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NWC TP 4824
Part 1
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THERMAL EXPOSURE OF AMMUNITION ON BOARD SHIP

Part 1. CRUISERS AND LARGE DESTROYERS

by

Sakaye Matsuda and Howard C. Schafer
Propulsion Development Department

ABSTRACT. The magazine air temperature records from CAG, CA, DDG, DLG, and DLG(N) type ships have been statistically analyzed to obtain the probable thermal exposure to be found on these type ships. The information is divided into the temperature expectancies for the 03, 02, 01, 1, 2, 3, 4, 5, and 6 deck levels as applicable. Effort has been made to eliminate information from compartments influenced by the engine room. This report includes 71,016 data points from the six ships. The ships were all assigned to the 7th Fleet in this time frame.

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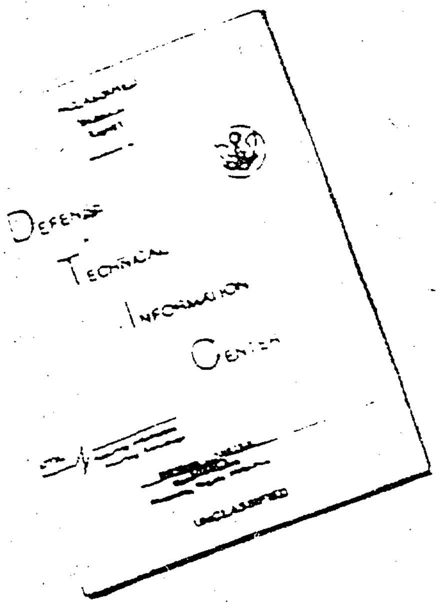

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M. R. Etheridge, CAPT, USN . . . . Commander
H. G. Wilson . . . . Technical Director (Acting)

FOREWORD

This effort has been undertaken to determine the valid shipboard environment of ammunition and was supported by the Naval Ordnance Systems Command, CHAFFROC Program, Allotment 17X1810.1718 (36700) OPN.

Part 1, Cruisers and Large Destroyers, covers the probable thermal exposure to be found on these types of ships.

Additional publications covering probable thermal exposure on DD type, ammunition, and other naval ships are anticipated. The shipboard magazine air temperature records are being collected at NWC, China Lake and will be statistically analyzed when funding becomes available.

This report has been reviewed for technical accuracy by Warren W. Oshel.

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The authors are also indebted to Lt. Comdr. J. W. Allen of NWC for his assistance in coordinating direct liaison with the USS ST. PAUL, USS LYNDE McCORMICK and USS BAINBRIDGE. He also provided pertinent information and the Booklet of General Plans of the ships. The explanation of deck levels and magazine compartment identifications he provided placed the data into meaningful context.

Acknowledgments are extended to Lt. McMurray of USS ST. PAUL, Lt. J. A. Dail of USS BAINBRIDGE, and Ens. H. O. Buzhardt, Jr. of USS LYNDE McCormick for the efficient guidance they provided to the author on board their respective ships.

Special acknowledgment is made to Mrs. Georgia Wagner who has generated, via computer and its peripheral equipment, the pertinent statistics and graphs presented in this report.

CONTENTS

INTRODUCTION

When designing a ship-launched weapon, it is important to know the environmental temperature range that the weapon will experience during storage and operation. It became evident early in the Shipboard Chaff Rocket Decoy System (Chaffroc) program that the thermal regime as it pertains to shipboard storage and use was not defined.

The Naval Weapons Center (NWC), China Lake, California was aware that the Fleet had been required to record the maximum and minimum air temperatures in each magazine on board every ship in all Fleets for years. The question was, how could these records be obtained, and how far back did they exist? On investigation, it was learned that the requirement was strictly for safety. The records had to be retained on board the ship for one to two years, and then were destroyed. NWC instigated a request that, instead of destroying these records, they be sent to a central collection point at NWC for use. In 1967 Chief of Naval Operations instructed all Fleet elements to send their obsolete magazine temperature records to China Lake, California. In an effort to define the maximum temperature environment in which the Chaff Rocket will be stored and fired, some of these records are herein reported.

At present 169 ships from the First, Second, Sixth, and Seventh Fleets are responding to the request for magazine temperature records. It was decided that the information from the cruisers and newer destroyers would be used in the pilot program and reported in Part 1 of this series. Eventually all ship classes will be divided into logical study units and similar reports detailing the storage temperatures for each group prepared.

It is realized that the information necessary for a complete definition of the extreme circumstances is not available. For example, the exact position of the ship, day by day, is not available to the authors. Therefore, it is possible that even with the masses of data presented, a chance exposure to less moderate temperatures could be experienced. Also, the authors have no control over ship deployment, nor the personnel actually recording the individual temperature readings. All the authors can do and have done, is to investigate the sources of error inherent in the existing collection system and compensate for them. For example, it became obvious that the measuring instrument, a "horseshoe" thermometer equipped with maximum and minimum temperature "tattletales," could be affected by ship vibration. If mounted on a resonating bulkhead, the vibration can shake the tattletales back down to the menisci of the mercury. This is evidenced in the records by identical maximum and minimum temperature entries for an interval of several days.

The lack of information on ship location for a given day should not invalidate the data obtained since a correlation was made during the investigation of the service temperature of the ASROC missile (Ref. 1 and 2). It consisted of comparing the recorded sea water temperature with the minimum recorded ASROC motor temperature for the same day and the results indicated that they were within a few degrees of each other. Therefore, since it is known that the data were from ships assigned to the Seventh Fleet when deployed, and the Seventh Fleet's area of interest is the Western Pacific, then given the month and minimum compartment temperatures a good guess of where the ship was located can be made. It was also indicated in Ref. 1 and 2 that the Western Pacific area could be the warmest area in which our ships will be required to deploy. The time frame of the reported data encompasses a period when the scene of action for the candidate ships was between 9 and 20° North latitude in the South China Sea. Based on these factors, it was decided that these data, though admittedly incomplete and imperfect, would be of extreme value in determining the environmental temperature criteria to which a majority of ship-launched ordnance will be exposed. This work is the basis of the maximum temperature entries under Shipboard Storage, Handling, At-Sea-Transfer, and Launch-to-Target as reported in Ref. 3, "Stockpile-to-Target Sequence for the Chaff Rocket."

SCOPE

The information reported herein applies only to ammunition and pyrotechnics stored in conventional compartments and above-deck lockers. The majority of these shipboard ammunition lockers have a double roof which is extremely effective in negating the maximum effect of solar radiation. If a special above-deck locker is designed and fabricated, then it is possible that these corresponding reported values could change. However, it appears that the values reported are generally consistent; even though the ready-service, pyrotechnic-grenade, and fuse lockers mounted above deck come in assorted shapes and sizes. Therefore, these data should provide a good indication of what to expect in any new storage locker, within reason.

These data, in all probability, are also useful in delineating the base line of exposure for electronic gear mounted on shipboard. However, it must be realized that electronics are heat-generating in nature; therefore, the maximum component temperatures will be higher than the magazine air temperatures.

INSTRUMENTATION

The maximum and minimum temperature data of the shipboard magazines were obtained from the horseshoe-type mercury thermometers equipped with floating steel tattletale devices (Fig. 1).

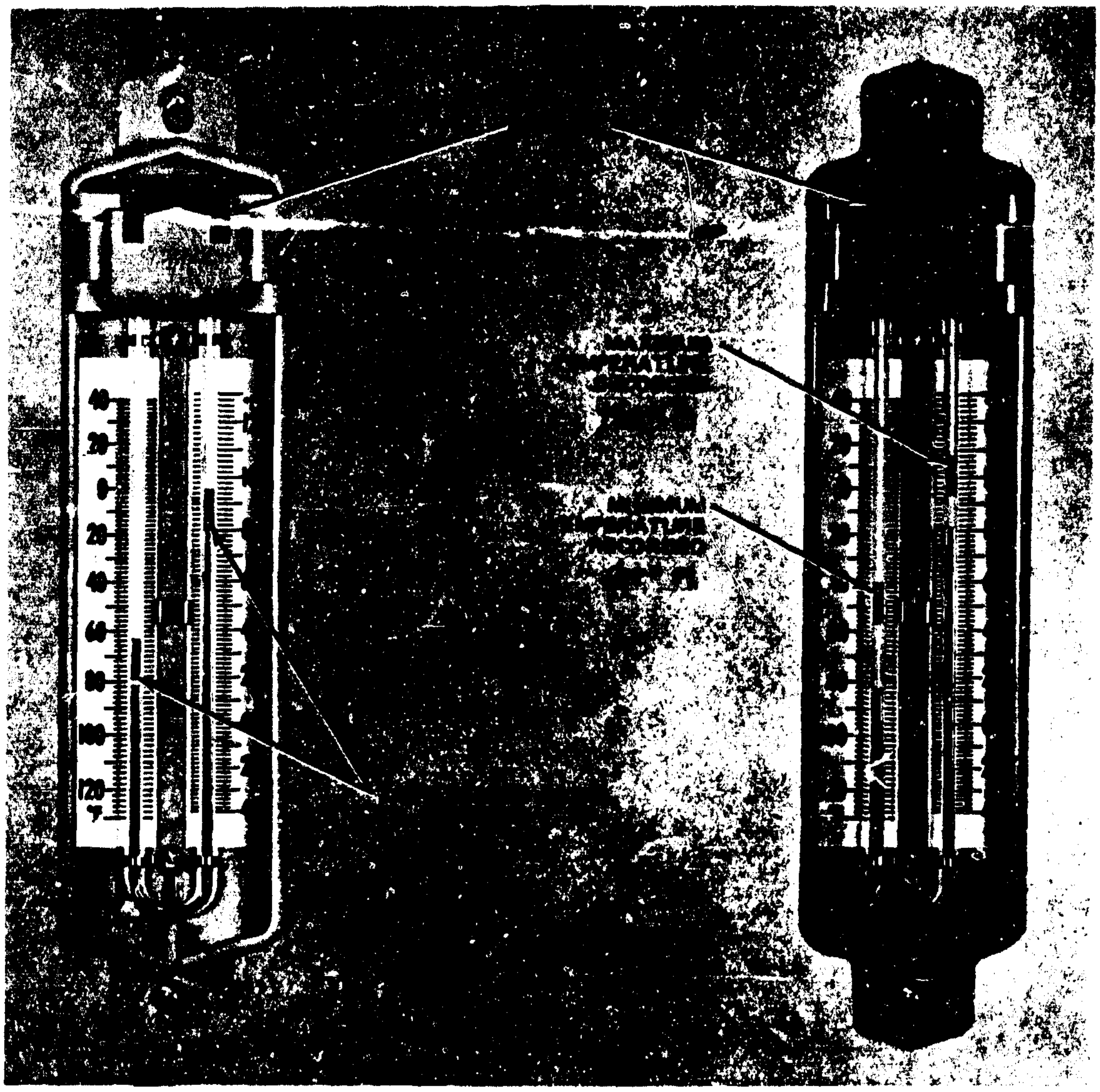


FIG. 1. Horseshoe-Type Thermometer.

The tattletale devices rest on the menisci of the mercury and are moved only in the upward direction. When a meniscus moves in the downward direction it leaves the tattletale at the departure point indicating the maximum or the minimum temperature for the measurement period. The tattletales are reset to rest on the menisci with a magnet after recording the maximum and the minimum temperatures.

The manufacturers of the thermometers (Taylor, Weksler, and Moeller) warrant that the temperature readings are accurate to within 2°F at the time of delivery. These thermometers are generally mounted on the bulkhead of the ship or laid on top of the ordnance within the locker.

PROCEDURES

The raw data were received from USS BOSTON (CAG1), USS ST. PAUL (CA73), USS LYNDE McCORMICK (DDG8), USS GRIDLEY (DLG21), USS ENGLAND (DLG22), and USS BAINBRIDGE (DLG(N)25) in various forms. In some cases, they were on individual sheets gathered together in an envelope. Some ships sent the individual monthly magazine temperature record cards (COMCRUDESPAC-GEN-8020/3), one for each magazine or locker on the ship per month. Figure 2 illustrates the condition of the data in general when received by NWC.

The candidate ships were selected on the basis of their submitted temperature records, area of deployment, and class. Their records were then processed, as detailed in Appendix A, by the Analysis Branch, Propulsion Development Department at NWC.

The raw data were reduced, tabulated, and plotted to yield meaningful statistics and significant points of interest for upper and lower deck levels of each ship.

The physical construction of the typical above-deck ammunition storage locker is shown in Fig. 3. As can be seen, the locker usually has a double roof and some have double sides as well. Access to these above-deck lockers can either be from a hinged top, or side. In general, the thermometer and temperature record card are placed on top of the stored ammunition or pyrotechnics. Therefore, if the locker is full, the measuring instrument is near the top of the locker and if nearly empty, the thermometer is close to the bottom. There is a distinct thermal gradient in any enclosed space. The nearer to the top a measurement is taken, the more extreme it will be since hot air rises.

The situation below decks is much more stable and predictable. The thermometer and record card are secured to a bulkhead in the magazine. This dual installation is usually about 4 feet above the floor of the compartment. The thermal gradient in a compartment is not as severe as

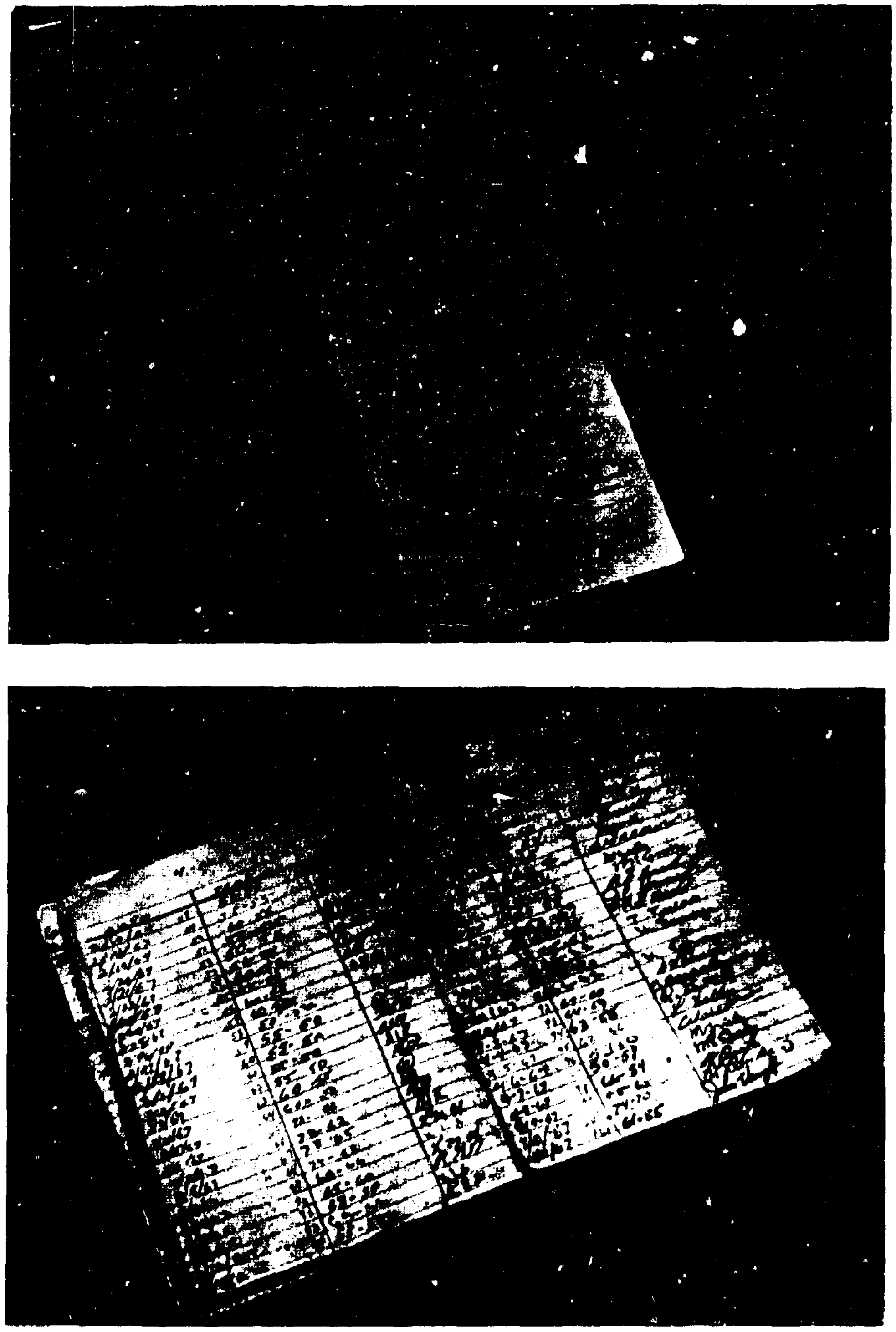


FIG. 2. Raw Data on Card and Log Book.

