THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
Department of Meteorology and Oceanography

AN INVESTIGATION OF ATMOSPHERIC TURBULENT TRANSFER PROCESSES OVER WATER

Report Number Two: Data, 1963 and 1964
(final report of Contract Cwb-10714)

by

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ORA Project 05982

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under contract with:

U. S. Department of Commerce
Weather Bureau
Washington 25, D. C.

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

February 1965

IMR0661

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ABSTRACT

Wind speed, temperature, and dew point were measured at eight heights up to 16 meters on the U. S. Lake Survey Lake Michigan Research Tower during September and October, 1963, and during August, 1964. Wave height spectra were measured during several days of August, 1964. The Research Tower was located in water fifty feet deep, one mile from shore near Muskegon, Michigan. Edited data are presented in both tabular and graphical form. Brief descriptions of the methods used for measurement are included.

1. INTRODUCTION

The research program, "An Investigation of Atmospheric Turbulent Transfer Processes over Water," initiated under Contract Cwb-10591 in June, 1963 has continued under Contract Cwb-10714. The original contract provided for instrumentation of a tower in Lake Michigan for measurement of wind speed, temperature, and water vapor profiles, water temperature and wave heights. The second contract provided for continuation of the measurement program.

The tower, constructed and installed by the U. S. Army Corps of Engineers, consists of a steel mast of braced construction extending 16 meters above the water surface. Sensors were placed on the mast at approximately logarithmic intervals with reference to the surface. Data were recorded during September and October, 1963 and during August, 1964.

This report describes the instrumentation used and presents the data collected. These data are presented in edited form with comments concerning reliability but with no intention of interpretation or explanation.

2. SENSOR AND RECORDING SYSTEMS

The U. S. Lake Survey, Lake Michigan research tower and associated instrumentation have been described in a previous report (Elder, 1963). An automatic data logging system was planned for use in the measurement program. This system was described in the previous report and final drawings are appended to this report. However, delays in delivery of the automatic recording system prevented its use during this contract period. A system of paper chart recorders was assembled from equipment available within the laboratories in order to realize the potential of the research tower that was already erected. All of the data reported herein were obtained from the improvised recording equipment described below.

Figure 1 shows the research tower as instrumented during the 1964 season. Wind speed, air temperature, and dew point sensors were permanently mounted at the five upper levels, while the sensors nearer the water surface were placed in position only during recording periods. The paper chart recorders were located just above the 4-meter level and were protected by canvas covers. The location of sensors and method of recording for 1963 differed slightly from those of 1964. They are, therefore, described separately.

2.1 Sensors and Recording System for 1963

Permanently mounted sensors were located at nominal heights of 16, 10, 6, 4 and 3 meters with reference to the mean water surface. The removable sensors were 2, 1 and 0.5 meters above the surface. These heights were changed between periods of measurements. Actual heights are given in presentation of data.

Air temperature and dew point sensors were as described in the previous report (Elder, 1963). Briefly, the temperature sensors at the permanent levels consisted of Honeywell Model 921AC, Nickel A resistance elements mounted in Climet Instruments, Inc., Model 016-1, aspirated radiation shields. The temperature sensors used at the removable levels were Victory Engineering Corporation, type 32A84 thermistors, mounted in non-aspirated, flat-plate radiation shields of a type described by Portman (1957). On October 8, a Barnes Infrared Thermometer, Model IT-2, was mounted at about 5 meters to sense the water surface temperature. A thermistor mounted on a floating cork board was also used for the same purpose, but it failed to give reliable data due to interference noise produced by wave motion. The dew point sensors were Honeywell Dew Probes, Model SSP129B, mounted in the aspirated radiation shields.

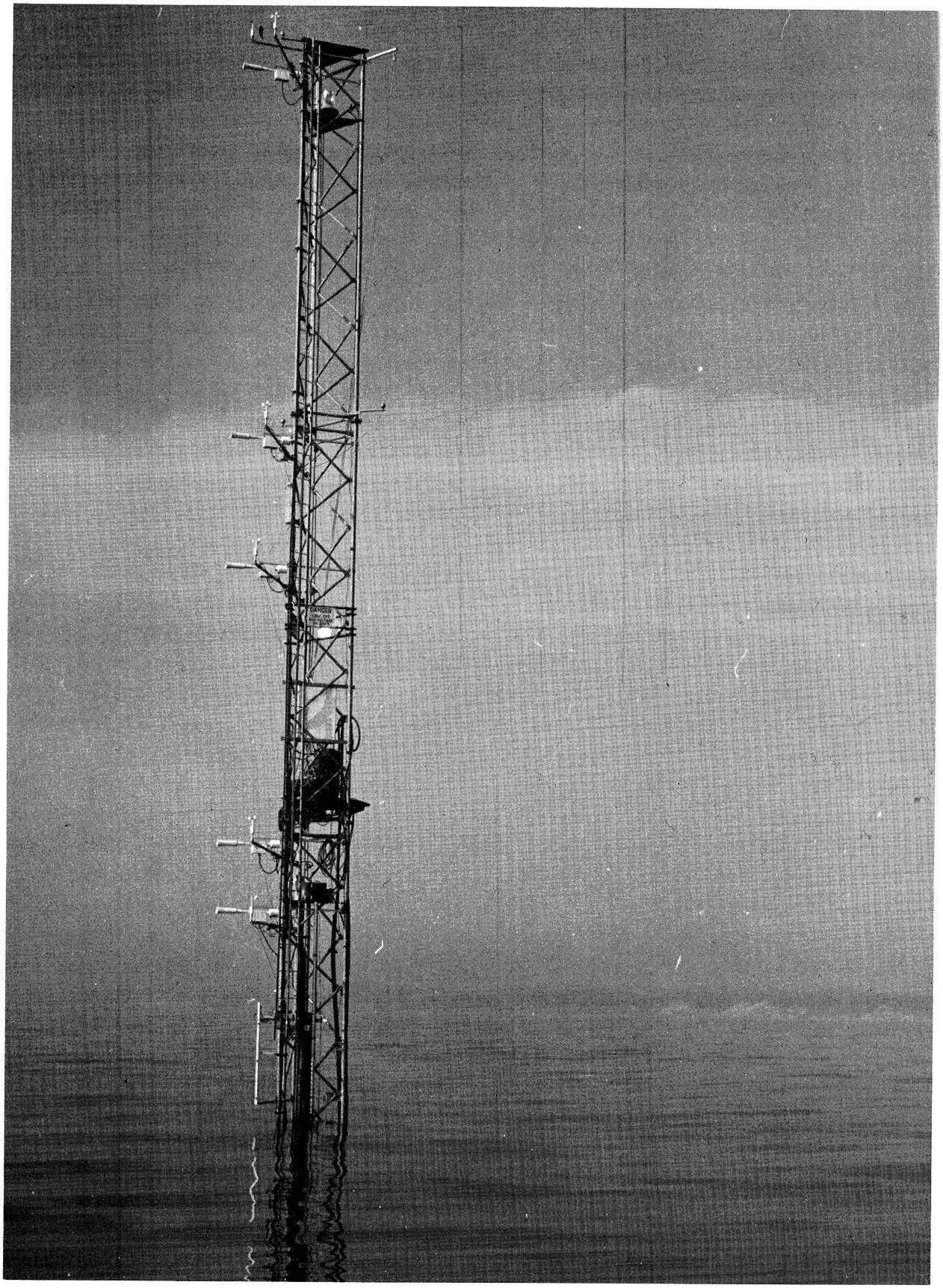


Figure 1. Lake Michigan research tower, 1964.

The wind speed sensors at the permanent heights were Beckman and Whitley, Inc., Model 170 anemometers, while those used at 4, 2, 1, and 0.5 meter heights were made by C. W. Thornthwaite Associates. The Beckman and Whitley anemometers were used in place of Climet Instruments, Inc. units described in the previous report (Elder, 1963) because they were compatible with the available recording system. The use of two anemometer units caused some calibration difficulty as discussed under data presentation.

Wind direction data were obtained from recordings of a vane mounted at 16 meters on the tower for periods August 27 through October 10. The recorder discontinued operation following that date, and wind direction is observer estimate for October 17. Data obtained from a vane mounted on the Muskegon harbor breakwater are used for October 18 and 22.

The temperature and dew point recording system employed an unbalanced bridge for each sensor. A commutator switched the bridge output voltage sequentially into a single-point potentiometer recorder. The commutation rate was once per two minutes, thus giving a record of each variable every two minutes. The record was obtained on a paper chart for manual reduction.

Wind speed was recorded in terms of anemometer revolutions. Electro-mechanical counters with decade switches (Barber Coleman) operated an Esterline Angus, 20 pen, event recorder. Each rotation of anemometer cups at each level was recorded on paper chart. The rotations were summed over the chosen time interval (usually 6 minutes) in data reduction. Air movement, averaged over the period of summation, at each height was thus obtained.

Because of the limitations of the paper chart recorder, the recording system could not operate on a full-time basis. A method was provided whereby the recorders could be started and stopped remotely from shore. In this way, records were obtained during periods when attendance at the tower was not possible.

2.2 Sensor and Recording System for 1964

During August 1964 an improvised recording system was once more employed. It consisted of basically the same system as employed during 1963 with a few modifications.

The temperature sensors were not changed, but the Barnes Infrared Thermometer was not available for use. Temperature records were obtained on a multipoint recording potentiometer that replaced the commutator and single-point recorder used during 1963. The

multipoint recorder provided a six-minute data cycle.

Beckman and Whitley anemometers were employed at only four heights with the lowest height being 2 meters above the mean water surface, The problem of calibration difference between the two sets of anemometers was thus avoided, but fewer data points were obtained. The anemometer at 2 meter height suffered damage on two occasions so that the exposure at that level was eventually abandoned. The data were recorded as described for 1963.

A wave height recording system, designed and constructed by the U. S. Army Coastal Research and Engineering Laboratories, was installed during July and operated until damaged by lighting on August 11, 1964. The system employed a pressure sensor mounted at ten-foot depth with analog recording on magnetic tape, This instrumentation was installed and maintained by personnel of the U. S. Lake Survey.

3. DATA COLLECTED DURING 1963

The meteorological recorders were operated during periods shown in Table I.

TABLE I

PERIODS OF OBSERVATION, 1963

DATE	TIME (EST)	DATE	TIME (EST)
27 Aug.	1010 - 1234	8 Oct.	1315 - 2100
10 Sept.	1313 - 1638	9 Oct.	0912 - 1208
			1401 - 1501
16 Sept.	1810 - 1838		
		10 Oct.	0902 - 1331
21 Sept.	1410 - 1850		1733 - 1814
22 Sept.	1115 - 1550	11 Oct.	0952 - 1130
	2101 - 2205		
		17 Oct.	1330 - 1630
26 Sept.	1314 - 1608		
		18 Oct.	1400 - 1600
27 Sept.	0806 - 1212		
		22 Oct.	1135 - 1800

Data for many of the periods of observation listed in Table I are not complete, due to instrument malfunction. In many cases this malfunction may have been due to causes as simple as failure of the recorder pen to write, but it nevertheless caused loss of data. Certain periods of data were selected for reduction due to completeness of coverage, or to the uniqueness of the prevailing conditions.

Data for the selected periods are given in Table III, presented as 6-minute averages ending at the time indicated. These same data are presented graphically in Figures 2 through 7. The vertical gradients presented in these figures are the result of averaging over the time intervals as shown. The longer period averages are also shown in Table III.

TABLE II

HEIGHTS OF LOWER SENSORS WITH REFERENCE TO MEAN WATER LEVEL

	Height (cm)		
August 27	60	110	210
September 10	50	100	200
September 22		98	198
September 26		98	198
September 27		98	198
October 9			198
October 10		98	
October 17 through 22			205

Table III lists nominal heights above the mean water surface at which the sensors were exposed. Actual heights of exposure for the permanent sensors were 1609, 1003, 603 and 405 centimeters with reference to the mean surface. Heights of the lower sensors changed somewhat between observations due to remounting prior to each period. The measured heights are shown in Table II for the different data periods.

TABLE III

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

27 August, 1963

TIME	WIND SPEED (cm./sec.)								WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1046	296	305	317	311	328	329	336	343	
1052	316	319	334	329	347	347	360	367	
1058	347	352	373	364	386	386	396	400	
1104	343	348	372	363	384	382	392	396	
1110	362	373	392	378	401	400	412	430	
Average	333	339	358	349	369	368	379	387	
10 September, 1963									
1356	295	312	331	339	344	354	366	366	
1402	319	337	360	371	378	383	395	401	
1408	321	338	359	370	376	389	405	405	
1414	344	365	385	401	406	414	428	429	
1420	336	357	379	388	392	402	416	420	
1426	356	379	406	414	420	427	438	440	
1432	358	380	404	415	420	428	440	443	
Average	333	353	375	386	391	400	413	415	282
1608	369	386	409	417	426	428	431	430	
1614	377	396		422	435	440	447	452	
1620	388	406		437	452	454	463	465	
1626	403	423		448	463	469	474	477	
1632	401	418		445	460	464	471	474	
Average	388	406		434	447	451	457	459	320

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

22 September, 1963

TIME	WIND SPEED (cm./sec.)							WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1520		595	646	638	669	674	696	703	
1526		591	641	628	657	660	677	692	
1532		592	652	639	665	669	687	700	
1538		591	649	636	664	668	683	697	
1544		592	647	636	662	672	699	716	
1550		628	677	675	703	712	741	759	
Average		598	652	642	670	676	696	711	204

26 September, 1963

1320	143	146	160	159	166	175	181	
1326	151	155	169	168	178	186	200	
1332	146	156	169	170	173	183	191	
1338	133	134	147	147	151	161	169	
1344	129	121	130	130	134	141	146	
1350	119	120	128	127	128	129	129	
1356	127	127	133	133	133	136	133	
1402	118	119	128	127	128	129	135	
1408	96	92	101	99	100	103	101	
1414	72	71	83	82	81	84	94	
1420	72	64	77	76	76	77	80	
1426								
1432	114	111	123	123	126	137	144	
1438	112	108	123	120	128	129	133	
1444	140	140	152	154	157	164	170	
1450	148	147	158	159	162	165	171	
1456	129	126	138	137	138	145	149	
1502	153	151	165	166	168	175	180	
1508	160	166	178	178	181	190	189	
1514	150	166	177	179	179	188	192	
1520	179	186	196	198	201	210	219	
1526	192	190	204	207	209	218	219	
Average	133	133	145	145	147	154	158	240

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

27 September, 1963

TIME	WIND SPEED (cm./sec.)							WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
0818		693	764	782	816	828	887	934	
0824		709	775	788	820	829	887	941	
0830		706	762	786	820	829	887	933	
0836		674	733	754	787	800	860	915	
0842		671	724	755	785	798	854	902	
Average		694	752	773	806	817	875	925	211
9 October, 1963									
1410			407	415	426	435	464	499	
1416			392	400	407	412	437	474	
1422			399	408	414	422	444	475	
1428			390	398	405	417	440	471	
1434			404	412	418	428	450	475	
Average			398	406	414	423	447	479	154
10 October, 1963									
1136		437		479	489	502	537	630	
1142		447		491	502	517	559	631	
1148		445		482	489	505	530	608	
1154		471		509	520	535	568	683	
1200		448		494	508	522	557	681	
1206		452		501	512	499	560	652	
1212		466		509	522	540	575	650	
1218		493		536	547	565	607	692	
Average		457		500	511	527	561	654	145

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

17 October, 1963

TIME	WIND SPEED (cm./sec.)								WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1342			402	421	424	450	487	551	
1348			454	469	471	499	535	604	
1354			479	498	504	528	570	615	
1400			492	506	498	543	585	651	
1406			489	504	511	542	584	663	
Average			463	480	482	512	552	617	
1412			463	482	488	514	550	619	
1418			438	453	457	486	525	590	
1424			374	392	393	404	502	531	
1430			294	308	309	335	374	433	
1436			251	267	269	294	311	384	
Average			364	380	383	410	456	511	
1440			232	245	245	272	307	363	
1446			209	225	230	256	298	363	
1452			224	243	249	273	313	383	
1458			179	200	206	227	255	314	
1504			181	198	201	224	253	310	
Average			205	222	226	250	285	346	
1510			172	191	190	208	230	274	
1516			154	169	174	195	216	263	
1522			148	163	168	186	208	248	
1528			132	141	145	163	189	240	
1534			148	158	156	172	194	243	
Average			151	164	167	185	208	254	

Wind Direction Estimated S to SSW

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

17 October, 1963

TIME	WIND SPEED (cm./sec.)								WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1540			132	142	140	155	170	205	
1546			181	193	190	198	205	228	
1552			189	205	214	221	213	226	
1558			185	198	209	215	211	216	
1604			173	187	196	206	202	207	
Average			172	185	190	199	200	217	
1610			160	172	175	187	197	208	
1616			169	182	186	196	194	198	
1622			160	173	178	190	189	194	
1628			186	203	203	215	217	221	
Average (20 minute)			169	182	185	197	199	205	

Wind Direction Estimated S to SSW

18 October, 1963

1408			536	549	553	573	609	670	
1414			555	569	558	598	638	692	
1420			553	564	555	594	627	689	
1426			556	568	577	604	646	704	
1432			570	583	588	609	648	711	
Average			538	567	573	596	633	693	185

