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Technical Report

CHLORDANE CONTAMINATION OF GOVERNMENT QUARTERS AND PERSONAL PROPERTY

Webb AFB TX

12 March 1970

EHL(K) 70-7

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This report has been reviewed and is approved for publication.

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USAF ENVIRONMENTAL HEALTH LABORATORY (AFLC)

UNITED STATES AIR FORCE

KELLY AFB, TEXAS 78241

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ABSTRACT

A substantial quantity of 2% Chlordane insecticide (emulsifiable solution) was introduced into the heating ducts of two Capehart type housing units at Webb AFB, Texas on 12 March 1970. The insecticide was being used as a subslab termite control agent in accordance with AFM 85-7(8-16), when it was accidentally introduced into the heating ducts formed within the concrete slab. Several hours after the treatments the heating systems were thermostatically activated and distributed the pesticide as an aerosol and vapors throughout the housing units during the night.

Conclusions and recommendations included:

a. Adult rehabitation can be safely accomplished when wall and ceiling residues are reduced to 50 ug/ft^2 and floor residues to 10 ug/ft^2. These values must be 7.0 ug/ft^2 and undetectable, or 3.4 and 0.5 ug/ft^2 respectively before children can live in these quarters.

b. Decontamination of painted surfaces - 3 vigorous scrubbings with 20% methanol:water solution, followed by repainting of walls and ceilings. Such scrubbings remove up to 90% of the Chlordane residues.

c. Decontamination of clothing, bedding and curtains - disposal of grossly contaminated curtains and other items the value of which did not justify cleaning costs.

d. Dry cleaning of all clothing, bedding and other such items twice. Disposal of contaminated dry cleaning solutions in a sanitary landfill.

e. Overstuffed furniture was recovered or replaced.

f. Base Civil Engineering at Webb AFB recommended the installation of new heating ducts vs further atiempts to clean the existing conduits. Investigations showed the conduits would be extremely difficult to clean due to faulty constructio

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I. INTRODUCTION

On 12 April 1970 a 2% water-chlordane insecticide solution was accidentally introduced into the heating ducts of two Capehart type housing units at Webb AFB TX. These heating ducts consisted of cardboard lined conduits within the concrete slab. Subsequent activation of the heating systems resulted in extensive human exposure and gross pesticide contamination of government housing and personal possessions. All exposed persons have remained asymptomatic to date.

A resumé of the activities that preceded this laboratory's involvement is presented by the Director, Base Medical Services, Webb AFB TX in Appendix 1. This report provides a detailed account of the on-site contamination survey conducted by laboratory personnel, the physical, chemical and toxicological properties of chlordane, establishes allowable chlordane residues in the home, and recommends decontamination procedures to reach these levels. Much of this information was needed by the personnel of Webb AFB immediately as it became available, and was given in the form of personal discussions, written letters, protocols, and by telecon. This report documents these recommendations and the reasons for them.

II. DISCUSSION

A. Toxicology and Maximum Allowable Daily Intakes of Chlordane

1. Chlordane is a chlorinated hydrocarbon, cyclodiene insecticide; it is a persistent pesticide of moderate acute toxicity and is readily absorbed through the skin. Long term exposure to very low levels of chlordane (1.0 ug/ml) have been shown experimentally to have marked physiological effects on animal and human cells (Appendix II). Such physiological changes must be considered a potential threat to health since their precise significance is incompletely understood.

2. The maximum Allowable Daily Intake (ADI) of chlordane is 1.0 ug/kg (1.0×10^{-6} g/kg) (Appendix IV). This ADI reflects the chronic toxicity hazard of chlordane. Approximately 1/2 of this quantity may be ingested with vegetables previously treated with chlordane and purchased commercially. Therefore, 0.5 ug/kg is the corrected ADI from sources other than food. Obviously, decontamination of this housing must be extremely thorough to prevent chronic chlordane exposures in excess of the ADI.

B. Chlordane Contamination of Quarters and Decontamination Procedures

1. Gas chromatographic analyses of over 300 samples indicate the following (Appendix III):

a. The walls and ceilings of both units were extensively contaminated averaging approximately 250 ug/ft^2.

b. The pesticide emerged from the forced hot air registers on the floors, rose with the warm air over the adjacent walls and ceilings, penetrated closets, cabinets and draws, and finally was recycled through the

return duct, the furnace and the contaminated conduits (Appendix III, Figs 1-8).

c. On contact with these surfaces chlordane vapors sublimated, leaving a residue.

d. The sublimation rate was inversely related to the temperature of the surface.

2. Tests of decontamination procedures indicated:

a. Glass surfaces are readily decontaminated.

b. Dry cleaning apparently removes chlordane from clothing.

c. Detergents were inefficient decontaminants of painted surfaces.

d. Methanol:water and vinegar:H_2O solutions were more efficient decontaminants of painted surfaces. Three washings as described in Appendix V, Protocol 1, will remove up to 90% of the residues from these surfaces. These washings must be very vigorous and thorough to be effective.

e. Furniture polish was ineffective at decontaminating wood finishes.

f. Duct residues were reduced over 90% 18 days after the cardboard liners were removed and they were swabbed with trichloroethylene.

g. Flooding two ducts with trichloroethylene (TCE):

(1) Immediately reduced the chlordane emitted from the ducts to 19 ug/m^3 (1/25 of the TLV).

(2) Resulted in the loss of approximately 30 gal of TCE into the subslab fill because of faulty duct construction.

(3) Resulted in the decision to seal the subslab conduits with concrete and install overhead heating and conduit systems in both

quarters. This decision eliminated the conduits as sources of chlordane contamination.

C. Dermal Absorption of Dry Chlordane and Maximum Allowable Household Residues

1. The absorption rate of chlordane from dry surfaces by dry skin was not known. This rate was measured by appling known residues of chlordane on glass slides to the denuded skin of rabbits for varying lengths of time (Appendix III). The reduction of chlordane residues on the slides as a function of time was analyzed by the Least Squares technique using the AFLC Rush Computer system, and was found to be $F(\chi) = -0.0124\chi^{-2} + 12.526\chi^{-1} + 0.817$. This corresponds to a disappearance rate of approximately 1.5%/min. Within the ranges tested, this rate was independent of pesticide concentration.

2. Combining this data with the ADI levels (Appendix IV) it was determined that wall, ceiling and floor residues of 50 ug/ft^2 will be safe for adult habitation. Ceiling and wall residues of 7.0 ug/ft^2 and virtually undetectable floor residues are necessary if children are to inhabit the quarters. If 0.5 ug/ft^2 floor residues are present with children, wall residues should be reduced to at least 3.43 ug/ft^2.

3. These estimates are conservative and fully protect personnel. It is anticipated that such residues will not result in measurable ambient air residues. Recommendations have been made to test this hypothesis by testing the ambient air in decontaminated housing as described in Appendix V.

D. Actions Taken to Date:

1. Both quarters and contents thoroughly sampled for chlordane contamination.

2. Both families moved to new quarters.

3. All articles of clothing made of fabric have been dry cleaned and the dry cleaning fluid disposed of in a sanitary landfill.

4. Household furnishing and utensils have been decontaminated or disposed of.

5. The decision has been made to replace the subslab heating system with an overhead duct system.

III. CONCLUSIONS

1. The residues remaining in the quarters must be reduced to a level so that the Maximum Allowable Daily Intake for Chlordane of 1 ug/kg body wt cannot be exceeded by personnel or dependents. Correcting this figure for chlordane which might be consumed with food, 0.5 ug/kg chlordane is the maximum allowable daily intake which can be absorbed from all sources other than food.

2. The absorption of dry chlordane residues from household surfaces by dry skin is less than $F(\chi) = -.0124\chi^{-2} + 12.526\chi^{-1} + .817$ where χ = time.

3. Assuming zero chlordane air concentrations, 50 ug/ft^2 on walls and ceilings and 10 ug/ft^2 concentrations on floors are the maximum allowable residues for adult rehabitation. The presence of children in the family requires residue levels of 7.0 ug/ft^2 on walls and ceilings and undetectable floor residues. Detectable floor residues require corresponding reductions in wall residues (0.5 ug/ft^2 on floor, 3.4 ug/ft^2 on walls and ceilings).

4. The evidence indicates that a substantial quantity of chlordane was introduced into one or more ducts in each unit. The fact that the ducts proved to be of faulty construction, that many previous subslab treatments have resulted in no contamination of heating systems, and that two houses on the same street were involved indicates the likelihood that the ducts deviated from the architect-engineer designs. This investigation was not, however, intended to fix the cause of the accident.

5. Incidents such as this illustrate the potential hazard of handling all toxic persistent chemicals and the benefits in proper chemical selection.

Aldrin and dieldrin have been extensively used in subterranean termite control. These chemicals are 5-10 times as toxic to humans as chlordane. The use of chlordane in military termite control likely prevented an expensive accident from being a tragedy.

IV. RECOMMENDATIONS

1. Decontamination operations should be concluded as described in Appendix V. The living room of Quarters 57-B should then be sampled, repainted and resampled.

2. The residue levels after decontamination should be used in conjunction with the criteria presented in Appendix IV to determine the safety of rehabitation. If established as safe for adult habitation the rest of the quarters should be repainted and resampled.

3. If decontamination and repainting does not lower the residues to the limits recommended for adult habitation all walls should be wiped with trichloroethylene under the supervision of a Bioenvironmental Engineer or similarly qualified individual.

4. All clothing and furniture should be decontaminated. Stuffed furniture, which will contain higher volumes of pesticides, should be reupholstered or replaced. All clothing should be dry cleaned twice and the dry cleaning solvent properly disposed of in a sanitary landfill. Children's toys which can be dry cleaned should be where the cash or sentimental value warrants it, others should be replaced. Ten percent of the dry cleaned items should be sampled by carefully removing 50-100 fibers for gas chromatographic analysis.

5. All kitchen utensils, dishes, glassware and flatware should be thoroughly washed in hot soapy water several times and tested for residues. Further decontamination can be accomplished by washing in a high grade kerosene, followed by soap and water.

6. Termite control of facilities constructed on a slab is best effected by

treating the prepared subslab surface just before the concrete is poured (AFM 85-7). Such treatments are the best preventive protection against termits and are very cheap. Protocols for such treatments can be obtained from any USAF Medical Entomologist or by consulting the referenced manual. Such treatment very likely would have prevented this incident by preventing termite infestation.

7. Cardboard lined heating ducts that communicate with the subslab soil invite termite infestation. Provisions should be made to prevent such faulty construction.

8. Three inches latitude was given for duct placement in subslab termite treatments at Webb AFB. It is recommended that in the future:

a. Fifteen inches latitude be given where possible.

b. Drill bits be checked for dirt, to confirm the slab has been penetrated.

c. After the holes have been drilled the heating system should be turned on and the hole checked for drafts prior to treatment. The system should then be turned off.

d. After treatment the heating system should be turned on once more and all ducts checked for the pungent odor of chlordane.

APPENDIX I

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 3560TH PILOT TRAINING WING (ATC)
WEBB AIR FORCE BASE, TEXAS 79720

REPLY TO ATTN OF: SG

10 April 1970

SUBJECT: Chlordane Contamination of Government Housing and Privately Owned Household Furnishings and Personal Clothing

TO: Environmental Health Laboratory (HKG)
Kelly AFB, TX 78241

Standard procedure for termite control on base consists of removing all physical evidence of termite damage and repair or replacement. This is followed by sub-slab injection of Chlordane to sterilize the soil in which the subterranean termites live. Base Capehart housing (468 units total) is built on poured concrete slab containing seven 3" cardboard ducts for dispersal of hot air from the downdraft type furnace. Each of these ducts is inclined slightly upward from the sump under the furnace and ends in 3" x 14" hot air registers in each room except the bathroom. Return air to the furnace is supplied through a 10" x 24" intake located high in the wall of the hallway near the furnace. The sub-slab injection of Chlordane is accomplished by drilling four or five 3/8" holes through the slab near the area of termite damage. The positioning of the holes is determined by using engineering drawings and allowing a minimum of 3" clearance from the depicted duct location. Through each of these holes, approximately 15 gallons of a 2% water emulsion of Chlordane under 200 psi pressure is injected.

Approximately 100 Capehart housing units had been treated in this manner without incident prior to 12 March 70.

On that date, sub-slab treatment was initiated in quarters 53A at approximately 1300 hours. No technical difficulty with the treatment process was noted at the time although it later became apparent that the last 15 gallons had been introduced into the air duct which ran between the toilet and the hall wall. At approximately 1400 hours, the same procedure was accomplished in quarters 57B with identical results.

Quarters 53A: Since the heating system was not operated until approximately 1830 hours, the insecticide odor was not noticed. As the odor became more intense, the windows were opened for ventilation, the thermostat was turned down somewhat, and the family went to bed. They

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noticed progressive odor through the night, reported it the next morning, and left the house at approximately 1100 hours, 13 March. They were subsequently quartered in the VOQ. Various family members reentered the well-ventilated house approximately three times daily for 15 minutes each subsequently for the purpose of removing personal clothing or other items.

Quarters 57B: Again, the heating system was not turned on until after 1800 hours. The family noticed the insecticide odor, but elected to remain in the house with the windows closed except in the master bedroom. Likewise they slept overnight and left the house at approximately 1100 hours on 13 March for the VOQ. Reentry by family members was similar to the above.

