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Applied Research in Statistics and Systems Analysis

STATISTICAL ANALYSIS OF RESULTS FROM A SURVEY OF HALON AND CFC CONSUMPTION ON U.S. NAVY SHIPS

by

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ABSTRACT

The Naval Sea Systems Command (NAVSEA) needs to determine the total fleet requirements for ozone-depleting substances until they are phased out. To provide information about the necessary reserves of these substances during the outyears, NAVSEA recently conducted a survey of CFC/Halon usage in the fleet.

This document provides a statistical analysis of the data from the survey, which includes reported usage for CFC-11, CFC-12, CFC-114, and Halon 1301. The information in this report can be used to estimate the required CFC/Halon reserves. The average consumption figures can be used as the basis for an expected value approach, while those corresponding to the statistical confidence levels can be used to provide various degrees of guarantee that the estimated reserve will not be depleted prematurely.

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1. INTRODUCTION

Production of Halons ceased as of 1 January 1994. Production of chlorofluorocarbon (CFC) refrigerants is scheduled to end by 1 January 1996. The Navy uses Halons and CFCs in several mission-critical applications. It wishes to establish an inventory of these chemicals sufficient to last until all fleet Halon and CFC systems have been retired or converted to use chemicals not listed as ozone-depleting substances.

To estimate current Halon and CFC usage, Naval Sea Systems Command (NAVSEA) Code 03V sent a survey to all ships in the fleet requesting data on consumption. Ships were asked to estimate total consumption for Halon 1211 and Halon 1301 fire-suppression systems, chilled-water AC plants using CFC-11, CFC-12 or CFC-114, and CFC-12 cargo and ship-stores refrigeration plants. Respondents were also asked, if possible, to separate normal usage from consumption caused by catastrophic failures or accidental discharges. For Halons, consumption data was requested for the period from 1 January 1994 to 30 April 1994 (4 months). For CFCs, the reporting period was 1 May 1993 to 30 April 1994 (12 months). A copy of the NAVSEA survey request is provided as an appendix to this report.

The survey was sent on 9 May 1994 with a request that reports be returned by 9 June 1994. While most results were returned by that deadline, responses continued to be received in the following weeks. This report presents a statistical analysis of data from 209 ships received through 11 July 1994.

Halon 1211 fire-suppression systems are installed only on the LCACs of Assault Craft Units (ACUs) 4 and 5. While both ACUs responded to the survey, neither reported Halon 1211 consumption. There is no data available to make inferences about usage of this chemical, so the analysis in this report is restricted to Halon 1301 and the CFCs.

2. SURVEY RESPONSE RATE

A list of the ship classes using relevant Halon or CFC systems is given in Table 1. The total number of ships and the number responding to the survey are given separately for the Atlantic and Pacific fleets. The response rates are presented graphically in Figure 1 for the two fleets and for ship classes containing a relatively large number of ships (CG-47, DD-963, FFG-7, SSN-637 and SSN-688). In general, the response rate was higher for the Atlantic fleet than for the Pacific fleet, especially for the surface combatants. However, the Pacific fleet response rate was still high enough that it is reasonable to make inferences from this data set.

Of the 209 ships responding to the survey, only 194 were used in the analysis. Of the other fifteen ships, one was inactivated during the survey period, six were newly commissioned, and eight reported overhauls in which the ships' forces did not have primary responsibility for the Halon or CFC systems. In addition, not all ships use all types of systems, and some ships provided incomplete responses to the survey. The number of ships used in the analysis for each type of system is given by ship class in Table 2.

3. ANALYSIS ASSUMPTIONS

In order to make inferences about fleet Halon and CFC usage during the survey periods, it is necessary to make the following assumptions:

(1) The ships responding to the survey constitute a representative sample from the fleet of ships with installed Halon and CFC plants.

(2) The reported survey data accurately reflects actual usage during the relevant periods.

In order for inferences concerning future usage to be valid, two additional assumptions must be met:

(3) The variability in year-to-year usage for a given ship is the same as the variability in usage between ships in a given year.

(4) The underlying factors affecting usage do not change from year to year. (For example, there will be no modifications in maintenance policies or procedures that alter Halon or CFC usage.)

The first assumption is reasonable as long as the data is examined separately for segments of the fleet known to have different response rates (Atlantic vs. Pacific, surface vs. submarine). The second assumption is necessary and has been partially validated by data from other sources (supply system, contractor surveys). The third assumption is more troublesome and cannot be checked using available data. It is equivalent to assuming that CFC and Halon consumption is random and not a function of individual ship practices.

The final assumption is probably not valid. Increasing environmental awareness, decreasing availability and increasing costs of Halons and CFCs, and improved reclamation abilities

should all combine to decrease future consumption rates. Thus, predictions made from the results presented here may be too high. However, there is no way to objectively estimate the extent of these effects.

4. ANALYSIS RESULTS

In order to characterize fleet Halon and CFC usage, consumption was considered as a function of four independent variables:

(1) Fleet (Atlantic vs. Pacific),

(2) Ship Class, particularly surface vs. submarine,

(3) Plant Charge,

and (4) Commission Date.

Both normal leakage and total consumption were considered as dependent variables. It should be noted that not all ships reported normal leakage and accidental/catastrophic usage separately. For those which did, there appeared to be some confusion as to which types of consumption should be classified in which category.

In general, attempts to explain consumption as a function of these independent variables were unsuccessful. The only significant difference found was between surface ships and submarines for CFC-114. (Submarines have significantly lower consumption rates.) The analysis results for the individual chemicals are discussed in the following subsections.

The Navy needs to establish a mission-critical inventory of Halons and CFCs. Although such an inventory can be based on the average usage estimated from the survey, it may be desirable to ensure that there is only a small chance that the inventory will not be depleted prematurely. Therefore, this report includes confidence limits for average (per ship) total consumption for each chemical.

Because of the lack of strong correlations between charge and consumption, confidence limits were calculated by treating each set of consumption data as a simple random sample. In order to avoid making any assumptions about the statistical distributions of those samples, a nonparametric bootstrap procedure was used. This procedure involves using the observed data to estimate the probability distribution, simulating samples from that distribution, and calculating the statistic of interest (here the mean) for the simulated samples. It has been shown to produce good results for a wide variety of problems. The specific technique used for this analysis incorporates bias adjustments and other corrections to produce better confidence limits.[1]

4.1 Halon 1301

Figure 2 is a plot of Halon 1301 consumption (4 months) versus plant charge for 150 ships. Both normal leakage and total consumption are plotted. There is no strong relationship between charge and consumption. In fact, the correlation between plant charge and total consumption is only 29%. For leakage alone, the correlation is somewhat higher (45%) but still evidence of only a weak relationship. The correlations with commission date are negligible.

Halon 1301 summary statistics are given in Table 3. These values are for a four-month survey period. The reported reserves

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[1]Efron, B. (1987), "Better Bootstrap Confidence Intervals," Journal of the American Statistical Association, Vol. 82, pp. 171-185.

are as of 30 April 1994. For estimates of yearly consumption, the averages, standard deviations, usage rates and confidence limits should be multiplied by three. There is no valid way to adjust the ranges (minimum and maximum).

It is doubtful that the reported standard deviations in Table 3 are of any relevance, since the usage distributions are highly skewed. For total consumption, 113 of the 150 ships reported zero consumption, while a few had very high usage (three greater than 1000 lbs. in four months). When a distribution is this skewed, the standard deviation does not provide a good measure of the spread of the data.

Figure 3 shows the average usage per ship broken out by fleet. There is some indication that the Pacific fleet has a higher total usage rate than the Atlantic fleet. However, the apparent difference results from only a few ships with extreme values. If the ship with the largest total consumption (4000 lbs., classified as accidental discharge/catastrophic failure) is dropped from the sample, the total Pacific fleet usage rate drops from 2.5% to 1.3%, much closer to the rate for the Atlantic fleet (0.9%). Given this sensitivity to extreme values, it should be concluded that there is no real evidence of a difference between the two fleets.

For normal leakage alone, the Pacific fleet appears to be better than the Atlantic fleet (0.05% vs 0.26%). However, that difference can again be attributed to a few large values. Only 14 of the 140 ships which reported leakage and accidental/ catastrophic usage separately had nonzero leakage. There is not

enough evidence to conclude that the fleets are different.

4.2 CFC-11 Chilled-Water AC Plants

Only eleven ships having CFC-11 plants responded to the survey, and two of those ships could not be used in the analysis because of overhauls. While this is a good percentage of the twenty-one ships in the fleet having such plants, it is a very small sample from which to draw inferences.

Summary statistics and confidence limits for CFC-11 consumption are provided in Table 4. Individual ship usage during the survey period is plotted in Figure 4, and average usage for the eleven ships is shown in Figure 5. Because the sample size is so small, the average usage rates should be viewed as only rough estimates of what can be expected in future years. The wide confidence limits reflect this uncertainty.

4.3 CFC-12 Refrigeration Plants

Figure 6 is a plot of CFC-12 usage for ship-stores and cargo refrigeration plants. There is some correlation between consumption and charge (31% for leakage, 45% for total), but the relationship is not strong. Figure 7 shows average total consumption, by fleet, for surface ships versus submarines. Consumption is somewhat higher for the Pacific fleet than for the Atlantic fleet, but that is an artifact of the composition of the two samples. The ships responding from the Pacific fleet have, on average, more or larger plants. While the relationship between plant charge and consumption is weak, it is not negligible. When

consumption rates are considered, those rates are actually somewhat smaller for the Pacific fleet.

Summary statistics for the CFC-12 Refrigeration plants are given in Table 5. In general, there are no dramatic differences between fleets or types of ships. Therefore, strategic reserve calculations should be based on the overall mean. Confidence limits for that mean are given in Table 6.

4.4 CFC-12 Chilled-Water AC Plants

Reported leakage and total consumption for CFC-12 AC plants are shown by ship in Figure 8. Once again, the correlations between consumption and charge are weak (16% for leakage, 47% for total). Summary statistics are provided in Table 7, and the averages are presented graphically in Figure 9. There is no indication of a difference between fleets.

Submarines do not use CFC-12 AC plants. Examination of different classes of surface ships revealed no large differences in consumption. Therefore, it is appropriate to treat the ships using these plants as a single population, using the mean or the confidence limits in Table 7.

4.5 CFC-12 Total Consumption

Summary statistics for total (refrigeration plus AC) CFC-12 consumption are provided in Table 8. Figure 10 shows the reported usage for individual ships, and the average usage is shown by fleet in Figure 11.

In order for these results to be useful in planning strate-

gic reserves, it is necessary for two assumptions to be met:

(1) The mix of refrigeration plants and AC plants in the sample must be representative of the mix in the fleet.

(2) The mix of plants must remain constant in future years.

It is known that submarines are underrepresented in the sample compared to surface ships, so the first assumption is invalid. Therefore, the values given here for total CFC-12 consumption should be used with caution. It would be best to calculate separate reserves for the two type of plants.

4.6 CFC-114 Chilled-Water AC Plants

Reported CFC-114 consumption for individual ships is plotted versus plant charge in Figure 12. There is little correlation between usage and charge (20% for leakage, 40% for total). There is even less of a relationship between usage and commission date (17% correlation between charge and either leakage or total consumption).

CFC-114 summary statistics are provided in Table 9 and shown graphically in Figure 13. There is little evidence of a difference between the two fleets, but there is a large difference between submarines and surface ships. Submarine usage rates are much smaller. Therefore, since the mix of submarines and surface ships is different for the sample than for the fleet as a whole, reserves should be calculated separately for the two types of ships. Separate sets of confidence limits are provided in Table 10.

5. USE OF THE SURVEY DATA IN DETERMINING RESERVES

The summarized information provided in this report can be used to estimate the critical CFC/Halon reserves. As indicated previously, there is strong statistical evidence that submarines consume less CFC-114 than do surface ships, both in actual usage and in usage rate. Therefore, reserves for CFC-114 should be calculated for surface ships and submarines separately. Furthermore, because CFC-12 consumption for refrigeration plants is significantly less than that for AC plants, CFC-12 reserves should be calculated separately for each type of plant. For each of the other substances, the calculations can be based on the combined data.

Although it might be thought, a priori, that consumption would be highly correlated with total plant charge, this proved not to be the case. Therefore, reserves could conceptually be calculated using either (1) the average consumption per ship or (2) the estimated usage rate on a plant basis. Because of the existence of some degree of positive correlation (albeit relatively weak) between usage and total charge, Desmatics recommends that the latter estimate be used.

