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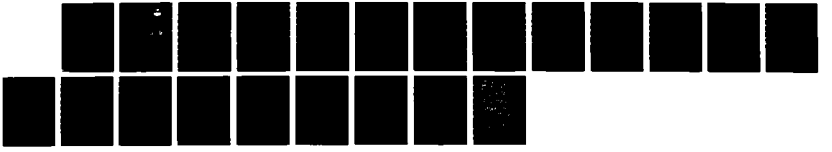

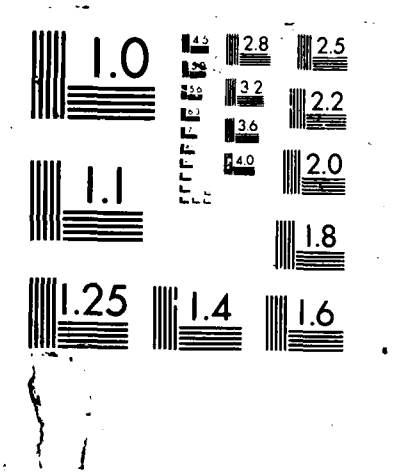
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USAFOEHL REPORT

87-154EQ0146MSB

Swimming Pool Survey, Offutt AFB NE

ROBERT D. BINOVI, Lt Col, USAF, BSC

December 1987

Final Report

USAF Occupational and Environmental Health Laboratory
Human Systems Division (AFSC)
Brooks Air Force Base, Texas 78235-5501

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A survey of three swimming pools was conducted at Offutt AFB Nebraska by Lt Col Robert D. Binovi, Chief Water Quality Function. Bacteriological contamination, as evidenced by positive total coliform samples, had been experienced at the three pools for about a month prior to the survey. The results of the survey showed that there was a chemical imbalance in the pools and insufficient alkalinity. A broken pipe, unstable water, possible dead areas in the pool, swimmers sanitary habits, inadequate cleaning practices could all have contributed to the problem.

Recommendations: (1) Positive total coliform samples should be confirmed; (2) Fecal coliform tests should be used to help determine the severity of the contamination; (3) Alkalinity needs to be checked frequently; (4) Soda ash should be substituted for caustic soda; (5) Unnecessary backwashing chlorine residual should be checked; (6) Free available and total available chlorine residuals should be checked at (over)

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least daily to determine organic loading. (7) Quaternary ammonium algicides should be avoided; (8) Replace leaking piping at the Officer's Club pool; and (9) Allow sufficient time for the pool to filter and stabilize the water before opening it after having been drained.

CONTENTS

I. INTRODUCTION

On 22 June 1987, USAF Regional Hosp/SGPB, Offutt AFB, requested a survey of the swimming pools on base. The swimming pools had been closed by the Director of Base Medical Services (DBMS) because bacteriological contamination had been found in each of the three pools. A survey was conducted from 24 to 26 June by LT Col Robert D. Binovi, Chief, Water Quality Function, Consultant Services Division, USAF Occupational and Environmental Health Laboratory (USAFOEHL/ECQ). The objective of this survey was to examine the design, condition, and operation of the pools as well as the analyses of bacteriological samples in an effort to determine the cause of positive samples in all three pools.

II. DISCUSSION

A. Background

Offutt AFB is located near Omaha, Nebraska and is headquarters for the Strategic Air Command. The base operates four swimming pools on a seasonal basis, the Capehart Housing Area pool, The Officer's Club pool, the Hilltop pool, and the Airman's pool. The Airman's pool was under renovation and was not included in this survey.

Base drinking water is supplied by the Metropolitan Utilities District of Omaha from groundwater sources. A copy of a Report of Water Analysis is included as Appendix A. The water is typically hard (173 mg/L), with high pH, (8.90), alkaline (131 mg/L $CaCO_3$), and with a tendency to deposit (Langelier Index 1.00).

