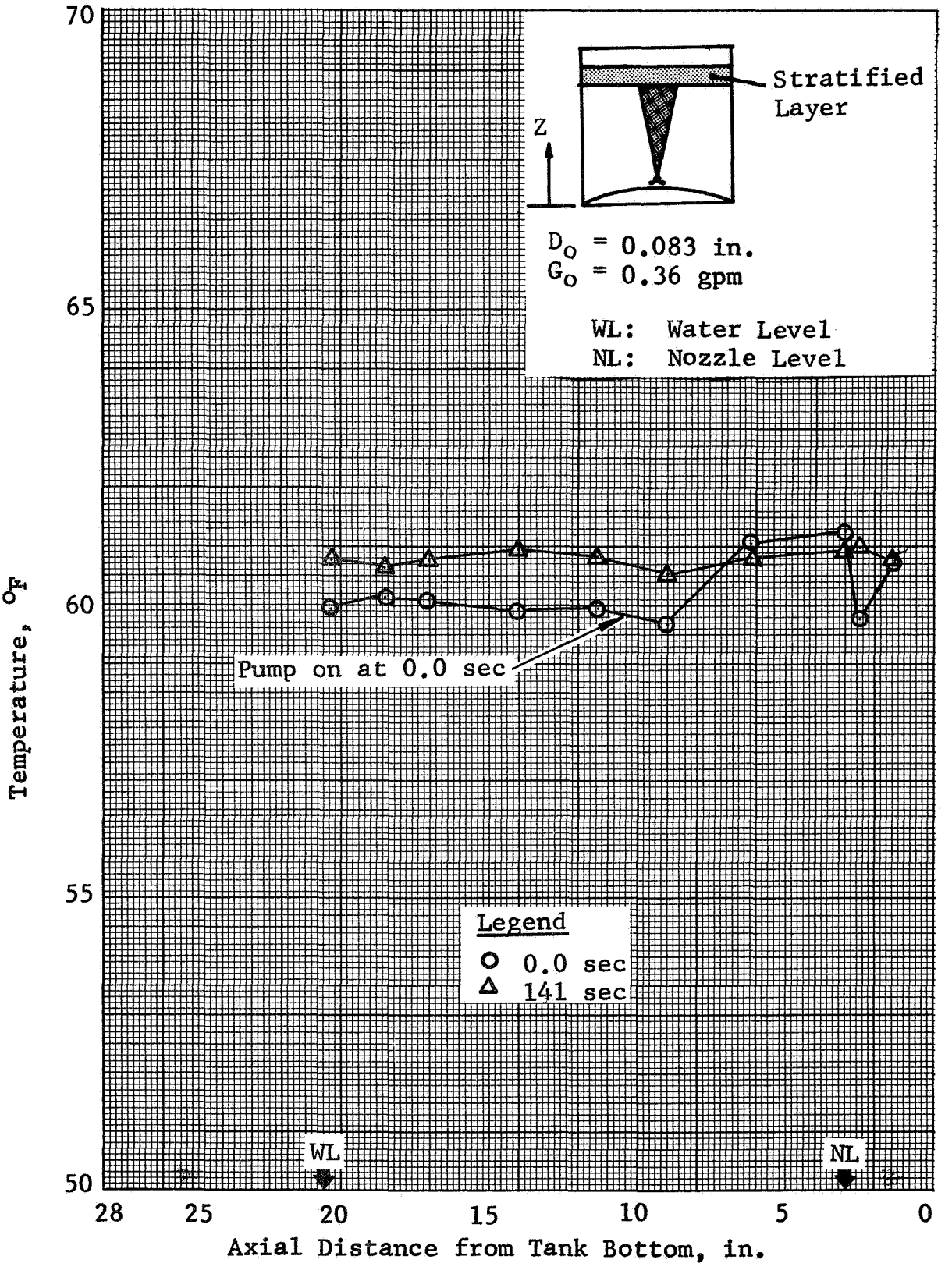


Figure 2.2-123 Temperature Distribution for Axial Jet Flow: Test 133, Run 43

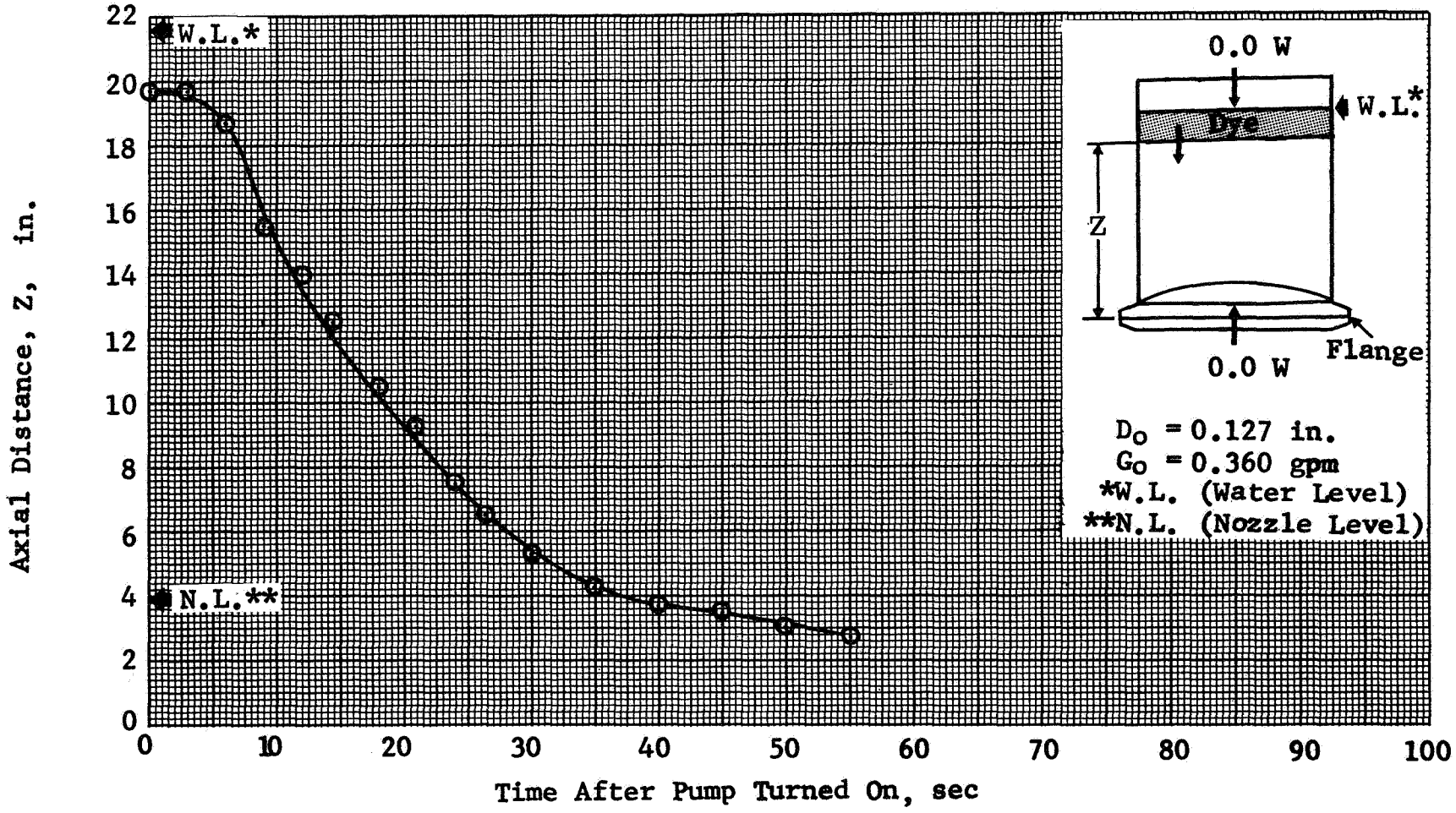


Figure 2.2-124 Axial Jet Dye Layer Motion: Test 134, Run 44

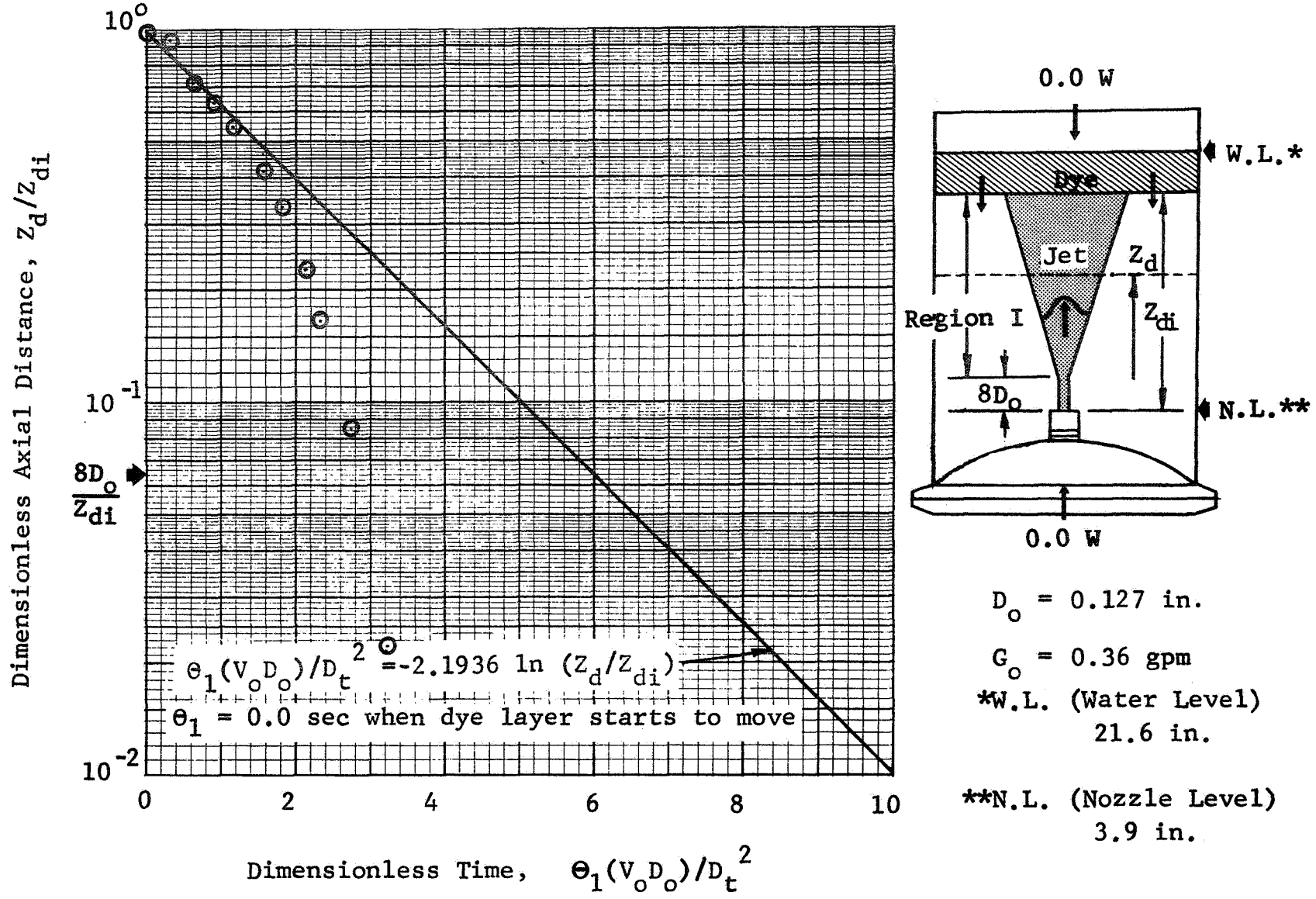


Figure 2.2-125 Correlation of Axial Jet Dye Layer Motion for Region I: Test 134, Run 44

GENERAL DYNAMICS
Fort Worth Division

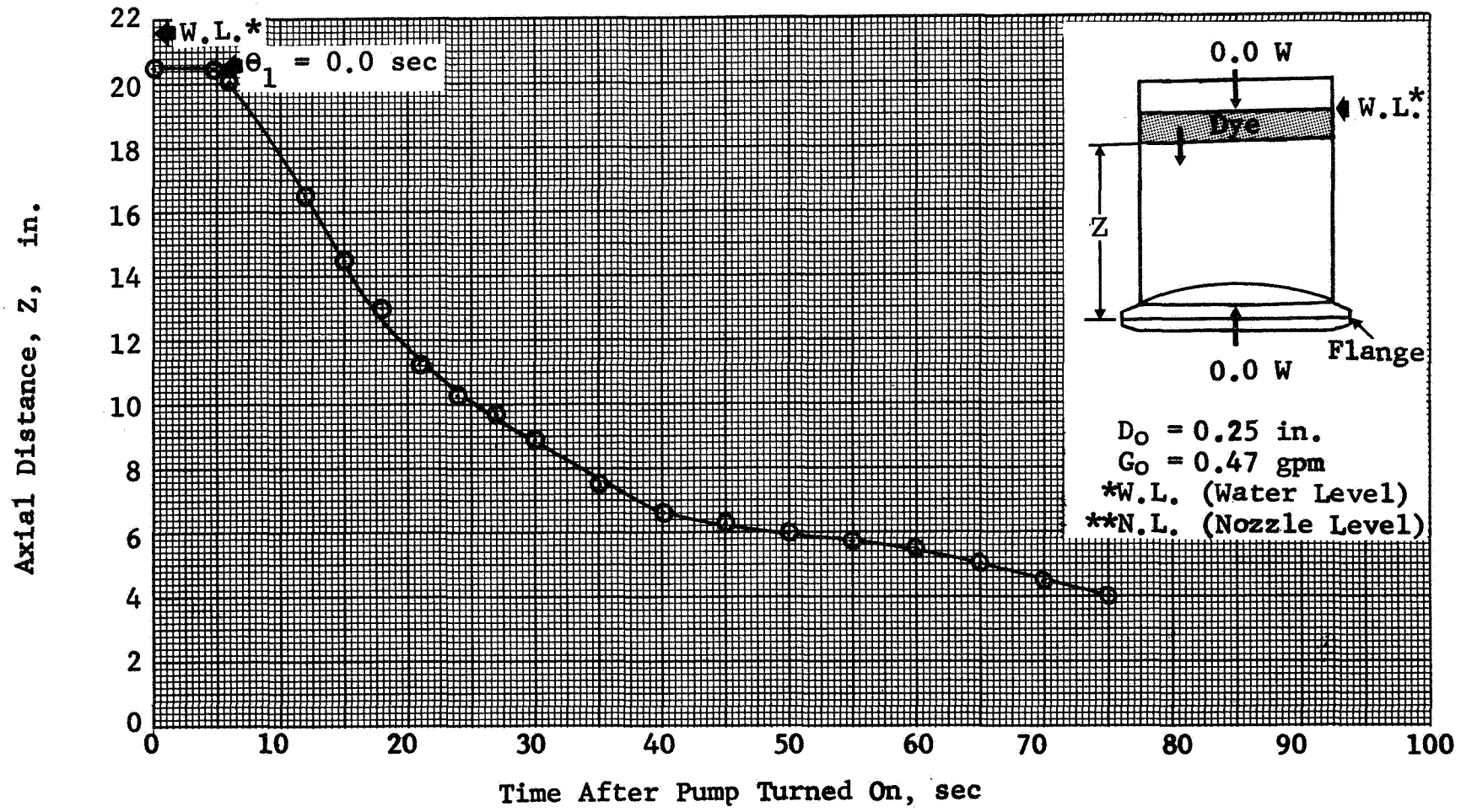


Figure 2.2-126 Axial Jet Dye Layer Motion: Test 135, Run 39

GENERAL DYNAMICS
Fort Worth Division

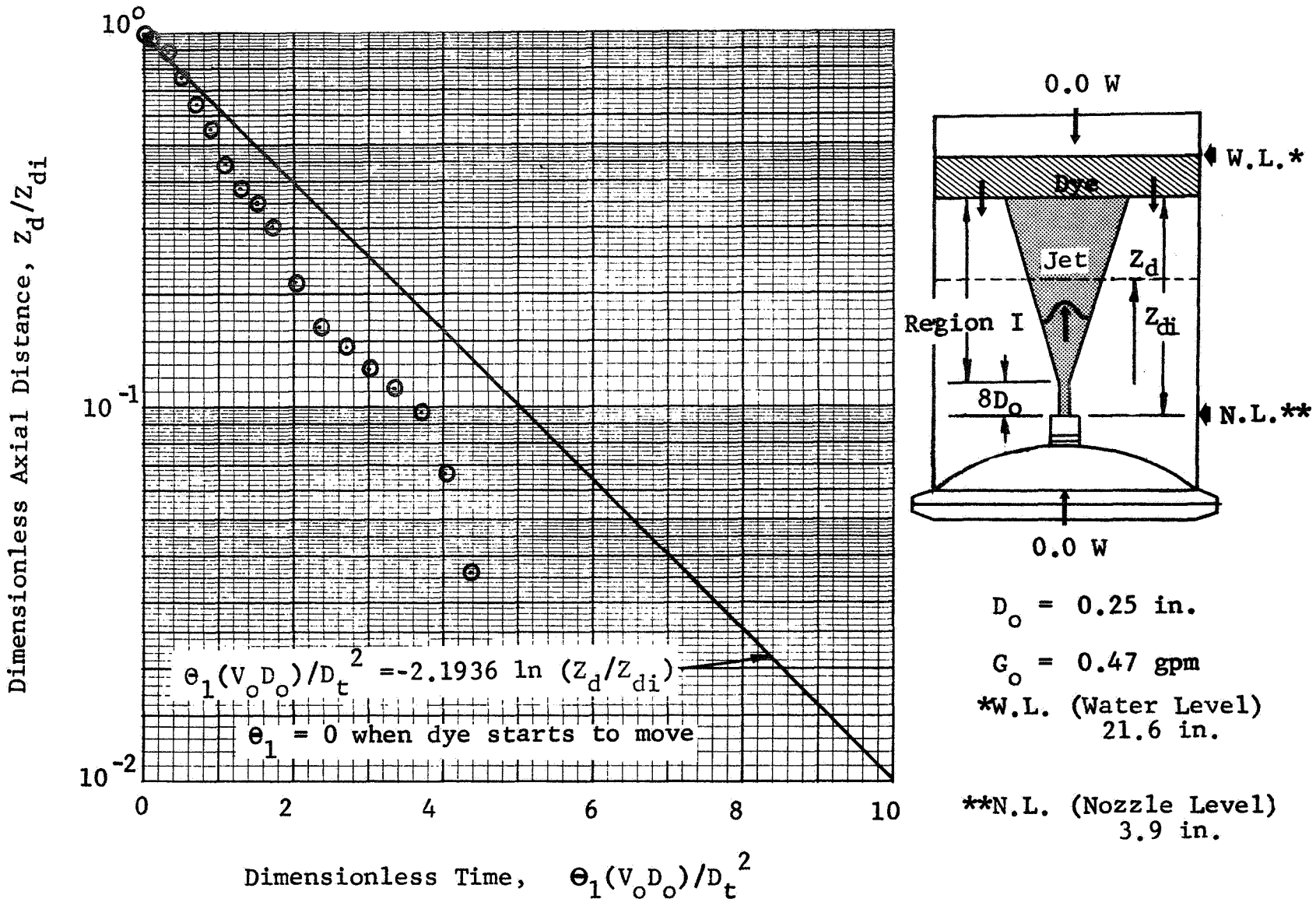


Figure 2.2-127 Correlation of Axial Jet Dye Layer Motion for Region I: Test 135, Run 39

GENERAL DYNAMICS
Fort Worth Division

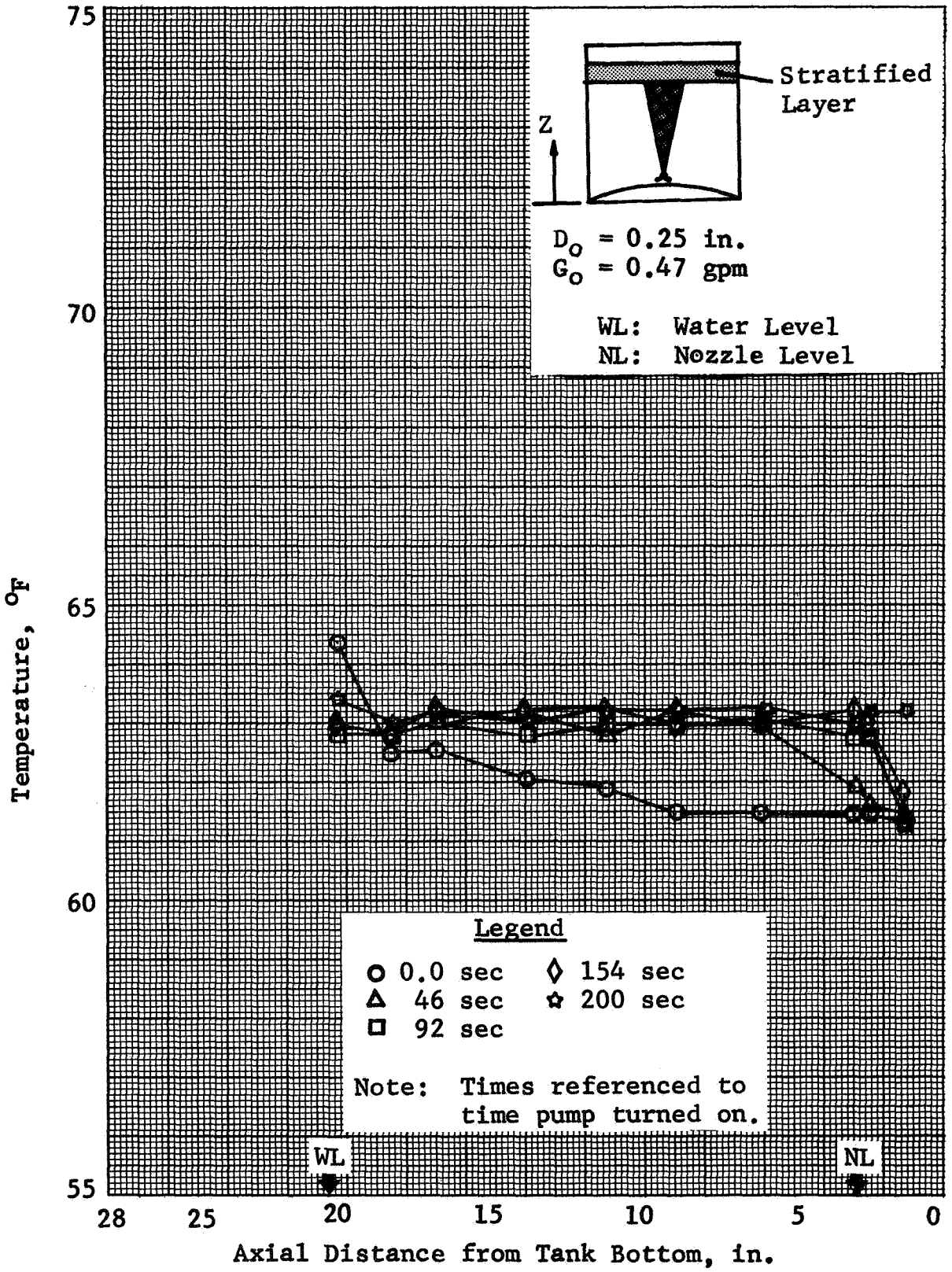


Figure 2.2-128 Temperature Distribution for Axial Jet Flow: Test 135, Run 39

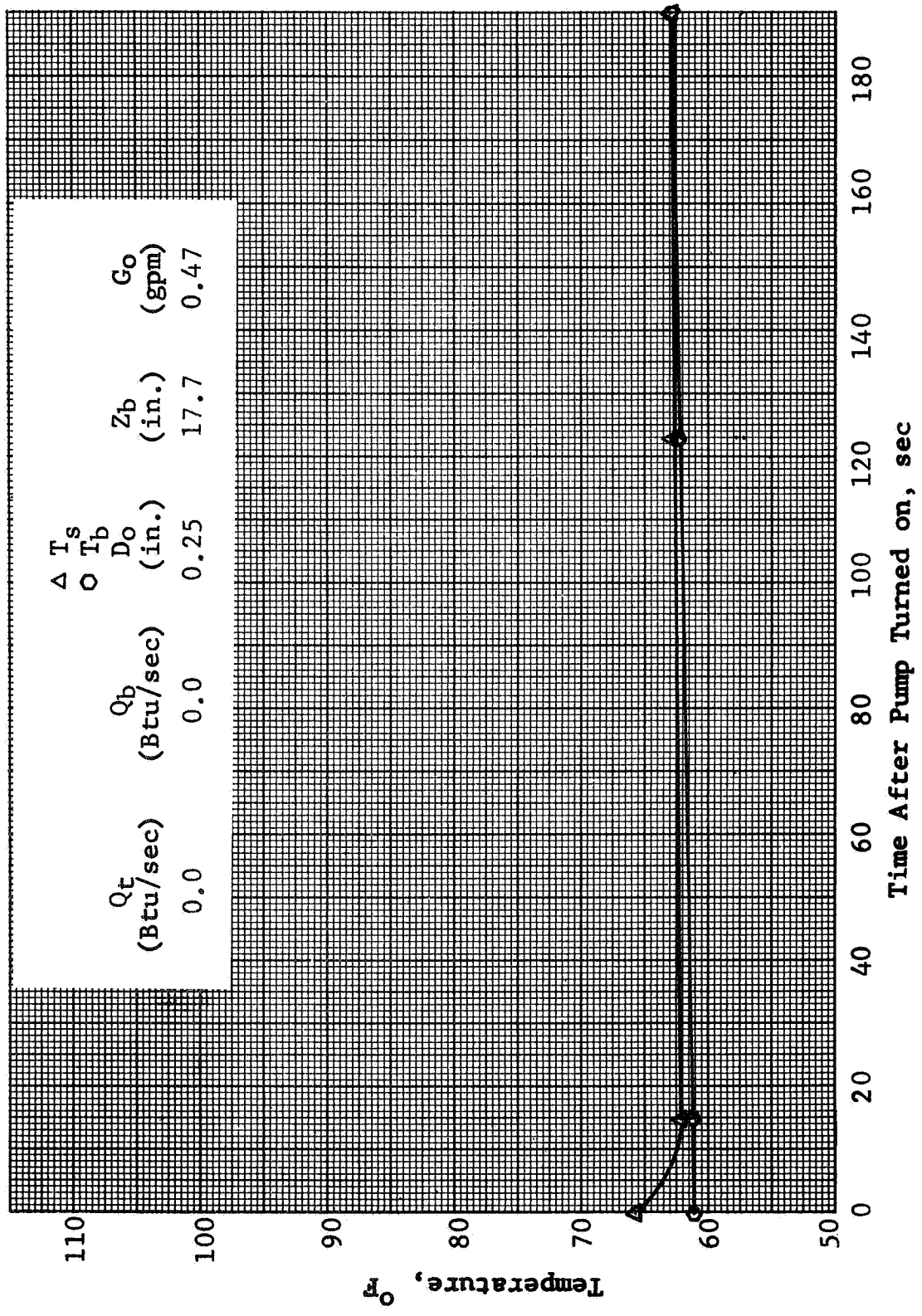


Figure 2.2-129 Transient Temperature Destratification: Test 135, Run 39

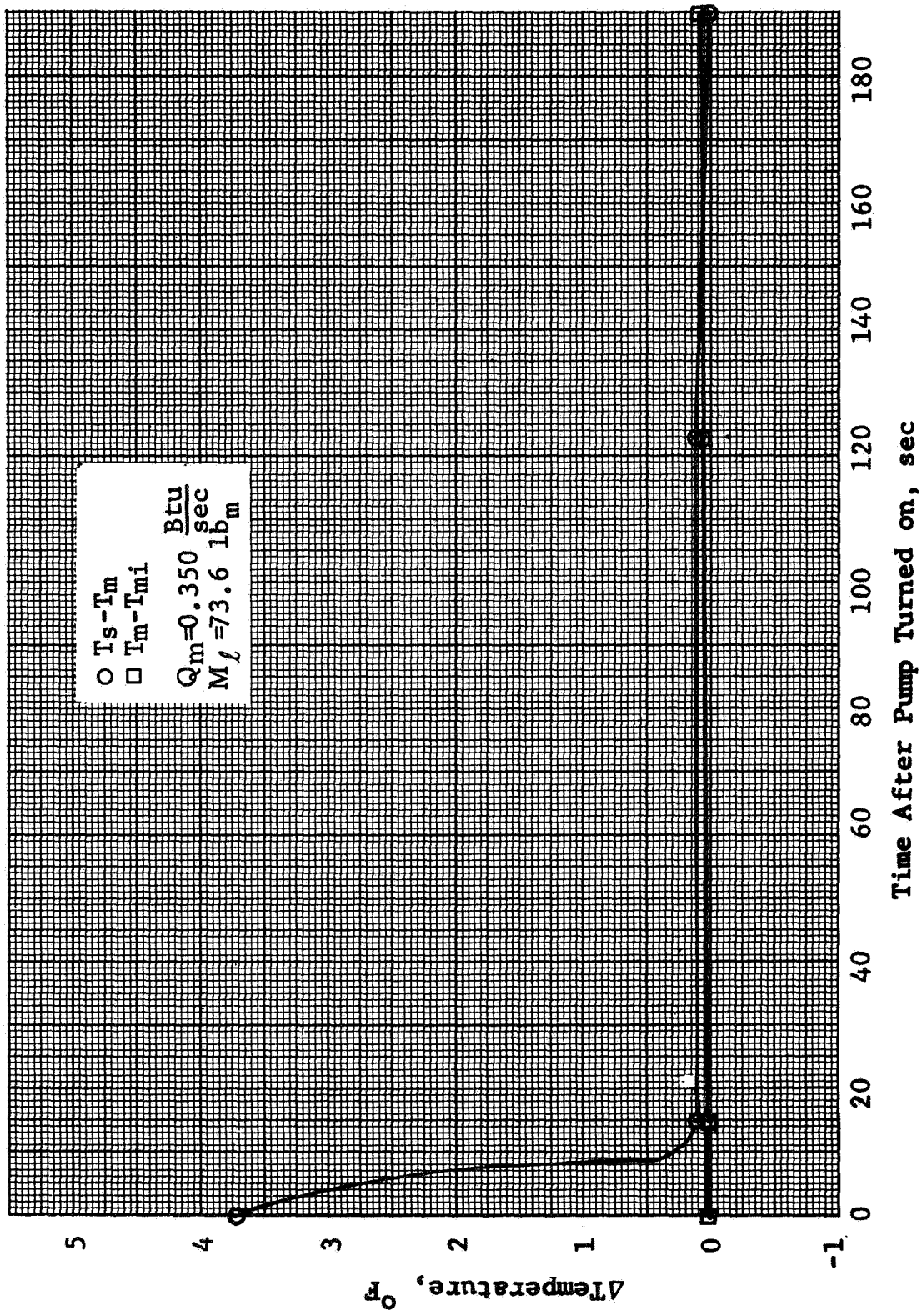


Figure 2.2-130 Transient ΔTemperature Destratification: Test 135, Run 39

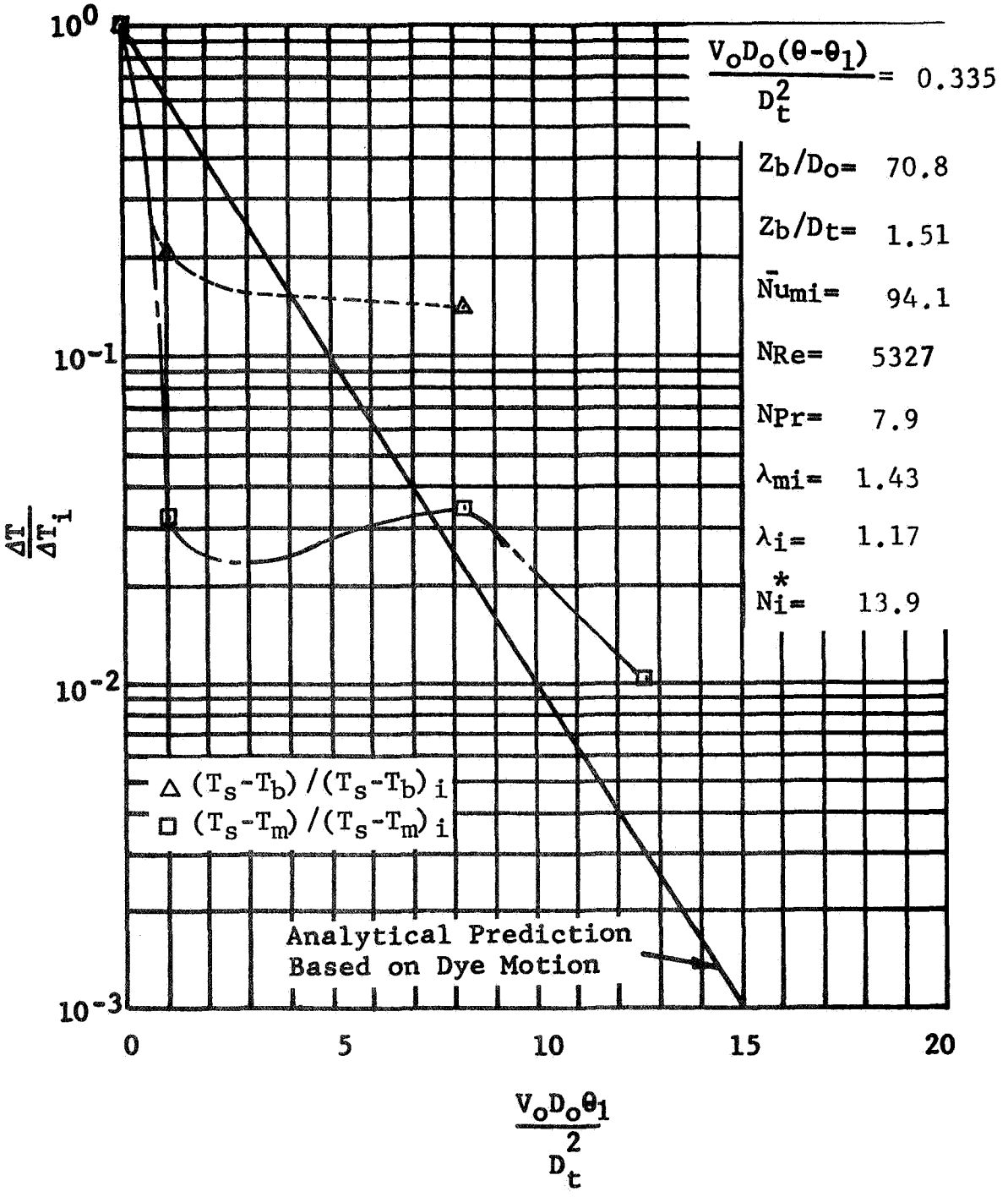


Figure 2.2-131 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 135, Run 39

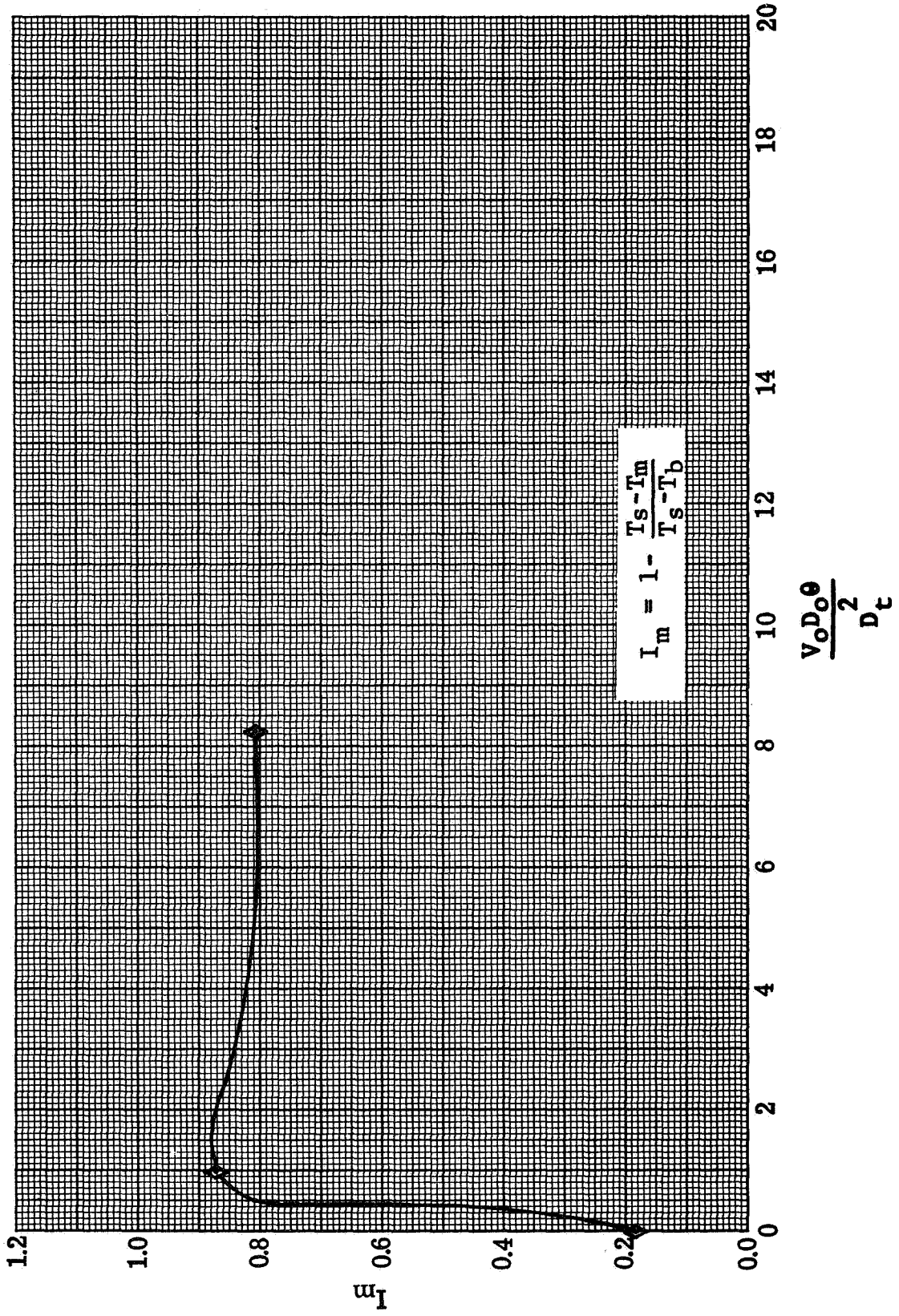


Figure 2.2-132 Transient Energy Integral: Test 135, Run 39

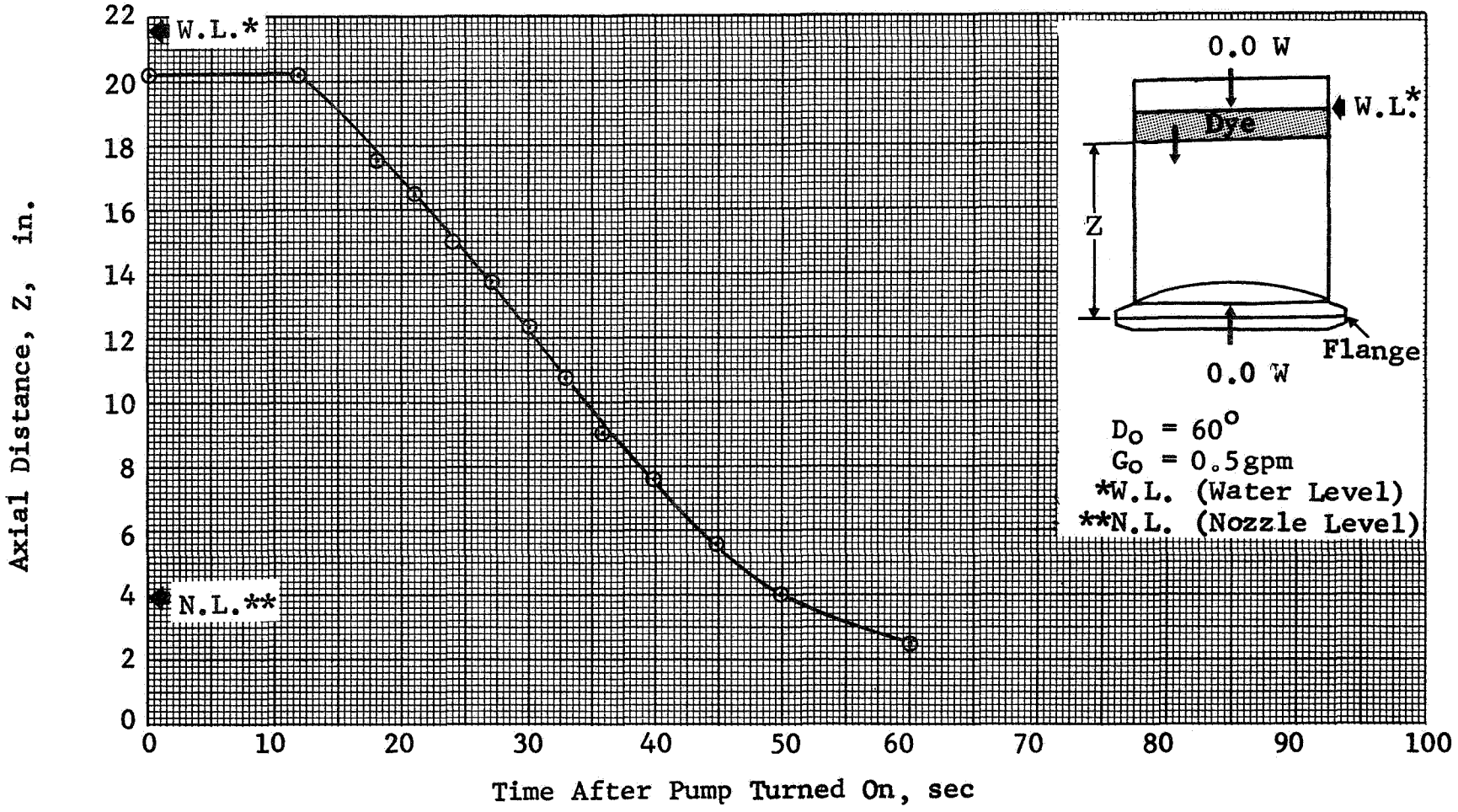


Figure 2.2-133 Axial Jet Dye Layer Motion: Test 136, Run 45

GENERAL DYNAMICS
Fort Worth Division

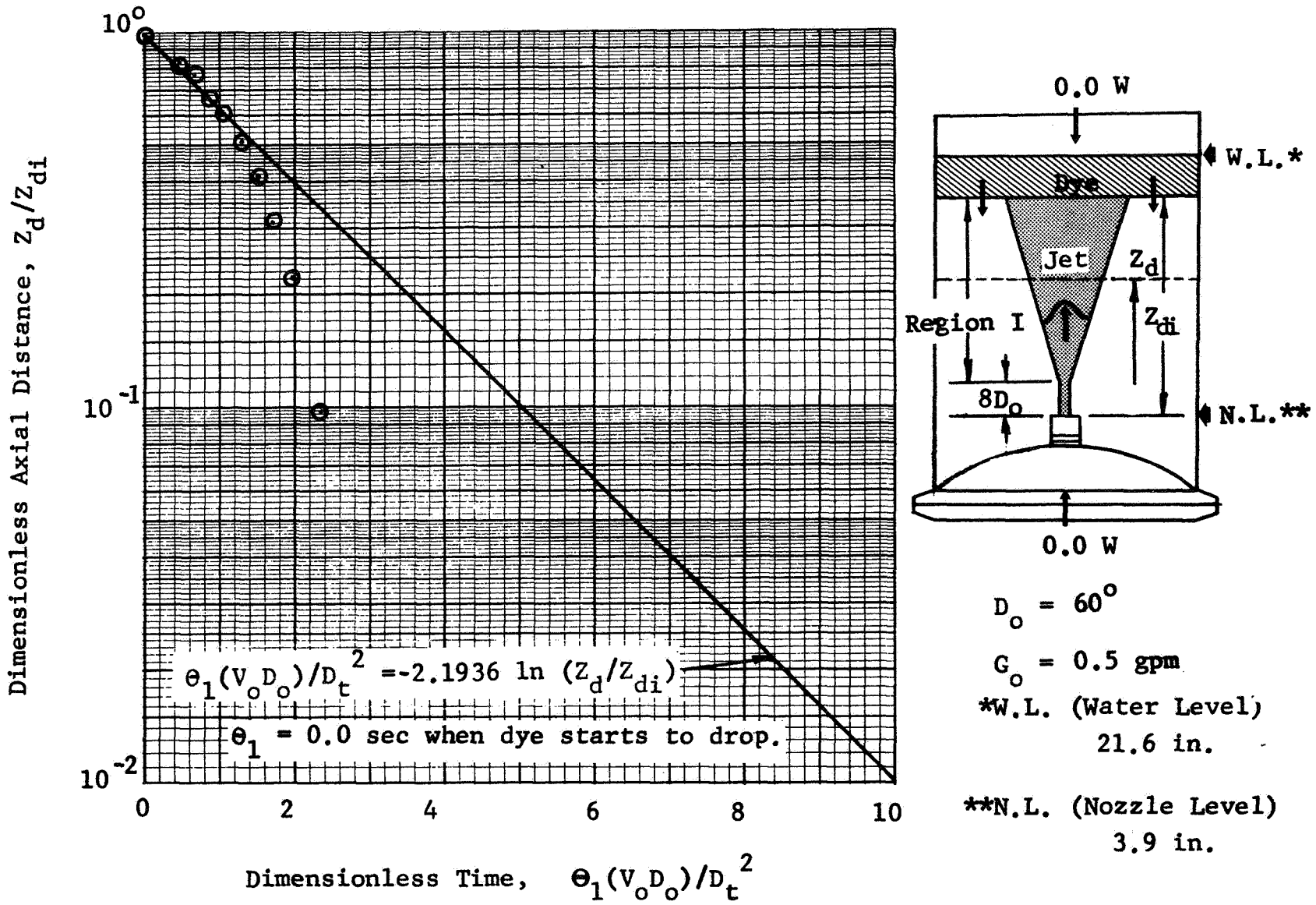


Figure 2.2-134 Correlation of Axial Jet Dye Layer Motion for Region I: Test 136, Run 45

GENERAL DYNAMICS
Fort Worth Division

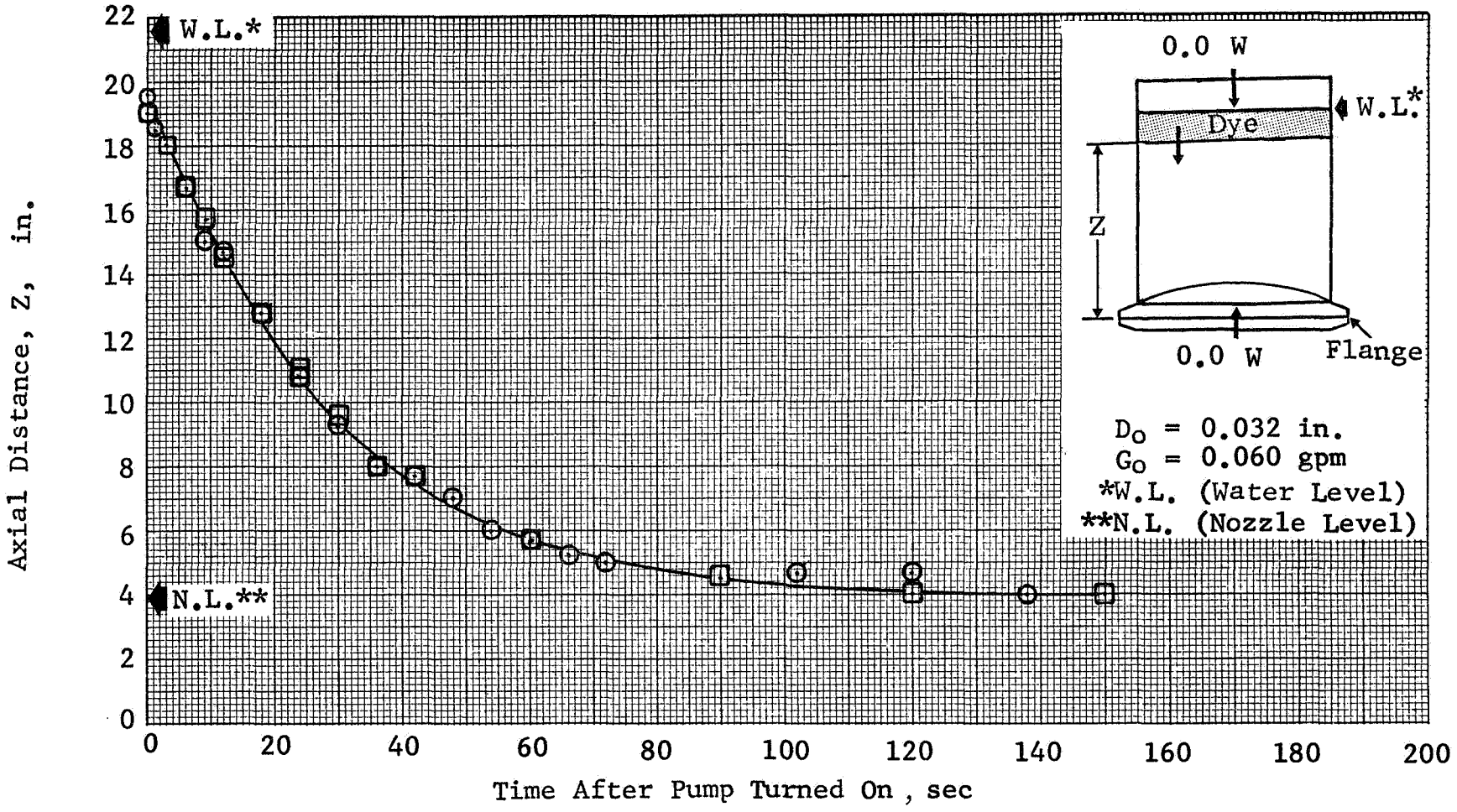


Figure 2.2-135 Axial Jet Dye Layer Motion: Test 138, Run 5

GENERAL DYNAMICS
Fort Worth Division

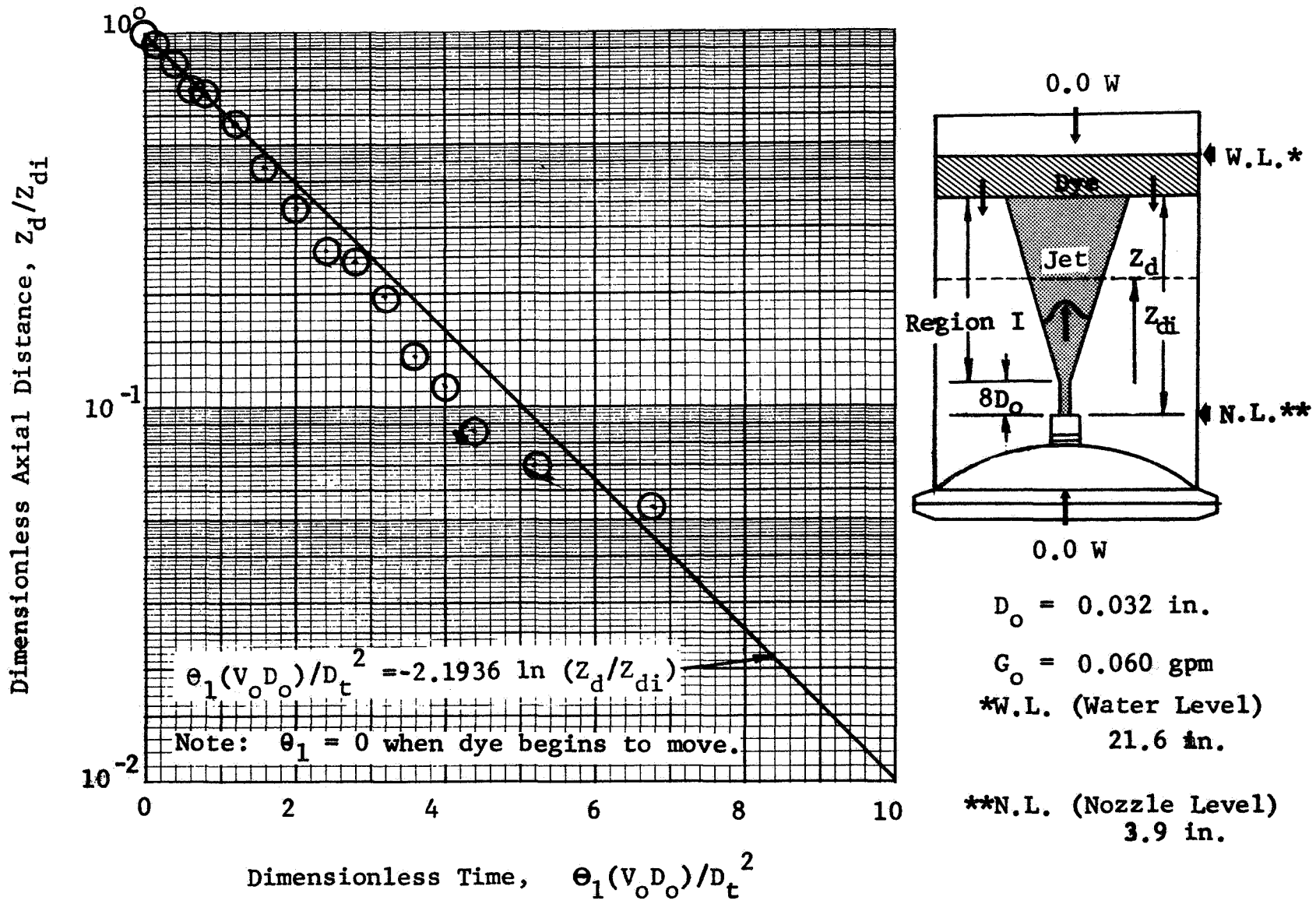


Figure 2.2-136 Correlation of Axial Jet Dye Layer Motion for Region I: Test 138, Run 5

GENERAL DYNAMICS
Fort Worth Division

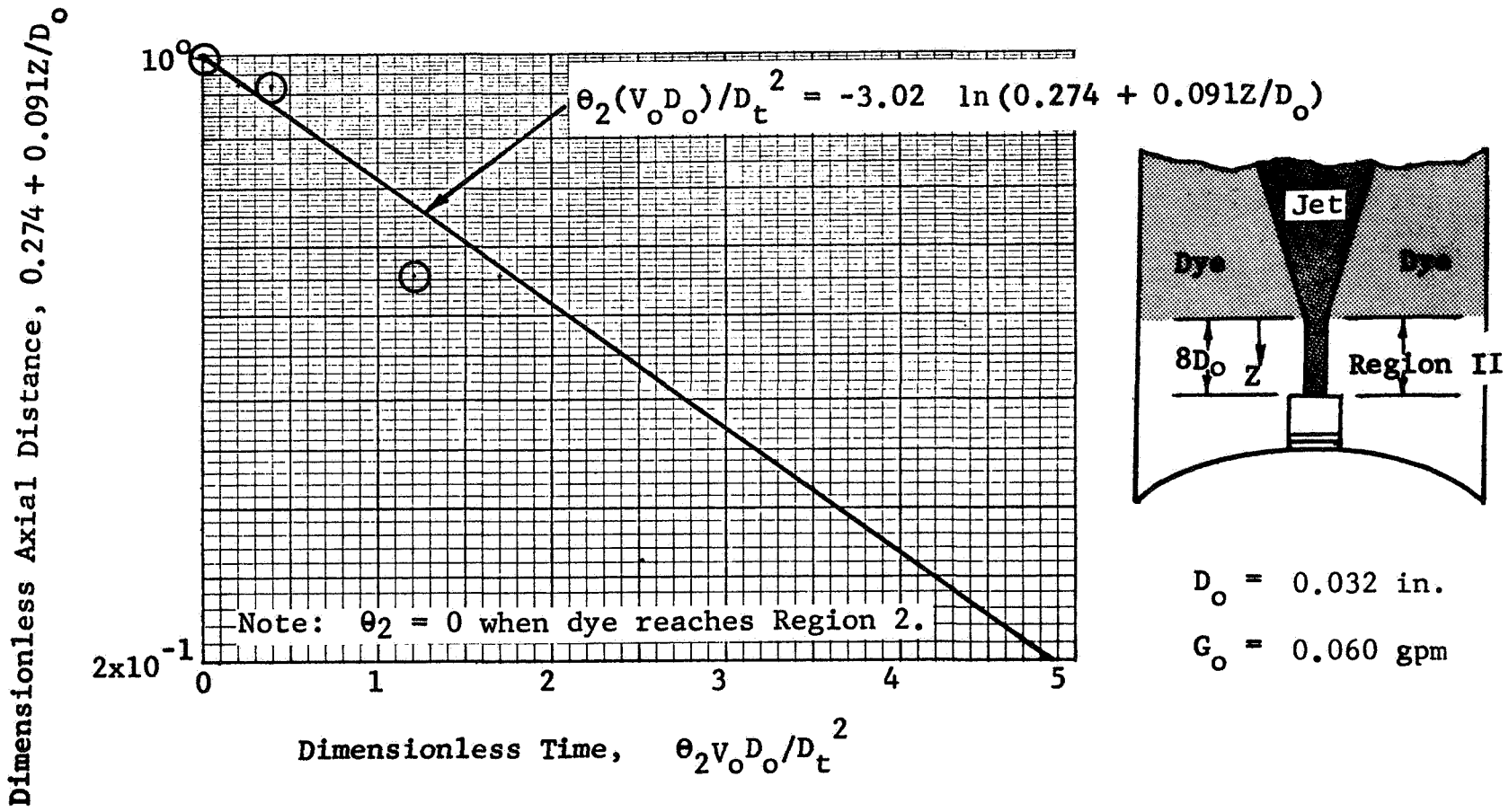


Figure 2.2-137 Correlation of Axial Jet Dye Layer Motion for Region II: Test 138, Run 5

GENERAL DYNAMICS
Fort Worth Division

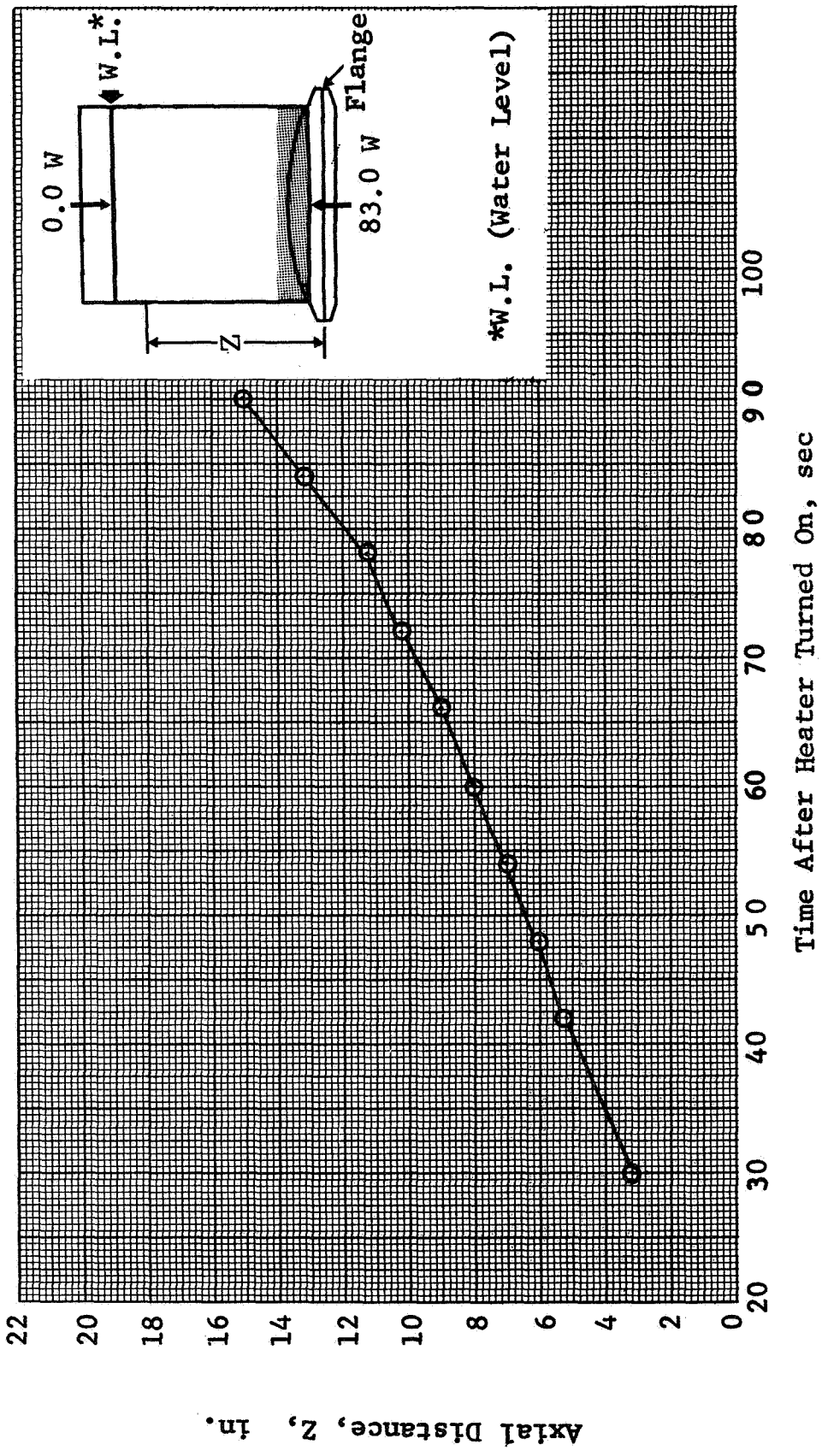


Figure 2.2-138 Axial Jet Dye Layer Motion: Test 146, Run 12

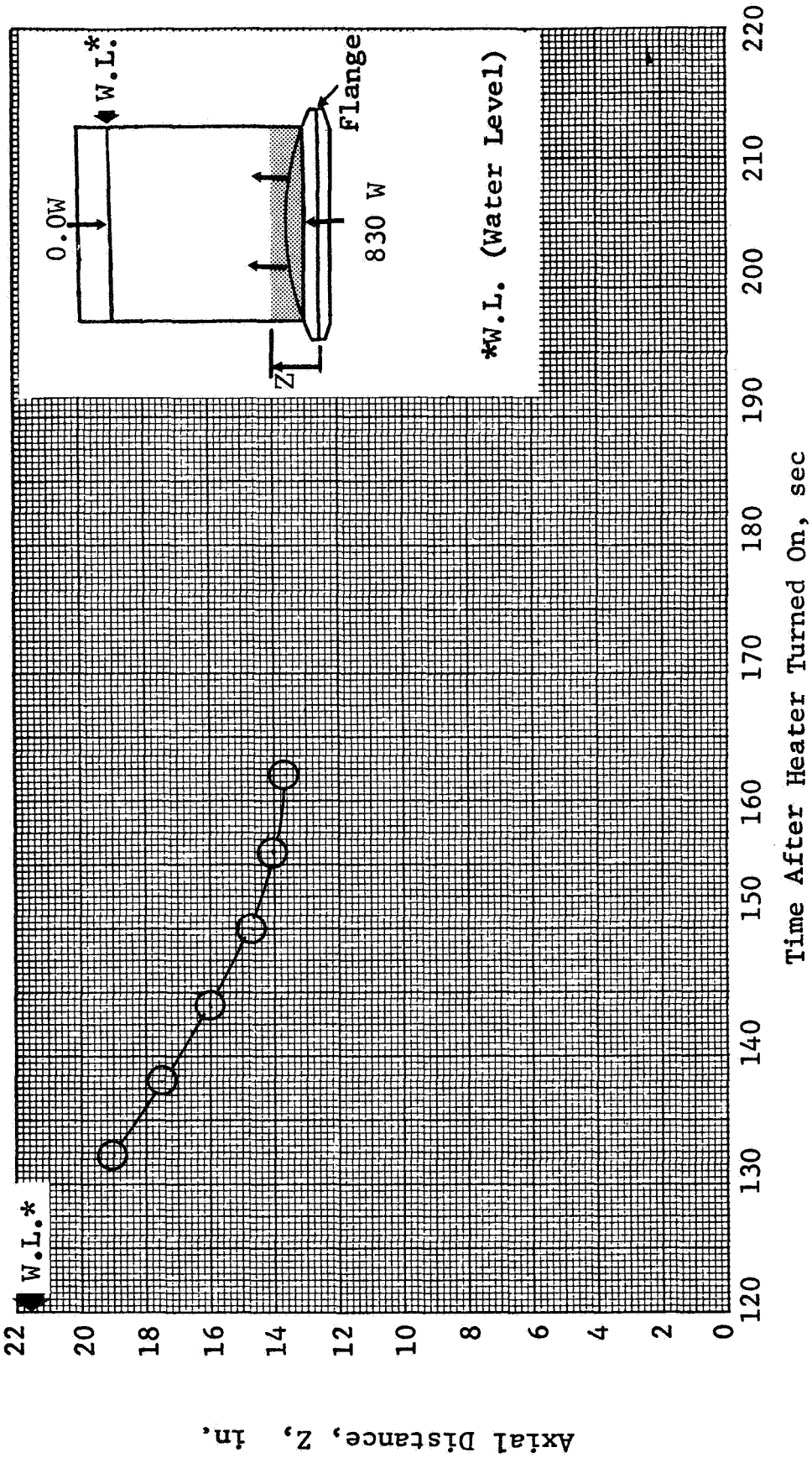


Figure 2.2-139 Axial Dye Layer Motion: Test 148, Run 23

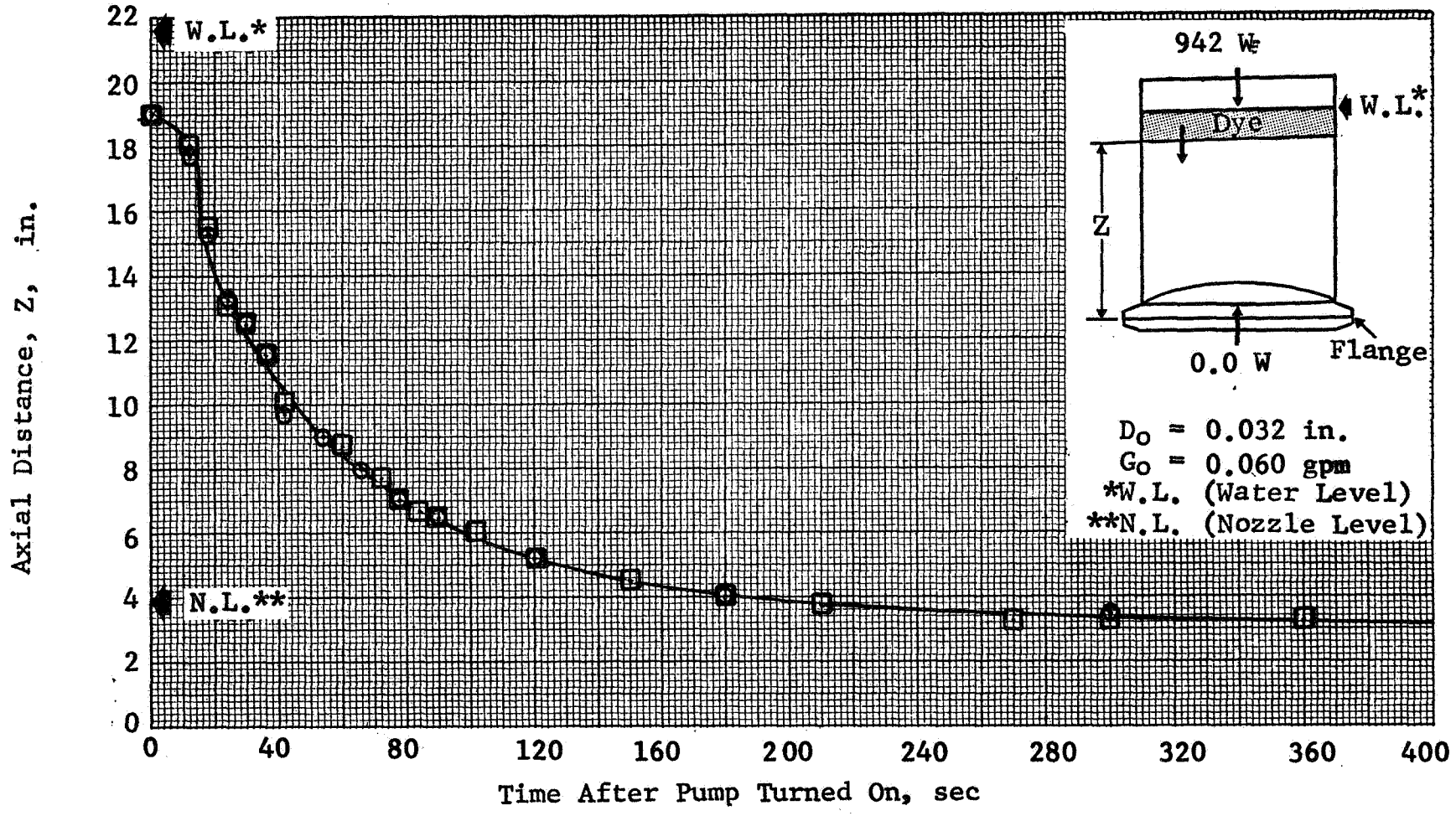
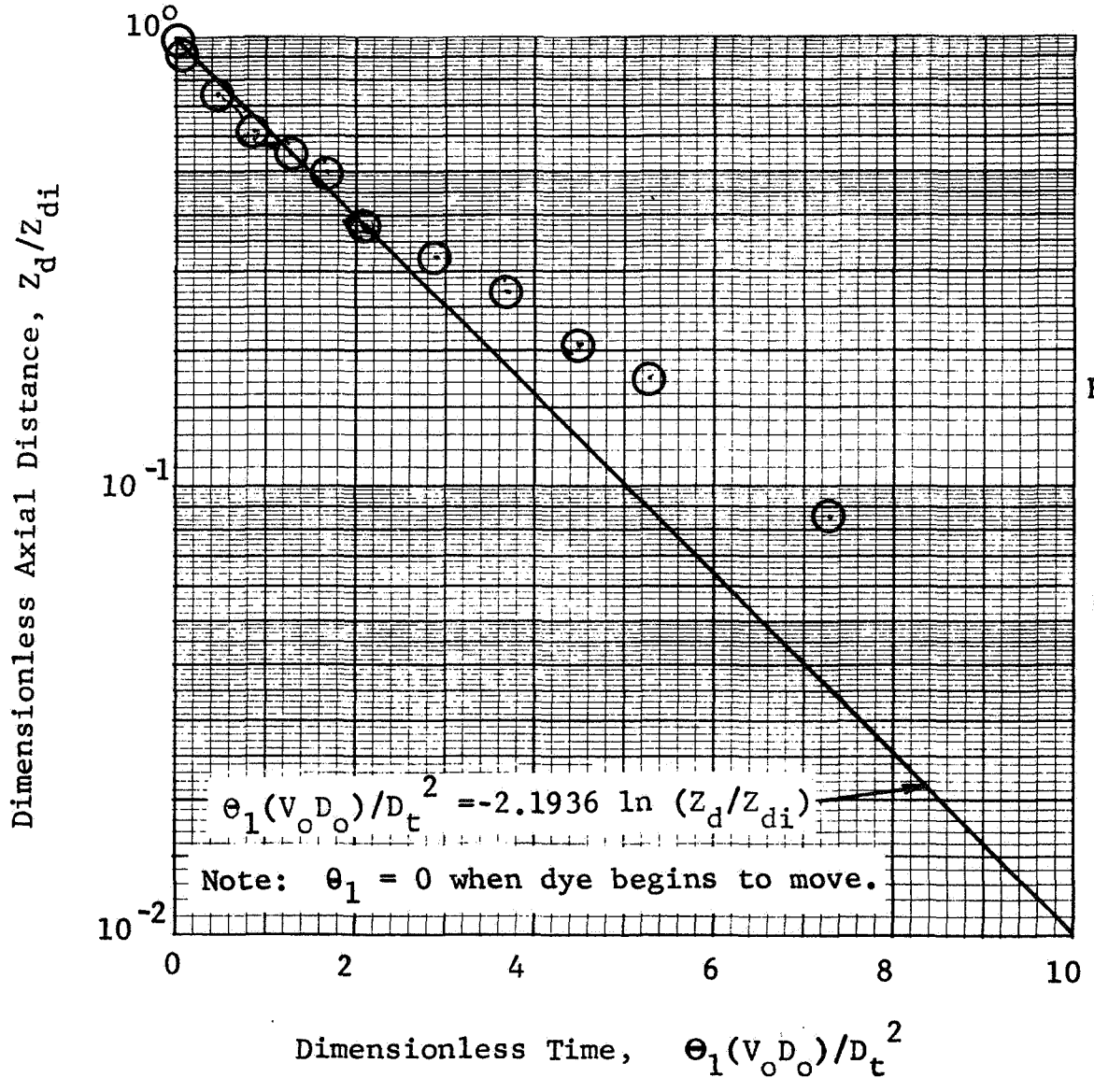
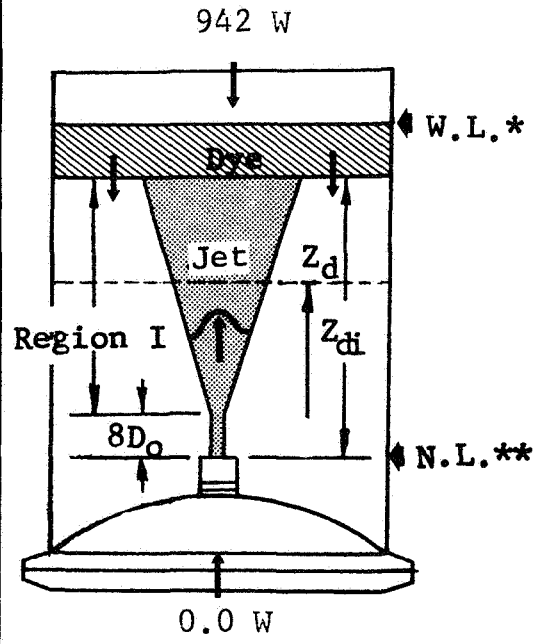


Figure 2.2-140 Axial Jet Dye Layer Motion: Test 151, Run 6

GENERAL DYNAMICS
Fort Worth Division





D_o = 0.032 in.

G_o = 0.060 gpm

*W.L. (Water Level) 21.6 in.

**N.L. (Nozzle Level) 3.9 in.

Figure 2.2-141 Correlation of Axial Jet Dye Layer Motion for Region I: Test 151, Run 6

GENERAL DYNAMICS
Fort Worth Division

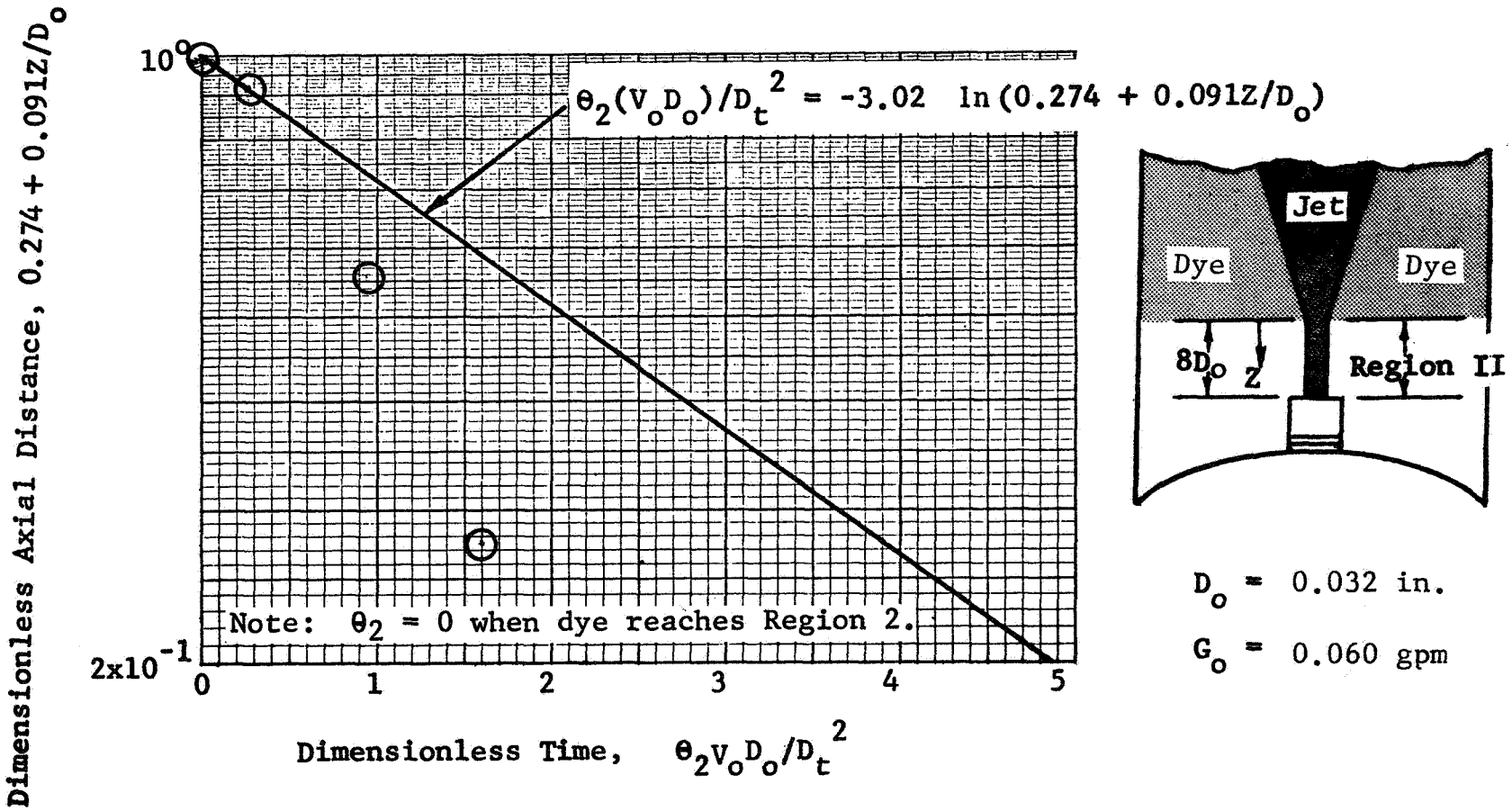
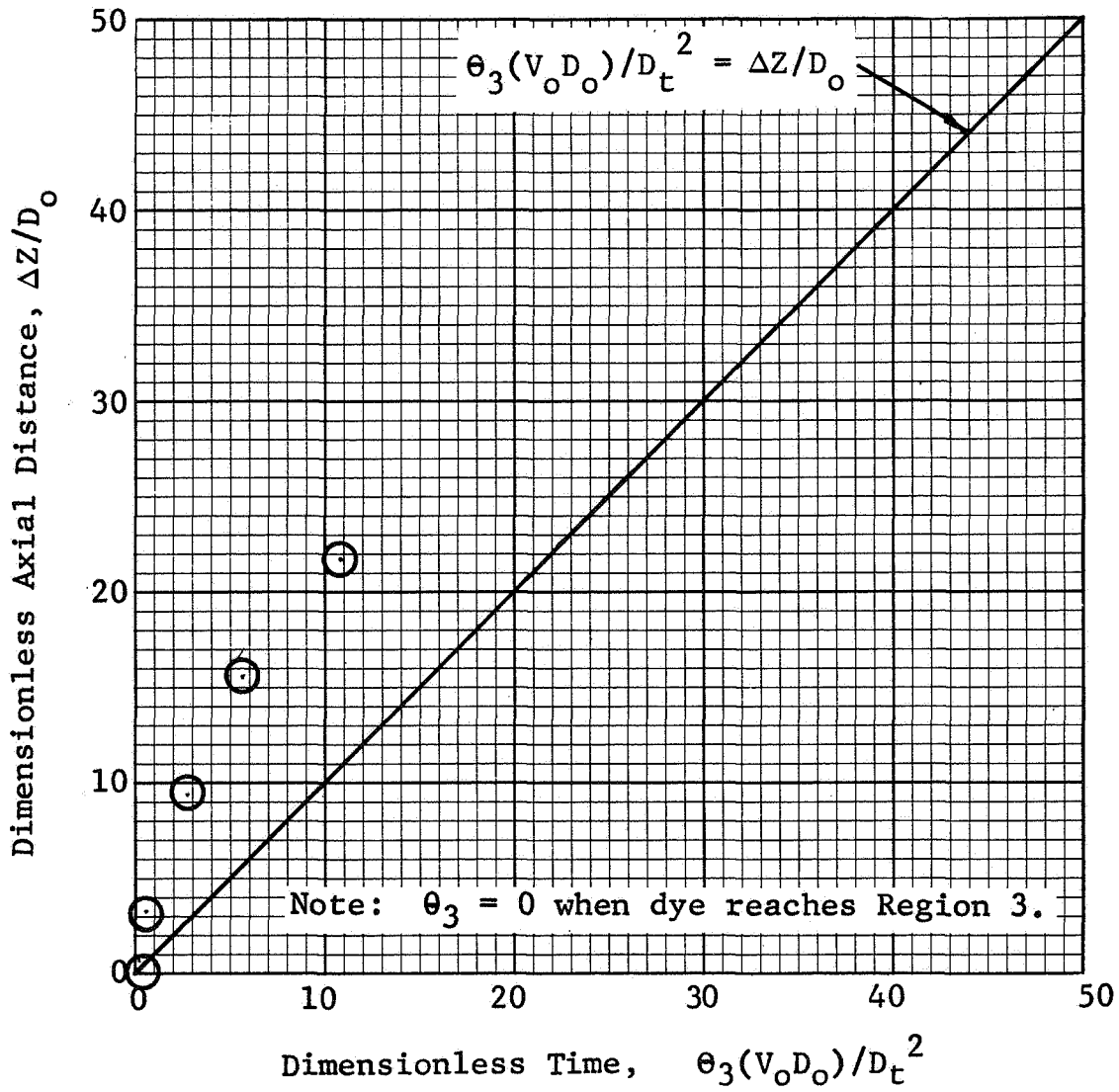
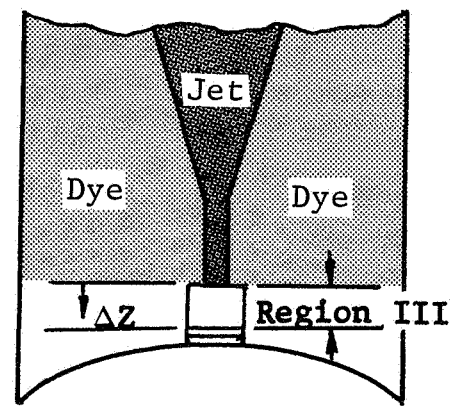


Figure 2.2-142 Correlation of Axial Jet Dye Layer Motion for Region II: Test 151, Run 6

GENERAL DYNAMICS
Fort Worth Division





D_o = 0.032 in.