There are three main approaches that may be adopted for calculation of critical reserves. The first, an expected value approach, would be based on the average consumption rates. For example, the CFC-114 reserves calculated throughout the outyears would be based on a 27.3% consumption rate for surface ships and on a 10.7% rate for submarines. In a sense, such an approach

provides a "best estimate" of the required reserves.

However, it may be worthwhile for NAVSEA to consider basing its reserve calculations on usage rates that provide some level of guarantee that the estimated reserve will not prove to be an underestimate. This approach can use the rates corresponding to the confidence levels given in the report. For example, to provide 90% confidence that the CFC-114 reserve would not be depleted prematurely, a usage rate of 32.1% for surface ships and 13.6% for submarines should be used.

A third, more detailed, approach would involve a study of the trade-offs between the costs, benefits, and penalties of prematurely running out of a substance compared with ending up with an overstock. Such an approach would, of course, require economic information not available in this report.

CLASS		NUMBER IN FLEET Atl.	NUMBER IN FLEET Pac.	NUMBER IN SURVEY Atl.	NUMBER IN SURVEY Pac.	FRACTION IN SURVEY Atl.	FRACTION IN SURVEY Pac.
AD-37	(SAMUEL GOMPERS)	1	1	1	1	100%	100%
AD-41	(YELLOWSTONE)	2	2	1	2	50%	100%
AE-21	(SURIBACHI)	1	1	1	0	100%	0%
AE-23	(NITRO)	1	2	1	0	100%	0%
AE-26	(KILAUEA)	3	4	3	3	100%	75%
AFS-1	(MARS)	1	3	0	1	0%	33%
AGF-3	(LASALLE)	1	0	0	0	0%	--
AGF-11	(CORONADO)	0	1	0	1	--	100%
AGSS-555	(DOLPHIN)	0	1	0	0	--	0%
AO-177	(CIMARRON)	3	2	2	1	67%	50%
AOE-1	(SACRAMENTO)	2	2	2	0	100%	0%
AOE-6	(SUPPLY)	1	0	1	0	100%	--
AOR-1	(WICHITA)	3	3	2	2	67%	67%
AR-5	(VULCAN)	0	1	0	1	--	100%
ARS-38	(BOLSTER)	2	3	1	2	50%	67%
ARS-50	(SAFEGUARD)	2	2	2	1	100%	50%
AS-31	(HUNLEY)	1	1	0	1	0%	100%
AS-33	(SIMON LAKE)	2	0	1	0	50%	--
AS-36	(L. Y. SPEAR)	1	1	1	1	100%	100%
AS-39	(EMORY S. LAND)	2	1	0	1	0%	100%
ASR-21	(PIGEON)	1	0	0	0	0%	--
ATS-1	(EDENTON)	1	2	1	1	100%	50%
CG-16	(LEAHY)	3	4	2	0	67%	0%
CG-26	(BELKNAP)	2	0	0	0	0%	--
CG-47	(TICONDEROGA)	14	12	13	3	93%	25%
CGN-9	(LONG BEACH)	0	1	0	1	--	100%
CGN-25	(BAINBRIDGE)	1	0	1	0	100%	--
CGN-35	(TRUXTUN)	0	1	0	1	--	100%
CGN-36	(CALIFORNIA)	1	1	1	1	100%	100%
CGN-38	(VIRGINIA)	2	1	1	0	50%	0%
CV-59	(FORRESTAL)	1	1	1	1	100%	100%

Table 1: Summary of Response to Halon/CFC Survey.

CLASS		NUMBER IN FLEET Atl.	Pac.	NUMBER IN SURVEY Atl.	Pac.	FRACTION IN SURVEY Atl.	Pac.
CV-63	(KITTY HAWK)	1	2	0	2	0%	100%
CV-67	(JOHN F. KENNEDY)	1	0	0	0	0%	--
CVN-65	(ENTERPRISE)	1	0	1	0	100%	--
CVN-68	(NIMITZ)	3	3	1	3	33%	100%
DD-963	(SPRUANCE)	16	15	16	5	100%	33%
DDG-51	(ARLEIGH BURKE)	2	0	2	0	100%	--
DDG-993	(KIDD)	2	2	1	2	50%	100%
FFG-7	(OLIVER H. PERRY)	30	21	27	9	90%	43%
FFT-1052	(KNOX)	8	0	5	0	63%	--
LCC-19	(BLUE RIDGE)	1	1	1	0	100%	0%
LHA-1	(TARAWA)	2	3	2	2	100%	67%
LHD-1	(WASP)	2	1	2	0	100%	0%
LPD-1	(RALEIGH)	1	2	1	2	100%	100%
LPD-7	(CLEVELAND)	2	4	2	2	100%	50%
LPD-14	(TRENTON)	2	0	2	0	100%	--
LPH-2	(IWO JIMA)	3	2	2	2	67%	100%
LSD-36	(ANCHORAGE)	2	3	0	0	0%	0%
LSD-41	(WHIDBEY ISLAND)	3	4	3	1	100%	25%
LST-1179	(NEWPORT)	7	8	5	2	71%	25%
MCM-1	(AVENGER)	12	0	7	0	58%	--
MHC-51	(OSPREY)	2	0	2	0	100%	--
MSO-422	(AGRESSIVE)	1	4	0	1	0%	25%
SSBN-640	(BENJAMIN FRANKLIN)	1	0	0	0	0%	--
SSBN-726	(OHIO)	6	8	1	2	17%	25%
SSN-594	(PERMIT)	1	0	0	0	0%	--
SSN-640	(BENJAMIN FRANKLIN)	1	1	0	1	0%	100%
SSN-637	(STURGEON)	19	12	5	4	26%	33%
SSN-688	(LOS ANGELES)	34	20	12	4	35%	20%
TOTALS		221 \ 170 / 391		139 \ 70 / 209		63% \ 41% / 53%	

Table 1 (cont.): Summary of Response to Halon/CFC Survey.

CLASS	COMPLETE DATA BASE	SHIPS USED	HALON 1301	CFC-11 A/C	CFC-12 REF	CFC-12 A/C	CFC-114 A/C
AD-37	2	2		2	1		
AD-41	3	3	3		3		3
AE-21	1	1	1		1	1	
AE-23	1	1	1		1	1	
AE-26	6	6	6		5	5	
AFS-1	1	1	1		1	1	
AGF-11	1	1	1		1	1	
AO-177	3	3	3		1	1	
AOE-1	2	2	2		1	1	
AOE-6	1						
AOR-1	4	4	4		3	3	
AR-5	1	1			1		
ARS-38	3	3			3		
ARS-50	3	3	3		3	3	
AS-31	1						
AS-33	1	1		1	1		
AS-36	2	2	1	2	2		
AS-39	1						
ATS-1	2	2			2	2	
CG-16	2	2	2		2		2
CG-47	16	16	16		16		16
CGN-9	1	1			1		1
CGN-25	1	1			1		
CGN-35	1	1			1		1
CGN-36	2	1		1	1		
CGN-38	1	1			1		1
CV-59	2	2	2				1
CV-63	2	2	2		2		2
CVN-65	1						
CVN-68	4	4	4		4		4
DD-963	21	19	19		19		19
DDG-51	2	2	2		2		2

Table 2: Number of Useable Responses by Ship Class for Each Chemical Surveyed.

CLASS	COMPLETE DATA BASE	SHIPS USED	HALON 1301	CFC-11 A/C	CFC-12 REF	CFC-12 A/C	CFC-114 A/C
DDG-993	3	3	3		3		3
FFG-7	36	35	35		23	23	
FFT-1052	5	5	5		4	4	
LCC-19	1	1	1	1	1		1
LHA-1	4	4	3		4		4
LHD-1	2	1	1		1		1
LPD-1	3	3	3		3	3	
LPD-7	4	4	3		4	4	
LPD-14	2	2	2		2	2	
LPH-2	4	4	4	2	3	1	1
LSD-41	4	4	4		3		3
LST-1179	7	7	6		6	6	
MCM-1	7	6	6		4	4	
MHC-51	2						
MSO-422	1	1	1		1	1	
SSBN-726	3	3			3		3
SSN-637	9	9			9		9
SSN-640	1	1			1		1
SSN-688	16	13			13		13
TOTAL	209	194	150	9	168	67	91

Table 2 (cont.): Number of Useable Responses by Ship Class for Each Chemical Surveyed.

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Atl.	Pac.	Combined	Atl.	Pac.	Combined
No. Ships	102	48	150	98	42	140
Average	49	163	85	14	3	11
Std. Dev.	150	641	384	55	14	47
Minimum	0	0	0	0	0	0
Maximum	1125	4000	4000	360	84	360
Charge/Ship	5459	6501	5792	5378	5593	5442
Usage Rate	0.89%	2.51%	1.47%	0.26%	0.05%	0.19%

REPORTED RESERVES

Number of Ships	122
Average Charge/Ship	5843
Reserve/Ship	1998
Reserve/Charge	34%

CONSUMPTION CONFIDENCE LIMITS

Confidence Level	Usage/Ship	Usage Rate
50.0%	89	1.54%
60.0%	98	1.70%
70.0%	109	1.89%
80.0%	123	2.13%
90.0%	148	2.55%
95.0%	171	2.96%
99.0%	227	3.92%
99.5%	255	4.39%

Table 3: Consumption of Halon 1301 (lbs.) From 1 January 1994 to 30 April 1994 and Reserves as of 30 April 1994.

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Atl.	Pac.	Combined	Atl.	Pac.	Combined
No. Ships	5	4	9	3	2	5
Average	850	2086	1399	267	400	320
Std. Dev.	1170	1995	1613	462	354	378
Minimum	0	150	0	0	150	0
Maximum	2750	4245	4245	800	650	800
Charge/Ship	2600	2488	2550	2383	2775	2540
No. Plants	17	13	30	11	6	17
Charge/Plant	765	765	765	650	925	747
Usage/Plant	250	642	420	73	133	94
Usage Rate	32.7%	83.9%	54.9%	11.2%	14.4%	12.6%

REPORTED RESERVES

Number of Ships	9
Number of Plants	30
Average Charge/Ship	2550
Average Charge/Plant	765
Reserve/Ship	678
Reserve/Plant	203
Reserve/Charge	27%

CONSUMPTION CONFIDENCE LIMITS

Confidence Level	Usage/Ship	Usage Rate
50.0%	1427	56.0%
60.0%	1566	61.4%
70.0%	1717	67.3%
80.0%	1899	74.5%
90.0%	2166	84.9%
95.0%	2393	93.9%
99.0%	2826	110.8%
99.5%	2983	117.0%

Table 4: Consumption of CFC-11 (lbs.) From 1 May 1993 to 30 April 1994 and Reserves as of 30 April 1994.

ATLANTIC FLEET

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	108	93	15	72	62	10
Average	305	328	165	173	181	121
Std. Dev.	376	397	157	266	280	147
Minimum	0	0	0	0	0	0
Maximum	2100	2100	500	1405	1405	400
Charge/Ship	489	525	266	463	495	264
No. Plants	237	207	30	156	136	20
Charge/Plant	223	236	133	214	226	132
Usage/Plant	139	147	83	80	83	61
Usage Rate	62.4%	62.4%	62.1%	37.3%	36.6%	45.8%

PACIFIC FLEET

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	60	49	11	39	31	8
Average	441	504	161	165	196	46
Std. Dev.	639	688	168	220	237	45
Minimum	0	0	0	0	0	0
Maximum	3950	3950	500	1215	1215	110
Charge/Ship	882	1006	331	877	1018	330
No. Plants	152	130	22	99	83	16
Charge/Plant	348	379	165	345	380	165
Usage/Plant	174	190	81	65	73	23
Usage Rate	50.0%	50.1%	48.8%	18.8%	19.3%	13.8%

COMBINED FLEETS

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	168	142	26	111	93	18
Average	354	389	164	170	186	87
Std. Dev.	489	520	158	250	265	117
Minimum	0	0	0	0	0	0
Maximum	3950	3950	500	1405	1405	400
Charge/Ship	629	691	293	608	669	294
No. Plants	389	337	52	255	219	36
Charge/Plant	272	291	147	265	284	147
Usage/Plant	153	164	82	74	79	44
Usage Rate	56.2%	56.3%	55.7%	28.0%	27.8%	29.8%

Table 5: Consumption of CFC-12 (lbs.) in Ship-Stores and Cargo Refrigeration Plants From 1 May 1993 to 30 April 1994.