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

22 October, 1963

TIME	WIND SPEED (cm./sec.)								WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1142				772	785	813	874	950	
1148				710	722	747	803	879	
1154				703	712	734	779	848	
1200				665	666	697	750	820	
1206				624	630	658	712	791	
Average				695	703	730	783	858	175
1212			629	640	653	681	734	800	
1218			628	640	644	670	724	809	
1224			596	607	614	642	697	774	
1230			562	578	582	610	664	740	
1236			495	543	549	578	626	701	
Average			585	602	609	636	689	765	175
1412			349	328	378	409	448	514	
1418			326	349	354	386	436	488	
1424			288	308	311	345	385	447	
1430			284	302	304	332	364	431	
1436			297	316	322	353	394	464	
Average			309	321	334	365	405	469	170

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

22 October, 1963

TIME	WIND SPEED (cm./sec.)							WIND DIR.
	50 cm.	100 cm.	200 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	
1442			299	322	325	359	400	429	
1448			305	327	333	363	412	488	
1454			331	350	360	396	450	534	
1500			392	415	420	456	515	592	
1506			359	384	388	423	478	555	
Average			337	360	365	399	451	520	170
1638			378	399	407	443	494	567	
1644			407	427	437	477	532	613	
1650			419	441	452	491	545	631	
1656			438	463	470	508	558	644	
1702			351	373	383	419	459	531	
Average			399	421	430	468	518	597	170
1708			358	381	387	422	468	539	
1714			409	428	440	476	525	608	
1720			418	446	453	488	544	629	
1726			454	478	490	531	598	694	
1732			461	480	496	536	601	700	
Average			420	443	453	491	547	634	170

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

27 August, 1963

TIME	WATER SURF. TEMP.	AIR TEMPERATURE °C							DEW POINT °C		
		50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
1046		16.8	17.1	16.9	16.9	16.9	16.9	16.8			
1052		16.8	17.1	17.0	16.9	17.0	17.0	16.8			
1058		16.8	16.7	17.0	17.0	17.0	17.0	16.9			
1104		16.8	16.7	17.0	17.0	17.0	17.0	16.9			
1110		16.9	17.2	17.1	17.1	17.0	17.1	16.9			
Aver.	18.9	16.8	17.0	17.0	17.0	17.0	17.0	16.8			
10 September, 1963											
1356		16.9	15.7	16.9	16.6	16.7	16.6	16.5			
1402		17.0	15.6	16.8	16.7	16.8	16.7	16.6			
1408		15.7	17.0	17.1	16.7	16.8	16.7	16.6			
1414		15.3	16.9	17.0	16.7	16.8	16.7	16.6			
1420		15.6	16.9	17.0	16.8	16.8	16.7	16.6			
1426		15.4	17.0	17.3	16.7	16.8	16.7	16.6			
1432		15.7	17.0	17.0	16.7	16.8	16.7	16.6			
Aver.	17.1	16.0	16.6	17.0	17.0	16.8	16.7	16.6			
1608		16.2	17.0	17.3	17.1	17.2	17.1	17.0			
1614		16.1	17.0	17.4	17.1	17.2	17.1	17.0			
1620		16.2		17.4	17.1	17.3	17.2	17.1			
1626		16.1		17.4	17.1	17.2	17.2	17.1			
1632		15.6		17.3	17.1	17.2	17.1	17.0			
Aver.	17.0	16.0	17.0	17.4	17.1	17.2	17.1	17.0			

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

TIME	WATER SURF TEMP.	AIR TEMPERATURE °C						DEW POINT °C		
		50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
22 September, 1963											
1520			12.9	13.0	13.0	13.2	12.8	12.8			
1526			12.9	13.0	12.9	13.1	12.8	12.7			
1532			13.0	13.0	13.0	13.2	12.8	12.7			
Aver.	12.1		12.9	13.0	12.9	13.2	12.8	12.7			
26 September, 1963											
1320				16.5	16.6	16.9	16.8	16.3			
		Temperature data is average of several minutes near 1330									
27 September, 1963											
		No temperature data									
9 October, 1963											
1410				15.9	15.7	15.8	15.7	15.6			
1416				15.9	15.8	15.9	15.8	15.6			
1422				16.0	15.8	16.0	16.0	15.6			
1428				16.0	15.8	16.0	16.0	15.6			
1434				15.9	15.8	16.0	16.1	15.6			
Aver.	*15.5			15.9	15.8	15.9	15.9	15.6			

*Averages are corrected values.

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

10 October, 1963

TIME	WATER SURF. TEMP.	AIR TEMPERATURE °C							DEW POINT °C		
		50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
1136				16.3	16.2	16.3	16.2	16.2			
1142				16.4	16.3	16.3	16.3	16.3			
1148				16.4	16.3	16.4	16.3	16.3			
1154				16.4	16.4	16.4	16.4	16.4			
1200				16.5	16.4	16.4	16.4	16.4			
1206				16.5	16.4	16.5	16.5	16.5			
1212				16.6	16.5	16.6	16.5	16.6			
Aver.	*15.9			16.4	16.4	16.4	16.4	16.4			

17 October, 1963

1342		14.7	16.4	16.4	16.6	16.7	16.4	14.1	13.3	12.1
1348		14.7	16.5	16.4	16.8	16.9	16.5	14.1	12.8	11.6
1354		14.6	16.6	16.5	16.8	16.9	16.5	13.9	12.4	11.4
1400		14.7	16.6	16.5	16.8	17.0	16.7	13.8	12.4	11.8
1406		14.5	16.7	16.6	16.8	17.2	16.7	13.7	12.2	11.5
Aver.	*16.9	14.6	16.6	16.5	16.7	16.9	16.6	13.9	12.6	11.5
1510		14.3	16.7	16.5	16.7	17.3	16.9	13.4	11.7	10.6
1516		14.0	16.5	16.5	16.8	17.2	17.0	13.6	11.9	10.7
1522		14.2	16.6	16.6	17.0	17.4	17.2	13.3	11.6	10.5
1528		14.2	16.6	16.4	17.0	17.4	17.2	13.3	11.5	10.2
1534		14.4	16.8	16.8	17.2	17.6	17.4	12.8	10.9	9.7
Aver.	*15.9	14.2	16.6	16.6	16.9	17.4	17.1	13.3	11.5	10.3

*Averages are corrected values

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

17 October, 1963

TIME	WATER SURF. TEMP.	AIR TEMPERATURE °C						DEW POINT °C		
	–	50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
1540			14.7	17.2	16.2	17.5	17.9	17.6	12.0	10.3	9.3
1546			14.6	17.4	17.6	17.6	18.0	17.7	12.0	10.3	9.3
1552			14.3	17.7	17.4	17.8	18.0	17.7	14.5	10.7	9.5
1558			14.3	17.2	17.4	17.8	18.0	17.6	12.3	10.6	9 5
1604			14.7	17.3	17.5	17.9	18.0	17.7	11.7	10.1	9.2
Aver.	*15.6		14.5	17.4	17.2	17.7	18.0	17.7	12.5	10.4	9.4
18 October, 1963											
1408				16.3	16.2	16.4	16.4	16.2			
1414				16.4	16.3	16.5	16.5	16.3			
1420				16.5	16.5	16.6	16.7	16.4			
1426				16.6	16.6	16.7	16.8	16.4			
1432				16.6	16.6	16.7	16.8	16.5			
Aver.	*17.7			16.5	16.4	16.6	16.7	16.3			
22 October, 1963											
1142				16.3	16.2	16.3	16.3	16.2	14.8	12.1	11.3
1148				16.3	16.2	16.4	16.4	16.3	14.9	12.3	11.6
1154				16.4	16.3	16.4	16.6	16.3	15.1	12.4	11.8
1200				16.4	16.4	16.5	16.7	16.4	15.1	12.4	11.7
1206				16.4	16.4	16.5	16.6	16.4	15.1	12.4	11.8
Aver.	*16.8			16.4	16.3	16.4	16.5	16.3	15.0	12.3	11.6

*Averages are corrected values.

TABLE III (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

22 October, 1963

TIME	WATER SURF. TEMP.	AIR TEMPERATURE °C							DEW POINT °C		
		50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
1212				16.4	16.4	16.5	16.7	16.4	15.0	12.5	11.8
1218				16.6	16.5	16.6	16.8	16.5	15.1	12.5	11.8
1224				16.6	16.5	16.7	16.9	16.6	15.0	12.5	11.8
1230				16.6	16.6	16.7	16.9	16.6	15.0	12.6	11.8
1236				16.7	16.6	16.8	16.9	16.7	15.1	12.6	12.0
Aver.	*16.6			16.6	16.5	16.7	16.8	16.6	15.1	12.5	11.9
1412				16.6	16.6	16.6	16.4	16.4	14.8	13.3	12.5
1418				16.7	16.9	16.7	16.5	16.5	14.9	13.4	12.5
1424				16.7	17.0	16.8	16.6	16.6	15.0	13.5	12.8
1430				16.6	17.0	16.8	16.6	16.6	15.0	13.6	12.9
1436				16.6	17.0	16.8	16.6	16.6	15.0	13.6	12.9
Aver.	*16.8			16.7	16.9	16.7	16.5	16.5	14.9	13.5	12.8
1442				16.7	17.1	16.9	16.6	16.7	14.4	13.6	13.0
1448				16.9	17.2	17.0	16.7	16.8	15.0	13.6	13.0
1454				17.1	17.3	17.1	16.8	16.8	15.0	13.6	12.9
1500				17.3	17.5	17.1	16.9	16.9	14.9	13.5	12.7
1506				17.3	17.6	17.2	16.8	17.0	14.8	13.5	12.7
Aver.	*16.5			17.1	17.3	17.0	16.8	16.8	14.8	13.6	12.9

*Averages are corrected values.

TABLE III (Concluded)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1963

22 October, 1963

TIME	WATER SURF. TEMP.	AIR TEMPERATURE °C						DEW POINT °C		
		50 cm.	100 cm.	300 cm.	400 cm.	600 cm.	1000 cm.	1600 cm.	600 cm.	1000 cm.	1600 cm.
1638				17.4	17.4	17.3	17.1	17.1	14.7	13.3	12.6
1644				17.3	17.5	17.3	16.8	17.0	14.6	13.3	12.4
1650				17.5	17.7	17.4	17.2	17.1	14.7	13.4	12.7
1656				17.6	17.8	17.5	17.2	17.2	14.5	13.3	12.6
1702				17.2	17.4	17.1	16.9	17.0	14.7	13.4	12.7
Aver.	*16.5			17.4	17.5	17.3	17.0	17.1	14.6	13.3	12.6
1708				17.0	17.2	17.0	16.8	16.7	14.6	13.6	12.8
1714				17.1	17.3	17.1	16.8	16.9	14.7	13.5	12.8
1720				17.3	17.4	17.1	16.9	16.9	14.6	13.4	12.6
1726				17.5	17.6	17.2	16.9	16.9	14.7	13.4	12.6
1732				17.5	17.5	17.2	16.9	16.9	14.5	13.3	12.6
Aver.	*16.5			17.3	17.4	17.1	16.7	16.9	14.7	13.4	12.7

*Averages are corrected values.

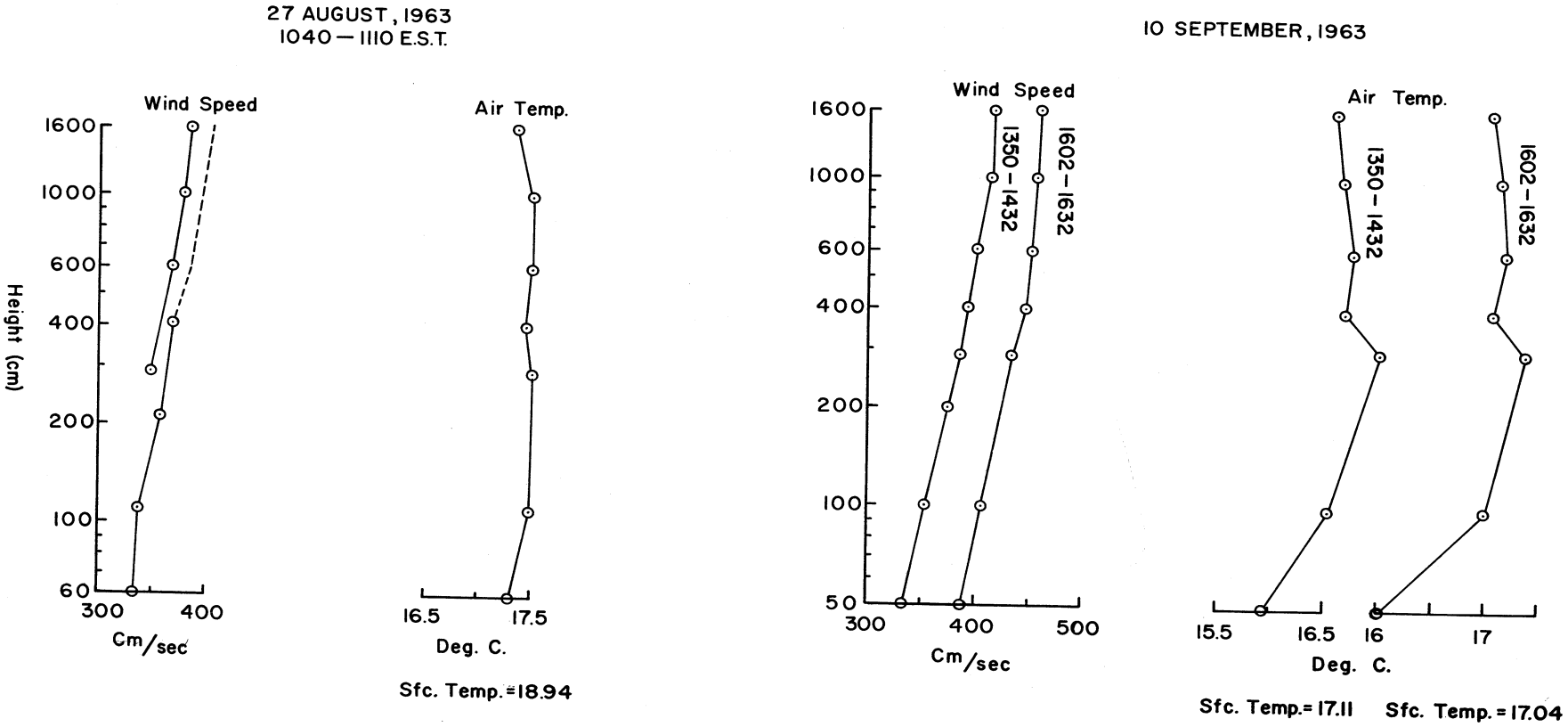


Figure 2. Wind speed and temperature profiles, 27 August and 10 September, 1963.

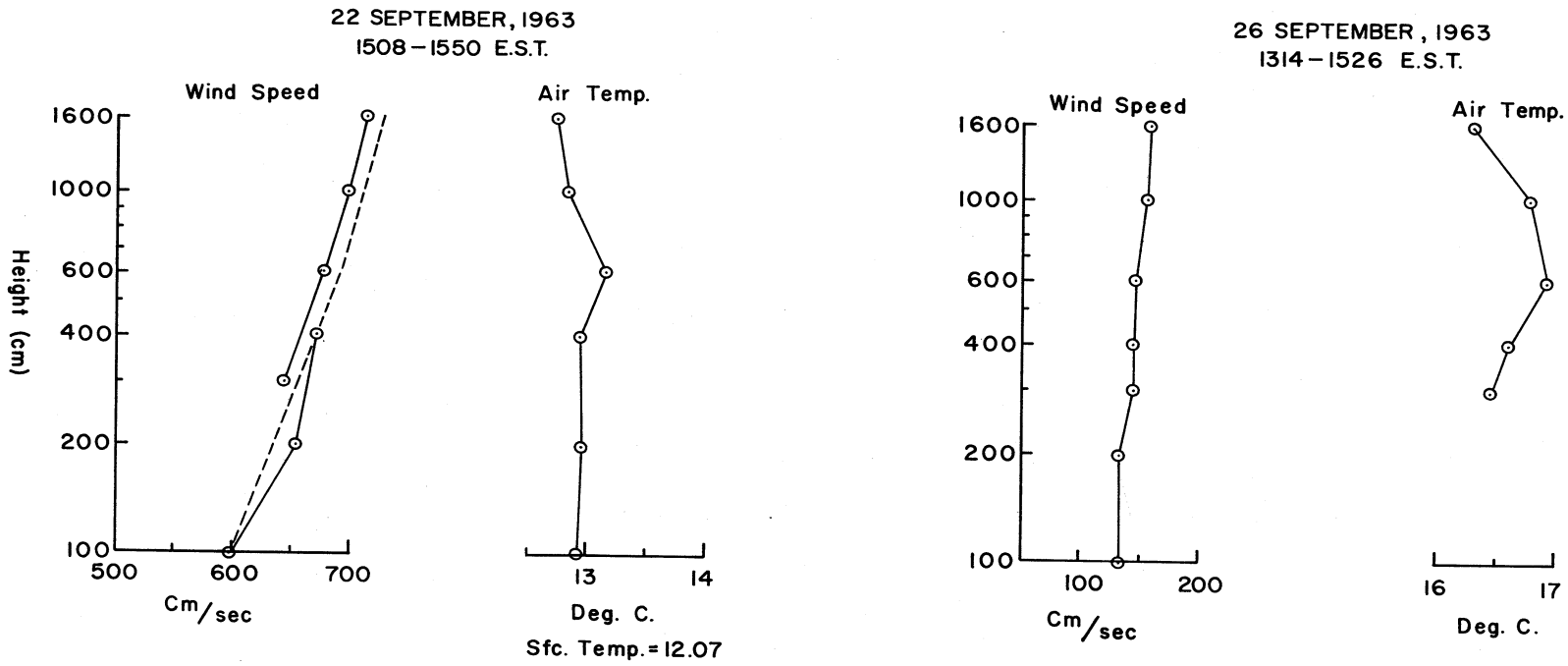


Figure 3. Wind speed and temperature profiles, 22 and 26 September, 1963.