On 13 and 14 March, Civil Engineer personnel attempted unsuccessfully to clean the ducts with water and to evaporate the material. The Director, Base Medical Services was notified of their unsuccessful efforts Monday, 16 March, and contact was established with the ATC Surgeon's office. On the advice of the ATC Bioenvironmental Engineer, the Regional Environmental Health Laboratory was contacted for support on 17 Mar 70.

EDWARD C PARKER, JR, Lt Colonel, USAF, MC
Director, Base Medical Services

5 Atch
1. Drawing, 57B
2. Drawing, 53A
3. Drawing, 53A, Duct
4. Samples List
5. Family Members

APPENDIX II

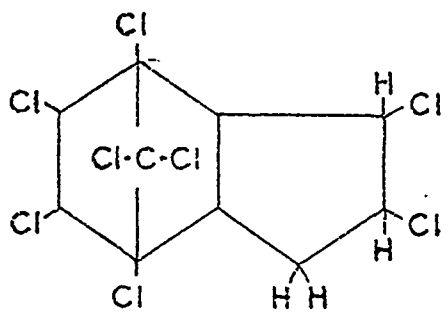
The Toxicity of Chlordane

APPENDIX II

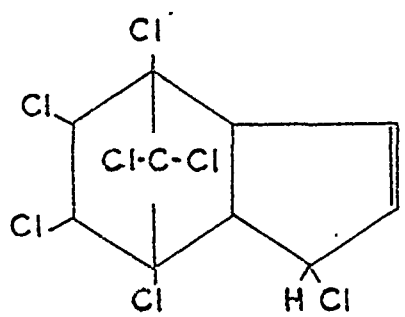
The Toxicity of Chlordane

A. Physical Characteristics and Acute Toxicology of Chlordane

1. Technical chlordane is a mixture of 10-14 cyclodiene constituents including heptachlor, α, B, and ∂-Chlordane. Typical structures are:



α-Chlordane



Heptachlor

The chemical name of Chlordane is 1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindan. Its density is 1.63; its boiling point, 175°C (2mm Hg); its flash point 56°C; vapor pressure $1x10^{-5}$ (25°C); and its molecular weight is 409.8. Chlordane is insoluble in water, soluble in petroleum ether and most organic solvents (1,2,3,4).

2. The acute toxicity of a substance is usually measured by the lethal dose tc 50% (LD_{50}) of an animal population (often rats) when applied in a standard fashion. The acute oral LD_{50} of chlordane to rats has been reported as 250 mg/kg body weight when fed in corn oil[6] and 457-590 mg/kg when fed on solid vehicles[7]. The apparent discrepancy between these authors is probably due to the increased absorption rate of the lipophilic pesticide in the presence

of lipids. Fifty mg/kg chlordane/day in cottonseed oil has been shown to be fatal to all rats tested when applied dermally. Identical oral dosages produced no fatalities. The authors interpret this data as indicating chlordane is more toxic dermally than orally[22]. It is important to note that chlordane is apparently more toxic to humans than to rats[c].

3. The insecticidal mode of action of chlordane has not been conclusively demonstrated. However, all chlorinated hydrocarbons are known to stimulate the insect nervous system to convulsions by causing a massive rise in acetylcholine levels. This increase is theorized to be caused by the release of the stored form of acetylcholine in the vesicles of the presynaptic nerve endings.[8] It is well established, however, that chlorinated hydrocarbons do not inhibit cholinesterase as is the case with organophosphate and carbamate insecticides. Symptoms of acute poisoning appear 45 minutes to several hours after exposure. Skin irritation and sensitization are rare.[24]

4. The data cited above indicates that chlordane is strongly soluble in nonpolar solvents and readily absorbed through the skin (a nonpolar barrier). As would be expected, chlordane is also highly soluble in lipid systems and is stored in fat, although to a lesser extent than some other cyclodienes such as dieldrin.

5. Table I presents the metabolic fate of α-chlordane as reported in the rat and the rabbit.[10,11] These data indicate that rabbits excrete approximately 70% of the α-chlordane ingested over a 10 week period in 12 weeks. Approximately twice as much α-chlordane was excreted by the urinary route than the fecal route. This indicates among other things, efficient absorption of chlordane through the gut. Conversely in the rat the primary excretory route is the

TABLE I

The Distribution of α Chlordane in Exposed Rabbits and Rats
(*data derived from Poonawalla, et al 10&11)

Dose C-14 αChlordane	Rabbit[a] 20 mg orally 5 times per week for 10 weeks (100 mg/wk)	Rat[b] I.V. 27 ug
% C-14 excreted in urine	47.2% (in 12 wks)	1% (60 hrs)
% C-14 excreted in feces	22.72 (in 12 wks)	29% (60 hrs)
% C-14 stomach + duodenum less contents	0.43 (13.62 ppm)	0.6 (0.163 ppm)
% C-14 gut less contents	0.27 (20.43 ppm)	5.7 (0.245 ppm)
% C-14 abdominal fat	2.59 (240.9 ppm)	11.9 (0.489 ppm)
% C-14 subcutaneous fat	1.53 (231.82 ppm)	7.0 (0.167 ppm)
% C-14 kidneys	0.05 (35.22 ppm)	1.2 (0.159 ppm)
% C-14 liver	0.52 (44.32 ppm)	1.6 (0.038 ppm)
% C-14 heart	0.09 (90.90 ppm)	<0.1
% C-14 spleen	0.03 (75.00 ppm)	<0.1
% C-14 brain	0.04 (25.0 ppm)	0.1 (0.030 ppm)
% C-14 carcass	11.25 (86.37 ppm)	26.2 (0.124 ppm)
% C-14 blood	0.34 (40.91 ppm)	<0.1

a. Animals were treated for 10 wks and sacrificed at 12 wks

b. Animals were treated once and sacrificed at 60 hours.

fecal route even though the dosage was administered intravenously. Comparable data for humans is unavailable.

B. Chronic Toxicity of Chlordane

1. Chemical substances introduced into the body at subacute levels may have deleterious physiological effects completely unrelated to their acute toxicology. Vast amounts of such evidence have recently accumulated on the chronic effects of alcohol, cigarette constituents, LSD and chlorinated hydrocarbon pesticides. The chemical complexity of living organisms (including man), the complexity and diversity of the organic compounds involved, their myriad metabolites, coupled with our current ignorance of physiological mechanisms and their interrelationships makes general statements about chronic toxicity impossible.

2. Recent research shows that, in general, the dosage of a given compound necessary to cause a physiological effect is inversely related to the length of exposure. Therefore, generally, the longer the exposure, the lower is the dose that will cause no physiological effect. A word of caution is appropriate at this time. When authors speak of "no effect levels" they mean no effect was observed in the parameters they tested. Obviously, if an investigator measures 5 or 10 parameters (more parameters than are usually considered) of the thousands of systems present in the animal and finds no effect this does not mean no effect exists. In the past (and to a lesser extent presently) chemical exposures were considered safe if clinical symptomology was not detectable; that is, the dose would not cause acute poisoning. Thus, pesticide applicators were tested periodically for cholinesterase depression. If this level was not "significantly"

TABLE II

Some Chronic Effects of Chlordane

Dose	Duration	Species	Sex	Organ System	Effect	Reference
~8 mg/kg	2 yrs	Rat	♂ & ♀	Total	Growth reduction	36
~8 mg/kg	"	"	"	Liver Kidney	Enlargement	6
~8 mg/kg	"	"	"	Lung	Thromboses & fibroses	6
~8 mg/kg	"	"	"	Heart	Edema & necrosis of myofibrils	6
~8 mg/kg	"	"	"	Duodenum	Necrosis of mucosa & submucosa	6
1 ppm	In 1 treatment	Rabbit	-	Brain Cortex	Inhibition of Mg, Na, K-ATPase	11 (In vitro)
25 mg/kg	10 days	Rat	♂	Liver	Increased polar metabolites of testosterone X 2.5	12 (In vitro)
"	"	"	"	"	Increased polar metabolites of Progresterone X 2.2	12 (In vitro)
"	"	"	"	"	Increased polar metabolites of Desoxycorticosterone X 1.8	12 (In vitro)
0.1 ug/ml	84 days	Human Cells	-	Derived from cervical carcinoma	Cytopathic effects & growth inhibition	13 (cell cultur
10 ug/ml	>107 days	"	-	"	Large abnormal rounded cells	"

TABLE II (contd)

Dose	Duration	Species	Sex	Organ System	Effect	Reference
0.1 ug/ml	77 days	Human Cells	-	Derived from cervical carcinoma	10 fold increase into poliovirus susceptibility	13 (cell culture)
5.0 ug/ml	11 days	"	-	"	~15% reduction in vaccinia virus replication	"
25 mg/kg	3 days	"	-	Liver	Proliferation of smooth Endoplasmic reticulum	14
25 mg/kg	3 days	"	-	"	31% increase in microsomal protein	15
<5 ppm	14 days	"	-	Brain	Shortens CNS depression by steriod hormones	16, 18
<5 ppm	14 days	"	-	Liver	Stimulates the metabolism of drugs (amino pyrine, warfarin, phenylbutazone, digitoxin, zorazolamine, chlorpromazine, hexabarbitol	17

depressed (in itself a difficult parameter to define) they were considered unaffected by their exposures to cholinesterase depressants. Such indexes of toxicity are now considered incomplete.

3. Table II is an incomplete summary of some of the known subacute chronic effects of chlordane. The health significance of these changes are largely unknown and a discussion of their possible significance would serve no purpose in this report. However, the physiological homeostasis of modern animals (including man) is the product of millions of years of selection. Considering our limited physiological understanding and limited diagnostic abilities it is proper to view any physiological change as deleterious until it is demonstrated to be innocuous rather than assuming it to be innocuous until proven deleterious.

4. Physiologically active substances such as chlordane which are readily absorbed, physiologically active at very low levels (Table II), and slowly metabolized and excreted necessitate a conservative approach where chronic exposures are a possibility. Where gross household contamination has occurred, additional precautions are necessary because of the constancy of exposure, the lack of any protective clothing or habits, the presence of children and the probability of pregnancy.

APPENDIX III

Chlordane Residues in Government Quarters

APPENDIX III

Chlordane Residues in Government Quarters

A. Measurement of Chlordane Contamination

1. Personnel from this laboratory visited Webb AFB 25-27 April 1970. The following data was collected during that period, or where indicated, by the MPH personnel, Webb AFB, subsequent to these dates. The following techniques were used to collect and analyze these data.

2. A Varian Aerograph Gas Liquid Chromatograph (GLC), Model 660, equipped with a tritium foil electron capture (EC) detector was used in all on-site analyses. A 5 ft 1/8" stainless steel column packed with 10% DC-200 on 100-110 mesh Chromosorb/W was used on the initial analyses. Temperature parameters were injector 220, column 200, and the detector 210°C.

3. Over 200 residue samples were taken from various surfaces by wiping within a 15 square inch (5x3) template. Samples from painted surfaces (walls & ceilings) were taken by thorough wiping within the template using a cotton ball dampened with hexane or petroleum ether. On furniture surfaces, samples were taken using dry cotton swabs. Care was taken to wipe each surface at least 4 times with each of 2 swabs. The swabs were composited.

4. Air samples were taken by drawing ambient air through two serially aligned impingers containing hexane at one liter per minute. Air flow varied between ducts and also across individual ducts. Estimates of the air flow per duct were made by dividing each duct into thirds, measuring the flow in each third and averaging the measurements. Flow measurements were made with an Anemotherm, Model 60, flow meter prior to removing the cardboard liners.

5. Chlordane was extracted from the collecting cotton by saturating the cotton with hexane and squeezing dry. On samples run 5-27 April, the volume of hexane was measured and the chlordane was roughly quantitated (±10%) because the DC-200 column did not completely separate the various chlordane constituents. This column had the advantage of taking only 10 minutes vs 20 minutes or more for each chromatogram. On this survey, numbers of samples were considered more important than fine accuracy.

6. More detailed analysis were made of wall, air, and clothing samples using a 6 ft ¼" column packed with 5% QF-1 in a Micro-Tek Model 220 GLC instrument equipped with a Ni60 EC detector on subsequent dates. Instrument conditions were identical to those cited by Thompson et al[22] concentrations were quantitated by comparing the height of peak #3[23] to that of a technical chlordane standard.

B. Chlordane Residues in Ambient Air

1. Flows from the ducts varied between registers and also varied greatly across each register. The chlordane delivered to each room was equal to the product of the concentration of chlordane/m^3 x m^3 air/unit time delivered by the ducts in that room + vapors entering the room through doors. Table III is a compilation of air flow measurements and concentrations of chlordane measured from the various ducts before and after cleaning.