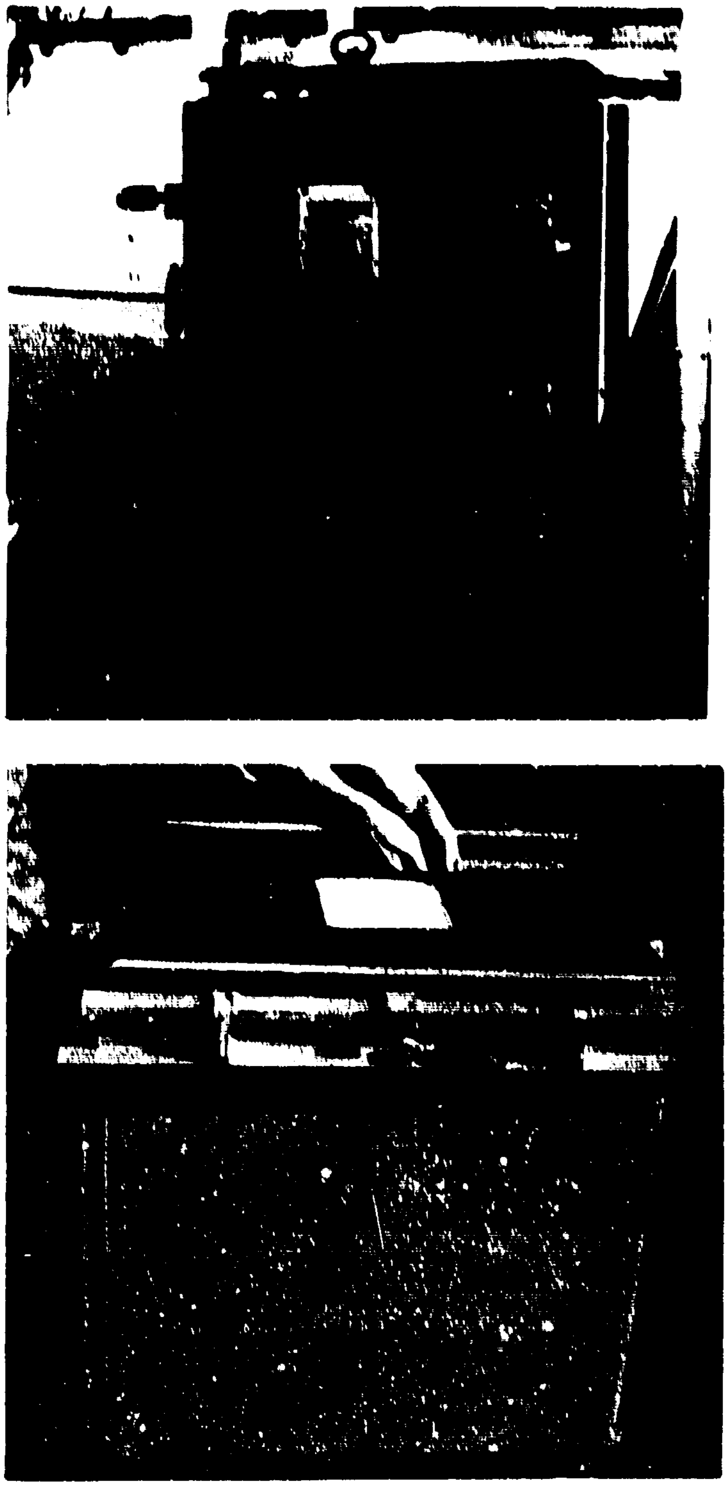


FIG. 3. Upper Deck Level Storage Lockers.

in an exposed locker. Also, on all post World War II ships, the magazines are below the waterline. Usually the only facilities for ammunition above the waterline in a ship are intermediary handling rooms for gun ammunition. Figure 4 depicts a typical below-deck storage situation.

FIG. 4. Lower Deck Level Storage Magazine.

RESULTS

The ship magazine data were grouped into upper and lower deck level data. The upper deck level data include all data from magazines located on the main deck (1 level) through all deck levels above the main deck. The lower deck level data include all data from magazines located below main deck level. An explanation of deck levels and magazine compartment identifications is given in Appendix B.

The ship identification, the year, the number of months, and the number of temperature data recorded for upper and lower deck levels are listed in Tables 1 and 2, respectively. The maximum temperature data were sorted into logical groups. The plan was to show the number of temperature readings less than or equal to 75 through 120°F at 5° increments for both levels per year per ship. The maximum temperature for the given period is also listed.

TABLE 1. DATA SUMMARY BY SHIPS - UPPER LEVELS

SHIPS	YRS.	MOS.[a]	N[b]	No. of maximum temperatures less than or equal to (°F) 75	80	85	90	95	100	105	110	115	120	Max. Temp. °F
CA 73	1966	11	3656	1409	460	713	791	259	24	0	0	0	0	98
DLG 21	1963	5	131	90	65	16	9	1	0	0	0	0	0	92
" "	1964	8	901	217	177	108	150	132	93	20	4	0	0	110
" "	1966	4	466	108	139	60	138	14	12	0	0	0	0	100
" "	1967	6	856	467	215	64	86	15	8	1	0	0	0	101
DDG 8	1961	4	538	250	151	54	80	1	2	0	0	0	0	98
" "	1962	8	827	438	187	102	71	4	25	0	0	0	0	98
" "	1963	12	2131	1057	458	205	249	96	45	11	9	1	0	112
" "	1964	1	36	25	11	0	0	0	0	0	0	0	0	80
DLG (N) 25	1963	8	1519	497	386	233	189	97	102	12	3	0	0	108
" "	1964	12	1902	690	373	286	321	159	73	0	0	0	0	100
" "	1965	11	1588	281	235	249	395	223	196	9	0	0	0	104
" "	1966	11	1748	253	233	329	318	217	344	42	9	3	0	113
CAG 1	1964	12	2904	1643	532	433	291	2	3	0	0	0	0	96
" "	1965	9	3085	2020	565	289	209	2	0	0	0	0	0	93
" "	1966	8	5158	3790	649	370	290	30	24	5	0	0	0	104
" "	1967	7	3050	368	668	751	789	301	164	8	1	0	0	106
SUMMATION		137	30496	13553	5499	4262	4376	1553	1115	108	26	4	0	

[a]Month - Number of months in a given period.

[b]Number of data points represented in the sample.

TABLE 2. DATA SUMMARY BY SHIPS - LOWER LEVELS

SHIPS	YRS.	MOS[a]	N[b]	No. of maximum temperatures less than or equal to (°F) 75	80	85	90	95	100	105	110	115	120	Max. Temp. °F
CA 73	1966	11	8018	4100	1646	1505	1351	406	16	0	0	0	0	99
DLG21	1963	6	1107	656	209	126	73	3	0	0	0	0	0	94
" "	1964	10	2317	934	787	393	186	9	8	0	0	0	0	98
" "	1966	4	682	443	163	64	12	0	0	0	0	0	0	88
" "	1967	6	1470	981	407	62	20	0	0	0	0	0	0	88
DLC22	1964	1	86	82	4	0	0	0	0	0	0	0	0	80
" "	1965	11	925	749	109	27	0	0	0	0	0	0	0	84
" "	1966	11	731	560	103	28	0	0	0	0	0	0	0	85
DDG8	1961	4	838	564	151	59	64	0	0	0	0	0	0	90
" "	1962	10	1851	1320	425	88	15	1	2	0	0	0	0	97
" "	1963	12	2485	1393	609	350	113	19	1	0	0	0	0	96
" "	1964	1	41	40	1									78
DLG (N) 25	1963	7	1287	898	242	127	19	1	0	0	0	0	0	94
" "	1964	12	2824	1951	629	208	36	0	0	0	0	0	0	88
" "	1965	11	2137	1093	542	375	120	7	0	0	0	0	0	94
" "	1966	11	1823	1035	351	357	78	2	0	0	0	0	0	97
CAG1	1963	6	319	319	0	0	0	0	0	0	0	0	0	75
" "	1964	12	730	697	25	8	0	0	0	0	0	0	0	85
" "	1965	12	2949	1716	840	324	66	3	0	0	0	0	0	94
" "	1966	8	4200	2712	787	379	280	40	2	0	0	0	0	98
" "	1967	7	3776	1091	404	930	1041	283	26	1	0	0	0	102
SUMMATION		173	40520	22378	8444	5450	3478	714	55	1	0	0	0	

[a]Month - Number of months in a given period.

[b]Number of data points represented in the sample.

The data presented in Tables 1 and 2 show variations in temperatures from ship-to-ship, upper deck level to lower deck level, and within the ship. Some of these differences can be attributed to the differences in the locations of the ships, and the magazine air temperatures being directly affected by solar radiation, sea water, etc.

The selected and combined data from all upper level magazines of the six ships are presented in Table 3. This set of data represents the monthly average temperature ($\bar{X}$) and its estimated standard deviation ($\hat{\sigma}$) multiplied by 3 ($3\hat{\sigma}$) added to the average temperature ($\bar{X} + 3\hat{\sigma}$). Data points showing the largest $\bar{X} + 3\hat{\sigma}$ variation in Table 3 were selected and combined to yield the plot on Fig. 5.

Similarly, the data were selected from the lower deck level magazines and processed to give the selected and combined data plots for the lower deck level (Table 4).

The monthly average temperature and the average temperature plus $3\hat{\sigma}$ value for upper and lower deck levels of each ship are presented in Fig. 6 through 8.

The histograms of the frequency distribution of the temperature readings of all data, from both upper and lower deck level magazines, with respect to the indicated temperature interval are shown in Fig. 9.

The histograms of the percentage distribution of the above frequency data with respect to the indicated temperature interval are shown in Fig. 10.

All temperature data available from the six ships were consolidated and grouped by month, upper and lower levels separately. The mean temperature ($\bar{X}$), maximum temperature (MAX), average temperature of the highest 10 temperatures recorded ($\bar{X}_{TOP\ 10}$) and the number of data samples (N) were determined for each group and presented in Fig. 11 and 12. The data were also grouped together and the mean temperature ($\bar{X}_G$), maximum temperature (MAX_{ALL}), average temperature of the highest 10 temperatures recorded ($\bar{\bar{X}}_{TOP\ 10}$), and the total number of data samples (N_{TOTAL}) were determined; these are listed in the Total column. The graphs presented in Fig. 11 and 12 show the mean temperature ($\bar{X}$) plot (solid points) and the average temperature of the highest 10 temperatures recorded ($\bar{X}_{TOP\ 10}$) plot (circled points) for the data group.

The data which support Tables 1 through 4 and the plots of Fig. 5 through 12 are available in permanent file at the Analysis Branch office. Sample copies of these data are presented in Appendix C.

Official U. S. Navy photographs of USS ST. PAUL, USS GRIDLEY, USS ENGLAND, USS LYNDE McCORMICK, USS BAINBRIDGE and USS BOSTON are presented in Appendix D.

TABLE 3. MONTHLY MEAN AND STANDARD DEVIATION DATA - UPPER LEVEL.

SHIPS	MOS.	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	MAX. TEMP.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	JAN	1962	125	75.8	11.72	98	35.16	110.96
DDG 8	JAN	1963	186	72.6	6.58	83	19.74	92.34
DLG(N) 25	JAN	1963	14	66.4	10.83	80	32.49	98.89
DDG 8	JAN	1964	36	11.2	6.37	80	19.11	90.31
DLG(N) 25	JAN	1964	334	67.0	12.64	100	37.92	104.92
CAG 1	JAN	1964	31	62.6	2.70	68	8.10	82.10
DLG 21	JAN	1964	4	74.0	3.74	79	11.22	85.22
DLG(N) 25	JAN	1965	155	76.2	12.32	98	36.96	113.16
CAG 1	JAN	1965	84	79.0	11.08	90	33.24	112.24
DLG(N) 25	JAN	1966	185	86.1	9.61	99	28.83	114.93
CAG 1	JAN	1966	793	64.2	8.13	86	24.39	88.59
CAG 1	JAN	1967	521	82.3	8.20	104	24.60	106.90
DLG 21	JAN	1967	154	74.4	9.17	98	27.51	101.91
DDG 8	FEB	1962	35	66.9	18.93	97	56.79	123.69
DDG 8	FEB	1963	168	55.5	7.80	76	23.40	78.90
DLG(N) 25	FEB	1964	154	75.5	13.85	100	41.55	117.05
CAG 1	FEB	1964	29	65.7	4.86	74	14.58	80.28
DLG(N) 25	FEB	1965	140	79.3	9.36	96	28.08	107.38
CAG 1	FEB	1965	174	78.2	6.32	90	18.96	97.16
DLG(N) 25	FEB	1966	166	88.9	8.16	99	24.48	113.38
CAG 1	FEB	1966	713	69.8	7.69	90	23.07	92.87
CA 73	FEB	1966	162	66.6	7.17	88	21.51	88.11
CAG 1	FEB	1967	29	60.0	7.44	72	22.32	82.32
DLG 21	FEB	1967	135	75.8	8.65	90	25.95	101.75
DDG 8	MAR	1962	15	78.1	2.07	80	6.21	84.31
DDG 8	MAR	1963	186	67.1	17.79	94	53.37	120.47
DLG(N) 25	MAR	1964	142	80.7	8.48	98	25.44	106.14
CAG 1	MAR	1964	31	64.0	3.09	70	9.27	73.27
DLG(N) 25	MAR	1965	124	77.0	9.38	92	28.14	105.14
CAG 1	MAR	1965	98	70.5	8.88	87	26.64	97.14
DLG(N) 25	MAR	1966	178	89.7	8.15	99	24.45	114.15
CAG 1	MAR	1966	848	68.1	11.48	88	34.44	102.54
CA 73	MAR	1966	279	68.8	6.77	84	20.31	89.11
CAG 1	MAR	1967	368	79.2	6.53	101	19.59	98.79
DLG 21	MAR	1967	155	73.4	5.84	88	17.52	90.92

TABLE 3. (CONTINUED)

SHIPS	MOS.	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	MAX. TEMP.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	APR	1963	174	82.9	4.75	92	14.25	97.15
DLG(N) 25	APR	1963	312	75.5	4.88	98	14.64	90.14
DLG(N) 25	APR	1964	62	77.9	8.57	98	25.71	103.61
CAG 1	APR	1964	186	67.1	8.97	88	26.91	94.01
DLG 21	APR	1964	88	79.6	9.94	97	29.82	109.42
DLG(N) 25	APR	1965	148	76.9	10.01	96	30.03	106.93
DLG(N) 25	APR	1966	160	91.7	8.21	113	24.63	116.33
CAG 1	APR	1966	765	56.4	9.37	85	28.11	84.51
CA 73	APR	1966	270	69.5	6.30	84	18.90	88.40
CAG 1	APR	1967	741	81.2	6.45	104	19.35	100.55
DLG 21	APR	1967	150	78.6	8.75	101	26.25	104.85
DDG 8	MAY	1963	174	83.6	11.24	103	33.72	117.32
DLG(N) 25	MAY	1963	299	79.9	4.95	94	14.85	94.75
DLG(N) 25	MAY	1964	153	80.8	4.51	90	13.53	94.33
CAG 1	MAY	1964	84	76.0	8.21	96	24.63	100.63
DLG 21	MAY	1964	124	76.0	10.28	99	30.84	106.84
DLG(N) 25	MAY	1965	153	88.2	6.06	88	18.18	106.38
DLG(N) 25	MAY	1966	186	92.8	8.41	110	25.23	118.03
CAG 1	MAY	1966	750	68.7	12.99	98	38.97	107.67
CA 73	MAY	1966	270	69.6	5.57	84	16.71	86.31
CAG 1	MAY	1967	819	87.6	6.22	106	18.66	106.26
DLG 21	MAY	1967	152	71.4	11.52	94	34.56	105.96
DDG 8	JUN	1963	177	70.1	12.62	84	37.86	107.96
DLG(N) 25	JUN	1963	305	82.7	8.06	97	24.18	106.88
DLG(N) 25	JUN	1964	150	86.9	5.50	98	16.50	103.40
CAG 1	JUN	1964	188	71.1	8.19	89	24.57	95.67
DLG 21	JUN	1964	111	78.7	7.61	99	22.83	101.53
DLG(N) 25	JUN	1965	128	88.0	6.17	101	18.51	106.51
DLG(N) 25	JUN	1966	180	85.4	10.50	108	31.50	116.90
CAG 1	JUN	1966	352	73.6	9.77	94	29.31	102.91
CA 73	JUN	1966	459	87.2	4.84	97	14.52	101.72
CAG 1	JUN	1967	546	86.1	6.20	100	18.60	104.70
DLG 21	JUN	1967	110	73.0	6.83	94	20.49	93.49