B. Facility Description

There were three swimming pools operating during this survey. A fourth, the Airman's Pool was undergoing major renovation. The following is a short description of the three pools:

1. Capehart Pool - The Capehart pool services the large housing area on base. It is the largest pool in terms of volume (294,000 gallons) with the largest swimming population. The pool is "T" shaped, with a separate diving area located at the shortened leg of the "T". This 80 ft X 46 ft pool was renovated in 1986 and opened this year with new piping, sand filter, skimmer return system, etc. Chlorine gas is used for disinfection. Sodium hydroxide (caustic soda) is used for alkalinity control. The chlorinator has a 100 lb/day capacity. The chemical pump delivers 5-8 gallons per hour of the 20% caustic soda. The chlorinator and caustic soda pump are controlled automatically by feedback from a pH sensor. Chlorine is injected into the return line of the pump. A main drain is provided at the deepest part of the diving area. Surface skimming is provided by gutters extending around the perimeter of the pool. Return water inlets are spaced around the pool. A 750 gallons per minute (gpm) pump circulates the water through the filtration system.

2. Officer's Club Pool - The Officer's Club Pool was built in 1961. The sand filters were installed in 1980. The pool holds 212,000 gallons with dimensions of 62 ft X 63 ft. Water is circulated through the filtration system by a 750 gpm pump. Chlorination and alkalinity equipment are identical to the equipment installed at the Capehart pool. Bottom drains, as well as surface gutters are provided.

3. Hilltop Pool - The Hilltop pool is provided for the enjoyment of the airman dormitory occupants. This motel type pool was built in 1979 and measures 16 ft X 32 ft and holds 18,000 gallons of water. It has one main drain and a surface skimmer. The water is circulated by a 60 gpm pump. A 50 lb/day gas chlorinator with automatic controller is provided. Alkalinity is maintained by caustic soda also controlled automatically.

C. Results of Base Bacteriological Analyses

The Offutt AFB Bioenvironmental Engineering Office, (EBUSAFRH/SGPB) analyzes bacteriological samples as required by AFR 161-14. Water samples are taken from the pools at least twice a week, and analyzed for total coliform organisms. Samples are also taken during a preseason inspection. AFR 161-14 requires the pool to be thoroughly tested and in proper operation at least 48 hours before it officially opens. A post season inspection is also required to determine the off season maintenance needs.

The presurvey of the pools was made on 22 May 87. All bacteriological samples were negative on that date at all the pools. The pools were opened and one sample taken the next day at the Capehart pool showed 4 coliform colonies. On 29 May the Officer's Club pool samples were positive for coliform organisms and on 1 June coliform contamination was found at the Hilltop pool. This led to a month of continually closing and opening the pools because of coliform organisms found in the water samples.

In all cases to confirm that the bacteria were of the coliform group, samples were submitted to the Hospital clinical laboratory for confirmation. The clinical lab identified the organism as Enterobacter cloacae, a coliform bacteria more commonly found in soil than in humans.

D. Procedures

The following section outlines the procedures USAFOEHL used to assess the chemical and microbiological quality of the pools.

1. Chemical parameter sampling

Samples for pH, chlorine residual, alkalinity, calcium, magnesium, and total hardness were taken from all three pools. Table 1 contains the analysis and preservation methods employed. All samples for laboratory analysis were sent to the USAFOEHL, Brooks AFB, Texas.

TABLE 1

ANALYSIS AND PRESERVATION METHODS

Analysis	Preservation	Method	Where
pH	none	E150.1 (1)	on site
Temperature	none	E170.1	on site
alkalinity	none	E310.1	on site
Calcium	HNO_3	E215.1	USAFOEHL
Magnesium	HNO_3	E242.1	USAFOEHL
Hardness, Ca	none	A314A (2)	USAFOEHL
Hardness, Total	none	A314A	USAFOEHL

A = Standard Methods (2)
E = USEPA Methods (1)

2. Microbiological Sampling

Microbiological samples were taken in sterilized amber bottles in accordance with Standard Methods 906 and 914.(2) Colonies from samples taken the day before were confirmed coliform colonies using the Millipore Colifirm coliform confirmation kit. This EPA approved kit adapts the ONPG positive reaction and cytochrome negative reaction to confirm coliforms after four hours.

E. Pool Characteristics

The 750 gpm pumps at Capehart and the Officer's Club pools change the water every 6.5 and 5.6 hours, respectively. The 53.5 gpm pump at Hilltop changes the water every 4.7 hours. This is assuming no short circuiting is occurring and the actual head is equal to the rated head.

