MEASUREMENTS IN A THERMAL BOUNDARY LAYER

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V.A. SANDBORN, C.Y. LIU AND M.C. TAO

Prepared for

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FLUID MECHANICS PROGRAM
ENGINEERING RESEARCH CENTER
COLLEGE OF ENGINEERING

COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

Technical Report

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SUMMARY

An exploratory set of measurements in the boundary layer over a heated, smooth, flat plate are reported. The boundary wall was maintained at approximately 85°F and the free stream air temperature was approximately 40°F. The free stream velocity was 20 feet per second. Measurements of the mean temperature, density and velocity distributions are given in both tabular and graphic data. Data on the fluctuating temperature, longitudinal velocity and velocity-temperature correlation are also presented.

INTRODUCTION

A problem encountered in the flow of atmospheric winds over the earth surface is that of cold air over a warm boundary. The present study is a part of a long range program directed toward understanding such flows. The present data was taken as an exploratory study to first determine the magnitude of the mean and turbulent terms in the boundary layer. Secondly, the present experiment indicated the problems to be overcome in measuring the thermal boundary layer. The present report is intended as a data report on the measurements, and as such it contains no analysis of the data.

TEST PROCEDURE

A. TEST FACILITY. - The measurements reported herein were taken along the smooth metal floor of the large CSU - Army wind tunnel, ref. 1. The wind tunnel has a cross-section of approximately 6 feet by 6 feet. The ceiling of the tunnel is adjustable for control of the axial pressure gradient. For the measurements reported herein, the ceiling was adjusted to give an approximate zero-pressure-gradient along the flow. The floor of the tunnel was heated to approximately 85^0F and the freestream temperature was held constant at 40^0F. The freestream approach velocity was set at 20 feet per second.

The heated plate starts at a distance of 40 feet from the inlet of the wind tunnel test section. Coarse gravel was attached to the floor and ceiling at the inlet of the test section. This roughness was employed to thicken the floor and ceiling boundary layers and to reduce the side wall effects. The first 40 feet of the test section is made of wood so that no appreciable heat transfer between the walls and the floor occur in this entrance region. The measurements reported herein began at the start of the heated plate, so that the development of the thermal effect is fully recorded.

B. INSTRUMENTATION. - The mean velocity profiles were taken with a pitot-static probe having an outside diameter of 1/8 inch. A photograph of the probe and actuator system is given in ref. 2, figure 2. The hot wire anemometer amplifier and probes are shown in figure 4 of ref. 2. A .0002 inch diameter, platinum coated tungsten wire was used for the measurements. To separate velocity and temperature measurements the wire was operated at two different temperatures (220^0F and 340^0F). Typical calibration curves for the wire at the two temperatures are shown in figure 1.

A 0.000025 inch diameter, platinum-rhodium wire, resistance thermometer was used to measure the temperature fluctuations. The operation of this resistance thermometer is outlined in ref. 3.

RESULTS

The evaluated mean-temperature, - density, and - velocity distributions at every two feet along the tunnel center line are listed in tabular form. The tables also include values of the longitudinal turbulent velocity, the temperature fluctuation, and the velocity-temperature correlation obtained from the measurements.

The turbulent velocity and velocity-temperature correlation was obtained from the hot wire output. It is assumed that the hot wire output can be represented by the following relation

$$e = \frac{\partial E}{\partial U} u + \frac{\partial E}{\partial T} t \qquad (1)$$

where U is the total velocity, u is the fluctuating velocity, T is the total temperature, and t is the fluctuating temperature. The fluctuating wire voltage e is related to the rate of change of the total wire voltage with respect to velocity and temperature. The sensitivities $\partial E/\partial U$ and $\partial E/\partial t$ were obtained from experimental calibration curves for the hct wire. The value of $\partial E/\partial U$ for the two operating temperatures is shown in figure 2. As a check of the evaluation, the solid curve is obtained by assuming the heat loss from the hot wire varies only as the square root of the velocity. The temperature sensitivity term is shown in figure 3.

The hot wire output was read as the mean square voltage, which is related by equation (1) to the following

$$\overline{e^2} = \left(\frac{\partial E}{\partial U}\right)^2 \overline{u^2} + 2\left(\frac{\partial E}{\partial U}\right)\left(\frac{\partial E}{\partial T}\right) \overline{ut} + \left(\frac{\partial E}{\partial t}\right)^2 \overline{t^2} \qquad (2)$$

The two wire temperatures correspond to two different values for $\partial E/\partial U$ and $\partial E/\partial T$. Thus, by knowing $\overline{t^2}$ from the resistance thermometer, the output of the hot wire at the two temperatures can be used to compute $\overline{u^2}$ and $\overline{ut}$.

Figure 4 is a plot of the mean flow quantities for each station and figure 5 is a plot of the turbulent quantities.

Values of δ^* and θ were computed from the mean velocity defect only neglecting the variation of density. Inclusion of the density variation in the parameter variation make at most a 5% correction.

The value of wall shear stress listed was computed from the Ludwieg-Tillmann equation

$$\frac{\tau}{\frac{1}{2}\rho U_1^2} = 0.246 \times 10^{-0.678H} \times R_\theta^{-0.268} \qquad (3)$$

The Nusselt number was computed from the measured values of the temperature gradient at the boundary.

REFERENCES

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3. Chao, J. L. and Sandborn, V. A.: A Resistance Thermometer for Transient Temperature Measurements. CSU Fluid Mechanics Paper No. 1, 1964.

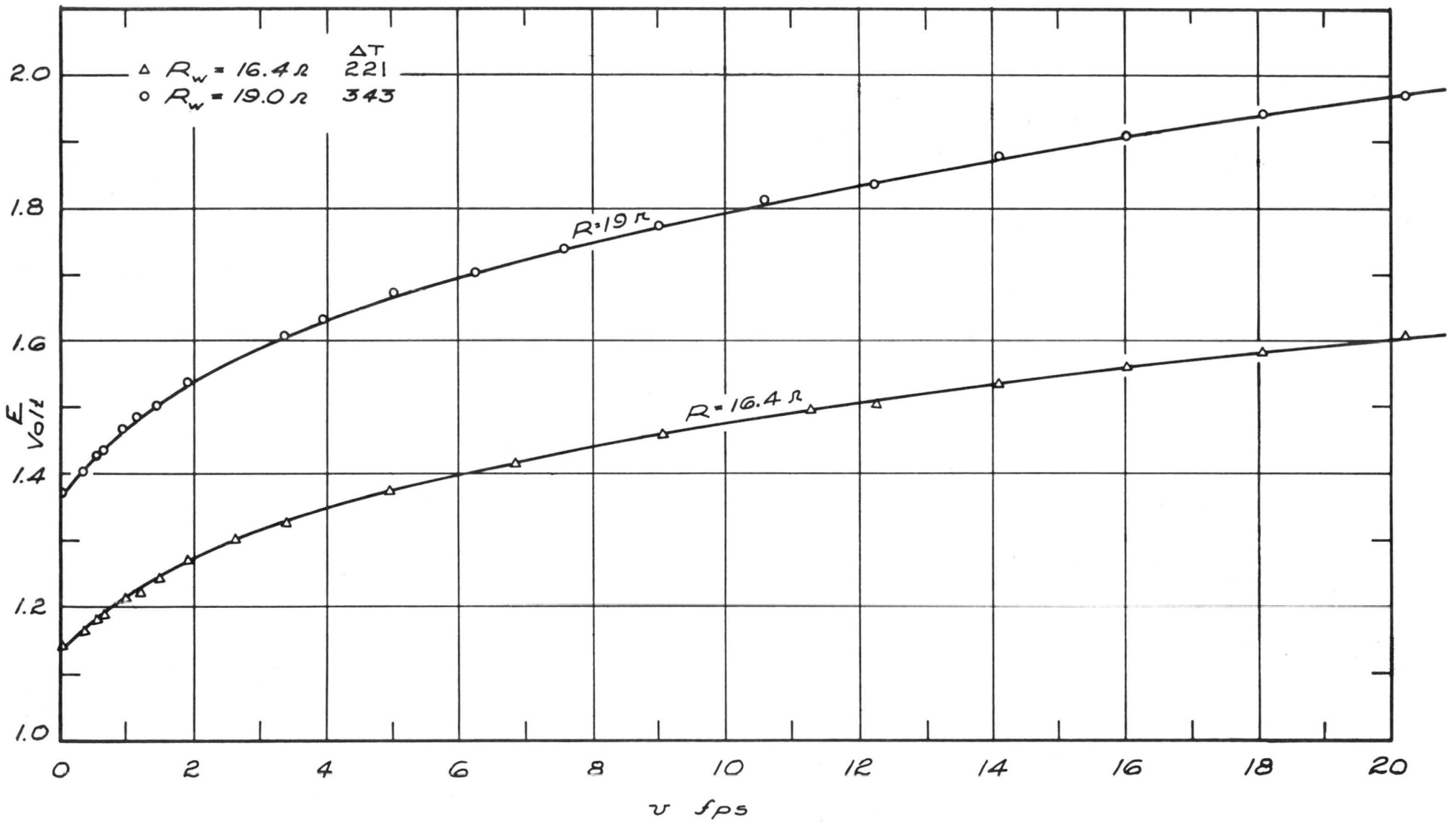


FIG. 1 CALIBRATION OF THE HOT WIRE

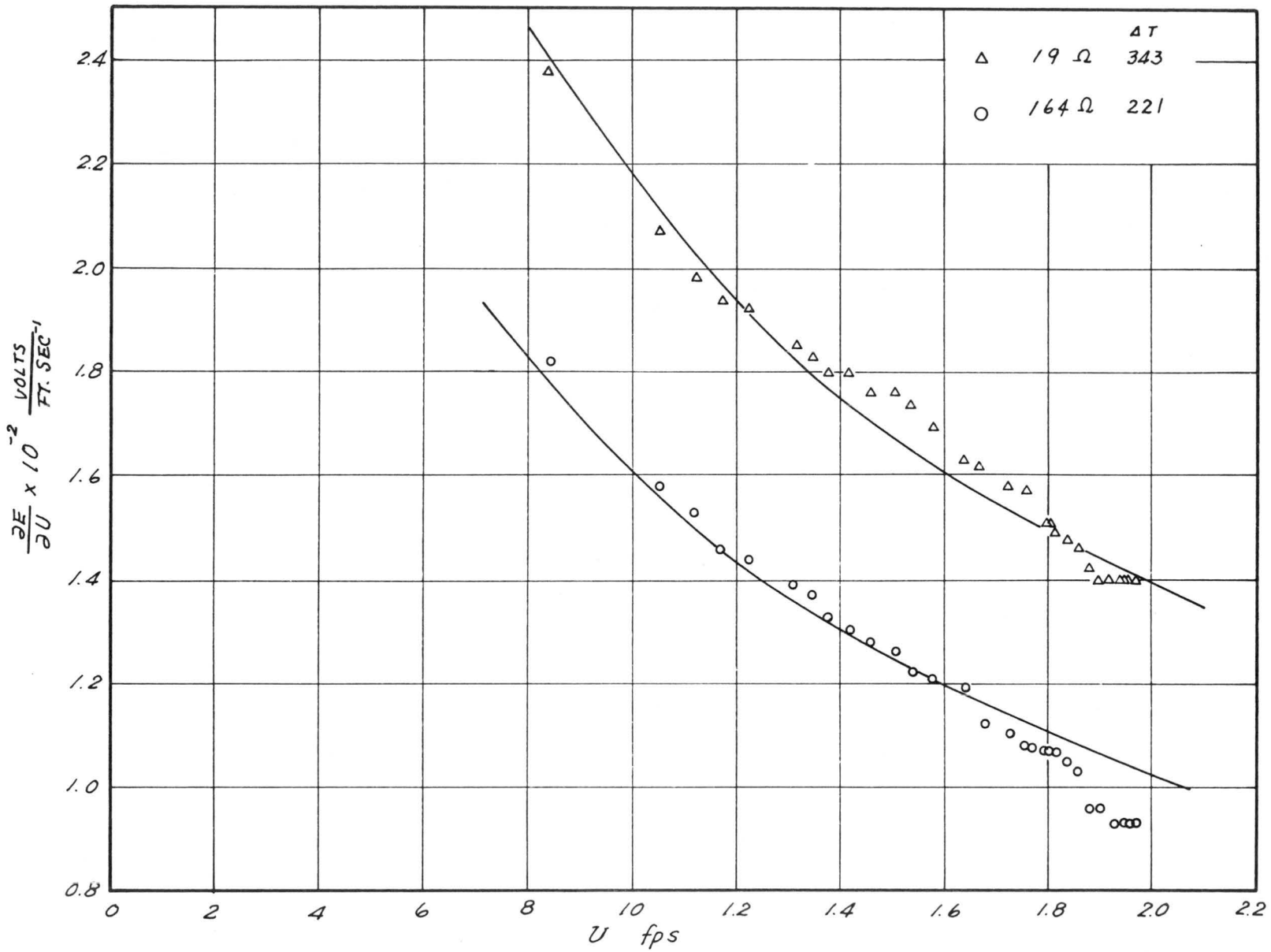


FIG. 2 VELOCITY SENSITIVITY OF HOT WIRE

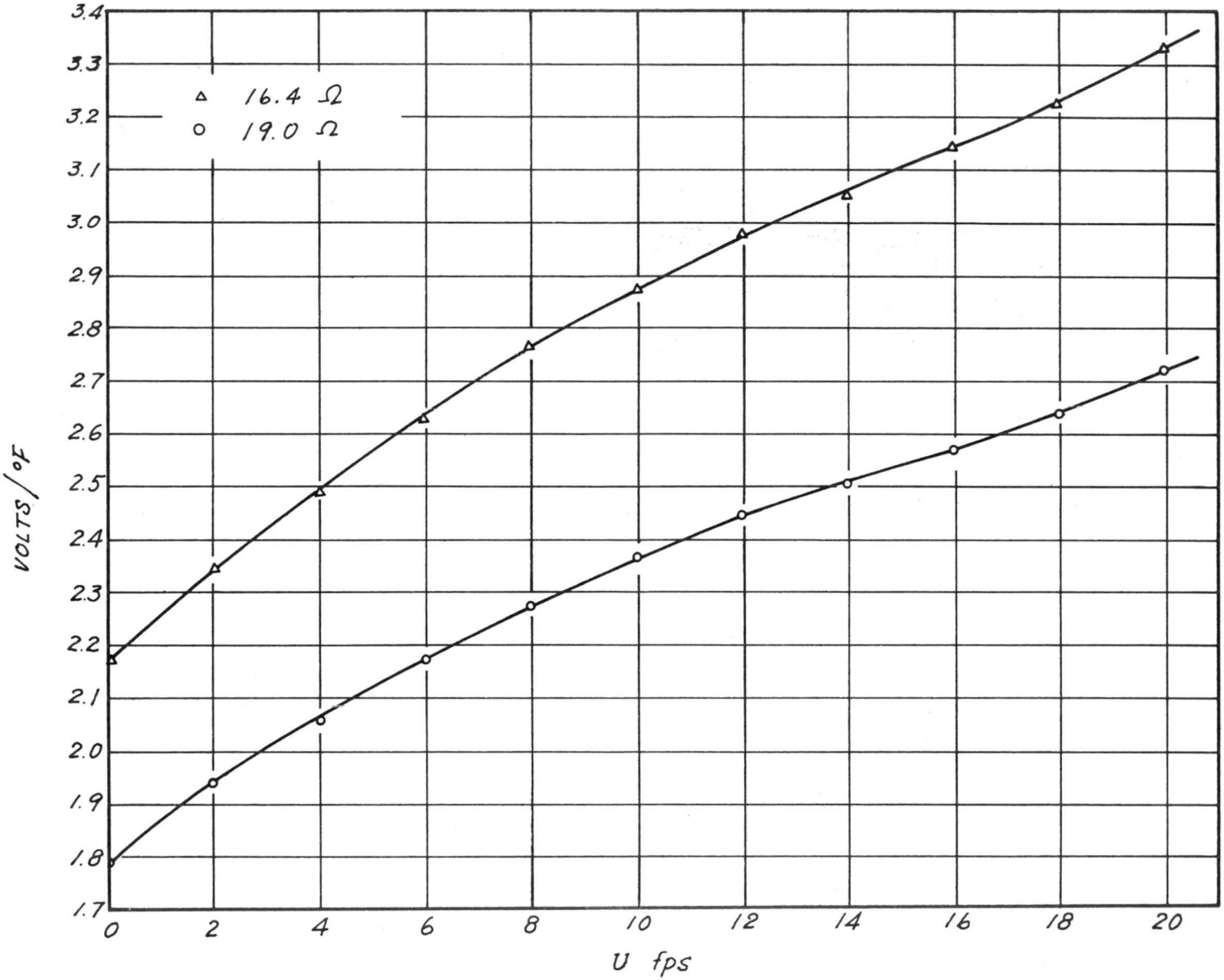


FIG. 3 TEMPERATURE SENSITIVITY OF HOT WIRE

STATION 40 ft.

Boundary Temp.	$T\omega = 80.2^0 F$	Freestream Velocity	$U_1 = 19.77$ ft/sec
Displacement Thickness	$\delta^* = 0.147$ ft	Momentum Thickness	$\theta = 0.1053$ ft
Boundary Layer Thickness	$\delta = 1.02$ ft	Form Factor	$H = 1.396$
Wall Shear Stress	$\tau\omega = 8.43 \times 10^{-4}$ lbf/ft^2		
Nusselt Number	$Nu = 5600$	Reynolds Number, $R_\theta = \frac{U_1\theta}{\nu}$	$= 9.97 \times 10^3$

dist. above boundary y, inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{uv}$ ft-^0F/sec
1/16	75.	1.855×10^{-3}	8.49	3.45	9.72	-4.96×10^{-1}
1/8	42.8	1.978×10^{-3}	10.34	2.93	1.75	-3.10×10^{-1}
1/4	42.2	1.981×10^{-3}	11.37	1.80	.814	-2.15×10^{0}
3/8	41.4	1.985×10^{-3}	11.85	2.35	.603	-1.176×10^{0}
1/2	41.1	1.987×10^{-3}	12.31	2.85	.512	-1.75×10^{0}
3/4	41.1	1.987×10^{-3}	12.53	1.163	.437	-2.84×10^{0}
1	41.1	1.987×10^{-3}	13.3	1.436	.407	-1.84×10^{0}
1-1/2	41.4	1.985×10^{-3}	14.0	1.14	.376	-1.89×10^{0}
1-3/4	41.6	1.984×10^{-3}	14.4	1.18	.392	-1.09×10^{0}
2	41.3	1.985×10^{-3}	14.6	0.604	.392	-2.40×10^{0}
2-1/2	41.4	1.985×10^{-3}	15.0	0.47	.361	-2.54×10^{0}
3	41.4	1.985×10^{-3}	15.35	0.577	.361	-2.19×10^{0}
3-1/2	41.6	1.980×10^{-3}	15.7	0.494	.361	-2.27×10^{0}
4	41.5	1.980×10^{-3}	16.25	0.492	.361	-2.06×10^{0}
4-1/2	41.5	1.980×10^{-3}	16.5	0.361	.382	-2.45×10^{0}
5	41.5	1.980×10^{-3}	16.85	0.053	.397	-2.58×10^{0}
5-1/2	41.1	1.982×10^{-3}	17.0	0.198	.382	-2.19×10^{0}
6	41.5	1.980×10^{-3}	17.2	0.191	.366	-2.04×10^{0}
6-1/2	41.5	1.980×10^{-3}	17.6	0.207	.366	-1.96×10^{0}
7	41.5	1.980×10^{-3}	17.8	0.288	.397	-1.63×10^{0}
7-1/2	41.7	1.978×10^{-3}	18.0	0.179	.382	-1.705×10^{0}
8	41.7	1.978×10^{-3}	18.15	0.1445	.367	-1.57×10^{0}
8-1/2	41.7	1.978×10^{-3}	18.4	0.049	.367	-1.715×10^{0}
9	41.7	1.978×10^{-3}	18.4	-0.0163	.367	-1.88×10^{0}
10	41.7	1.978×10^{-3}	18.78	0.174	.352	-2.95×10^{0}
11	41.7	1.978×10^{-3}	19.1	0.0201	.382	-1.27×10^{0}
12	41.7	1.978×10^{-3}	19.5	0.126	.367	-8.51×10^{-1}
13	41.7	1.977×10^{-3}	19.66	0.139	.336	-4.77
14	41.7	1.977×10^{-3}	19.66	-0.0117	.276	-4.23