Confidence Level	Usage/Ship	Usage Rate
50.0%	356	56.5%
60.0%	366	58.1%
70.0%	377	59.9%
80.0%	391	62.1%
90.0%	412	65.4%
95.0%	429	68.2%
99.0%	469	74.6%
99.5%	487	77.4%

Table 6: Confidence Limits for Average Consumption per Ship of CFC-12 in Ship-Stores and Cargo Refrigeration Plants.

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Atl.	Pac.	Combined	Atl.	Pac.	Combined
No. Ships	45	22	67	30	13	43
Average	989	1068	1015	349	418	370
Std. Dev.	845	1135	942	513	423	484
Minimum	10	140	10	0	30	0
Maximum	3560	5100	5100	2250	1570	2250
Charge/Ship	753	916	806	718	1108	836
No. Plants	137	87	224	90	56	146
Charge/Plant	247	232	241	239	257	246
Usage/Plant	325	270	304	116	97	109
Usage Rate	131.4%	116.7%	125.9%	48.6%	37.7%	44.2%

CONSUMPTION CONFIDENCE LIMITS

Confidence Level	Usage/Ship	Usage Rate
50.0%	1019	126.5%
60.0%	1049	130.1%
70.0%	1082	134.2%
80.0%	1123	139.3%
90.0%	1182	146.6%
95.0%	1235	153.1%
99.0%	1346	166.9%
99.5%	1386	171.9%

Table 7: Consumption of CFC-12 (lbs.) in Chilled-Water AC Plants From 1 May 1993 to 30 April 1994.

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Atl.	Pac.	Combined	Atl.	Pac.	Combined
No. Ships	125	68	193	80	41	121
Average	875	961	905	446	339	410
Std. Dev.	1080	1431	1212	765	456	676
Minimum	0	0	0	0	0	0
Maximum	6025	8865	8865	5100	1773	5100
Charge/Ship	867	1296	1018	813	1369	1001
No. Plants	470	283	753	292	170	462
Charge/Plant	231	311	261	223	330	262
Usage/Plant	233	231	232	122	82	107
Usage Rate	100.9%	74.2%	88.9%	54.9%	24.8%	40.9%

REPORTED RESERVES

Number of Ships	162
Number of Plants	624
Average Charge/Ship	1021
Average Charge/Plant	265
Reserve/Ship	444
Reserve/Plant	115
Reserve/Charge	43%

CONSUMPTION CONFIDENCE LIMITS

Confidence Level	Usage/Ship	Usage Rate
50.0%	909	89.2%
60.0%	931	91.5%
70.0%	956	94.0%
80.0%	986	96.9%
90.0%	1033	101.5%
95.0%	1071	105.2%
99.0%	1151	113.0%
99.5%	1184	116.3%

Table 8: Total Consumption of CFC-12 (lbs.) From 1 May 1993 to 30 April 1994 and Reserves as of 30 April 1994.

ATLANTIC FLEET

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	59	44	15	38	31	7
Average	742	928	197	348	403	100
Std. Dev.	844	902	160	507	546	87
Minimum	0	0	0	0	0	0
Maximum	5500	5500	500	2070	2070	200
Charge/Ship	2670	2863	2104	2685	2857	1923
No. Plants	204	159	45	130	111	19
Charge/Plant	772	792	701	785	798	708
Usage/Plant	215	257	66	102	113	37
Usage Rate	27.8%	32.4%	9.3%	12.9%	14.1%	5.2%

PACIFIC FLEET

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	32	21	11	25	17	8
Average	690	909	272	342	449	114
Std. Dev.	704	768	251	549	637	130
Minimum	0	0	38	0	0	0
Maximum	2790	2790	900	2790	2790	350
Charge/Ship	3675	4464	2169	3873	4788	1928
No. Plants	122	91	31	97	77	20
Charge/Plant	964	1030	770	998	1057	771
Usage/Plant	181	210	96	88	99	46
Usage Rate	18.8%	20.4%	12.5%	8.8%	9.4%	5.9%

COMBINED FLEETS

	TOTAL CONSUMPTION			"NORMAL" LEAKAGE ONLY		
	Overall	Surface	Sub	Overall	Surface	Sub
No. Ships	91	65	26	63	48	15
Average	724	922	228	345	420	107
Std. Dev.	794	855	202	520	573	108
Minimum	0	0	0	0	0	0
Maximum	5500	5500	900	2790	2790	350
Charge/Ship	3023	3380	2132	3157	3541	1925
No. Plants	326	250	76	227	188	39
Charge/Plant	844	879	729	876	904	741
Usage/Plant	202	240	78	96	107	41
Usage Rate	23.9%	27.3%	10.7%	10.9%	11.9%	5.6%

Table 9: Consumption of CFC-114 (lbs.) From 1 May 1993 to 30 April 1994.

REPORTED RESERVES

Number of Ships	77
Number of Plants	280
Average Charge/Ship	3155
Average Charge/Plant	868
Reserve/Ship	1249
Reserve/Plant	343
Reserve/Charge	40%

CONSUMPTION CONFIDENCE LIMITS

	ALL SHIPS		SURFACE SHIPS		SUBMARINES	
Confidence Level	Usage/ Ship	Usage Rate	Usage/ Ship	Usage Rate	Usage/ Ship	Usage Rate
50.0%	728	24.1%	928	27.4%	230	10.8%
60.0%	750	24.8%	956	28.3%	241	11.3%
70.0%	774	25.6%	987	29.2%	252	11.8%
80.0%	805	26.6%	1027	30.4%	267	12.5%
90.0%	851	28.2%	1085	32.1%	289	13.6%
95.0%	892	29.5%	1140	33.7%	308	14.4%
99.0%	974	32.2%	1263	37.4%	349	16.4%
99.5%	1007	33.3%	1308	38.7%	363	17.0%

Table 10: Reported Reserves for CFC-114 (lbs.) as of 30 April 1994 and Confidence Limits for Yearly Consumption per Ship.

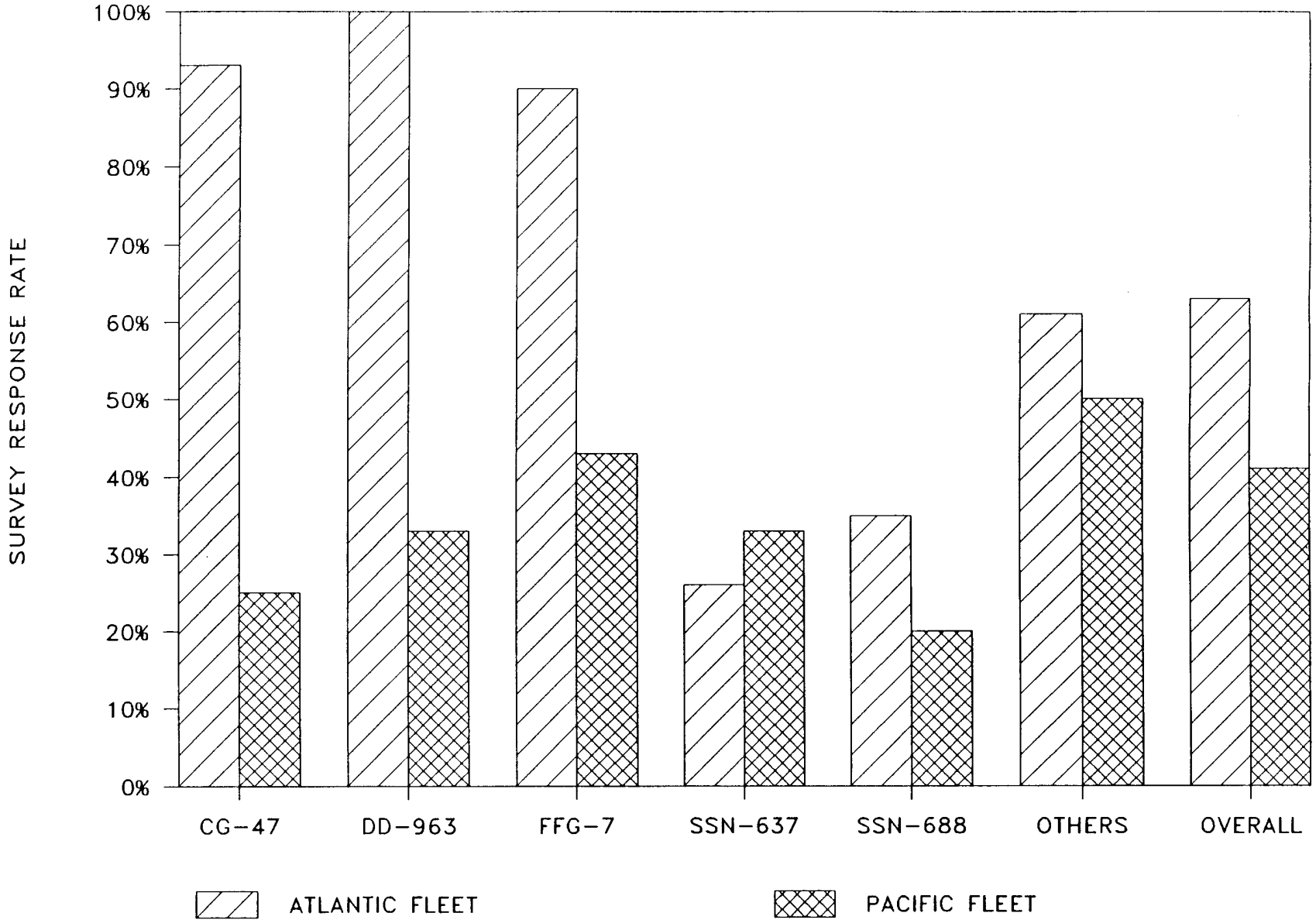


Figure 1: Percentage of Ships Responding to the Halon/CFC Survey.