2. Flow variances across individual registers caused the amount of chlordane, the velocity of the air, and air temperature to vary on all planes at a given distance above each heating register. Table III indicates that the stripping operation immediately lowered the chlordane delivery by the ducts from 48-82%. Figure 1 indicates that the three ducts showing the largest

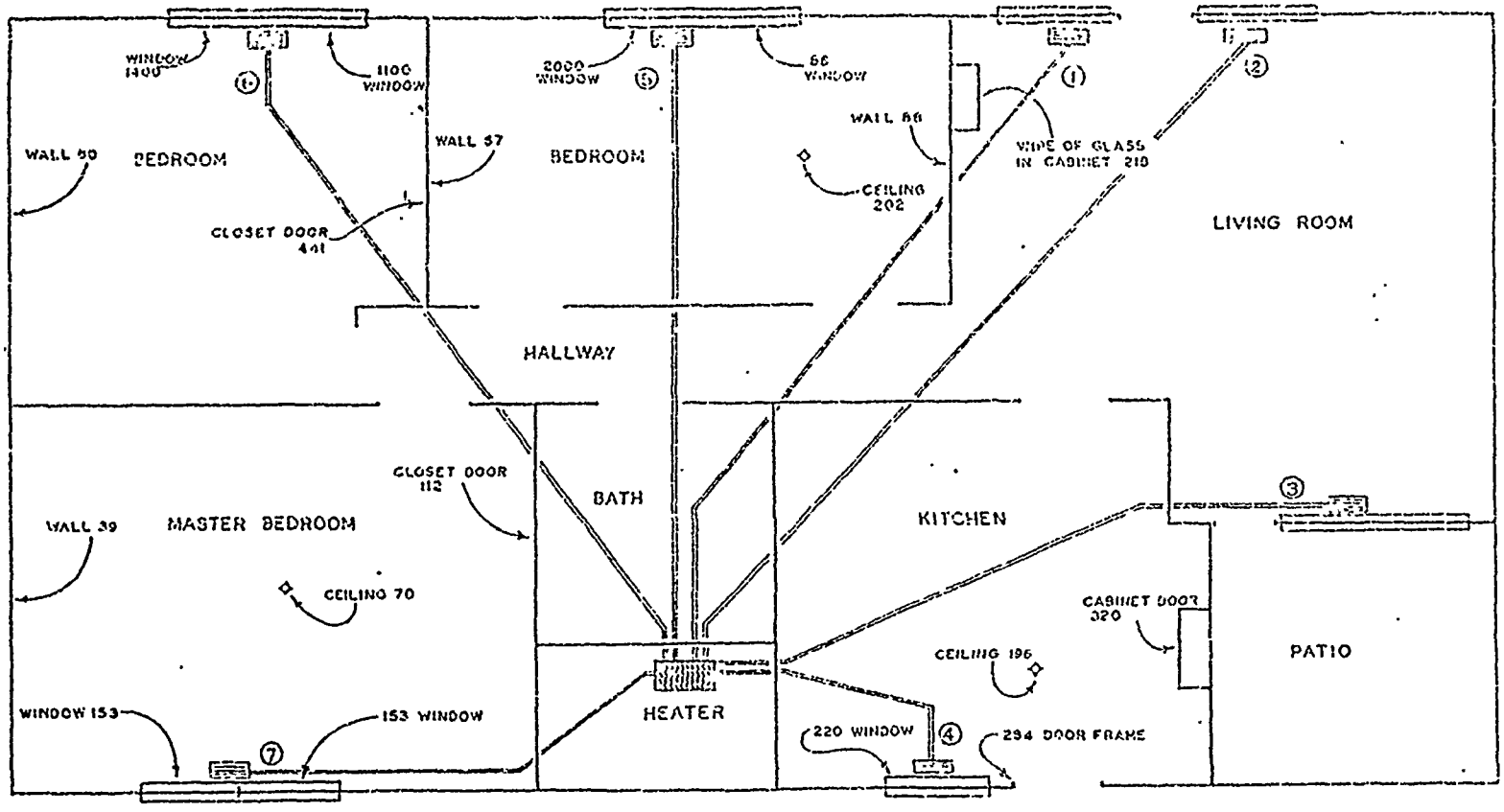


FIG. 1

Q1TS 53A

GENERAL ROOM AIR SAMPLE TAKEN IN LIVING ROOM, HEATER OFF, DOORS AND WINDOWS CLOSED 0.65 Mg/M^3

GENERAL ROOM AIR SAMPLE TAKEN IN LIVING ROOM, HEATER ON, DOORS AND WINDOWS OPENED 025 Mg/M^3

MEAS. CONC. (Mg/M^3) BEFORE ATTEMPTED CLEANING	DUCTS	MEAS. CONC. (Mg/M^3) AFTER ATTEMPTED CLEANING
1.06	(1)	0.37
0.84	(2)	0.44
0.84	(3)	0.37
0.80	(4)	0.31
1.58	(5)	0.29
1.00	(6)	0.41
1.20	(7)	0.68

TABLE III

Airborne Concentration of Chlordane in Forced Air Ducts

Duct No.††	Cu Ft/Min(M^3/min) Qtrs 57B	Qtrs 53A	Initial* Conc. mg/M^3 57B	53A	Initial* µg/min Before Cleaning 57B	53A	mg/M^3** 1 day† Post Cleaning 53A	µg/min** 1 day† Post Cleaning 53A	mg/M^3** 18 days† Post Cleaning 53A	µg/min** 18 days† Post Cleaning 53A	% Reduct 1 day Post Cleaning	% Reduct 18 days Post Cleaning
1	24(0.66)	12(.34)	1.14	1.06	770.0	350.4	0.37	125.8	0.034	11.5	65.1	96.8
2	10(.28)	24(.68)	0.80	0.84	224.0	571.2	0.44	299.2	0.058	39.4	47.6	93.1
3	17(.48)	30(.84)	0.92	0.84	441.0	705.6	0.37	310.8	0.066	55.4	55.9	92.1
4	9(.25)	17(.48)	1.10	0.80	275.0	384.0	0.31	148.8	0.059	28.3	61.2	92.6
5	7(.20)	9(.26)	0.96	1.58	192.0	410.8	0.292	75.9	0.180	46.8	81.5	88.6
6	12(.34)	15(.43)	1.02	1.00	346.8	430.0	0.41	176.3	0.056	24.1	59.0	94.4
7	21(.60)	11(.31)	0.80	1.20	480.0	372.0	0.68	210.8	0.058	17.9	43.3	95.2

*In both houses ducts had been drained and rinsed with H_2O, some liner was removed in Qtrs 57B prior to these measurements.

**Cardboard liners removed, concrete surface swabbed with trichloroethylene soaked rags and blown out with hot air.

†Qtrs 57-B cleaning not accomplished.

††Refer to floor plans.

initial reductions, 5, 1, and 4 respectively, were either comparatively straight or were short. Percent reduction was apparently independent of residue concentration and is probably an indication of the success in removing the cardboard.

3. This variability coupled with the number of samples analyzed make quantitative analyses of the chlordane content of each room, wall, or house impossible. Such an estimate would require many hundreds of analyses and were considered beyond the needs of the USAF.

4. Note that before these samples were taken the heating units were removed, the ducts were rinsed with water and in Qtrs 57-B the cardboard liners were partially removed. These "initial" values are therefore substantially lower than the values actually delivered immediately after contamination.

5. Eighteen days after the cardboard liners were removed the ducts of Qtrs 57-B, although reduced 89-97%, were still emitting about 60 ug/m^3 of air (Table III). Obviously, additional action was needed. On 14 Apr 1970 a protocol for further cleaning the ducts was given to Lt Col Parker at Webb AFB by telecon. On 17 Apr 1970 a letter (Appendix V) with the written protocol was forwarded to Webb AFB. The letter suggested two alternative courses of action:

a. Replace the heating ducts.

b. Clean heating ducts with trichloroethylene (TCE).

6. Subsequent telecon with Lt Turner (CE) at Webb AFB established that it was possible to isolate one or two ducts from the rest of the heating system of Qtrs 53-A, allowing a test of the cleaning technique to be accomplished

on two ducts alone. This test established that at least one duct (Fig 1 #1) is not completely enclosed with cement but is open at the bottom. The TCE therefore ran into the fill under the slab and could not be retrieved. This cleaning technique was abandoned since other ducts were likely to share the same faulty construction and complete removal of TCE under such conditions was not assured. It is interesting to note that TCE cleaning was successful in removing the chlordane from the ducts. After flooding with TCE chlordane residues from these ducts were >1.0 ug/m^3. Installation of new heating ducts would have been prevented if the ducts had been built properly. In addition, houses constructed with cardboard lined ducts in contact with subslab fill are extremely vulnerable to termite infestation.

C. Patterns of Chlordane Disposition on Surfaces

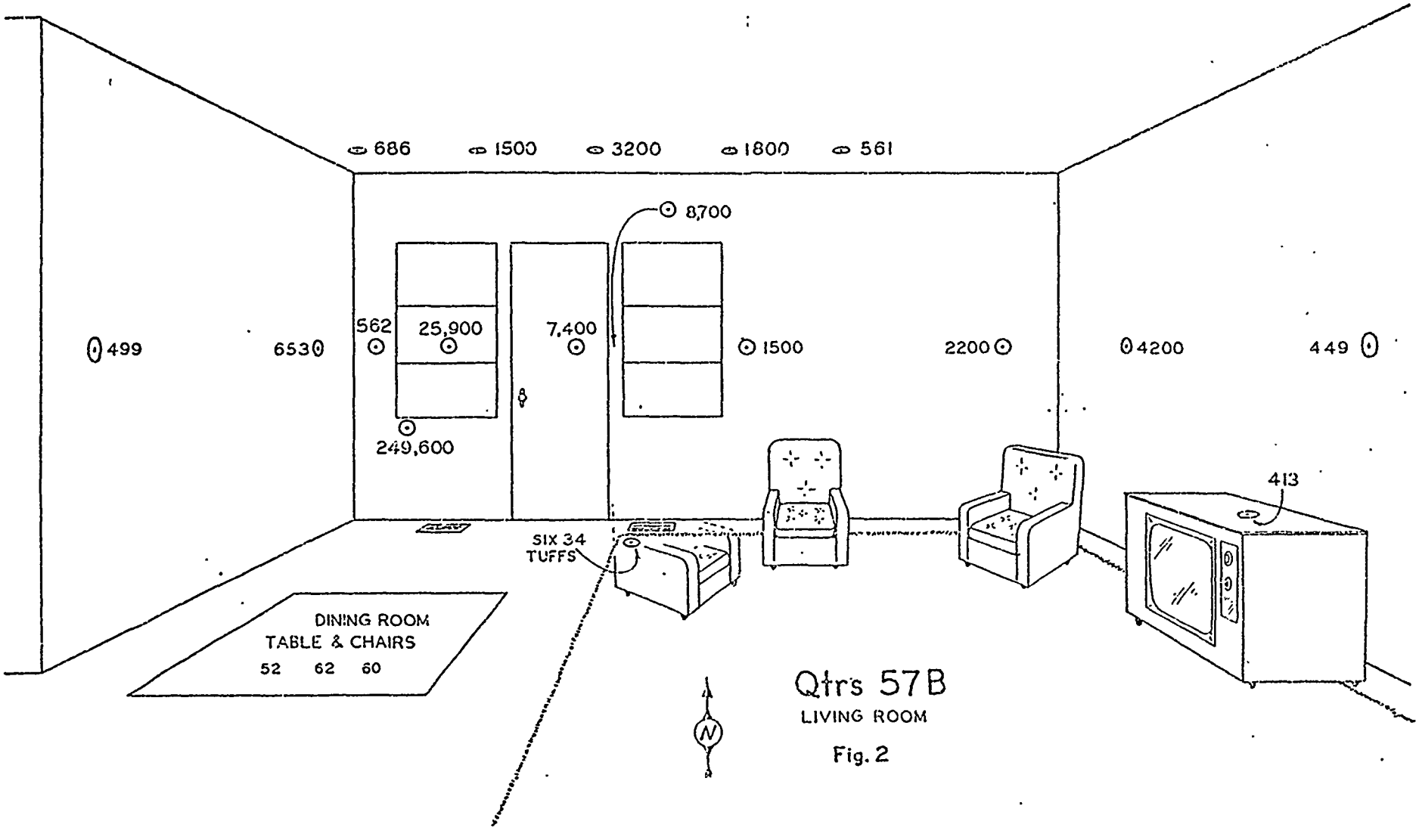
1. As mentioned above, sufficient numbers of samples were not taken to quantitate the chlordane residues within the house. Sufficient analyses were made, however, to indicate patterns of residue disposition. Figure 2 is a three dimensional view of the living room of Quarters 57-B. The air intake is approximately 15 ft up the hallway to the left of the room. The view is looking at the north wall, (west wall to the left, east wall to the right, see Figures 3 and 9).

2. Several things are readily apparent from these figures:

a. Chlordane levels decline rapidly as one proceeds horizontally from the ducts.

b. The greater the contact with contaminated air the higher the residue.

