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Environmental Statement

DISPOSITION OF ORANGE HERBICIDE BY INCINERATION

NOVEMBER 1974

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FINAL ENVIRONMENTAL STATEMENT
ON
DISPOSITION OF ORANGE HERBICIDE BY INCINERATION

Summary Sheet

This final environmental statement was prepared by the Department of the Air Force. For additional information about this proposed action, contact Dr. Billy E. Welch, Special Assistant for Environmental Quality, SAF/ILE, Washington, D.C. 20330, 202-697-9297.

1. The proposal described is an administrative action.

2. Description:

The Air Force plans to incinerate Orange herbicide in a remote area of the Pacific Ocean. Incineration will be of only that quantity of the approximately 2.3 million gallons of Orange herbicide which is not registered by the Environmental Protection Agency. The 2.3 million gallons include approximately 1.4 million gallons stored on Johnston Island, and 0.86 million gallons stored at the Naval Construction Battalion Center, Gulfport, Mississippi. Empty drums which once contained the herbicide will be recycled into the manufacture of steel.

The proposed action of incineration on a specially designed vessel in the open tropical sea near Johnston Island would take place during three 7 to 9 day periods. Since publication of the revised draft environmental statement, the EPA has reversed their previous position that the Marine Protection, Research and Sanctuaries Act does not apply to incineration at sea aboard an "incineration vessel". The EPA position is now that ocean incineration requires an ocean dumping permit. The Air Force plans to seek a permit for ocean incineration of Orange herbicide. If, however, the EPA Administrator decides not to issue a permit, the Air Force will pursue the principal alternative of incineration in an incineration facility that would be constructed on Johnston Island.

3. Environmental impact and adverse environmental effects of the proposed action:

The proposed incineration will convert the Orange herbicide to its combustion products of carbon dioxide, hydrogen chloride, and water which will be released without scrubbing into the atmosphere. Also, a relatively small amount of elemental carbon and carbon monoxide will be generated in the incineration process and discharged into the atmosphere. Evidence is presented to demonstrate the incineration process can reduce the levels of Orange herbicide to below the detectable limits in the combustion gases. Based on achievable efficiencies ranging from 99.9 to 99.999 percent, environmentally insignificant amounts of unburned and pyrolyzates of herbicide and its impurity 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) may be released into the atmosphere.

There will be no adverse effect on the environment caused by the incineration of Orange herbicide in a remote area of the Pacific.

4. Alternative methods of disposition:

- a. Principal alternative of incineration on Johnston Island.
- b. Incineration in one of the 50 States.
- c. Use of herbicide.
- d. Return to manufacturer.
- e. Deep well disposal.
- f. Burial in underground nuclear test cavities.
- g. Sludge burial.
- h. Microbial reduction.
- i. Fractionation.
- j. Chlorinolysis.
- k. Soil biodegradation.
- l. No disposal action.

5. Federal and State Agencies and other sources from which written comments have been received:

Atomic Energy Commission
Department of Agriculture
Department of Commerce
Department of Defense (Health and Environment)
Department of Health, Education and Welfare
Department of Interior
Department of Transportation
Environmental Protection Agency
State of Hawaii
State of Mississippi
American Eagle Foundation
Center for Law and Social Policy (representing Friends of the Earth
and the National Audubon Society)
The Marquardt Company

6. The draft environmental statement was made available to the Council on Environmental Quality and the public in January 1972. The revised draft environmental statement and final environmental statement were made available in April 1974 and November 1974, respectively.

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ABBREVIATIONS

AAAS	American Association for the Advancement of Science
ACGIH	American Conference of Governmental Industrial Hygienists
BOD	biochemical oxygen demand
BTU	British Thermal Unit
¹⁴ C	radioactive carbon
cbm	cubic meters
CJTF	Commander, Joint Task Force
cm	centimeter
CONUS	Continental United States
2,4-D	2,4-dichlorophenoxyacetic acid
DASA	Defense Atomic Support Agency
DMA-2,4-D	dimethylamine salt of 2,4-D
DNA	Defense Nuclear Agency
DoD	Department of Defense
EHL(K)	USAF Environmental Health Laboratory, Kelly AFB TX
EHL(M)	USAF Environmental Health Laboratory, McClellan AFB CA
EPA	Environmental Protection Agency
ESSA	Environmental Sciences Service Agency
GB	nerve agent
HAC	Herbicide Assessment Commission of the AAAS
HATV	High Altitude Test Vehicle
HEW	Department of Health, Education and Welfare
H & N	Holmes and Narver, Inc.
IMCO	Inter-Governmental Maritime Consultative Organization
JCS	Joint Chiefs of Staff

JP-4	jet engine fuel
kg	kilogram
km	kilometer
KW	kilowatt
l	liter
lb/A	pounds per acre
lb ai/A	pounds of active ingredient per acre
LD50	Dose which will kill 50% of a species of test animals in a stated period.
LORAN	Long Range Air to Navigation
m	meter
MG	million gallons
mg	milligram
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mm	millimeters
MUSTARD	a blister agent
NBE (nbe)	normal butyl ester
NCBC	Naval Construction Battalion Center
NNTRP	National Nuclear Test Readiness Program
PCB	Polychlorinated biphenyl
PERT	Program Evaluation and Review Technique
PGBE	propylene glycol butyl ester
ppb	parts per billion (weight to weight ratio)
ppb _{v/v} (ppb _v)	parts per billion (volume to volume ratio)
ppm	parts per million (weight to weight ratio)
ppm _{v/v} (ppm _v)	parts per million (volume to volume ratio)
pps	Pounds per second

pKa	Acid dissociation constant
ppt	parts per trillion (weight to weight ratio)
ppt _{v/v} (ppt _v)	parts per trillion (volume to volume ratio)
RDES	revised draft environmental statement
RMA	Rocky Mountain Arsenal
SMAMA	Sacramento Air Material Area (Sacramento Air Logistics Center)
SUE [®]	"Sudden Expansion" Burner, Registered Trade Mark, The Marquardt Company
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
TACAN	Tactical Air Navigation
TCDD	2,3,7,8-tetrachlorodibenzo- <i>p</i> -dioxin
THOR	a medium-range ballistic missile
USDA	U.S. Department of Agriculture
VX	a nerve agent
μg	micrograms
μg/l	micrograms per liter
~	approximately
>	greater than

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EXECUTIVE SUMMARY

In April 1970 the Secretaries of Agriculture, HEW, and Interior jointly announced the suspension of certain uses of 2,4,5-T. As a result of this announcement the Department of Defense suspended the use of Orange herbicide since this herbicide consists of approximately 50 percent 2,4,5-T and 50 percent 2,4-D. This suspension left the Air Force with 1.5 million gallons of Orange herbicide in Vietnam and 0.8 million gallons in Gulfport, Mississippi. In September 1971, the Department of Defense directed that the Orange herbicide in Vietnam be returned to the United States and that the entire 2.3 million gallons be disposed in an ecologically safe and efficient manner. The 1.5 million gallons were moved from Vietnam to Johnston Island for storage in April 1972.

The initial method proposed for disposal was incineration at a commercial facility in the United States. The details of this proposed course of action were documented in a draft environmental statement which was filed with the Council on Environmental Quality and the public in January 1972. The draft statement discussed the studies that were being accomplished but not completed when the statement was filed. Based on the fact that studies were still in progress and the interest evidenced in comments received on the draft statement, the Air Force decided to conduct additional studies on incineration as well as additional investigation of alternative disposal methods. (See Appendix L for comments.)

As a result, numerous studies were conducted to determine the feasibility of soil biodegradation, fractionation, chlorinolysis, and incineration. Also, the Air Force submitted an application to the Environmental Protection Agency (EPA) for registration of that portion of the herbicide which was expected to meet EPA criteria. Return of the herbicide to the original manufacturers was investigated. In addition, the possibility of deep well disposal, burial in underground nuclear cavities, and sludge burial were investigated. It was concluded that the best disposal technique is incineration in a remote area. The revised draft environmental statement was published to update the work accomplished between January 1972 and April 1974.

Thermal decomposition research using differential thermal analysis was conducted to determine the temperatures required for complete combustion of Orange herbicide and its impurity 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Dynamic laboratory studies were next completed to further substantiate the feasibility of incineration and to refine monitoring techniques for subsequent tests. A test program was conducted in a commercial incinerator to document the feasibility of destroying undiluted Orange herbicide by means of combustion. Particular emphasis was placed on the ability to destroy the low quantity of TCDD (low milligram per kilogram concentration, mg/kg) present in the herbicide. Extensive sampling, utilizing time-weighted and concentration techniques, was conducted to evaluate the unscrubbed combustion gases, the scrubbing liquid used to cool and scrub the combustion gases, scrubbed effluent gases, and any solid residues deposited in the system. Program objectives were outlined to determine, among other things, engineering data relative to controlling and monitoring the incineration process, the composition of the combustion products, the toxicity of discharged scrubber water to several aquatic organisms, and the

toxicity of scrubbed effluent gases to tomato plants. These series of tests demonstrated that incineration of Orange herbicide can be accomplished in an environmentally acceptable manner. In addition to the above tests, information on combustion of chlorinated hydrocarbons aboard incinerator ships indicates destruction efficiencies of at least 99.9 percent.

The average concentration of TCDD in the herbicide is about 2 mg/kg and the total amount of TCDD in the entire Orange stock is approximately 50 pounds. The commercial incinerator test program indicates that if any TCDD were present in the exhaust stream, it was analytically nondetectable. Orange destruction efficiencies of 99.9 percent or better appear feasible for a large scale incineration project. This will result in a total discharge of 0.05 pounds or less of TCDD via the exhaust streams over the duration of the project.

The data accumulated, together with theoretical considerations and applied thermochemistry, clearly indicate that the production of incomplete combustion products can be minimized to insignificant levels. Incineration will convert the Orange herbicide to its combustion products of carbon dioxide, hydrogen chloride, and water which will be released to the atmosphere. In addition, a relatively small amount of elemental carbon and carbon monoxide will be generated in the incineration process and discharged to the atmosphere. With proper concern for the environment in which such incineration will take place, incineration is an environmentally safe method of disposal of Orange herbicide.

The Air Force proposes incineration upon the open tropical sea west of Johnston Island on a specially designed vessel of that quantity of Orange herbicide not registered by the EPA. Since publication of the revised draft environmental statement, the EPA has reversed their previous position that the Marine Protection, Research and Sanctuaries Act of 1972 does not apply to incineration at sea aboard an "incineration vessel". The EPA position is now that incineration at sea requires an ocean dumping permit. Therefore, the Air Force plans to apply for a permit for disposal of Orange herbicide via incineration at sea. The incineration would occur during three 7 to 9 day periods. The effects of combustion gas discharges upon the environment was accomplished by utilizing "worst case" analyses techniques. A dispersion zone model was used to estimate mass concentrations of unburned Orange and hydrogen chloride in the air and water environment in the vicinity of the discharge, and a meteorological model was applied to predict the atmospheric concentration of unburned Orange and hydrogen chloride at sea level downwind of the discharge location. Predicted results from these models revealed that there will be no significant environmental impact upon either the air or ocean environment.

If, however, the EPA Administrator decides not to issue a permit for incineration at sea, the Air Force will pursue the principal alternative of incineration in facility that would be constructed on Johnston Island. Incineration on Johnston Island would require a higher efficiency owing to the ecology of the Atoll and would, for the analysis presented in the text, require approximately 200 days. A complete ecological survey was conducted of Johnston Island by the Smithsonian Institution in order to document the areas of concern. Incineration on-board a specially designed ocean vessel and incineration in a facility of Johnston Island both meet the criteria of remoteness. Incineration can be successfully conducted using either method; however, the predicted environmental effects are minimized by incineration in a remote area of the Pacific on the open tropical ocean.

PART I INTRODUCTION

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A. THE PROBLEM AND PROPOSED ACTION: The Air Force is charged with the responsibility for the ecologically safe, efficient and, if possible, low cost disposal of approximately 2.3 million gallons of Orange herbicide. Proposed action is to incinerate the herbicide in a remote area of the Pacific Ocean either on a specially designed vessel or on Johnston Island. Combustion gases from both options are discharged into the atmosphere in an environmentally safe manner and without any significant effect upon the beneficial uses of the area.

1. DESCRIPTION OF ORANGE: This herbicide consists of approximately 50% by volume of the normal butyl ester of 2,4-dichlorophenoxyacetic (2,4-D) acid and 50% by volume normal butyl ester of 2,4,5-trichlorophenoxyacetic (2,4,5-T) acid. A small quantity, known as Orange II, contained the isooctyl ester of 2,4,5-T in place of the normal butyl ester. Unfortunately, as a result of a malfunction in the production process, certain lots of the herbicide contain a contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). In experimental animals this compound was shown to be teratogenic, i.e., it caused the production of malformed fetuses and living offspring in animals. For this reason the military and certain other uses of 2,4,5-T ceased in 1970.

2. LOCATION OF ORANGE: The herbicide is stored in 55 gallon steel drums at two locations. At the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi, there are approximately 860,000 gallons and on Johnston Island, Central Pacific Ocean, there are approximately 1,400,000 gallons.

B. HISTORICAL DOCUMENTATION OF EVENTS

1. In 1962, the herbicide formulation, Orange, was developed for military use as a defoliant. This herbicide formulation is a mixture of n-butyl esters of 2,4-D and 2,4,5-T.

2. South Vietnamese newspapers reported an increased occurrence of birth defects during June and July 1969. This action elicited far-reaching reactions from governmental agencies, segments of the scientific community, lay groups concerned with environmental problems, and from the communications media. Government-sponsored panels of experts, special commissions established by scientific organizations, hearings before subcommittees of the U.S. Congress, and conferences attended by representatives from industry, government, and universities examined available data and heard expert opinions. These groups were not able to provide a generally acceptable answer to the central question of whether 2,4,5-T as currently produced and used, constituted a risk for human pregnancy (HAC, 1972).

3. On October 29, 1969, it was announced that a series of coordinated actions were being taken by several governmental agencies to restrict the use of the herbicide 2,4,5-T. This was precipitated by release a few days earlier of the findings of a study by Bionetics Research Laboratories, Litton Industries, Inc., in which it was found that mice and rats treated during early pregnancy with large doses of 2,4,5-T gave birth to defective offspring.

4. Additional animal experiments performed early in 1970 confirmed that pregnant mice did deliver some malformed offspring. The question then was one of whether, or to what extent, such animal data could be extrapolated to man. On April 14, 1970, the Secretary of Health, Education and Welfare (HEW), advised the Secretary of Agriculture that: "In spite of these uncertainties, the Surgeon General feels that a prudent course of action must be based on the decision that exposure to this herbicide may present an imminent hazard to women of child-bearing age." Accordingly, on the following day, the Secretaries of Agriculture, HEW and Interior jointly announced the suspension of the registration of 2,4,5-T for: "I. All uses in lakes, ponds or on ditch banks. II. Liquid formulations for use around the home, recreation areas and similar sites" (USDA-PR 70-1, 1970). A notice for cancellation of registration was issued on May 1, 1970 for: "I. All granular 2,4,5-T formulations for use around the home, recreation areas and similar sites. II. All 2,4,5-T uses on crops intended for human consumption" (USDA-PR 70-3, 1970).

5. All registrants of 2,4,5-T were advised of these actions. Two of the registrants, Dow Chemical Co. and Hercules Inc., exercised their right under Section 4.c. of the Federal Insecticide, Fungicide and Rodenticide Act (7 USC 135 et seq) to petition for referral of the matter to an Advisory Committee. The National Academy of Sciences supplied a list from which was selected a nine-member Advisory Committee of scientists with appropriate qualifications from universities and research institutes over the country. It was the consensus of the committee that the central issue was whether use of the herbicide does in fact constitute an imminent health hazard, especially with respect to human reproduction.

6. During the intervening months since restrictions were placed on the use of 2,4,5-T, a number of additional studies have been carried out on several animal species and a few reports of human exposure during pregnancy have been further evaluated. Although the new data have not answered all of the questions that have been or could be raised, they undoubtedly provided a more substantial basis for making a scientific judgment about possible effects of this herbicide on prenatal development than previously existed. In undertaking such judgment, the committee took into account certain considerations that seemed appropriate to the issue, as follows: 1) As is frequently the case, available data are insufficient for a definitive statement of conditions under which a specified risk might occur, assuming that freedom from risk is ever attained; 2) Since most chemicals under suitable laboratory conditions could probably be demonstrated to have teratogenic effects, and certainly all could be shown to produce some toxic effects if dosages were high enough, it would not be reasonable to consider the demonstration of toxic effects under conditions of greatly elevated dosage to be sufficient grounds for prohibiting further use of a particular chemical; and 3) Benefits are to be expected from the continued use of 2,4,5-T. The necessity of making a value judgment of benefit versus risk, therefore, must be accepted, not only for this herbicide, but for numerous valuable drugs, some natural nutrients, and many other chemicals, some of which are known to be teratogenic in laboratory animals. The risk versus benefit judgment for a particular herbicide or drug can be evaded only if it can be shown that another compound is equally as efficient and involves less risk. This presupposes that the risk potential of a substitute herbicide is at least as well known as that of the original (in this case 2,4,5-T) -- a fact that may be difficult or impossible to ascertain. The substitution of a relatively unknown pesticide for an older one with known adverse effects is not a step to be taken lightly.

7. The task of making a judgment about the central question of hazard to human pregnancy is complicated by still other considerations. Although herbicides are of economic benefit to man, their use is not without possible hazard to the environment and to other aspects of human welfare. In various connections, questions have been raised about: a) damage to nontarget plants caused by spray drift or by movement in water, b) damage to subsequently planted sensitive crops owing to herbicide persistence in the soils, and c) acute or chronic toxicity to man or other animals aside from that related to pregnancy.

8. It is scientifically impossible to prove that a chemical is without hazard. Pesticide regulations now require that new agents be tested for acute and chronic toxicity, mutagenicity and carcinogenicity. These tests may involve the use of two or more species of animals taken through several generations and the examination of thousands of individuals. Since it is necessary to extrapolate from effects in test animals to man and since species are known to differ in sensitivity to chemicals, the permissible residue levels in food must always be manifold below the minimal effect level for the species tested.

9. A major producer of 2,4,5-T submitted evidence that the 2,4,5-T used in the Bionetics test contained 27 ± 8 ppm of an impurity identified as TCDD. This impurity was tested and found to produce teratogenic effects in several species of animals at widely varying dose/body weight ratios and by different routes of administration.

10. Human exposure to an environmental chemical such as 2,4,5-T depends on: a) pattern of usage, i.e., how widely and frequently it is applied and in what amounts and b) its fate in the environment, i.e., how it accumulates and degrades in relation to its application rate. The chlorophenoxy herbicides 2,4-D and 2,4,5-T have been widely used to control broad-leaved weeds for over 20 years. Because 2,4,5-T is more expensive than 2,4-D, it has been primarily used to control woody plants and a few herbaceous species against which it is more effective than 2,4-D. Also because of the cost difference, commercial formulations containing 2,4,5-T are usually mixtures of the two herbicides.

11. Most of the 2,4,5-T is applied as a spray to foliage. Lesser amounts are sprayed on the trunks and branches of dormant trees, injected into the bases of trees, poured or sprayed into frills around the trunks of trees, sprayed or painted on newly cut stumps of trees. Amino salts of 2,4,5-T dissolved in water are most often used when the herbicide is applied to foliage and esters dissolved in oil are most often used when it is applied to bark. The spray concentrations usually vary between 0.1 and 2.5% and the rates of application are usually between 0.5 and 8 pounds per acre, depending on the size and sensitivity of the plants being treated. Higher rates and concentrations were used in Vietnam for military purposes (U.S. Army, 1969).

12. In September 1971, the Secretary of Defense directed the Joint Chiefs of Staff (JCS) to dispose both Continental United States (CONUS) and Vietnam stocks of herbicide Orange. The Air Force was assigned this responsibility.

C. USES OF PHENOXY HERBICIDES

1. REASONS FOR USE: The phenoxy herbicides 2,4-D and 2,4,5-T, their salts, esters and other compounds, are well established pesticides for the control of

weeds and shrubs in agriculture. In particular, as noted by Kingman and Shaw (1967), the phenoxy herbicides are especially useful because; a) they are selective, they kill most broad leaf plants but do not kill grasses or grain crops; b) they are potent, many species of weeds are controlled by less than one pound of active ingredient per acre; c) they are easy to use; d) they are only mildly to moderately toxic to man, domestic animals, or wildlife when applied as recommended; and e) they do not accumulate in the soil and they have minimal if any harmful effects on soil organisms. Kingman and Shaw noted that ester formulations are generally more potent, pound for pound, than salt formulations. The esters are more effective than salts for killing weeds that are growing slowly; and because esters are oily, they are less likely to be washed off the foliage if rain falls soon after application.

2. EXTENT OF USE: The herbicides 2,4-D and 2,4,5-T were first employed by farmers and ranchers in the mid-1940's and remain the most common synthetic organic herbicides. The largest use of 2,4-D is for broadleaf weed control in corn and other grains; the major use of 2,4,5-T is to kill brush (Fox et al., 1970). The combined production of 2,4-D and 2,4,5-T has increased steadily from 34.6 million pounds in 1958 to 96.8 million pounds in 1968. At present, the phenoxy herbicides are the only group of herbicides used to any extent on pasture and rangeland. In 1964, the uses of 2,4,5-T were: rights-of-way - 49%; nonfarm forests - 10%; hay, pasture, and rangelands - 7%; all other farm uses - 12%; lawns and turfs - 7%; federal agencies - 6%; and other miscellaneous uses - 9% (Advisory Committee). Incomplete information indicates that about nine million pounds of 2,4,5-T esters, acids, and salts were domestically used during 1970. Weeds and brush infesting pasture and rangeland are most widely controlled by 2,4-D and 2,4,5-T, respectively. In 1966, nearly 8 million acres (more than 1 percent) of pasture and rangeland were treated with phenoxy herbicides (Fox et al., 1970). The herbicide 2,4,5-T is a particularly effective tool for vegetation management on forest lands (Montgomery and Norris, 1970). It is used on power-line, railroad rights-of-way; but its most important use is in connection with the establishment and release of conifers on forest lands. For these purposes, 0.5 to 4 pounds of 2,4,5-T per acre were applied as low volatile esters dissolved or emulsified in diesel oil or water.

3. REGISTRATION

a. The 15 April 1970 government edict on 2,4,5-T suspended the registration of liquid formulations for use around the home and recreational areas, and for uses on lakes, ponds, and ditch banks. This restriction did not include its use on range and pasture lands, nonagricultural lands, or in weed and brush control programs on communications and highway rights-of-way. Several formulations of 2,4-D and 2,4,5-T are currently registered for domestic use. Orange herbicide is not a registered herbicide and cannot be domestically used or sold.

b. The Orange herbicide stock to be destroyed by the action proposed in this environmental statement, incineration at sea, or by the principal alternative of incineration on Johnston Island represents a resource of considerable monetary value. The safe and appropriate utilization of all or part of this resource would be a beneficial action, see Part V.C. The Air Force has been and is continuing to pursue the possibility of EPA registration of portions of the Orange herbicide stock. The Air Force is seeking registration of the maximum possible quantity found acceptable by the EPA. Depending upon the level of TCDD allowed, approximately 1.5 million gallons could conceivably be registered.

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A. INTRODUCTION: This part of the Environmental Statement is primarily to describe the proposed incineration of Orange herbicide from the standpoint of facility and operational requirements and effluent stream characteristics. The proposed action of incineration at sea and the principal alternative of incineration on Johnston Island are described. Since publication of the revised draft environmental statement, the EPA has taken the position that the Marine Protection, Research and Sanctuaries Act of 1972 does not apply to incineration at sea. Therefore, the Air Force plans to apply for a permit for disposal of Orange herbicide via incineration at sea. The factors applicable to the selection of a disposal site and the situation regarding disposal of empty herbicide drums is also discussed. In view of the importance and interest in the properties of the herbicide, a section titled "Characteristics of the Herbicide" has been included as the final section of this part.

B. INCINERATION SITE CRITERIA: This Environmental Statement is for the disposal of Orange herbicide via incineration in a remote area. The proposed action will take place aboard a specially designed incinerator vessel in an isolated location of the Pacific Ocean. The principal alternative would be incineration on the west side of Johnston Island. Either location meets the remoteness requirement. Either location will involve an industrial operation of considerable magnitude in which the undiluted herbicide will be handled and will be the fuel feed into the incinerator(s). Since Johnston Island and the surrounding area will be involved in the proposed action or the principal alternative, considerable information on this locale is presented in Appendix H. General considerations that were used for site selection are summarized and presented below.

1. PHYSICAL FACTORS

a. The site should be as remote as possible from both residential and industrial population centers and from land currently in agronomic production. Vegetation should be sparse, of little agronomic value, and of species resistant to the phenoxyacetic acid herbicides contained in Orange or to the pyrolytic products of these herbicides. The site should be selected so that women of childbearing age have the lowest possible probability of contact with the Orange.

b. The topography or surface features of the surrounding area should be relatively flat and with a symmetrical, uniform surface.

c. A prevailing wind of as nearly constant direction and velocity as possible would be highly desirable. Insofar as possible, the incinerator(s) should be sited downwind of any inhabited areas such as housing, work shop and storage areas, recreational areas, etc.

d. The site should be located to provide accessibility of water, rail, or truck transportation but cause negligible interference with any existing patterns of transportation. Further discussion of transportation is contained in Appendix I.

2. BIOLOGICAL FACTORS

a. The site should be so located to minimize any unacceptable adverse impact on municipal water supplies, shellfish beds, wildlife, fisheries (including spawning and breeding areas), or recreational areas.

b. The site should be located such that the disposal operations will cause no unacceptable adverse effects to known nursery or productive fishing areas. The currents should be such that any suspended or dissolved matter would not be carried to known nursery or productive fishing areas or populated or protected shoreline areas.

3. MANAGEMENT FACTORS: The site should be so located and configured such that it will be conducive to single manager control of the entire disposal operation and peripheral activities, and that adequate control can be exercised over the general population in the area to allow immediate response in the event of an accident, incident, or act of God. Adequate communications must be available that will further enhance management at all levels.

4. SOCIO-POLITICAL FACTORS: The site selected or the transport of the Orange should not require the exercise of the right of eminent domain or result in a trespass or encroachment to private citizens within the U.S. or its possessions or to any other nation's interests. If possible, the site should be completely under the control of the Federal Government to minimize the local political controversial effects on state or other government units. The site location should not result in international controversy, be in conflict with international law, or impair the economic activity of any commercial enterprise.

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C. METHOD OF INCINERATION

1. INTRODUCTION: Incineration of Orange has been investigated and it has been concluded that high temperature incineration is capable of destroying the Orange herbicide and its TCDD content in an environmentally safe manner. Appendix D, "Incineration of Orange Herbicide," describes the theoretical aspects of Orange incineration, reviews five separate studies directed toward the evaluation of Orange incineration, and concludes that incineration is an acceptable disposal method. These studies were performed by: 1) the USAF Environmental Health Laboratory, Kelly AFB, TX; 2) the U.S. Department of Agriculture and Mississippi State University, State College, MS; 3) the Combustion Power Company, Menlo Park, CA; 4) the Marquardt Co., Van Nuys, CA; and 5) a joint effort between The Marquardt Co. and the USAF Environmental Health Laboratories (EHLs) at Kelly and McClellan AFB. As shown in Appendix D the first four studies conducted on Orange (1 through 4 above) were of small scale as regards quantity of Orange incinerated and sampling and analyses conducted. To further evaluate the high temperature combustion of Orange and to obtain incinerator operation parameters which may be appropriate to a commercial incinerator system, it was apparent that a large scale completely monitored Orange test burn using an incinerator with an acid gas scrubbing system was required. As an initial choice, a large scale test burn of Orange incineration was programmed at the Rollins Environmental Services facility in New Jersey. This project never passed the planning state and was concluded because of technical, environmental and regulatory problems. With this setback and after careful consideration of alternative incineration options, the Marquardt Company SUE[®] incinerator was selected for a test burn. Factors in this decision included: 1) The SUE[®] is a flame incinerator which could utilize Orange herbicide as the fuel and air to supply the required oxygen; and 2) The modular concept of the SUE[®] is very advantageous because it eliminates scale-up considerations (capacity is increased by increasing the number of modules), and permits ease of shipment, installation, maintenance and dismantling. The purpose of the test burn was to obtain data on Orange incineration and not to determine specifically if the SUE[®] system was acceptable for the disposal of the entire Orange stock. It is the Air Force opinion that selection of the SUE[®] was a sound choice for a test burn and that while pure data extrapolations are not possible, the requirements for an overall incineration system for the destruction of Orange can now be specified with a high degree of certainty. The report on the study with a SUE[®] incinerator, prepared by the Marquardt Co. and both the USAF EHLs, is titled "Report on the Destruction of Orange Herbicide by Incineration," and is presented as Appendix E. In view of these studies and the disposal site criteria, this environmental statement proposes the action of destruction of Orange herbicide via incineration on a ship at sea. In addition, this Environmental Statement proposes the principal alternative of incineration on Johnston Island. It is noted that this proposal is for "incineration as a method of destruction of Orange" and in no way is it intended to imply or state that the product of any given contractor, firm, company, etc., must be used.

2. INCINERATION AT SEA

a. Introduction: As stated, the Air Force proposes the destruction of Orange herbicide via incineration on a ship at sea; however, its implementation is dependent on the EPA issuing a permit in accordance with the Marine Protection, Research and Sanctuaries Act of 1972. The above mentioned studies and other information from Ocean Combustion Service B.V., Rotterdam, The Netherlands, indicate that shipboard incineration would be capable of destroying Orange herbicide and its TCDD content in an environmentally safe manner. Since September 1972, a ship, the "Vulcanus" has been equipped to carry certain hazardous liquid chemical cargoes from northern European ports and approved by participating countries to incinerate the waste cargo in prescribed areas of the North Sea. Additionally, U.S. companies have suggested shipboard incineration and have indicated a willingness to investigate it. The following information describes the "Vulcanus" from material supplied by the Ocean Combustion Service B.V.

b. The Vessel

(1) The ship is a double hulled and double bottom tanker with an overall length of 331.4 feet, a beam of 47.2 feet and a draft of 22.9 feet. Her construction complies with the latest Inter-Governmental Maritime Consultative Organization (IMCO) regulations of bulk carriage of dangerous chemicals at sea. Because of her size, the vessel is able to operate world-wide, and she is able to operate in very rough weather. The ship has a crew of ten to operate the ship and a crew of six solely to operate and continuously man the incineration process. Two diesel engines drive the single propeller to give service cruising speeds of 10-13 knots.

(2) The vessel's cargo tank capacity of 3,503 cubic meters (cbm) (925,493 gallons) is divided into 15 cargo tanks ranging in volume from 115 cbm to 574 cbm. None of these tanks are in contact with the vessel's hull and/or bottom. The engine room is separated from the cargo tanks by double bulkheads, the pump room and generator room being situated in between.

c. Incineration System

(1) Physical Features: The two combustion chambers are installed right aft of the upper deck. Each of the bricklined incinerators has a maximum outer diameter of 5.50 meters (m), and inside diameter of 4.80 m, and a total height, including the stack, of 10.45 m. The volume of each combustion chamber is calculated to be 87.9 cbm. Each chamber has three burners with rotating cup fuel injection systems which provide vortex turbulence and distribution of fuel feed throughout the whole chamber. This incinerator is considered a conventional incinerator as discussed in Part V.B.

(2) Operation: Incineration will be conducted in a designated area 50-60 miles clear of normal shipping lanes and on the open tropical sea down wind of Johnston Island. Gas or diesel oil will be used to bring the chambers to the required combustion temperature, normally 1400°C (2552°F); the maximum operating temperature is reported as 1650°C. Only when the required temperature is reached will the feed pumps allow waste to enter the combustion chambers. Waste feed flow and air will be carefully controlled to insure complete combustion. Once the required temperature is obtained, the chambers will be fed solely by the undiluted Orange. The Orange can be pumped to each of two chambers at a rate of 10-12 tons per hour for a total daily pump rate of

about 576 tons. Therefore, about 22-26 days of continuous incineration would be required to burn the entire Orange stock (2.3 million gallons). The vessel's capacity of about 925,000 gallons of Orange will require three voyages; 925,000 gallons of Orange would be burned during each of the first two voyages, and the remaining 380,000 gallons of Orange plus any solvents used in drum cleaning would be burned during the third voyage.

(3) Effluent Discharges: Data presented in Appendices D and E indicate that incineration of herbicide Orange can be accomplished in an environmentally acceptable manner. A comparison of the incineration characteristics of the "Vulcanus" versus those known to be acceptable based on the data presented in Appendices D and E indicated that Orange herbicide can be successfully incinerated on board the "Vulcanus." (Acceptable parameters: measured combustion temperatures 2400 - 2800°F; dwell time equal to or greater than 0.14 seconds; a fuel to air mass ratio of approximately 0.1; and excess air greater than 30%. Vulcanus data: 2550°F; 0.6 seconds; 0.1 to 0.12; and 35% respectively.) Information from Ocean Combustion Services has been used to predict the inorganic constituents of the exhaust stack discharges. A total throughput of 576 tons per day (24 tons/hour) of Orange with an average of 30 percent (by weight) chlorine content will give a discharge of approximately 178 tons/day of hydrogen chloride, some 1,000 tons/day of carbon dioxide, about 50 tons/day of carbon monoxide, and about 3.0 tons/day of carbon particles. Although very low quantities of unchlorinated hydrocarbon pyrolyzates ($\mu\text{g/l}$ range) were detected in the combustion areas of Orange in a commercial incinerator (Appendix E), information from Ocean Combustion Service indicated 99.9 percent of a chlorinated hydrocarbon feed is destroyed. At this high efficiency, approximately 0.576 ton/day (48 pounds/hour) of Orange feed constituents and their pyrolyzates are not completely incinerated and are thus discharged hourly into the atmosphere. Ocean Combustion Services reported that negligible amounts of combustion chamber coke deposits have ever accumulated in the ship's incinerators. This has been attributed to their waste injection system, very high vortex turbulence in the chambers, and 1400°C temperatures on the chamber's firewalls. From such experience, no consequent combustor chamber coke deposit is expected.

(4) Monitoring

(a) Operational Monitoring: A special monitoring panel continuously displays the following: temperature near the center of each incinerator chamber, temperature in the centerline and about two meters from each incinerator stack exit, date and time, on/off mode of each feed pump and each burner, and grid location of the vessel. This panel is photographed at preset desired intervals by an automatic camera. This panel and camera can be sealed by regulatory authorities to prevent tampering and provide accurate documentation of the incinerator operation and location. Additionally, a navigation plotter automatically charts the vessel's course on a map and is made available to authorities along with certified copies of the ship's log. These operational and navigational documentations have been used to establish the ship's successful incineration of waste cargoes in a designated area. For this project, automatic photographs of the panel and manual observation records

of the incineration parameters will be accomplished. However, the navigational log book rather than the automatic plotter will be acceptable due to the vast expanse affordable in the Pacific Ocean as compared to the North Sea. Based upon the successful past history of incinerating some 60,000 tons of chlorinated hydrocarbons and upon the basis of documentation of operational parameters as outlined above, success of this option is predicted. Additional documentation can be provided by a regulatory representative who can accompany the vessel. As no significant impact is envisioned (See Part III), combustion gas analyses is not necessary as an operational requirement.

(b) Ecological Monitoring: Ecological monitoring is neither required nor feasible for the following reasons: 1) the ship will complete the project within a month and always be moving and operating over a large area of the open tropical sea; and 2) as described in Part III, the predicted impact will be very minimal and transient for this incineration option.

(5) Additional Environmental Considerations: The ship does not have on board facilities for handling, emptying, or cleaning the drums nor does it have pumping capability for on-loading the Orange herbicide. This means that facilities for transferring of the herbicide, emptying and cleaning of drums, and pumping the herbicide aboard the ship will be necessary. Additionally, ultimate disposal of the empty drums will also be required. Duplication of these required facilities at Johnston Island and Gulfport MS depends on either of two methods to be selected for transporting the Gulfport herbicide to Johnston Island: 1) provide facilities at Gulfport for transferring Orange to the ship's cargo tanks, or 2) transport the Gulfport herbicide in existing drums to Johnston Island for loading onto the incinerator ship. The selection of either of these alternatives will depend on considerations of economic, environmental, and operational aspects of the drum disposal method selected.

3. PRINCIPAL ALTERNATIVE - INCINERATION ON JOHNSTON ISLAND

a. Introduction: The system described below is conceptual and based upon prior studies which developed the operational parameters required for successful incineration of undiluted Orange herbicide (see Appendices D and E).

b. Proposed Incinerator on Johnston Island

(1) Incineration System

(a) The proposed incineration system on Johnston Island would incinerate the Orange herbicide at a rate of 1.4 pounds per second (pps) for 24 hours per day and discharge the combustion gases directly into the atmosphere on the west end of the island. At this rate, 11,300 gallons or 206 drums of herbicide could be incinerated per day for 200 burn days to incinerate the entire stock of 2.3 million gallons. The details and design of the hardware for the entire system have not been addressed. However, incinerator systems both with and without combustion gas scrubbers have been considered in order to demonstrate the potential impact of spent scrubber water versus unscrubbed combustion gas dispersions into the atmosphere. For a system operating within the acceptable parameters described in Appendix E (measured combustion chamber

temperatures of 2400-2800°F; dwell time equal to or greater than 0.14 seconds; fuel to air mass ratio of about 0.1; and excess air greater than 30%), it can be stated that: 1) combustion gas and scrubbed effluent gases are free to undetectable levels ($\sim 0.20 \times 10^{-3}$ $\mu\text{g}/\text{l}$ for each compound) of herbicide esters, acids, and TCDD; 2) about 10% of the carbon dioxide and greater than 99.9% of both the hydrogen chloride and carbon particulates are removed from the combustion gases via an alkaline scrubber; 3) combustion pyrolyzates are unchlorinated hydrocarbons whose total concentrations average less than 0.50 $\mu\text{g}/\text{l}$; 4) alkali scrubbing removes a small fraction of the pyrolyzates from the combustion gases, and with gaseous condensation in presence of chlorine, converts some of the pyrolyzates into chlorinated hydrolyzates; 5) total unchlorinated pyrolyzates average less than 13.0 $\mu\text{g}/\text{l}$ and total chlorinated hydrolyzates average less than 3.0 $\mu\text{g}/\text{l}$ in the spent scrubber water; 6) carbon particulates contain no detectable levels of any type of hydrocarbon and the mass of these particulates was less than 0.5% of the carbon in the herbicide; 7) carbon dioxide, carbon monoxide, and heat of combustion gases are not environmentally significant; and 8) dispersions of scrubbed effluent gases into the atmosphere have no effect on tomato plant bioassays and attest to the lack of phytotoxicity of the gases.