TABLE 3. (CONTINUED)

SHIPS	MOS.	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	MAX. TEMP.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	JUL	1962	21	79.6	6.26	86	18.78	98.38
DDG 8	JUL	1963	185	80.6	10.24	112	30.72	111.32
DLG(N) 25	JUL	1963	155	87.5	7.32	100	21.96	109.48
DLG 21	JUL	1963	20	74.0	6.86	88	20.58	94.58
DLG(N) 25	JUL	1964	155	88.4	5.79	98	17.37	105.77
CAG 1	JUL	1964	317	80.8	6.52	90	19.56	100.36
DLG 21	JUL	1964	123	90.4	9.53	110	28.59	118.99
DLG(N) 25	JUL	1965	143	91.7	6.60	102	19.80	111.50
CAG 1	JUL	1965	268	70.7	8.85	93	26.55	97.25
DLG(N) 25	JUL	1966	185	81.6	6.88	94	20.64	102.24
CAG 1	JUL	1966	26	79.9	9.68	98	29.04	108.04
DLG 21	JUL	1966	10	76.2	3.63	82	10.89	87.09
CA 73	JUL	1966	423	86.4	4.56	96	13.68	100.08
CAG 1	JUL	1967	45	80.4	4.88	86	14.64	95.04
DDG 8	AUG	1963	183	76.7	9.62	90	28.86	105.56
DLG(N) 25	AUG	1963	161	93.0	7.57	108	22.71	115.71
DLG 21	AUG	1963	31	78.8	5.16	86	15.48	94.28
DLG(N) 25	AUG	1964	155	85.0	6.85	96	20.55	105.55
CAG 1	AUG	1964	434	81.8	6.05	89	18.15	99.95
DLG 21	AUG	1964	120	90.2	6.35	100	19.05	109.25
CAG 1	AUG	1965	163	78.9	10.81	92	32.43	111.33
DLG(N) 25	AUG	1966	186	87.1	8.47	100	25.41	112.51
CA 73	AUG	1966	430	86.1	4.21	98	12.63	98.73
DDG 8	SEP	1961	116	83.4	5.67	98	17.01	100.41
DDG 8	SEP	1962	85	79.9	6.27	92	18.81	98.71
DDG 8	SEP	1963	176	83.8	9.19	109	27.57	111.37
DLG(N) 25	SEP	1963	20	84.8	7.24	97	21.72	106.52
DLG 21	SEP	1963	30	78.8	6.01	92	18.03	96.83
DLG(N) 25	SEP	1964	150	72.7	10.71	96	32.13	104.83
CAG 1	SEP	1964	406	78.4	6.76	89	20.28	98.68
DLG 21	SEP	1964	89	88.7	6.51	99	19.53	108.23
DLG(N) 25	SEP	1965	75	88.9	8.65	104	25.95	114.85
CAG 1	SEP	1965	197	78.3	5.83	89	17.49	95.79
DLG(N) 25	SEP	1966	54	89.0	4.51	97	13.53	102.53
CA 73	SEP	1966	376	86.0	4.27	96	12.81	98.81

TABLE 3. (CONTINUED)

SHIPS	MOS.	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	MAX. TEMP.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	OCT	1961	124	78.8	6.38	90	19.14	97.94
DDG 8	OCT	1962	186	78.0	5.59	98	16.77	94.77
DDG 8	OCT	1963	167	75.0	7.62	90	22.86	97.86
DLG 21	OCT	1963	46	76.9	3.82	86	11.46	88.36
DLG(N) 25	OCT	1964	155	78.0	9.01	96	27.03	105.03
CAG 1	OCT	1964	434	74.0	6.97	88	20.91	94.91
DLG 21	OCT	1964	120	85.1	8.47	97	25.41	110.51
DLG(N) 25	OCT	1965	186	83.9	7.93	99	23.79	107.69
CAG 1	OCT	1965	521	76.2	7.16	89	21.48	97.68
DLG(N) 25	OCT	1966	103	79.9	8.73	98	26.19	106.09
DLG 21	OCT	1966	125	82.0	8.90	100	26.70	108.70
CA 73	OCT	1966	374	82.6	6.32	97	18.96	101.56
DDG 8	NOV	1961	176	72.9	6.95	90	20.85	93.75
DDG 8	NOV	1962	174	75.0	8.53	97	25.59	100.59
DDG 8	NOV	1963	179	67.8	7.92	84	23.76	91.56
DLG 21	NOV	1963	4	75.8	5.19	79	15.57	91.37
DLG(N) 25	NOV	1964	144	81.2	8.43	98	25.29	106.49
CAG 1	NOV	1964	419	67.9	6.30	86	18.90	86.80
DLG 21	NOV	1964	73	71.8	8.86	86	26.58	98.38
DLG(N) 25	NOV	1965	150	88.1	8.24	99	24.72	112.82
CAG 1	NOV	1965	640	68.5	7.58	88	22.74	91.24
DLG(N) 25	NOV	1966	166	77.2	8.65	97	25.95	103.1[illegible]
CAG 1	NOV	1966	162	61.8	10.40	83	31.20	93.00
DLG 21	NOV	1966	150	76.0	7.74	88	23.22	99.22
CA 73	NOV	1966	312	69.0	6.91	88	20.73	89.73
DDG 8	DEC	1961	122	70.6	6.42	86	19.26	89.86
DDG 8	DEC	1962	186	53.7	11.26	86	33.78	87.48
DDG 8	DEC	1963	179	69.3	8.17	88	24.51	93.81
DLG(N) 25	DEC	1963	253	58.8	13.11	94	39.33	98.13
DLG(N) 25	DEC	1964	148	71.4	10.95	86	32.85	104.25
CAG 1	DEC	1964	345	64.4	8.95	88	26.85	91.25
DLG(N) 25	DEC	1965	186	88.3	7.55	99	22.65	110.95
CAG 1	DEC	1965	940	68.1	6.97	90	20.91	89.01
CAG 1	DEC	1966	775	75.4	13.73	104	41.19	116.59
DLG 21	DEC	1966	181	83.8	6.04	100	18.12	101.92
CA 73	DEC	1966	301	66.5	7.07	84	21.21	87.71

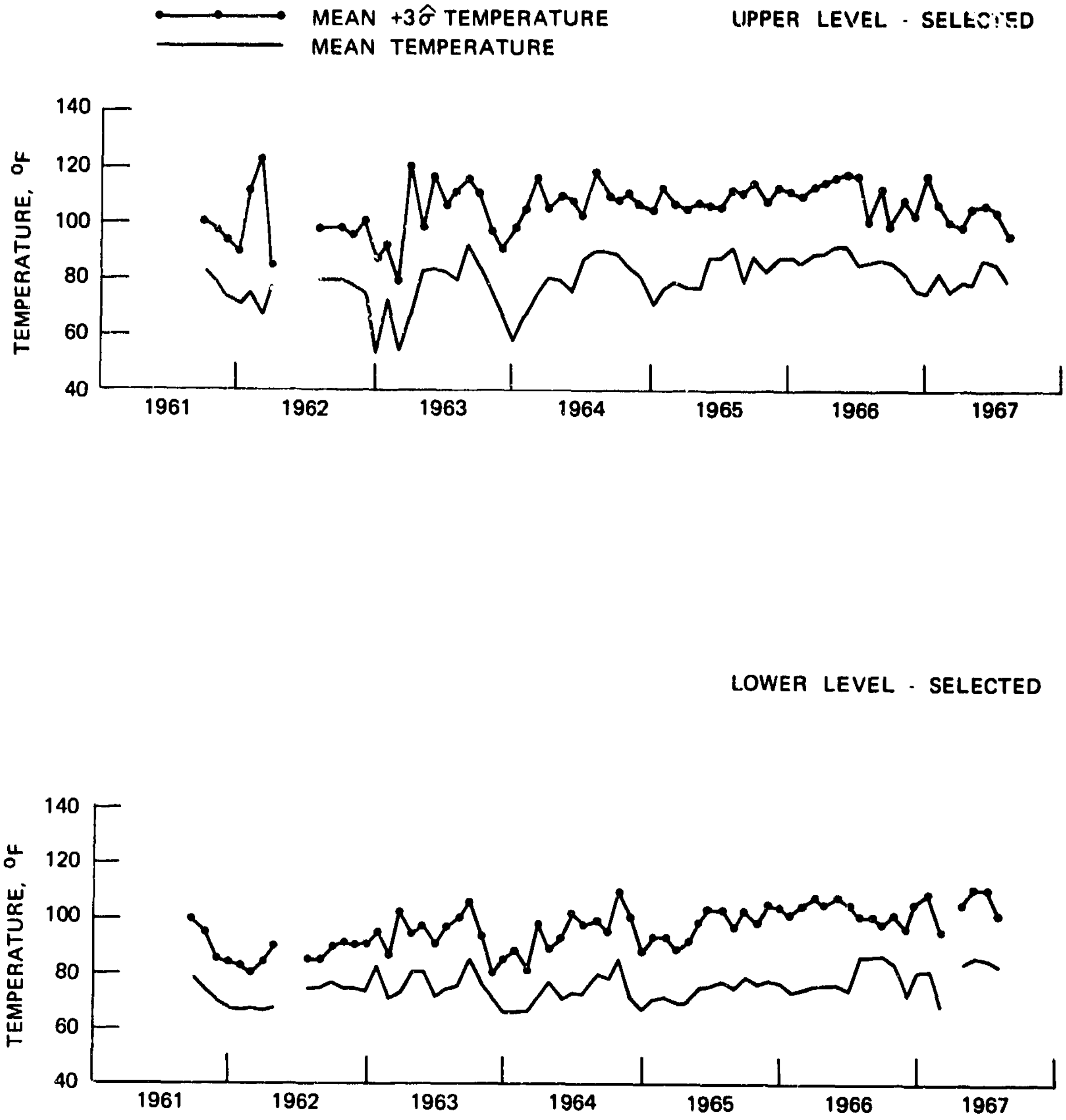


FIG. 5. Plots of Mean and Mean +3σ̂ Temperature Data, Selected and Combined.

TABLE 4. MONTHLY MEAN AND STANDARD DEVIATION DATA-LOWER LEVEL.

SHIPS	MONTH	YEAR	N	MEAN $\overline{X}$	$\hat{\sigma}$	Max. Temp.	$3\hat{\sigma}$	$\overline{X} + 3\hat{\sigma}$
DDG 8	JAN	1962	217	66.7	5.22	84	15.66	82.36
DDG 8	JAN	1963	217	82.7	3.96	92	11.88	94.58
DDG 8	JAN	1964	41	67.9	3.40	78	10.20	72.10
DLG 21	JAN	1964	43	72.3	4.98	84	14.69	86.99
DLG(N) 25	JAN	1964	213	66.4	7.35	85	22.05	88.45
CAG 1	JAN	1964	62	62.7	2.43	68	7.29	69.99
DLG 22	JAN	1965	115	69.8	3.42	80	10.26	80.06
DLG(N) 25	JAN	1965	216	70.4	7.69	88	23.07	93.47
CAG 1	JAN	1965	62	59.1	3.82	68	11.50	70.60
DLG 22	JAN	1966	60	72.7	1.95	77	5.85	78.55
DLG(N) 25	JAN	1966	186	73.6	9.16	89	27.48	101.08
CAG 1	JAN	1966	651	72.9	5.74	89	17.22	90.12
DLG 21	JAN	1967	248	72.5	5.66	88	16.98	89.48
CAG 1	JAN	1967	756	81.0	9.00	96	27.00	108.00
DDG 8	FEB	1962	154	66.6	4.51	83	13.53	80.13
DDG 8	FEB	1963	196	70.9	5.29	85	15.87	86.77
DLG(N) 25	FEB	1964	203	69.7	8.65	90	25.95	95.65
CAG 1	FEB	1964	58	66.1	5.17	75	15.51	81.11
DLG 22	FEB	1965	57	76.0	3.32	80	9.96	85.96
DLG(N) 25	FEB	1965	191	70.8	7.28	85	21.84	92.64
CAG 1	FEB	1965	56	60.8	4.86	71	14.58	75.38
CA 73	FEB	1966	468	70.8	5.80	88	17.40	88.20
DLG 22	FEB	1966	56	71.2	1.71	76	5.13	76.33
DLG(N) 25	FEB	1966	168	73.8	10.15	88	30.45	104.25
CAG 1	FEB	1966	615	72.2	5.19	88	15.57	87.77
DLG 21	FEB	1967	214	71.7	6.67	86	20.01	91.71
CAG 1	FEB	1967	670	67.6	9.11	92	27.33	94.93
DDG 8	MAR	1962	155	65.9	6.16	81	18.48	84.38
DDG 8	MAR	1963	217	72.6	10.00	92	30.00	104.60
DLG(N) 25	MAR	1964	242	71.1	8.98	88	26.94	98.04
CAG 1	MAR	1964	62	64.2	3.37	75	10.11	74.31
DLG(N) 25	MAR	1965	215	69.1	6.46	85	19.38	88.48
CAG 1	MAR	1965	62	63.7	4.76	77	14.28	77.98
DLG 22	MAR	1965	124	72.9	3.81	82	11.43	84.33
DLG(N) 25	MAR	1966	186	75.8	10.53	96	31.59	107.39
CAG 1	MAR	1966	682	72.2	4.88	89	14.64	86.84
DLG 22	MAR	1966	93	70.8	3.00	80	9.00	79.80
CA 73	MAR	1966	805	72.1	5.80	87	17.40	89.50
DLG 21	MAR	1967	247	72.5	5.66	88	16.98	89.48
CAG 1	MAR	1967	679	77.9	9.69	94	29.01	106.91

TABLE 4. (CONTINUED)

SHIPS	MONTH	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	Max. Temp.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	APR	1962	200	67.5	7.35	89	22.05	89.55
DDG 8	APR	1963	210	80.9	4.61	96	13.83	94.73
DLG(N) 25	APR	1963	204	67.4	6.74	82	20.22	87.62
DLG(N) 25	APR	1964	2[illegible]6	67.9	6.68	81	20.04	87.94
CAG 1	APR	1964	60	66.9	4.13	76	12.39	79.29
DLG 21	APR	1964	218	76.6	4.17	95	12.51	89.11
DLG 22	APR	1965	63	73.7	4.73	83	14.19	87.89
DLG(N) 25	APR	1965	207	69.1	7.35	86	22.05	91.15
CAG 1	APR	1965	60	60.2	2.75	67	8.25	68.45
DLG 22	APR	1966	89	71.3	5.75	76	17.25	88.55
DLG(N) 25	APR	1966	180	75.3	10.13	90	30.39	105.69
CAG 1	APR	1966	635	69.4	5.67	86	17.01	86.41
CA 73	APR	1966	780	74.1	5.70	99	17.10	91.20
CAG 1	APR	1967	656	83.4	7.25	96	21.75	105.15
DLG 21	APR	1967	241	72.4	6.54	88	19.62	92.02
DDG 8	MAY	1963	205	80.6	5.43	94	16.29	96.89
DLG(N) 25	MAY	1963	217	69.9	5.42	82	16.26	86.16
DLG(N) 25	MAY	1964	217	70.2	7.52	83	22.56	92.76
CAG 1	MAY	1964	62	69.1	3.27	75	9.81	78.91
DLG 21	MAY	1964	308	75.5	4.54	95	13.62	89.12
DLG 22	MAY	1965	124	68.6	2.48	74	7.44	76.04
DLG(N) 25	MAY	1965	202	74.5	8.07	89	24.21	98.71
CAG 1	MAY	1965	62	63.1	3.34	72	10.02	73.12
DLG 22	MAY	1966	91	72.3	1.77	76	5.31	77.61
DLG(N) 25	MAY	1966	181	75.7	10.50	89	31.50	107.20
CAG 1	MAY	1966	495	73.9	8.89	94	26.67	100.57
CA 73	MAY	1966	780	74.6	5.03	88	15.09	89.69
CAG 1	MAY	1967	498	85.9	8.25	102	24.75	110.65
DLG 21	MAY	1967	248	69.8	6.66	86	19.98	89.78
DDG 8	JUNE	1963	210	72.3	4.85	89	14.55	86.85
DLG(N) 25	JUNE	1963	210	70.8	6.41	94	19.23	90.03
DLG(N) 25	JUNE	1964	210	73.2	9.26	88	27.78	100.98
CAG 1	JUNE	1964	60	70.8	3.84	79	11.52	82.32
DLG 21	JUNE	1964	283	77.0	4.03	89	12.09	89.09
DLG 22	JUNE	1965	122	68.0	2.95	73	8.85	76.85
DLG(N) 25	JUNE	1965	206	75.8	9.00	90	27.00	102.80
CAG 1	JUNE	1965	60	66.1	4.27	76	12.81	78.91
DLG 22	JUNE	1966	85	70.3	4.82	82	14.46	84.76
DLG(N) 25	JUNE	1966	180	73.3	10.32	97	30.96	104.26
CAG 1	JUNE	1966	186	76.3	7.60	95	22.80	99.10
CA 73	JUNE	1966	775	84.9	5.35	97	16.05	100.95
CA 1	JUNE	1967	449	85.2	8.40	98	25.20	110.40
DLG 21	JUNE	1967	176	72.18	4.23	80	12.69	84.87