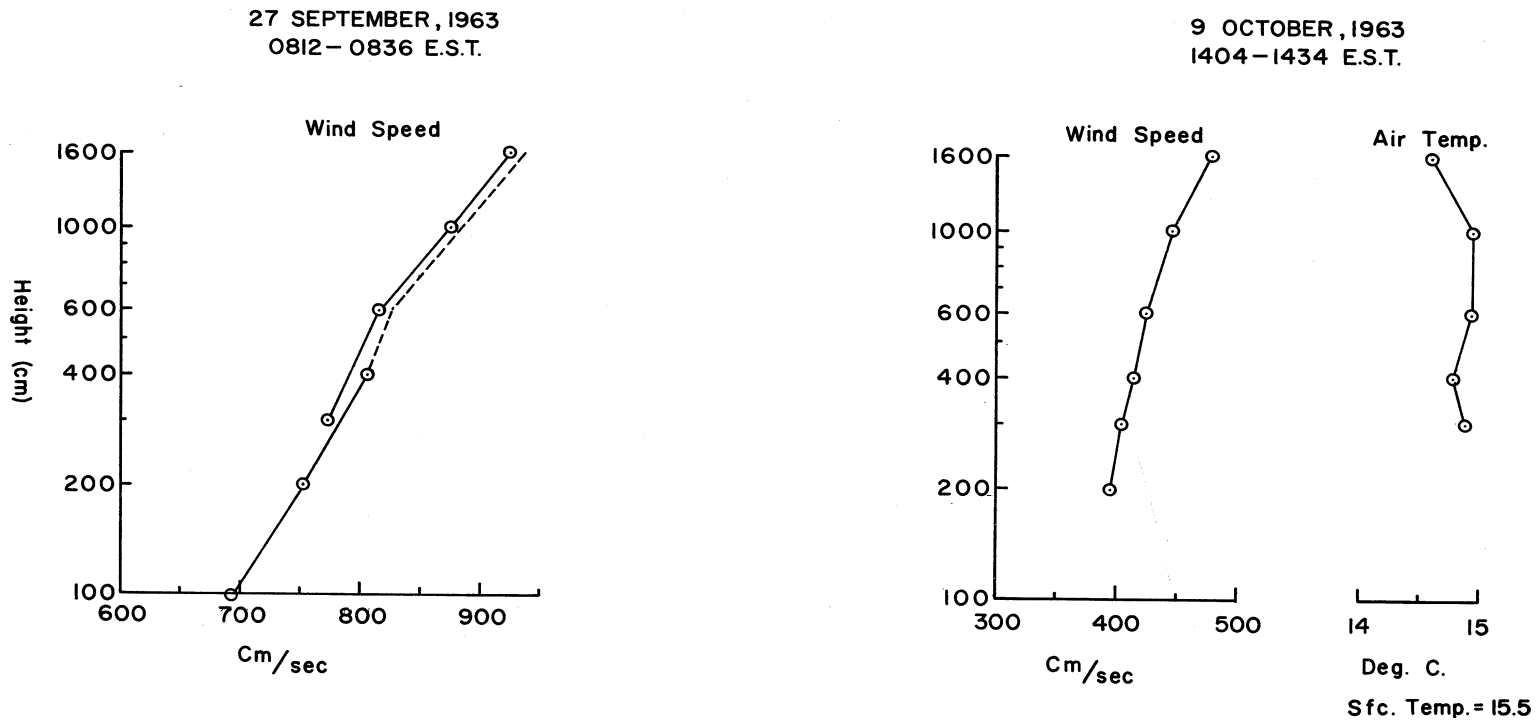


Figure 4. Wind speed profile, 27 September, 1963 and temperature and wind speed profile, 9 October, 1963.

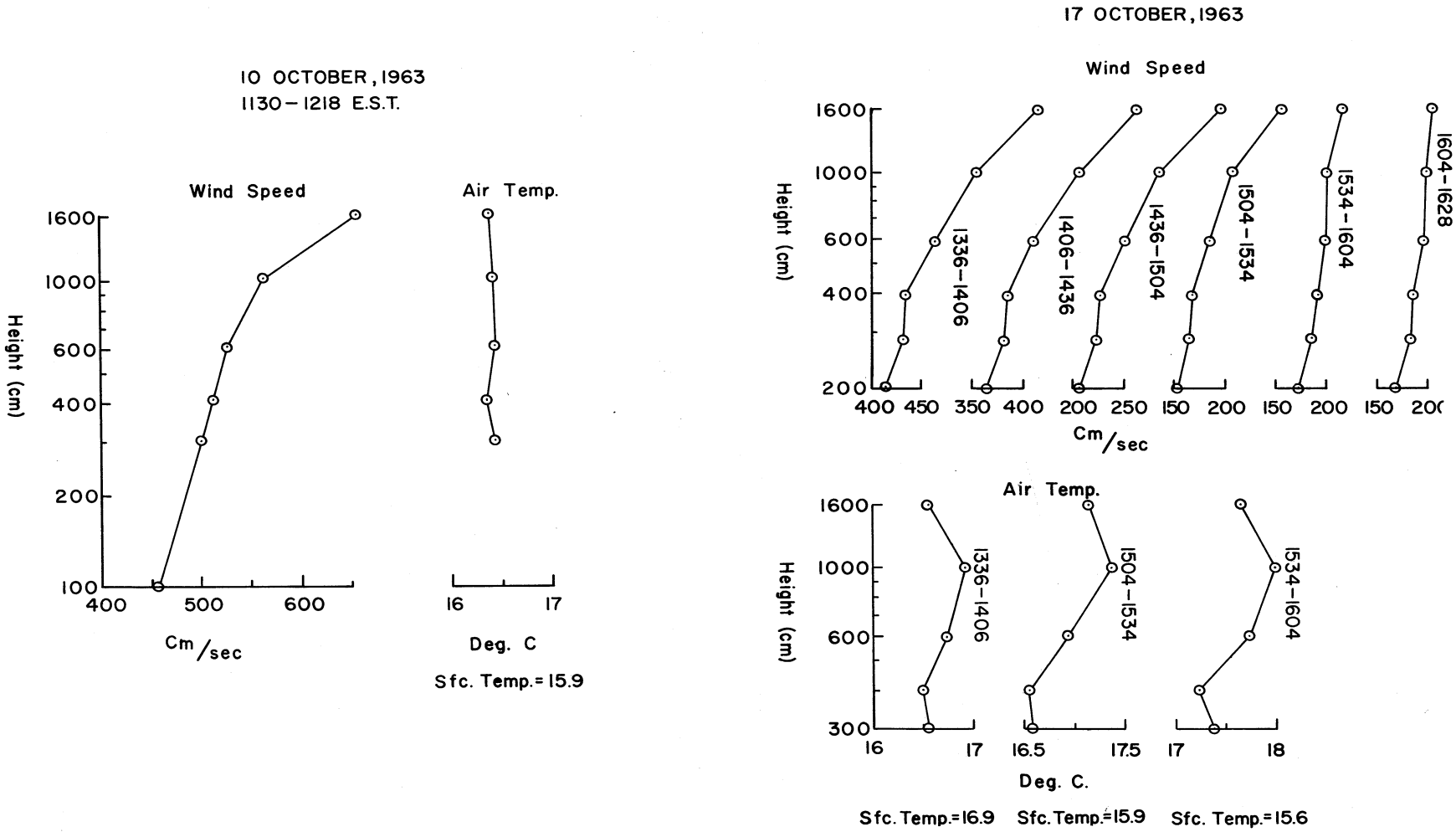


Figure 5. Wind speed and temperature profiles, 10 and 17 October, 1963.

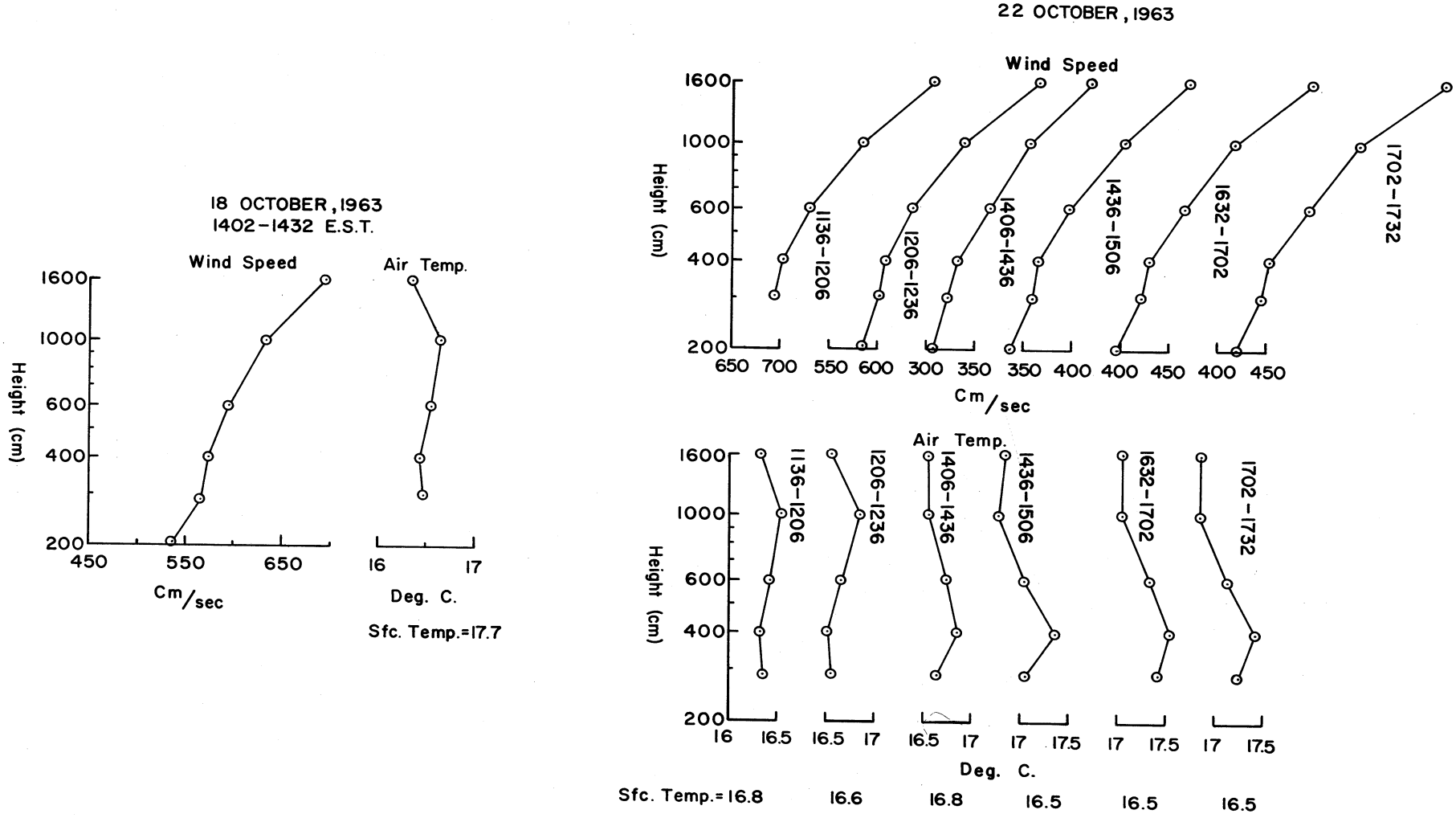


Figure 6. Wind speed and temperature profiles, 18 and 22 October, 1963.

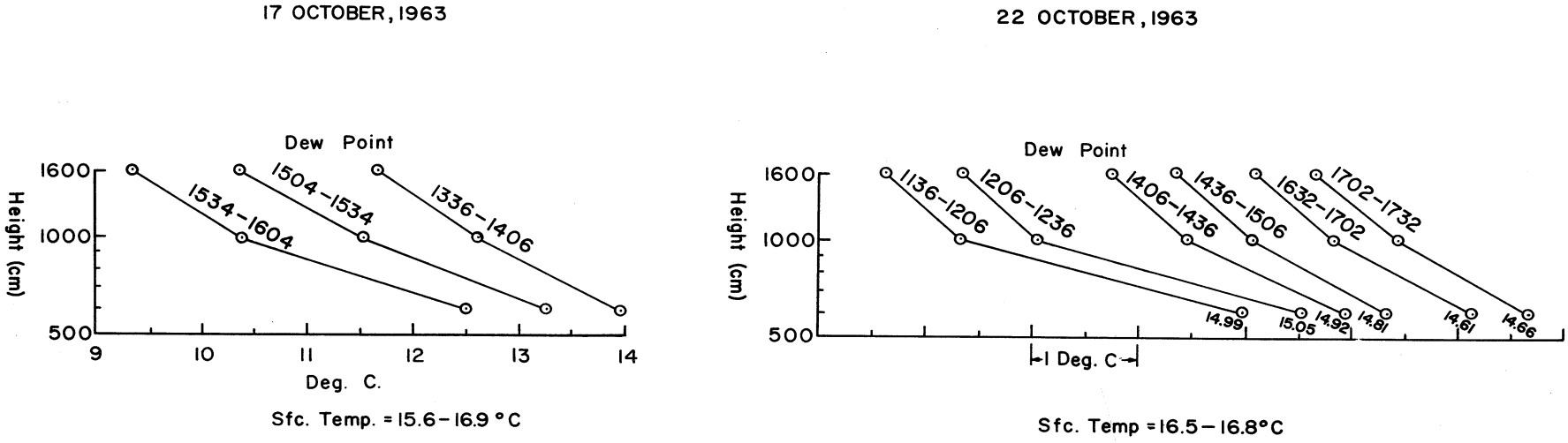


Figure 7. Dew point profiles, 17 and 22 October, 1963.

3.1 Data Corrections

The data tabulated in Table III have been carefully checked and corrected for known instrumental errors, and cases of obvious instrument malfunction have been removed from the record. Derivation of applied corrections is discussed in following sections.

3.1.1 Wind Speed and Direction

The wind speed profile data were obtained by use of two sets of low inertia three-cup anemometers of different design, and therefore, of different calibration and somewhat different distance constants. However, it was assumed that with known calibration constants, the two sets of anemometers would give comparable measurements of the mean wind speed when exposed under identical conditions.

Prior to use in the measurement program, the anemometers were subjected to extensive testing to determine the correct calibration, and to detect small differences in calibration between individual units. Two methods of calibration comparison were employed.

First, one unit of both the Beckman and Whitley and Thornthwaite sensors was operated in a low-speed wind tunnel to check its conformity to the calibration as stated by the manufacturer. While some deviation was observed, it was accepted that the manufacturer's calibration was sufficiently accurate to describe the average response of a group of sensors. Means available to measure tunnel wind speed do not permit determination with an error of less than one percent as desired in wind speed profile measurements. The test section of the wind tunnel employed did not permit exposure of several units simultaneously to compare calibrations precisely.

A simultaneous exposure of all anemometers on a horizontal bar in natural wind was used as a second method to compare directly calibrations of all units. The exposure site was about 2 meters above a closely mowed grass-covered surface on the east side of Willow Run Airfield. A uniform flat surface existed for at least 1 mile upwind. The anemometers were exposed for periods of several hours in low wind speeds, less than 1 mps, and at higher speeds, about 8 mps. Percentage differences between anemometer revolutions were calculated.

Anemometers within each set were reasonably consistent in calibration. However, calibration differences of 2.0% between two of the Thornthwaite units, and 2.6% between Beckman and Whitley units

were observed. An average difference of about 5% existed between the calibration of the two sets as is expected from published calibrations. A systematic dependency of calibration differences upon wind speed was not observed. The comparison data were accepted as a valid indication of calibration differences. Factors were calculated that would normalize calibration of all units to that of the anemometer used at the lowest level of the tower.

On September 28, a storm caused loss of the anemometer cups for the 1-meter height and damage to cups at 10 meters. The lost and damaged cups were replaced with others that had not been compared with the remaining units. Following removal of anemometers from the tower, a second comparison, of the type described above, was performed. The results of this comparison were used to normalize observations made following September 28.