STATION 40 ft (cont'd)

Boundary Temp.	$T\omega = 80.2^0 F$	Free stream Velocity	$U_1 = 19.77$ ft/sec
Displacement Thickness	$\delta^* = 0.147$ ft	Momentum Thickness	$\theta = 0.1053$ ft
Boundary Layer Thickness	$\delta = 1.02$ ft	Form Factor	$H = 1.396$
Wall Shear Stress	$\tau\omega = 8.43 \times 10^{-4} lb_f/ft^2$		
Nusselt Number	$Nu = 5600$	Reynolds Number, $R_\theta = \frac{U_1 \theta}{\nu}$	$= 9.97 \times 10^3$

dist. above boundary y, inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
15	41.7	1.977×10^{-3}	19.66	0.0188	.244	-1.55
16	41.7	1.977×10^{-3}	19.66	-0.0486	.214	-1.61
17	41.7	1.977×10^{-3}	19.66	----	.153	----
18	41.7	1.977×10^{-3}	19.66	----	.153	----
19	41.7	1.977×10^{-3}	19.66	----	.122	----

STATION 42 ft

Boundary Temp. $T_\omega = 85.5^0F$
Displacement Thickness $\delta^* = 0.16$ ft
Boundary Layer Thickness $\delta = 1.115$ ft
Wall Shear Stress $\tau_w = 8.52 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 4630$

Freestream Velocity $U_1 = 19.68$ ft/sec
Momentum Thickness $\theta = 0.117$ ft
Form Factor $H = 1.368$
Reynolds Number, $R_\theta = \frac{U_1 \theta}{\nu} = 1.08 \times 10^4$

dist. above boundary (inches)	temp. ^0F.	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F.	$\overline{ut}$ ft-^0F/sec
1/16	86.8	1.81×10^{-3}	8.04	1.81	15.2	-6.6
1/8	59.0	1.908×10^{-3}	9.51	5.25	14.8	17.6
1/4	51.5	1.936×10^{-3}	11.1	1.52	9.79	-0.788
3/8	49.2	1.943×10^{-3}	11.6	2.98	8.57	4.40
1/2	48.6	1.946×10^{-3}	11.84	2.33	7.97	2.18
3/4	45.8	1.960×10^{-3}	12.5	2.08	6.26	3.50
1	44.7	1.962×10^{-3}	12.82	1.78	4.28	2.76
1-1/2	42.9	1.972×10^{-3}	14.04	1.335	2.05	-1.11
1-3/4	42.9	1.972×10^{-3}	14.15	1.37	1.25	-0.676
2	42.9	1.972×10^{-3}	14.34	0.878	.948	-1.32
2-1/2	42.9	1.972×10^{-3}	14.64	0.77	.458	-1.55
3	42.3	1.975×10^{-3}	15.01	0.53	.397	-1.79
3-1/2	42.3	1.975×10^{-3}	15.4	0.706	.367	-1.136
4	42.3	1.975×10^{-3}	15.66	0.633	.352	-1.31
4-1/2	42.3	1.975×10^{-3}	16.1	0.957	.368	-0.479
5	42.3	1.975×10^{-3}	16.6	0.712	.352	-0.983
5-1/2	42.3	1.975×10^{-3}	16.96	0.323	.336	-1.55
6	42.3	1.975×10^{-3}	17.22	0.322	.322	-1.54
6-1/2	42.9	1.972×10^{-3}	17.4	0.225	.336	-1.71
7	42.9	1.972×10^{-3}	17.45	0.225	.322	-1.35
7-1/2	42.9	1.972×10^{-3}	17.7	0.276	.352	-1.265
8	42.9	1.972×10^{-3}	18.01	0.318	.306	-1.047
8-1/2	42.9	1.972×10^{-3}	18.19	0.302	.336	-0.975
9	42.9	1.972×10^{-3}	18.5	0.279	.336	-0.694
10	42.9	1.972×10^{-3}	18.94	0.439	.382	-0.486

STATION 42 ft. (cont'd)

Boundary	$T_\omega = 85.5^0F$	Freestream Velocity	$U_1 = 19.68$ ft/sec
Displacement Thickness	$\delta^* = 0.16$ ft	Momentum Thickness	$\theta = 0.117$ ft
Boundary Layer Thickness	$\delta = 1.115$ ft	Form Factor	$H = 1.368$
Wall Shear Stress	$\tau_w = 8.52 \times 10^{-4}$ lbf/ft^2		
Nusselt Number	$Nu = 4630$	Reynolds Number, $R_\theta = \frac{U_1 \theta}{\nu}$	$= 1.08 \times 10^4$

dist. above boundary (inches)	temp. ^0F.	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F.	$\overline{ut}$ ft-^0F/sec
11	42.9	1.970×10^{-3}	19.14	0.254	.397	-0.478
12	42.9	1.970×10^{-3}	19.4	0.159	.352	-0.461
13	42.9	1.970×10^{-3}	19.53	0.1505	.336	-0.251
14	42.9	1.970×10^{-3}	19.68	0.0625	.275	-0.159
15	42.9	1.970×10^{-3}	19.68	-0.0622	.275	-0.271
16	42.9	1.970×10^{-3}	19.68	-0.00868	.184	-0.0795
17	42.9	1.970×10^{-3}	19.68	-0.000253	.184	-0.028
18	42.9	1.970×10^{-3}	19.68	-0.00153	.122	-0.0158
19	42.9	1.970×10^{-3}	19.68	-0.00094	.122	-0.01205

STATION 44 ft.

Boundary Temp.	$T_\omega = 86.6^0F$	Freestream Velocity	$U_1 = 19.71$ ft/sec
Displacement Thickness	$\delta^* = 0.16$ ft	Momentum Thickness	$\theta = 1.20$ ft.
Boundary Layer Thickness	$\delta = 1.173$ ft	Form Factor	$H = 1.334$
Wall Shear Stress	$\tau_\omega = 8.94 \times 10^{-4}$ lbf/ft^2		
Nusselt Number	$Nu = 4410$	Reynolds Number, $R_\theta = \frac{U_1 \theta}{\nu}$	$= 1.104 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	89.1	1.804×10^{-3}	8.42	4.0	14.0	1.37
1/8	58.5	1.906×10^{-3}	10.53	5.40	12.65	19.4
1/4	53.8	1.925×10^{-3}	11.28	1.22	10.50	0.078
3/8	52.1	1.934×10^{-3}	11.76	2.70	9.87	-4.06
1/2	51.0	1.936×10^{-3}	12.23	2.92	9.25	5.58
3/4	49.8	1.941×10^{-3}	12.22	2.22	8.49	3.64
1	48.0	1.948×10^{-3}	13.2	1.70	6.79	0.854
1-1/2	45.8	1.958×10^{-3}	13.6	0.968	5.06	-0.89
1-3/4	45.1	1.960×10^{-3}	13.8	1.02	4.00	-1.124
2	44.7	1.961×10^{-3}	14.2	0.77	3.08	-2.13
2-1/2	44.7	1.961×10^{-3}	14.6	0.87	1.815	-1.64
3	43.5	1.970×10^{-3}	15.04	0.62	1.51	-1.95
3-1/2	43.5	1.970×10^{-3}	15.41	0.536	0.893	-1.97
4	42.9	1.965×10^{-3}	15.80	0.507	0.507	-2.37
4-1/2	42.9	1.965×10^{-3}	15.7	0.289	0.477	-2.03
5	42.9	1.965×10^{-3}	16.4	0.496	0.415	-1.44
5-1/2	42.9	1.965×10^{-3}	16.81	0.237	0.415	-2.14
6	42.9	1.965×10^{-3}	17.24	0.106	0.354	-2.19
6-1/2	42.9	1.963×10^{-3}	17.6	0.227	0.354	-1.86
7	42.9	1.963×10^{-3}	17.74	0.130	0.354	-2.01
7-1/2	42.9	1.963×10^{-3}	17.98	0.169	0.339	-1.795
8	42.9	1.963×10^{-3}	18.05	0.175	0.339	-1.605
8-1/2	42.9	1.963×10^{-3}	18.15	0.333	0.339	-1.605
9	42.9	1.963×10^{-3}	18.4	0.314	0.323	-0.953
10	42.9	1.963×10^{-3}	18.77	0.187	0.307	-1.04

STATION 44 ft. (cont'd)

Boundary Temp.	$T_\omega = 86.6^0F$	Freestream Velocity	$U_1 = 19.71$ ft/sec
Displacement Thickness	$\delta^* = 0.16$ ft	Momentum Thickness	$\theta = 1.20$ ft.
Boundary Layer Thickness	$\delta = 1.173$ ft	Form Factor	$H = 1.334$
Wall Shear Stress	$\tau_\omega = 8.94 \times 10^{-4}$ lbf/ft^2		
Nusselt Number	$Nu = 4410$	Reynolds Number, $R_\theta = \frac{U_1 \theta}{\nu}$	$= 1.104 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
11	42.9	1.963×10^{-3}	19.0	0.263	0.307	0.161
12	42.9	1.963×10^{-3}	19.41	0.162	0.368	0.571
13	42.9	1.962×10^{-3}	19.5	0.273	0.354	0.358
14	42.3	1.965×10^{-3}	19.55	0.228	0.307	0.0272
15	42.3	1.965×10^{-3}	19.7	0.115	0.246	0.0270
16	42.3	1.965×10^{-3}	19.7	0.0406	0.215	0.0522
17	42.9	1.962×10^{-3}	19.71	0.00559	0.184	0.0648
18	42.9	1.962×10^{-3}	19.71	0.0154	0.154	0.0612
19	42.9	1.962×10^{-3}	19.71	0.00463	0.154	0.0594

STATION 46 ft.

Boundary Temp. $T\omega = 89.7\ ^0F$ Freestream Velocity $U_1 = 19.78 ft/sec$

Displacement Thickness $\delta^* = 0.16$ ft.

Boundary Layer Thickness $\delta = 1.218$ ft. Momentum Thickness $\theta = 0.117$ ft.

Wall Shear Stress $\tau\omega = 8.54 \times 10^{-4} lb_f/ft^2$ Form Factor $H = 1.368$

Nusselt Number $Nu = 3800$ Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.066 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft.-^0F/sec
1/16	89.6	1.798×10^{-3}	8.45	0.568	2.33	-2.56
1/8	71.1	1.86×10^{-3}	9.31	-----	-----	-----
1/4	58.5	1.908×10^{-3}	10.08	3.00	12.86	9.00
3/8	55.0	1.918×10^{-3}	11.8	4.07	11.12	9.92
1/2	52.7	1.93×10^{-3}	12.6	3.39	9.88	6.87
3/4	50.4	1.937×10^{-3}	13.35	4.24	9.27	8.52
1	48.0	1.945×10^{-3}	13.32	3.04	8.02	5.86
1-1/2	45.8	1.955×10^{-3}	14.11	1.54	6.00	.283
1-3/4	45.8	1.955×10^{-3}	14.50	1.34	5.22	-0.51
2	45.8	1.955×10^{-3}	14.7	0.93	4.30	-2.02
2-1/2	44.7	1.960×10^{-3}	15.0	0.833	3.53	-1.655
3	43.5	1.965×10^{-3}	15.24	0.877	2.60	-1.477
3-1/2	43.5	1.965×10^{-3}	15.62	1.07	1.94	0.961
4	43.5	1.965×10^{-3}	16.0	0.815	1.473	-1.316
4-1/2	43.5	1.965×10^{-3}	16.26	0.876	1.075	0.989
5	43.5	1.965×10^{-3}	16.41	0.767	.860	0.945
5-1/2	43.5	1.965×10^{-3}	16.85	0.802	.676	0.901
6	43.5	1.965×10^{-3}	17.1	0.971	.461	0.357
6-1/2	43.5	1.965×10^{-3}	17.51	0.936	.368	0.480
7	43.5	1.965×10^{-3}	17.68	0.676	.353	0.827
7-1/2	43.5	1.965×10^{-3}	17.9	0.691	.322	0.432
8	43.5	1.965×10^{-3}	18.09	0.663	.353	0.627
8-1/2	43.5	1.965×10^{-3}	18.24	0.437	.308	0.899
9	43.5	1.965×10^{-3}	18.46	0.300	.308	1.18

STATION 46 ft. (cont'd)

Boundary Temp.	$T_w = 89.7^0F$	Freestream Velocity	$U_1 = 19.78$ ft/sec
Displacement Thickness	$\delta^* = 0.16$ ft.	Momentum Thickness	$\theta = 0.117$ ft.
Boundary Layer Thickness	$\delta = 1.218$ ft.	Form Factor	$H = 1.368$
Wall Shear Stress $\tau_w = 8.54 \times 10^{-4} lb_f/ft^2$			
Nusselt Number	$Nu = 3800$	Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.066 \times 10^{-4}$	

dist. above boundary inches	temp. ^0F	density slug /ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\overline{\Delta t^2}$ ^0F	$\overline{u^2}$ ft-^0F/sec
10	43.5	1.965×10^{-3}	18.85	0.618	.322	0.0779
11	43.5	1.965×10^{-3}	19.22	0.492	.337	0.173
12	43.5	1.965×10^{-3}	19.44	0.197	.368	0.544
13	42.3	1.97×10^{-3}	19.53	0.0884	.307	0.486
14	41.1	1.973×10^{-3}	19.68	0.104	.307	0.227
15	41.1	1.973×10^{-3}	19.72	0.0708	.276	0.0767
16	42.3	1.97×10^{-3}	19.78	0.0163	.369	0.0973
17	42.3	1.97×10^{-3}	19.78	0.0124	.215	0.0266
18	42.3	1.97×10^{-3}	19.78	0.0118	.215	0.00126
19	----	----	----	----	----	----

STATION 48 ft.

Boundary Temp.	$T_\omega = 86.6^0F$	Freestream Velocity	$U_1 = 19.82$ ft/sec
Displacement Thickness	$\delta^* = 0.1612$ft	Momentum Thickness	$\theta = 0.1193$ ft
Boundary Layer Thickness	$\delta = 1.26$ ft	Form Factor	$H = 1.352$
Wall Shear Stress	$\tau_\omega = 8.70 \times 10^{-4}$ lb$_f$/ft^2		
Nusselt Number	$Nu = 2910$	Reynolds Number	$R_\theta = \frac{U_1 \theta}{\nu} = 1.105 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	89.6	1.798×10^{-3}	8.25	0.295	1.94	-24.7
1/8	63.0	1.89×10^{-3}	10.15	5.29	16.55	22.2
1/4	60.7	1.895×10^{-3}	10.7	6.78	15.25	25.3
3/8	56.1	1.917×10^{-3}	11.82	4.91	11.70	13.0
1/2	53.8	1.925×10^{-3}	12.27	4.00	11.40	10.9
3/4	51.5	1.932×10^{-3}	12.8	2.79	10.12	6.38
1	50.4	1.937×10^{-3}	13.24	2.52	9.18	5.58
1-1/2	48.0	1.945×10^{-3}	14.04	2.39	7.56	3.97
1-3/4	46.9	1.950×10^{-3}	14.33	2.23	7.10	3.49
2	45.8	1.955×10^{-3}	14.6	2.01	6.30	2.27
2-1/2	44.7	1.960×10^{-3}	15.09	0.79	4.72	-1.86
3	43.5	1.965×10^{-3}	15.42	0.213	3.93	-3.10
3-1/2	43.5	1.965×10^{-3}	15.89	0.04	3.14	-2.40
4	43.5	1.965×10^{-3}	16.14	0.55	2.68	-1.83
4-1/2	43.5	1.965×10^{-3}	16.4	0.508	1.95	-1.29
5	42.3	1.970×10^{-3}	16.81	0.327	1.51	-1.94
5-1/2	42.3	1.970×10^{-3}	17.23	0.751	1.26	-0.87
6	42.3	1.970×10^{-3}	17.23	0.528	.945	-1.24
6-1/2	42.3	1.970×10^{-3}	17.61	0.541	.788	-1.097
7	42.3	1.970×10^{-3}	17.61	0.628	.662	-0.971
7-1/2	42.3	1.970×10^{-3}	17.79	0.783	.472	-0.443
8	42.3	1.970×10^{-3}	18.02	0.44	.472	-0.991
8-1/2	42.3	1.970×10^{-3}	18.26	0.309	.410	-1.086
9	42.3	1.970×10^{-3}	18.4	0.0597	.379	-1.53
10	42.3	1.970×10^{-3}	18.8	0.159	.379	-1.174

STATION 48 ft. (cont'd)

Boundary Temp.	$T\omega = 86.6^0F$	Freestream Velocity	$U_1 = 19.82$ ft/sec
Displacement Thickness	$\delta^* = 0.1612$ ft	Momentum Thickness	$\theta = 0.1193$ ft
Boundary Layer	$\delta = 1.26$ ft.	Form Factor	$H = 1.352$
Wall Shear Stress	$\tau\omega = 8.70 \times 10^{-4}$ lbf/ft^2		
Nusselt	$Nu = 2910$	Reynolds Number $R_\theta = \frac{U_1\theta}{\nu}$	$= 1.105 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
11	41.1	1.975×10^{-3}	19.09	0.0112	.394	-1.24
12	41.1	1.975×10^{-3}	19.42	0.102	.347	-1.03
13	42.3	1.970×10^{-3}	19.53	0.0253	.379	-0.607
14	42.3	1.970×10^{-3}	19.7	0.0632	.314	-0.557
15	42.3	1.97×10^{-3}	19.78	0.00991	.394	-0.193
16	42.3	1.97×10^{-3}	19.82	0.0417	.410	-0.0319
17	42.3	1.97×10^{-3}	19.82	0.0197	.472	-0.00541
18	42.3	1.97×10^{-3}	19.82	0.0103	.441	-0.0236
19	----	-----	----	----	----	-----

STATION 50 ft

Boundary Temp.	$T_\omega = 88.7^0F$	Freestream Velocity	$U_1 = 19.82$ ft/sec
Displacement Thickness	$\delta^* = 0.177$ ft	Momentum Thickness	$\theta = 0.1288$ ft
Boundary Layer Thickness	$\delta = 1.295$ ft	Form Factor	$H = 1.374$
Wall Shear Stress	$\tau_\omega = 8.45 \times 10^{-4}$ lb$_f$/ft^2		
Nusselt Number	$Nu = 2.12 \times 10^3$	Reynolds Number	$R_\theta = \frac{U_1 \theta}{\nu} = 1.088 \times 10^{-4}$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	89.6	1.80×10^{-3}	8.43	----	1.72	-----
1/8	63.0	1.89×10^{-3}	10.44	5.77	14.50	19.55
1/4	59.5	1.904×10^{-3}	11.45	3.85	12.30	10.16
3/8	57.3	1.912×10^{-3}	11.7	4.13	11.65	11.17
1/2	55.0	1.920×10^{-3}	12.17	4.37	10.70	10.57
3/4	52.7	1.928×10^{-3}	12.63	3.26	10.06	7.1
1	51.5	1.933×10^{-3}	13.23	3.54	9.44	8.41
1-1/2	48.0	1.946×10^{-3}	14.15	3.00	7.84	5.84
1-3/4	46.9	1.950×10^{-3}	14.42	2.21	7.38	3.89
2	46.9	1.950×10^{-3}	14.42	2.00	6.89	3.19
2-1/2	45.8	1.957×10^{-3}	14.61	1.81	6.25	2.87
3	44.7	1.961×10^{-3}	15.04	1.195	5.32	0.261
3-1/2	44.7	1.961×10^{-3}	15.53	1.516	4.07	0.86
4	43.5	1.967×10^{-3}	15.7	0.955	3.43	-0.0254
4-1/2	43.5	1.967×10^{-3}	16.13	1.134	2.80	0.156
5	43.5	1.967×10^{-3}	16.49	0.87	2.49	-0.202
5-1/2	42.3	1.970×10^{-3}	16.65	0.65	2.18	-0.642
6	42.3	1.970×10^{-3}	16.97	0.929	1.56	0.0284
6-1/2	42.3	1.970×10^{-3}	17.23	0.191	1.09	-1.484
7	41.1	1.975×10^{-3}	17.55	0.48	.935	-0.827
7-1/2	41.1	1.975×10^{-3}	17.78	0.479	.780	-0.689
8	41.1	1.975×10^{-3}	18.02	0.426	.717	-0.531
8-1/2	42.3	1.970×10^{-3}	18.2	0.502	.561	-0.365
9	42.3	1.970×10^{-3}	18.4	0.477	.469	-0.308