TABLE 4. (CONTINUED)

SHIPS	MONTH	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	Max. Temp.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	JULY	1962	171	74.0	3.83	91	11.49	85.49
DDG 8	JULY	1963	213	73.0	3.68	84	11.04	84.04
DLG (N) 25	JULY	1963	217	74.4	7.72	89	23.16	97.56
CAG 1	JULY	1963	14	67.2	3.04	71	9.12	76.32
DLG 21	JULY	1963	178	73.3	8.04	90	24.12	97.42
DLG (N) 25	JULY	1964	217	72.8	8.46	85	25.38	98.18
CAG 1	JULY	1964	62	71.2	5.73	84	17.19	88.39
DLG (N) 25	JULY	1965	173	76.4	9.05	89	27.15	103.55
CAG 1	JULY	1965	62	62.4	4.14	80	12.42	74.82
DLG 22	JULY	1966	40	75.9	4.82	82	14.46	90.36
DLG (N) 25	JULY	1966	183	67.0	8.51	83	25.53	92.53
DLG 21	JULY	1966	10	76.2	3.63	82	10.89	87.09
CA 73	JULY	1966	803	85.7	4.85	96	14.55	100.25
CAG 1	JULY	1967	82	82.0	6.33	89	18.99	100.99
DLG 21	JULY	1964	310	78.2	6.17	98	18.51	92.71
DDG 8	AUG	1962	203	74.0	3.84	90	11.52	85.52
DDG 8	AUG	1963	209	75.5	4.02	88	12.06	87.56
DLG (N) 25	AUG	1963	216	75.6	8.15	90	24.45	100.05
CAG 1	AUG	1963	62	65.2	2.52	74	7.56	72.76
DLG 21	AUG	1963	308	74.0	6.79	94	20.37	94.37
DLG (N) 25	AUG	1964	217	72.9	8.47	88	25.41	98.31
CAG 1	AUG	1964	62	67.8	4.13	79	12.39	80.19
DLG 21	AUG	1964	300	79.9	6.44	97	19.32	99.22
DLG 22	AUG	1965	48	74.1	7.56	84	22.68	96.78
CAG 1	AUG	1965	84	66.9	7.23	85	21.69	88.59
DLG (N) 25	AUG	1966	186	70.2	8.14	90	24.42	94.62
DLG 22	AUG	1966	55	74.7	5.02	84	15.06	89.76
CA 73	AUG	1966	806	86.0	4.69	98	14.07	100.07
DDG 8	SEP	1961	203	78.5	6.59	88	19.77	98.27
DDG 8	SEP	1962	121	76.5	4.45	88	13.35	89.85
DDG 8	SEP	1963	209	76.2	2.99	88	8.97	85.17
DLG (N) 25	SEP	1963	27	84.8	7.24	97	21.72	106.52
CAG 1	SEP	1963	60	67.0	2.91	75	8.73	75.73
DLG 21	SEP	1963	300	75.1	4.81	88	14.43	89.53
DLG (N) 25	SEP	1964	210	65.9	7.52	86	22.56	88.46
CAG 1	SEP	1964	58	65.7	4.17	75	12.51	78.21
DLG 21	SEP	1964	299	78.4	5.69	98	17.07	95.47
DLG (N) 25	SEP	1965	101	78.6	8.07	91	24.21	102.81
DLG 22	SEP	1965	60	71.9	7.56	84	22.68	94.58
CAG 1	SEP	1965	424	74.2	7.39	94	22.17	96.37
DLG (N) 25	SEP	1966	75	70.6	8.45	81	25.35	95.95
DLG 22	SEP	1966	60	70.8	6.92	80	20.76	91.56
CA 73	SEP	1966	781	86.1	3.87	97	11.61	97.71

TABLE 4. (CONTINUED)

SHIPS	MONTH	YEAR	N	MEAN $\bar{X}$	$\hat{\sigma}$	Max. Temp.	$3\hat{\sigma}$	$\bar{X} + 3\hat{\sigma}$
DDG 8	OCT	1961	215	73.8	6.95	90	20.85	94.65
DDG 8	OCT	1962	215	74.8	5.65	97	16.95	91.75
DDG 8	OCT	1963	180	82.5	3.05	82	9.15	91.65
CAG 1	OCT	1963	62	67.3	2.64	73	7.92	75.22
DLG 21	OCT	1963	271	76.1	6.11	91	18.33	94.43
DLG(N) 25	OCT	1964	215	69.8	8.24	86	24.72	94.52
CAG 1	OCT	1964	62	66.3	3.86	85	11.58	77.88
DLG 21	OCT	1964	295	85.1	8.47	97	25.41	110.51
DLG(N) 25	OCT	1965	216	75.9	7.34	94	22.02	97.92
DLG 22	OCT	1965	93	69.6	4.82	78	14.46	84.06
CAG 1	OCT	1965	647	75.9	6.12	87	18.36	94.26
DLG(N) 25	OCT	1966	136	69.6	6.91	82	20.73	90.33
DLG 22	OCT	1966	62	72.6	8.57	85	25.71	98.31
DLG 21	OCT	1966	200	70.1	5.83	84	17.49	87.59
CA 73	OCT	1966	741	83.6	5.60	98	16.80	100.40
DDG 8	NOV	1961	210	70.3	5.1	82	15.30	85.60
DDG 8	NOV	1962	203	74.0	5.5	88	16.50	90.50
DDG 8	NOV	1963	209	70.7	3.2	80	9.60	80.30
CAG 1	NOV	1963	60	67.0	3.9	75	11.70	78.70
DLG 21	NOV	1963	30	65.5	2.91	76	8.73	74.23
DLG(N) 25	NOV	1964	204	71.8	9.45	88	28.35	100.15
CAG 1	NOV	1964	60	66.6	3.45	80	10.35	76.95
DLG 21	NOV	1964	230	74.7	5.19	88	15.57	90.27
DLG(N) 25	NOV	1965	207	76.7	9.65	92	28.95	105.65
DLG 22	NOV	1965	60	69.3	3.37	74	10.11	79.41
CAG 1	NOV	1965	659	74.9	5.36	89	16.08	90.98
DLG(N) 25	NOV	1966	210	70.2	8.60	89	25.80	96.00
DLG 22	NOV	1966	40	72.5	7.88	81	23.64	96.14
CAG 1	NOV	1966	192	73.0	5.69	88	17.07	90.07
DLG 21	NOV	1966	240	70.3	5.95	86	17.85	88.15
CA 73	NOV	1966	758	73.2	5.07	88	15.66	88.86
DDG 8	DEC	1961	210	67.9	5.07	79	15.21	83.11
DDG 8	DEC	1962	211	73.9	5.48	90	16.44	90.34
DDG 8	DEC	1963	210	68.4	3.84	80	11.52	79.92
DLG(N) 25	DEC	1963	196	65.6	6.78	86	20.34	85.94
CAG 1	DEC	1963	61	61.9	3.32	70	9.96	71.86
DLG 21	DEC	1963	20	65.6	3.51	70	10.53	76.13
DLG(N) 25	DEC	1964	216	67.3	6.94	83	20.82	88.12
DLG 22	DEC	1964	86	67.7	4.74	80	14.22	81.92
CAG 1	DEC	1964	62	65.3	4.54	85	13.62	78.92
DLG 21	DEC	1964	31	66.9	1.46	69	4.38	71.28
DLG(N) 25	DEC	1965	203	75.9	9.25	91	27.75	103.65
DLG 22	DEC	1965	59	71.4	2.09	74	6.27	77.67
CAG 1	DEC	1965	649	75.7	5.50	91	16.50	92.20
CAG 1	DEC	1966	724	80.1	8.37	98	25.11	105.21
CA 73	DEC	1966	794	71.2	5.41	94	16.23	87.43
DLG 21	DEC	1966	238	75.9	6.21	88	18.63	94.53

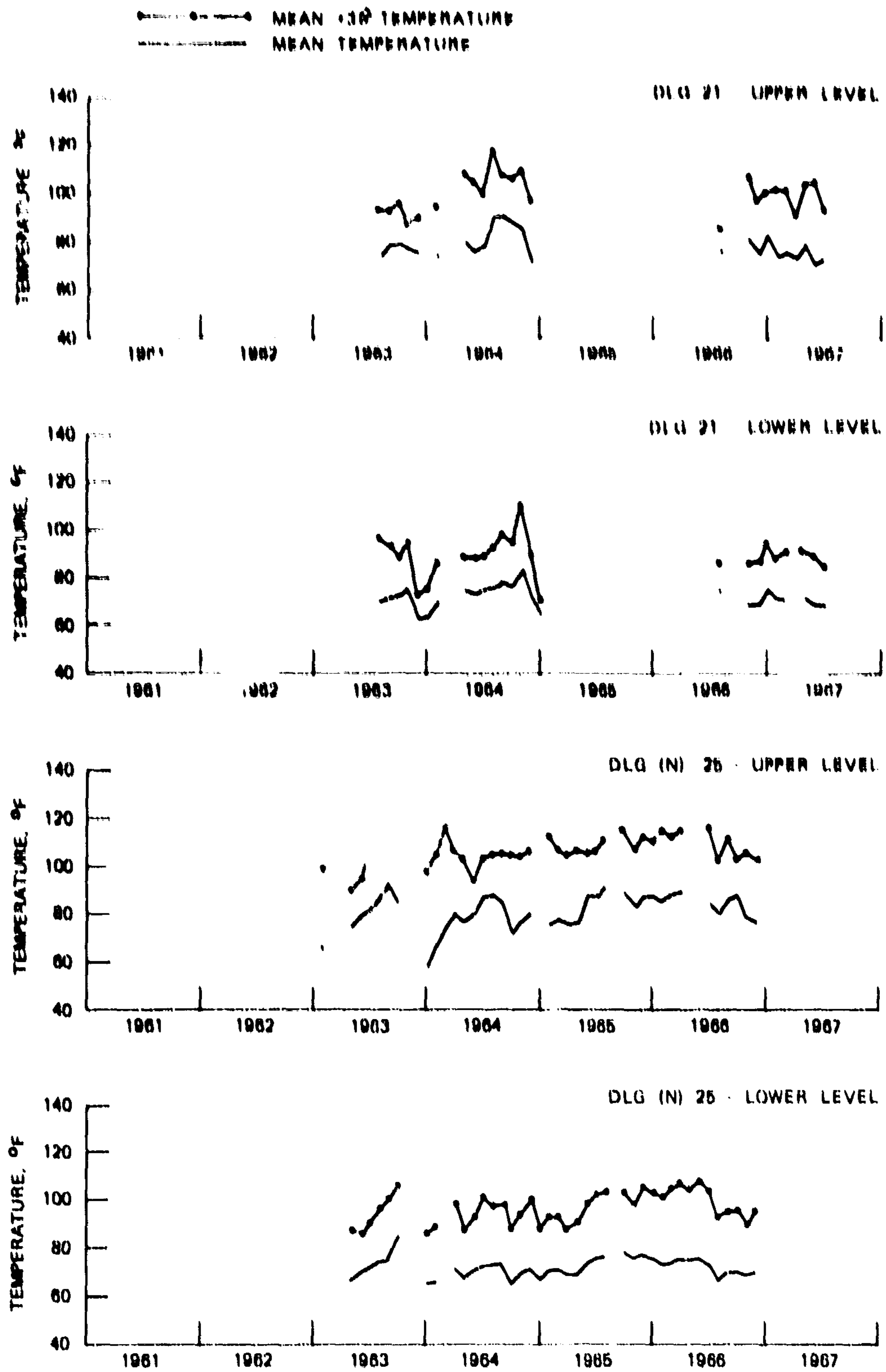


FIG. 6. Plots of Monthly Mean and Mean +3σ Temperature Data.

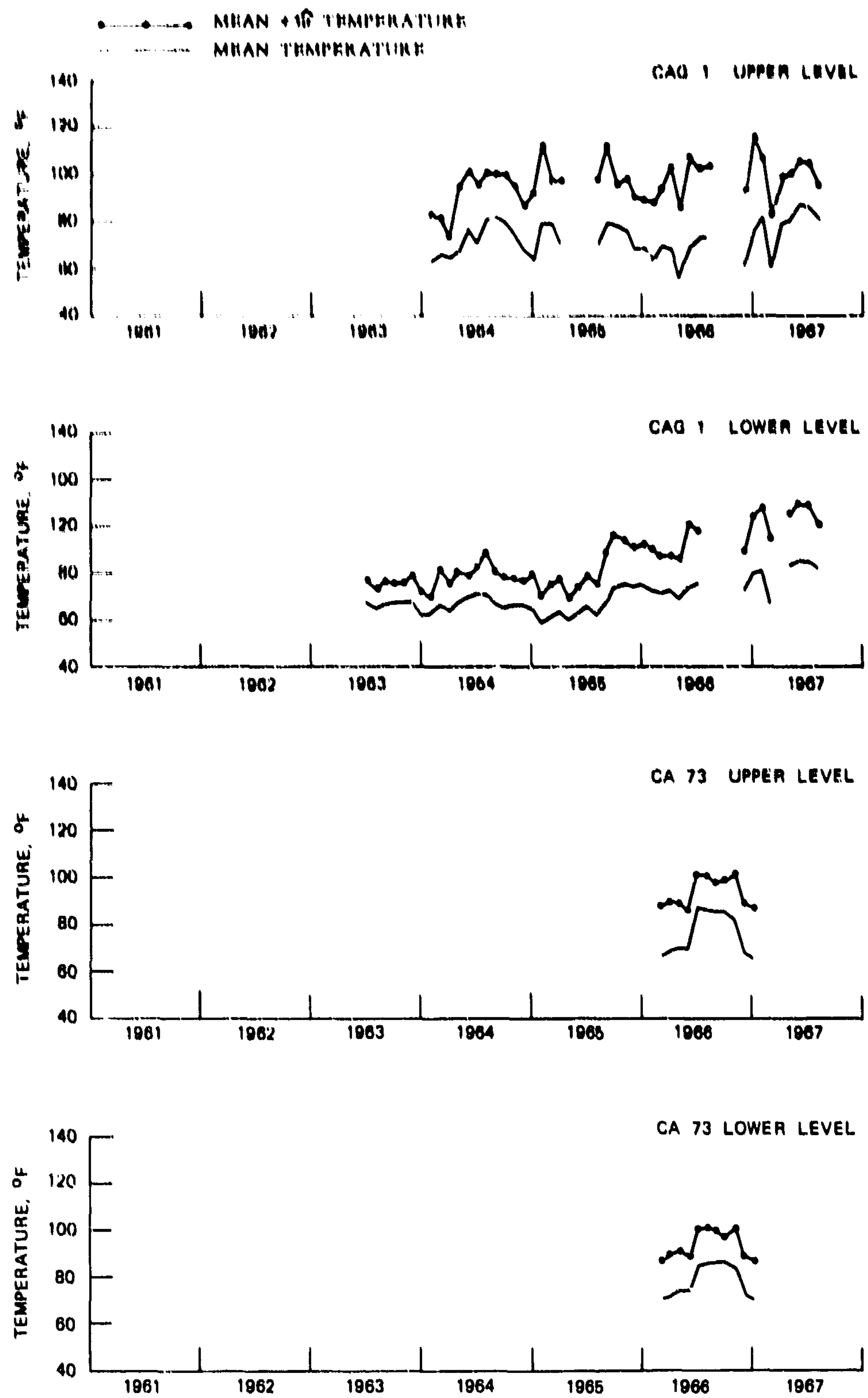


FIG. 7. Plots of Monthly Mean and Mean +3σ̂ Temperature Data.