The normalization factors were applied to all data presented in Table III and Figures 2 through 6. Examination of wind speed profiles shows that the normalization factors produced consistent and reasonable results with data in agreement between the two anemometer sets in some cases while in other cases, disagreement remains. Data for August 27, September 22, and September 27 are most noticeable in their disagreement. In these cases, an arbitrary correction was applied to bring the two sections of the profile into coincidence as shown by the dashed curves in Figures 2, 3, and 4.

3.1.2 Temperature and Dew Point

The air temperature data presented in Table III and in Figures 2 through 6 have been edited and represent the best estimate of the existing thermal regime. Some error in the temperature measurement probably exists because of lack of provision to calibrate accurately the bridges in the improvised recording system. This error could amount to a few tenths of a degree, and may not be consistent throughout the period of measurements due to repeated efforts to improve calibration as the work progressed.

Water surface temperature was measured by the floating thermistor from August 27 through September 26. These measurements are subject to doubt as the float movement with the wave surface produced a high noise level in the record. On September 27 the float was removed from the tower, and on October 18 the Barnes Infrared thermometer was installed. Surface temperatures following that date are measured by the infrared sensor.

The surface temperatures indicated by the infrared thermometer were compared on three occasions with water temperature

measured with a slightly immersed thermometer shielded from solar radiation. The comparative readings are shown in Table IV.

TABLE IV

COMPARISON OF RADIOMETER AND THERMOMETER MEASUREMENTS OF WATER SURFACE TEMPERATURE

	Barnes Radiometer	Thermometer	Difference
October 8	14.0°C	16.2°C	2.2°C
October 9	13.8°C	16.2°C	2.4°C
October 10	14.3°C	16.1°C	1.8°C

On October 10, the radiometer measurements were compared to the temperature of a bucket of stirred water as measured by a thermometer. The radiometer had previously been adjusted to read zero when exposed to a stirred ice-water bath. Agreement with the thermometer was good at that temperature, but departed at higher temperatures. The comparison data are shown in Table V.

TABLE V

COMPARISON OF RADIOMETER AND THERMOMETER MEASUREMENTS OF STIRRED WATER TEMPERATURE

Barnes Radiometer	Thermometer	Difference
0.0°C	0.0°C	0.0°C
5.4°C	5.5°C	0.1°C
8.7°C	9.0°C	0.3°C
11.3°C	12.0°C	0.7°C
13.1°C	14.1°C	1.0°C
15.4°C	16.7°C	1.3°C
17.9°C	19.1°C	1.2°C
19.5°C	20.7°C	1.2°C

Since most of the water temperatures measured were near 16°C, a correction of +1.3°C was applied to all radiometer readings. The remaining discrepancy between water surface temperatures as measured by the radiometer, and by an immersed thermometer are probably due to the temperature gradient that may exist near the water surface. This factor has been discussed by Ewing and McAllister (1960), Clark and Stone (1964) and Franceschini (1964).

Dew point profile measurements are tabulated in Table III, and shown in Figure 7 for October 17 and October 22 only. The Dew Probe instruments were exposed throughout most of the measurement period, but a thorough verification of the record was not obtained. The data appear to be inconsistent with measured water temperatures in some cases. A sufficient number of comparisons with psychrometer measurements were not obtained to give great confidence in data.

4. DATA COLLECTED DURING 1964

Data were collected with the recording system described in Section 2.2 during periods shown in Table VI.

TABLE VI

PERIODS OF OBSERVATION 1964

DATE	TIME (EST)	DATE	TIME (EST)
August 2	1802 - 2050	August 10	1346 - 1436
			1606 - 1654
August 3	1124 - 1236		2020 - 2120
	1700 - 1812		
		August 11	1200 - 1636
August 5	1212 - 1642		
		August 12	1200 - 1254
August 7	0800 - 0918		1500 - 1600
	1736 - 1836		
		August 15	0830 - 1000
August 8	0746 - 0840		
	1200 - 1300	August 16	1318 - 1648
	2000 - 2100		
August 9	1200 - 1300		
	1700 - 1800		

The data have been reduced and edited in a manner similar to that described for the data of 1963. Obviously erroneous data have been deleted where malfunction of equipment could be determined as the cause.

The wind speed, air temperature, dew point, and water temperature data were averaged over 6-minute periods. The averaged data are given in Table VII. Longer period averages, usually 30 minutes, were formed and are shown graphically as Figures 8 through 13. The longer period average values are also shown in Table VII.

Table VII lists observations at nominal heights above the mean water surface. The actual heights from a quiet water surface, measured at time of installation of sensors, were 205.9, 408.9, 799.1 and 1604.5 cm. Changes in mean water level throughout the measurement period were not great, probably amounting to no more

than a few centimeters. Actual measure of water level was recorded, but the record had not been reduced by the time of this writing.[1]

Dew point measurements are tabulated for only two days. The Dew Probe sensors were installed on August 9, and two units were damaged during a storm on August 11. They were not restored to operation.

Wave height spectra for periods coincident with periods of meteorological data have been supplied by U. S. Lake Survey. The spectrum for each period is presented in Figures 14 through 17 as analyzed by personnel of U. S. Army, Coastal Research and Engineering Laboratory. In each case, the spectral distribution of linear average of wave height is presented. Each curve represents data averaged over a 20-minute period using a filter bandwidth of 0.027 cps as described by Caldwell and Williams (1961). The data have not been adjusted for the depth of exposure of the pressure sensor.

1. The records of mean water level during August, 1964, should be available from U. S. Lake Survey at a later date.

TABLE VII

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

2 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1808	243		342	425		23.0		24.2		24.6		
1814	288		373	447	E	22.9		23.9		24.4		
1820	280		349	408	s	23.0		24.4		24.8		
1826	253		437	502	t	23.0		24.3		24.7		
1832	403		493	517	i	22.4		23.8		24.6		
1838	375		463	512	m	22.5		23.9		24.6		
Average	317.7		403.9	461.8	a t e	22.8		24.0		24.6	17.8	11.0
1844	401		475	531	d	22.9		24.1		24.8		
1850	394		477	542		22.2		23.3		24.0		
1856	363		463	538		22.4		23.2		23.7		
1862	334		440	547	S	22.7		23.8		24.5		
1908	377		480	570	o	23.0		24.2		25.0		
1914	352		454	562	u t	23.9		25.2		25.7		
Average	370.1		464.8	548.3	h	22.8		24.0		24.6	17.8	11.9
1920	323		405	508		23.2		24.6		25.5		
1926	375		463	543		22.9		24.3		25.4		
1932	400		492	559		22.7		23.9		25.0		
1938	363		465	541		22.2		24.4		25.3		
1944	357		452	539		22.8		24.2		25.3		
1950	365		465	563		22.0		23.4		24.6		
Average	363.7		457.0	542.1		22.8		24.1		25.2	17.5	11.3

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

2 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C				WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1600 cm.	4 m.	13 m.
1956	365		460	562	E	22.6		23.9	24.8		
2002	373		466	535	s	22.0		23.1	24.0		
2008	403		502	574	t	21.9		23.0	23.9		
2014	409		505	575	i	21.8		22.8	23.8		
2020	455		562	627	m	21.8		22.8	23.8		
2026	423		531	634	a	21.8		22.9	24.0		
					t						
Average	404.8		504.2	584.4	e	22.0		23.1	24.1	17.9	11.3
					d						
2032	399		502	609		21.3		22.3	23.4		
2038	408		513	609	S	21.5		22.4	23.1		
2044	362		469	573	o	21.9		22.9	23.6		
2050					u	22.0		23.3	24.0		
					t						
Average	389.6		494.8	596.2	h	21.5		22.6	23.4	17.8	11.0

3 August, 1964

1130	245	255	266	295	E	21.8	22.3	22.5	22.5		
1136	313	337	363	409	s	21.9	22.3	22.5	22.6		
1142	328	358	389	444	t	22.0	22.7	22.9	22.9		
1148	249	275	306	360	i	22.3	22.8	23.1	23.0		
1154	221	242	264	315	m	22.0	22.9	23.0	23.0		
1200	221	235	258	290	a	22.0	22.6	22.9	22.9		
					t						
Average	262.8	283.8	307.7	352.1	e	22.0	22.6	22.8	22.8	20.0	12.9
					d						
					W						
					N						
					W						

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

3 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C				WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1206	247	265	288	340		22.0		22.6	22.8	22.8		
1212	297	309	328	368		22.0		22.6	22.8	22.9		
1218	289	310	322	365	E	22.1		22.6	22.8	22.8		
1224	300	313	329	380	s	22.0		22.6	22.7	22.8		
1230	354	378	398	456	t	22.1		22.6		22.8		
1236	374	395	413	465	i	22.2		22.8	23.0	23.1		
					m							
Average	310.2	328.5	346.4	395.6	a	22.1		22.6	22.8	22.9	20.0	13.2
					t							
1706	580	606	675	736	e	23.8		24.6	24.8	25.3		
1712	560	616	668	765	d	23.7		24.6	24.9	25.3		
1718	591	645	710	836		23.8		24.9	25.0	25.9		
1724	536	587	652	780	W	23.8		25.0	25.3	26.2		
1730	521	572	631	764	N	23.7		24.9	25.2	26.0		
1736	519	572	632	763	W	23.7		24.8	25.0	25.7		
Average	551.0	599.8	661.4	773.7		23.8		24.8	25.1	25.8	21.0	13.5
1742	546	601	663	780		23.6		24.7	24.9	26.0		
1748	584	638	705	842		23.7		24.8	25.0	25.8		
1754	492	545	608	733		23.6		24.8	25.0	25.8		
1760						23.5		24.6	24.9	25.4		
1806	350	426	475	553		23.5		24.5	24.9	25.4		
1812	343	417	454	525		23.5		24.6	24.9	25.4		
Average	478.6	525.4	581.0	686.6		23.6		24.7	24.9	25.5	20.5	12.4

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

5 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1218	617	660	690	723		20.0	20.0	20.1	20.2	20.2		
1224	635	680	711	740		20.1	20.1	20.1	20.2	20.2		
1230	632	674	708	741		20.1	20.1	20.2	20.2	20.2		
1236	624	668	702	730	E	20.1	20.0	20.2	20.2	20.2		
1242	647	692	727	769	s	20.1	20.2	20.2	20.3	20.3		
					t							
Average	630.9	674.8	707.5	740.7	i	20.1	20.1	20.2	20.2	20.2	18.1	12.0
					m							
1248	658	700	728	765	a	20.2	20.2	20.3	20.3	20.3		
1254	649	697	730	768	t	20.2	20.2	20.3	20.3	20.3		
1300	641	885	721	758	e	20.3	20.3	20.3	20.4	20.4		
1306	683	735	773	807	d	20.3	20.3	20.3	20.5	20.4		
1312	712	757	790	825		20.4	20.3	20.4	20.5	20.4		
1318	725	775	815	863	W	20.4	20.4	20.4	20.5	20.5		
					N							
Average	677.8	724.6	759.4	797.8	W	20.3	20.3	20.3	20.4	20.4	18.4	11.7
1324	705	757	795	835		20.4	20.4	20.4	20.5	20.5		
1330	692	736	768	807		20.5	20.5	20.6	20.6	20.6		
1336	697	743	772	818		20.5	20.4	20.5	20.5	20.5		
1342	705	754	782	829		20.5	20.4	20.5	20.5	20.5		
1348	725	771	803	842		20.5	20.5	20.5	20.5	20.5		
1354	715	767	802	847		20.6	20.5	20.6	20.6	20.6		
Average	706.2	754.6	786.9	829.8		20.6	20.5	20.5	20.4	20.5	18.8	11.3
1400	734	780	813	847		20.7	20.6	20.7	20.7	20.7		
1406	712	760	796	839		20.6	20.6	20.7	20.7	20.7		
1412	757	818	859	897		20.7	20.6	20.7	20.7	20.7		
1418	725	773	802	842		20.7	20.6	20.7	20.7	20.7		
1424	747	800	823	848		20.7	20.6	20.7	20.7	20.7		
1430	763	809	846	884		20.7	20.6	20.7	20.7	20.7		
Average	738.1	787.8	823.2	861.6		20.7	20.6	20.7	20.7	20.7	18.9	11.1

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

5 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1436	780	834	875	913		20.7	20.7	20.8	20.6	20.7		
1442	732	785	821	863		20.7	20.7	20.8	20.8	20.8		
1448	756	809	839	886		20.0	20.6	20.7	20.7	20.7		
1454	746	800	834	884		20.7	20.7	20.8	20.8	20.8		
1500	765	817	855	888	E	20.7	20.7	20.8	20.8	20.8		
1506	834	898	936	980	s	20.6	20.5	20.7	20.7	20.7		
					t							
Average	768.7	823.6	860.1	902.1	i	20.7	20.7	20.7	20.8	20.8	18.9	10.7
					m							
1512	790	850	884	930	a	20.6	20.5	20.6	20.6	20.7		
1518	811	874	909	959	t	20.5	20.5	20.6	20.6	20.6		
1524	796	859	888	937	e	20.6	20.5	20.7	20.7	20.7		
1530	763	838	875	922	d	20.5	20.4	20.6	20.6	20.6		
1536	817	900	934	980		20.6	20.5	20.6	20.6	20.7		
1542	880	946	975	1030	W	20.6	20.5	20.7	20.7	20.7		
					N							
Average	809.3	877.8	910.7	959.4	W	20.5	20.5	20.5	20°6	20.7	18.5	11.3
1548	837	900	942	1005		20.7	20.5	20.6	20.7	20.8		
1554	822	880	923	990		20.7	20.6	20.7	20.8	20.8		
1600	800	860	900	947		20.6	20.5	20.6	20.7	20.8		
1606	792	849	886			20.4	20.0	20.4	20.5	20.6		
1612	796	855	899			20.4	20.4	20.4	20.5	20.6		
1618	772	830	872			20.4	20.4	20.5	20.5	20.5		
1624	732	780	809			20.5	20.4	20.5	20.6	20.6		
Average	793	850	890.2			20.5	20.5	20.5	20.6	20.6	18.5	11.3

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

7 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
0806	488	530	603	648		20.3	20.4	20.7	20.8	21.0		
0812	447	487	548	651		20.2	20.4	20.6	20.7	20.9		
0818	452	490	553	662	Est.	20.3	20.5	20.7	20.8	21.0		
0824	465	505	574	671		20.3	20.5	20.8	20.8	21.0		
0830	457	497	560	665	210°	20.2	20.4	20.6	20.7	20.9		
0826	462	500	560	671		20.2	20.4	20.6	20.7	20.9		
Average	462	501	564	667		20.3	20.4	20.7	20.8	21.0	18.1	13.3
0848	432	476	540	644		20.1	20.3	20.6	20.6	20.9		
0854	407	447	514	618		20.0	20.2	20.5	20.6	20.8		
0900	390	436	504	608	Est.	20.0	20.2	20.5	20.6	20.8		
0906	381	422	495	600		20.0	20.2	20.4	20.6	20.8		
0912	382	425	495	598	250°	20.0	20.1	20.4	20.6	20.8		
0918						20.0	20.1	20.4	20.6	20.8		
Average	398	441	510	614		20.0	20.2	20.1	20.6	20.8	18.1	13.4
1742						22.0	21.9	22.2	22.3	22.6		
1748	650	710	759	830		21.9	21.9	22.1	22.1	22.4		
1754	649	626	754	813	Est.	21.7	21.7	22.4	22.0	22.2		
1800	639	694	731	800		21.5	21.6	21.8	21.8	22.0		
1806	657	706	751	817	300°	21.4	21.4	21.7	21.6	21.8		
Average	649	684	749	815		21.6	21.6	21.9	21.9	22.1	18.9	10.9
1812	649	708	750	817		21.2	21.2	21.4	21.5	21.7		
1818	633	700	746	805	Est.	21.4	21.4	21.5	21.7	22.0		
1824	645	709	756	827		21.7	21.7	22.0	22.0	22.3		
1830	638	694	746	820	300°	21.6	21.7	22.0	22.0	22.2		
1836	695	761	807	855		21.8	21.9	22.0	22.1	22.4		
Average	652	714	761	825		21.5	21.6	21.8	21.9	22.1	18.9	12.3

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

8 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
0754	862	941	976	988		17.6	17.5	17.5	17.5	17.5		
0800	831	913	939	925		17.5	17.5	17.4	17.4	17.4		
0806	792	913	949	910		17.4	17.4	17.4	17.3	17.3		
0812	784	854	883	908	E	17.4	17.3	17.3	17.3	17.2		
0818	833	934	970	941	s	17.4	17.3	17.3	17.3	17.2		
					t							
Average	817	905	937	933	i	17.5	17.4	17.4	17.4	17.3	18.1	10.2
					m							
0824	812	901	930	921	a	17.3	17.3	17.2	17.2	17.2		
0830	809	861	884	909	t	17.3	17.3	17.2	17.2	17.1		
0836	760	814	850	877	e	17.3	17.2	17.1	17.2	17.1		
0840	812	872	894	906	d	17.3	17.3	17.2	17.2	17.1		
					300°							
Average	805.1	876	905	911		17.3	17.2	17.2	17.2	17.1	17.9	10.3
1206	920	978	1003	1027		15.6	15.5	15.4	15.4	15.3		
1212	950	1009	1037	1083	Est.	15.6	15.5	15.4	15.4	15.3		
1218	1028	1100	1141	1185		15.5	15.4	15.3	15.3	15.3		
1224	1085	1156	1195	1226	310°	15.4	15.3	15.2	15.2	15.3		
1230	1029	1095	1142	1192		15.4	15.3	15.2	15.2	15.2		
Average	1002	1068	1104	1142		15.5	15.4	15.3	15.3	15.2	16.0	9.4