G_o = 0.060 gpm

Figure 2.2-143 Correlation of Axial Jet Dye Layer Motion for Region III: Test 151, Run 6

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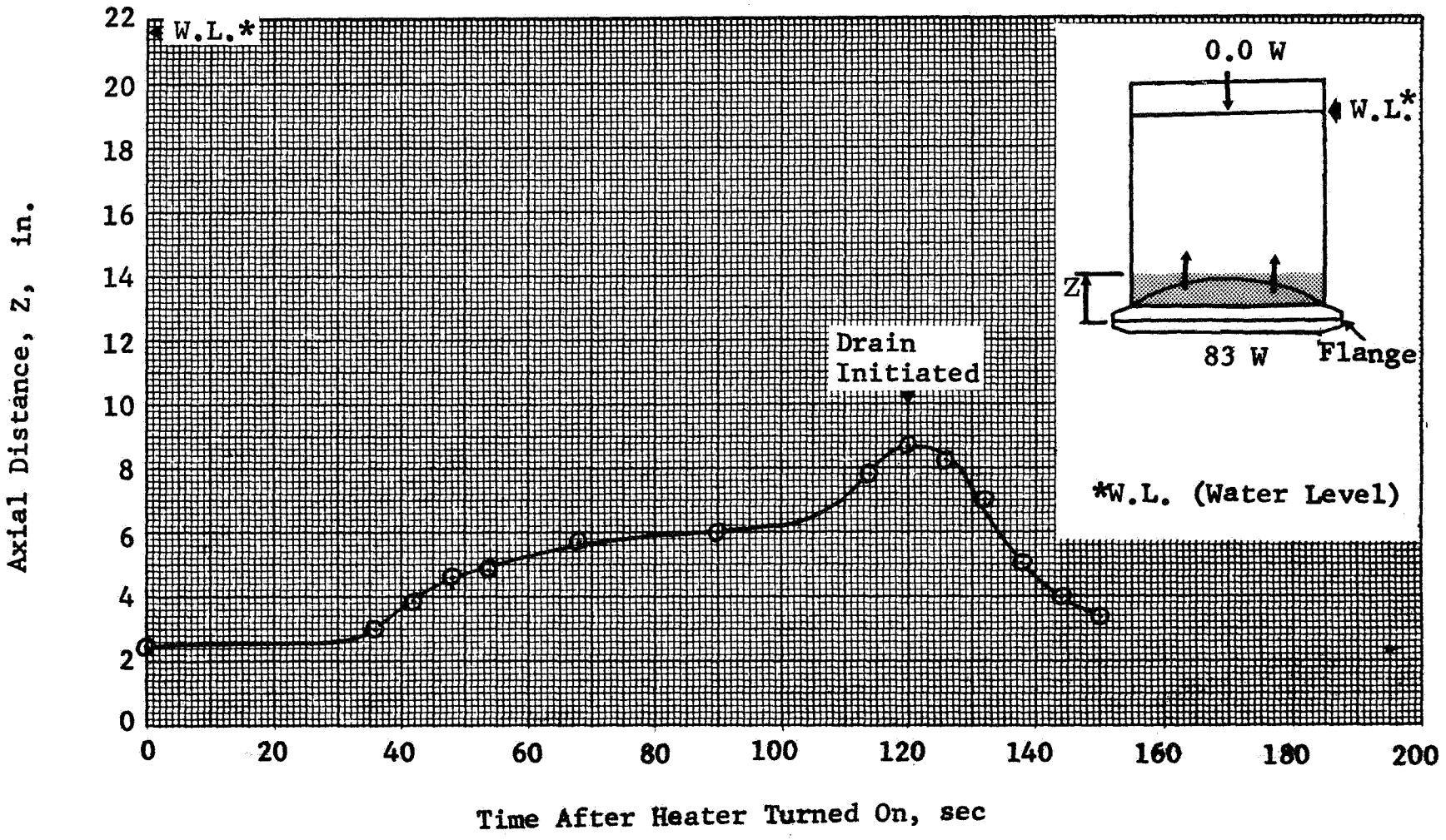

Figure 2.2-144 Axial Dye Layer Motion: Test 152, Run 15

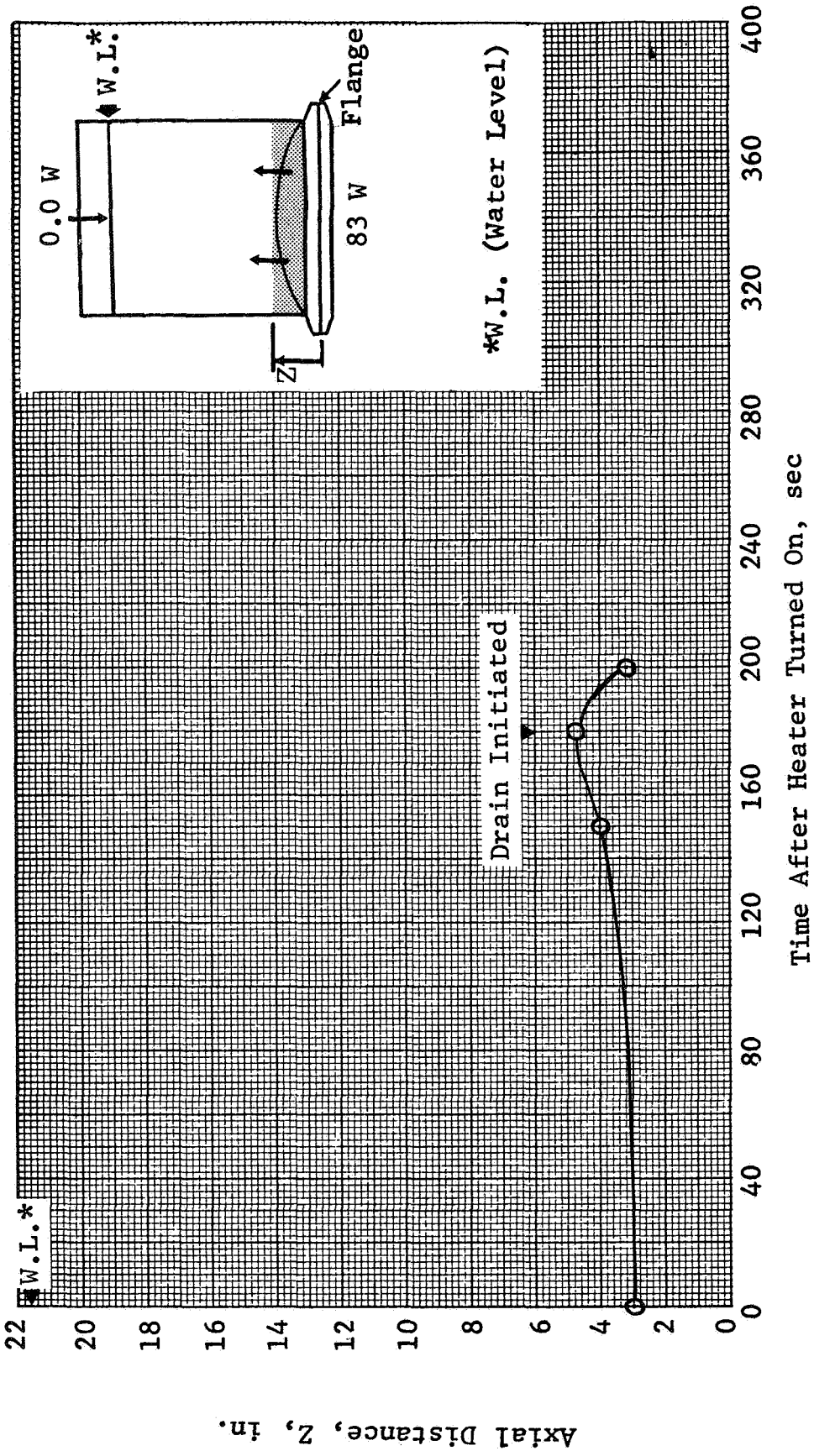

Figure 2.2-145 Axial Dye Layer Motion: Test 154, Run 16

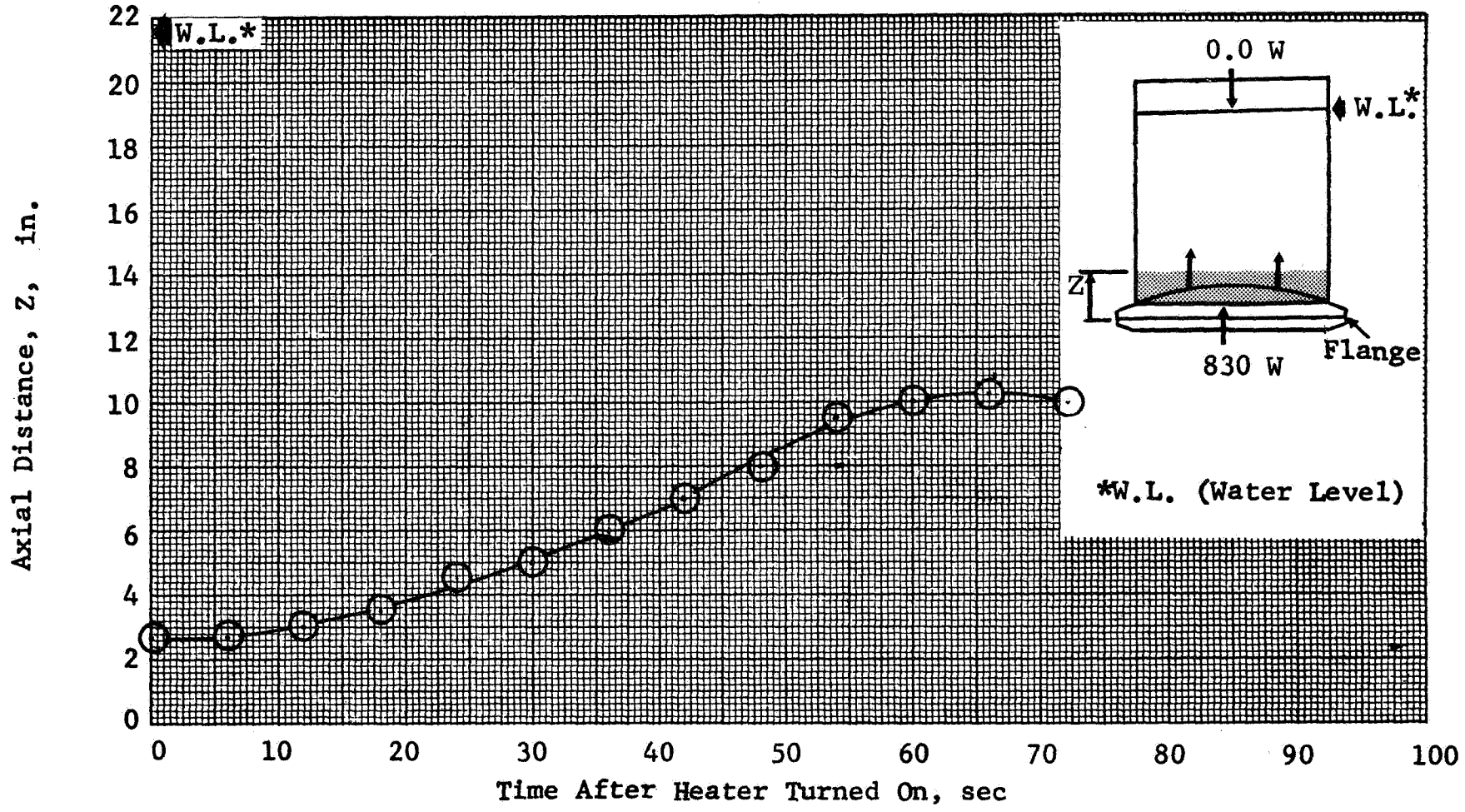

Figure 2.2-146 Axial Dye Layer Motion: Test 155, Run 19

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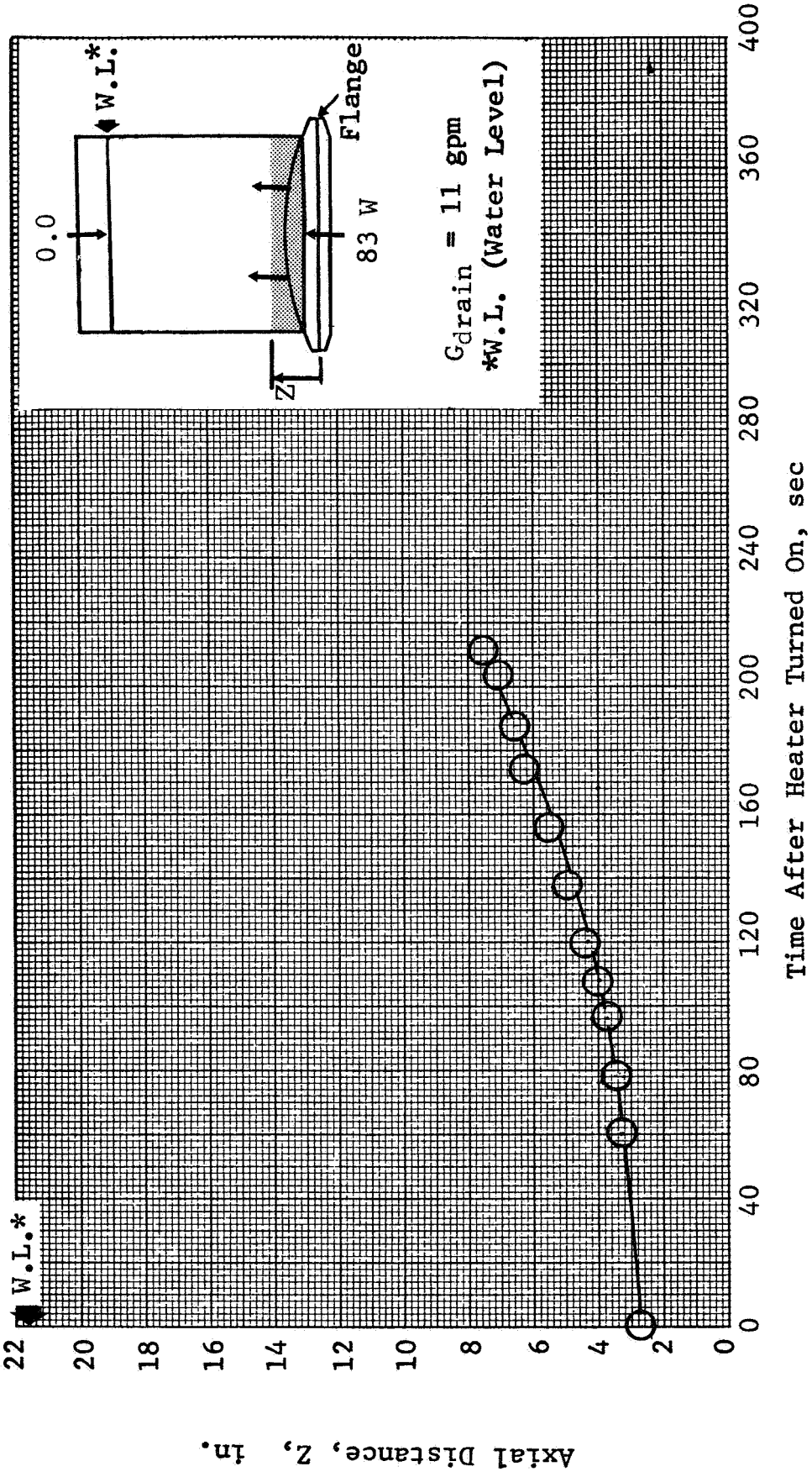

Figure 2.2-147 Axial Dye Layer Motion: Test 156, Run 20

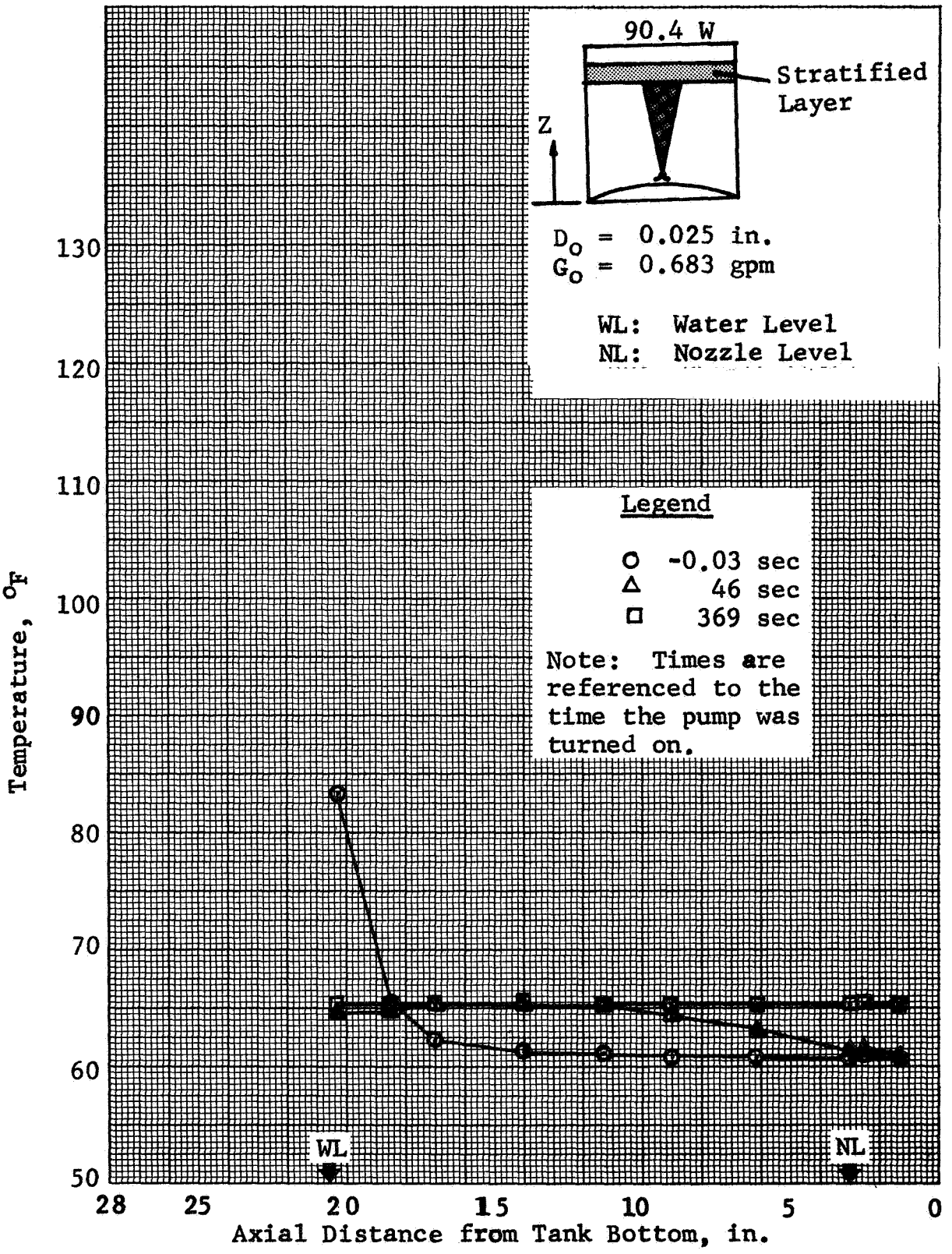

Figure 2.2-148 Temperature Distribution for Axial Jet Flow: Test 158, Run 42

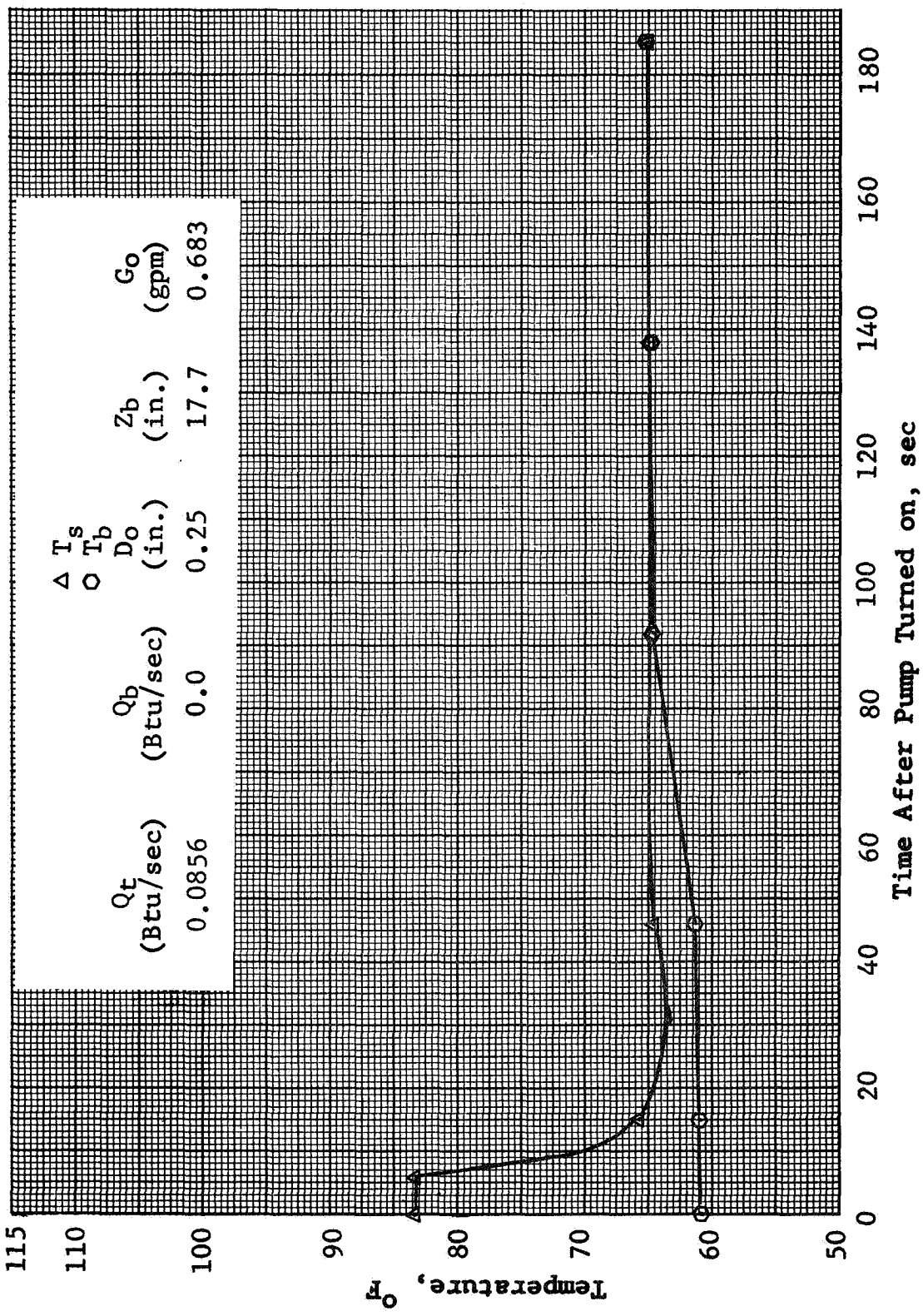

Figure 2.2-149 Transient Temperature Destratification: Test 158, Run 42

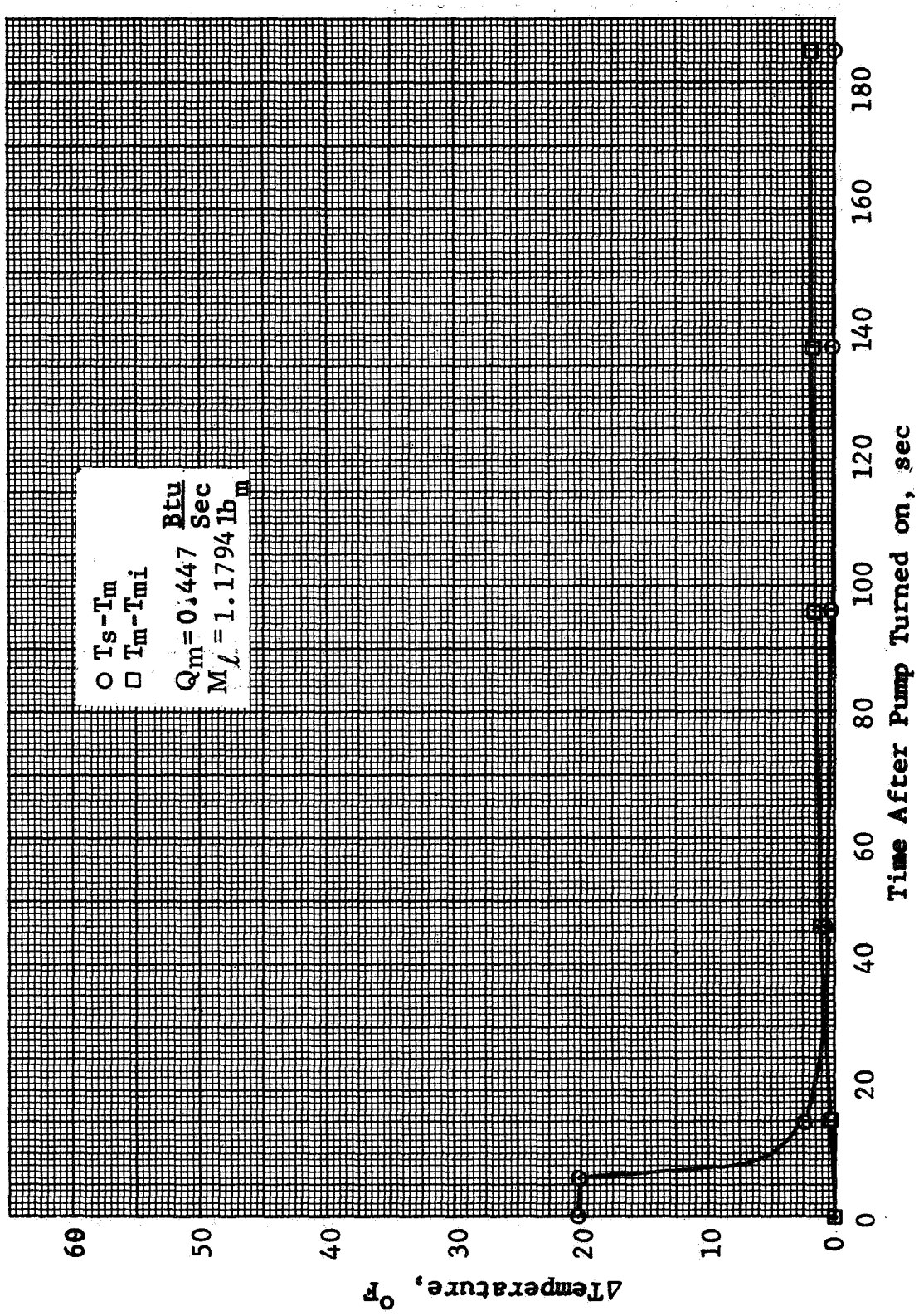

Figure 2.2-150 Transient ΔTemperature Destratification: Test 158, Run 42

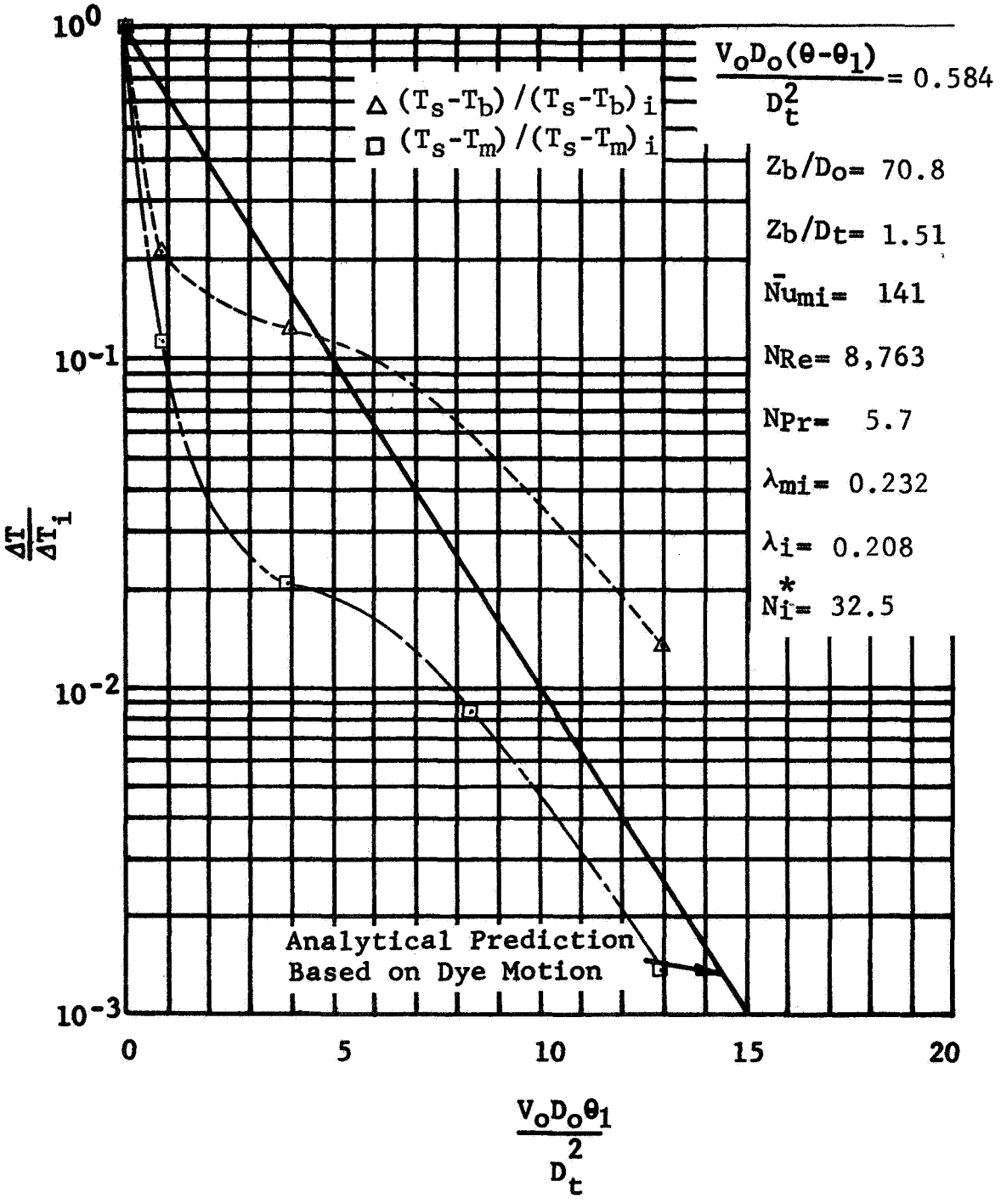

Figure 2.2-151 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 158, Run 42

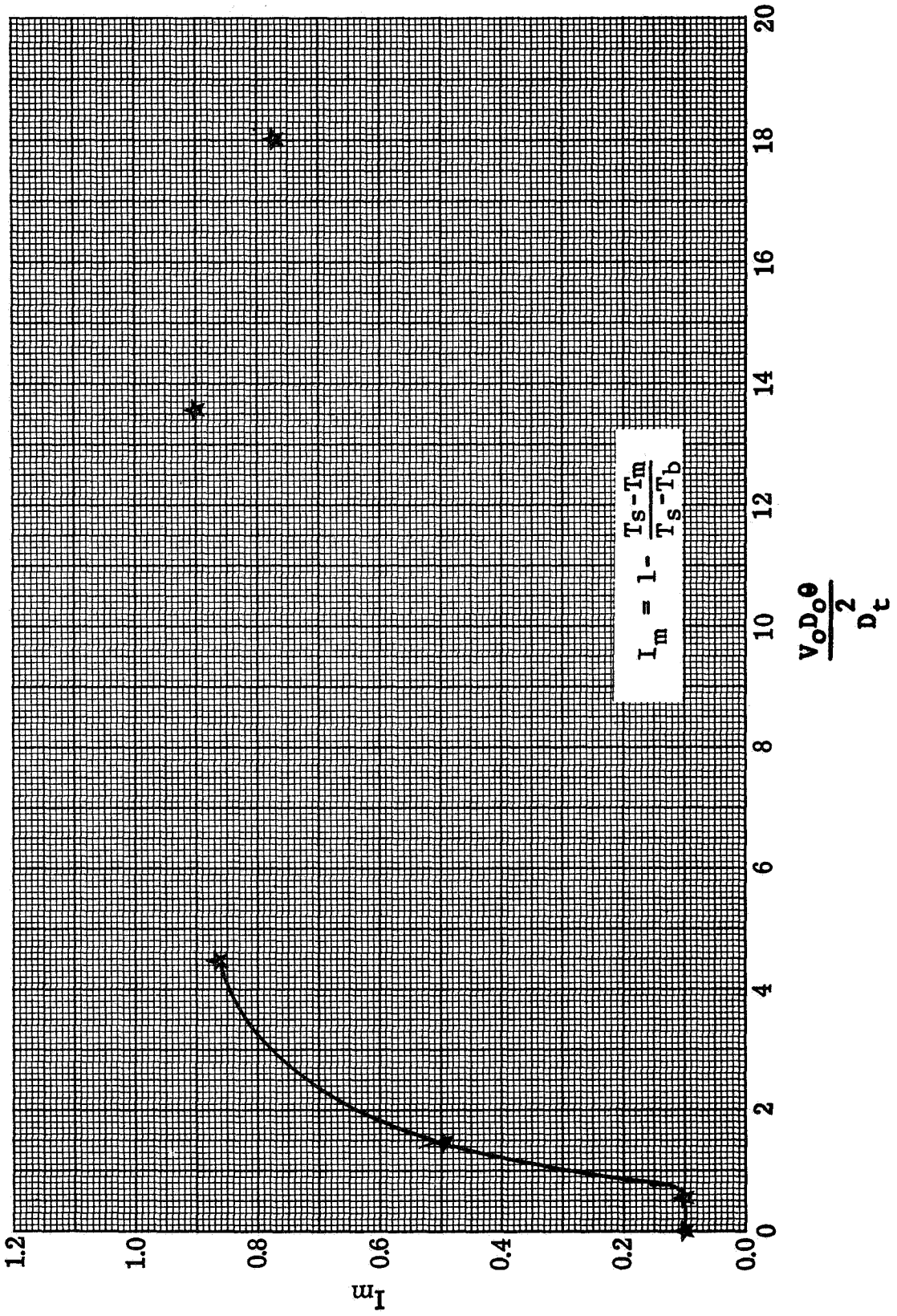

Figure 2.2-152 Transient Energy Integral: Test 158, Run 42

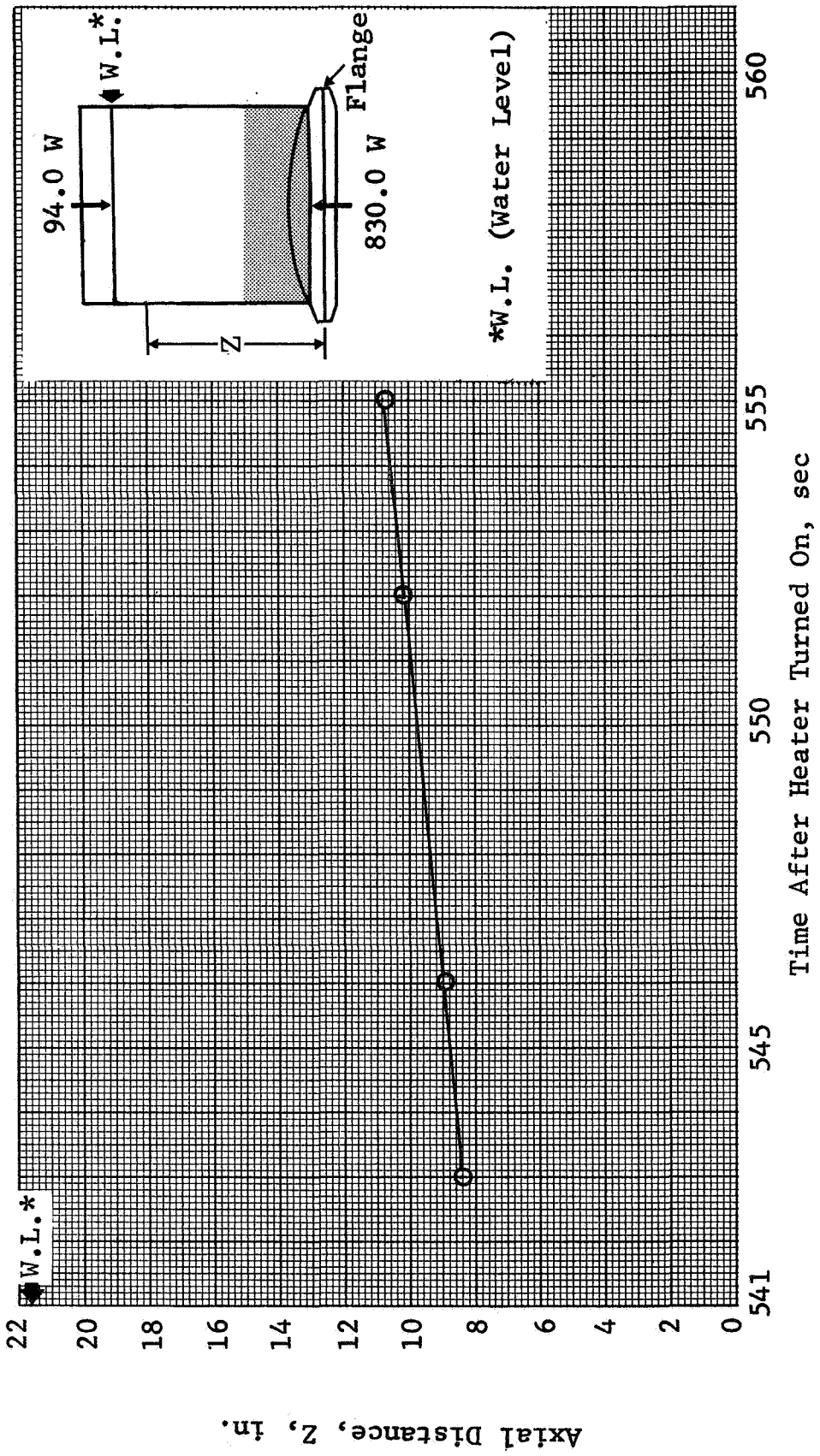

Figure 2.2-153 Axial Jet Dye Layer Motion: Test 161 , Run 28

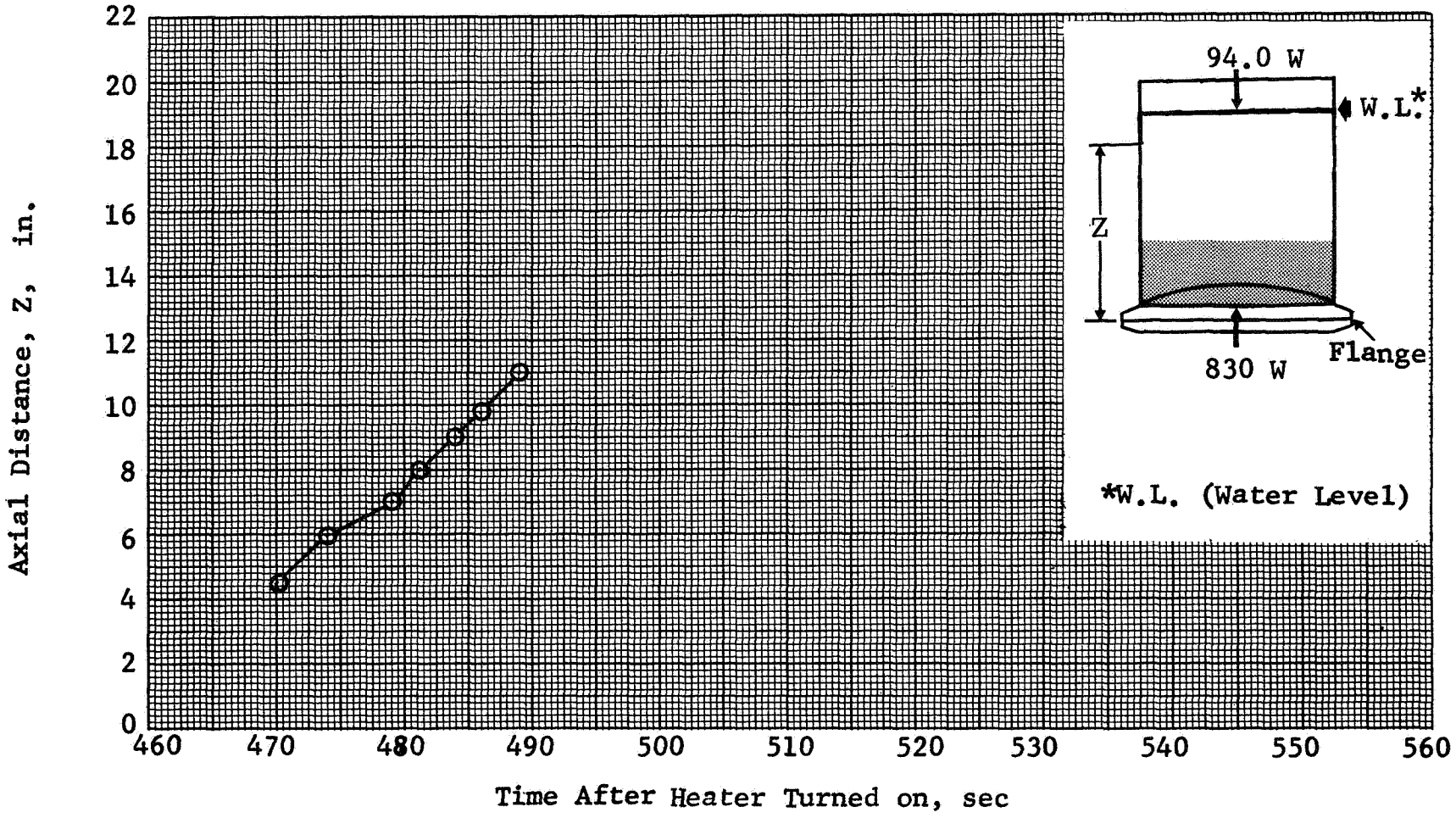

Figure 2.2-154 Axial Jet Dye Layer Motion: Test 161, Run 28

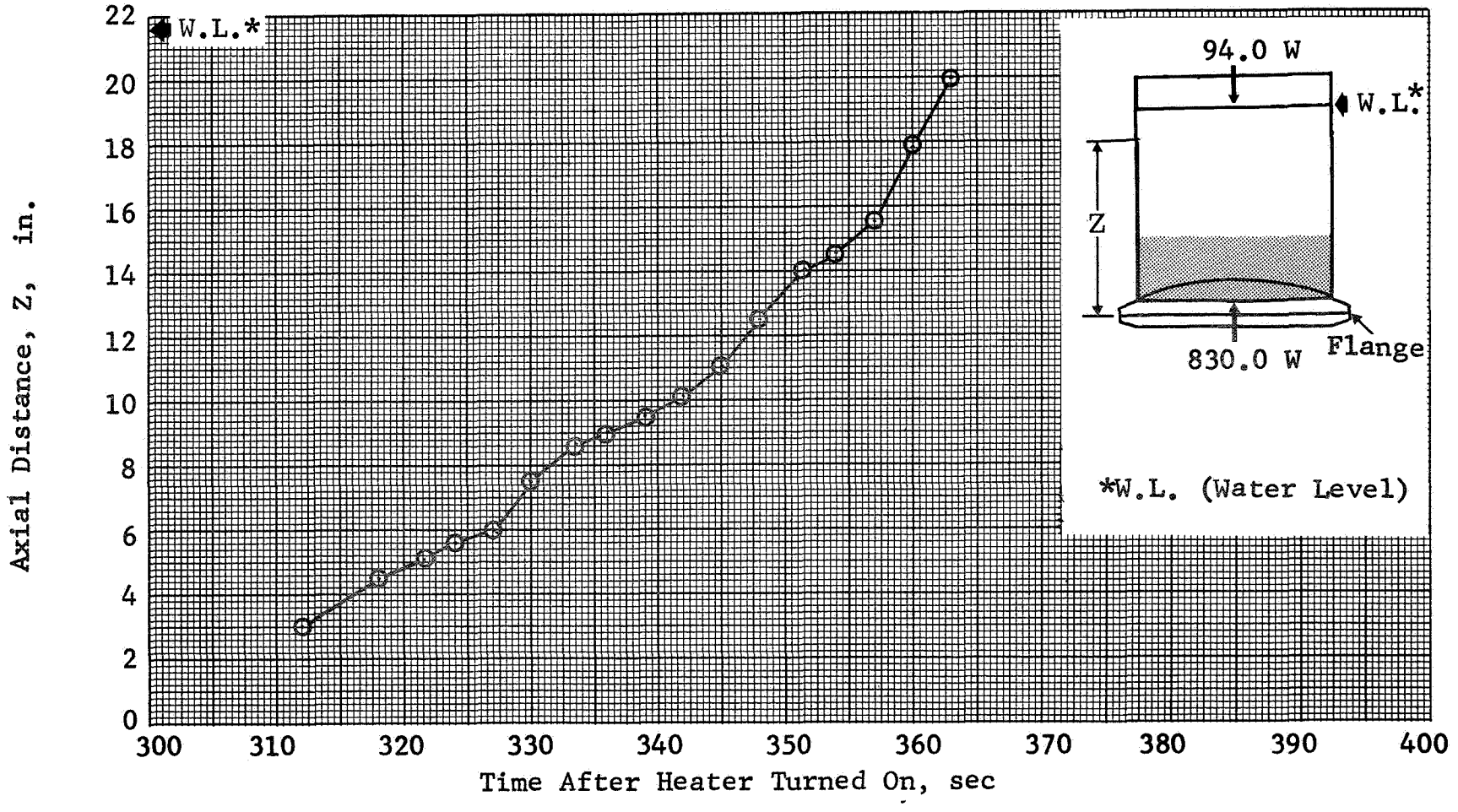

Figure 2.2-155 Axial Jet Dye Layer Motion: Test 161 , Run 29

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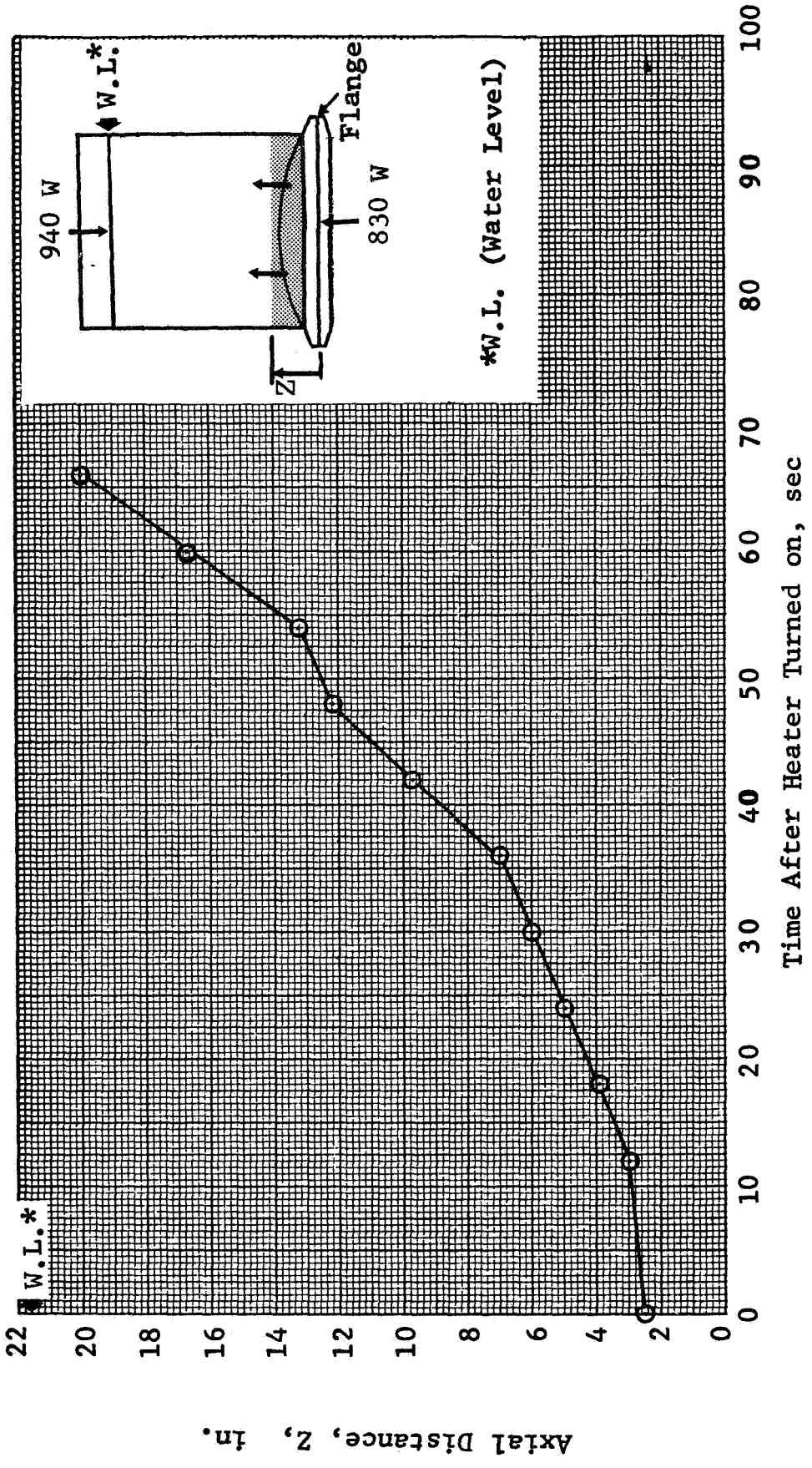

Figure 2.2-156 Axial Dye Layer Motion: Test 162, Run 9

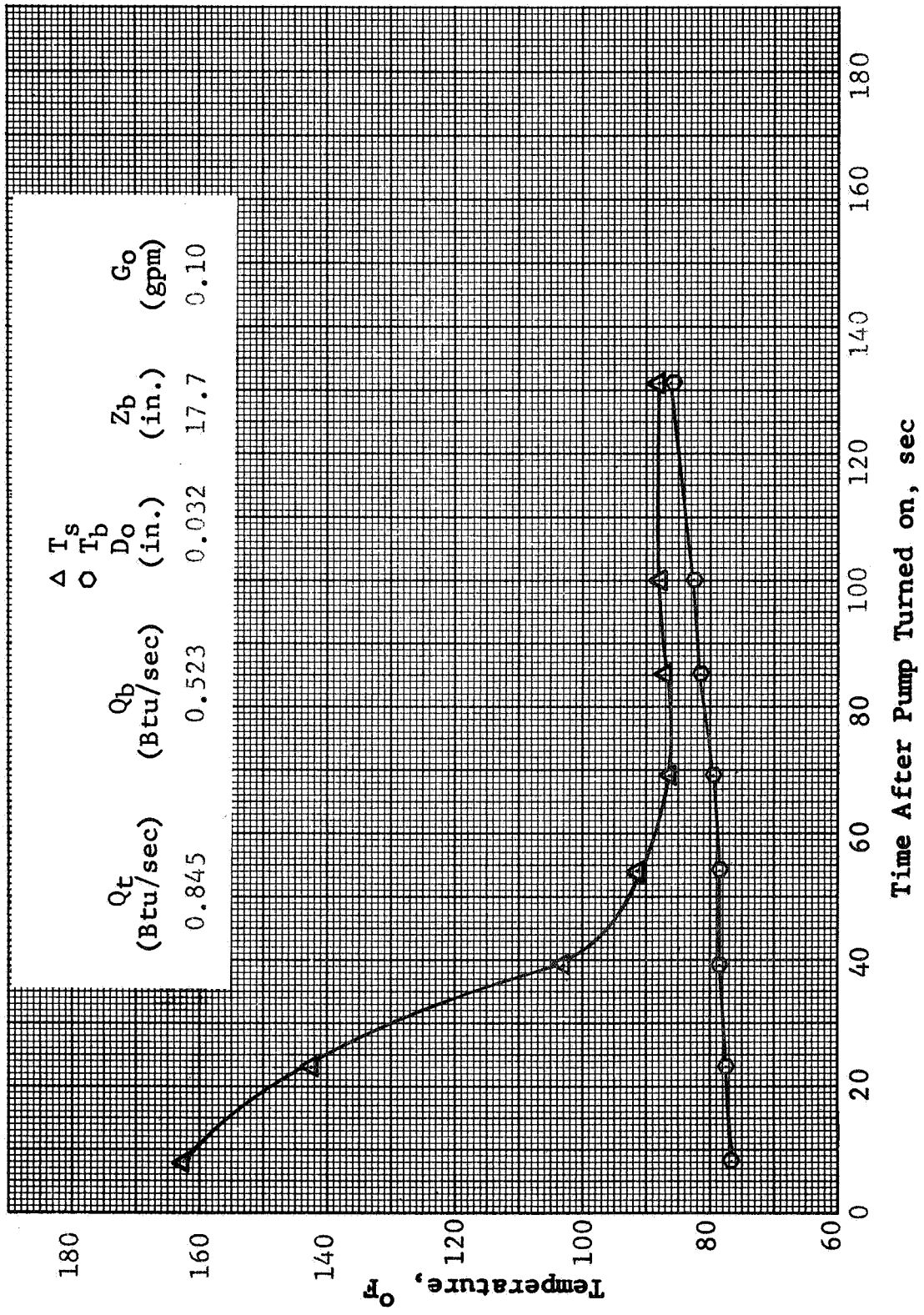

Figure 2.2-157 **Transient Temperature Destratification:** Test 162, Run 9

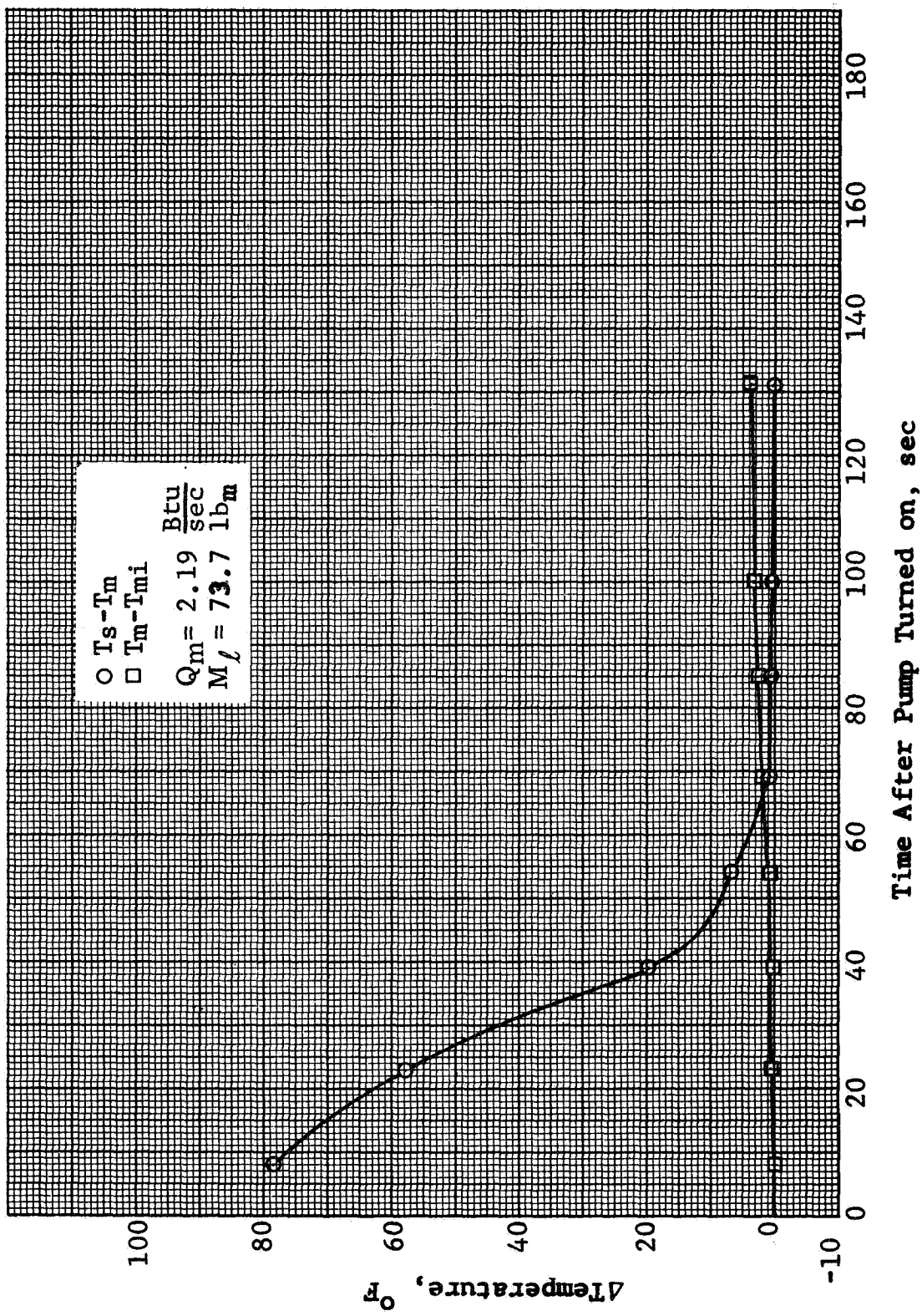

Figure 2.2-158 Transient ΔTemperature Destratification: Test 162, Run 9

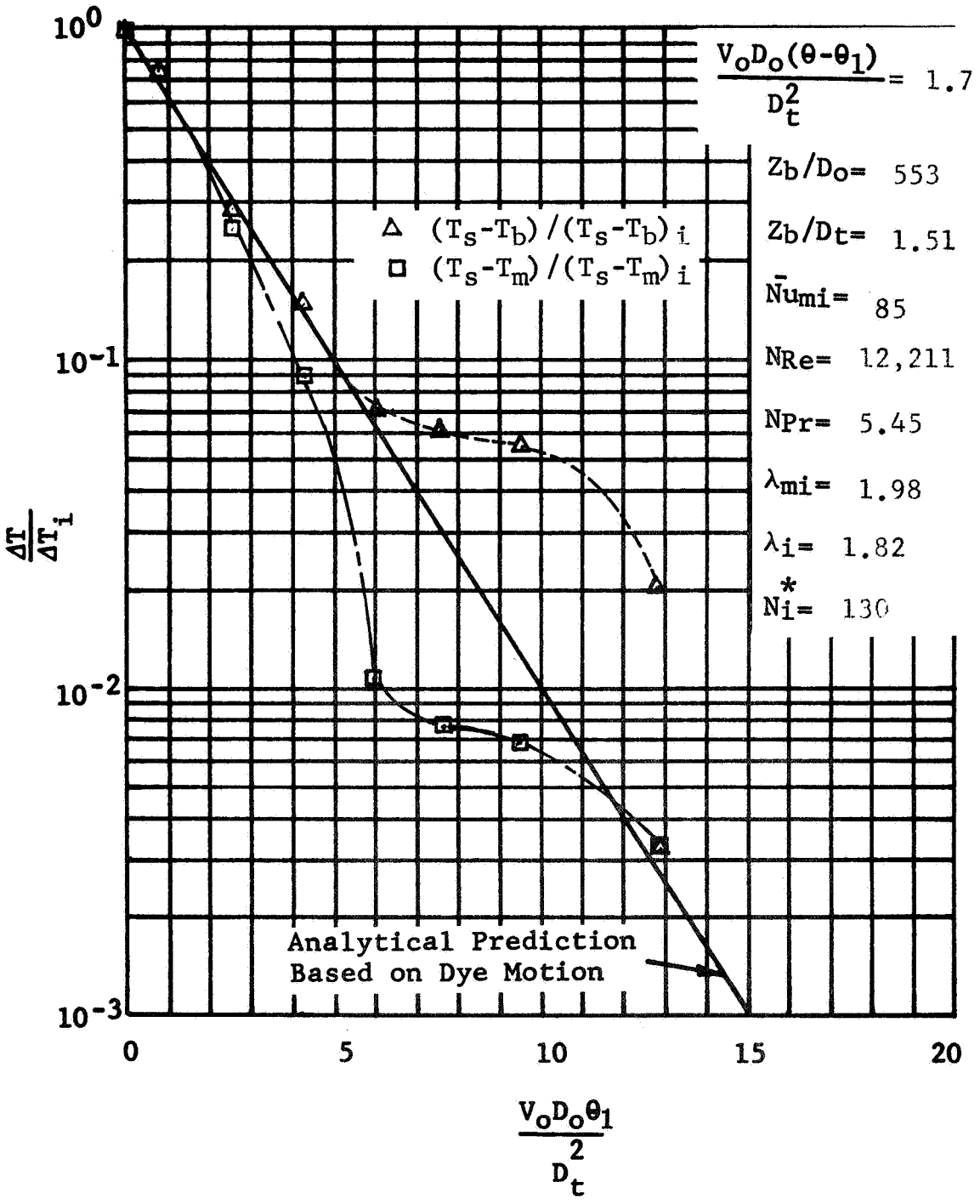

Figure 2.2-159 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 162, Run 9

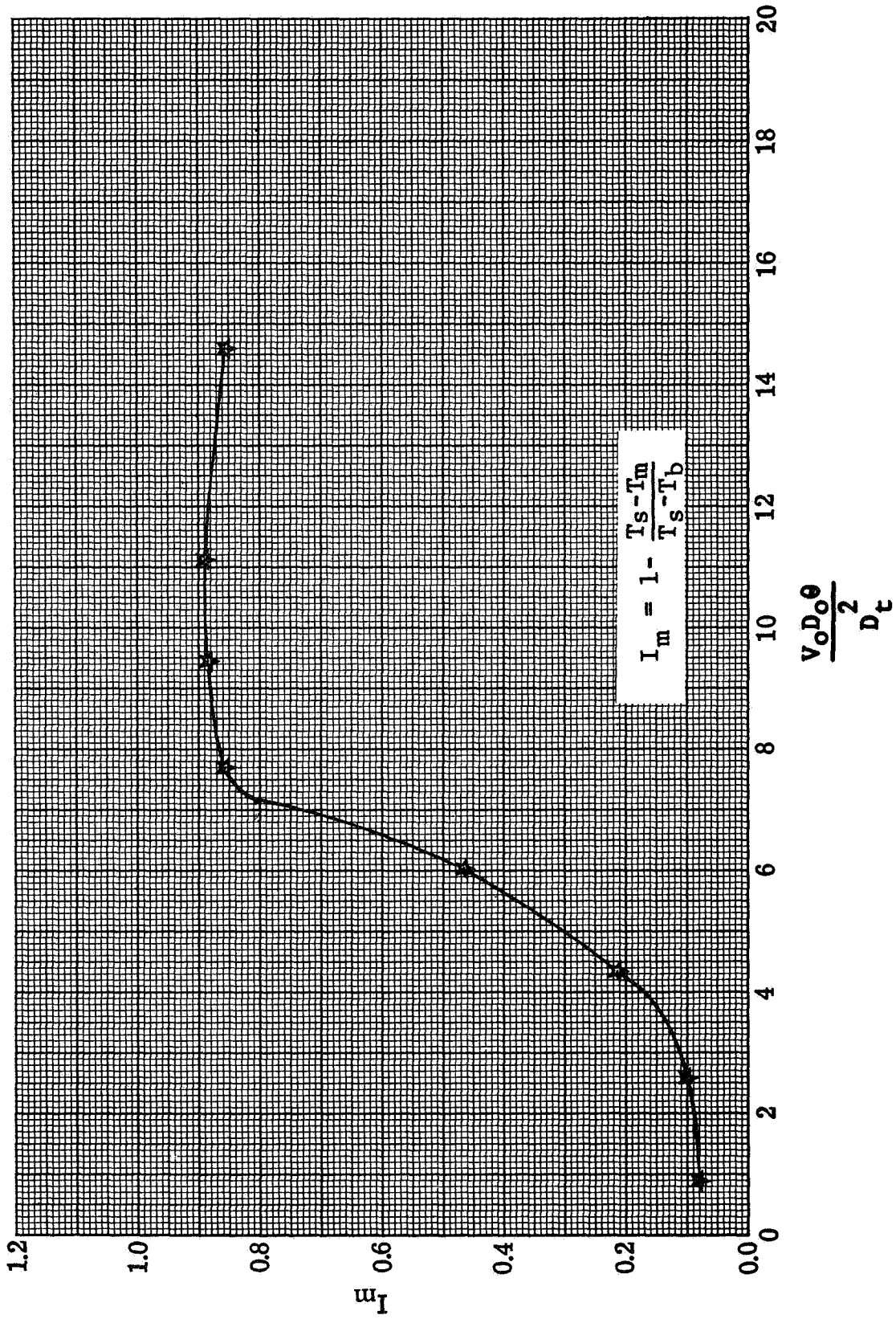

Figure 2.2-160 Transient Energy Integral: Test 162, Run 9

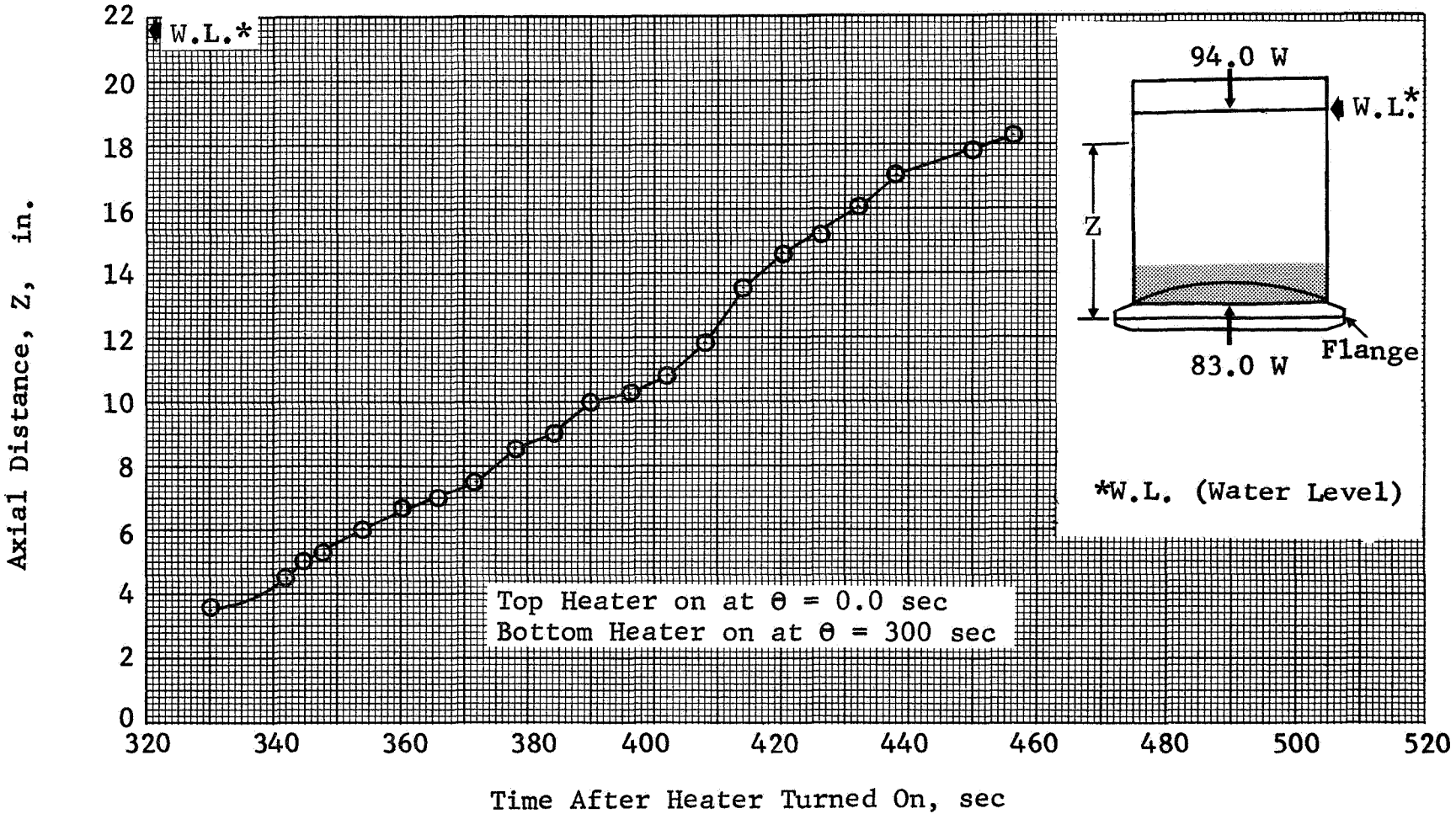

Figure 2.2-161 Axial Jet Dye Layer Motion: Test 163, Run 30

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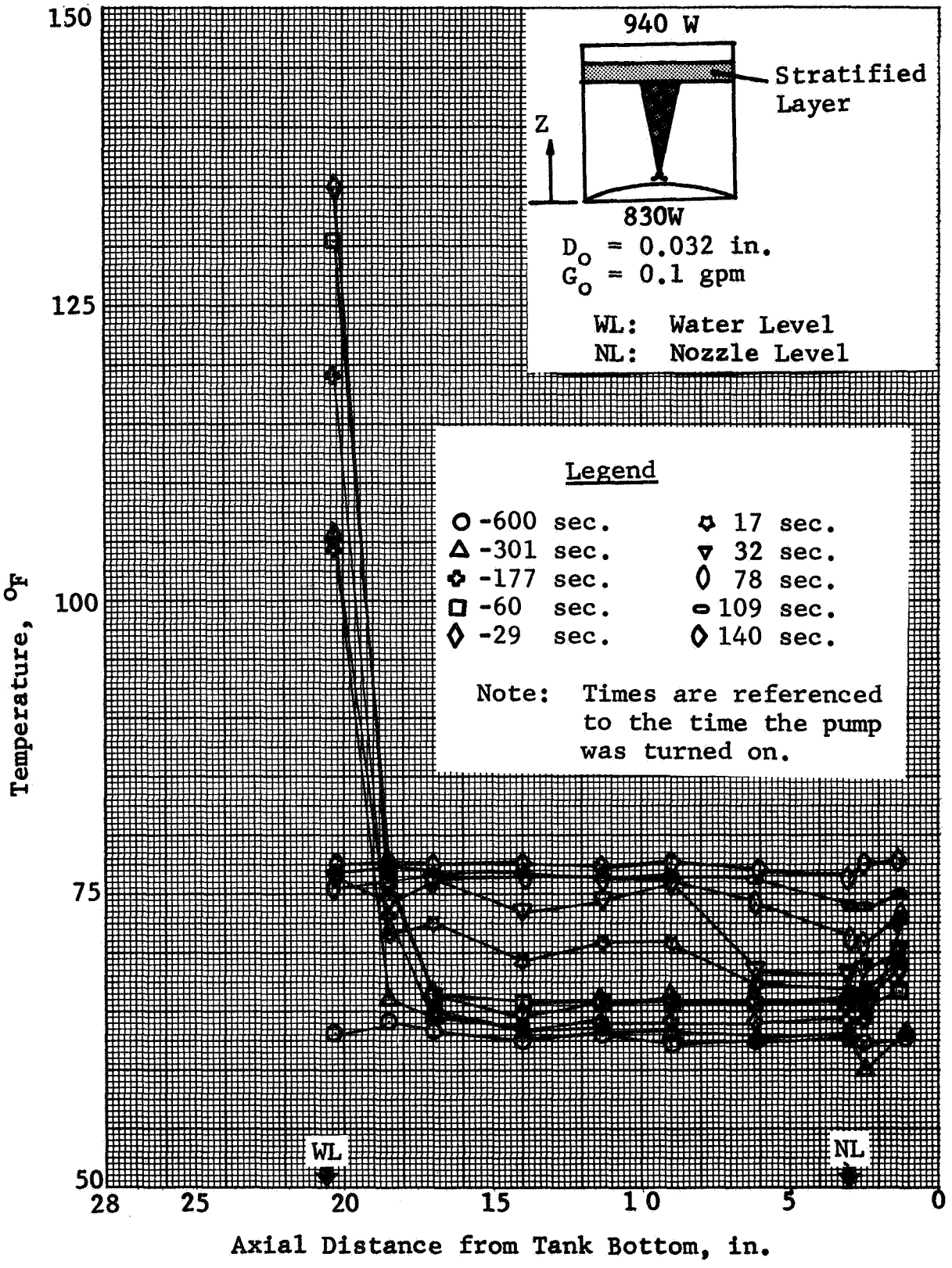