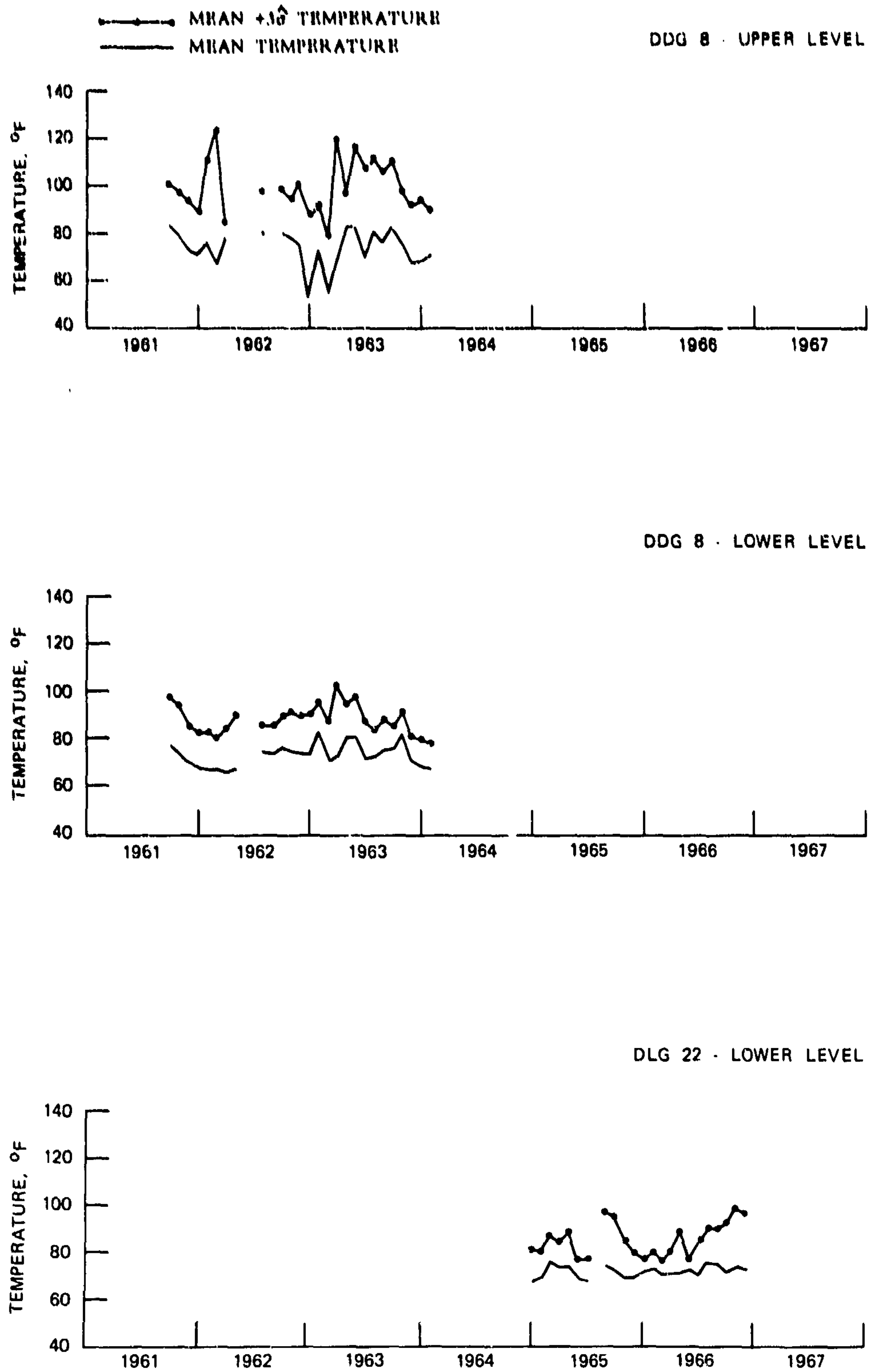


FIG. 8. Plots of Monthly Mean and Mean +3σ̂ Temperature Data.

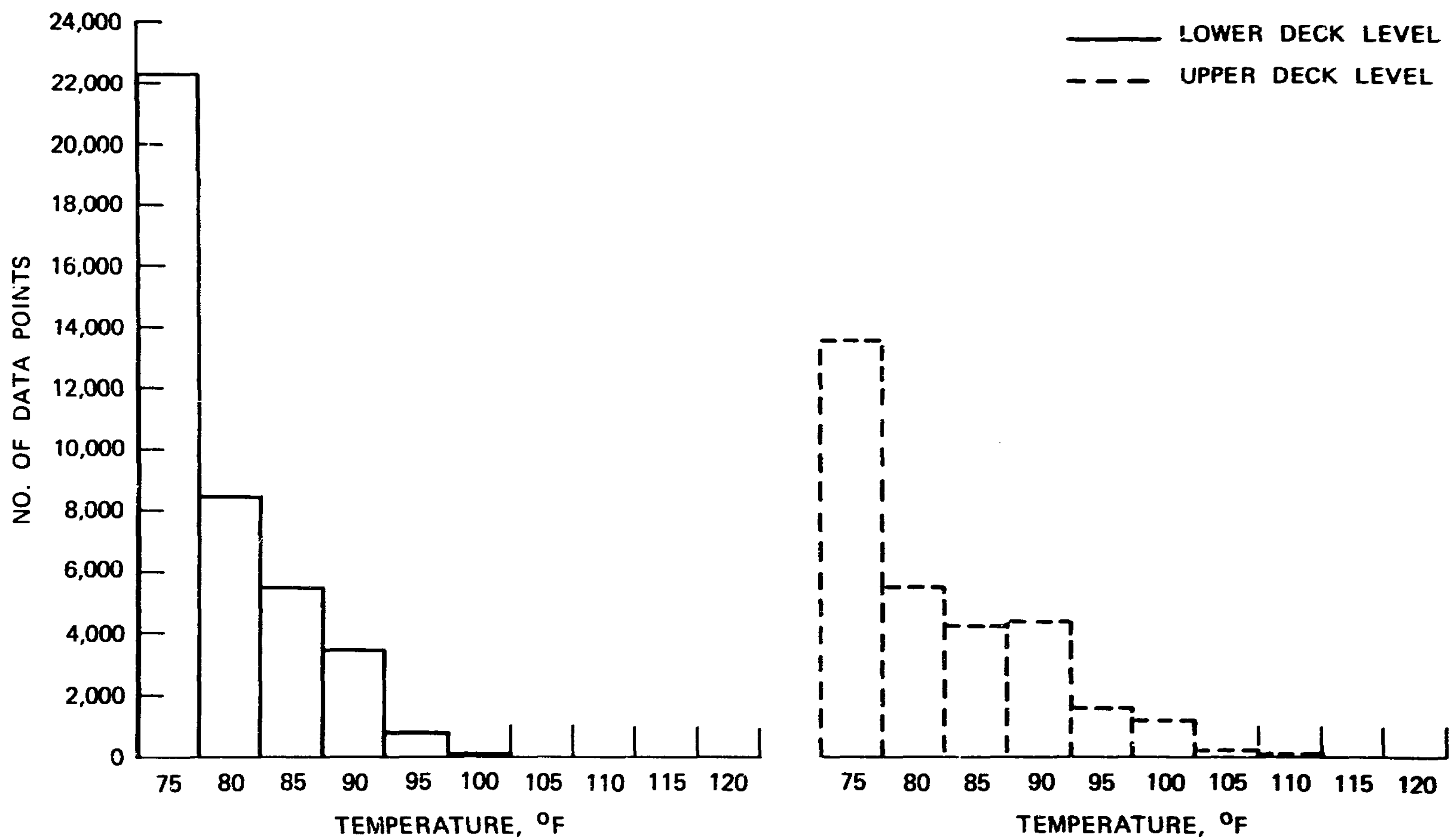


FIG. 9. Histograms of Temperature Frequencies for Upper and Lower Deck Levels.

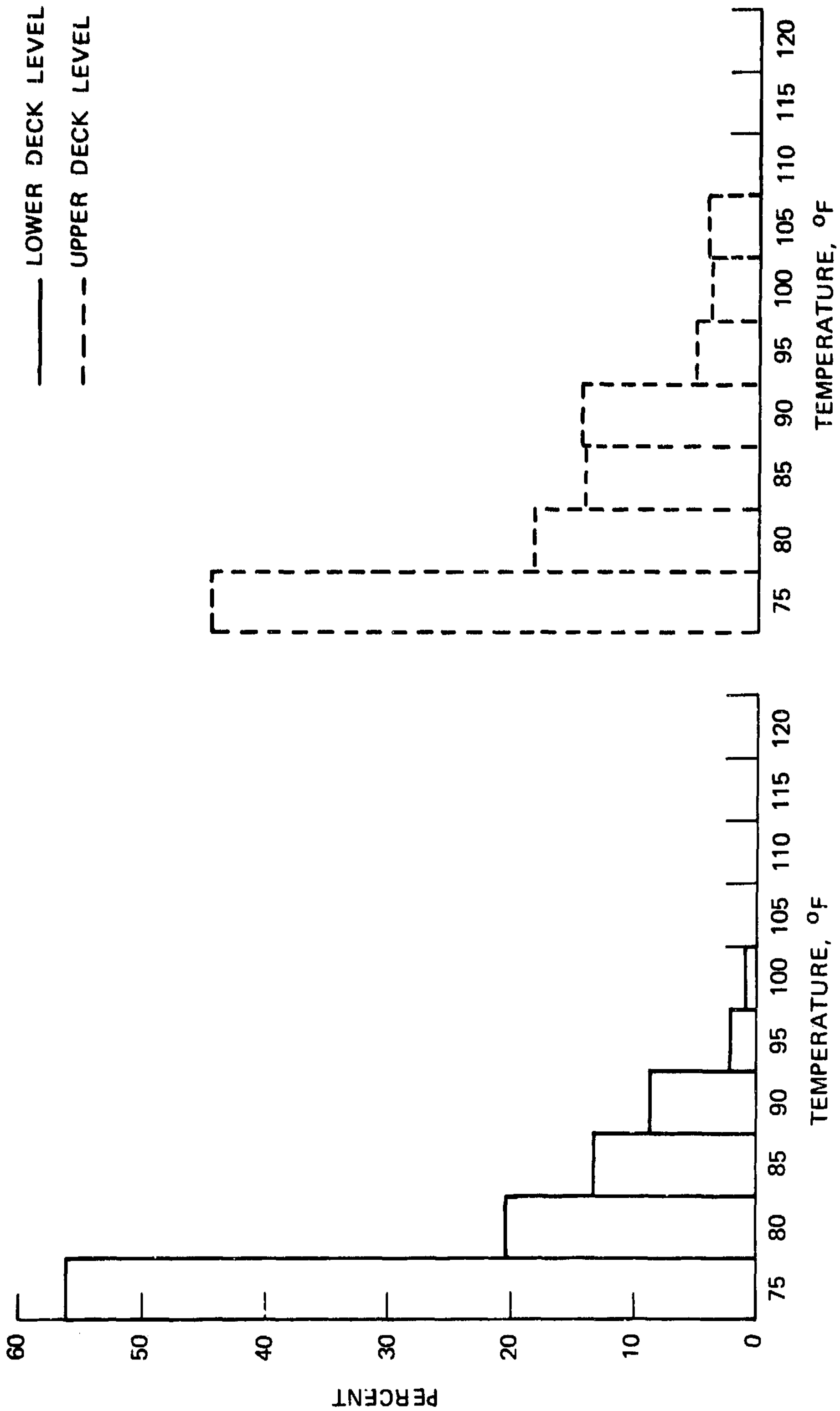
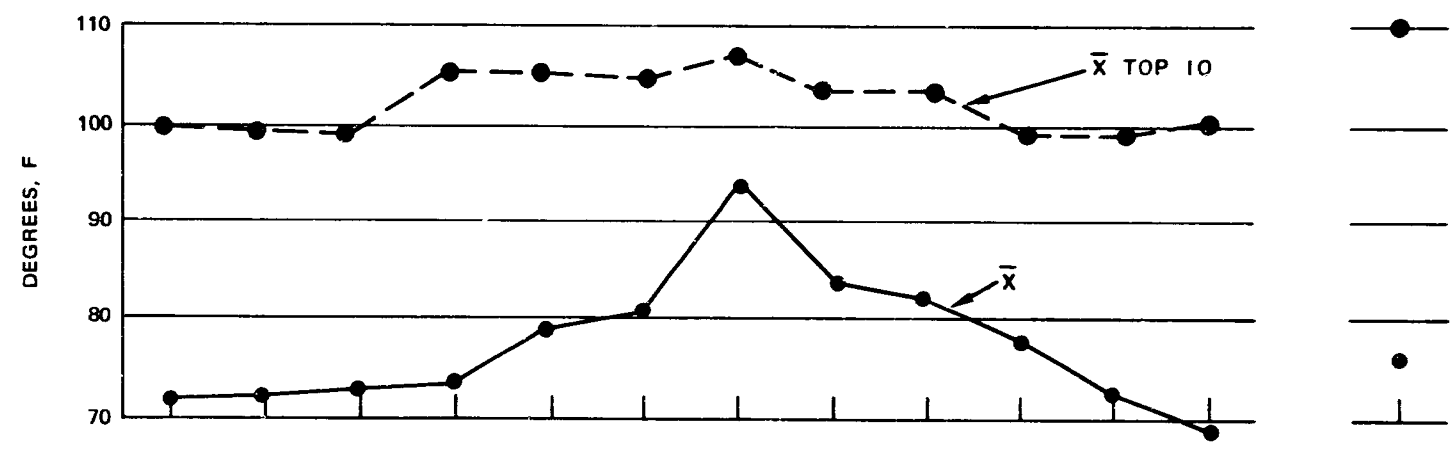


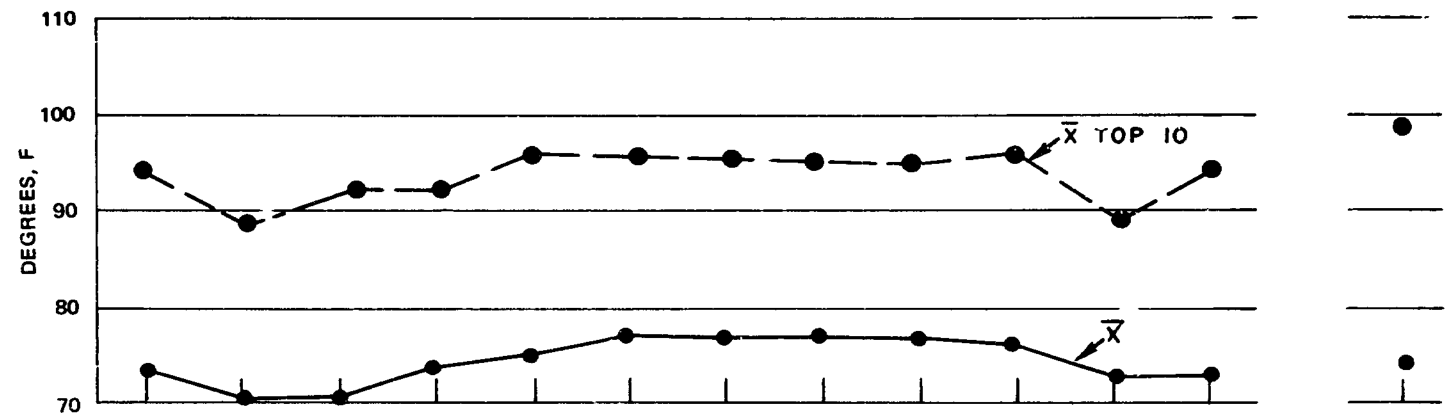
FIG. 10. Histograms of Percentages of Temperature Frequencies for Upper and Lower Deck Levels.



MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
$\bar{X}$	72.4	72.0	72.8	73.5	79.1	81.4	94.2	84.3	92.8	78.5	72.0	68.7
MAX	104	100	101	113	110	108	112	108	109	100	98	104
$\bar{X}_{TOP\ 10}$	99.9	99.2	99.2	106.6	106.1	105.0	108.3	103.9	103.9	99.1	98.7	100.0
N	2,622	1,905	2,424	3,056	3,164	2,706	2,706	1,863	1,774	2,541	2,949	3,616

TOTAL	
$\bar{X}_G$	76.9
'AX$_{ALL}$	113
$\bar{X}_{TOP\ 10}$	110.6
N_{TOTAL}	30,496

FIG. 11. Consolidated Data for Upper Deck Level.



MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
$\bar{X}$	73.1	70.1	71.4	73.7	75.0	77.5	77.3	77.5	77.4	76.4	72.7	73.0
MAX	96	92	96	99	102	98	98	98	98	98	92	98
$\bar{X}_{TOP\ 10}$	93.5	88.4	92.0	92.4	96.8	96.3	96.4	95.7	95.2	96.4	99.2	94.0
N	3,087	3,112	39.69	4019	3,690	3,2[illegible]2	2,735	2,956	2,988	3,610	3,572	3,970

TOTAL	
$\bar{X}_G$	74.4
MAX_{ALL}	102
$\bar{X}_{TOP\ 10}$	98.4
N_{TOTAL}	40,520

FIG. 12. Consolidated Data for Lower Deck Level.