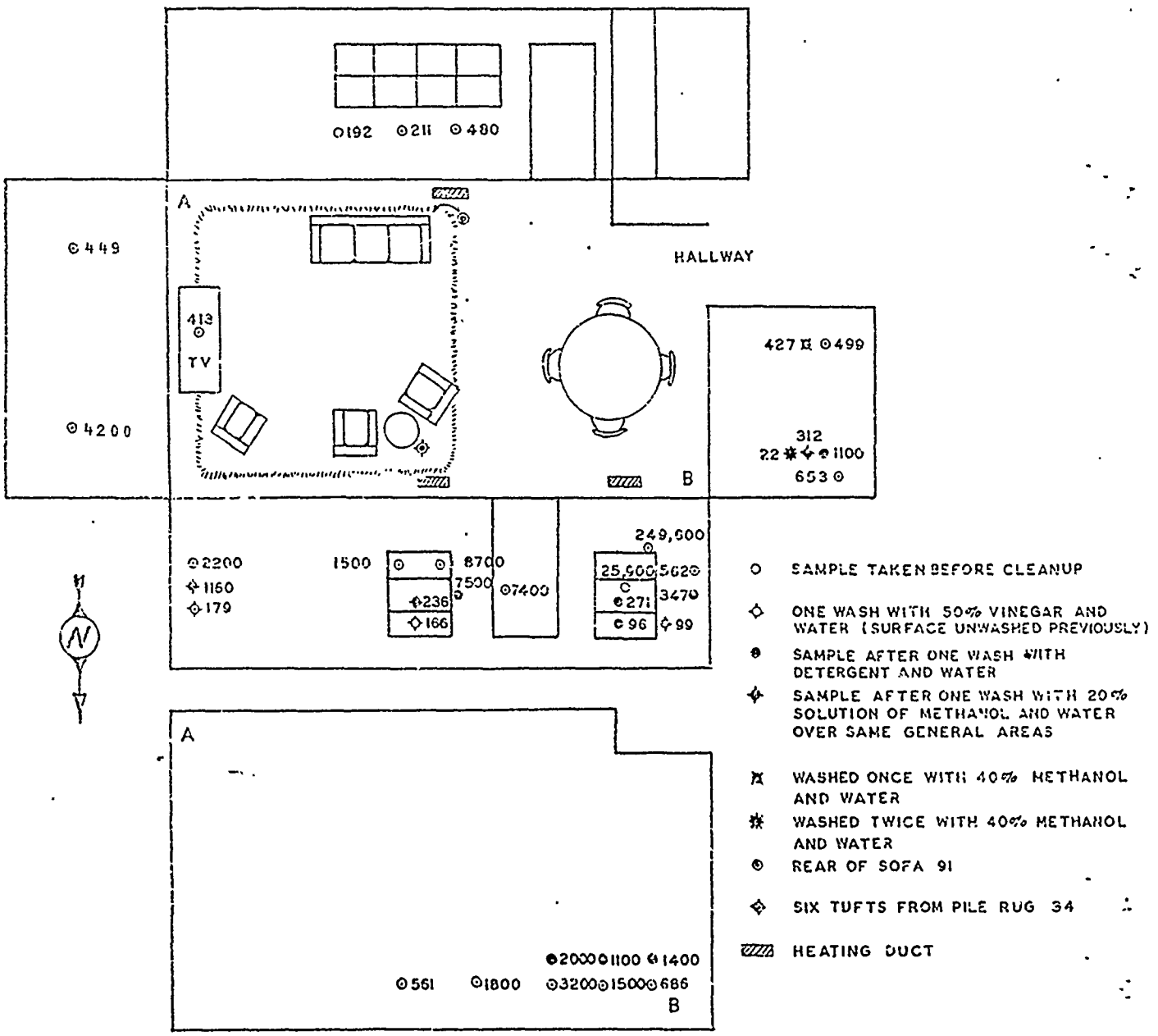
c. Windows have many times the residues as similarly exposed walls. This increase is due to the cool temperature of the window panes; glass exposed



Qtrs 57B
LIVING ROOM

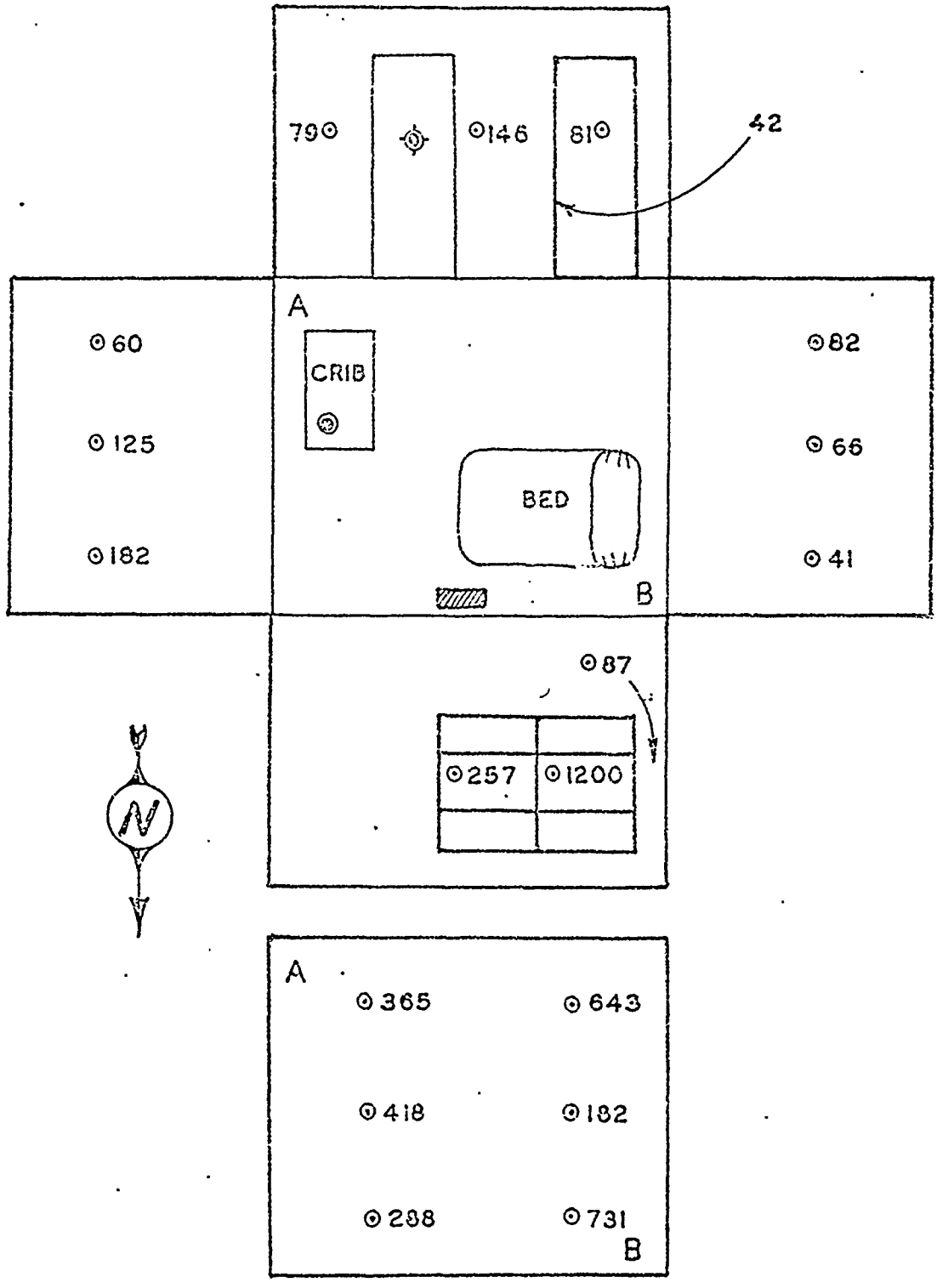
Fig. 2

FIG. 3
QUARTERS 57 B
LIVING ROOM



- ○ SAMPLE TAKEN BEFORE CLEANUP
- ✧ ONE WASH WITH 50% VINEGAR AND WATER (SURFACE UNWASHED PREVIOUSLY)
- ⊙ SAMPLE AFTER ONE WASH WITH DETERGENT AND WATER
- ✧ SAMPLE AFTER ONE WASH WITH 20% SOLUTION OF METHANOL AND WATER OVER SAME GENERAL AREAS
- ⊠ WASHED ONCE WITH 40% METHANOL AND WATER
- ✱ WASHED TWICE WITH 40% METHANOL AND WATER
- ⊙ REAR OF SOFA 91
- ✧ SIX TUFTS FROM PILE RUG 34
- ▨ HEATING DUCT

FIG. 4
QUARTERS 578
BEDROOM (CHILD'S)