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

8 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1236	1063	1145	1193	1248	Est.	15.5	15.4	15.3	15.3	13.7		
1242	1074	1157	1195	1223		15.4	15.3	15.2	15.2	13.8		
1248	999	1077	1122	1150	310°	15.6	15.5	15.4	15.4	13.6		
1254	1032	1108	1141	1179		15.6	15.4	15.3	15.3	13.6		
1300	1155	1115	1072	1002		15.5	15.3	15.3	15.3	13.4		
Average	1064	1120	1144	1161		15.5	15.4	15.3	15.3	15.2	15.8	9.4
2006	39	42	40	37		13.2	13.3	13.5	13.6	13.7		
2012	40	45	44	43	E	13.1	13.3	13.5	13.6	12.8		
2018	55	58	56	55	s	12.8	13.0	13.6	13.4	18.6		
2024	54	64	59	60	t	13.0	15.3	13.3	13.5	13.6		
2030	55	65	61	62	i	12.6	15.3	12.5	12.1	13.4		
Average	49	55	52	51	m a t	12.9	13.1	13.3	13.4	13.6	8.2	5.5
2036	52	59	58	62	e	12.4	13.5	12.9	13.0	13.4		
2042	54	57	60	63	d	12.0	13.5	12.4	12.5	12.8		
2048	50	53	57	56		11.9	13.3	12.5	12.7	12.8		
2054	47	50	54	52	360°	11.7	13.3	12.0	12.1	12.5		
2100	49	55	52	49			13.0	12.0	12.1	12.4		
Average	50	55	56	57		11.9	12.1	12.4	12.5	12.8	6.2	5.5

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

9 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1206						12.8	12.8	12.0	13.0	13.0		
1212	390	436	482	538	E	13.3	13.3	12.6	13.9	13.6		
1218	407	446	497	556	s	13.5	13.4	12.9	14.0	14.0		
1224	367	400	454	532	t	13.6	13.5	13.0	14.1	14.1		
1230	408	447	507	577	i	13.4	13.4	13.9	14.0	14.0		
					m							
Average	393	432	485	551	a	13.3	12.3	13.9	13.8	13.7	9.3	5.9
					t							
1236	422	462	518	594	e	13.6	13.6	13.0	14.1	14.2		
1242	420	457	517	590	d	13.6	13.6	13.1	14.2	14.3		
1248	389	427	488	566		13.8	13.8	13.2	14.3	14.4		
1254	366	405	467	539	240°	13.8	13.7	13.2	14.3	14.5		
1300	388	427	480	552		13.8	13.8	13.4	14.4	14.6		
Average	397	436	494	568		13.7	13.7	13.2	14.3	14.4	9.2	5.9
1706	258	300	375	450	312	13.9	14.2	14.1	15.6	15.4		
1712	251	308	388	478	312	13.7	14.1	14.4	15.5	15.9		
1718	242	300	376	466	315	13.5	13.9	14.2	15.4	15.7		
1724	222	276	350	430	320	13.6	14.4	14.3	15.4	15.9		
1730	198	265	330	425	325	13.4	14.0	14.2	15.3	15.5		
Average	234	290	364	450		13.6	14.1	14.2	15.4	15.7	7.4	5.5
1736	145	210	291	299	332	13.3	14.1	14.3	15.4	15.9		
1742	136	192	261		332	12.5	13.1	13.7	15.0	15.5		
1748	166	220	278		341	13.2	13.6	13.6	14.9	15.5		
1754	154	247	265		340	13.4	13.7	13.9	15.2	15.9		
1800	173	229	272	291	338	13.2	13.6	13.9	15.3	15.7		
Average	155	220	273			13.1	13.6	13.9	15.1	15.7	7.2	5.6

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

10 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1354	315	359	437		187	15.6	15.8	15.8	16.8	17.1		
1400	305	351	423		198	15.6	15.9	15.9	16.8	17.2		
1406	272	313	381		199	15.5	15.8	15.7	16.6	16.9		
1412	252	293	347		194	15.5	15.8	15.8	16.6	16.8		
Average	286.3	328.7	397.1			15.5	15.8	15.8	16.7	17.0	10.0	5.9
1418	245	384	337		188	15.3	15.4	15.5	16.4	16.7		
1424	252	283	305		184	14.8	15.0	15.1	16.0	16.3		
1430	270	297	311		176	15.4	15.6	15.3	16.1	16.1		
1436	372	299	319		165	15.2	15.5	15.1	16.0	16.0		
Average	259.8	290.6	317.9			15.2	15.4	15.3	16.2	16.3	9.9	6.0
1612	222	265	338		152	15.4	15.7	16.7	17.3	17.4		
1618	254	305	361		141	15.4	15.9	17.1	17.5	17.7		
1624	238	290	344		142	15.5	16.2	17.6	18.0	18.2		
1630	223	287	355		156	15.8	16.7	18.0	18.2	18.3		
Average	234.3	286.6	349.6			15.5	16.2	17.4	17.7	17.9	10.6	6.0
1636	225	281	354		170	16.2	16.8	17.9	18.4	18.6		
1642	244	300	370		183	16.4	17.1	18.1	18.4	18.7		
1648	270	335	382		185	16.5	17.5	18.2	18.5	18.7		
1654	266	323	383		182	16.4	17.3	18.3	18.6	19.0		
Average	251.4	309.5	372.3			16.36	17.2	18.2	18.5	18.8	10.4	6.0

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

10 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
2026	340	317	381		120	17.6	18.8	20.2	20.9	21.2		
2032	352	317	416		123	17.1	18.4	20.1	20.8	21.4		
2038	299	378	454		121	17.6	19.1	20.6	21.0	21.3		
2044	356	430	501		123	17.7	19.0	20.5	21.9	21.1		
2050	386	459	525		122	17.9	18.9	20.3	20.7	21.2		
Average	306.6	380.2	455.3			17.6	18.9	20.3	20.9	21.3	10.2	6.0
2056	371	439	511		121	17.7	18.8	20.2	20.6	21.0		
2102	387	457	526		119	17.9	19.1	20.2	20.6	21.0		
2108	377	444	519		125	17.8	18.8	20.0	20.5	21.0		
2114	408	477	561		120	17.8	18.9	20.2	20.7	21.1		
2120	419	492	580		123	17.9	18.0	20.3	20.7	21.2		
Average	392.4	462.0	540			17.8	18.9	20.2	20.6	21.1	10.2	6.0

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

9 August, 1964

TIME	DEW POINT			
	200 cm.	400 cm.	800 cm.	1000 cm.
1206	7.4	7.6		7.8
1212	8.2	7.6		8.2
1218	7.8	8.0		7.8
1224	7.9	8.0		7.8
1230	8.0	8.3		8.2
Average	7.8	8.1		8.0
1236	8.1	8.3		8.2
1242	8.0	8.3		8.3
1248	8.0	8.2		8.2
1254	8.0	8.1		8.0
1300	7.8	8.0		7.8
Average	8.0	8.2		8.1
1706	9.1	9.5		9.4
1712	9.0	9.5		9.5
1718	9.1	9.8		9.8
1724	9.2	9.9		9.6
1730	9.3	9.8		9.8
Average	9.2	9.7		9.6
1736	9.3	9.8		9.8
1742	9.2	9.8		10.2
1748	9.1	9.5		9.9
1754	9.0	9.6		9.7
1800	9.0	9.6		9.5
Average	9.1	9.6		9.8

10 August, 1964

TIME	DEW POINT			
	200 cm.	400 cm.	800 cm.	1000 cm.
1354	10.7	11.1		11.3
1400	10.7	11.1		11.3
1406	10.7	11.1		11.3
1412	10.8	11.1		11.8
Aver.	10.8	11.2		11.5
1418	11.1	11.5		12.0
1424	10.9	11.4		12.5
1430	11.1	11.5		12.1
1436	11.1	12.5		12.2
Aver.	11.1	11.5		12.1
1612	10.5	11.7	11.6	11.9
1618	10.4	11.5	11.3	11.7
1624	10.1	11.3	11.1	11.3
1630	11.0	11.0	10.8	11.1
Aver.	10.6	11.4	11.2	11.5
1636	10.8	11.1	10.8	10.9
1642	10.8	10.9	10.7	10.8
1648	10.7	10.7	10.7	10.9
1654	10.9	10.9	10.7	10.8
Aver.	10.8	10.9	10.7	10.9

10 August, 1964

TIME	DEW POINT			
	200 cm.	400 cm.	800 cm.	1000 cm.
2026	11.0	11.5	11.8	12.9
2032	11.0	11.4	11.9	12.2
2038	11.0	11.5	12.2	12.3
2044	11.0	11.6	12.1	12.4
2050	11.0	11.6	12.1	12.4
Aver.	11.0	11.5	12.0	12.3
2056	11.0	11.5	12.1	12.4
2102	11.0	11.7	12.2	12.5
2108	11.0	11.6	12.2	12.5
2114	11.1	11.7	12.3	12.6
2120				
Aver.	11.0	11.6	12.2	12.5

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

11 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C				WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1206	459	498	575		252			19.8	20.0	20.2		
1212	475	519	581		255			19.9	20.1	20.2		
1218	466	509	578		255			19.9	20.1	20.2		
1224	473	519	584		262			19.9	20.1	20.2		
1230	479	522	586		262			20.0	20.1	20.3		
Average	470.2	513.5	580.7					19.9	20.7	20.2	14.7	11.1
1236	454	494	563		262			19.9	20.1	20.2		
1242	418	457	523		263			19.9	20.1	20.3		
1248	420	463	525		263			20.0	20.2	20.4		
1254	391	434	499		262			20.0	20.2	20.4		
1300	390	430	497		262			20.0	20.2	20.4		
Average	414.6	455.7	521.4					19.9	20.2	20.3	13.4	11.3
1306	389	437	509		261			20.0	20.3	20.5		
1312	372	418	490		260			20.0	20.3	20.5		
1318	330	375	437		261			20.0	20.2	20.5		
1324	319	362	430		262			19.9	20.2	20.4		
1330	345	388	456		262			20.1	20.3	20.6		
Average	350.7	396.0	464.2					20.0	20.3	20.5	13.1	11.3
1336	379	423	494		265			20.1	20.3	20.6		
1342	375	415	477		261			20.3	20.4	20.7		
1348	370	415	486		257			20.4	20.5	21.0		
1354	352	402	472		257			20.4	20.7	20.9		
1400	350	396	470		257				20.7	20.9		
Average	365.1	410.3	479.8					20.3	20.6	20.8	12.7	11.5

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

11 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1406	314	363	440		259		20.4		20.7	21.0		
1412	304	354	427		246		20.5		20.7	21.0		
1418	290	337	411		241		20.3		20.6	20.9		
1424	334	384	467		248		20.1		20.4	20.9		
1430	336	385	470		250		20.3		20.6	21.0		
Average	315.3	364.7	443.1				20.3		20.6	20.9	12.6	11.6
1436	375	430	507		249		20.5		20.7	21.2		
1442	462	512	585		250		20.6		20.8	21.1		
1448	513	562	635		247		20.7		20.9	21.1		
1454	567	618	694		253		20.8		21.0	21.2		
1500	533	583	662		262		20.7		20.9	21.1		
Average	490.1	561.0	616.4				20.6		20.9	21.1	12.5	10.9
1506	566	621	684		274		20.9		21.1	21.3		
1512	583	630	696		288		20.7		20.9	21.0		
1518	682	735	794		290		20.7		20.9	21.0		
1524	643	698	755		294		20.4		20.6	20.9		
1530	612	656	727		301		20.3		20.6	20.8		
Average	617.2	667.8	731.2				20.6		20.8	21.0	12.1	10.4

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

11 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1536	589	640	696		303			20.2	20.4	20.7		
1542	550	598	667		301			20.3	20.4	20.7		
1548	526	575	638		297			20.0	20.3	20.6		
1554	574	621	679		301			20.0	20.2	20.4		
1600	600	645	714		299			20.0	20.3	20.5		
Average	567.7	615.7	678.8					20.1	20.3	20.6	12.1	10.3
1606	752	803	858		297		20.0	20.5	20.7	20.8		
1612	827	895	965		301		19.8	20.2	20.4	20.5		
1618	796	853	909		311		19.5	19.9	20.1	20.2		
1624	979	1044	1106		314		19.6	19.9	20.1	20.2		
1630					313		19.5	19.8	20.0	20.1		
1636					311		19.2	19.6	19.8	19.9		
Average	838	899	959				19.6	20.0	20.2	20.3	11.9	10.3

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

12 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1206		822			344	10.7	11.1	11.2	11.6	11.7		
1212		737			347	10.6	11.1	11.2	11.7	11.9		
1218		650			344	10.6	11.1	11.3	11.8	12.2		
1224		585			342	10.4	10.8	11.2	11.7	12.0		
Average		698.5				10.6	11.0	11.2	11.7	11.9	8.0	5.8
1230		550			334	10.1	10.6	10.9	11.5	11.8		
1236		517			335		10.4	10.7	11.2	11.5		
1242		546			326		10.5	10.7	11.1	11.3		
1248		533			326	10.1	10.6	10.8	11.2	11.3		
1254					329		10.2	10.7	11.4	11.3		
Average		536.5					10.5	10.8	11.2	11.4	7.7	5.6
1506		390			331		10.1	11.0	11.0	11.4		
1512		499			322			11.0	11.0	11.2		
1518		421			328		10.3	11.2	11.2	11.4		
1524		463			333		10.2	11.0	11.0	11.2		
1530		487			341		10.3	11.3	11.3	11.7		
Average		431.9					10.2	10.6	11.1	11.4	7.0	5.4
1536		456			341		10.4	10.9	11.5	11.8		
1542		430			339		10.5	11.0	11.5	11.8		
1548		439			333		11.6	11.1	11.6	11.8		
1554		464			334	10.2	11.7	11.1	11.6	11.8		
1600		471			337	10.1	11.7	11.2	11.7	11.1		
Average		452.1					10.6	10.1	11.6	11.9	6.9	5.4

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

15 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
0830		-						-				
0836		322	380	433	165	13.2	13.5	14.0	14.6	14.7		
0842		327	392	443	168	13.4	13.9	14.4	14.8	14.8		
0848		310	388	435	168	13.5	13.9	14.4	14.8	14.8		
0854		307	376	441	168	13.4	13.8	14.4	14.8	14.9		
0900		306	370	430	165	13.4	13.9	14.5	14.9	14.9		
Average		314.3	379.2	436.2		13.4	13.8	14.3	14.8	14.8	10.8	10.3
0906		285	342	430	163	13.5	13.9	14.4	14.9	14.9		
0912		323	377	446	165	13.5	14.0	14.5	14.8	14.9		
0918		309	374	429	170	13.9	14.1	14.5	14.9	15.0		
0924		260	330	395	168	13.6	14.0	14.6	14.9	14.9		
0930		316	362	432	173	13.6	14.0	14.5	14.8	14.9		
Average		298.5	357.0	426.3		13.6	14.0	14.5	14.9	14.9	11.1	10.7
0936		312	347	420	173	13.9	14.2	14.6	15.0	15.2		
0942		223	281		168	14.0	14.3	14.6	15.0	15.2		
0948		278	320		173	13.7	14.0	14.4	14.9	15.0		
0954		266	309		170	14.0	14.4	14.7	15.1	15.3		
1000		240	278		185	14.5	14.7	15.0	15.3	15.6		
Average		263.8	307.2			14.0	14.3	14.7	15.1	15.3		

TABLE VII (Continued)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

16 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1324		452	504		220	18.2	18.3	18.5	18.7	18.8		
1330		435	487		217	18.2	18.3	18.5	18.7	18.8		
1336		435	487		217	18.4	18.6	18.8	18.7	18.8		
1342		409	452		220	18.3	18.4	18.6	18.7	18.8		
1348		417	462		217	18.2	18.3	18.5	18.8	18.9		
Average		429.7	478.6			18.3	18.3	18.6	18.7	18.8	16.8	16.4
1354		405	450	535	216	18.2	18.3	18.5	18.8	18.9		
1400		431	482	558	213	18.2	18.4	18.6	18.8	18.9		
1406		397	449	530	210	18.2	18.4	18.6	18.8	18.8		
1412		380	425	505	212	18.3	18.4	18.6	18.8	18.8		
1418		423	423	500	211	18.3	18.4	18.6	18.7	18.7		
Average		407.0	445.8	525.3		18.3	18.4	18.6	18.8	18.8	16.7	16.4
1424		404	427	507	215	18.3	18.4	18.6	18.7	18.7		
1430		405	451	542	212	18.3	18.4	18.5	18.8	18.9		
1436		411	457	540	216	18.2	18.3	18.5	19.0	19.1		
1442		390	437	525	207	18.4	18.5	18.8	18.9	19.0		
1448		376	424	504	207	18.5	18.7	18.9	19.0	19.0		
Average		397.2	439.2	523.7		18.3	18.5	18.7	18.9	18.9	16.7	16.5
1454		375	413	496	206	18.4	18.5	18.7	18.9	18.9		
1500		390	433	517	208	18.2	18.4	18.6	18.7	18.8		
1506		408	460	547	208	18.3	18.5	18.7	18.8	18.9		
1512		427	471	553	204	18.2	18.4	18.6	18.7	18.8		
1518		405	454	540	208	18.2	18.4	18.6	18.8	18.9		
Average		401.0	446.2	530.8		18.3	18.4	18.6	18.8	18.9	16.7	16.5