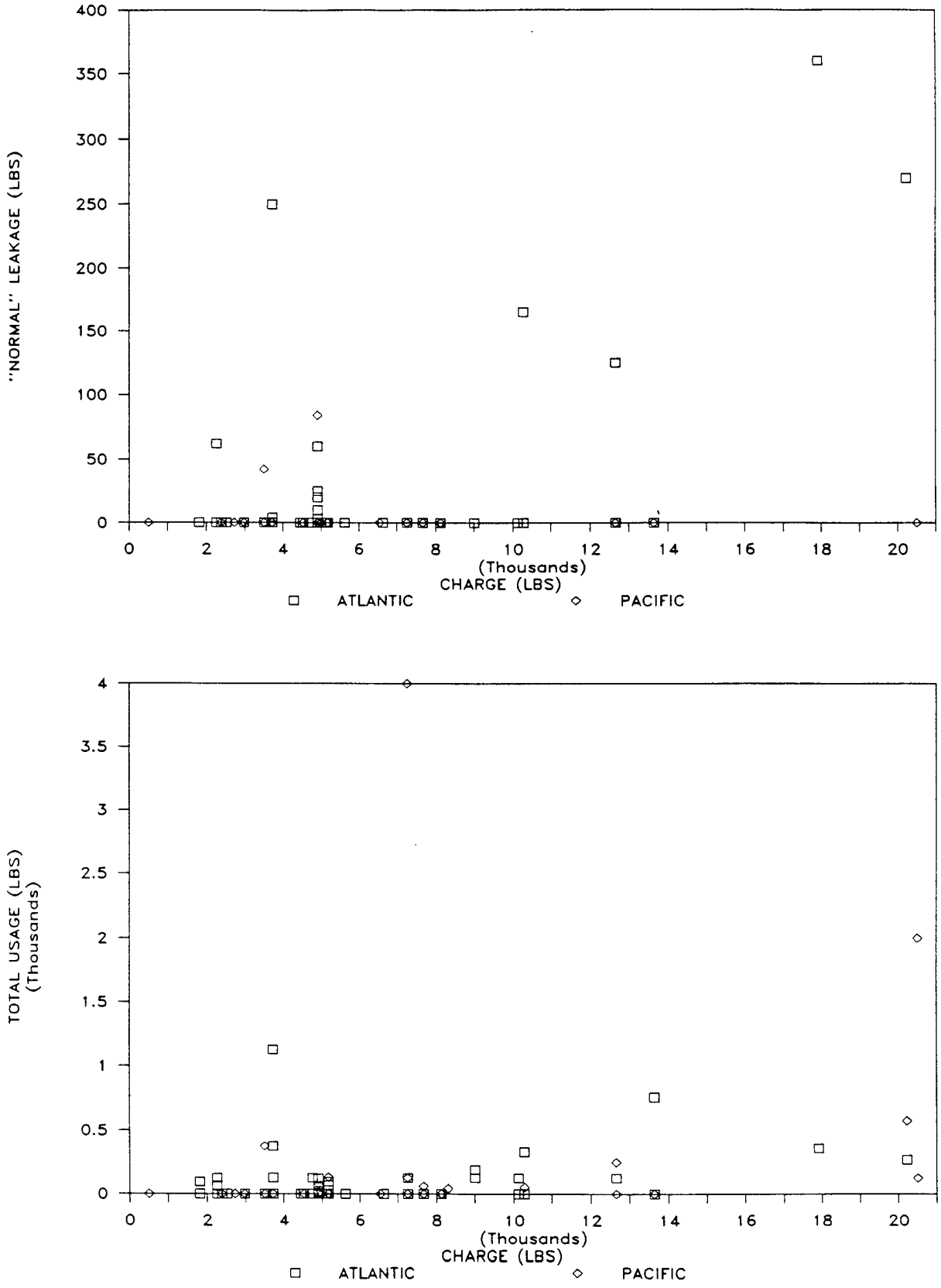
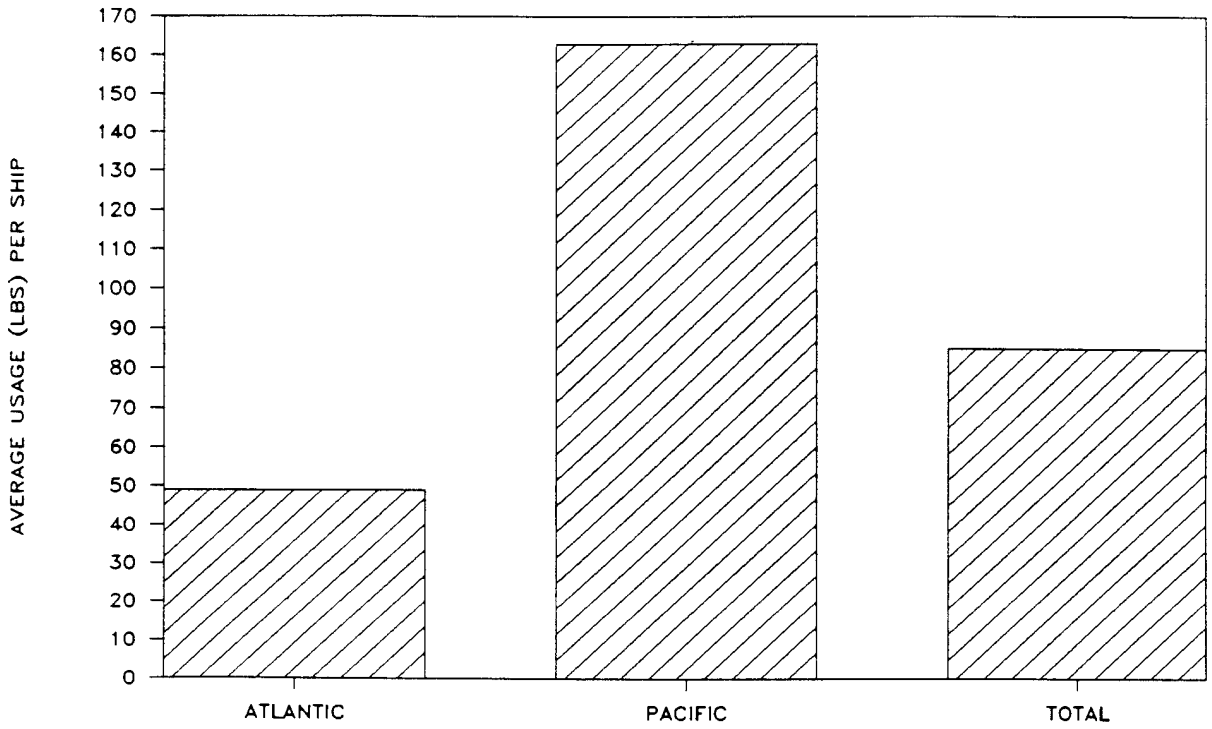


Figure 2: Halon 1301 Four-Month Usage vs. Charge per Ship.



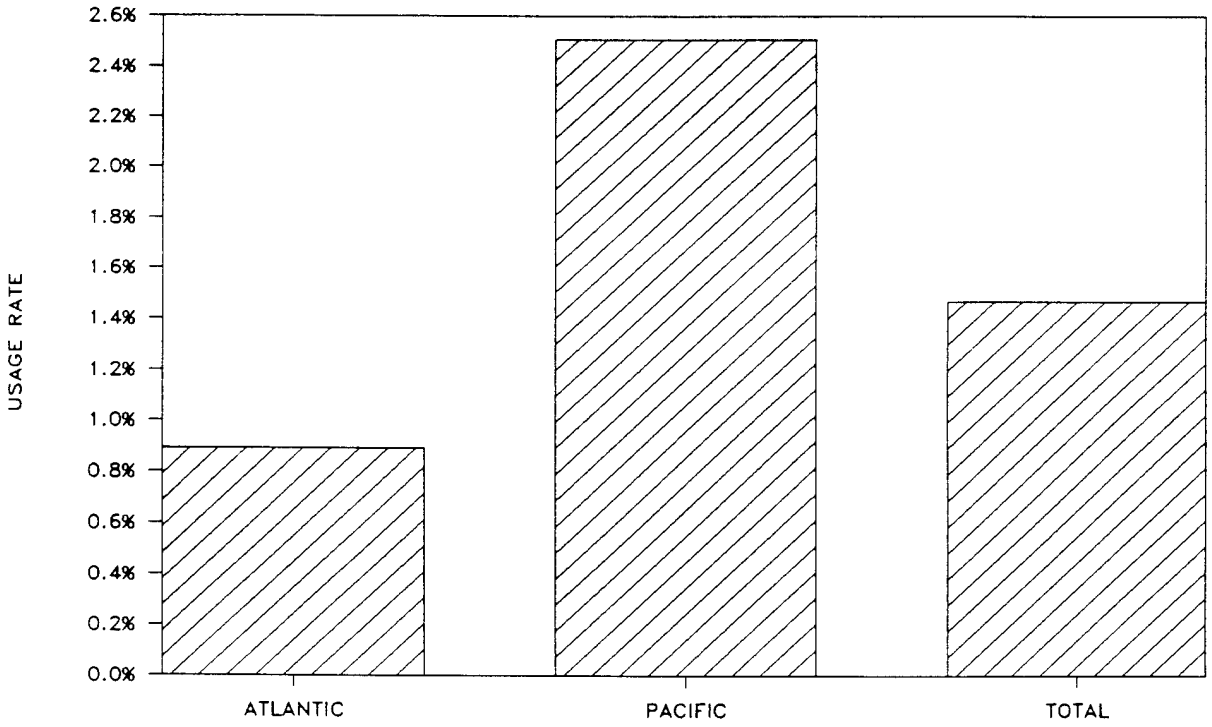
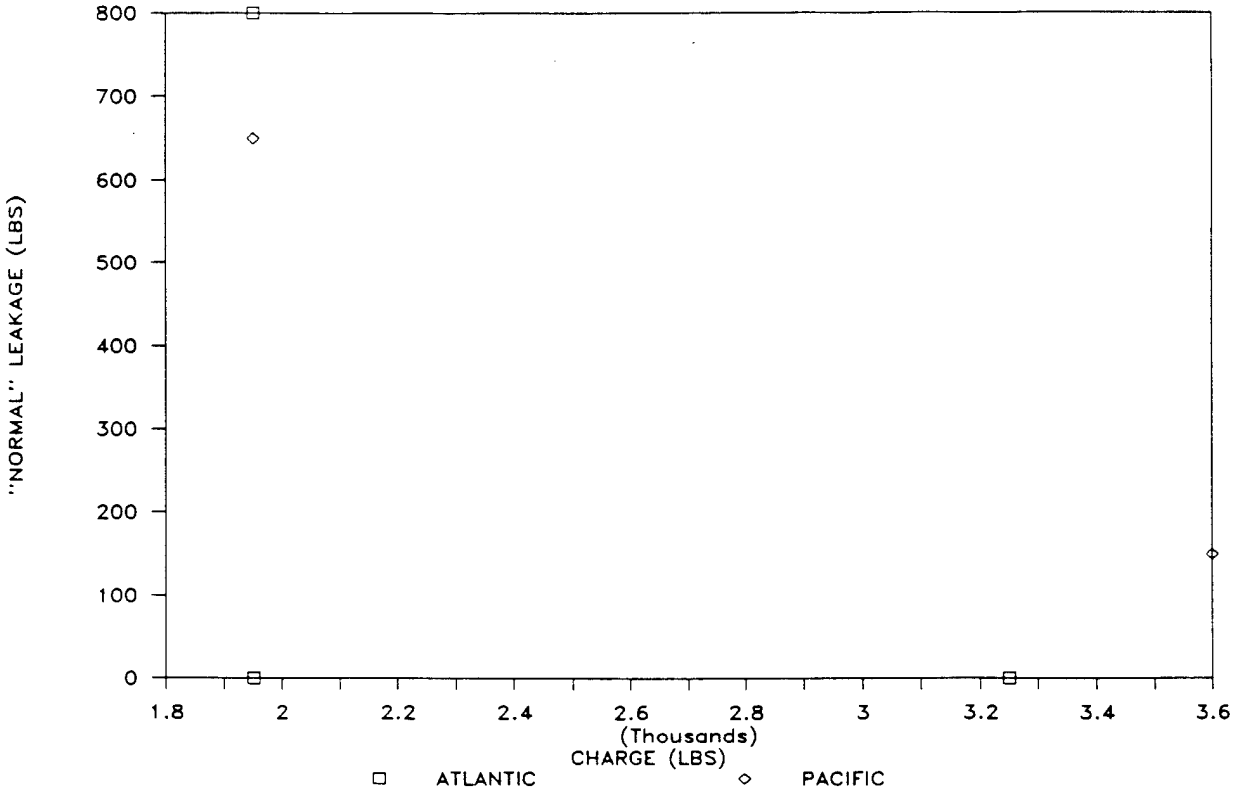


Figure 3: Halon 1301 Estimated Four-Month Usage per Ship.



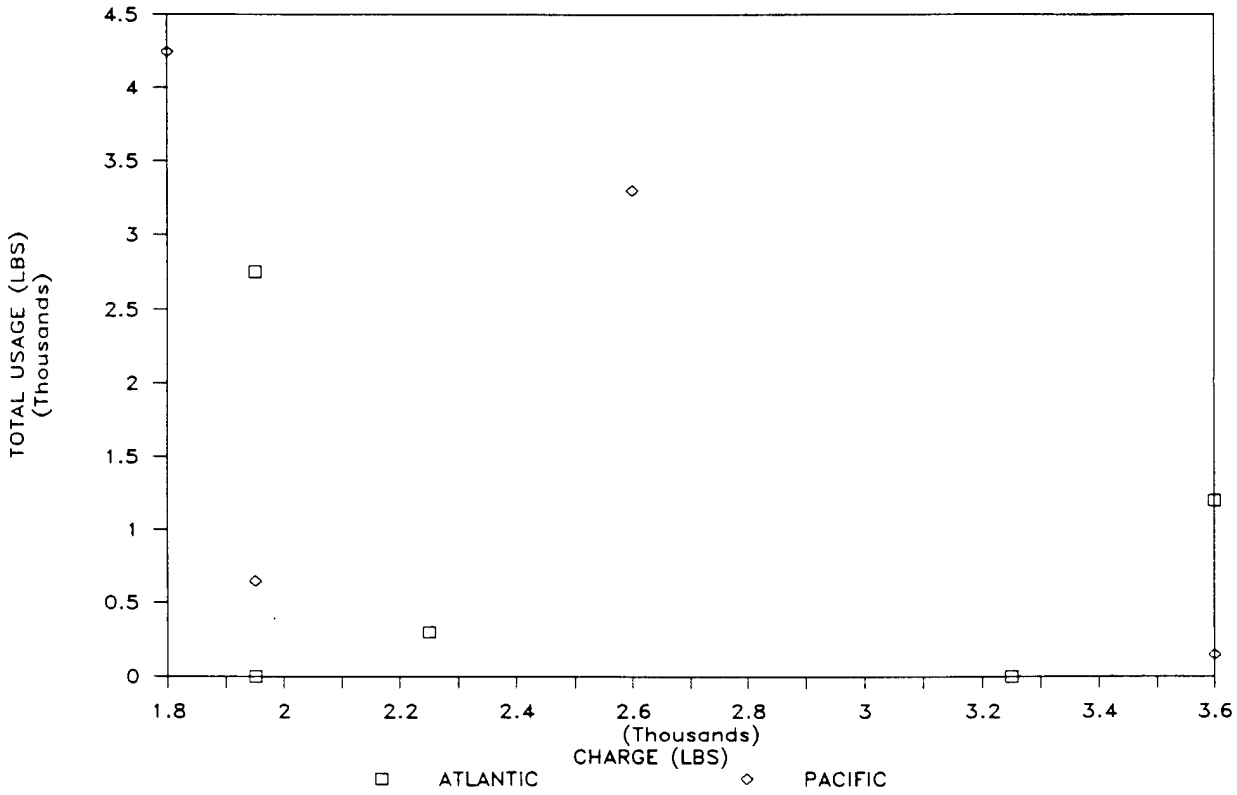


Figure 4: CFC-11 Chilled-Water AC Plants Annual Usage vs. Charge per Ship.