(b) Considering the quality of the combustion gases and absence of herbicide feed constituents and TCDD content, treatment of the combustion gases is not required. Discharged combustion gases from the west end of the island will have minor environmental significance but spent scrubber water discharges, if used, could have an impact on the island's aquatic environment. For completeness both here and in Part III, both alkali and sea water scrubbers are discussed, but it is emphasized that the most environmentally acceptable incineration system on Johnston Island is one which does not scrub the combustion gases.

(c) Combustion gases would be discharged without scrubbing via a high stack on the west end of the island. These gases would be free to undetectable levels of herbicide feed constituents and TCDD but would discharge some 18.5 tons of hydrogen chloride during each burn day. Additionally, the stack gas would also discharge about 0.3 tons of particulate carbon per day and contain microgram per liter concentrations of unchlorinated hydrocarbon pyrolyzates. This option is attractive because it eliminates environmental problems associated with the discharge of spent scrubber water and the economic and logistic problems associated with the procurement and handling of neutralization chemicals and/or acidic scrubber water.

(2) Discussion of Scrubbers Considered

(a) Alkaline Scrubber

1. Hydroxide as a Neutralizer: An average volume of 250,000 gallons of fresh scrubber water containing about 81,000 pounds of sodium hydroxide (NaOH) would be required to scrub/neutralize the 37,000 pounds of hydrogen chloride produced per burn day in the combustion gas. The excess amount of sodium hydroxide required in the scrubber water is attributed to combustion gas carbon dioxide reactions with the alkali and scrubber system efficiency. If the NaOH were supplied in 55 gallon drums of 50 percent by weight NaOH, then 1-1/4 drums of this NaOH stock solution would be required per drum

of herbicide incinerated for a total of 50,000 drums of NaOH. This NaOH requirement may be reduced by 25% if the alkali were recycled and the scrubber design optimized to discharge spent scrubber water at pH 8.5. Daily discharge of spent scrubber water would be about 200,000 gallons because about 50,000 gallons of fresh scrubber water feed are volatilized and discharged with the stack gas as water vapor, see Appendix E.

2. Coral Carbonate as a Neutralizer: Coral is the primary constituent of the geological mass of Johnston Island. As primarily calcium carbonate (CaCO_3) it represents a source of alkalinity which may be suitable as a neutralizer for scrubber water which contains acid gas, hydrogen chloride. On the basis of hydrogen chloride neutralization only, about 43 pounds of CaCO_3 would be required for each 100 pounds of Orange burned. The daily incineration of 206 drums of Orange would require approximately 26 tons of CaCO_3 . For consideration of the incineration of 2.3 million gallons (200 days), the neutralization of HCl would require approximately 5,000 tons of CaCO_3 . This figure would undoubtedly be higher when system efficiencies and absorption of carbon dioxide are considered. Since CaCO_3 does not dissolve in sea water, the scrubber neutralizing system would require two units consisting of a sea water scrubber and a crushed coral contact unit for exposure of the scrubbing water to the coral. The availability of coral and a small scale test of coral usage would be required prior to selection of this method of combustion gas treatment.

3. Spent Alkali Scrubber Water Character: For an incineration system operating at the acceptable parameters, the spent scrubber waters are free to undetectable levels (~45 nanograms/l for each compound) of herbicide esters, acids, and TCDD and contain less than 16.0 $\mu\text{g/l}$ of total hydrocarbon pyrolyzates and hydrolyzates. However, the spent scrubber water is 160-170°F and contains significant concentrations of suspended solids, 80-100 mg/l; free available chlorine, 250 mg/l; and chlorides, 20,000 mg/l (see Appendix E). The free available chlorine, 417 pounds in 200,000 gallons of spent scrubber water per day, and the heat content are primary problems in disposing of the scrubber water. Bioassays on the spent scrubber water required conditioning of the water for heat and chlorine removal, after which, the toxicity of the spent scrubber water was essentially the same as that of the fresh scrubber water and synthetically prepared spent scrubber water.

4. Spent Alkali Scrubber Water Treatment and Discharge: Spent scrubber water would need processing through cooling towers or spray ponds to reduce heat and free available chlorine content. The scrubber water would then have to be transferred via force main to the existing sewage outfall pumping station on the southside of the island for discharge with the sanitary sewage. Mixing sanitary sewage with spent scrubber water would further reduce the heat and free available chlorine content to levels acceptable for discharge. The outfall discharge point would be near the north-south axis of the island and approximately 500 feet from the shore.

5. Scrubbed Effluent Gas Character/Discharge: Scrubbed effluent gases would be free to undetectable levels of herbicide feed ester, acids, and TCDD. Expected hydrocarbons would be unchlorinated pyrolyzates whose total concentration is less than 0.30 $\mu\text{g/l}$. Inorganic quality of scrubbed ef-

fluent gases would be excellent: particulates, <0.1 grains per standard cubic foot, consisting of scrubber water salts and negligible amounts of carbon particles; carbon dioxide, 12-13% by volume; carbon monoxide, <1.0% by volume; water vapor, <50% by volume; nitrogen oxides, <100 ppm; and essentially free of hydrogen chloride. The scrubbed effluent gases would be discharged via stack on the incinerator site on the west end of the island.

(b) Sea Water Scrubber

1. Treatment: A scrubber system, utilizing sea water as the scrubbing liquid without an alkali agent, could be used for removal of carbon particulates and hydrogen chloride from the combustion gas. Water absorption devices are used to collect hydrogen chlorides gas in the manufacture of hydrochloric acid. Such devices are also used as gas emission control systems.

2. Scrubber Water Character: The heat, hydrogen chloride, suspended carbon particles, and hydrocarbon pyrolyzates and hydrolyzate mass loadings in the spent sea water scrubber would be similar to those obtained with alkali scrubbers. In this system, however, the absorption and reactions of hydrogen chloride would make the scrubber water very acidic. For example, if 500,000 gallons of sea water were 100 percent efficient in absorbing 18.5 tons of hydrogen chloride during each day's burn, the resulting spent scrubber water would be about a 1.0 percent HCl solution and have a pH of <1. Incineration of the 2.3 million gallon herbicide stock would result in the release via a sea water scrubber outfall of about 3,700 tons of hydrogen chloride into the receiving water environment.

3. Scrubber Water Discharge: The acidic nature of the scrubber water would preclude its discharge with sanitary sewage due to material incompatibility with existing sewage pipeline. A separate discharge line and outfall would be required to insure that the reef is not affected by this acidic discharge. The outfall would be located either on the southside of the island beyond the location of the present sewage discharge or to the southwest of the island.

4. Scrubbed Effluent Gas Character/Discharge: The scrubbed effluent gas quality will be essentially the same as that described for the alkaline scrubber except that the hydrogen chloride concentration may be greater. Assuming a 90 percent efficiency of scrubbing, some 370 tons of hydrogen chloride would be discharged in the exhaust gases. The discharge would be from a stack located at the incineration site on the west end of the island.

c. Summary: Incineration systems can be used on Johnston Island to provide 99.999 percent efficient incineration of undiluted Orange herbicide. Discharge effluent streams will be free of herbicide feed constituents and TCDD to undetectable levels, see Appendices D and E. An incinerator system has been described which would incinerate the 2.3 million gallons of herbicide in about 200 burn days and discharge the combustion gases from an exhaust stack on the west end of the island. Scrubbing of the combustion gases was discussed for completeness only and to demonstrate the quality and quantity of expected spent scrubber waters.

D. FAILSAFE: As with any process involving mechanical equipment, incineration operations are subject to malfunction and therefore require adequate safeguards to protect the environment and provide safety of personnel. The necessary safeguards for each of the incineration options are discussed below.

1. INCINERATION AT SEA

a. Procedures and construction of facilities to transfer the Orange to the ship will be accomplished in a manner to preclude and contain any spillage/leakage into the soil or waters. Procedures will include action to be taken during any unforeseen event resulting in the spillage of Orange.

b. The ship has been constructed according to IMCO regulations and will meet current U.S. Coast Guard requirements regarding loading and carriage of hazardous liquid cargoes. Her double hull and double bottom provide added containment protection from collision or other marine hazards. Crew quarters are not located above cargo space, and the incinerator is located on the stern at a safe distance from the crew quarters. Fuel oil for the ship's engines is isolated by double bulkhead from the waste cargo tanks.

c. The vessel is designed so that liquid waste cargoes can only be on-loaded via pumps on shore. Once loaded, shipboard pumps are only capable of discharging the liquid wastes directly into the combustion chambers. However, international regulations require that in the event the safety of the vessel and crew may be threatened, there must be some means of discharging the cargo directly into the sea. This could be effected through gravity release valves which remain officially sealed in normal circumstances.

d. Incinerator system monitoring and control of operational parameters have the following failsafe items:

(1) Electric waste pumps will not operate to feed herbicide to an incinerator's burners if that incinerator's combustion chamber temperature falls below 1400°C. If such a situation occurs, the incinerator malfunction is corrected and the combustion chamber temperature is returned to above 1400°C with fuel oil before any herbicide is reintroduced.

(2) An incinerator's burner is automatically shut down if any of the following conditions fall below preset levels: the air feed pressure to a burner, the herbicide feed rate to a burner, and the flame intensity of the burner.

(3) Operational controls and monitoring panels are manned at all times by an engineer whose sole ship responsibility is operating and maintaining the incinerator system at the desired combustion parameters.

2. PRINCIPAL ALTERNATIVE - INCINERATION ON JOHNSTON ISLAND

a. The incinerator complex will be constructed so that all transfer operations, such as transfer of Orange from the drums to storage or feed tanks, will be accomplished in a curbed or diked area to insure containment of spills. Procedures will be instituted so that spillage will be minimized during maintenance operations and so that operations will cease if any leaks develop in transfer systems.

b. The incinerator will be instrumented so that the combustion zone temperature will be constantly read-out and recorded. An automatic system will be included to notify the incinerator operator if the prescribed temperature condition is violated; upon notification, procedures will provide for immediate cut-off of fuel (Orange). The incinerator will be operated by qualified personnel continuously during an incineration of Orange herbicide. The fuel feed rate, air flow rate, and certain operating pressures will be read-out and recorded at prescribed intervals. Any deviation from acceptable values will require immediate cut-off of the fuel feed. Possible accidental modes will be investigated and procedures will be written for action to counter the situation. These procedures will provide for the immediate cut-off of fuel.

c. Real-time stack gas monitoring will be incorporated into the final design. Monitoring of combustion gas temperature and inorganic parameters (carbon monoxide, hydrocarbons, etc.) to determine concentrations and efficiency will be accomplished because of concern for the environment of Johnston Island. A system of operator notification in the event of unacceptable levels will be included.

d. The incinerator system will be run by electric power. Probable power failure modes will be identified and investigated, and procedures will be developed for system shut down and corrective action.

E. HERBICIDE DEDRUM/TRANSFER AND DRUM DISPOSAL

1. INTRODUCTION

a. The proposed action, incineration at sea, will result in the accumulation of about 15,700 empty fifty-five gallon drums at NCBC and about 25,000 empty drums at Johnston Island. These drums will accumulate because the herbicide will be bulk loaded aboard the incinerator ship; the ship will be loaded once at the port of Gulfport and twice at Johnston Island. For the principal alternative, incineration at Johnston Island, the Orange stored at Gulfport will be shipped in drums to Johnston Island; therefore, about 40,000 empty drums will result from an incineration operation at Johnston Island. These empty drums will require disposal, and, in either case the ultimate drum disposal will consist of recycling the drums as "scrap steel" into steel manufacturing. Recycling as scrap steel is in accordance with the EPA preference for smelting as expressed in their comments to the revised draft environmental statement (Appendix O), and recycling is also deemed to be within the intent of the recommended EPA guidelines on disposal of pesticides and pesticide containers (39 FR85).

b. For the proposed action, incineration at sea, it is planned that the incinerator ship be bulk loaded at a rate equivalent to 1000 drums per day. Facilities are being designed at NCBC Gulfport and at Johnston Island by the Naval Ordnance Station MD to accommodate this transfer operation. To obtain data relative to this operation, the EHL(K) has conducted ecological surveys at NCBC Gulfport and Johnston Island, and conducted an Orange herbicide drum draining experiment at Gulfport. During the drum draining experiment, personnel from the EHL(M) conducted air sampling for the herbicide in the immediate work area occupied by the personnel performing the drum draining experiment. The ecological survey at NCBC revealed that the normal flora in proximity to NCBC are not generally susceptible to damage from Orange herbicide vapors. The transfer operation is presently planned for the winter months when the plant life would be least susceptible to damage from herbicide exposure. Therefore, the transfer operation can be accomplished with little or no concern for herbicide vapor control as regards phytotoxicity at NCBC and the surrounding area. The air sampling conducted during the drum draining experiment revealed that the atmospheric concentrations of Orange vapors (0.6 ppb_v for 2,4-D and 0.4 ppb_v of 2,4,5-T) were well below the ACGIH Threshold Limit Values (TLV) of 10 mg/cbm for 2,4-D acid (1100 ppb_v) and 2,4,5-T acid (960 ppb_v). These very low results were anticipated because the vapor pressure of Orange is only 3.6×10^{-4} mm mercury at 30°C, and therefore the atmospheric saturation concentration is calculated to be 470 ppb_v. This is the maximum concentration attainable by vaporization, and it is well below the above mentioned TLV. While it is realized that the surface area available for vaporization will be greater during the actual transfer operation than during the drum drainage experiment (16 drums), the concentration of Orange is expected to remain at least an order of magnitude below the TLV during the transfer operation. Therefore, the atmospheric concentration to which some unprotected project personnel will be exposed during the 16 day project will be below the acceptable value for an occupational life time exposure. The low concentration of Orange in the atmosphere existing in the drum draining area will be rapidly decreased by diffusion and dispersion as this air moves downwind, thus the transfer project could be accomplished with little or no concern for herbicide vapor control

as regards exposure to either project or non-project personnel. Despite the predicted ecological and personnel safety of the operation, it is the Air Force's intention to insure that all appropriate action is taken to minimize the emission of herbicide vapors and, therefore, minimize any possible impact upon personnel or the environment. Also, the controversial situation which has surrounded the use of Orange herbicide ("The Effects of Herbicides in South Vietnam, Part A," National Academy of Sciences, 1974) dictates that any herbicide exposure to personnel or herbicide loss to the environment should be minimized. The action to accomplish this at NCBC Gulfport will consist of protective clothing, mechanical ventilation, and where required the use of cartridge type respirator protective devices. Concerning the latter, Orange herbicide has a very strong, persistent phenol-like odor that is present below the TLV and which can be very disagreeable to personnel. At Johnston Island the precautions will be similar; however, ventilation will not be required because the natural ventilation will be adequate and the environmental impact of vapors from the transfer operation will not be significant. At both locations, a monitoring program will be conducted to document herbicide exposures and environmental effects should they occur. It is anticipated that this program will generate sufficient data to demonstrate the personnel and environmental safety of this operation. For the principal alternative, the NCBC Gulfport bulk transfer operation will not be required and the Johnston Island operation will be expanded. However, under the principal alternative, the drum rate would probably be lowered to about 200 drums per day (Part II.C.3.) as opposed to the 1,000 drums per day required under the proposed action.

c. The drum experiment at NCBC Gulfport revealed that about 1.5 pounds of herbicide remains in a well drained drum. This quantity when carried as a film on "scrap drum metal" into the furnaces associated with steel manufacturing is of negligible environmental significance. However, to eliminate any potential for adverse environmental impact during the shipment and storage period between drum drainage and placement of the scrap metal into a furnace, action will be taken to reduce the quantity of residual Orange in the drums. At NCBC, the drums will be drained and rinsed with solvent; the solvent will be allowed to drain, and the drums will be crushed for storage and subsequent disposal. At Johnston Island, the drums will be drained and then allowed to weather, i.e. be exposed to the environment, after which they will be crushed for storage and subsequent disposal. This action, solvent rinse and weathering, while of questionable necessity as regards environmental impact is being accomplished in keeping with the overall intent of minimizing the potential for adverse environmental impact from the disposal project. Details of the drum draining/cleaning procedures, transfer operation, and recycling of the drums are presented in the following paragraphs of this section.

2. HERBICIDE RESIDUAL IN DRAINED DRUMS

a. General: Data obtained during the incineration project at the Marquardt Co. (Appendix E) and the Orange herbicide drum draining experiment conducted at NCBC have indicated that about 1.0 and 1.5 pounds of herbicide, respectively, remains in a well-drained drum. Most of this residual was removed effectively from the drum by rinsing with a solvent - about 83 per cent removal after 3 rinses of JP-4 (Marquardt Study) and greater than 97 per cent removal after 4 rinses with diesel fuel (Gulfport Study). The diesel fuel appeared to be a more effective solvent for the Orange than did the JP-4. Rinse schemes involving various volumes of fresh rinse solvent and different numbers of rinses were investigated and it was found that the initial solvent rinse was responsible for practically all of the Orange which was removed by the rinsing process. It was also found during the Gulfport test that weathering, i.e. allowing the drained drums to remain exposed to the environment, could reduce the Orange residual in the drums markedly. The drums which were deheaded, drained, and weathered for 14 days prior to the rinse protocol had about 0.32 pounds of herbicide remaining and similarly drained and weathered notched drums averaged about 0.66 pounds of herbicide remaining. It was concluded that the Orange residual in the notched drum was removed more slowly by weathering than such residual in deheaded drums. A comparison of draining efficiency between drums which were opened by being "deheaded" or "notched" revealed no significant differences and it was concluded that either method was acceptable. The notched drums actually contained slightly less herbicide than the deheaded drums as revealed by the rinse analyses. The deheaded drums were drained in an essentially vertical position and the notched drums were drained at about a 30° angle. The drum draining experiments are described below.

b. The Marquardt Company - Drum Draining: During the test burn conducted at the Marquardt Co., the 28 drums involved were drained and triple rinsed with various quantities of JP-4. Samples of each rinse were collected and analyzed for 2,4,D and 2,4,5-T esters. The quantity of Orange in each rinse was back calculated and extrapolated to determine the quantity of Orange remaining in a drained drum. The data analysis and discussion of these experiments are contained in the Marquardt Co. Final Report in (Appendix E). Less than two quarts of Orange remained in the drums after initial emptying and some of the emptied drums had been sitting in a vertical position for 20 - 25 days when the draining was started. Each drum was upended and allowed to free board drain through the bung; the draining was continued until the steady dripping stopped. The drain time ranged from 6 to 9 minutes and the air temperature during the drum draining was 60°F. The data analyses revealed that approximately one pound of herbicide remains in a drum after drainage under the above conditions. In addition, a single rinse with five gallons of JP-4 removed about 75% of the herbicide from the drum. The second and third rinse (5 gal) increased the removal efficiency to approximately 79% and 83% respectively. The rinses were accomplished by adding the required JP-4, replacing the cap, and rotating the drum on a drum rolling device for five minutes.

c. NCBC, Gulfport Drum Draining: On 10 and 11 September 1974, tests were conducted on 16 Orange herbicide drums at NCBC Gulfport MS. The purpose of these tests was to determine the quantity of Orange remaining immediately after draining for a specified time. In preparation for the tests all but

3 to 9 gallons of herbicide was removed from the drums. These drums remained in a vertical position until the draining test; however, just prior to starting the drain experiment on a given drum, that drum was rotated on a drum spinning device to coat the interior of the drum with herbicide to simulate realistic drum draining conditions. The drums were opened by a manual "notcher" device or deheaded with an electric device. The notcher device leaves a hole in the head of a drum which is similar to the hole left by an opener/spout for one quart cans of motor oil. Unlike a typical can opener which removes only the lid, the deheading device cuts off both the head and the associated "lip". Upon opening, the deheaded drums were drained in a vertical position and the notched drums at a 30° angle for from 10 - 18 minutes. The volume of herbicide dripping from the drum after 5 minutes of draining was caught and measured volumetrically until the diesel fuel rinse was accomplished. A representative portion of the diesel fuel rinse was collected and subsequently analyzed and the quantity of Orange in the drum back calculated. In addition to the immediate rinse test, some drums were stored for two weeks after drainage and then rinsed so that the effect of evaporation could be evaluated. This action was taken because inspections of the empty drum storage area (drums which contained Orange but were drained because they were leaking) at Johnston Island have revealed that this area does not have a strong odor of Orange and that the individual drums appeared relatively clean and dry. It is felt that evaporation of Orange from the drums is responsible for significantly reducing the Orange content of an empty drum. At Johnston Island, the drums could be allowed to weather after a complete draining, thus providing for additional reduction of the Orange remaining in a drum. The Gulfport data although somewhat variable was sufficient so that valid conclusions could be reached on the Orange remaining in an unrinsed drum and on the efficacy of solvent rinsing. The Gulfport data is most important to actual plans for drum handling and the appropriate findings were stated in paragraph 2(a) above.

3. HERBICIDE DEDRUM AND TRANSFER TO INCINERATOR VESSEL

a. Gulfport MS: Under the proposed action, incineration at sea, the 863,000 gallons (15,700 drums) of Orange presently stored at NCBC Gulfport will be bulk loaded aboard the incinerator ship at the Port of Gulfport. A dedrum facility will be established at the NCBC and the bulk Orange will be transported via railroad tank car to the pier for loading aboard the ship. The dedrum facility will include a drum deheading and pumping station drainage racks, a solvent spray rinse station and a collection sump. Aircraft refuelers will be used to transfer the Orange from the collection sumps to railroad tank cars. The tank cars will be conveyed once per day during daylight hours to the pier where the Orange will be pumped aboard the incinerator ship. The facility will be designed and operated to dedrum and load 1,000 drums of Orange per day for a total of 16 days. The deheaded drums will be drained in a vertical position for at least 5 minutes, rinsed with high pressure solvent spray (~2 gal.), drained for 2 minutes and then crushed. The spray rinse solvent will be collected with the herbicide and loaded onto the incinerator vessel. All transfer areas including the pier area will be protected to insure that any spillage of material is contained. Strict industrial hygiene measures will be adhered to throughout the operation. As stated in the introduction, the public and scientific controversy associated with Orange necessitates the maximum possible precautions and the documentation of environmental factors during the transfer operation. Appropriate safety clothing/equipment will be used in all operations. Local exhaust ventilation for the drum draining area will discharge

through activated carbon which will absorb odors and further minimize the chance of damage to nearby flora. Ambient air samplers will be utilized to document conditions throughout the operation. The normal flora of the area will be continuously observed and its condition documented, and biomonitoring with selected plants will also be accomplished. All equipment and the railroad tank cars will be flushed with solvent at the completion of the transfer operation, and the flushings will be loaded aboard the incinerator ship for incineration along with the Orange. The Naval Ordnance Station, Indian Head, MD is responsible for the engineering design and installation of the transfer system and will oversee the actual transfer operation.

b. Johnston Island: The 1.4 million gallons (25,000 drums) of orange presently stored at Johnston Island will be bulk loaded aboard the incinerator ship at Johnston Island. Two loadings to the ship will be required. The dedrums and ship loading rate will be 1,000 drums per day; approximately 13 days will be required for each load. A dedrum facility will be established at the storage area on Johnston Island. The dedrum facility will include a drum drainage rack where the drums will be opened with a notching device for herbicide drainage into a collection sump. The Orange will be pumped from the sump to the aircraft refuelers which will then transport the Orange to the pier where the Orange will be pumped onto the incinerator ship. To prevent Orange from entering the ocean, the pier transfer area will be configured to contain any spillage. The drums will be drained for at least 30 minutes. They will then be left to weather (at least 1 month) after which they will be crushed and stored for disposal. All equipment and refuelers will be flushed with solvent at the completion of the transfer operation, and the solvent will be loaded onto the ship for incineration with the Orange. Industrial hygiene measures and monitoring will be accomplished similarly to that described above for NCBC Gulfport. The Naval Ordnance Station, Indian Head MD is designing/co-ordination on the design and installation of the transfer and will oversee the transfer operation.

4. ULTIMATE DRUM DISPOSAL:

a. The drums generated by accomplishment of either the proposed action, incineration at sea, or the principal alternative of incineration at Johnston Island will be disposed of by recycle as "scrap" metal into steel manufacturing. Disposal as scrap is considered more favorable from the long term environmental standpoint than disposal of unrinsed drums in a landfill because the Orange and its components would be rapidly destroyed in the steel making process. As the scrap drum metal is reprocessed into new steel, it would be subjected to high temperatures (~2900°F) for an extended period of time (~6 hours). This exposure is much more severe than that which would be received if the non-combustible drums were subjected to incineration in a pesticide incinerator (2000°F, 2 sec) as defined by EPA in 39FR85. Recycle into steel not only conserves the drum metal but also raw materials for steel making are conserved. The utilization of one ton of scrap steel in the steel making process conserves about 4 tons of iron ore, coal, and limestone. Therefore the recycle of 45,000 - 50 pound drums as scrap will conserve approximately 4,500 tons of raw material. This method of ultimate disposal will also preclude the return of any Orange herbicide drums to manufacturers, formulators, or drum reconditioners for reuse.

b. It has never been the Air Force's intention that the Orange herbicide

drums be reconditioned for reuse. Beside the negative public relations aspect of reuse, the solvent requirements to affect a triple rinse as recommended by the EPA prior the reuse of containers (39FR85), concomitant complication and the expansion of the disposal project associated with such rinsing operations is not desirable. The solvent volume of 660,000 gallons for rinsing represents greater than one fourth the volume of the total Orange herbicide stock. Since this solvent would require incineration along with the herbicide the incineration phase of the project would be greatly expanded. The logistics of supply and handling of the solvent, including the drum rinse operation, would complicate the industrial management of the project. The frequency of handling and the tremendous quantity solvent involved would increase the possibilities of a fire hazard and spillage of Orange contaminated solvent. In addition, the use of a large quantity of a petroleum solvent during a period of energy conservation is not a prudent action if it can be safely avoided. In this regard, the rinsing operation at Gulfport may be altered to minimize solvent use i.e. recycle, if appropriate.

5. POTENTIAL FOR ENVIRONMENTAL IMPACT

a. Although the procedures described above will be accomplished to minimize the potential for any environmental impact as a result of the herbicide transfer and drum disposal aspects of this project, it is necessary to consider the following situations:

(1) The Orange residual remaining on the crushed drums which are put into the steel manufacturing process;

(2) The Orange residual which remains on the drums while the drums are in storage and or being transported to the steel manufacturing site;

(3) The operations at Gulfport and Johnston Island to reduce the Orange residual in drained drums.

b. For the drums at Gulfport, it is anticipated that the pressure solvent rinse will remove greater than 90 percent of the Orange which remains after draining, thus a crushed drum may contain a residual of about 0.15 pound of herbicide. The first rinse of deheaded drums at Gulfport removed greater than 92 percent of the herbicide which was removed by the subsequent rinses. The third and fourth rinses removed almost negligible amounts of herbicide; therefore, the quantity removed in four rinses can be considered as being just slightly less than the actual Orange residual in a drum. Since the Orange residual after draining is a film on the interior drum surface it is anticipated that a pressure spray will be even more effective than simple addition of solvent with gentle mixing.

c. At Johnston Island, the drums will be weathered for 30 days to allow for evaporation of a portion of the residual which remains after draining. It is anticipated that 30 days weathering at Johnston Island can reduce the residual in the drums to about 0.3 pound of herbicide. As indicated in paragraph 3.b. above the drums will be crushed after weathering for subsequent disposal as "scrap" for recycle in steel manufacturing.

6. ENVIRONMENTAL IMPACT

a. The environmental impact associated with the placement of crushed drums containing a film of Orange of 0.15 to 0.3 pounds into a steel making furnace is not significant. During the process the Orange would be converted to essentially hydrogen chloride, carbon dioxide, and water. The air pollution

control equipment normally associated with steel making operations would be sufficient to minimize any environmental impact of the combustion products.

b. The environmental impact associated with the storage and transport of crushed drums which contain a residual of 0.15 to 0.3 pounds of herbicide is not significant. Since the herbicide is a film on the inner surface of the crushed drums, any evaporation would be retarded. The herbicide is not water soluble nor is it easily translocated by water, thus it would also tend to remain in the drums even if subjected to rainfall.

c. The environmental impact associated with the solvent cleaning crushing, and storage of drums at NCBC Gulfport will not be significant. The solvent spray will rapidly reduce the Orange residual in the drum and the Orange removed will be contained within the solvent. The drums will be crushed after drainage of the solvent spray. The crushing of the drums will reduce the opportunity of any residual herbicide from entering the environment while the crushed drums await shipment to a steel manufacturing plant. It should be emphasized that the solvent spray cleaning process at Gulfport is being accomplished to minimize any environmental impact associated with the storage of drums at Gulfport and is not to be confused with the triple rinse recommended before reuse of pesticide containers. The use of "weathering" of the drums at Gulfport was considered as a means of reducing the Orange residual to an acceptable level for subsequent storage and transportation of the drums. A subjective evaluation of this method revealed that while a portion of the drums may be safely weathered, it was not environmentally prudent to weather the entire stock (15,700 drums) at NCBC; therefore the use of the solvent spray to minimize the potential for environmental impact is justified.

d. The environmental impact associated with weathering of drums on Johnston Island is not significant. The storage area is located such that the prevailing winds would carry any Orange vapor immediately off shore and away from the island. About 5,000 drums which were emptied and drained as part of the regular maintenance of the Orange storage area have in fact weathered at Johnston Island with no noticeable environmental impact.

F. CHARACTERISTICS OF THE HERBICIDE

1. PROCUREMENT SPECIFICATIONS:

a. The USAF procured Orange under Purchase Description AFPID 6840-1, dated 23 February 1968, and Amendment 1, dated 11 April 1968. The Orange Purchase Description containing the changes and additions of Amendment 1 is quoted below:

1. SCOPE

This purchase description prescribes requirements for an herbicide identified as Orange. The material is used as a systemic growth regulator to kill and defoliate vegetation.

2. APPLICABLE DOCUMENTS

PPP-D-729, Drums: Metal 55-gallon, for shipment of noncorrosive material.

MIL-H-51148, Herbicide N-Butyl 2,4,5 Trichlorophenoxyacetate.

MIL-H-51147, Herbicide N-Butyl 2,4 Dichlorophenoxyacetate.

MIL-STD-105, Sampling Procedures and Tables for Inspection of Attributes.

MIL-I-45208, Inspection System Requirements.

3. REQUIREMENTS

3.1 Materials. The herbicide shall be composed of the following two ingredient materials.

a. N-Butyl 2,4,5 Trichlorophenoxyacetate.

b. N-Butyl 2,4 Dichlorophenoxyacetate.

3.1.1 The ingredient materials shall meet the following requirements:

a. Specification MIL-H-51148, N-Butyl 2,4,5 Trichlorophenoxyacetate, except free acid will be .5% maximum by weight.*

*Changed per Amendment 1

b. Specification MIL-H-51147, N-Butyl 2,4 Dichlorophenoxyacetate except composition (purity) shall be 98.0% minimum by weight, acid equivalent shall not be less than 79.0% nor more than 8.0% and free acid shall be .5% maximum by weight.**

3.2 Finished Mixture (Orange).

3.2.1 Composition.

50% by volume N-Butyl 2,4,5 Trichloro-phenoxyacetate

50% by volume N-Butyl 2,4 Dichlorophenoxy-acetate

3.2.1.1 Tolerance. Tolerance range for amount of each composition ingredient contained in the final mix will be $\pm 1.5\%$ including the precision allowance for the analytical method used.

a. Range for N-Butyl 2,4,5 Trichloro-phenoxyacetate is 48.5 to 51.5% by volume

b. Range for N-Butyl 2,4 Dichlorophenoxy-acetate is 48.5 to 51.5% by volume.

3.2.2 Free Acid. A maximum of 0.5% by weight.

3.2.3 Total Acid Equivalent (as 2,4-D Acid).

90.0% minimum by weight.

94.0% maximum by weight.

3.2.4 Specific Gravity.

1.275 to 1.295 at 20^o/20^oC.

3.2.5 Color. A Clear reddish brown color.

3.2.6 Weight per Gallon - 10.70 \pm 0.08 lbs at 20^oC (55 gallons will weigh 584.10 to 592.90 lbs on a 20^oC basis).*

4. QUALITY ASSURANCE PROVISIONS

4.1 Test Methods.

*Changed per Amendment 1

**Added per Amendment 1

4.1.1 Composition. Determined by infrared spectrophotometer - Beckman IR-4 or equivalent. An official standard will be used to calibrate the spectrophotometer made up a known 50/50% by volume mixture of the 2,4-D and 2,4,5-T normal butyl esters. This standard for calibration and quality analysis work may be obtained from the government. Request for standards should be forwarded to:

Defense Supply Agency
Defense General Supply Center
Directorate of Procurement and Production
Richmond, Virginia 23219

The infrared analysis method is attached to this purchase description.

4.1.2 Free Acid. A sample is dissolved in 91% isopropyl alcohol and titrated potentiometrically with standard alkali solution to a pH of 4.5.

a. Apparatus.

(1) pH meter equipped with glass - calomel electrodes.

(2) Stirrer.

b. Reagents.

(1) Alcohol, isopropyl, 91% neutral. Use commercial 91% isopropyl alcohol or mix 920 ml of 99% isopropyl alcohol and 80 ml of distilled water.

(2) Sodium hydroxide solution, 0.1 N accurately standardized against potassium acid phthalate.

(3) Buffer solutions for checking pH meter, pH 7.

c. Procedure.

(1) With a graduate or automatic pipet measure 100 ml of 91% isopropyl alcohol into a 250 ml beaker. Weigh 10 grams of sample into the alcohol. Turn on the stirrer and mix the solution.

(2) Insert the electrodes of the pH meter and measure the pH of the solution. Titrate with 0.1 N NaOH solution to pH 4.5 and record the volume of titrant. If the initial pH is about pH 4.5, conclude that the herbicide is free of acid.

d. Calculation.

Calculate the percent free acid using the formula -

$$A = \frac{F \times V \times N}{W}$$

A = percent free acid

F = molecular weight of acid $\times \frac{100}{1000}$

V = milliliters of 0.1 N sodium hydroxide

N = normality of sodium hydroxide used

W = weight of sample in grams

4.1.3 Total Acid Equivalent.

a. Ingredient Specifications MIL-H-51148 and MIL-H-51147. The saponification back titration method or the biphenyl reagent with chloride titration method will be used to determine total acid equivalent.

b. The final Orange mix. Determine total acid equivalent using the biphenyl reagent - chloride titration methods.

4.1.4 Specific Gravity. Determine by hydrometer or other method accurate to three significant figures.

4.1.5 Color. Visual observation of a 10 ml sample in a 16 mm x 125 mm glass test tube.

4.1.6 Weight per Gallon. Specific gravity calculation or other appropriate weight measurement.

4.2 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. The government reserves the right to perform any of the inspections set forth in the purchase description where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.3 Contractor Inspection System Requirements. Specification MIL-I-45208 applies.

4.4 Sampling for Test. Sampling shall be conducted in accordance with MIL-STD-105.

4.5 Acceptance.* Acceptance of the final Orange mixture will be based on test results for conformance to requirements of paragraph 3.2. Test results for conformance to requirements of paragraph 3.1 will be reported.

5. PREPARATION FOR DELIVERY

Packing and marking requirements shall be specified by the procuring agency.

6. NOTES

6.1 This AFPID replaces AFPID 6840-1 dated 7 Nov 1967.

6.2 The ingredient material requirements contained herein (para 3.1.1) are based on Specification MIL-H-51147A (MU) and MIL-H-51148A (MU) dated 7 Nov 1966.

b. The USAF procured Orange II under a separate Purchase Description which was unnumbered, undated and is quoted below:

1. Orange II shall be composed of:

a. 50 percent by volume N-Butyl 2,4 Dichlorophenoxyacetate conforming to MIL-H-51147A (MU) dated 7 Nov 1966 except acid purity shall be 99.0 percent minimum by weight and acid equivalent shall not be less than 79.9 percent nor more than 80.0 percent by weight, and free acid maximum 0.5 percent.

b. 50 percent by volume of Isooctyl 2,4,5 Trichlorophenoxyacetate conforming to MTL-H-60724 (MU) dated 1 May 1967, except free acid maximum 0.5 percent.

2. The final herbicide mixture shall meet the following requirements:

a. Specific gravity - 1.220 to 1.242 at 20°C.

*Added per Amendment 1

- b. Free acid maximum - 0.5 percent by weight.
- c. Weight per gallon - 10.6 to 10.34 per gallon at 20°C.

2. CHEMICAL AND PHYSICAL PROPERTIES: All available reference data on the general properties of Orange herbicide are summarized and presented in Table II-1 and 2. General properties of TCDD are presented in Table II-3; the statistical analyses for the TCDD content in the Orange herbicide stocks is discussed in paragraph 3. below. The following references were used in preparation of these tables: USAF EHL(K) a, 1973; U.S. Army, 1969; USAF RPL, 1972 (Dept. Agr.); USDA, 1972; USAF EHL(K) b, 1973.

3. STATISTICAL ANALYSES OF TCDD CONCENTRATIONS IN ORANGE HERBICIDE STOCKS

a. Sampling from Johnston Island and Gulfport: Two different types of sampling procedures were used to supply samples to the Analytical Laboratory (Dow Chemical Co.). The Orange herbicide at Johnston Island could not be separated into identifiable processing lots. Therefore, two hundred separate samples were collected to represent the entire population of Orange at Johnston Island. It is assumed that these 200 samples were a random, representative sample of the population at Johnston Island. In contrast, the samples taken at Gulfport could be grouped to represent concentrations of TCDD in stocks supplied by certain manufacturers. Generally, six samples were taken to represent each manufacturer's stocks. There were seven major stocks at Gulfport. Specific gravity was assumed to be 1.285.

b. Results of Johnston Island Analyses: At the time that the 200 samples were collected the inventory of Orange stock at Johnston Island was 26,689 fifty-five gallon drums. The arithmetic mean TCDD concentration was found to be 1.909 mg/kg; therefore, the total TCDD in the Orange stock at Johnston Island is estimated to be 13.63 kg. Figure II-1 below demonstrates that the TCDD concentrations in the 200 samples from Johnston Island did not follow a normal distribution. Of the 200 samples, 153 or 76.5% contained TCDD concentrations of 1.0 mg/kg or less. Of the 200 samples, 195 or 97.5% had TCDD concentrations of 10.0 mg/kg or less. Only 5 samples (2.5%) had TCDD concentrations larger than 10.0 mg/kg. These larger values were 13, 17, 22, 33 and 47 mg/kg. None of these values were discarded as "outliers" in computing the arithmetic mean TCDD concentration of 1.909 mg/kg.

c. Results of Gulfport Analyses: Table II-4 is a compilation of the results of the TCDD analyses of the seven major manufacturer's Orange stock at Gulfport. The number of drums was obtained from the inventory at the time of the sampling. The calculations for weighted values were based on the following formula:

$$\text{average statistic} = \frac{\text{sum of each statistic times its weight}}{\text{sum of weighting values}}$$

At Gulfport, the total milligrams of TCDD were 7,265,975.8. The total kilograms of Orange were 4,100,225.7 kg. The average concentration of TCDD was therefore 1.772 mg/kg of Orange.

d. TCDD Content of Total Orange Herbicide Stocks: At the time of sample collection, the total Air Force inventory of Orange herbicide at Gulfport and Johnston Island was 42,015 fifty-five gallon drums or 2.3 million gallons. The weighted average concentration of TCDD is 1.859 mg/kg. Therefore, the total amount of TCDD in the entire Air Force inventory is estimated to be 20.1 kg.