Figure 2.2-162 Temperature Distribution for Axial Jet Flow: Test 165, Run 32

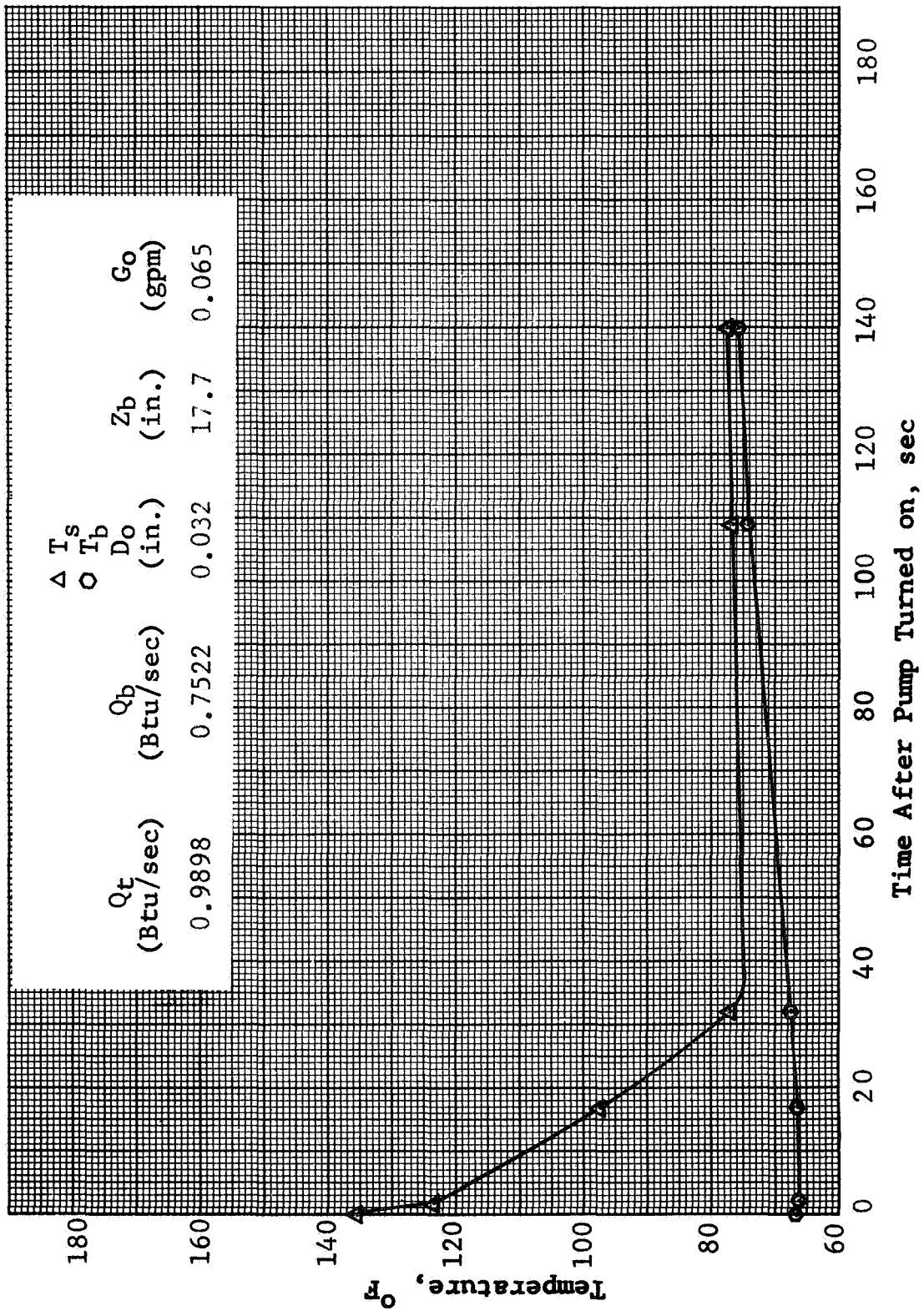

Figure 2.2-163 Transient Temperature Destratification: Test 165, Run 32

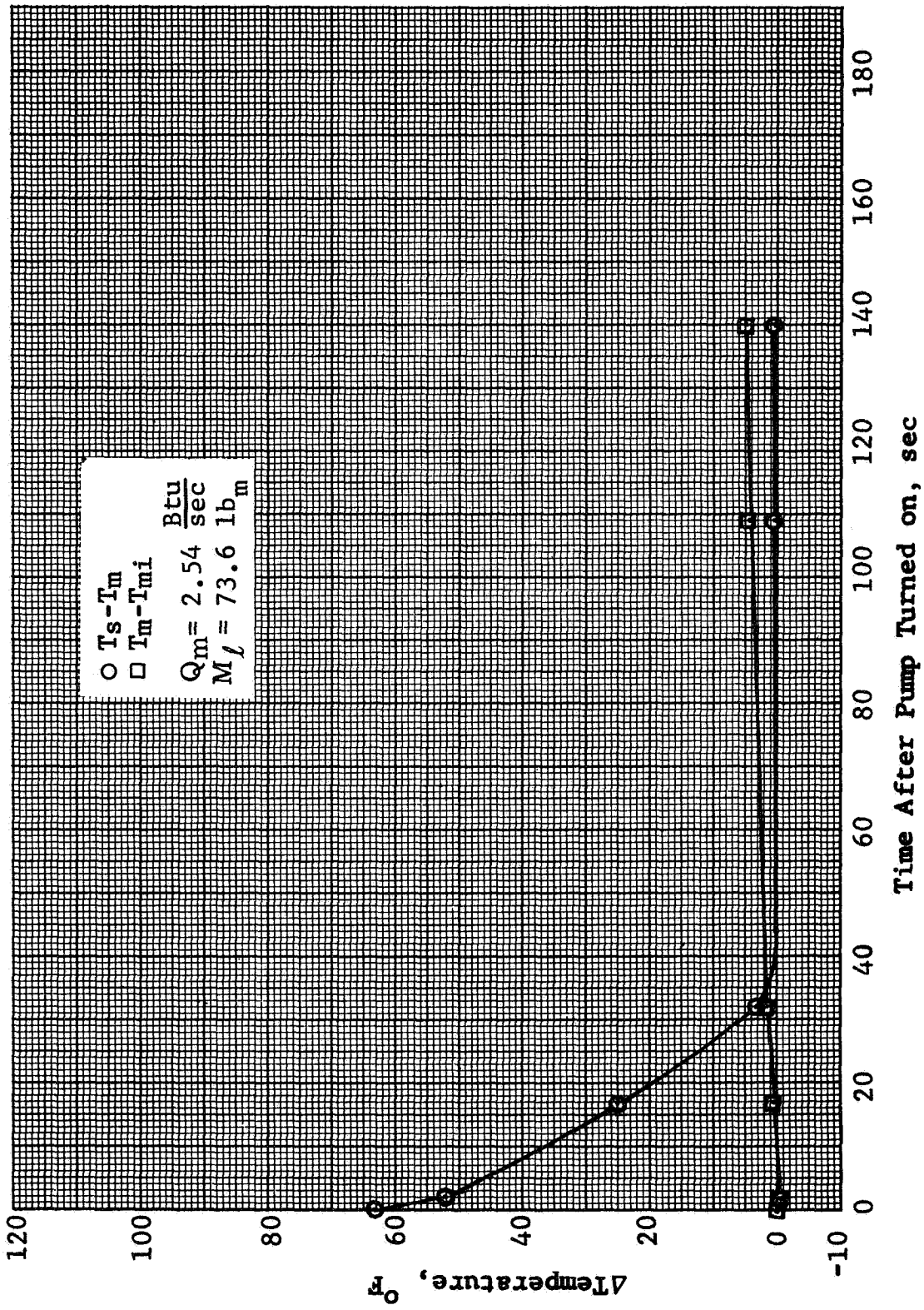

Figure 2.2-164 Transient ΔTemperature Destratification: Test 165, Run 32

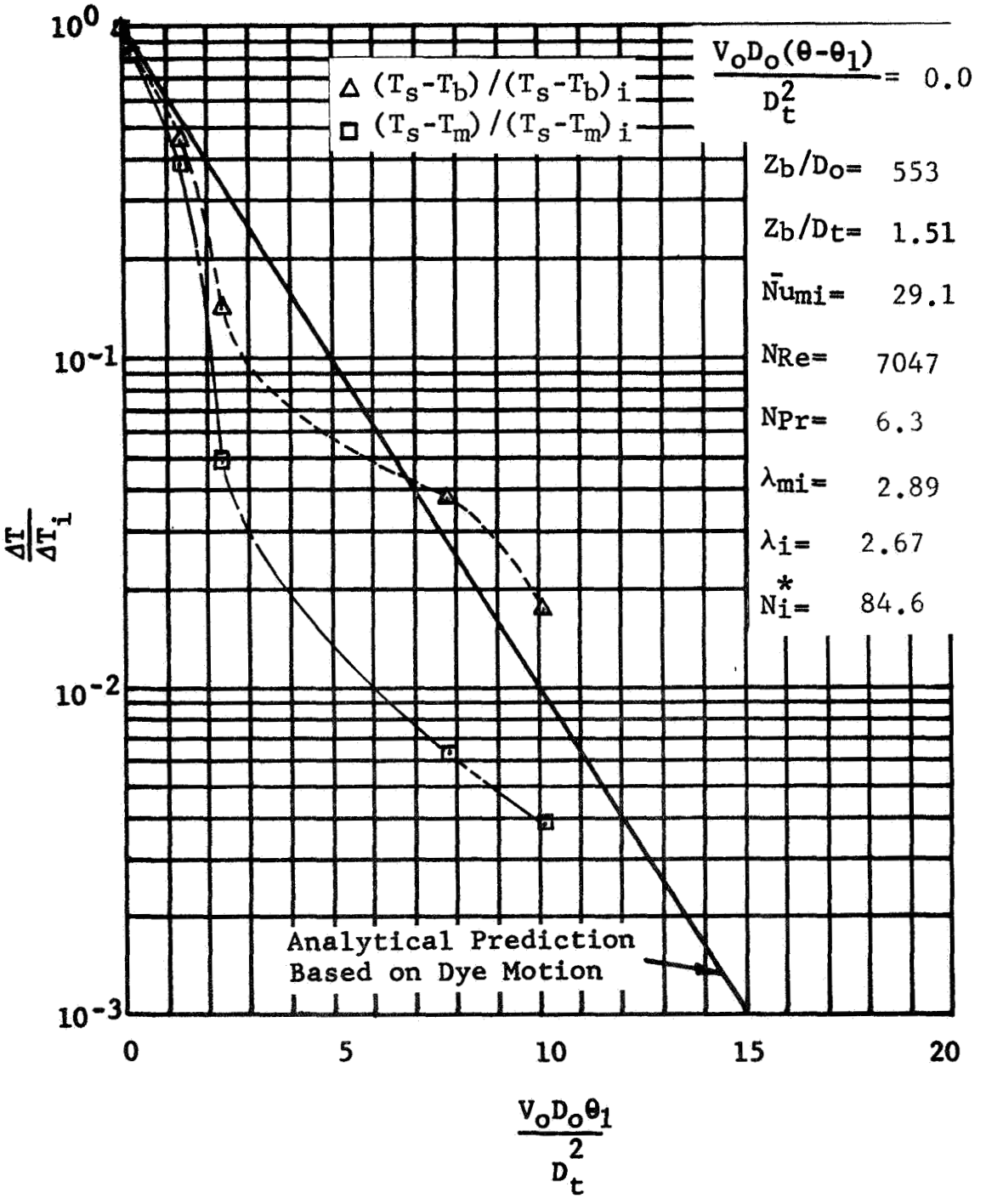

Figure 2.2-165 Fraction of Initial Temperature Difference After Surface Temperature Starts to Drop (Pump on at θ=0.0 sec; Surface Temp. Drops at θ_1=0.0 sec): Test 165, Run 32

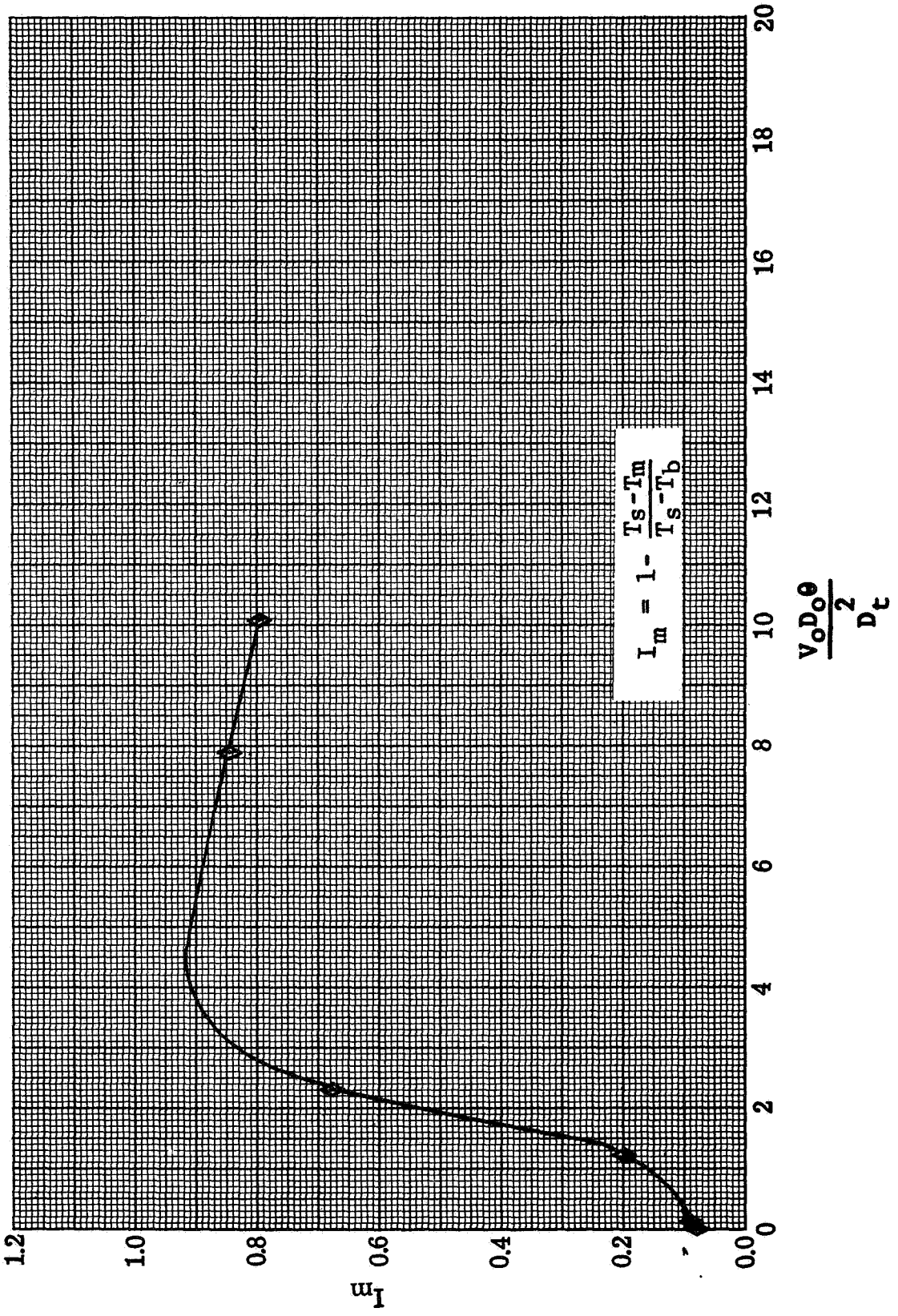

Figure 2.2-166 Transient Energy Integral: Test 165, Run 32

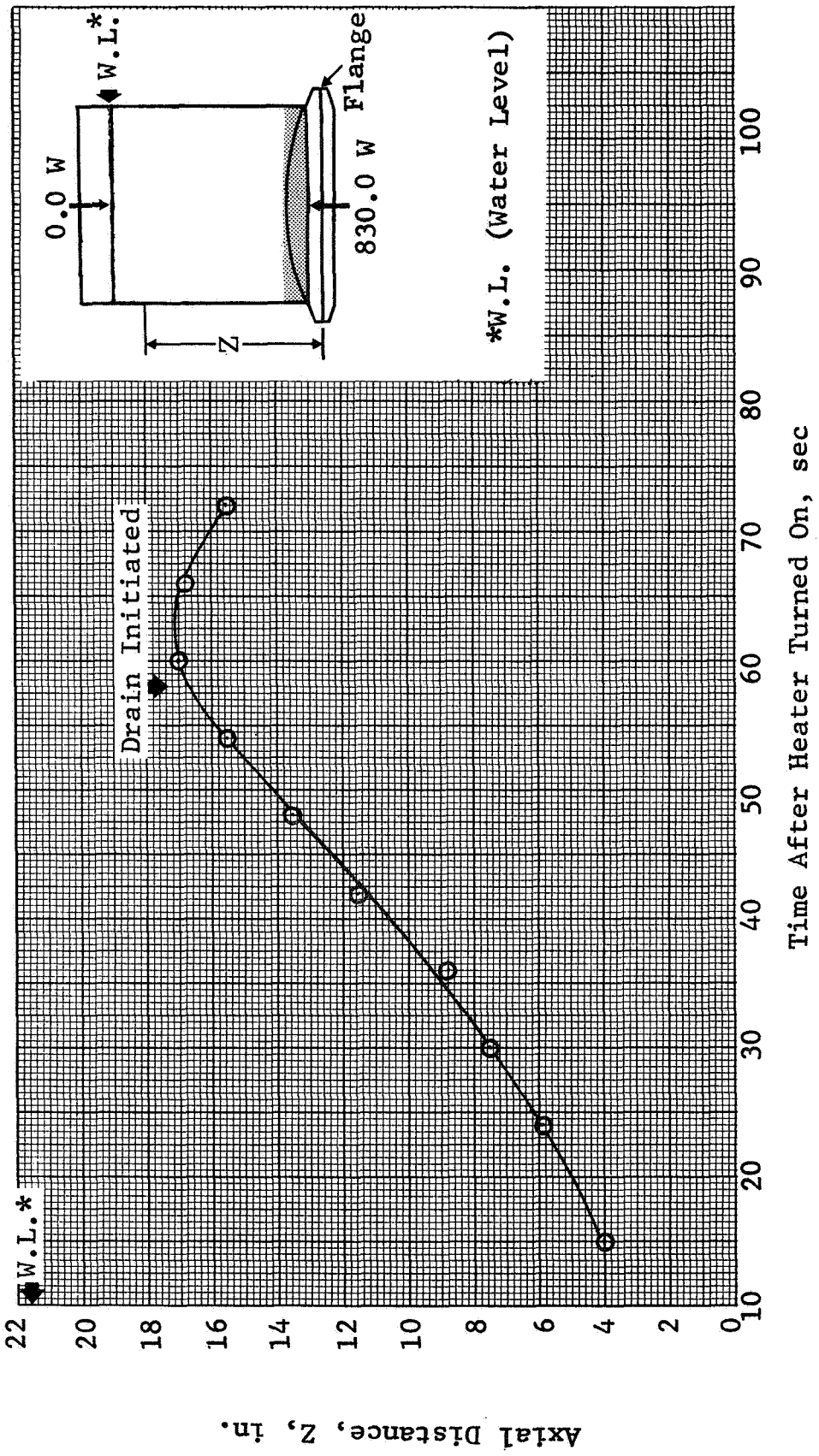

Figure 2.2-167 Axial Jet Dye Layer Motion: Test 166, Run 33

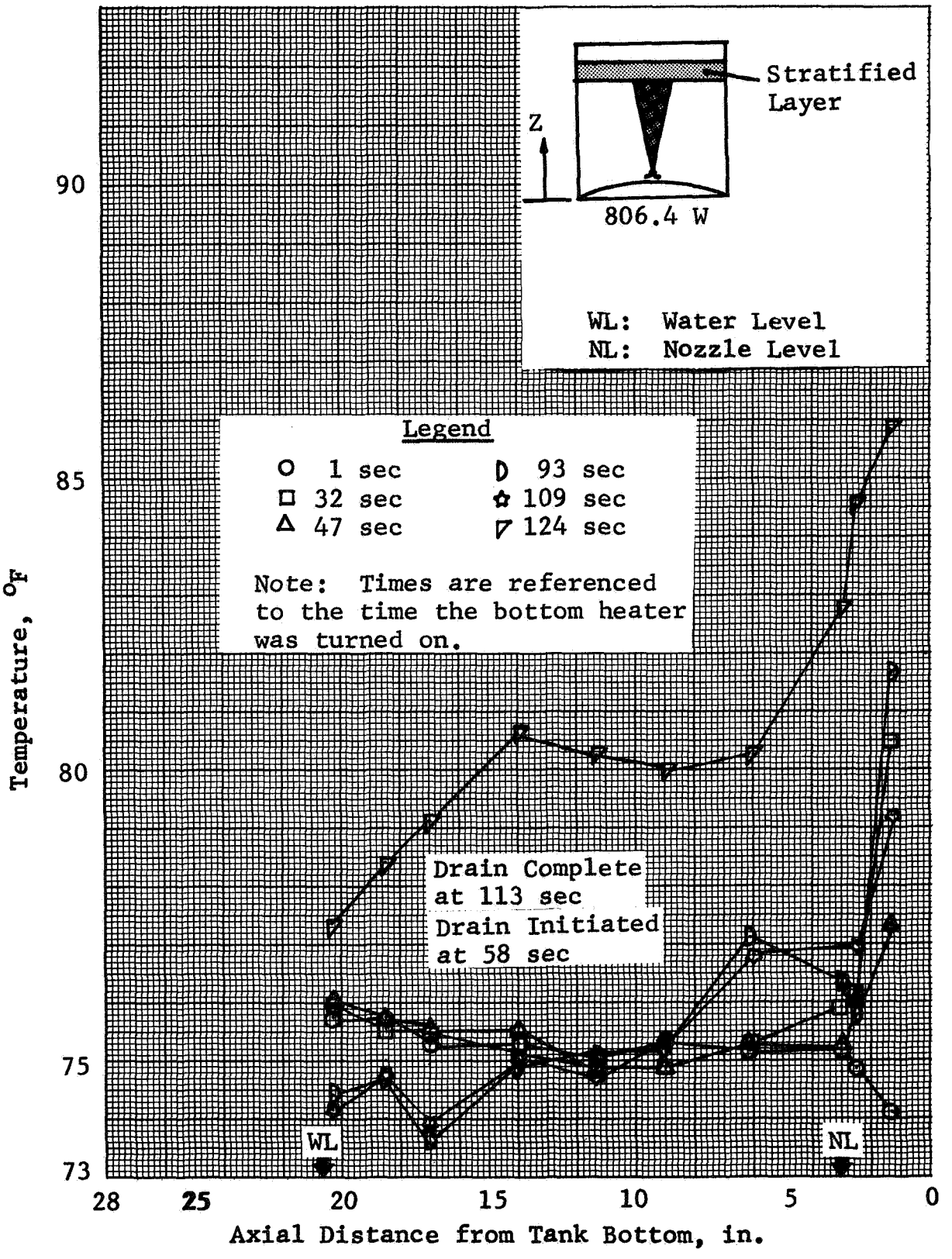

Figure 2.2-168 Temperature Distribution for Axial Jet Flow: Test 166, Run 33

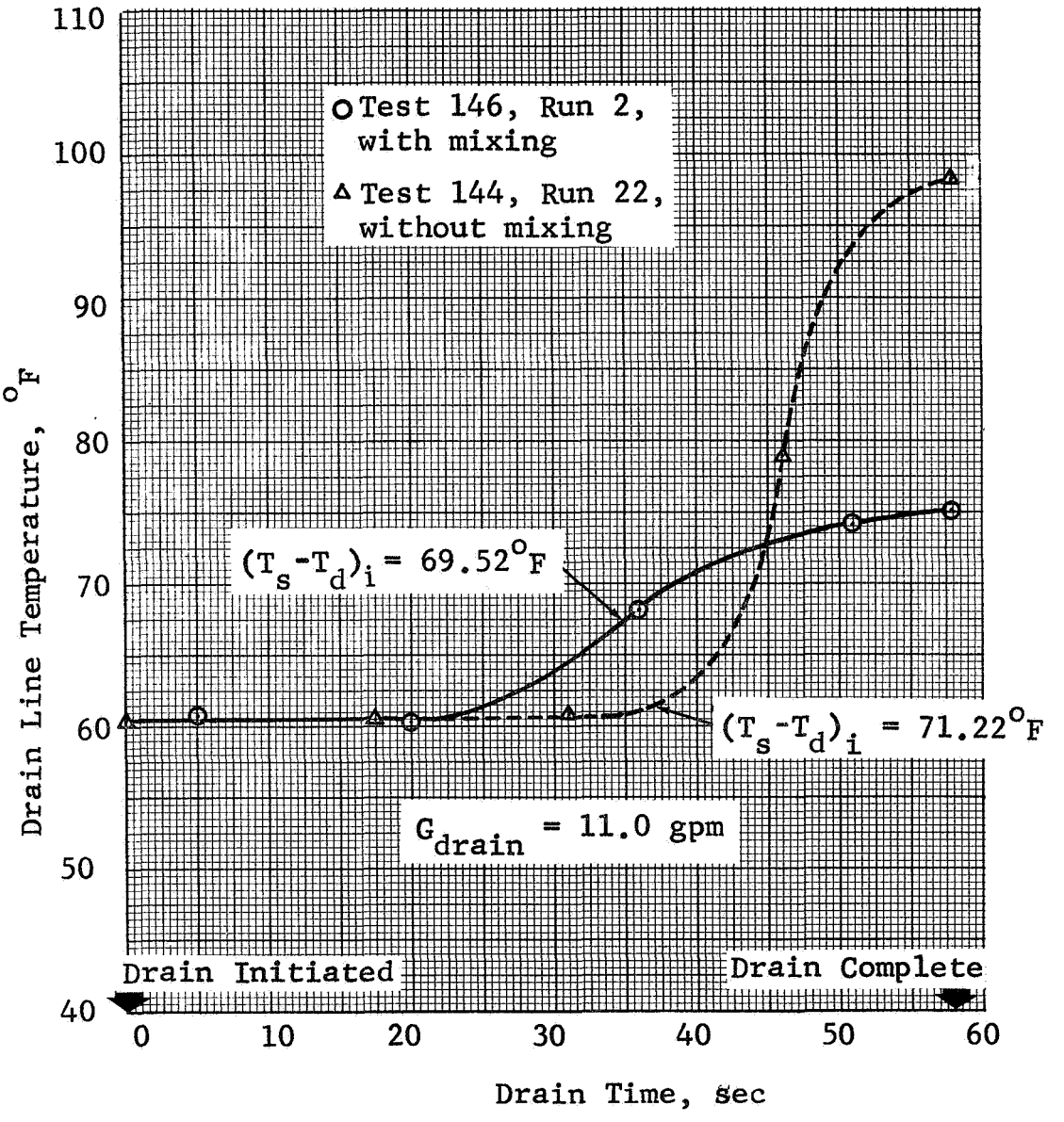

Figure 2.2-169 Drain Line Temperature With and Without Mixing

SECTION 3

CLOSED-TANK TEST DATA

Table 3.0-1

SUMMARY OF CLOSED TANK TESTS

Run	Test	Bulkhead	Liquid Level	Heating Condition Top	Side	Bottom	Nozzle Diameter	Flow Rate	Initial Tank Pressure
			in.		watts		in.	gpm	psia
1	1	Convex	15.2	1283	0	0	0.032	0.1	14.7
2	2	Convex	15.2	1283	0	0	0.032	0.1	14.7
			15.2	1283	0	0	0.032	0.1	40.0
3	12	Convex	15.2	1285.2	0	0	0.032	0.15	14.7
			15.2	1285.2	1500	0	0.032	0.15	46.0
4	11	Convex	15.2	1280	0	0	0.032	0.08	26 in.Hg
5	11	Convex	15.2	1280	0	0	0.032	0.1	7.1
								0.1	14.5
								0.1	20.8
								0.1	22.9
								0.1	23.1
								0.1	23.8
								0.1	24.4
								0.1	25.4
								0.1	28.0
								0.1	29.9
								0.1	29.8
								0.1	31.8
								0.15	20.7
6	12	Convex	15.2	1280	0	1500	0.032	0.15	4.8

Table 3.0-1 (Cont'd)

Run	Test	Bulkhead	Liquid Level	Heating Condition Top	Side	Bottom	Nozzle Diameter	Flow Rate	Initial Tank Pressure
			in.	watts			in.	gpm	psia
7	12	Convex	15.2	1280	0	1500	0.032	0.15	8.0
8	12	Convex	15.2	1280	0	1500	0.032	0.15	9.9
9	12	Convex	15.2	1280	0	1500	0.032	0.15	10.2
10	12	Convex	15.2	1280	0	1500	0.032	0.15	10.7
11	12	Convex	15.2	1280	0	1500	0.032	0.15	14.1
12	12	Convex	15.2	1280	0	1500	0.032	0.15	11.5
13	12	Convex	15.2	1280	0	1500	0.032	0.15	17.9
14	13	Convex	14.7	1280	0	0	0.032	0.09	4.0
15	13	Convex	14.7	1280	0	0	0.032	0.15	7.9
16	13	Convex	14.7	1280	0	0	0.032	0.15	9.4
17	13	Convex	14.7	1280	0	0	0.032	0.15	11.7
18	13	Convex	14.7	1280	0	0	0.032	0.15	25.8
19	13	Convex	14.7	1280	0	0	0.032	0.234	25.3
20	14	Convex	12.36	1280	0	0	0.032	0.15	6.9
21	14	Convex	12.36	1280	0	0	0.032	0.15	10.4

Table 3.0-1 (Cont'd)

Run	Test	Bulkhead	Liquid Level	Heating Condition Top	Side	Bottom	Nozzle Diameter	Flow Rate	Initial Tank Pressure
			in.	watts			in.	gpm	psia
22	15	Convex	14.7	300	0	0	0.032	0.15	2.4
23	15	Convex	14.7	1280	0	0	0.032	0.15	10.1
24	15	Convex	14.7	1280	0	0	0.032	0.15	12.7
25	15	Convex	14.7	1280	0	0	0.032	0.22	16.3
26	15	Convex	14.7	1280	0	0	0.032	0.22	21.2
27	16	Convex	15.2	0	0	0	0.032	0.1	1.9
28	16	Convex	15.2	1280	0	0	0.032	0.22	29.0
29	16	Convex	15.2	1280	0	0	0.032	0.22	35.5
30	16	Convex	15.2	1280	0	0	0.032	0.22	42.0