CONCLUSION

It was observed from the daily temperature data that the highest temperature ever recorded on these ships over the given period was 113°F.

It appears, judging from the derived temperature data, that the shipboard ordnance stored in these lockers and magazines will probably never be subjected to a temperature above 120°F.

The temperature data show that the upper deck level storage magazines were encountering higher air temperature than the lower deck level magazines, and that the daily temperature fluctuation was more stable and predictable in the lower deck level magazines. These differences can be attributed to direct solar radiation and wind impinging on upper deck level storage lockers and magazines. Also, the lower deck level compartments and magazines seem to have better temperature control systems and the sea water moderates the below-waterline magazines causing the temperature to be more stable.

The maximum temperature and $\overline{X} + 3\hat{\sigma}$ data listed in Tables 3 and 4 indicate, in general, that the recorded maximum temperatures are not necessarily exceeding the upper $\overline{X} + 3\hat{\sigma}$ values. This can be attributed to the fact that the data distributions are, contrary to the assumption, not necessarily Gaussian. A possible flatness and skewness in the data distribution had taken place since some of these data were obtained from temperature controlled magazines resulting in truncation of the upper and lower temperatures. The flatness and the skewness of a distribution are discussed in Appendix E.

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Appendix A
DATA HANDLING

The data is handled as follows:

1. The log data is key punched (Fig. 13).

Column	Entry
1 and 2	blank
3 and 4	month
5 and 6	day
7 and 8	year
9 through 35	blank
36 through 38	minimum temperature
39 through 41	blank
42 through 44	maximum temperature
45 through 47	blank
48 through 50	day of year
51 through 68	compartment identification
69 through 80	ship hull number

2. The daily maximum and minimum temperatures are plotted on a bar graph.

Data flow is as follows (Fig. 14):

1. The keypunched data are used as input to the ITAPE program; this program writes and stores the data in a series of files on a magnetic tape. A set of storage data for one storage magazine per year constitutes a file.

2. The magnetic tape is then used as input to the TEMP and TEMPA programs. The TEMP program computes the mean and standard deviation for each compartment for each month and lists the daily high and low temperatures recorded. The TEMPA program sorts out the high temperatures over the given interval of °F and can cover any one or more of the compartments for any given month.

3. The TEMP and TEMPA programs provide the tabulation and punched cards that are used as input to the PLOT program; this program provides plots of the reduced data.

4. Tabulations and plots are bound and kept for permanent records. Also, the magnetic tape written for input is kept for permanent storage.

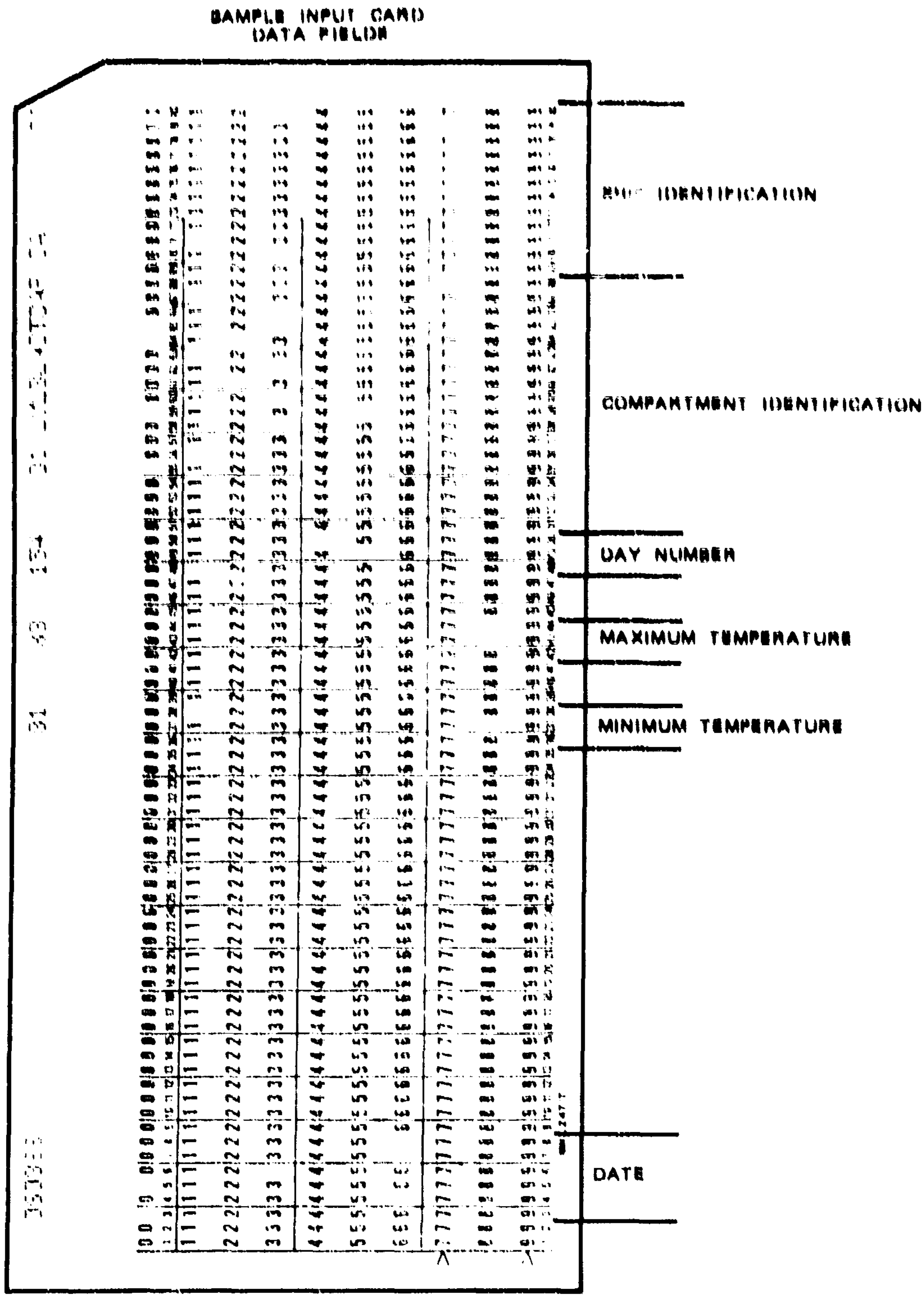

FIG. 13. Sample Input Card With Data Fields.

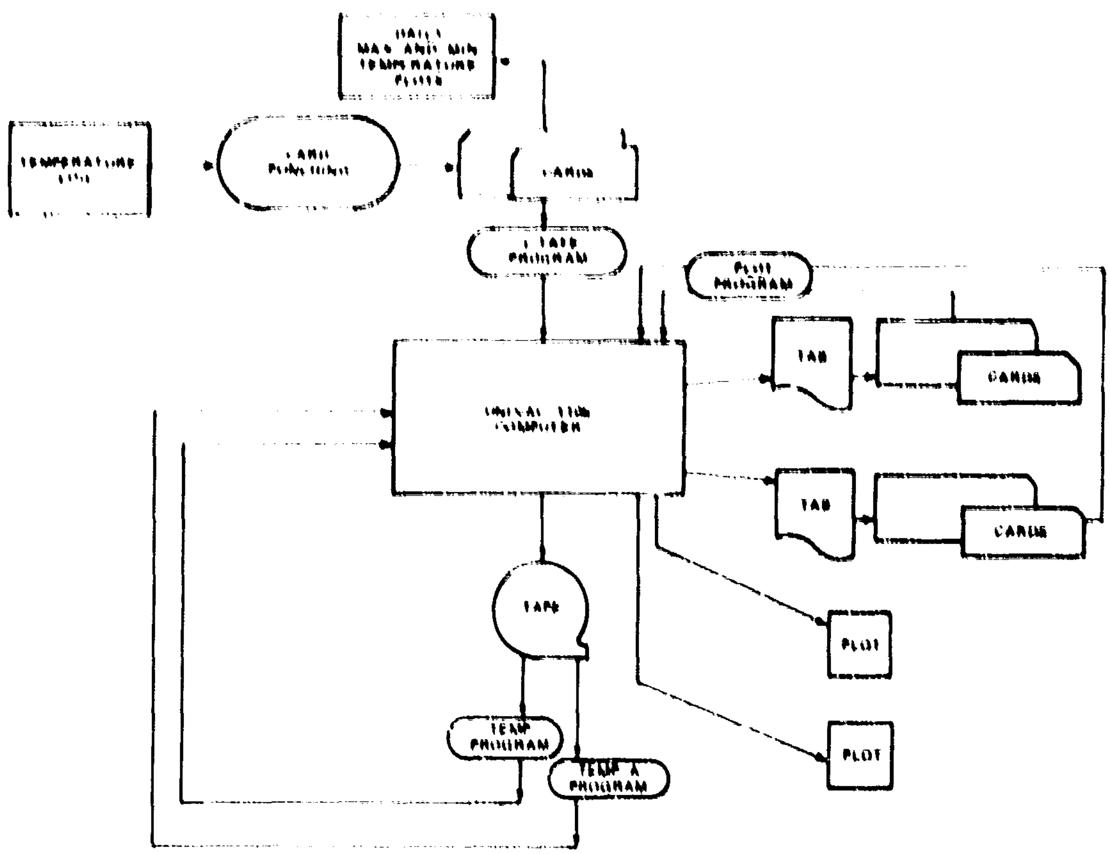

FIG. 14. Data Handling Flow Chart.

Appendix B

EXPLANATION OF DECK LEVEL AND COMPARTMENT IDENTIFICATIONS[1]

The various decks of a ship are numbered, using the main deck as a base line. On all ships except aircraft carriers, the main deck is the uppermost deck that runs the length of the ship; on aircraft carriers the hangar deck is the base line. Below the main deck are the second deck, third deck, etc. Above the main deck are the 01 (pronounced oh one) level, 02 level, etc.

Two systems of compartment numbering are presently in use, but only the newer system (begun in March 1949) is described here. Compartments are designated by a grouping of various letters and numbers, separated by hyphens. Each compartment is designated by its deck number, frame number (starting at zero at the bow and increasing towards aft), relation to ship's centerline, and usage. An example of this numbering system is 3-75-4-M. The 3 indicates the third deck; the 75 indicates that the forward boundary of the compartment is at frame 75; the 4 indicates that it is on the port of the ship (an odd number would indicate starboard side); and the M indicates that the compartment is used as a magazine. Other compartment designations are A for storage spaces, C for control spaces (areas normally manned, such as CIC communications spaces, and the pilot house), E for engineering spaces, F for fuel storage, Q for miscellaneous spaces (shops, offices, laundry, and galley), T for vertical access trunks, and L for living (berthing) spaces.

[1] General Guide for Shipboard Visitors, Naval Weapons Center, China Lake, Calif.

Appendix C
SAMPLE DATA

Daily maximum and minimum temperature data are plotted on a bar-graph (Fig. 15). A bar-graph is available for each storage magazine on the six ships.

The daily maximum and minimum temperature data from each storage magazine are tabulated, and the monthly mean maximum and minimum temperatures with their standard deviations are computed as shown in Fig. 16. The number of temperatures and the maximum temperature recorded for the month are also listed in this tabulation.

A sample plot of the computer output is presented in Fig. 17. This plot gives the monthly means of the maximum and minimum temperature data.

"Level Up" temperature data presented in Fig. 18 shows the number of given temperatures encountered for the given month for all combined upper deck level magazine temperature data. The mean maximum and minimum temperatures and their standard deviations are also computed and listed as well as the total number of data points for the month.

A typical plot for the upper deck level data is presented in Fig. 19.

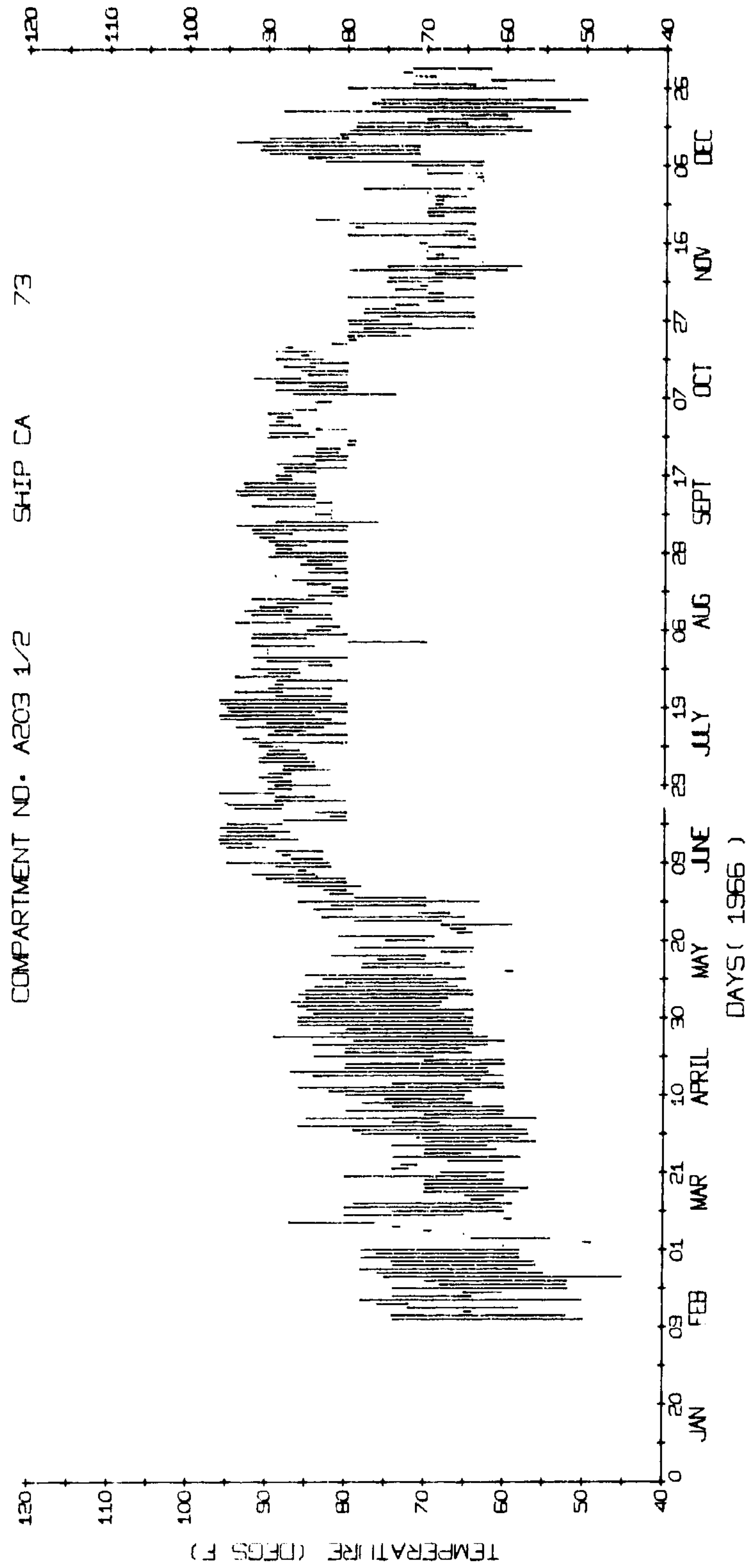

FIG. 15. Typical Bar Graph of Daily Maximum and Minimum Temperatures.