The 100 pounds/day chlorinators at Capehart and the Officer's Club pools have chlorination rates of 3.4 and 4.7 pounds/day X 10,000 gallons, respectively. The Hilltop chlorinator's maximum application rate is 27.7 pounds/day X 10,000 gallons.

The caustic soda pumps at Capehart, Officer's Club and Hilltop distribute 20% caustic soda at 5 to 8 gallons per hour, or 120 to 192 pounds per day.

The Capehart and Officer's Club pools have gutters provided around the periphery of the pools to remove the floating debris. The Hilltop pool has a single surface skimmer.

F. Chemical Sampling Results

The results of the chemical analyses of the three pools are shown on Table 2.

TABLE 2

CHEMICAL SAMPLING RESULTS

POOL	pH	HARDNESS (mg/L as $CaCO_3$)	ALKALINITY (mg/l as $CaCO_3$)	TEMP °C	CHLORINE (mg/L)	Ca (mg/L)	Mg (mg/L)
Capehart	6.57	115a 170b	26	26	3.0c 4.0d 4.0e	45.9	13.5
Officer's Club	7.57	116a 172b	90	26	3.0c 3.0d	46.6	13.4
Hilltop	7.42	101a 151b	52	27	1.0c 1.0d 1.0e	40.5	12.2

a Calcium Hardness
b Total Hardness
c Free Available Chlorine Residual in Pool
d Total Combined Chlorine Residual in Pool
e Free Available Chlorine Residual from the Filter Backwash

A condensed version of the Langelier saturation index (SI) using an average total dissolved solids concentration is calculated by the following equation:(4)

(1) $SI = pH + TF + CF + AF - 12.1$

TF = temperature factor
CF = calcuim hardness factor
AF = alkalinity factor

The SI was calculated and the following are the results:

TABLE 3

LANGELIER SATURATION INDEX RESULTS

Pool	pH	TF	CF	AF	SI
Capehart	6.57	0.6	1.7	1.4	- 1.83
Hilltop	7.42	0.65	1.6	1.3	- 1.13
Officer's Club	7.57	0.6	1.7	1.98	- 0.25

G. Microbiological Sampling Results

Samples taken on 25 June contained no coliform colonies from any of the pools. A sample with unconfirmed coliform colonies from two days before was confirmed as coliform colonies using the Millipore Coli-firm system.

III. CONCLUSIONS

A. Pool Characteristics

The volume of water in the pool should be filtered every six to eight hours (3). Using this criterion filtration rates are adequate for the three pools surveyed.

The chlorinator should be rated to apply 3 pounds of chlorine per day per 10,000 gallons.(4) Each pool had adequate chlorination capability.

When chlorine gas is dissolved in water (eq. 2), 2 moles of caustic soda are needed to restore one mole of alkalinity ($CaCO_3$) used up in the pool water by the hydrochloric acid formed (eq. 3 and 4). Hypochlorous acid dissociates, the degree dependent on pH, and reacts with the carbonates to reduce the alkalinity further (eq 5 and 7).

(2) $Cl_2 + H_2O \quad H = CL^{-} = HOCL$

(3) $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2CO_3$

(4) $Cl_2 + H_2O \rightleftharpoons HOCl + HCl$

(5) $HCl + NaOH \rightleftharpoons NaCl + H_2O$

(6) $HOCl \rightleftharpoons OCl^- + H^+$

(7) $HOCl + NaOH \rightleftharpoons NaOCl + H_2O$

(8) $2HOCl + CaCO_3 \rightleftharpoons Ca(OCl)2 + 2H^{+1} + CO_3^{-2}$

Therefore from .7 - 1.41 mg/L of alkalinity is used for each 1 mg/L of chlorine. The alkalinity of the water supply is approximately 130 mg/L. For example, the Capehart pool contains only about 320 pounds of alkalinity from the supply water. The chlorinator, set to deliver 5 mg/L of chlorine to maintain a 1 mg/L residual, would deliver 45 pounds of chlorine per day. Alkalinity is consumed up to 1.4 times this rate. If alkalinity is not added, normally from caustic soda or soda ash, at this rate at least, (it takes .8 mg/L and 1.15 mg/L and Na_2CO_3, respectively, to restore 1 mg/L alkalinity) the pH would plummet in a matter of days. The capacity of the sodium hydroxide feeders (120-192 pounds per day) is adequate to maintain alkalinity for routine chlorination but not adequate to maintain the water pH when chlorine levels are increased for superchlorination (> 4.0 mg/L) at Capehart and the Officer's Club.