TABLE II-1. GENERAL CHEMICAL/PHYSICAL PROPERTIES OF ORANGE HERBICIDE

Property	Orange	Orange II
BTU Content per Pound ⁽¹⁾	10,017 (s=80)	
Physical State	Liquids at room temperature.	
Color	Clear, reddish brown to straw color.	
Appearance	Dark, rust-colored liquid of oily consistency.	
Solubility	Soluble in diesel fuel and organic solvents. Insoluble in water.	
Freezing Point (°C)	7 to 8	9
Flash Point	146°C (295°F)	Unknown
Specific Gravity @ 25°C	1.275 to 1.295	1.220 - 1.242
Weight (lb/gal) ⁽²⁾		
Total ester	(@20°C) 10.7 (+0.08)	10.2 (+0.09)
Acid equivalent	8.6	7.6
Vapor Pressure (30°C)	~3.6 x 10 ⁻⁴ mm Hg ††	
Viscosity, centipoises @: (2)		
-17.7°C	5,000	unknown
- 6.6°C	940	unknown
0.0°C	390	unknown
10.0°C	134	unknown
23.8°C	43	67
37.7°C	24	27
Viscosity, centipoises @: (3)		
20°C	46	-
30°C	24	-
35°C	18	-
40°C	14	-
45°C	11	-
Theoretical % Weight ⁽⁴⁾		
Carbon	49.11*	52.12†
Chlorine	29.87*	27.27†
Oxygen	16.37*	15.20†
Hydrogen	4.65**	5.41**
Free Acid (by weight)	0.5% maximum	0.5% maximum
Total Acid Equivalent	90.0% minimum	79.9% minimum
(% by weight as 2,4-D)	94.0% maximum	80.0% maximum
Corrosiveness	Noncorrosive on most metals. Deleterious to some paints, natural rubber, and neoprene. Teflon, viton, polyethylene and butyl rubber are resistant.	

*Sample contained 14 ppm TCDD.

†Sample contained 3.7 ppm TCDD.

††Calculated and confirmed by EHL(M).

**Calculated by EHL(K), Kelly AFB TX as (100-%C,Cl,O weight percents).

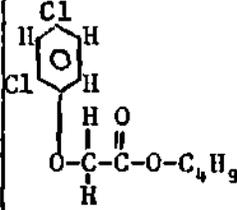
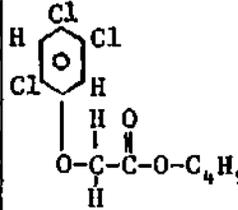
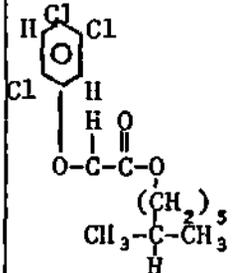
1. USAF EHL(K) a, 1973.

2. U.S. Army, 1969.

3. USAF RPL, 1972 (Dept. Agr.).

4. USDA, 1972.

Table II-2. GENERAL CHEMICAL/PHYSICAL PROPERTIES OF INGREDIENT ESTERS OF ORANGE HERBICIDE

Property	Normal Butyl 2,4-dichloro- phenoxyacetate NB 2,4-D	Normal Butyl 2,4,5-trichloro- phenoxyacetate NB 2,4,5-T	Iso-octyl 2,4,5-trichloro- phenoxyacetate IO 2,4,5-T
Purity (ester by weight)	98.0% minimum	95% minimum	95% minimum
Appearance	Clear,	reddish brown	liquids
Acid Equivalent (by weight)	79.0% minimum	78-82%	66-69.5%
Free Acid (by weight)	0.5% maximum	0.5% maximum	0.5% maximum
Specific Gravity(20°/20°)	1.200 to 1.220	1.316 to 1.340	1.200 to 1.220
Freezing Point (°C)	-21 to -23	29(1,2,3)*	-21 to -23
Molecular Weight	277.15	311.60	367.71
Molecular Elements	C ₁₂ H ₁₄ Cl ₂ O ₃	C ₁₂ H ₁₃ Cl ₃ O ₃	C ₁₆ H ₂₁ Cl ₃ O ₃
Structural Formula			
Theoretical % Weight			
Carbon	57.99(4)*	46.23(4)†	52.24(4)
Chlorine	25.60(4)	34.14(4)†	28.94(4)
Oxygen	17.33(4)	15.41(4)†	13.06(4)
Carbon	52.01**	46.26**	52.26**
Chlorine	25.58**	34.13**	28.93**
Oxygen	17.32**	15.40**	13.05**
Hydrogen	5.09**	4.21**	5.76**
Heat of Formation(3) (cal/mole)	-152,000***	-159,000***	

*Considered by EHL(K) to have been an error in the reference.

†Same value for ester containing 0.1 ppm of 2,3,7,8-tetrachlorodibenzo-p-dioxin ("Dioxin" or TCDD).

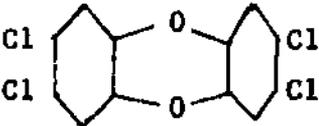
**Calculated by EHL(K), Kelly AFB TX 78241.

***"...estimated by taking the heats of formation of similar compounds and adding/subtracting the heats of formation of similar/dissimilar groups."

3. USAF RPL, 1972.

4. U.S. Dept. Agr., 1972.

TABLE II-3. GENERAL CHEMICAL/PHYSICAL PROPERTIES OF TCDD

Property	Data
Content in Orange or Orange II	Range 0-47 mg/kg. Estimated mean of 1.9 mg/kg with a 95% upper and lower confidence limit of 2.6 and 1.2 mg/kg, respectively. ⁽⁵⁾
Molecular Weight Structural Formula	321.97 
Theoretical % Weight	
Carbon	44.77* 45.41 ⁽⁴⁾
Chlorine	44.04* 44.61 ⁽⁴⁾
Oxygen	9.94* 9.95 ⁽⁴⁾
Hydrogen	1.25*

*Calculated by EHL(K), Kelly AFB TX

- 4. U.S. Dept Agr, 1972.
- 5. USAF EHL(K) b, 1973.

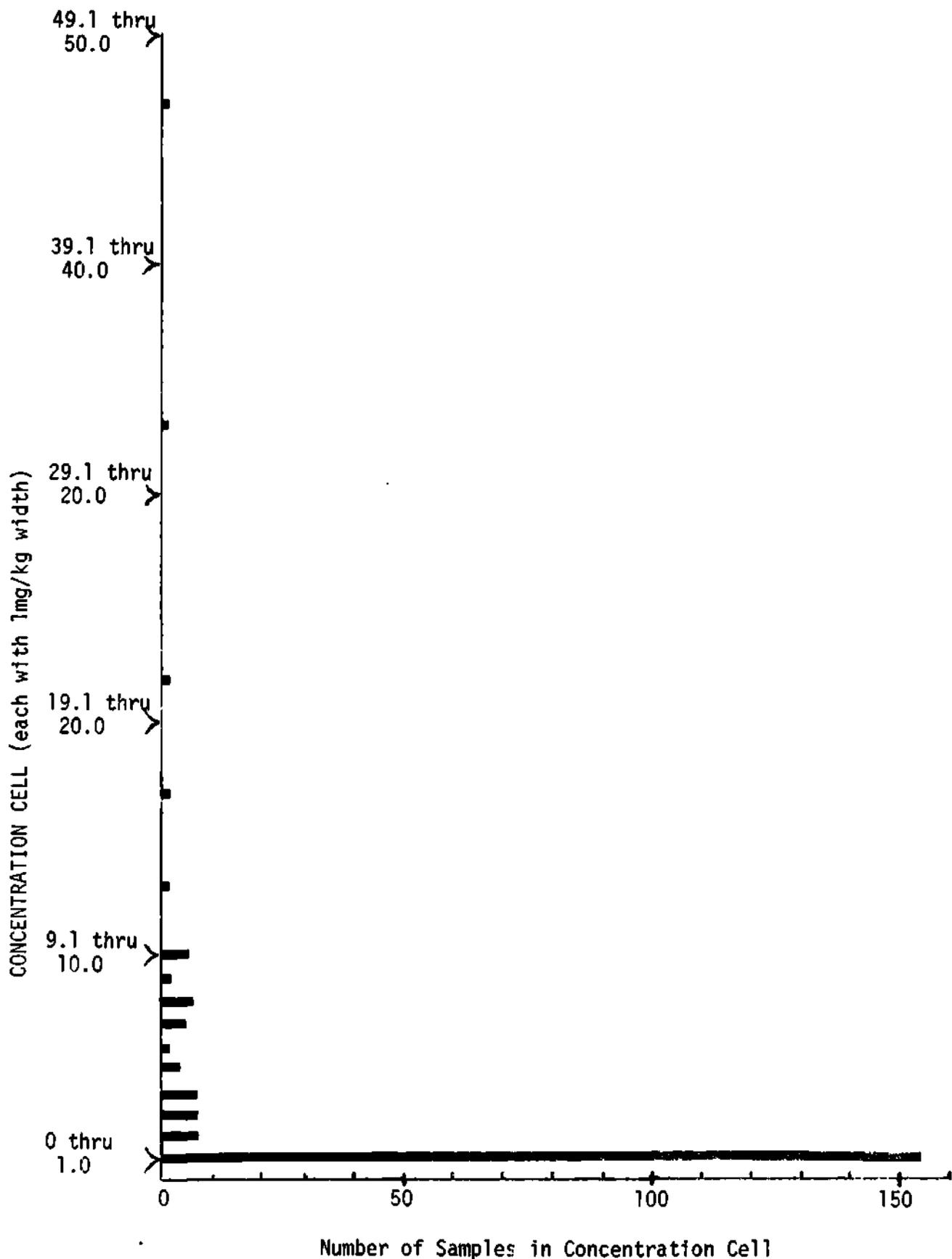


FIGURE II-1. HISTOGRAM REPRESENTATION OF TCDD CONCENTRATIONS MEASURED IN 200 ORANGE HERBICIDE SAMPLES FROM JOHNSTON ISLAND.

TABLE 11-4

TCDD ANALYSES OF MAJOR MANUFACTURER STOCKS - GULFPORT

<u>Number of Drums</u>	<u>Number of Gallons</u>	<u>Kg Orange</u>	<u>Mg/Kg Conc. of TCDD</u>	<u>Mg of TCDD</u>	<u>Cumulative Total Mg of TCDD</u>
2,652	145,860	709,500.1	<0.05	35,475.0	35,475
6,981	383,955	1,867,654.7	0.12	224,118.6	259,593.6
934	51,370	249,876.7	0.17	42,479.0	302,072.6
1,560	85,800	417,353.0	0.32	133,556.9	435,629.5
2,185	120,175	584,561.7	7.62	4,454,360.2	4,889,985.7
984	54,120	263,253.4	8.62	2,269,244.3	7,159,230.0
30	1,650	8,026.0	13.3	106,745.8	7,265,975.8
<hr/>	<hr/>	<hr/>			<hr/>
15,326	842,930.0*	4,100,225.7			7,265,975.8

* Represents 98% of the 860,000 gallons of total Gulfport Stock.

4. TOXICOLOGICAL AND ECOLOGICAL CHARACTERISTICS OF CHLOROPHENOXY HERBICIDES PERTINENT TO POTENTIAL BIOLOGICAL EFFECTS OF N-BUTYL ESTERS OF 2,4-D AND 2,4,5-T: There have been many scientific studies to determine the behavior of chlorophenoxy herbicides in plant and animal systems under varied environmental conditions. The following paragraphs are not meant to list all those studies. Rather, the purpose is to logically describe the known and probable behavior of Orange herbicide components in biological systems by utilizing the most current and relative information obtainable from the literature and from studies at EHL(K). It is important to note at the outset that in biological systems and aquatic systems the N-butyl esters (NBE) of 2,4-D and 2,4,5-T can hydrolyze. Thus, the behavior of the pure acids and their salts are also pertinent and will be discussed in the following paragraphs along with characteristics of ester forms. The differences in toxic effects produced by the various salts, amines and esters of 2,4-D and 2,4,5-T can often be explained on a pharmacokinetic basis in which the concentrations at the receptor sites in the organism depends on the absorption and distribution rates in relation to the rates of metabolism and excretion. The rate of absorption into plants or animals will be dependent upon various inter-related factors such as route of entry and rate of membrane transport. Specific membrane transport rate will depend upon the characteristics of the membrane in relation to the size, shape, polarity and lipid solubility of the particular herbicide molecule being considered in each cited study.

a. Behavior in Terrestrial Animals

(1) Metabolism and Excretion Kinetics: Most of the data derived from acute toxicity studies indicate that neither 2,4-D nor 2,4,5-T are particularly toxic. (Gleason et al., 1969; Bjorklund and Erne, 1966). In the rat, the single dose, LD₅₀ ranges from about 250-270 mg/kg depending on the forms of the chemical administered (Christensen, 1971). Several workers have suggested that part of the reason for this lack of toxicity is that the excretion of the herbicides is very rapid in most mammals (Clark et al., 1964; Khanna and Fang, 1966). Most studies indicate that animals possessing highly developed renal function will rapidly eliminate 2,4-D and 2,4,5-T by active tubular secretion. Cattle and rabbits, which normally actively metabolize compounds mostly by acetylation, excrete 2,4-D and 2,4,5-T in the urine mostly unchanged. Erne, (1966) found that in the rat, rabbit, calf and chicken, 2,4-D and 2,4,5-T had a biological half-life varying from three to twelve hours and that urinary excretion was the most common route of elimination. Data exist to indicate that only very small amounts of 2,4-D are metabolized by the rabbit (Clark et al., 1964; Khanna and Fang, 1966). Berndt and Koschier (1973) studied the in vitro uptake of 2,4-D and 2,4,5-T by the renal cortical tissue of rabbits and rats. Renal cortical slices from both species accumulate 2,4-D and 2,4,5-T with greater uptake occurring in rabbit tissue. Nitrogen and various metabolic inhibitors reduced the uptake thus indicating that both of these organic acid herbicides are transported by the renal organic anion mechanism. Berndt and Koschier (1973) concluded that renal tubular transport by the organic anion mechanism may account for the relatively rapid disappearance of these compounds and this may account for their low toxicity.

(2) Absorption and Distribution: The most common route of accidental absorption of chlorophenoxy herbicide in terrestrial animals is via ingestion. This is especially true in herbivores. However, absorption of toxic doses via inhalation and cutaneous routes is possible, if uncommon. The literature indicates that gastric absorption of 2,4-D and 2,4,5-T and their amines and alkali salts occur readily as would be predicted from classical Henderson-Hasselbalch relationships. However, the gastro-intestinal absorption of 2,4-D in the form of an ester may be incomplete. Erne (1966) administered 2,4-D ester orally and found no detectable esters in the plasma. However, detection of low levels of 2,4-D in the plasma indicated that some hydrolysis of the ester had occurred. Erne (1966) in studies with rats, calves, chickens, and pigs found that the highest tissue levels of 2,4-D and 2,4,5-T were found in liver, kidney, lung and spleen, the levels sometimes exceeding the plasma level. In blood cells, 10-20% of the plasma level was found. Penetration of 2,4-D into adipose tissue and into the central nervous system was restricted, whereas a ready placental transfer was demonstrated in swine. The distribution pattern did not show any significant species or--in rats--sex differences. Klingman *et al.* (1966) measured ppb amounts of 2,4-D in the milk from cows grazing on pasture probably sprayed with esters of 2,4-D. However, these levels dropped to undetectable amounts (< 1 ppb) on the third day after the pasture had been sprayed.

(3) Acute Toxicity: One of the essential prerequisites in the selection of a herbicide for defoliation programs is selective toxicity. Orange herbicide is characterized by a low order of toxicity to man and terrestrial animals. When properly applied, chlorophenoxy herbicides have presented very minimal hazards to animal life in target areas. The acute oral toxicity of Orange herbicide is summarized below. The data are expressed as LD₅₀s in units of mg of chemical per kg of body weight. This is the single oral dose which was lethal for 50% of the test species. Orange herbicide LD₅₀: rat 566, sheep 250 and cattle 250. The oral toxicities of 2,4-D and 2,4,5-T are quite similar to those of Orange herbicide (e.g., the acute oral LD₅₀ of 2,4-D and 2,4,5-T in the rat are 620 and 480 mg/kg, respectively). Tables II-5 and II-6 summarize the results of several acute toxicity studies with various salt, ester and amine forms of 2,4-D and 2,4,5-T.

(4) Chronic Toxicity: Because of the active secretion of chlorophenoxy herbicides, rather large amounts must be administered over a long period of time to produce symptoms of toxicity. Enormous amounts of Orange herbicide were applied to test plots at Eglin AFB without visible toxic effects or development of herbicide residues in the native animals in the test plots (Young, 1973). In one study, (Palmer and Raceleff, 1964) sheep were given 2 gm of the acid daily and sacrificed on the day following the final dose. Residues in the tissues were less than 1 ppm in all tissues and usually less than 0.05 ppm, which was the sensitivity of the analytical method. Mitchell and co-workers (1946) pastured sheep and cattle on treated foliage without harmful effects to the animals. They also fed a lactating cow 5.5 gm of 2,4-D daily for 106 days without producing poisoning. Palmer (1963) found that cattle were not harmed by 112 daily doses (administered 5 days each week) of 5 mg/kg of alkanolamine salt and that 44 daily doses of 200 mg/kg or 20 doses of 250 mg/kg were

TABLE II-5

ACUTE TOXICITY OF 2,4-D DERIVATIVES TO TERRESTRIAL ANIMALS

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>DOSE</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Alkanolamine	Chick	380-765 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Isopropyl ester	Rat	700 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Isopropyl ester	Chicks	1420 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Isopropyl ester	Guinea pig	550 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Butyl ester	Rat	620 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Butyl ester	Guinea pig	848 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Butyl ester	Chicks	2000 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
PGBE	Rat	570 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Acid	Dog	100 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Acid	Chick	541 mg/kg	LD ₅₀	Rowe, <u>et al.</u> (1954)
Triethanclamine	Swine	50 mg/kg	No effect	Bjorklund & Erne (1966)
Triethanclamine	Swine	500 mg/kg	Lethal	Bjorklund & Erne (1966)
butyl ester	Swine	100 mg/kg	No effect	Bjorklund & Erne (1966)
Triethanclamine	Chicken	300 mg/kg	No effect	Bjorklund & Erne (1966)
butyl ester	Rat	620 mg/kg	LD ₅₀	Edson <u>et al.</u> (1964)
Isopropyl ester	Rat	700 mg/kg	LD ₅₀	Hayes, (1963)
Unspecified amine	Mallard duck	2000 mg/kg	LD ₅₀	Tucker & Crabtree (1970)
Acid	Pheasant	472 mg/kg	LD ₅₀	Tucker & Crabtree (1970)
Acid	Mule deer	400-800 mg/kg	LD ₅₀	Tucker & Crabtree (1970)

TABLE II-6

ACUTE TOXICITY OF 2,4,5-T DERIVATIVES TO TERRESTRIAL ANIMALS

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>DOSE</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Acid	Rat	500 mg/kg	LD ₅₀	Rowe & Hymas (1954)
Isopropyl ester	Mice	551 mg/kg	LD ₅₀	Rowe & Hymas (1954)
Butyl ester	Mice	940 mg/kg	LD ₅₀	Rowe & Hymas (1954)
Amyl ester	Rat	750 mg/kg	LD ₅₀	Rowe & Hymas (1954)

required to produce fatal poisoning. Palmer and Radeleff (1964) reported that sheep were given 481 daily doses of 100 mg/kg doses of 2,4-D without producing poisoning. 2,4,5-T has not been investigated as thoroughly as 2,4-D, but the reaction of cattle and sheep to massive doses would indicate that absorption and excretion must follow a similar pattern. A study by Palmer and Radeleff (1964) showed that sheep required 369 doses of 100 mg/kg each to induce intoxication. The above results are summarized in Table II-7.

b. Behavior in Humans: Gehring et al., (1973) studied the effects of 2,4,5-T at a dose level of 5 mg/kg ingested directly or in a slurry of milk. Analytical grade 2,4,5-T having a purity of greater than 99% and containing less than the detectable level 0.05 ppm, of TCDD was used. Complete medical histories, physical and laboratory studies were accomplished before and repeated after the study. It was found that the clearances of 2,4,5-T and the excretion from the body were by first-order rate processes with half-lives of 23.10 and 23.06 hours, respectively. Essentially all of the ingested 2,4,5-T was absorbed into the body and was excreted unchanged in the urine. Following ingestion, 65% of the 2,4,5-T remained in the plasma where 98% was reversibly bound to the plasma proteins. "No untoward effects associated with the ingestion of 5 mg/kg 2,4,5-T were detected in any of the subjects." (Gehring et al., 1973) A metallic taste lasting 1-2 hours following ingestion was reported by most of the subjects. It was also concluded that essentially all of the ingested 2,4,5-T was absorbed and then eliminated unchanged in the urine.

c. Behavior in Aquatic Systems and Aquatic Animals

(1) Metabolism and Distribution

(a) General Comparisons: The behavior of the chlorophenoxy herbicides in non-mammalian aquatic animals is quite different than the behavior described for terrestrial mammals and birds. The herbicides have a greater toxic potential for aquatic animals. First, the route of entry is different in most instances. The aquatic animal absorbs the herbicide which is distributed throughout his total environment (absorption is mainly via gills in fish). Then, the differences in renal function must be considered. Generally, non-mammalian aquatic animals do not have highly developed kidneys. Thus, once the herbicide is in the aquatic animal's body, some metabolic changes must occur in the molecule to make it more polar if it is to be excreted. Toxicity testing is also necessarily different with aquatic animals. Usually, aquatic animals are placed in a concentration of the toxicant to gradually absorb the material at a rate depending on the animal's physiology and the behavior of the toxicant in the particular water conditions. Therefore, the actual dose to each animal is not known in most studies with aquatic animals. In contrast, toxicity studies with terrestrial animals usually allow calculation of a known dose per unit weight of each animal. Thus, toxicities are often reported as "LD_{XX}" (Lethal Dose) for terrestrial animals and "LC_{XX}" (Lethal Concentration) for aquatic animals.

(b) Metabolism in Fish: Donald P. Schultz (Fish-Pesticide Research Laboratory, Bureau of Sport Fisheries and Wildlife, 1973) studied the uptake, distribution, and dissipation of ¹⁴C-label dimethyl amine salt of 2,4-D (DMA-2,4-D). Three species of fish were exposed to 0.5, 1.0 or 2.0 mg/l concentrations of herbicide for up to 84 days exposure period. No mortalities

TABLE II-7*

CHRONIC TOXICITY OF 2,4-D AND 2,4,5-T DERIVATIVES TO TERRESTRIAL ANIMALS

Chronic Toxicity of 2,4-D

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>DOSE</u>	<u>DURATION</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Triethanolamine	Swine	50/mg/kg/day	3 doses	None	Bjorklund & Erne (1966)
Triethanolamine	Swine	50/mg/kg/day	8-10 doses	Minor transient effects	Bjorklund & Erne (1966)
Butyl ester	Swine	50/mg/kg/day	<5 doses	None	Bjorklund & Erne (1966)
Triethanolamine	Swine	500 ppm in feed.	1 month	Some locomotory disturbance, depressed growth rate, no gross pathology	Bjorklund & Erne (1966)
Triethanolamine	Rats	1000 ppm in water	10 mos.	Depressed growth rate, no gross pathology	Bjorklund & Erne (1966)
Triethanolamine	Chicken	1000 ppm in water	Daily from hatching through first 2 mos. of egg production	Egg size normal, production reduced 30%	Bjorklund & Erne (1966)
Alkanolamine	Sheep	100/mg/kg/day	481 days	No effect	Palmer & Radeleff (1964)
Alkanolamine	Cattle	50/mg/kg/day	112 days	No effect	Palmer & Radeleff (1964)
PGBE ester	Sheep	100/mg/kg/day	481 days	No effect	Palmer & Radeleff (1964)
Ethylhexyl ester	Cattle	250/mg/kg/day	14 days	Ill in 3 days, survive & recover from 9 doses. 14 doses lethal.	Hunt, et al. (1970)
Ethylhexyl ester	Sheep	250/mg/kg/day	17 days	Ill in 3 days, 17 doses lethal	Hunt, et al. (1970)

TABLE II-7 (Continued). "Chronic Toxicity"

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>DOSE</u>	<u>DURATION</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Ethylhexyl ester	Sheep & Cattle	100/mg/kg/day	10 days	None to minor effects	Hunt, <i>et al.</i> (1970)
Not specified	Dog	500 ppm in feed	2 years	None	House <i>et al.</i> (1967)
Not specified	Rat	1250 ppm in feed	2 years	No effects on growth, survival hermatology or tumor incidence	House, <i>et al.</i> (1967)
Not specified	Rat	500 ppm in feed	2 years	No effects in reproduction studies	House, <i>et al.</i> (1967)
Alkanolamine	Chicken	100 mg/kg/day	10 days	No effect on weight gain	Palmer & Radeleff (1969)
PGBE ester	Chicken	50 mg/kg/day	10 days	No effect on weight gain	Palmer & Radeleff (1969)
PGBE ester	Cattle	100 mg/kg/day	10 days	No effect	Palmer & Radeleff (1969)
Acid	Mule deer	80 and 240 mg/kg/day	30 days	Minor symptoms no weight loss	Tucker and Crabtree (1970)

Chronic Toxicity of 2,4,5-T

<u>FORMULATION</u>	<u>ORGANISM</u>	<u>DOSE</u>	<u>DURATION</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Not specified	Dog	10 mg/kg/day	5 days per wk. for 90 days	Minor weight loss, no other effects	Drill & Hiratzka (1953)
Not specified	Dog	20 mg/kg/day	5 days per wk. for 90 days	Lethal between 11 and 75 days	Drill & Hiratzka (1953)
PGBE ester	Cattle	100 mg/kg/day	10 days	None	Palmer & Radeleff (1969)
PGBE ester	Sheep	50 mg/kg/day	10 days	None	Palmer & Radeleff (1969)

TABLE II-7 (Continued). "Chronic Toxicity of 2,4,5-T"

<u>FORMULATION</u>	<u>ORGANISM</u>	<u>DOSE</u>	<u>DURATION</u>	<u>EFFECT</u>	<u>REFERENCE</u>
PGBE ester	Sheep	100 mg/kg/day	369 days	(dosed by capsule) Ill at 367 doses, lethal at 369	Palmer & Radeleff (1969)
PGBE ester	Chicken	100 mg/kg/day	10 days	No effect on weight gain	Palmer & Radeleff (1969)
Triethylamine	Sheep	100 mg/kg/day	481 days	No effect	Palmer & Radeleff (1964)
Not specified	Mice	21 mg/kg/day 600 ppm in diet.	4 weeks 18 months	No mortality	Innes, et al. (1969)

* From Oregon E.I.S. (EIS-OR, 1973)

occurred, nor were adverse biological effects observed at these exposure levels. The highest radioactive residue found in muscle tissue occurred in Bluegills exposed to 2.0 mg/l for 84 days (1.065 mg/kg). However, gas-liquid chromatography indicated that over 90% of the radioactive residues consisted of metabolites of 2,4-D. The major metabolite in the fish was found to be 2,4-D glucuronic acid conjugate. Current investigations have found at least six metabolites of 2,4-D in fish. Thus, in contrast to many of the organochlorine pesticides which undergo biomagnification through the food chain, DMA-2,4-D is metabolized in fish without accumulation of the parent compound.

(2) Behavior in Aquatic Systems

(a) Solubility Limits and Rates Vs. Hydrolysis Rates: The esters of 2,4-D or 2,4,5-T found in Orange herbicide have a very limited solubility in water. Because of this very low solubility, the actual concentrations of esters produced in a body of water by accidental contamination would likely be much less than the "expected value" calculated from the volumes involved. The USAF EHL(K) is in the process of studying the behavior of Orange herbicide in aquatic systems especially sea water. In one study using artificial sea water*, Orange herbicide was mixed into the water in an amount equal to 150 mg/l. Had all components gone right into solution, by computation, ester concentrations would have been 64 mg/l (2,4-D NBE) and 61 mg/l (2,4,5-T NBE). The actual, measured concentrations were 2 mg/l (2,4-D NBE) and 1.8 mg/l (2,4,5-T NBE) immediately after mixing. These increased to 18 and 22 mg/l of 2,4-D NBE and 2,4,5-T NBE, respectively, at 24 hours and then started a rapid decline to 7.5 and 9.5 mg/l at 48 hours after mixing. The rate of disappearance of the ester of 2,4-D was fairly rapid and was assumed to be mainly a result of hydrolysis. The half-life of the ester was 15 hours. The addition of natural biota such as bacteria, algae and fish would be expected to produce an even faster disappearance of 2,4-D NBE. Evidence that this occurs was observed in studies EHL(K) is conducting with marine animals at the National Marine Fisheries Laboratory in Port Aransas, Texas. In one of these studies, shrimp were exposed in five different concentrations of 2,4-D NBE and natural sea water. The average half-life of the ester in the five concentrations was 5 hours. This was 1/3 of the half-life observed in the situation where no biological systems existed.

(b) Circulation of Water in Relation to Availability of Herbicide for Absorption: Some of the toxicity studies completed so far indicate the complexity of trying to predict the ecological results of a planned or accidental contamination of a body of water with phenoxy herbicides. At EHL(K), Orange herbicide was mixed in a fish tank at a concentration that would theoretically produce a 200 ppm_{v/v} concentration if such a high concentration were possible. Most of the herbicide rapidly sank to the bottom of the tank after mixing. Fathead minnows placed in the tank showed no ill effects during two weeks of exposure. Yet in a toxicity study under the same conditions but with continuous agitation of the water by aeration, all of the fish died in a "20 ppm concentration" of Orange herbicide water in 24 hours. Subsequent studies revealed that some circulation of the

*Instant Ocean Aquarium Systems, Inc., East Lake, Ohio

water was essential if a dose-related response was to be established in toxicity studies with the N-butyl esters of 2,4-D and 2,4,5-T. Thus, the actual effect seen in nature might well depend on a factor such as the degree of mixing in the affected body of water.

(c) Importance of Hydrolysis: It is important that when the esters of 2,4-D and 2,4,5-T hydrolyze, their toxicity to aquatic animals is decreased by almost a factor of 10 (paragraph (3)(b) below). In the static situation described in the paragraph above (no aeration), the rate of hydrolysis was probably faster than the rate that the ester went into solution so that lethal concentrations were never attained. Toxicity studies with freshwater and saltwater animals at EHL(K) have been the so-called "Static Bioassay" in which no attempt is made to maintain a constant concentration of the herbicide ester in each test chamber. "Concentrations" are theoretical and based on volumes of herbicide and water mixed together rather than from analysis of water to quantitate the herbicide. Most studies reported from literature are of the same type. The toxicity tests at EHL(K) revealed that in both freshwater and saltwater, most of the test organisms had responded at twelve hours of exposure. There was rarely any increase in mortality past 24 hours.

(d) Other Factors Affecting Actual Concentration: Many other factors can influence the concentration of N-butyl esters of 2,4-D and 2,4,5-T in a body of water. In studies where large amounts of Orange herbicide were placed in water, the globules of the herbicide appeared to become coated with an opaque material that may have inhibited the ester from going into solution. Cope (1970) treated ponds with 0.5 ppm to 10 ppm propylene glycol butyl ether ester (PGBE) of 2,4-D. He was able to measure residues of herbicide absorbed or adsorbed in vegetation and bottom sediment for 6 weeks after treatment in the 10 ppm treated pond. Crosby (1966) reported that 2,4-D decomposes rapidly in the presence of water and ultraviolet light.

(3) Toxicity

(a) Factors Affecting Toxicity: The toxicity of the chlorophenoxy herbicides to aquatic animals varies considerably with many factors such as water chemistry variables, temperature, and the particular salt, ester or amine form of the herbicide considered. Species susceptibility varies greatly. For example, the 96-hour TL_{50} * for fathead minnows exposed to DMA-2,4-D was found to be 335 mg/l. Yet, for bluegills and channel catfish the TL_{50} values were 177 and 193 respectively. A temperature increase from 17°C to 20°C increased the relative toxicity to the catfish from a TL_{50} of 193 mg/l to 125 mg/l (Schultz, 1973).

(b) Toxicity Comparisons by EHL(K): The USAF EHL(K) (1974), performed static toxicity studies with Orange herbicide. Also, toxicity studies were performed using each individual N-butyl ester of 2,4-D and 2,4,5-T. Freshwater bioassays using the fathead minnow (*Pimephales promelas*) resulted in a 48 hr LC_{50} of 3.4 ppm for Orange herbicide containing 14 ppm TCDD. The 48 hr LC_{50} s for esters of 2,4-D and 2,4,5-T were 2.8 ppm and 5 ppm respectively. The 48 hr LC_{50} for 2,4-D in the minnows was 270 ppm. The 2,4,5-T 48 hr LC_{50} concentration was 333 ppm. Note that the toxicity of ester formulations were considerably more toxic than the respective acid. Also, EHL(K) found the N-butyl ester of 2,4-D to be more toxic than the N-butyl ester of 2,4,5-T.

*See page 47 for explanation of TD and LC

In salt water studies by EHL(K), the 48 hr LC₅₀ values in the shrimp (*Penaeus* sp.) were 5.6 ppm for 2,4-D NBE and 33 ppm for 2,4,5-T NBE. Oysters (*Crassostrea virginica*) were exposed to "potential concentrations" of 2,4-D NBE ranging from 0.5 ppm to 85 ppm. The only acute effect observed was the death of one of the oyster (10%) in the highest concentration at 48 hours.

(c) Other Animals and Other Effects: Many other aquatic animals besides fish can be affected by phenoxy herbicides. Saunders (1971) studied the effects of the propylene glycol butyl ether ester (PGBE) of 2,4-D on six freshwater crustaceans. He found the following 48 hr TL₅₀ values: *Daphnia magna* = 0.10 ppm, seed shrimp = 0.32 ppm, scud = 2.6 ppm, sowbug = 2.2 ppm, glass shrimp = 2.7 ppm, and crayfish had an unknown value larger than 100 ppm. Cope (1970) studied the chronic effects of PGBE ester of 2,4-D on the bluegills. Survivors of ponds treated with high concentrations (10 and 5 ppm) had a 2 week delay in spawning. For pathologic lesions, high-treatment fish had earlier and more severe effects than did low-treatment fish. The pathology involved the liver, vascular system and brain. Remarkably, growth of the fish was faster in the ponds receiving the high-treatment than in the lower-treatment ponds. Tables II-8 and II-9 were extracted from a U.S. Forest Service Environmental Impact Statement (EIS-OR. 1973). The tables indicate the effects of herbicides on other aquatic species and point out some toxic effects that can be measured other than death of the organisms.

d. Behavior in Plants

(1) Distribution and Metabolism: Orange herbicide is a systemic herbicide that affects plants by a hormonal type of action usually described as "auxin-like" or "auxin-type". Auxins are any of a group of substances which promote plant growth by cell elongation, bring about root formation, or cause bud inhibition or other effects. 2,4-D and 2,4,5-T are compounds of this type. When applied to leaves of a plant, chlorophenoxy herbicides are absorbed through the cuticle into the plant system. The N-butyl ester forms of 2,4-D and 2,4,5-T found in Orange herbicide are usually more effective than more polar forms because of better absorption into the plant. This is also demonstrated in Yamaguchi's work (1965) in which he found that 2,4-D moves into plant leaves better from acidic solutions than from alkaline solutions. Approximately ten times as much 2,4-D was absorbed from a medium having pH 3 than one with pH 11. 2,4-D has a pK_a of 2.8 and would be highly disassociated at pH 11. Once the herbicide is in the plant it is translocated to areas where food is being stored as in rapidly growing new roots and shoots. The chlorophenoxy herbicides can be stored in certain cells of the plant. Also, metabolism occurs through degradation of the acetic acid side chain, hydroxylation of the aromatic ring, or conjugation.

*TL₅₀ and LC₅₀ (Tolerance Limit and Lethal Concentration) are concentration values statistically derived from the establishment of a dose-related response of experimental organisms to a toxicant. The LC is based on a measured response of death only. The TL is based on a count of unaffected organisms. The subscript number for both indicates the percent response expected for the calculated concentration. Therefore, in most cases, the TL₅₀ = LC₅₀ or the concentration in which 50% death is expected. Note that a more toxic chemical has a smaller LC₅₀.

TABLE II-8

ACUTE EFFECTS OF 2,4-D DERIVATIVES UPON AQUATIC ANIMALS

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>CONCENTRATION</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Isooctyl esters (From 3 manufacturers)	Bluegill	10-31 ppm	48 TLm	Hughes & Davis (1963)
PGBE ester	Bluegill	17 ppm	48 TLm	Hughes & Davis (1963)
butoxyethanol ester	Bluegill	1.4 ppm	48 TLm	Hughes & Davis (1963)
PGBE ester	Shrimp	1 ppm (48 hrs)	20% mortality or paralysis	Butler (1965)
PGBE ester	Fish (salt water)	0.32 ppm	48 hr TLm	Butler (1965)
Alkanolamine Salt	Bluegill	435-840 ppm	48 hr LC ₅₀	Lawrence (1966)
dimethylamine Salt	Bluegill	166-458 ppm	48 hr LC ₅₀	Lawrence (1966)
Isooctyl ester	Bluegill	8.8-59.7 ppm	48 hr LC ₅₀	Lawrence (1966)
Dimethylamine Salt	Fathead Minnow	10 ppm	96 hr LC ₅₀	Lawrence (1966)
Acetamide	Fathead Minnow	5 ppm	96 hr LC ₅₀	Lawrence (1966)
Oil soluble amine salt	Bluegill, Fathead Minnow	2 ppm	4 mo. LC ₁₀	Lawrence (1966)
PGBE Ester*	Bluegill, Fathead Minnow	2 ppm	4 mo. LC ₁₀	Lawrence (1966)
Butoxyethyl ester	Bluegill & Fathead	2 ppm	72 hr LC ₅₀	Lawrence (1966)
Butyl and isopropyl esters, mixed	Bluegill	1.5 - 1.7 ppm	48 hr LC ₅₀	Lawrence (1966)
N,N-Dimethyl coco- amine salt	Bluegill	1.5 ppm	48 hr LC ₅₀	Lawrence (1966)
Ethyl ester	Bluegill	1.4 ppm	48 hr LC ₅₀	Lawrence (1966)
Butyl Ester	Bluegill	1.3 ppm	48 hr LC ₅₀	Lawrence (1966)
Isopropyl ester	Bluegill	1.1 ppm	48 hr LC ₅₀	Lawrence (1966)

*Propylene Glycol Butyl Ether

TABLE II-9

NON-LETHAL EFFECTS OF 2,4-D DERIVATIVES UPON AQUATIC ANIMALS

<u>DERIVATIVE</u>	<u>ANIMAL</u>	<u>DOSE</u>	<u>EFFECT</u>	<u>REFERENCE</u>
Butoxyethanol ester	Oyster	3.75 ppm (96 hrs)	50% decrease in shell growth	Butler (1965)
Butoxyethanol ester	Shrimp	1 ppm (48 hrs)	No effect	Butler (1965)
Butoxyethanol ester	Fish (salt water)	5 ppm	48 hr. TLM	Butler (1965)
Butoxyethanol ester	Phyto- plankton	1 ppm	16% decrease in CO ₂ fixation	Butler (1965)
Dimethylamine	Oyster	2 ppm (96 hrs)	No effect on shell growth	Butler (1965)
Dimethylamine	Shrimp	2 ppm (48 hrs)	10% mortality or paralysis	Butler (1965)
Dimethylamine	Fish (salt water)	15 ppm (48 hrs)	No effect	Butler (1965)
Dimethylamine	Phyto- plankton	1 ppm (4 hrs)	No effect on CO ₂ fixation	Butler (1965)
Ethylhexyl ester	Oyster	5 ppm (96 hrs)	38% decrease in shell growth	Butler (1965)
Ethylhexyl ester	Shrimp	2 ppm (48 hrs)	10% mortality or paralysis	Butler (1965)
Ethylhexyl ester	Fish (salt water)	10 ppm (48 hrs)	No effect	Butler (1965)
Ethylhexyl ester	Phyto- plankton	1 ppm (4 hrs)	49% decrease in CO ₂ fixation	Butler (1965)
PGBE 1/ ester	Oyster	1 ppm (96 hrs)	39% decrease in shell growth	Butler (1965)
PGBE 1/ ester	Shrimp	1 ppm (48 hrs)	No Effect	Butler (1965)
PGBE 1/ ester	Fish (salt water)	4.5 ppm	48 hr TLM	Butler (1965)

1/ PGBE is propylene glycol butyl ether.