STATION 50 ft. (cont'd)

Boundary Temp.	$T\omega = 88.7^0F$	Freestream Velocity	$U_1 = 19.82$ ft/sec
Displacement Thickness	$\delta^* = 0.177$ ft	Momentum Thickness	$\theta = 0.1288$ ft
Boundary Layer Thickness	$\delta = 1.295$ ft	Form Factor	$H = 1.374$
Wall Shear Stress	$\tau\omega = 8.45 \times 10^{-4} lb_f/ft^2$		
Nusselt Number	$Nu = 2.12 \times 10^3$	Reynolds Number	$R_\theta = \frac{U_1 \theta}{\nu} = 1.088 \times 10^{-4}$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	41.1	1.975×10^{-3}	18.53	0.527	.375	0.278
11	41.1	1.975×10^{-3}	18.79	0.189	.343	-0.368
12	41.1	1.975×10^{-3}	19.09	0.0828	.343	-0.354
13	41.1	1.975×10^{-3}	19.29	-0.1496	.343	-0.596
14	41.1	1.975×10^{-3}	19.52	0.0053	.328	-0.104
15	41.1	1.975×10^{-3}	19.67	0.0149	.312	-0.00852
16	41.1	1.975×10^{-3}	19.71	0.0173	.312	+0.0161
17	41.1	1.975×10^{-3}	19.71	0.01305	.281	+0.0105
18	42.3	1.970×10^{-3}	19.78	0.01514	.249	+0.00842
19	42.3	1.970×10^{-3}	19.82	-----	.312	----

STATION 52 ft

Boundary Temperature $T_\omega = 82.4^0F$
Displacement Thickness $\delta^* = 0.1486$ ft
Boundary Layer Thickness $\delta = 1.327$ ft
Wall Shear Stress $\tau_\omega = 9.12 \times 10^{-4} lbf/ft^2$
Nusselt Number $Nu = 1.88 \times 10^3$

Freestream Velocity $U_1 = 19.7$ ft/sec
Momentum Thickness $\theta = 0.1107$
Form Factor $H = 1.342$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.02 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	66.8	1.870×10^{-3}	8.28	----	14.38	-----
1/8	57.8	1.902×10^{-3}	9.98	2.52	11.36	3.46
1/4	55.4	1.911×10^{-3}	11.45	3.87	10.24	6.28
3/8	53.8	1.920×10^{-3}	12.03	3.47	9.93	5.30
1/2	52.0	1.925×10^{-3}	12.5	3.44	9.63	5.91
3/4	50.9	1.929×10^{-3}	12.71	4.12	8.85	8.48
1	49.2	1.935×10^{-3}	13.57	3.46	8.19	6.26
1-1/2	46.9	1.945×10^{-3}	14.16	2.57	7.73	5.24
1-3/4	46.2	1.950×10^{-3}	14.52	3.04	7.10	5.17
2	45.8	1.951×10^{-3}	14.71	2.76	6.80	5.33
2-1/2	45.0	1.952×10^{-3}	15.1	2.21	5.72	2.53
3	46.9	1.950×10^{-3}	15.50	0.946	4.95	-0.747
3-1/2	45.8	1.955×10^{-3}	15.82	1.195	4.33	-0.644
4	44.7	1.960×10^{-3}	15.99	1.83	3.72	1.635
4-1/2	45.1	1.958×10^{-3}	16.18	1.42	2.95	0.299
5	44.0	1.962×10^{-3}	16.86	0.896	2.32	-0.503
5-1/2	42.9	1.968×10^{-3}	17.16	1.00	2.26	0.0137
6	42.9	1.968×10^{-3}	17.24	0.732	1.70	-0.635
6-1/2	44.0	1.958×10^{-3}	17.3	0.641	1.24	-0.651
7	42.3	1.97×10^{-3}	17.8	0.457	0.992	-0.917
7-1/2	42.9	1.968×10^{-3}	18.04	0.621	0.992	-0.466
8	42.9	1.968×10^{-3}	18.43	0.928	0.712	0.368
8-1/2	42.3	1.97×10^{-3}	18.65	0.848	0.496	0.267
9	42.3	1.97×10^{-3}	18.68	0.743	0.464	0.925

STATION 52 ft (cont'd)

Boundary Temperature $T_\omega = 82.4^0F$
Displacement Thickness $\delta^* = 0.1486$ ft
Boundary Layer Thickness $\delta = 1.327$ ft
Wall Shear Stress $\tau_\omega = 9.12 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.88 \times 10^3$

Freestream Velocity $U_1 = 19.7$ ft/sec
Momentum Thickness $\theta = 0.1107$
Form Factor $H = 1.342$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.02 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	42.3	1.97×10^{-3}	18.68	0.743	0.417	0.385
11	42.9	1.968×10^{-3}	19.20	0.712	0.402	0.592
12	42.3	1.97×10^{-3}	19.53	0.356	0.386	0.0835
13	42.3	1.97×10^{-3}	19.60	0.374	0.417	0.345
14	42.9	1.968×10^{-3}	19.7	0.291	0.541	0.388
15	42.9	1.968×10^{-3}	19.7	0.136	0.386	0.151
16	42.3	1.970×10^{-3}	19.7	0.128	0.804	0.261
17	42.3	1.970×10^{-3}	19.7	0.0249	0.356	0.0266
18	42.9	1.968×10^{-3}	19.7	0.0091	0.326	0.0019
19	42.9	1.968×10^{-3}	19.7	0.00592	0.929	0.00216

STATION 54 ft.

Boundary Temperature $T_\omega = 86.6^0F$
Displacement Thickness $\delta^* = 0.1486$ ft
Boundary Layer Thickness $\delta = 1.36$ ft
Wall Shear Stress $\tau_\omega = 8.81 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.9 \times 10^3$

Freestream Velocity $U_1 = 19.8$ ft/sec
Momentum Thickness $\theta = 0.1088$ ft
Form Factor $H = 1.366$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.006 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta T^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	72.3	1.855×10^{-3}	9.17	----	13.58	-----
1/8	62.4	1.891×10^{-3}	11.05	4.82	12.50	14.5
1/4	60.1	1.90×10^{-3}	11.45	5.28	12.20	15.66
3/8	56.7	1.914×10^{-3}	11.81	4.17	10.93	11.2
1/2	53.8	1.925×10^{-3}	12.61	2.69	9.98	5.66
3/4	52.7	1.928×10^{-3}	13.4	2.86	9.06	5.45
1	51.5	1.933×10^{-3}	13.59	3.20	8.74	6.03
1-1/2	49.2	1.940×10^{-3}	14.29	3.30	7.94	7.78
1-3/4	48.0	1.945×10^{-3}	14.65	2.63	7.32	5.73
2	48.0	1.945×10^{-3}	15.14	2.13	6.86	4.48
2-1/2	46.9	1.950×10^{-3}	15.50	1.93	6.38	3.78
3	45.8	1.955×10^{-3}	15.63	1.56	5.45	1.625
3-1/2	45.8	1.955×10^{-3}	15.83	1.61	4.67	1.636
4	44.7	1.960×10^{-3}	15.99	1.30	3.89	1.114
4-1/2	44.7	1.960×10^{-3}	16.60	1.047	3.26	0.069
5	44.7	1.960×10^{-3}	17.28	1.07	3.12	0.210
5-1/2	44.0	1.962×10^{-3}	17.20	0.622	2.65	-0.607
6	44.0	1.962×10^{-3}	17.35	0.533	2.18	-0.661
6-1/2	43.5	1.965×10^{-3}	17.9	0.453	1.93	-0.636
7	42.9	1.968×10^{-3}	18.05	0.1127	1.523	-1.49
7-1/2	42.9	1.968×10^{-3}	18.2	0.094	1.340	-1.28
8	42.9	1.968×10^{-3}	18.43	0.294	1.057	-0.757
8-1/2	42.9	1.968×10^{-3}	18.5	0.286	0.840	-0.836
9	42.9	1.963×10^{-3}	18.77	0.0304	0.747	-1.305

STATION 54 ft. (cont'd)

Boundary Temperature $T_\omega = 86.6^0F$
Displacement Thickness $\delta^* = 0.1486$ft
Boundary Layer Thickness $\delta = 1.36$ ft
Wall Shear Stress $\tau_\omega = 8.81 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.9 \times 10^3$

Freestream Velocity $U_1 = 19.8$ ft/sec
Momentum Thickness $\theta = 0.1088$ ft.
Form Factor $H = 1.366$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu}$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	42.9	1.963×10^{-3}	19.08	-0.161	0.544	-0.71
11	42.3	1.965×10^{-3}	19.22	0.223	0.420	-0.534
12	41.7	1.970×10^{-3}	19.48	0.380	0.373	-0.0707
13	42.3	1.965×10^{-3}	19.64	-0.147	0.357	-0.721
14	42.3	1.965×10^{-3}	19.64	-0.186	0.373	-0.655
15	42.3	1.965×10^{-3}	19.7	-0.0721	0.496	-0.310
16	42.3	1.965×10^{-3}	19.7	-0.0753	0.466	-0.250
17	42.3	1.965×10^{-3}	19.7	0.0127	0.342	-0.0296
18	42.3	1.965×10^{-3}	19.8	0.0063	0.342	0.0134
19	42.3	1.965×10^{-3}	19.8	0.0063	0.342	0.0134

STATION 56 ft.

Boundary Temperature	$T_\omega = 85.5^0F$	Freestream Velocity	$U_1 = 19.7$ ft/sec
Displacement Thickness	$\delta^* = 0.1506$ft	Momentum Thickness	$\theta = 0.113$ ft
Boundary Layer Thickness	$\delta = 1.387$ ft	Form Factor	$H = 1.344$
Wall Shear Stress	$\tau_\omega = 8.89 \times 10^{-4} lb_f/ft^2$		
Nusselt Number	$Nu = 1.94 \times 10^3$	Reynolds Number $R_\theta = \frac{U\theta}{\nu}$	$= 1.025 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	74.8	1.842×10^{-3}	9.04	-----	13.60	----
1/8	61.8	1.89×10^{-3}	11.25	0.719	12.95	-2.94
1/4	57.8	1.903×10^{-3}	11.96	2.54	11.59	5.05
3/8	57.1	1.906×10^{-3}	12.32	3.62	10.93	9.24
1/2	56.2	1.910×10^{-3}	12.78	2.80	10.61	7.33
3/4	53.3	1.921×10^{-3}	13.30	2.21	9.99	5.25
1	52.7	1.923×10^{-3}	13.5	1.51	9.21	2.64
1-1/2	50.4	1.932×10^{-3}	14.20	2.30	8.44	5.35
1-3/4	49.8	1.935×10^{-3}	14.40	2.08	8.10	4.29
2	48.7	1.940×10^{-3}	14.69	1.84	7.64	2.07
2-1/2	47.5	1.944×10^{-3}	15.41	2.52	6.71	2.57
3	45.8	1.952×10^{-3}	15.59	1.67	6.08	0.954
3-1/2	45.8	1.952×10^{-3}	15.94	1.55	5.61	1.35
4	44.7	1.954×10^{-3}	16.20	0.857	4.67	-0.628
4-1/2	43.5	1.959×10^{-3}	16.52	0.977	4.06	-0.661
5	42.9	1.961×10^{-3}	16.85	0.716	3.28	-1.47
5-1/2	42.3	1.965×10^{-3}	17.10	0.766	3.12	-1.68
6	42.3	1.965×10^{-3}	17.41	0.679	2.80	-1.59
6-1/2	42.3	1.965×10^{-3}	17.68	0.758	2.49	-1.35
7	41.1	1.968×10^{-3}	17.80	0.705	1.87	-1.25
7-1/2	41.1	1.968×10^{-3}	18.05	0.610	1.87	-1.35
8	41.1	1.968×10^{-3}	18.20	0.658	1.495	-1.09
8-1/2	41.1	1.968×10^{-3}	18.43	0.463	1.185	-1.46
9	41.1	1.969×10^{-3}	18.60	0.413	0.935	-1.18

STATION 56 ft. (cont'd)

Boundary Temperature $T_\omega = 85.5^0F$
Displacement Thickness $\delta^* = 0.1506$ ft
Boundary Layer Thickness $\delta = 1.387$ ft
Wall Shear Stress $\tau_\omega = 8.89 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.94 \times 10^3$

Freestream Velocity $U_1 = 19.7$ ft/sec
Momentum Thickness $\theta = 0.112$ ft
Form Factor $H = 1.344$
Reynolds Number $R_\theta = \frac{U\theta}{\nu} = 1.025 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	41.1	1.969×10^{-3}	18.8	0.376	0.810	-1.12
11	41.1	1.969×10^{-3}	19.0	0.543	0.624	-0.457
12	41.1	1.969×10^{-3}	19.34	0.410	0.436	-0.512
13	41.1	1.969×10^{-3}	19.4	0.266	0.404	-0.355
14	41.1	1.969×10^{-3}	19.5	0	0.343	0.541
15	41.1	1.969×10^{-3}	19.6	0.234	0.343	0.0314
16	41.1	1.969×10^{-3}	19.6	0.1465	0.343	0.0643
17	41.1	1.969×10^{-3}	19.7	0.0732	0.312	0.0143
18	41.1	1.969×10^{-3}	19.7	0.0362	0.249	-0.031
19	41.1	1.969×10^{-3}	19.7	0.0362	0.312	0.028

STATION 58 ft

Boundary Temperature $T_\omega = 88.7^0F$ Freestream Velocity $U_1 = 19.67$ ft/sec

Displacement Thickness $\delta^* = 0.1612$ ft Momentum Thickness $\theta = 0.1217$ ft

Boundary Layer Thickness $\delta = 1.415$ ft Form Factor $H = 1.325$

Wall Shear Stress $\tau_\omega = 8.94 \times 10^{-4}$ lb$_f$/ft^2

Nusselt Number $Nu = 1.687 \times 10^{-3}$

Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.103 \times 10^4$

dist. above boundary inches	temp. F^0	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	73.5	1.848×10^{-3}	8.85	-----	13.33	----
1/8	61.9	1.89×10^{-3}	10.71	3.95	13.53	13.2
1/4	59.5	1.90×10^{-3}	11.1	3.82	12.28	11.66
3/8	56.1	1.912×10^{-3}	12.42	3.50	11.60	10.73
1/2	53.8	1.921×10^{-3}	12.84	3.26	10.95	9.2
3/4	52.7	1.924×10^{-3}	13.50	4.18	10.33	11.8
1	52.7	1.924×10^{-3}	13.92	3.86	9.68	10.6
1-1/2	49.2	1.938×10^{-3}	14.79	3.06	8.44	7.37
1-3/4	49.2	1.938×10^{-3}	14.79	2.97	7.81	7.33
2	48.0	1.945×10^{-3}	14.86	2.98	7.81	7.99
2-1/2	47.5	1.948×10^{-3}	15.21	2.62	6.86	6.04
3	45.8	1.955×10^{-3}	15.64	2.10	5.93	3.88
3-1/2	45.8	1.958×10^{-3}	16.10	1.71	5.93	3.57
4	44.7	1.960×10^{-3}	16.17	1.364	4.98	2.01
4-1/2	44.7	1.960×10^{-3}	16.41	1.21	4.53	1.50
5	42.9	1.965×10^{-3}	16.85	1.27	3.90	1.55
5-1/2	42.3	1.970×10^{-3}	16.90	0.981	3.43	0.926
6	42.3	1.970×10^{-3}	17.13	1.007	3.12	1.017
6-1/2	42.3	1.970×10^{-3}	17.47	1.044	2.80	1.14
7	42.3	1.970×10^{-3}	17.61	0.91	2.39	0.716
7-1/2	41.7	1.971×10^{-3}	17.70	0.525	1.83	-0.1445
8	41.1	1.974×10^{-3}	17.92	0.339	1.375	-0.551
8-1/2	41.1	1.974×10^{-3}	18.08	0.375	1.375	-0.428
9	41.1	1.974×10^{-3}	18.23	0.283	1.07	-0.507

STATION 58 ft. (cont'd)

Boundary Temperature $T_\omega = 88.7^0F$
Displacement Thickness $\delta^* = 0.1612$ ft
Boundary Layer Thickness $\delta = 1.415$ ft
Wall Shear Stress $\tau_\omega = 8.94 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.687 \times 10^{-3}$

Freestream Velocity $U_1 = 19.67$ ft/sec
Momentum Thickness $\theta = 0.1217$ ft
Form Factor $H = 1.325$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.103 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	41.1	1.974×10^{-3}	18.53	0.192	.765	-0.547
11	41.1	1.975×10^{-3}	18.84	0.1696	.55	-0.542
12	41.1	1.975×10^{-3}	19.0	0.0569	.397	-1.035
13	41.1	1.975×10^{-3}	19.0	0.133	.367	-0.845
14	41.1	1.975×10^{-3}	19.12	0.0619	.352	-1.057
15	41.1	1.975×10^{-3}	19.37	0.155	.336	-0.732
16	41.1	1.975×10^{-3}	19.52	0.149	.336	-0.597
17	41.1	1.975×10^{-3}	19.58	0.000927	.306	-0.151
18	41.1	1.975×10^{-3}	19.67	0.00439	.275	-0.171
19	41.1	1.975×10^{-3}	19.67	0.00292	.245	-0.112

STATION 60 ft.

Boundary Temperature $T_\omega = 87.6^0F$
Displacement Thickness $\delta = 0.162$ft
Boundary Layer Thickness $\delta = 1.44$ ft
Wall Shear Stress $\tau_\omega = 1.03 \times 10^{-3} lb_f/ft^2$
Nusselt Number $Nu = 1.63 \times 10^3$

Freestream Velocity $U_1 = 19.66$ ft/sec
Momentum Thickness $\theta = 0.133$ ft
Form Factor $H = 1.219$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.22 \times 10^4$

dist. above boundary y inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	75.7	1.845×10^{-3}	8.86	-----	13.38	-----
1/8	61.9	1.895×10^{-3}	11.12	5.43	12.90	13.4
1/4	59.5	1.903×10^{-3}	11.70	2.62	11.94	6.32
3/8	58.5	1.906×10^{-3}	11.96	3.38	11.32	9.69
1/2	56.1	1.915×10^{-3}	12.08	3.61	10.70	10.0
3/4	53.8	1.925×10^{-3}	13.18	2.97	9.30	6.23
1	51.5	1.932×10^{-3}	13.37	3.25	8.70	3.90
1-1/2	50.4	1.936×10^{-3}	14.50	3.37	8.10	7.01
1-3/4	49.2	1.942×10^{-3}	14.67	2.76	8.10	6.35
2	48.0	1.947×10^{-3}	14.95	2.67	7.50	5.61
2-1/2	46.9	1.951×10^{-3}	15.30	1.09	6.90	4.20
3	45.8	1.956×10^{-3}	15.64	1.76	6.30	2.74
3-1/2	45.8	1.956×10^{-3}	15.91	1.205	5.40	0.822
4	44.7	1.960×10^{-3}	15.98	1.345	4.80	1.25
4-1/2	43.5	1.965×10^{-3}	16.31	1.30	4.64	1.17
5	44.7	1.960×10^{-3}	16.32	0.945	4.16	1.06
5-1/2	45.8	1.956×10^{-3}	16.17	1.575	4.30	2.26
6	41.1	1.975×10^{-3}	17.43	1.075	3.70	0.945
6-1/2	40.	1.980×10^{-3}	18.15	0.696	2.83	-0.361
7	38.8	1.982×10^{-3}	18.42	0.696	2.24	-0.428
7-1/2	38.8	1.982×10^{-3}	18.2	0.623	2.03	-0.369
8	40.	1.980×10^{-3}	18.3	0.555	1.79	-0.287
8-1/2	40.	1.980×10^{-3}	18.48	0.477	1.49	-0.281
9	42.3	1.970×10^{-3}	17.87	0.436	2.09	-0.0875

STATION 60 ft. (cont'd)

Boundary Temperature	$T_\omega = 87.6^0F$	Freestream Velocity	$U_1 = 19.66$ ft/sec
Displacement Thickness	$\delta^* = 0.162$ ft	Momentum Thickness	$\theta = 0.133$ ft
Boundary Layer Thickness	$\delta = 1.44$ ft	Form Factor	$H = 1.219$
Wall Shear Stress	$\tau_\omega = 1.03 \times 10^{-3} lb_f/ft^2$		
Nusselt Number	$Nu = 1.63 \times 10^3$	Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu}$	$= 1.22 \times 10^4$

dist. above boundary y inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	43.5	1.967×10^{-3}	17.41	1.097	1.49	0.970
11	44.7	1.960×10^{-3}	17.92	0.982	0.896	0.682
12	46.7	1.953×10^{-3}	17.71	0.414	0.596	-0.223
13	44.7	1.960×10^{-3}	17.92	0.445	0.506	-0.00876
14	44.7	1.960×10^{-3}	18.62	0.433	0.387	0.0683
15	44.7	1.960×10^{-3}	18.62	0.503	0.299	0.403
16	44.7	1.960×10^{-3}	19.09	0.280	0.209	0.146
17	44.3	1.970×10^{-3}	19.53	0.203	0.269	0.0888
18	41.1	1.975×10^{-3}	19.59	0.184	0.239	0.164
19	41.1	1.976×10^{-3}	19.66	0.166	0.239	0.211

STATION 62 ft.