Dead areas, a term referring to areas where water does not circulate adequately, are places where the chlorine residual may drop to zero despite adequate chlorine residual in other areas of the pool. The Capehart pool design, combining diving and swimming pools into a "T" shape, is known to have dead spots, especially at the corners of the diving area. Sampling from these dead spots may reveal water of unacceptable bacteriological quality, while in the other areas quality may be quite good. The location and extent of dead areas can be determined by observing the pool after introduction of a dye into the filtration system. The dye test is normally performed just before the pool is emptied for another reason, i.e, cleaning, renovation.

No maintenance or operating instructions were provided when the Capehart pool was renovated. The operators were unclear how to balance the flow between floor drains and skimmers. Also, the filters were being backwashed daily. The backwash water did not appear very turbid, indicating the clean condition of the new filter and the lack of any appreciable "schmutzdecke," a term used to describe a beneficial silt layer on top of the sand.

The single surface skimmer at the Hilltop pool did not appear to be able to draw floating material across the pool. Debris and mucous were observed not moving toward the overflow pipe.

The Officer's Club pool had been losing water at a rate of one to two inches per day. It was thought that the water was leaking through the walls but instead large leaks were found in the return lines under the decking. At the time of the survey, a large leak had just been repaired but water was still seeping through the soil, running along the return pipes and into the pump room. The soil around the pool was saturated by pool water from this leak and from backwash water that is pumped to grade. The backwash water is not released to the sewer because the sewer is believed to have insufficient capacity.

The pools are drained during the winter to prevent ice damage. This season the pools were filled one or two days before they were opened for swimming. Whenever a pool is filled, water velocities, in the branches of the water distribution system near the pool which were essentially dead end lines during the winter months, increase sufficiently to scour these pipes of sediment which commonly contain either P. aeroginosa or E. cloacae and transport it into the pool. It takes a few days to remove and disinfect this sediment from the pool and also takes time to stabilize the water from the addition of chlorine and soda ash or caustic soda.

B. Chemical Analysis

The chlorine levels were too high and the alkalinity level was too low in the Capehart and Officer's Club pools. The DBMS had recommended superchlorination when the pools were found to have coliform contamination. The chlorine levels of 3.0 to 4.0 mg/L at Capehart and the Officers Club had reduced the alkalinity to 26 and 90 mg/L, respectively.

AFR 161-14 states that levels for free chlorine residual must be kept between 0.4-0.6 mg/L. AFR 161-14 levels may be adequate for maintaining bacteriological quality in well circulating areas of the pool; however, there is little margin for safety in other areas of the pool. These levels are not adequate to maintain algal control. Algae can be effectively controlled by maintaining free available chlorine at levels from 1 to 2 mg/L.(4) These levels should not cause swimmer discomfort if the pH is maintained between 7.4-7.8.

Chlorine is being introduced into the discharge side of the pump at each of the pools. The problem with this arrangement is that, depending on the chlorine levels maintained in the pool, chlorine residuals may not reach and sanitize the filter. Chlorine was being maintained in the filters, as evidenced by the chlorine concentration of the backwash. This may not be the case when chlorine residuals return to normal operating levels.

Determining free available chlorine and total available chlorine is essential in assessing pool water quality. Free available chlorine (use LaMotte No. 1 tablet) is the disinfectant species of choice and is responsible for "burning up" organic matter and keeping the pool crystal clear. Combined chlorine, in the form of mono, di, or trichloramines is free available chlorine that has combined with nitrogenous organic compounds from sweat, urine, or quaternary ammonium algicides. Chloramines are less effective disinfectants, smell like chlorine, do not "burn up" organic compounds or produce the crystal clear water associated with a properly operated pool. The concentrations of free available and total combined chlorine residuals add up to form the total available chlorine residual (LaMotte No. 4 Tablet). The free available chlorine concentration should be at least 50-75% of the total available chlorine residual.