TABLE VII (Concluded)

LAKE MICHIGAN TOWER OBSERVATIONAL DATA, 1964

16 August, 1964

TIME	WIND SPEED (cm./sec.)				WIND DIR.	AIR TEMPERATURE °C					WATER TEMP.	
	200 cm.	400 cm.	800 cm.	1600 cm.		200 cm.	400 cm.	800 cm.	1000 cm.	1600 cm.	4 m.	13 m.
1524		430	485	564	202	18.4	18.6	18.8	18.9	19.0		
1530		418	468	547	206	18.5	18.6	18.8	18.9	19.0		
1536		514	458	542	208	18.5	18.7	18.9	19.0	19.0		
1542		430	477	554	208	18.7	18.6	19.1	19.2	19.2		
1548		408	456	541	203	18.6	18.8	19.1	19.2	19.2		
Average		420.2	468.7	549.5		18.5	18.7	18.9	19.0	19.1	16.5	16.5
1554		436	489	575	208	18.5	18.6	18.9	19.0	19.0		
1600		436	492	581	203	18.7	18.9	19.1	19.2	19.3		
1606		409	458	536	214	18.8	19.0	19.2	19.3	19.3		
1612		412	464	550	214	18.9	19.1	19.3	19.4	19.4		
1618		422	472	559	210	19.0	19.1	19.4	19.5	19.5		
Average		423.1	475	559.8		18.8	19.0	19.2	19.3	19.3	16.6	16.5
1624		442	495	584	209	18.9	19.1	19.3	19.5	19.5		
1630		448	507	596	205	19.0	19.2	19.4	19.6	19.6		
1636		423	477	560	201	19.0	19.2	19.5	19.6	19.6		
1642		422	471	562		19.1	19.3	19.6	19.7	19.8		
Average		433.7	487.5	575.5		19.0	19.2	19.5	19.6	19.6	16.4	16.5

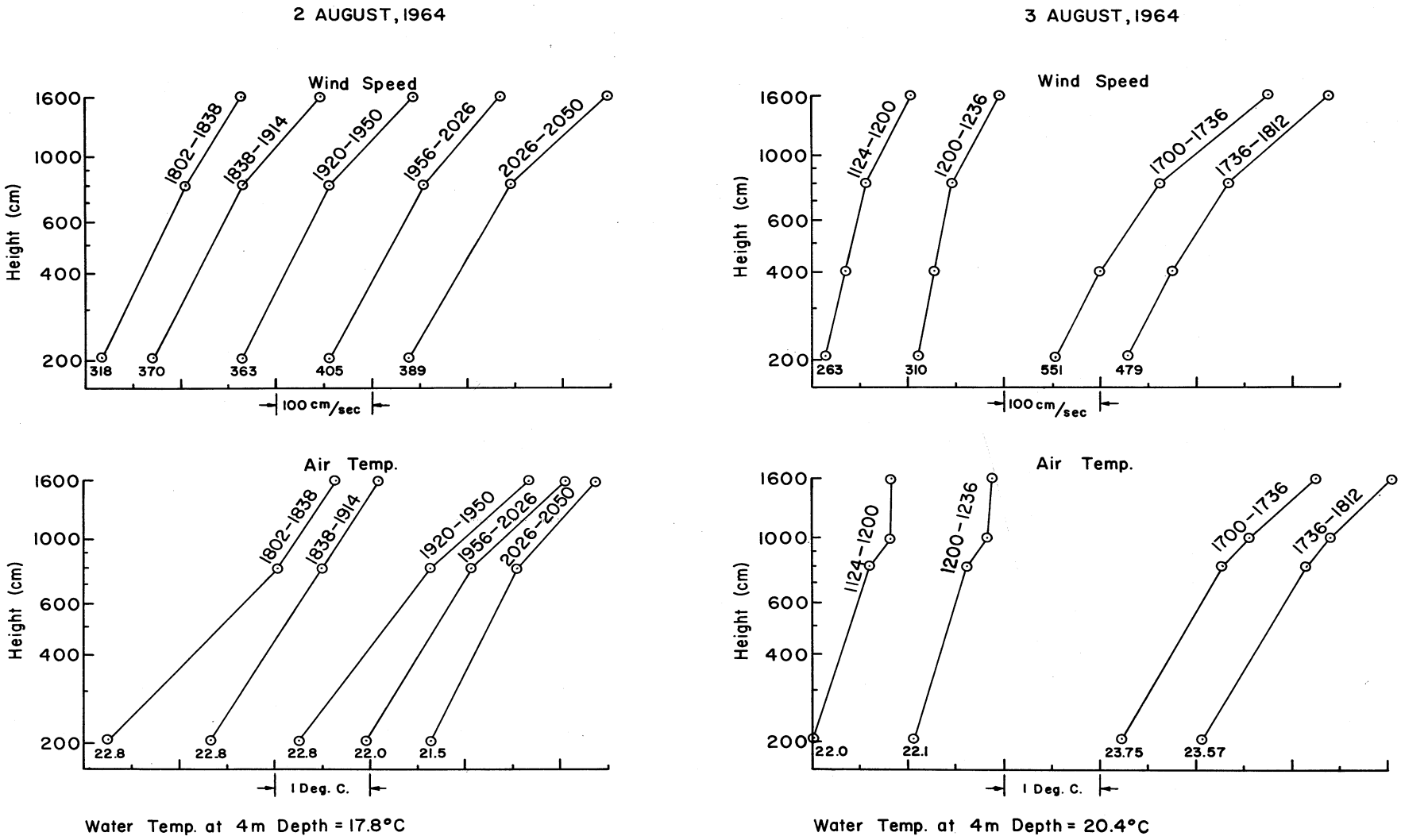


Figure 8. Wind speed and temperature profiles, 2 and 3 August, 1964.

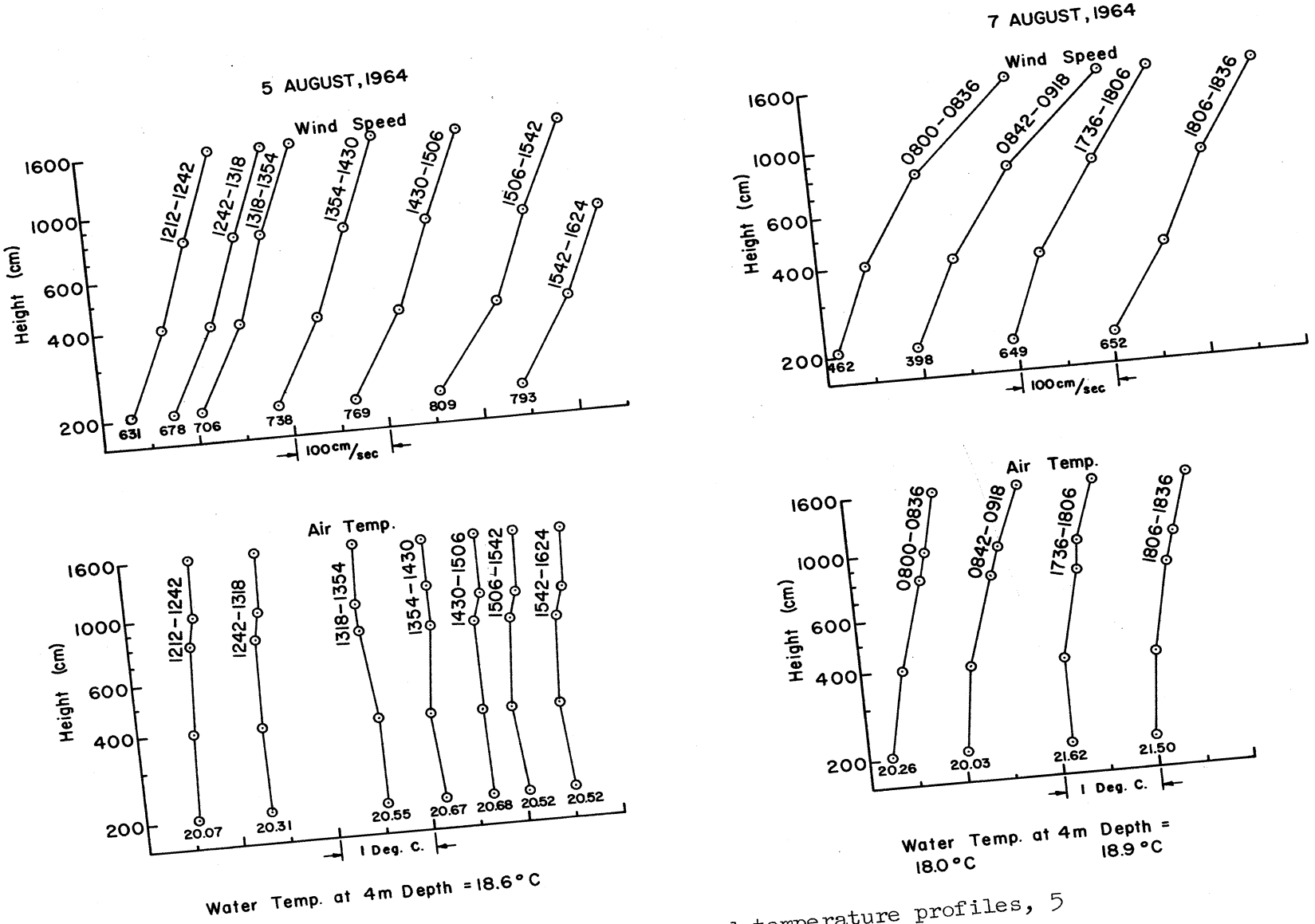


Figure 9. Wind speed and temperature profiles, 5 and 7 August, 1964.

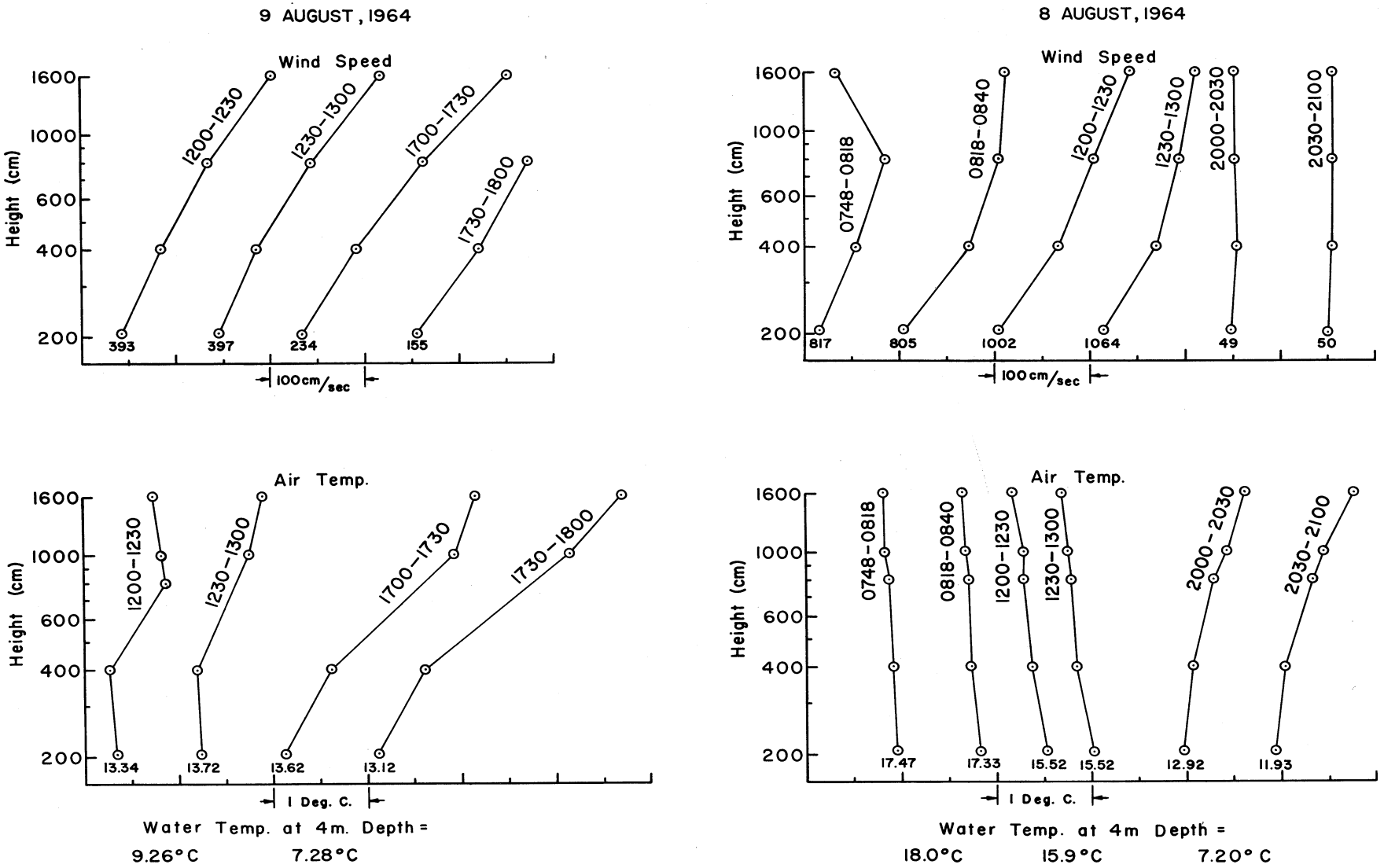


Figure 10. Wind speed and temperature profiles, 8 and 9 August, 1964.

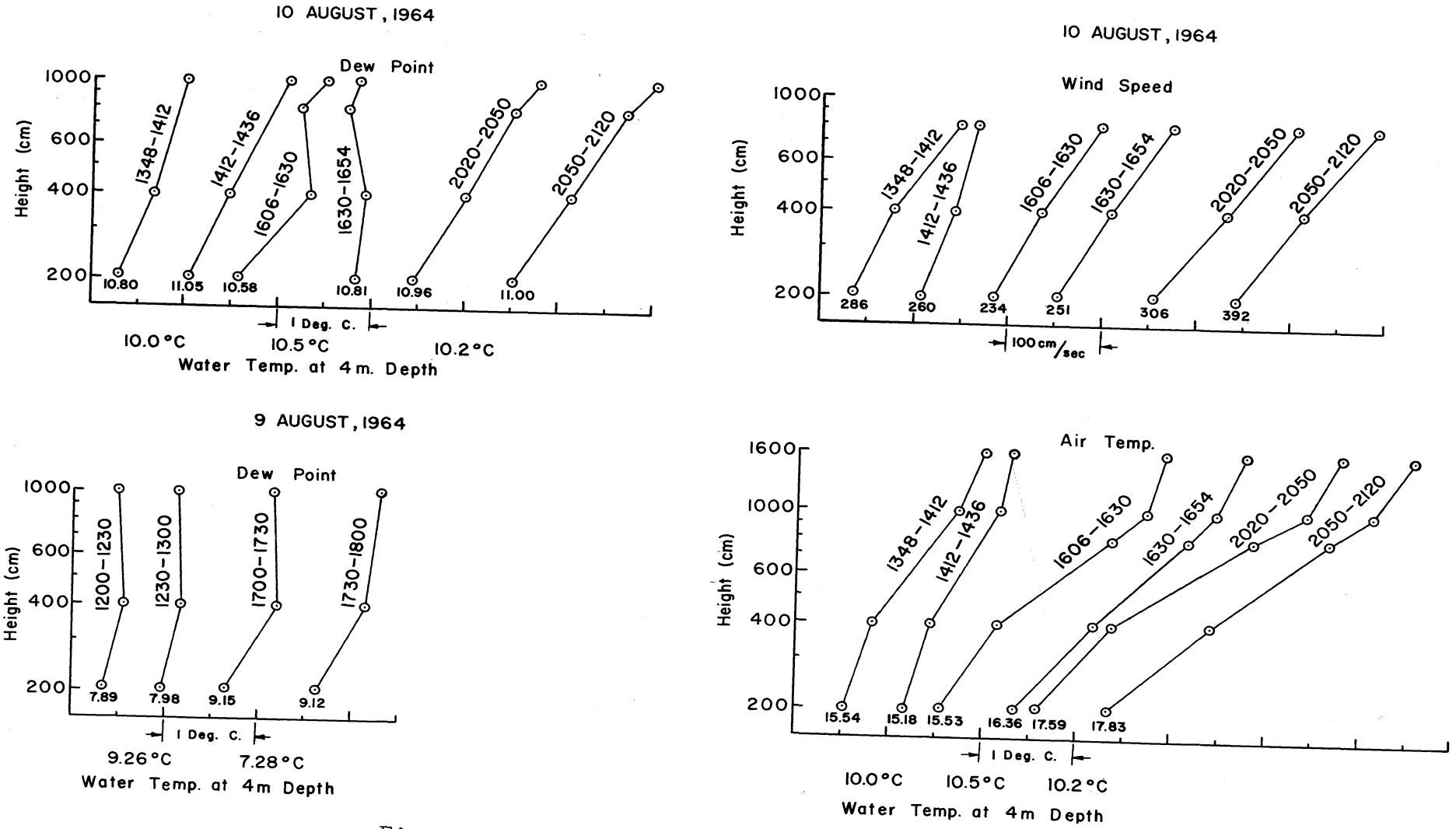


Figure 11. Dew point profiles, 9 and 10 August, and wind speed and temperature profiles, 10 August, 1964.