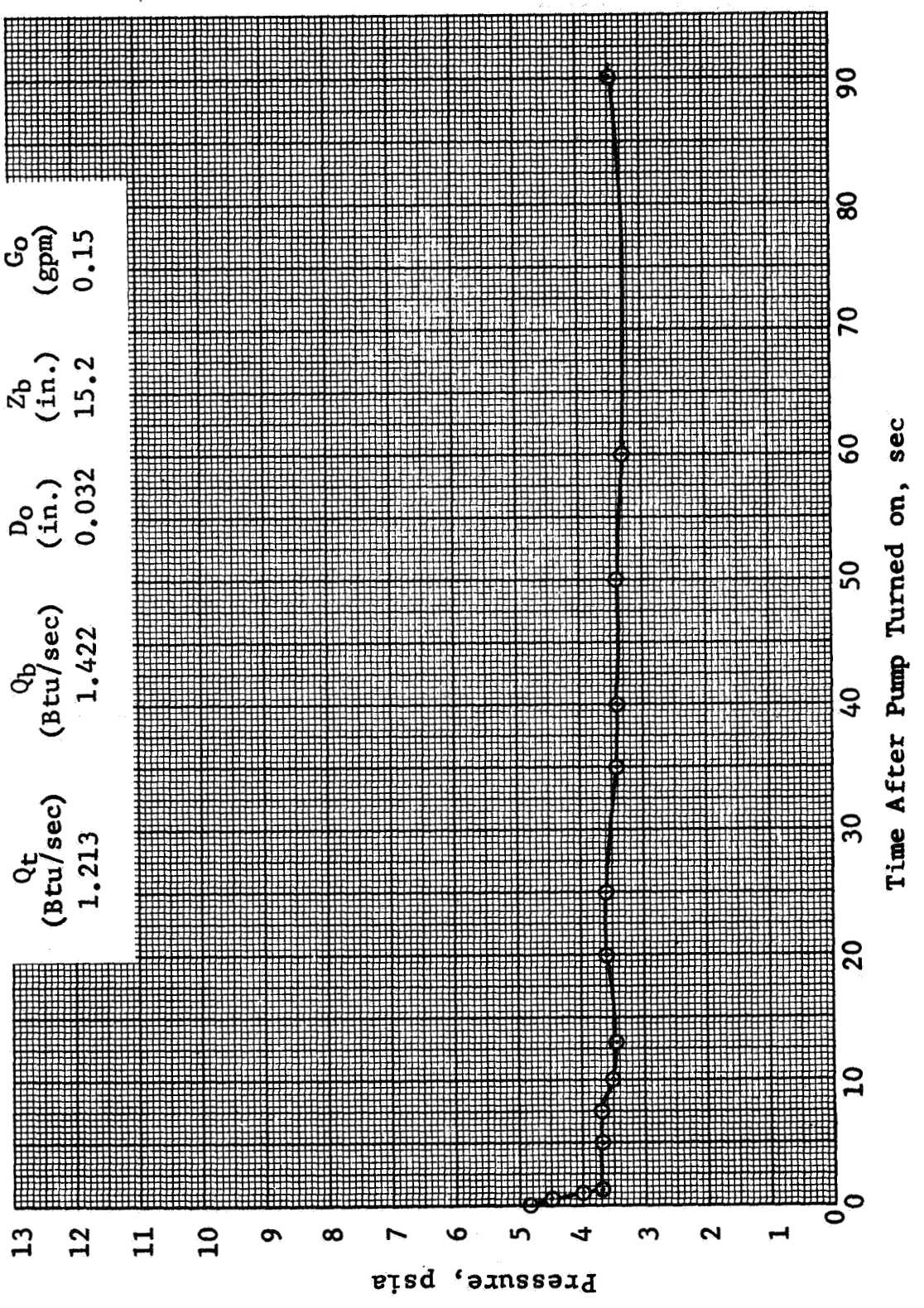

Figure 3.0-1 Transient Pressure Decay: Test 12, Run 6

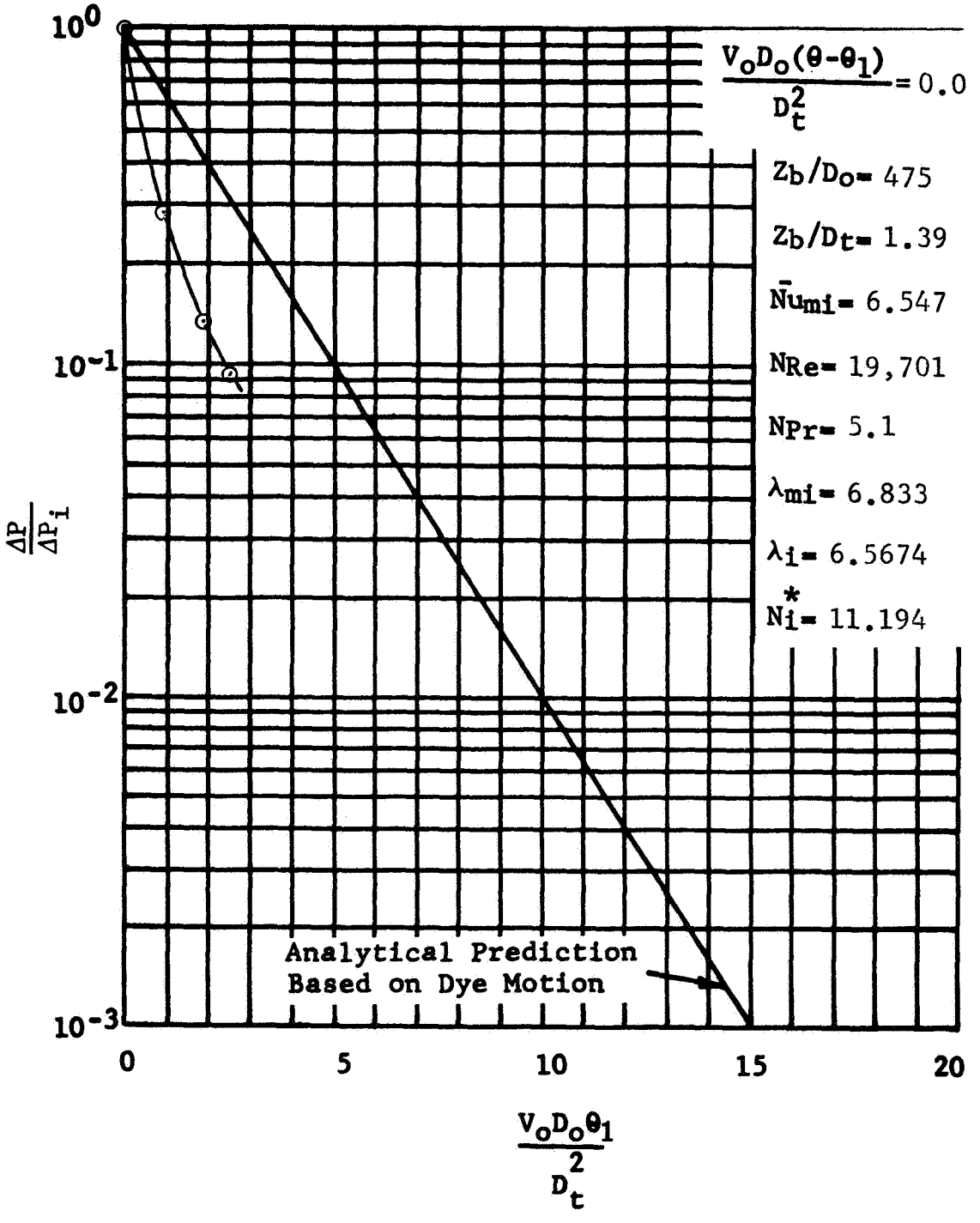

Figure 3.0-2 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 6

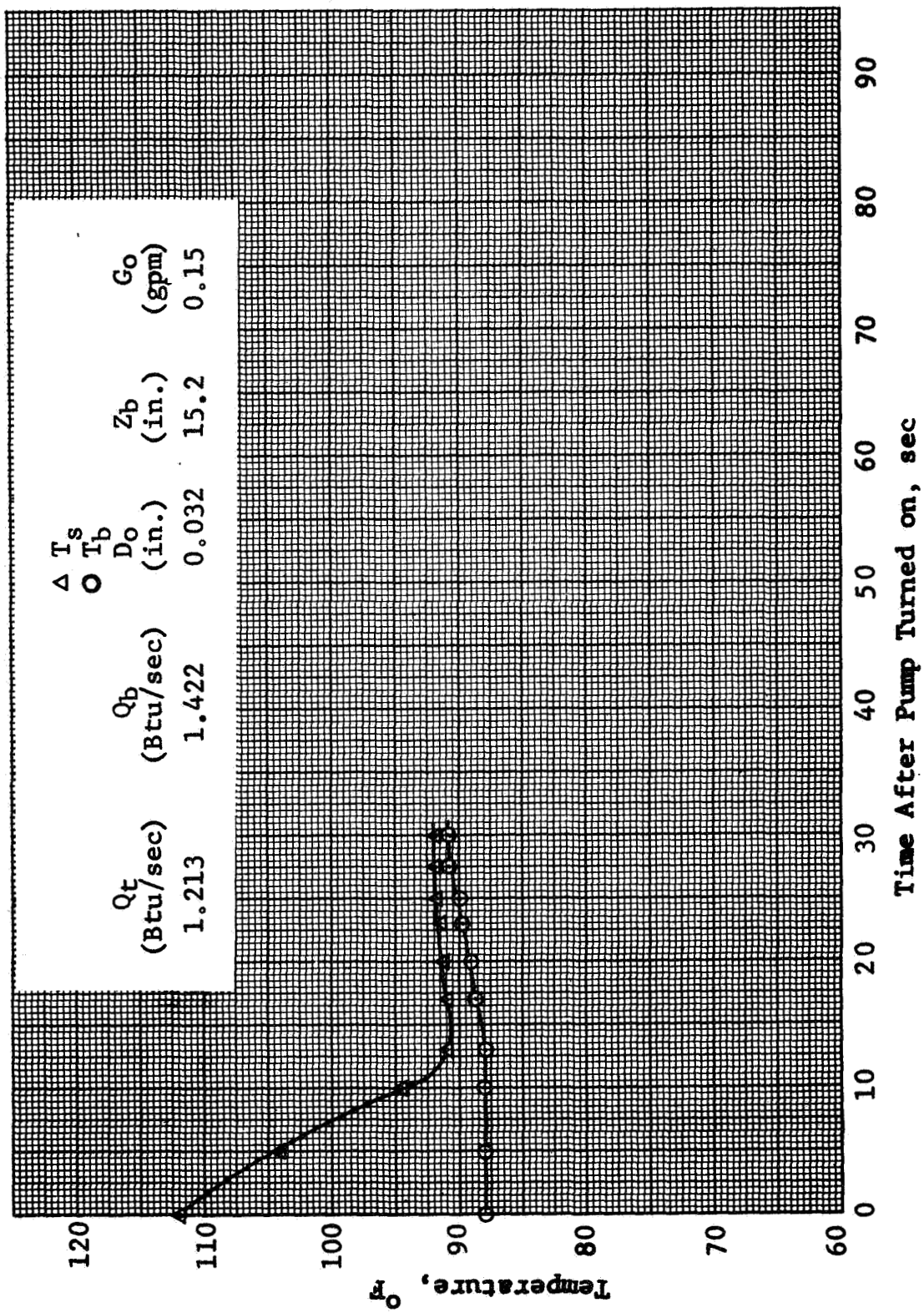

Figure 3.0-3 Transient Temperature Destratification: Test 12, Run 6

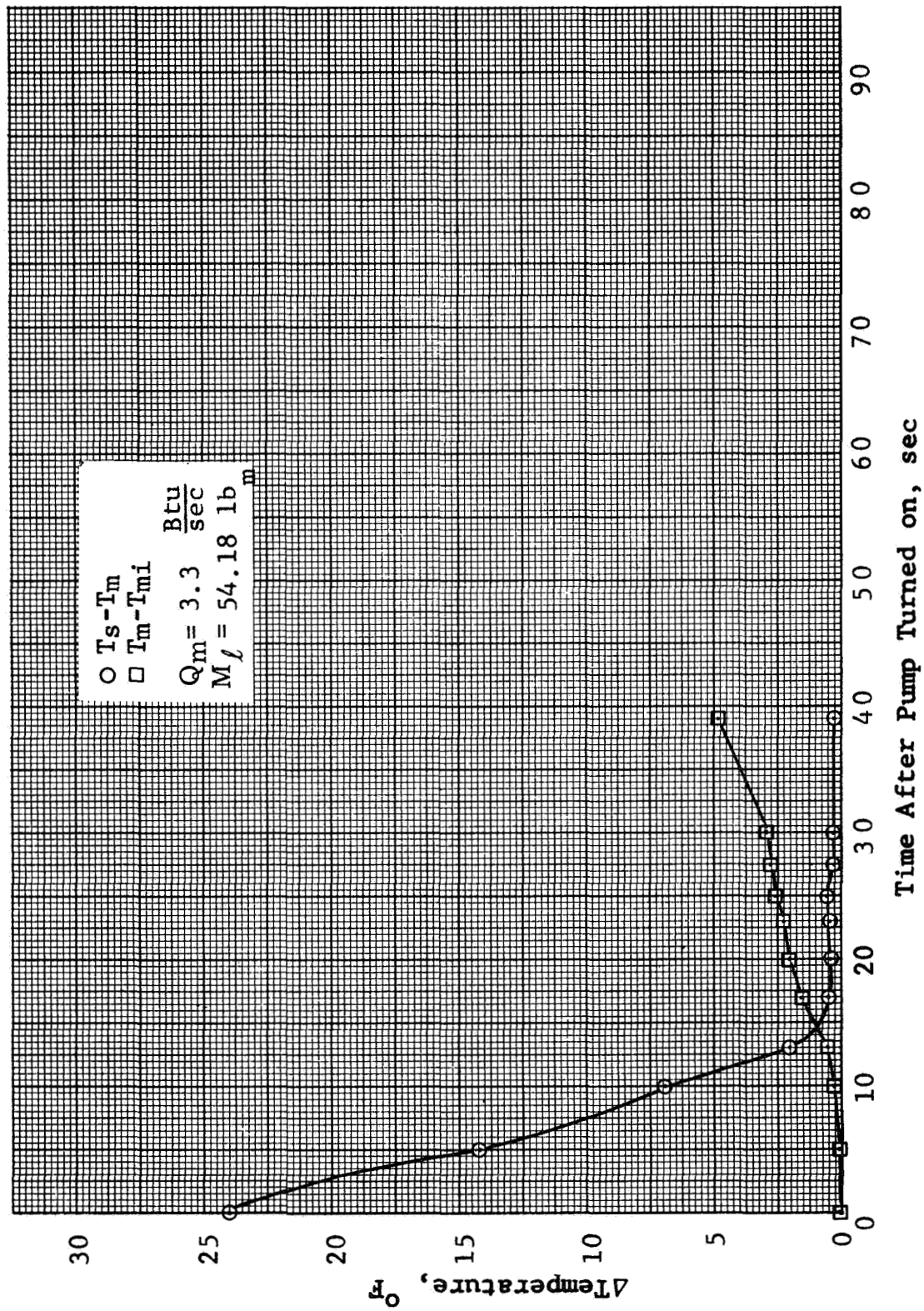

Figure 3.0-4 Transient ΔTemperature Destratification: Test 12, Run 6

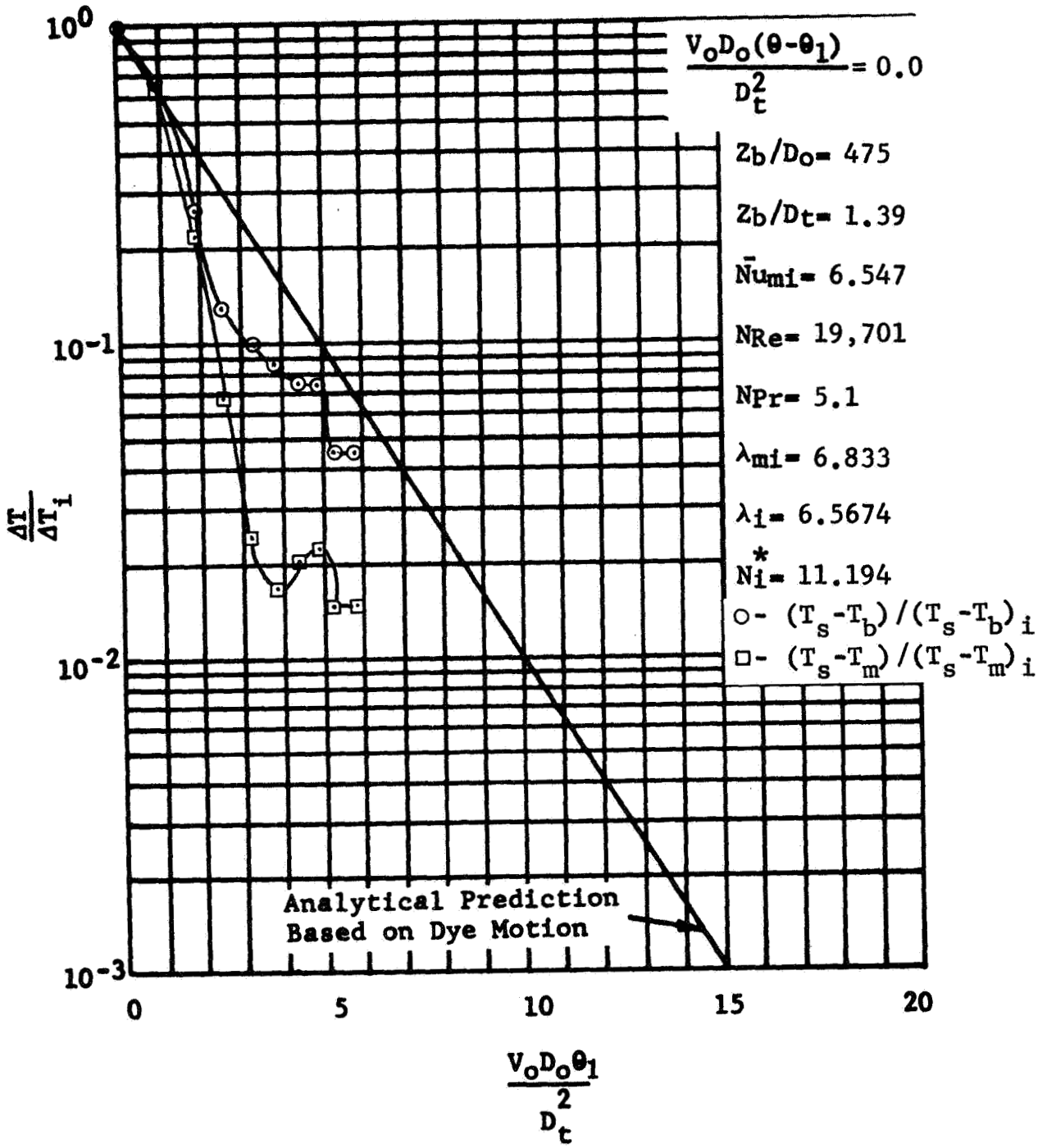

Figure 3.0-5 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 6

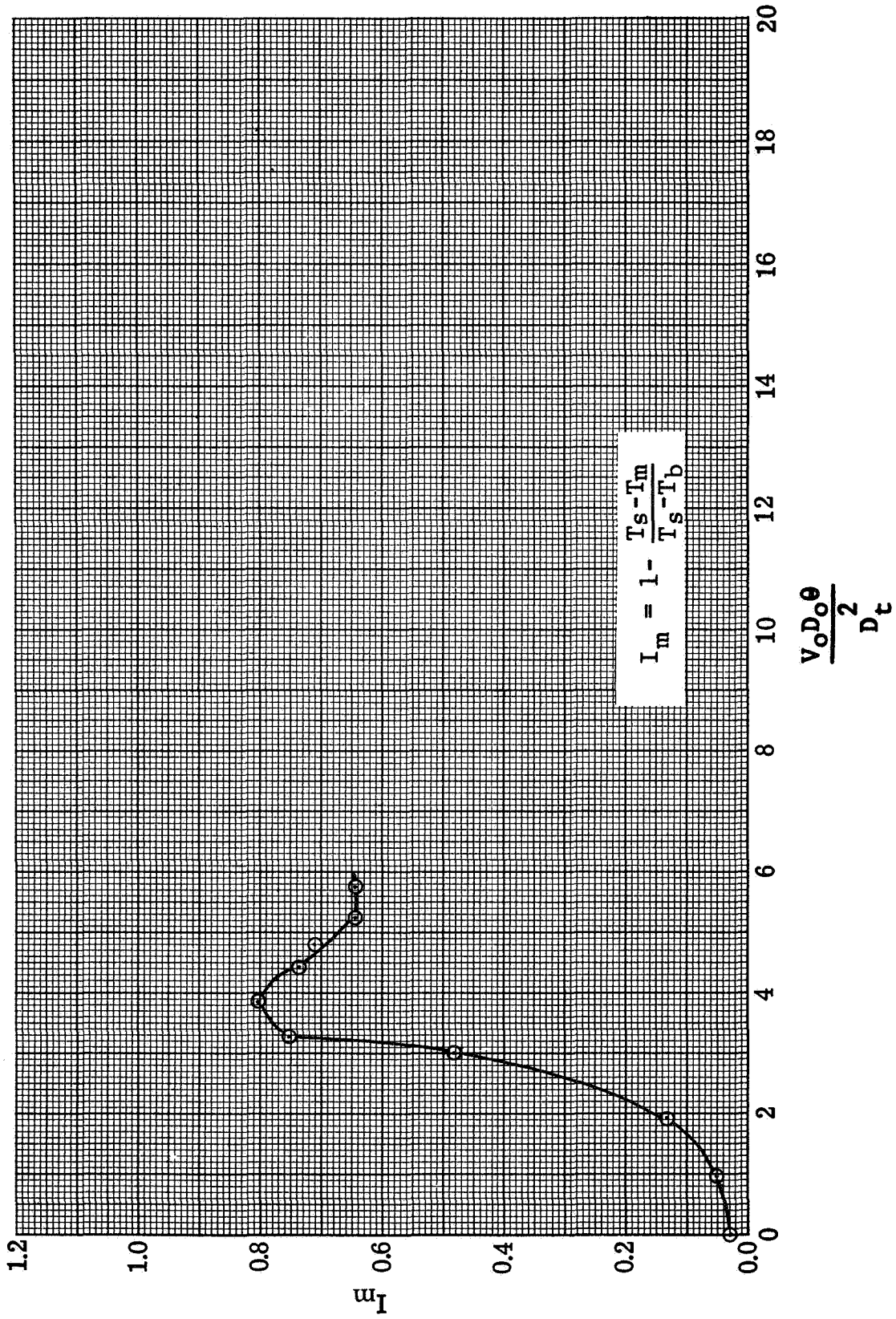

Figure 3.0-6 Transient Energy Integral: Test 12, Run 6

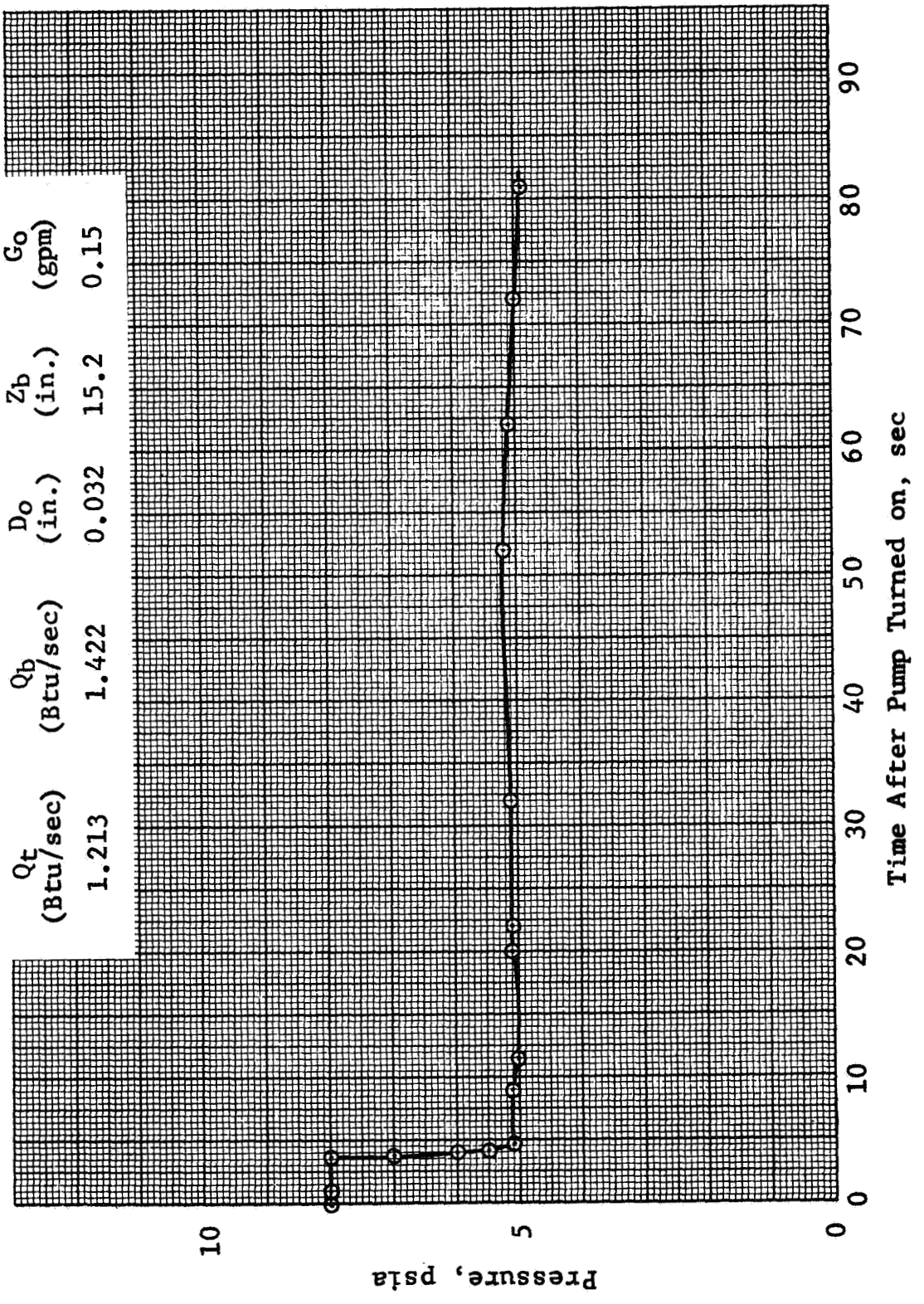

Figure 3.0-7 Transient Pressure Decay: Test 12, Run 7

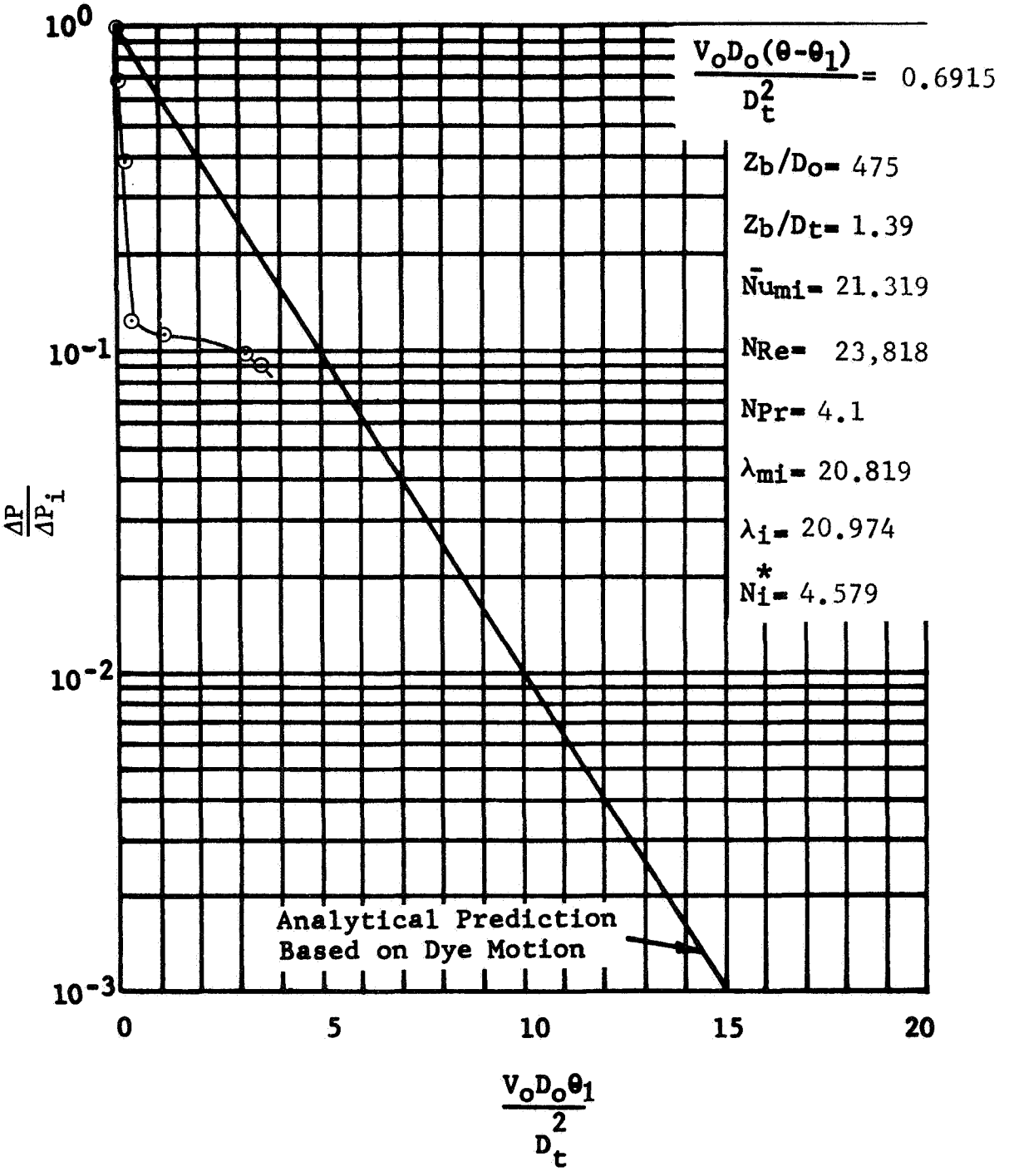

Figure 3.0-8 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 7

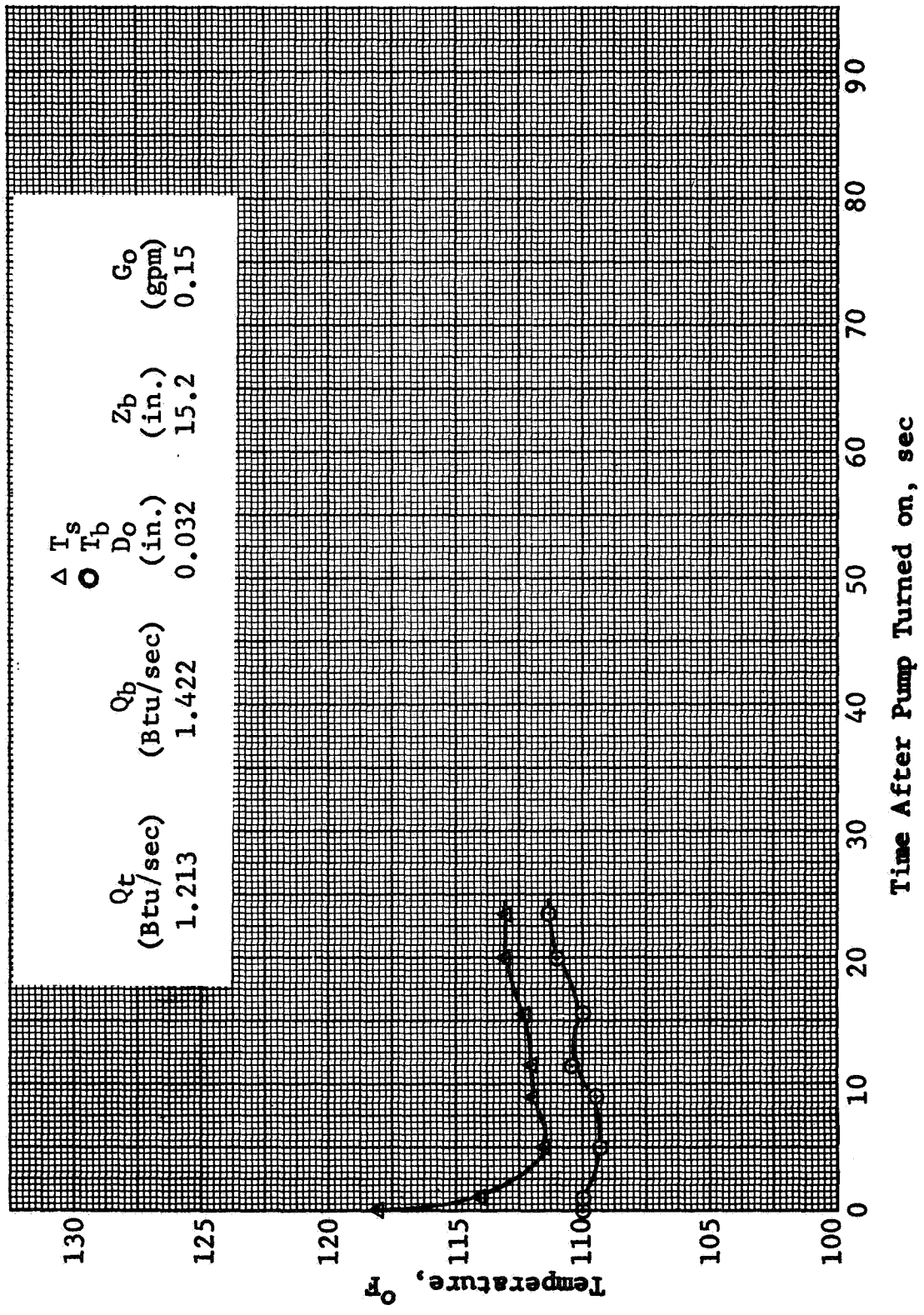

Figure 3.0-9 Transient Temperature Destratification: Test 12, Run 7

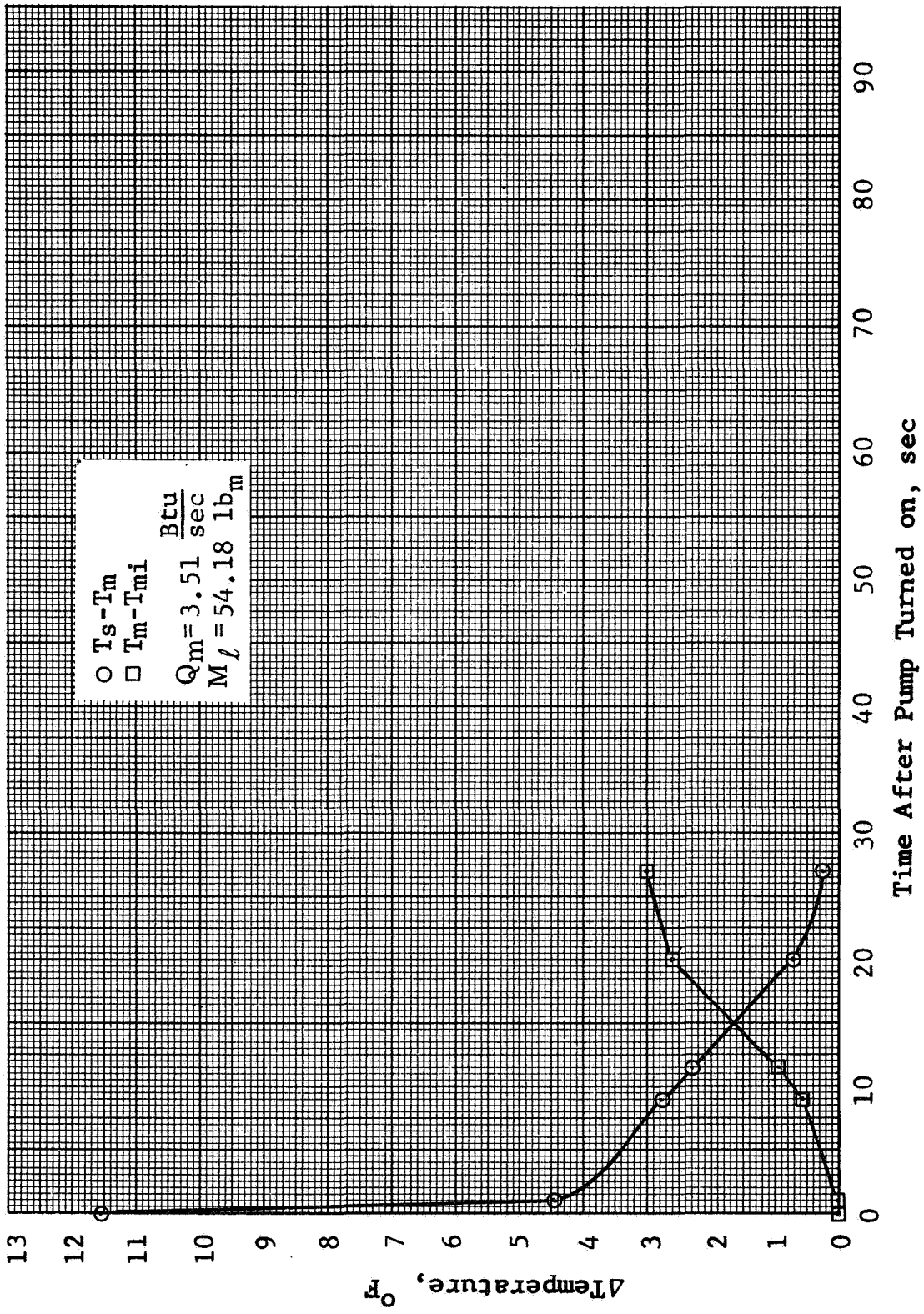

Figure 3.0-10 Transient ΔTemperature Destratification: Test 12, Run 7

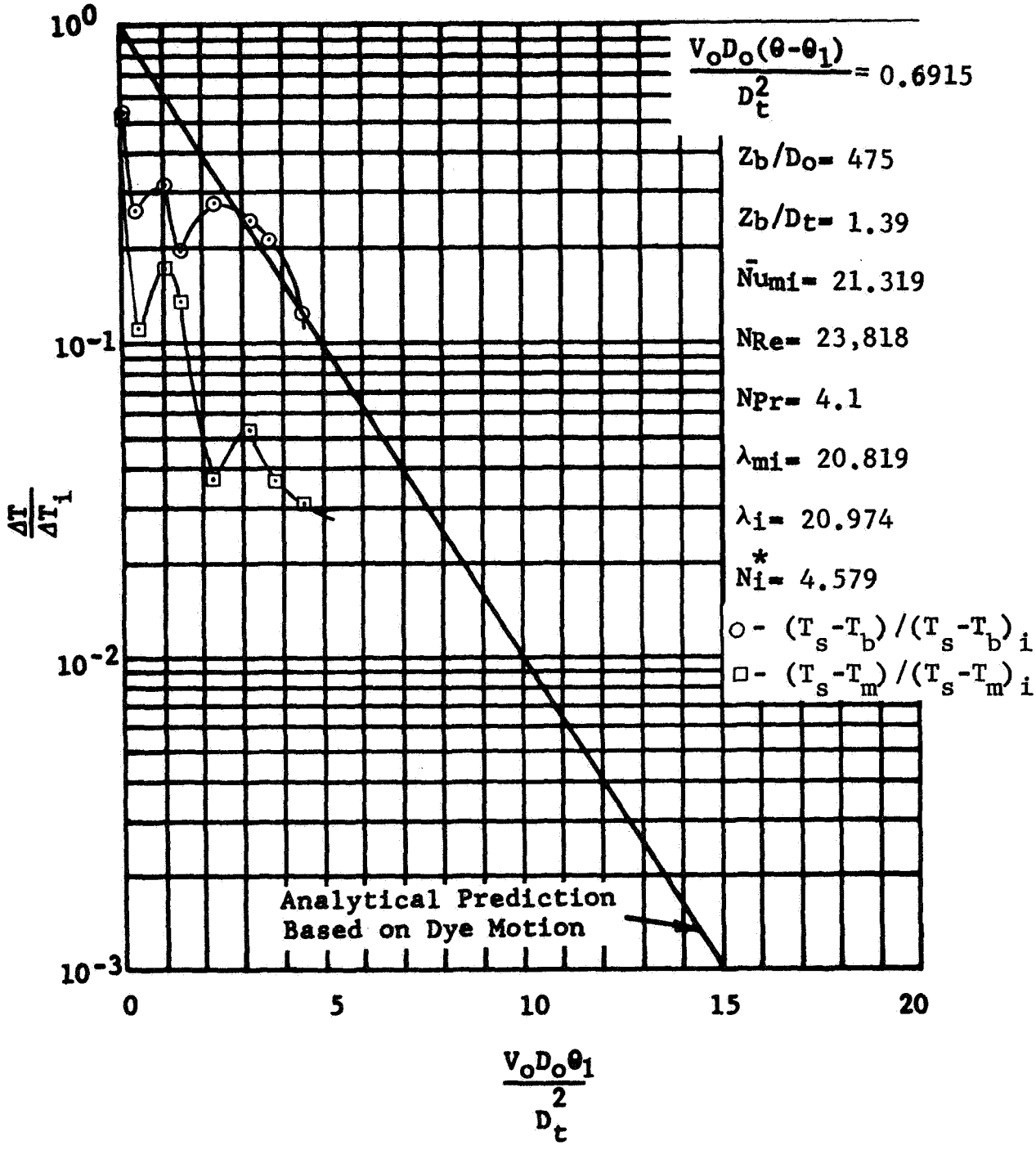

Figure 3.0-11 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 7

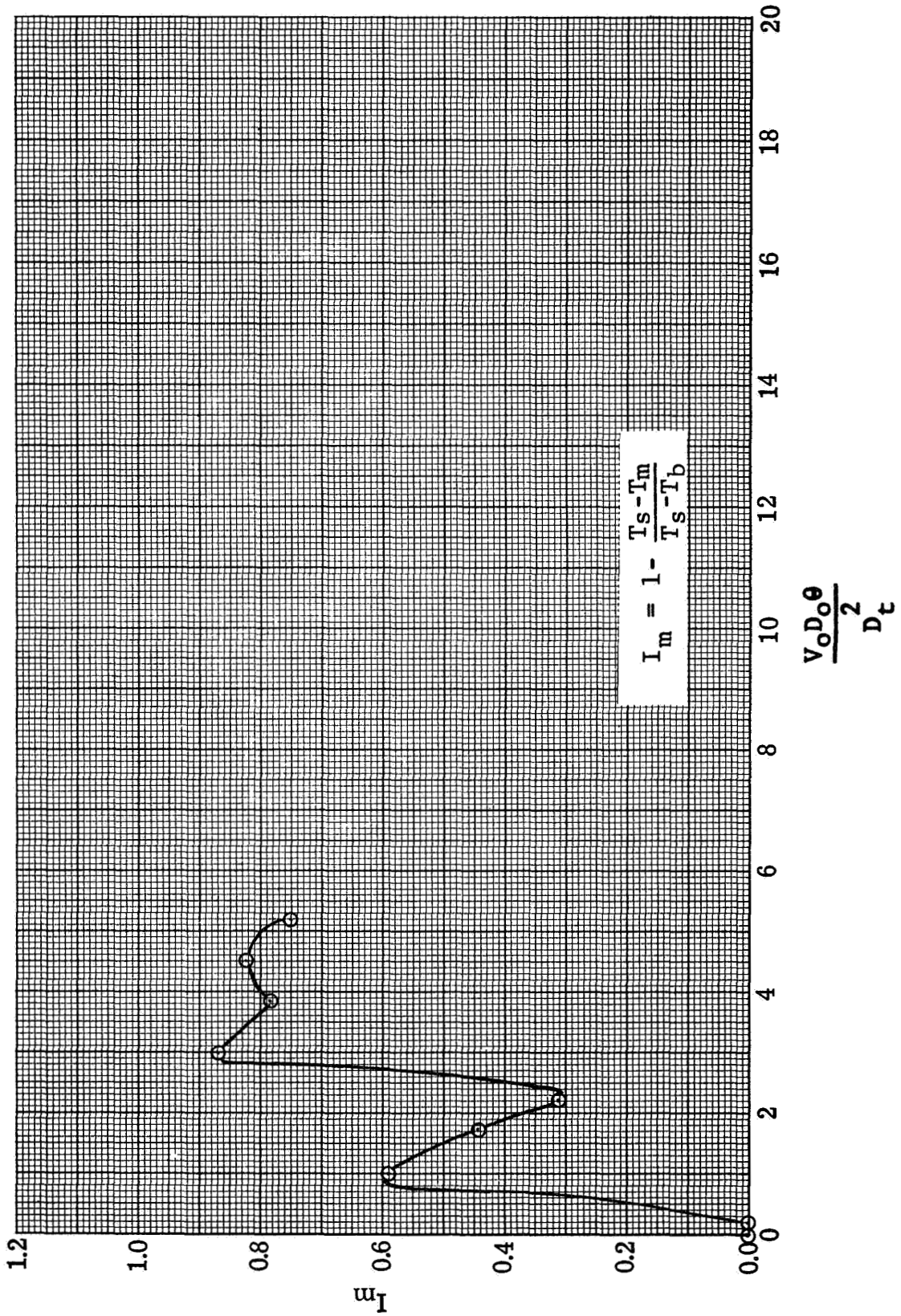

Figure 3.0-12 Transient Energy Integral: Test 12, Run 7

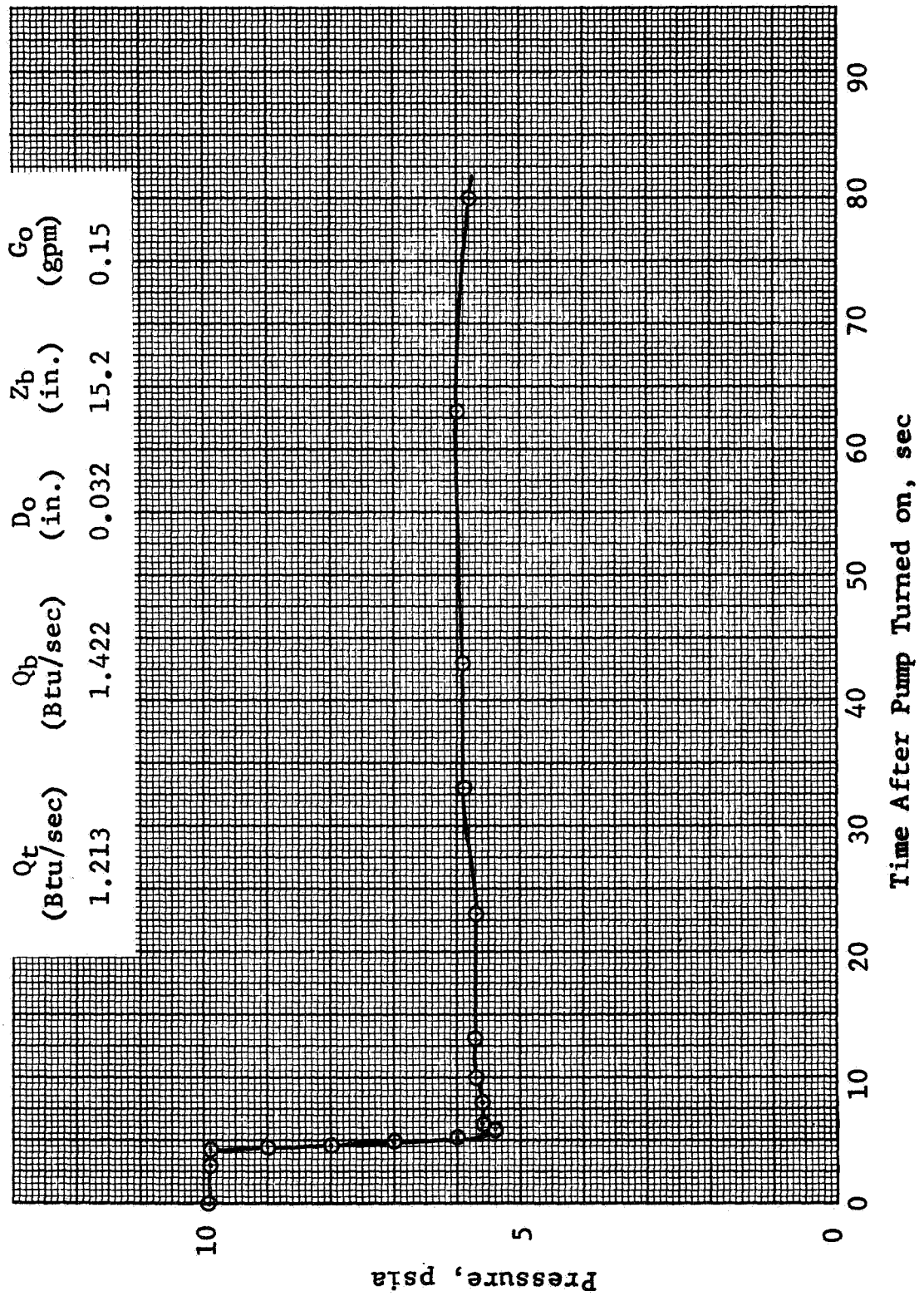

Figure 3.0-13 Transient Pressure Decay: Test 12, Run 8

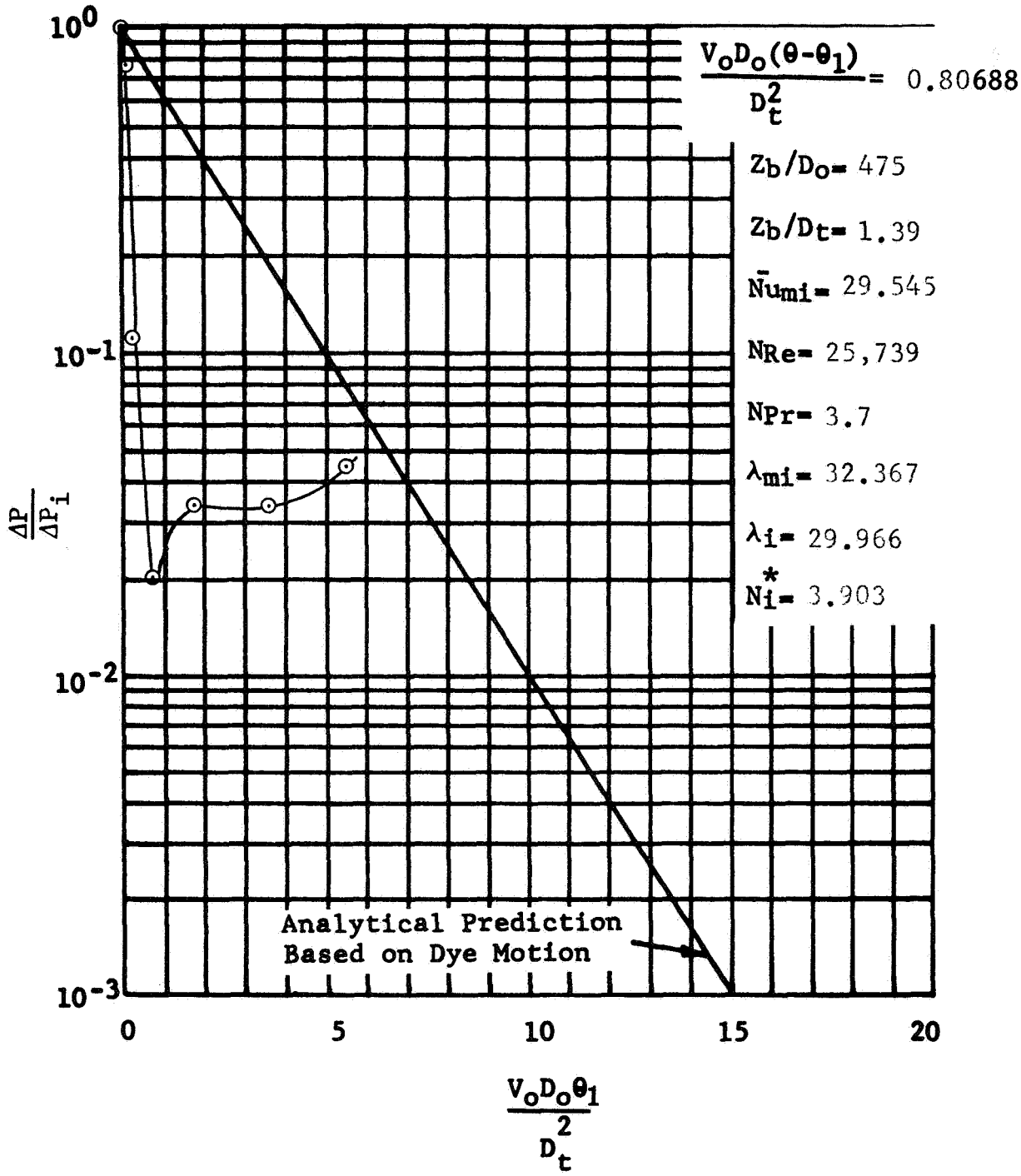

Figure 3.0-14 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 8

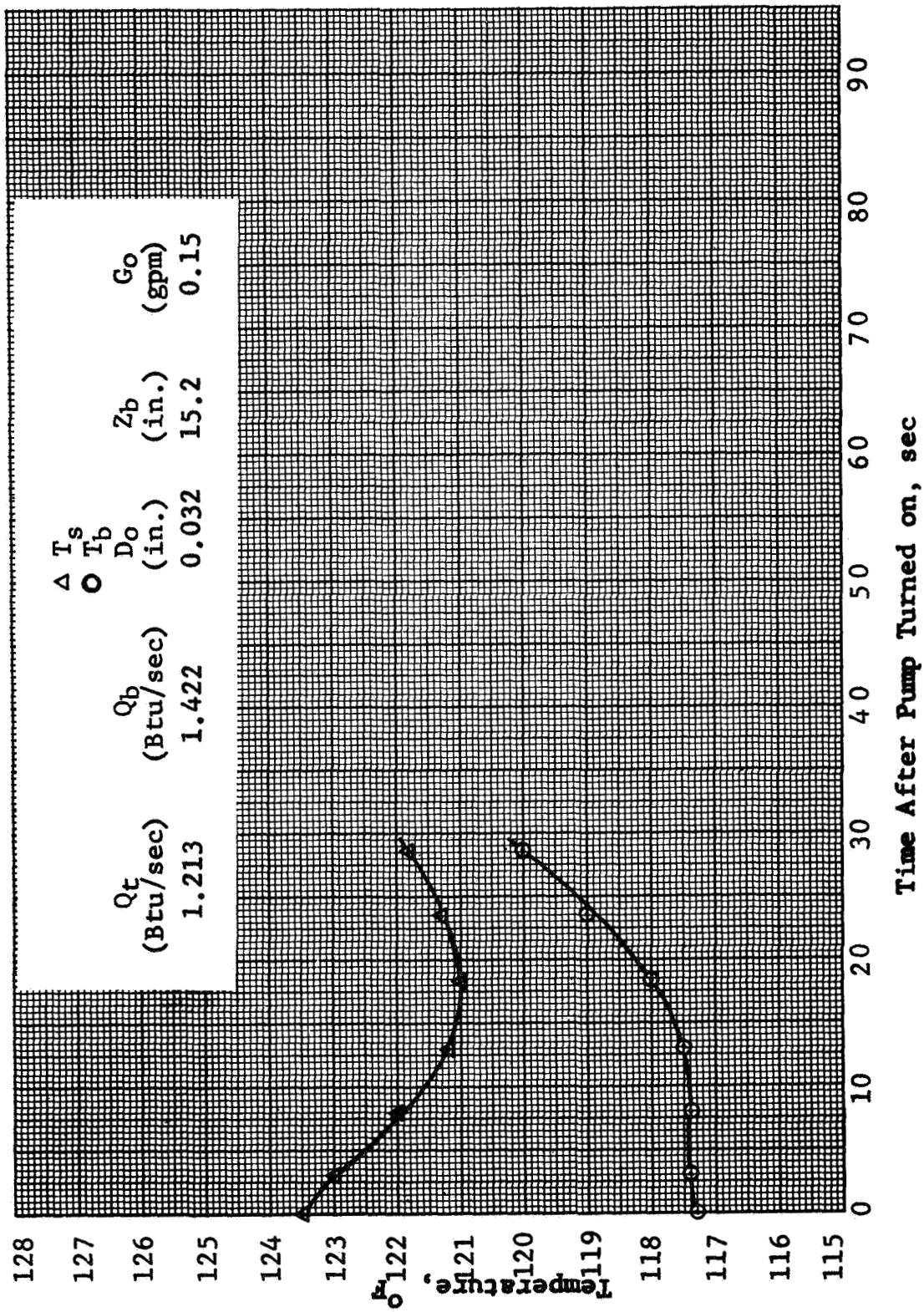

Figure 3.0-15 Transient Temperature Destratification: Test 12, Run 8

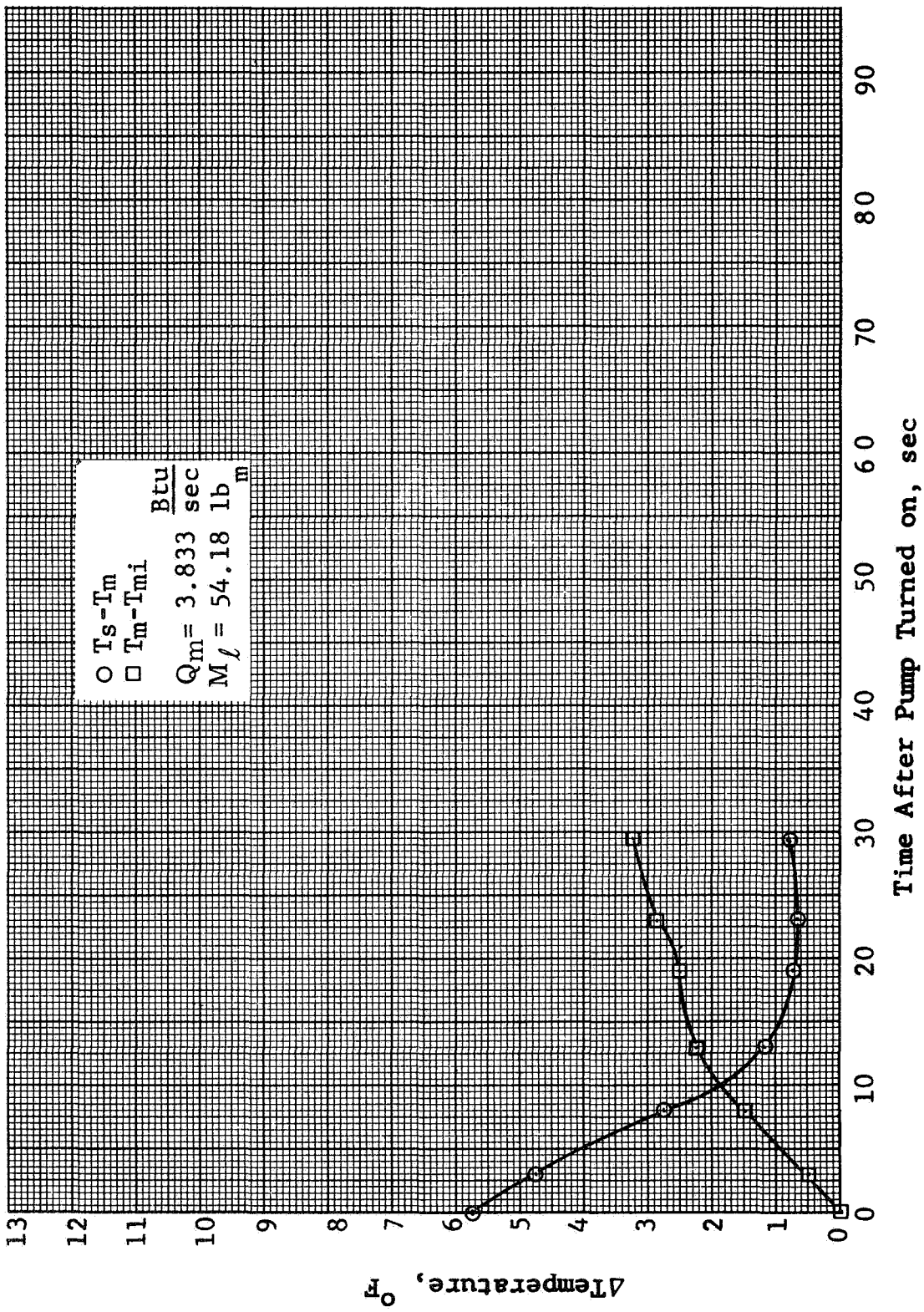

Figure 3.0-16 Transient ΔTemperature Destratification: Test 12, Run 8

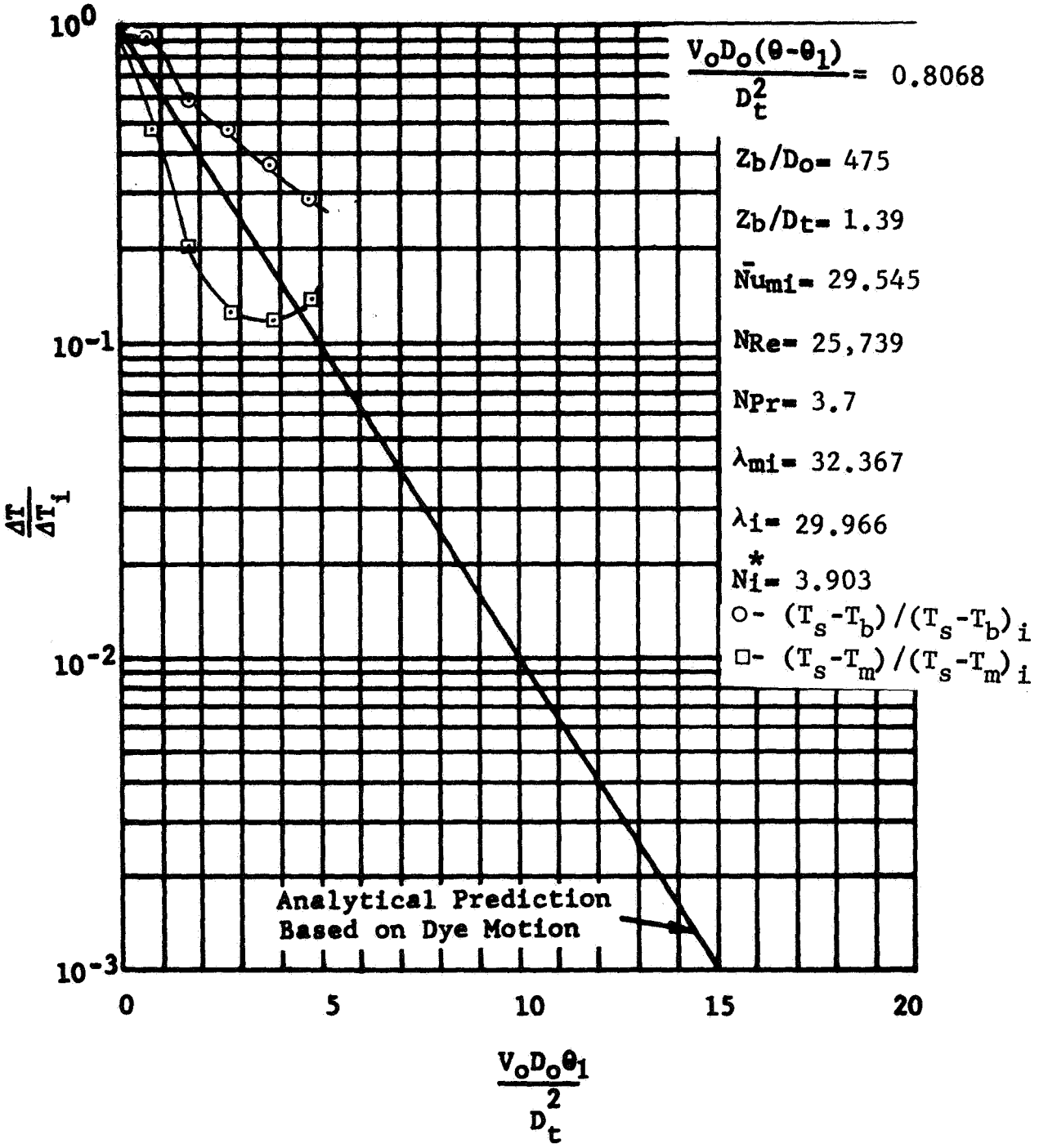

Figure 3.0-17 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 8

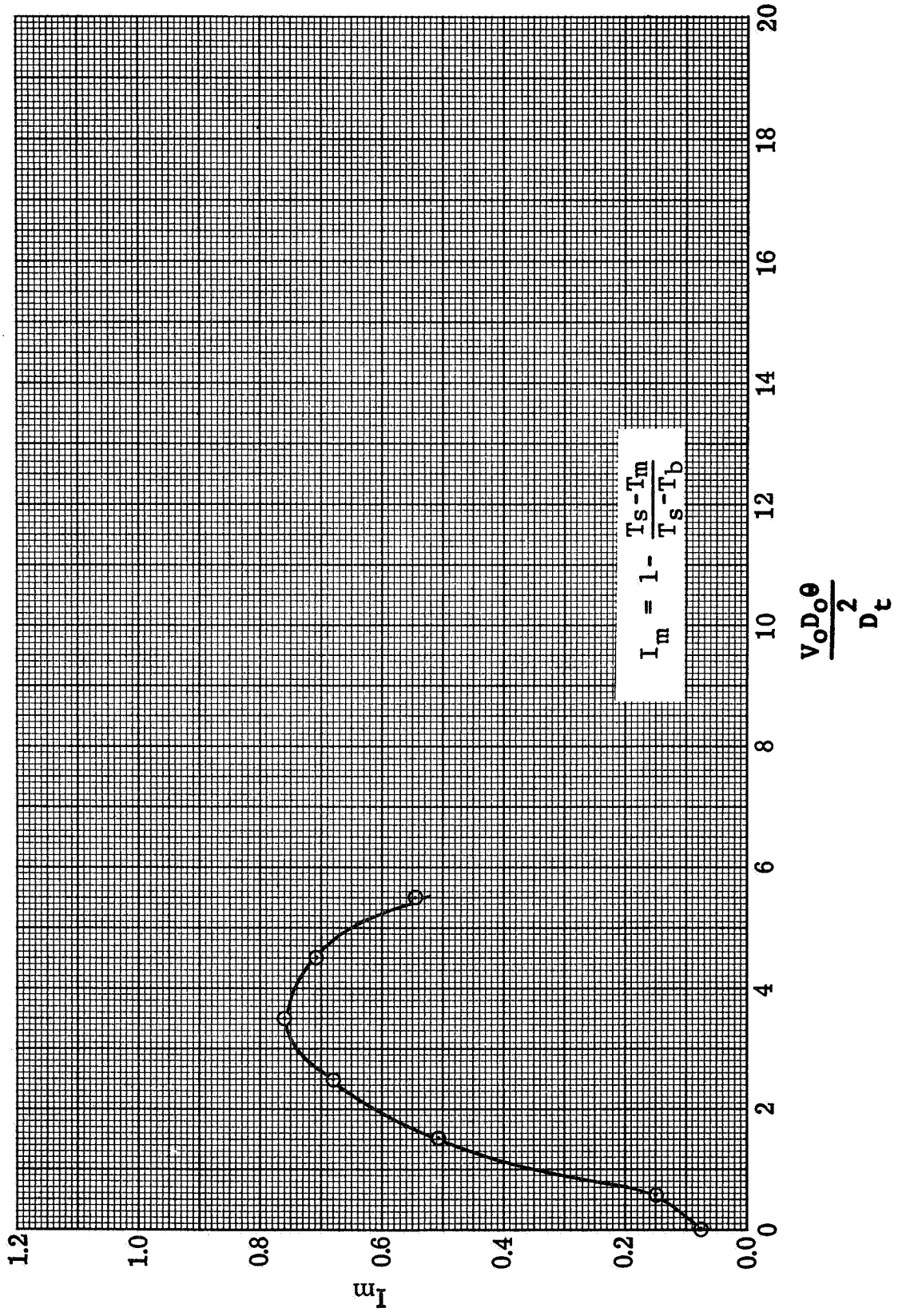

Figure 3.0-18 Transient Energy Integral: Test 12, Run 8

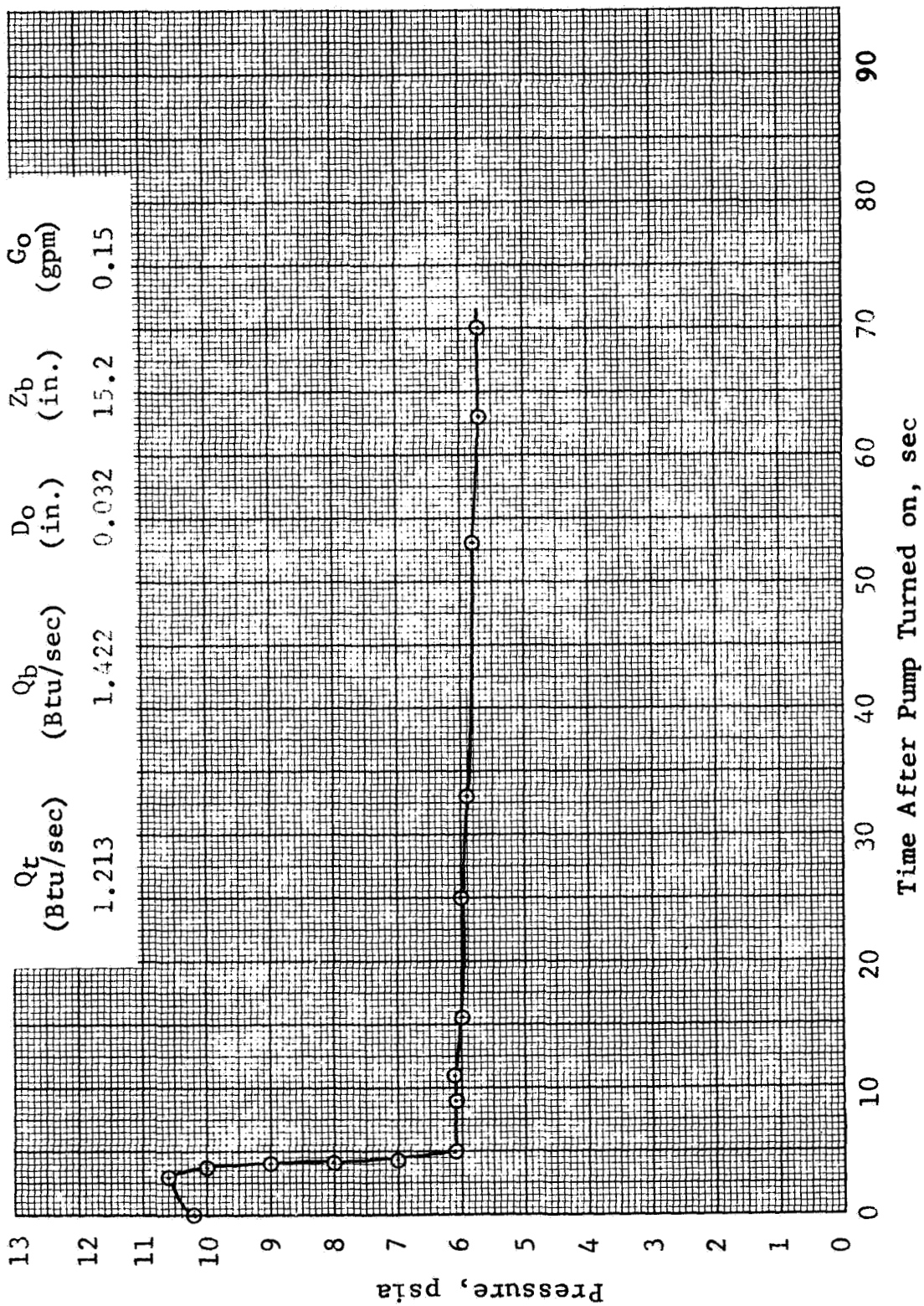

Figure 3.0-19 Transient Pressure Decay: Test 12, Run 9

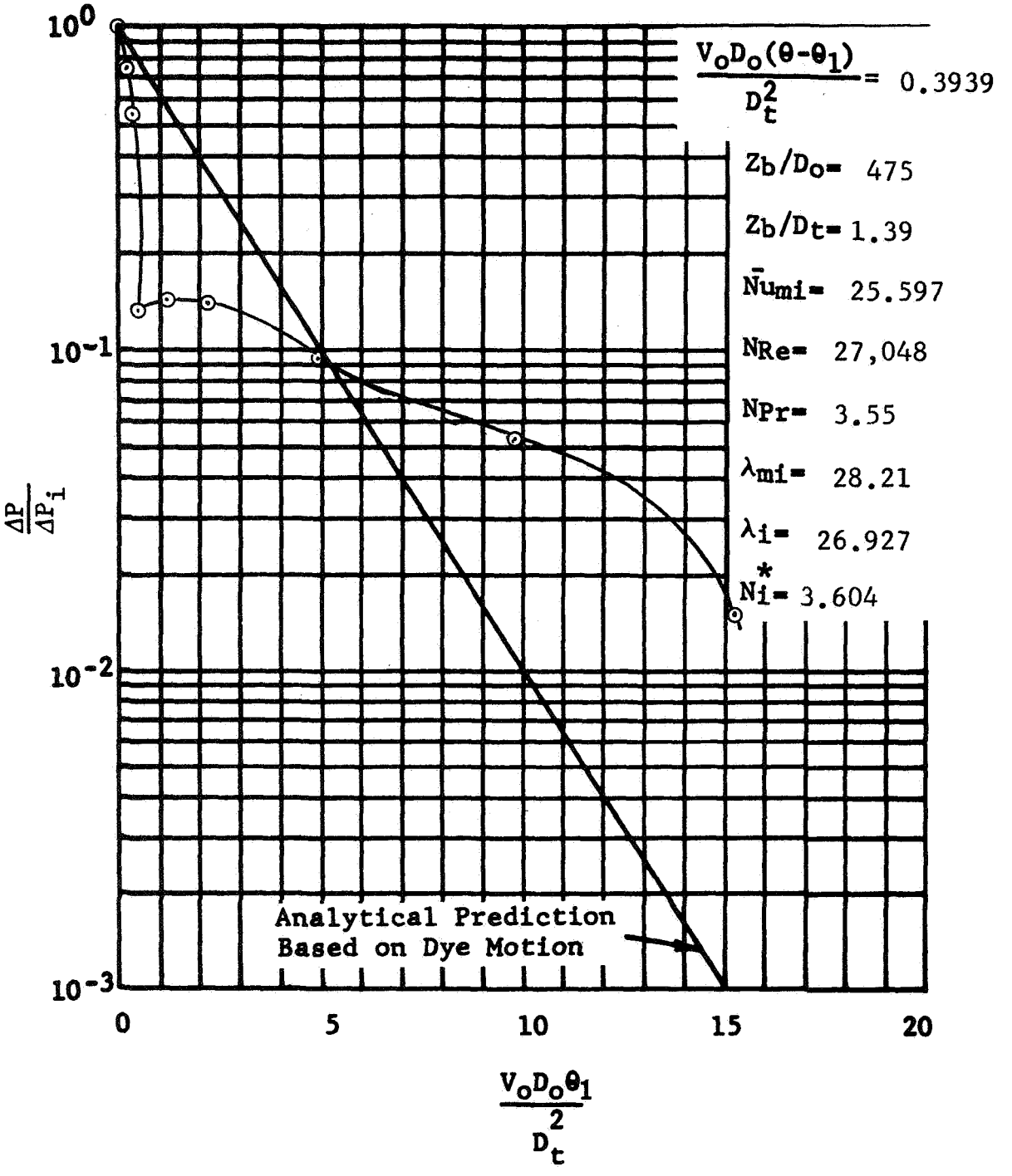

Figure 3.0-20 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 9

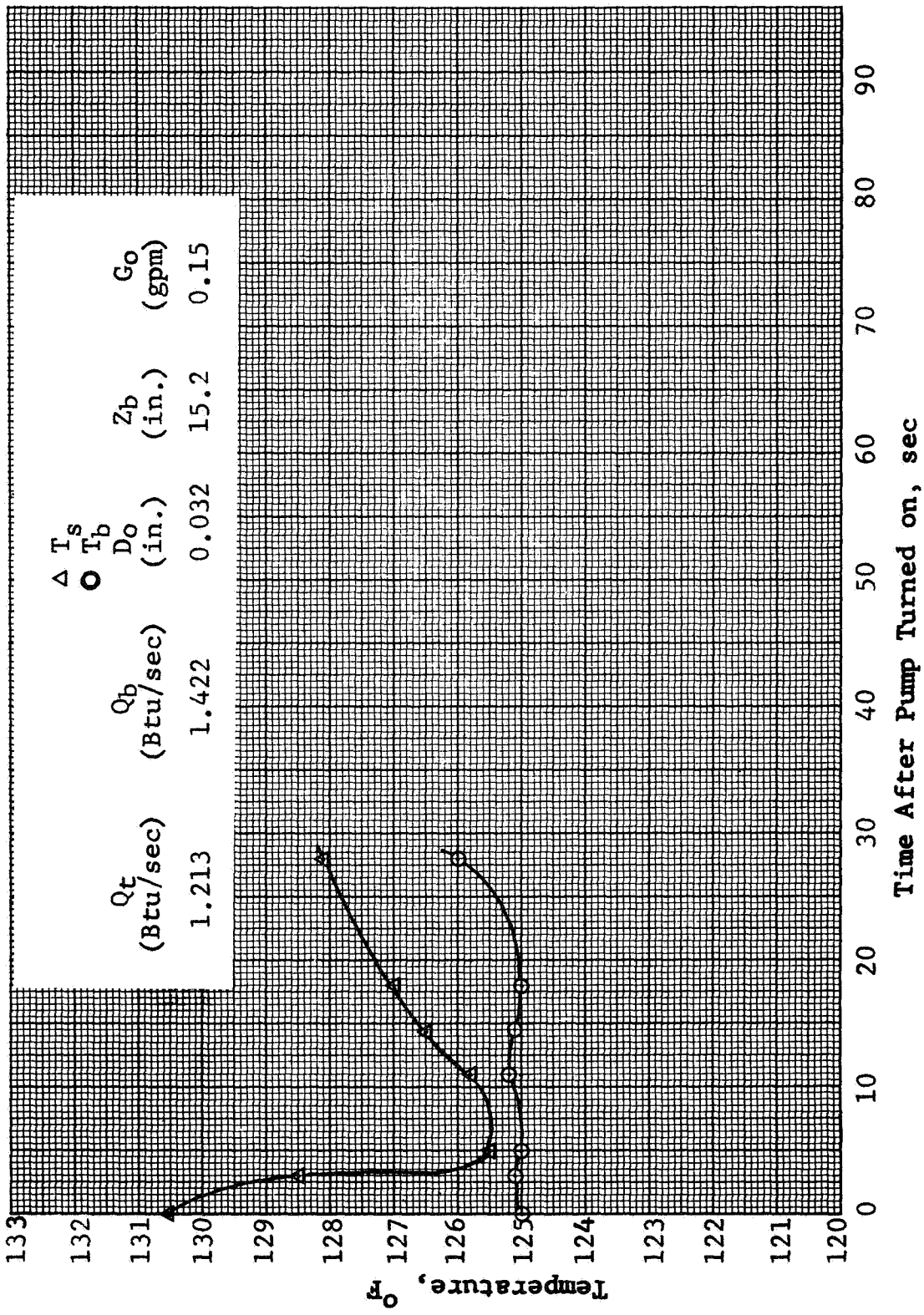

Figure 3.0-21 **Transient Temperature Destratification:** Test 12, Run 9

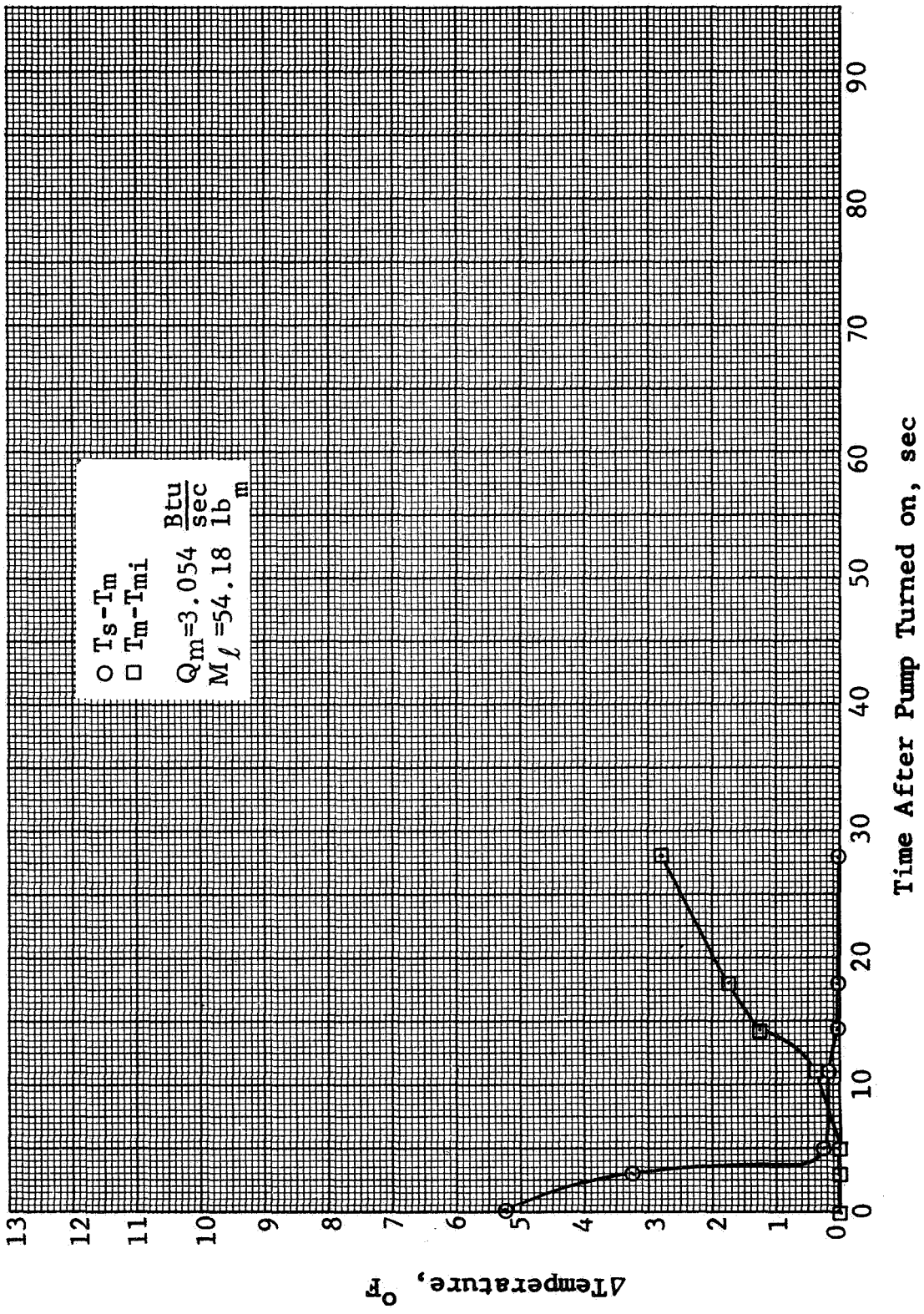

Figure 3.0-22 Transient ΔTemperature Destratification: Test 12, Run 9