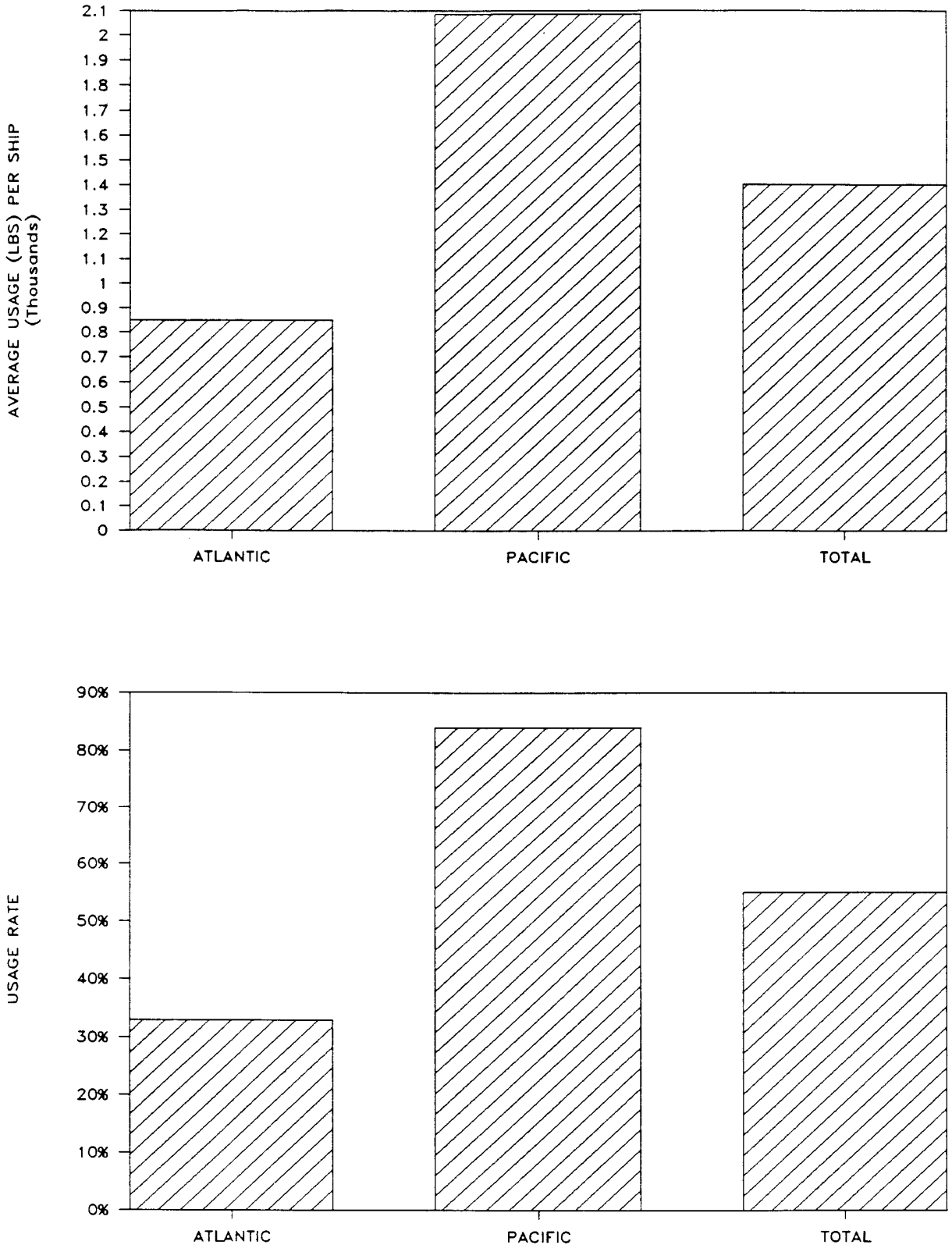


Figure 5: CFC-11 Chilled-Water AC Plants Estimated Annual Usage per Ship.

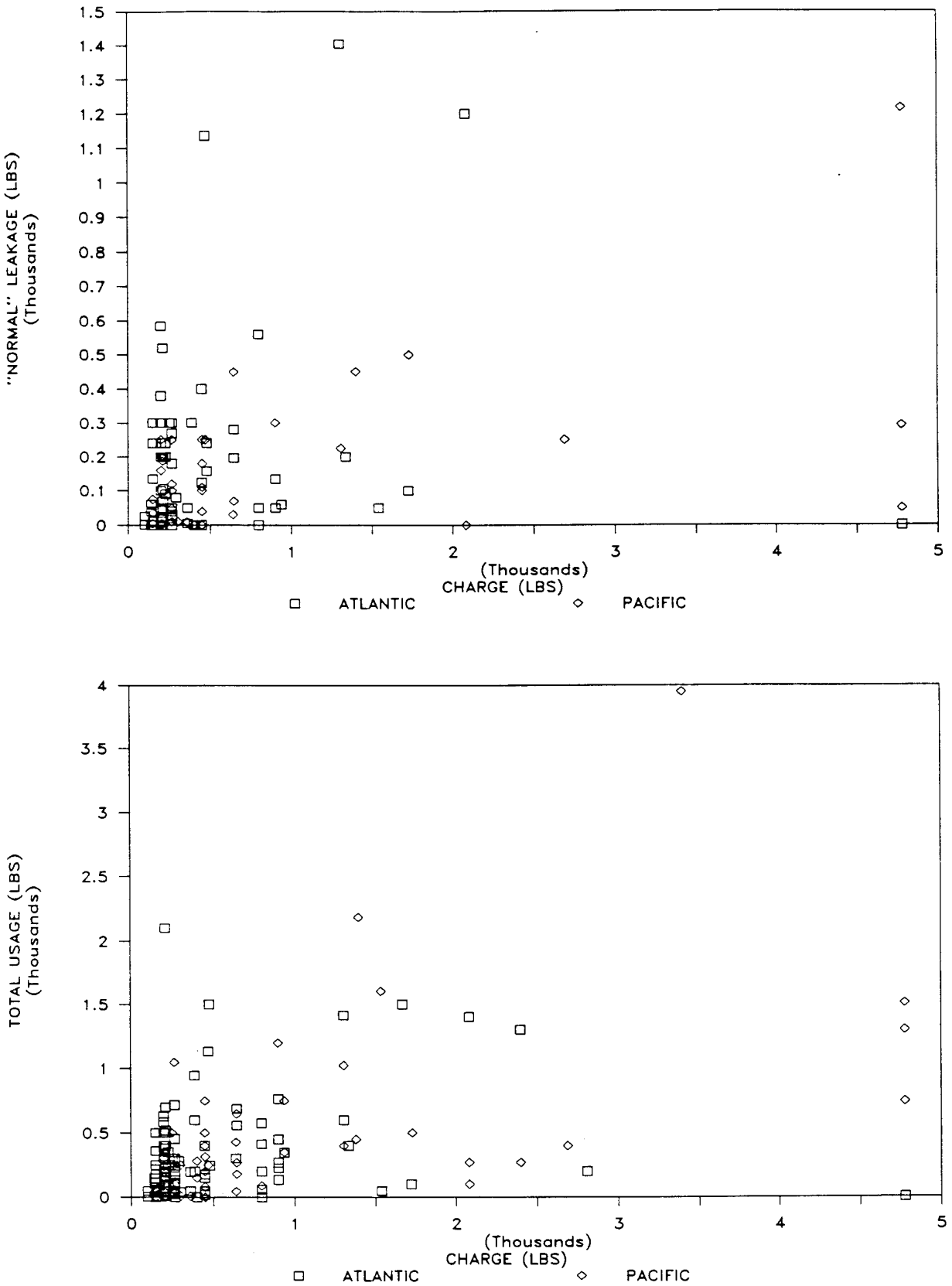


Figure 6: CFC-12 Refrigeration Plants Annual Usage vs. Charge per Ship.

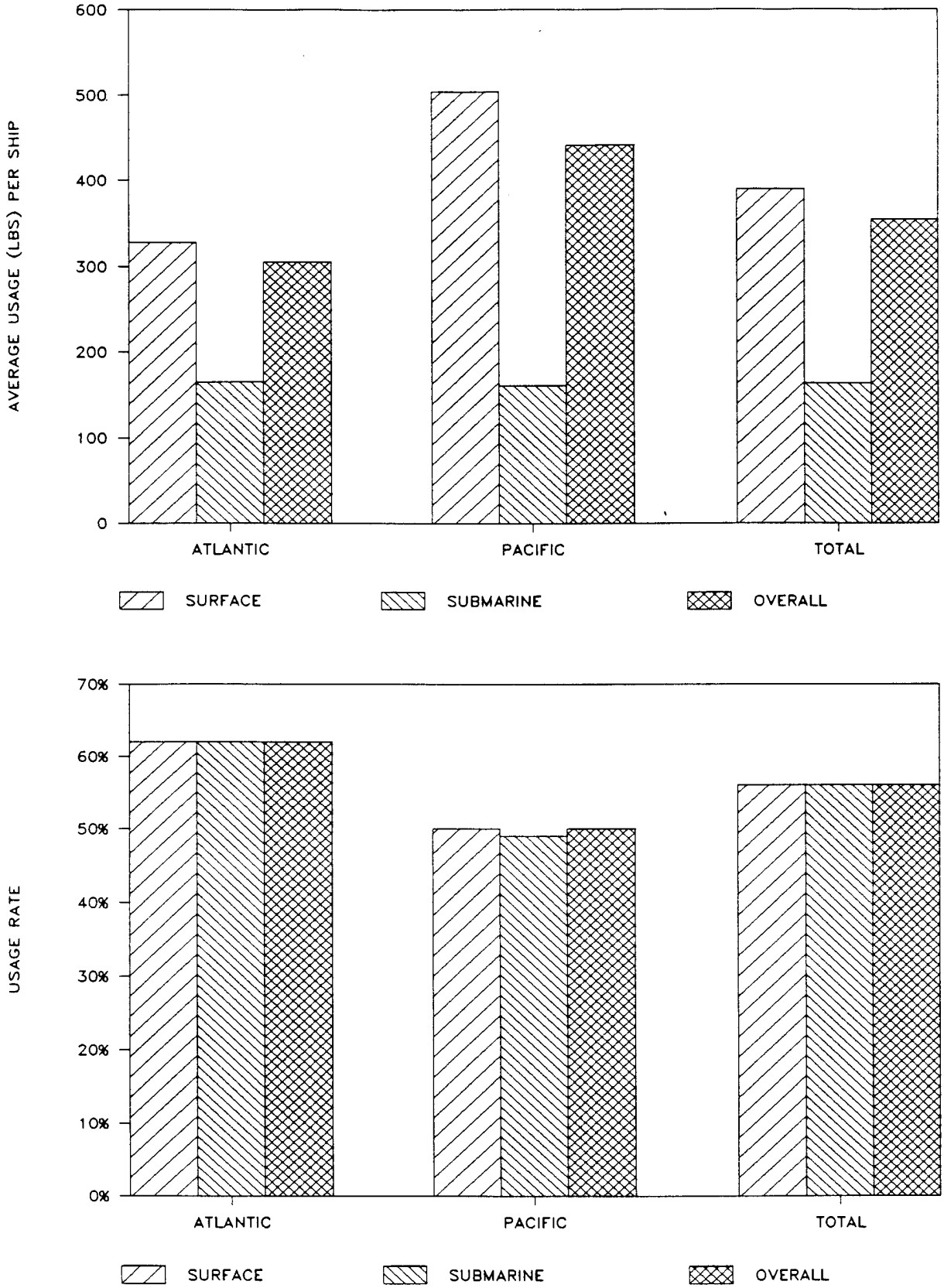
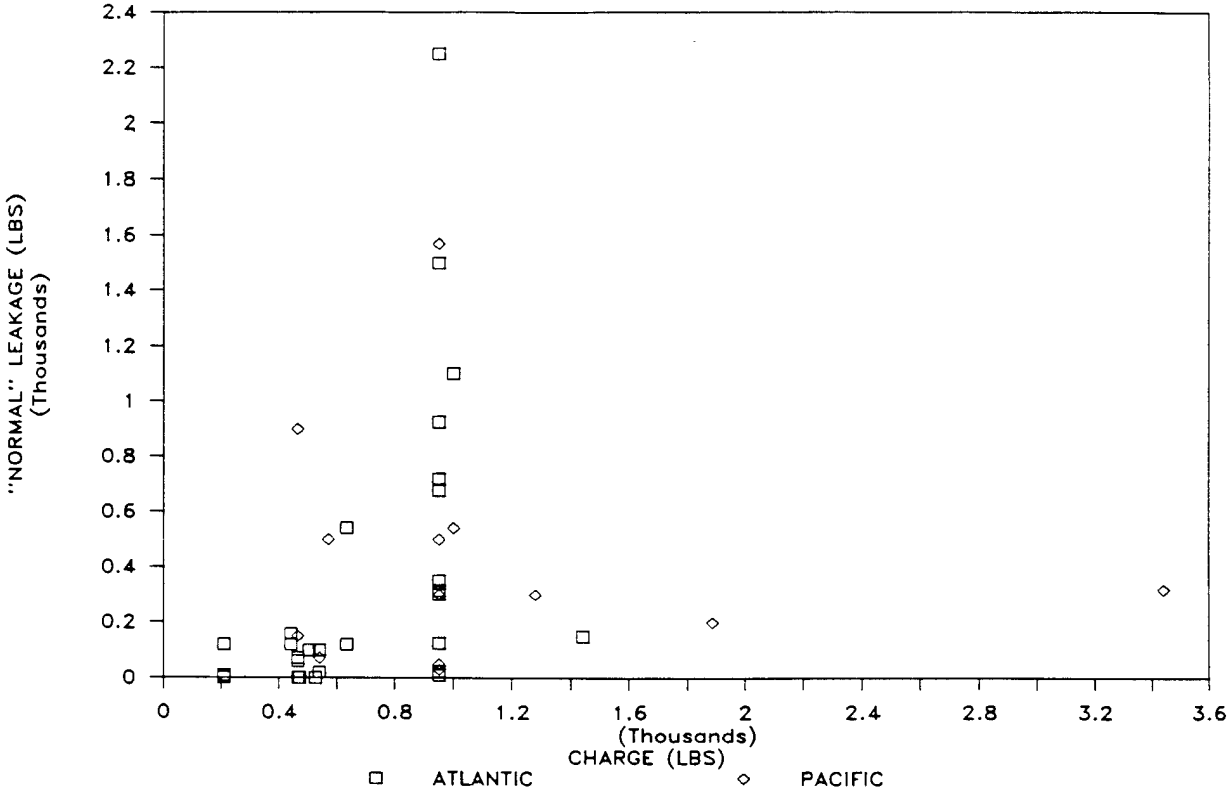