Boundary Temperature $T_\omega = 89.7^0F$
Displacement Thickness $\delta^* = 0.1733$ft
Boundary Layer Thickness $\delta = 1.468$ ft
Wall Shear Stress $\tau_\omega = 8.55 \times 10^{-4} lb_f/ft^2$
Nusselt Number $Nu = 1.462 \times 10^3$

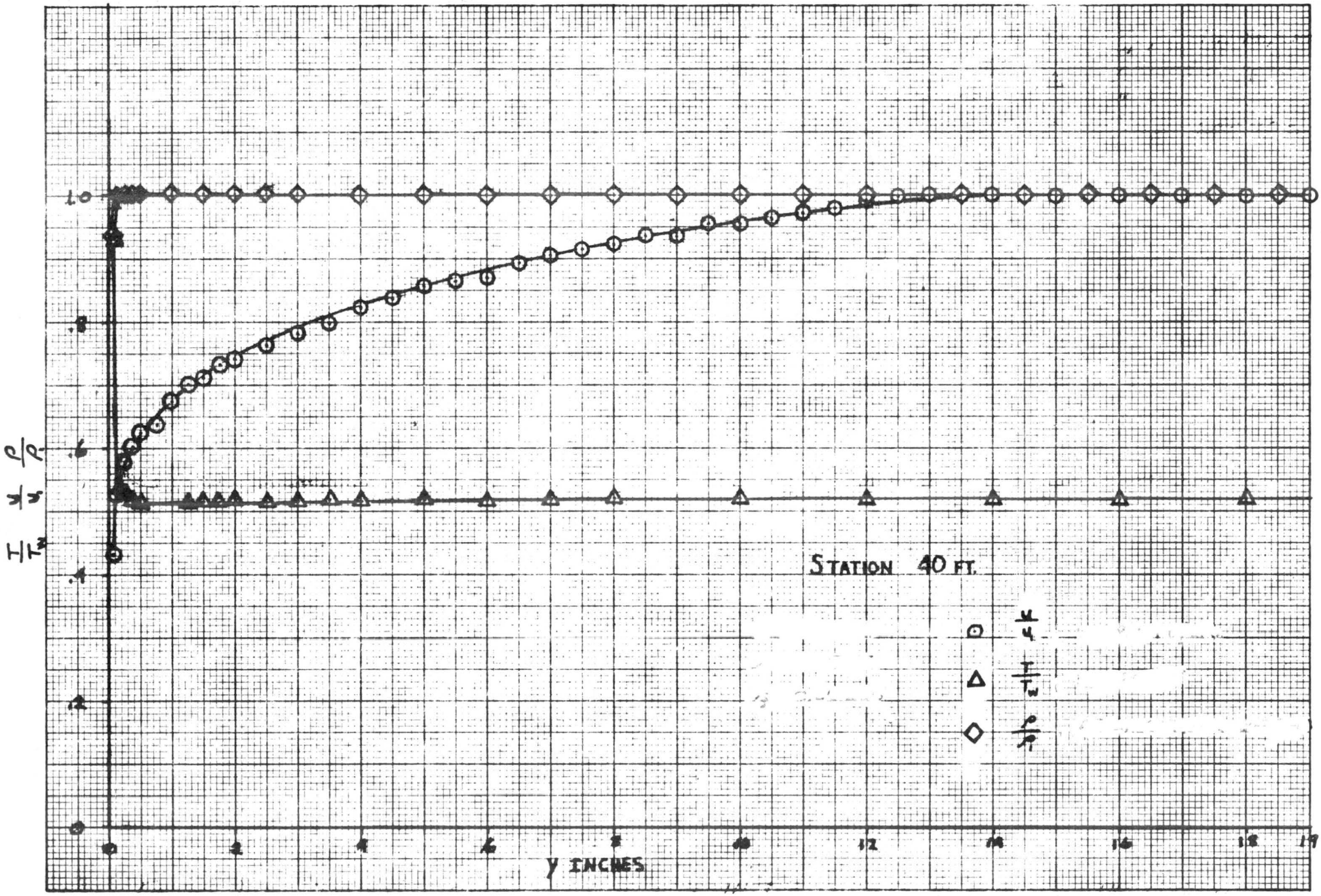
Free stream Velocity $U_1 = 19.55$ ft/sec
Momentum Thickness $\theta = 0.1295$ ft
Form Factor $H = 1.34$
Reynolds Number $R_\theta = \frac{U_1 \theta}{\nu} = 1.167 \times 10^4$

dist. above boundary inches	temp. F^0	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
1/16	68.2	1.875×10^{-3}	8.08	-----	13.77	-----
1/8	61.8	1.90×10^{-3}	9.98	1.81	11.00	0.156
1/4	59.5	1.907×10^{-3}	10.81	2.58	9.84	2.71
3/8	58.5	1.915×10^{-3}	11.58	2.63	9.51	3.33
1/2	56.1	1.921×10^{-3}	12.03	3.45	9.22	6.78
3/4	53.8	1.930×10^{-3}	12.81	2.87	8.56	4.64
1	53.3	1.933×10^{-3}	13.14	2.43	8.25	3.62
1-1/2	51.5	1.938×10^{-3}	14.20	2.20	7.50	3.35
1-3/4	50.4	1.942×10^{-3}	14.57	2.61	7.19	4.94
2	49.8	1.945×10^{-3}	14.96	2.08	6.88	3.90
2-1/2	48.5	1.950×10^{-3}	15.10	2.14	6.42	3.73
3	48.5	1.950×10^{-3}	15.50	1.84	5.80	2.68
3-1/2	48.0	1.952×10^{-3}	15.58	1.845	6.10	3.15
4	47.5	1.955×10^{-3}	15.66	1.58	5.49	2.45
4-1/2	46.3	1.958×10^{-3}	16.19	1.09	4.27	0.39
5	45.8	1.961×10^{-3}	16.40	1.17	3.97	1.09
5-1/2	45.8	1.961×10^{-3}	16.68	0.88	3.67	0.602
6	45.8	1.961×10^{-3}	16.86	0.728	3.67	0.516
6-1/2	45.8	1.961×10^{-3}	17.02	0.489	2.75	-0.585
7	44.0	1.967×10^{-3}	17.25	0.543	2.44	-0.348
7-1/2	44.7	1.965×10^{-3}	17.31	0.403	2.44	-0.267
8	45.2	1.964×10^{-3}	17.41	0.521	2.44	0.235
8-1/2	44.7	1.965×10^{-3}	17.60	0.602	1.68	0.0605
9	44.7	1.965×10^{-3}	17.90	0.74	1.372	0.211

STATION 62 ft. (cont'd)

Boundary Temperature	$T\omega = 89.7^0F$	Freestream Velocity	$U_1 = 19.55$ ft/sec
Displacement Thickness	$\delta^* = 0.1733$ft	Momentum Thickness	$\theta = 0.1295$ ft
Boundary Layer Thickness	$\delta = 1.468$ ft	Form Factor	$H = 1.34$
Wall Shear Stress	$\tau\omega = 8.55 \times 10^{-4} lb_f/ft^2$		
Nusselt Number	$Nu = 1.462 \times 10^3$	Reynolds Number	$R_\theta = \frac{U_1\theta}{\nu} = 1.167 \times 10^4$