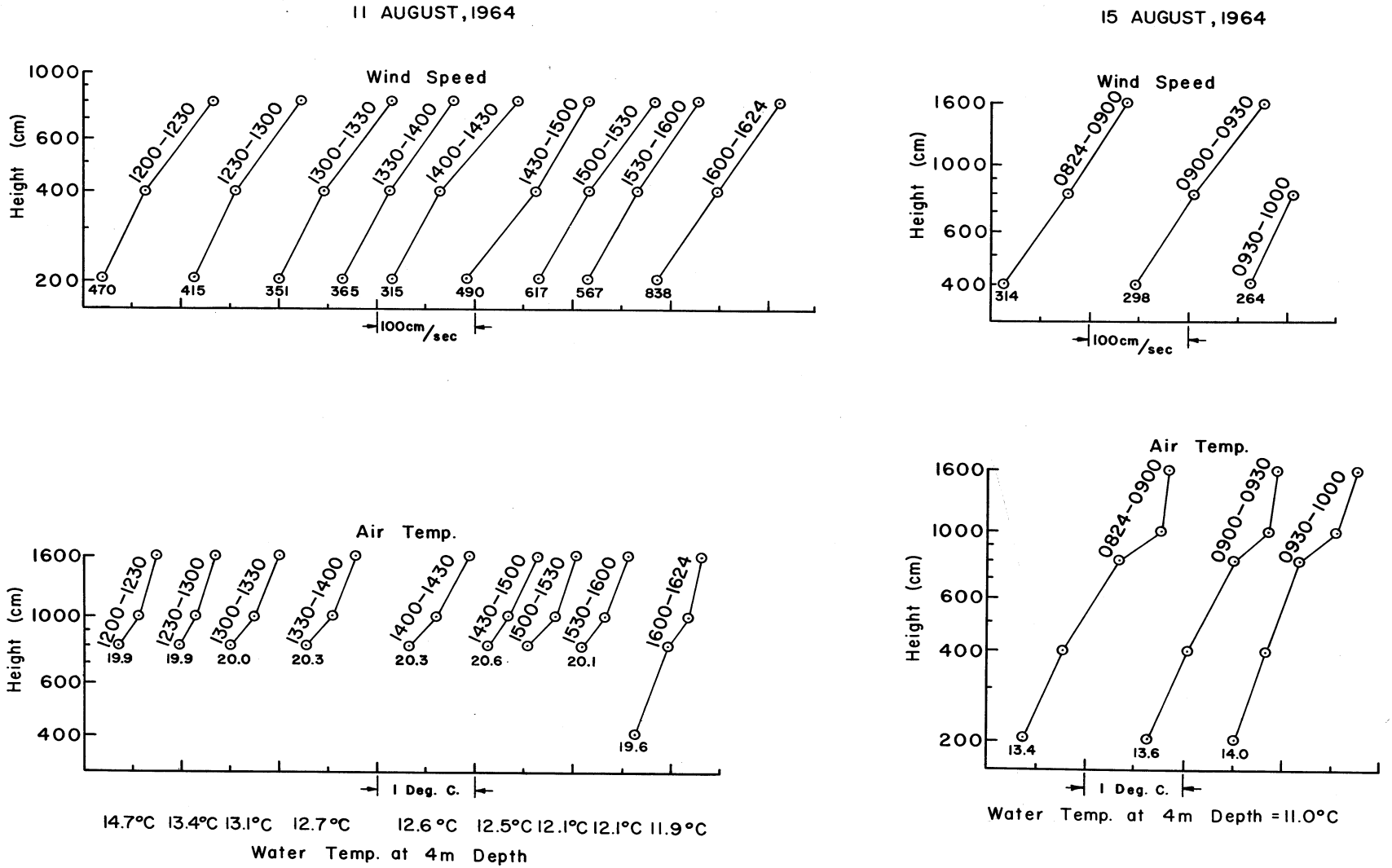


Figure 12. Wind speed and temperature profiles, 11 and 15 August, 1964.

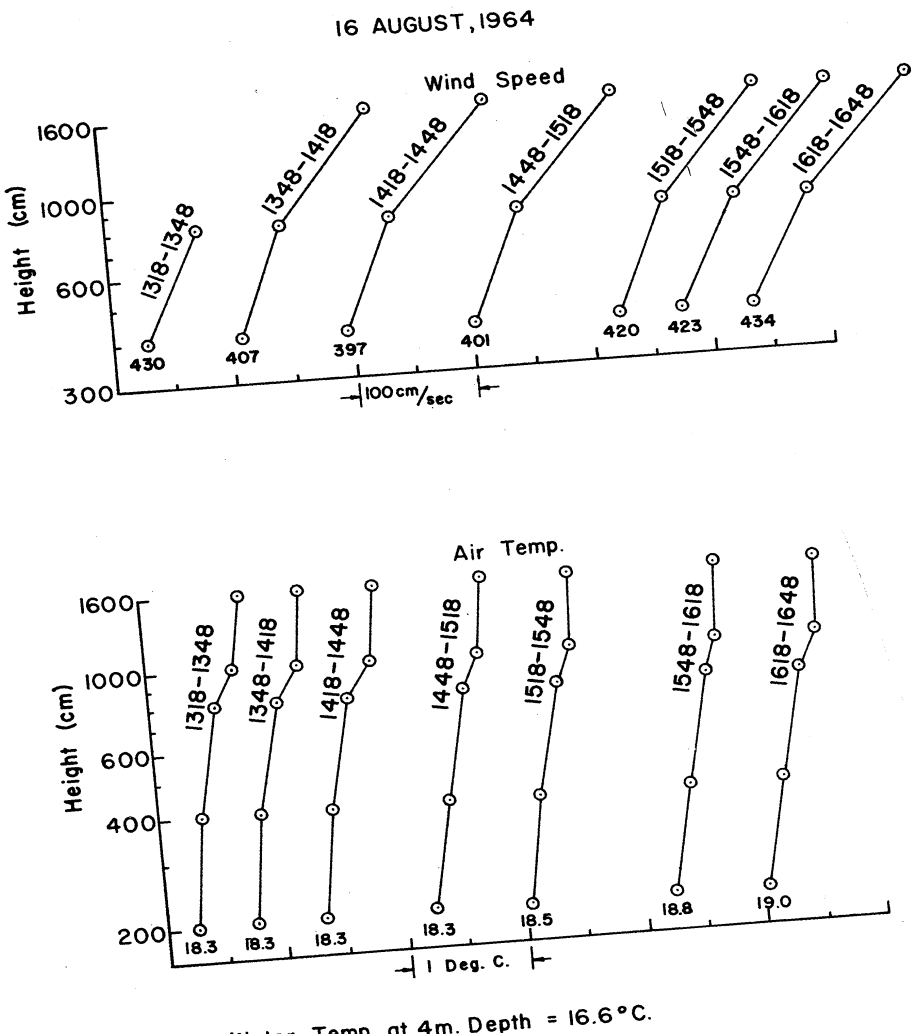


Figure 13. Wind speed and temperature profiles, 16 August, 1964.

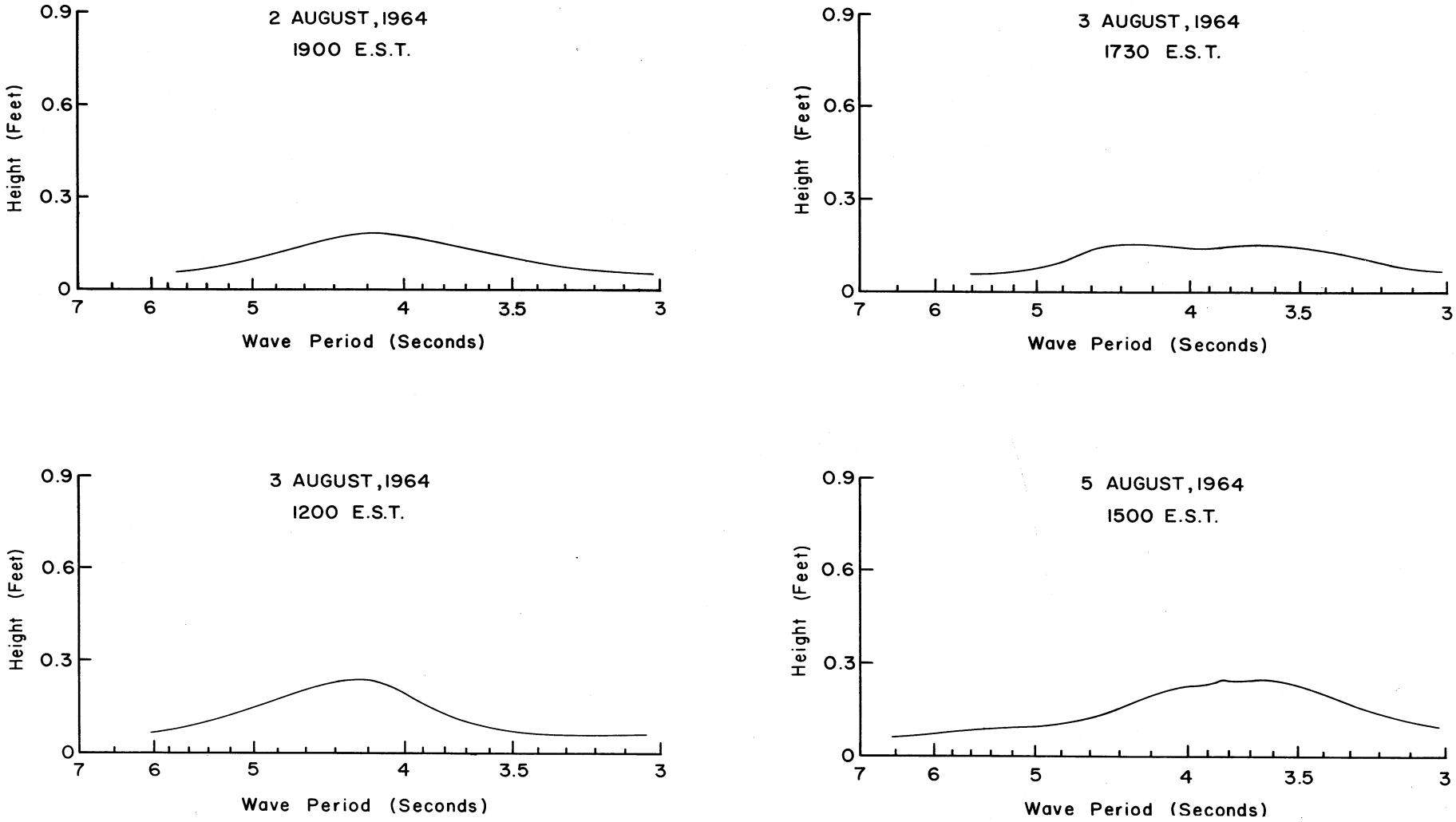
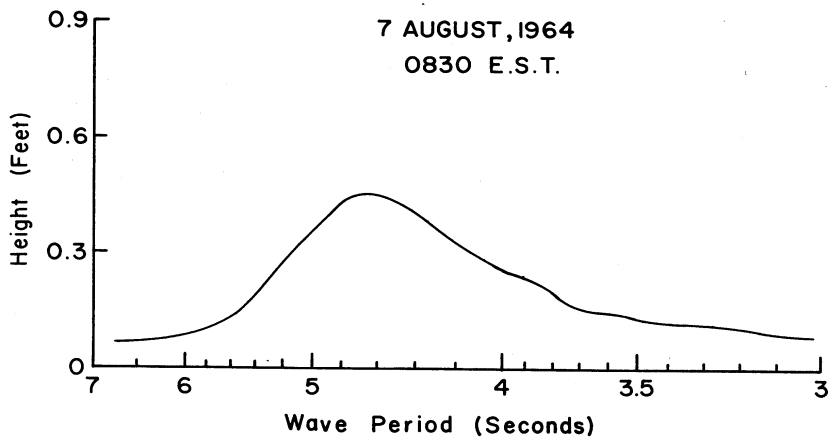
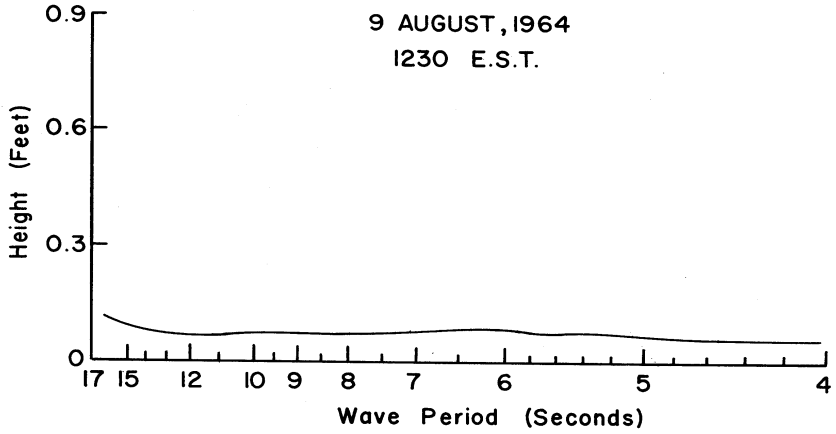
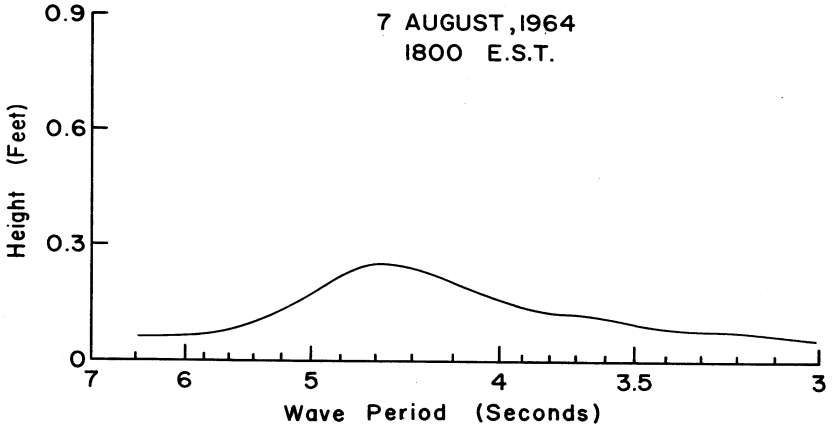


Figure 14. Wave height spectra, 2, 3 and 5 August, 1964.
(Courtesy U. S. Lake Survey)







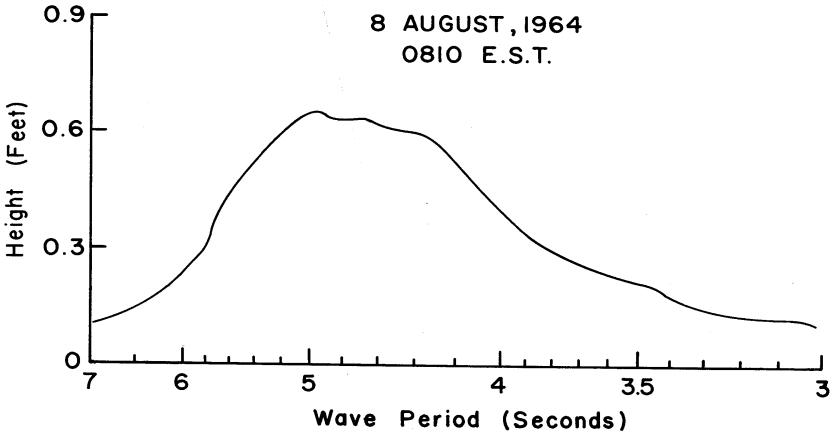
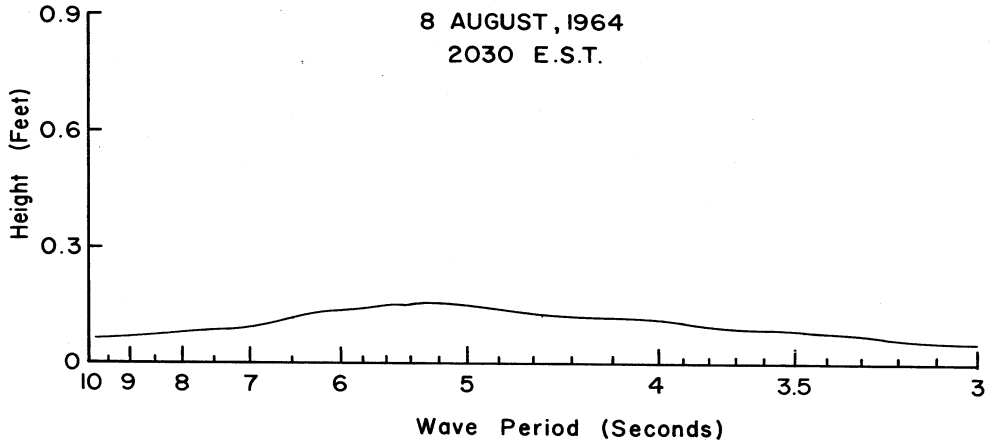