Figure 7: CFC-12 Refrigeration Plants Estimated Annual Usage per Ship.



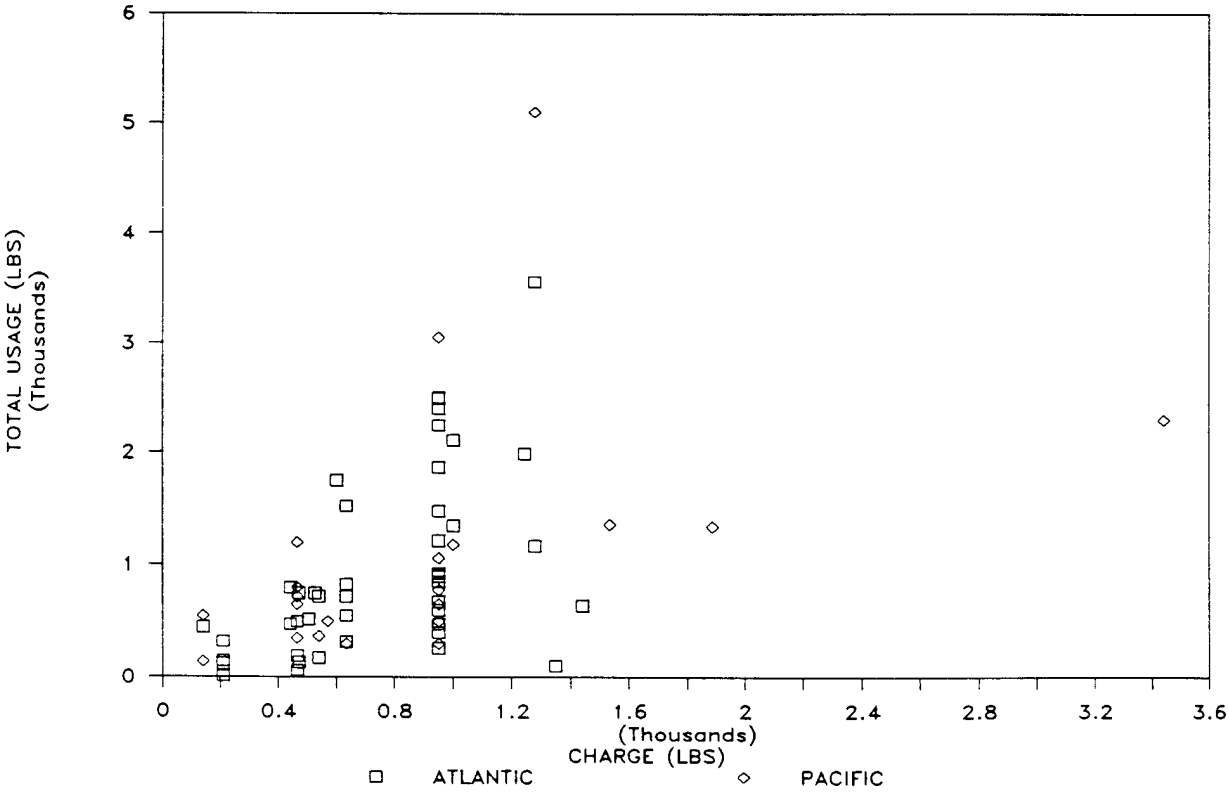


Figure 8: CFC-12 Chilled-Water AC Plants Annual Usage vs. Charge per Ship.

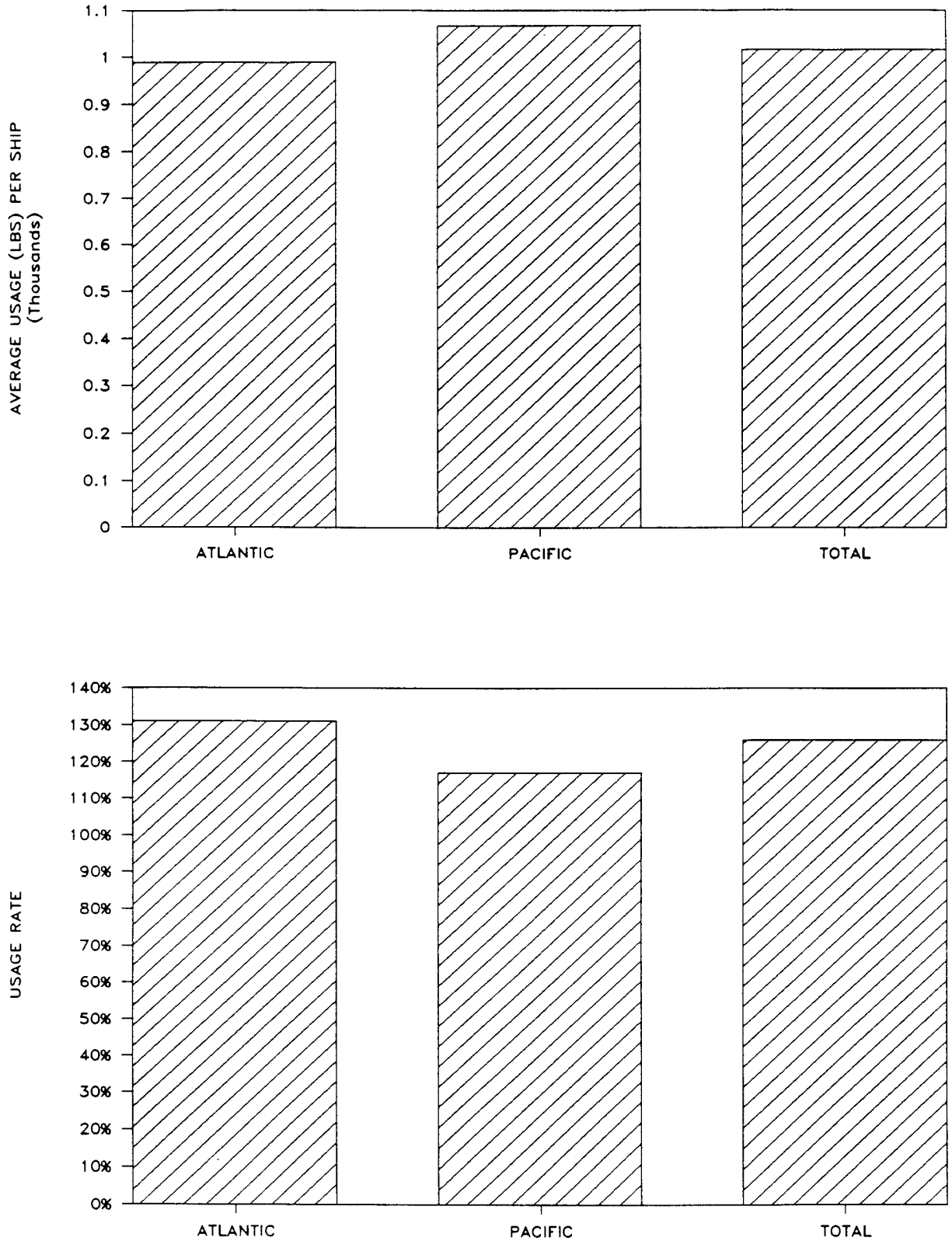


Figure 9: CFC-12 Chilled-Water AC Plants Estimated Annual Usage per Ship.