dist. above boundary inches	temp. ^0F	density slug/ft^3	velocity fps	$\overline{u^2}$ ft^2/sec^2	$\sqrt{\overline{\Delta t^2}}$ ^0F	$\overline{ut}$ ft-^0F/sec
10	43.5	1.970×10^{-3}	18.41	0.27	0.976	-0.671
11	44.0	1.967×10^{-3}	18.11	0.156	0.976	-0.752
12	44.0	1.967×10^{-3}	18.68	0.0638	0.550	-0.965
13	43.5	1.970×10^{-3}	18.87	-0.0552	0.382	-1.13
14	43.5	1.970×10^{-3}	19.19	0.0615	0.458	-1.10
15	43.5	1.970×10^{-3}	19.40	0.0657	0.336	-1.02
16	43.5	1.970×10^{-3}	19.19	0.00725	0.275	-0.692
17	44.0	1.967×10^{-3}	19.41	0.00362	0.1832	-0.549
18	44.7	1.965×10^{-3}	19.55	0.0273	0.1832	-0.377
19	44.0	1.967×10^{-3}	19.55	0.000200	0.1832	-0.204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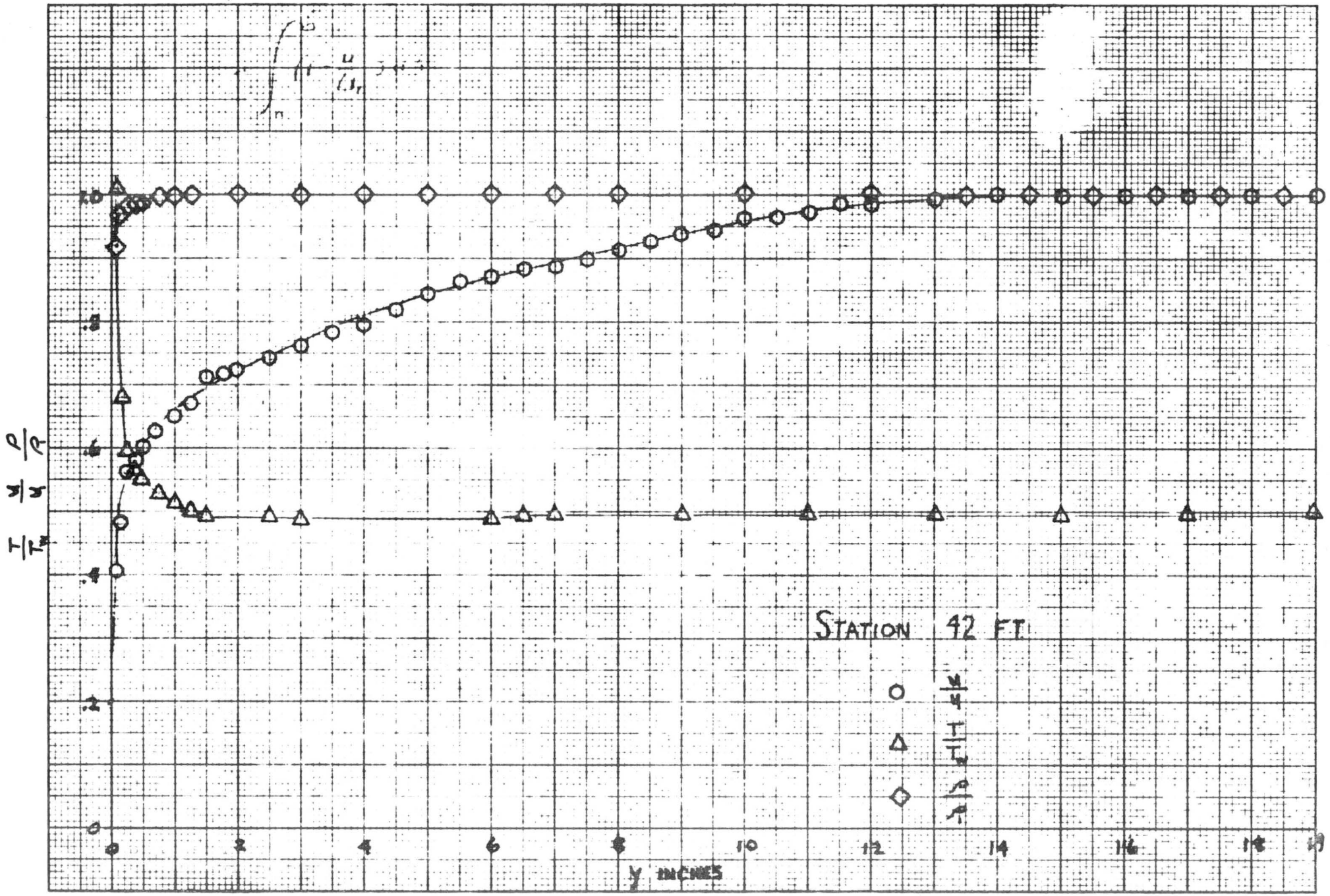
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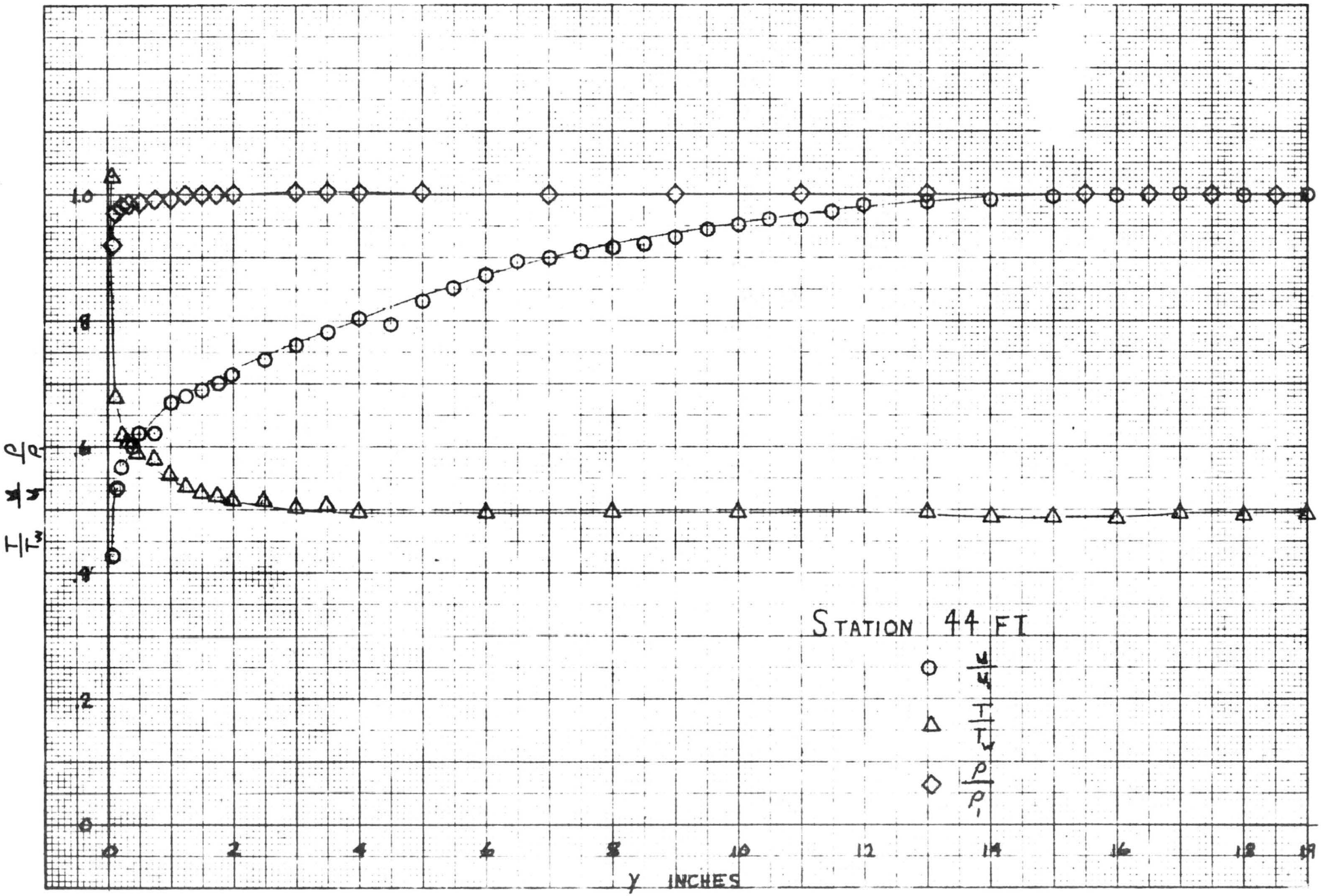