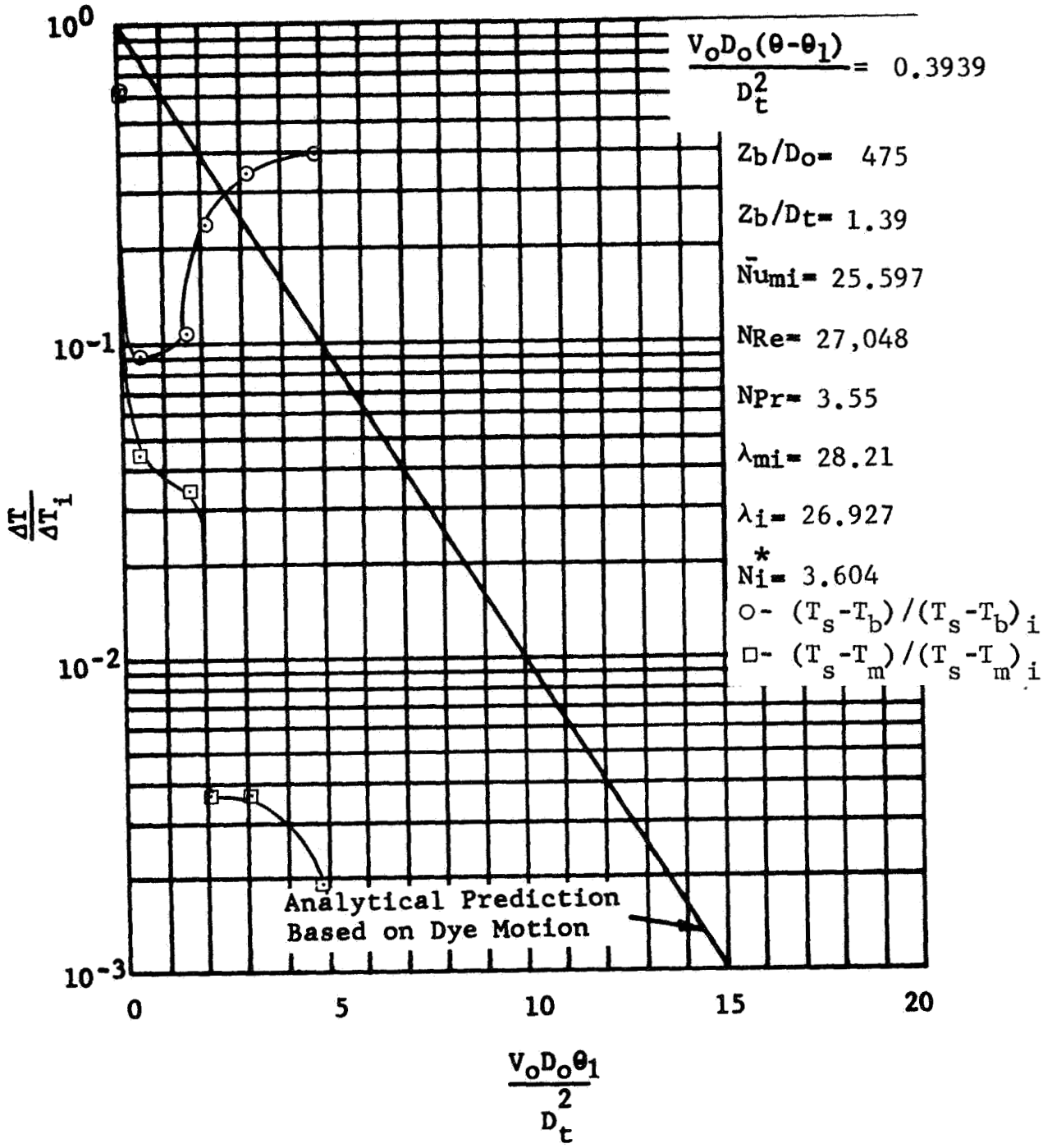

Figure 3.0-23 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 9

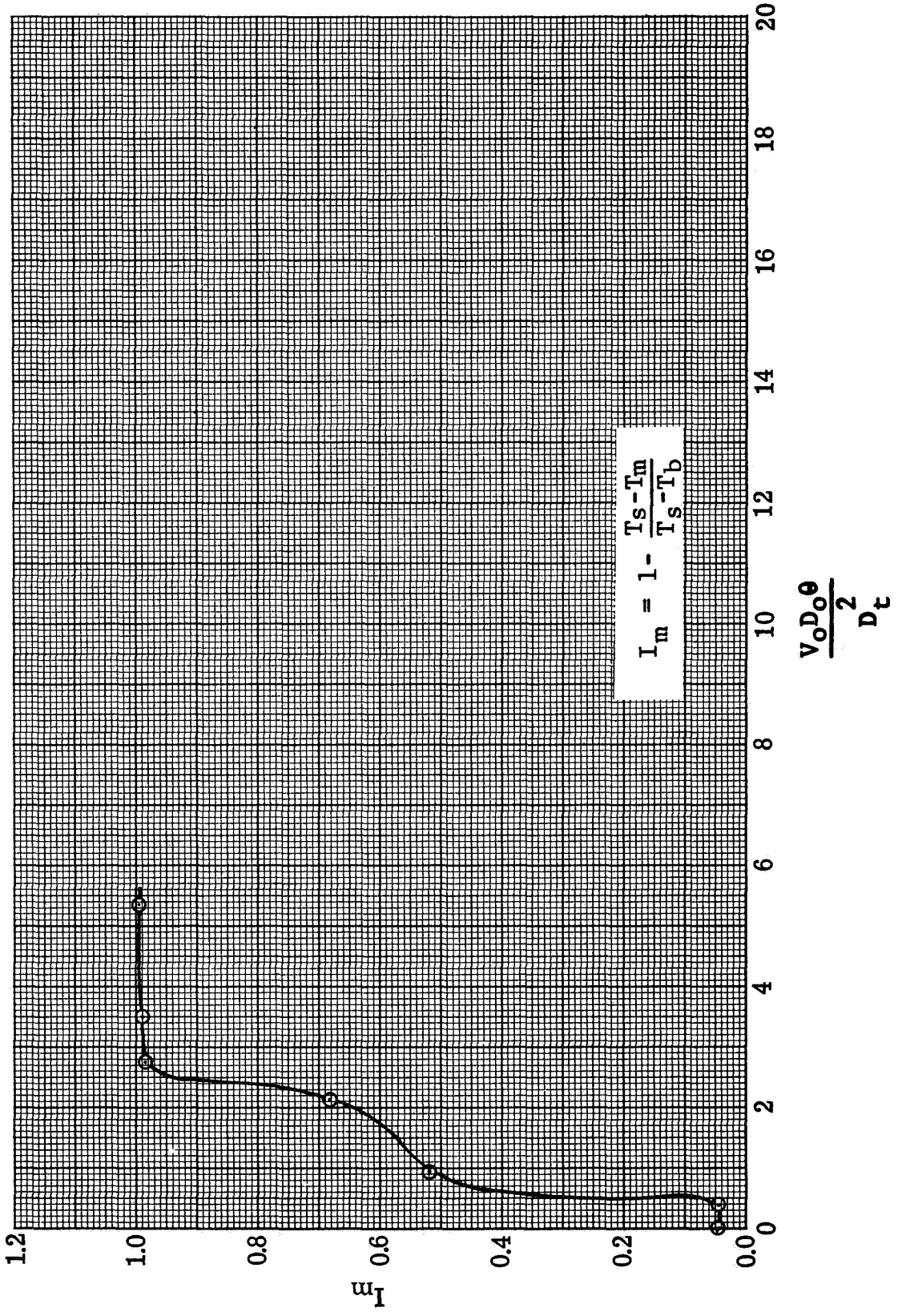

Figure 3.0-24 Transient Energy Integral: Test 12, Run 9

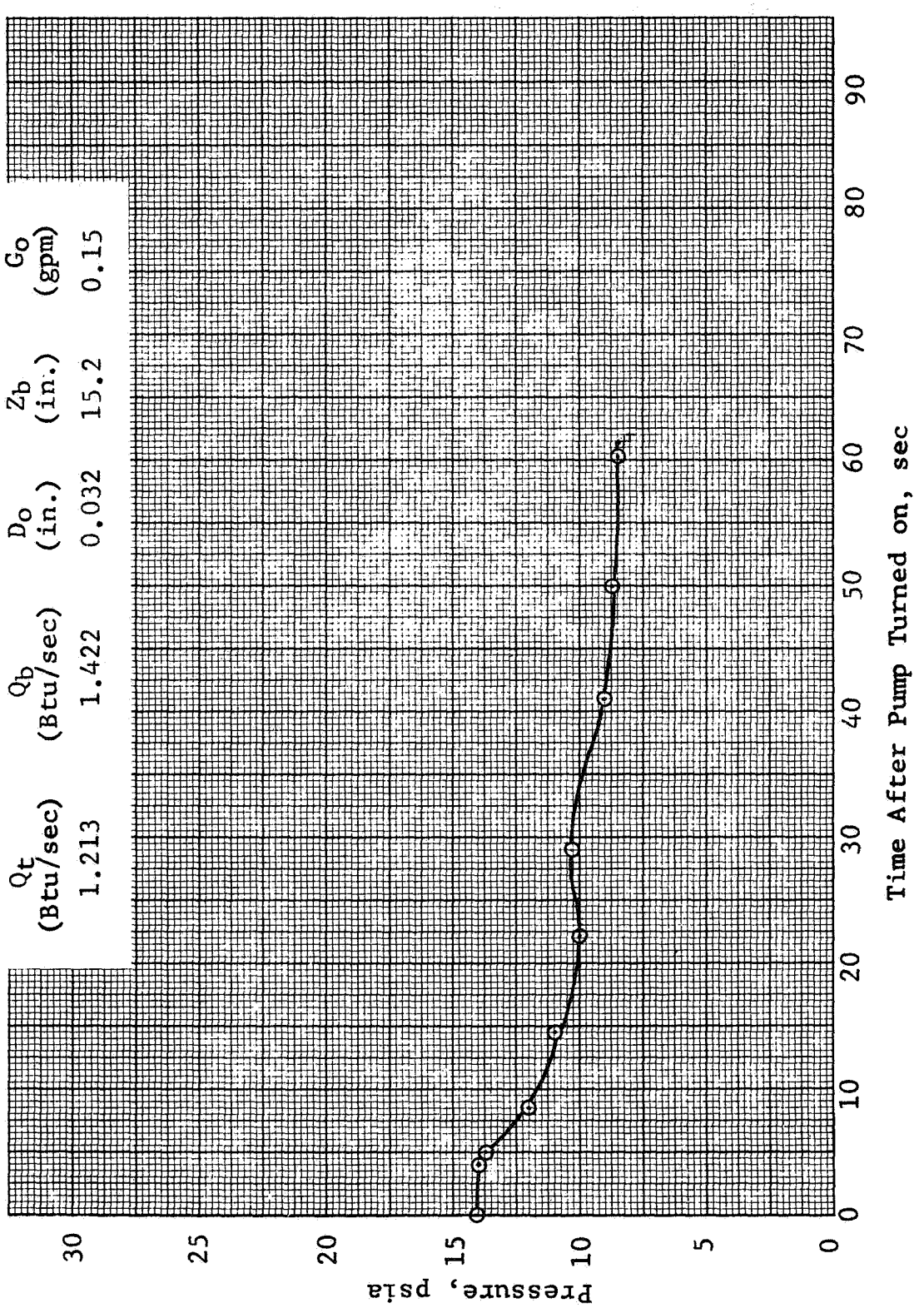

Figure 3.0-25 Transient Pressure Decay: Test 12, Run 11

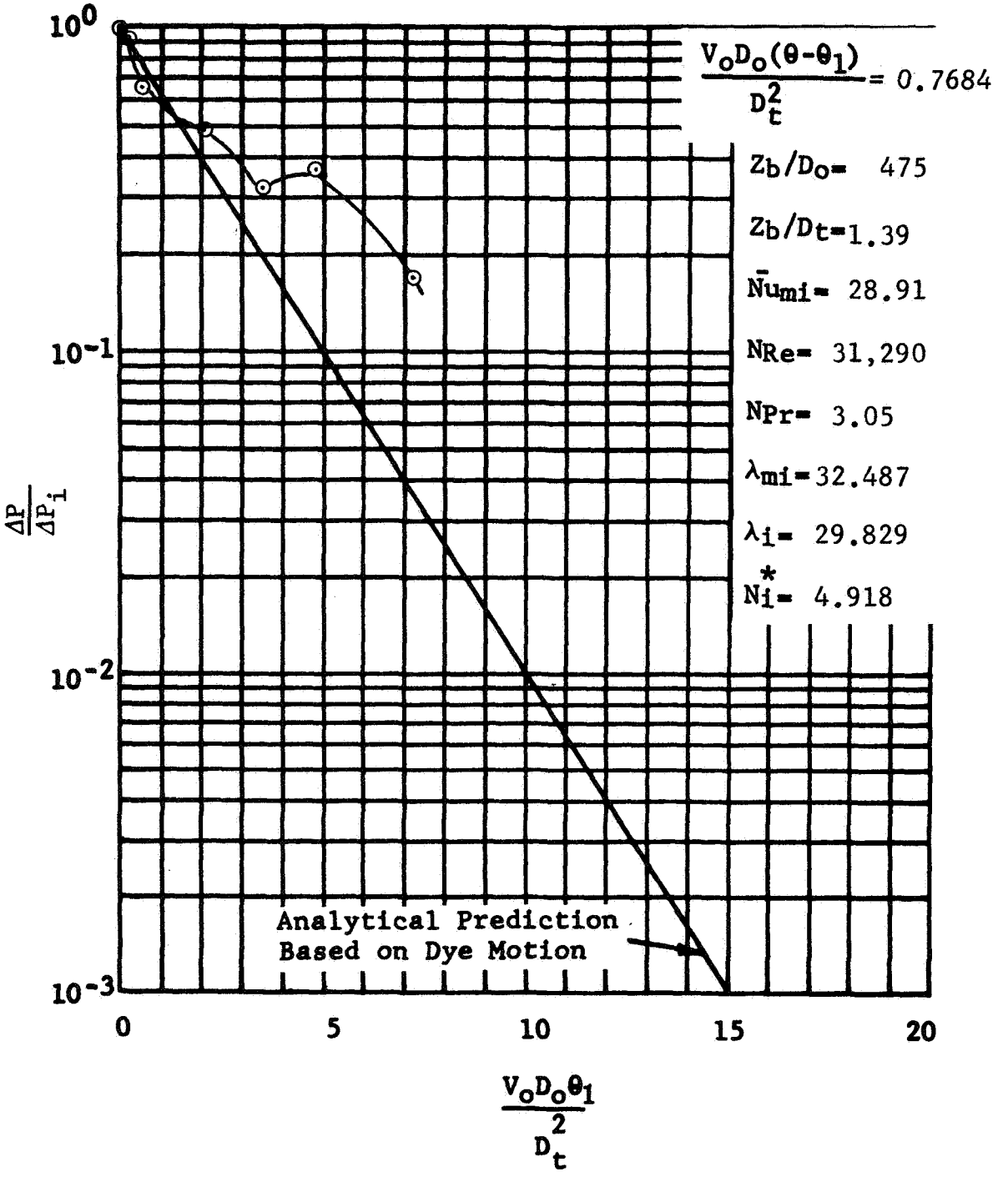

Figure 3.0-26 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 11

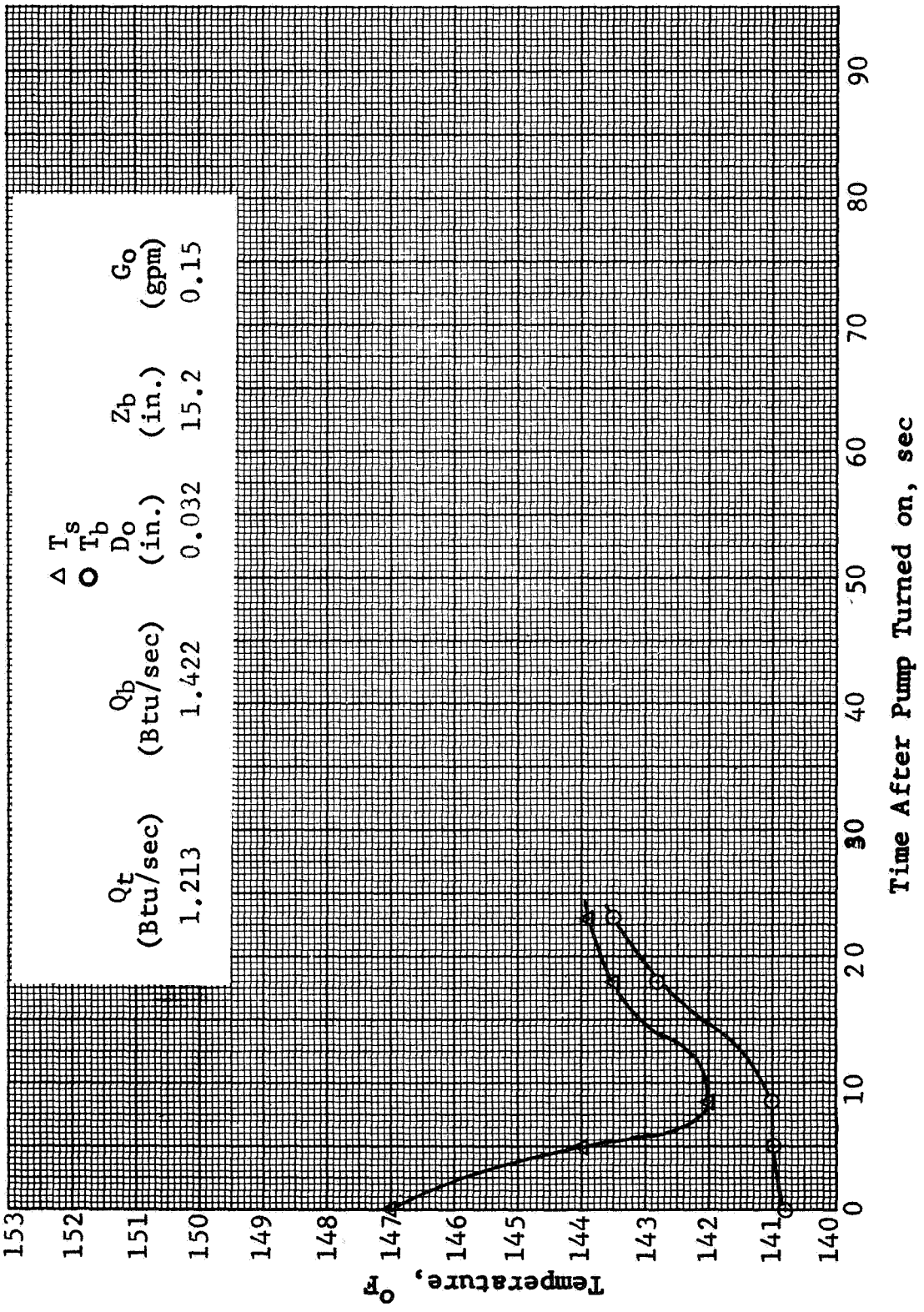

Figure 3.0-27 **Transient Temperature Destratification:** Test 12, Run 11

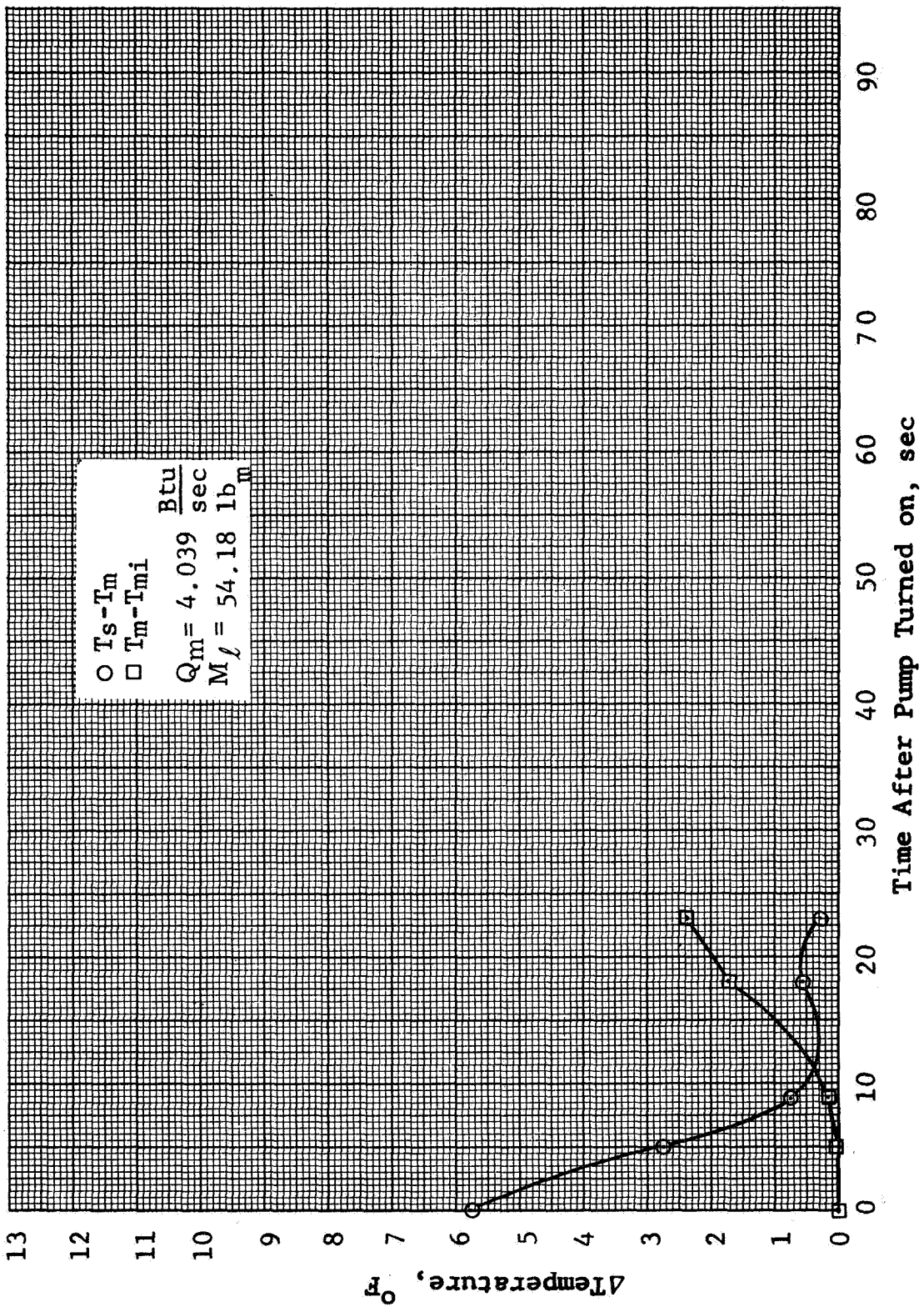

Figure 3.0-28 Transient ΔTemperature Destratification: Test 12, Run 11

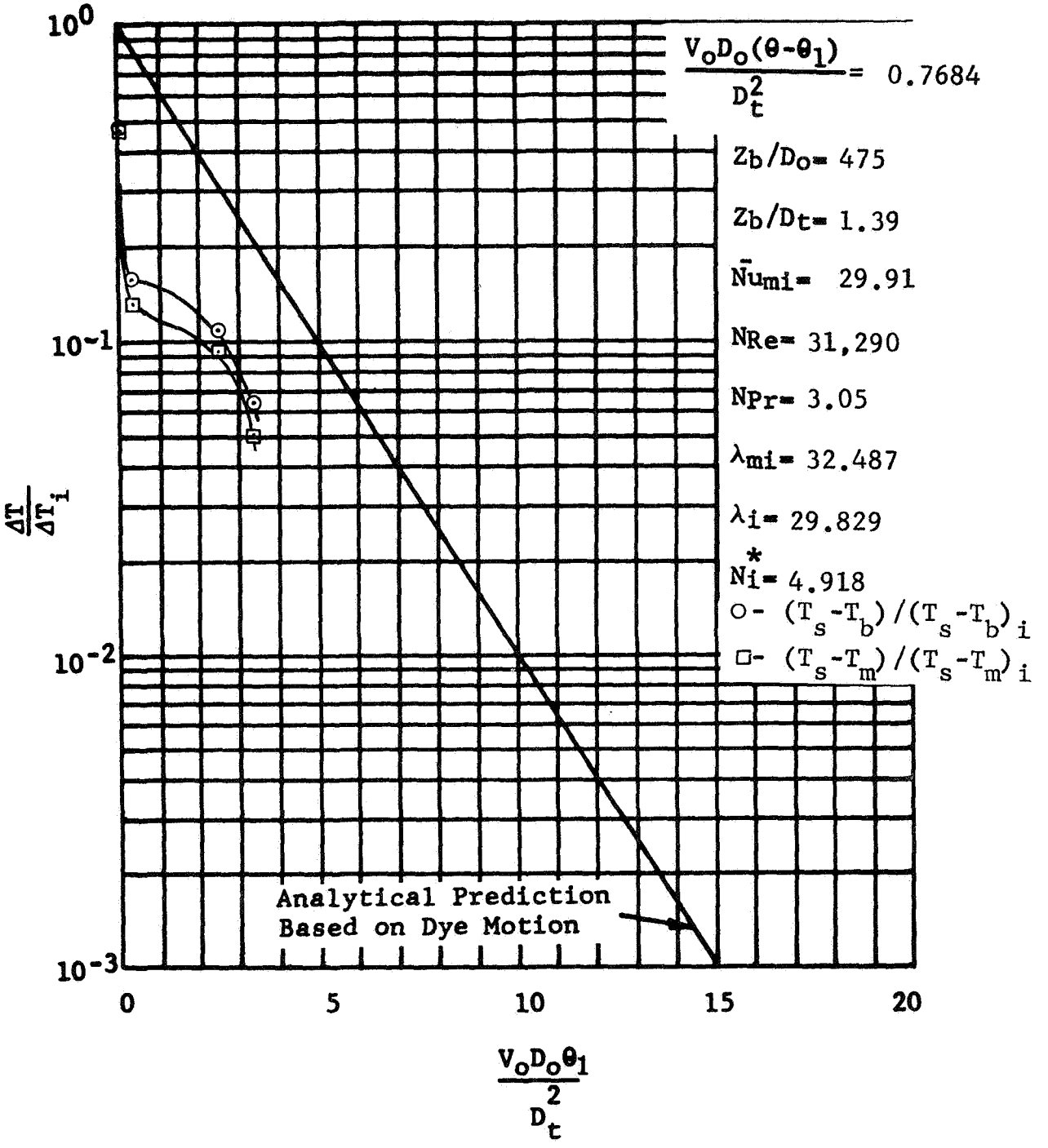

Figure 3.0-29 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 12, Run 11

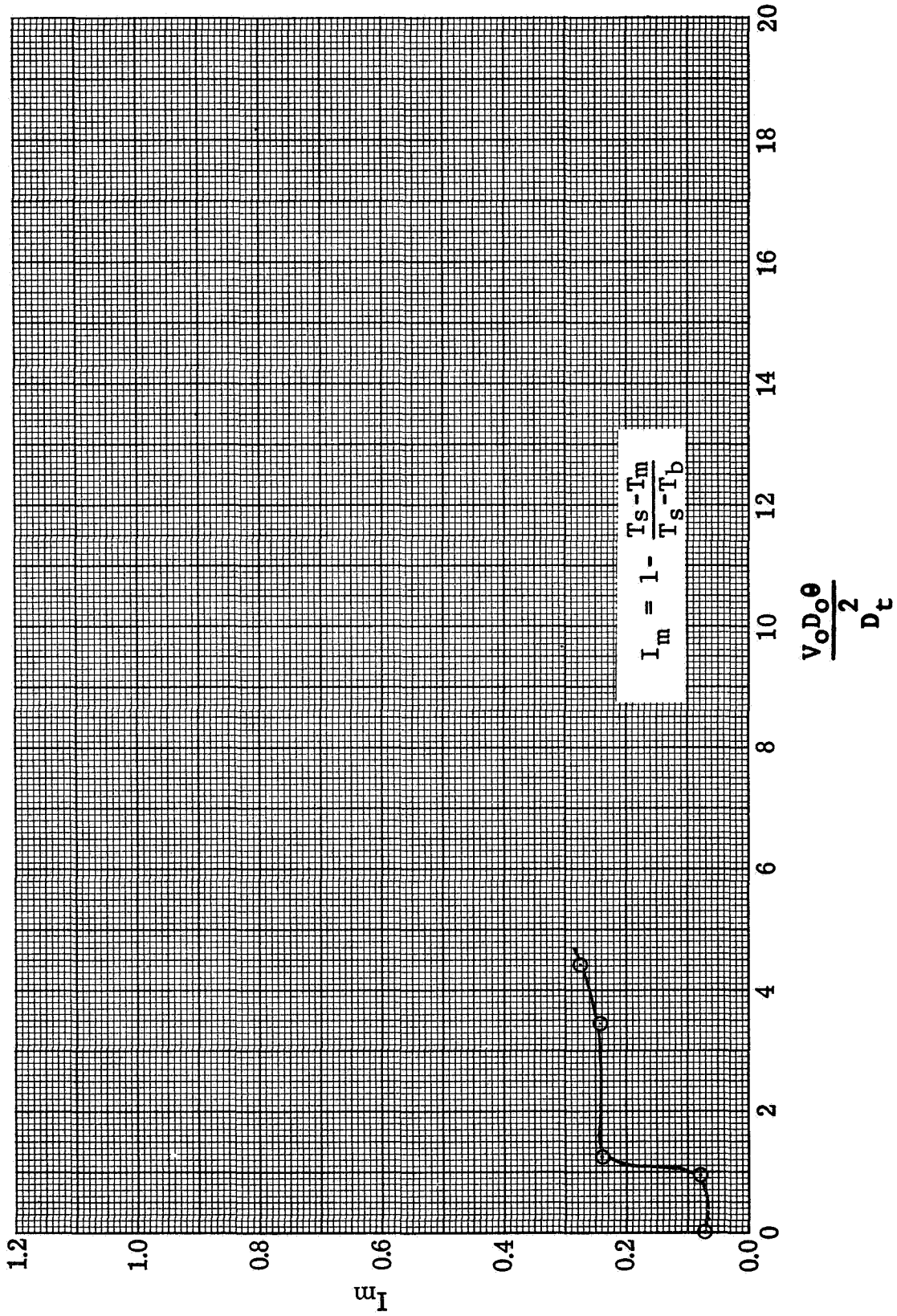

Figure 3.0-30 Transient Energy Integral: Test 12, Run 11

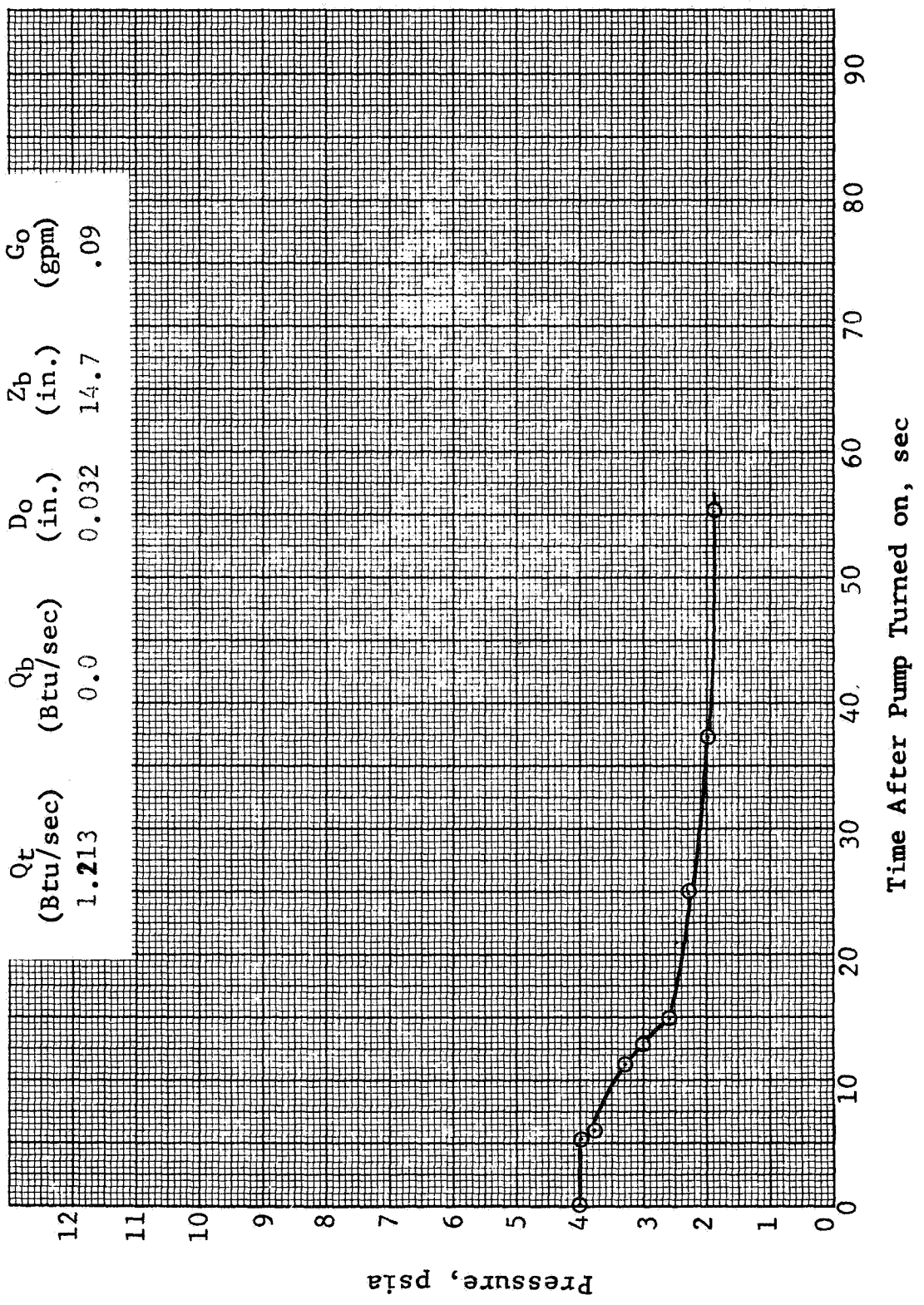

Figure 3.0-31 Transient Pressure Decay: Test 13, Run 14

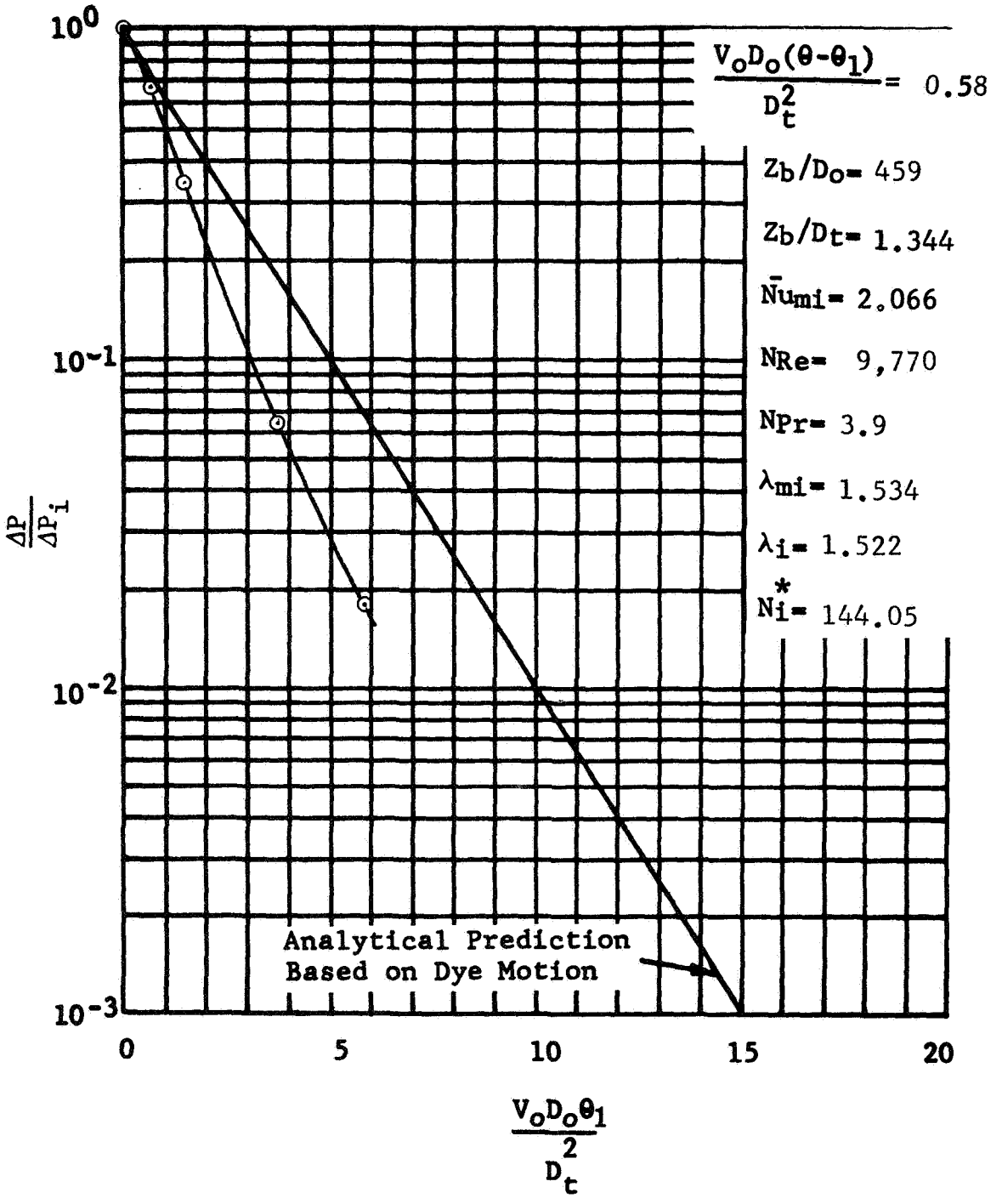

Figure 3.0-32 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 14

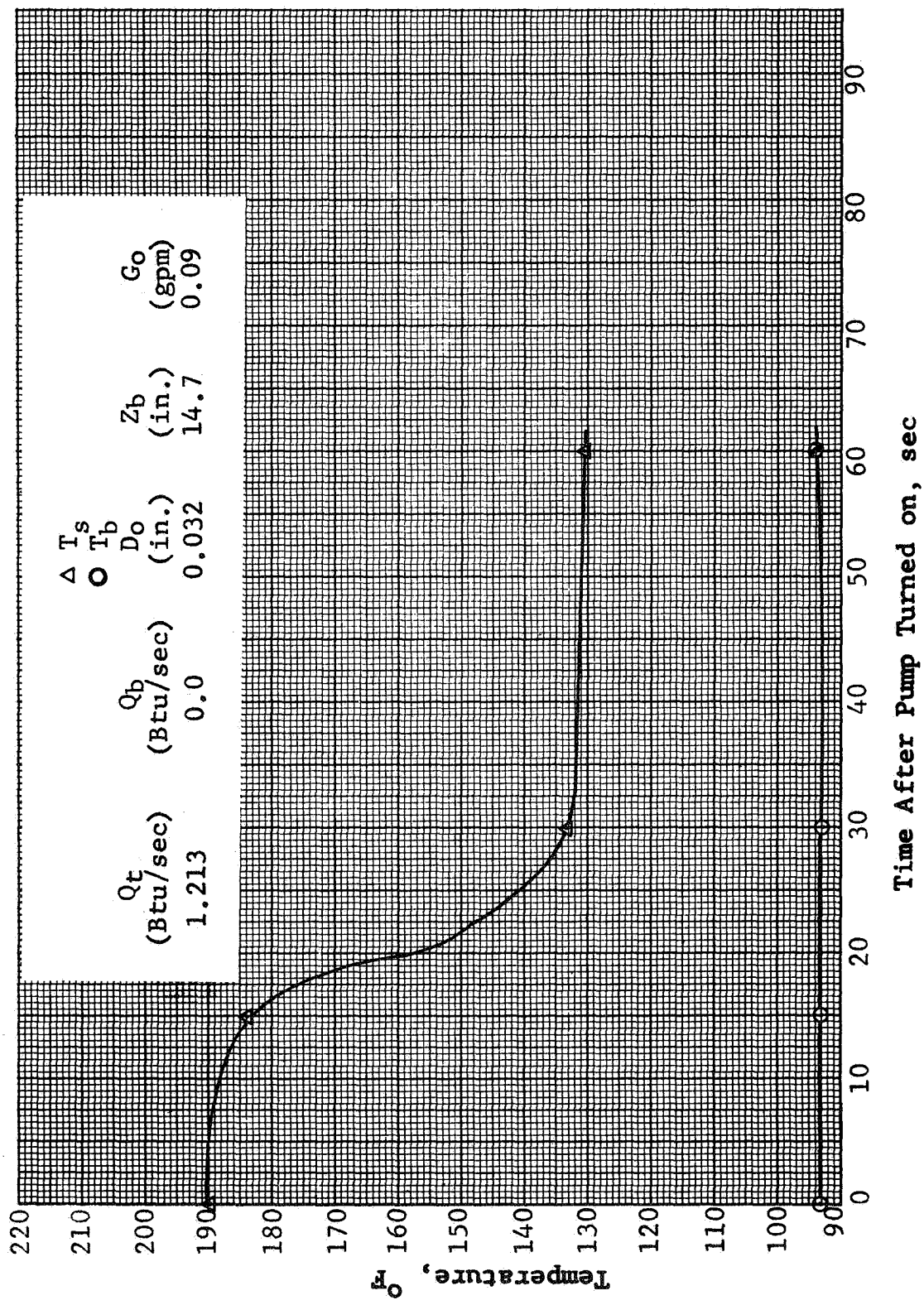

Figure 3.0-33 Transient Temperature Destratification: Test 13, Run 14

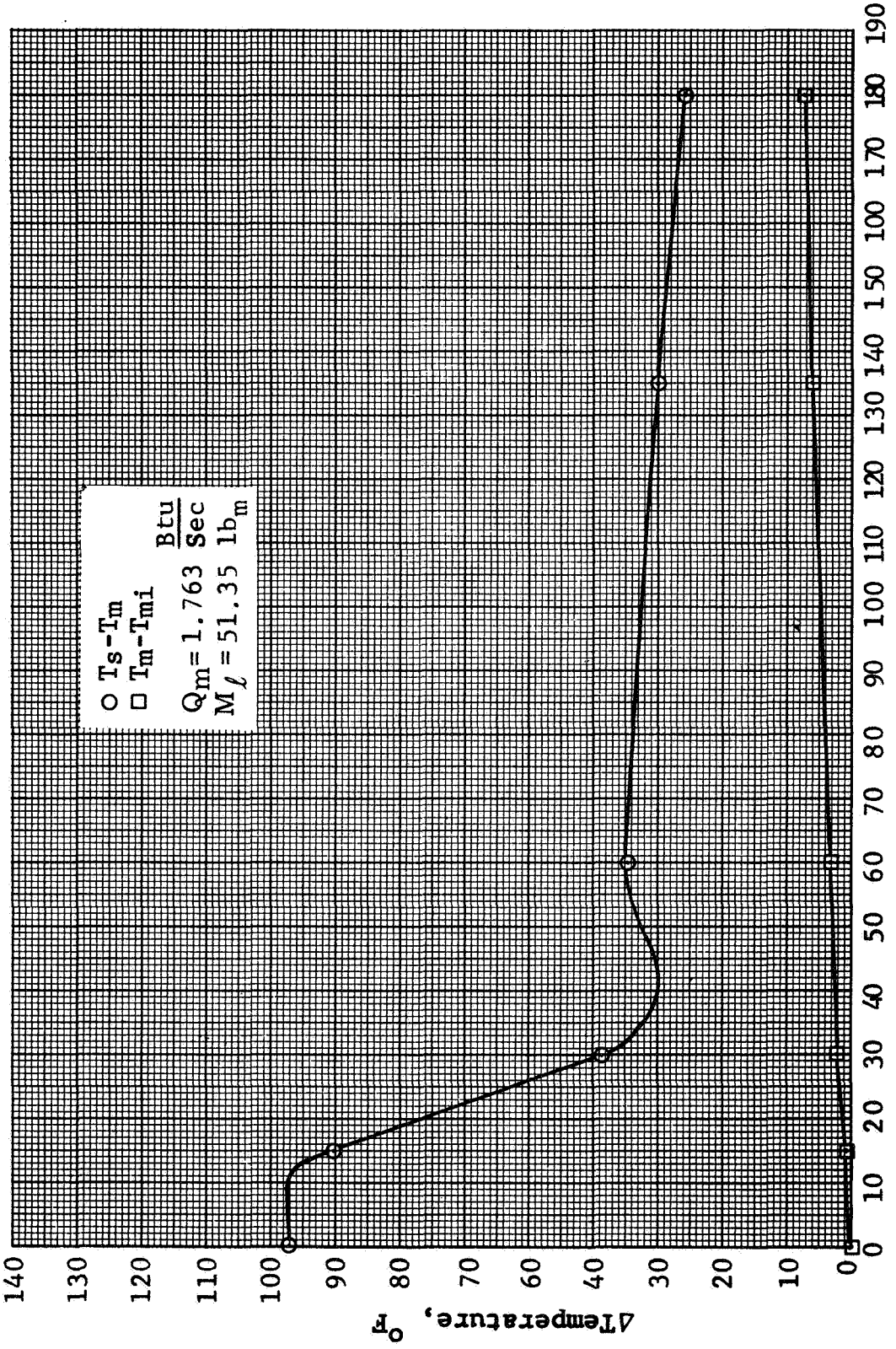

Figure 3.0-34 Transient ΔTemperature Destratification: Test 13, Run 14

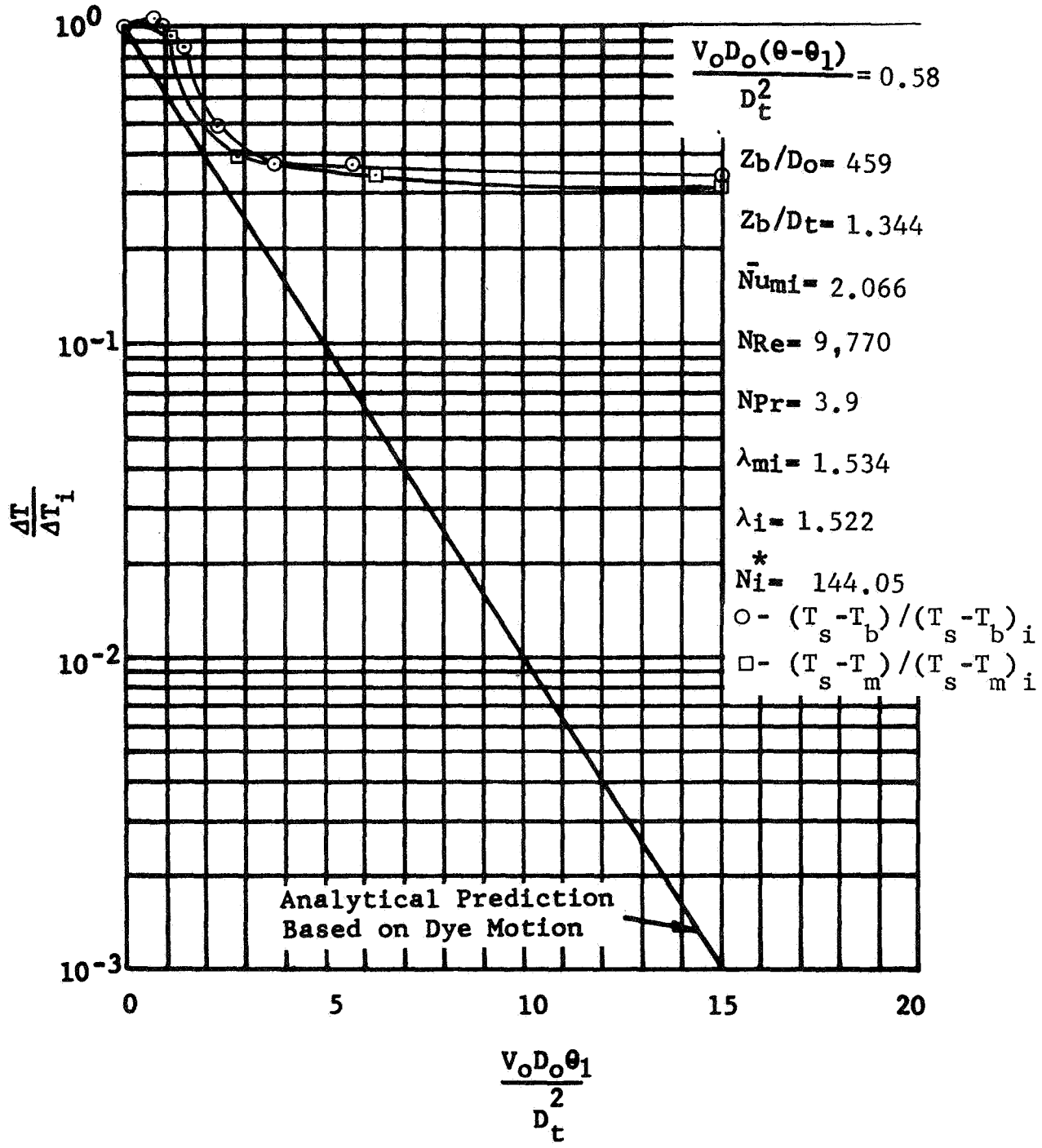

Figure 3.0-35 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 14

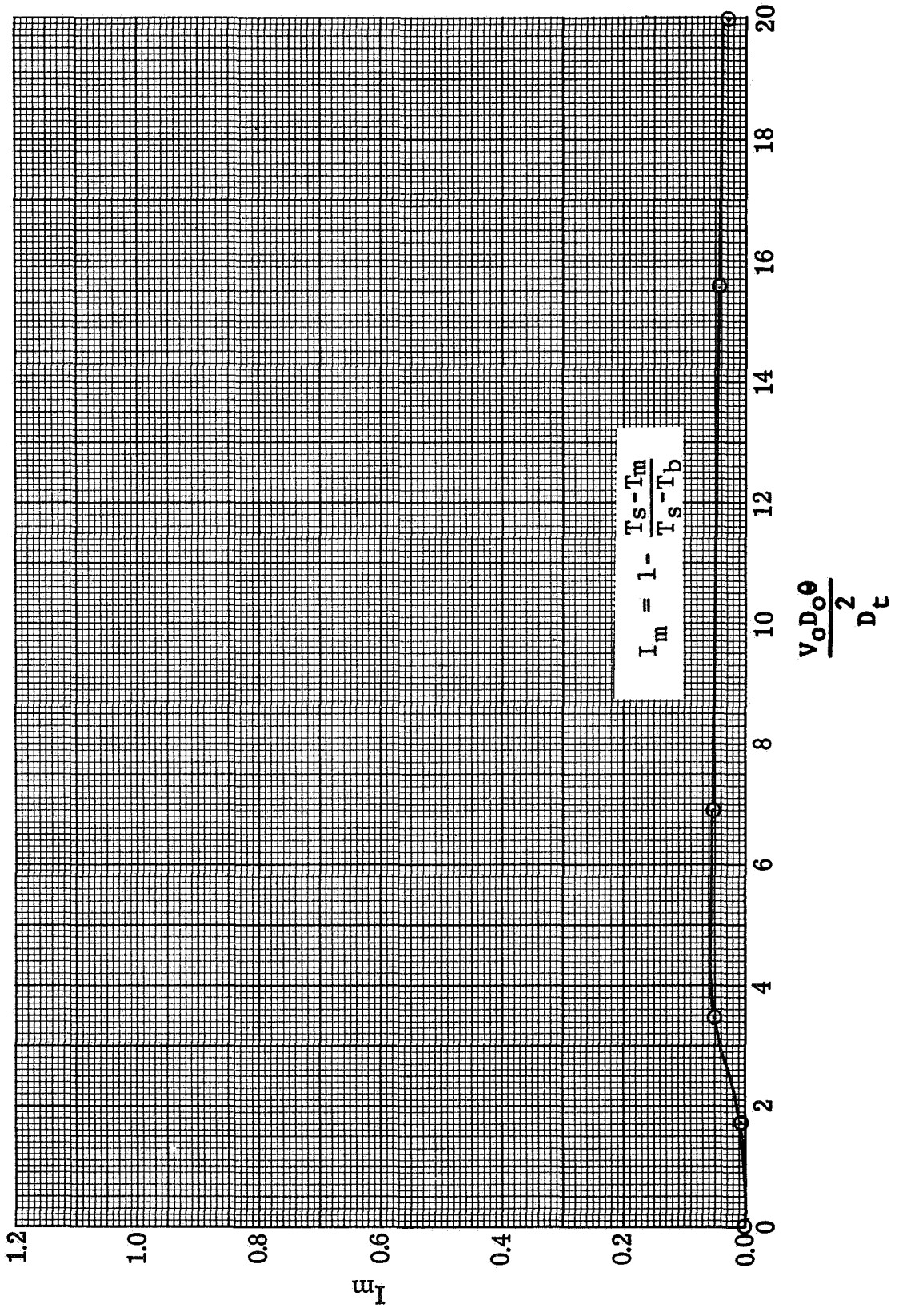

Figure 3.0-36 Transient Energy Integral: Test 13, Run 14

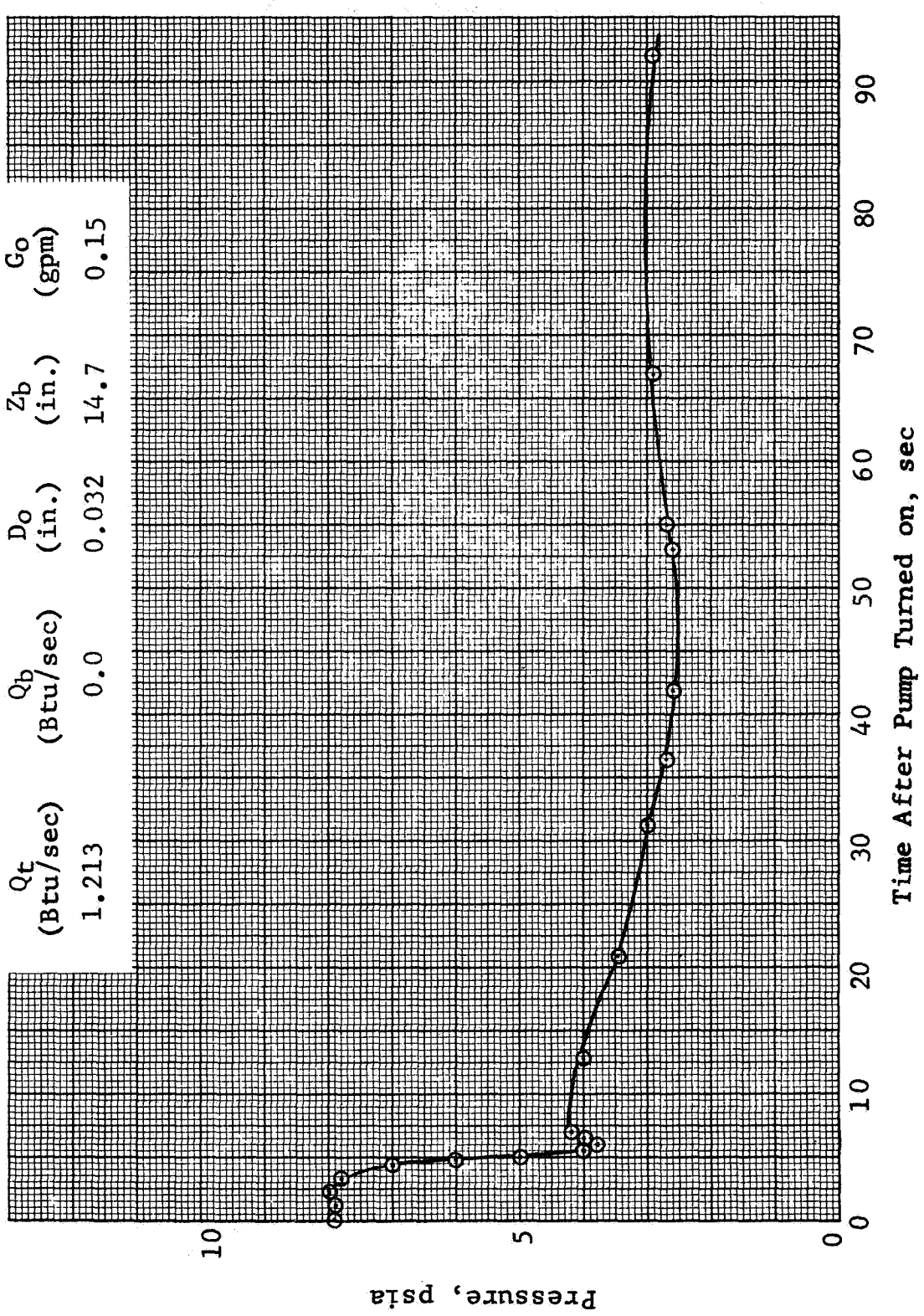

Figure 3.0-37 Transient Pressure Decay : Test 13, Run 15

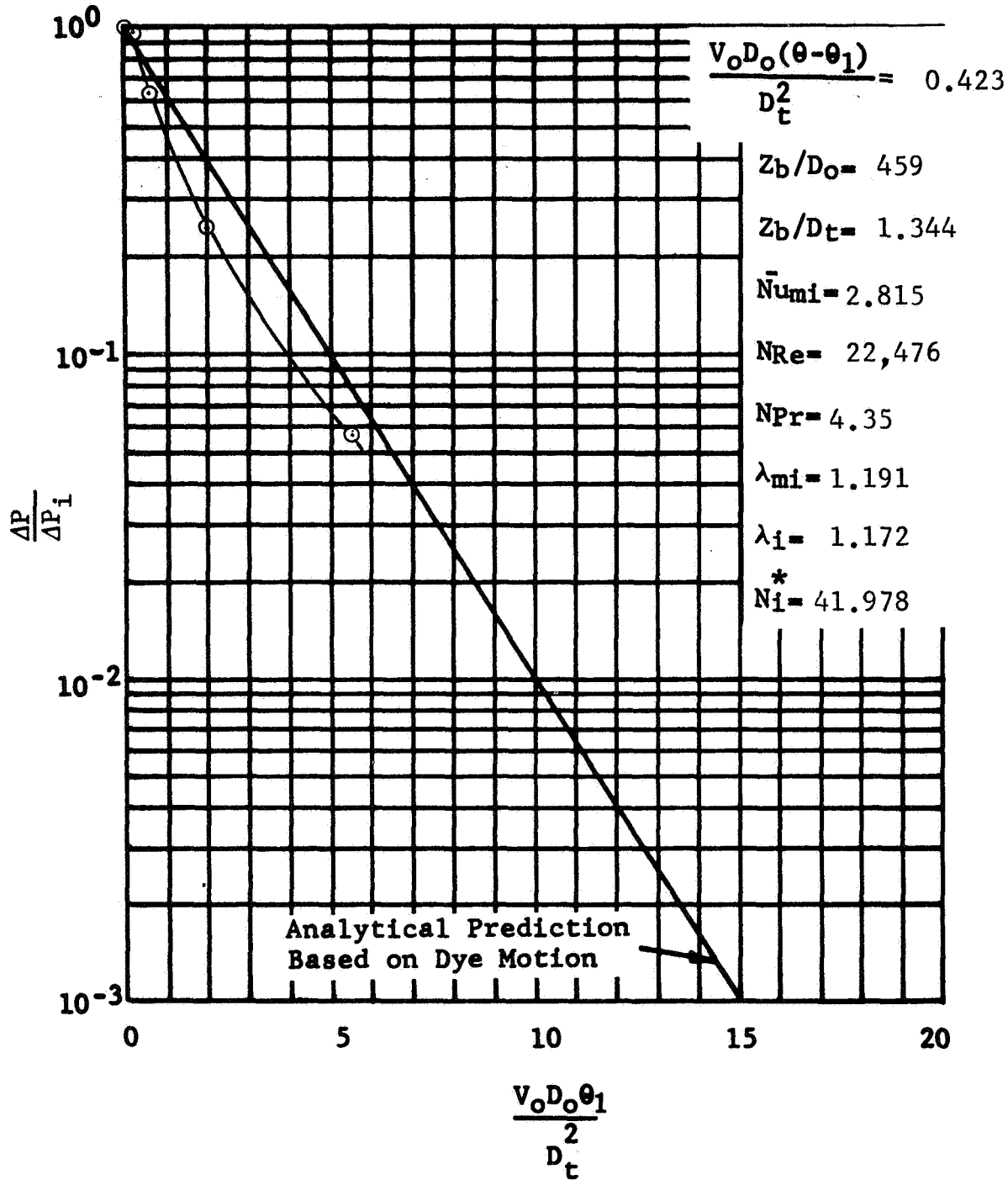

Figure 3.0-38 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 15

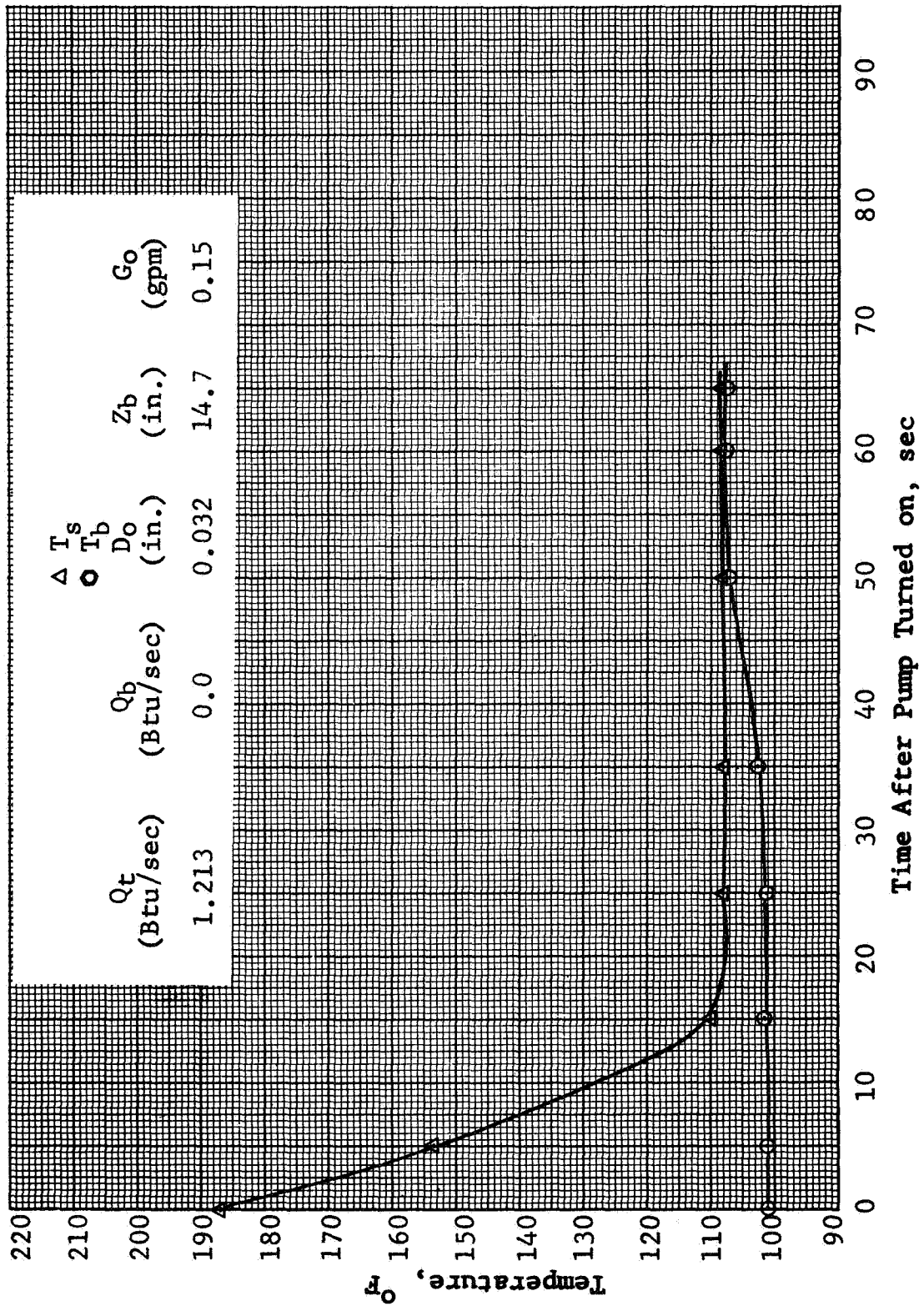

Figure 3.0-39 **Transient Temperature Destratification:** Test 13, Run 15

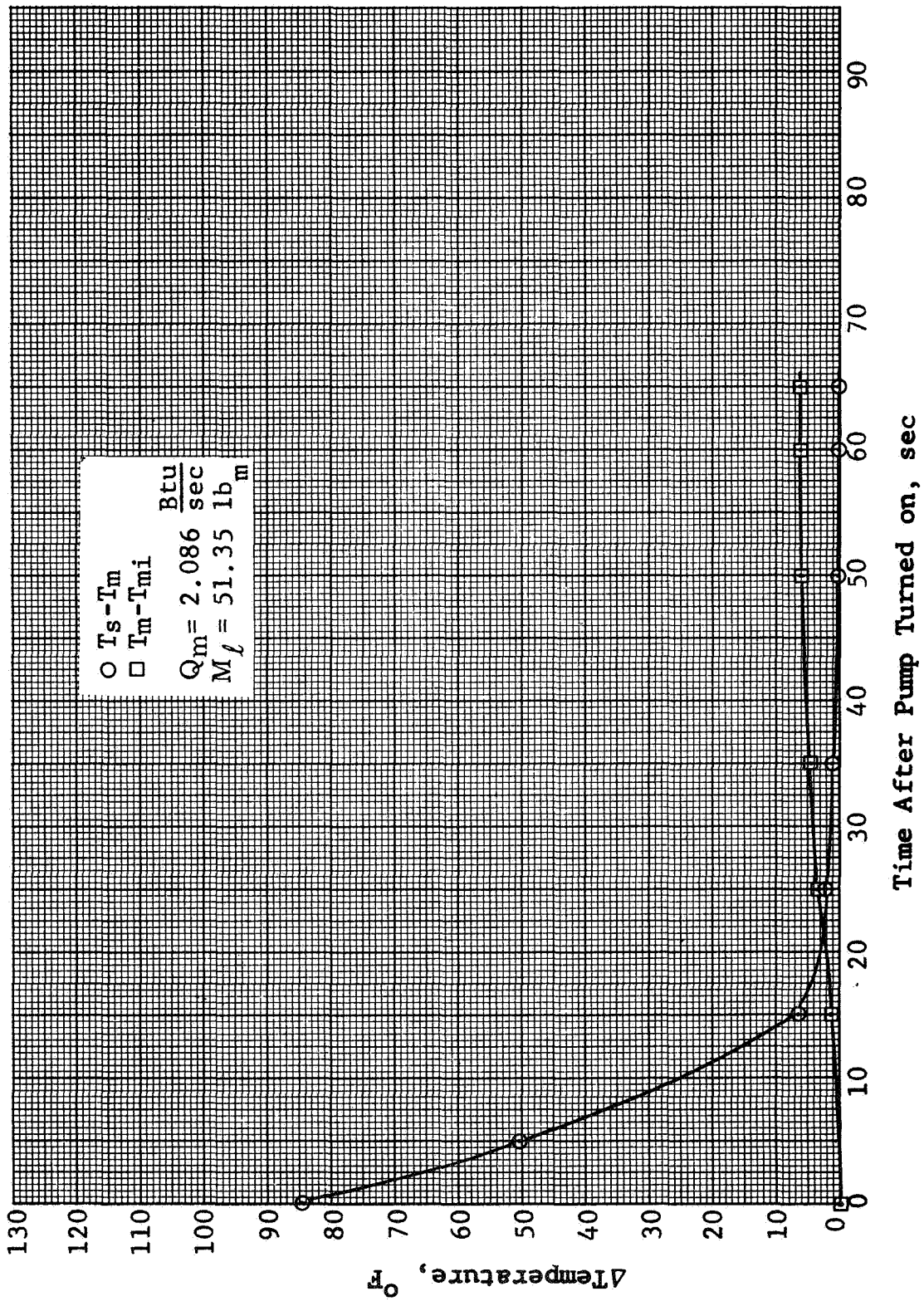

Figure 3.0-40 Transient ΔTemperature Destratification: Test 13, Run 15

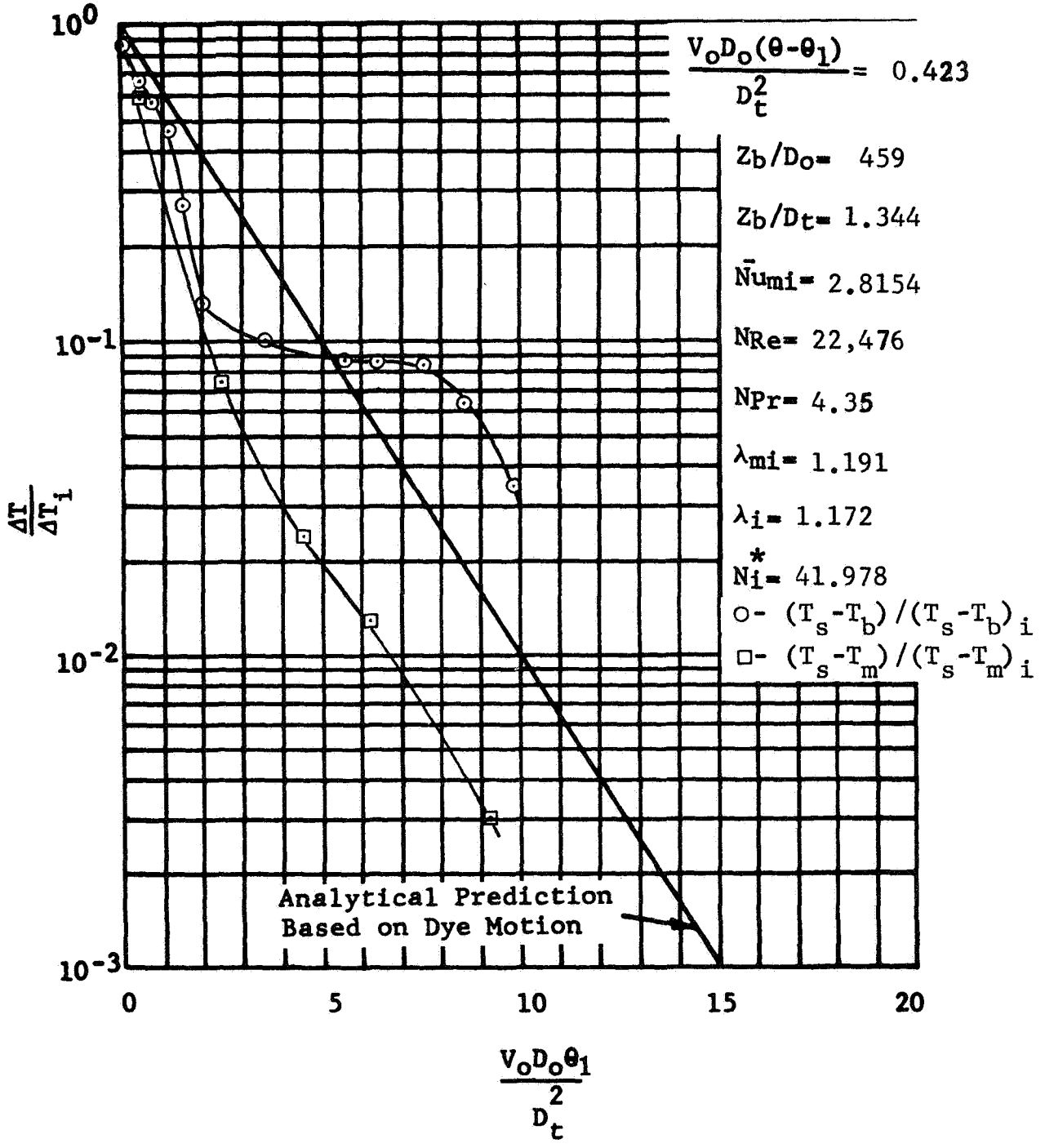

Figure 3.0-41 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 15

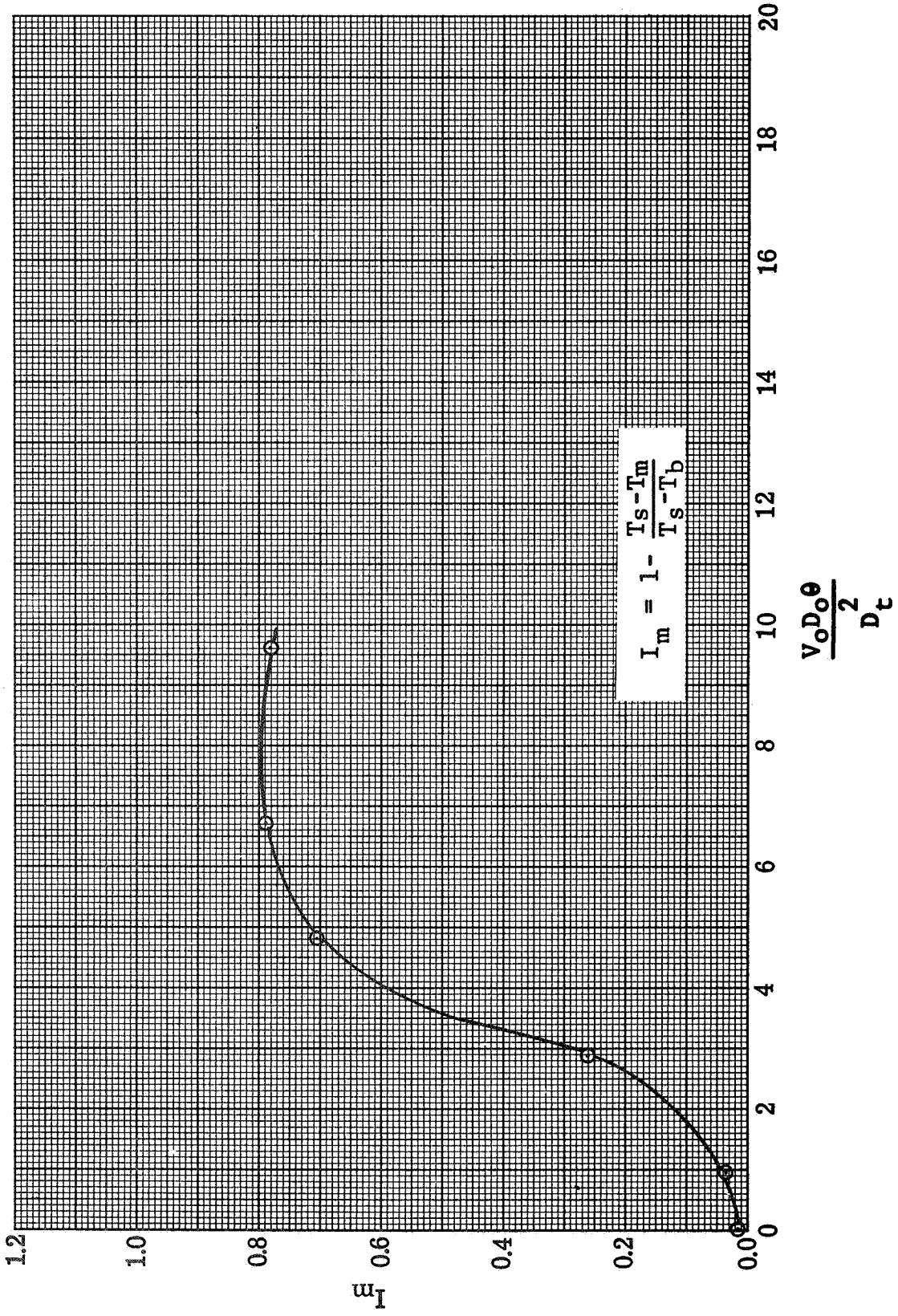

Figure 3.0-42 Transient Energy Integral: Test 13, Run 15

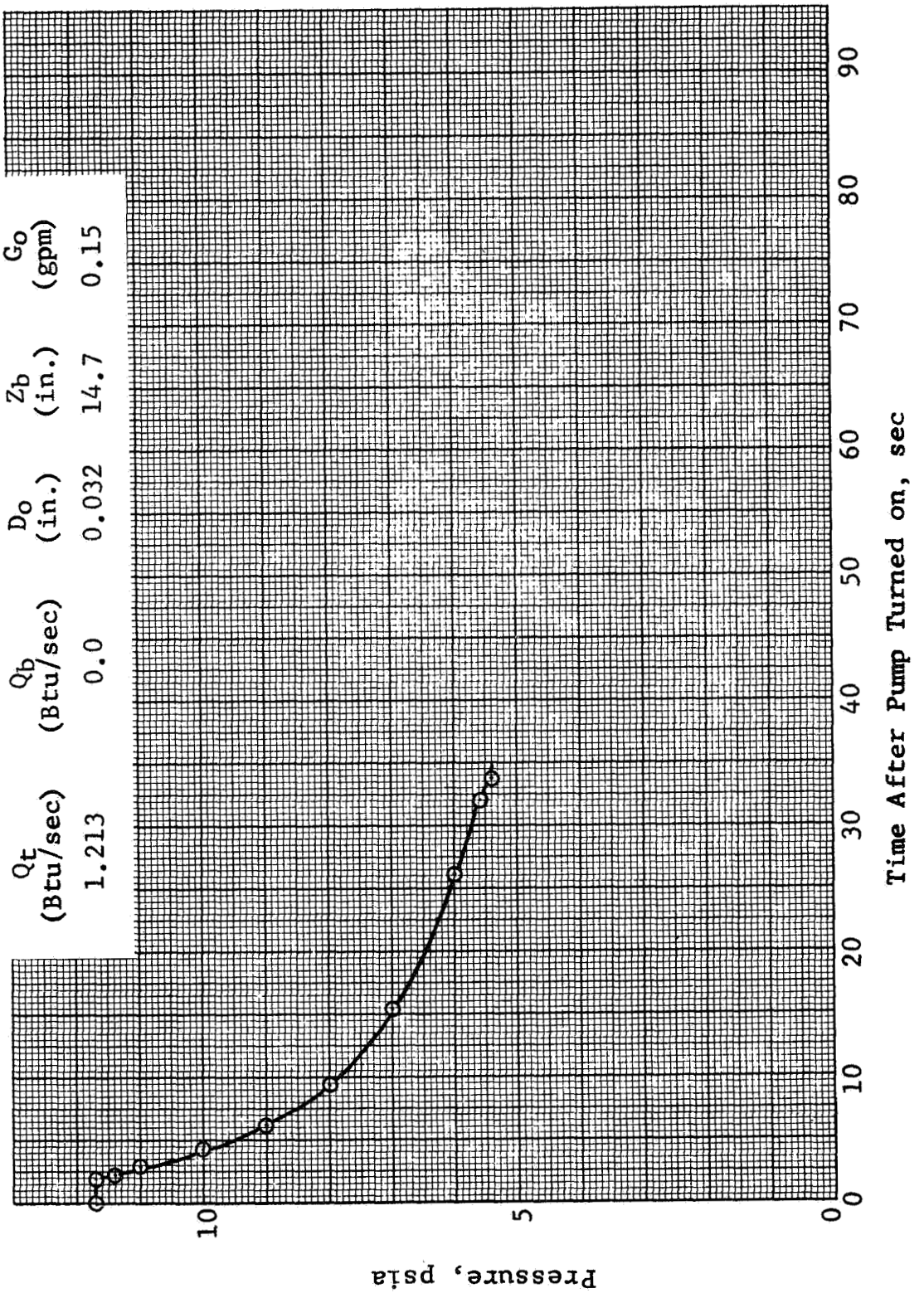

Figure 3.0-43 Transient Pressure Decay: Test 13, Run 17

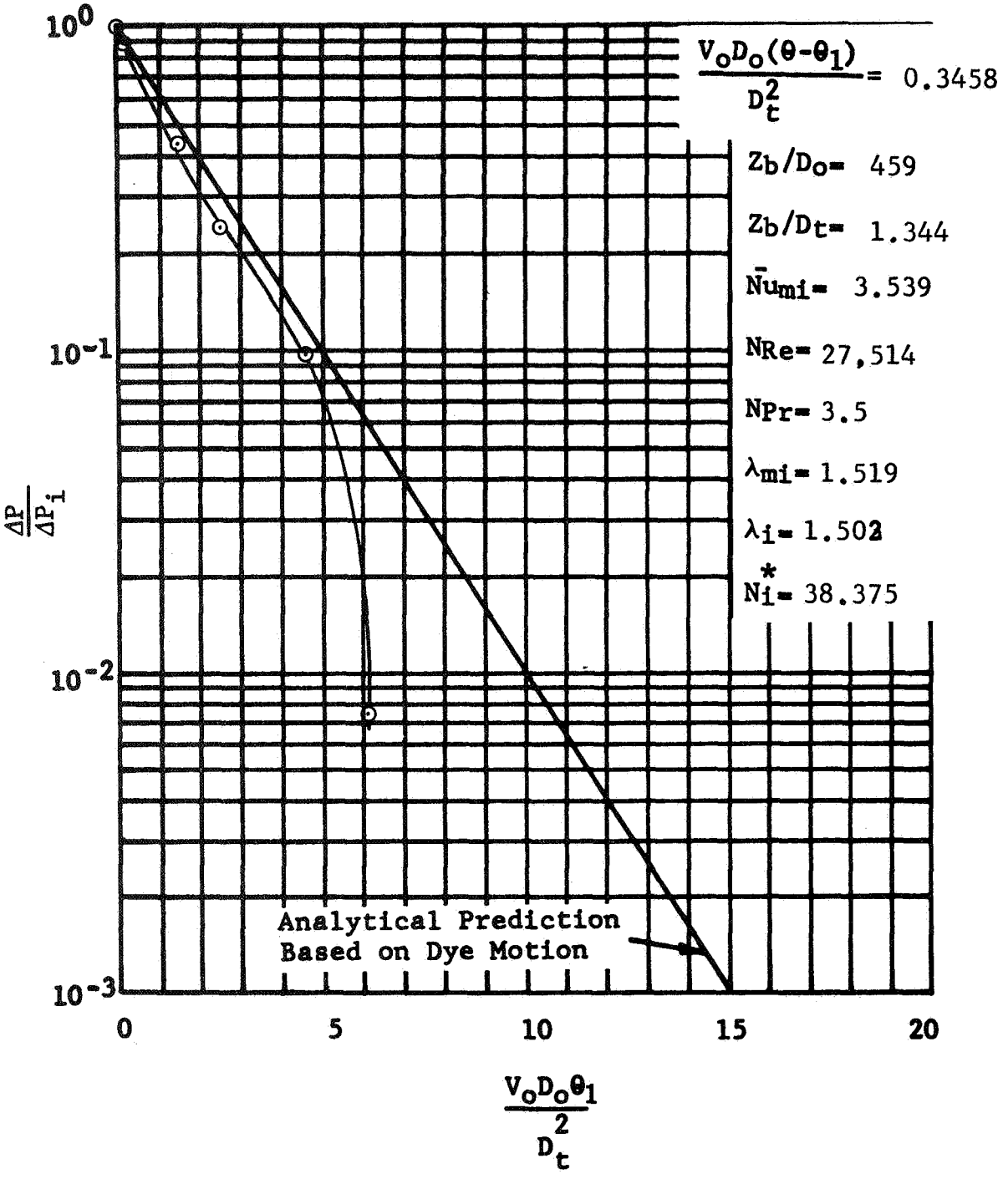