Alkalinity is a measure of the carbonate, bicarbonate and hydroxide content, though other titerable bases may contribute. Alkalinity is important in swimming pools with gas chlorinators because the alkalinity balances the effects of the hydrochloric and hypochlorous acid formed. Without sufficient alkalinity the pH would drop to unacceptable levels, causing pool corrosion, deterioration, and swimmer discomfort. The alkalinity should be maintained between 100-250 mg/L (as $CaCO_3$). None of the pools had alkalinities in this range, because of the higher than normal chlorine residuals and the failure to monitor for alkalinity. Other factors influencing water stability are included in the Langelier saturation index or SI. The SI is a measure of the chemical stability of water.

The Langelier saturation index is an equation in which pH, temperature, calcium hardness and total alkalinity are factors. If the value of the equation is zero, the water is perfectly balanced. If the value is negative, the water tends to be aggressive. If the value is positive the water tends to deposit. The SI should be used with caution in the practice of corrosion control, as it is a thermodynamic measure of the tendency of a water to deposit or dissolve calcium carbonate, but overlooks other factors such as electrochemical processes.(5) Values between -0.5 and +0.5 are considered acceptable for pool operation.

The SI for the Capehart pool and the Hilltop pool were less than -0.5, each showing the tendency for aggressiveness. The Officer's Club pool was operating within the recommended SI.

The base is using caustic soda (NaOH) instead of soda ash (Na_2CO_3). Soda ash has the advantage of adding carbonate hardness to the pools increasing the TF factor in Equation 1 as well as the AF factor. The carbonates form a protective coating on pipes, whereas a hydroxide coating does not form until the pH is substantially higher (>10).

C. Microbiological Analysis

Aside from carrying sample bottles loosely in a wire basket, subject to cross contamination from other bottles and dirt, the microbiological procedures should have precluded false positive samples during the period when pool samples were routinely positive. Samples were verified toward the end of the period as primarily a soil bacteria. The Officer's Club pool water has a direct connection with the soil because of the leaking return lines. All pools are subject to blowing soil from close-by construction. Efficient vacuuming will help alleviate this problem.

Enterobacter cloacae is primarily a soil bacteria, however, one cannot rule out that this or previous samples contained coliforms of human origin. Fecal material was found in the Capehart pool hair trap, and diapered children had been seen by BEE technicians in the Officer's Club pool this summer. AFR 161-14 is specific on not allowing children not toilet trained into the main pool. Fecal material may contain E. coli, the main indicator for the total coliform test. However, E. coli can also originate and live in soil. Therefore, the fecal coliform test should be considered in evaluations of potential contamination incidents, since fecal coliforms account for 97% of the total kinds of coliforms in humans.

IV. RECOMMENDATIONS

A. The BEE should verify (confirm) the presence of coliforms in microbiological sampling using an approved method. Either the lauryl tryptose and brilliant green lactose bile broth fermentation tube method, Standard Method 908 B.(2), or alternate approved coliform verification procedures, such as the Millipore Corp. Coli-firm kit, or the Roche's Enterotube II should be used. The Coli-firm kit is preferable since it can be performed the same day.

B. When total coliforms are found, the fecal coliform test should be used in combination with the total coliform test in swimming pool evaluations to determine the severity of future contamination problems.

C. In order to maintain pool water stability, alkalinity should be checked preferably daily but not less frequently than every five days. Alkalinity should be maintained between 100 and 250 mg/L.

D. Soda ash should be substituted for caustic soda, as it is less dangerous to use, and provides a protective coating on metal pipes if the SI is maintained at +0.5.

E. The frequency of backwashing should be determined by sight glass and pressure drop observations. Unnecessary backwashing should be avoided.

F. Free available and total available chlorine residuals should be checked at least once a day to determine organic loading. If the free available is less than 50% of the total, all or a portion of the pool should be drained and refilled with fresh water.

G. Quaternary ammonium algicides should be avoided. Effective algal control is possible by maintaining from 1-2 mg/L free available chlorine and pH between 7.4 and 7.8.

H. The piping at the Officer's Club Pool, including connections to the intakes, should be inspected and replaced where necessary to eliminate the water-soil interface caused by leaking pipes.

I. Sufficient time for filtration and chemical addition should be allowed before the pools are opened for the season. AFR 161-14 recommends 48 hours but a week is not unreasonable to assure bacteriological and chemical water quality.