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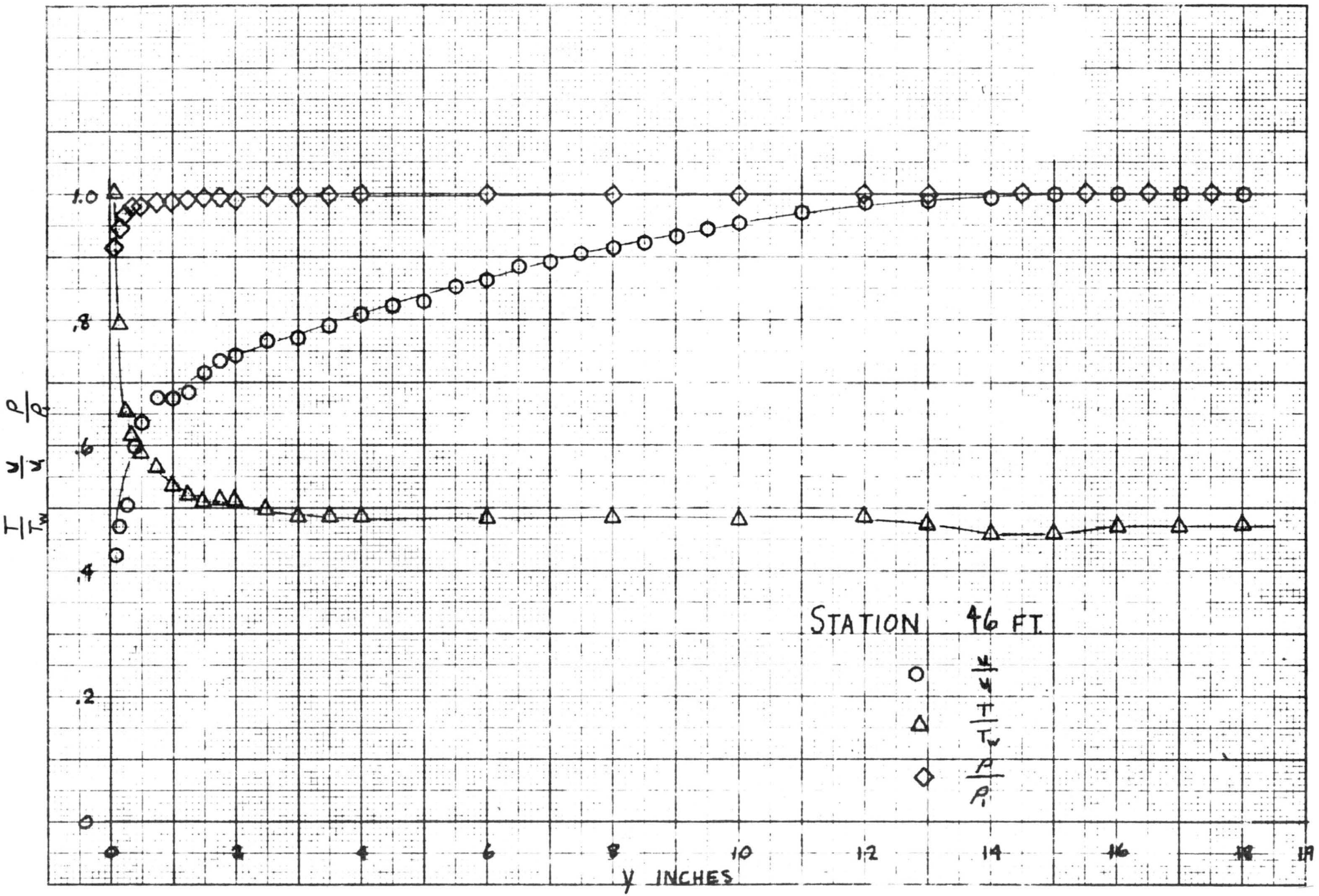
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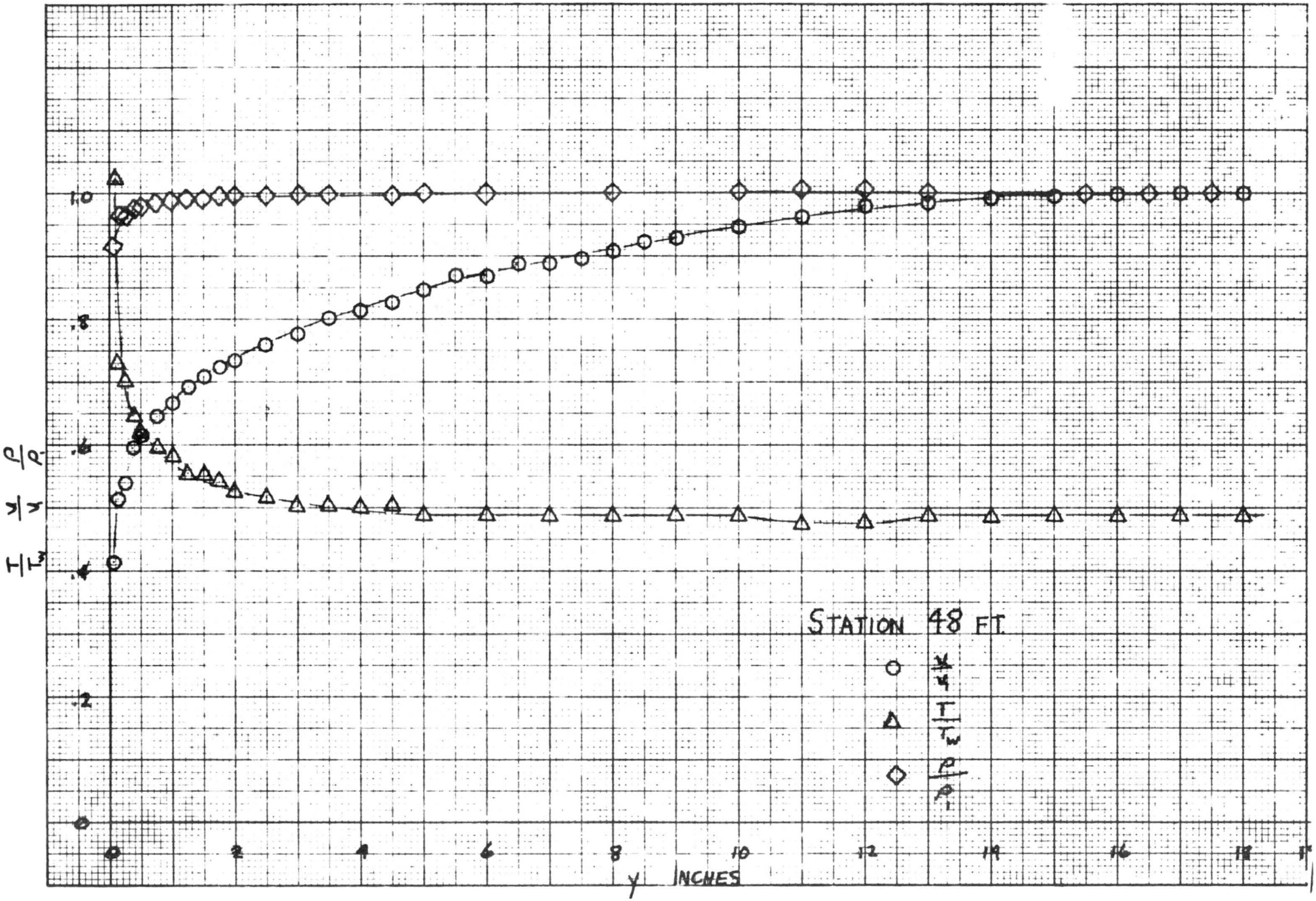
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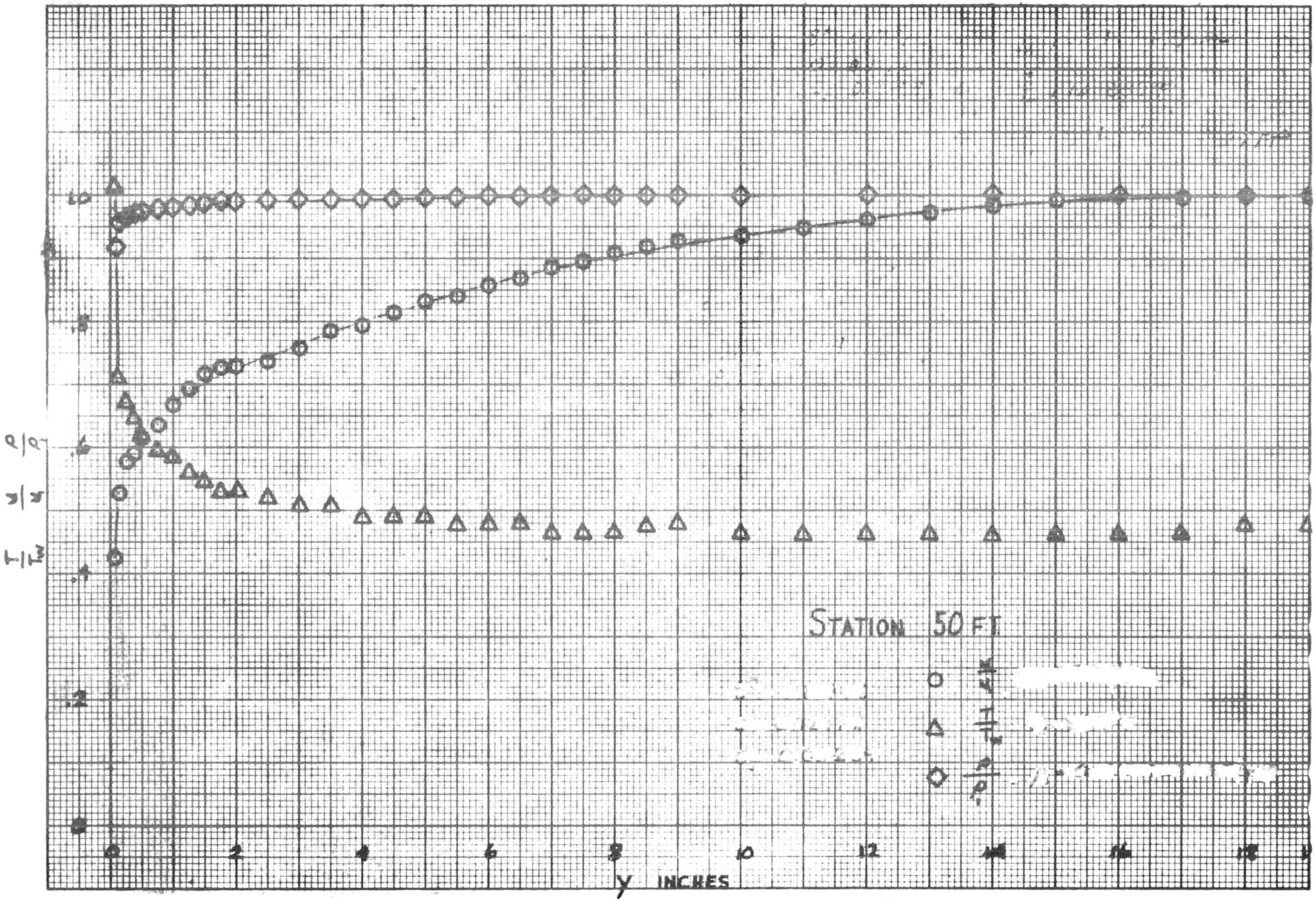
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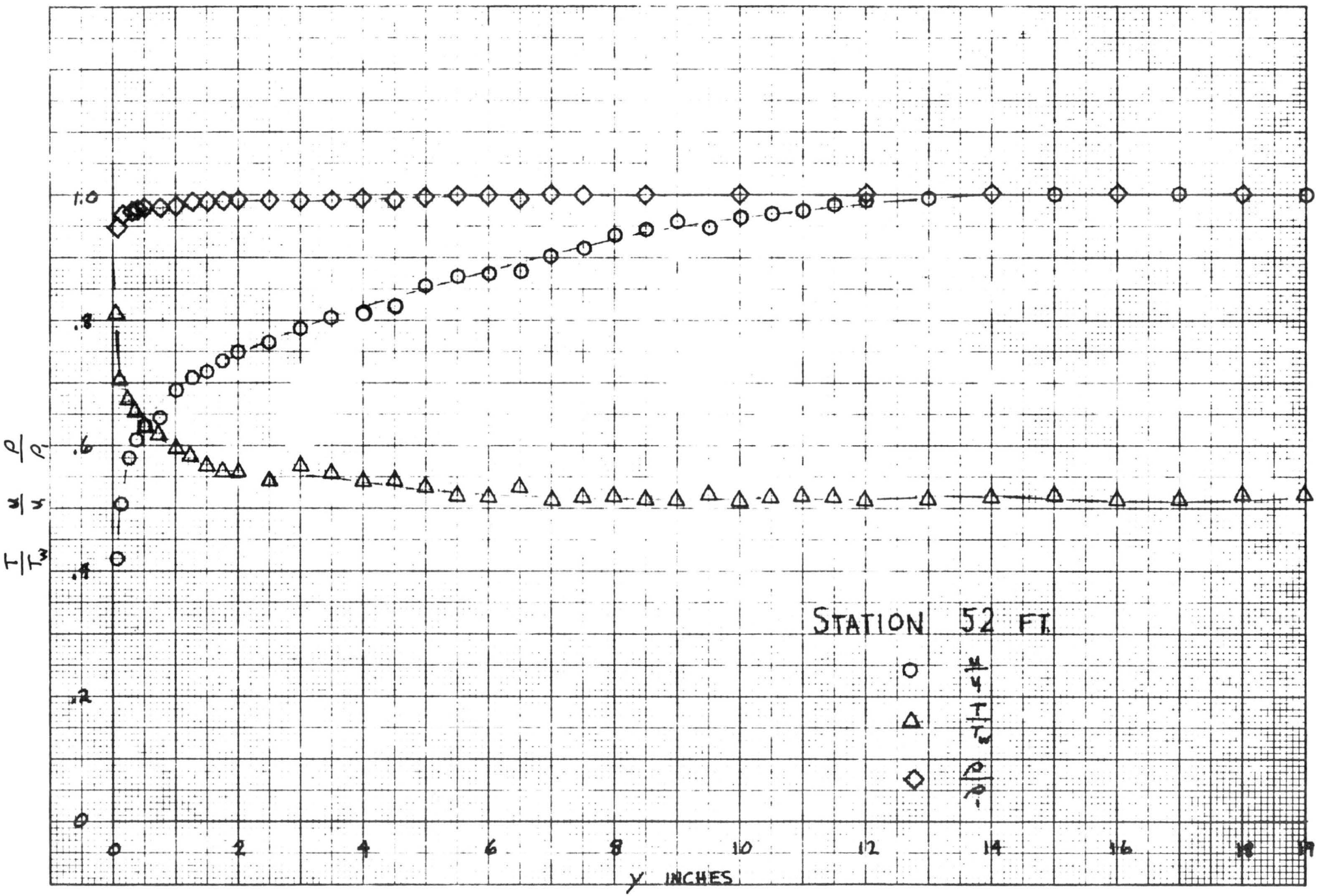
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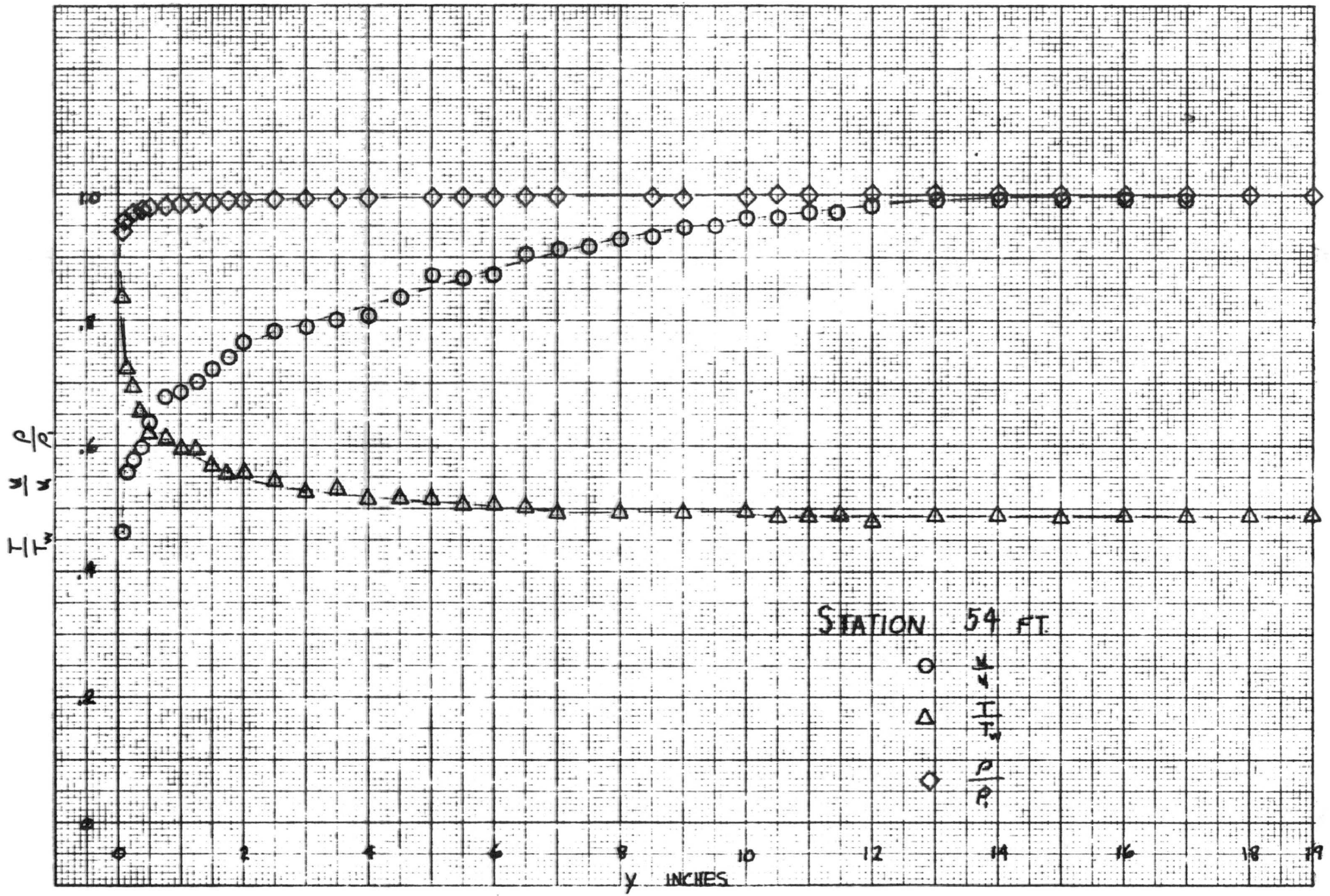
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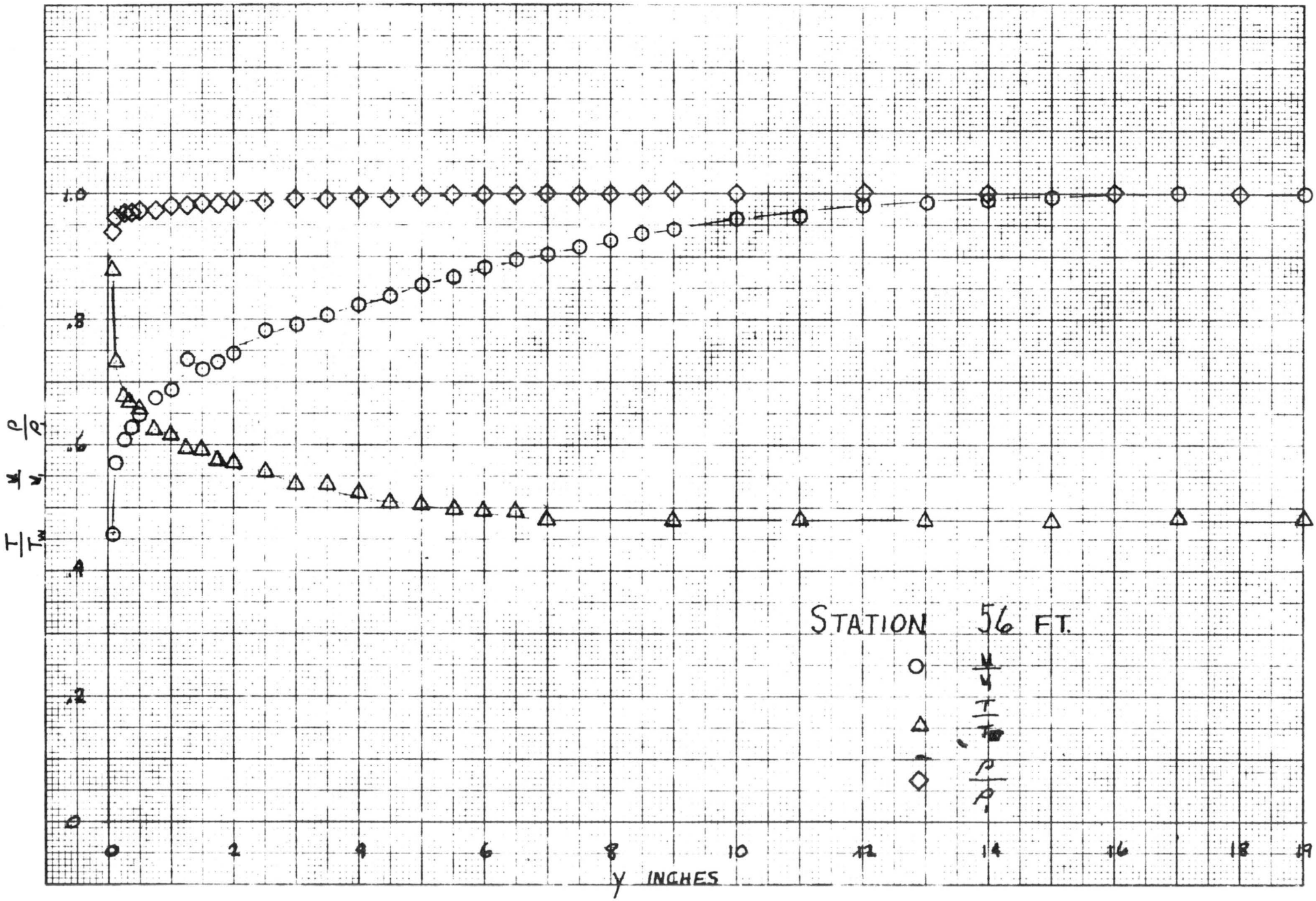
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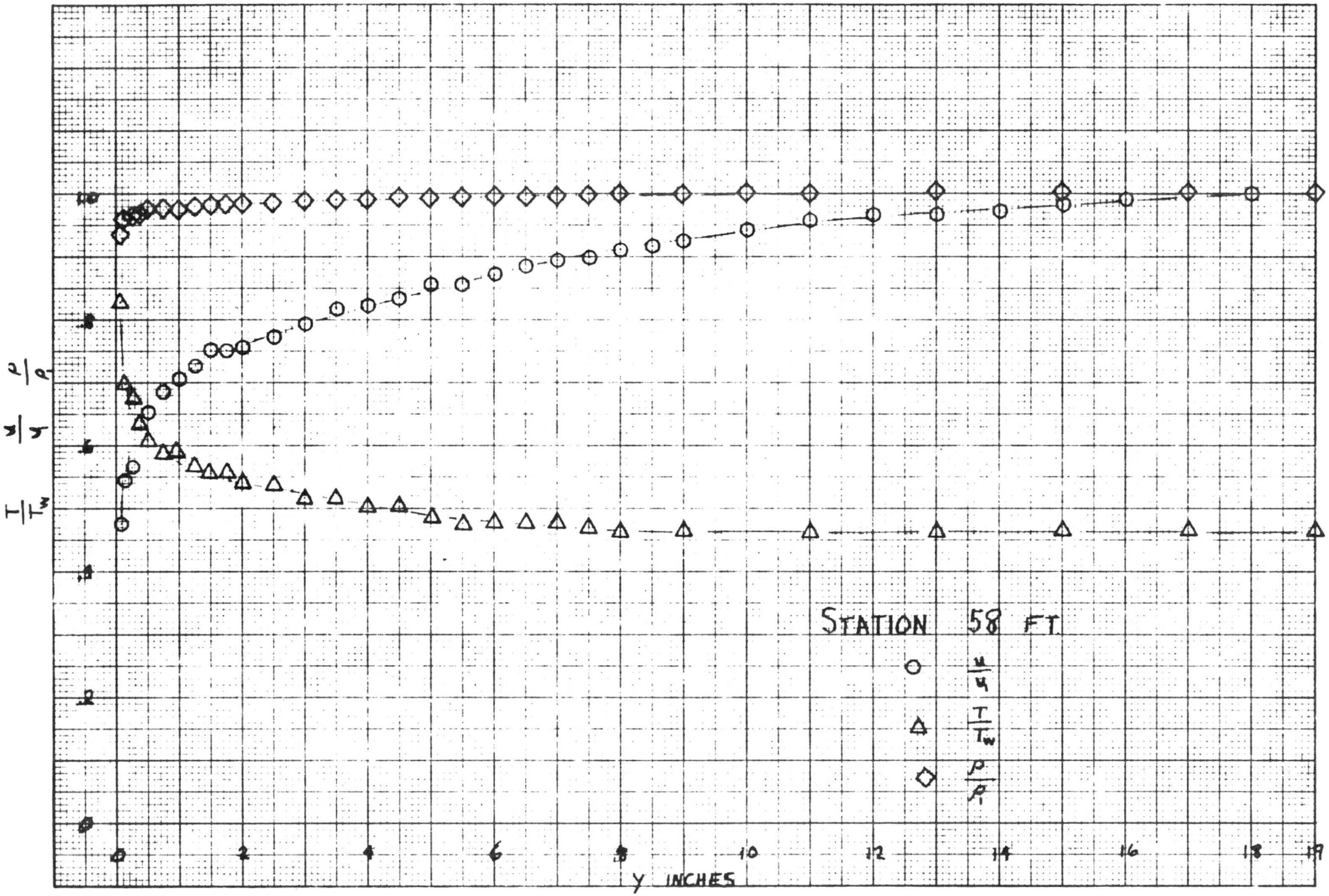
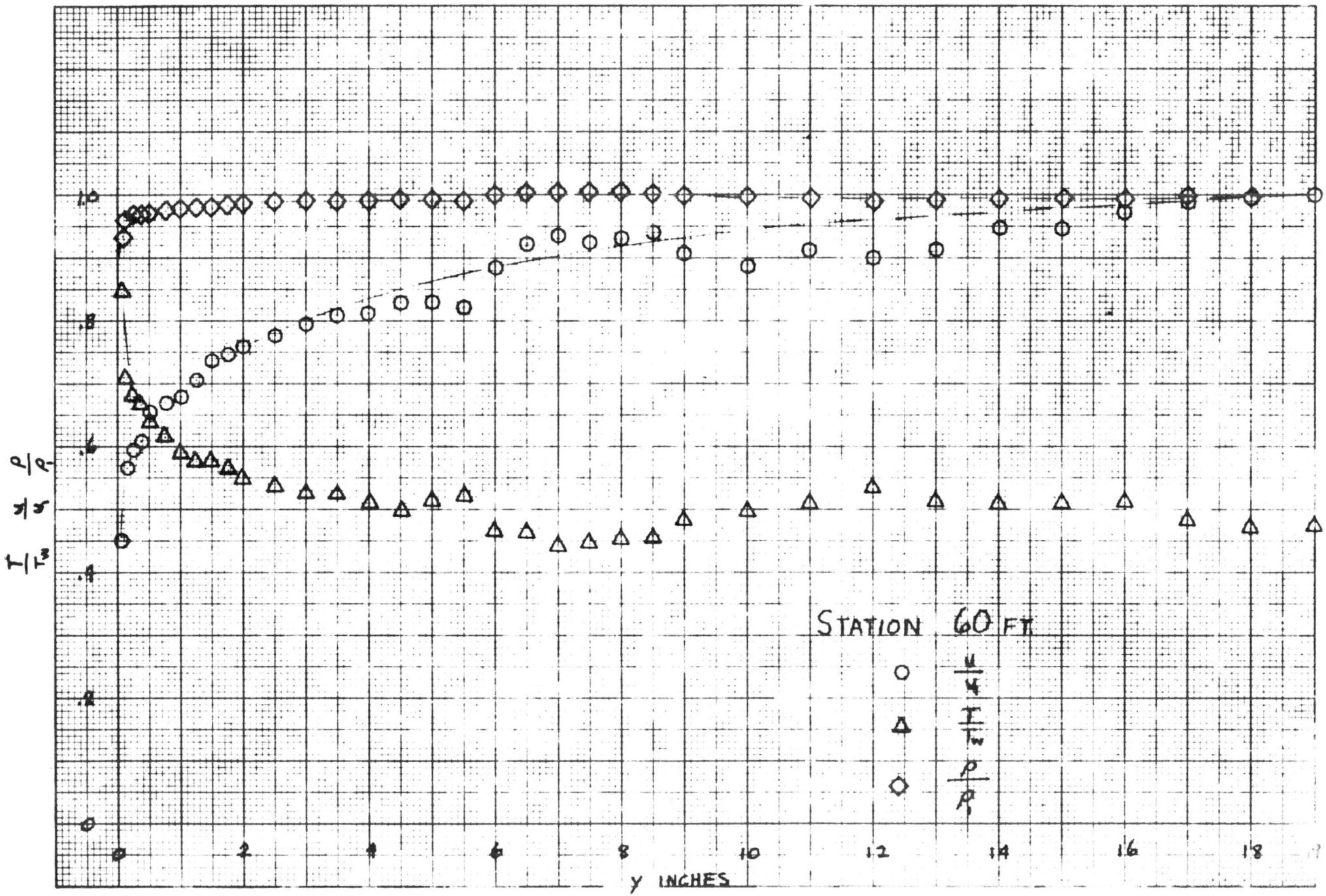
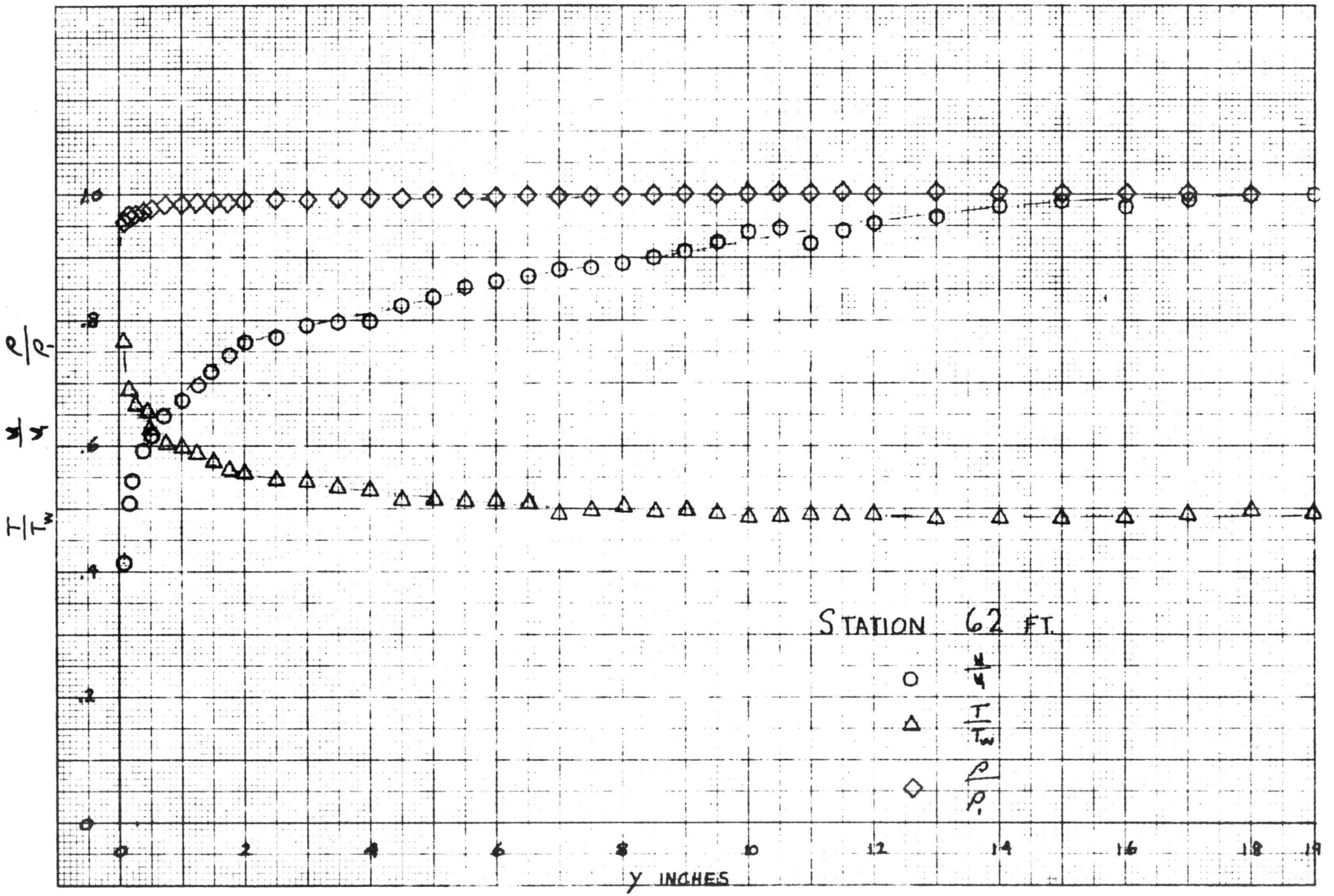
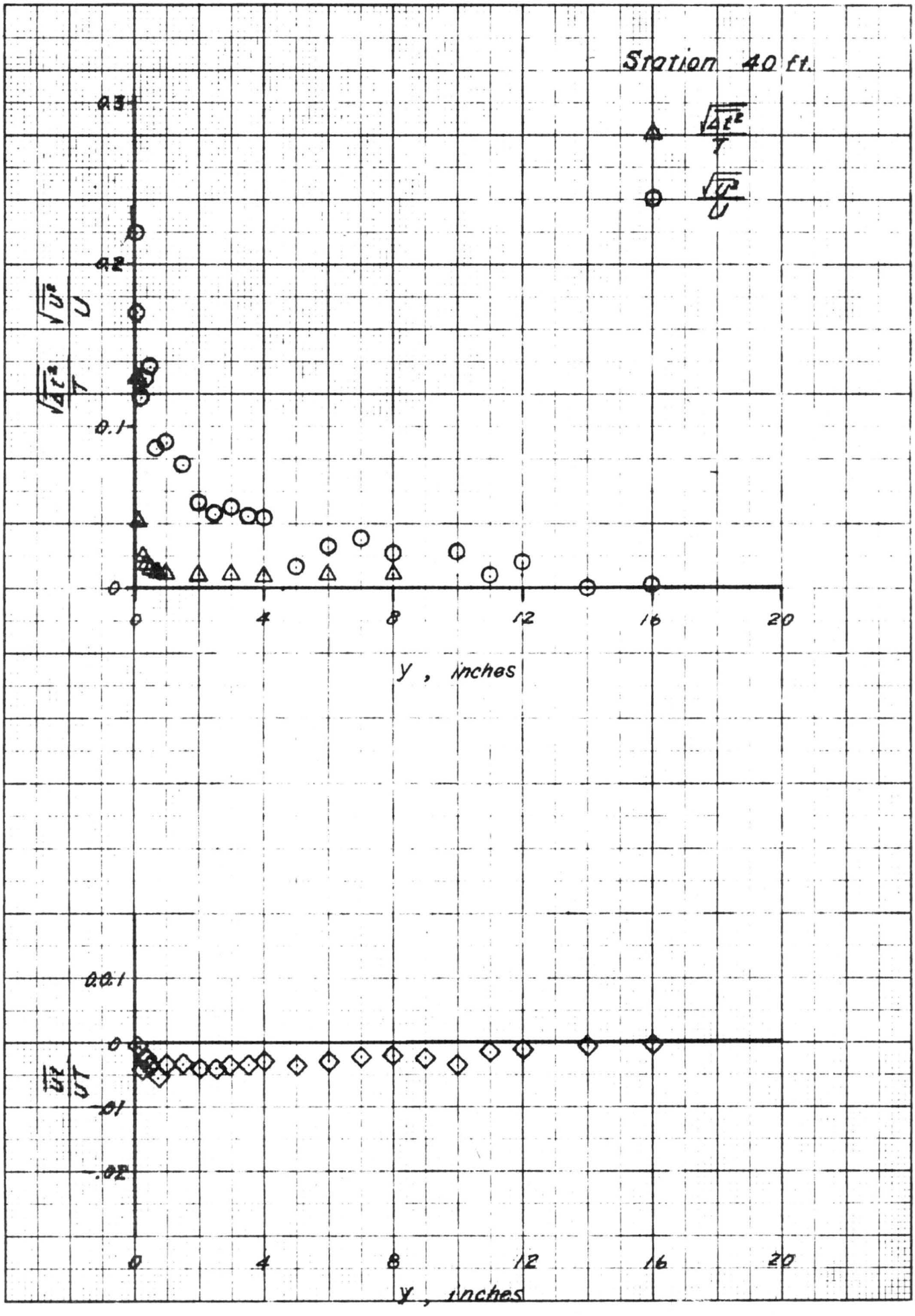
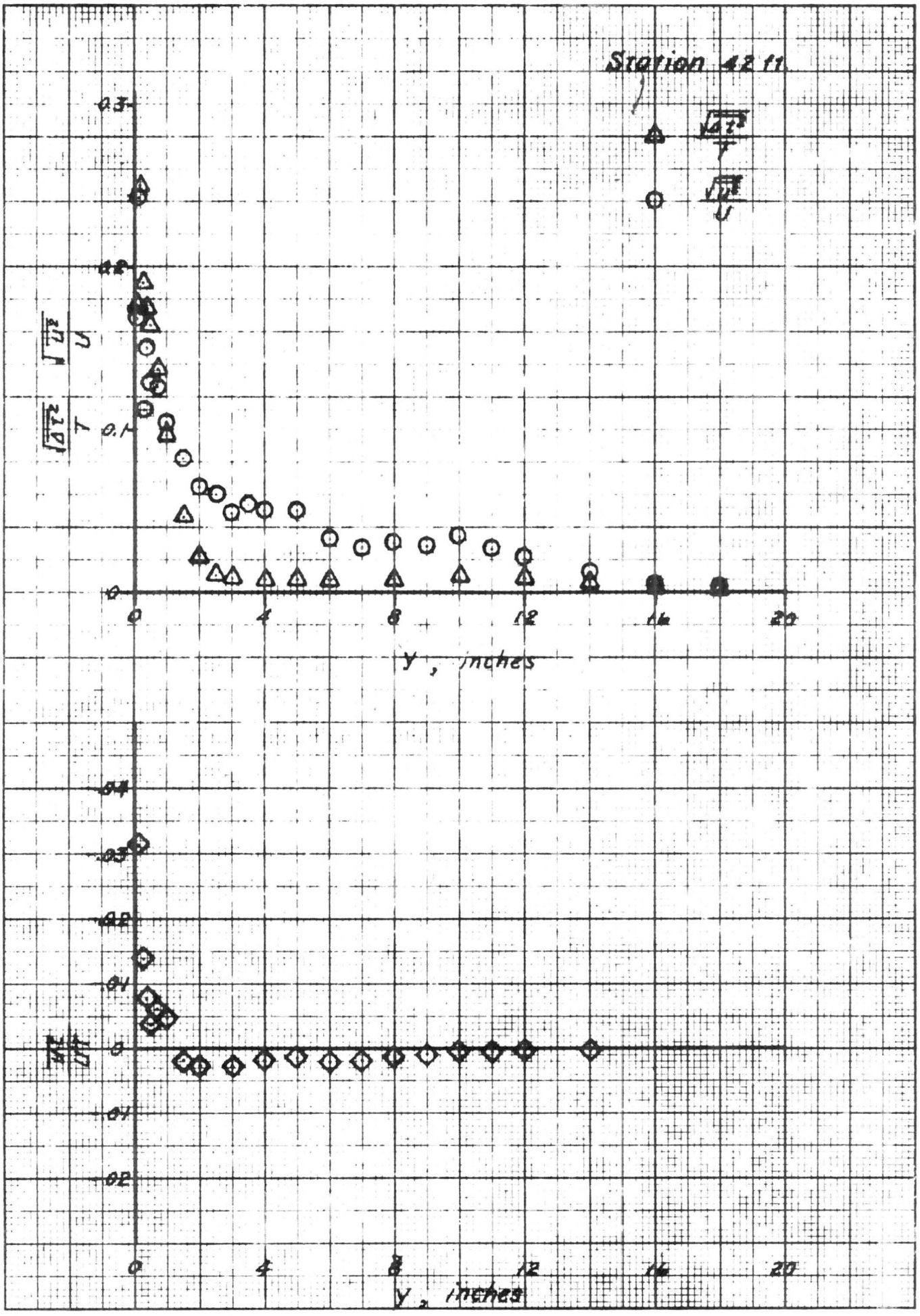
T/T₁
ρ/ρ₁