(2) Toxicity: Once in the plant, herbicides act by interfering with the photosynthetic, respiratory, and other plant processes causing the plant to lose its leaves and ultimately die. Plant susceptibility to sub-lethal exposures of 2,4-D is markedly influenced by the growth condition of the plant and by environmental factors. Since most of the injury is expressed by growth response, the plant must be growing in order to show injury. In addition, plants in shaded areas respond more slowly than those exposed to direct sunlight. Because of these various factors which affect plant response to the 2,4-D type herbicide, differences in lists showing plant susceptibility should be expected. Orange herbicide is effective on a wide variety of woody and broadleaf plant species. Other lower plant forms can also be affected by auxin-type herbicides. Even unicellular algae exhibit toxic effects or die when exposed to 2,4-D or 2,4,5-T (Walsh, 1972). However, much higher doses of the herbicides are required than for plants with a more complex structure.

(3) Herbicides as Air Pollutants: Although herbicides have long been accepted as environmental pollutants which affect sensitive vegetation, the air pollution aspects of volatile herbicides have not been widely explored. However, there is growing evidence that some 2,4-D compounds may be present in the ambient atmosphere in some parts of the United States at levels sufficient to cause adverse growth effects on sensitive vegetation. During 1962 through 1964, Verneti and Freed measured 2,4-D concentrations in air samples taken in an agricultural area of eastern Oregon. Concurrently, they surveyed for auxin-like plant damage in the areas where the air samples were taken. In the spring of 1962, measured concentrations of the isopropyl ester of 2,4-D in the air ranged from 0.015 ppm to 0.64 ppb. This was during the time of year when the huge wheat fields of the area were being treated for weeds by aerial application of the isopropyl ester. Plant damage to tomato crops appeared to coincide with periods of highest measured concentrations of the isopropyl ester. Other plants, especially locust trees, also showed growth regulator symptoms. Legislation in the state curtailed the use of the isopropyl ester and decidedly reduced the contamination and resulting plant damage. Laboratory studies by Verneti and Freed indicated that 0.015 ppm would be the threshold concentration of isopropyl ester that tomato plants could be exposed to and still survive under the conditions of the experiment. Volatility studies by the same workers demonstrated that the isopropyl ester was three times more volatile than the butyl ester. In fact, complex analyses of the air samples ruled out butyl and other esters of 2,4-D as principal contaminants.

(4) Relative Species Sensitivity: Different researchers vary in their results of relative plant sensitivity to phenoxy herbicides. From field observations, grapevines and box elder appear to be among the most sensitive since they respond to 2,4-D air pollution when other plants showed no evidence of injury. Injury to grapevines may result from exposure to levels in the ppb range. Other workers report tomato plant damage in the ppt range. Walsh (1972) reports a 50% reduction in growth of unicellular marine algae exposed to phenoxy herbicide concentrations of 50 to 300 ppm. Other relative sensitivities are indicated in Table II-10.

TABLE II-10.

Sensitivity of selected plants to 2,4-dichlorophenoxyacetic acid*

Sensitive		
Apple <i>Malus</i> , sp.	Hickory <i>Carya</i> , sp.	Sumac <i>Rhus</i> , sp.
Birch <i>Betula</i> , sp.	Lambs-quarters <i>Chenopodium allium</i> , L.	Tobacco <i>Nicotiana</i> , sp.
Boxelder <i>Acer negundo</i> , L.	Linden <i>Tilia</i> , sp.	Tomato <i>Lycopersicon esculentum</i> , Mill.
Dogwood <i>Cornus</i> , sp.	London plane tree <i>Platanus acerifolia</i> (Ait.) Willd.	Treeofheaven <i>Ailanthus altissima</i> , Mill.
Elderberry <i>Sambucus</i> , sp.	Maple, Norway <i>Acer platanoides</i> , L.	Wisteria <i>Wisteria</i> , sp.
Forsythia <i>Forsythia</i> , sp.	Oak, black <i>Quercus velutina</i> , Lam.	Yellow wood <i>Cladrastis lutea</i> , Koch
Grape <i>Vitis</i> , sp.	Sorrell <i>Rumex</i> , sp.	Zinnia <i>Zinnia</i> , sp.
Intermediate		
Aster, wild <i>Aster</i> , sp.	Mulberry <i>Morus</i> , sp.	Ragweed, giant <i>Ambrosia trifida</i> , L.
Cedar	Oak, pin <i>Quercus palustris</i> , L.	Rhododendron <i>Rhododendron</i> , sp.
Cherry <i>Prunus</i> , sp.	Oak, red <i>Quercus palustris</i> , L.	Rose <i>Rosa</i> , sp.
Cherry, choke <i>Prunus virginiana</i> , L.	Peach <i>Prunus persica</i> , Sieb. & Zucc.	Spruce, Colorado blue <i>Picea pungens</i> , Englm.
Corn <i>Zea mays</i> , L.	Potato <i>Solanum tuberosum</i> , L.	Sweetgum <i>Liquidambar styraciflua</i> , L.
Gladiolus <i>Gladiolus</i> , sp.	Privet <i>Ligustrum</i> , sp.	Yew <i>Taxus</i> , sp.
Heemlock <i>Tsuga</i> , sp.		
Resistant		
Ash <i>Fraxinus</i> , sp.	Eggplant <i>Solanum melongena</i> , L.	Rhubarb <i>Rheum rhaponticum</i> , L.
Bean, bush <i>Phaseolus vulgaris</i> , L.	Pea <i>Pisum commutis</i> , L.	Sorghum <i>Sorghum vulgare</i> , Pers.
Cabbage <i>Brassica oleracea</i> , L.	Peony <i>Paeonia</i> , sp.	

* FROM AIR POLLUTION CONTROL ASSOCIATION REPORT NO. 1

5. TOXICOLOGICAL CHARACTERISTICS OF TCDD: The word teratology has rather recently become quite familiar to biologists, chemists and certain other persons working in various scientific disciplines. It was applied to 2,4,5-T when studies by Bionetics Research Laboratory, Division of Litton Industries, Bethesda MD in 1969-70 implied that 2,4,5-T was teratogenic in mice and rats (Courtney *et al.*, 1970). Subsequently, studies revealed that a toxic contaminant was responsible for the findings originally attributed to 2,4,5-T. The sample of 2,4,5-T employed in the Bionetics study contained 27 ± 8 ppm TCDD. Some studies have shown that oral administration of 2,4,5-T containing < 1 ppm TCDD produces no teratogenic effects on rats, rabbits, mice and other species.

a. Toxicity to Animals: TCDD was found to be the most toxic chlorodibenzo-p-dioxin studied. It was found to have LD₅₀s in the $\mu\text{g}/\text{kg}$ range for several species of animals and was acnegenic, highly embryotoxic and positive for the chick edema factor. "The no-effect dose levels for embryotoxicity and chick edema were 0.03 to $0.1\mu\text{g}/\text{kg}/\text{day}$ respectively" (Schwetz *et al.*, 1973).

(1) Acute Toxicity: Studies performed on TCDD by the Biochemical Research Laboratory, Dow Chemical Co., can be summarized as follows with the data presented as the LD₅₀ in $\mu\text{g}/\text{kg}$ of body weight for several species: rats 20-40; mice, males >64 , females 130; guinea pig 0.6-2.0; rabbits ≈ 30 ; dogs >30 (Rowe *et al.*, n.d.). The signs of intoxication are characterized by a chronic illness and liver damage. Half of the deaths occur more than two weeks after treatment while some animals died after 48 hours. Excretion is primarily by way of feces and is very slow. The highest concentrations are found in the liver and fat with a smaller amount being found in the testes. The LD₅₀ for the rabbit is about the same whether administered intraperitoneally or applied to the skin. In the eye it does not cause corneal injury but does produce thickening of the lids. It does cause severe chloracne when applied to the ears of rabbits in μg quantities.

(2) Toxic Effects on the Fetus

(a) Hamsters: Commercial samples of 2,4,5-T were shown by Collins and Williams (1971) to be fetidal and teratogenic in the golden Syrian hamster. Dose levels of 2,4,5-T ranged from 20 to 100 mg/kg/day while TCDD content varied from 0.1 to 45 ppm. Doses of 100 mg/kg/day of 2,4,5-T approach levels causing maternal mortality.

(b) Rats: TCDD is highly embryotoxic in the rat. No effect was seen at a dose level of $0.03 \mu\text{g}/\text{kg}/\text{day}$ but at the $0.125 \mu\text{g}/\text{kg}/\text{day}$ dose level there was a significant incidence of fetuses with intestinal hemorrhage; fetal deaths and resorptions increased. Delayed skeletal maturation was seen. At $2 \mu\text{g}/\text{kg}/\text{day}$ there were few viable fetuses and the survivors had a high incidence of anomalies. At $8 \mu\text{g}/\text{kg}/\text{day}$ there was severe maternal toxicity and there were no viable fetuses. King *et al.* (1971) studied the effect of 2,4,5-T and 2,4-D administered by gavage and an intrauterine technique using Sprague-Dawley rats as the test species. "Purified" and "technical" grade 2,4,5-T were applied to Millipore® filters that were then placed on the amniotic sac of the embryo. "Purified" 2,4,5-T intrauterinely applied to 93 embryos on any one day of gestation from day 12 to 16 at a dose range of 50 to 120 μg per embryo resulted in no cleft palates. Substituting the

technical for purified grade and using the same technique on 118 embryos resulted in two cleft palates. Oral administration of 2,4-D and 2,4,5-T at a total dose range of 60 to 120 mg/kg to 245 rats yielded 2,231 fetuses, nine of which had cleft palates. Again, these are high dose levels.

b. Industrial Exposure: Dow Chemical Co. prepared an extensive health inventory of 126 manufacturing personnel in an effort to identify harmful effects of inhaled 2,4,5-T. The inhalation rate of the agent was estimated to be from 1.6 to 8.1 mg/day/worker, depending on work assignment, for periods of up to three years. The survey indicates that no illness was associated with 2,4,5-T intake. In plants where 2,4,5-T contained a high proportion of TCDD, Bleiberg *et al.* (1964) found 18% of the exposed employees suffered from moderate to severe chloracne, the intensity of which correlated significantly with the presence of hyperpigmentation, hirsutism and eye irritation. In the late 1940's a pressure overload resulted in the accidental rupture of a vessel containing the sodium salt of 2,4,5-trichlorophenol, a precursor of 2,4,5-T. During the following months, 228 persons developed chloracne, not only plant employees, but members of their families including wives and children. In workers more intensively exposed as a result of the accident, chloracne appeared about two weeks followed by moderate to severe pain in the skeletal muscles of the legs, arms, back and breath, decreased libido and intolerance to cold. Comedones appeared in areas of adult hair which is not typical of juvenile acne. There were pustules on the face, neck, abdomen, back and scrotum. Serum lipids, prothrombin time and glucuronates were all elevated. Biopsy of peripheral nerves revealed destruction of myelin sheaths and in some instances nerve fibers. Hyperpigmentation, fatigue and marked nervous irritability appeared. Over a period of several months, all of the symptoms and findings, except the scars of acne, returned to normal after removal from exposure. Cases in the families of the workers probably resulted from contaminated clothing and poor personal hygiene. The causative agent was not identified at the time. However, in the light of current knowledge, it was almost certainly a polychlorinated dibenzodioxin and possibly TCDD (Suskind, 1973).

c. Evaluation of Toxicological Testing

(1) Requirement for Establishing Dose-Related Response: Insistence on administering a "maximum tolerated dose" may be terribly misleading if this is the only dose tested, as in the Bionetics study (Innes, et al., 1969). There is no justification for abrogating the need to establish a dose-response relationship, which is fundamental to all toxicological experimentation. The route of administration is all important in tests for teratogenesis. We are told that "Parenteral administration is an appropriate test route for pesticides to which humans are exposed by inhalation, or for pesticides which are systemically absorbed, following ingestion" (USDHEW, 1969). It is safe to predict that, by appropriate choice of dose, concentration of solution and frequency of administration by subcutaneous route, any chemical agent can be shown to be a carcinogen or a teratogen in the rat and probably in other laboratory rodents (Goldberg, 1971).

(2) Bionetics Study: The Bionetics study began with the observation that 2,4,5-T was teratogenic and fetidical in two strains of mice when administered either subcutaneously or orally and in one strain of rats when administered orally (Courtney et al., 1970). Analyses of the sample of 2,4,5-T that had been tested against the animals revealed the presence of 27 ± 8 ppm TCDD. Subsequent study of standard 2,4,5-T containing less than 1 ppm TCDD given to rats by gavage in doses up to 24 mg/kg daily, failed to reveal evidence of teratogenic or embryotoxic effects (Emerson et al., 1970). Under similar conditions, TCDD produced no effect at a dose of $0.03 \mu\text{g}/\text{kg}/\text{day}$ while doses of $0.125 \mu\text{g}/\text{kg}/\text{day}$ or greater manifested toxicity to the fetus and at $8.0 \mu\text{g}/\text{kg}/\text{day}$ to the mother also (Sparschu et al., 1970).

(3) Evaluating Data from Animal Models: The metabolism of a test compound is a highly relevant consideration in teratogenesis. If the metabolic pathway in the test animal differs radically from that in man, then the results of a study are unlikely to be useful for the assessment of hazards arising from trace contaminants. The findings of teratogenesis or embryotoxicity has meaning only in the appropriate animal species (Goldberg, 1971). Theodor D. Sterling (1971) of the Department of Applied Mathematics and Computer Science, Washington University, St Louis, examined the difficulty of evaluating the toxicity and teratogenicity of 2,4,5-T from existing animal data. He notes that the question has been raised as to whether the herbicide 2,4,5-T is toxic and teratogenic to an extent to preclude its use, in this country at least. Sterling states, "Although we can learn a great deal from animal experiments, toxicological and teratological information from animal experiments turns out to be much less useful, especially for making broad policy decisions, than is commonly thought."

(4) Design of Recent 2,4,5-T Toxicity Studies: To quote Sterling (1971) again, "...there are less than a dozen key reports...of study on toxicity of 2,4,5-T, dating back to the early 1950's for the most part, and on its teratogenicity, mostly done in the last two years. Whereas the toxicity studies were done at some leisure and the teratogenicity studies had some aspect of emergency about them, they are indistinguishable in their lack of adequate statistical experimental design and analysis of data."

6. EVALUATION OF ENVIRONMENTAL CONTAMINATION POSSIBILITY: The possibility that an extraordinarily toxic contaminant of a widely used herbicide may be sufficiently stable in the environment and soluble in fat or other tissues to enter food chains and ultimately the human diet is worthy of consideration. It was known, of course, that 2,4,5-T does not accumulate to any significant degree in animal tissues, but data on tissue storage of dioxin were not available. Chlorinated dibenzo-*p*-dioxins long have been recognized as by-products from the manufacture of certain chlorinated phenols. For example, 2,4,5-trichlorophenol is prepared industrially by the hydrolysis of 1,2,4,5-tetrachlorobenzene at elevated temperatures and pressures, a process which can also result in the formation of traces of heterocyclic impurities including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin if temperatures are permitted to exceed 160°C and if the reaction becomes alkaline. This dioxin is toxic, teratogenic and acrogenic and its presence appears to account satisfactorily for the alleged teratogenic effects of trichlorophenol derivatives such as the herbicide 2,4,5-T.

a. Knowledge Available From Use: No proven instance of toxicity associated with 2,4,5-T intake in man has been found in agricultural or industrial workers known to have had repeated, relatively high levels of exposure to 2,4,5-T of low dioxin content. The safety factor for the general population is estimated to be several orders of magnitude greater than that for 2,4,5-T factory workers. Data are too limited for a firm conclusion, but there is no evidence to suggest that TCDD as a contaminant in 2,4,5-T is likely to be encountered by animal or man in sufficient dosage to cause toxic reactions (Advisory Committee, 1971).

b. Application of Testing: "Since most chemicals under suitable laboratory conditions could probably be demonstrated to have teratogenic effects, and certainly all could be shown to produce some toxic effects if dosage were raised high enough, it would not be reasonable to consider the demonstration of toxic effects under conditions of greatly elevated dosage sufficient grounds for prohibiting further use of a particular chemical" (Goldberg, 1971).

c. Possibility of Pyrolytically Produced Contamination: The question of the formation of TCDD as a result of the pyrolysis or burning of wood, including brush treated with 2,4,5-T, has been a matter of some concern. Langer (1973) states, "The derivatives of 2,4-D, 2,4,5-T and Silvex as well as their sodium salts and esters have not produced dioxins in pyrolytic reactions whether carried out in the solid state, in the melt, or in solution. Even after conditions of extreme hydrolysis, followed by pyrolysis we could observe only trace amounts of dioxins." Langer (1973) further stated, "Even extreme conditions such as burning of treated wood or vegetation after the use of 2,4-D, 2,4,5-T, Silvex or their derivatives is not expected to produce detectable amounts of dioxins or dibenzofuran." However, in a memorandum dated

July 30, 1973, Baughman and Meselson (1973) reported that the pyrolysis of the sodium salt of 2,4,5-T at temperatures from 300 to 450°C for 30 minutes to 12 hours caused the formation TCDD ranging in concentrations from 0.1 to 0.3% (1,000 to 3,000 ppm).

d. Evaluation by EPA Advisory Committee: The data are indeed very limited. Nevertheless, certain conclusions can be made and these as made by the Advisory Committee on 2,4,5-T to the Administrator of the Environmental Protection Agency are, in part, as follows:

(1) The herbicide 2,4,5-T does not accumulate in any compartments of the biosphere, nor does it accumulate in any animal tissues or products used for human consumption.

(2) The risk of human exposure to 2,4,5-T in food, air and water is negligible.

(3) There is no indication that TCDD accumulates in air, water or plants, although it might accumulate and remain active for some time in soils after heavy application of a highly contaminated sample of 2,4,5-T.

(4) Less than 0.2% of TCDD in soil is known to be absorbed into plants.

(5) 2,4,5-T is rapidly excreted in animals studied using doses in the range of those likely to be encountered in the environment.

(6) Limited data indicate that TCDD is also eliminated, at least some by metabolic breakdown, with a half-life of 20 days.

(7) The solubility of TCDD in fat is limited which would preclude appreciable accumulation in body fat.

PART III PROBABLE ENVIRONMENTAL IMPACT OF PROPOSED ACTION

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I. BENEFICIAL ASPECTS OF THE PROPOSED ACTION----- 113

A. SUMMARY STATEMENT OF TOTAL IMPACT: The environmental impact is discussed in the following paragraphs for the proposed action of incineration at sea and the principal alternative of incineration on Johnston Island. In either case the incineration operation will destroy 99.9 to 99.999 percent of the herbicide. These efficiencies will insure that any unburned or pyrolyzates of herbicide and its TCDD content will not have any significant impact upon the environment. Since the herbicide will be essentially destroyed, the environmental impact of the following major combustion products have been considered: water, heat, carbon dioxide, carbon monoxide, carbon particulates, and hydrogen chloride. These combustion products will be discharged directly into the atmosphere toward the west of Johnston Island over the open tropical ocean. Incineration in either case can be accomplished with minimal environmental impact which will be transient and not significant. Incineration at sea has an advantage in that the beneficial uses of the environment in which the incineration takes place, i.e., tropical ocean, are limited. Under the principal alternative, incineration on Johnston Island, the beneficial usages of the atoll are more numerous and must receive considerations of potential impact - particularly the drinking water source, reef and aquatic community, and bird refuge.

B. AIR QUALITY

1. DISPERSION MODEL STUDIES: A dispersion study utilizing a meteorological model was accomplished by the USAF Environmental Health Lab, McClellan AFB. This study was for the emissions of hydrogen chloride and Orange herbicide for the proposed action of incineration at sea and the principal alternative of incineration on Johnston Island. The study is presented as Appendix K.

2. ENVIRONMENTAL IMPACT

a. General: The environmental impact on the air environment will be discussed for the proposed action and the principal alternative described in Part II. In either case, untreated combustion gases will be discharged directly into the atmosphere. The remote location of the incineration process combined with the high efficiency of incineration indicates that the discharge of the combustion gases directly into the atmosphere will not result in any irreversible detrimental environmental impact. The absence of any inhabited land masses or agricultural based economies in the locale of the proposed combustion gas discharges is also favorable. Although the impact upon the atmosphere of unscrubbed combustion gases is minimal and transient, even this impact could be reduced for the principal alternative by using combustion gas scrubbers on Johnston Island. However, the impact of the spent scrubber wastewater discharge would be significant. In the analyses that follows, there is no consideration required for TCDD. If any TCDD were present in the combustion gases, its calculated concentration would be an order of magnitude below the analytical detectable limit (typically 0.20 nanograms/l). The additional dispersion of the combustion gas into the atmosphere will further decrease such concentrations.

b. Incineration at Sea

(1) Potentials for Impact: The evaluation of the impact of the combustion gas will require consideration of the following combustion gas constituents: unburned or pyrolyzates of herbicide, hydrogen chloride, carbon monoxide, carbon particles, carbon dioxide, and heat. The latter three constituents are discharged daily in considerable quantities (~3.0 tons, 1,000 tons, and ~1650°F, respectively) are not significant as regards impact on the environment. That is, the open tropical sea and atmosphere west of Johnston Island will readily absorb these quantities of carbon particulates, carbon dioxide, and heat during three - 7 to 9 day incineration periods. However, hydrogen chloride discharged at about 178 tons per day and carbon monoxide discharged at about 50 tons per day are toxic and were environmentally assessed. As presented below, the impact of carbon monoxide discharge was minimal and negligible in comparison to the hydrogen chloride discharge.

(2) Probable Impact: Atmospheric impacts of hydrocarbons, hydrogen chloride, carbon monoxide, and carbon particulates in combustion gas discharges have been assessed by using two approaches: 1) determining the average mass concentration which would be present in the atmosphere in the immediate zone of the incineration operation by estimating a "worst case" dispersion zone, and 2) determining the maximum sea level concentrations at specified distances downwind from the incineration operation by utilizing a "worst case" meteorological model. Upon determination of such concentrations, judgments regarding the environmental impact are made.

(a) Hydrocarbons: An efficiency of 99.9 percent Orange herbicide destruction has been applied to the shipboard incineration process. Therefore, a daily discharge of 0.576 tons of unburned or pyrolyzates of Orange herbicide must be considered for probable environmental impact. To gain a perspective of the environmental impact, the analyses have also been accomplished for efficiencies of 99.0 and 95.0 percent, i.e. a discharge of 5.76 and 28.8 tons, respectively, of unburned or pyrolyzates of Orange. It is noted that all resulting concentrations described for all the "worst case" analyses in the next paragraph are below the ACGIH threshold limit value of 10 mg/cbm for either 2,4-D acid (1.1 ppm) or 2,4,5-T acid (0.96 ppm) which has been established for occupational exposures. Since the RDES was published the Air Force has received information on incineration from the Antillian Incinerating Company N.V. of Curaco and the Hague Holland. This packet of information is entitled "Information/Data/Analysis Incinerator Ships Mathias I & II" and a portion of it is included in Appendix N. The following quote is taken from page 1 of the "Extract from Dr. Klaus Grasshoff of Kiel University's report on possible effects of burning hydrocarbons at sea" (Appendix N). "By means of extensive controlled measurements, the Bayer Company of LeVenhusen, Germany, has established that if burning of chlorinated hydrocarbons is carried out at a temperature higher than 1000°C, more than 99.9 percent of the materials are completely burnt." The monitoring program conducted by the Bayer Co. is described below and this report is also included in Appendix N. Three separate mixtures of hydrocarbons containing chlorinated hydrocarbons were combusted at temperatures between 1400°C and 1500°C during a 3 to 6 hour operating time. Combustion gas sampling and analyses revealed that the combustion efficiency in all three cases was greater than 99.9 percent. Bioassays conducted on condensates of exhaust gas collected during each burn were satisfactory. The Air Force has also received information concerning incineration at sea which was generated by the French government as a result of requests for authorization by Ocean Combustion Services (Vulcanus) and Incimer (Mathias I & II) to incinerate chlorine wastes (hydrocarbons and chlorinated solvents) produced by the chemical industry. This information (as translated) appears in Appendix N. The information includes data from a test burn of chlorinated hydrocarbons on the Mathias II and Vulcanus. The incinerative efficiency is attested to in the following quote: "...The pyrolysis is then practically complete in the case of the Vulcanus." For the Mathias II, pyrolysis was also very efficient, but the unburned compounds included light molecular weight compounds and "tars" which are insoluble in water. The presence of the light compounds was attributed to the failure to maintain the required temperature throughout the incinerator. The presence of the tars was not accounted for. The French Environmental Agency proposed that "...very soon a number of arrangements will be made so that the incinerator ships can operate from french ports, and inside a marine zone which will be specially designated for this use, with all precautions concerning the protection of the sea life." The Environmental Agencies also comment on the importance of knowing physical/chemical characteristics, having test burn data from an incinerator and attaining the temperature for proper incineration, and the minimal environmental impact of chlorine and hydrogen chloride in the exhaust gases. The above is only a summary of the French document which is presented in its entirety in Appendix N. In addition to the above, information relative to the combustion efficiency of the Vulcanus for chlorinated hydrocarbons was presented at a public hearing in Houston TX on 4 Oct 74. The hearing was conducted by the EPA concerning a Shell Chemical Company application to utilize the Vulcanus for incineration of chlorinated hydrocarbon wastes. Mr. H. Compaan, National Research Council of the Netherlands, testified that tests aboard the Vulcanus revealed a combustion efficiency of 99.996 percent, the testimony appears in Appendix N.

1. Dispersion Zone: A "worst case" dispersion zone can be predicted by considering the wind speed, the speed and direction of the incinerator ship during incineration, and the mixing height for the material being dispersed. For these analyses the dispersion zone is based on a one knot wind speed, "crosswind" of the ship's course, 10 knot speed for the ship during incineration, and an effective mixing height of 50 meters above sea level. The ship's speed is realistic based on information received from the shipping company; the wind speed and effective mixing height are very conservative. For such a low wind speed, it is anticipated that the combustion gases would actually rise higher than 50 meters above sea level before thermal equilibrium is attained. The calculated daily area of this "worst case" dispersion zone is 240 by 24 nautical miles with a calculated daily volume of about 1.0×10^{12} cubic meters. Assuming uniform mixing, the concentration of unburned pyrolyzates of Orange in the zone described would be approximately 42 part per trillion by volume ($\text{ppt}_{\text{v/v}}$) at an incinerative efficiency of 99.9 percent (420 $\text{ppt}_{\text{v/v}}$ for 99.0% and 2,100 $\text{ppt}_{\text{v/v}}$ for 95%). These concentrations represent the average mass loadings in the volume described and are not a function of distance/elevation from the source. As such, their interpretation is limited, however, average mass loadings of these calculated concentrations for a 22-26 day period would be acceptable for the environment affected. A meteorological model, next paragraph, has been utilized to determine sea level concentrations of the material downwind of the ship. The disposition of the unburned herbicide upon the ocean surface via fallout or plume/ocean interface reactions and its impact upon the ocean is discussed under Part III.C., Water Quality.

2. Meteorological Model: These analyses determine the concentration of unburned or pyrolyzates of Orange herbicide at/or near sea level downwind from the ship. Input conditions for the model were selected to insure that maximum sea level concentrations would be attained. These conditions include a wind speed of ~18 knots, a stationary ship, and a highly unstable atmosphere. The analyses revealed the maximum sea level concentration to be 0.81 $\text{ppb}_{\text{v/v}}$ (99.9% efficiency) at 0.47 kilometers (km) on a line directly downwind of the ship (8.1 $\text{ppb}_{\text{v/v}}$ for 99.0% and 40.5 $\text{ppb}_{\text{v/v}}$ for 95%). At a distance of 10 km from the discharge, the sea level concentration will be approximately 19 $\text{ppt}_{\text{v/v}}$ at an incinerative efficiency of 99.9 percent (190 $\text{ppt}_{\text{v/v}}$ for 99% and 950 $\text{ppt}_{\text{v/v}}$ for 95.0%). These unburned or pyrolyzate concentrations of Orange herbicide are not significant for the relatively small open tropical sea atmosphere which would be affected. Additionally, the ship will always be moving, and although the volume of affected atmosphere will be increased, the downwind concentrations of these hydrocarbons will be greatly reduced. See the vertical and horizontal distributions of these concentrations in Appendix K.

(b) Hydrogen Chloride: The hydrogen chloride discharge, 178 tons per day is also analyzed using the "worst case" dispersion zone and the meteorological model as described above.

1. Dispersion Zone: Assuming the same dispersion zone as above for hydrocarbons, the average mass concentration of hydrogen chloride in the zone would be ~ 0.11 ppm_{v/v}. The highly reactive nature of hydrogen chloride will result in considerable deposition of hydrogen chloride into the ocean; a "worst case" analyses, in which all of hydrogen chloride generated, is discharged into the ocean in the ship's wake is presented in Part III, C, Water Quality. The dispersion zone is quite large due primarily to the distance which the ship travels during the incineration. Limited data are available on hydrogen chloride dispersions over the ocean; however, information is available on hydrogen chloride emissions over broad, populated, land areas. For example in a study of air contaminant emissions in Niagara County, N.Y., it was found that 4,083 tons of hydrogen chloride were emitted into the atmosphere per year. Of this total 2,911 tons originated from processing plants, and 1,172 from the consumption of coal and oil for heating purposes. It is concluded that a discharge of 178 tons per day of hydrogen chloride by, an incinerator ship, for three periods of 7-9 days, will not cause any detrimental environmental impact to the atmosphere above the open tropical sea.

2. Meteorological Model: This analysis determines the hydrogen chloride concentration at/or near sea level downwind from the ship. This information is used to evaluate the impact of the ship's discharge upon other possible uses of the area in which the ship is operating. However, it is emphasized that the ship will be required to incinerate in selected areas which will insure no interference with other uses of the area---particularly those of other ships. Using the same "worst case" situation for sea level concentrations as described for the hydrocarbon meteorological model, the maximum sea level concentration will be 2.28 ppm_{v/v} and it will occur 0.47 km directly downwind of the ship. At a distance of 10 km from the discharge the sea level concentration will be about 50 ppb_{v/v}. This analyses indicates that the sea level concentration does not exceed the American Conference of Governmental Hygienists' Threshold Limit Value (ACGIH TLV) of 5 ppm_{v/v} at any point downwind of the ship's discharge. Also, the downwind ground level zone in which low ppm_{v/v} concentrations exist is relatively small. The ship will be moving during the incineration operation and therefore the downwind concentrations will be even less than these presented for a stationary ship. For a wind which is crosswind at practically any angle to the ship's course, the downwind sea level hydrogen chloride concentrations will be reduced essentially to insignificance. The vertical and horizontal concentration distribution for the ship's hydrogen chloride discharge is given in Appendix K.

(c) Carbon Monoxide: In analogous fashion to the models used above, the ship's daily discharge of about 50 tons of carbon monoxide were assessed. Average mass concentrations of carbon monoxide would be about 0.04 ppm_{v/v} within the "worst case" dispersion zone. Maximal "worst case" sea level concentrations predicted by the meteorological model would be 0.8 ppm_{v/v} at 0.47 km directly downwind of the ship. This sea level concentration would decrease to about 18 ppb_{v/v} at a distance of 10 km downwind. These predicted concentrations are very conservative because continued oxidation of carbon monoxide to carbon dioxide in the exhaust stack and discharge plume are neglected. The affected concentrations predicted by the meteorological model would actually be much smaller because the ship is not a stationary source. None of these predicted atmospheric carbon monoxide concentrations exceed the ACGIH TLV of 50 ppm_{v/v}

or ambient air quality standards: 9 ppm for eight hours only once a year or 35 ppm for one hour only once a year (National Primary and Secondary Ambient Air Quality Standard 40 CFR 50.8). Taking even the most conservative approach, the expected carbon monoxide discharges from the ship will cause no adverse impact on the environment of the open tropical sea.

(d) Particulates: The daily discharge of 3.0 tons of carbon particles is based on an assumption of 0.5 percent conversion of Orange to elemental carbon. With the same "worst case" dispersion zone as assumed above, the concentration of suspended particulates would be several orders of magnitude less than dust concentration of clean country air (0.2 mg per cubic meter). In reality, the majority of the particles would be deposited on the ocean surface in a relatively small impact zone; this aspect has been considered in Part III, C, Water Quality. These discharges of particulates would have no significant effect on the air environment.

(3) Monitoring: In view of the negligible impact predicted and the remoteness of the incineration area on the open tropical sea, ambient air monitoring is not considered necessary.

c. Principal Alternative - Incineration On Johnston Island

(1) Potentials for Impact: Consideration is given to the following combustion gas constituents: hydrocarbons, i.e., unchlorinated pyrolyzates of Orange herbicide and undetectable concentrations of herbicide feed constituents, hydrogen chloride, carbon particles, carbon monoxide, carbon dioxide, and heat. The latter two, while discharged at considerable quantities, 110 tons per day of carbon dioxide and a stack gas temperature of ~ 1700°F, are not environmentally significant; in fact, they can be readily absorbed into the atmosphere. The carbon monoxide, while a toxic gas and estimated to be discharged at a rate of 5.5 tons per day, is not considered environmentally significant. This statement is based on a comparison between the mass discharge rates of the carbon monoxide and hydrogen chloride (18.5 ton/day) and the impact analyses for hydrogen chloride which is described later. If scrubbers were used, the general character of the stack gas would be improved and essentially no hydrogen chloride or carbon particulates would be discharged into the atmosphere. However, the scrubber wastewater discharge would have potential for environmental impact and is discussed under Part III. C, Water Quality.

(2) Probable Impact: The potential atmospheric impact of pyrolyzates with undetectable herbicide feed constituents, hydrogen chloride, and carbon particulates are based on: 1) calculated average concentrations of these materials within a "worst case" dispersion zone downwind of the discharge point, and 2) predicted downwind concentration profiles provided by a meteorological model (see Appendix K). For the carbon particulates, only the dispersion zone analyses was accomplished. The dispersion zone is based on a wind speed of one knot (calm) and a very conservative width and height of 100 meters. On a daily basis, the area of the zone would be 24 nautical miles by 100 meters and its volume would be 4.44×10^8 cubic meters. While seemingly large, this zone represents a "worst case" volume for dispersion and it is felt that the gases will actually disperse through a greater volume on a daily basis. Similarly, "worst case" conditions were chosen for the meteorological model, i.e., wind speed of 13.6 knots and extremely unstable atmospheric conditions.

(a) Hydrocarbons: Considering a 99.999 percent destruction efficiency of herbicide feed, the daily mass emission of unchlorinated pyrolyzates and undetectable levels of feed constituents would be 1.2 pounds. This value is approximately three times that which was found in a test incineration program described in Appendix E. It is also noted that the 1.2 pounds of hydrocarbons is essentially all unchlorinated pyrolyzates since no herbicide feed constituents were ever detected in the combustion gases. The average daily mass concentration in the "worst case" dispersion zone is ~100 ppt_{v/v}. The maximum sea level concentration predicted by the meteorological model is approximately 7.0 ppt_{v/v} and occurs 0.2 km downwind of discharge. When discharged from the west end of the island over the open tropical ocean, no significant environmental impact can be attributed to these predicted "worst case" atmospheric concentrations of these hydrocarbons. The impact of the deposition of these pyrolyzates or any Orange constituents into the ocean from the stack plume is discussed under Part III. C, Water Quality.

(b) Hydrogen Chloride: The discharge of hydrogen chloride will be approximately 18.5 tons per day. The daily average mass concentration in the atmospheric dispersion zone described above will be ~25 ppm_{v/v}. The

maximum sea level concentration predicted by the meteorological model, for "worst case" sea level conditions, is 1.85 ppm_{v/v} which occurs at 0.2 km directly downwind of the stack. At a distance of 10 km from the stack, the predicted sea level concentration decreases to 0.007 ppm_{v/v}. The maximum concentration predicted by the model occurs at a distance of 0.2 km from the stack and an elevation 38.3 meters; this concentration is 2.26 ppm_{v/v}. These predicted hydrogen chloride concentrations in the atmosphere were accomplished to evaluate probable impacts of the hydrogen chloride discharge as regards: 1) interference with ships downwind of the stack, 2) interference with aircraft, particularly those on approach to landing at the west end of the runway, and 3) possible alterations of reef calcification processes due to downwind deposition of hydrogen chloride and resultant depressions of the pH of reef waters. The analyses indicates there is no significant detrimental environmental impact attributable to the hydrogen chloride discharge and resultant hydrogen chloride concentrations in the atmosphere west of Johnston Island. Interference with ships or aircraft, due to transient exposure to low ppm concentrations of hydrogen chloride, would not be a serious constraint on the operation. The reaction between hydrogen chloride and saturated air was considered in the Department of Air Force Draft ES "United States Air Force Space Launch Vehicles." Hydrogen chloride in a clear atmosphere of saturated air is not expected to result in the formation of droplets which may fall out. Droplets occur in fog or in natural clouds and due to the great affinity of hydrogen chloride for water an acid may be expected. The hydrogen chloride concentration of such droplets has been estimated at less than 1 percent. Although hydrochloric acid mists and solutions are very corrosive to most metals, a literature review in preparation of "Air Pollution Aspects of Hydrochloric Acid" (Stahl, 1969) did not reveal any information describing corrosion or damage to material from environmental concentrations of hydrochloric acid. However, meteorological constraints will be implemented to insure that the incineration is stopped during weather conditions which are not favorable for dispersion of the stack gas westward from the island. The effect upon the fringing reef is discussed under Part III.C., Water Quality.