⊙ SAMPLE TAKEN BEFORE CLEANUP

◉ FIBER FROM TOY IN CRIB 117

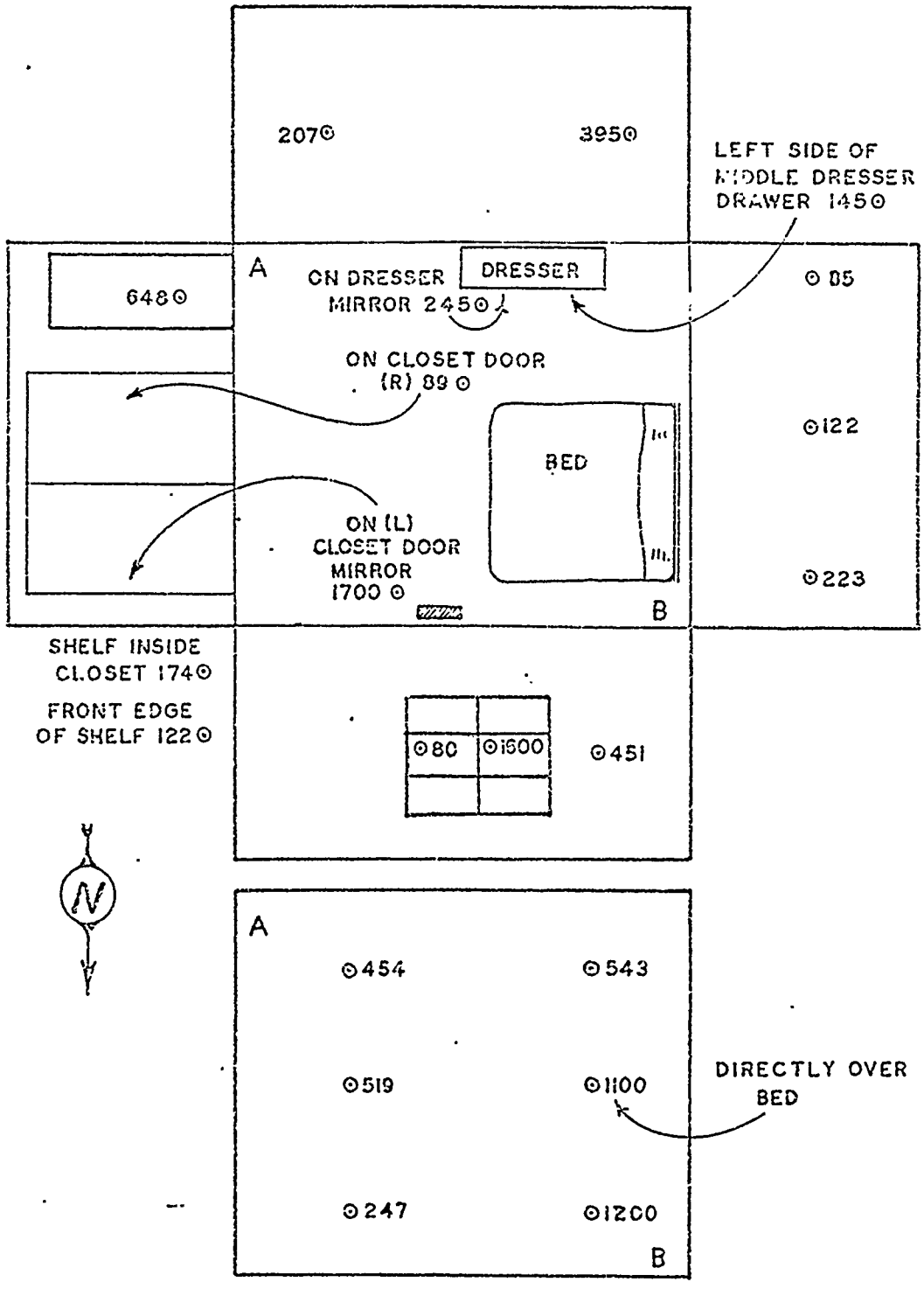
⊙ FIBER FROM COAT IN CLOSET 17

HEATING DUCT

FIG. 5

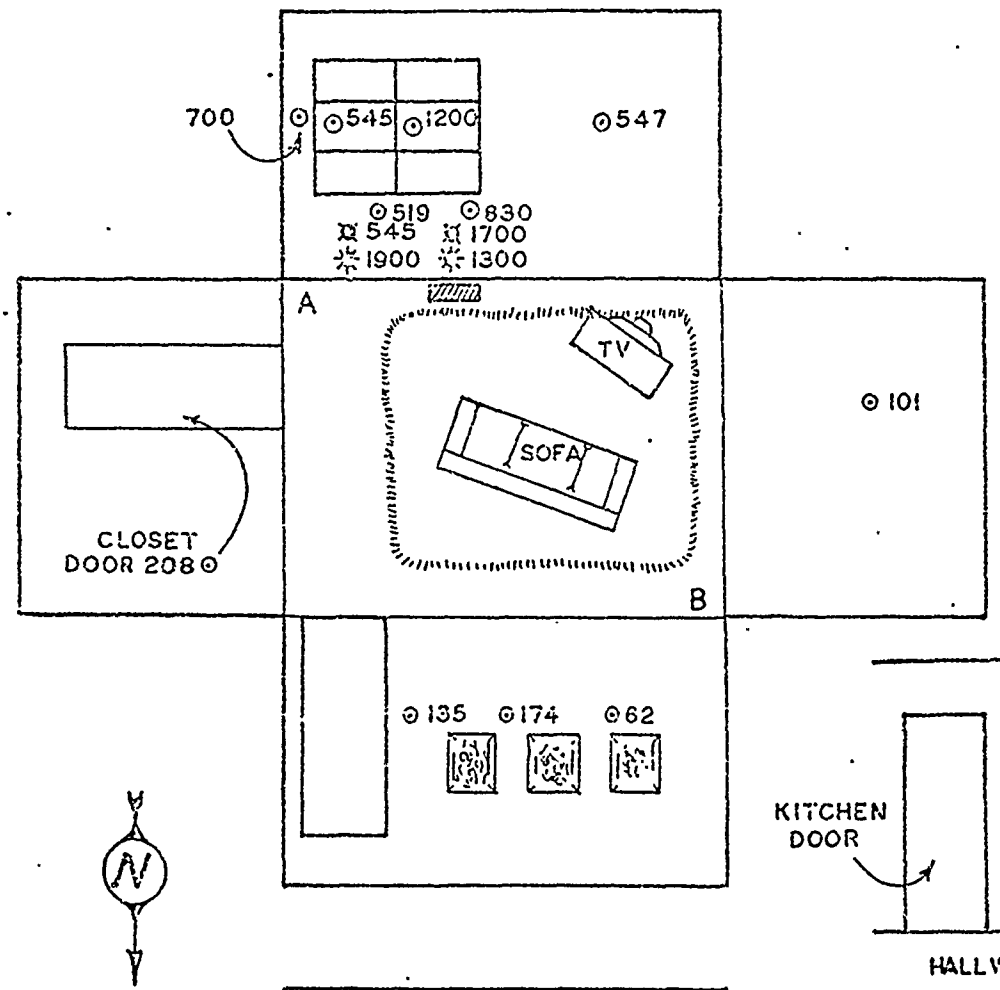
QUARTERS 57B

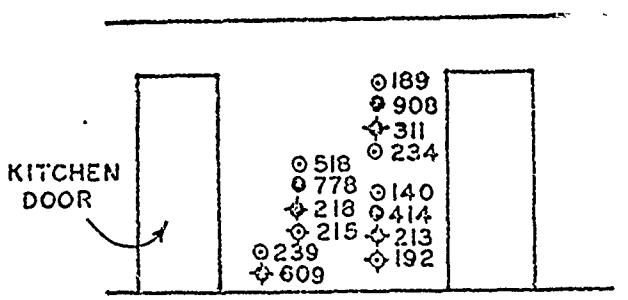
MAST. BEDROOM



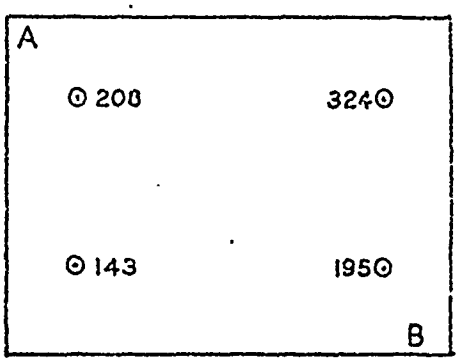
⊙ SAMPLE TAKEN BEFORE CLEANUP

FIG. 6
QUARTERS 57B
LOUNGE





HALLWAY WALL, KITCHEN SIDE



⊙ SAMPLE TAKEN BEFORE CLEANUP

⊙ SAMPLE TAKEN AFTER ONE SPRAY WASH WITH 20% METHANOL AND WATER SOLUTION

✧ SAMPLE AFTER 2 WASH AS ABOVE

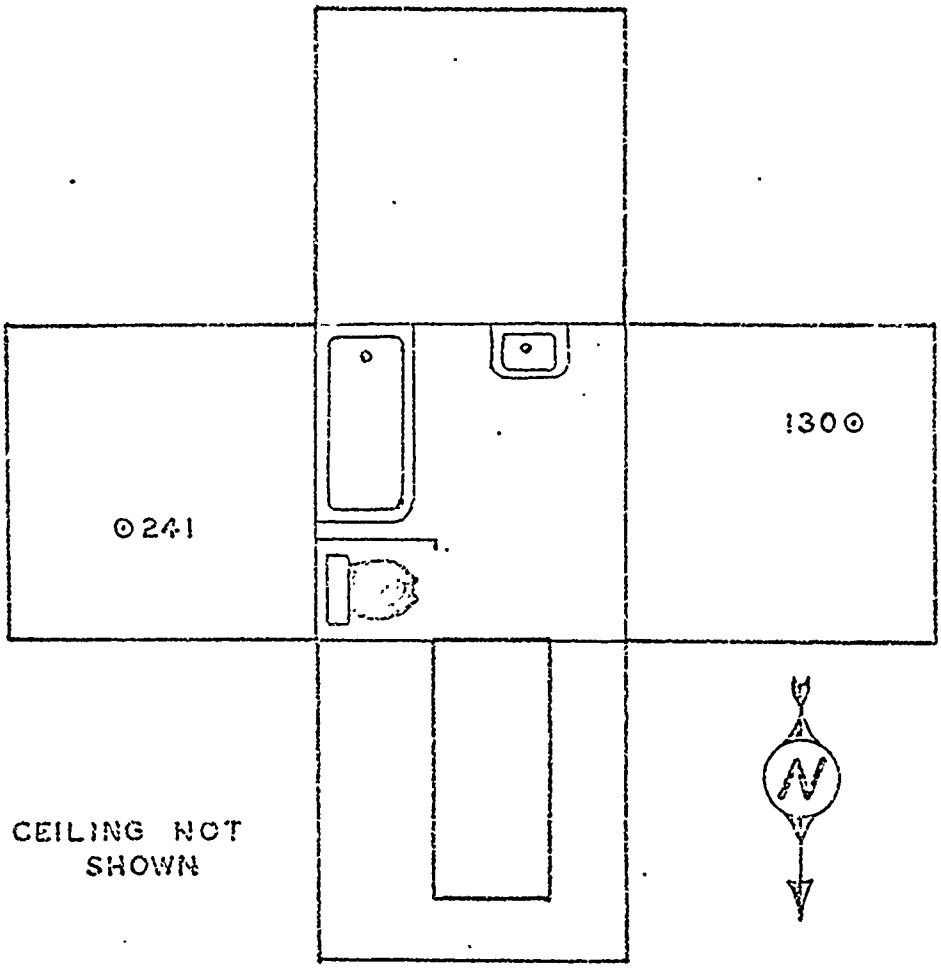
✧ SAMPLE AFTER 3 WASH AS ABOVE

▩ ONE WASH 50% VINEGAR

✲ ONE WASH, 40% METHANOL AND WATER

▨ HEATING DUCT

FIG. 7
QUARTERS 57 B
BATHROOM



⊙ SAMPLE TAKEN BEFORE CLEANUP

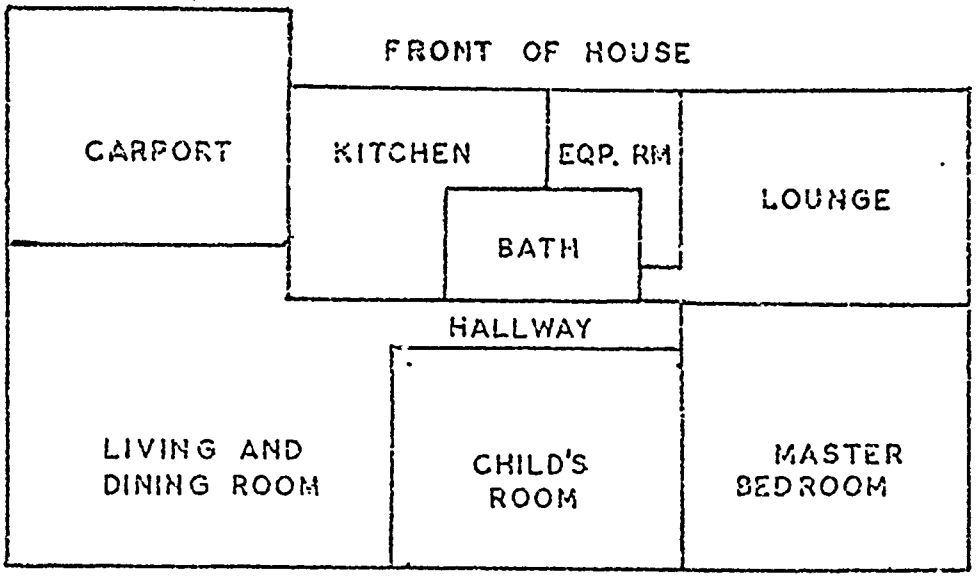
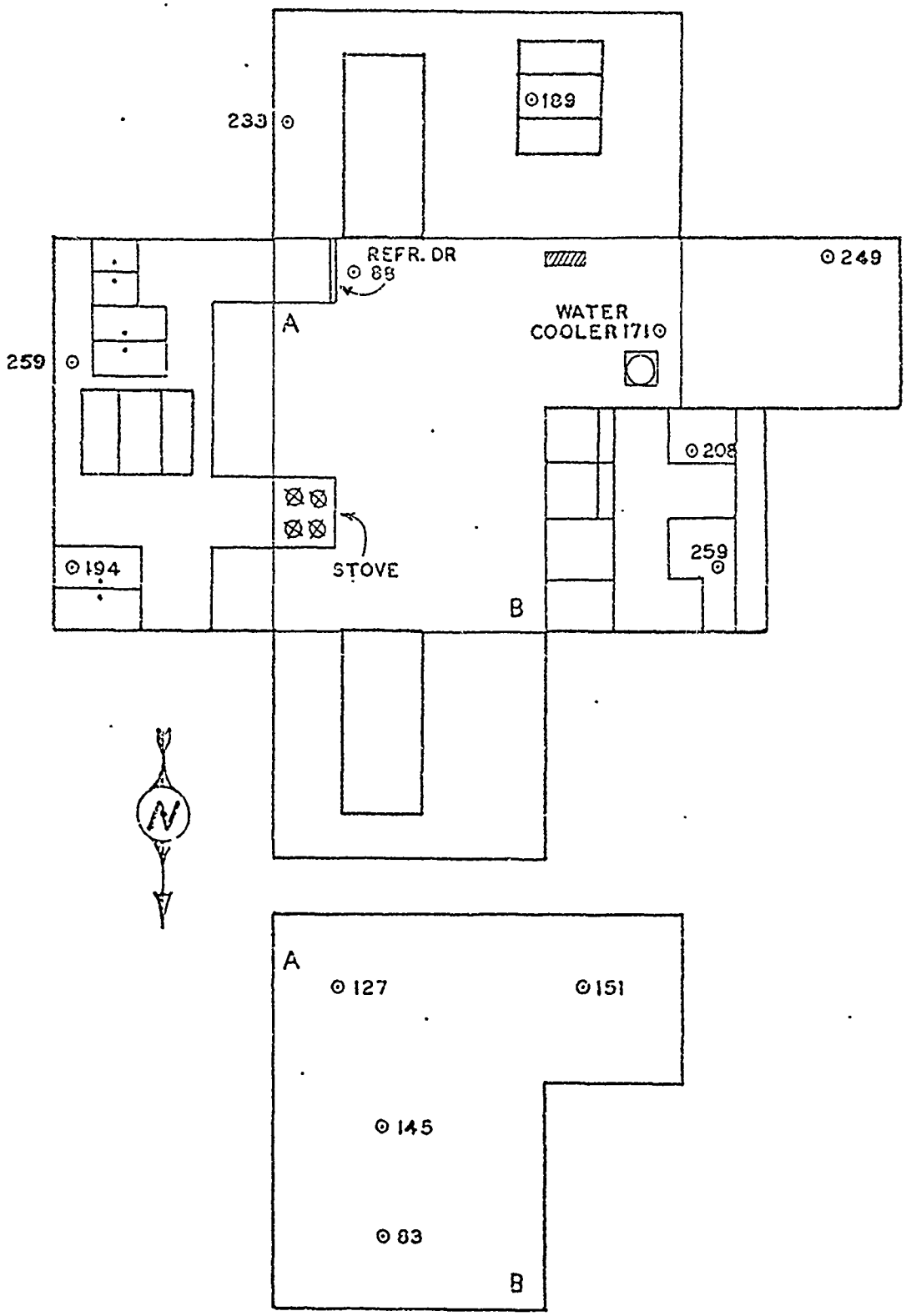
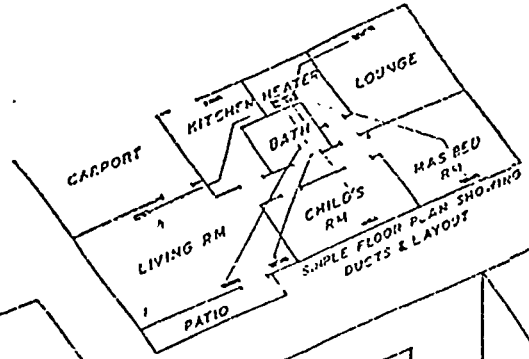


FIG. 8
QUARTERS 57B
KITCHEN



⊙ SAMPLE TAKEN BEFORE CLEANUP



DUCTS	MEAS CONC (Mg/M^3)
1	1.14
2	0.80
3	0.92
4	1.10
5	0.90
6	1.02
7	0 80

Qtrs 57B

Fig. 9

to chlordane at ambient temperatures (such as mirrors, Table IV, #44) corresponded well with surrounding areas.

d. Away from the heating registers residues become lower and more constant (west, (left) wall).

e. Areas of air eddies (NE rt, corner) had high residues.

These data indicate that chlordane rapidly sublimates from the gaseous phase on to any surface. The sublimation rate is strongly influenced by temperature. This is similar to experiences we have had in this Laboratory working with Dieldrin, a similar cyclodiene insecticide.

3. The implications of this rapid sublimation effect are obvious. As long as any Chlordane is being emitted from the ducts it will accumulate on all exposed surfaces in the house. This is an additional reason why contaminated ducts have to be extremely well cleaned prior to rehabitation.

4. This pattern of residues is similar in the other rooms of Quarters 57-B as illustrated in Figures 3 through 8. These data are tabulated in Table IV. Less detailed sampling was made of Quarters 53-A because the consistency of the residues in Quarters 57-B (especially away from the heating registers) indicated a general estimate of residue levels could be made without such extensive sampling. These data are presented in Table V and Figure 1.