Figure 3.0-44 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 17

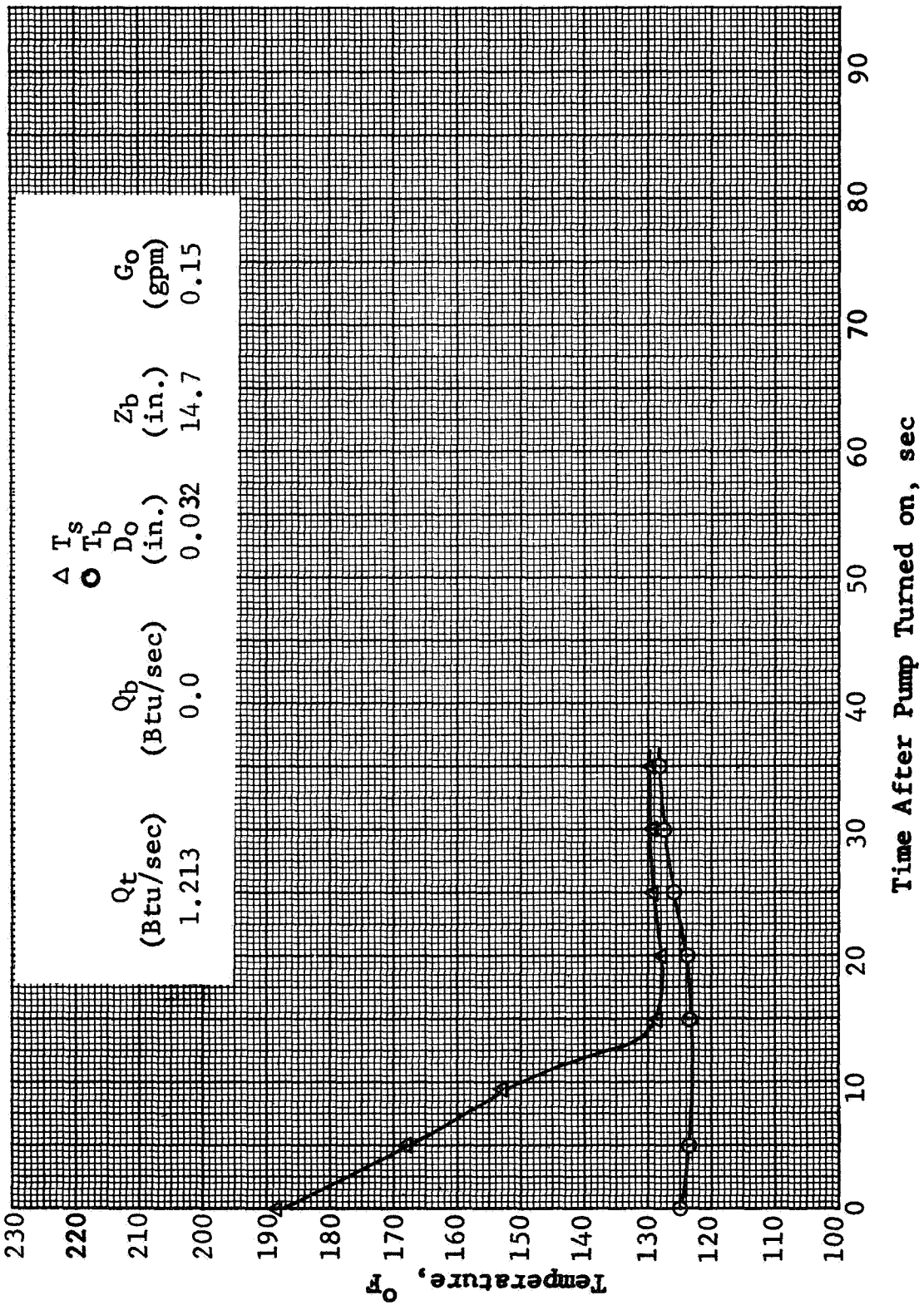

Figure 3.0-45 **Transient Temperature Destratification:** Test 13, Run 17

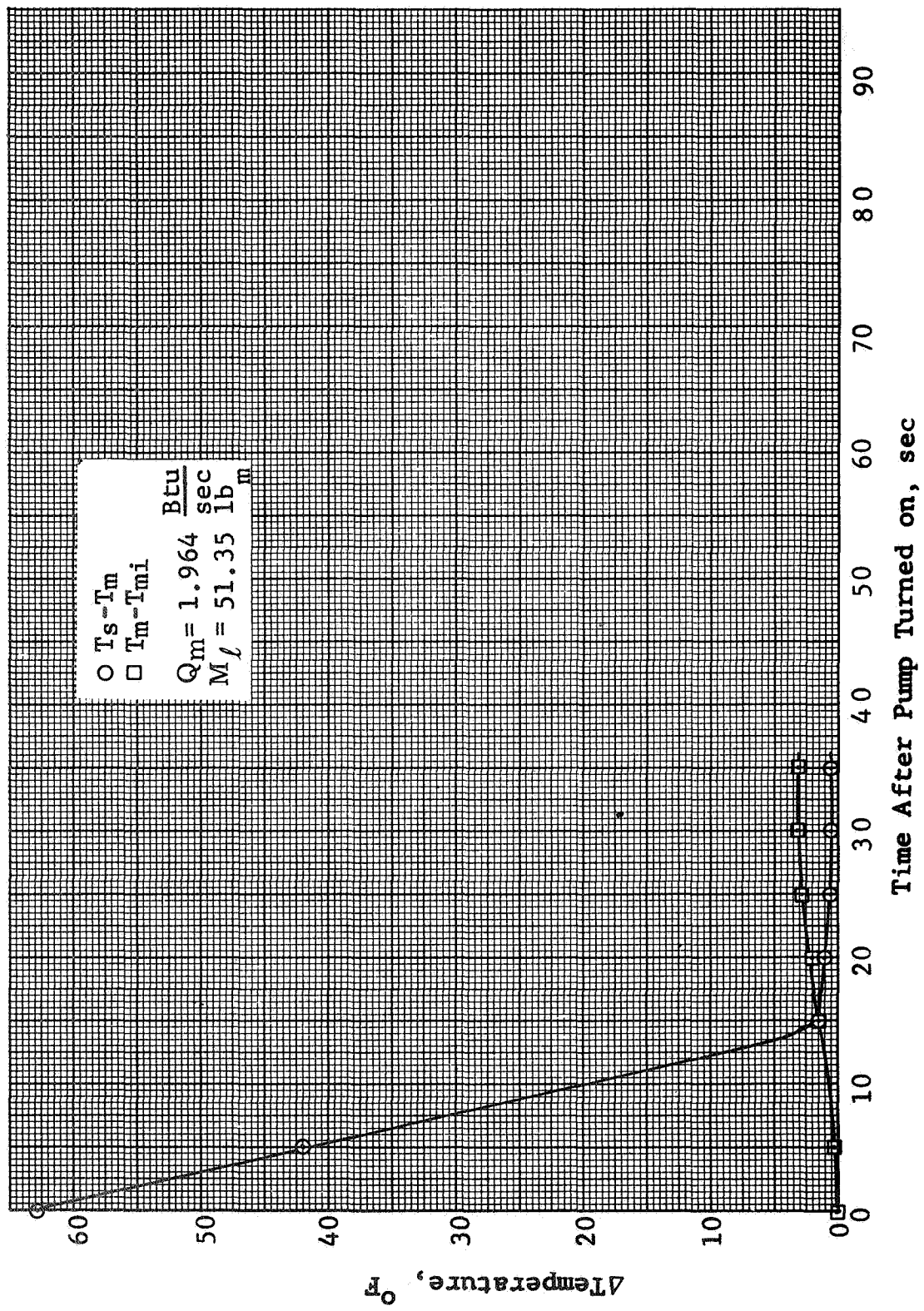

Figure 3.0-46 Transient ΔTemperature Destratification: Test 13, Run 17

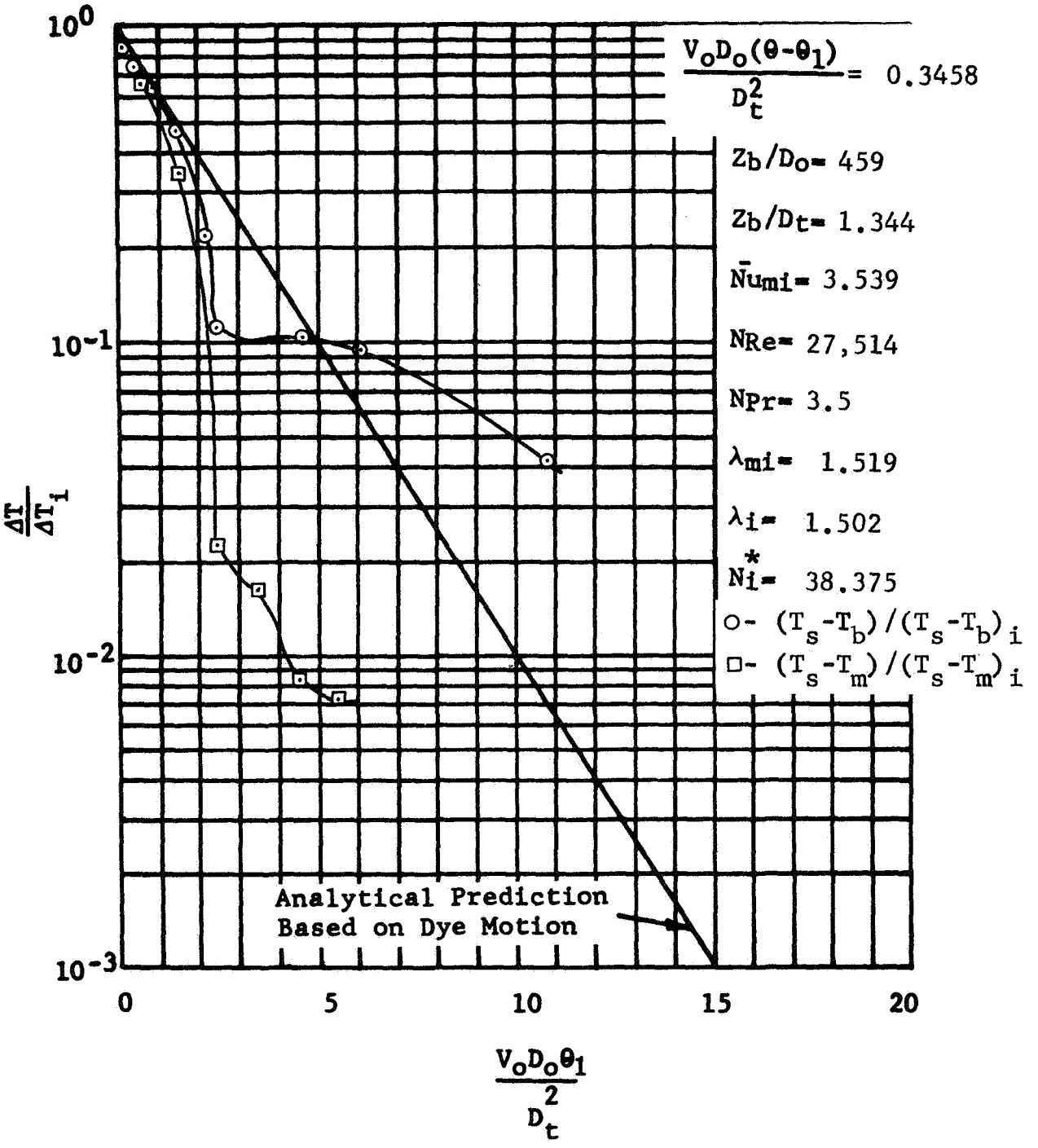

Figure 3.0-47 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 17

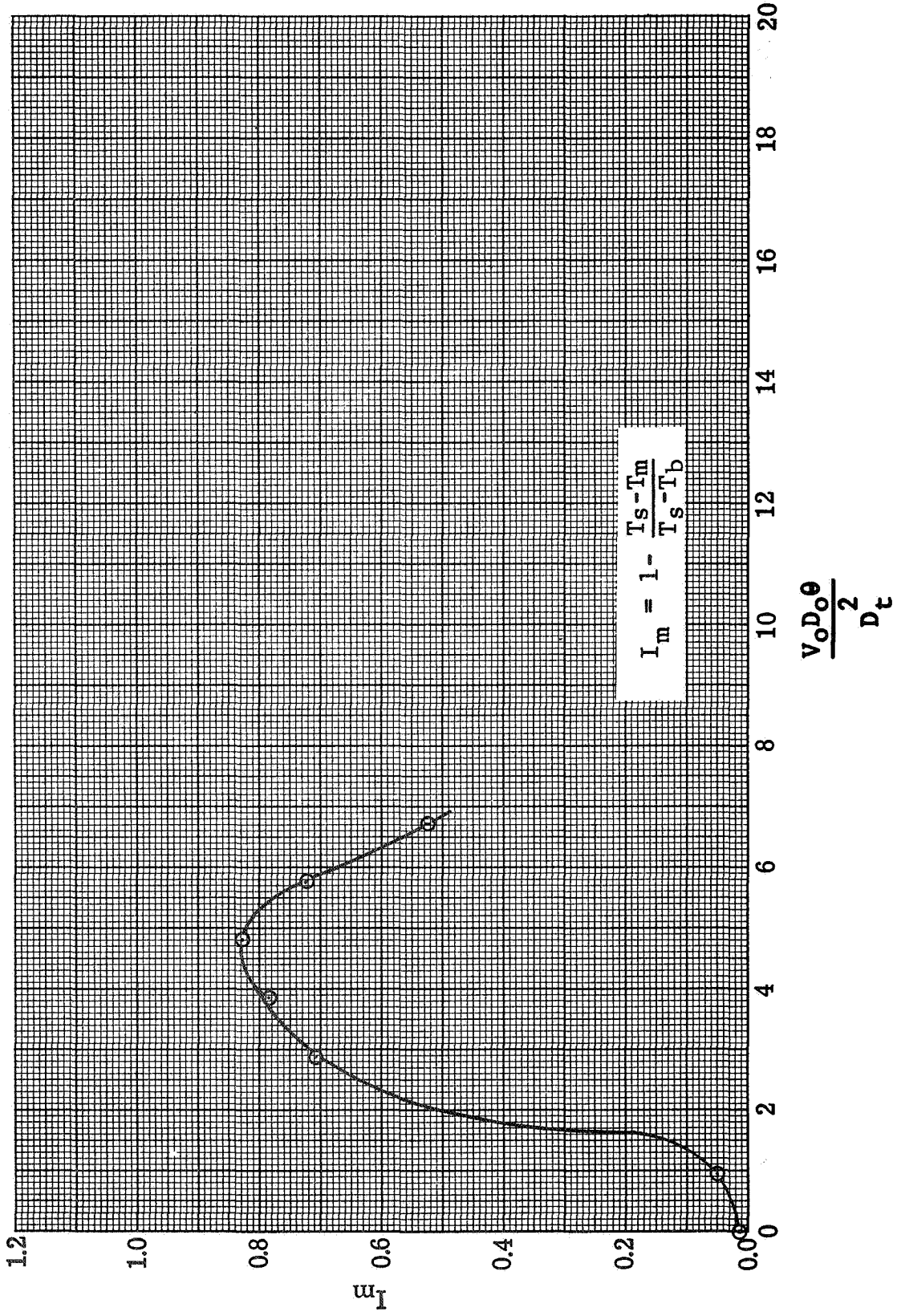

Figure 3.0-48 Transient Energy Integral: Test 13, Run 17

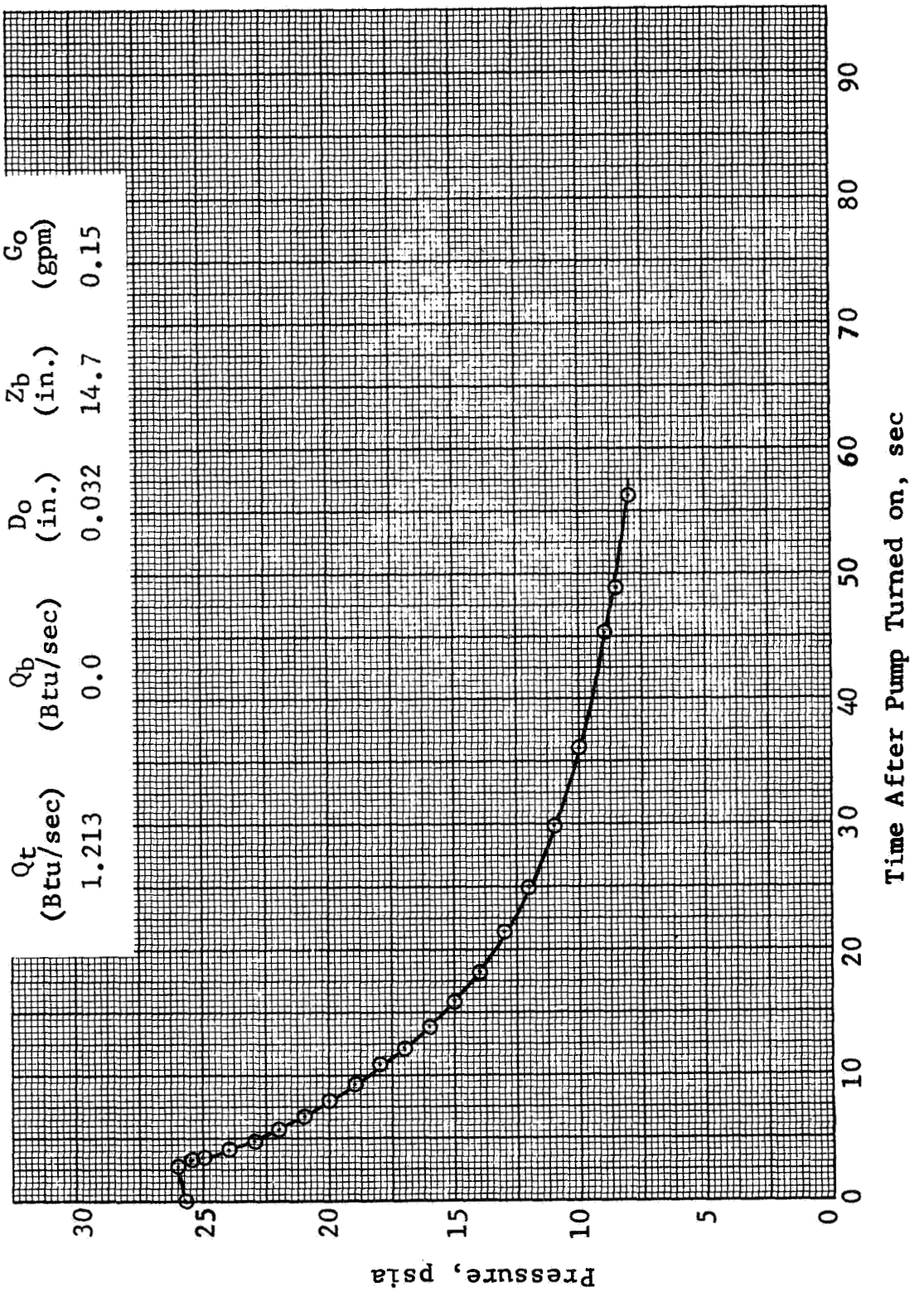

Figure 3.0-49 Transient Pressure Decay: Test 13, Run 18

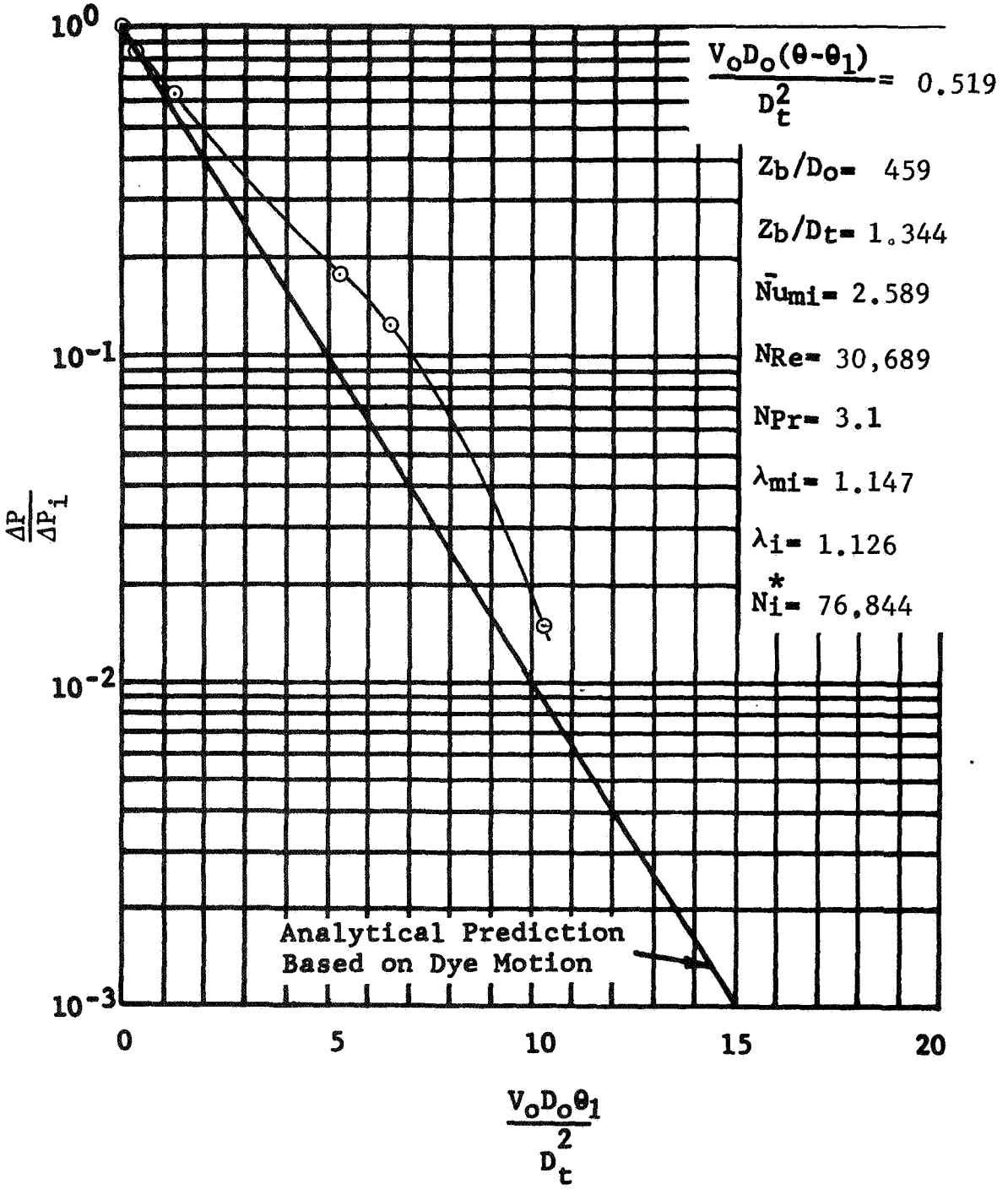

Figure 3.0-50 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 18

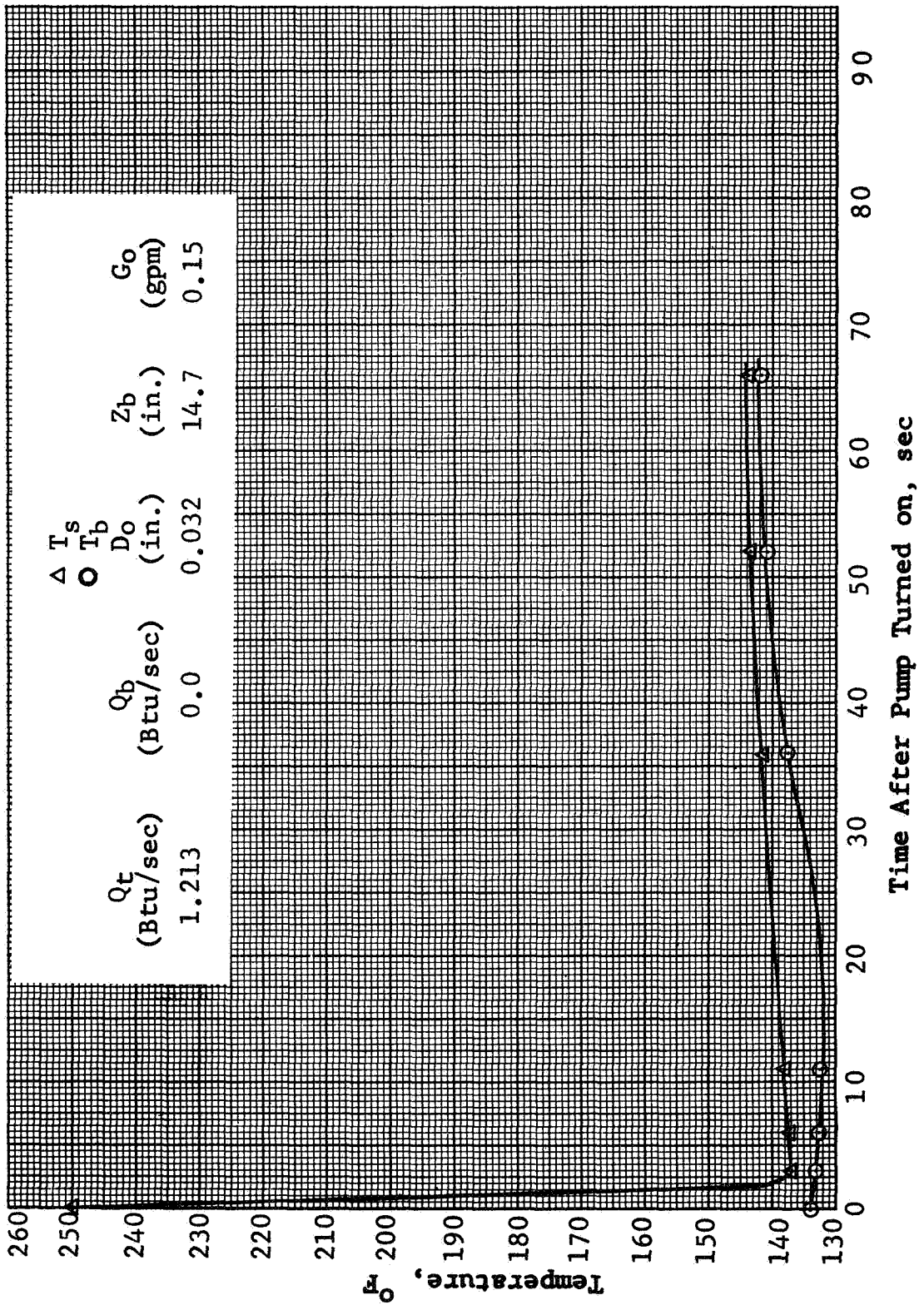

Figure 3.0-51 **Transient Temperature Destratification:** Test 13, Run 18

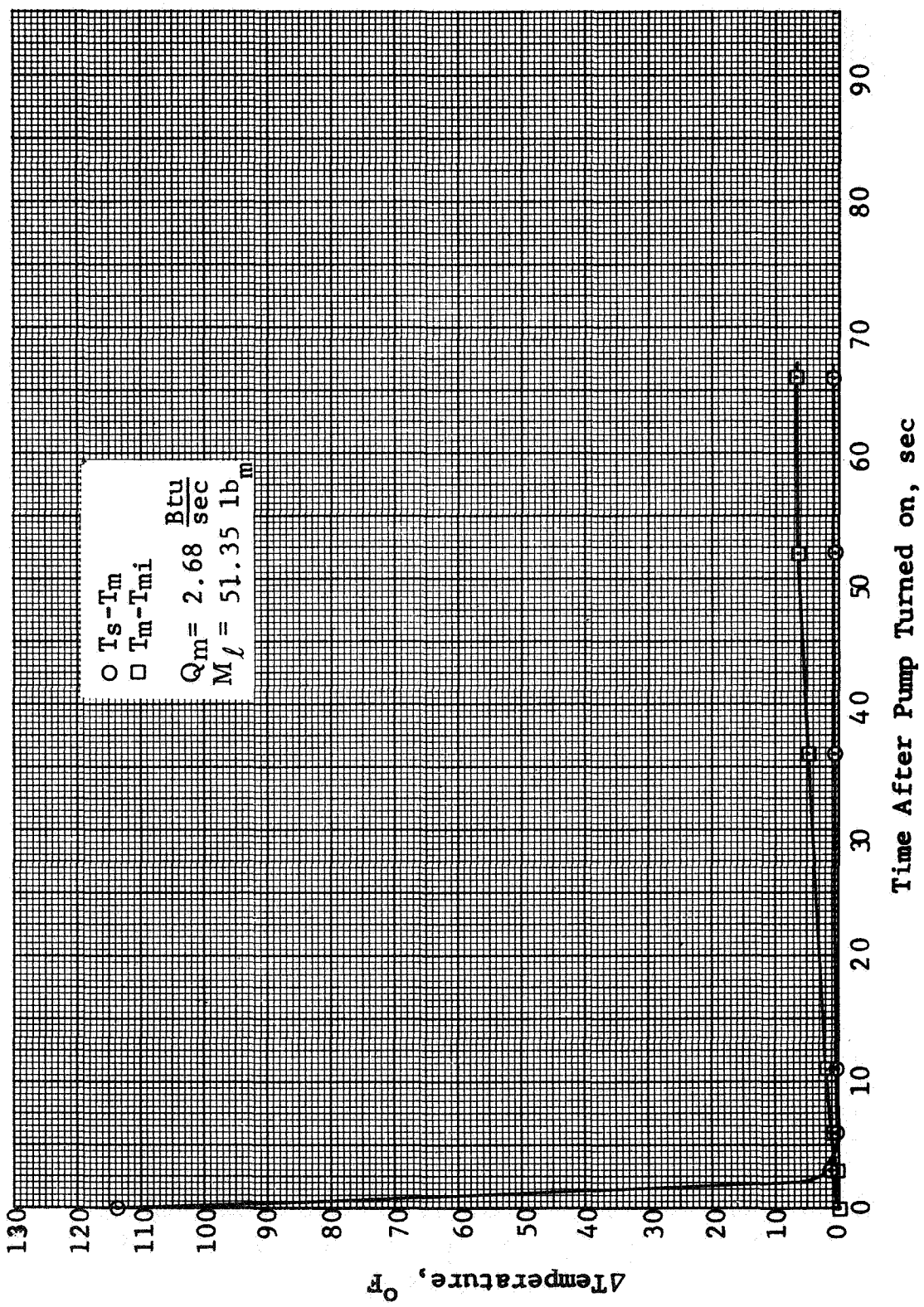

Figure 3.0-52 Transient ΔTemperature Destratification: Test 13, Run 18

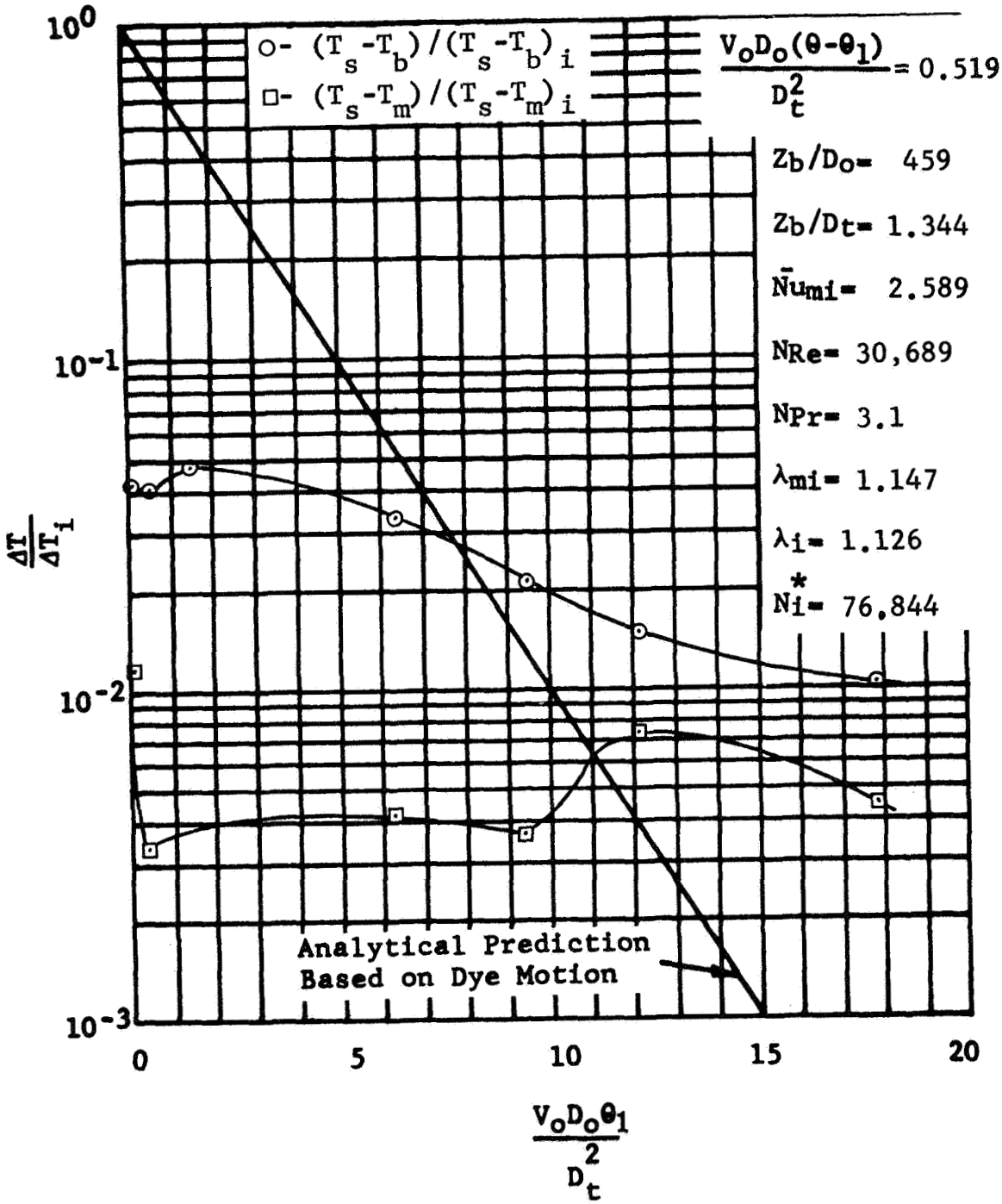

Figure 3.0-53 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 18

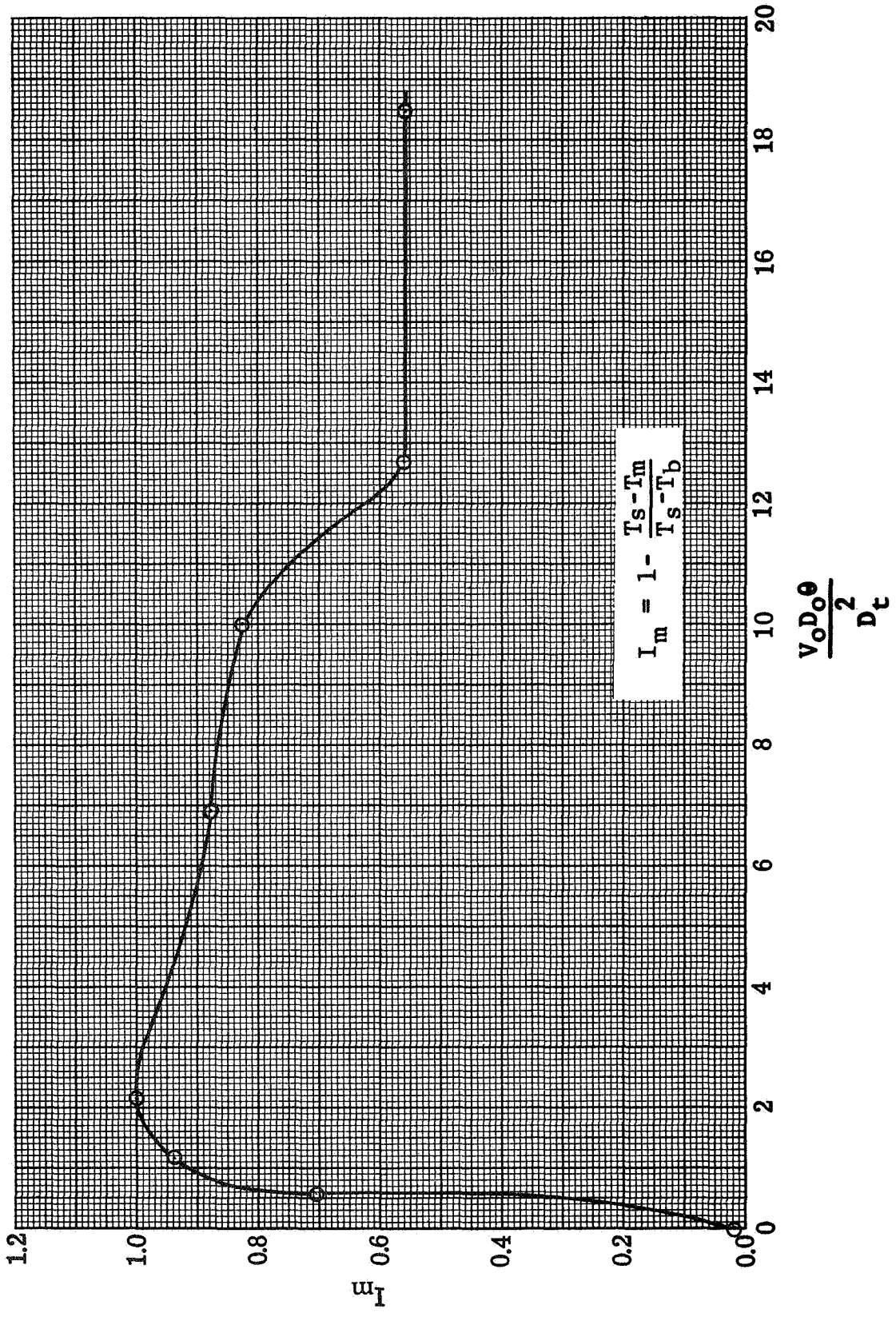

Figure 3.0-54 Transient Energy Integral: Test 13, Run 18

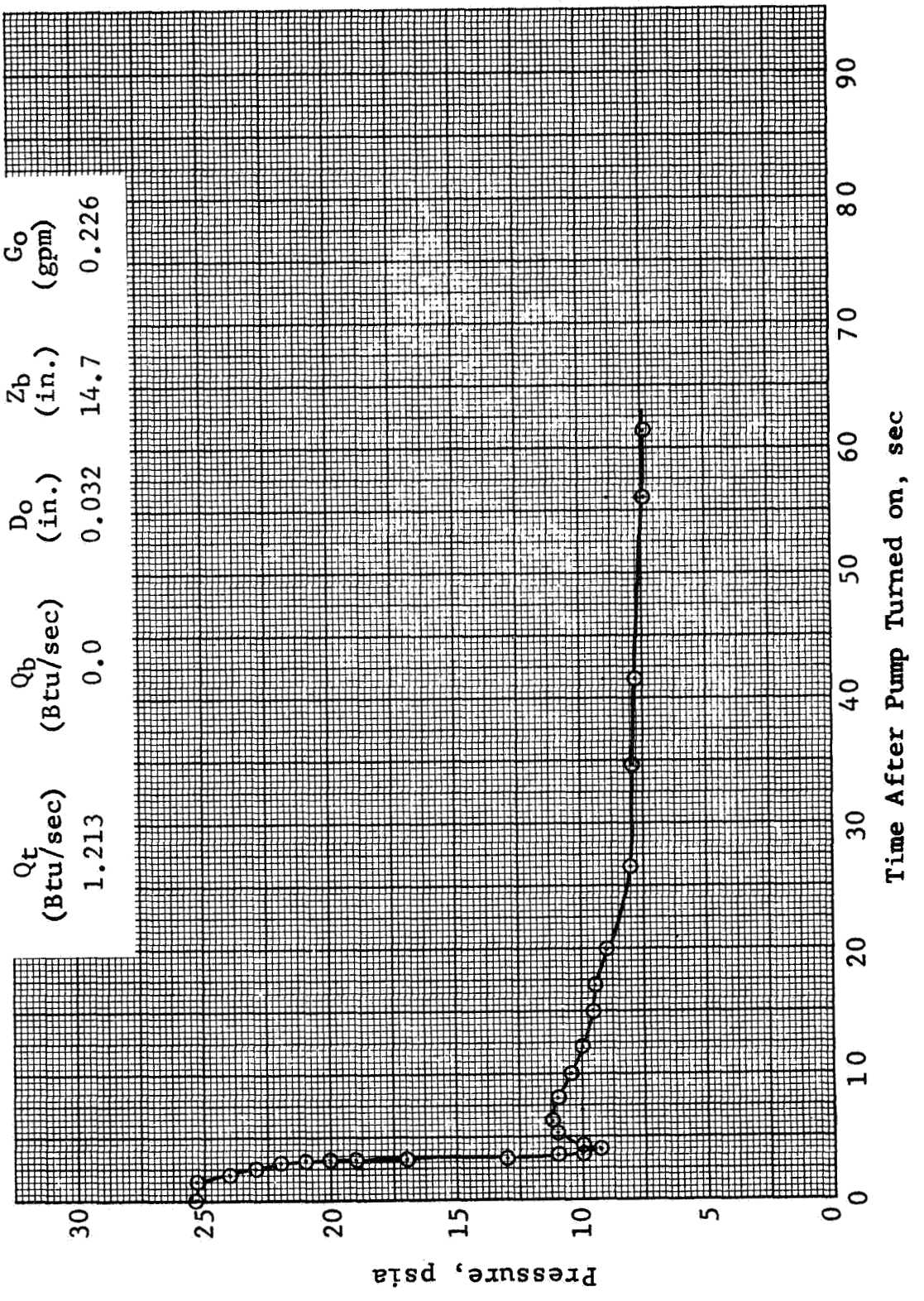

Figure 3.0-55 Transient Pressure Decay: Test 13, Run 19

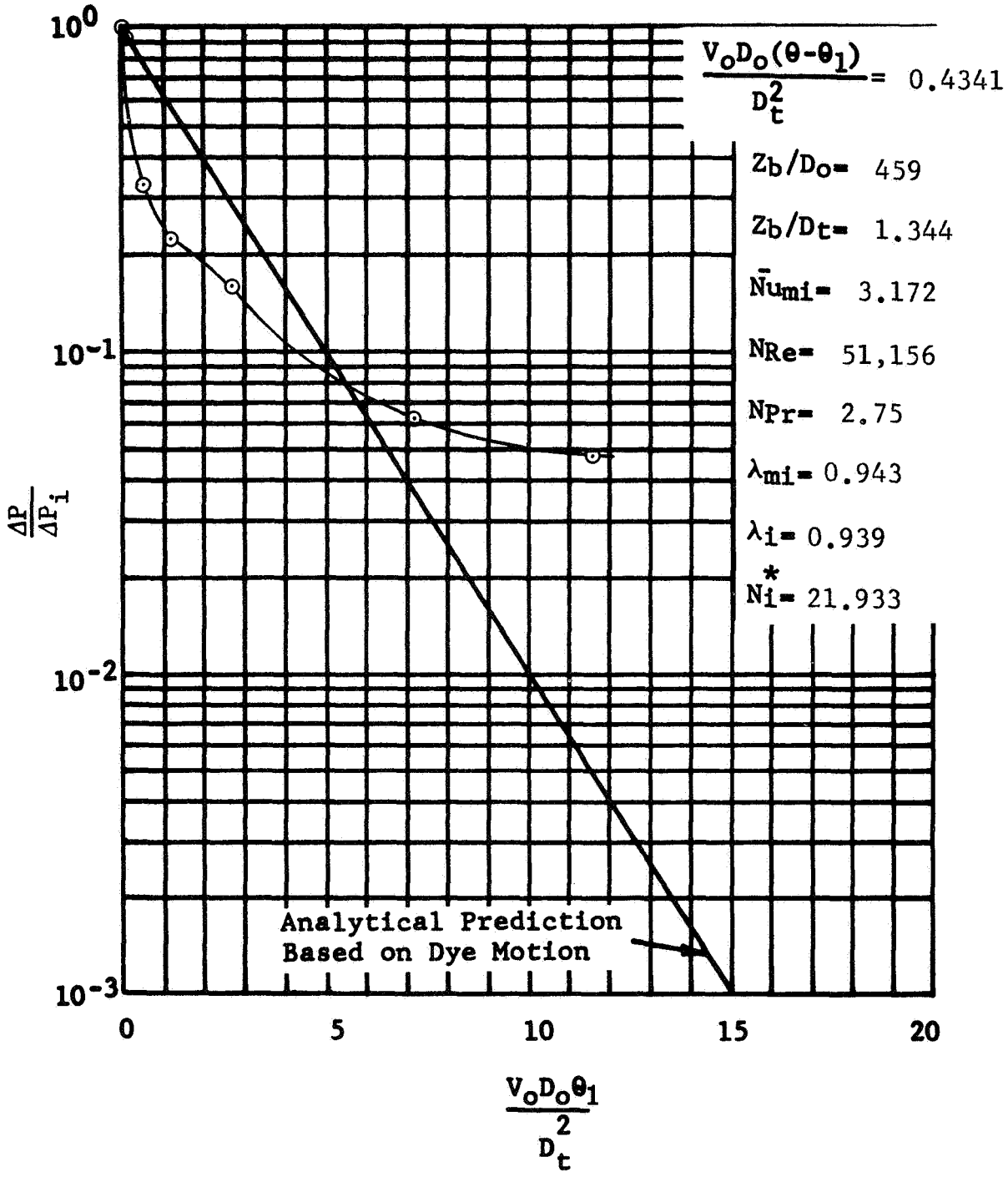

Figure 3.0-56 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 19

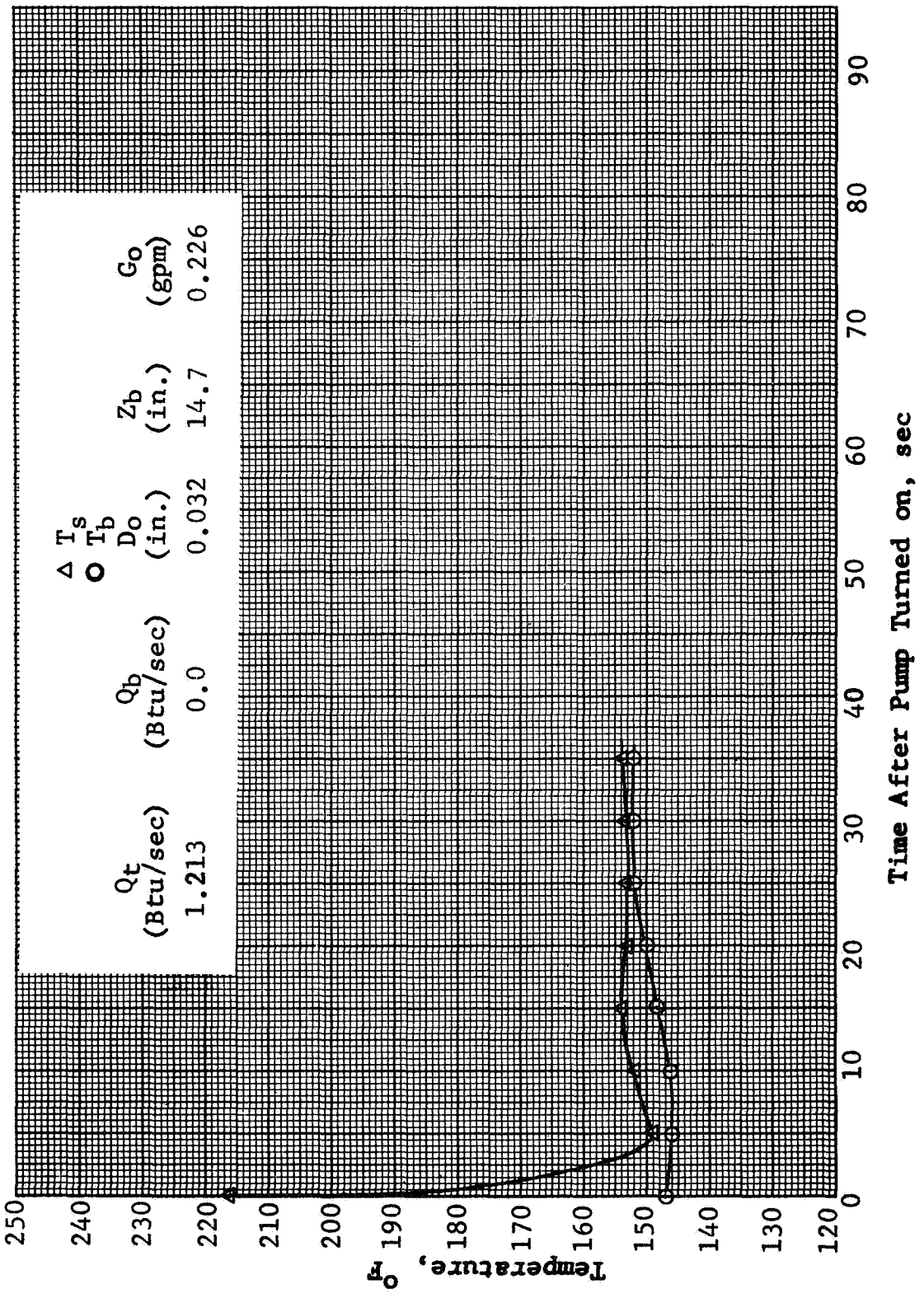

Figure 3.0-57 **Transient Temperature Destratification:** Test 13, Run 19

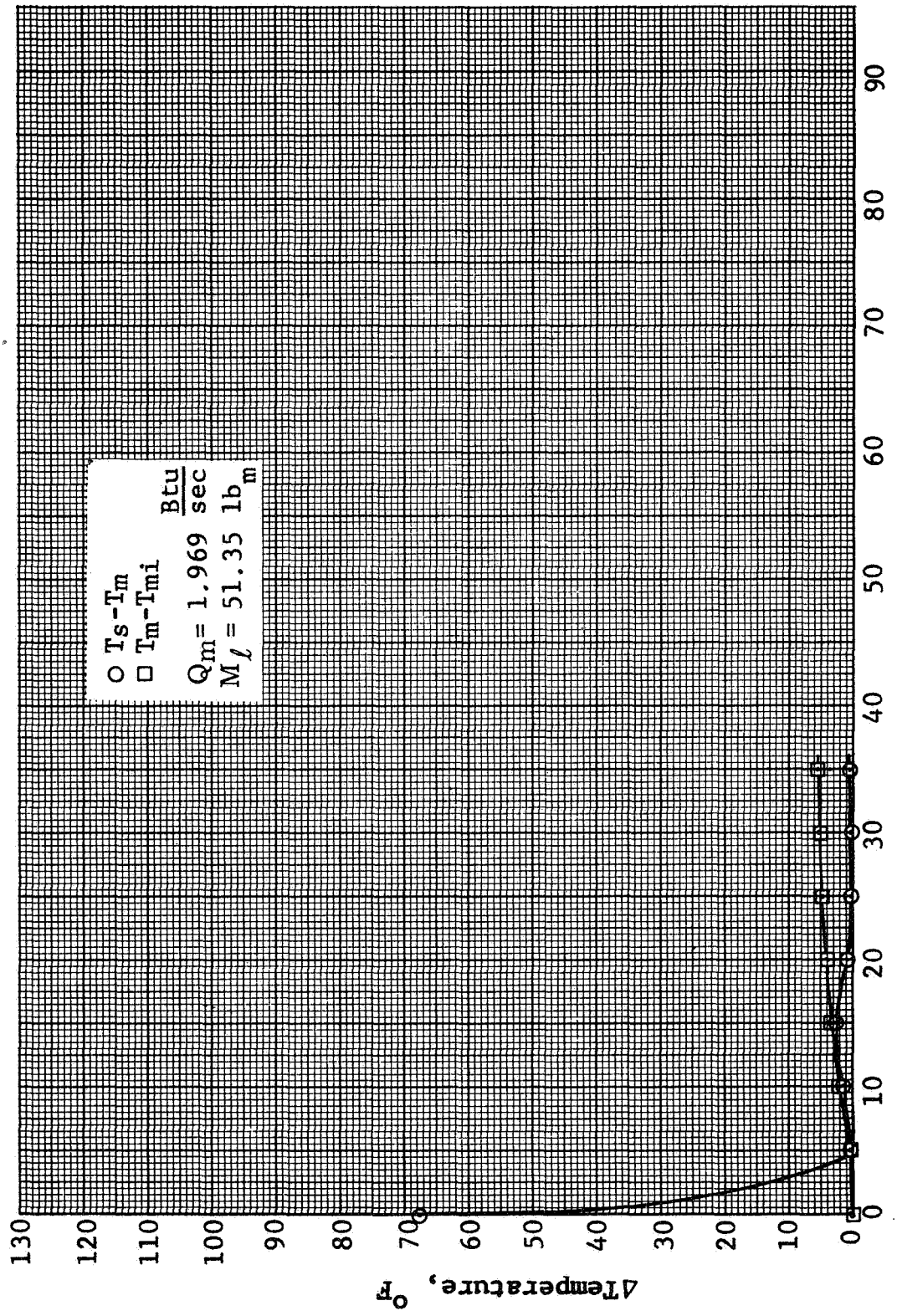

Figure 3.0 - 58 Transient ΔTemperature Destratification: Test 13, Run 19

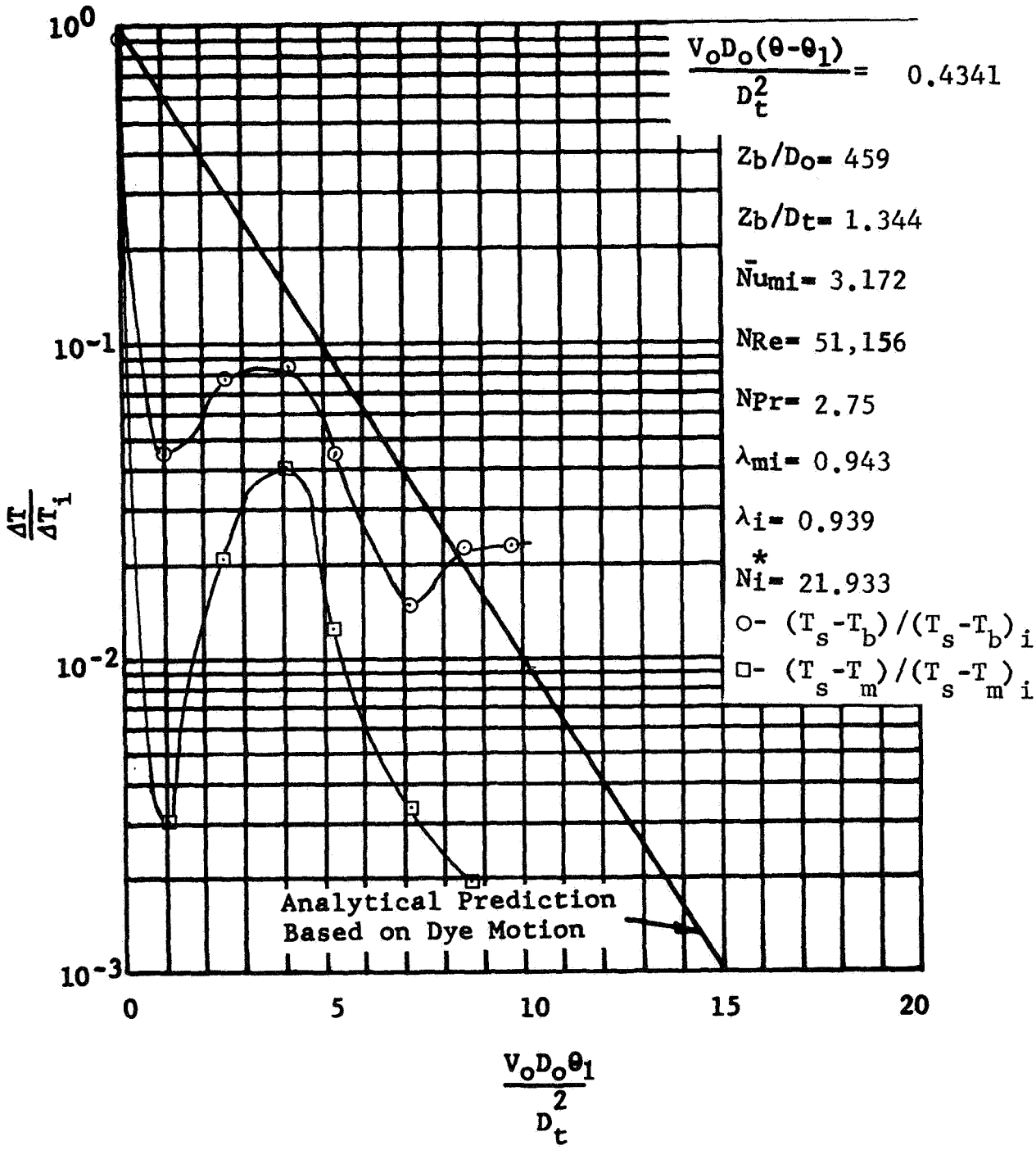

Figure 3.0 - 59 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 13, Run 19

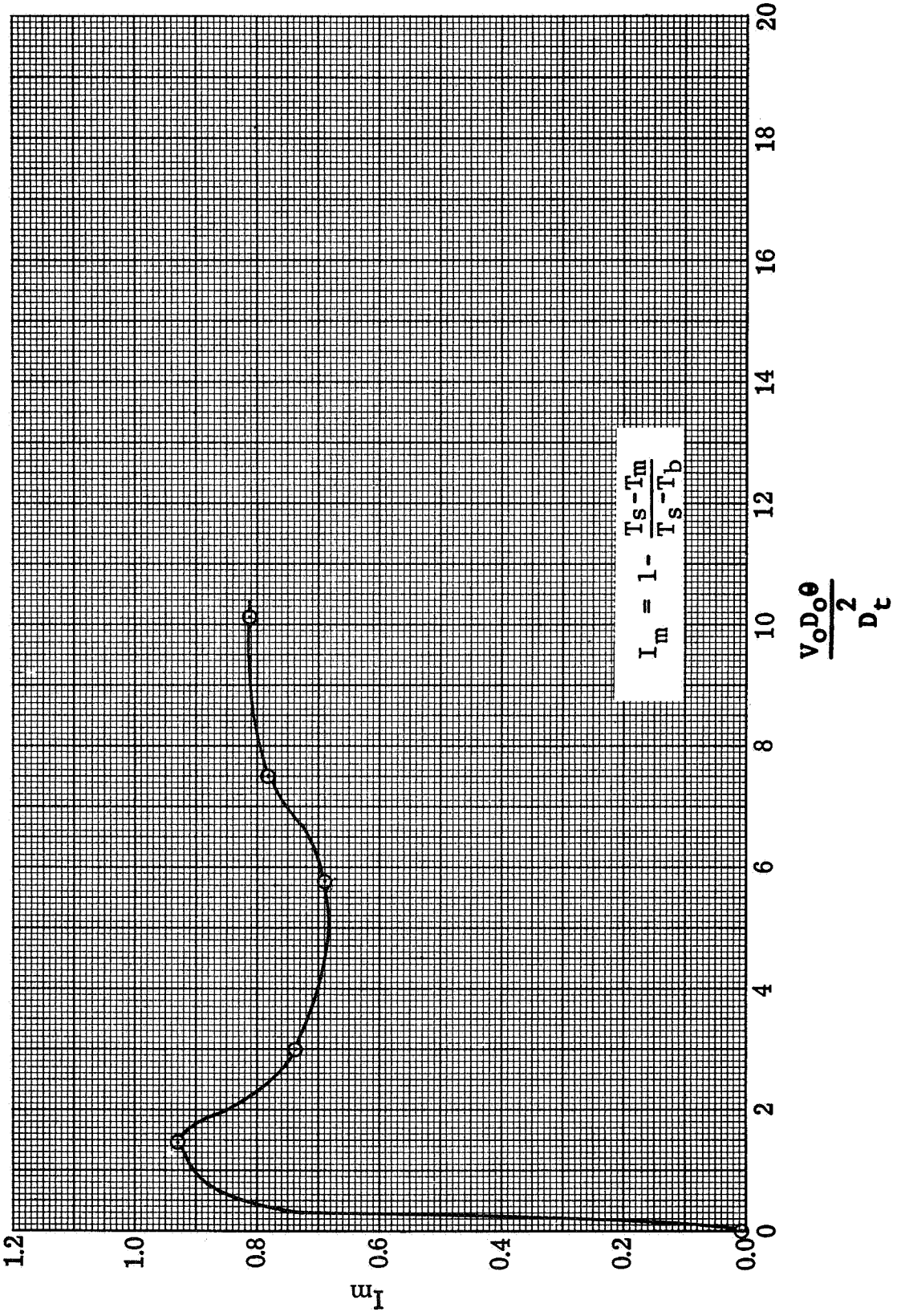

Figure 3.0-60 Transient Energy Integral: Test 13, Run 19

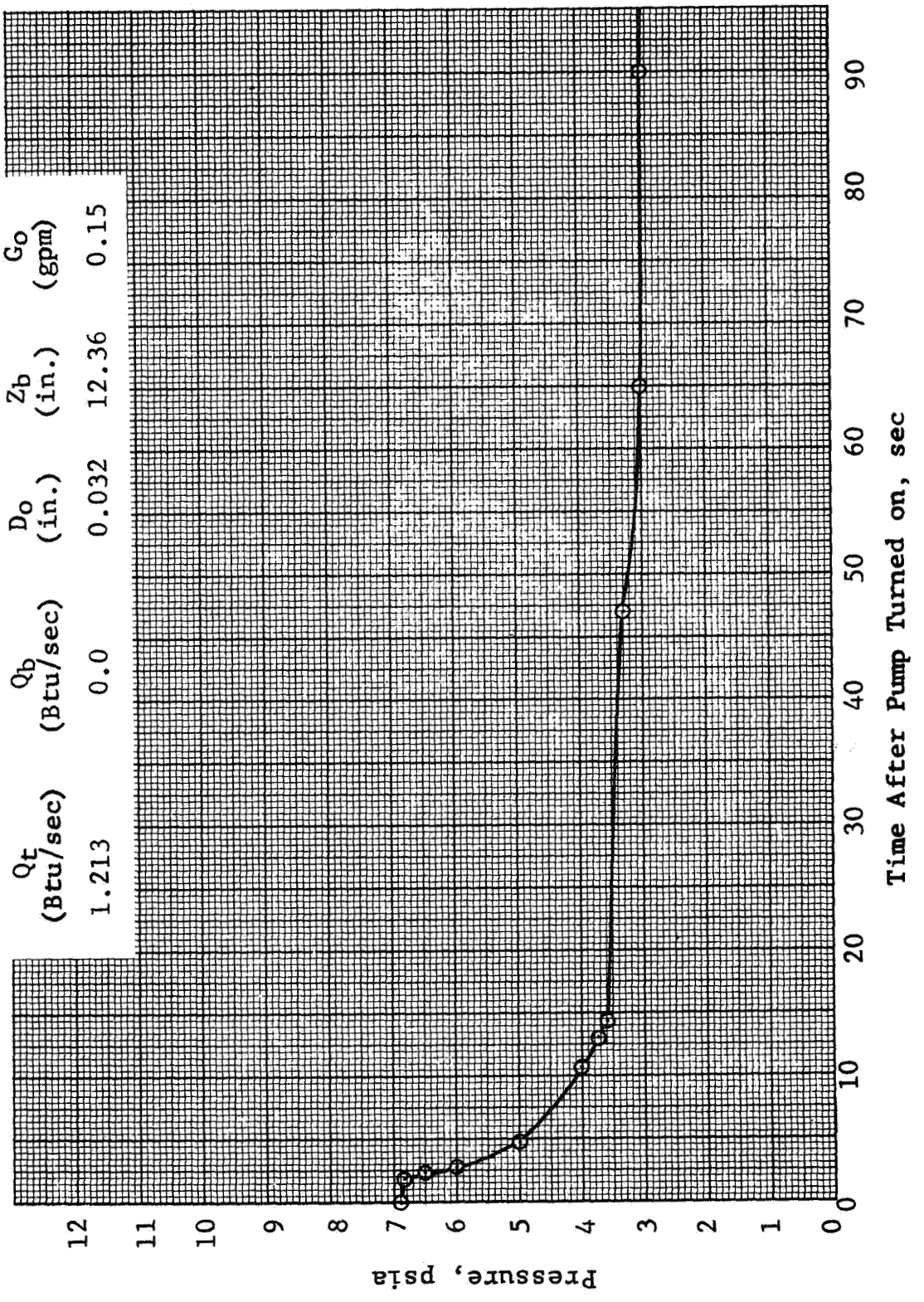

Figure 3.0-61 Transient Pressure Decay : Test 14, Run 20

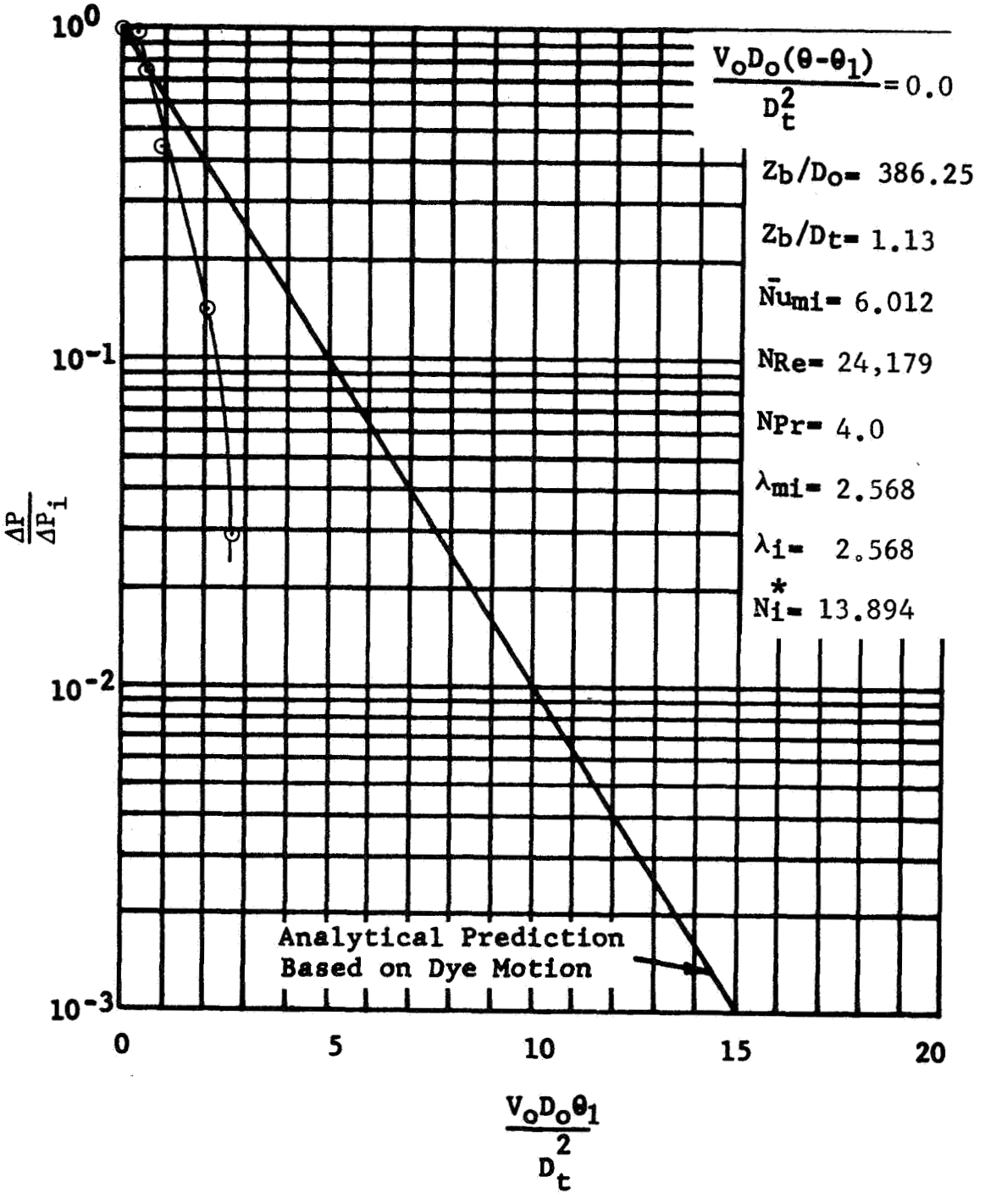

Figure 3.0-62 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 14, Run 20

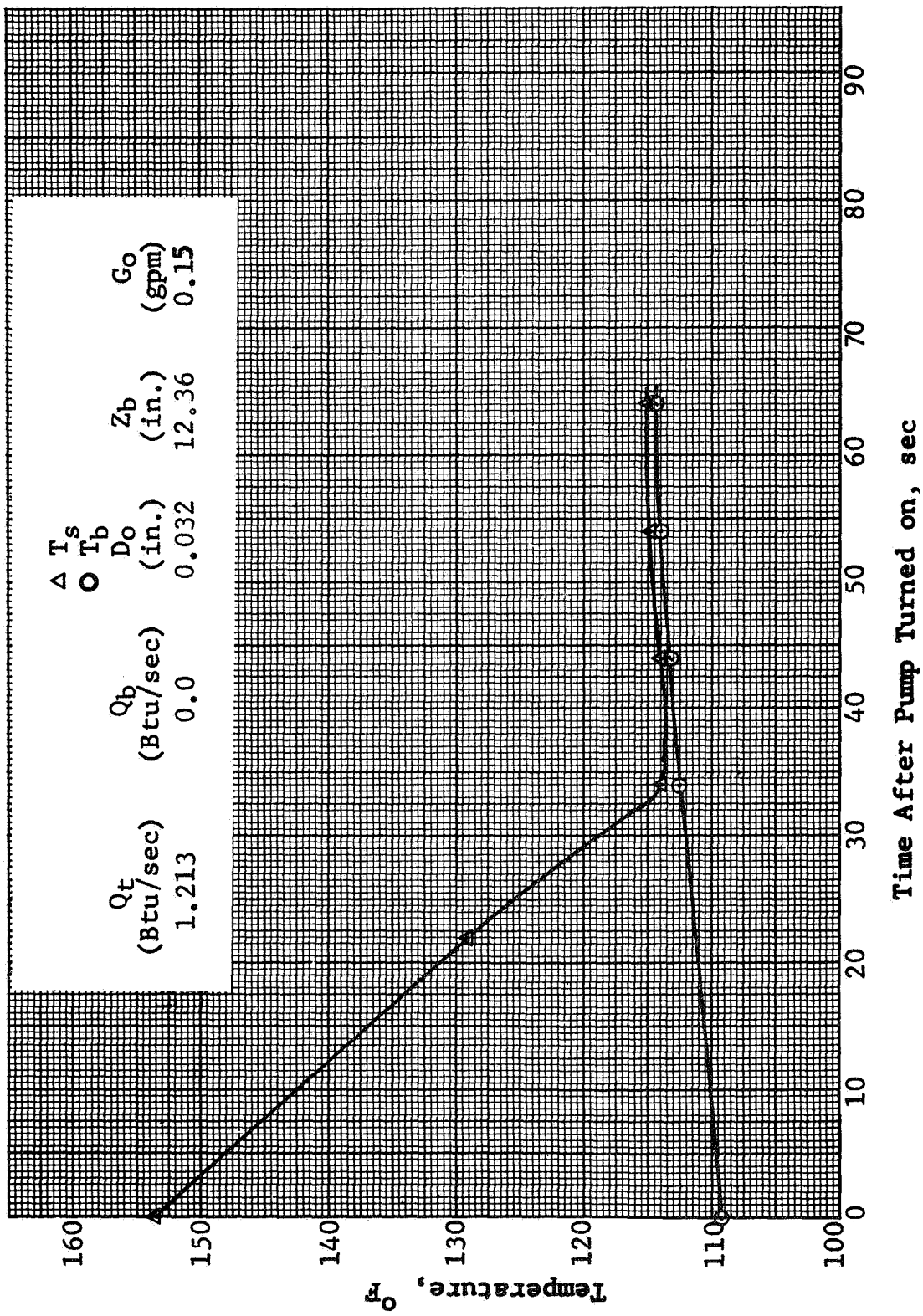

Figure 3.0-63 Transient Temperature Destratification: Test 14, Run 20

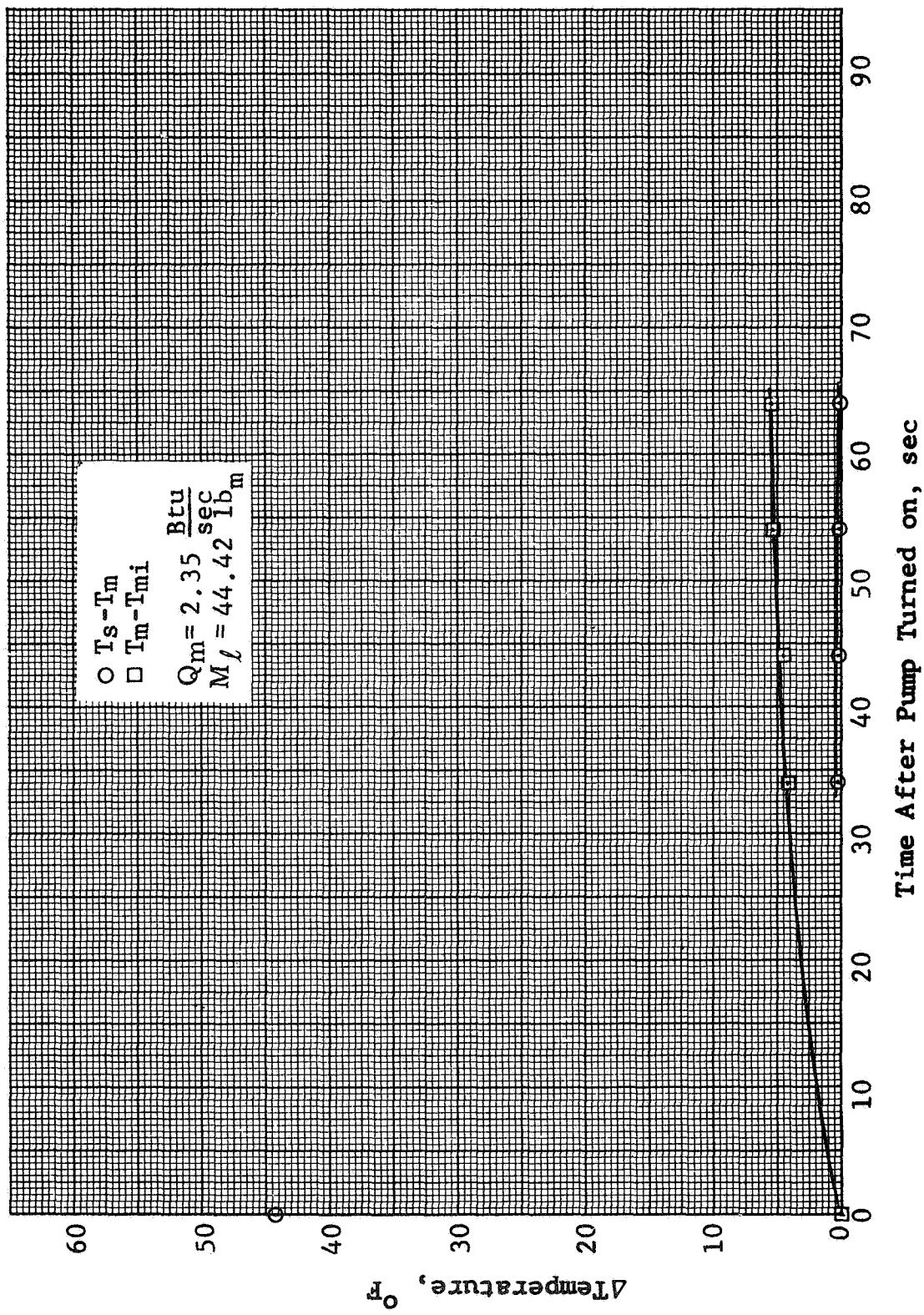

Figure 3.0-64 Transient ΔTemperature Destratification: Test 14, Run 20

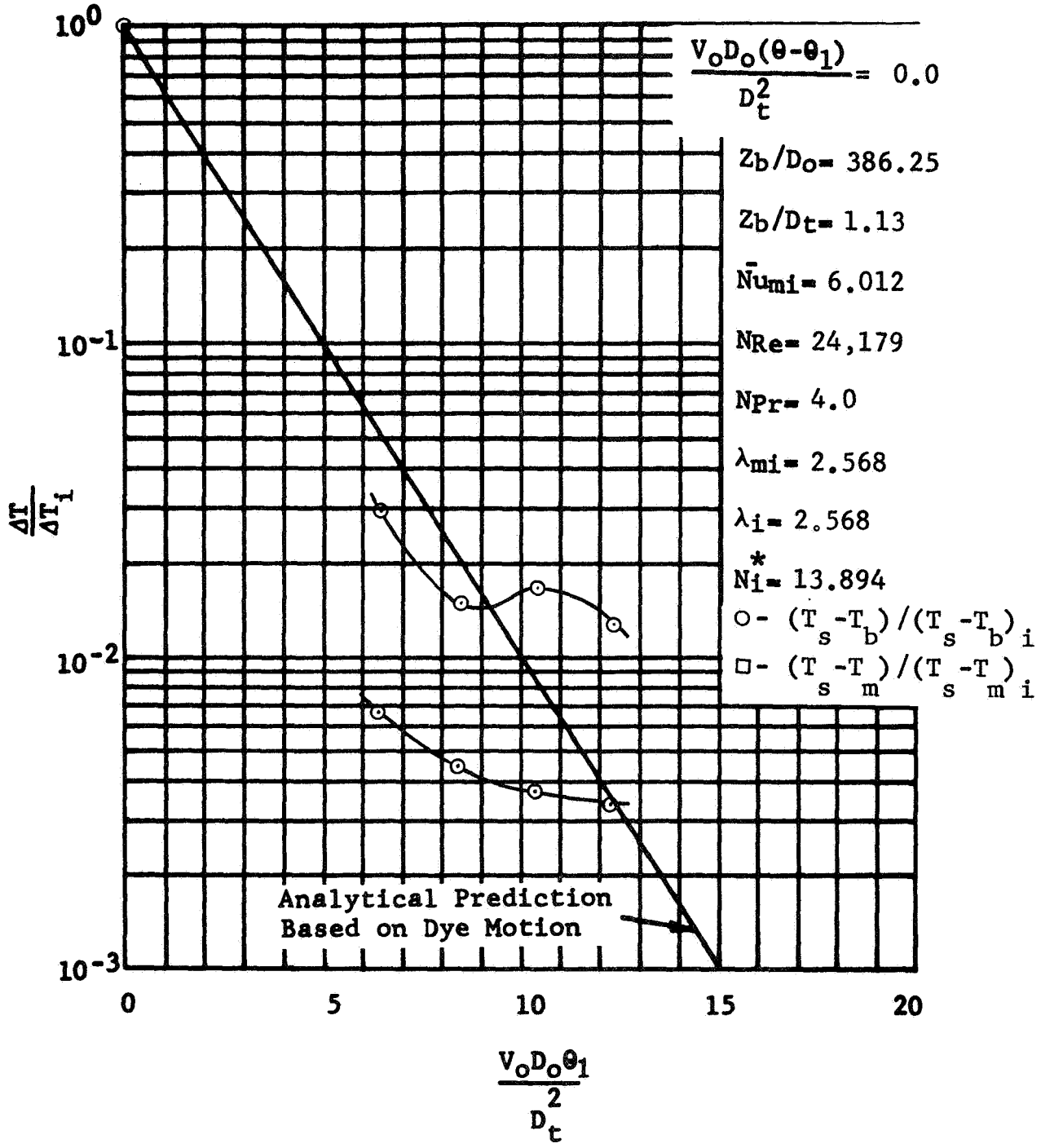

Figure 3.0-65 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 14, Run 20