(c) Particulates: The daily discharge of elemental carbon particulates (0.3 tons) is based on the conversion of 0.5 percent of Orange particulates. Based upon proposed incineration parameters, these particulates would not be expected to contain any detectable hydrocarbons. Dispersion of these particles in the "worst case" dispersion zone described above will result in a concentration slightly greater than that of clean country air (0.2 mg/cubic meter). Although a smaller zone will be affected at higher concentrations, the majority of particles are actually expected to fall out in the ocean over a relatively small impact area. This fallout effect on the ocean is discussed in Part III.C., Water Quality.

(3) Monitoring: Ambient air monitoring including sample collection for analytical chemistry analyses and biomonitoring with selected plants will be required to document the impact of the incineration process. The odor perception of humans to hydrogen chloride is very acute, being reported as low as 0.067 ppm_{v/v}. The low sensitivity to odor can be considered as a back-up

monitoring program to supplement the meteorology constraints on the incineration operation and the chemical/biological sampling program. The odor perception is obviously not to be used for quality control of the incineration operation. It is fortunate, however, that hydrogen chloride is the major quantitative constituent of concern in the stack gas and that it can be readily detected at concentrations below that considered safe for occupational exposure.

C. WATER QUALITY

1. PRESENT WATER QUALITY

a. Survey at Johnston Atoll: A visit was made to Johnston Atoll in October 1973 by personnel of the USAF Environmental Health Laboratory, Kelly AFB (EHL(K)) to collect water samples and marine biological samples for analyses for Orange herbicide components and TCDD.

b. Water Sample Collection: A total of 17 duplicate water samples were taken during the survey; see Fig III-1, and Table III-1. The rationale of the water sampling was to obtain a comprehensive set of samples which would include:

- (1) Ocean samples near the herbicide storage area.
- (2) Ocean samples from locations around the island.
- (3) An indisputable ocean control sample.
- (4) Samples at the intake and outlet of the distillation unit.
- (5) Samples of the freshwater reservoir and distribution system.
- (6) Samples of test wells in the herbicide storage area.

c. Biological/Sediment Sample Collection: The rationale for this sampling was to obtain representative samples of high food chain predators, coral feeders, coral sediments, etc. for subsequent analysis for herbicide components and TCDD. Figure III-2 illustrates the biological sampling locations. Area I, consisting of five locations off the west side of Johnston Island, was the most likely area for contamination due to the location of the Orange storage area and the nature of the ocean currents. Area II was north and east of North (Akau) Islands where four locations were selected as controls that would be free of possible contamination. Area III was a "catch-all area," including any area except I & II which was expected to have minimal herbicide contamination but which could have industrial/chemical products indicating man's influence. Table III-2 lists the biological specimens and the sampling areas from which they were collected. Duplicate sediment samples were collected in Biological Sampling Areas I and II and at the shoreline near the Orange storage area. The latter corresponds to the same location as water sample number 8, see Table III-1.

d. Sample Disposition:

(1) Water: One set of water samples was delivered to the Environmental Health Laboratory, McClellan AFB (EHL(M)) to be analyzed for 2,4-D and 2,4,5-T esters and acids and for polychlorinated biphenyls (PCB). The other set was delivered to the EPA Laboratory at Bay St Louis MS. The samples were prepared for analysis at this facility and then sent to the EPA Laboratory at Perrine FL for determination of TCDD.

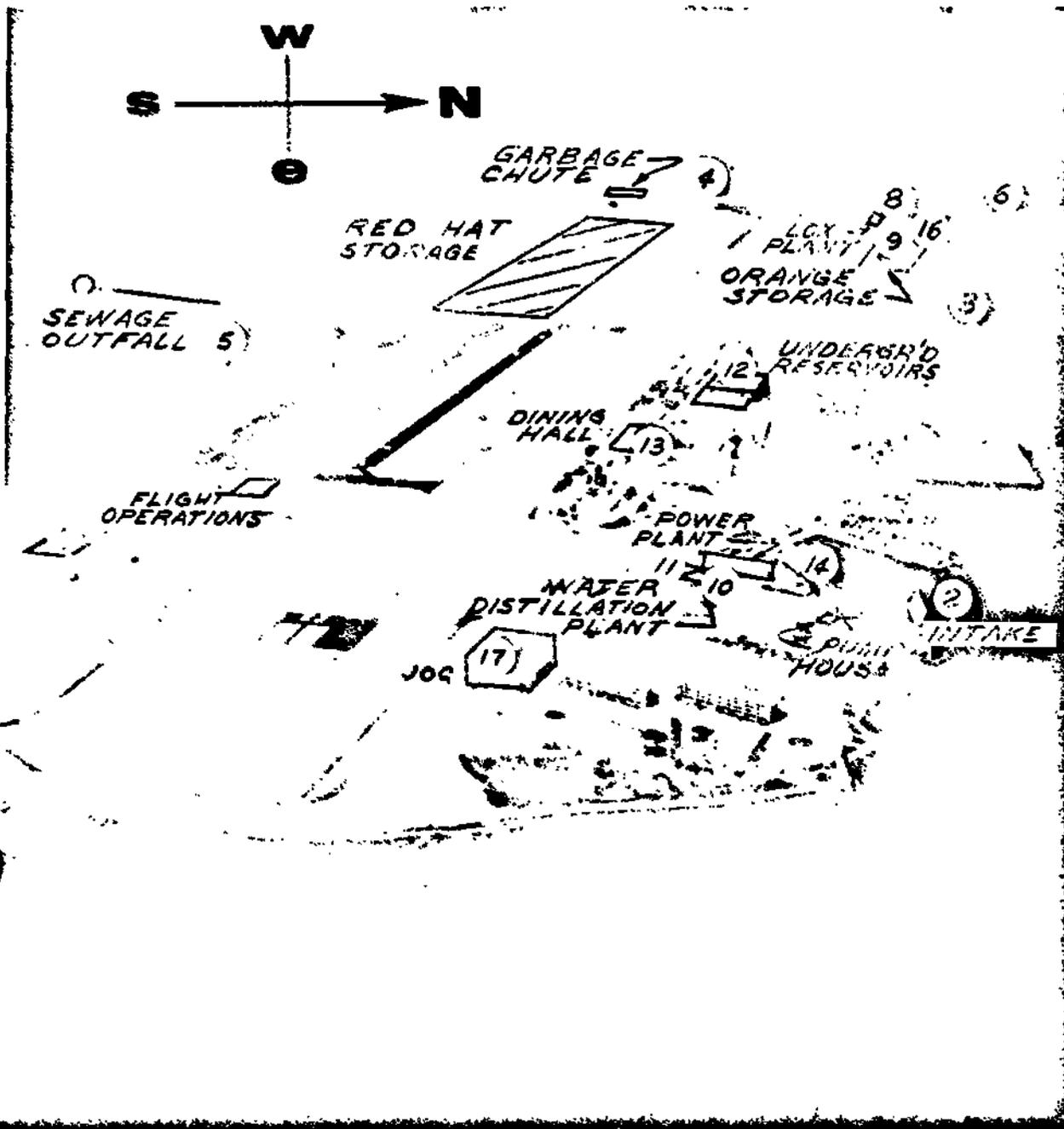
(2) Biological: One set of six frozen biological samples identified in Table III-2 was sent to Dow Chemical Co., Midland MI for TCDD analysis. A full set of frozen samples was sent with the water samples to the EPA

FIGURE III-1
JOHNSTON ISLAND
WATER SAMPLES
OCTOBER 1973

USAF ENVIRONMENTAL
HEALTH LABORATORY
KELLY AFB TX 78241

○ INDICATES WATER
SAMPLE LOCATIONS

CONTROL SAMPLES 1 & 15 ARE
SHOWN IN FIGURE III-2



JOHNSTON ISLAND

TABLE III-1 WATER/SEDIMENT SAMPLES

EHL(K) FIELD TRIP, JOHNSTON ISLAND, OCT 73

General Location	Sample Ident.	Specific Location	Date	Time	Approx Sample Depth - Feet	Approx Bottom Depth - Feet
Ocean Samples	1	East of North Island - Inside Reef (Control Sample)	1 Oct	1530	20	40
	2	Distillation Plant Intake*	1 Oct	1510	12	20
	3	North Shore	1 Oct	1415	13	20
	4	Garbage Chute - 10 yds from shore	1 Oct	1430	below surface	--
	5	Sea Turtle Area	1 Oct	1440	8	15
	6	Northwest of Herbicide Area	1 Oct	1425	10	17
	7	East End of Runway	1 Oct	1500	15	30
	8 15	West of Herbicide Area - Shoreline ~1.2 Miles Northwest of North Island Outside Reef (Control Sample)	1 Oct 3 Oct	1720 0900	-- below surface	-- --
Potable Water Supply System	10	Salt Water Reservoir	2 Oct	1445	below surface	--
	11	Distillation Unit Discharge (Sample Tap)	2 Oct	1500	--	--
	12	Potable Water Reservoir	2 Oct	1545	--	--
	13	Dining Hall (sink tap)	3 Oct	1000	--	--
	14	Distillation Unit Brine	2 Oct	1510	--	--
	17	JOC Bldg (sink tap)	3 Oct	1030	--	--
Test Wells	9	Well Hole - Center of Herbicide Area	2 Oct	1000	-8	--
	16	Well Hole - West side of Herbicide Area	3 Oct	1115	-8	--
Sedi-ment	I	Biological Sampling Area I	2 Oct	0830	15	15
	II	Biological Sampling Area II	3 Oct	1000	25	25
	S8	Same as Water Sample 8	3 Oct	1100	Shoreline	--

* Diver stated that water had a petroleum product taste

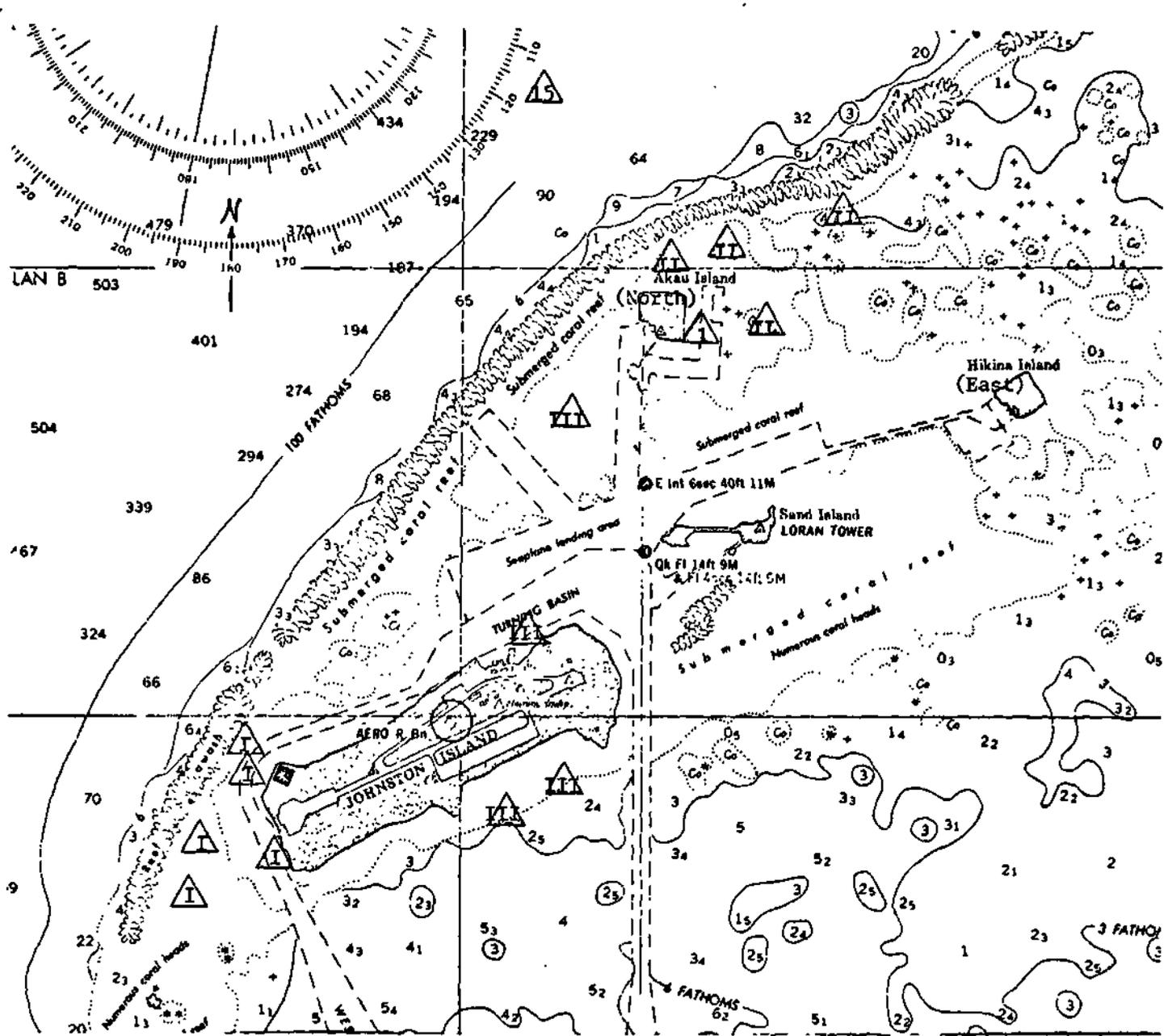


FIGURE III-2 MARINE SAMPLING LOCATIONS
EHL(K) FIELD TRIP, JOHNSTON ATOLL, OCT 73.

-  Sampling locations offshore from Orange Herbicide storage area.
-  Control sampling locations north and east of North (Akau) Island.
-  Miscellaneous control sampling locations.
-   Control locations for marine water samples.
-  Orange Herbicide Storage Area.

TABLE III-2 MARINE BIOLOGICAL SPECIMENS

EHL(K) FIELD TRIP, JOHNSTON ISLAND, OCT 1973

SPECIMEN*	COLLECTION AREA**		
	I	II	III
A. White-tipped reef shark, <u>Triaenodon obesus</u> Gray reef shark, <u>Charcharinus amblyrhynchos</u>	x (liver) x (muscle)		x (liver)† x (muscle)
B. Moray eel, <u>Gymnothorax javanicus</u>	x (body)† section)		
C. Sand eel, (Anguilliformes)	x		
D. Green sea turtle, <u>Chelonia mydas</u> (?)			x (liver) x (muscle)
E. Surgeon fish, <u>Acanthurus nigroris</u> (?)			x
F. Surgeon fish, <u>Acanthurus achilles</u>	x†	x†	
G. Squirrel fish, <u>Adioryx spinifer</u>	x	x	x
H. Parrot fish, (Scaridae)	x	x	
I. Sea Cucumber, <u>Holothurea atra</u> & other species	x†	x†	
J. Mushroom (razor) coral, <u>Fungia scutaria</u>	x		x
K. Staghorn coral, <u>Acropora</u> sp	x	x	
L. Algae species #1 <u>Schizothrix calicola</u> mixed with other species	x	x	
M. Algae species #2, <u>Halimeda Discoidea</u>		x	
N. Algae species #3, <u>Bryopsis</u> sp.			x

*Sample is composed of whole specimen(s) unless otherwise noted

**Collection areas are indicated on attached map, Figure 2

†Specimens sent to Dow Chemical for dioxin analysis

Laboratory at Bay St Louis MS for preparation with subsequent TCDD analysis at the EPA Laboratory at Perrine FL. The remaining biological samples were retained at EHL(K) for 2,4-D and 2,4,5-T analysis.

(3) Sediment: One set of sediment samples was delivered to the EPA Laboratory at Bay St Louis MS for subsequent dioxin analysis at Perrine FL. The second set was analyzed at EHL(K) for 2,4-D and 2,4,5-T.

e. Results of Analysis

(1) Water: As shown in Table III-3 no TCDD was found in any water samples. Acids of 2,4-D and 2,4,5-T were found at the shoreline adjacent to the storage area and in the test wells in the storage area as seen in Table III-4. The well openings are at grade and the presence of the acid is probably from water-carried (rain) drainage of leaked herbicide into the wells. The shoreline station was just below the redrumming area so it also could receive leaked herbicide.

(2) Marine Biological and Sediment: Table III-5 shows no TCDD in any of the marine samples analyzed except for sample I-I, Sea Cucumber which is reported as 2.2 ppt (by weight). The analysis which resulted in this concentration was the second analyses conducted on sample I-I by the EPA. The first analyses resulted in a "non-detectable" report but the recovery was low resulting in a TCDD detection limit of 64 ppt. A portion of sample I-I was one of the six samples which was forwarded to the Dow Chemical Company for analyses. Dow split the sample into "flesh" and "internal organs" and the analyses of each portion resulted in a non-detectable concentration of TCDD at a detection limit of 1 ppt. The remaining samples forwarded to the Dow Chemical Company were also negative for TCDD with detection limits ranging from 1 to <11 ppt. The latter limit, <11 ppt, was for sample III-A, the grey reef shark liver, and was attributed to an interfering substance present in the sample. Table III-6 shows that all samples were negative for 2,4-D and 2,4,5-T; the detection limits ranged from 0.07 to 2.0 µg/kg for the biological samples and was 5.0 µg/kg for the sediment samples.

f. Conclusions: From the results of analyses of ocean water, drinking water, marine biological and sediment samples collected in October 1973 by the survey team from EHL(K), it was concluded that there was no evidence of Orange herbicide pollution or environmental effects.

g. Analytical Procedures: See Appendix J.

TABLE III-3 TCDD RESULTS
 EPA LABORATORY, BAY ST LOUIS MS AND PERRINE FL

Sample Code	Location	TCDD Detection Limit (PPT)	Remarks
1	East of North Island - Inside Reef	0.10	ND
2	Distillation Plant Intake	0.11	ND
3	North Shore	0.14	ND
4	Garbage Chute - 10 yds from shore	0.15	ND
5	Sea Turtle Area	0.23	ND
6	Northwest of Herbicide Area	0.31	ND
7	East End of Runway	0.37	ND
8	West of Herbicide Area - Shoreline	0.60	16% Recovery, ND
15	1.2 Miles Northwest of North Island Outside Reef	0.19	ND
10	Salt Water Reservoir	0.85	14% Recovery, ND
11	Distillation Unit Discharge	0.27	ND
12	Potable Water Reservoir	0.16	ND
13	Dining Hall (Sink Tap)	0.20	ND
14	Distillation Unit Brine	0.23	ND
17	JOC Bldg (Sink Tap)	0.26	ND
9	Well Hole - Center Herbicide Area	0.37	ND
16	Well Hole West Side Herbicide Area	0.24	ND
8	Sediment	-	Contained contaminant
I	Sediment	1.7	ND
II	Sediment	0.88	ND

TABLE III-4 WATER SAMPLE ANALYSES RESULTS (EHL(M))

General Location	Sample #	Specific Location	Analyses Results, ng/l				
			2,4-D		2,4,5-T		Aroclor 700*
			Ester 200*	Acid 100*	Ester 50*	Acid 20*	
OCEAN SAMPLES	1	East of North Island - Inside Reef (Control Sample)	ND**	ND	ND	ND	ND
	2	Distillation Plant Intake	ND	ND	ND	ND	ND
	3	North Shore	ND	-***	ND	-	ND
	4	Garbage Chute - 10 yds from shore	ND	ND	ND	ND	ND
	5	Sea Turtle Area	ND	ND	ND	ND	ND
	6	Northwest of Herbicide Area	ND	ND	ND	ND	ND
	7	East End of Runway	ND	ND	ND	ND	ND
	8	West of Herbicide Area - Shoreline	ND	1170	ND	910	ND
	15	~1.2 Miles Northwest of North Island Outside Reef (Control Sample)	ND	ND	ND	ND	ND
POTABLE WATER	10	Salt Water Reservoir	ND	ND	ND	ND	ND
	11	Distillation Unit Discharge (Sample Tap)	ND	ND	ND	ND	ND
	12	Potable Water Reservoir	ND	ND	ND	ND	900
	13	Dining Hall (Sink Tap)	ND	ND	ND	ND	700
	14	Distillation Unit Brine	ND	ND	ND	ND	900
	17	JOC Bldg (Sink Tap)	ND	ND	ND	ND	900
TEST WELLS	9	Well Hole - Center of Herbicide Area	ND	44,000	ND	1,200	ND
	16	Well Hole - West Side of Herbicide Area	ND	77,000	ND	3,600	ND

*Detection Limits, ng/l

**Less than the detectable limit

***Analyses not accomplished

TABLE III-5 TCDD RESULTS
 EPA LABORATORY, BAY ST LOUIS MS AND PERRINE FL

<u>Johnston Island Collection Area</u>	<u>Specimen</u>	<u>TCDD Detection Limit (ppt)</u>	<u>TCDD Concentration (ppt)</u>
I-A	White-Tipped Reef Shark Liver	56	ND
I-A	White-Tipped Reef Shark Muscle	9.5	ND
I-B	Moray Eel	6.0	ND
I-C	Sand Eel	3.7	ND
I-F	Surgeon Fish	8.7	ND
I-G	Squirrel Fish	20.1	ND
I-H	Parrot Fish	78.7	ND
I-I	Sea Cucumber	1.9	2.2
I-J	Mushroom Coral	-	Contaminated Extract
I-K	Staghorn Coral	-	Contaminated Extract
I-L	Algae #1	1100	ND
II-F	Surgeon Fish	14.3	ND
II-G	Squirrel Fish	29.7	ND
II-H	Parrot Fish	27.4	ND
II-I	Sea Cucumber	1.3	ND
II-K	Staghorn Coral	-	Contaminated Extract
II-L	Algae #1	7.1	ND
II-M	Algae #2	13.1	ND
III-A	Grey Reef Shark Liver	9.3	ND
III-A	Grey Reef Shark Muscle	6.7	ND
III-D	Green Sea Turtle Liver	4.0	ND
III-D	Green Sea Turtle Muscle	8.7	ND
III-E	Surgeon Fish	5.0	ND
III-G	Squirrel Fish	2.2	ND
III-J	Mushroom Coral	-	Contaminated Extract
III-N	Algae #3	8.3	ND

TABLE III-6 RESULTS OF BIOLOGICAL AND
SEDIMENT SAMPLE ANALYSES BY EHL(K)*

<u>Johnston Island Collection Area</u>	<u>Specimen</u>	<u>2,4-D</u>	<u>2,4,5-T</u>	<u>Detection Limit Microgram/Kg</u>
I-A	Shark Liver	N.D.	N.D.	0.25
I-A	Shark Muscle	N.D.	N.D.	0.33
I-B	Moray Eel	N.D.	N.D.	0.15
A-I-C	Sand Eel	N.D.	N.D.	2.00
I-F	Surgeon Fish	N.D.	N.D.	2.00
I-G	Squirrel Fish	N.D.	N.D.	0.67
I-H	Parrot Fish	N.D.	N.D.	0.67
I-I	Sea Cucumber	N.D.	N.D.	0.20
I-J	Mushroom (Razor) Coral	N.D.	N.D.	0.07
I-K	Staghorn Coral	N.D.	N.D.	0.10
I-L	Algae Species #1(Blue Green)	N.D.	N.D.	1.00
II-F	Surgeon Fish	N.D.	N.D.	2.00
II-G	Squirrel Fish	N.D.	N.D.	0.67
II-H	Parrot Fish	N.D.	N.D.	0.40
II-I	Sea Cucumber	N.D.	N.D.	0.67
II-K	Staghorn Coral	N.D.	N.D.	0.04
II-L	Algae Species #1(Blue Green)	N.D.	N.D.	1.00
II-M	Algae Species #2	N.D.	N.D.	1.00
III-A	Grey Reef Shark Liver	N.D.	N.D.	0.50
III-A	Grey Reef Shark Muscle	N.D.	N.D.	1.00
III-D	Green Sea Turtle Liver	N.D.	N.D.	1.00
III-U	Green Sea Turtle Muscle	N.D.	N.D.	0.50
III-E	Surgeon Fish	N.D.	N.D.	0.67
III-G	Squirrel Fish	N.D.	N.D.	1.00
III-J	Mushroom (Razor) Coral	N.D.	N.D.	0.07
III-N	Algae Species #3 (Green)	N.D.	N.D.	1.00
#8	Sediment	N.D.	N.D.	5.00
I	Sediment	N.D.	N.D.	5.00
II	Sediment	N.D.	N.D.	5.00

N.D. - None Detected

*Samples were analyzed for the components of Orange herbicide by Gas Chromatography with Electron Capture detector. Two columns of different polarity were used. Fifteen of the 29 samples analyzed were found to be suspect since they had peaks with the same relative retention time, on both columns, as the methyl esters of 2,4-D and 2,4,5-T. These samples required confirmation of the compounds. The fifteen samples were then analyzed by Gas Chromatography/Mass Spectrometry. The suspected compounds were not confirmed by this technique. Therefore, it was concluded that Orange herbicide was not present in any samples.

2. MOVEMENT: The present Orange storage site is on the northwest corner of Johnston Island, and from a meteorology standpoint, the incineration facility should be sited at the same location (dominant east to west wind). There will be a potential for admittance of Orange into the ocean at this location due to accidents resulting in spillage during handling and transfer of the Orange for incineration. However, stringent precautions to prevent accidental spillage and to contain any such spillage will be accomplished. The determination of a location for the programmed long term discharge of scrubber water in the ocean was evaluated to demonstrate the environmental impact of the scrubber water. Selection of a suitable location is complicated by the difference in ocean water circulation and turbid water outflows from Johnston Island. The most detailed work on water patterns in and around the reef complex at Johnston Island has been accomplished by Kopenski and Wennekens (1965). Most of the information to follow is from this reference; the Smithsonian Report, Appendix A, also includes a summary of Kopenski-Wennekens report. During the study by Kopenski and Wennekens, the investigators were able to utilize turbid water, caused by current and wave action on the island's coral shore, as a tracer. Observation of turbid water, documented by aerial photography, was utilized in both the winter and summer surveys to show the transport of turbid water from the island's environment to the main ocean. In addition, parachute drogues, current meters, and dye studies were also conducted. Johnston Island is a projection of a shallow platform (80 square nautical miles) which is nearly submerged. This shallow platform is a truncated portion of a submarine mountain. A reef and extensive coral shoals occupy most of the northwestern section of the platform. The island is located in the Northwest Trade Belt and is in the North Equatorial Current. The above stated natural geographical factors disrupt the ocean's flow, and the extensions to Johnston Island and the dredging of ship channels have had an affect on the local (island's) flow patterns. In addition, the flow is dependent upon: tidal currents, wave-driven flow over the reef, and the North Pacific Equatorial Current, which during the Kopenski-Wennekens study was fairly strong and steady from the east in the winter but weak and variable in the summer. The flow patterns about Johnston Island for these conditions are shown in Figures III-3, 4, and 5, which were taken from the Kopenski-Wennekens Report. Inspection of these figures reveals that the Orange storage site is generally satisfactorily located as regards water transport of any Orange which may be accidentally spilled into the ocean at the site. Transport is to the south from the west ship channel in both the Winter Survey, Figure III-3 and the Summer Survey - Easterly Flow, Figure III-4. Transport is to the north with the outlet through the reef cut for the Summer Survey - Westerly Flow, Figure III-5. It is this summer flow condition that is responsible for the sluggish action of sanitary sewage discharge commented on in the referenced report. The summer fluctuation is due to tides which occur twice daily and therefore increase the residence time of water in the lagoon on the north side of the island. Transport from the lagoon to the ocean is therefore greater in the winter than in the summer. Under the three flow conditions shown, the west reef below the reef cut is the primary reef area affected by the turbidity transport, and this turbidity has already had a detrimental effect upon the reef (Brock, et al, 1965).

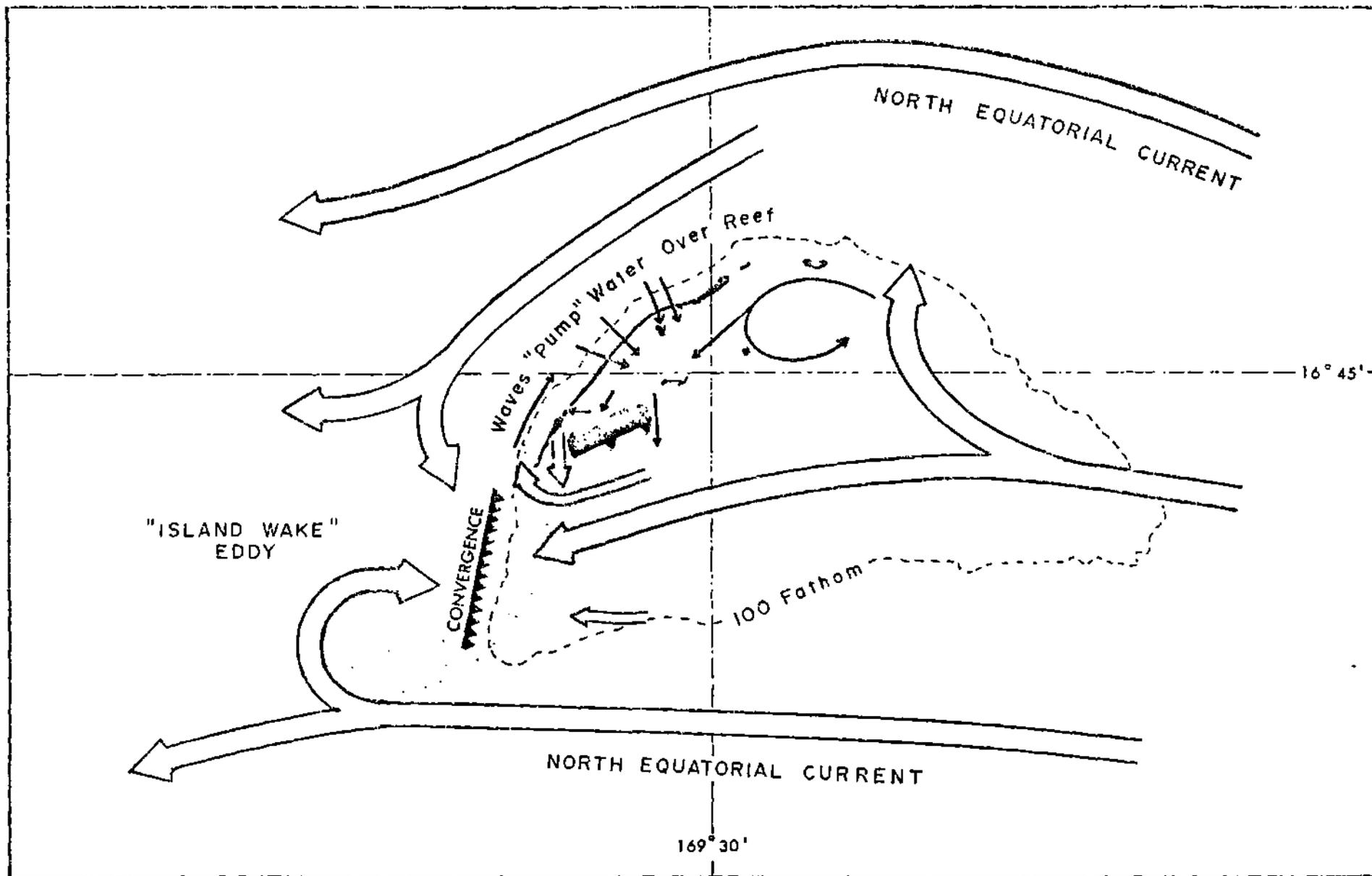


FIGURE III-3 JOHNSTON ISLAND-INFERRED CIRCULATION, JANUARY-FEBRUARY 1965
(KOPENSKI AND WENNEKENS 1965)

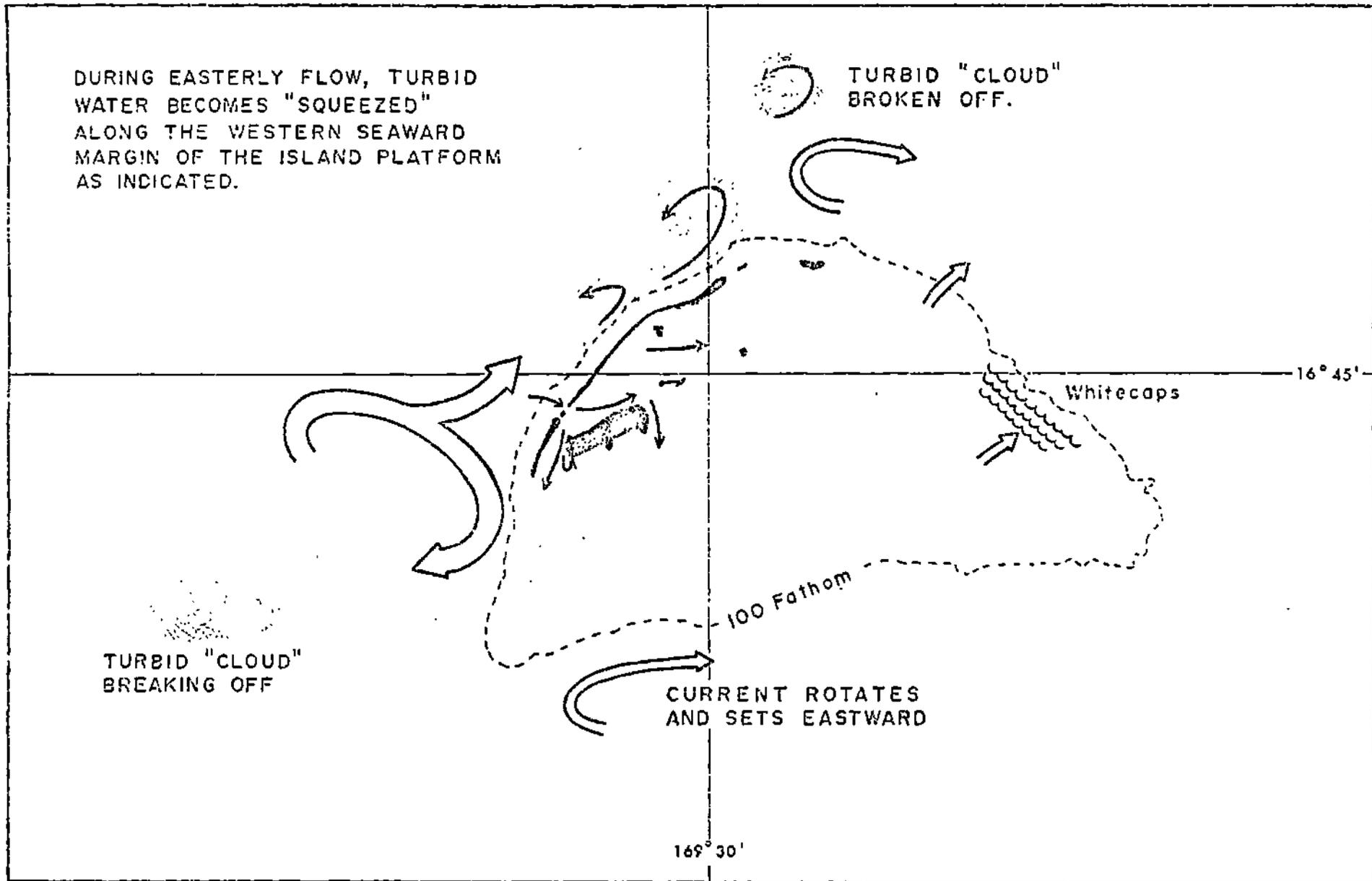


FIGURE III- 4 . JOHNSTON ISLAND-EASTERLY FLOW, INFERRED CIRCULATION AND TURBID OUTFLOW, JULY-AUGUST 1965
(KOPENSKI AND WENNEKENS 1965)

DURING WESTERLY FLOW, TURBID WATER
IS TRANSPORTED TO THE WEST AND
SOUTHWEST AS INDICATED

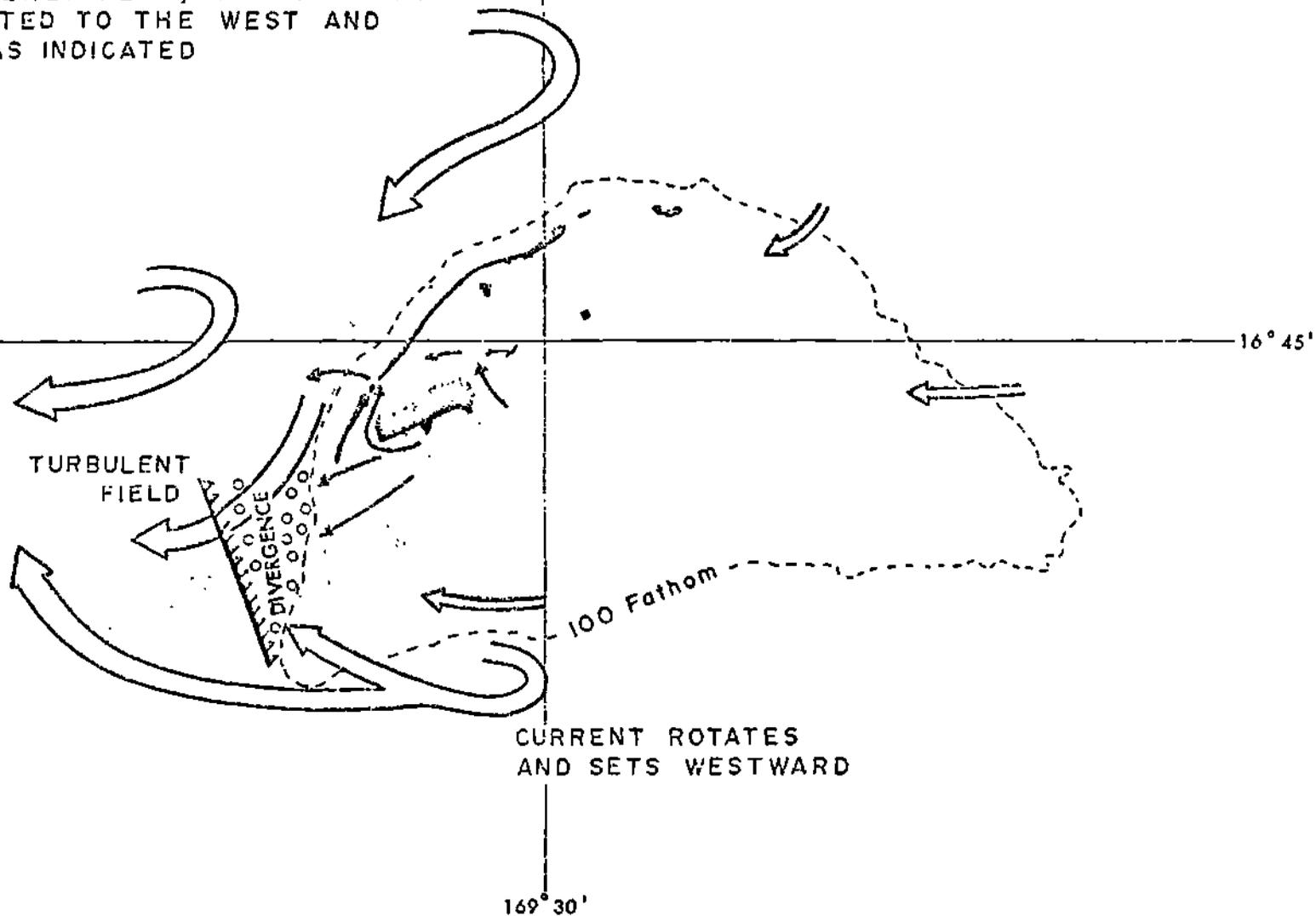


FIGURE III-5 JOHNSTON ISLAND-WESTERLY FLOW, INFERRED CIRCULATION AND TURBID OUTFLOW, JULY-AUGUST 1965
(KOPENSKI AND WENNEKENS 1965)

3. PERSISTENCE

a. General: The composition of the liquid discharge from an incinerator operation may include sodium chloride, calcium chloride, hydrogen chloride, particulates (primarily elemental carbon), chloride residual, hydrocarbons (uncombusted or partially combusted Orange) and heat. Excluding the hydrocarbons, only the particulates represents a material which is persistent or which will not be dissipated by the receiving water. Essentially complete destruction of the herbicide and TCDD is anticipated in the combustion process; however, for the sake of completeness, the interactions of this material with the water environment is discussed. Any herbicide which enters the ocean would be subject to various phenomena including: hydrolysis, photodecomposition, sorption, and biodegradation.

b. Hydrolysis: The herbicide esters are hydrolyzed to 2,4-D and 2,4,5-T acid and butyl alcohol when subjected to aqueous alkaline conditions; the acid is obtained as its salt and can be liberated by the addition of mineral acid. The ester and acid are not soluble in water, but the salt is water soluble. Aly and Faust (1964), in a study on the fate of 2,4-D and ester derivatives in natural surface waters, have found the solubility of the calcium and magnesium salts of 2,4-D in distilled water at 25°C to be 4,000 and 1,000 mg/l respectively. An alkaline scrubber using sodium or calcium hydroxide would readily convert very low concentration of ester in the combustion gases (should they occur) to the sodium or calcium salts. Smith (1972) found the hydrolysis of 2,4-D ester to be extremely fast in a 0.1N sodium hydroxide solution - greater than 50 percent of the ester being hydrolyzed in less than one minute, and negligible hydrolysis was noted in distilled water over a five-hour period. The Environmental Health Laboratory, Kelly AFB, is presently conducting studies in the hydrolysis of Orange herbicide in aqueous sodium hydroxide solutions and in ocean water. Preliminary data analysis indicates good comparison with Smith's results for the hydroxide solutions, and for the ocean water studies, 90% of the Orange esters were hydrolyzed within 7 days.

c. Photodecomposition: The phenomena of photodecomposition of 2,4-D has been studied by several investigators. Crosby and Tutass (1966) conducted an experimental study to compare the effect of sunlight on aqueous 2,4-D solutions and to identify any major decomposition products. They concluded:

"2,4-D acid decomposes rapidly in the presence of water and ultra-violet light. This decomposition results in the formation of 2,4-dichlorophenol, 4-chlorocatechol, 2-hydroxy-4-chlorophenoxyacetic acid, 1,2,4-benzenetriol, and, finally, polymeric humic acids. The results with artificial light and with sunlight are essentially identical."