5. Table VI is a compilation of the mean residues per sq ft found in the various rooms of Quarters 57-B and 53-A. These data are not quantitative measurements but merely indices of contamination.

TABLE IV

Distribution of Chlordane Residue on Walls and Ceilings

QUARTERS 57B*

No.	Relative Location of Wiped Area	Chlordane Residue Prior** to Attempted Clean-up (micrograms per sq ft)
1	Living rm, rear wall (north wall), left corner	562
2	" on left window	25,900
3	" rear door	7,400
4	" on right window	8,700
5	" on right window	1,500
6	" rear wall, right corner	2,200
7	" East wall, left third	4,200
8	" " " right third	449
9	" Front wall (south wall) left third	192
10	" " " " middle third	211
11	" " " " right third	480
12	" West wall, left third	499
13	" " " right third	653
14	" ceiling, near north wall, left of left window	686
15	" " " above left window	1,500
16	" " " right of left window	3,200
17	" " " left of right window	1,800
18	" " " above right window	562
19	Hallway wall, left side of kitchen door	499
20	" right side of kitchen door	125
21	Bedroom adjacent to living room, east wall, left third	162
22	" " " " " " middle third	125
23	" " " " " " right third	60***
24	" " " " south wall, left third	79***
25	" " " " " " middle third	146
26	" " " " " " right third	42
27	" " " " room side of door	81
28	" " " " west wall, left third	82
29	" " " " " " middle third	66
30	" " " " " " right third	41†
31	" " " " north wall, left third	87†
32	" " " " " " left half of window	1,200

*All wall wipe samples taken approximately 4½-5 feet above the floor; all ceiling samples taken approximately 1½-2 feet from wall.

**As measured 7 & 8 days after initial contamination.

***Wall areas adjacent to crib.

†Wall areas adjacent to child's bed.

TABLE IV (cont'd)

33	Bedroom adjacent to living room, north wall, right half of window	257
34	" " " ceiling near west wall, left third	643
35	" " " " " middle third	181
36	" " " " " right third	731††
37	" " " ceiling above window	288
38	" " " " above center of room	418
39	" " " " above crib	365
40	Master BR, East wall, on mirror on left closet door	1,700
41	" " on right closet door	89
42	" hallway door	648
43	" southwall, left third	207
44	" " mirror above dresser	245
45	" " right third	395
46	" westwall, left third	85
47	" " middle third, above bed	122
48	" " right third	223
49	" northwall, left third	451
50	" " left half of window	1,600
51	" " right half of window	80
52	" ceiling above left half of window	1,200
53	" " " right half of window	247
54	" " " bed	1,100
55	" " " right side of dresser	543
56	" " " left side of dresser	454
57	" " middle third near east wall	519
58	Lounge, east wall and closet door	208
59	" south wall, left corner	701
60	" " left half of window	545
61	" " right half of window	1,200
62	" " right third	547
63	" middle third of west wall	101
64	" north wall, left third	62
65	" " middle third	174
66	" " right third	135
67	" ceiling above left half of window	208
68	" " " right half of window	324
69	" " near east wall, left third	143
70	" " northwest quarter	195

††Ceiling above child's bed.

TABLE IV (contd)

71	Bathroom wall above heater	130
72	" wall above tub	241
73	Kitchen, east wall, left third	195
74	" " middle third, on cabinet	259
75	" " right third, on door	88
76	" south wall above door	233
77	" " on window	189
78	" west wall, left third	249
79	" on water dispenser	171
80	" ceiling, southeast corner	127
81	" " southwest corner	151
82	" " center	145
83	" " above hallway door	83

TABLE V

Distribution of Chlordane Residue on Walls and Ceilings

QUARTERS 53A*

No.	Relative Location of Wiped Area	Chlordane Residue Prior to Attempted Clean-up (micrograms per sq ft)
1	Kitchen, west wall, on cabinet door	320
2	" on ceiling, near north wall	196
3	" north wall, right side of door frame	284
4	" north wall, on window	220**
5	Bedroom adjoining living rm, south wall, left window	2,000**
6	" " " " right window	86**
7	" " " east wall, middle third	67
8	" " " west wall, middle third	88
9	" " " light mid-ceiling	202
10	Master Bedroom, east wall, middle third	39
11	" " west wall, middle third	112
12	" " north wall, left window	153**
13	" " " right window	153**
14	" " mid-ceiling, next to light	70
15	Playroom & child's room, south wall, left window	1,400**
16	" " right window	1,100**
17	" east wall, middle third	60
18	" west wall, middle third, on closet door	441

*All wall wipe samples taken approximately 4½-5 feet above the floor; all ceiling samples taken approximately 1½-2 feet from wall.

**All windows in this house were washed twice by occupants with Windex® before samples were taken.

TABLE VI

Mean Chlordane Residues in Contaminated Quarters

Room	Qtrs 57-B (Including Windows) ug/sq ft	Nr of Samples	Qtrs 57-B (Excluding Windows) ug/sq ft	Nr of Samples	Qtrs 53-A (Excluding Windows)* ug/sq ft	Nr of Samples
Living Room	3371	18	1639.6	15	-	0
Bedroom (Children's)	267	19	212	17	119	3
Bedroom (Master 57-B) (Children's 53-A)	550	18	514	16	250	2
Lounge 57-B M.Bedroom 53-A	349.5	13	254	11	73.7	3
Kitchen	175	10	173	9	266	3

*All windows in Qtrs 53-A were washed with Windex® prior to sampling.

All rooms were substantially contaminated. Chlordane contamination in Quarters 57-B can be ranked by rooms: living >> master bedroom > lounge $\geq$ children's bedroom $\geq$ kitchen. The data indicate that Quarters 53-A had similar levels of contamination with the exception of the master bedroom, which appears to have been less contaminated.

6. It is interesting to note that ranking the flow rates measured at the registers (Table III) in 57-B yields a comparison in some ways similar to the contamination levels listed above.

a. The living room received the most air and had the highest contamination.

b. The kitchen and the children's bedroom had the lowest residues

and the lowest flow rates. However, the lounge had a flow rate almost double that of the master bedroom (21 vs 12 cu ft/min) yet the master bedroom was substantially more contaminated than the lounge. This inversion of contamination vs flow rate indicates a higher content of chlordane in the duct of the master bedroom than in the child's bedroom, the lounge or the kitchen. This duct may have had chlordane introduced directly into it, or the pesticide may have accumulated in it because of its pitch.

D. Chlordane Residues on Personal Possessions

1. Table VII lists the chlordane residues found on objects in various locations in Quarters 57-B and 53-A. Figures 3 through 8 depict many of these items and their residues in situs. In general, these data confirm the distribution patterns already established on the walls and ceilings. They also establish that items of furniture were heavily contaminated. The dry wiping technique undoubtedly does not remove all of the chlordane residues; therefore, residues recovered by this technique are lower than actually present.

2. The rug sample consisted of six tufts of material (approx 10 mg). This sample indicates the rug to be extremely contaminated as would be expected from its proximity to heating register #2 (Figure 2).

3. The wet wipe of the sofa recovered only a small percentage of the chlordane actually present because the solvent on the cotton swab was absorbed by the sofa fabric and stuffing, carrying the pesticide away from the swab. No other nondestructive sampling technique was available.

4. The substantial residues within the closet, bureau and hutch,

TABLE VII

Chlordane Residue on Miscellaneous Surfaces*

Object	Qtrs	Location of Object During Exposure	Area, Quantity, etc. of Material Sampled	Chlordane Residue
TV Console	57B	Liv Rm, east wall	15 sq inch on top, dry wipe	413 ug/ft^2
Water Cooler	"	Kitchen, west wall	15 sq inch, wet wipe	171 "
End Table	"	Liv Rm	15 sq inch, dry wipe	91 "
End Table	"	Liv Rm	15 sq inch, dry wipe	83 "
Rug	"	Liv Rm floor; sample from NW corner	6 fibers from rug area near window	34 ug total
Sofa Back	"	Liv Rm, South Wall over register	15 sq inch, wet wipe	91 ug/ft^2
Stuffed Toy	"	BR, child's crib	5 doll hair fibers	117 ug total
Shelf	"	Master BR closet	15 sq inch, wet wipe	174 ug/ft^2
Shelf	"	" closet, front vedge	"	122 "
Venetian Blind	"	Liv Rm, north wall	"	249,600 "
Bureau Drawer	"	Master BR, in dresser	15 sq inch, sample from right draw panel	145 "
Dining Table	"	Liv Rm & Dining Area	15 sq inch, dry wipe	62 "
"	"	"	"	52 "
"	"	"	"	60 "
Drinking Glass	53A	Liv Rm, in Hutch	Total inner&outer Surfaces	218 ug
Pot (small)	"	Kitchen	Inner Surface	78 ug**
Pot (large)	"	"	Inner Surface	55 ug**

*As measured 9 days after initial contamination; prior to any clean up attempts.
**These utensils had been washed twice by owner in a dishwasher before samples were taken.

indicates a penetrating fumigant effect. This indicates extensive contamination of all articles in the house; a fact substantiated by samples taken 3, 5 and 6 April by Military Public Health personnel at Webb AFB. These samples and their residues are listed in Table VIII.

E. Decontamination Procedures

1. Table VIII also demonstrates that dishwashing provides inadequate cleaning and that dry cleaning appears a promising method of decontaminating clothing. Additional samples of dry cleaned clothes will be analyzed at a later date.

2. Various methods of decontaminating painted walls and furniture; and waxed furniture were tested with limited success. The data presented in Table IX indicate:

a. Chlordane residues can be easily removed from glass surfaces.

b. Chem-i-san Concentrate® (and probably other detergents) is an inefficient chlordane decontaminant for walls.

c. Methanol:water and vinegar:water solutions gave fair removal when scrub cloths are used. Spraying and brushing 20% methanol:water solution gave consistently poor results.

d. Increasing the methanol concentration to 40% increased performance.

e. Guardian Furniture Polish® gave very inconsistent results.

As discussed in Appendix II chlordane is soluble in nonpolar solvents such as waxes. Therefore, cleaning agents which leave wax residues simply redistribute the chlordane in the wax. Better results would be expected using a wax solvent. Care must be taken to select a solvent which will not damage the underlying finish.

TABLE VIII

Chlordane Residues from Miscellaneous Protected Surfaces
3-6 April 1970

	Object	Qtrs	Location During Exposure	Quantity & Type Sample	µg Chlordane	Previous Cleaning
1	Plate	57-B	Kitchen Cupboard	Total wet wipe	24.0	dishwashing
2	Plastic Glass	"	"	"	20.0	"
3	Metal Spoon	"	"	"	62.0	"
4	Drinking Glass	53-A	"	"	5.4	"
5	Spoon	"	Kitchen Drawer	"	5.7	"
6	Plate	"	" Cupboard	"	5.7	"
7	Cooking Ladle	"	" "	"	30	"
8	Small Pot	"	" "	"	78	"
9	Large Pot	"	" "	"	65	"
10	Box Spring Ticking	57-B	Underside of bed/M Bedroom	123.5 mg	220 ug (1781 ppm)	none
11	Blue Sweater	"	Bureau/M Bedroom	4.3 mg	0.00	none
12	Black Sweater	"	"	69.3 mg	1.6(23ppm)	none
13	Blue Knit	"	Closet/Child's room	3.2 mg	0.00	dry cleaned
14	Box Spring Ticking	53-A	Child's Bed	69.3 mg	3.7(53.3)	none

TABLE IX

Results of Cleaning Miscellaneous Surfaces by Various Methods

Item No.	Method of Cleaning	Qtrs	Surface Cleaned	Residue Level Before Cleaning (ug/ft^2)	Residue Level After Cleaning 1X	2X	3X	% Change ↓ - apparent decrease ↑ - apparent increase 1X	2X	3X
1	Chem-i-San Concentrate & H_2O FSN 7930-973-2196 8:1 H_2O:stock solution	57-B	wall/living room	562	347	-	-	↓38.0	-	-
2	"	"	"	652	1100	-	-	↑40.0	-	-
3	"	"	Ceiling/ "	686	1400	-	-	↑104	-	-
4	"	"	"	1500	1100	-	-	↓27	-	-
5	"	"	"	3200	2000	-	-	↓38	-	-
6	"	"	Window/ "	25900	96	-	-	↓99.6	-	-
7	20% Methanol & Water (cloth scrub)	"	Wall/living room	652	312	22	-	↓52	↓96.6	
8	"	"	"	2200	1160	-	-	↓47.2		
9	"	"	"	347	-	-	247	↓ -	-	↓29
10	"	"	Window/"	8700	236	-	-	↓97.3	-	-
11	"	"	Table/Kitchen(painted)	-	960**	-	-	-	-	-
12	"	"	Chair/Kitchen(painted)	-	295.7**		-	-	-	-

TABLE IX (contd)

Item No.	Method of Cleaning	Qtrs	Surface Cleaned	Residue Level Before Cleaning (ug/ft^2)	Residue Level After Cleaning 1X	2X	3X	% Change ↓ - apparent decrease ↑ - apparent increase 1X	2X	3X
13.	20% Methanol & Water Sprayed & Brushed	57-B	Wall Hallway	189 518 140 $\bar{x}$ 282	908 778 415 $\bar{x}$ 700.3	311 218 213 247	223 215 192 210	↓148	↓12.4	↓25.5
14	40% Methanol:Water (cloth scrub)	"	Wall/Living Room	499	427	-	-	↓14		
15	50% Vinegar:Water (cloth scrub)	"	"	1160	179	-	-	↓84.5	-	-
16	"	"	Window/"	7500	166	-	-	↓97.7	-	-
17	Guardian Furniture Polish	"	TV Console/Liv Rm	241	120	222	-	↓50.2	↓7.8	-
18	"	"	Table Top/Dining Rm	58	114	101	-	↓99.9	↓74	-
19	"	"	TV Console/Liv Rm	241*	46	-	-	↓80.9**		
20	"	"	End Table/Liv Rm	-	32.6**	-	-			
21	"	"	Table/Dining Rm	114*	96.0	-	-	15.7		
22	"	"	Cedar Chest/Bedroom	-	50.88**	-	-	-	-	-
23	"	53-A	Table/Dining Rm	-	263.04**	-	-	-	-	-
24	"	"	Chair/Dining Rm	-	8.35**	-	-	-	-	-

TABLE IX (contd)

Item No.	Method of Cleaning	Qtrs	Surface Cleaned	Residue Level Before Cleaning (ug/ft^2)	Residue Level After Cleaning 1X	2X	3X	% Change ↓ - apparent decrease ↑ - apparent increase 1X	2X	3X
25	Guardian Furniture Polish	53-A	Coffee Table/Liv Rm	-	30.72**	-	-	-	-	-
26	"	"	End Table/Liv Rm	-	13.4**	-	-	-	-	-
27	"	"	Dresser/Bedroom	-	1.92**	-	-	-	-	-
28	"	"	China Hutch/Liv Rm	-	36.4**	-	-	-	-	-

*Control taken 8 days after exposure.
**Sample taken 21 days after exposure.