TEMPERATURE DATA
DEGREES F

SHIP : CA 73

STORAGE LOCATION: A203 1/2

MONTH	YEAR	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
FEB	1966	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
		50	74	52	74	64	65	58	72	72	76	50	78	64	74	60	65	52	74	52	68
		52	70	45	75	55	76	58	78	56	74	56	74	58	78	58	76	***	***	***	***
		***	***																		

NUMBER OF DATA POINTS MEASURED: 18
MEAN MINIMUM TEMPERATURE : 56.22 STANDARD DEVIATION: 6.292
MEAN MAXIMUM TEMPERATURE : 73.39 STANDARD DEVIATION: 4.002
MAXIMUM TEMPERATURE RECORDED : 78.00

MONTH	YEAR	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
MAR	1966	58	78	60	60	49	50	54	64	65	65	69	70	73	74	76	87	59	60	65	80
		60	74	60	80	59	79	61	64	60	65	58	70	57	70	60	70	60	70	62	80
		60	68	72	74	71	73	60	67	58	74	64	70	61	70	62	74	56	70	58	71
		57	78																		

NUMBER OF DATA POINTS MEASURED: 31
MEAN MINIMUM TEMPERATURE : 61.42 STANDARD DEVIATION: 5.755
MEAN MAXIMUM TEMPERATURE : 70.94 STANDARD DEVIATION: 7.294
MAXIMUM TEMPERATURE RECORDED : 87.00

MONTH	YEAR	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
APR	1966	57	79	59	86	68	74	56	85	60	70	60	80	60	74	64	78	65	75	65	90
		64	82	60	86	60	74	63	65	60	84	62	87	62	80	60	80	60	70	69	84
		64	80	65	80	62	84	60	79	62	89	64	82	64	80	64	86	64	86	64	86
		***	***																		

NUMBER OF DATA POINTS MEASURED: 30
MEAN MINIMUM TEMPERATURE : 62.23 STANDARD DEVIATION: 2.932
MEAN MAXIMUM TEMPERATURE : 80.17 STANDARD DEVIATION: 5.736
MAXIMUM TEMPERATURE RECORDED : 89.00

*** INDICATES TEMPERATURE DATA NOT AVAILABLE.

FIG. 16. Sample of Computer Output Tabulation.

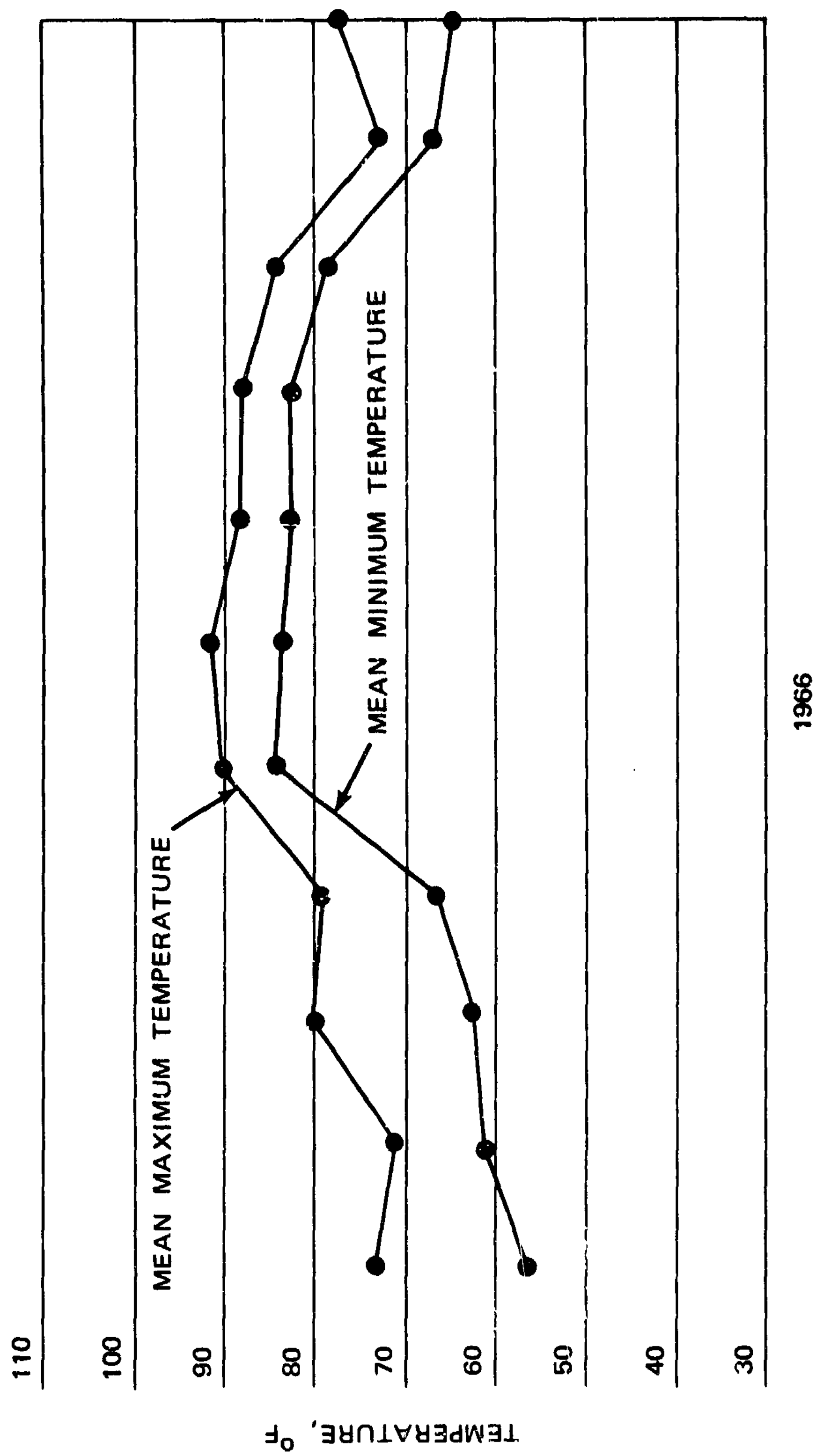

FIG. 17. Sample of Computer Output Plot.

TEMPERATURE DATA
DEGREES F

SHIP : CA 73
STORAGE LOCATION: LEVEL UP
TIME PERIOD : 2-11-66 TO 2-28-66

LESS THAN	OR	EQUAL TO	NUMBER
75		75	144
80		80	14
85		85	3
90		90	1
95		95	0
100		100	0
105		105	0
110		110	0
115		115	0
120		120	0
125		125	0
130		130	0
135		135	0
140		140	0
TEMPERATURE GREATER THAN 140			0

MAXIMUM TEMPERATURE RECORDED: 88.
MEAN MAXIMUM TEMPERATURE : 66.6 STANDARD DEVIATION: 7.17
MEAN MINIMUM TEMPERATURE : 61.2 STANDARD DEVIATION: 6.34

FIG. 18. Sample of Computer Output Tabulation on Monthly Upper Deck Level Data.

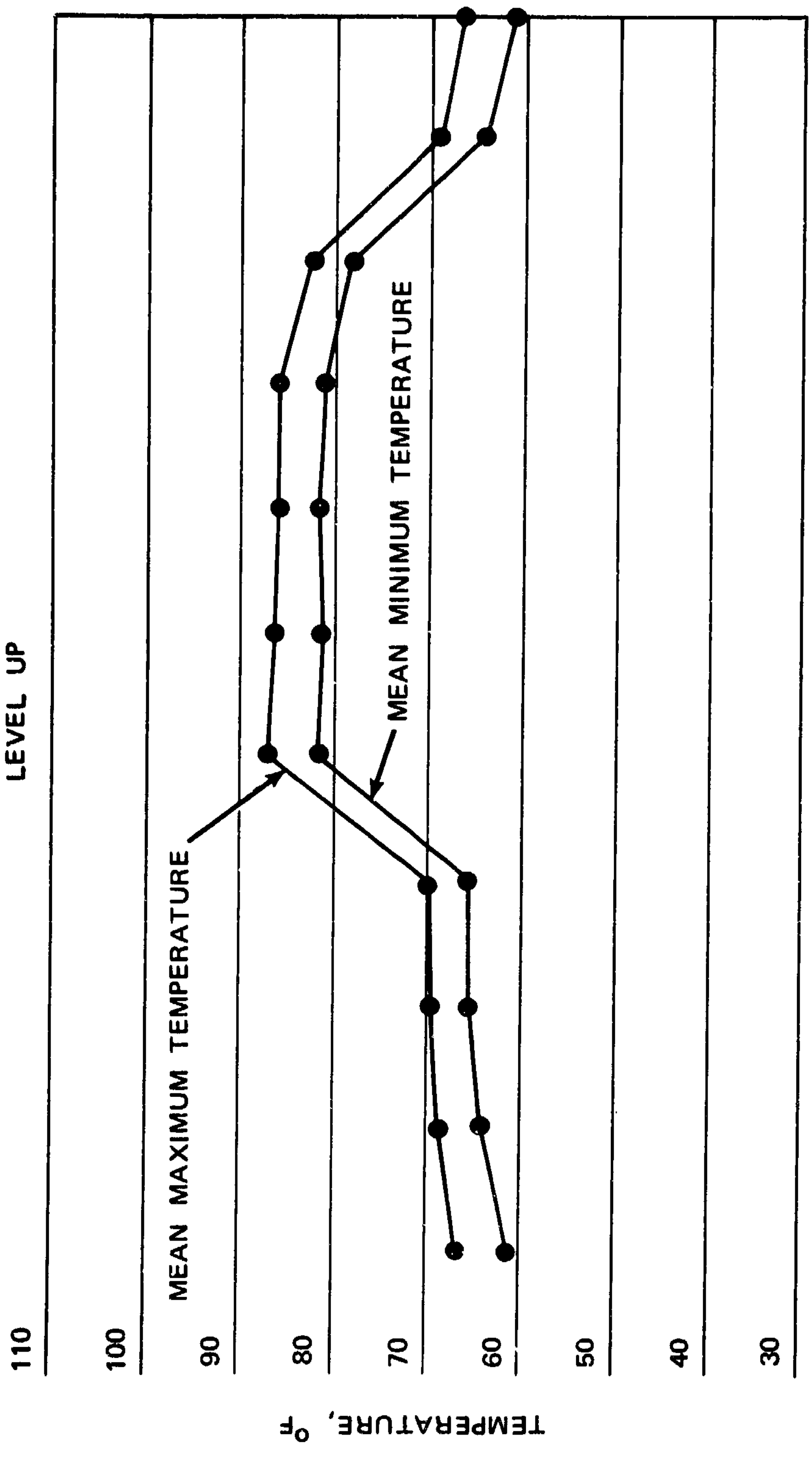

FIG. 19. Sample of Computer Output Pilot on Monthly Upper Deck Level Data.

Appendix D

OFFICIAL U. S. NAVY PHOTOGRAPHS

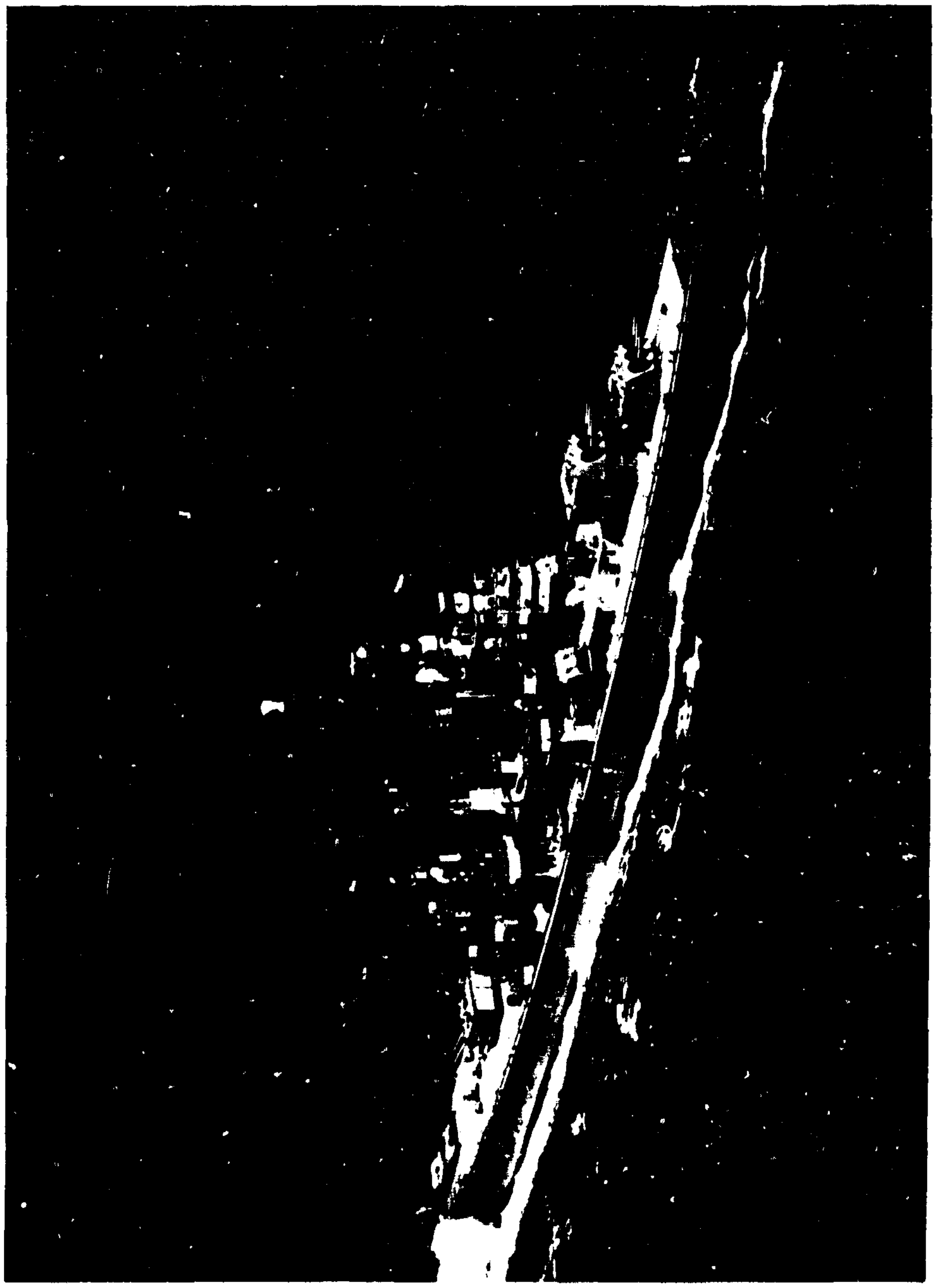

FIG. 20. USS ST. PAUL (CA73).

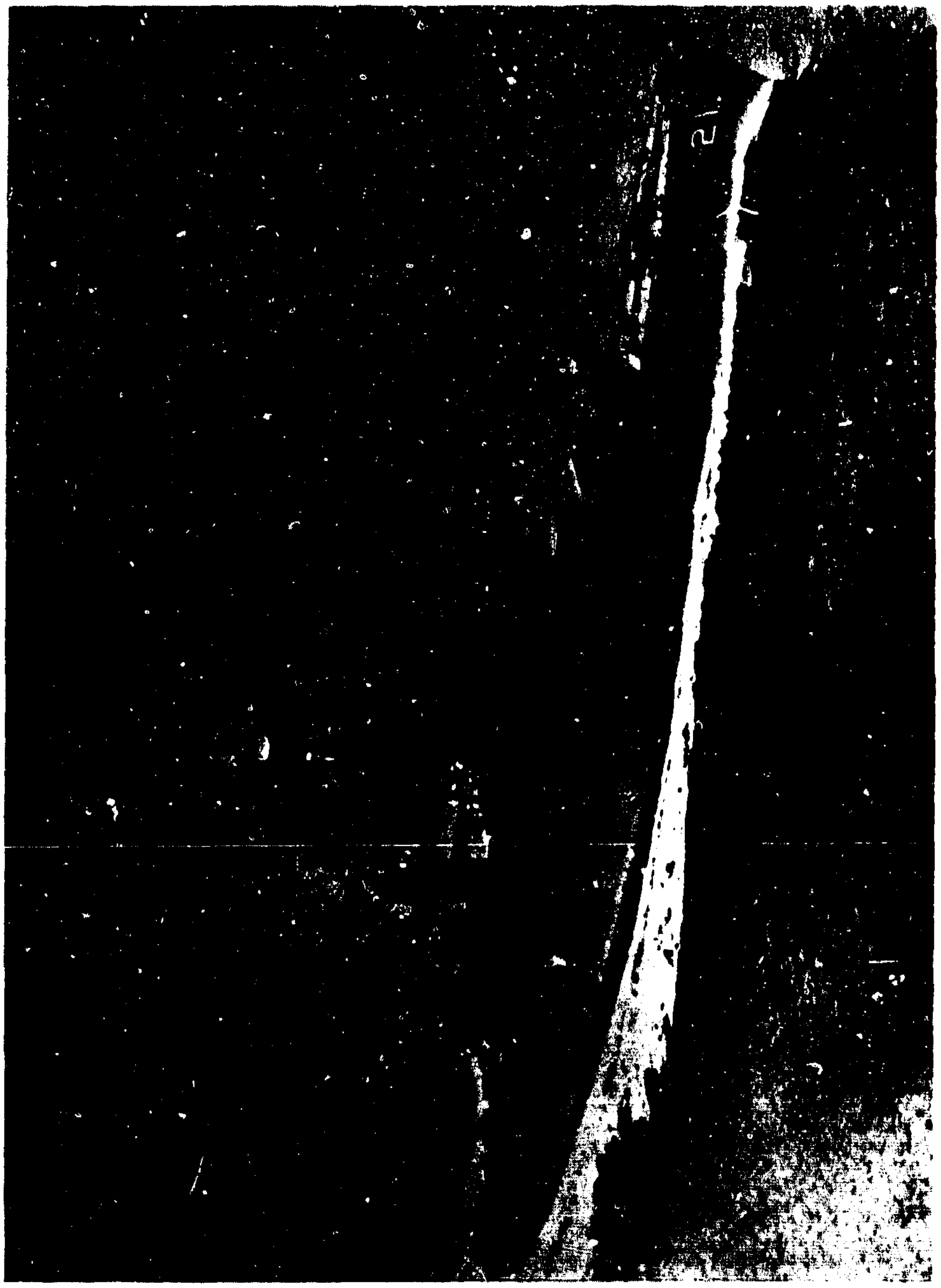

FIG. 21. USS GRIDLEY (DLG-21).