In tests under field conditions, Penfound and Minyard (1947) investigated the relationship of light intensity to the effect of the herbicide on water hyacinth and kidney bean and observed more necrosis and greater epinasty in shaded plants than in those in sunlight. TCDD is known to be photosensitive in alcohol to the extent that analytical standards are protected from sunlight by storage in amber glass. Crosby, et al. (1971) stated as a result of

experiments "Abstract. The toxic herbicide impurity 2,3,7,8-tetrachlorodibenzo-p-dioxin and its homologs decomposed rapidly in alcohol under artificial light and natural sunlight, the rate of decomposition depending upon the degree of chlorination. However, photodecomposition was negligible in aqueous suspensions and on wet or dry soil," (Emphasis added).

d. Sorption: Aly and Faust (1973) performed studies on the sorption of 2,4-D ester and sodium salt on three clay minerals, bentonite, illite, and kaolinite; the amounts sorbed were 0.02 to 0.14 mg per gram which was considered to be small and insignificant. The primary cause of turbidity in the ocean near Johnston Island is the coral which is eroded from the shore. Dry coral is a very good absorber of Orange and handling procedures call for the absorption of spilled Orange with coral or calcium carbonate. No data are available on the release of herbicide from contaminated coral particles which may enter the ocean, nor on the absorption/adsorption of herbicide salts or acids which may be in the ocean water.

e. Biological Degradation: Aly and Faust (1964) performed studies on the biological degradation of 2,4-D compounds in lake waters and in bottom muds. 2,4-D ester concentrations of 50 mg/l were placed in biochemical oxygen demand (BOD) dilution water seeded with 5% settled sewage. Oxygen utilization exceeded that of the control, but each ester concentration was not changed after nine days, suggesting biological hydrolysis into the free 2,4-D acid and corresponding alcohol. The oxygen uptake was attributed to biodegradation of the alcohol moieties. Concentrations of 2,4-D sodium salts at 20, 80 and 150 mg/l were prepared in 50 and 100 percent solutions of settled domestic sewage and oxygen uptake measured over nine days. The oxygen uptake was not different from the control, and no biodegradation of the 2,4-D was concluded. In lake water studies, solutions of 3 mg/l of 2,4-D sodium salt prepared at various pH's and aerated over a period of 120 days showed no change in the original 2,4-D concentration. In lake mud studies, initial concentrations of 2,4-D of 20 to 30 mg/l were decomposed biologically from 81 to 85 percent within 24 hours, but only after extensive microbial adaptation techniques. No data are available on biological degradation in sea water but based on the above it is not felt that such action would be significant in very low concentrations in the ocean environment.

f. Summary: The phenomena discussed above would tend to indicate that small amounts of herbicide esters discharged to the ocean would be hydrolyzed and exist as the water soluble sodium salt. This compound would be considered persistent because of the lack of removal mechanisms except for photodecomposition. The persistence of TCDD in the ocean cannot be accurately predicted. Baughman and Meselson (1973) have reported TCDD concentrations in fish and shellfish collected in 1970 in Viet Nam from the Dong Hai and Saigon Rivers and along the Can Guo Coast. The Vietnamese fish contained from 18 to 814 ppt TCDD, and a Cape Cod butterfish used for comparison contained not more than 3 ppt TCDD. The rivers from which the samples were collected drained areas on which 45,000 tons of Orange were sprayed between 1962 and 1970. This information is more appropriate to a discussion of biological sampling and analyses for TCDD; however, it attests indirectly to the persistence of TCDD in an aquatic ecosystem.

4. MONITORING METHODOLOGY: Monitoring of the water environment around Johnston Island can be readily and accurately accomplished. The water sampling program would consist of periodic grab samples. Grab samples collected by authorized personnel in specially prepared glass containers with teflon-lined lids are preferred over a continuous sampler arrangement. Samples can be collected along any of the shoreline of Johnston Island, and throughout the lagoon utilizing a motorized catamaran platform. Scuba divers are available on Johnston Island for sample collection within the water column. In addition to water samples, sediment samples, high food chain predators, reef and shoreline scavengers, bottom feeders (sea cucumbers), algae and coral can be readily sampled. Ocean water samples can also be collected beyond the reef, in a limited range, by a vessel which is located at Johnston Island. The rationale for selection of the location of the sampling points would include consideration of: storage and incinerator location, outfall location and ocean currents, impact on the reef and its community, and the island drinking water supply. The analysis of these samples would be performed by approved analytical chemistry procedures utilizing extraction techniques and gas chromatography-mass spectrometer instrumentation (Appendix J).

5. ENVIRONMENTAL IMPACT

a. General

(1) The environmental impact on the water environment will be discussed for the proposed action and the principal alternative described in Part II. Incineration on Johnston Island will be discussed in terms of no combustion gas scrubber; however, an alkaline scrubber and a sea water scrubber are discussed for completeness and to demonstrate the potential for impact due to any scrubber water discharge. For either incineration at sea or incineration on Johnston Island, the destruction of the herbicide and TCDD will be essentially complete as a result of the incineration process. Quality control and failsafe procedures are incorporated into both cases to insure that the Orange is incinerated only under optimal conditions. Since either action involves activities at Johnston Island, the impact upon the island's water supply (lagoon) and the fringing reef is of paramount importance. In this regard, either the proposed action, or the principal alternative which does not include combustion gas treatment, are favorable since neither includes the discharge of scrubber water to the ocean. Of the two, incineration at sea is most favorable since there is literally no chance of impact upon the Johnston Island environment as a result of the incineration process. Potential impact on the island's drinking water supply from the shipboard method is limited to any accidental spillage while loading Orange on the ship for subsequent incineration at sea. This possibility will be remote because stringent precautions will be taken to preclude any accidental spillage. Incineration on Johnston Island has potential for the combustion gas plume to impact on the waters just west of the island. If either alkali or sea water scrubbers were used, the spent scrubber waters would discharge into the water environment. This scrubbing would also include major expenses in treatment unit, chemical procurement, shipment, handling and the ocean outfall. In the analyses that follows there is no consideration for TCDD because, even if it were present in the combustion gases, its concentration would be at least an order of magnitude below its typical detectable limits of 0.2 nanograms/l. As for the possibility of bioaccumulation of TCDD, incineration at sea would be the better option in that if bioaccumulation does occur, the possibility of occurrence would be slight in the sparsely populated ecosystem of the open tropical sea. At Johnston Island, no evidence of bioaccumulation was revealed during the ecological survey previously discussed.

(2) As noted under Part II.D. Failsafe, it is possible to dump the waste cargo if the safety of the crew/vessel is threatened. Also, the possibility of the vessel's sinking while loaded with waste is an environmental as well as personnel concern. Both of these contingencies were considered early in the planning for incineration at sea, and the low probability of occurrence was acceptable when compared with other positive aspects of this proposed action. The vessel has been approved by the U.S. Coast Guard for operations from U.S. ports and will follow all applicable maritime regulations. The vessel has operated for about two years without encountering a situation which required cargo jettison. The loading and conveyance via barge or ship of toxic or ecologically harmful cargo (chlorine, petroleum, fertilizer, etc.) is a normal occurrence. Quantification of the impact of cargo jettison or ship sinkage is not prudent because of the many assumptions required. Such an event in the harbor at Gulfport or at Johnston Island would present a very grave situation as regards environmental

resources. At Johnston Island, the island's water supply (ocean water for distillation), portions of the fringing reef and the biological reef communities would be very adversely affected. Cargo jettison or vessel sinkage in the open tropical ocean is not anticipated to be environmentally disastrous. Any effects would be generally localized and not persistent. The tremendous dilution afforded by the ocean, the physical chemical properties of Orange, i.e. hydrolysis to the less toxic acid, settling due to specific gravity and insolubility, biodegradation and photodecomposition of residual concentration would all tend to reduce the hazard of a large scale release of Orange into the ocean. It is noted that the Orange herbicide stock on Johnston Island was transported there via vessel and that the Orange in Gulfport would be transported to Johnston Island by vessel if the incineration occurred on Johnston Island.

b. Incineration at Sea

(1) Potential for Impact

(a) Evaluation of the environmental impact of incineration of Orange herbicide at sea requires the consideration of six major emission components: 1) unburned or pyrolyzates of Orange herbicide, 2) hydrogen chloride, 3) particulate carbon, 4) carbon monoxide, 5) carbon dioxide, and 6) heat.

(b) In order to calculate the quantities of these materials emitted to the atmosphere and ocean during incineration, a set of "worst case" conditions was established, and emission/dilution values were determined. Based on technical literature concerning the operation of the incinerator ship, an incineration efficiency of 99.9 percent for chlorinated hydrocarbon chemicals was used in these calculations. For perspective, the analyses was also accomplished for incinerator efficiencies of 99.0 and 95.0 percent. The service speed of the ship is 13 knots, but in these calculations a figure of 10 knots was used. The average monthly wind velocity in the vicinity of Johnston Atoll is 15 mph (13 knots), although the calculations used a condition of calm, with the combustion gas plume dispersing directly behind the ship and the plume dispersing to no greater width than the 14.4 meter beam of the ship. Ocean currents were not added to the dispersive forces in the following computations, although mass water movement would certainly play a positive role in the total dilution of the incinerative emissions contacting the water. An effective mixing depth of two meters was assumed for these calculations. This depth was an estimated figure that attempts to include such factors as mixing in the wake of the ship, chemical interaction of emission products with sea water, and the possible effects of toxic products on marine organisms, especially phytoplankton, which are the most prevalent life form.

(c) The biological aspects of the open sea require further discussion because these waters are generally poor in nutrients, and therefore the marine life (from plankton through the food web to large fish and mammals) is scarce when compared to that found in coastal areas or near localized upwellings due to islands. This lack of nutrients, and therefore, lack of productivity, is compounded in tropical/subtropical seas where vertical mixing of water due to seasonal changes is minimal. The clear waters of the tropical

ocean will thus contain relatively small amounts of phytoplankton per unit volume, but these populations may occur to a depth of 100 meters due to light penetration (Kinne, 1970). Similarly, most phytoplankton are not found at the surface of the water, but are located at variable depths, dependent on their specific limitations and requirements regarding light wave lengths, temperature and other physical/chemical factors. Thus, incinerative emissions from the ship which interface with the water will require some degree of mixing to establish substantial contact with the marine biota. However, the greater the amount of mixing, the greater the dilution and hydrolysis of chemical compounds. Therefore, the compromise figure of a two meter mixing depth is quite conservative for dilution and toxicity calculations.

(d) The beneficial uses of the open sea are generally limited to commercial fishing, and this utilization is even more limited in tropical/subtropical latitudes due in large part to the low primary productivity discussed above. The only major ecosystems that have lower gross per unit area primary productivity than the open ocean are desert and tundra (Odum, 1971). Therefore, the only commercially important organisms that might occur in the vicinity of the ship during the incineration process would be scattered unpredictable populations of transient biota. As will be discussed below in paragraph (2)(a), even the oxygen production of the phytoplankton community should not be impaired by the incinerative emissions.

(e) Included in Appendix N is a report prepared by the Center of Biological Studies and Research and of Oceanographic Medicine, Nice, France on "Effect on the Marine Environment of the Combustion at Sea of Some Industrial Waste." The objective of the study was to obtain data on environmental aspects during incinerator ship operations in the North Sea and then to make judgments on the effects of such operation in the Mediterranean Sea. The data acquisition was environmental in nature and did not include monitoring of the incineration process directly (stack samples). This study was of short duration but quite comprehensive. Areas of study include: smoke plume effects, pH, salinity, plankton, toxicity tests (for combustion gas collected 5 meters from the incinerator stack), food chain test and chemical and biological analyses. A conclusion of the report is: "In the present state of our knowledge, it seems that the process of incineration does not cause, certainly not short term, any special harm to the oceanic environment". This conclusion is conditional in that it may not hold for the long term and is only for the specific waste being incinerated. While the wastes incinerated were not Orange herbicide, the satisfactory results obtained certainly support the case for incineration of Orange at sea.

(2) Probable Impact

(a) Application of the above set of "worst case" conditions to an evaluation of the impact of the unburned or pyrolyzates of herbicide on the marine environment yields the following results. An incinerative efficiency of 99.9 percent allows 0.576 ton of herbicide to escape the stacks per day (24 hour incineration day) (5.76 tons at 99.0% and 28.8 tons at 95.0%). The speed of the ship as discussed would be 10 knots or 18.5 km/hour, producing a dispersal distance in one dimension of 444 km (444,000 meters) per day. The minimal

lateral dispersal as discussed would be 14.4 meters, and the mixing depth is calculated as two meters. The volume of the dispersion zone, on a daily basis, is 12.6×10^6 cubic meters. Complete mixing of the 0.576 ton of unburned herbicide produces an average concentration of 0.041 mg/l in the sea water mixing zone (0.41 mg/l at 99.0% and 2.05 mg/l at 95.0%). Walsh (1972) found that oxygen production in four species of marine algae was decreased by 50 percent when the algae were exposed for a period of 90 minutes to 50-60 ppm of the technical acid of 2,4-D (author's terminology), 100-200 ppm of the butoxy-ethanol ester of 2,4-D, and 50-150 ppm of the technical acid of 2,4,5-T. Walsh found very similar results when measuring the effects of the same herbicides on the growth rates of the four algal species. Algal bioassays at the USAF Environmental Health Laboratory at Kelly AFB similarly showed Orange herbicide to inhibit growth at concentrations of 50-100 mg/l. Comparison of bioassay results with the above emission calculation for 99.9 percent incinerative efficiency illustrates that under "worst case" conditions there will exist a safety factor of three orders of magnitude before moderate toxicity effects would occur in the phytoplankton populations. (Reference Part II.F.4. of this statement for further toxicity data and literature.) In several of the referenced cases, Orange herbicide or its components showed greater toxicity (1-10 ppm) to organisms other than phytoplankton; however, the small floating plants of the euphotic zone were chosen for detailed discussion due to their much greater likelihood of exposure to any unburned herbicide fraction. Regardless of the organisms chosen for sensitivity studies, the safety factor involved continues to be at least 2-3 orders of magnitude with a 99.9 percent efficiency of incineration. It must be emphasized that "worst case" analyses is very extreme in that all of exhaust stack emission is considered to be transferred to the ocean directly behind the vessel and mixed to a depth of only two meters. In reality, it is expected that some of the unburned Orange would remain airborne for a considerable time period and that the ocean mixing zone would be much greater than that selected. Therefore, it is felt that even the concentration of unburned as pyrolyzates of herbicide after a 95.0 percent incinerative efficiency would be acceptable, particularly in view of the short duration of the incineration period.

(b) Hydrogen chloride production and discharge rate from the ship will be about 178 ton/day. Assuming this total daily amount enters the ocean, an average concentration of 12.8 mg hydrogen chloride would be added to each liter of sea water in the previously defined mixing zone. The pH excursion resulting from the addition of this amount of hydrogen chloride to sea water was calculated to be not greater than 0.5 pH units. This calculation was based on buffer capacity equations in which the carbonate system was the primary buffer. The predicted results were confirmed in the laboratory by the addition of hydrochloric acid to sea water. Any transitory effects produced by the hydrogen chloride emission should have very little disturbance on planktonic organisms and certainly no long-term effect on these populations.

(c) Calculation of particulate carbon emissions was based on about 0.5 percent of the incinerated herbicide going to the carbon form. An estimated 3.0 ton/day of carbon would be produced in this process, with an average concentration of 0.22 mg/l in the ocean mixing zone. The carbon emissions should produce no detrimental effect on the ocean environment.

(d) Carbon monoxide and carbon dioxide mass emissions to the atmosphere were calculated/estimated to be about 50 and 1000 tons per day, respectively. While these compounds are major combustion products, their mass emissions should produce no environmentally detrimental effect.

(e) Heat production from the ship incineration process was calculated on the basis of a caloric value of 10,000 BTU per pound of undiluted herbicide. A daily amount of heat equal to 1.15×10^{10} BTU will be produced during incineration. The emission of heat can be considered in a similar context with particulate carbon and carbon dioxide (as well as the water produced by hydrocarbon combustion); i.e., these products are major components of the combustion of standard ship fuel oils. Thus, in terms of the environmental impact of these inorganic products, the ship can simply be considered to have two additional engine exhaust plumes for the duration of the incineration period.

(3) Environmental Monitoring at Sea: The above discussion of environmental impact indicates a very minimal and transient effect resulting from the shipboard incineration of Orange herbicide on the open tropical sea. The "worst case" analysis is quite conservative, and realistic incorporation of normal wind and ocean current dispersal factors will further reduce even these minimal environmental effects. In view of these facts, and the short duration and nature of the proposed operation, off-ship environmental monitoring of the ocean and air is considered unnecessary and lacking feasibility to adequately detect any transient environmental changes that may occur.

c. Principal Alternative - Incineration at Johnston Island

(1) No Combustion Gas Treatment: The remote location on Johnston Island and its meteorology indicates that the discharge of untreated combustion gases directly into the atmosphere would not result in any irreversible detrimental environmental impact to the air environment, see Part III. B. The immediate Johnston Island environment is the major concern and meteorological constraints may be required to insure that Johnston Island, the atoll, and the other islands are not affected due to changes in the normal weather pattern. There is a fringing reef to the west of Johnston Island, and this reef has been seriously damaged by turbidity from past dredging operations and continues to be affected by turbidity from erosion of the island's shoreline. Although the condition of the west reef would appear to be of the least significance to the maintenance of the atoll, it is imperative that the reef not be further degraded by fallout of constituents of the stack gas.

(a) Potentials for Impact: The constituents of concern as regards deposition from the stack plume, and reaction at the plume/ocean interface are unburned Orange and pyrolyzates, hydrogen chloride, and particulates. For the analyses that follows, the daily discharge rates are 1.2 pounds of unburned Orange and pyrolyzates, 18.5 tons of hydrogen chloride and 0.3 tons of particulates. The above discharge rate for the unburned Orange and pyrolyzates is approximately 3 times greater than that reported in Appendix E, in which the Orange constituents were undetectable and reported as less than 0.00095 pounds per day, and the pyrolyzates are 0.387 pounds per day.

(b) Probable Impact: This discussion is in two parts, impact upon the open ocean and impact upon the lagoon (primarily as related to interference with the development of the reef).

1. Open Ocean: As a "worst case" situation, it is assumed that the entire mass of each of the above combustion gas constituents is deposited onto a very small area of the ocean surface. The area has been selected to be plume shaped with a major axis of 1,000 feet and a minor axis of 100 feet. The mixing depth is conservatively estimated to be six feet, thus providing about 300 thousand cubic feet as a mixing zone. It is further assumed that ocean current in this impact area is 0.5 knots and that this condition would provide for the mixing zone to be replenished about 72 times per day. Therefore, an effective mixing volume of about 21.6 million cubic feet of ocean water can be considered to receive the deposition/reaction of the constituents of the plume. The average daily mass concentration of the unburned Orange and pyrolyzate, the hydrogen chloride, and the particulates in deep ocean water would be 0.0009 mg/l, 28 mg/l, and 0.45 mg/l, respectively. From a comparison of these concentrations with the concentrations and predicted effects on the ocean discussed under the proposed action, it is concluded that the discharge of the combustion gases into the atmosphere with resultant deposition on the open ocean surface would not cause any detrimental environmental impact in the water environment.

2. Reef Area: The major concern of this analysis is the impact of hydrogen chloride deposition on the pH of ocean water in the reef area and thus on possible inhibition of the deposition/precipitation of calcium carbonate by the reef community. The discussion will consist of a comparison of two approaches to "worst case" analysis of this discharge with a format as follows: Case 1 - assume a "worst case" deposition (that is, deposition of the entire discharge) in the general area of the reef, calculate the resulting concentration of hydrogen chloride, and comment on the significance of this calculated concentration; Case 2 - predict (utilizing the meteorological model, Appendix K) the mass of hydrogen chloride which is present in the atmosphere above the reef impact area, and comment on the significance of the deposition of the entire predicted mass.

a. Case 1: Entire Discharge-Reef Area: It is assumed that the entire daily hydrogen chloride discharge is deposited into the ocean over a square area (0.25 sq. mile) with the reef running through the center of the area. For a mixing depth of 1 meter (based on depth at the edge of the reef), the average additional concentration of hydrogen chloride from the stack discharge would be about 26 mg/l per day. The water in the impact zone is not stagnant, as assumed in the above calculation. The current can be conservatively estimated at 0.1 knot thus providing for replacement of the water in the impact zone about five times per day. This replacement factor would adjust the calculated addition of hydrogen chloride to about 5 mg/l in the ocean water. This would cause a reduction of less than one-half pH unit which would be acceptable for practically any ecosystem except possibly a living reef. Although not considered in the above calculations, the natural buffer capacity of the water in the zone described is higher than normal ocean water due to the

presence of turbidity in the form of coral (calcium carbonate) which has been eroded from Johnston Island. Therefore, even under "worst case" situation, the extent of damage on an acute basis to the reef in the localized impact zone may be quite minimal. However, the damage to the reef on a chronic basis over the duration of the disposal project cannot be predicted and continuous discharge with the deposition described under this "worst case" situation would not be recommended.

b. Case 2: Predicted Discharge-Reef Area: In actuality, the deposition of hydrogen chloride in the general area of the reef will be much less than under the above "worst case" situation. The sea level concentration of hydrogen chloride below the centerline of the stack discharge plume, at points 0.25 miles inshore of the reef, at the reef, and 0.25 miles beyond the reef are predicted under "worst case" sea level conditions to be 0.78 ppm_{v/v}, 0.12 ppm_{v/v}, and 0.05 ppm_{v/v} respectively. The isopleths shown in Appendix K are for these sea level concentrations. The concentrations in the vertical direction can also be calculated. The results of the meteorological model represent a steady state solution showing the distribution of the mass of hydrogen chloride on a daily basis. The model results were applied to determine the quantity of hydrogen chloride which is present on a daily basis in the space above the impact area (0.25 sq. mile) to a height of 100 meters. This mass has been calculated to be 0.082 tons and represents 0.44 percent of the daily discharge. For determination of the average concentration within the zone, the highest level found by the meteorological model, 0.78 ppm_{v/v} was applied. This value is very conservative. If the entire predicted available mass under this "worst case" approach were deposited into the ocean impact zone (1 meter deep), the average daily concentration of hydrogen chloride would be increased by 0.12 mg/l. Application of the ocean water replacement factor of five would result in a lowering of this concentration. The pH depression in this case would be negligible and, therefore, would not cause any acute or chronic damage to the reef. Comparison of above concentrations of hydrogen chloride calculated under both Case 1 and 2 with those calculated for the "worst case" situation described under the "open ocean" above indicates that the respective values of Orange and pyrolyzates and carbon particles would not cause any significant detrimental environmental impact.

(c) Monitoring: Monitoring of the ocean area is not necessary from an environmental standpoint. Monitoring of the Johnston Atoll would be accomplished to insure that the local area was not to be affected by disposal operation.

(2) Combustion Gas Scrubbers

(a) Alkaline Scrubber

1. Potentials for Impact: The constituents of the spent scrubber water which may have an environmental effect include: heat, chlorine residue, total dissolved solids, suspended solids, and hydrocarbons. The heat and chlorine residual would constitute major pollutant loads and, therefore these constituents are to be reduced by an appropriate treatment device, i.e.

cooling tower, spray pond, etc. Such treatment would also reduce the suspended solids concentration in the discharge. The hydrocarbon content is a minor fraction of the scrubber water and the discharge rate would consist of: undetectable Orange constituents <0.00036 pounds per day, pyrolyzates and hydrolyzates at 0.021 and 0.005 pounds per day, respectively (Appendix E). The major substance in the scrubber water will be the total dissolved solids. Although not specifically addressed, the alkaline scrubber will be operated so that the pH of the spent scrubber water will be about 8.5 units.

2. Probable Impact: The spent scrubber water will be discharged to the marine environment on the south side of the island via the sanitary sewage outfall. The mass transport of the sea water and its suspended matter (turbidity) from the sewage outfall is generally to the southwest and therefore, the remainder of the island's aquatic environment is minimally involved. However, during certain conditions, summer season and easterly regional flow, sluggish circulation has been observed along the southern shore of the island. This has resulted in a long residence time and very limited mixing for the sewage discharge (Koeniski and Wennekens, 1965). The reef area which would be primarily affected by this flow situation is located on the west side of the island. The disruption and extensive silt production from the major dredging operation in the early 1960's and the characteristic of the ocean currents (high turbidity from erosion of the south side of the island) have already resulted in a depauperate reef community on the island's west shore (Brock et al., 1965). The high total dissolved solids concentration of the spent scrubber water will cause a relatively small mixing zone in the area of the discharge where the specific gravity will be adjusted. Calculations show that one million gallons of ocean water will be more than enough to adjust the specific gravity of one day's flow of spent scrubber water to a specific gravity which is essentially the same as that of the ocean. For an ocean current of 0.25 knots and a dispersal pattern 10 feet wide and 10 feet deep, approximately one million gallons of ocean water would be available to adjust the specific gravity of one hour's spent scrubber water flow (8,300 gallons). In addition, a major part of the total dissolved solids is sodium chloride ~35,800 mg/l (chloride ~22,000 mg/l), with the normal ocean chloride concentration being ~20,000 mg/l. Therefore, under the above conditions, the mixing zone should not extend farther than 3,000 feet from the outfall line. The suspended solids (80-100 mg/l), some of which may be removed in the treatment processes, represents a discharge of solids. The suspended solids are primarily elemental carbon, see Appendix E, and at a maximum of about 200 pounds per 200,000 gallons are not considered significant. The turbidity present in the Johnston Island aquatic environment, particularly south and southwest of the island, would tend to negate the impact of a wastewater discharge containing suspended solids. The minor fraction of hydrocarbons would be further diluted in the receiving water and not be significant from an environmental standpoint. The environmental impact of this alternative is minimal and would be manifested in a small mixing zone near the wastewater outfall.

3. Monitoring: This alternative is excellent from the monitoring aspect in that water, sediment, and marine biological samples in the impact area can be readily collected. The discharge occurs in the lagoon ecosystem and extensive analytical chemistry and biomonitoring of spent scrubber water prior to discharge will be required.

(b) Sea Water Scrubber

1. Potential for Impact: The constituents of the spent scrubber water which would have environmental impact include: heat, chlorine residue, hydrogen chloride (hydrochloric acid), suspended solids and a minor hydrocarbon fraction. Of primary concern are the heat, chlorine residue, and the dissolved hydrogen chloride. A daily discharge of 500,000 gallons of spent scrubber water would contain some 37,000 pounds (~1.0%) of hydrogen chloride, and have a temperature of ~160°F and a chlorine content of ~250 mg/l. The hydrocarbon content would be similar in magnitude to that stated above for the alkaline scrubber.

2. Probable Impact: Although the environmental impact of this wastewater stream could be significant, the major constituents are not considered as persistent pollutants; the heat and chlorine residual will be dissipated and the hydrochloric acid is readily absorbed in the ocean. The buffer capacity of ocean water and its regenerative natural forces make the ocean an acceptable sink for certain acids, particularly hydrochloric acid. On a mass basis, the discharge of 18.5 tons of hydrogen chloride into the ocean is insignificant; however, the impact of such a discharge on the pH in the discharge zone must be considered. Buffer calculations, using the carbonate species as the only buffer, reveal that if 75 million gallons of ocean water are mixed with one burn day's discharge that the pH excursion would be from 8.3 to 6.5 units. It is noted that the pH change will be temporary and the normal ocean pH will be rapidly established. On a mass basis, the chloride added to this volume (75 million gallons) is 58 mg/l which is of minor consequence when compared to the usual concentration of ~20,000 mg/l. The ocean water required to dissipate the heat and chlorine residual is less than that required for absorption of the hydrogen chloride. To determine a mixing zone, the rate and method of waste stream discharge and the flow of the receiving water is required. If an ocean flow of 0.25 knots and a dispersal zone of 10 feet wide by 10 feet deep is assumed, then in one hour some one million gallons of water will flow by the outfall. Since approximately three million gallons are required for neutralization of one hour's wastewater discharge, the mixing zone may extend to 6,000 feet from the discharge point. This relatively long mixing zone will require that the outfall be placed so that the acidity of the discharge does not affect the reef during the time duration of the project. The ability of the ocean to accommodate acid waste on a "slug" discharge basis has been documented. The following is from Technical Memorandum No.39, U.S. Army Corp of Engineers: "The permissible pH range for the coastal waters of New York and New Jersey, according to water quality criteria (EPA, 1972), should be from 6.5 to 8.5. The pH range observed in the vicinity of the dumping grounds of the N.Y. Bight, ranges from 7.10 to 8.40, and does not exceed the prescribed limits. The only drop in pH would be observed in the waters of the acid dumping grounds, immediately after an acid dump. The low pH value in this area would occur for brief periods. As discussed earlier, Redfield and Walford (1951) have shown that the pH of the water from the wake of an acid dumping barge was above 6.0 in all samples collected more than 3 minutes after dumping and a pH of 7 was reached about 3.5 minutes after dumping." The daily discharge of 500,000 gallons of spent scrubber water containing 18.5 tons of hydrogen chloride represents a

stream of sufficient acidity to cause certain detrimental environmental effects. In addition, the heat and chlorine residual of this stream are sufficient to cause localized detrimental effects. The suspended solids and the minor hydrocarbon fraction of the wastewater are, as previously described, not considered significant as regards environmental impact. It is imperative that this stream not be discharged into the ocean where there are beneficial uses, i.e., swimming, fishing, reefs, water supply within the mixing zone.

3. Monitoring: The discharge point would be located within the vicinity of Johnston Island, either in an area further off-shore than the present sanitary sewage discharge or in an area to the southwest of the island. In either case, ecological monitoring, primarily in the form of water samples and other samples which can be collected from a boat, can be readily accomplished within the impact zone.

D. MARINE FLORA AND FAUNA ON JOHNSTON ISLAND

1. **SCOPE OF CONSIDERATIONS:** The potential for adverse effects on marine ecosystems is greater with incineration on Johnston Island than with incineration on the open ocean. The fertile waters of the atoll yield a biomass many times greater than that of the relatively nutrient deficient open ocean. The potential effects of the incineration of Orange herbicide on both marine flora and fauna of Johnston Atoll are considered together in this section since the potential for harmful effects will originate from the same source and will concern the same areas of the underwater atoll. The distribution of fish on the atoll is divided into three zones: 1) the northern peripheral reef area, 2) the southern shoal reef area and 3) the bank or lagoon shoals. The "northern reef area" is characterized by pelagic species of fish such as the shark on the seaward side of the reef and by inshore types of fish on the lagoon side of the reef. The "southern reef area" has fewer numbers and varieties of fish. The "bank shoals" or lagoon area is characterized by large numbers of inshore types of fish. In all, 194 species of inshore fish have been identified on the atoll. Gosline (1965) classifies the Johnston Atoll fish fauna into 4 components: 1) endemics, 2) fish that have made Johnston a stopping point on their migrations north, 3) fish that have made Johnston a stopping point in their southward travels, and 4) the pelagic fish to whom Johnston is of little or no significance. Only two species of Johnston fishes have not been taken elsewhere. These are Centropyge nigriocellus and C. flammeus, both butterfly fishes; neither are abundant at Johnston. A total of 175 species of marine arthropods inhabit the lagoon water together with 37 species of Echinodermata and 18 species of Cnidaria (e.g. jellyfish, corals). Dredging operations in 1964 directly destroyed 700 acres of living coral. The silt from the operation seriously affected much larger areas of coral. A parallel reduction in the number of associated invertebrate species and fish also occurred (Amerson, 1973). A large portion of the southwestern reef was seriously affected and remains so today. The algae were also damaged by the increased silt in the dredging operation. Also, the dredging affected the distribution of the 67 benthic marine algae identified on the atoll. At least 58 species of mollusca and 12 species of annelida inhabit the atoll. The ocean currents approaching the atoll have a relatively sparse plankton population.

2. **POTENTIALS FOR IMPACT ON AQUATIC PLANTS AND ANIMALS:** It is obvious that contamination of the waters of Johnston Atoll with large amounts of Orange herbicide would result in disastrous effects upon the biota of the lagoon and reef. Thus, the storage of the herbicide and the proposed incineration site was so situated that any unenvisioned, catastrophic accident would not affect the majority of the barrier reef and lagoon. The use of a scrubber system to treat combustion gas would produce a certain localized and controlled amount of water pollution in the down-current area of the cutfall. The use of no scrubber system would be expected to affect a larger area where the exhaust gases contact the ocean. However, meteorological models, Part III, C., indicate that combustion gas components at the plume/ocean interface would be in such low concentrations that there would be minimal effect on the marine ecosystem.

3. PROBABLE ENVIRONMENTAL IMPACT ON AQUATIC PLANTS AND ANIMALS

a. Toxic Chemical and Acid-Base Effects

(1) Incomplete Combustion Products: Possible toxic chemicals from incomplete combustion would include Orange herbicide components and their pyro-

lytic products. However, the test incinerations and bioassays (see Appendix E) proved that Orange herbicide can be incinerated without the production of highly toxic effluents. Continuous analytical monitoring, biomonitoring and failsafe mechanisms described in this report will safely protect against the release of harmful toxic chemicals. Therefore, environmental effects from incomplete combustion products are not considered probable. Biomonitoring would detect very minute amounts of unoxidized herbicide.

(2) Complete Combustion Products: Environmental effects could result from the planned, efficient combustion of Orange herbicide which will produce potentially harmful corrosive gases, carbon particles, heat and a minor fraction of hydrocarbons. Two situations are considered where no treatment (scrubbing) of the gases would be used: 1) incineration on the boat would have no impact on the waters around Johnston Island, especially because of wind and distance factors, and 2) incineration on Johnston Island using no scrubber would be expected to impact on the waters west of the island in a manner quantitatively similar to that predicted for incineration at sea. The major difference between the two is the increased numbers of plants and animals in the waters on, and closely surrounding the atoll. If the saltwater scrubber were to be used, the scrubber water must be delivered into the ocean far enough beyond the reef to provide sufficient dilution in deep water and to insure that the diluted effluent does not flow back onto the reef. The alkaline scrubber system would neutralize the acidic elements' potential toxicity by conversion to their salt forms. Other treatments described earlier would remove chlorine and produce cooling of spent scrubber water. Therefore, probable environmental impact will be confined to a small, definitive mixing zone. The salinity changes would be expected to be of minimum consequence in the warm surface water which has a normal salinity between 34.6‰ and 34.8‰.

b. Thermal Pollution: The size and position of the thermal mixing zone will affect the extent of the environmental impact of thermal pollution from the incineration of Orange herbicide. Normally, the extent of a mixing zone is directly related to requirements for maintaining free passage of migrating aquatic organisms in the body of water. In contrast, the major concern for Johnston Atoll was to select a mixing area away from the lagoon and reef. The location required that currents would direct the effluent away from the atoll in the most efficient manner available. The current sewer outfall on the south side of Johnston Island would be the optimum site for the alkaline scrubber water outfall. This already-proven site would place the thermal mixing zone in an area where a mixing zone already exists and ecological alterations have already occurred. Thus, the major expected impact would be the resulting shift to more heat tolerable species of plants and animals inhabiting the mixing zone. The warm-water inshore fishes of the lagoon and migrating fishes can easily avoid the mixing zone without harmful effects from the increased warmth of the water. Since the salt water scrubber effluent would entail a much larger mixing zone, the outfall would be placed southeast of the reef. This will place the effluent mixing zone in deeper, colder water in an area where currents will direct it away from the reef. The effects of the heat should be rapidly dissipated.

c. Carbon Particle Effects: Fine carbon particles, suspended solids, in the effluent could produce damage to living coral. Suspended fine particles from earlier dredging operations and sediment-laden water from the shoals have severely affected the coral on the southwest portion of the reef. Carbon particles from the incineration operation are not expected to contact the living coral

reef. The observations made during the test burn of Orange herbicide indicate that these particles will rapidly settle out. However, the situation will have to be monitored to determine any impact on living coral. Again, the alternative salt water scrubber effluent would be placed so that currents would carry the carbon particles away from the reef. The use of no scrubber system would result in such a widespread dispersion of the particles as to be of no ecological significance.