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APPENDIX A

Report of Water Analysis

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Form 1267 R-3

METROPOLITAN UTILITIES DISTRICT OF OMAHA
REPORT OF WATER ANALYSIS

Platte River Plant

Source Laboratory Tap (Avg.) Date May 1987

Temperature	13.8	°C
Turbidity (NTU)	<0.05	Units
Suspended Solids	-	mg/L
Color	1	Units
Dissolved Oxygen (O_2)	-	mg/L
Langelier Index	1.00	
Chemical Oxygen Demand (O_2)	-	mg/L
Specific Conductance	510	umhos
Dissolved Solids (Calculated)	441	mg/L
Silica (SiO_2)	22	mg/L
pH	8.90	Units
Alkalinity ($CaCO_3$)		
Phenolphtalein (P)	11	mg/L
Total (M)	131	mg/L
Total Hardness ($CaCO_3$)	173	mg/L
Carbonate	131	mg/L
Non-Carbonate	42	mg/L
Nitrogen (N)		
Ammonia	-	mg/L
Nitrate	1.23	mg/L
Chlorine (Cl_2)		
Free Residual	0.80	mg/L
Combined Residual	-	mg/L
Surfactants (MBAS)	0.04	mg/L

Radioactivity:

Gross Alpha & Beta	-	pCi/L
Iodine 131	-	pCi/L
Radium 226	-	pCi/L
Strontium 90	-	pCi/L
Tritium	-	pCi/L

Bacteriological Quality:

Meets U.S. E.P.A. Drinking Water Standards: <0.001/100ml

Cations:

Calcium	(Ca)	49	mg/L
Magnesium	(Mg)	13	mg/L
Sodium	(Na)	47	mg/L
Potassium	(K)	8	mg/L

Anions:

Bicarbonate	(HCO_3)	133	mg/L
Carbonate	(CO_3)	14	mg/L
Hydroxide	(OH)	-	mg/L
Fluoride	(F)	0.95	mg/L
Chloride	(Cl)	35	mg/L
			mg/L
Nitrate	(NO_3)	5.45	mg/L
Sulfate	(SO_4)	113	mg/L
Phosphate	(PO_4)		
Ortho		0.18	mg/L
Total		0.22	mg/L

Trace Inorganics:

Arsenic	(As)	-	mg/L
Barium	(Ba)	-	mg/L
Cadmium	(Cd)	-	mg/L
Chromium	(Cr)	-	mg/L
Lead	(Pb)	-	mg/L
Mercury	(Hg)	-	ug/L
Selenium	(Se)	-	mg/L
Silver	(Ag)	-	mg/L
			mg/L
Aluminum	(Al)	0.00	mg/L
Copper	(Cu)	-	mg/L
Iron	(Fe)	0.00	mg/L
Lithium	(Li)	<0.05	mg/L
Manganese	(Mn)	0.00	mg/L
Strontium	(Sr)	0.32	mg/L
Zinc	(Zn)	-	mg/L

Organics:

Lindane	N.D.	ug/L
Endrine	N.D.	ug/L
Methoxychlor	N.D.	ug/L
Toxaphene	N.D.	ug/L
2, 4, D	-	ug/L
2, 4, 5 T P	-	ug/L
TTHM	-	ug/L

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HQ SAC/DEEV Offutt AFB NE 68113-5001	1
Ehrling Berquist USAF Rgn Hosp/SGPB Offutt AFB NE 68113-5300	2
AAMRL/TH Wright Patterson AFB OH 54533-6573	1
USAF Regional Medical Center Wiesbaden/SGB APO New York 09220-5300	1
OL AD, USAFOEHL APO San Francisco 96274-5000	1
HSD/EV Brooks AFB TX 78235-5000	1
USAFSAM/TSK Brooks AFB TX 78235-5301	1
USAFSAM/EDH Brooks AFB TX 78235-5301	1
Defense Technical Information Center (DTIC) Cameron Station Alexandria VA 22319	2
HQ USAF/LEEV Bolling AFB DC 20330-5000	1
HQ AFESC/RDV Tyndall AFB FL 32403-6001	1

END

DATE

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MARCH

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