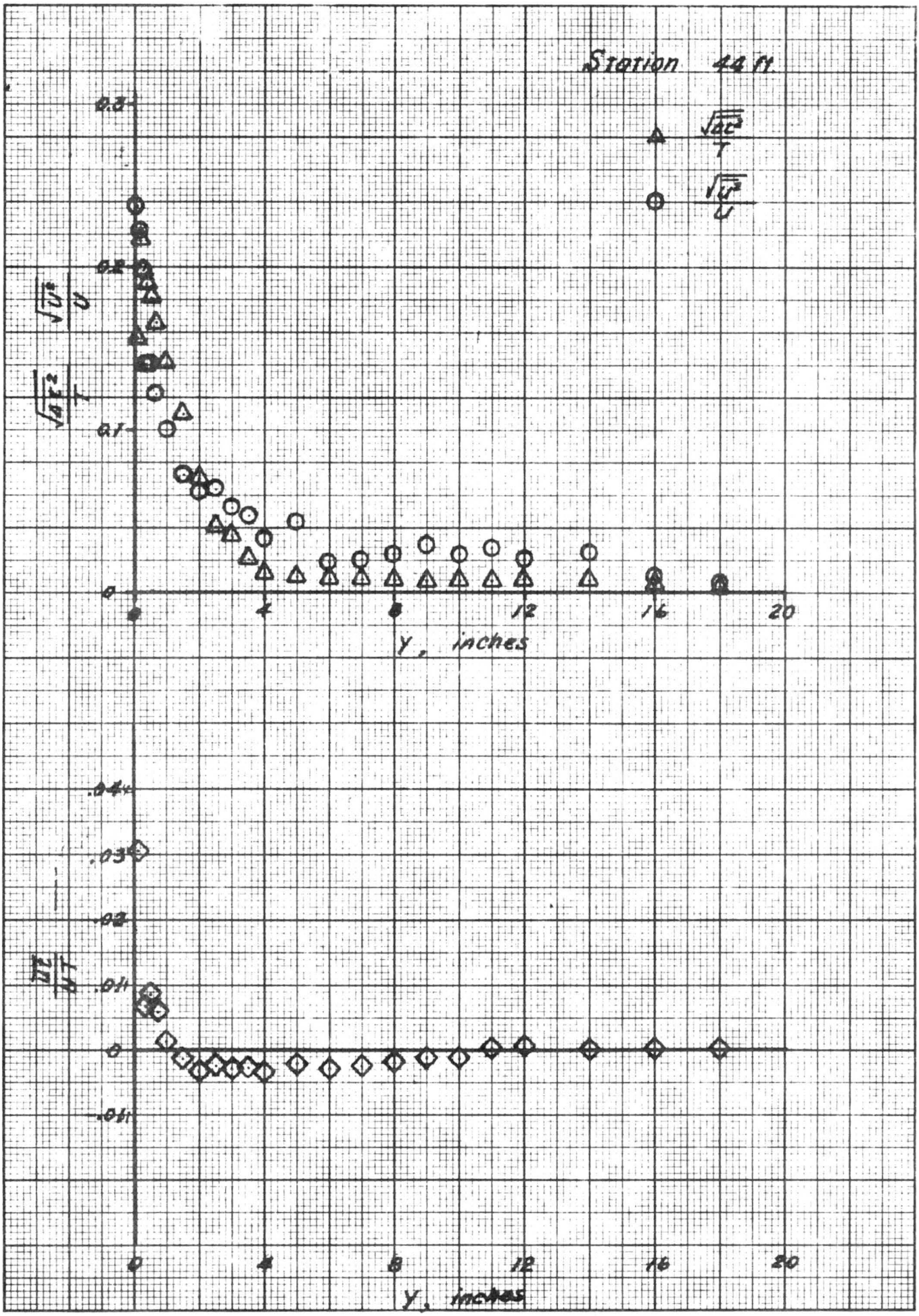

STATION 58 FT
u/u1
T/Tw
ρ/ρ1
y INCHES
0
2
4
6
8
10
12
14
16
18
19

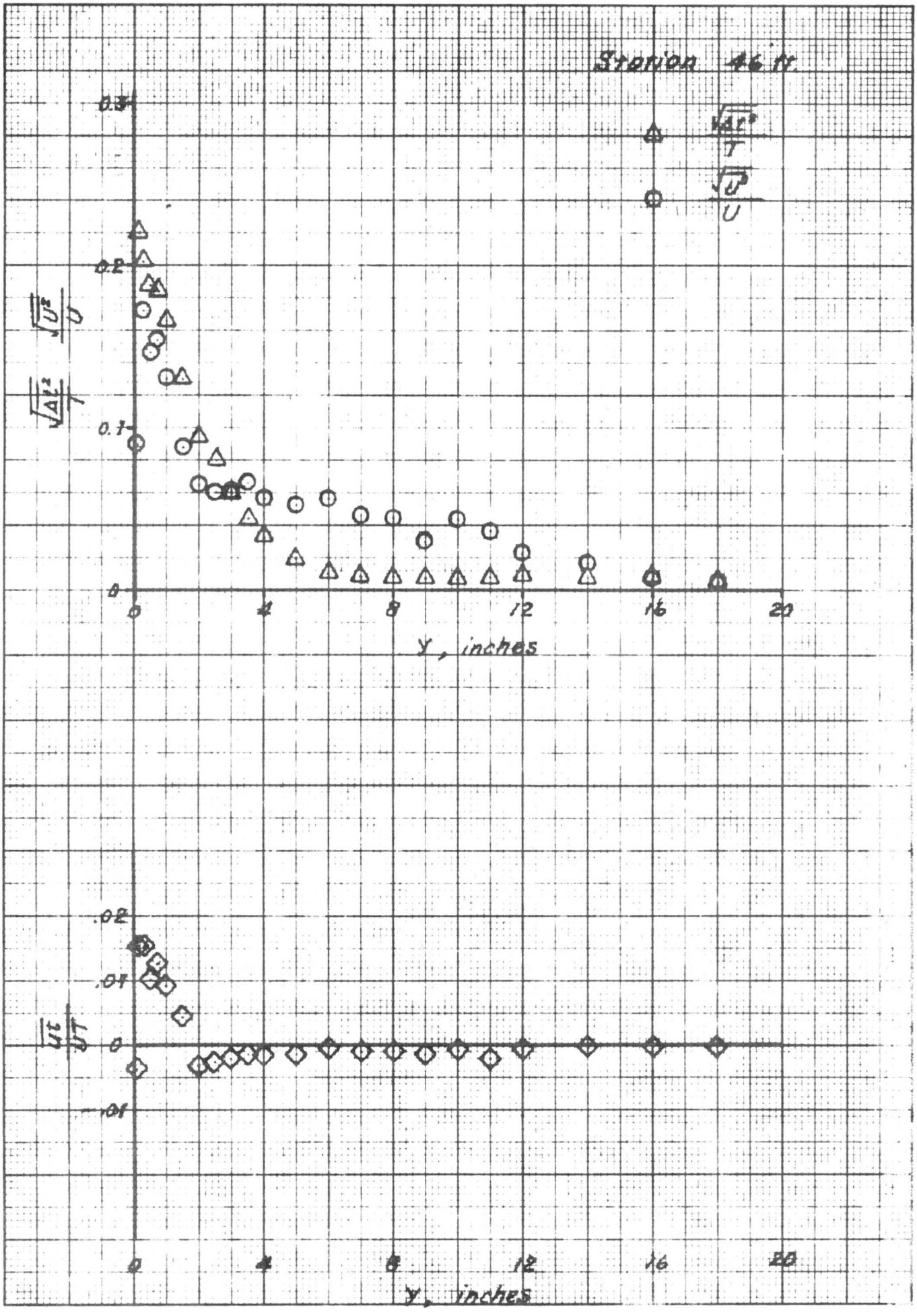

1.0
.8
.6
.4
.2
0
$\frac{\rho}{\rho_1}$
$\frac{u}{u_1}$
$\frac{T}{T_w}$
STATION 60 FT
$\frac{u}{u_1}$
$\frac{T}{T_w}$
$\frac{\rho}{\rho_1}$
0
2
4
6
8
10
12
14
16
18
y INCHES

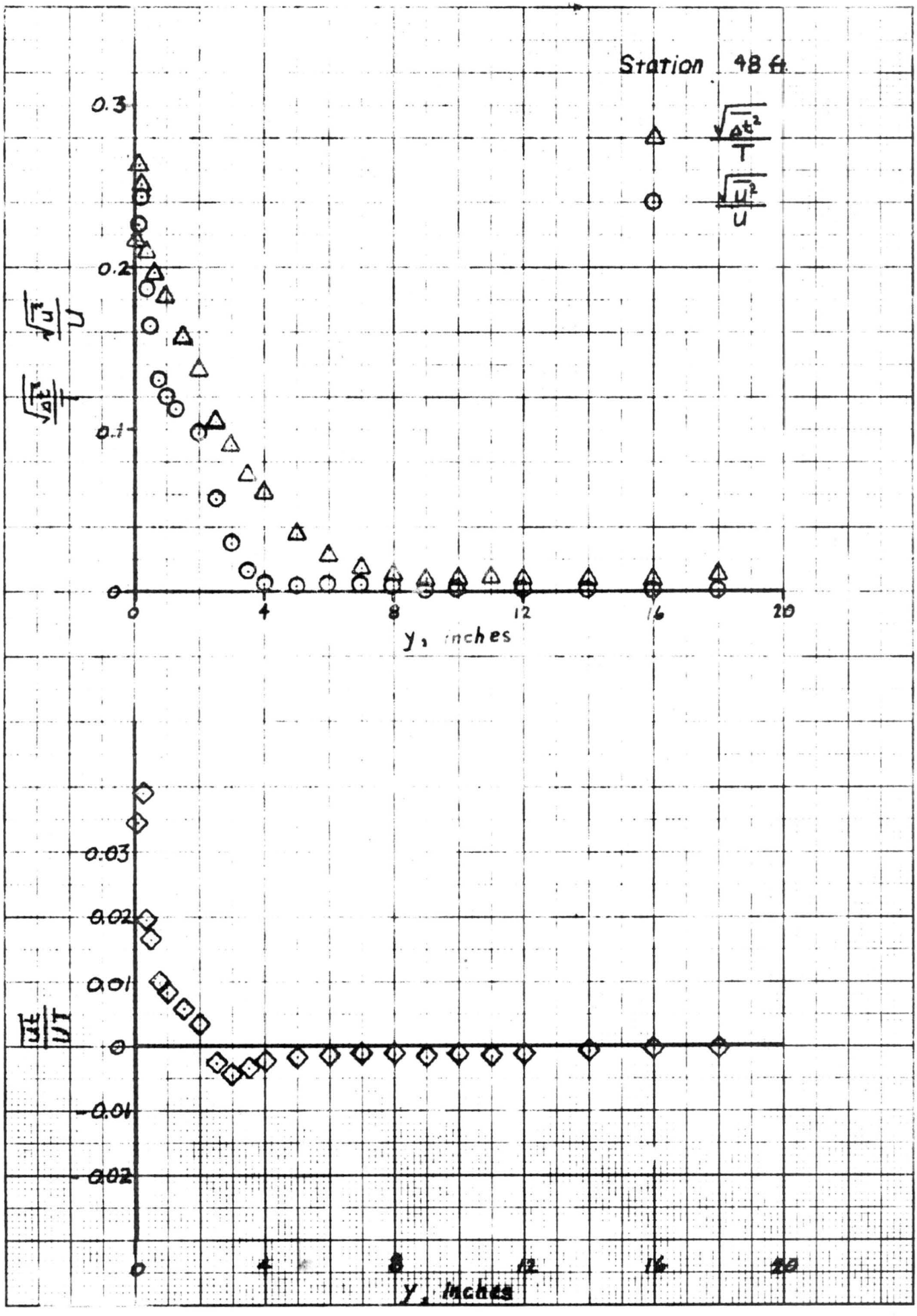

ρ/ρ.
u/u
T/Tw
1.0
.8
.6
.4
.2
0
0
2
4
6
8
10
12
14
16
18
19
y INCHES
STATION 62 FT.
u/u
T/Tw
ρ/ρ.

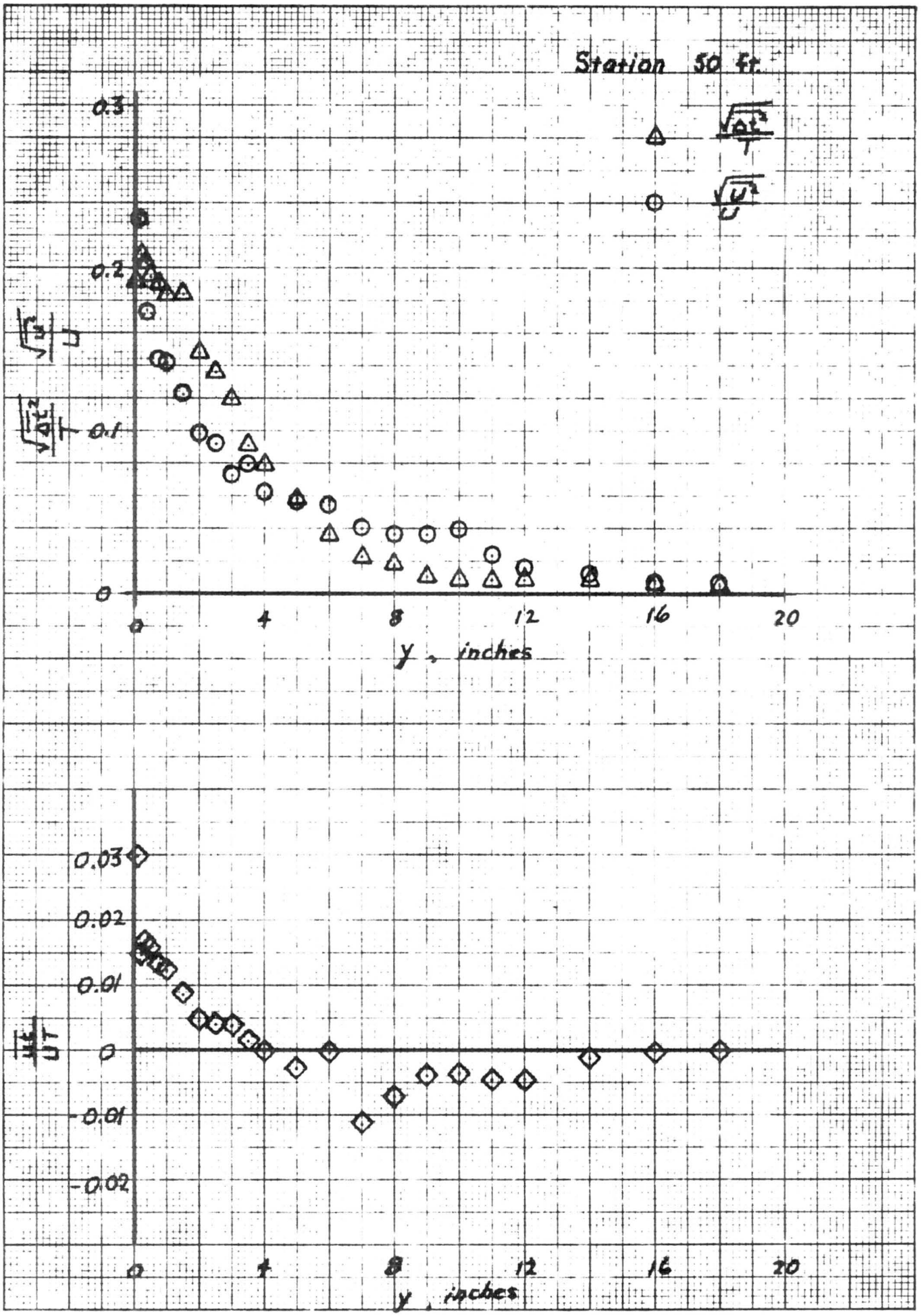

Station 40 ft.
$\frac{\sqrt{\Delta t^2}}{T}$
$\frac{\sqrt{v^2}}{U}$
$\frac{\sqrt{U^2}}{U}$
$\frac{\sqrt{\Delta t^2}}{T}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y , inches
0.01
0
-.01
-.02
$\frac{\overline{uv}}{UT}$
0
4
8
12
16
20
y , inches

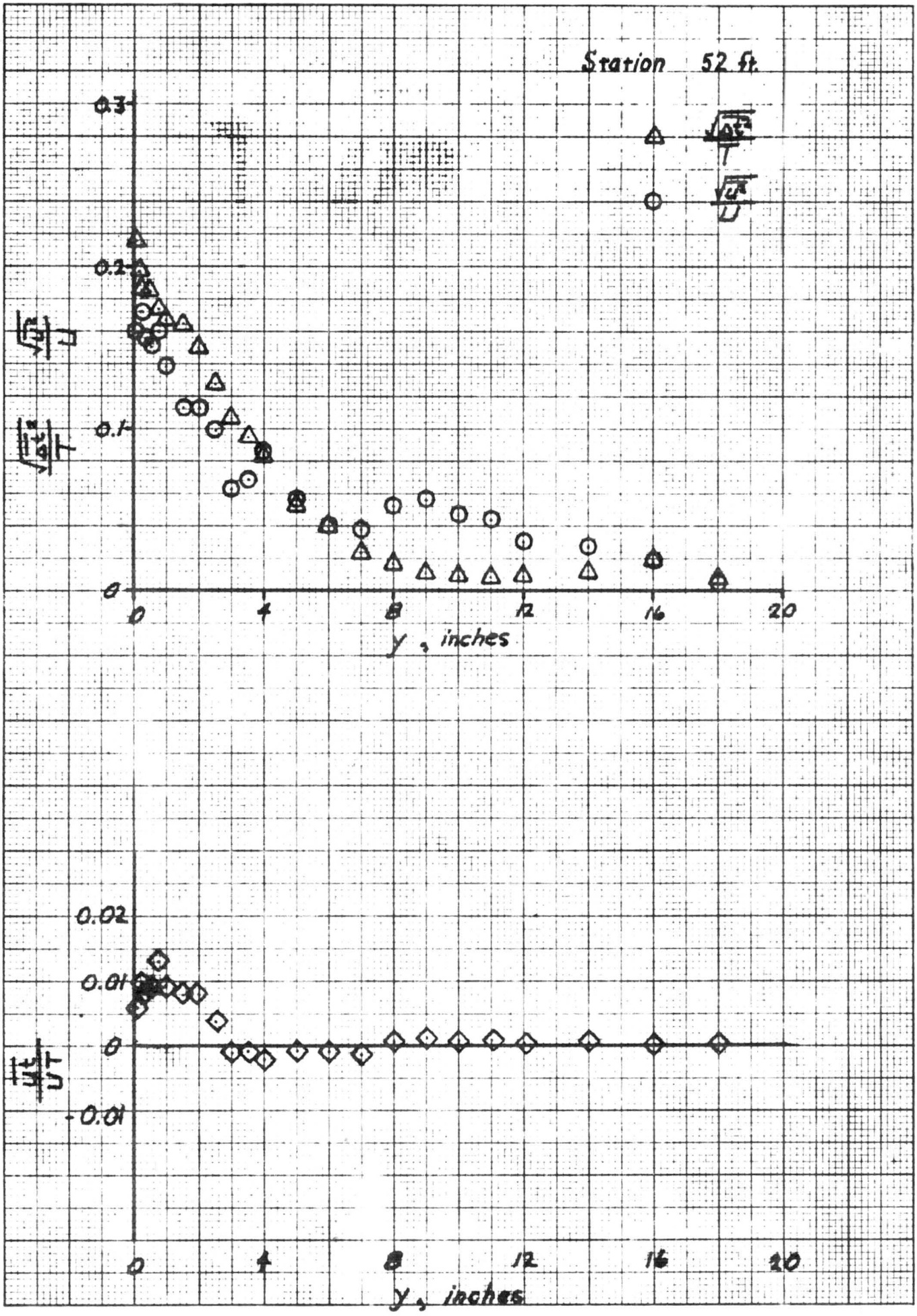

Station 42 ft
$\frac{\sqrt{u'^2}}{U}$
$\frac{\sqrt{v'^2}}{U}$
$\frac{\sqrt{u'v'}}{U^2}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
0.4
0.3
0.2
0.1
0
0.1
0.2
0
4
8
12
16
20
y, inches