E. TERRESTRIAL FLORA AND FAUNA

1. FLORA OF ISLANDS

a. Scope of Considerations: Terrestrial vegetation is relatively sparse on the 4 islands of Johnston Atoll. Only three species of native, vascular plants existed in 1923. However, the activities of man upon the islands have been responsible for most of the intentional or accidental introduction of 124 other species. Many species are ornamental and exist only by benefit of special care. Other introduced species or adventive types have adapted to the coral soil and climatic conditions. Damage to the terrestrial flora on Johnston Atoll, is not expected to occur due to Orange disposal.

b. Potentials for Impact

(1) Complete Combustion of Orange herbicide resulting in the production of corrosive hydrogen chloride and chlorine in the exhaust gases.

(2) Incomplete Combustion resulting in escape of unoxidized herbicide and other pyrolytic products in exhaust gases.

(3) Accidental Spills of liquid herbicide on land producing localized effects on terrestrial plants.

c. Probable Impact: No detrimental effects to terrestrial vegetation would be expected from the incineration of Orange herbicide on Johnston Island. Meteorological constraints would be utilized to insure that the effluent gases from the unscrubbed stack gases do not impact on the islands in harmful concentrations. The incinerator operation under the principal alternative would contain sufficient safeguards to protect against incomplete combustion or accidental spills. However, should even these safeguards fail and the unlikely event of an atmospheric contamination occurs, the physical position of the operation on the atoll in relation to prevailing winds would protect the flora on the four islands from atmospheric exposure.

d. Monitoring Methodology for Air Contamination: With incineration aboard ship no products of combustion would ever reach the atoll area so that monitoring will not be necessary. For the principal alternative of incineration on Johnston Island both analytical and biological monitoring for air pollution would be used. Biological monitoring using highly sensitive indicator plants would signal trace air contamination with herbicides or corrosive chemicals in time to prevent extensive damage to other plants should man-made safeguards fail.

2. FAUNA OF ISLANDS

a. Scope of Considerations: Except for man, seabirds are the most ecologically important species on the four islands of Johnston Atoll. There were originally no mammals on the islands and only one species of reptile. Man introduced the dog and cat, rodents and three species of geckos. Also, sixty-eight species of arthropods are associated with and distributed in relation to the bird populations on the islands. All the terrestrial animals on the atoll are of relatively little importance in relation to the considerations that must be given to protect the large number of seabirds that use the islands for breeding and nesting grounds. Sand Island is the major island of importance to the birds. Man's activities on the other islands limit the size of their bird populations.

b. Potentials for Impact: Exposure of the animals on the atoll's islands to atmospheric contamination from improper functioning of the incinerator could result in harmful effects related to the concentration-dose of such theoretical contamination. The noise and activity of the incineration operation could discourage seabirds' nesting activities if placed too close to the nesting areas. Damage to the birds' food supply would also be detrimental if it should occur.

c. Probable Impact: No impact on the terrestrial fauna of Johnston atoll is expected from the incineration of Orange herbicide. Any atmospheric contamination would be signaled early by indicator plant damage at concentrations low enough to forestall damaging doses to animal life should any incineration safeguard systems fail. Most certainly, incineration of the herbicide on shipboard, downwind from the atoll, poses the least chance of all of exposing the animals of the atoll to combustion gases. With the option of incineration on Johnston Island, the proposed location of the incinerator on the southwestern tip of the island is purposely positioned so that any air contaminants will be carried away from the other islands. Winds are from between northeast and east 85% of the time on the yearly average. Also, the site of the incinerator will be far enough from Sand Island to prevent any disturbance of the birds there. Sand Island is 2-1/2 nautical miles from the proposed incinerator site. The seabirds feed from the ocean in a 100 mile radius around Johnston Atoll rather than from the shallow waters of the atoll. Thus, their food supply could not be affected by the incineration operations. As noted earlier, studies with phenoxy herbicides indicate that they are not highly toxic to birds. Also, these herbicides do not accumulate in the food chain.

F. SOIL (CORAL AND SAND)

1. MOVEMENT: There are no research data on the movement of the herbicide Orange in compacted coral. However, it is known that CaCO_3 rapidly "fixes" herbicide Orange and in fact has been suggested as a chemical compound to "clean up" spills of the herbicide. Based on observations made on Johnston Island, spills of the herbicide are readily and rapidly contained. After 2,4-D, 2,4,5-T and TCDD reach the soil each moves through the biosphere and accumulates or degrades according to its own chemical and physical properties (Advisory Committee, 1971). Once the herbicides and TCDD reach the soil they become immediately subjected to physical and chemical actions that continually reduce the amount remaining at the site of application. These actions include degradation by soil microorganisms, leaching and surface movement by water, volatilization, movement by wind and photochemical decomposition (Amerson, 1973).

2. PERSISTENCE: There are no available data on the persistence of 2,4-D and 2,4,5-T in compacted coral. However, the limited diurnal and annual variation of the relatively high temperatures - annual mean of 79.3°F with daily variations of only 7-8°F - and of the high relative humidity (annual mean is 75%) (Amerson *et al.*, 1973) should favor the rapid decomposition of the herbicide. The persistence of 2,4,5-T, influenced by its rate of application, climatic conditions and other factors, occurs most rapidly under conditions that are optimal for the growth of soil bacteria (Zelinski and Fishbein, 1967). Loss of all phytotoxicity of 2,4,5-T applied to the soil was reported to occur in 3 - 6 months after application (Kearney and Negh, 1972).

G. THE ECOLOGICAL SIGNIFICANCE OF JOHNSTON ISLAND: AUTHORITATIVE OPINIONS.

Amerson (1973) states in the "Ecological Baseline Survey of Johnston Atoll, Central Pacific Ocean" that the document was reviewed by four well known ecologists in various fields. The purpose of the reviews was to assess the ecological significance of Johnston Atoll. Their opinions have been summarized as follows:

1. Ray Dasman of the International Union for Conservation of Nature states: "Because of its small size, and extreme isolation Johnston Atoll was originally of considerable ecological interest as an area in which it would have been possible to follow the slow process of colonization and establishment of species on oceanic islands and to study over the years the processes that may have led to the development of new races or species in its limited biota. The opportunity was lost with the exploitation of the island and later with its development as a naval and air base. However, human occupancy of the island followed by the introduction and establishment of many new species of plants and animals has created an equally interesting ecological situation in which the interactions among its still limited biota could profitably be studied. Such situations, however, occur on many other isolated oceanic islands, and Johnston cannot be considered as particularly unusual or of outstanding interest from this point of view."

"Considering the dry land area of Johnston Atoll, the greatest concentration of ecological interest is to be found on the remaining natural island, the ten acres of the western portion of Sand Island. This is the principal breeding area for seabirds and appears to support the most complex terrestrial biota. Sand Island is of major importance for its breeding population of Sooty Terns and of significant importance for breeding populations of Red-footed Boobies, Brown Noddies, Wedge-tailed Shearwaters and Great Frigatebirds. It is significant also as a wintering area for shorebirds, notably the Golden Plover and Ruddy Turnstone. Every effort should be made to minimize disturbance of this area in the future and to maintain it as a refuge for seabirds. With protection and freedom from disturbance its value as a seabird breeding center can be expected to increase, and it will achieve greater value as a site for ecological studies. By contrast, the ecological interest of the eastern, man-made portion of Sand Island, of Johnston Island, of Akau and of Hikina Islands is slight at the present time, although if disturbance of these areas were to be greatly reduced in the future, they would no doubt be colonized in time by breeding populations of seabirds." (Emphasis Added)

"The marine area of Johnston Atoll can be considered of equal interest to the terrestrial area. Although the marine biota has not been thoroughly studied, the inshore fish population appears to be of considerable biological interest and it is likely that further studies will reveal a higher degree of endemism than is now reported, particularly among the marine invertebrates. Considerable damage to the marine fauna has resulted from past dredging and filling operations. Future activities of this nature, when necessary, should be conducted with greater precautions to minimize damage to reef and lagoon fauna."

"Considering that Johnston Atoll may continue to be used for a variety of purposes in the future it is recommended that particular attention be given to protection of the western portion of Sand Island for the purpose of maintaining the seabird breeding colonies and their associated biota and to maintaining

the reef and lagoon biota in a healthy state, allowing for its recovery from past disturbance. Avoidance of pollution and siltation of the reef-lagoon complex should be given priority."

2. Robert E. Jenkins of The Nature Conservancy states:

"Of particular importance to Johnston Atoll is the recurring theme of its seabirds. In spite of all of the "reconstruction" which has severely changed the original natural environments in the area, there is still a tremendous seabird population using the near-shore feeding grounds or breeding--primarily on Sand Island. The information collected on these birds forms a truly impressive body of data. The monumental accomplishment of having banded over 300,000 individual birds in the course of 6 years has already added greatly to our knowledge of population dynamics, distribution, faunal exchange, site constancy, breeding systems, species composition, etc., and in the years ahead should add even more to our understanding of some important components of the oceanic system."

"There have also been fairly extensive studies made on the effect of the dramatic and pervasive human alteration of Johnston Atoll. A continuation of these studies will give us new insight into the effect of dredging on the physical and biological environment of coral reefs, the effects of greatly enlarging the terrestrial mass in the area through the creation of entirely new supraaquatic platforms from native materials, and the effects of stocking these (however haphazardly) with a large number of exotic species of plants and animals. The increase in the vascular plant flora from three species in 1923 to 127 in 1973 provides us with a very interesting case in point. In the last few years, the relatively young discipline of island biogeography has been yielding new insights on a number of ecological and evolutionary phenomena such as colonization, competition, extinction, community stability, genetic adaptation, ecological exclusion, niche dimensions, etc., and the Johnston Atoll situation represents a unique experiment in this field which could richly reward intense scrutiny. Aside from the population and community phenomena which are favorably isolated for investigation, the effects of the biota in modifying the raw, new substrates over time should be carefully observed and documented. Within the aquatic environment, the same processes of ecological recovery from the effects of dredging and filling provide us similar opportunities."

3. Lee M. Talbot, Senior Scientist, Council on Environmental Quality states:

"Johnston Atoll has high ecological significance for two primary reasons. The first derives from its isolated location in the central Pacific Ocean. Study of the organisms found there can contribute significantly to the understanding of migration and distribution mechanisms and evolutionary ecology of a variety of types of organisms. The inshore fishes are exemplary of this in connection with the distribution, dispersion, and introduction of warm-water fishes."

"Another allied source of ecological significance to this isolated Atoll derives from what studies based there can indicate about the migratory movements of birds, their parasites and pathogens, marine mammals, reptiles, and fishes. The bird studies have been the most extensive to-date, of course, and the detail in this paper reflects that."

"The other, and in my opinion more important reason for its significance, derives from the history and nature of the Atoll. In its present form it is very largely man-made. Even those parts that have not literally been constructed by man have been very significantly modified. This history is well documented with scientific collections, descriptions, and maps and with extensive photographs. At the same time, it is a relatively simple ecosystem from the standpoint of topography and other physical aspects. A high percentage of the terrestrial organisms have been introduced by man (e.g., 124 out of 127 species of vascular plants, and all of the terrestrial mammals and reptiles). Since most of these introductions are of comparatively recent origin and many can be reasonably well dated, the Atoll provides an almost unique laboratory in which the mechanisms of dispersion, introduction, adaptation, and development of an ecosystem and its component species can be studied. The uniformity and simplicity of a substrate further facilitates study and comprehension of the mechanisms and isolation and understanding of the dynamic processes involved."

4. George W. Watson, Curator of Birds, National Museum of Natural History states:

"The birds frequenting the atoll may be classified according to activity into breeders, offseason or prebreeding migrants, and vagrants. The ecological significance of the last is nil. The island does not play any role in the survival of the species and perhaps very little role in the long-term survival of the errant individual. Far and away the most important breeding bird is the Sooty Tern which produces about 50,000 chicks a year on Johnston Atoll. Lesser numbers of Brown Noddies and Wedge-tailed Shearwaters use the island for breeding as do relatively insignificant numbers of other species. None of these species is restricted to Johnston Atoll nor is the population on Johnston Atoll a significant fraction of the Pacific Ocean population of the species. There are no endemic landbirds or seabirds restricted to the islands."

"The same is true of the five species of shorebirds that regularly visit the islands on migration. Most of these are wide-ranging and scatter from their largely arctic breeding grounds over much of the tropical oceans of the world. One species, the Bristle-thighed Curlew is considered rare and endangered on its breeding grounds in Alaska. It disperses so extensively to islands in the tropical Pacific Ocean, however, that even if the Johnston Atoll birds were eliminated, the total species population would not be jeopardized."

"What still remains unknown is the importance of seabirds in the overall marine environment. Obviously in the waters near the island concentrations of birds can exert predation pressure on small fish, crustaceans and squid and thus limit populations in relatively infertile tropical waters. There is little feeding by seabirds in the lagoon or other waters near the atoll. (Emphasis Added) Sooty Terns are probably feeding at up to a full day's flight away from the atoll. Some of the other species may also have great daily flight ranges. Nor is it known exactly where most of the individuals that breed on the island go during the period when they are not breeding. It is known that the island serves as resting or roosting ground for numbers of birds that breed elsewhere, particularly boobies from islands to the north in the tropical Pacific Ocean."

H. HUMAN WELFARE: The discharge of effluent streams resulting from the incineration of Orange at sea or on Johnston Island will not endanger the health of any personnel either aboard ship or on Johnston Island. The data contained in Appendices D and E attest to the essentially complete destruction of herbicide by the incineration process. For the proposed action of incineration at sea, only those personnel who are directly involved in the disposal project, that is the ship's crew, will be subject to any of the project's risks. The potential for exposure of personnel aboard the ship to herbicide will be very minimal. The Orange storage tanks are enclosed and the exhaust gases from the ship's incinerators will be carried away from the ship. In addition, there is no means possible for contamination of the ship's drinking water supply with Orange. The relatively few personnel involved, the fact that all personnel involved are actually working on the project, and the complete lack of a means of exposure of personnel to the incinerator effluent stream, makes incineration at sea highly favorable from the human welfare standpoint. For incineration on Johnston Island, consideration must be given to all of the personnel employed on Johnston Island both from the standpoint of potential air and drinking water contamination. The exhaust stack will be located on the west side of the island so that the normal and dominant winds will carry the combustion gases away from the atoll. Drinking water is provided for Johnston Island via distillation and the water intake is located on the north side of the island. The scrubber water discharge, if a scrubber was to be used, would have to be constantly monitored, and the discharge point would have to be selected so as to minimize any potential for contamination of the water supply. If a scrubber was not used, the water supply will still be constantly monitored to insure that any impact by fallout of stack gases will be detected. In addition, the stack height will be such that the majority of the exhaust gas will not fallout in the atoll. The principal alternative - incineration on Johnston Island - while acceptable as regards human welfare is not as favorable as the proposed action - incineration at sea. This is due to the proximity of personnel not directly related to the project and of the source of the island's water supply. In addition, the proposed action is more favorable since it minimizes exposure time of personnel who will be involved in handling and transfer operations. While proper industrial hygiene procedures will be required, incineration at sea can be completed much faster than incineration on Johnston Island and, therefore, any exposure time will be reduced. The safety and industrial hygiene aspects of each option have not been discussed, but any contractor working on this project will be required to concur with all applicable legislative criteria.

I. BENEFICIAL ASPECTS OF THE PROPOSED ACTION: There are no beneficial aspects, in the absolute sense, for the proposed disposal action. However, there are very important benefits to be obtained by performing the disposal action in a timely manner. These benefits include: 1) minimizing the cost involved in maintenance of the Orange storage areas, 2) making the land in the current storage areas available for other use, and 3) eliminating potential contamination/pollution of the Johnston Island lagoon. The present storage of the Orange at Johnston Island is in 55-gallon drums at a site adjacent to the lagoon which is not a desirable situation from these three aspects. Routine maintenance of the storage site is accomplished to identify leaking drums, fix or redrum the leakers, and contain (by absorption in coral) any spillage resulting from the leakers or the redrumming operation. This operation is quite expensive. The land area which comprises the storage site on Johnston Island is high value property and its dedication for long term storage of Orange represents a constraint on future plans and activities on the island. The normal operation of the storage site represents a low level potential for contamination of the lagoon water. However, a catastrophic event affecting the herbicide storage area could cause massive spillage and could result in pollution of the lagoon, possible contamination of the drinking water supply, and possible damage to the reef. Incineration at sea is favorable from these considerations in that the Orange herbicide would be quickly and totally removed from the Johnston Island environment. The removal of Orange at Johnston Island would require two loadings of the ship, which means that all of the Orange could be removed from Johnston Island in less than one month from the start of the project. Incineration on Johnston Island would require that operations involving Orange handling and transfer be continued for the duration of the incineration process. It would also probably require use of even more land, for installation of the incinerator, than is currently used for storage. The time period for incineration on Johnston Island has not been fixed since an incineration scheme has not been decided as yet; however, it is felt that, in a trade off between facilities and manpower cost, about one year would be required. Another somewhat indirect benefit which can be discussed on the basis of the time and place of the incineration project is the costs associated with ecological and technical monitoring associated with the project. Monitoring programs are very expensive as regards equipment, manhours, travel requirements, chemical analyses, and data analyses. Incineration at sea which does not require ecological monitoring would be more favorable than the principal alternative of incineration on Johnston Island, in which an extensive monitoring program will be required during and for a distinct time period after completion of the project. In summary, there are very important beneficial aspects which can be attained by the timely completion of the disposal project and these are best served by incineration at sea.

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PART IV ADVERSE ENVIRONMENTAL IMPACT WHICH CANNOT BE AVOIDED: There will be no adverse environmental effects from the disposal of Orange herbicide by the proposed incineration. A manufactured product, which cannot be utilized for the purpose for which it was manufactured and purchased, is to be disposed of via incineration which converts it into the basic chemical compounds: carbon dioxide, water, and hydrogen chloride. The incineration process will discharge these compounds in exhaust streams into the environment. Their discharge will result in a minimal impact of a transient nature in a relatively small zone near the point of discharge; however, these compounds are compatible with the atmosphere and ocean environment of the open tropical sea. It is feasible to destroy at least 99.9 percent of all the herbicide and its TCDD content, see Appendices D and E. Any pyrolytic hydrocarbon products of undetectable herbicide feed constituents in the combustion gases will not be of sufficient magnitude to be environmentally significant, see Appendix E. Less than one percent of the herbicide will be converted to particulate material, primarily elemental carbon, which will be discharged with the exhaust stream. These particulates will not be of sufficient magnitude to result in other than minimal localized environmental effects.

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PART V ALTERNATES TO THE PROPOSED ACTION

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A. **PRINCIPAL ALTERNATIVE - INCINERATION ON JOHNSTON ISLAND:** The Air Force proposes the destruction of Orange herbicide via incineration on a ship at sea. However, this action is dependent on the EPA issuing a permit in accordance with the Marine Protection, Research and Sanctuaries Act of 1972. If the EPA administrator decides not to issue a permit, the Air Force will pursue the principal alternative of incineration in a facility which would be constructed on the west side of Johnston Island. A detailed description of the incineration parameters and the environmental analyses of the operation are presented in Parts II and III. The facility on Johnston Island would probably be designed to incinerate about 206 drums of herbicide per day. At this rate, approximately 200 burn days would be required to incinerate all 2.3 million gallons of the Orange stocks. If a portion of the herbicide is registered by EPA, then the project time would be shortened or a smaller facility would be constructed. The incineration facility on Johnston Island would provide essentially complete destruction of undiluted Orange herbicide, and the environmental impact of the facility would be minimal. The potential impact on the delicate ecosystem of Johnston Atoll and lengthy project duration make this alternative less desirable than the proposed action.

B. **CONVENTIONAL INCINERATION IN THE CONUS**

1. **LIQUID WASTE INCINERATORS**

a. **General:** The term "conventional" is used to describe incineration systems which have a refractory lined combustion chamber and afterburner section and use a "flame" concept of combustion. These systems can handle a wide range of waste volumes from 1,000 to 10,000 pounds per hour. The normal design temperature range is 1800 to 2100°F; above 2100°F construction material becomes an operational and economic problem. The temperature attained in a given incinerator is a function of the physical unit, i.e. size, shape, construction materials, the caloric value of the waste fuel, and the fuel to air ratio. To insure efficient combustion, at least 20 percent excess air is required. The means of conditioning and injecting of the fuel are also important factors in incineration efficiency. A turbulent environment is desired in the combustion zone to insure exposure of the fuel to the heat sink and to prevent insulation of fuel particles by other fuel particles. Fuel injection systems are designed to insure intimate mixing in the combustion chamber; the viscosity and atomization of the fuel must be controlled to insure thorough vaporization and combustion before being exhausted from the incinerator. Atomization can be accomplished mechanically (nozzles), by two phase flow (fuel/air mixture) or by a combination of both methods. For atomization, the liquid waste should have a maximum viscosity of about 160 centipoises. At greater viscosities, atomization may not be fine enough and the resultant droplets of unburned liquid may cause smoke or other unburned particles to leave the unit. Viscosity is usually controlled by heating the liquid with tank coils or in-line heaters. Another important factor in system efficiency is the "stay time," i.e. the time duration in which a fuel particle remains in the combustion zone. The longer the "stay time" for a fuel particle the better its chance for combustion. The stay time, around three seconds for conventional incinerators, is limited by system size, air flow, turbulence, and gas dynamics. A conventional incinerator is best operated on a continuous basis as the cooling and heating of refractory material must be done properly to insure that such materials are

Scrubber Combustion Gases
Vented To Atmosphere

120

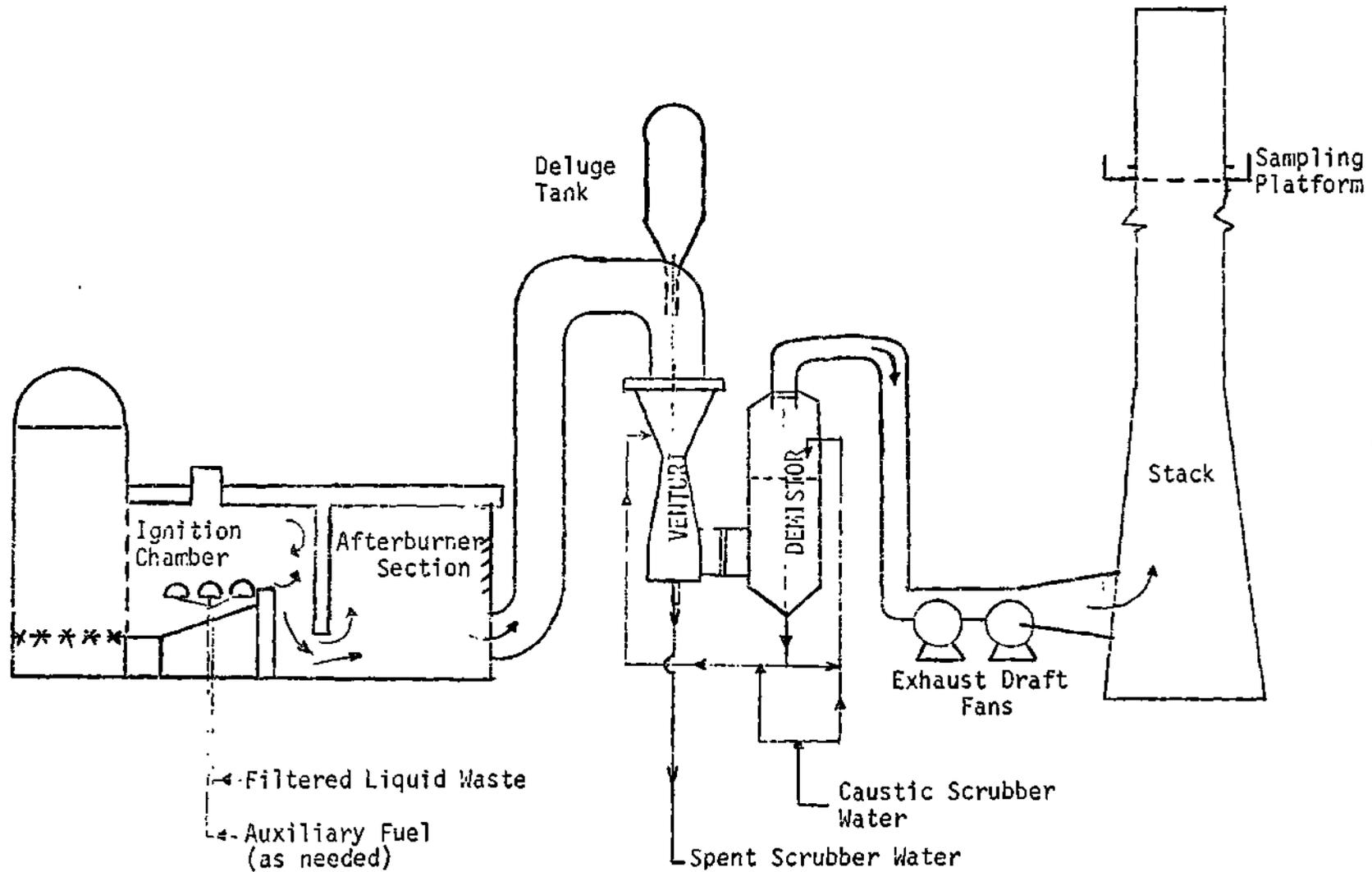


FIGURE V-1: SCHEMATIC OF COMMERCIAL INCINERATOR FACILITY

not damaged. This situation makes the conventional incinerator more appropriate to long term burning projects as opposed to projects which require frequent start/stop procedures. In addition, the size of the units and the type of construction are not generally conducive to transportation and construction on a portable or semi-permanent basis.

b. Diagram: A schematic of a commercial incinerator system is shown in Fig V-1. Incineration of chlorinated hydrocarbon fuels such as Orange will result in hydrogen chloride in the combustion gas; the hydrogen chloride is removed by the venturi scrubber which uses a caustic scrubbing liquid. The scrubber water may require neutralization prior to discharge to a natural water system. The incinerator system also includes gas analysis equipment, accessory fuel storage/feed systems, and process control systems.

2. INCINERATION AT ROCKY MOUNTAIN ARSENAL

a. Introduction: An incineration system has been constructed, installed, and operated at the U.S. Army Rocky Mountain Arsenal (RMA) in Colorado which, by technical investigation, appears to be capable of incinerating the Orange in an environmentally safe manner. The RMA incinerator is used to destroy mustard agent and many of the problems associated with the incineration of mustard and Orange are similar. The problems arise from the similarity between mustard and Orange as regards certain physical and chemical properties and environmental impact. These problems include: fuel conditioning, high temperature incineration, acceptable effluents, real time monitoring and drum disposal. The problems are handled at RMA; but, the facility is necessarily of considerable value, and the waste feed rate of ~2 gallons per minute (gpm) requires considerable time to incinerate a given quantity of material. The information below regarding the RMA facility has not been reviewed by U.S. Army, nor has any action been taken to contract the RMA facility for Orange incineration. This proposal is presented to show that incineration in the CONUS is a viable technical and environmental option. For additional information on the RMA facility the reader is directed to "Final Environmental - Impact Statement for Project Eagle - Phase I, The Disposal of Chemical Agent Mustard at Rocky Mountain Arsenal, Denver Colorado, Headquarters, Department of the Army, Washington 25, D.C."

b. System Description: The system consists essentially of fuel feed tanks, incinerator, packed tower scrubbers, electrostatic precipitator, a spray drier, and a "thaw house" for temperature control of the fuel. The combustion gases are passed through a packed column liquid scrubber which utilizes sodium hydroxide for acid gases removal, and then through an electrostatic precipitator for particle removal. The gases are then discharged to the atmosphere through a stack; there is a stack gas monitoring system; and RMA has established monitoring stations on the facility's perimeter. The scrubber water is spray evaporated, and a sodium salt is produced as a residue. There is no liquid effluent from the system, but the solids generated in the precipitator and evaporator require final disposal. Fifty-five gallon drums can be treated by being "burned-out" in two special furnaces which are adjacent to the main incinerator. The exhaust from these furnaces is treated in the same manner as

that from the incinerator unit. The heat destroys the integrity of the drums and they are sold as scrap. Paragraphs 4 and 5 of Tab C to the Final Environmental Impact Statement for Project Eagle - Phase I concern the combustion of mustard in a bench scale unit which does not include effluent gas scrubbing. Mustard agent, as the sole fuel, was destructed to 99.9999994 percent in the laboratory unit under conditions less than the design criteria for the full scale RMA facility: shorter residence time, no atomization of fuel, lower air supply, lower temperature, and less turbulence. Personal communications with a representative of RMA revealed that no combustion gas samples (prescrubber) have been collected, but that scrubbed gas samples are collected and analyzed on a continuous basis. To date, Jul 74, no mustard has been detected in these samples, and the detection limit is 0.03 mg/cbm. In addition, RMA representatives were of the opinion that mustard agent would not be removed in the scrubber process. Therefore, based on the detection limit and an input of 2 gallons per minute the calculated destruction efficiency is 99.9887 percent. The chemical/physical similarities between Orange and mustard considered with the demonstrated capability of Orange combustion and the very efficient combustion of mustard accomplished at RMA indicate that the facility could adequately destruct the Orange.

c. Proposed Incineration - RMA: Incineration of 2.3 million gallons would require approximately 27 months. The system can operate at $>2,000^{\circ}\text{F}$ with a stay time of 2-6 seconds. Although no actual Orange incineration data is available, it is felt that the experimental data, Appendix D and E, show that such operating conditions will adequately destroy the herbicide and TCDD. In addition, the caustic scrubber will provide additional treatment of the combustion gas. The elimination of the liquid discharge, the slow rate of incineration, the combustion gas treatment, the monitoring systems installed, and the drum cleaning capability make this option extremely attractive.

d. Exhaust Gas Discharge: The exhaust gas is discharged through a 55 feet stack located near the center of the RMA facility. The stack gas will contain essentially no herbicide esters and acids, TCDD, and particulates. The amount of hydrocarbons, based on comparison with data from Orange incineration projects, in the stack gas will be extremely small (fractional microgram per liter concentration).

3. APPLICATION TO ORANGE: Based on technical and environmental considerations, incineration in the CONUS in units such as the RMA facility could be safely accomplished. Unfortunately incineration units of sufficient capacity are located near centers of population and industry, and these areas are already marginally acceptable from a pollution viewpoint because of presently occurring degrees of air pollution. Furthermore, local and state governments are generally opposed to the importation of waste for disposal within their areas of jurisdiction. For the above reasons, incineration in the CONUS is not a viable alternative.

C. USE

1. DESCRIPTION OF ACTION

a. General

(1) Orange herbicide is not an EPA registered pesticide and cannot be domestically used or sold. The Orange herbicide stock to be destroyed by the action proposed in this environmental statement represents a resource of considerable monetary value. The safe and appropriate utilization of all or part of this resource would certainly be a beneficial action. The Air Force has been and is continuing to pursue the possibility of EPA registration of portions of the Orange herbicide stock. Affirmative action on registration prior to the contractual initiation of the proposed action, incineration at sea, or the principal alternative, incineration on Johnston Island, would insure that the stock which is registered would not be destroyed. Orange herbicide has a potential use on Federal lands as well as on privately owned lands; however, any use would require registration. The prudent disposition of Orange herbicide for use on privately owned or governmentally owned lands may have a tremendous impact on increasing the availability of certain natural resources, e.g. rangelands and forests.

(2) Undesirable weed and brush species are widespread in every region of the United States. Their combined impact on rangelands and production of commercial timber is enormous. Approximately half of the total land area of the United States is used for pasture and grazing purposes, and weeds and brush are a problem on nearly all these forage lands. Economic losses from weeds on forage lands are virtually incalculable and include low yield of forage and animal products per unit area, reduced livestock gains, and livestock poisoning. Although herbaceous weeds are found on all rangelands in the United States and result in forage losses, brush is the primary problem. Various brush species dominate an estimated 320 million acres of rangelands (Palm, 1968). More than 80 percent of 107 million acres of grazing land in Texas alone is infested to some extent with brush. Once established, woody plants such as mesquite (Prosopis spp.), juniper (Juniperus spp.), oak (Quercus spp.), and Sagebrush (Artemisia spp.) cannot be eliminated by good grazing practices alone. Measures must be taken to convert brush-dominated rangeland to more productive types of vegetation. Good brush control and striking improvements in the grazing capacity of rangeland may be obtained most economically by low-rate and low-volume applications of phenoxy herbicides (Kirch, 1967).

(3) Commercial forest land in the United States is estimated at 509 million acres. Although much of this land is not under any form of planned management for production of forest products, management for an increased productivity will soon become essential to meet the needs of the United States population (Palm, 1968). Walker (1973) summarized the total area of forest lands supporting important amounts of undesirable vegetation at some 300 million acres, or a land area of potentially commercial timberland equal to roughly the combined areas of Texas, California, and Washington. Gratkowski, Hopkins and Lauterback (1973) have estimated that there are some 4.7 million acres of commercial forest land in western Oregon and Washington on which the land is occupied by vegetation whose presence precludes reestablishment of conifers. Much of the area is in the highest productivity class for growth of forest products.

(4) Concepts of selective brush control have been developed for reforestation with the aid of commercial formulations of 2,4-D and 2,4,5-T. There are presently some 100,000 acres being treated each year with various formulations of these materials, all as the low-volatile esters. Success has been good, especially in operations on the slower-growing brush species (Lauterback, 1967) (Theisen, 1967).

b. Purpose: The purpose for using herbicide Orange on rangelands and reforestation is to reduce the amount of undesirable vegetation that dominates in selected regions of the United States because of past disturbances and improper grazing and/or timber practices. With the use of herbicide Orange, a more diversified and desirable variety of plant species may become established. This in turn will have a substantial impact on increasing productivity of these regions.

2. ENVIRONMENTAL IMPACT: The environmental impact of using herbicide Orange for chemical brush control will vary from region to region and whether it is for range or forest use. However, regardless of the region of use, or for rangeland or reforestation, critical assessments of effects on vegetation, wildlife, domestic livestock, soil microorganism, aquatic life, rangeland or forest waters, and man must be evaluated. Young et al. (1974) have evaluated the ecological consequences of massive quantities of 2,4-D and 2,4,5-T, i.e., Orange. Their five-year study documents the persistence, degradation, and/or disappearance of the herbicides from soils and drainage waters of an approximately one square mile area that had received 345,117 pounds of herbicide. Moreover, ecological assessments were made of the herbicides' subsequent effects (direct and indirect) upon the vegetative, faunal, and microbial communities. The summary of their five year field study is included as Appendix F.

D. RETURN TO MANUFACTURERS: In March 1972, seven manufacturers of herbicide Orange were contacted regarding the possibility of chemically reprocessing Orange herbicide whereby all impurities, including dioxin, would be extracted or destroyed. Results from all manufacturers were essentially the same; i.e., they did not feel that they were capable of reprocessing the product without extensive investment in equipment and/or development of new processes. Lead time for this type of action would require in excess of 18 months before large scale reprocessing could begin. As a result of EPA's action on 24 Jun 74 to cancel hearings on the possible further restriction of 2,4,5-T, the manufacturers have again been contacted (Aug 74) via letter to determine if their position may have changed. Manufacturers have indicated that they do not have the capability to reprocess Orange without major research efforts and capital expenditures.

E. DEEP (INJECTION) WELL DISPOSAL: This process involves injection of the herbicide into a deep sub-surface formation. This well hole down into the formation is lined with casing which has been cemented into place to prevent fluids from rising to the surface outside of the casing. A packer tube runs from the surface inside the casing to a permeable geologic formation. The herbicide drums are emptied into tanks or vats on the surface where the Orange is diluted and then pumped down the tubing to the permeable formation. The packer tool prevents fluid from returning to the surface inside the casing and impermeable upper and lower formations adjacent to the permeable formation restrict vertical movement. This process has not been approved by state agencies, or the EPA, and deep well injection is not considered environmentally safe or desirable disposal method for waste materials. The policy is to oppose all storage or disposal of wastes in deep wells without strict controls and a clear demonstration that such disposal will not: a) interfere with present or potential use of sub-surface water supplies, b) contaminate interconnected surface waters, or c) otherwise damage the environment. Little concrete information is available on what degradation of the Orange would occur at the depths, temperatures, and pressures encountered in deep wells. This coupled with the possibility of sub-surface disturbance at a later date allow Orange to migrate into formations leading to water supplies or other valuable formations, has prevented any of the firms interested in disposing of Orange in deep wells from obtaining state or Federal permits.

F. BURIAL IN UNDERGROUND NUCLEAR TEST CAVITIES: The Atomic Energy Commission was contacted regarding the possibility of disposing of the Orange by burying it in an earth cavity formed during underground nuclear testing. They advised that a major research, development, and experimentation effort would be required to prove the practicality of this alternative. In view of the time required for this effort, it is not considered a feasible alternative.

G. SLUDGE BURIAL

1. **GENERAL:** This technique offered definite promise, but there was a lack of interested and qualified industries to undertake the necessary preliminary investigations. This process involves one concept of destroying the Orange through bacterial action. The proposal envisions constructing trenches in geologically suited formations on isolated government land. The type of formations picked for the trenches would preclude vertical and lateral movement of the Orange. The trenches would be filled with drums containing the Orange and would then be surrounded by secondary sewage plant sludge, which would provide a growth medium for the bacteria. The tops of the drums would be holed to allow a controlled release of the Orange. The trenches would then be mounded with dirt fill and aggregate. Depending upon the type of bacteria selected to decompose the Orange, vents might also be required. This process is not considered acceptable because of the time to completely destroy the herbicide is quite lengthy, possibly as long as 10 to 25 years, and because a system of monitoring would be required throughout this time period. The earth covering would require maintenance and additional time would also be required to develop a strain of bacteria suitable for use with Orange.