APPENDIX IV

Dermal Absorption of Dry Technical Chlordane Residues and the Maximum Quantity Permissible on Household Surfaces

APPENDIX IV

A. The Dermal Absorption of Dry Chlordane Residues

The transfer of chlordane from a glass surface to denuded rabbit skin was measured in an experiment conducted as follows:

1. Two ♀ Albino New Zealand rabbits 9 & 10 months old were placed in two stock type restraining boxes, shaved with a #40 clipper, and finally denuded of hair with a surgical depilatory (Surgex®; 5% calcium thioglycolate cream). Hair was removed in a square shaped area from the scapula posterior to the crest of the ischium and ventrad approximately half way to the midline. The depilatory was carefully washed from the skin with cotton and tap water.

2. Technical Chlordane (Nutritional Biochemical Company, Cleveland OH) was diluted in hexane (nanograde) to 505 micrograms (ug)/ml and 1204 ug/ml standards. One hundred microliters, (0.1 ml) of these solutions were separately applied to the free surface of two sets of 1 sq in (22 mm^2) cover slips previously attached to Band-Aid brand, Clear Air-Vent® tape. The solutions were applied in two 50 ul aliquots, the hexane was allowed to evaporate and the slides rotated to assure even pesticide application. Each rabbit received eleven slides containing 50.5 ug/sq inch left of the backbone, and eleven slides covered with 120.4 ug/sq inch to the right of the backbone. The slides were applied 2.5 hours after the depilatory was removed. Each slide was numbered and randomly removed at six time intervals, using a table of random numbers[21] as illustrated in Table X. Slides removed from the rabbits were separated from the tape and immediately immersed in hexane.

TABLE X

Chlordane Absorption Sampling Schedule
50.5 ug/sq in - 120.4 ug/sq in

Hrs After Application	No. of Slides Removed	No. of Slides Removed
1	4	4
2	4	4
3	4	-
7	-	4
8	4	-
16.5	-	4
17.5	4	-
23	-	2
24	2	4
TOTAL SLIDES	22	22

3. Chlordane was removed from the coverslips by an additional 10 ml wash with hexane in an ultrasonic cleaner. The washes were composited and analyzed in the Micro-Tek GLC using a QF-1 column as described by Thompson et al[23].

4. The chlordane residues recovered from the coverslips are presented in Table XI. Residues recovered from coverslips having no contact with rabbits indicated the recovery method was accurate (Table XI).

5. The results presented in Tables XI & XII and Figure 10 indicate that half the chlordane transferred from the glass to the rabbit after

10-12 minutes of contact. The decontamination data presented in Appendix III, Table VIII, indicate that chlordane is more readily removed from the glass than from painted surfaces. The denuded rabbit skin maximized absorption because no hair was present to insulate the skin from the chlordane. This experiment, therefore, has a built-in safety factor because it was designed to maximize the absorption rate by using a glass surface in contact with denuded skin. This experiment is therefore designed not to establish an exact dermal absorption rate, but to establish a rate that equals or exceeds the true rate.

B. Maximum Permissible Daily Intake of Chlordane

1. The above information makes abundantly clear the necessity of strictly monitoring the daily chronic intake of chlordane. The specific problem remains as to what levels are safe and what are not. Several guides to such "safe" dosages are available. The "Threshold Limit Value of Airborne Contaminants (TLV)"[19] refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. The TLV of chlordane is 0.5 mg/m^3. This value is not applicable to household contamination because:

a. The TLV of chlordane refers only to respired exposures not to dermally absorbed chlordane. The literature and data cited above indicate that chlordane is dermally absorbed very rapidly; at least as quickly as through the alimentary tract. The TLV committee notes this danger.

b. The TLV values refer to industrial worker exposures, i.e., 8 hr/day - 5 day workweek, whereas 24-hr/day 7-day/week exposures must be assumed in the home. The TLV values also assume adult exposures whereas in the home infant and fetal exposures may occur.

2. For all these reasons it is obvious that household levels must be much below the TLV of 0.5 mg/M^3. A value more appropriate for chronic household exposure is the "Maximum Acceptable Daily Intake," (ADI) of the Joint Meeting of the FAO (Food and Agriculture Organization) Working Party, and the WHO (World Health Organization) Expert Committee.[20] The ADI is, "...the daily intake which, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time." The ADI for chlordane is 0.001 mg/kg. It must be noted that this ADI includes the maximum intake for all sources of exposure. Chlordane is presently a registered pesticide to be used on many crops. These include root, leafy and stalk vegetables, curcurbits (cucumbers, etc.) surgar beets, berries, tomatoes and other garden crops.[20] Obviously, chlordane residues will be ingested daily with food. The actual amount ingested will be dependent on many unmeasurable variables. A review of the particular residues allowed by law on the various crops indicates that it is extremely unlikely that 1/2 of the ADI will be consumed through food intake. The author of this report believes this opinion maximizes the amount of chlordane that could possibly be ingested with food conforming to federal standards.

3. The Department of HEW is currently considering recommending that the USDA restrict the use of chlordane.[9] If such restrictions are enforced they would further reduce food residues and the safety of the above assumption. The above considerations indicate that 0.0005 mg/kg (0.5 ug/kg) is the maximum acceptable chlordane intake in addition to that ingested with food. Table XIII lists maximum acceptable chlordane intakes in addition to that likely to be ingested with food for individuals of various weights.

C. Maximum Permissible Household Residues of Chlordane

1. In contaminated housing two methods of chlordane entry are likely: (1) respired chlordane entering through the lung, and (2) chlordane dermally absorbed from contaminated surfaces. As discussed previously chlordane is absorbed rapidly through cell walls and therefore undoubtedly through the lung and skin. The precise absorption rates are important here because knowing the allowable daily intake, the knowledge of such rates would allow intelligent estimates of safe residues in household air and on surfaces. Such absorption rates are unabailable. Absorption through the lung must be assumed to be very rapid because of the tremendous surface-air contact and the thin-epithelial lining of the alveoli walls.

2. The normal adult inspires approximately 9201 liters of air per day.[25] Assuming 90% absorption per inspiration a 150 lb man will receive his ADI (Table XI) from the air alone at a concentration of 4.112 ug/m^3. The faulty construction of the slab conduits (Appendix III) precluded their cleaning. The decision was made to seal the old ducts with concrete and install new heating systems, including new overhead ducts, in the quarters. This action eliminated chlordane vapors originating in the old ducts as a source of contamination.

3. Table VI, Appendix III, indicates that wall residues averaged approximately 250 ug/sq ft in both quarters. At this level a 150 lb man would attain his adjusted ADI of 34.05 ug/day (Table XIII) after 9.1 minutes of bare skin contact with 1 sq ft of glass surface which continually maintained this raidue (Table X and Fig 10). One square foot contact with a wall surface is a near physical impossibility; 18.2 minutes of ½ ft^2 contact would give the

same ADI. This exercise is significant because it indicates that a 5 fold decrease in wall residues (a mean residue of 50 ug/ft^2 would not exceed the corrected ADI of a 150 lb man if he had 90 minutes of bare skin contact with ½ square foot of glass wall. As mentioned above contact with painted surfaces would greatly lessen absorption. Since people do not come in direct skin contact with ½ ft^2 wall surfaces for 90.8 minutes/day; 50 ug/ft^2 is certainly a safe level on house walls for adults.

4. This same exposure level of 50 ug/ft^2/min would supply the (corrected) ADI of a 20 lb child with ½ ft^2 contact in about 12 minutes. The residues wouldhave to be reduced to 6.8 ug/ft^2 to give the same 90 minutes of ½ ft^2 skin contact time to a 20 lb child. If mean wall levels of 7.0 ug/ft^2 or under cannot be achieved it would be unwise to allow children to live in Quarters 53-A and 57-B.

5. An additional structural surface not measured for chlordane residues in the initial survey is the floor. Adults normally have more skin contact with floors than with walls, therefore, the 50 ug/ft^2 criteria of walls should be reduced to 10 ug/ft^2 for adults (ADI achieved in 7.5 hrs). Moreover, children have long periods of intimate floor-skin contact; quarters with children must, therefore, have less than 0.5 ug/ft^2 chlordane on the floors. On glass, such a residue would supply the corrected ADI of a 20 lb child in 20.2 hrs with ½ ft^2 skin contact. When such residues are present on floors, wall residues should be reduced to 3.43 ug/ft^2. At these levels, a 20 lb child can have ½ ft^2 skin contact with the floor for 12 hrs and with walls (3.43 ug/ft^2) for 67 minutes. These levels offer enough latitude that the ADI will not be exceeded even by small children unless they are lain

nude on the floor for long periods of time. If parents are instructed to avoid such behavior the above parameters offer totally safe residue levels for rehabitation.

TABLE XI

Chlordane Residues Recovered From Glass Coverslips in Contact With Rabbit Skin

Time Hrs	56.2 ug/in^2	$\bar{X}$	% Reduction	120.4 ug/in^2	$\bar{X}$	% Reduction
1	3.0 6.3 1.5 1.9	3.17	94.36	11.0 14.0 15.5 8.5	12.25	90.0
2	5.3 1.9 3.0 2.0	3.05	94.58	16.0 8.0 9.5 4.0	9.37	92.22
3	2.3 .6 .9 1.6	1.35	97.6			
8	0.6 0.4 1.8	0.933	98.3	2.5 1.7 3.0 3.1	2.57	97.8
16.5				0.6 1.1 0.7 1.0	0.85	99.3
17.5	.3 .2 .4 .2	0.27	99.5			
23				2.0 1.0	1.5	98.76
24	0.1 0.0	0.05	99.92	1.3 .3 .4	0.66	99.46
Control (air dried 10 minutes)	50.0 48.2 51.0 53.0	50.5	+0.59			

TABLE XII

The Disappearance Function of 120.4 ug/in^2 Chlordane
From Glass Slides in Contact with Rabbit Skin

X = Time Y = Chlordane Residue

THE FUNCTION IS:
F(X)=-.01240661155*X**-2 +12.52619481*X**-1 +.816722671

DO YOU WANT TO SEE THIS FUNCTION EVALUATED AT THE DATA POINTS?
\YES

X	Y	Y-CAL	DIFF
1.000E-05	1.204E+02	1.204E+02	-1.73E-05
1.000E-05	1.204E+02	1.204E+02	-1.73E-05
1.000E-05	1.204E+02	1.204E+02	-1.73E-05
1.000E-05	1.204E+02	1.204E+02	-1.73E-05
1.000E+00	1.100E+01	1.333E+01	2.331E+00
1.000E+00	1.400E+01	1.333E+01	-6.69E-01
1.000E+00	1.550E+01	1.333E+01	-2.17E+00
1.000E+00	8.500E+00	1.333E+01	4.831E+00
2.000E+00	1.600E+01	7.077E+00	-8.92E+00
2.000E+00	8.000E+00	7.077E+00	-9.23E-01
2.000E+00	9.500E+00	7.077E+00	-2.42E+00
2.000E+00	4.000E+00	7.077E+00	3.077E+00
8.000E+00	2.500E+00	2.382E+00	-1.18E-01
8.000E+00	1.700E+00	2.382E+00	6.823E-01
8.000E+00	3.000E+00	2.382E+00	-6.18E-01
8.000E+00	2.100E+00	2.382E+00	2.823E-01
1.650E+01	6.000E-01	1.576E+00	9.758E-01
1.650E+01	1.100E+00	1.576E+00	4.758E-01
1.650E+01	7.000E-01	1.576E+00	8.758E-01
1.650E+01	1.000E+00	1.576E+00	5.758E-01
2.300E+01	2.000E+00	1.361E+00	-6.39E-01
2.300E+01	1.000E+00	1.361E+00	3.613E-01
2.400E+01	1.300E+00	1.339E+00	3.863E-02
2.400E+01	3.000E-01	1.339E+00	1.039E+00
2.400E+01	4.000E-01	1.339E+00	9.386E-01

STANDARD DEVIATION IS 2.3756897272516

DO YOU WANT TO PLOT THIS FUNCTION?