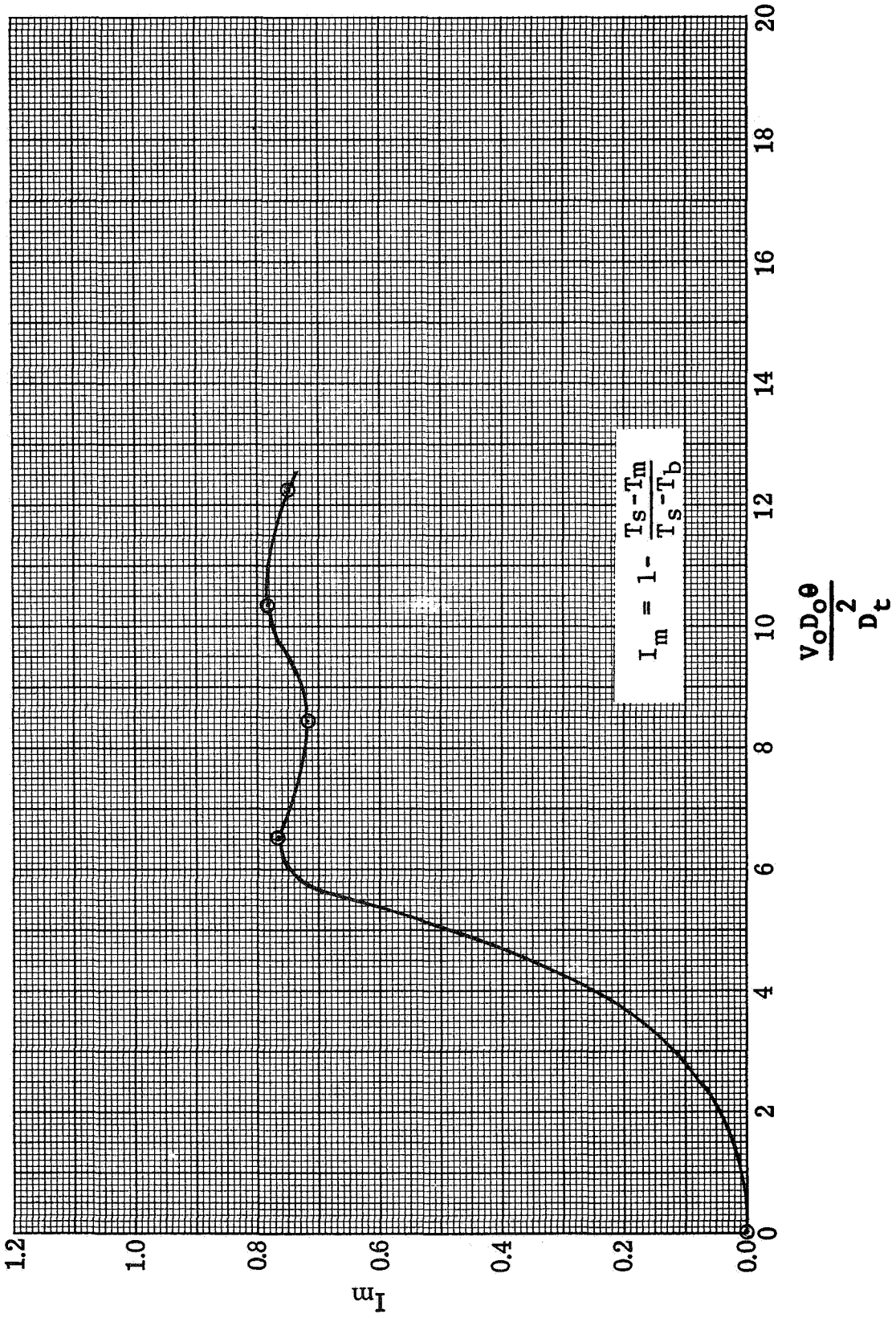

Figure 3.0-66 Transient Energy Integral: Test 14, Run 20

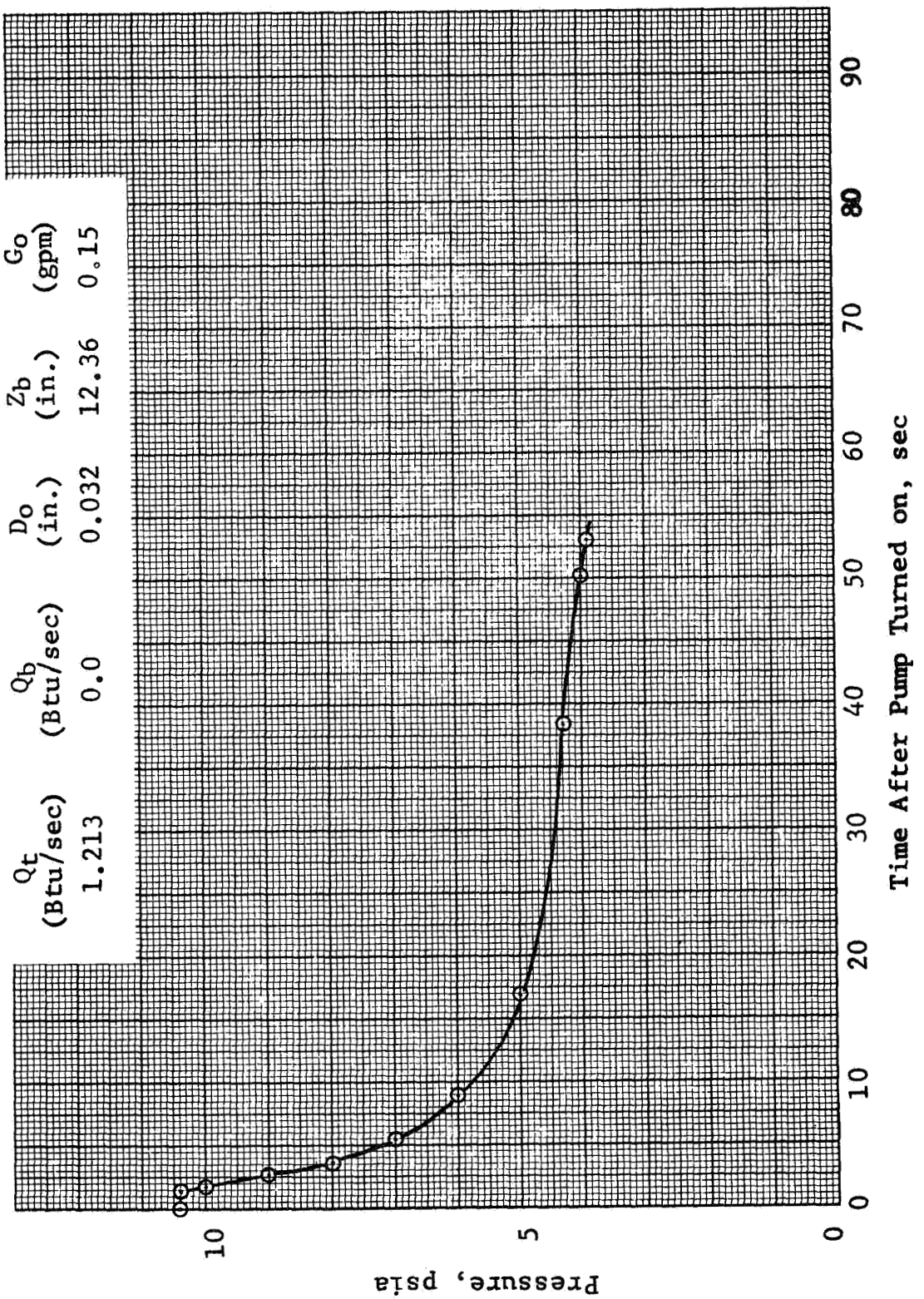

Figure 3.0-67 Transient Pressure Decay: Test 14, Run 21

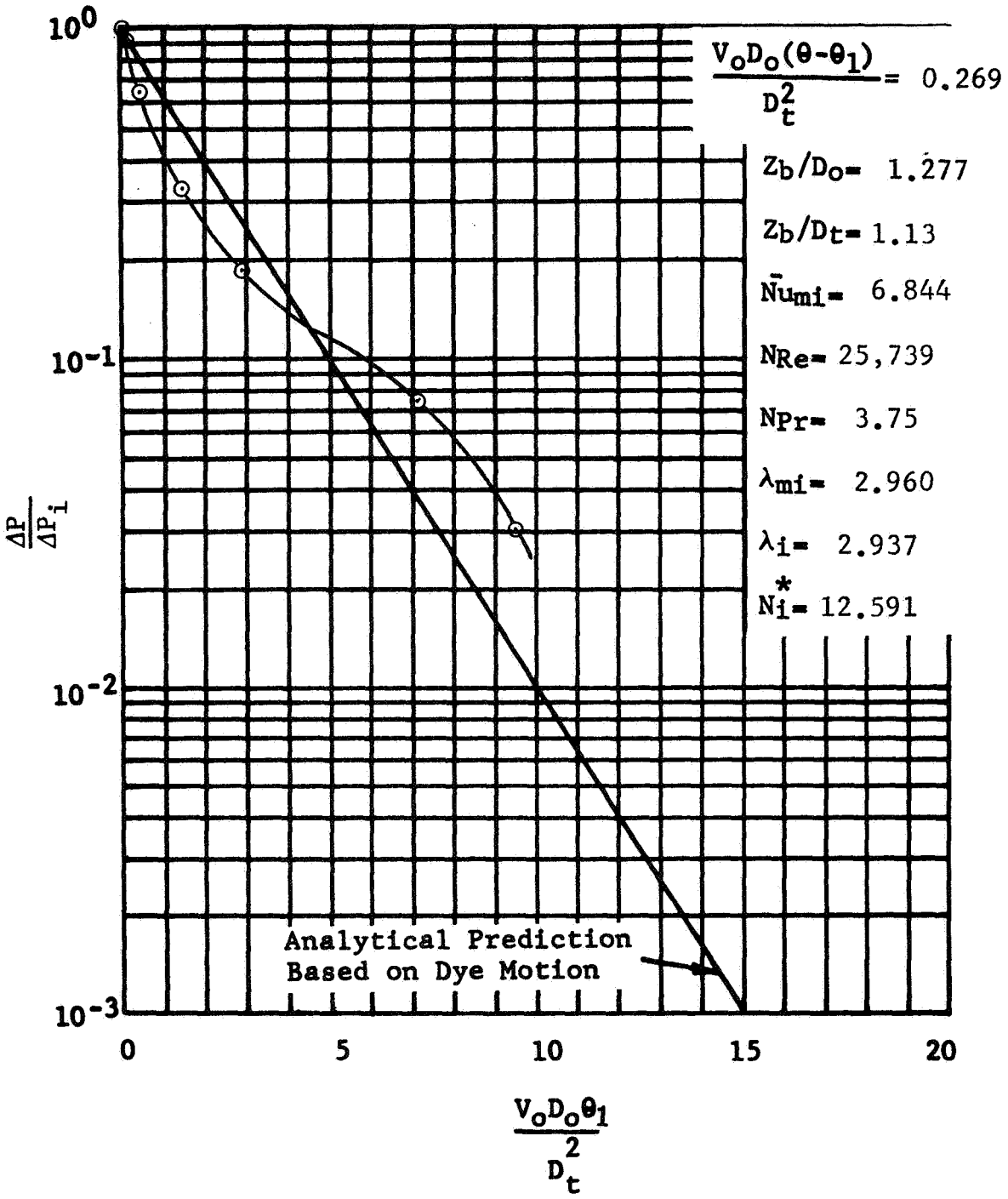

Figure 3.0-68 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 14, Run 21

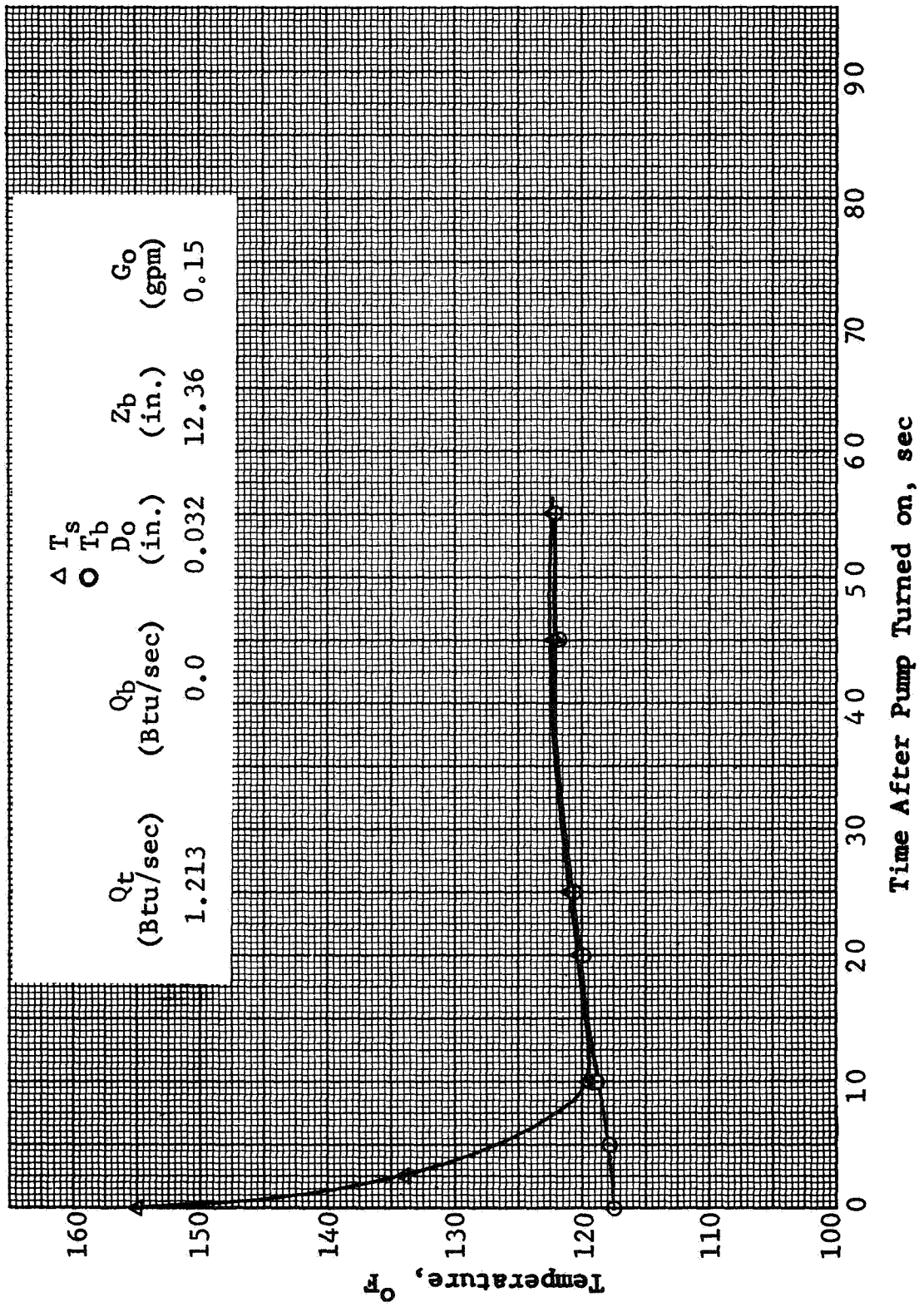

Figure 3.0-69 **Transient Temperature Destratification:** Test 14, Run 21

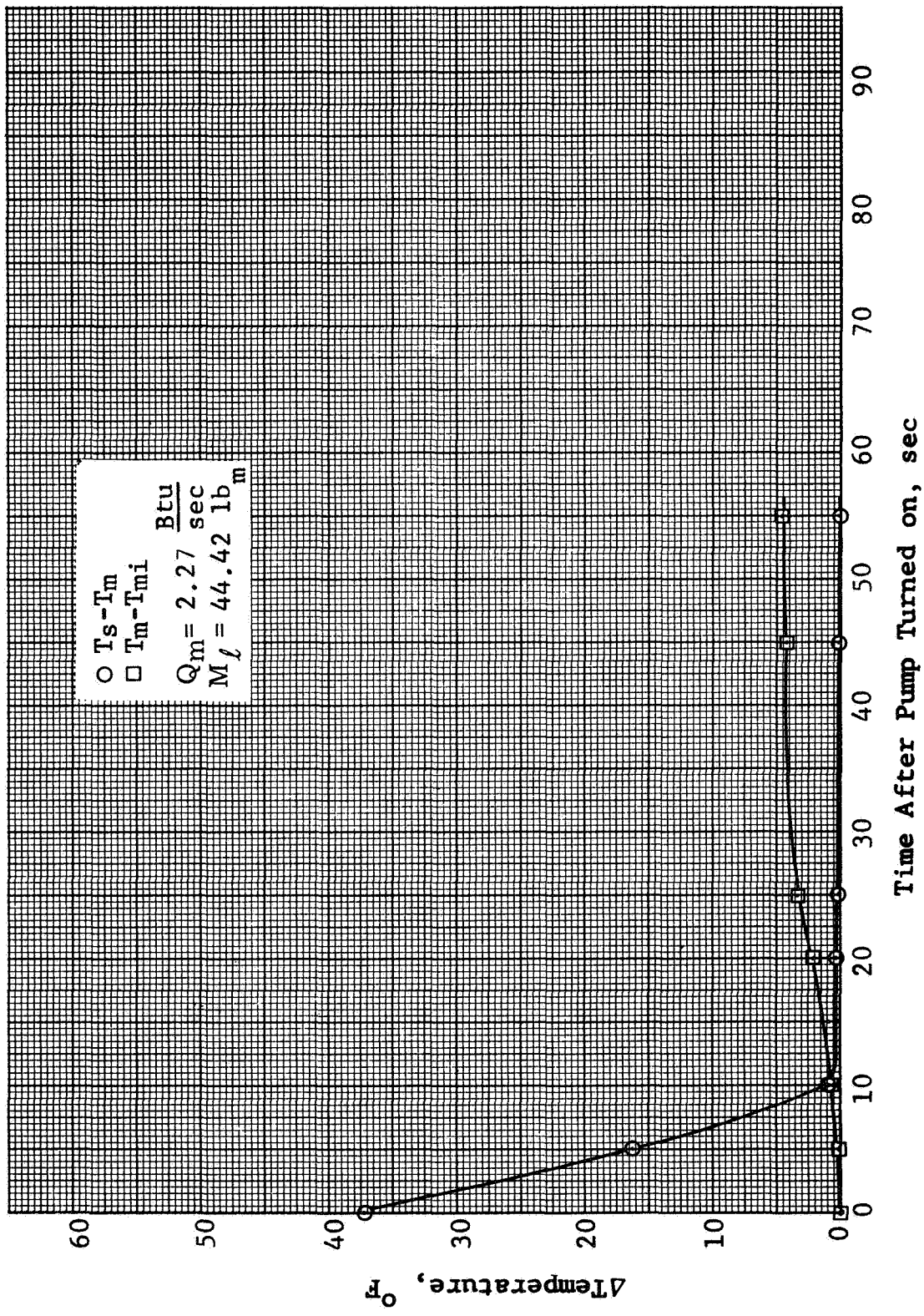

Figure 3.0-70 Transient ΔTemperature Destratification: Test 14, Run 21

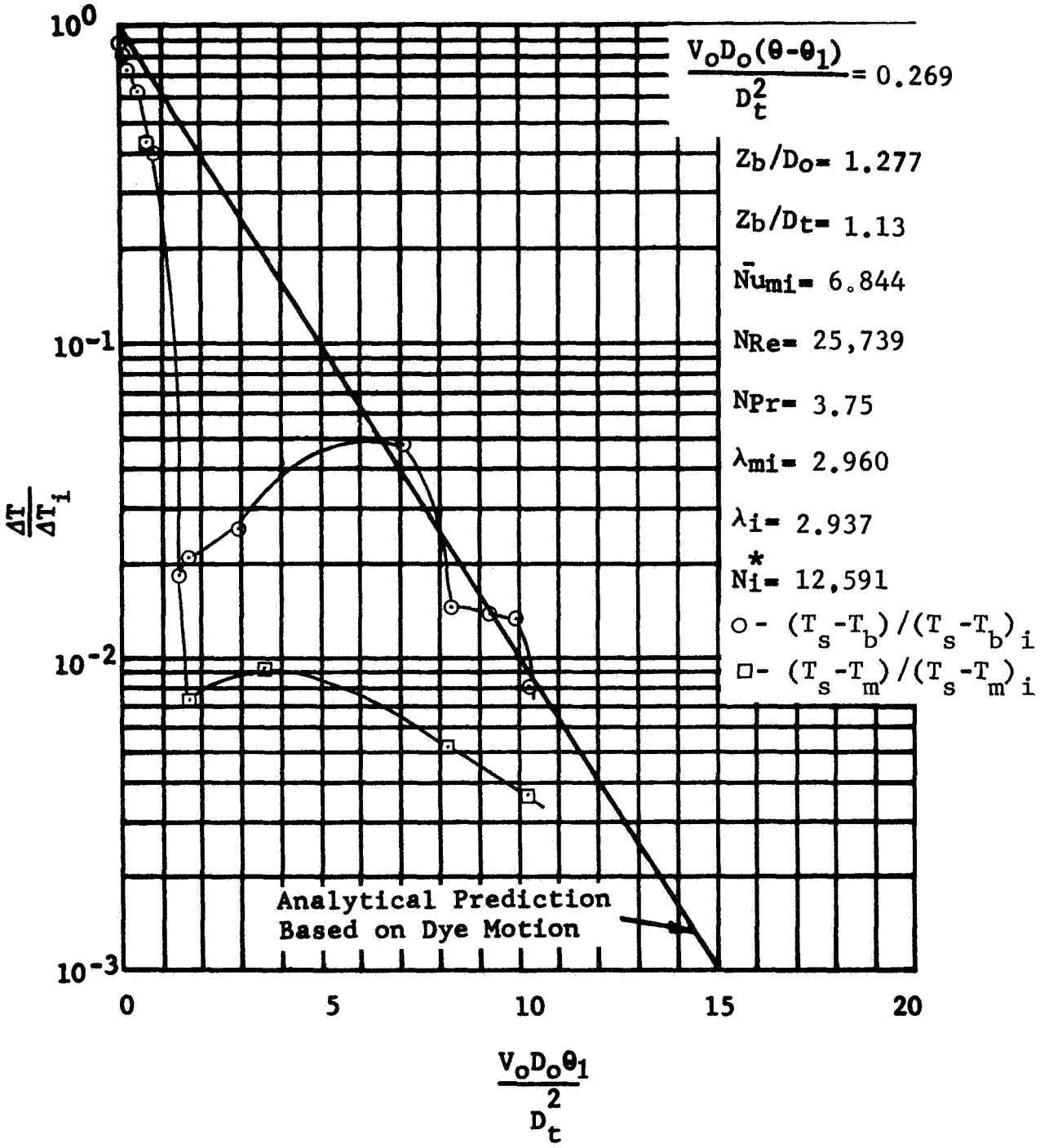

Figure 3.0-71 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 14, Run 21

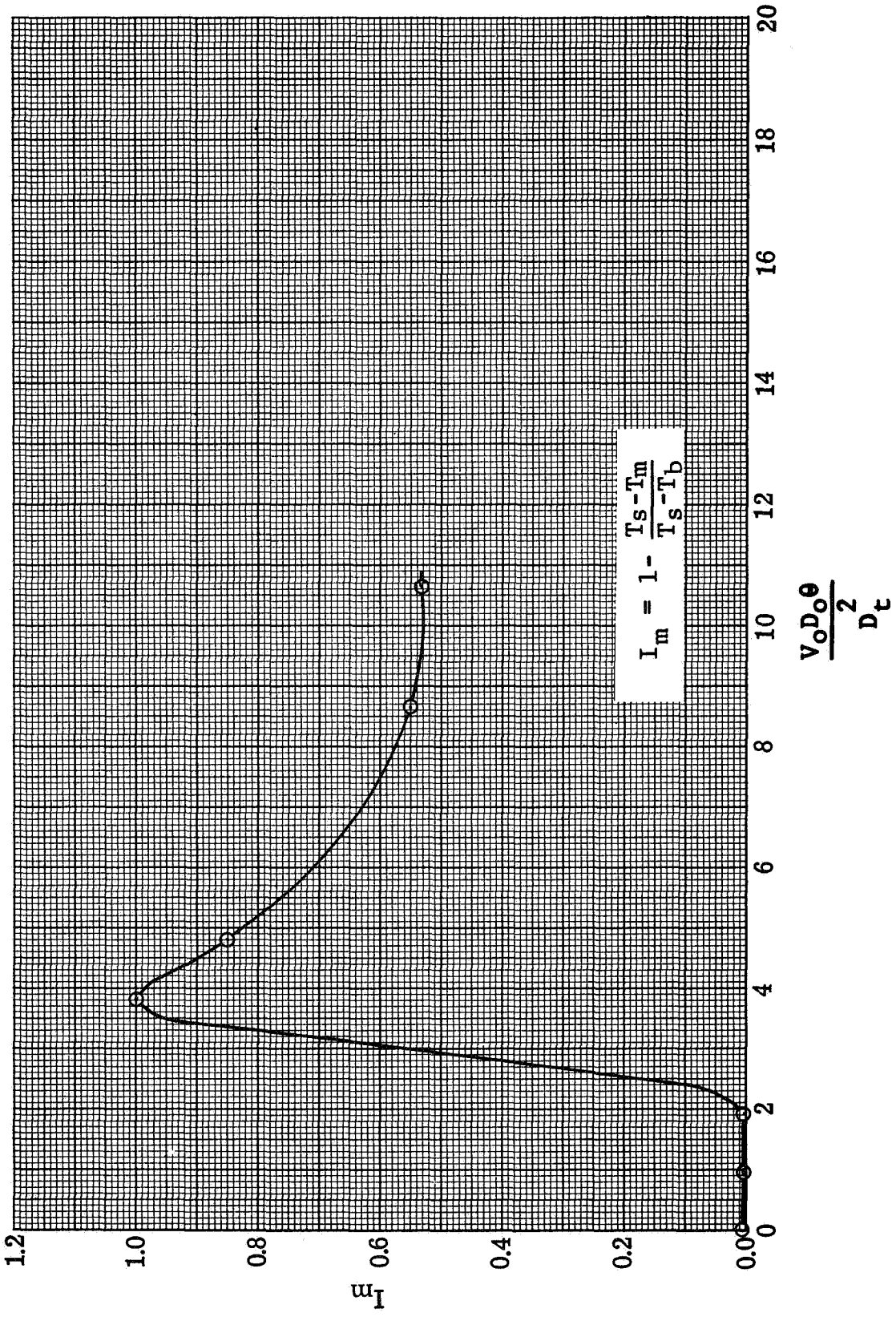

Figure 3.0-72 Transient Energy Integral: Test 14, Run 21

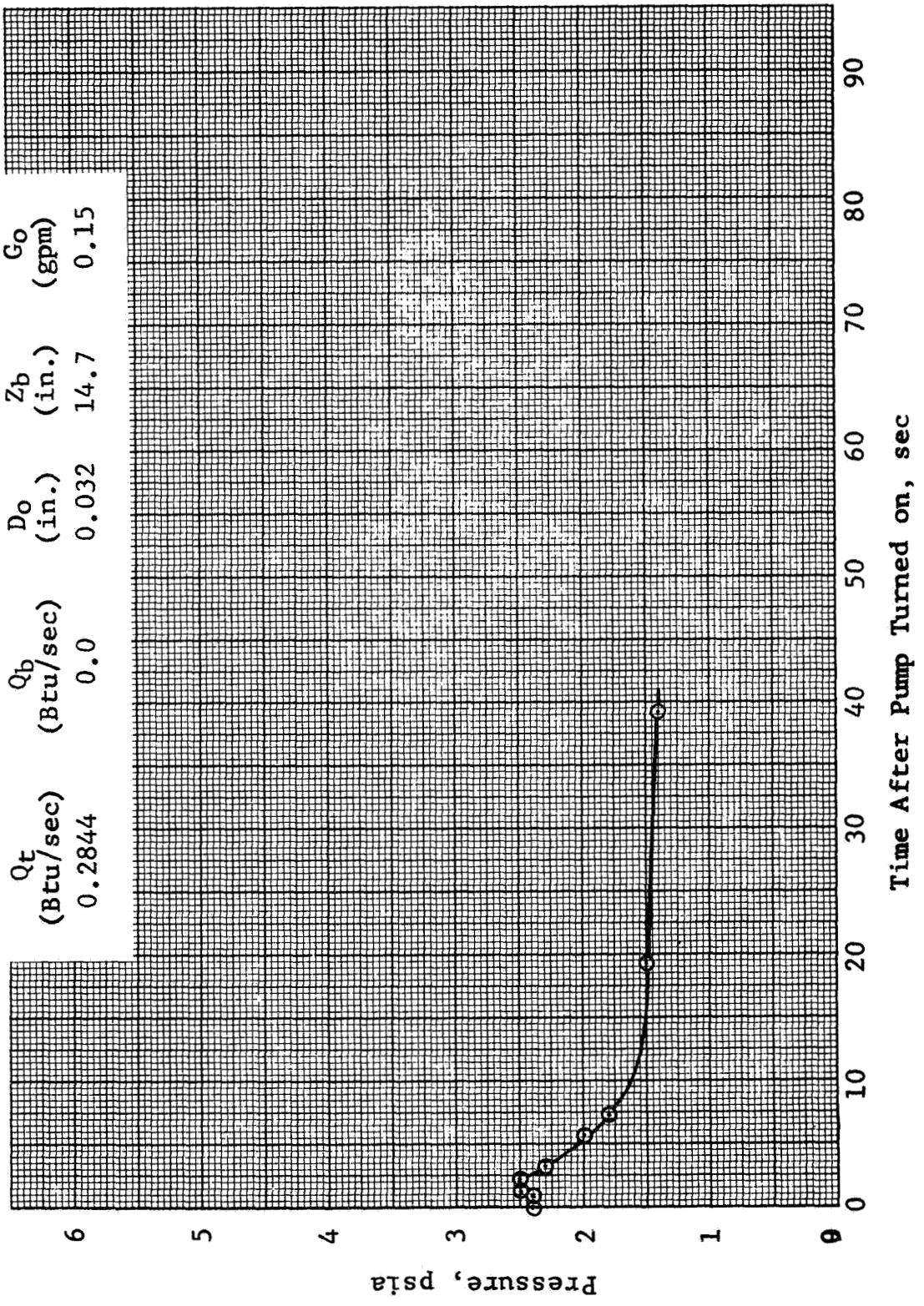

Figure 3.0-73 Transient Pressure Decay: Test 15, Run 22

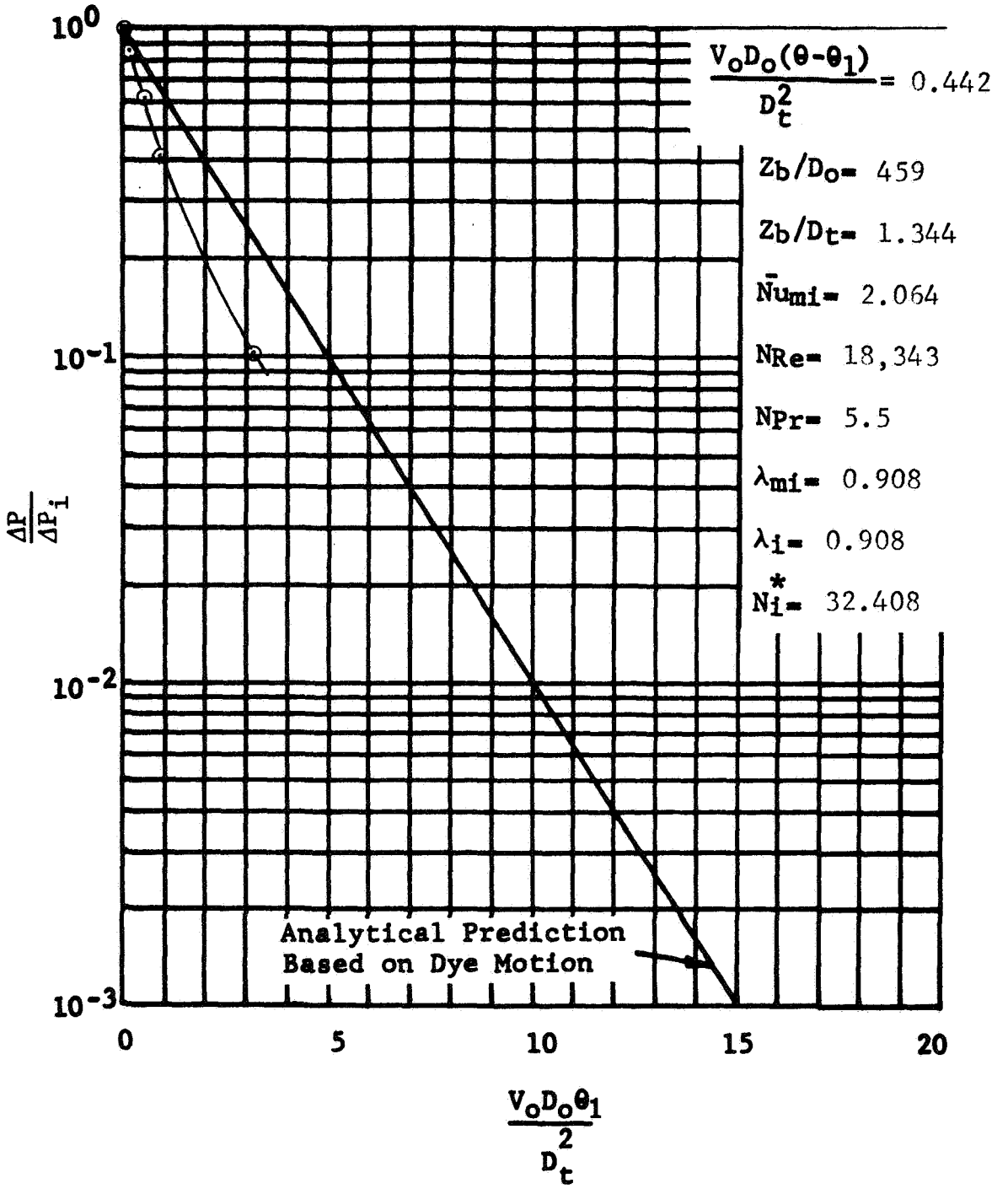

Figure 3.0-74 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 22

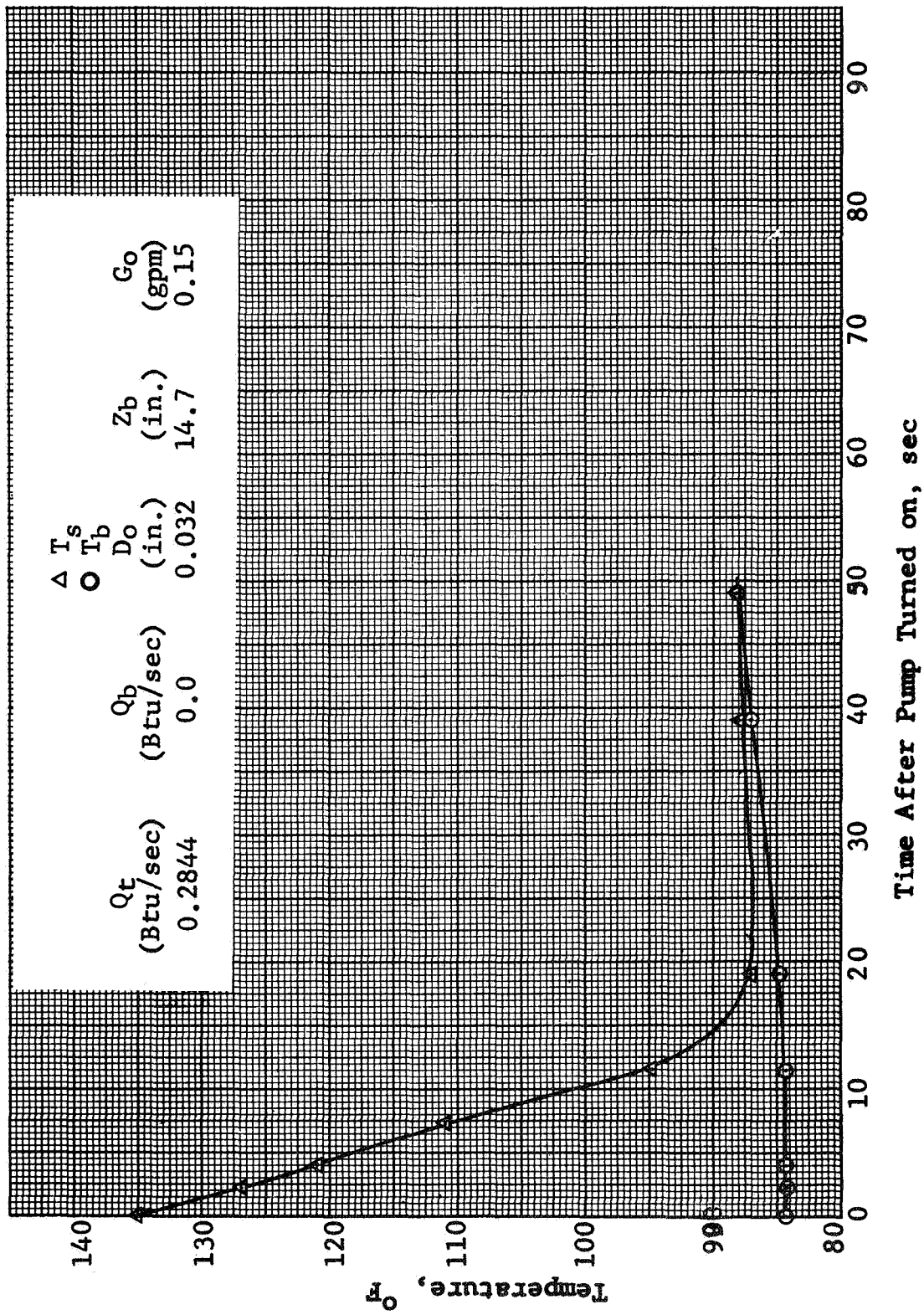

Figure 3.0-75 Transient Temperature Destratification: Test 15, Run 22

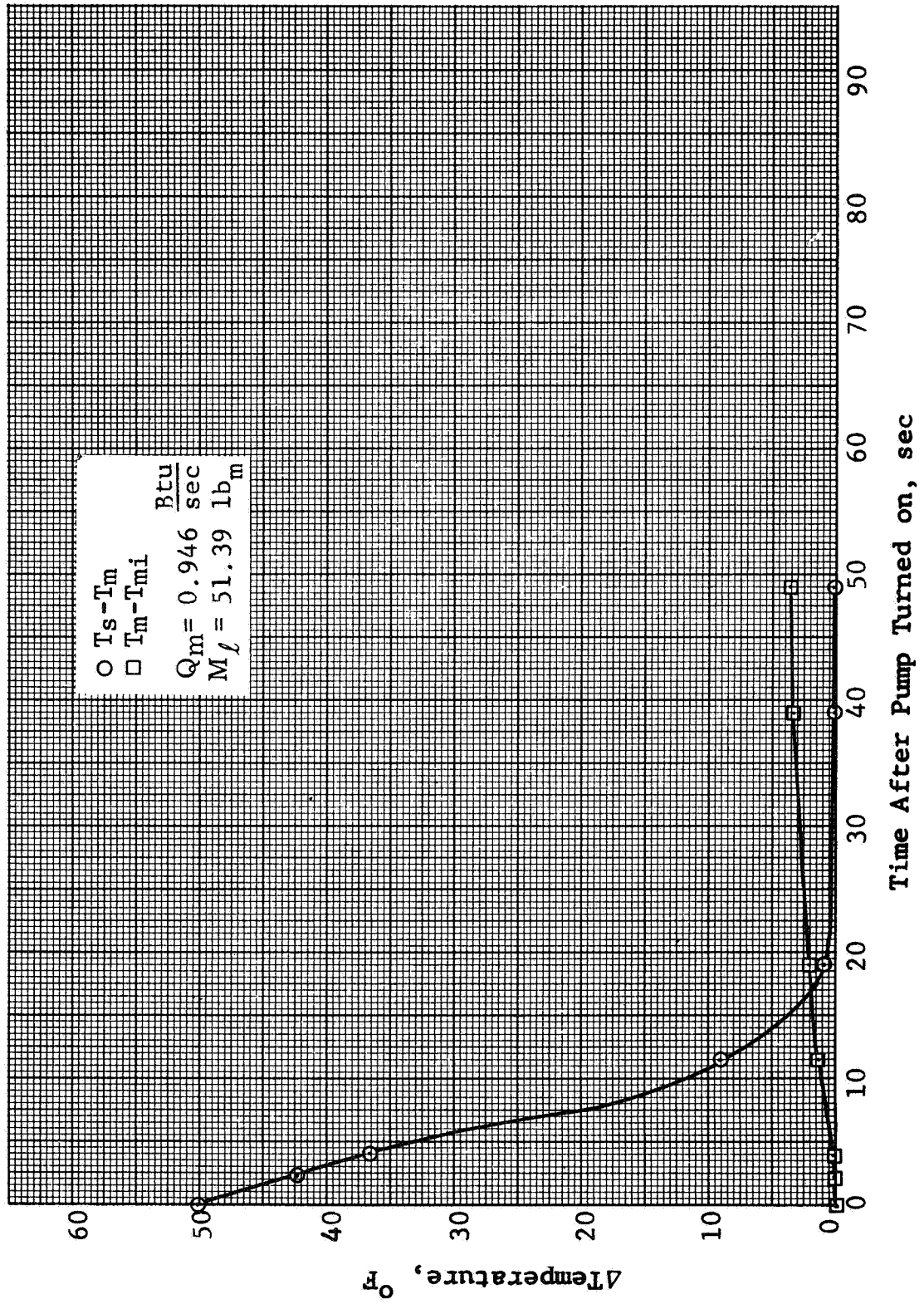

Figure 3.0-76 Transient ΔTemperature Destratification: Test 15, Run 22

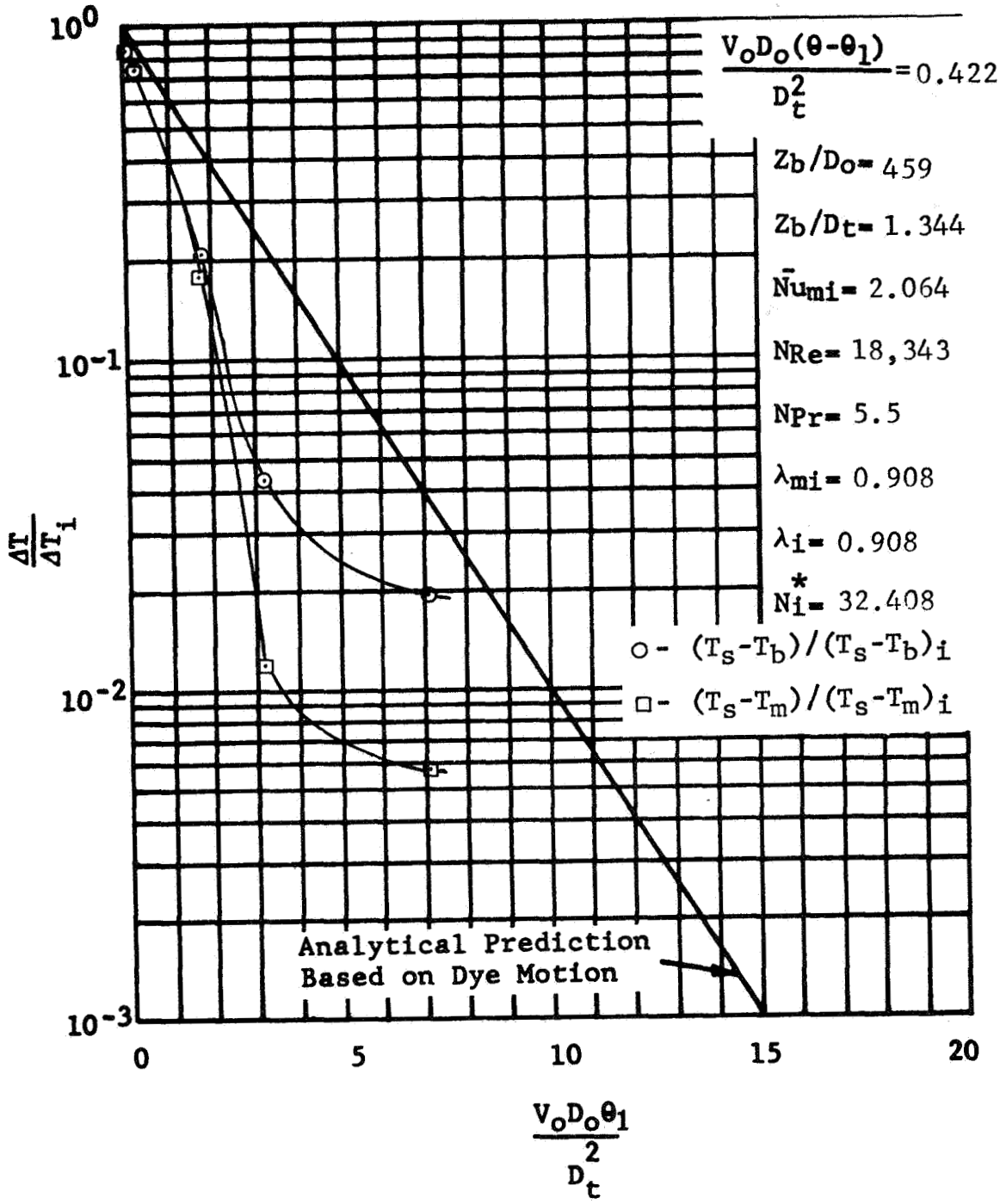

Figure 3.0-77 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 22

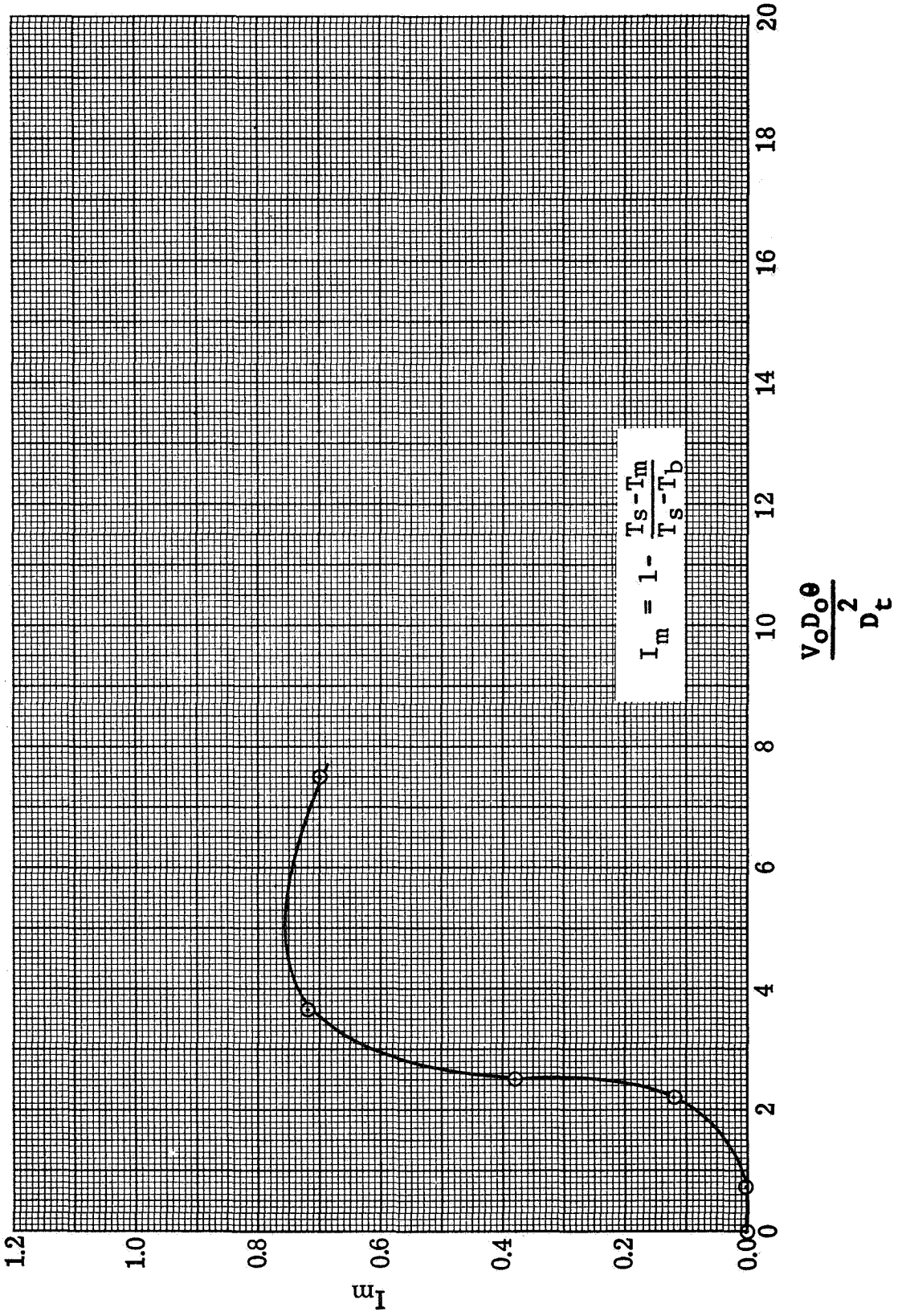

Figure 3.0-78 **Transient Energy Integral:** Test 15, Run 22

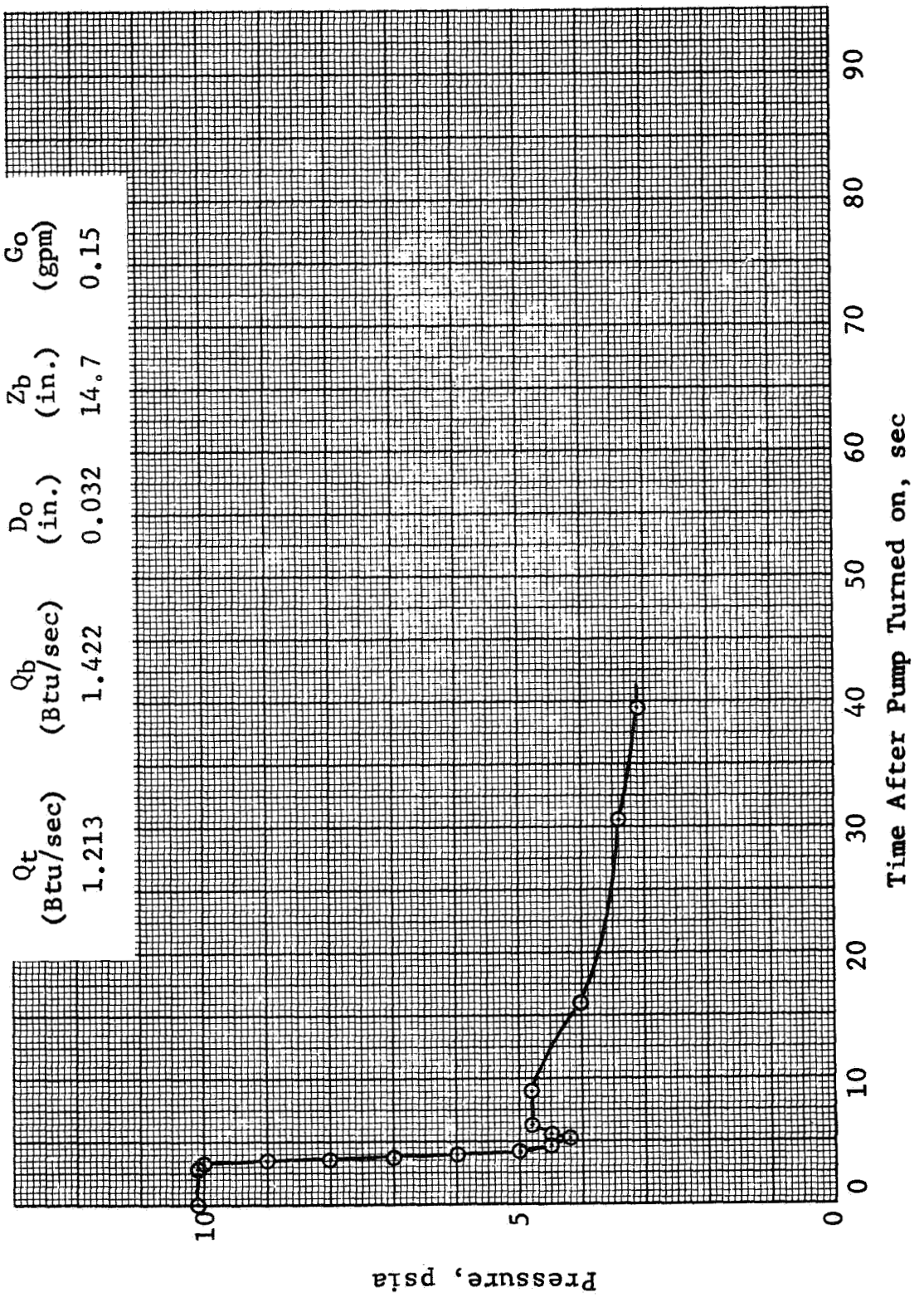

Figure 3.0-79 Transient Pressure Decay: Test 15, Run 23

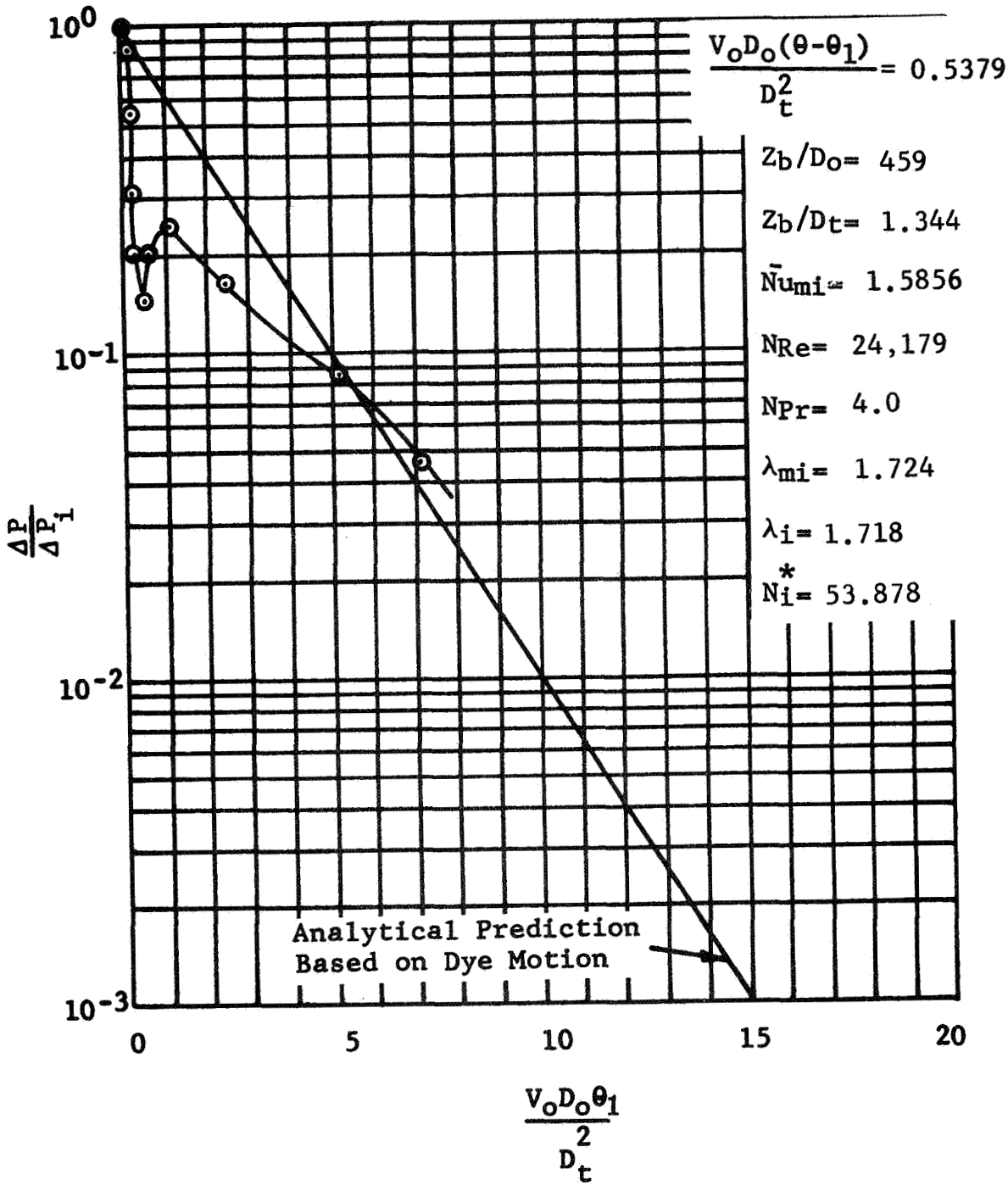

Figure 3.0-80 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 23

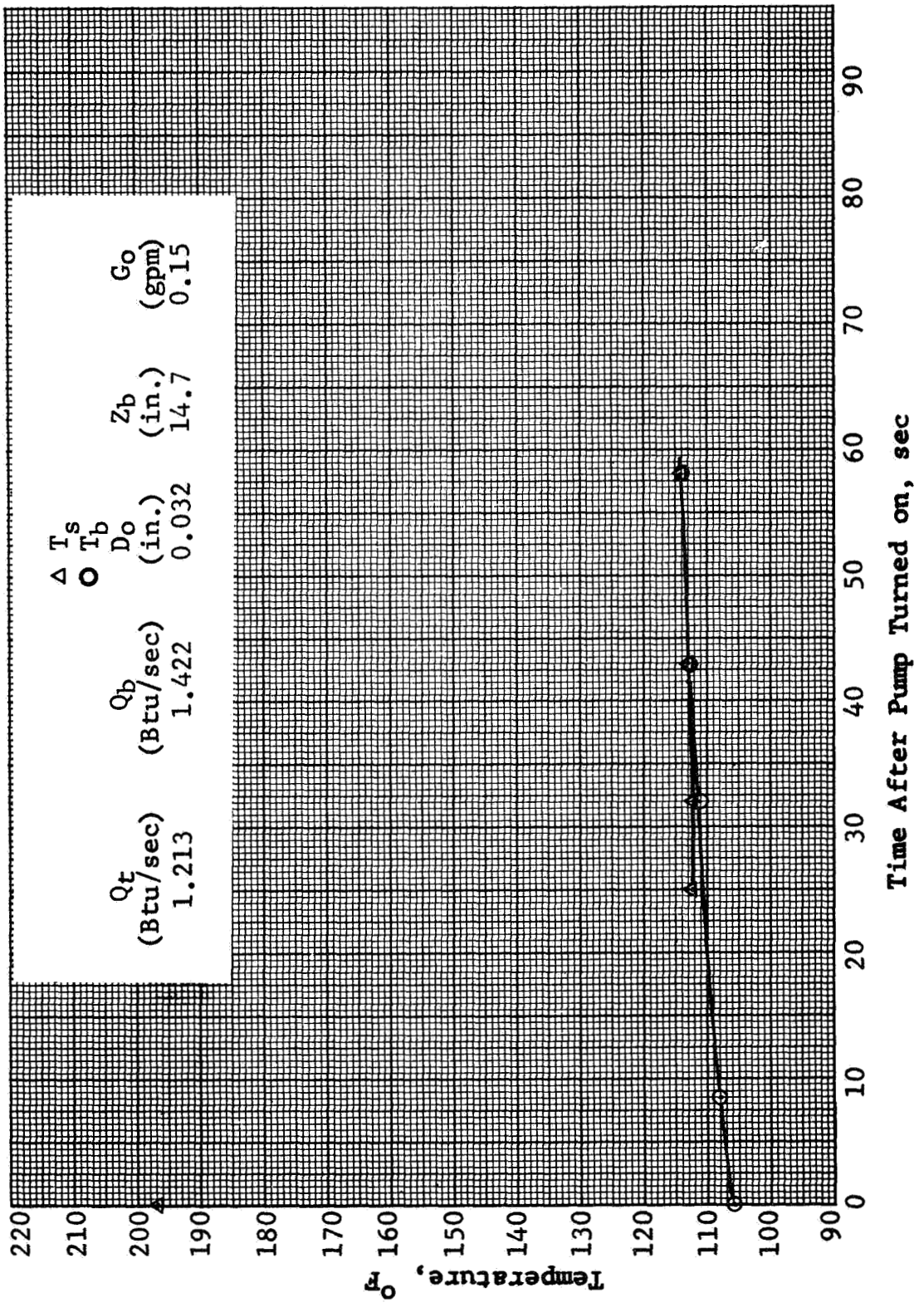

Figure 3.0-81 Transient Temperature Destratification: Test 15, Run 23

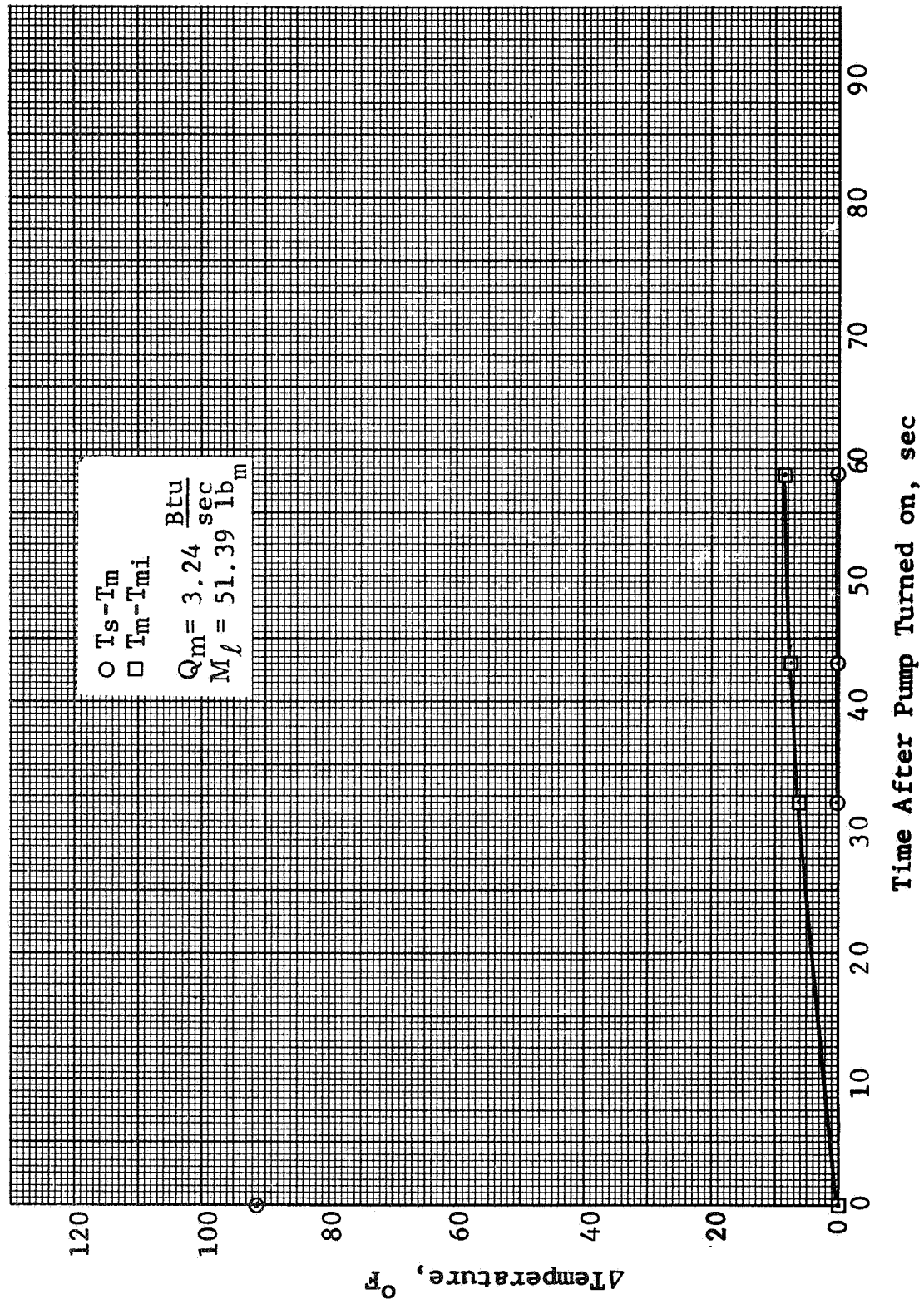

Figure 3.0-82 Transient ΔTemperature Destratification: Test 15, Run 23

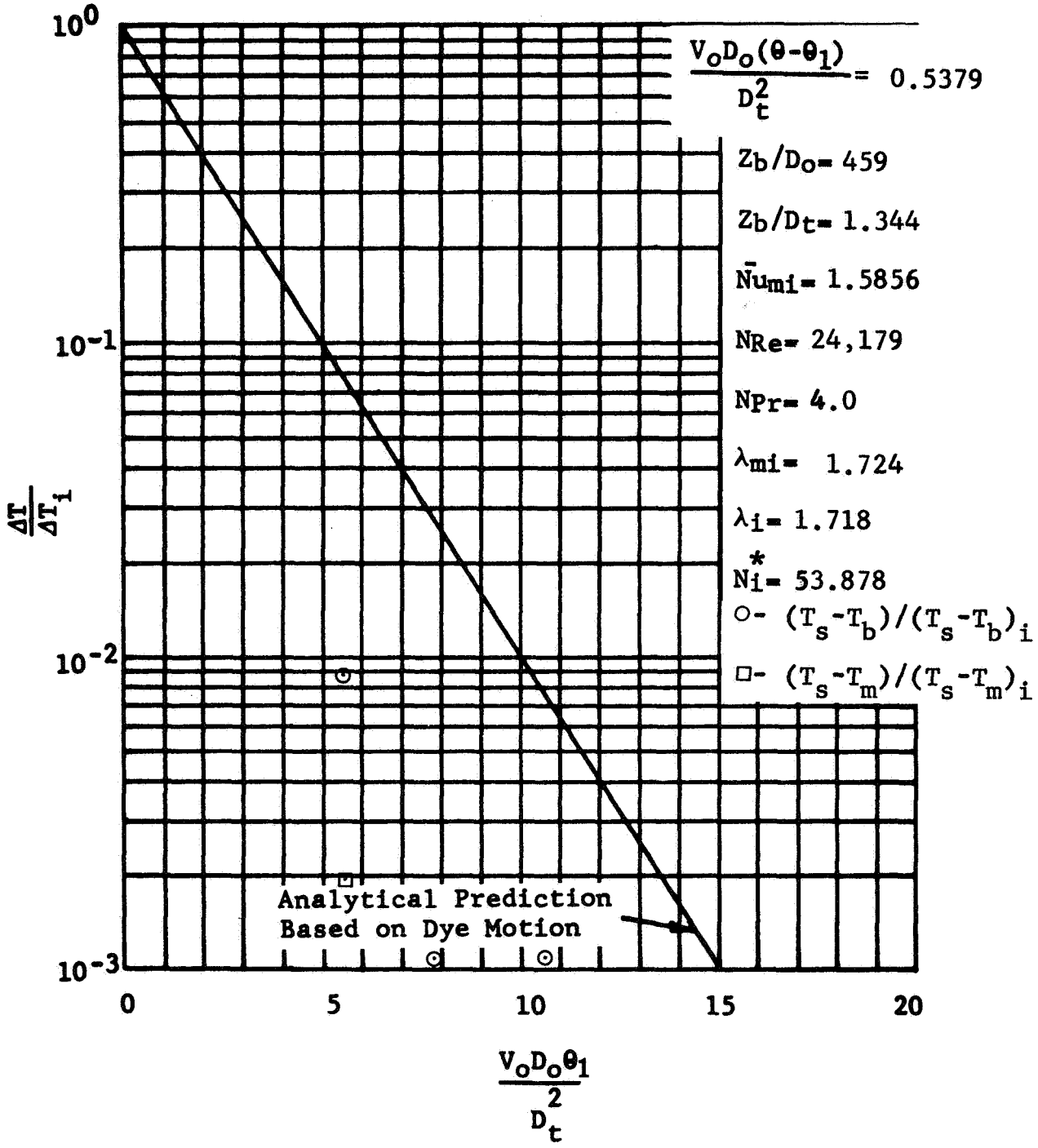

Figure 3.0-83 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 23

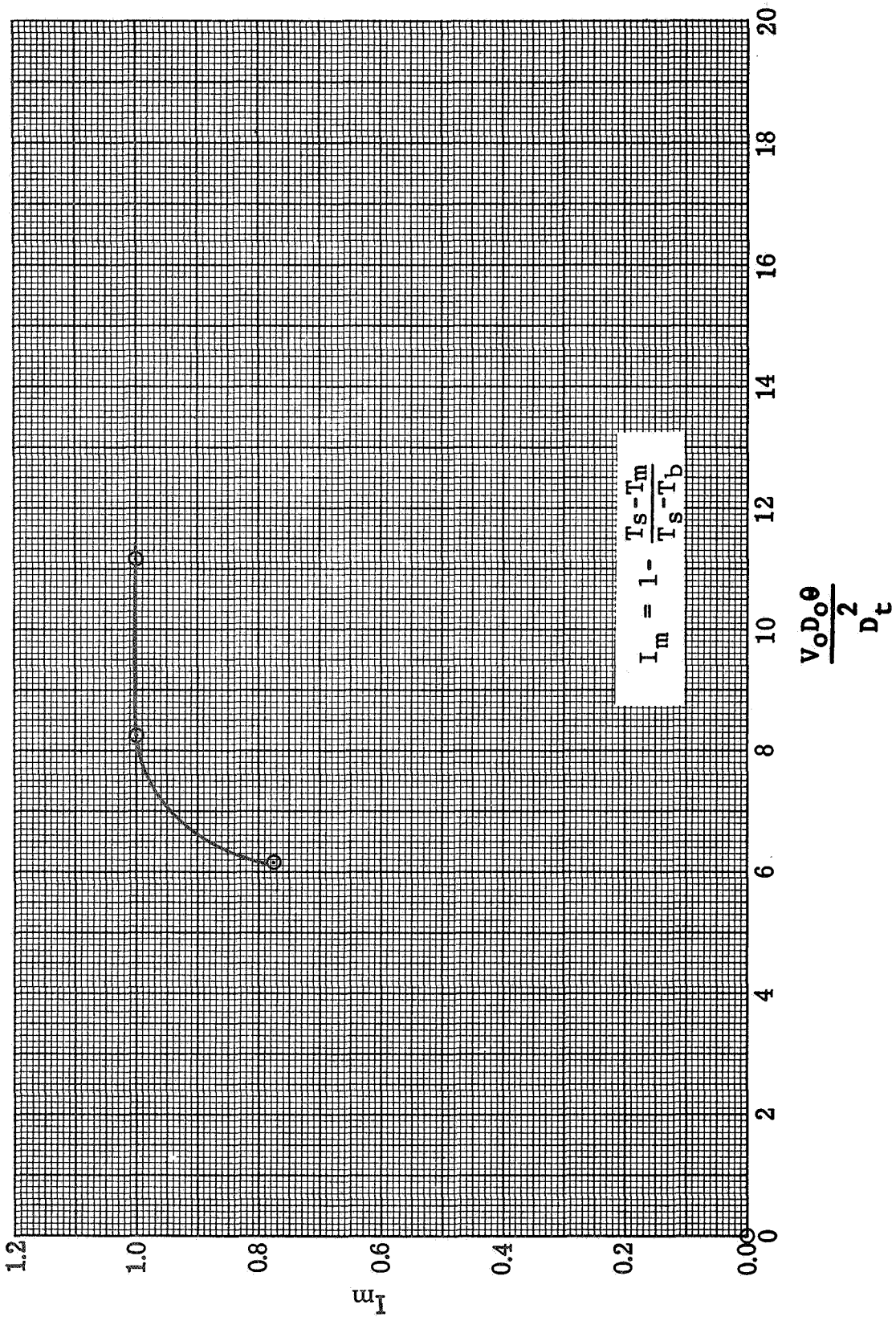

Figure 3.0-84 Transient Energy Integral: Test 15, Run 23

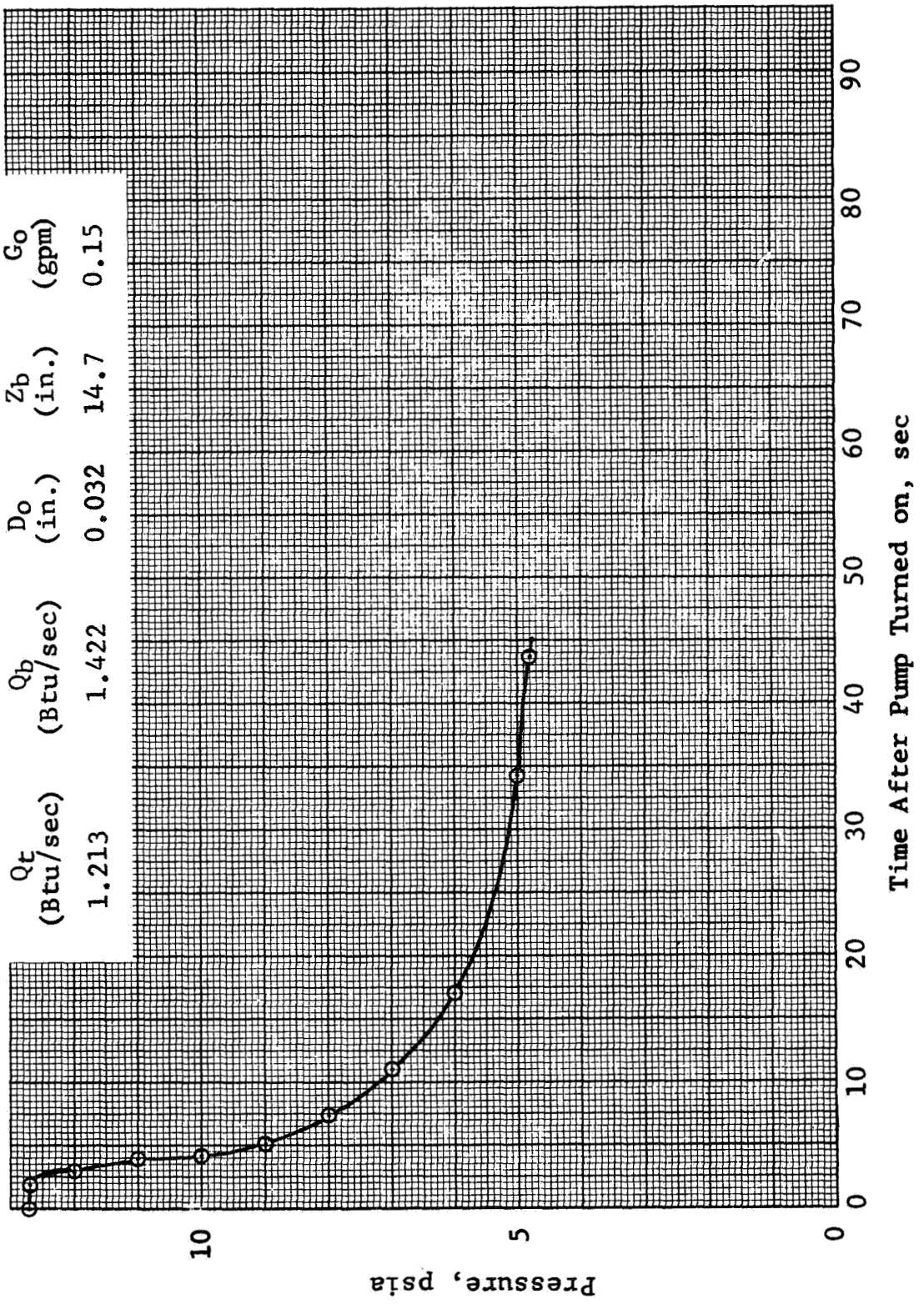

Figure 3.0-85 Transient Pressure Decay: Test 15, Run 24

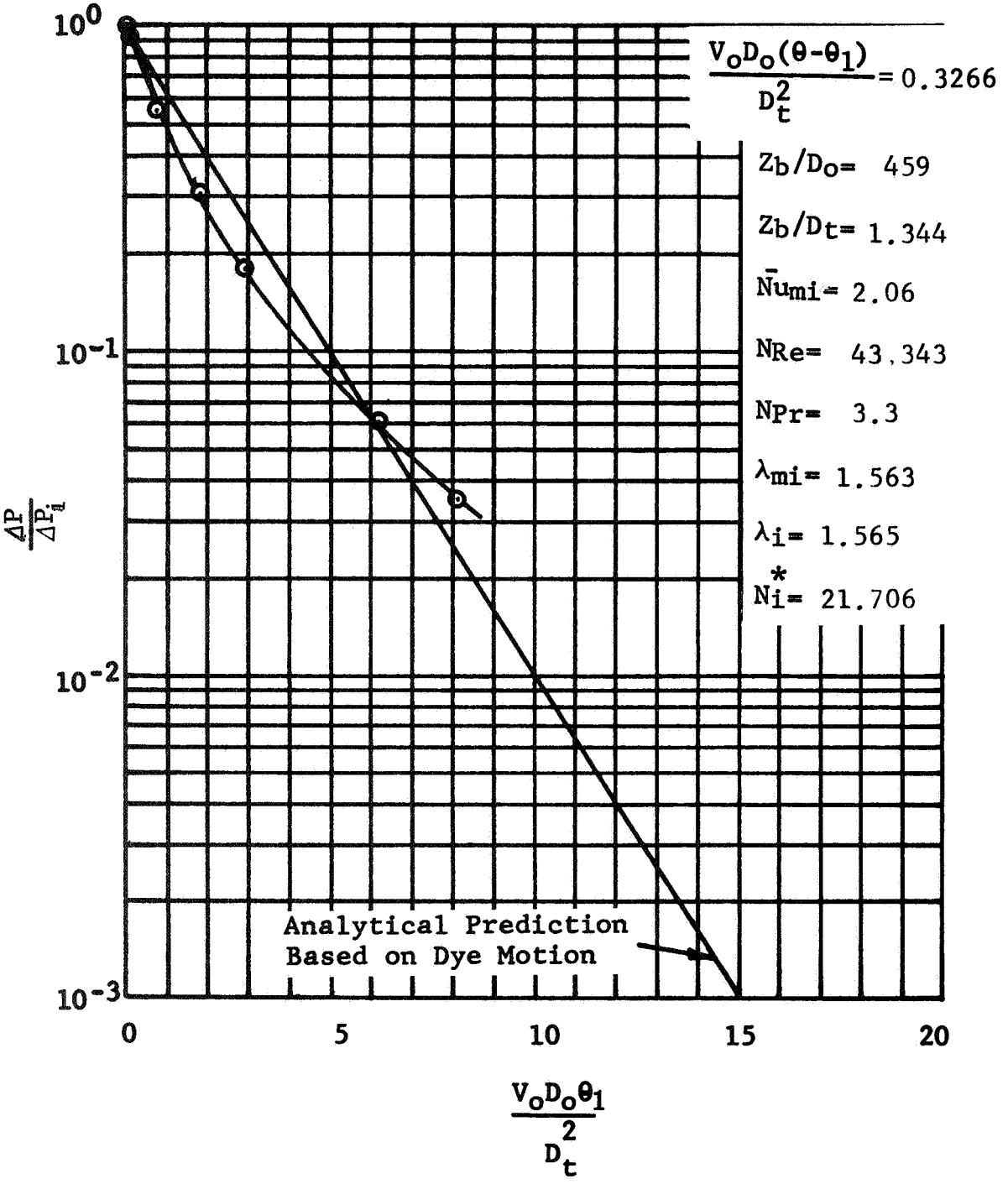

Figure 3.0-86 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_I=0.0 sec): Test 15, Run 24