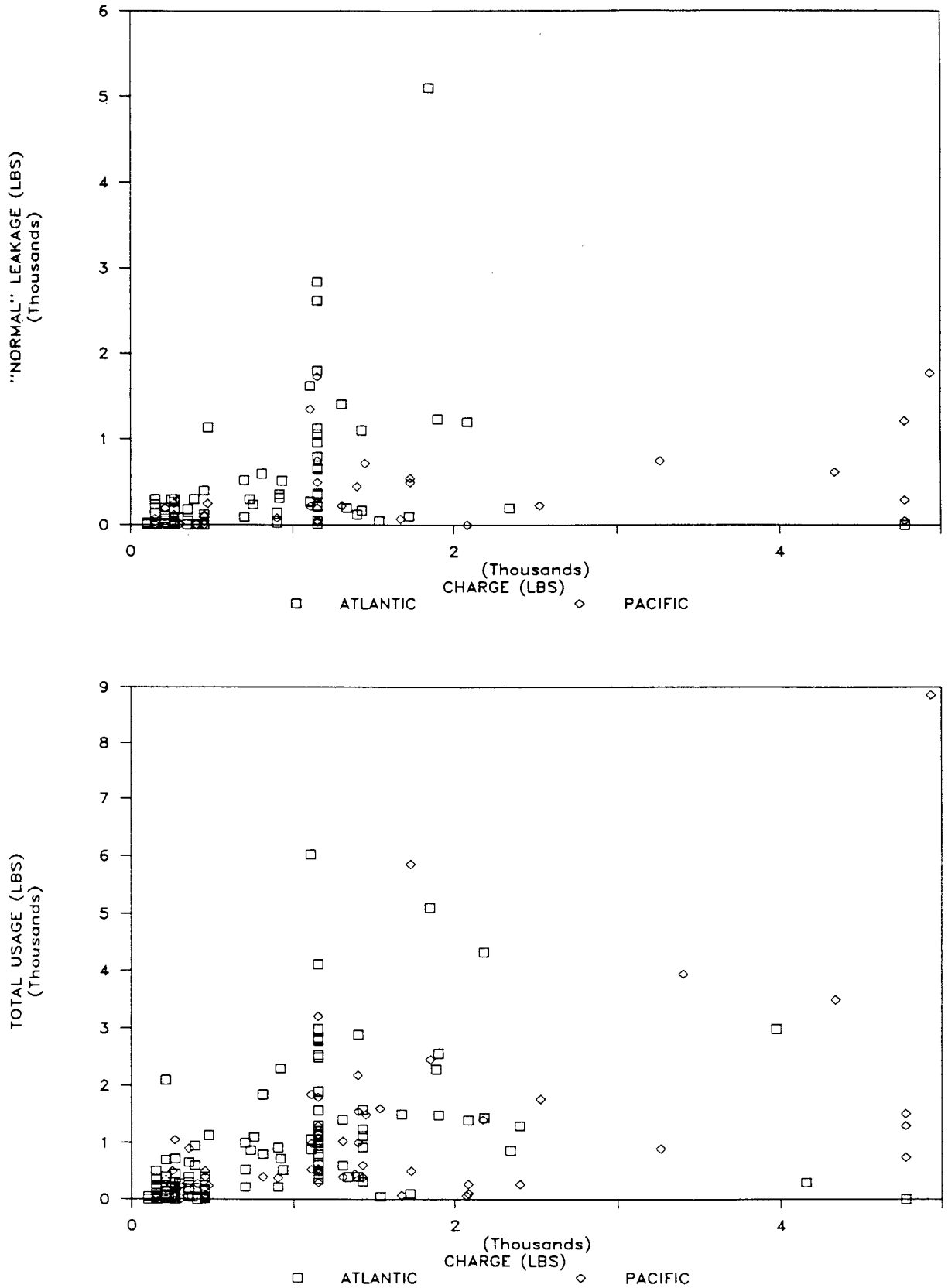
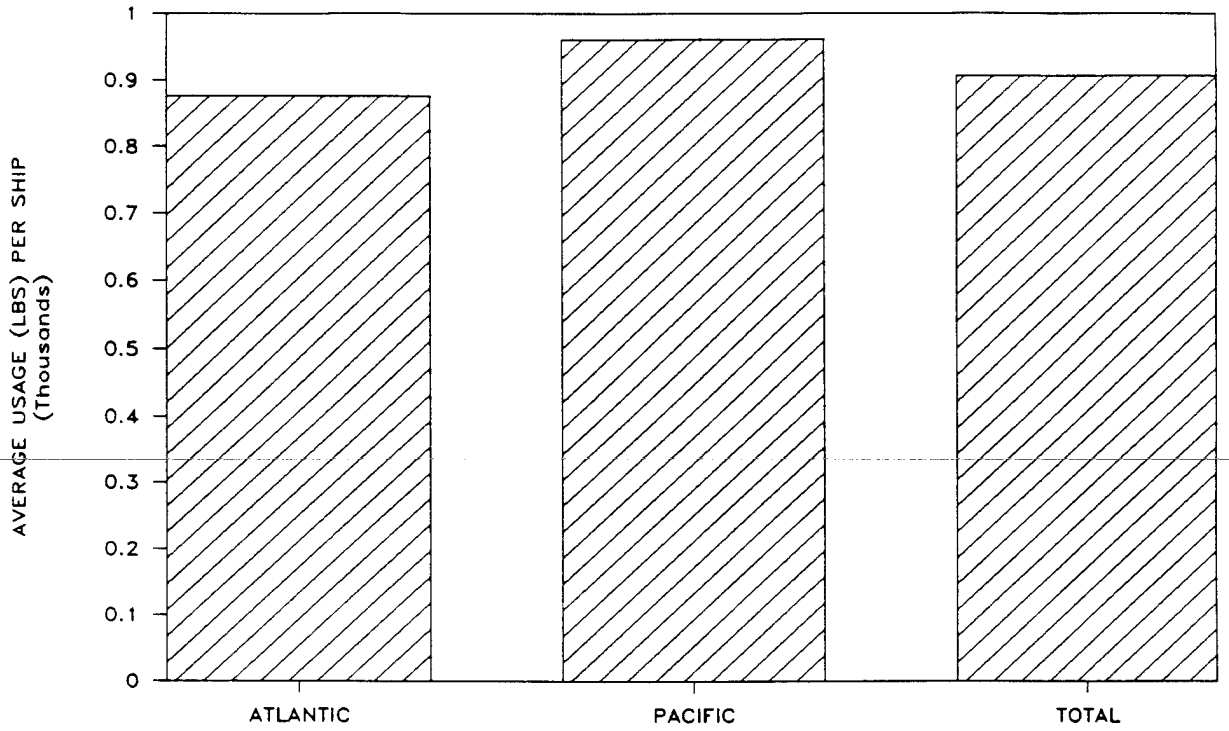


Figure 10: CFC-12 Total Annual Usage (Refrigeration + AC) vs. Charge per Ship.



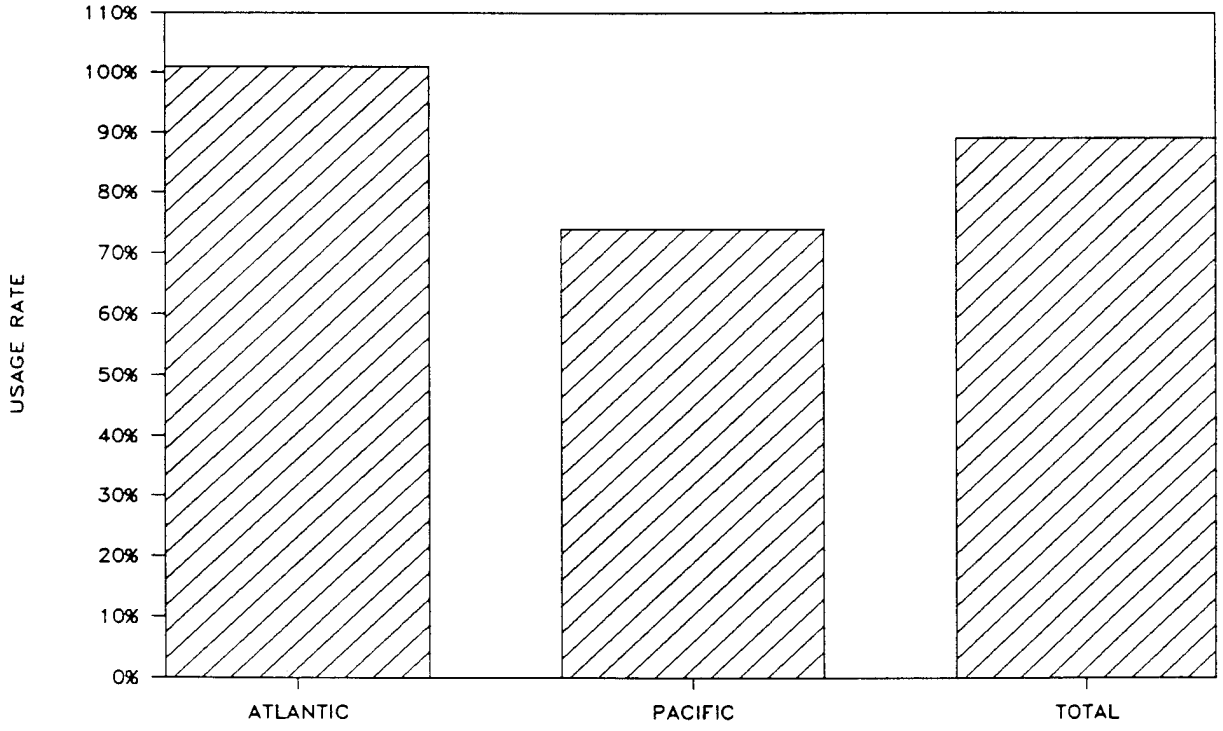


Figure 11: CFC-12 Estimated Total (Refrigeration + AC) Annual Usage per Ship.

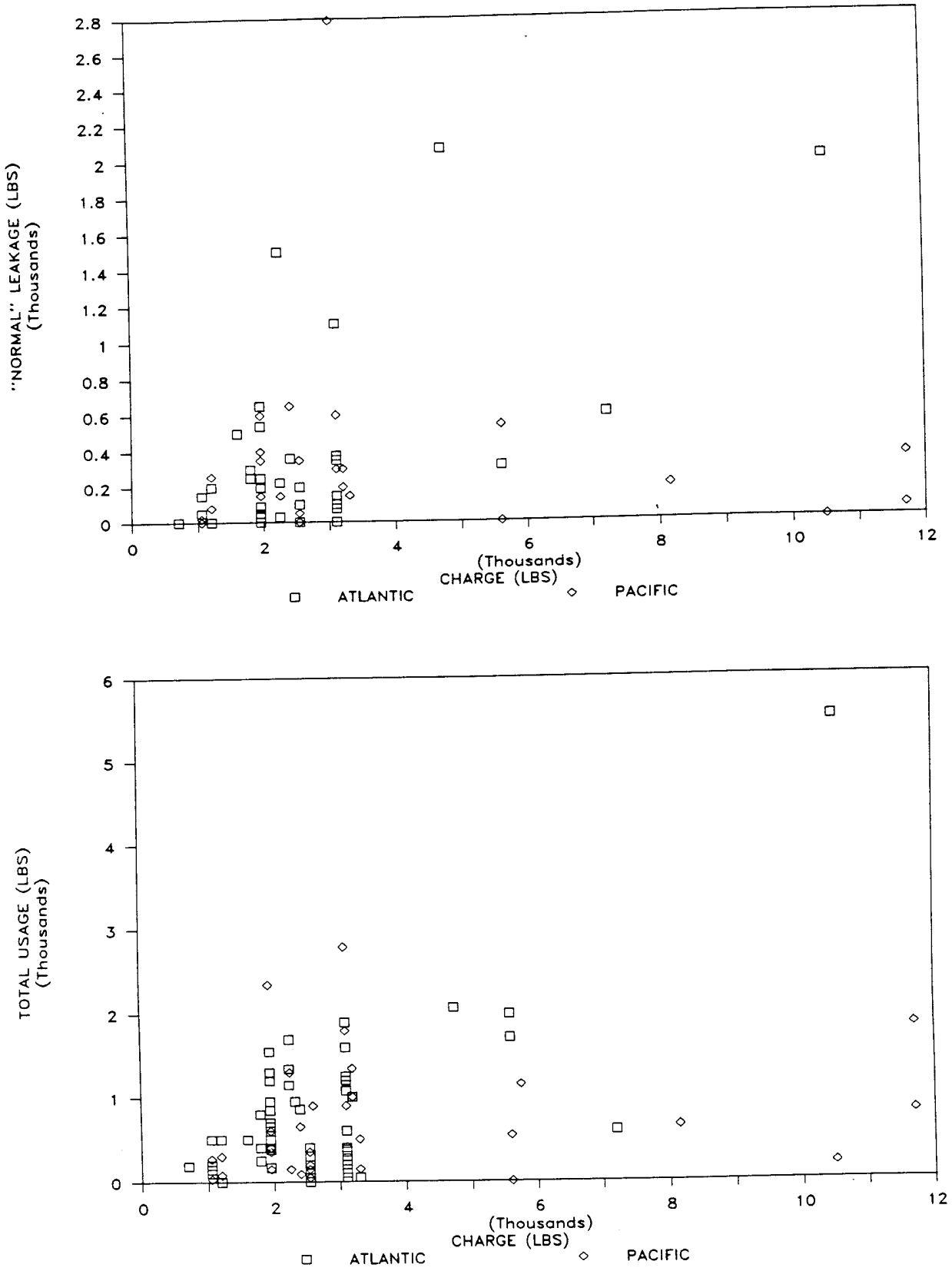


Figure 12: CFC-114 Chilled-Water AC Plants Annual Usage vs. Charge per Ship.