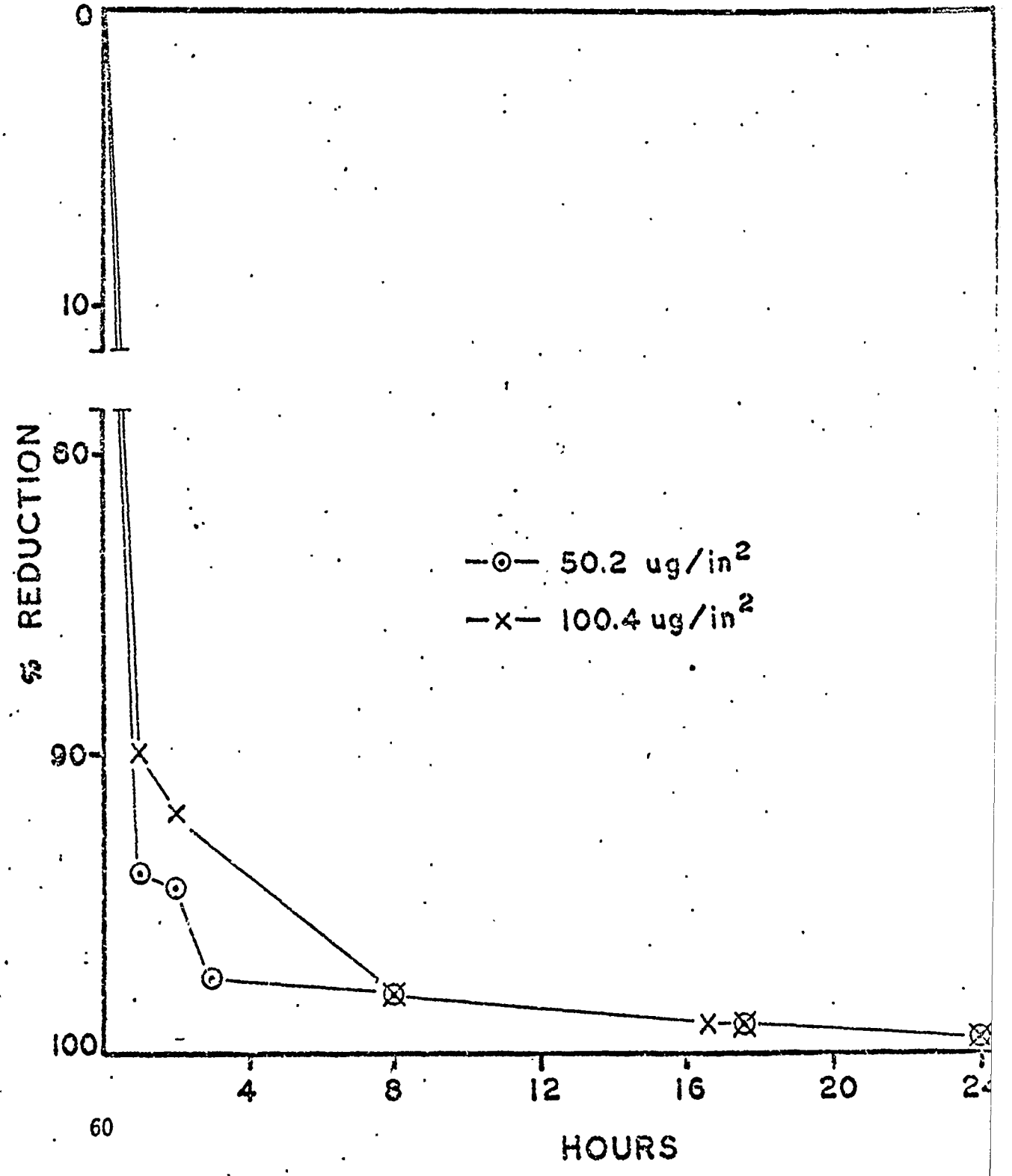
TABLE XIII

Maximum Acceptable Non-Food Chlordane Intakes Assuming 0.5 ug/kg Daily Intake With the Diet[20]

Wt. Lbs	Wt. Kg	Ug Chlordane/Day in Excess of Food
5	2.27	1.135
10	4.54	2.27
20	9.08	4.54
40	18.16	9.08
80	36.32	18.16
100	45.4	22.70
120	54.48	27.24
140	63.56	31.78
150	68.10	34.05
200	90.80	45.40

FIGURE 10

PERCENT REDUCTION OF CHLORDANE RESIDUES FROM GLASS SLIDES IN CONTACT WITH RABBIT SKIN



APPENDIX V

Written Communications With Webb AFB Concerning Decontamination and Sampling Procedures

APPENDIX V

1. Protocol 1 - Cleaning Sequence

NOTE: See fire prevention notes pertaining to cleaning with methanol solution.

1. Clean ducts. The ducts are the primary sources of chlordane; hence, they must be thoroughly cleaned before other clean up activities can be successful.

a. Strip out all cardboard liners out of all ducts. Swab ducts with rags which have been dipped in trichloroethylene and wrung out. (Workers wringing rags should have rubber gloves on; all windows should be opened to minimize the TCE vapor concentration.) Be thorough to eliminate having to remove heater again to reclean ducts.

b. Dry ducts by blowing or suction. Air flow should be such that the vapors are discharged outside of the house.

c. Clean all internal surface of heater with solvent on rags (TCE). Allow ample time, at least one-half hour for evaporation of TCE.

d. Reconnect heater.

e. Turn on heater let run for two hours (set thermostat to keep heater running during test). After two hours have elapsed take a general room air sample and sample each duct individually (all 20 min). Ship to Kelly immediately (shut off heater until results from lab are received). If sample is okayed by Kelly proceed to Step 2.

2. Clean floors, walk, inside of closets, ceilings, window, etc. (see protocol for cleaning) (See Fire Safety notes)

3. Clean all furniture, clothes, dishware, etc., which remains in house and for which permission to clean has been received. If possible, store those items that are still in question (as to cleaning methods, etc.) in plastic bags. See protocol for cleaning all items mentioned above. Take wipe sample as specified and ship to USAF EHL.

4. After all clean ups are accomplished and contaminated articles which will not be cleaned immediately are bagged or stored away from house, shut windows and doors; set heater thermostat to 85°F and do not disturb house for 48 hours.

5. After 48 hours have elapsed enter house, keep windows and doors closed, and take the extended air sample and duct samples (1 hour) also take wall and ceiling samples as specified in protocol and ship all samples to the USAH EHL K, for analysis. (NOTE: Personnel entering house should have respirators for use if detectable odors are noted.)

6. After these samples have been analyzed recommendations concerning occupancy of the house will be made.

B. Protocol 2 - Cleaning Interior Surfaces of Chlordane Contaminated Houses

1. Mix 20% (2:8) methanol:water solution.

2. Wash from ceiling to floor wearing rubber gloves with felt liner.

3. First Wash:

*a. Removing chlordane involves getting it off the surface into the solution (scrubbing) and then removing all the solution. If the scrubbing is not vigorous the chlordane will remain on the wall, if all of the solution is not removed immediately after scrubbing the chlordane will go back onto the wall.

*NOTE: All methanol washing should be done with all electricity off, electrical outlets taped, windows and doors open and no sparks, flames, etc., and all pilot lights out.

b. Spray methanol:water solution on center of ceiling, proceed slowly toward wall and down to floor.

c. As solution is flowing on surface 2nd man scrub vigorously and thoroughly entire ceiling, wall and all moldings, joints, etc..

d. Immediately after scrubbing 3rd man remove solution with sponges, wringing sponges into pail frequently.

4. 2nd and 3rd Washes:

a. Soak cloth in clean methanol:water solution, partially wring.

b. Starting on ceiling and working down walls scrub 2'x2' square area thoroughly, remove water with sponge and squeeze into dirty water pail.

c. Repeat, overlapping each square by several inches.

NOTE: *Carefully segregate clean and dirty water. Reapplying dirty water to

surface, replaces the chlordane on the wall.

5. Strip all old wax from floors.

6. Scrub with floor detergent, rinse and rewax.

C. Protocol 3 - Sampling Procedure for Use in Chlordane Contaminated Houses

1. DUCTS: Prior to cleaning ceiling, walls, and floors

a. Shut house and take 20 minute living room ambient air samples using two impingers at one liter per minute flow before turning on heat. Replace pet ether as needed.

b. Turn heat on for two hours at 85°F.

c. Retake ambient air as in "a".

d. Take one 20 minute air sample at each duct, being careful to sample stream of highest flow. The flow rate of samples equals one liter per minute.

e. Place samples in glass containers with screw caps. Rinse impingers with pet ether and combine wash with samples.

f. Tightly cap in such a way that pet ether does not come in contact with cap (pack in upright position and so label box).

g. Ship immediately.

2. HOUSE AFTER CLEANING:

a. Shut up house. Before turning on heat, take two samples above each duct: one on a wall surface at about 4-5 feet; another on the ceiling. Do not take wall samples off of glass. Total of 14 samples per house or 28 samples for two houses. Place samples in glass containers and refrigerate or freeze.

b. Turn on heat at 85°F for 48 hours.

c. Take ambient air sample in living room as instructed in "1.a".

d. Take duct samples as instructed in "1.d".

e. Take two samples from each wall and two ceiling samples in each room. (As instructed by EHL-K personnel during TDY to Webb)

f. Place in glass containers and ship with pre-heating samples mentioned above.

D. Protocol 4 - Cleaning Cement Enclosed Air Ducts With Trichloroethylene

Chlordane is highly soluble in trichloroethylene (TCE). TCE is inflammable, evaporates rapidly and is readily available. The following procedure is therefore recommended:

1. Remove furnace.

2. Tightly stuff the sump openings of six ducts with rags.

3. Slowly fill the sump and the 7th duct with TCE. (Have observers placed by all registers to insure TCE does not overflow into the house.)

4. Wait one hour and pump TCE from sump back into drum. (Maintain TCE level in the sump during this hour by adding TCE as necessary.)

5. Swab duct dry with rags.

6. Stop up treated duct and repeat on other ducts reusing TCE.

7. Blow ducts dry with hot air.

CAUTION: TCE fumes are toxic. Experienced supervision must be provided at all times. All personnel within the house should wear a self-contained breathing apparatus including eye protection, (such as a Scott Air Pack). Gloves should be worn and any skin coming in contact with TCE should be promptly and thoroughly washed with water. TCE must not be allowed to come in contact with flooring, etc.

8. Reconnect furnace and retake duct samples after 48 hours as described in previous protocol.

DEPARTMENT OF THE AIR FORCE
ENVIRONMENTAL HEALTH LABORATORY (AFLC)
KELLY AIR FORCE BASE, TEXAS 78241

REPLY TO ATTN OF: HKG

17 April 1970

SUBJECT: Protocol for Cleaning Heating Ducts of Qtrs 53-A and 57-B

TO: 3560 USAF Hosp (Lt Col Parker)
Webb AFB TX 79720

1. An international group of experts(1) has established that the Chlordane residues acceptable for chronic adult human exposure is 20 ug/day after allowance is made for residues consumed in food. Analysis of air samples taken from the duct of quarters 53-A on 5 April indicate prohibitive residues still persist.

2. Two courses of action remain:

a. Install new heating ducts.

b. Attempt cleaning the present ducts with trichloroethylene as described in Atch 1. I would estimate such a procedure has a 50:50 chance of providing adequate cleaning. Dry cleaning clothes with similar solvents eliminates detectable residues.

3. I recommend attempting the cleaning procedure for the following reasons.

a. The cost of the trichloroethylene is reasonable, a 55 gallon drum costs $80.00.

b. Labor cost are largely fixed if base personnel are used. Although diverting personnel from their usual duty assignments upsets workloads, the increase in actual cost to the USAF for one day would be a fraction of the total fixed labor cost.

c. Installation of heating ducts would be expensive.

d. The knowledge gained by trying such a procedure would in itself justify the cost. This Laboratory is increasingly being asked to deal with pesticide contamination problems. Experience in connection with the current problem has demonstrated a national ignorance of decontamination procedures. This cleaning technique would at the least provide information that could be used in a similar contamination situation. It may well save the costs of installing new heating ducts in the quarters.

FOR THE COMMANDER

Richard A. Callahan

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RICHARD A. CALLAHAN, Ph.D.
Captain, USAF, BSC
Chief, Entomological Studies Branch

1 Atch
Protocol

(1) Rept of the 1967 Joint Mtg of FAO Working Party & WHO Expert Committee. WHO Tech Rept Series No. 391. Geneva 1968.

APPENDIX VI

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APPENDIX VII

Persons Contacted at Webb AFB

PERSONS CONTACTED AT WEBB AFB

Colonel John Grow, Base Commander

Lt Colonel Edward C. Parker, Director of Base Medical Services

Lt Colonel Ernest Cutler, Base Executive Officer

Capt and Mrs James Clevenger, Occupants, Qtrs 53A

Capt and Mrs John K. Bray, Occupants, Qtrs 57B

Capt Paul C. Foraste, Chief, Aeromedical Services

Capt Hirim West, Civil Engineering

1st Lt Daniel Turner, Civil Engineering

Mr William Mims, Asst Civil Engineer

TSgt William H. Roy, Jr., NCOIC, Military Public Health

SSgt William Webster, NCOIC, Water & Sanitation

SSgt Edward J. McCall, PM Technician

Sgt Joe Woodard, PM Technician