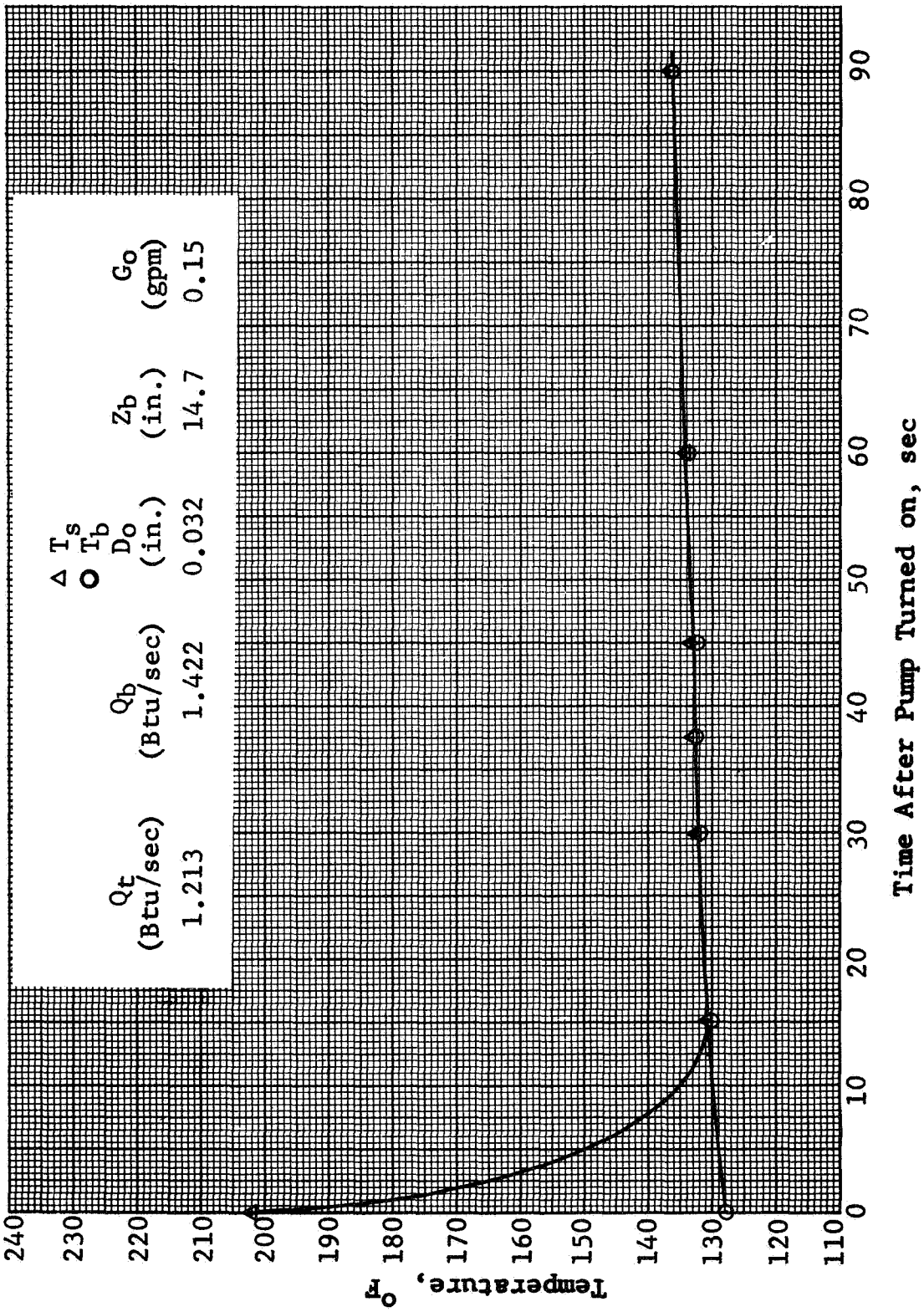

Figure 3.0-87 **Transient Temperature Destratification:** Test 15, Run 24

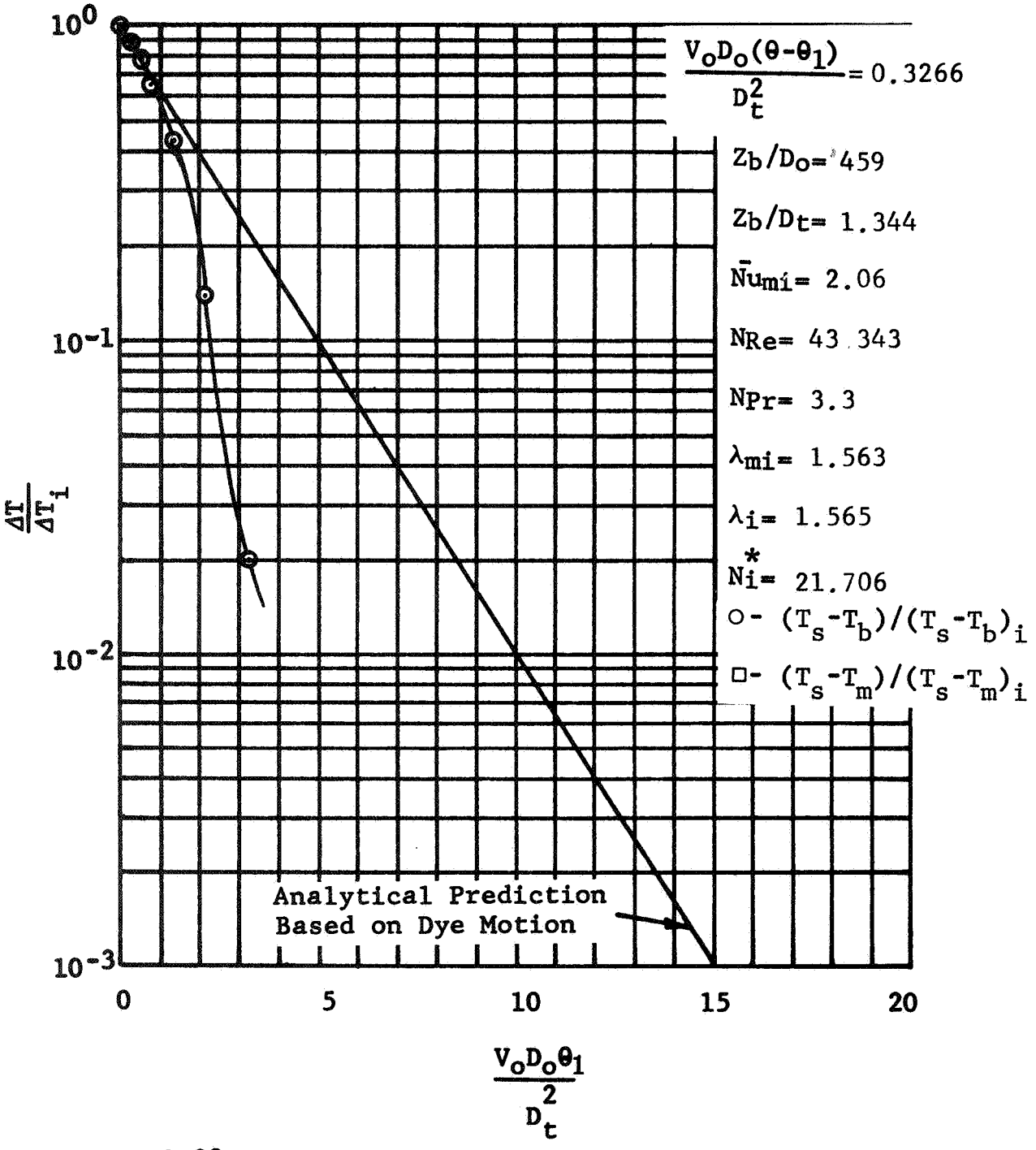

Figure 3.0-88 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 24

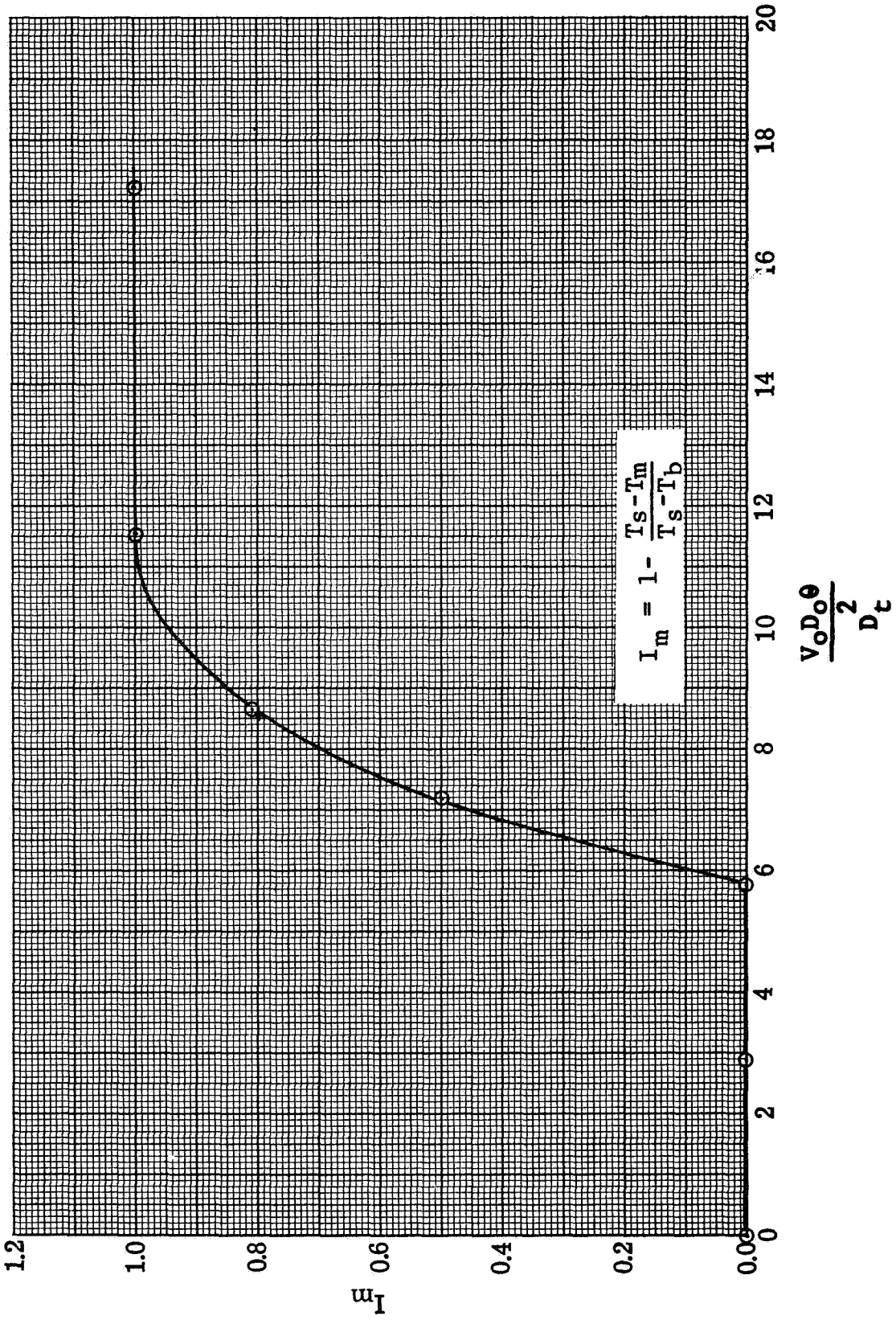

Figure 3.0-89 Transient Energy Integral: Test 15, Run 24

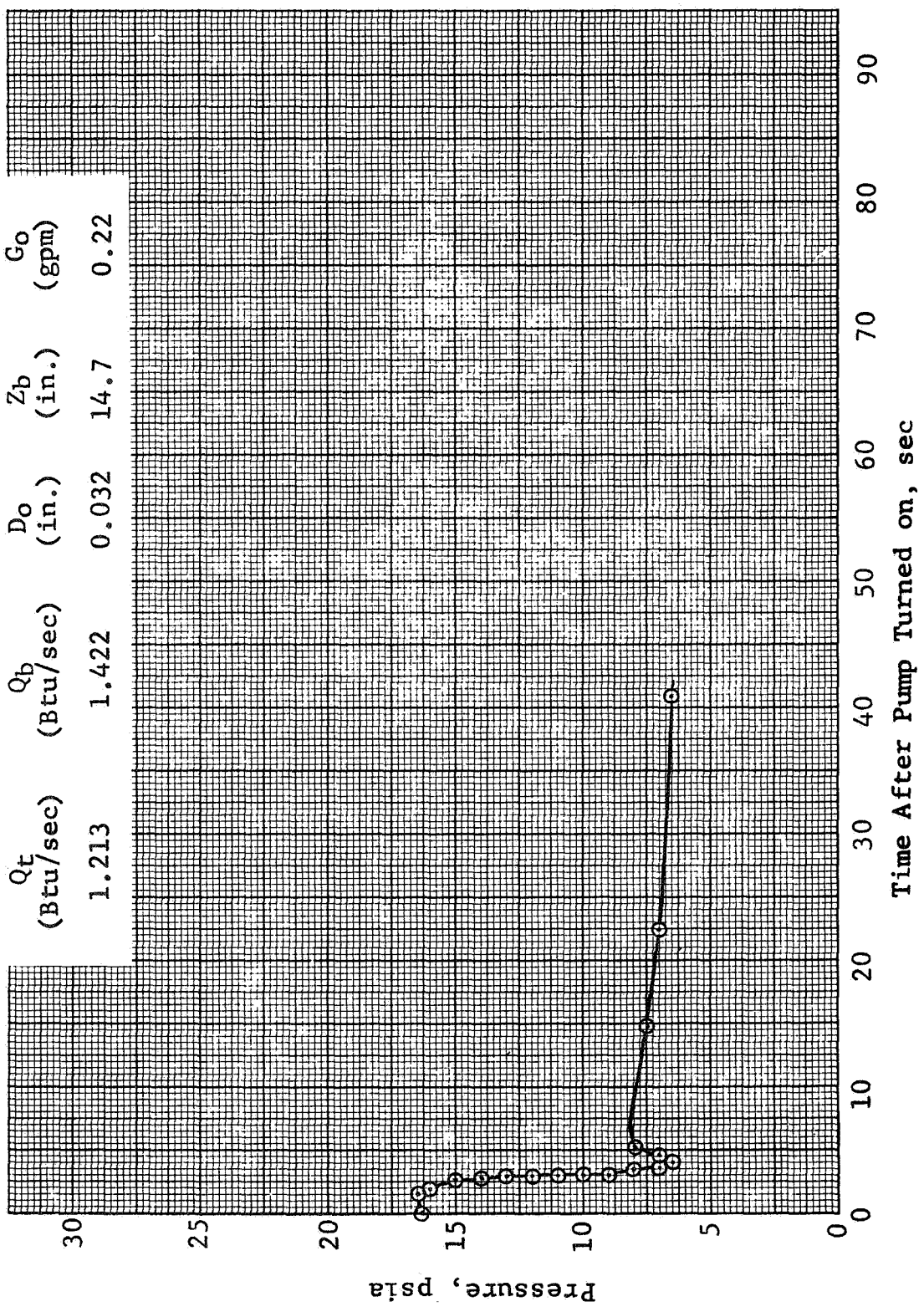

Figure 3.0-90 Transient Pressure Decay: Test 15, Run 25

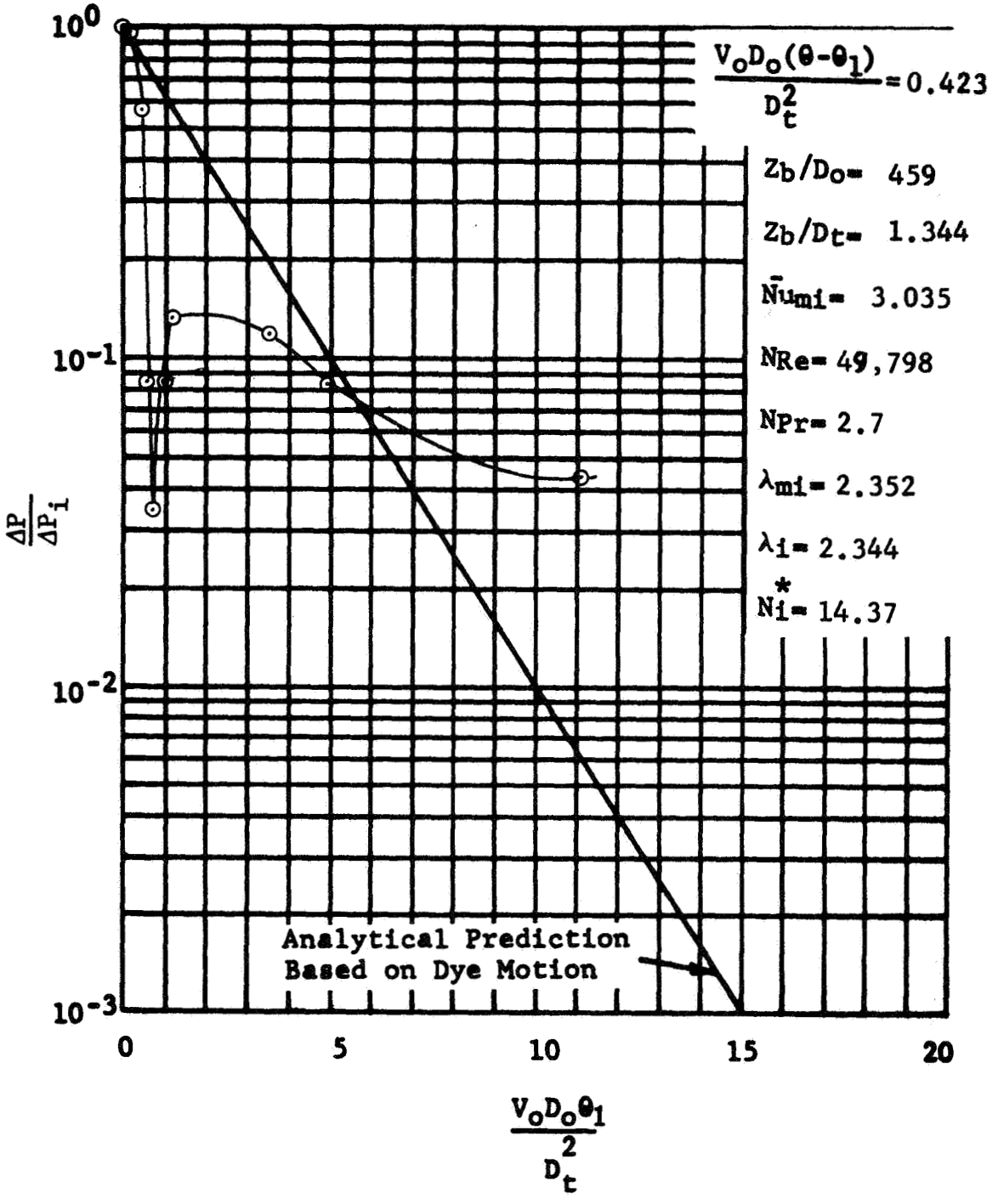

Figure 3.0-91 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 25

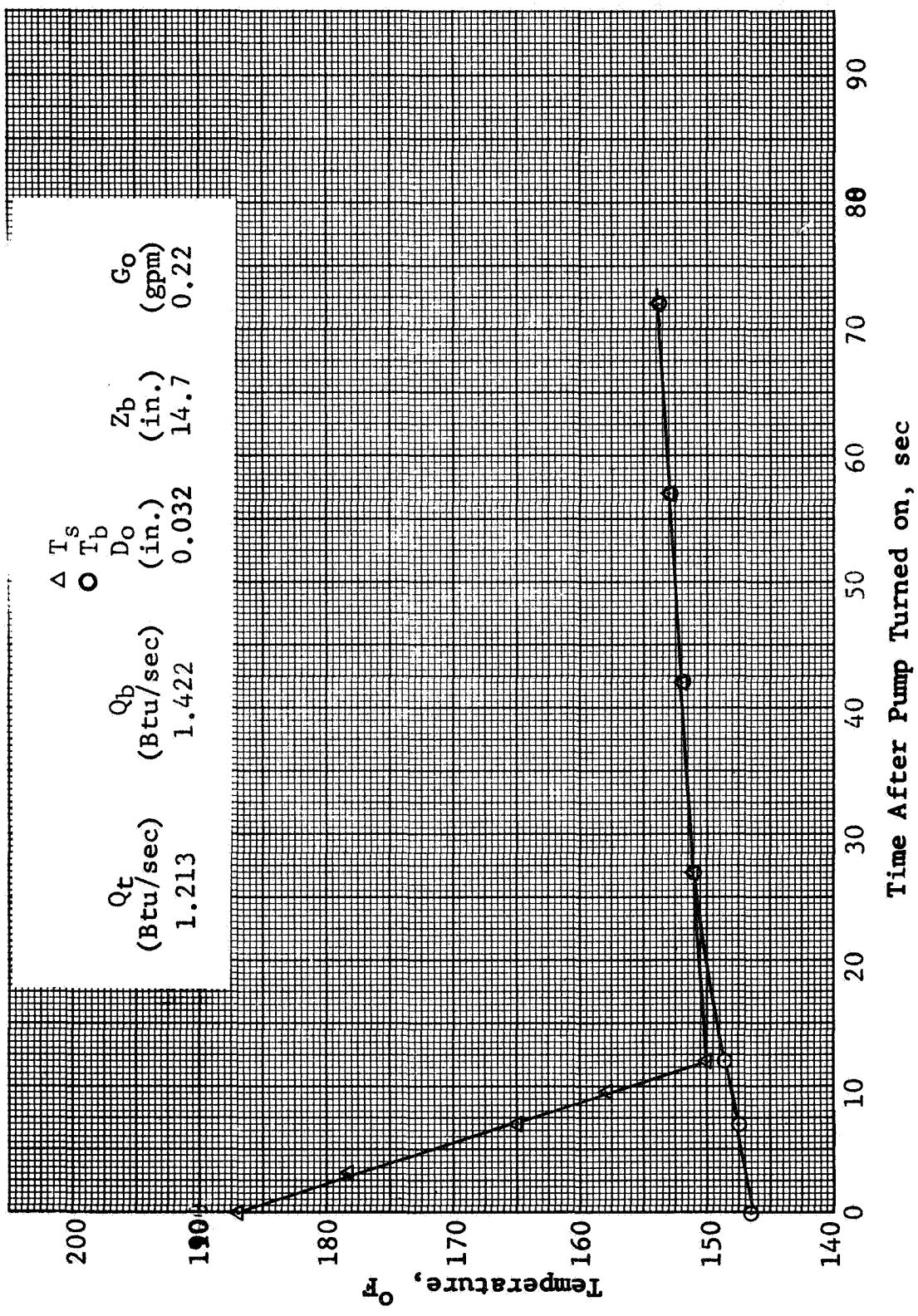

Figure 3.0-92 Transient Temperature Destratification: [illegible], Run 25

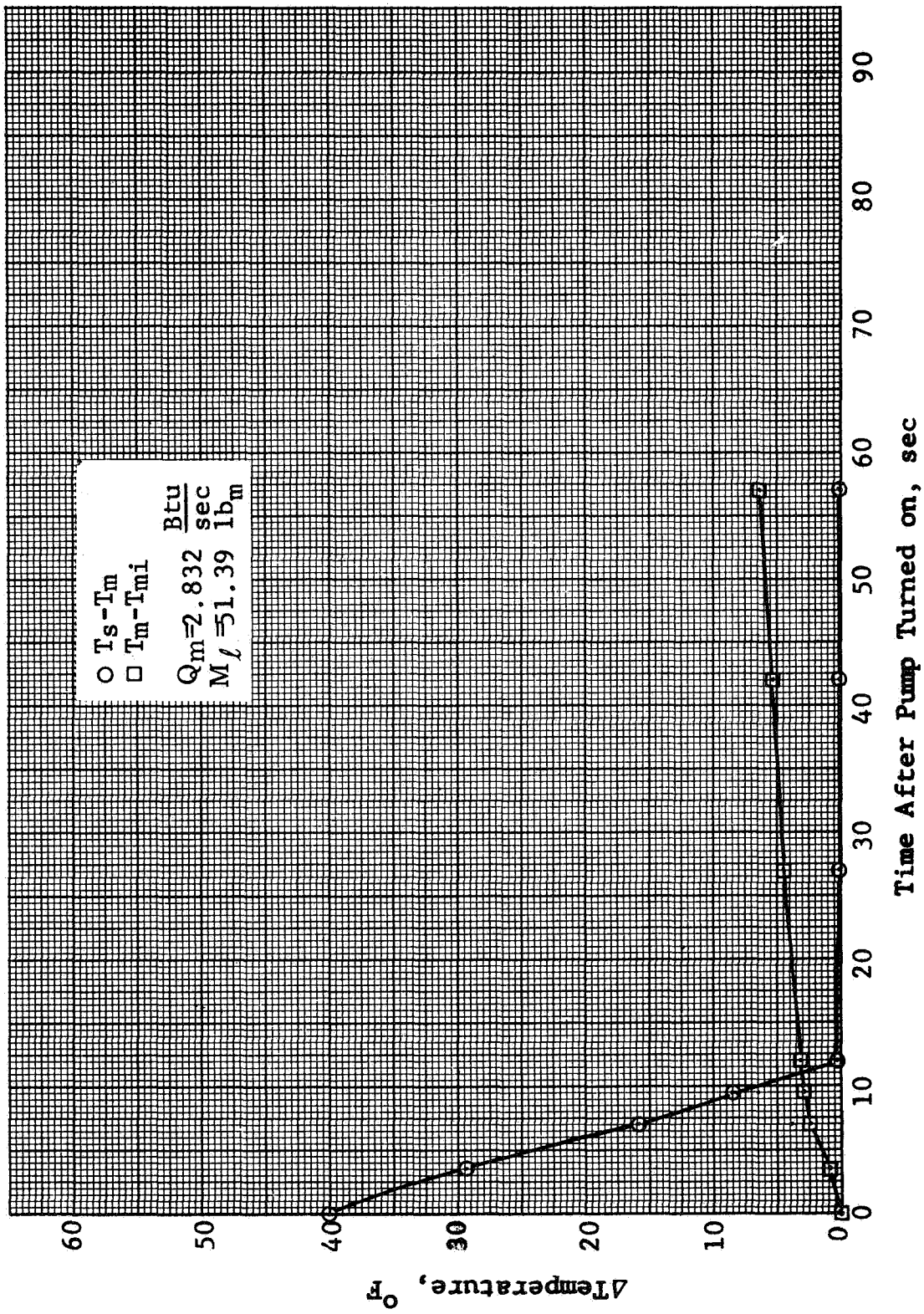

Figure 3.0-93 Transient ΔTemperature Destratification: Test 15, Run 25

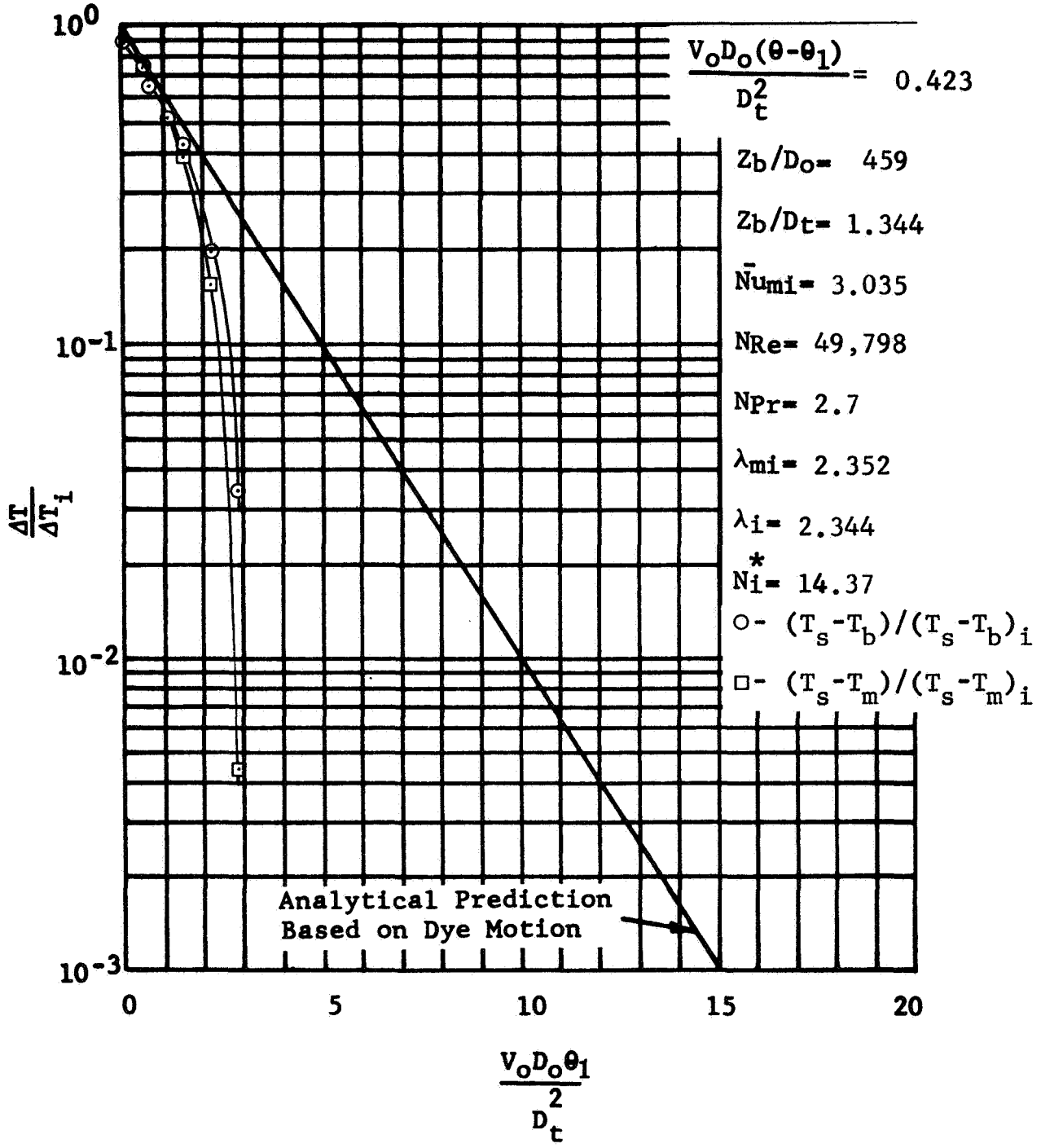

Figure 3.0-94 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 25

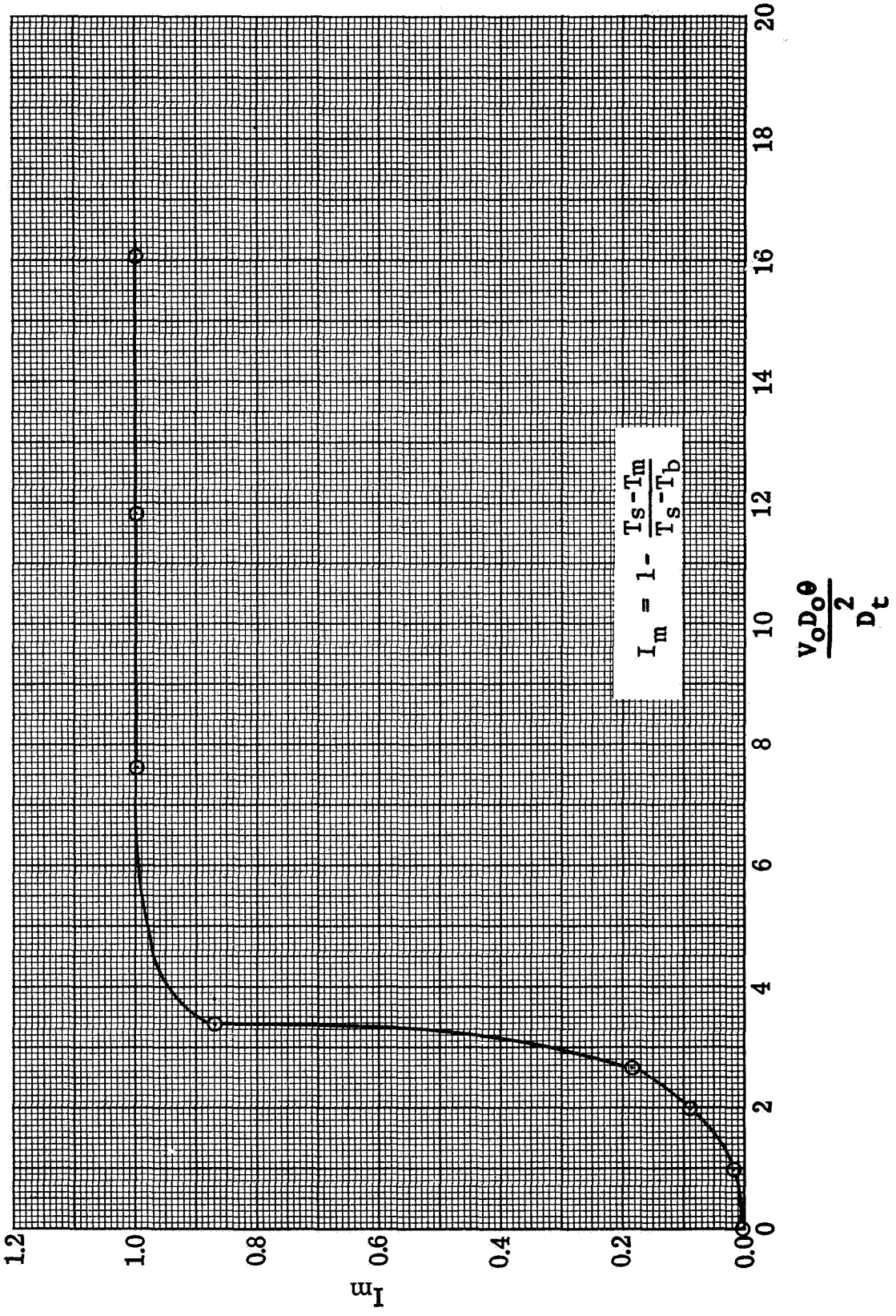

Figure 3.0-95 Transient Energy Integral: Test 15, Run 25

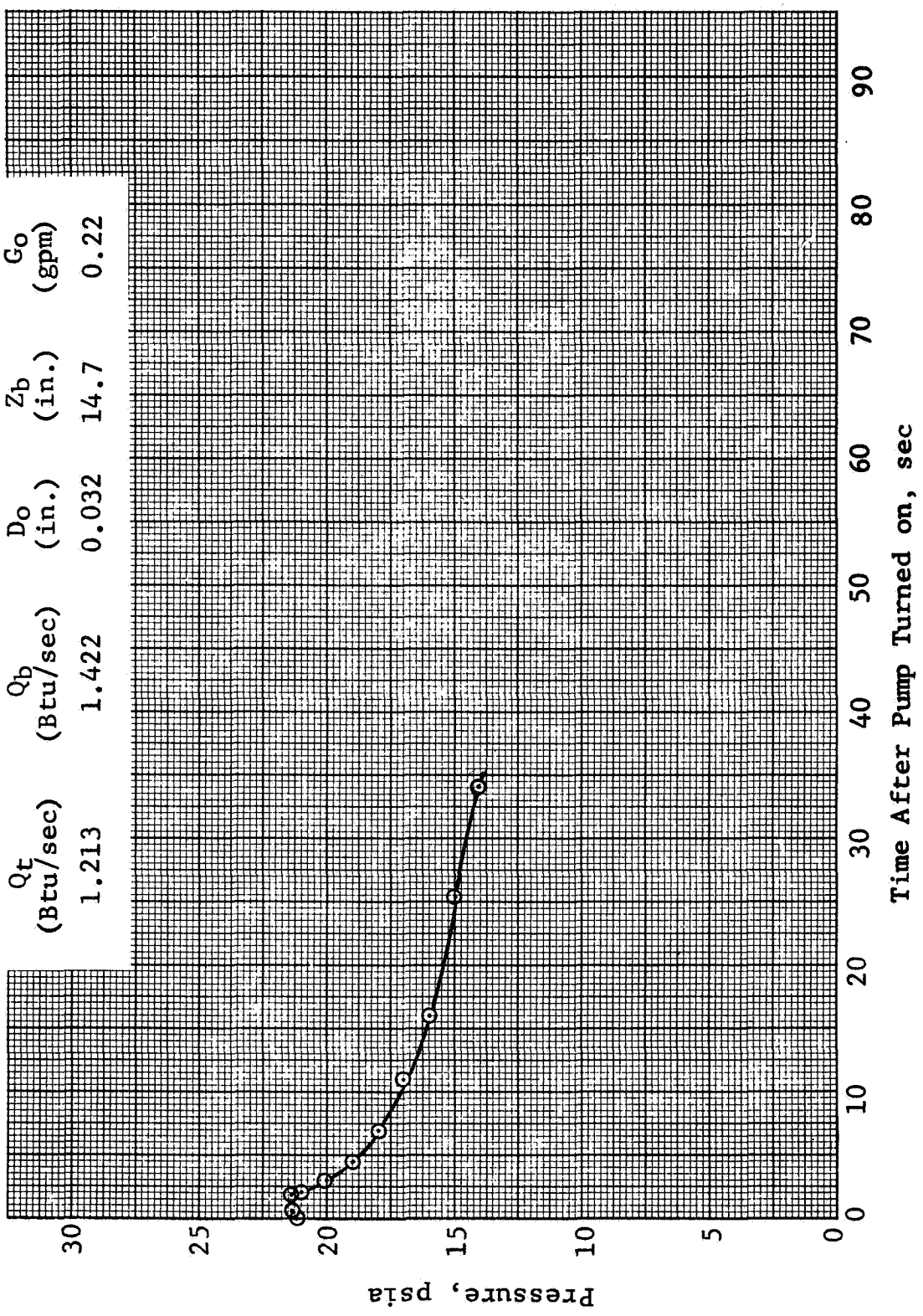

Figure 3.0-96 Transient Pressure Decay: Test 15, Run 26

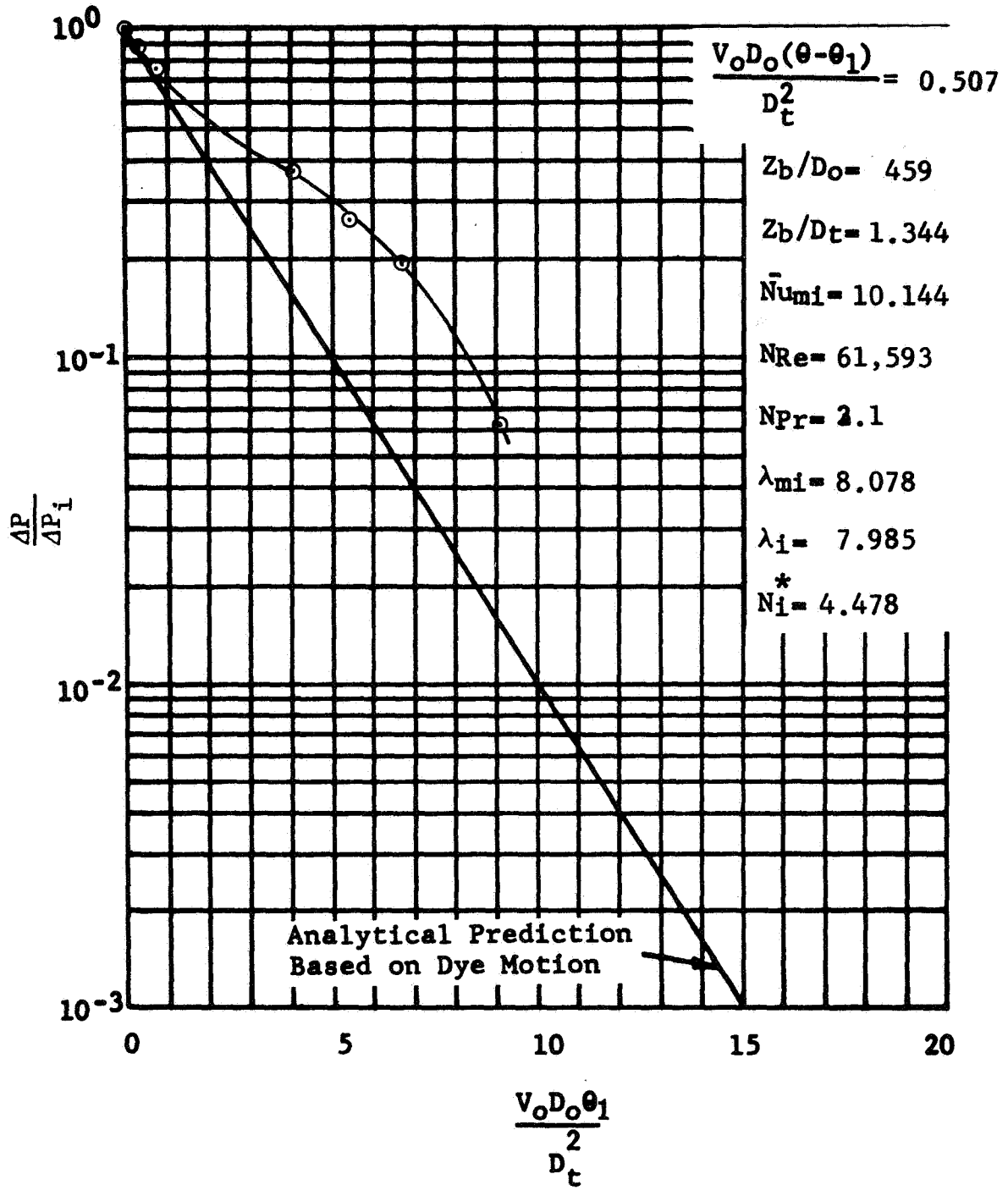

Figure 3.0-97 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 26

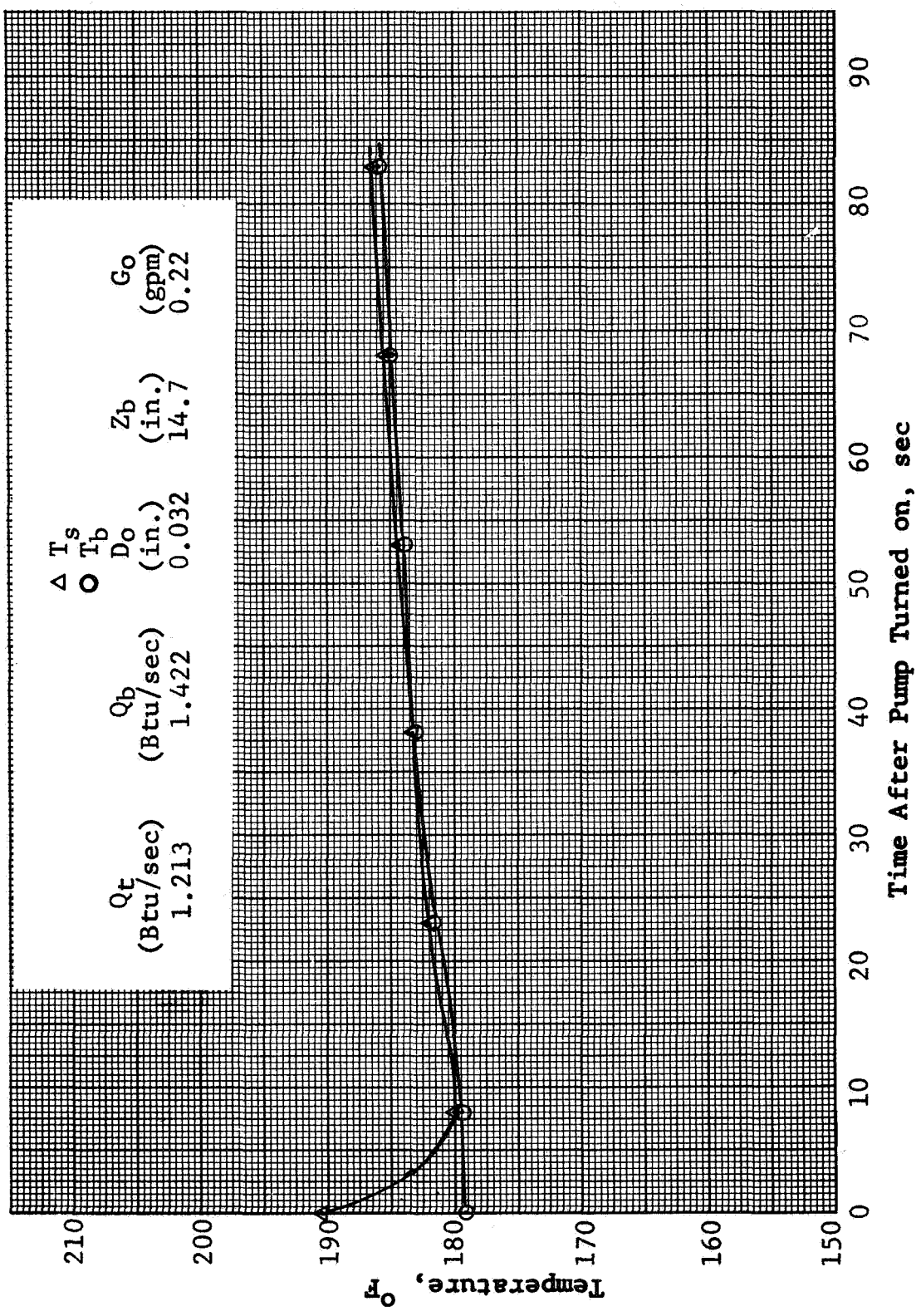

Figure 3.0-98 Transient Temperature Destratification: Test 15, Run 26

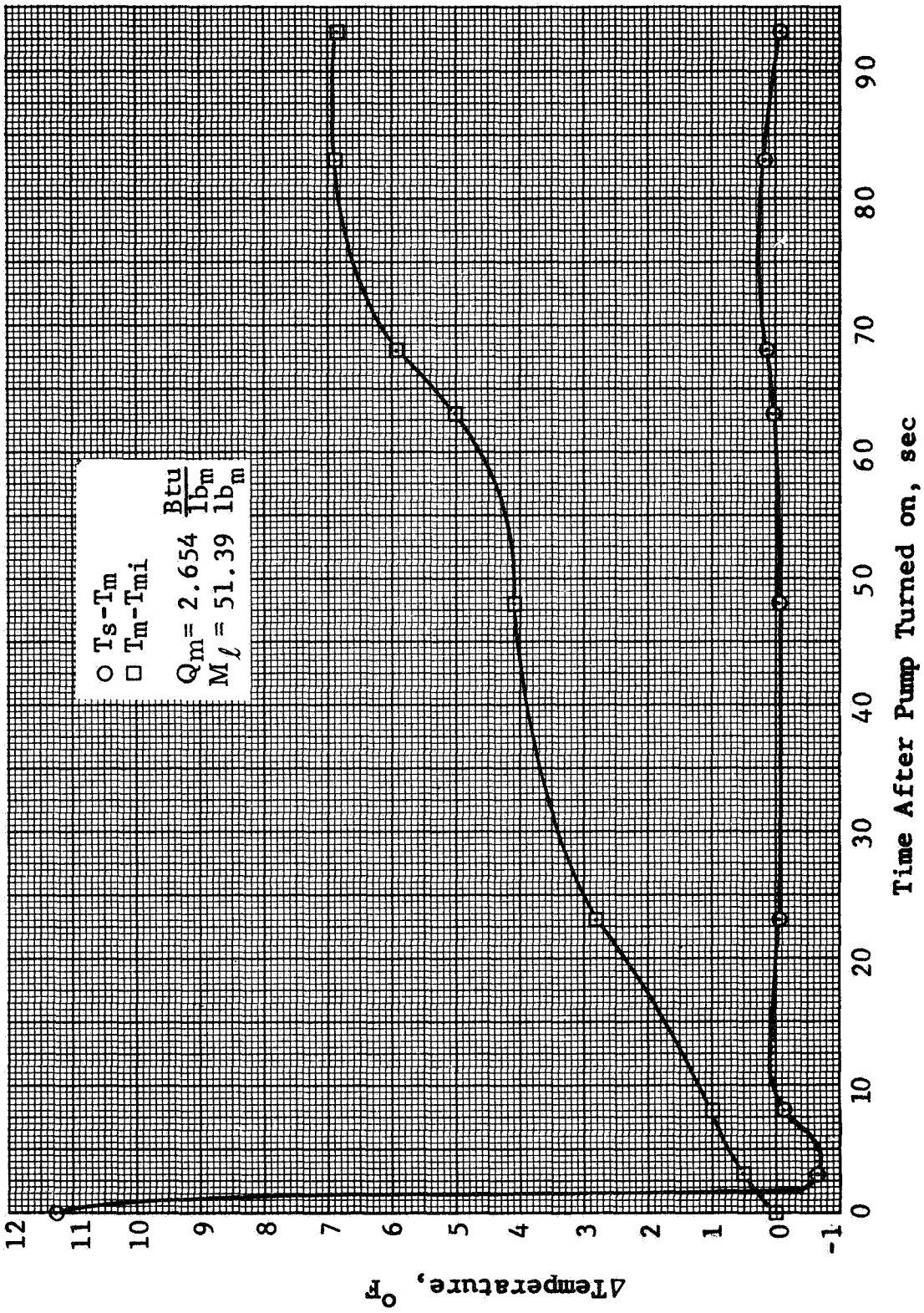

Figure 3.0-99 Transient ΔTemperature Destratification: Test 15, Run 26

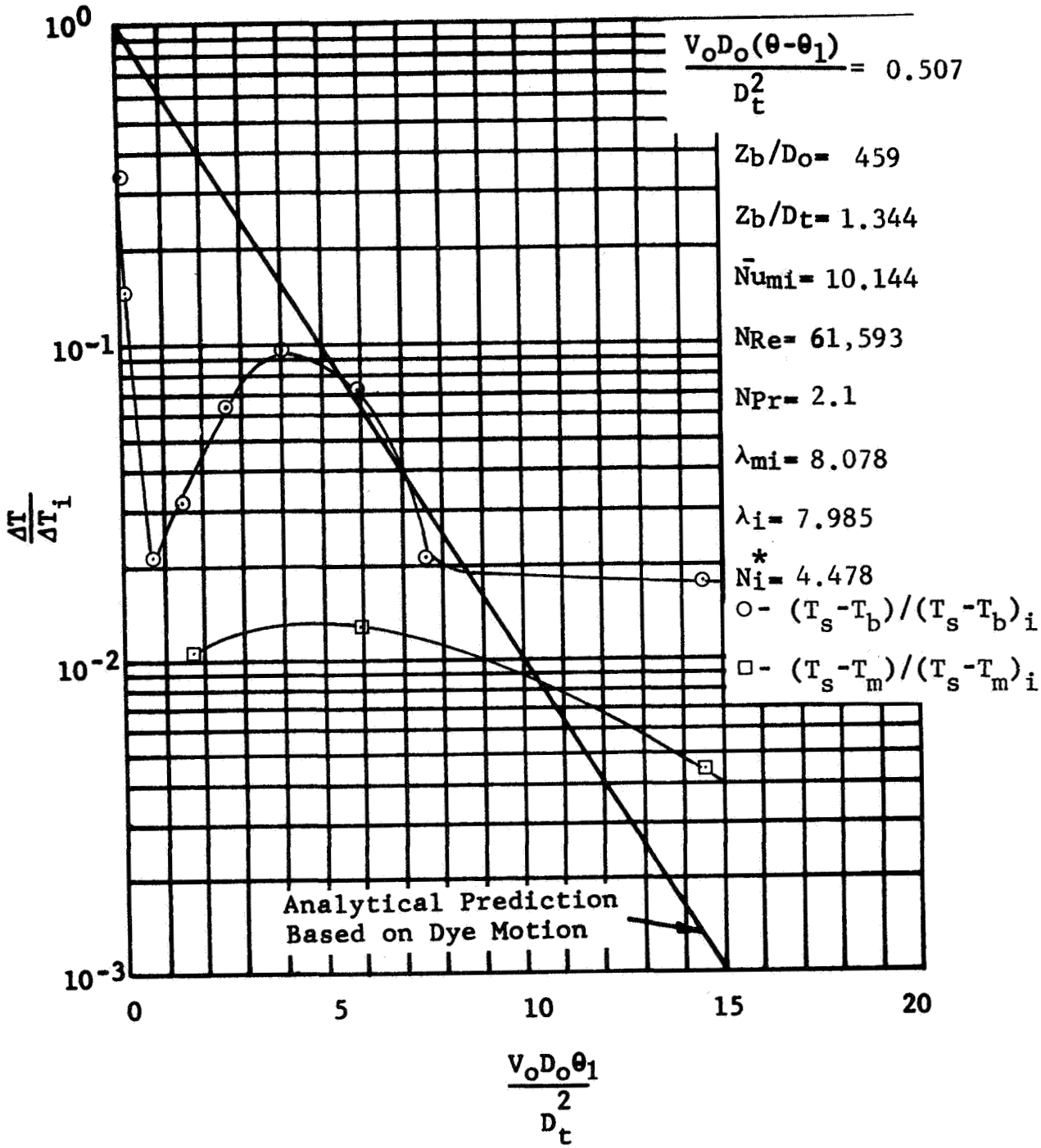

Figure 3.0-100 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 15, Run 26

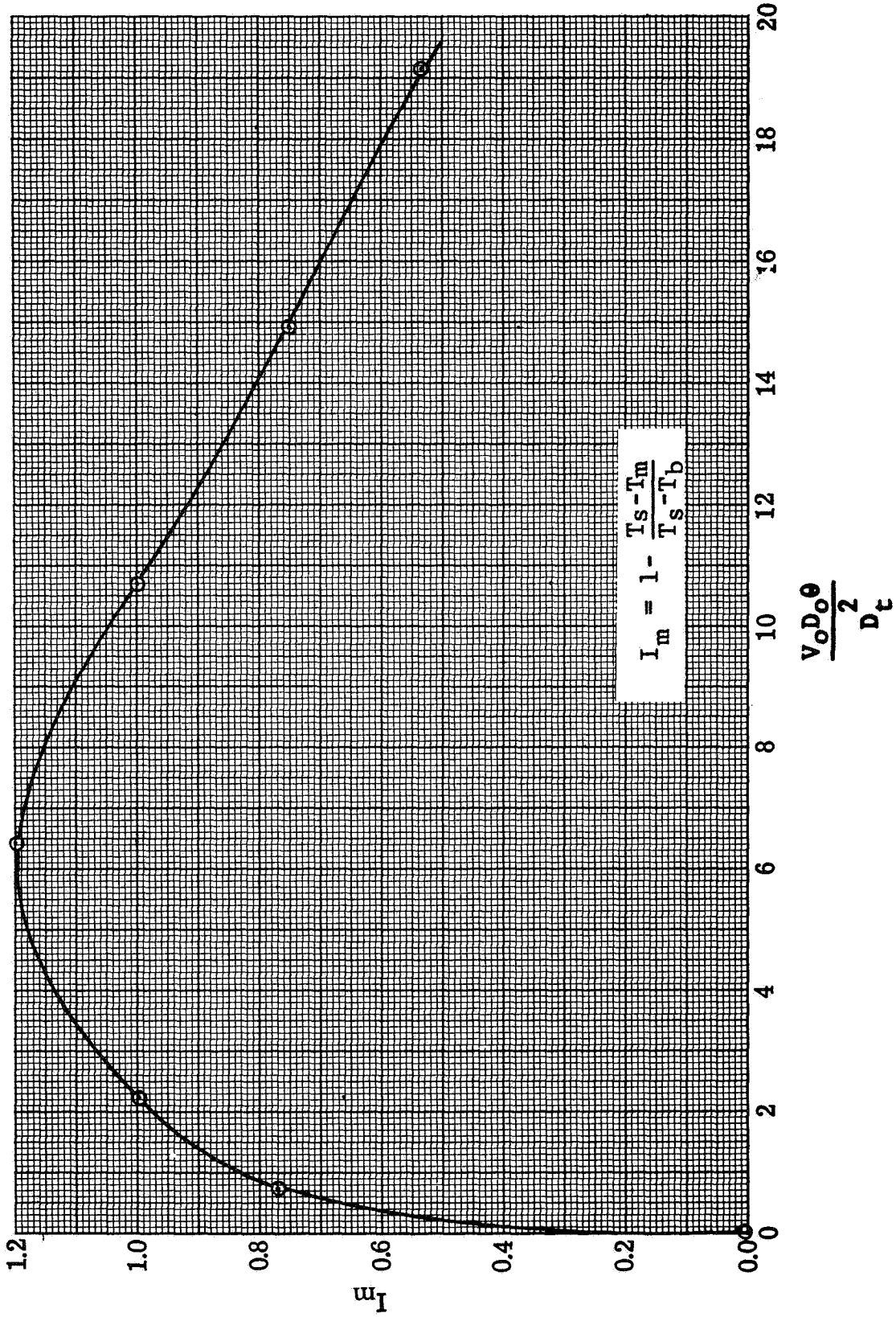

Figure 3.0-101 Transient Energy Integral: Test 15, Run 26

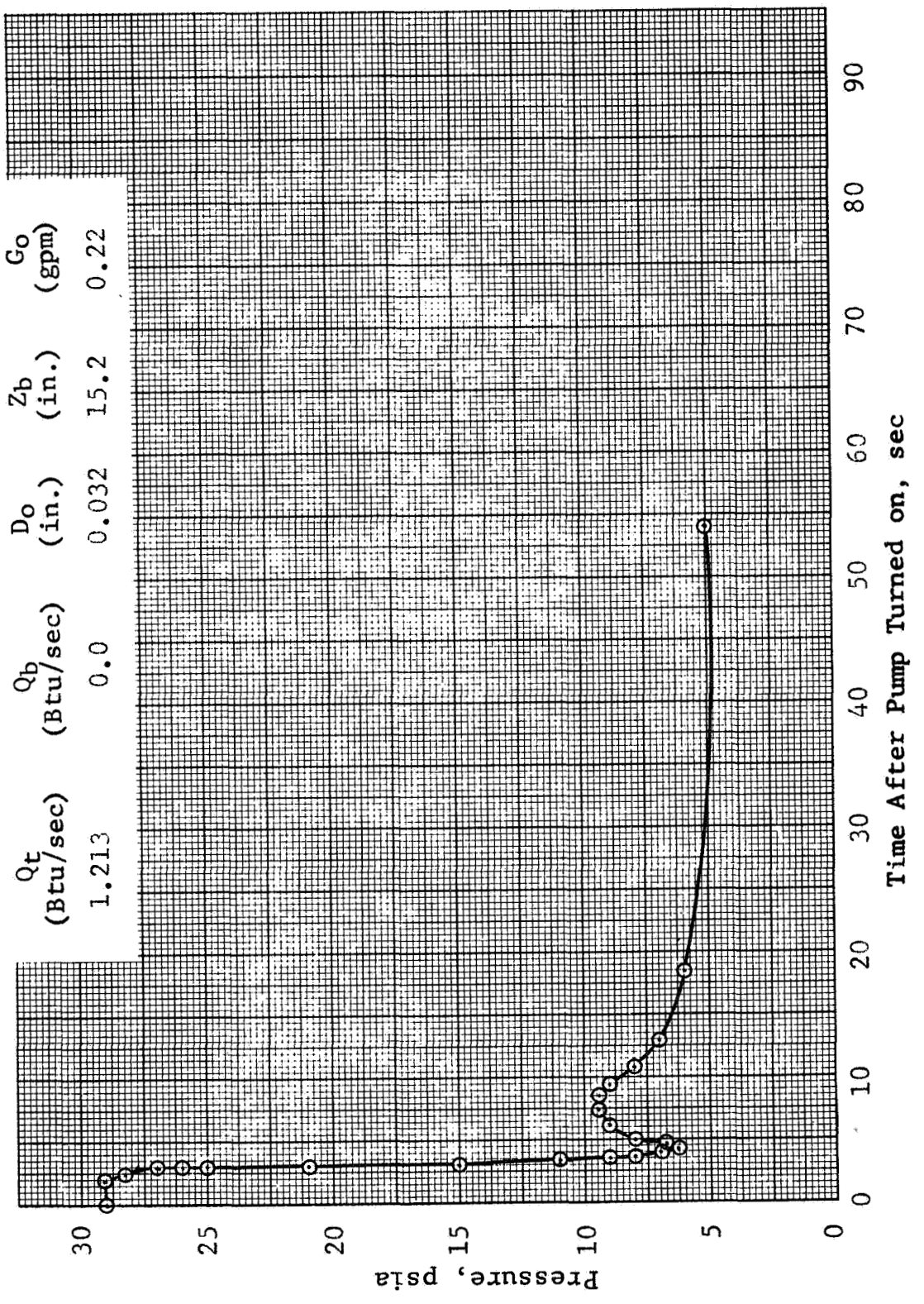

Figure 3.0-102 Transient Pressure Decay: Test 16, Run 28

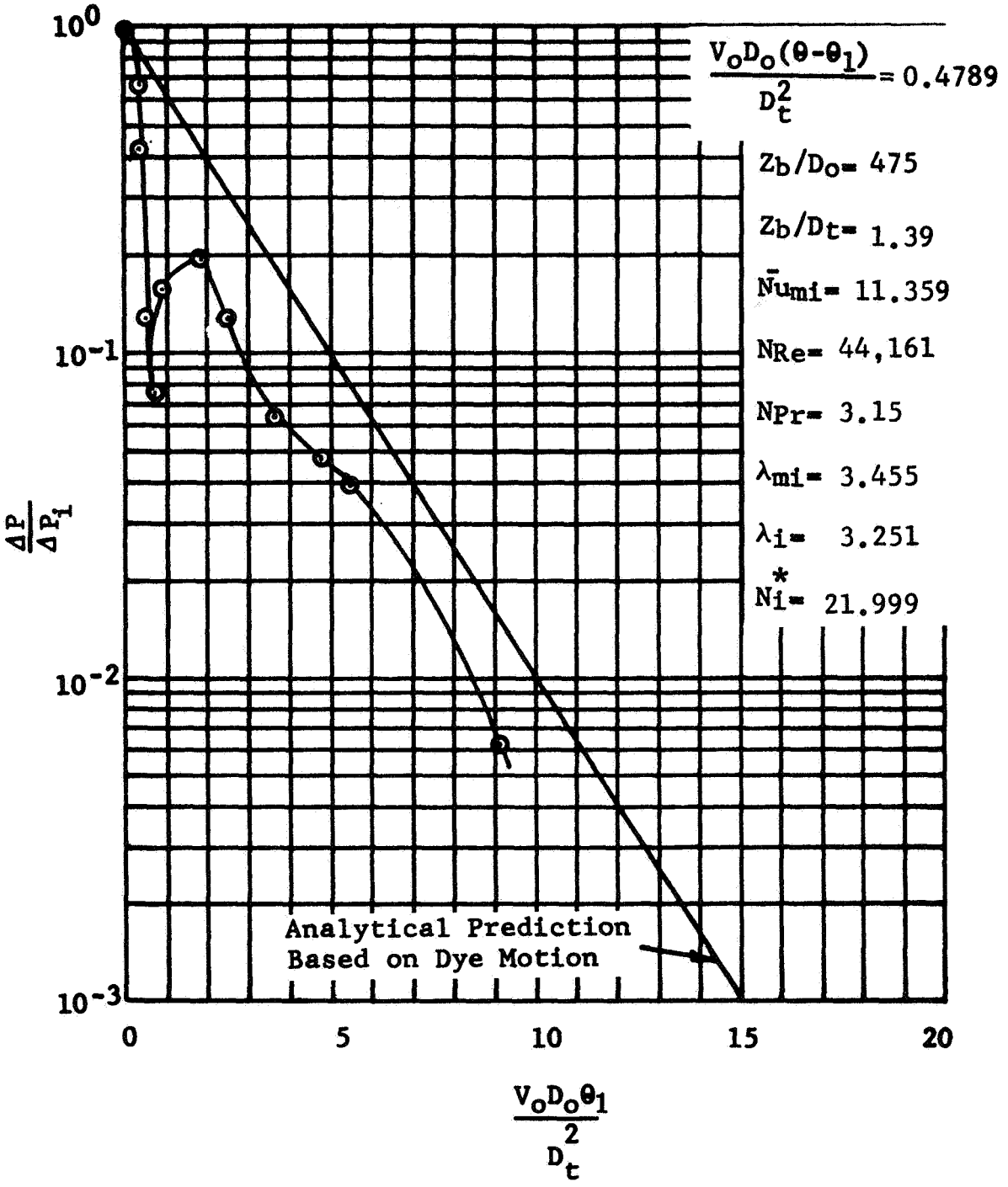

Figure 3.0-103 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 16, Run 28

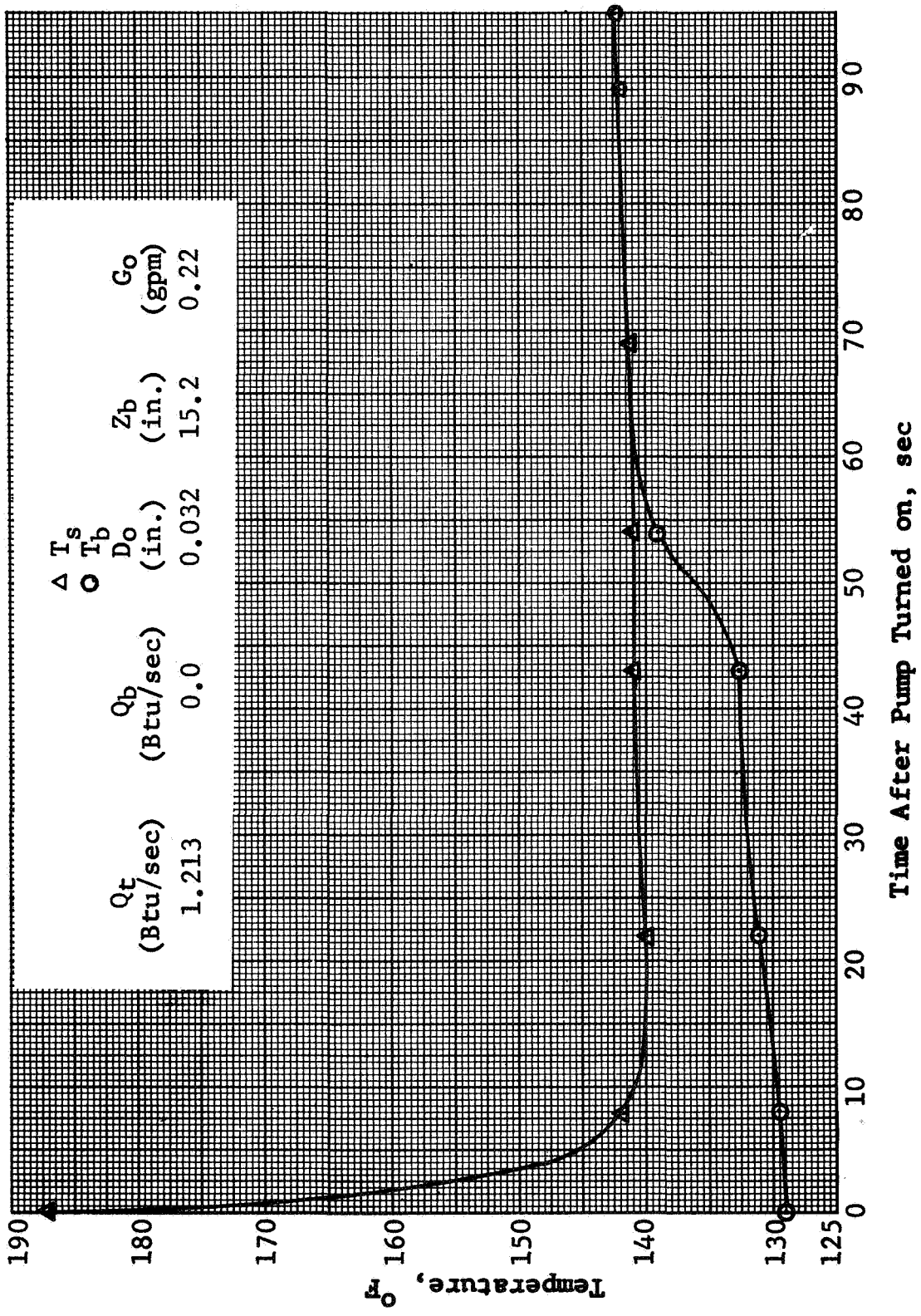

Figure 3.0-104 **Transient Temperature Destratification:** Test 16, Run 28

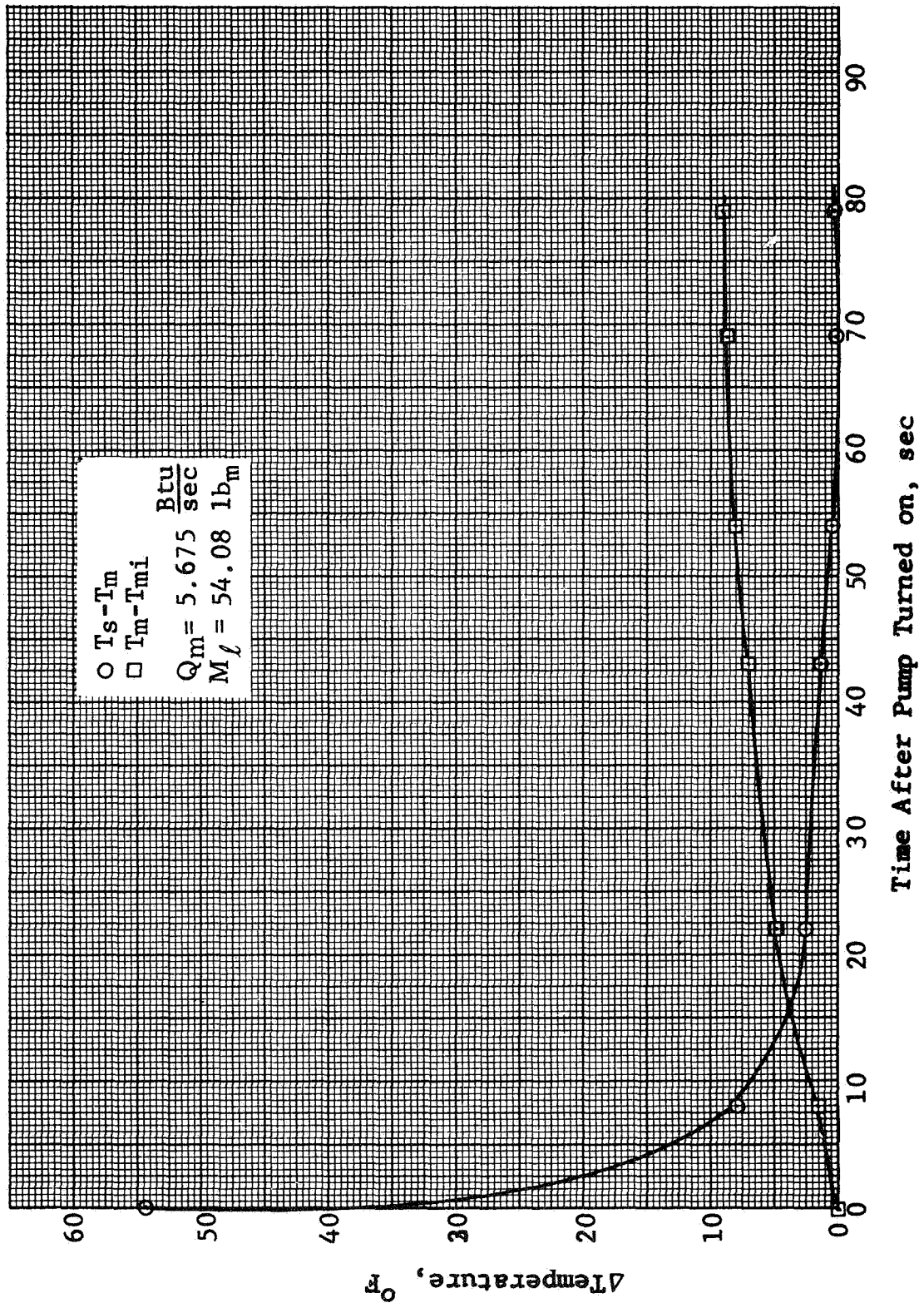

Figure 3.0-105 Transient ΔTemperature Destratification: Test 16, Run 28

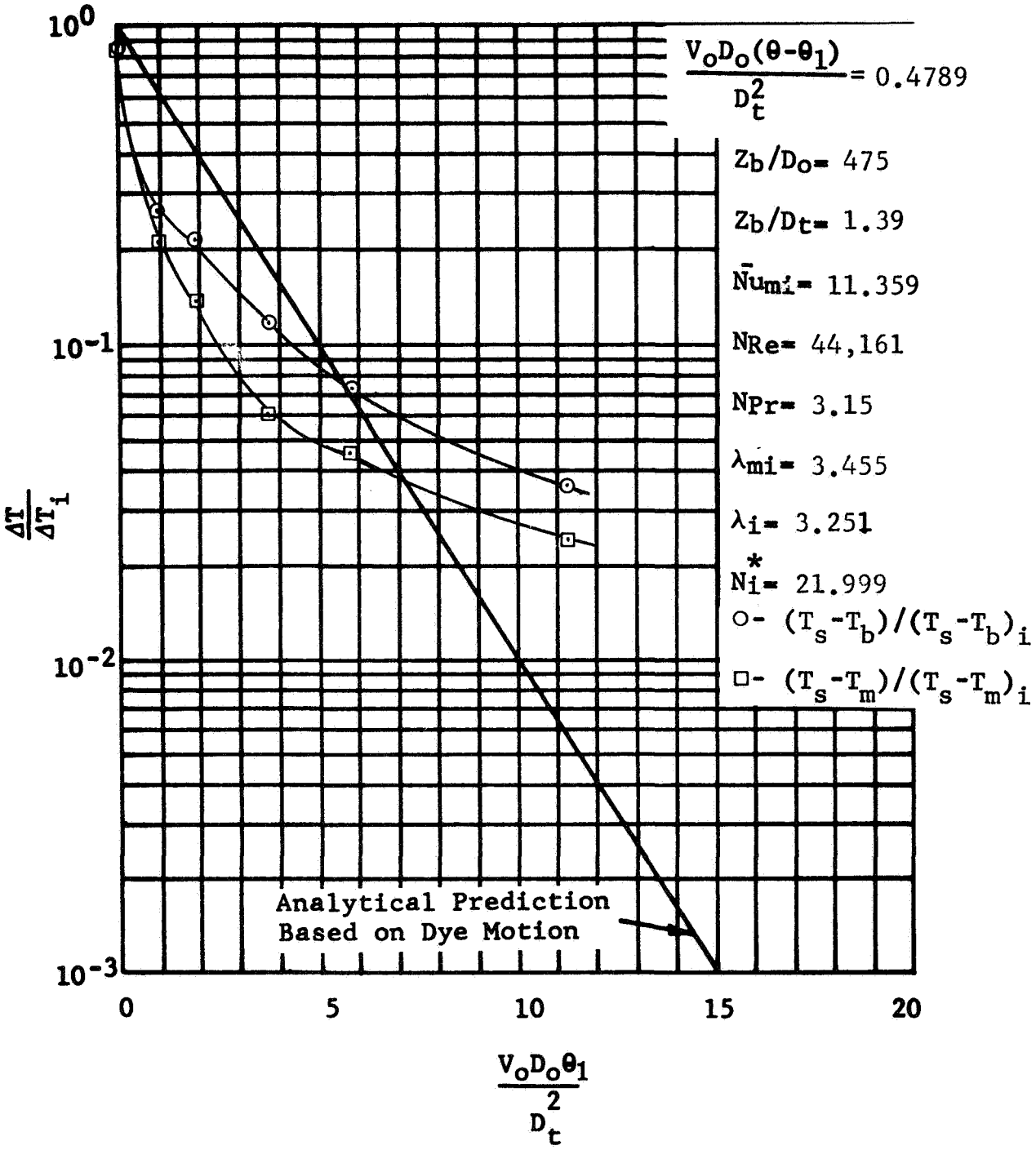

Figure 3.0-106 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 16, Run 28

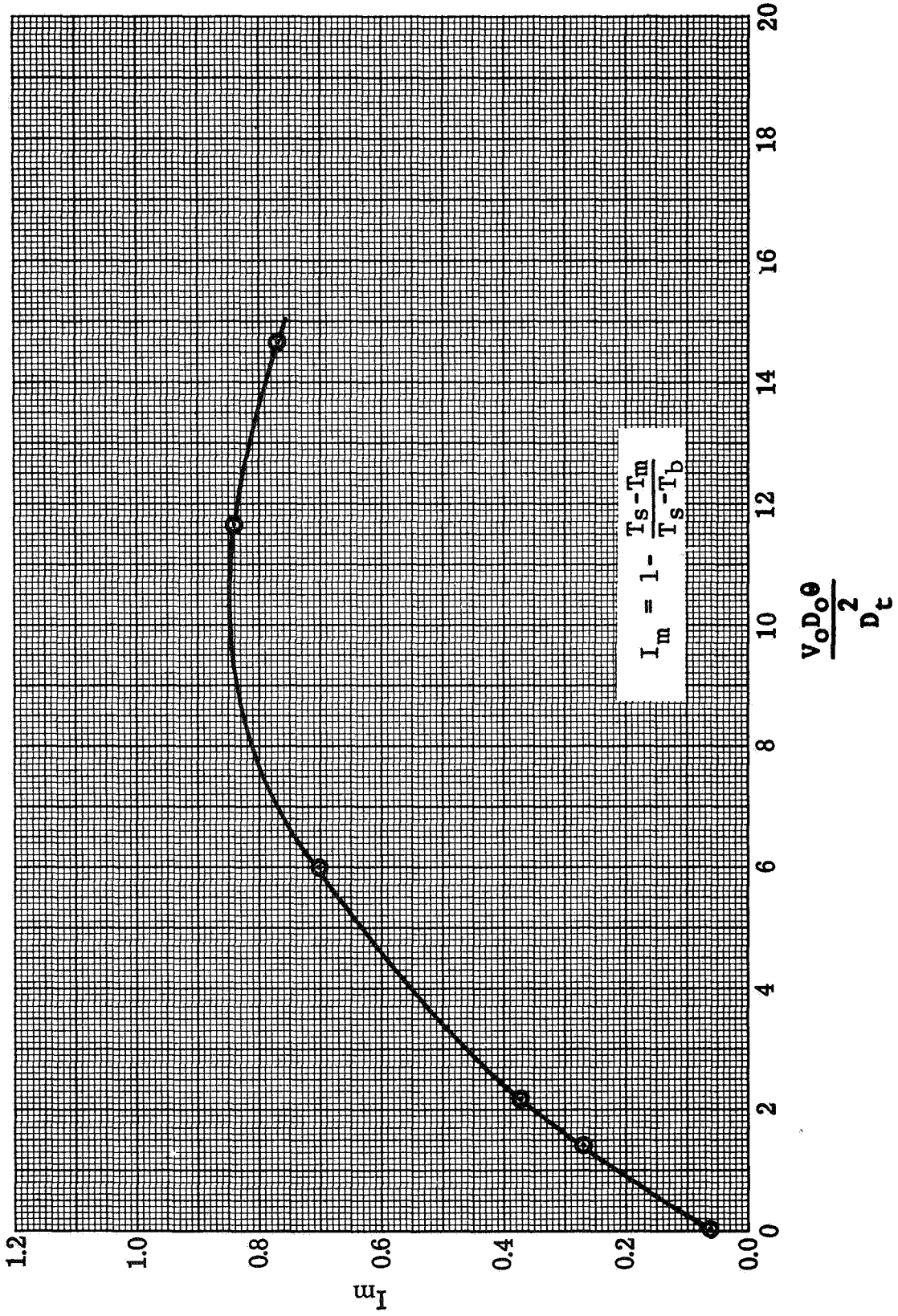

Figure 3.0-107 Transient Energy Integral: Test 16, Run 28

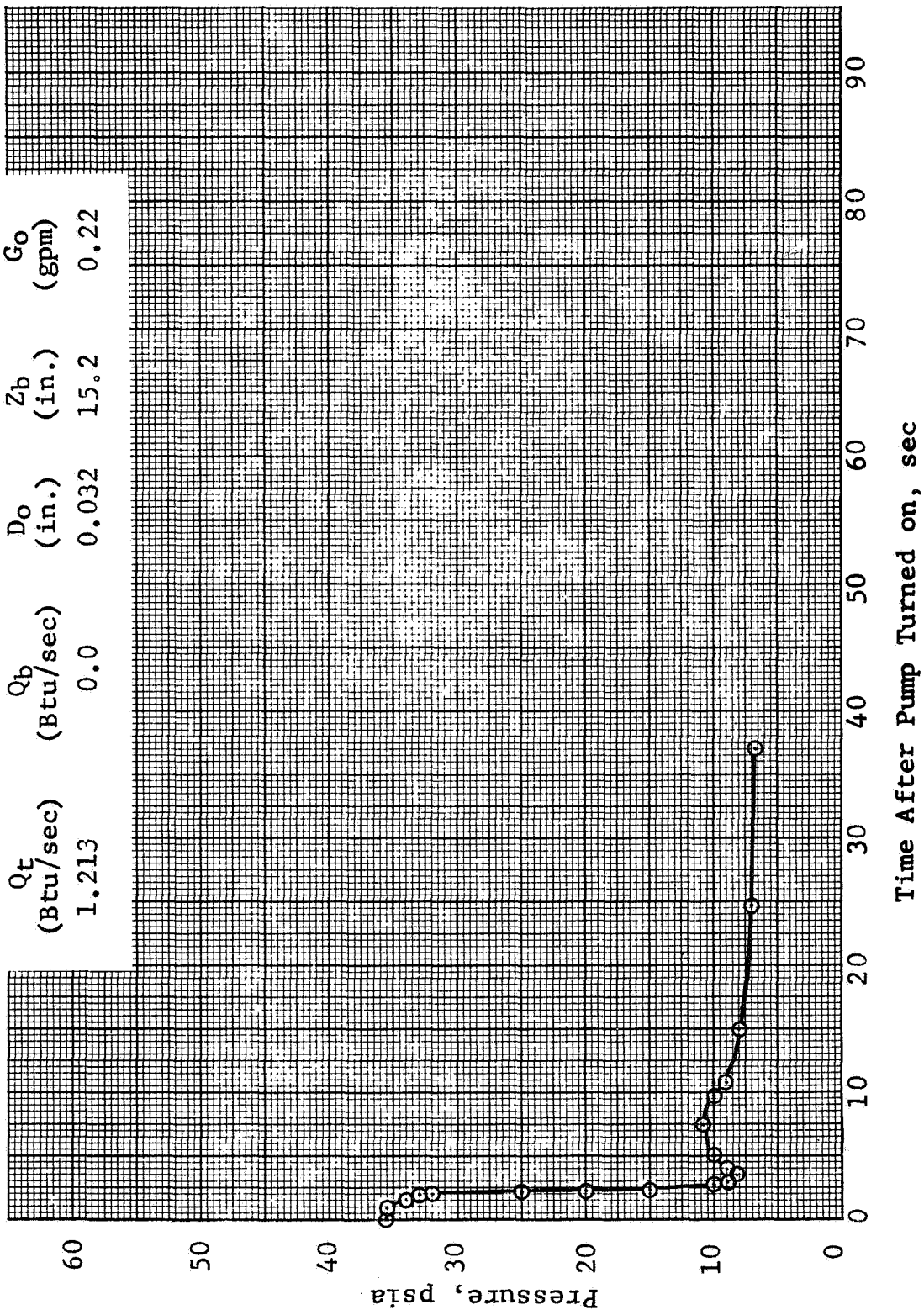

Figure 3.0-108 Transient Pressure Decay: Test 16, Run 29

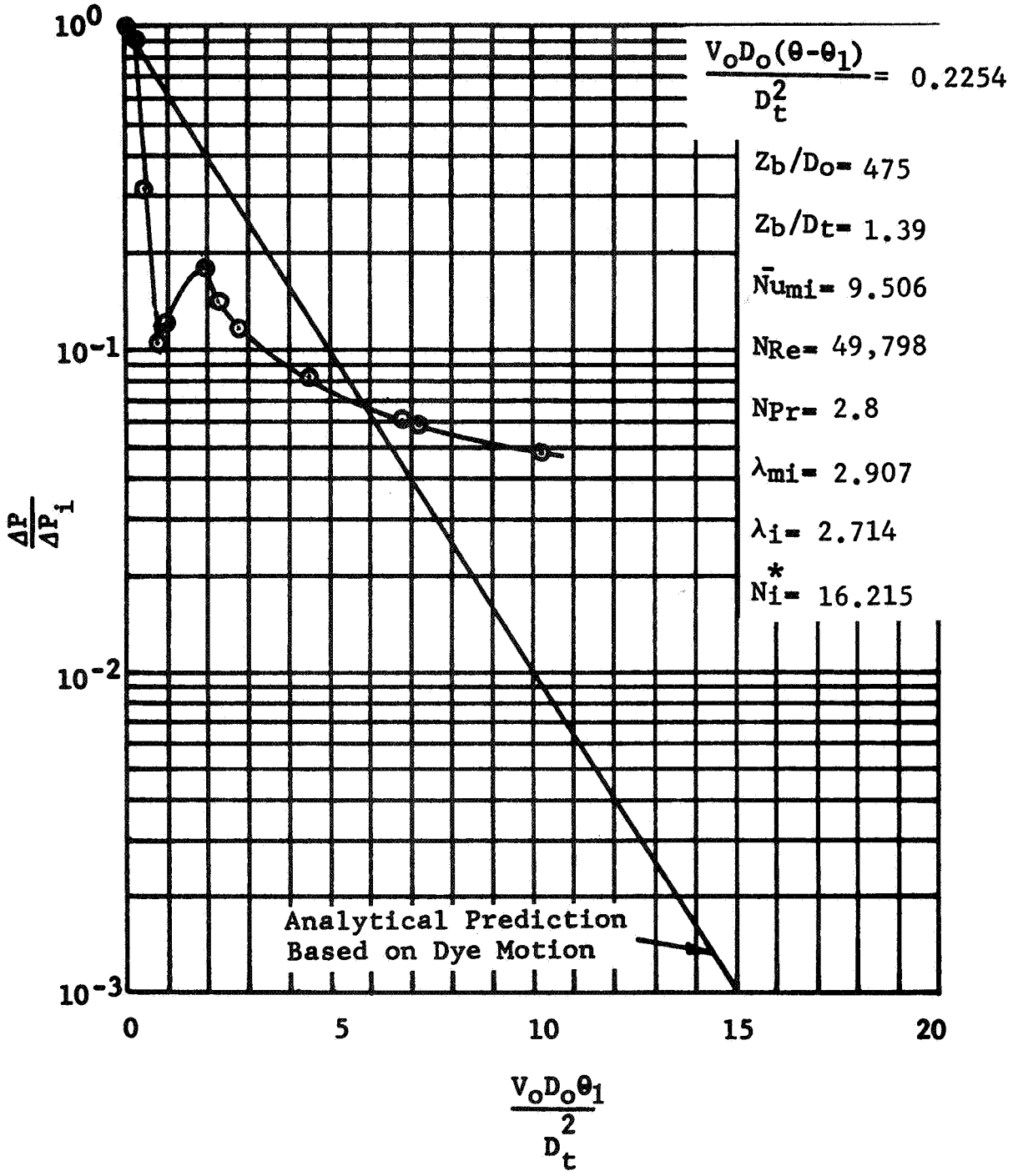

Figure 3.0-109 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1= 0.0 sec): Test 16, Run 29

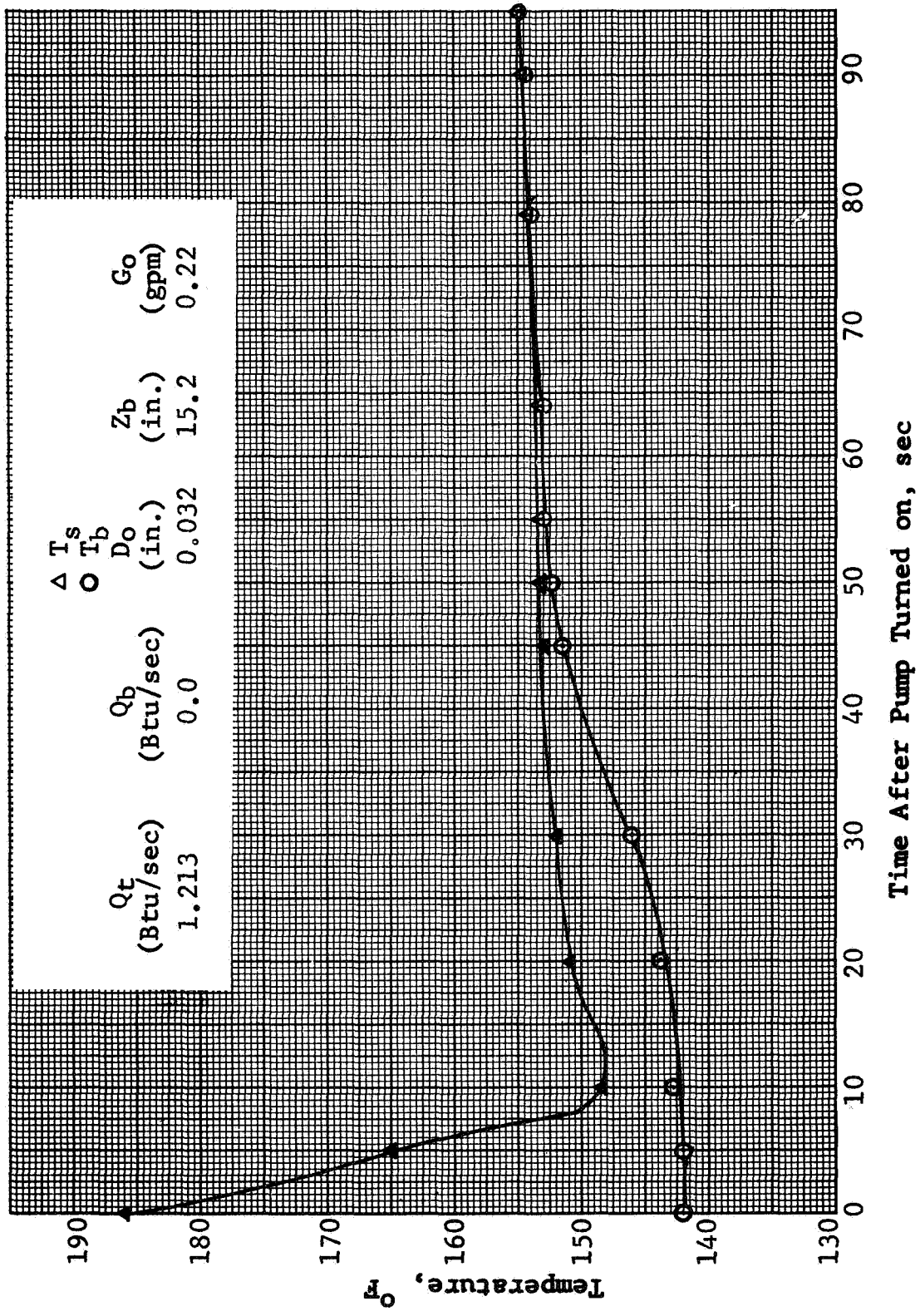

Figure 3.0-110 Transient Temperature Destratification: Test 16, Run 29

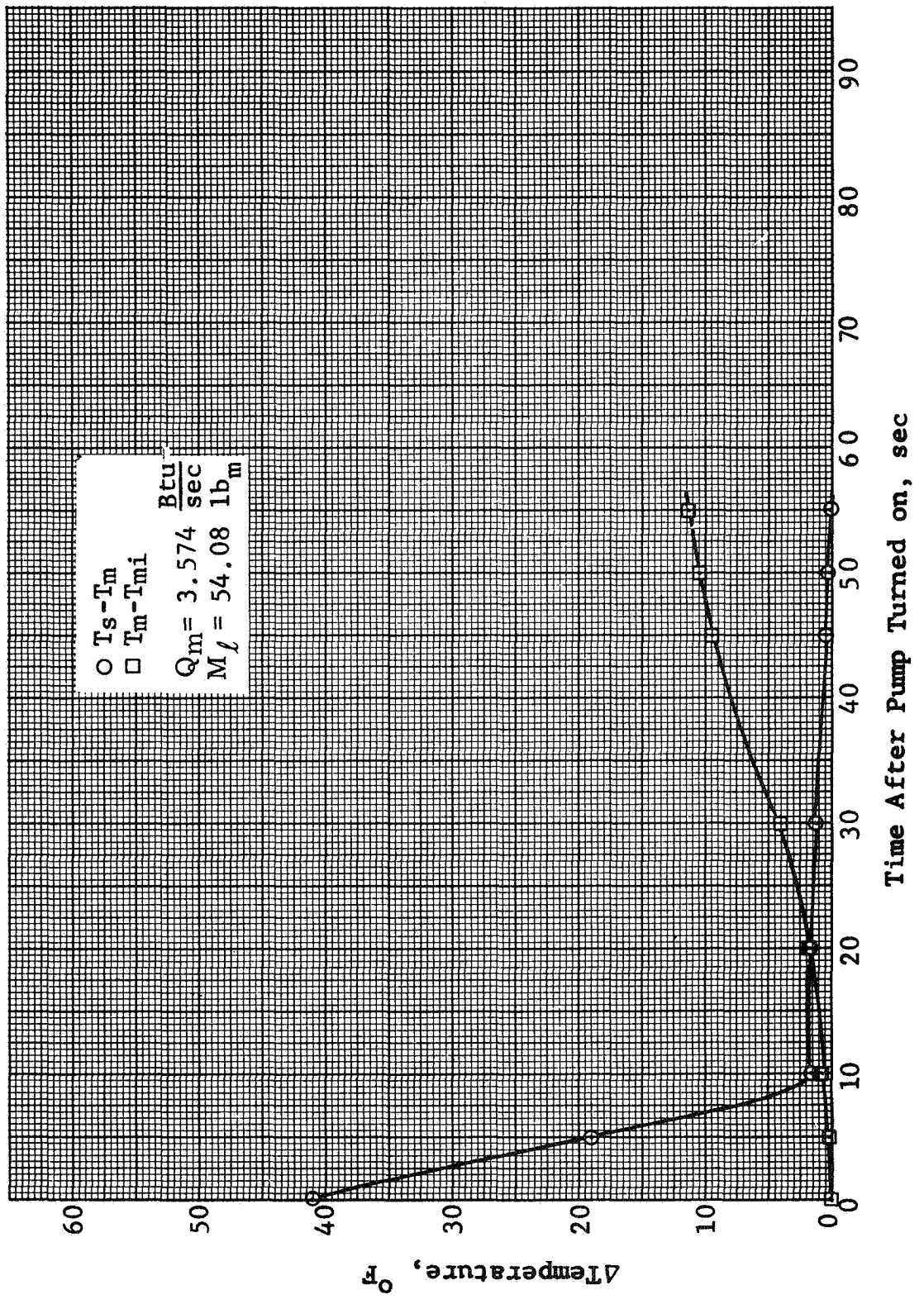

Figure 3.0-111 Transient ΔTemperature Destratification: Test 16, Run 29

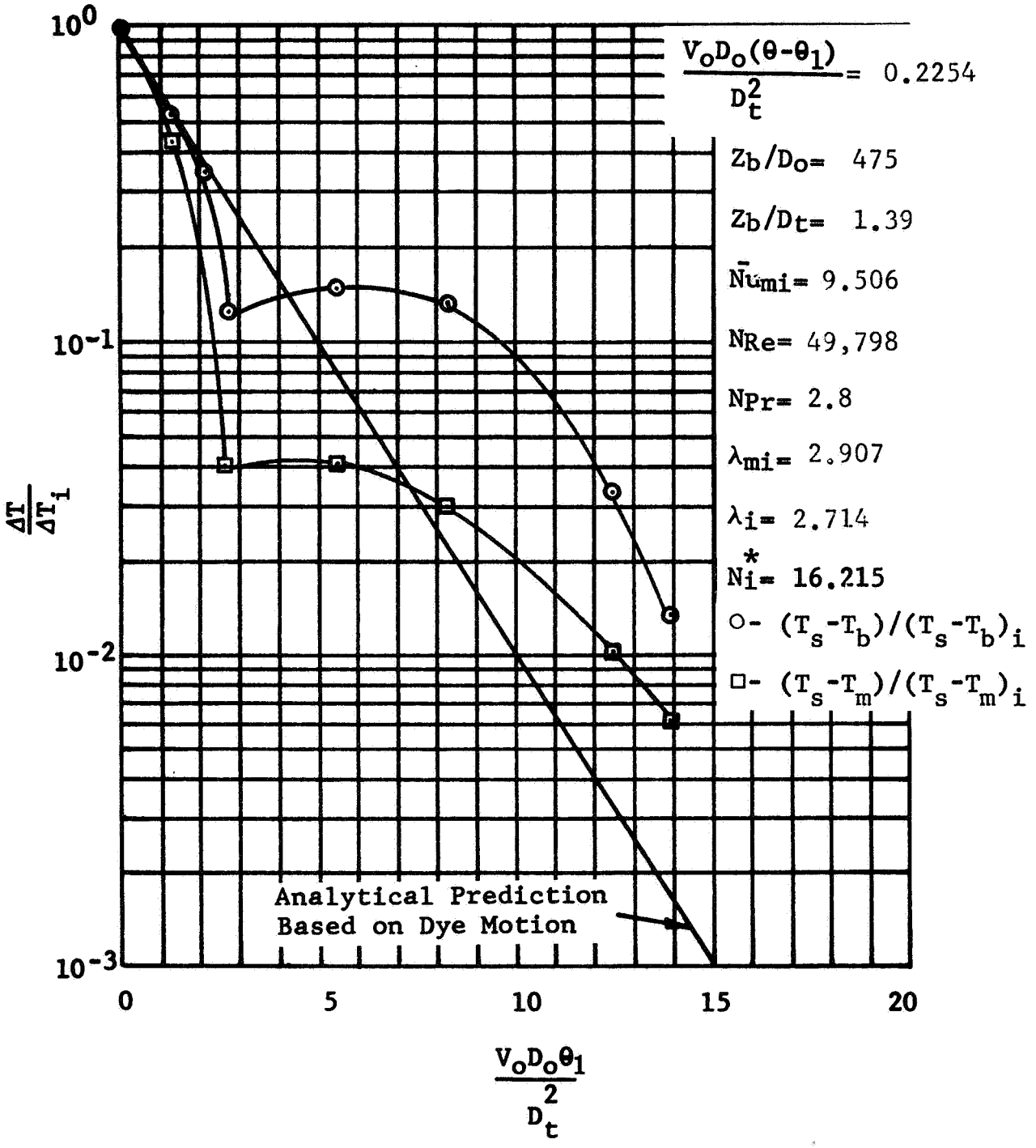

Figure 3.0-112 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 16, Run 29

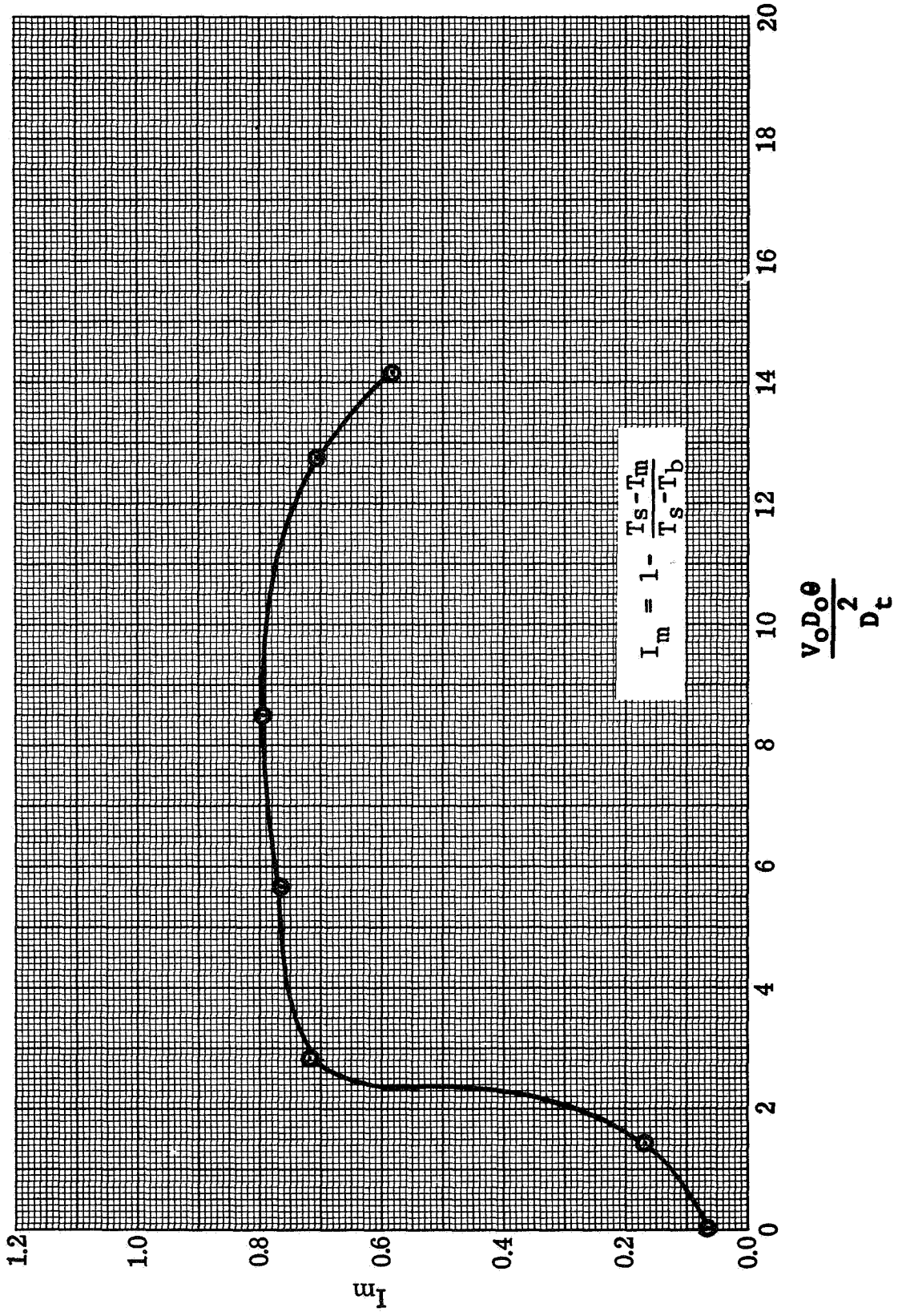

Figure 3.0-113 Transient Energy Integral: Test 16, Run 29

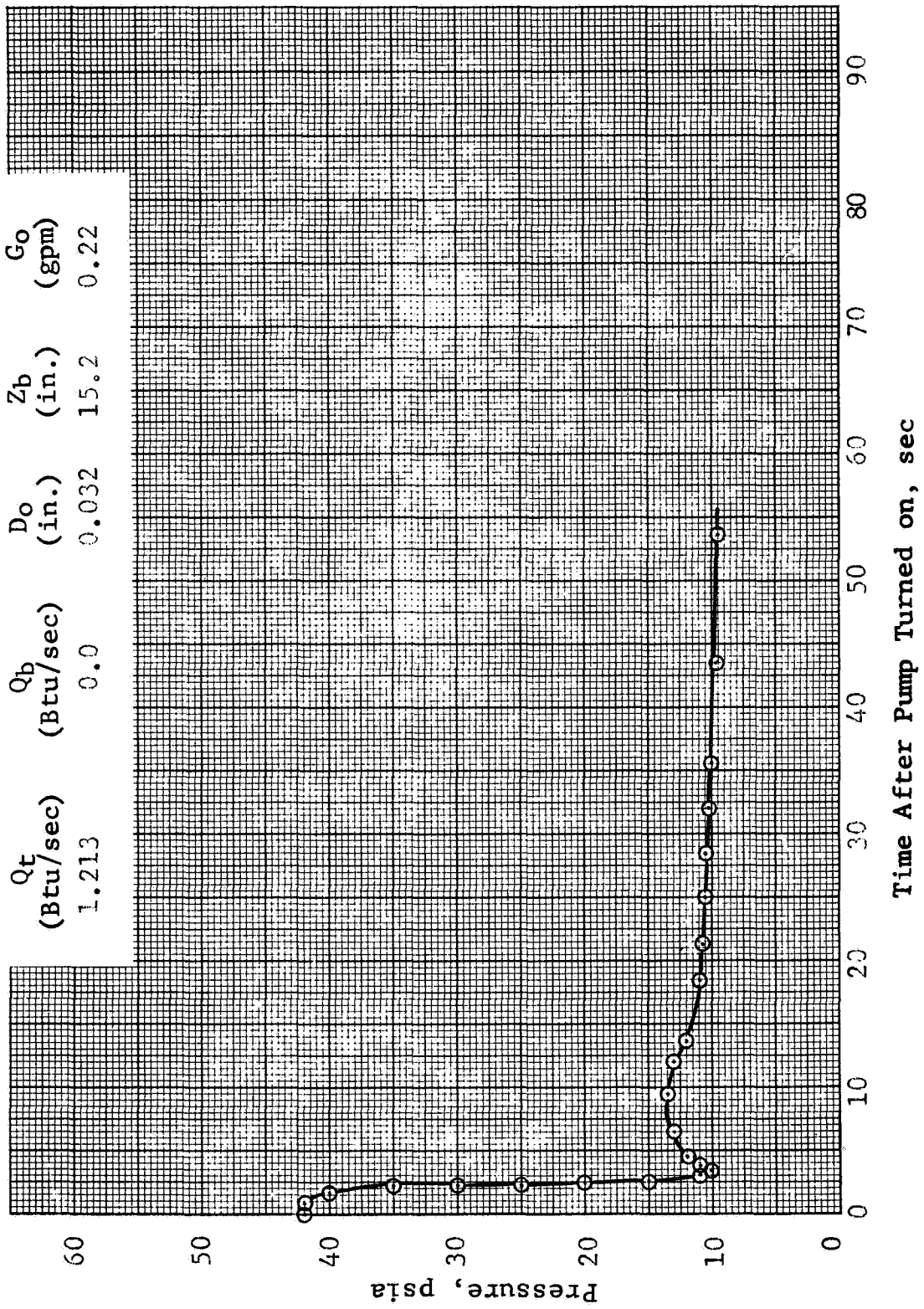

Figure 3.0-114 Transient Pressure Decay: Test 16, Run 30

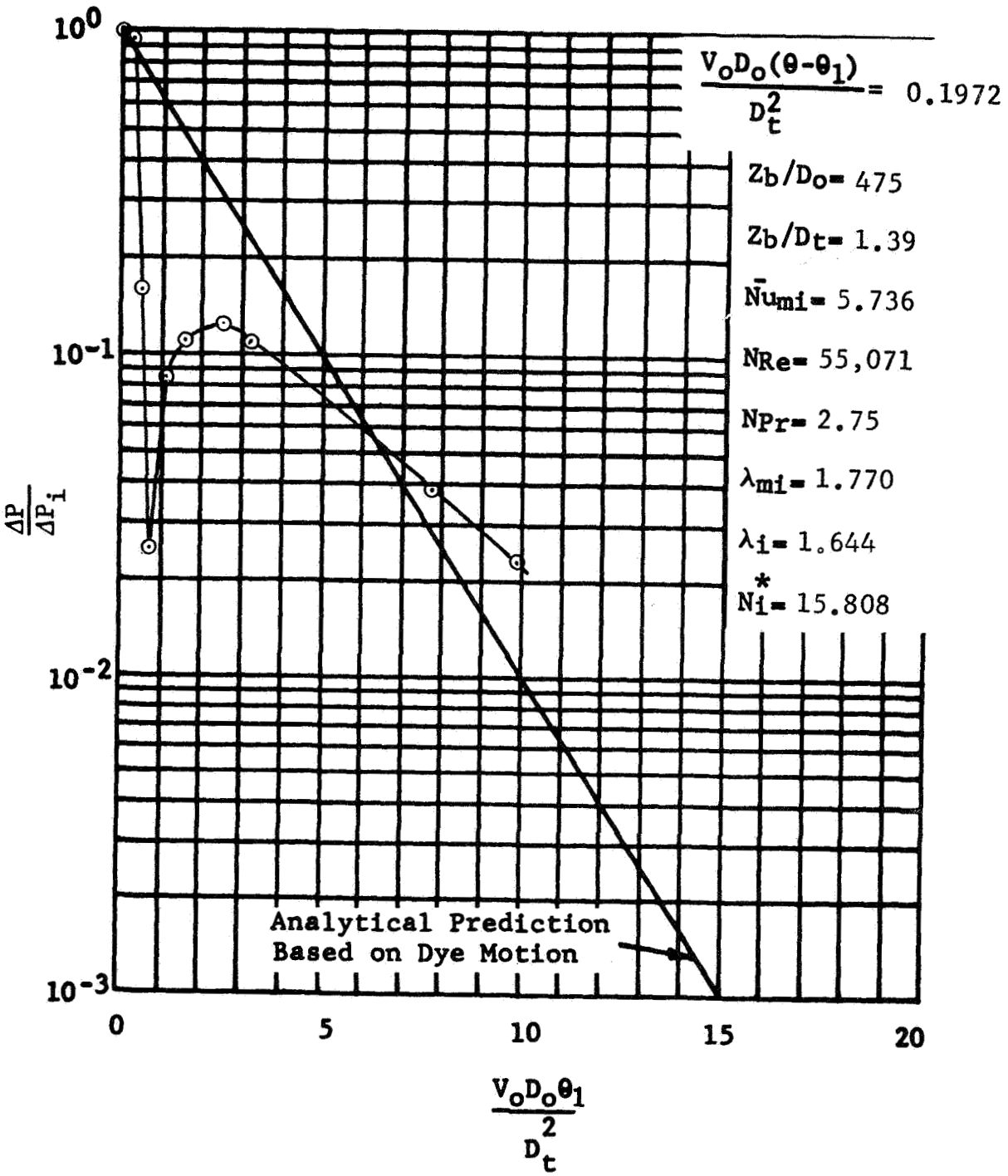

Figure 3.0 - 115 Fraction of Initial Pressure Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 16, Run 30

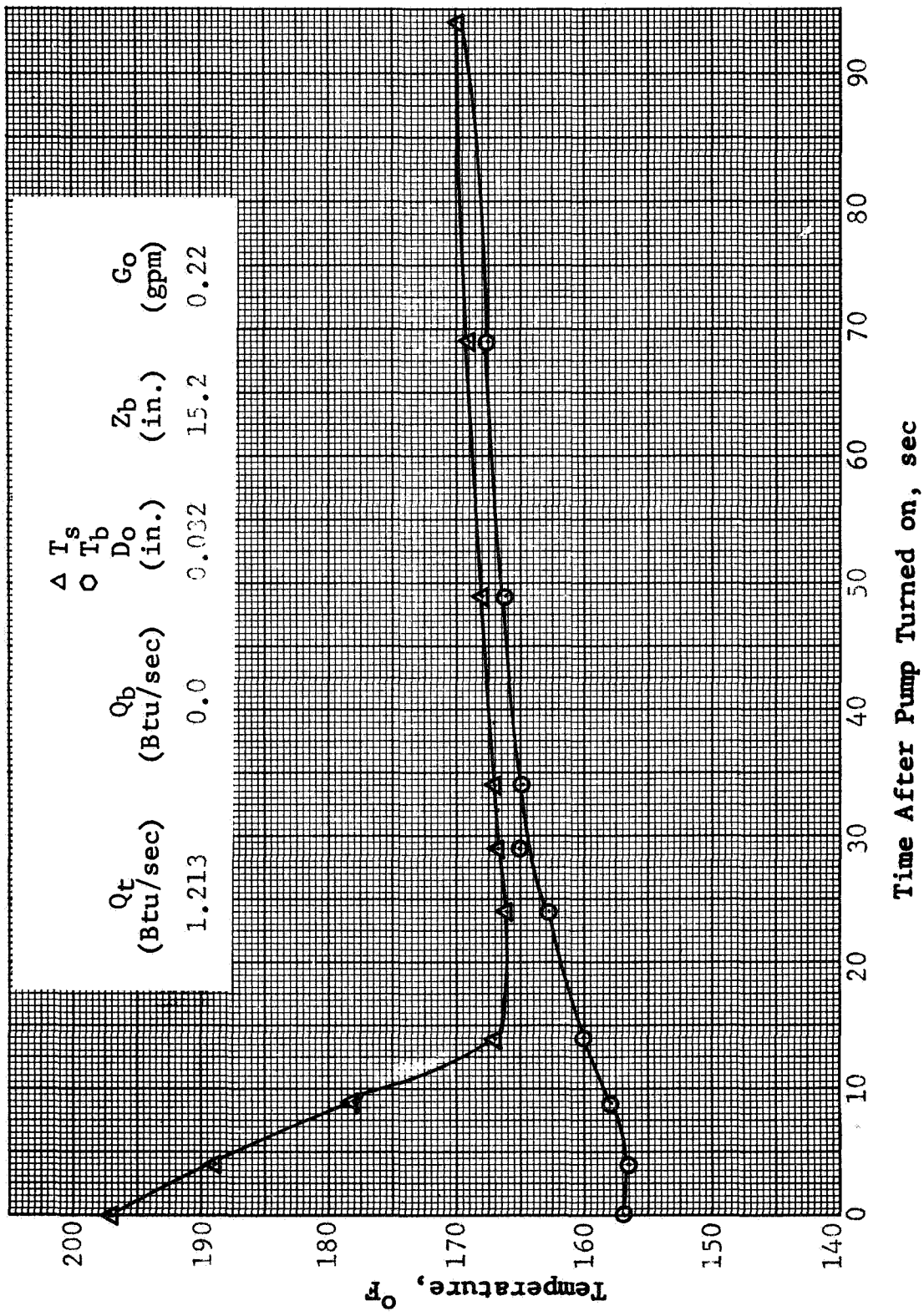

Figure 3.0 - 116 Transient Temperature Destratification: Test 16, Run 30

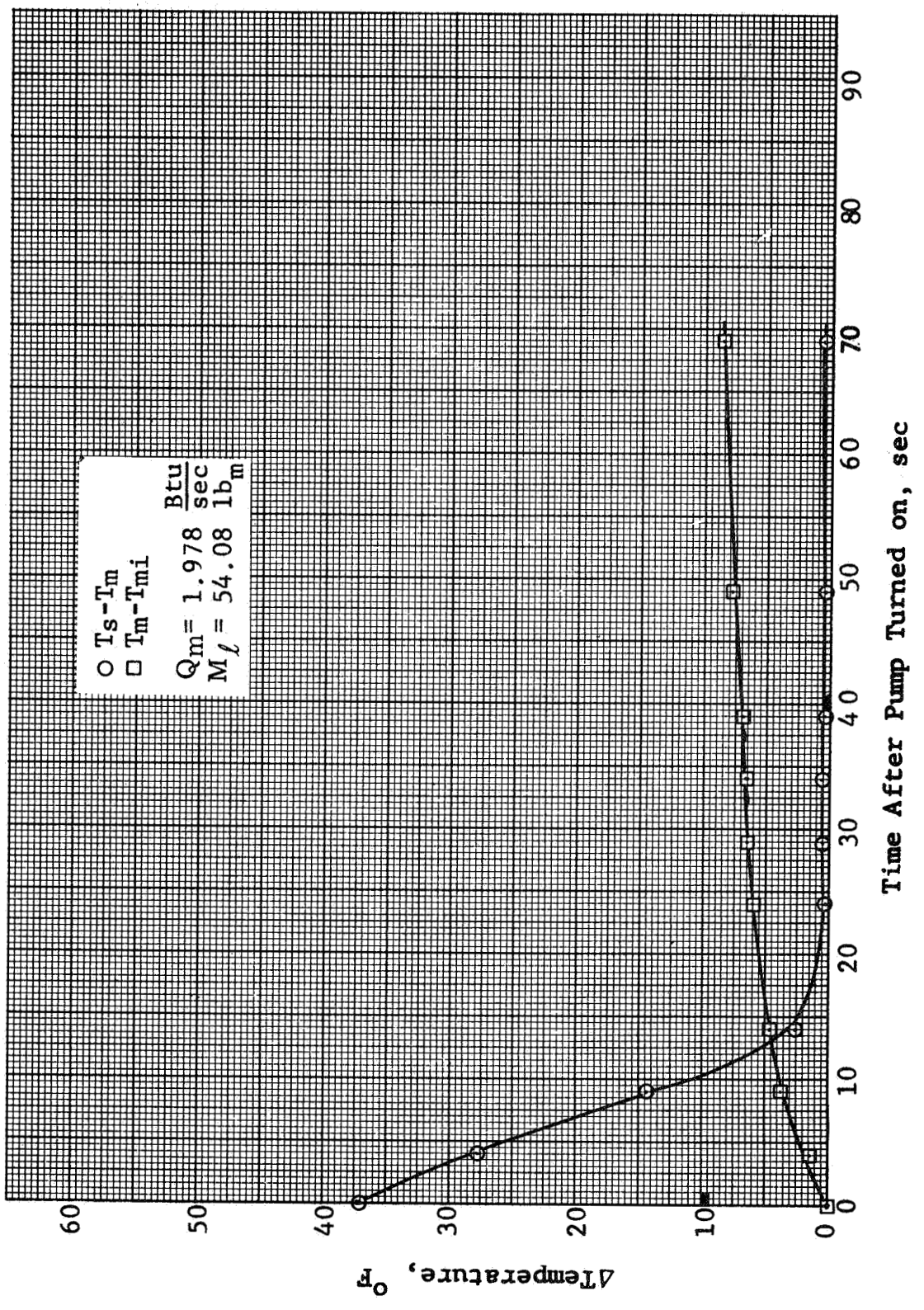

Figure 3.0 - 117 Transient ΔTemperature Destratification: Test 16, Run 30

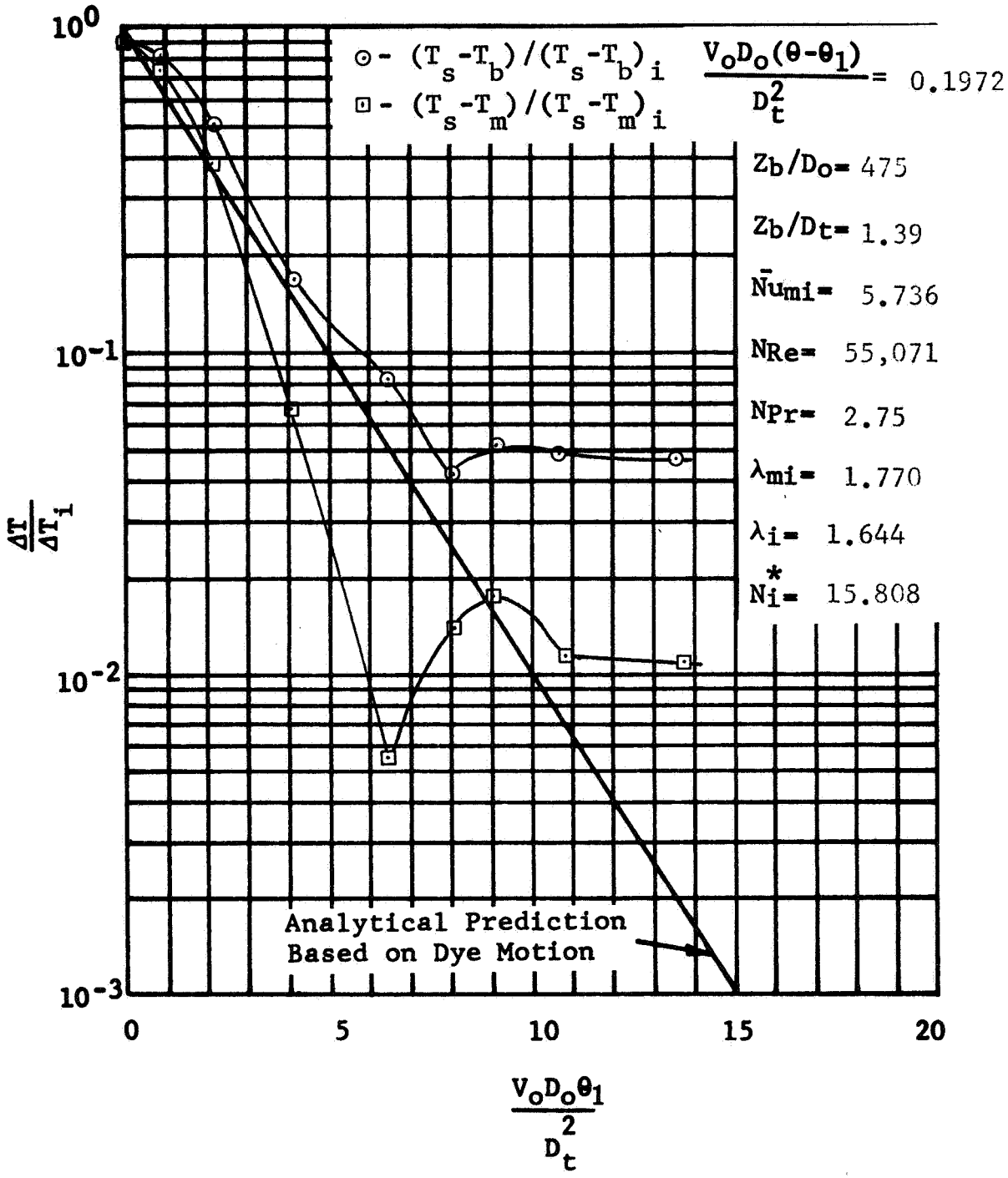

Figure 3.0 - 118 Fraction of Initial Temperature Difference After Ullage Pressure Starts to Drop (Pump on at θ=0.0 sec; Ullage Pressure Drops at θ_1=0.0 sec): Test 16, Run 30

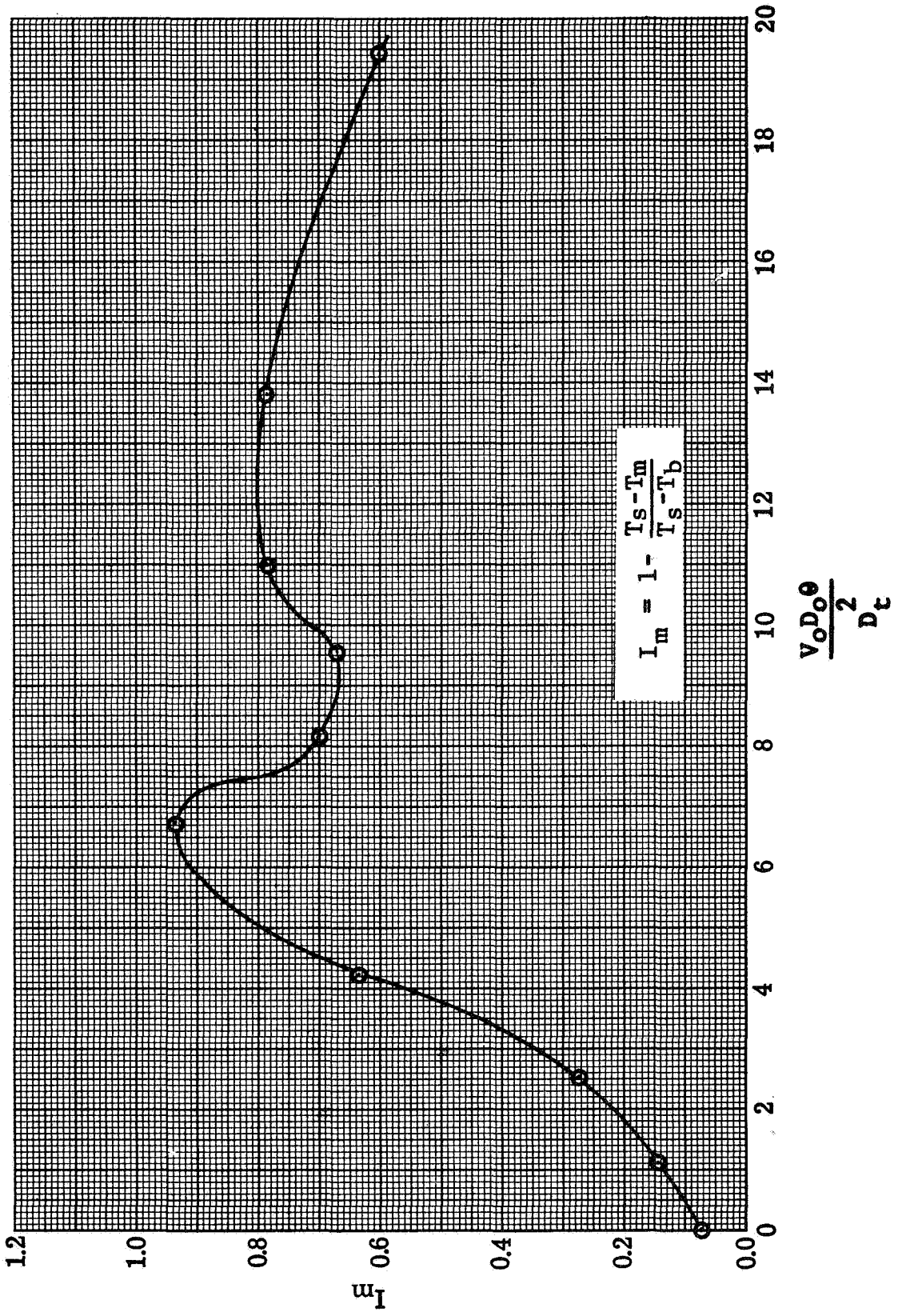

Figure 3.0 - 119 Transient Energy Integral: Test 16, Run 30

GENERAL DYNAMICS

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