FIG. 22. USS ENGLAND (DLG-22).

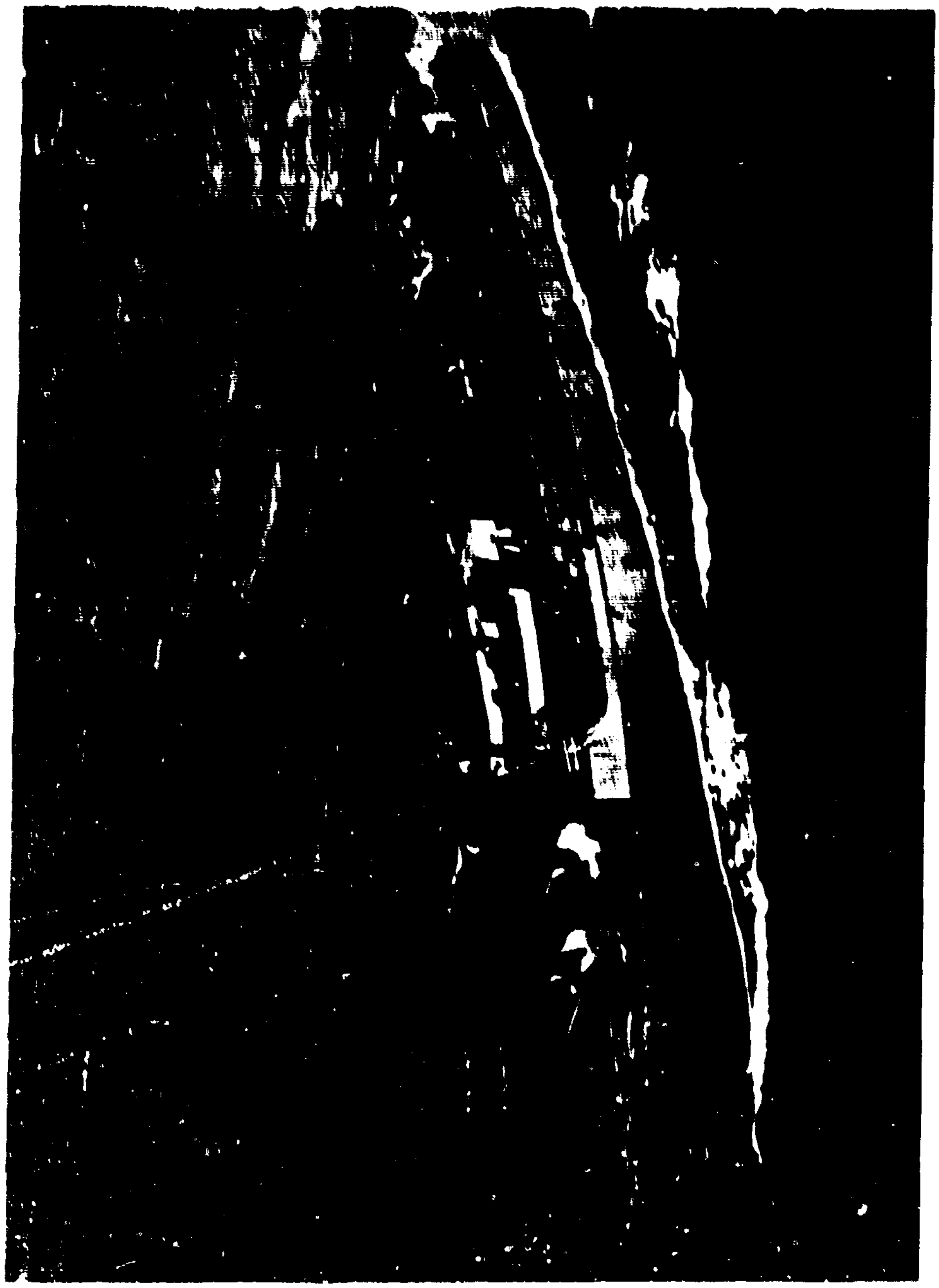

FIG. 23. USS LYNDE McCORMICK (DDG-8).

FIG. 24. USS BAINBRIDGE (DLG(N)25).

FIG. 25. USS BOSTON (CAG 1).

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Appendix E

APPLICABLE STATISTICS

The sample mean, denoted $\overline{X}$, is the arithmetic average of the maximum temperatures recorded for the given month and ship magazine.

The estimate of standard deviation, denoted $\hat{\sigma}$, is a measure of dispersion, spread, or variability of the observed temperature data about the sample mean temperature and is defined as follows:

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{N-1}}$$

where:

X_i is the observed temperatures,

$\overline{X}$ is the sample mean temperature, and

N is the total number of observations.

If the data are assumed to be dispersed or distributed normally (Gaussian distribution) within the given month, then $\hat{\sigma}$ can be used for calculating the percentage of temperature readings that would exceed the nominal temperature.

The Guassian distribution is a symmetrical bell-shaped curve about the mean extending infinitely in both positive and negative directions and defined as follows:

$$Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2\left(\frac{X-\mu}{\sigma}\right)^2}$$

where:

Y is the normal curve,

$\pi = 3.1416$,

$e = 2.7183$,

σ is the standard deviation,

μ is the true mean, and

X is the measured data.

The total area between this curve and the X axis is equated to unity, 1. The curve is concave downward for X within 1σ of the mean and concave upward for X farther than 1σ from the mean.

The normal (or Gaussian) distribution and the skewed distributions are illustrated in Fig. 26. The areas included between $\pm 1\sigma$, $\pm 2\sigma$, and $\pm 3\sigma$ are equal respectively to 67.27%, 95.45%, and 99.73% of the total area under the curve which is normalized to unity.

It is noted here that the distribution for within-month temperatures may vary from month to month in that the skewness and the kurtosis of these distributions differ. The degree of departure of the distribution from the symmetrical bell-shaped curve is the skewness of the distribution and is defined as follows:

$$\text{skewness} = \frac{3\ (\text{mean-median})}{\text{standard deviation}}\text{, where}$$

the median is the arithmetic mean of the two middle values of a set of values arranged in order of magnitude. For an example, a set of values (8, 9, 10, 7, 6, 7) is rearranged to (6, 7, 7, 8, 9, 10) and the median for this set is defined as follows:

$$\text{median} = \frac{7 + 8}{2} = 7.5$$

The mode shown in Fig. 26 is defined as the value which occurs with the greatest frequency in the set of data, in the example above, the mode is 7.

The kurtosis is the degree of peakedness of a distribution illustrated in Fig. 27 and normally given relative to a normal distribution.

Graphically, as shown in Fig. 27, when the distribution is a relatively high peak, then the standard deviation (σ) of the distribution can be expected to be relatively smaller than that of the Gaussian distribution. On the other hand, when the distribution is relatively flat-topped, then the standard deviation of the distribution can be expected to be relatively greater than that of the Gaussian distribution.

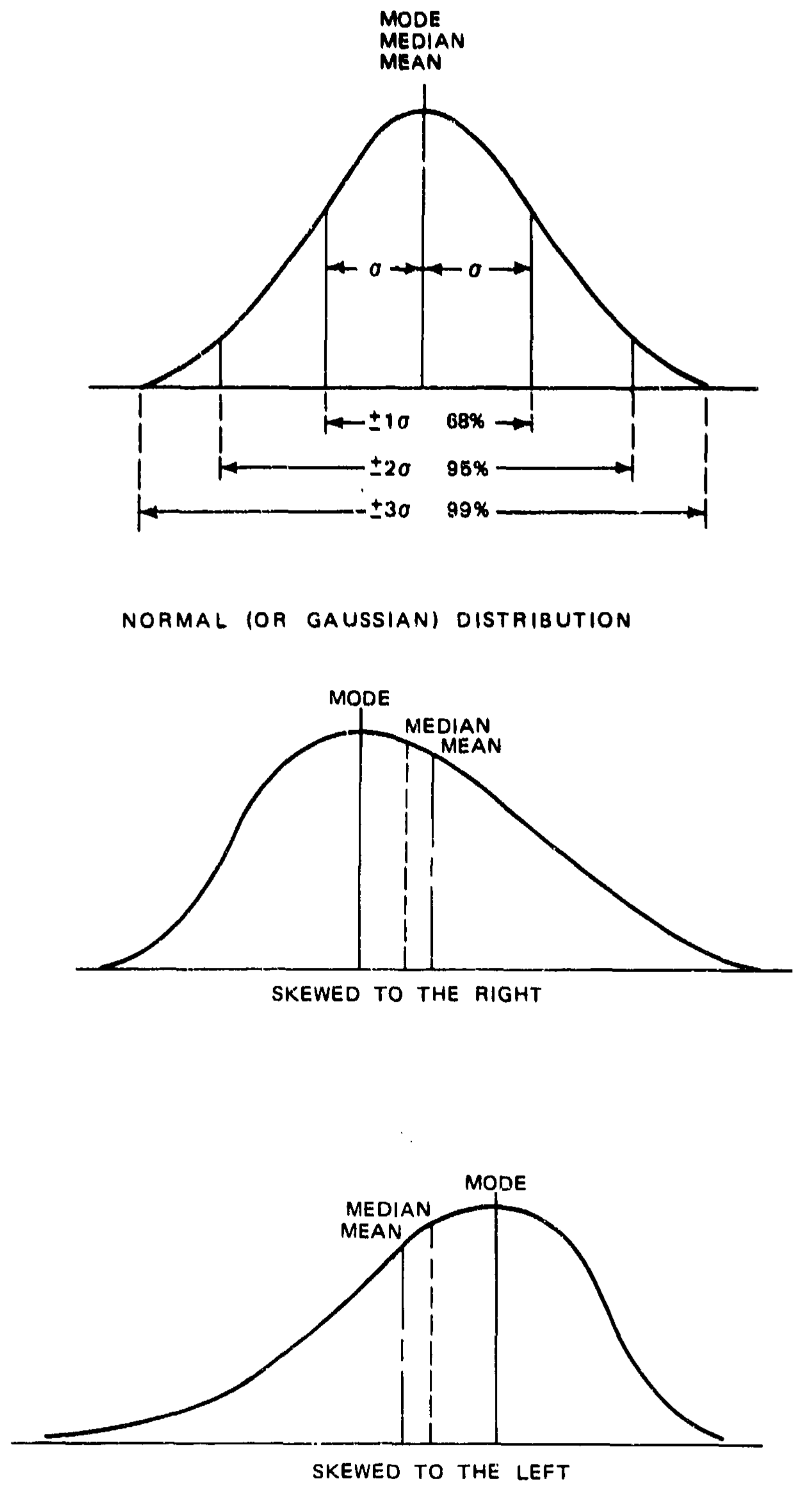

FIG. 26. Gaussian Distribution and Skewed Distributions.

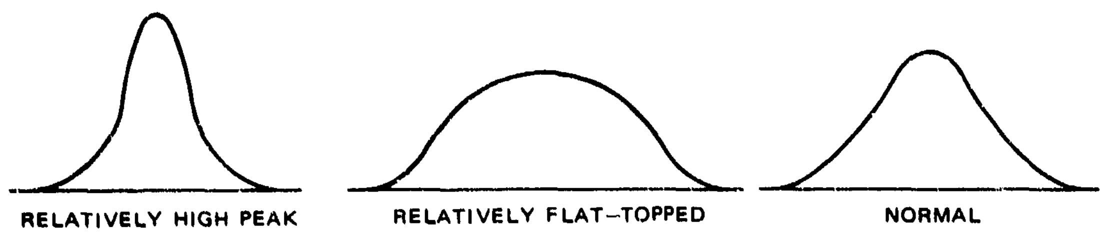

FIG. 27. Distribution Curves.

This leads to the interpretation of the maximum temperature not exceeding the $\overline{X} + 3\hat{\sigma}$ values due to the temperature data distribution being somewhat flat-topped and certainly deviating from the Gaussian distribution which would have smaller standard deviation than the flat-topped distribution as shown in Fig. 28.

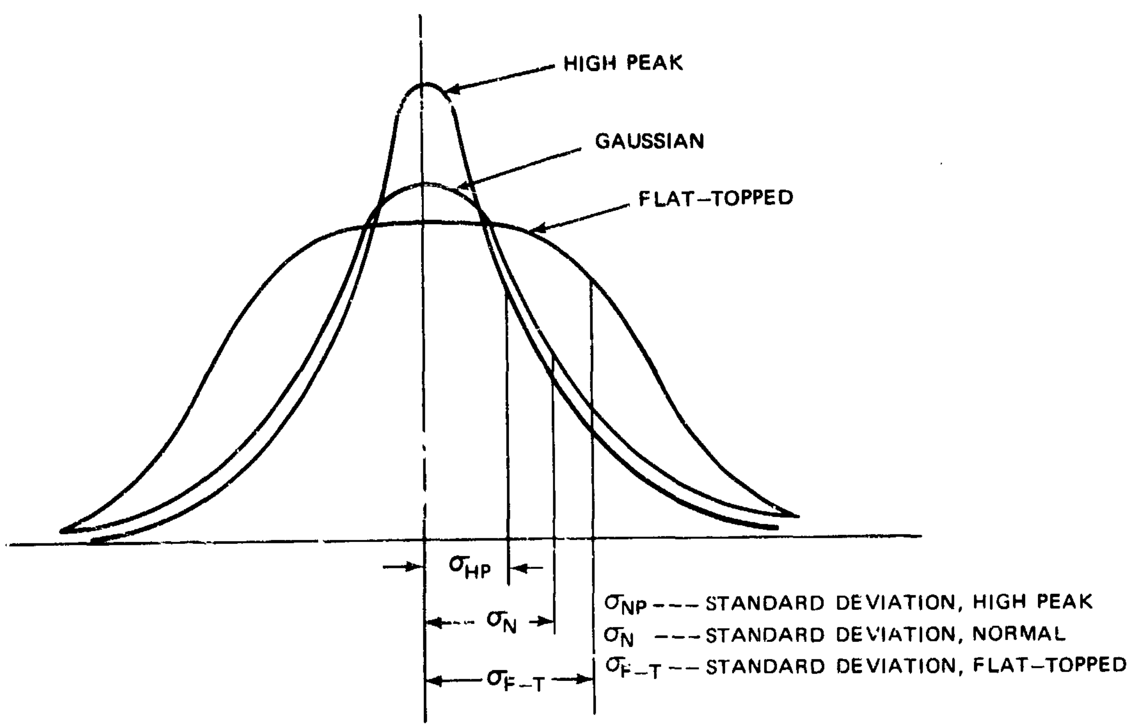

FIG. 28. Variations in Standard Deviation.

Further study was made to yield the data shown in Fig. 11 and 12. These data were consolidated (upper level and lower level separately) to augment the statement made in the conclusion. If the data shown in these figures are representative temperature data, then it can be said that the chance of the upper level storage magazine encountering a temperature of 113°F or greater is 1 in 30,496 or less (essentially zero), and the chance of encountering a temperature of 111°F or greater, 1 in 3,049 or less (essentially very small). Similarly, the chance of the lower level magazine encountering a temperature of 102°F or greater is 1 in 40,520 or less, and of encountering a temperature of 98°F or greater, 1 in 4,052.

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3. ------. Environmental Criteria Determination for Chaff Rocket (Southeast Asia), by Howard C. Schafer. China lake, Calif., NWC, November 1968. (NWC TP 4619), UNCLASSIFIED.

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13. ABSTRACT

The magazine air temperature records from CAG, CA, DDG, DLG, and DLG(N) type ships have been statistically analyzed to obtain the probable thermal exposure to be found on these type ships. The information is divided into the temperature expectancies for the 03, 02, 01, 1, 2, 3, 4, 5, and 6 deck levels as applicable. Effort has been made to eliminate information from compartments influenced by the engine room. This report includes 71,016 data points from the six ships. The ships were all assigned to the 7th Fleet in this time frame.

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