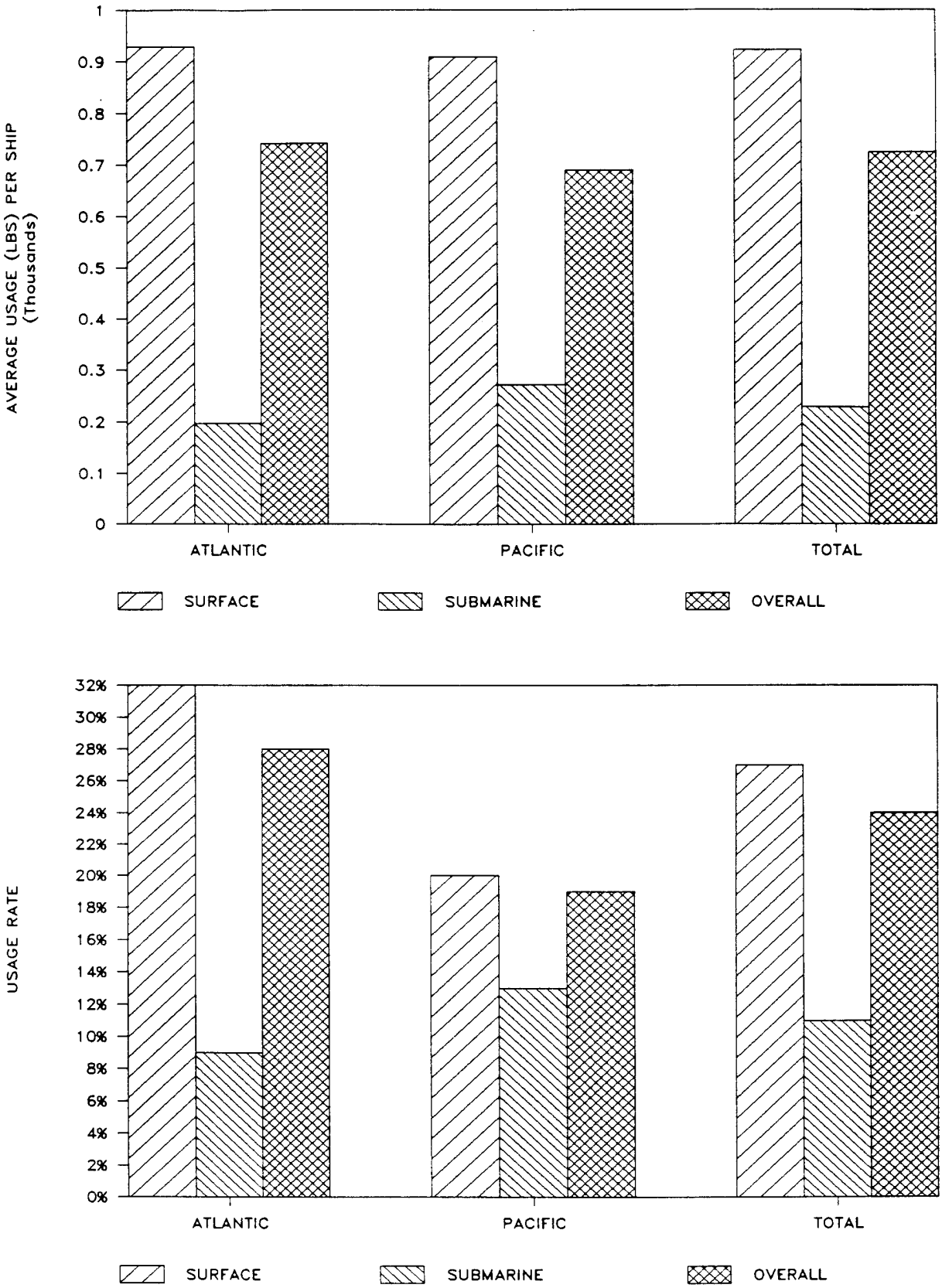


Figure 13: CFC-114 Chilled-Water AC Plants Estimated Annual Usage per Ship.

APPENDIX: SURVEY TO SUPPORT ESTABLISHMENT OF MISSION-CRITICAL RESERVE OF HALONS AND CFCS

RTTUZYUW RULSSGG2564 1291030-UUUU--RULSSEA RULSSAD.
ZNR UUUUU
R 090348Z MAY 94 ZYB PSN 790341M24

FM COMNAVSEASYSCOM WASHINGTON DC//03V//

TO RUCBCLF/CINCLANTFLT NORFOLK VA//N44/N43/N8/N6/N021//

RHHMHAH/CINCPACFLT PEARL HARBOR HI//N44/N43/N8/N02L//
RULSSAD/COMNAVSUPSYSCOM WASHINGTON DC//424/41//
INFO RUENAAA/CNO WASHINGTON DC//N451//
RUCBTFA/COMNAVSURFLANT NORFOLK VA//N43/N8/N6/N1//
RUCOSAA/COMNAVAIRLANT NORFOLK VA//N43/N8/N6/N1//
RUCBKMC/COMSUBLANT NORFOLK VA//N43/N8/N6/N1//
RUWDEAA/COMNAVSURFPAC SAN DIEGO CA//N43/N8/N6/N1//
RUWFEAA/COMNAVAIRPAC SAN DIEGO CA//N43/N8/N6/N1//
RHHMDBA/COMSUBPAC PEARL HARBOR HI//N43/N8/N6/N1//
AIG ONE ONE ZERO ZERO ONE
AIG ONE ONE ZERO ZERO ZERO
RULSNAA/COMNAVAIRSYSCOM WASHINGTON DC//PMS205-3C7//

UNCLAS //N09510//

MSGID/GENADMIN/NAVSEA 03V24//

SUBJ/SURVEY TO SUPPORT ESTABLISHMENT OF MISSION-CRITICAL RESERVE OF HALONS AND CFCS//

REF/A/40 CFR PART 82 SUBPART A//
REF/B/TEL/NAVSEA 03V24/940429//
REF/C/TEL/NAVSEA 03V24/940506//
REF/D/TEL/NAVSEA 03VB/940506//
NARR/REF A EPA FINAL RULE ON ACCELERATED PHASEOUT OF HALONS AND CFCS DTD 10 DEC 93. REF B TELCON BTWN NAVSEA 03V24 (MR. BRESLIN)/ CINCLANTFLT N434 (LCDR WARREN). REF C TELCON BTWN NAVSEA 03V24 (MR. BRESLIN)/CINCPACFLT N431 (CAPT PATCH). REF D TELCON BTWN NAVSEA 03VB (CDR SMITH)/NAVSUP 424 (MR. BOB LAW).//
POC/D. BRESLIN/SEA 03V24/-/-/TEL: 703-602-9025 X240//
AKNLDG/-//
RMKS/1. SUMMARY: THE PURPOSE OF THIS MESSAGE IS TO SOLICIT HELP TO CONDUCT A COMPREHENSIVE SURVEY OF HALON AND CFC CONSUMPTION BY THE FLEET IN ORDER TO DETERMINE THE SIZE OF A MISSION-CRITICAL RESERVE OF HALONS AND CFCS NEEDED UNTIL ALL ODS SYSTEMS ARE EITHER REPLACED OR RETIRED.
2. BACKGROUND: PROVISIONS UNDER REF A STIPULATE THAT DOMESTIC PRODUCTION OF HALONS CEASE ON 01 JAN 94 AND DOMESTIC PRODUCTION OF CHLOROFLUOROCARBON (CFC) REFRIGERANTS CEASE ON 01 JAN 96. DUE TO THE NAVY'S CONTINUED DEPENDENCE ON HALONS AND CFCS FOR MISSION-CRITICAL APPLICATIONS, THE DLA HAS BEEN TASKED TO

ESTABLISH A MISSION-CRITICAL RESERVE DESIGNED TO CARRY THE NAVY FROM THE POINT OF PRODUCTION CESSATION TO THE POINT WHERE THE LAST HALON AND CFC SYSTEMS ARE EITHER RETIRED OR CONVERTED TO "OZONE-FRIENDLY" CHEMICALS. MISSION CRITICAL IS DEFINED AS THOSE USES THAT HAVE A DIRECT IMPACT ON COMBAT MISSION CAPABILITY SUCH AS FIRE SUPPRESSION SYSTEMS AND COOLING OF WEAPON SYSTEMS ON-BOARD VESSELS INCLUDING HALON 1211 AND 1301 FIRE-SUPPRESSION SYSTEMS, CFC-11 (R-11), CFC-12 (R-12), AND CFC-114 (R-114) AC CHILLED-WATER PLANTS, AND CFC-12 (R-12) CARGO AND SHIP-STORES REFRIGERATION PLANTS. COMMERCIALLY-AVAILABLE SUPPLIES OF HALONS AND CFCS ARE SUFFICIENT IN THE SHORT-TERM FOR THE ESTABLISHMENT OF A MISSION-CRITICAL RESERVE. HOWEVER, IT IS PROJECTED THAT COMMERCIAL SUPPLIES OF HALONS AND CFCS WILL QUICKLY BECOME UNAVAILABLE.

3. NAVSEA HAS BEEN DIRECTED BY CNO TO PROVIDE DLA WITH THE QUANTITIES OF HALONS AND CFCS REQUIRED FOR SHIPBOARD MISSION-CRITICAL USES. THESE QUANTITIES WILL BE BASED ON CURRENT FLEET-WIDE CONSUMPTION RATES (LBS PER YEAR), CORRECTED FOR PLANNED DECOMMISSIONINGS AND SYSTEM CONVERSIONS, AND PROJECTED OUT TO THE POINT WHERE THE LAST HALON AND CFC SYSTEMS ARE EITHER RETIRED OR CONVERTED. DUE TO THE FACT THAT THE MISSION-CRITICAL RESERVE WILL HAVE TO SUPPORT FLEET REQUIREMENTS WELL INTO THE NEXT CENTURY (THE 2040S IN THE CASE OF HALON 1301), THE MISSION-CRITICAL RESERVE MUST BE SIZED SUCH THAT THERE IS A HIGH LEVEL OF CONFIDENCE THAT SHORTAGES WILL NOT OCCUR PRIOR TO THE POINT IN TIME AT WHICH THE LAST SYSTEMS ARE EITHER RETIRED OR CONVERTED. IN ORDER TO ENSURE THIS HIGH LEVEL OF CONFIDENCE, IT IS ABSOLUTELY NECESSARY THAT AN ACCURATE ANALYSIS OF CONSUMPTION IS COMPLETED AT THIS TIME.

4. IN ORDER TO SUPPORT THIS ANALYSIS, THE FOLLOWING INFORMATION IS REQUIRED FROM ALL AFLOAT UNITS (DISREGARD THOSE SYSTEMS THAT ARE NOT APPLICABLE TO YOUR UNIT):

A. FOR SHIPBOARD HALON 1211 FIRE-SUPPRESSION SYSTEMS (NOTE: HALON 1211 APPLIES TO ASSAULT CRAFT UNITS 4 AND 5 (LCACS) ONLY): REPORT TOTAL ESTIMATED CONSUMPTION OF HALON 1211 BETWEEN 01 JAN 94 AND 30 APR 94 (4 MONTHS) IN LBS. IF POSSIBLE, ESTIMATE CONSUMPTION DUE TO NORMAL LEAKAGE AND CONSUMPTION DUE TO ACCIDENTAL DISCHARGES/ CATASTROPHIC FAILURES. REPORT TOTAL INSTALLED SPARE CHARGE OF HALON 1211 ON 30 APR 94 IN LBS, INCLUDING DEPLOY DETACHMENTS.

B. FOR SHIPBOARD HALON 1301 FIRE-SUPPRESSION SYSTEMS: REPORT TOTAL ESTIMATED CONSUMPTION OF HALON 1301 BETWEEN 01 JAN 94 AND 30 APR 94 (4 MONTHS) IN LBS. IF POSSIBLE, ESTIMATE CONSUMPTION DUE TO NORMAL LEAKAGE AND CONSUMPTION DUE TO ACCIDENTAL DISCHARGES/CATASTROPHIC FAILURES. REPORT TOTAL INSTALLED SPARE CHARGE OF HALON 1301 ON 30 APR 94 IN LBS.

C. FOR SHIPBOARD CFC-11 (R-11) CHILLED-WATER AC PLANTS: REPORT TOTAL ESTIMATED CONSUMPTION OF CFC-11 BETWEEN 01 MAY 93 AND 30 APR 94 (12 MONTHS) IN LBS. IF POSSIBLE, ESTIMATE CONSUMPTION DUE TO NORMAL LEAKAGE AND CONSUMPTION DUE TO ACCIDENTAL DISCHARGES/CATASTROPHIC FAILURES. REPORT TOTAL INSTALLED SPARE CHARGE OF CFC-11 ON 30 APR 94 IN LBS.

D. FOR SHIPBOARD CFC-12 (R-12) CHILLED-WATER AC PLANTS: REPORT TOTAL ESTIMATED CONSUMPTION OF CFC-12 BETWEEN 01 MAY 93