Figure 15. Wave height spectra, 7, 8 and 9 August, 1964.
(Courtesy U. S. Lake Survey)



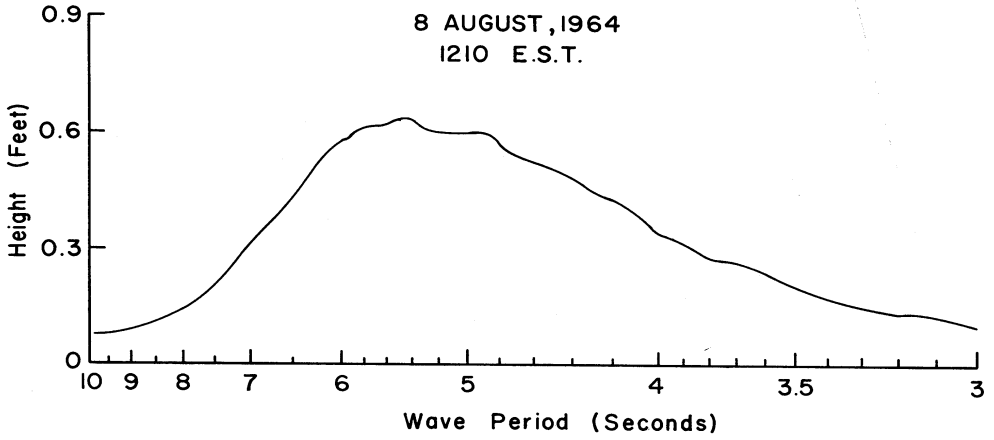
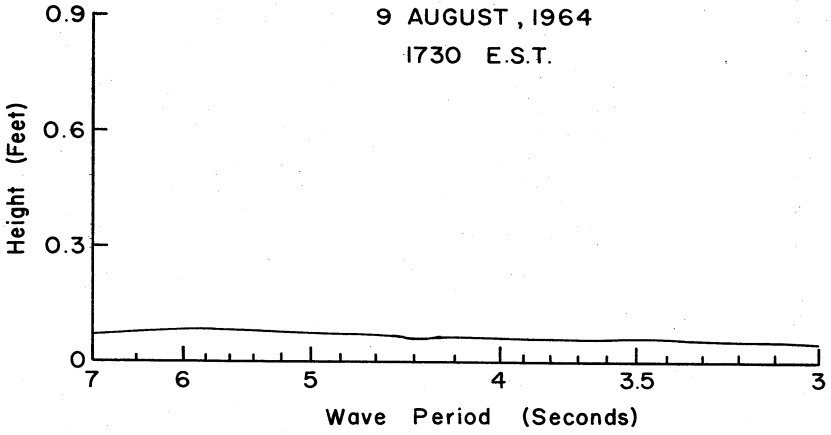
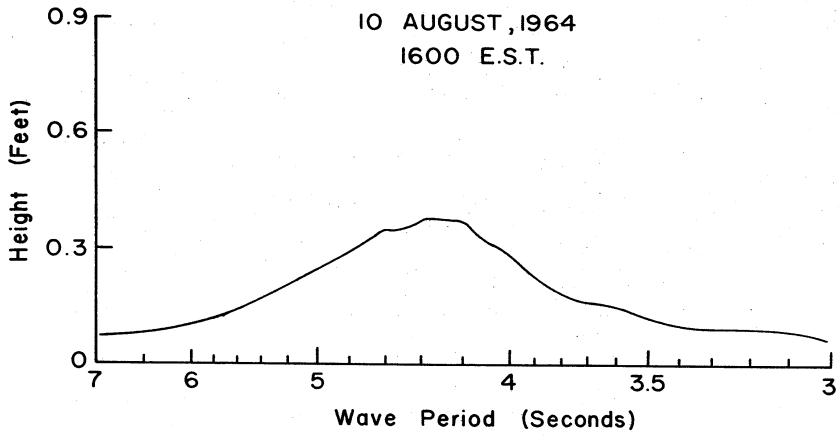
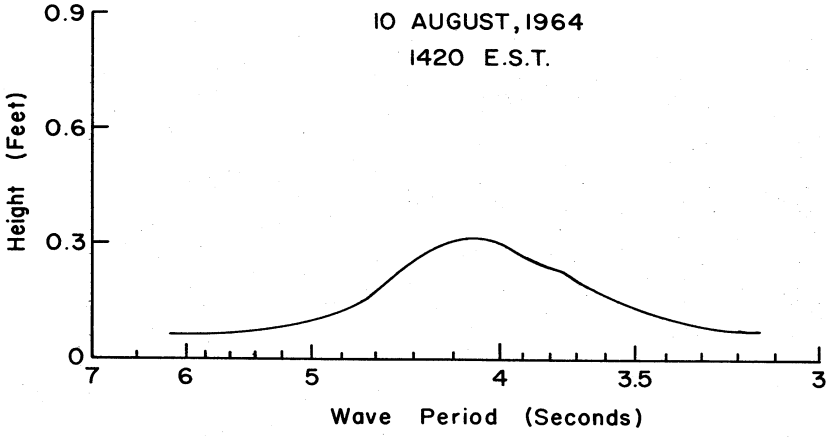


Figure 16. Wave height spectra, 8 August, 1964 (Concluded). (Courtesy U. S. Lake Survey)







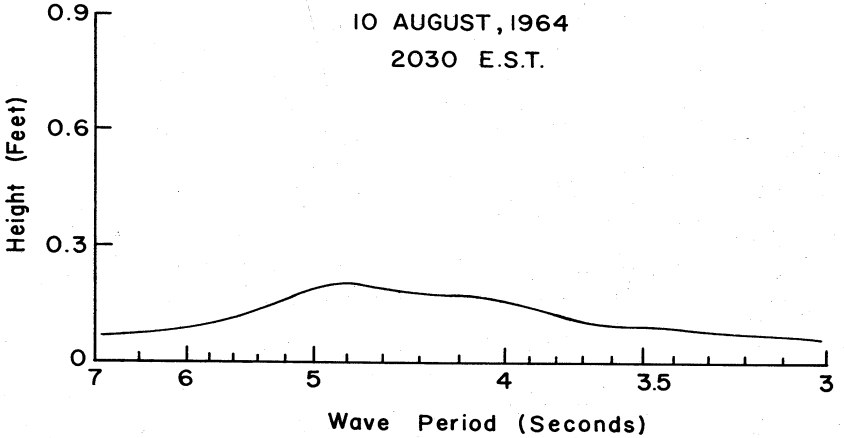


Figure 17. Wave height spectra, 9 and 10 August, 1964.
(Courtesy U. S. Lake Survey)

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of other persons and organizations who aided in the conduct of the research reported. The contribution of the U. S. Army Engineer District, Lake Survey and of other groups within the Corps of Engineers in erection and maintenance of the tower was essential to the program. The assistance of personnel from those organizations, the U. S. Weather Bureau, and the U. S. Public Health Service is gratefully acknowledged.

The effort of others within the Department of Meteorology and Oceanography is recognized. Program direction was provided by Professor Donald J. Portman. Edward Ryznar and Larry McMillin helped in collection and reduction of the data. H. K. Soo and John Casey aided in design and construction of the instrumentation. Mrs. Lenwood Paddock typed the report, and assisted in other aspects of its preparation.

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APPENDIX A

1. Telemetering and Recording System

The automatic telemetering and data recording system designed for recording data from the research tower facility has been described in functional form in a previous report (Elder, 1963). The schematic diagrams of the electronic components were not available for inclusion in that report. They are, therefore, included in this Appendix. The diagrams are largely self-explanatory and require only brief elaboration.

Figure A1 is a photograph of the recorder and telemetering system. The record logic, magnetic tape recorder, and manual read-out counter are shown as the unit at the left of the photograph. The telemetering system is shown on the right.

1.1 Telemetering System

Figures A2 and A2a are schematic drawings of the electronic components of the telemetering system. The power supplies, temperature bridges and data commutator system are also shown.

Figure A2 is the wiring diagram of the sensor input circuits and data commutator. PC-1 through PC-18 are input plugs for binary counters and digital to analog converters, K. J. Law Engineers, Model 407. One unit is required for each anemometer. The input signal is a pulse from the anemometer. Pulses are accumulated and an analog voltage proportional to the accumulated count is provided for the telemetering system. The counter is reset upon read-out. Schematic diagrams of the Model 407 counters and digital to analog converter are not shown. The units are available commercially.

P-2 through P-21 accommodate bridge circuits for measurement of up to 20 temperature values. P-7 through P-11 are designed for use with VECO-type 32A84 thermistors. Linearization of thermistor output is accomplished by the resistor network mounted on the range switch. Position 1 provides linearization for the range -10 to 10°C; position 2, for 0 to 20°C; and position 3, for 10 to 30°C. P-2 through P-6, and P-12 through P-21 are designed for use with Honeywell Model 921A3, Nickel A resistance thermometers, or Honeywell Dew Probe, Model SSP129D. The output of these sensors is essentially linear so that no further linearization is provided.

APPENDIX A

A typical plug-in bridge circuit is shown. Provision is made for adjustment of bridge balance from about -10 to 10°C, and for adjustment of range to 20°C. The values of components shown will match approximately the sensor elements specified above. Minor adjustments may be required to match individual element calibration. Switches S-2 through S-21 provide means to adjust bridge calibration. When in the calibrate position, the sensor element is replaced by the calibrate resistor. If the temperature-resistance relationship of the sensor is known, the appropriate value can be set on the calibrate resistor and the bridge adjusted for range or balance.

The outputs of the digital to analog converters and bridges are adjusted to a full scale value of 20 Mv. These output voltages plus the direct output of the wind vane potentiometer are applied to successive channels of the commutator switch S-24. The commutator consists of 36 gold-plated, magnetically-operated, reed switches. Three channels are required for logic control functions, leaving 33 channels for data inputs.

Figure A2a is the schematic wiring diagram of the commutator logic and telemetering system. Logic components are shown in conventional symbols and commercially available modules are identified.

The commutator drive logic may operate in one of two modes. In the manual mode, the commutator steps one channel at each actuation of the manual advance switch. This function is controlled either at the tower or at shore. The automatic mode is controlled by the timing motor. Every two minutes the logic is actuated and causes the commutator to advance through an entire cycle at the rate of 15 steps per second.

The commutator switches the analog voltages successively into the voltage-controlled oscillator, Vidar Model 260A, which functions as a telemetering transmitter. A signal varying from 0 to 30 Kcs in proportion to the applied voltage is transmitted to shore through the cable driver and submarine coaxial cable.

1.2 Digital Recording System

Figure A3 and Figure A3a are logic diagrams of the automatic digital recording system. Conventional logic symbols have been used. Schematic circuit drawings are not included because the logic components are standard, and may be obtained from commercial sources.

APPENDIX A

The series of incoming pulse trains from the tower telemetering system is received by the shore recording system. After amplification and squaring, the pulses are applied simultaneously to a) an integrator-discriminator and switching control logic, b) a twelve-bit binary counter, and c) a decimal display counter.

The first 66 millisecond pulse train of the incoming series is the control signal which the discriminator senses. The discriminator output signal actuates the counter and recorder logic circuits. Thereafter, successive 33 millisecond portions of the 66 millisecond pulse trains are counted, converted to twelve-bit binary words and recorded on magnetic tape. The 35th pulse train contains a second control signal that turns off the binary counter and record logic. Synchronization between the telemetering and recording systems is based on the 60-cycle line power with some phase shift adjustment provided in the recording system.

As stated above, the telemetering system commutation rate is 15 points per second, or 66 milliseconds per point. Thus, the signal from each sensor is of 66 millisecond duration. The binary counter is allowed to count between the 15th and 48th millisecond of each incoming pulse train. The counter output is a twelve-bit binary work which is recorded in the IBM format during the remaining 18 milliseconds of the data point period. The counter is then reset and is ready to count the pulse train from the following data point. Because of the direct proportionality of the voltage-to-frequency conversion in the telemetering system, the pulse count is a direct measure of the value of the input variable.

Manual inspection of the data for calibration and system performance checks is made possible by the use of the decimal counter having a visual display. Switch S1 selects the data channel for display as identified by the indicator lights. Data from the channel selected is gated to the counter where frequency of the signal is displayed in cycles per second. This frequency is directly convertible into magnitude of the variable measured. Display of this value continues until the next commutator scan at which time a new measure of the same variable will be displayed or that of another channel, if selected. The visual display may be employed as a data monitor while recording continues, or may be used as a display for system calibration with the manual commutator advance.

Both the telemetering and data recording systems were designed and constructed by K. J. Law Engineers, Detroit, Michigan. More complete details of component specifications may be requested from them.

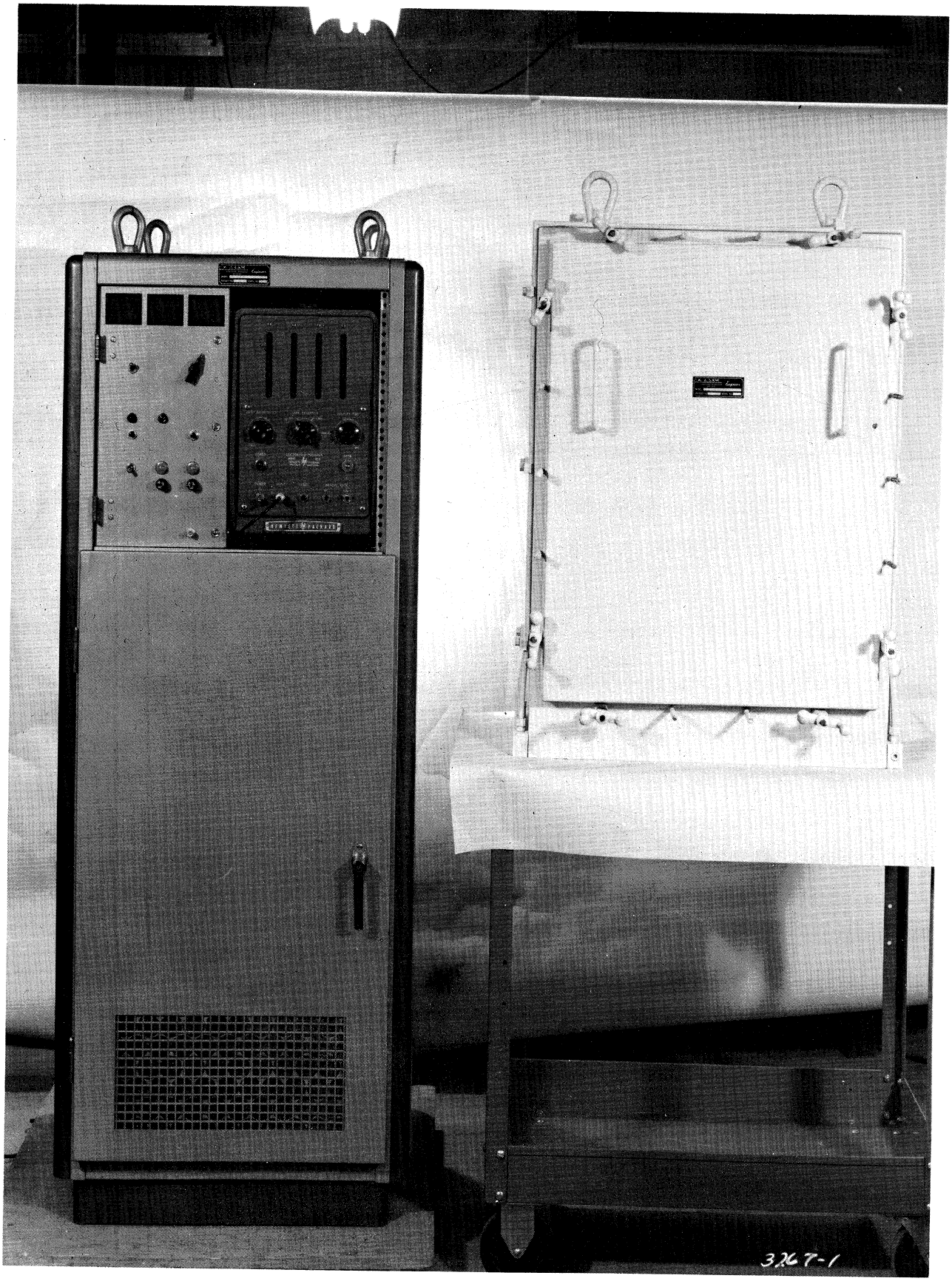

Figure A1. Telemetering and digital recording system.