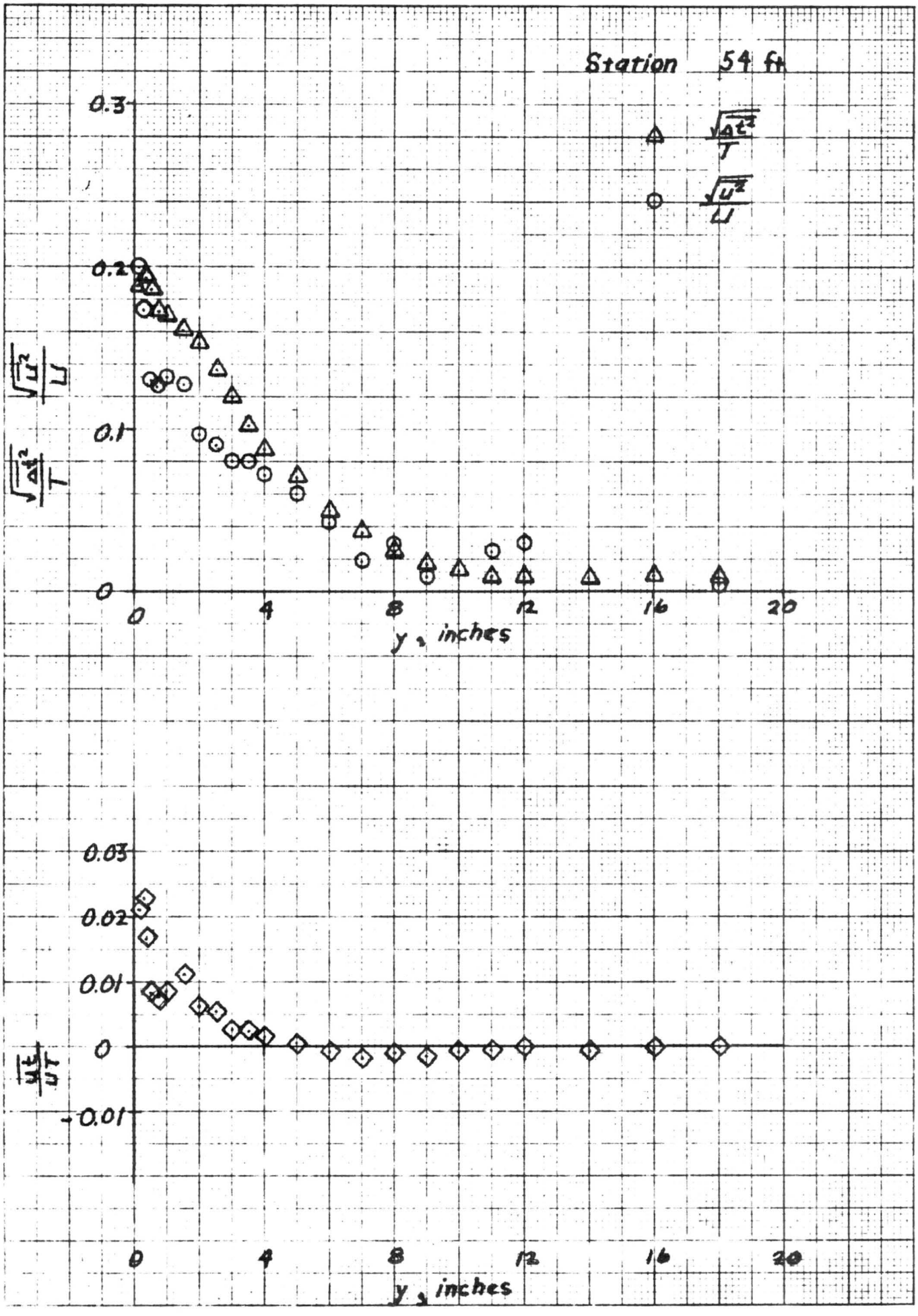

Station 44 ft.
$\frac{\sqrt{\overline{ac}^2}}{T}$
$\frac{\sqrt{\overline{v}^2}}{U}$
$\frac{\sqrt{\overline{v}^2}}{U}$
$\frac{\sqrt{\overline{u}^2}}{U}$
0.3
0.2
0.1
0
4
8
12
16
20
y, inches
.04
.03
.02
.01
0
-.01
$\frac{\partial \overline{uv}}{\partial y}$
0
4
8
12
16
20
y, inches

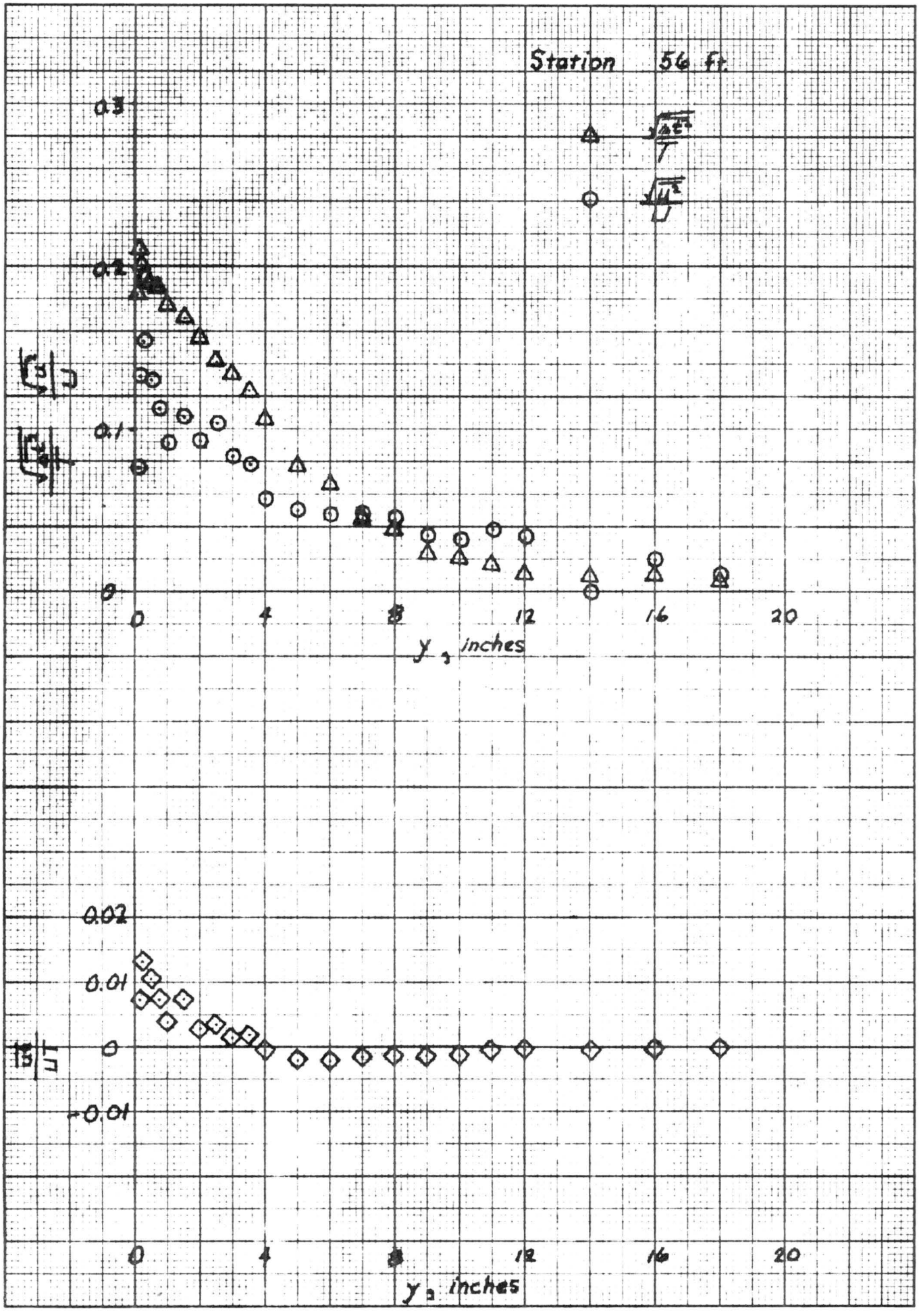

Station 46 ft.
$\frac{\sqrt{\Delta t^2}}{T}$
$\frac{\sqrt{u^2}}{U}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
.02
.01
0
-.01
$\frac{\overline{uv}}{UT}$
0
4
8
12
16
20
y, inches

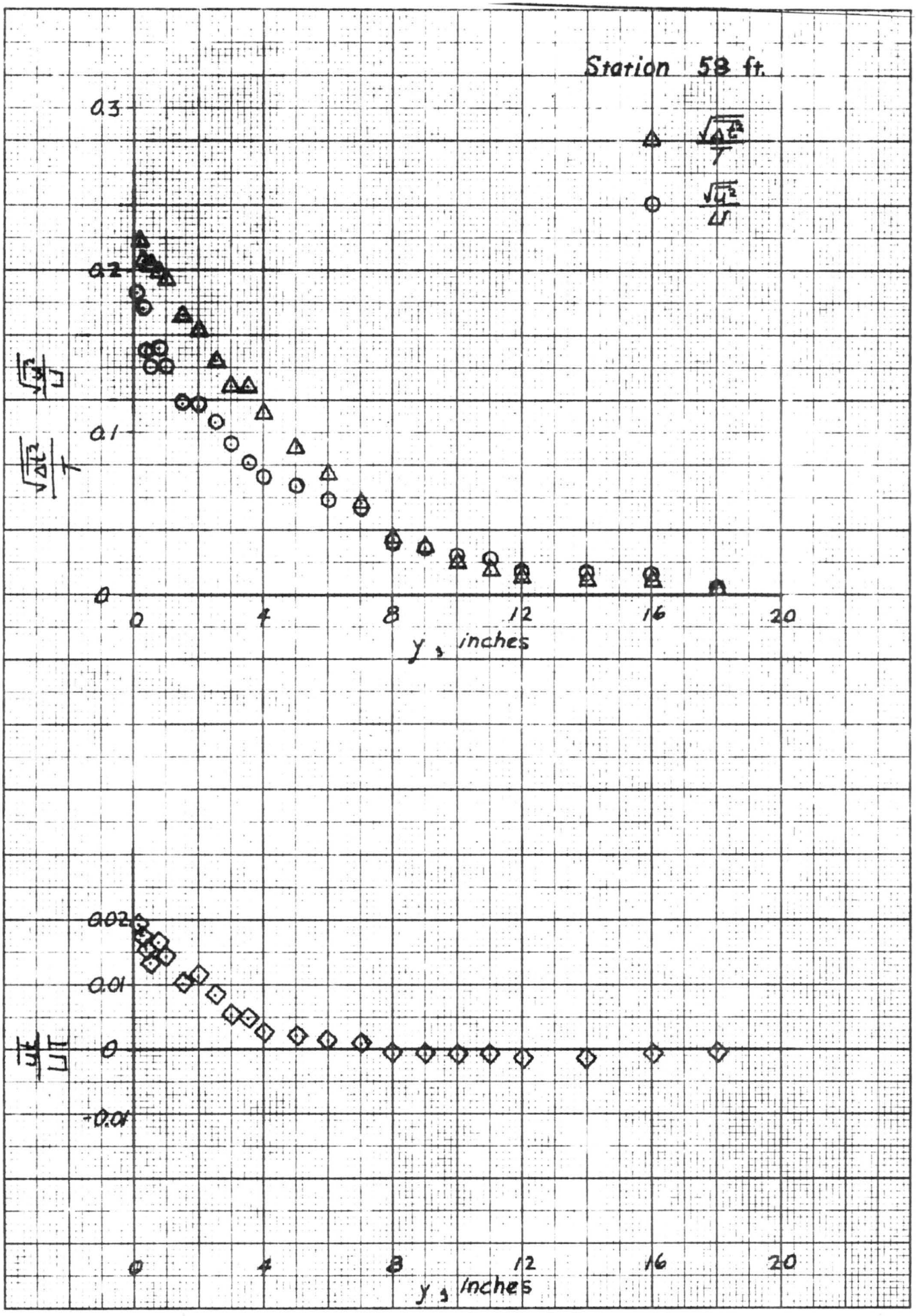

Station 48 ft
$\frac{\sqrt{\overline{e^{t^2}}}}{T}$
$\frac{\sqrt{\overline{u^2}}}{U}$
$\frac{\sqrt{\overline{T^2}}}{T}$
$\frac{\sqrt{\overline{T^2}}}{U}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
$\frac{\overline{ue}}{UT}$
0.03
0.02
0.01
0
-0.01
-0.02
0
4
8
12
16
20
y, inches

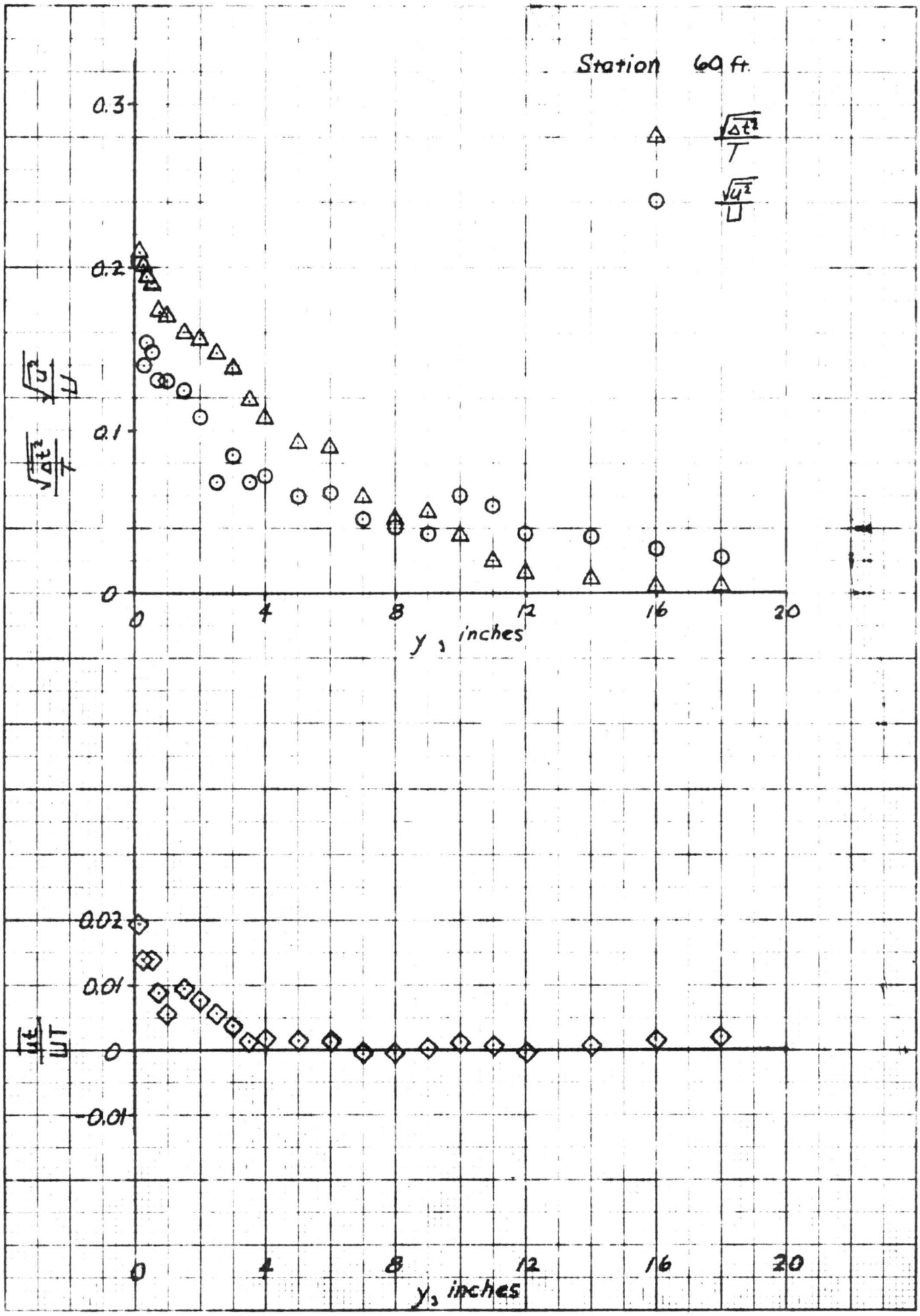

Station 50 ft.
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
0.03
0.02
0.01
0
-0.01
-0.02
0
4
8
12
16
20
y, inches

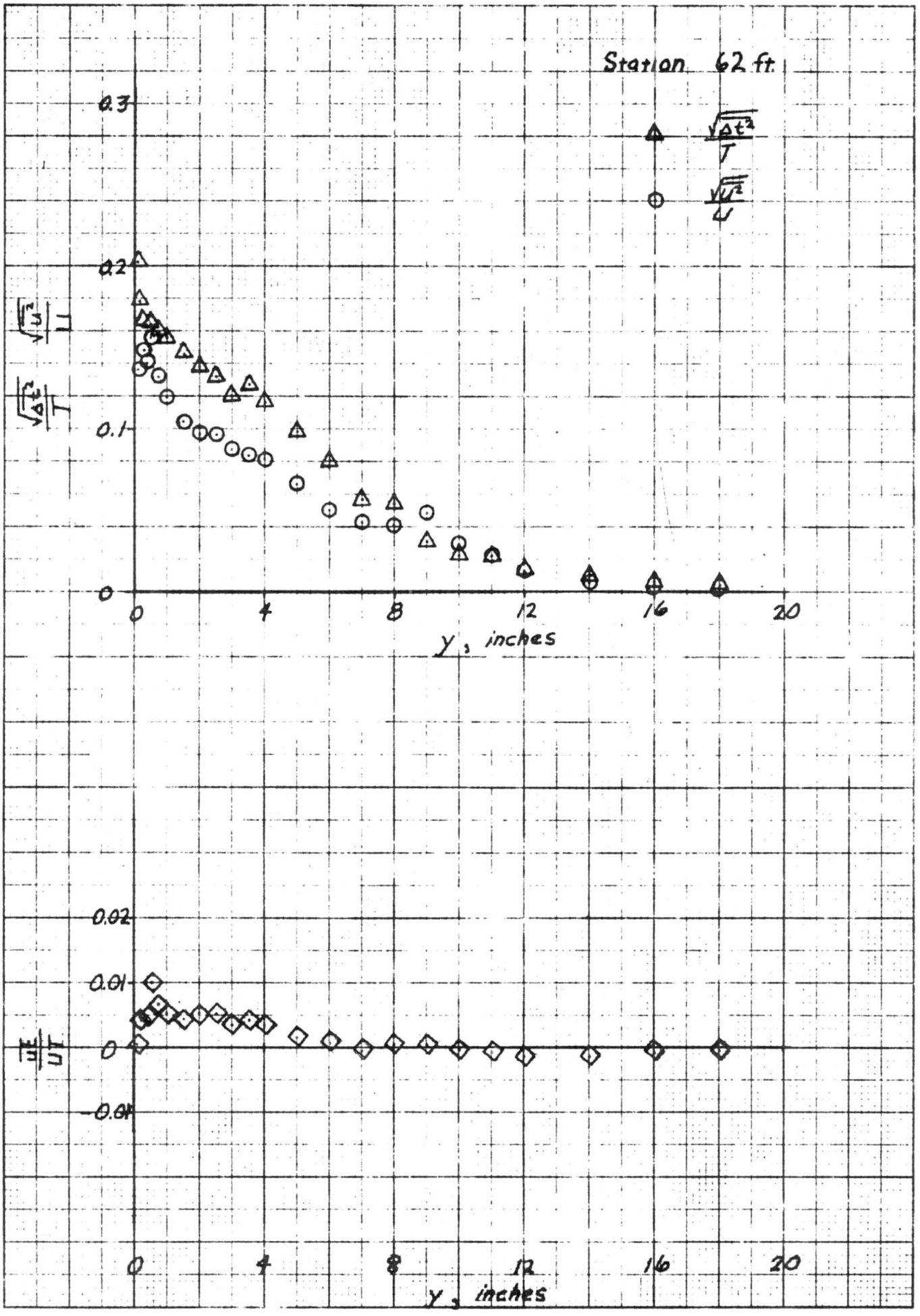

Station 52 ft.
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
0.02
0.01
0
-0.01
0
4
8
12
16
20
y, inches


Station 54 ft
$\frac{\sqrt{\Delta t^2}}{T}$
$\frac{\sqrt{u^2}}{U}$
$\frac{\sqrt{u^2}}{U}$
$\frac{\sqrt{\Delta t^2}}{T}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
$\frac{\overline{uv}}{UT}$
0.03
0.02
0.01
0
-0.01
0
4
8
12
16
20
y, inches


Station 56 ft.
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
0.02
0.01
0
-0.01
0
4
8
12
16
20
y, inches


Station 58 ft.
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
0.02
0.01
0
-0.01
0
4
8
12
16
20
y, inches


Station 60 ft.
$\frac{\sqrt{\Delta t^2}}{T}$
$\frac{\sqrt{u^2}}{U}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y_3 inches
$\frac{\sqrt{u^2}}{U}$
$\frac{\sqrt{\Delta t^2}}{T}$
0.02
0.01
0
-0.01
$\frac{\overline{uv}}{UT}$
0
4
8
12
16
20
y_3 inches


Station 62 ft.
$\frac{\sqrt{\Delta t^2}}{T}$
$\frac{\sqrt{u^2}}{U}$
$\frac{\sqrt{u^2}}{U}$
$\frac{\sqrt{\Delta t^2}}{T}$
0.3
0.2
0.1
0
0
4
8
12
16
20
y, inches
$\frac{\overline{uv}}{UT}$
0.02
0.01
0
-0.01
0
4
8
12
16
20
y, inches