2. ENVIRONMENTAL IMPACT:

a. General Impact: Environmental impact of a sludge burial proposal will be concentrated for the most part in the approximately 30 acres of land utilized for the operation. The most significant impact of this proposal is the denial of land for reclamation or recreational uses for a period ranging from 15 to 25 years. Other effects include alteration of the soil profile and structure, temporary destruction of all vegetation, and disturbance and possible destruction of ecosystems in the area. The impact on air and water quality of the site is anticipated as minimal, providing site selection criteria and proposed burial procedures are followed.

b. Impact on Air Quality: The biological degradation of organic matter results in the formulation of various gaseous products including, in this case, phenol, carbon dioxide, methane, and the volatile fraction of the normal butyl ester of the herbicide. Dependent upon various parameters, these products may exist in significant quantities. To contain the fractions, five feet of compacted earth cover is proposed with an additional two feet of earth placed at the center line of each drum row. Indications are that this cover will be adequate to preclude escape of gases into the atmosphere. It should be noted that two feet of compacted earth is used as final cover for a sanitary landfill. Odor problems will be prevalent during the dumping of the sludge into the trenches. Volatilization of the normal butyl ester will occur to some extent prior to covering of the drums. The extent of volatilization will depend upon atmospheric conditions at the time, the number and size of holes punched into the drums, and the time period during which the punched drums are uncovered. To a lesser degree, air pollutants in the form of dust and emissions from the excavating equipment will be emitted during "construction" of the trenches. Significant degradation of air quality during this phase is not anticipated.

c. Impact on Water Quality: The site selected for sludge burial will be either a portion of a flat dry lake bed where the depth to the water table is several hundred feet, or on an alluvial fan bordering a saline playa where the water table beneath the fan is also several hundred feet deep. In either case, several hundred feet of unsaturated earth exists between the bottom of the trenches and the water table. Precipitation in both of these settings

would tend to be insufficient (less than five inches per year) for unchanneled water to penetrate through the unsaturated materials and reach the water table. Prior to the selection of a suitable site, data must be gathered describing the parent material and underlying rock formations with indications of possible discontinuities, including a geological profile and information on the existence of faults or fissures. Having satisfied these requirements, the selected site would have no significant adverse effect on the water quality of the area selected.

d. Land Use: A significant impact of a sludge burial disposal alternative is denial of land for a significant length of time. Approximately 30 acres of land will be denied for reclamation or recreational uses for a period ranging from 15-25 years.

e. Soil: The sludge burial proposal involves construction of trenches. These trenches will vary in number and dimensions. Trench depths of 10 to 15 feet minimum will be required for the operation. Excavation of these trenches will cause complete destruction of vegetation and the soil profile, disturbance and possible destruction of wildlife habitat, and disturbance of the bioecology of the particular area. The total environmental impact can only be determined if base line data is gathered prior to construction. This data should include an accurate description of (1) permanent inhabitants (2) migratory inhabitants and (3) the identification of any endangered species which may occupy the site.

f. Vegetation: Approximately 30 acres of vegetation would be destroyed if the proposal were implemented. Depending upon the geographic location of the site, natural vegetation will begin to reestablish itself within a year with weed species being the first to invade.

H. MICROBIAL REDUCTION

1. DESCRIPTION OF ACTION

a. General: This process involves the biological degradation of the herbicide through fermentation. It requires the development of a microorganism to "feed" on the herbicide. From the literature, it seems apparent that microorganisms have developed unbelievable capabilities for handling organic compounds. However, two factors severely complicate the biological degradation of this refractive material: 1) its insolubility in water and 2) its chemical structure (specifically the number and position of chlorine atoms attached to the aromatic ring). Many investigators have showed that 2,4-D is rapidly decomposed in soils, and that high concentrations of the material have no appreciable effect on the soil population of bacteria, fungi, and actinomycetes (Stojanovic, 1972). The persistence of 2,4,5-T is usually two to three times longer than 2,4-D (DeRose, 1947) and very few microorganisms have been identified as having the ability to break down the 2,4,5-T molecules (Aly, 1964). Leopold, VanSchaik, and Neal (1960) found that increasing chlorination of phenoxyacetic acid decreased its water solubility while increasing its absorption onto activated carbon and organic matter, thus making less available for microbial degradation. Stojanovic *et al.* (1972) added a mixture of 2,4-D and 2,4,5-T to soil at a concentration of 5 tons/A (5,000 ppm in top 6 inches). It appeared that mixtures of 2,4,5-T were more rapidly degraded than were the single compounds. Very little work has been done on the microbial degradation of TCDD; however, Matsumura and Benzet (1973), have studied the problem. Using 100 microbial strains, they found that only 5 strains showed some ability to degrade the compound. Thus far, Matsumura and Benzet have not been able to manipulate cultural conditions to increase the rate of degradation of TCDD in any of the microorganisms. Worne (1972) reported in a paper presented at Ghent, Belgium, that he has developed mutated organisms which have the capability to cause 100 percent disruption of the aromatic ring of several chlorinated phenols. He reported a detention time of 52 hours for concentrations of 200 ppm.

b. Treatment Methodology: Detoxification of the herbicide would be accomplished utilizing one of many conventional systems, including lined stabilization ponds, activated sludge, anaerobic digestion, or complete mixing activated sludge. The latter method offers many advantages. A plant in Canada uses complete mixing activated sludge (Besselièvre, 1969) to treat phenol bearing wastes containing up to 3,000 ppm phenol, the effluent containing .04 ppm. Utilizing a 20 MGD conventional activated sludge facility with treatment capability of 200 ppm, the herbicide would be treated in a period of 2 years. Plant cost would approach \$2 million. The feasibility of and using microbial fermentation as a disposal alternative is largely contingent upon the concentration of waste to be treated. Treatment of concentrations of between 1,000 to 3,000 ppm herbicide would make this alternative attractive.

2. ENVIRONMENTAL IMPACT: The environmental impact of a microbial reduction method is dependent upon the fate of TCDD in a biological treatment facility. It must be established that no TCDD is remaining in the effluent, or a problem of enormous consequences can occur. Thus far no data are available on the fate of TCDD in a biological system. All other aspects of such an alternative can be controlled and minimized to an acceptable level. Monitoring methodology and a failsafe system would be required. Until more data are developed the

particular environmental aspects cannot be evaluated. More specific information concerning the process, size of facility, land acreage required, and effluent parameters are needed.

I. FRACTIONATION: Fractionation is the process of converting Orange into its acid ingredients by means of distillation. This would separate the normal butyl esters of 2,4-D and 2,4,5-T and its contaminant TCDD. The 2,4-D and 2,4,5-T would be reformulated for commercial use. TCDD would then be destroyed by chemical, biological or incineration techniques. Actual distillation efficiencies theoretically could approach 90-95%. One investigator stated that any TCDD residue could be destroyed by splitting the ether bonds of the molecule. In the process of fractionation, the dioxin would be isolated or destroyed. A small scale study was funded, but the results were inconclusive. Fractionation is not acceptable because: a) the fate of the dioxin has not been demonstrated, b) in the process, 3% of the Orange processed could not be accounted for, c) standards to control and monitor vapor and fluid emissions into the environment have not been identified. Further discussion is contained in paragraph J.

J. CHLORINOLYSIS

1. From the theoretical engineering point of view, chlorinolysis offers an efficient, controlled, and safe method for disposal of the herbicide, as well as other hydrocarbon formulations. Chlorinolysis is a process that breaks down the molecule and adds a chlorine molecule to produce carbon tetrachloride, phosgene, and anhydrous hydrogen chloride, all of which have established commercial value.

2. Chlorinolysis as a means to dispose of Orange herbicide was evaluated over a period of almost two years. In July of 1972, discussions and correspondence with the Environmental Protection Agency (EPA) committed the Air Force to pursue the testing and research program necessary to determine the feasibility of converting Orange to salable products by chlorinolysis. In September 1972 a Memorandum of Agreement between the EPA and the Air Force was initiated. The objective of the agreement was the development of a laboratory program to evaluate the practicality of the application of chlorinolysis for the disposal of Orange. The investigation was also to determine the extent of destruction of the impurity dioxin. The information and data obtained in this research was to be utilized by the Air Force to determine whether the proposed concept could be applied and used to dispose of Orange and by the Environmental Protection Agency to determine if it could contribute toward solving the disposal problems of the petrochemical industry. It was agreed that the EPA would manage the research and provide a report containing all data collected, together with conclusions and recommendations. The Air Force agreed to fund the effort in the amount of \$35,000. An additional \$10,000 was provided for analysis of dioxin. Three drums of Orange containing 14 ppm dioxin (analysis by Dow Chemical Company) were provided by the Air Force.

3. Reports received in November 1972 indicated that no dioxin was detected (sensitivity level of 100 ppb) in the carbon tetrachloride extracted during the first run. A later report of analysis indicated no dioxin at a sensitivity of less than 10 ppt of dioxin in carbon tetrachloride subjected to improved distillation. 2,4-D which was fractionally distilled from Orange by the Diamond Shamrock Company contained less than 1 ppb of dioxin. The material remaining after distillation is predominantly 2,4,5-T and dioxin. After fractionation the residual must still be disposed of by an acceptable method.

4. In December 1972 a presentation was made by EPA to the Air Force regarding total and partial chlorinolysis (fractionation of 2,4-D followed by chlorinolysis of the 2,4,5-T and dioxin residual). It was explained by EPA that to convert 26.5 million pounds of Orange to carbon tetrachloride, phosgene and hydrogen chloride would require about 170 million pounds of chlorine. For a 10-ton per day chlorinolysis plant, the cost to the Air Force for the worst case commercial sale value of the produced products would be about \$9.1 million. For the best case sales, the cost would be about \$2.4 million. A cost uncertainty of \$6.7 million results. One of the disadvantages pointed out by EPA was that quartz lined reactors of the size needed do not exist and that development of a large scale reactor would be required. It was estimated that 18 to 24 months

would be needed to design and construct a plant after a 6 month pre-engineering study. It was further estimated that 24 to 30 months would be needed to process the Orange. A total time of 38 to 60 months would thus be required.

5. In January 1973 Air Force officials, accompanied by two consultants, visited the Diamond Shamrock facilities and essentially confirmed the cost estimates and time frames previously presented by the EPA. It was confirmed that some 85,000 tons of chlorine would be needed. The Diamond Shamrock officials discussed a commercial operation by a German firm which had been successfully processing hydrocarbons by chlorinolysis using a higher pressure process than that of Diamond Shamrock. An advantage of the German process was that a quartz reactor was not necessary.

6. The EPA investigated the German plant for the possibility of chlorinating Orange herbicide. Two drums of Orange were provided by the USAF to the EPA for testing purposes in Germany. EPA officials visited the German facilities in July 1973. In September 1973 EPA officials reported that because Orange is approximately 16 percent oxygen (by weight), corrosion of the reaction vessel was feared. Bench scale tests indicated 20-30 percent greater corrosion than observed when hydrocarbons containing no oxygen were tested. This observation may have occurred due to the problem of test size as the full scale plant has not experienced any corrosion processing hydrocarbons which do not contain oxygen. Nevertheless, additional tests were thought to be needed prior to conducting a full scale evaluation. The reaction kinetics and thermodynamic differences between the Diamond Shamrock process of high temperature/low pressure and the German process of low temperature/high pressure also needed to be understood according to the EPA before any full scale test. During the bench scale tests CO₂ was unexpectedly produced. The reason for its formation was not known and further testing was indicated as being required. Further tests and another visit were planned for December 1973. It was indicated that a final report containing the Diamond Shamrock, German, and EPA data would be provided shortly.

7. In April 1974, the EPA, in discussing chlorinolysis in a newsletter indicated that "The process...has been proven on a small scale and research is continuing to demonstrate its usefulness on a large industrial scale."

8. The EPA report, "Study of Feasibility of Herbicide Orange Chlorinolysis" (EPA-600/2-74-006, July 1974), covering only the work of Diamond Shamrock Company was delivered on 2 Oct 1974. A limited number are also available for loan from the USAF Environmental Health Laboratory, Kelly AFB Texas 78241. The report covers the results of bench scale tests and concludes, based on these bench scale tests, that chlorinolysis under the proper conditions effectively converts Orange herbicide and its TCDD contaminant to carbon tetrachloride, carbonyl chloride and hydrogen chloride. Destruction of the TCDD was complete, and preliminary toxicology tests of the recovered carbon tetrachloride on rabbits showed no evidence of TCDD contamination. The report also contains cost estimates which include credit for the sale of chemicals from a 25 ton/day plant. The cost in the worst case is shown to be \$11 million and in the best \$4 million.

9. Owing to the uncertainties associated with developing this technique to a full scale plant capable of processing 2.3 million gallons of Orange in a timely and economic manner, partial or total chlorinolysis was not selected as the method of disposal even though it is satisfactory from an environmental point of view.

K. SOIL BIODEGRADATION

1. DESCRIPTION OF ACTION

a. General

(1) Soil biodegradation is a soil incorporation technique based on the premise that high concentrations of the Orange herbicide and the contaminant TCDD will be degraded to innocuous products by the combined action of soil microorganisms and soil chemical hydrolysis. The rationale for soil incorporation of herbicide as an ecologically-safe disposal method comes from pertinent laboratory and field studies.

(2) When soil microorganisms are exposed to high concentrations of a herbicide, there is usually a lag period before utilization of the material begins. This lag period represents the time required for the microorganisms to become adapted. Once breakdown of the herbicide is initiated and completed, the soil microorganisms retain an enhanced capacity for degradation of that herbicide. For example, Audus (1960) treated a soil with 100 ppm 2,4-D and 20 days were required for 80% detoxification, but when the soil was treated again only three days were required for 80% detoxification. Colmer (1953) found that 5,000 ppm 2,4-D were at first inhibitory to a bacterium, but after subculturing three times the organisms grew rapidly in the 5,000 ppm concentration. Stojanovic, Kennedy, and Shuman (1972) added a mixture of 2,4-D and 2,4,5-T (similar to the formulation of herbicide Orange) to soil at a concentration of 5 tons/acre (5,000 ppm in top 6 inches of soil). Seventy-eight percent of the herbicide carbon was given off as carbon dioxide in 56 days. It also appeared that mixtures of the herbicides were more rapidly degraded than were single compounds.

(3) In the laboratory, Shennan and Fletcher (1965) subjected 38 species of soil bacteria fungi, actinomycetes to 2,4-D and 2,4,5-T at concentrations of 100 to 10,000 ppm in the soil, respectively. Twenty-six species were not inhibited by 10,000 ppm 2,4-D. Twenty-four organisms required 10,000 ppm 2,4,5-T for growth restriction to occur. In the study by Stojanovic, Kennedy, and Shuman (1972), 5,000 ppm of an equal mixture 2,4-D and 2,4,5-T inhibited growth of bacteria and actinomycetes but the total number of fungi increased during the 56-day incubation period. Kearney, Woolson, and Ellington (1972) in the laboratory studied the persistence of TCDD in two soils, Lakeland sand and Hagerstown silty clay loam, at three rates of application (1, 10, and 100 ppm) for 360 days. The soils represented extremes in biological activity and in physical and chemical properties. The soils were maintained at 28 to 30°C with a moisture content equivalent to 70% of field capacity. After 1 year, 56 and 63% of the originally applied TCDD was recovered in the Hagerstown and Lakeland soils, respectively. As Kearney et al. (1972) pointed out, however, a concentration of 1 ppm of TCDD in soils is 10^6 times greater than the residues likely to be encountered in a 2 pound/acre (1b/A) application of 2,4,5-T containing 1 ppm TCDD. However, Young et al. (1974) has reported soil persistence of TCDD in Lakeland sand which had received 947 pounds/acre 2,4,5-T nine years earlier (1962-1964). A TCDD concentration of 0.71 parts per billion (ppb) was found in the 0-6 inches of soil profile, see Appendix G.

(4) It seems apparent from laboratory studies that microorganisms have developed extensive capabilities for handling organic compounds. Moreover,

most organisms seem to have a latent ability for decomposition of halogenated hydrocarbons. However, the amount of active herbicide applied to soil may diminish by means other than biological decomposition; e.g., chemical degradation, absorption, volatilization, leaching, and photodecomposition.

(5) Lutz, Byers, and Sheets (1973) studied the persistence and movement of 2,4,5-T in soils of a western North Carolina watershed. They found that at 50 and 100 days following applications of 2 lb/A 2,4,5-T less than 10 ppb remained at depth below 7.5 cm (3 inches). O'Connor and Wierenga (1973) studied the persistence of 2,4,5-T in greenhouse lysimeter studies. They found 3 ppm 2,4,5-T at a depth of 24 cm (14 inches) in soil cores following 3 irrigations with 80 ppm 2,4,5-T (10.5 months elapsed time from first to the third irrigation). Total degradation time for 2,4,5-T was calculated to be 85 days for this pretreatment and concentration. Hanks (1946) has shown that 2,4-D was much more resistant to leaching from alkali soil than from a peat soil.

(6) Until recently there was very little information concerning the breakdown of 2,4-D or 2,4,5-T in a soil incorporation site. However, Goulding (1973) has conducted field experiments on the use of soil incorporation as a method of disposing of massive quantities (approximately 1-1/4 million gallons) of 2,4-D and waste by-products. Goulding found that when he employed a trenching technique, simulating subsurface injection, he could place 500 lb/A 2,4-D (plus waste) at a depth of 10 inches into 5-inch bands on two-foot centers. With this placement the actual concentration of herbicide within these bands was approximately 1250 ppm. Samples taken between trenches and in soil profile segments from the surface down through the point of application indicated minimal vertical and horizontal movement of the herbicide (or phenolic waste) from the site of initial deposition. Results from this experiment indicated little differences in rates of degradation in the trenched plots or a surface application of 500 lb/A: 95% degradation in 540 days.

(7) Young, Arnold and Wachinski (1974) have studied the persistence and movement of herbicide Orange (and TCDD) following soil incorporation at rates of 1,000, 2,000 and 4,000 pounds active ingredient 2,4-D and 2,4,5-T/acre (lb ai/A). The percent loss of herbicide over a 330 day sampling period was 78.2%, 75.2% and 60.8% for the 1,000, 2,000 and 4,000 lb ai/A plots, respectively. They calculated that the half-life of herbicide Orange in alkaline (pH = 7.8) desert soils was approximate 150 days at these massive rates. Data on soil penetration indicated that less than 3.7% of the herbicide was found at depths greater than 18 inches 282 days after soil incorporation of 4,000 lb ai/A. Preliminary data based on levels of TCDD in the formulation (3.7 ppm) and those encountered in the soil profile 265 days following soil incorporation suggested that under these environmental conditions the half-life of TCDD was 88 days. A copy of this report is attached as Appendix G.

b. Site Criteria for Soil Biodegradation: It is important that the criteria for selection of a site for soil biodegradation include certain physical, biological, and managerial factors.

(1) Physical Factors: From the standpoint of just physical consideration, the soil incorporation technique provides an array of alternatives as to the selection of site. In general:

- (a) A minimum of 2,000 acres must be available.
- (b) The site must be remote. It cannot be adjacent to land currently in agronomic production.
- (c) The land must have a low-use potential, i.e., it should be marginal land. Moreover, the land should not be considered land that will be significantly productive in the foreseeable future.
- (d) Water resources must be sufficiently far away so as not to be contaminated.
- (e) The topography of the land must be relatively flat with a uniform surface.
- (f) The texture of the soil should be sandy-loam or silty-loam with a pH of approximately 8.0.
- (g) The area should not be characterized by rock outcrops or areas of marked deflation or dunes. The area should also have minimal surface erosion.
- (h) Data should be available on subsurface geology and hydrology.

(2) Biological Factors: The vegetation that characterizes the particular site must be uniform with a ground cover of at least 10-15%. Such a plant community will provide the organic matter and microclimate that supports the growth and maintenance of the microflora (e.g., fungi and bacteria). Ideally, the vegetation should be low-growing shrubs, forbs and grasses to facilitate the incorporation equipment.

(3) Management Factors: The management factors that will influence the selection of the site are:

- (a) The requirement for established all weather roadbeds to and within the disposal site.
- (b) The distance to the disposal site from an off-loading station (e.g., rail to truck).
- (c) The requirement for security of the disposal site.
- (d) Availability of personnel facilities.
- (e) Adequate storage space at the disposal site.

c. Method of Incorporation: A subsurface injection system will be used to incorporate the herbicide into the soil at a depth of 6-10 inches. The injection would be done by using a conventional agricultural subsoiler, drawn by a heavy industrial tractor. The subsoiler would consist of a vertical blade on which a chisel, or foot, is mounted at an angle of approximately 15° from horizontal. A piece of metal tubing will be attached to the blade (and terminating at the base of the chisel) in such a manner that a piece of hose from the injection pump could be inserted to permit deposition of the herbicide immediately behind the chisel. The equipment, with eight injectors (shanks), should be calibrated to apply 4000 lb/A of Orange. The eight shanks should be on 20-inch centers. During the process of application the overlying vegetative structure will be damaged. To prevent the loss of soil moisture and to reseal the soil (thus minimizing volatility and damage from wind), a soil compactor (cultipacker) will be required and a drought resistant, salt tolerant grass will be planted.

2. ENVIRONMENTAL IMPACT

a. General: The environmental impact of soil biodegradation will be expressed in two major areas; the most significant of which is the denial of a 1,000 - 2,000 acre tract of land for reclamation or recreation use for a 3 - 5 year period during biodegradation. The proposed site would require continuous monitoring during the lifetime of the project. Also occurring will be damage and/or kill of the overlying vegetative structure in the immediate disposal area, drastic alteration of the soil structure, and disturbance and/or temporary destruction of local ecosystems. Adherence to the above site criteria and incorporation method will optimize the soil biodegradation procedure and minimize adverse environmental impact.

b. Air Quality: Impact on air quality will be confined to the period of incorporation. Some volatilization of the n-butyl esters will occur during loading of the incorporation equipment. To a lesser degree volatilization may occur while actually injecting the herbicide into the soil. Air pollutants in the form of dust and emissions from the incorporation equipment will be emitted during the treatment of the site.

c. Impact on Water Quality: The impact on water quality will be minimal. Actual field data for soil incorporation at 4,000 lb ai/A herbicide Orange indicated only minimal leaching (in alkaline soils) below 18 inches of depth. However, the incorporation site should be in an area of sufficiently deep soil to prevent unchanneled water from penetrating through the unsaturated materials.

d. Vegetative and Animal Communities: The soil biodegradation method would disrupt and/or kill the vegetation on a minimum of 1,000 acres of land. This would significantly influence the animal community dependent on this vegetation. However, if a site is selected that fits the criteria, the animal population will be minimal. Immediate action to establish salt-tolerant grasses will minimize potential long-term damage to the animal community.

L. NO DISPOSAL ACTION

1. INTRODUCTION: If none of the disposal methods listed above can be employed at the present time because: 1) they are not ecologically acceptable, 2) technology not sufficiently far advanced, 3) excessive capital investment required, 4) unacceptable time delay, and 5) socio-political opposition, it is possible to put herbicide Orange into "permanent" storage in an above ground steel storage tank on Johnston Island. The required capacity of the tank would be approximately 1.8 million gallons. This volume is an estimate based on the assumption that about 500,000 gallons having a TCDD content of 0.1 ppm or less and presently in storage at the NCBC, Gulfport MI will be registered. The estimated cost of construction of a storage tank with a capacity of 1.8 - 2.3 million gallons on Johnston Island is \$875,000 - \$1,000,000. The transportation of the drums presently stored at the NCBC, Gulfport MI to Johnston Island would probably add another \$450,000 to the total cost increasing it to about \$1.35 to \$1.45 million dollars. There are several methods of treatment available which could be used to prevent external corrosion of the tank. Pitting or abrasion of the paint or other coating due to blowing sand might constitute a problem. Orange and dioxin are inert to mild steel and, in the absence of water, internal corrosion should not be a problem. This "permanent" storage offers several advantages as follows: 1) it would eliminate the cost of continuing redrumming on Johnston Island where redrumming is a major problem and would also eliminate the same problem at the NCBC, Gulfport MI where the problem is not as acute, 2) during the period of storage advances in technology would occur, 3) the cost of certain closed systems, i.e., chlorinolysis, microbial degradation, etc., would be technologically advanced and probably reduced in cost. If for any reason the construction of a tank or tanks is not considered feasible on Johnston Island, storage in already existing tanks or other Pacific islands might be considered.

2. ENVIRONMENTAL IMPACT: Only during the construction phase would there be any impact on the environment. If it became necessary for any reason to provide additional land area for the construction (placement) of the storage tank, dredging would be necessary. However, it is believed that sufficient land area is available on the southwest corner of the island to permit the construction of a storage tank with a capacity of 2 to 2.3 million gallons. The land area for a storage tank of the above stated capacity and the necessary impoundment area and dikes would be about 2 acres. This area includes a part of the storage site where drums of Orange are currently stored and it would be necessary, probably, to move some and perhaps all of these drums. Extensive construction has been conducted on Johnston Atoll in the past. This work has involved drilling and blasting; the use of heavy earth moving equipment and dredging. Explosive devices have been detonated in the area and nuclear devices have been fired at high altitude. Except for dredging which almost certainly altered the ecosystem of the lagoon and nearby waters, changed the direction and velocity of the currents, altered tidal and wave actions, increased the land area of the island, resulted in the creation of two man-made islets and altered the shoreline of all islands, none of these activities has resulted in the permanent disturbance of the ecosystems of the atoll. While space may be available for tank construction at this time, the available land on the island is very limited and competing missions must be considered. Storage has been continuous for a number of years since the cessation of use. The alternative simply prolongs storage at great expense but does not dispose of the material. Ultimate disposal of the Orange is only delayed and for no purpose as an acceptable disposal method has been identified.

PART VI. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USE OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY: Bio-accumulation in the environment has been proposed as an adverse environmental consequence of using 2,4,5-T as a defoliant. This Orange herbicide disposal action is not expected to contribute to the bioaccumulation of TCDD in the biosphere on or near Johnston Island because of the high efficiency of the proposed incinerator and the sparsely populated ecosystem of the open tropical sea. The destruction by incineration would eliminate the short- and long-term risks that may be involved with continued storage of the material. Incineration under the controls and precautions to be included in the final contract would not narrow the range of beneficial uses of the environment or pose long-term risks to health or safety.

PART VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE PROPOSED ACTION IF IMPLEMENTED: This action would not involve the irrevocable use of resources other than the small amount of fuel required to bring the incinerator to proper operating temperature. The action would not involve changes in land use, destruction of archaeological or historical sites, or unalterable disruptions in ecosystems. It will not curtail the beneficial uses of the environment.

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APPENDIX A
ECOLOGICAL BASELINE SURVEY OF JOHNSTON ATOLL
CENTRAL PACIFIC OCEAN

by

A. Binion Amerson, Jr.

Ecology Program
Office of Environmental Sciences
The Smithsonian Institution
Washington DC 20560

17 December 1973

(The document consists of over 300 pages. For the sake of space conservation, the Table of Contents and Summary only are included here. Copies of the document are available on a loan basis to qualified interested parties and may be obtained by request from USAF Environmental Health Laboratory, Kelly AFB Texas 78241.)

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SUMMARY

Johnston Atoll, located between the Hawaiian Islands and the Line and Phoenix Islands, is one of the most isolated coral atolls in the world. Military activity has greatly altered the atoll: two of the four islands are man-made and the original two have been greatly changed. Since World War II, the atoll has been a military base. The wildlife on the atoll is protected under a little-known 1926 Executive Order.

The flora of Johnston Atoll is well known. There are 67 species of benthic marine algae known from the lagoon. Increased silt from dredging activities in 1963 and 1964 decreased the number of algal species in the dredged areas. Three vascular plants occurred on the original two islands; man has apparently introduced 124 species since 1923.

The invertebrate fauna is not well known and dredging has further reduced or eliminated some species. The known groups are: 18 species of Cnidaria (Coelenterata), 58 species of Mollusca, 12 species of Annelida, 75 species of marine Arthropoda, 85 species of terrestrial Arthropoda (including 2 tick species, 7 chiggers, 23 biting lice, and 2 louse flies), and 37 species of Echinodermata.

The vertebrates are well known. There are at least two species of pelagic fishes and 194 species of inshore fishes. Dredging operations have drastically reduced the fish population in certain

lagoon areas. Ciguatera is prevalent among the inshore fishes, with the moray eel, white-tipped reef shark and grey sand shark being most toxic.⁴ Five species of reptiles are known; all but one were introduced by man. Likewise, no mammals are native to the atoll; however, man has introduced six species. Fifty-six species of birds, whose total population ranges upward to 600,000, are known from the atoll. Of the 22 seabird species, 12 species are breeders, 3 are former breeders, and 7 are visitors. Of the 34 species of waterfowl, marsh, and land birds, 7 species are regular migrants, 6 are irregular visitors, 2 are stragglers, 16 are accidentals, and 3 are introductions. Analysis of 60,932 returns of 303,901 birds comprising 21 species banded at Johnston Atoll reveals that the atoll is the major focal point for interisland movements in the north-central Pacific. A total of 733 individual banded birds have moved to or from Johnston Atoll; most interisland movement involves the northwestern Hawaiian Islands.

Johnston Atoll is perhaps the most scientifically studied atoll in the central Pacific. Despite man's disturbance, the atoll is ecologically significant because of its isolation and from the standpoint of its opportunities for island ecological research. Although much ecological research has been accomplished, the potential of additional ecological understanding of the atoll is great.

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APPENDIX B

EXECUTIVE ORDERS (NOS. 4467, 6935, & 8682)
ESTABLISHING JURISDICTION OVER JOHNSTON ISLAND

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Executive Order

It is hereby ordered that two small islands known as Johnston island and Sand island, located in the Pacific Ocean, approximately in latitude $16^{\circ} 44' 45''$ North and longitude $169^{\circ} 30' 30''$ West from Greenwich, as segregated by the broken line upon the diagram hereto attached and made a part of this order, be and the same are hereby reserved and set apart for the use of the Department of Agriculture as a refuge and breeding ground for native birds.

It is unlawful for any person to hunt, trap, capture, wilfully disturb or kill any bird of any kind whatever, or take the eggs of such bird within the limits of this reserve, except under such rules and regulations as may be prescribed by the Secretary of Agriculture.

Warning is expressly given to all persons not to commit any of the acts herein enumerated, under the penalties prescribed by Section 84 of the U. S. Penal Code, approved March 1, 1909 (35 Stat., 1088), as amended by the Act approved April 15, 1924 (43 Stat., 98).

This reservation to be known as Johnston Island Reservation.

CALVIN COOLIDGE

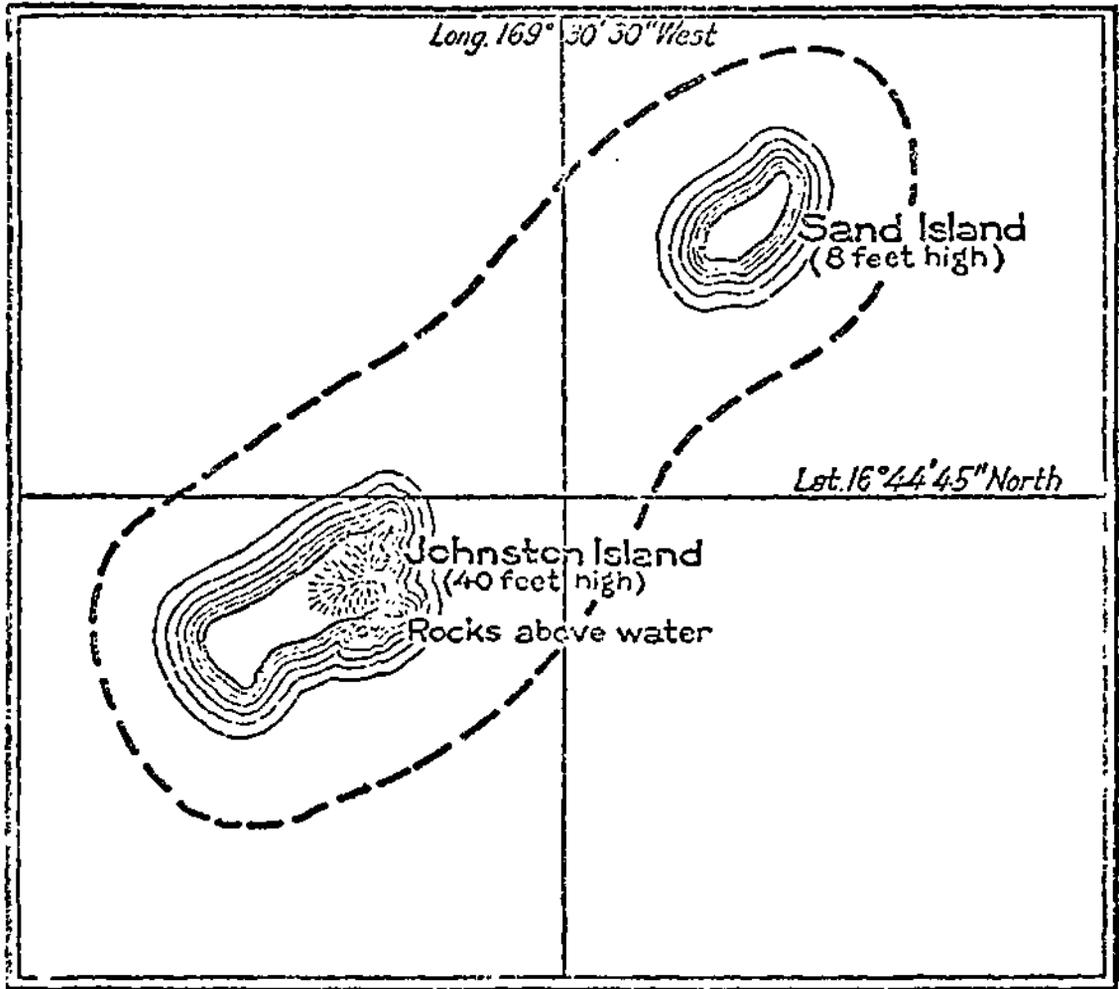
THE WHITE HOUSE,
June 29, 1926.

[No. 4467]

JOHNSTON ISLAND RESERVATION

For the Protection of Native Birds

Embracing two small islands known as Johnston Island and Sand Island located in the Pacific Ocean approximately in Latitude 16°44'45" North, Longitude 169°30'30" West.



DEPARTMENT OF THE INTERIOR

Hubert Work, Secretary

GENERAL LAND OFFICE

William Spry, Commissioner

DEPARTMENT OF THE INTERIOR

Executive Order

PLACING CERTAIN ISLANDS IN THE PACIFIC OCEAN UNDER THE CONTROL AND JURISDICTION OF THE SECRETARY OF THE NAVY

WAKE ISLAND, KINGMAN REEF, AND JOHNSTON AND SAND ISLANDS

By virtue of and pursuant to the authority vested in me by the act of June 25, 1910, ch. 421, 36 Stat. 847, as amended by the act of August 24, 1912, ch. 369, 37 Stat. 497, and as President of the United States, it is ordered that Wake Island located in the Pacific Ocean approximately in latitude $19^{\circ}17'28''$ N. and longitude $168^{\circ}34'42''$ E. from Greenwich, Kingman Reef located in the Pacific Ocean approximately in latitude $6^{\circ}24'37''$ N. and longitude $162^{\circ}22'$ W. from Greenwich, and Johnston and Sand Islands located in the Pacific Ocean approximately in latitude $16^{\circ}44'32''$ N. and longitude $169^{\circ}30'59''$ W. from Greenwich, together with the reefs surrounding all the aforesaid islands, as indicated upon the diagram hereto attached and made a part of this order, be, and they are hereby, reserved, set aside, and placed under the control and jurisdiction of the Secretary of the Navy for administrative purposes, subject, however, to the use of the said Johnston and Sand Islands by the Department of Agriculture as a refuge and breeding ground for native birds as provided by Executive Order No. 4467 of June 29, 1926.

This order shall continue in full force and effect unless and until revoked by the President or by act of Congress.

FRANKLIN D ROOSEVELT

THE WHITE HOUSE,

December 29, 1934.

[No. 6935]

EXECUTIVE ORDER 8682

ESTABLISHING NAVAL DEFENSIVE SEA AREAS
AROUND AND NAVAL AIRSPACE RESERVA-
TIONS OVER THE ISLANDS OF PALMYRA,
JOHNSTON, MIDWAY, WAKE, AND KING-
MAN REEF

PACIFIC OCEAN

By virtue of the authority vested in me by the provisions of section 44 of the Criminal Code, as amended (U.S.C., title 18, sec. 96), and section 4 of the Air Commerce Act approved May 20, 1926 (44 Stat. 570, U.S.C., title 49, sec. 174), the territorial waters between the extreme high-water marks in the three-mile marine boundaries surrounding the islands of Palmyra, Johnston, Midway, Wake, and Kingman Reef, in the Pacific Ocean, are hereby established and reserved as naval defensive sea areas for purposes of national defense, such areas to be known, respectively, as "Palmyra Island Naval Defensive Sea Area", "Johnston Island Naval Defensive Sea Area", "Midway Island Naval Defensive Sea Area", "Wake Island Naval Defensive Sea Area", and "Kingman Reef Naval Defensive Sea Area"; and the airspaces over the said territorial waters and islands are hereby set apart and reserved as naval airspace reservations for purposes of national defense, such reservations to be known, respectively, as "Palmyra Island Naval Airspace Reservation", "Johnston Island Naval Airspace Reservation", "Midway Island Naval Airspace Reservation", "Wake Island Naval Airspace Reservation", and "Kingman Reef Naval Airspace Reservation".

At no time shall any person, other than persons on public vessels of the United States, enter any of the naval defensive sea areas herein set apart and reserved, nor shall any vessel or other craft, other than public vessels of the United States, be navigated into any of said areas, unless authorized by the Secretary of the Navy.

At no time shall any aircraft, other than public aircraft of the United States, be navigated into any of the naval airspace reservations herein set apart and reserved, unless authorized by the Secretary of the Navy.

The provisions of the preceding paragraphs shall be enforced by the Secretary of the Navy, with the cooperation of the

local law enforcement officers of the United States and of the Territory of Hawaii; and the Secretary of the Navy is hereby authorized to prescribe such regulations as may be necessary to carry out such provisions.

Any person violating any of the provisions of this order relating to the above-named naval defensive sea areas shall be subject to the penalties provided by section 44 of the Criminal Code as amended (U.S.C., title 18, sec. 96), and any person violating any of the provisions of this order relating to the above-named naval airspace reservations shall be subject to the penalties prescribed by the Civil Aeronautics Act of 1938 (52 Stat. 973).

This order shall take effect ninety days after date hereof.

FRANKLIN D. ROOSEVELT

THE WHITE HOUSE,

February 14, 1941.

EXECUTIVE ORDER 8683

ESTABLISHING NAVAL DEFENSIVE SEA AREAS
AROUND AND NAVAL AIRSPACE RESERVA-
TIONS OVER THE ISLANDS OF ROSE, TU-
TUILA, AND GUAM

PACIFIC OCEAN

By virtue of the authority vested in me by the provisions of section 44 of the Criminal Code, as amended (U.S.C., title 18, sec. 96), and section 4 of the Air Commerce Act approved May 20, 1926 (44 Stat. 570, U.S.C., title 49, sec. 174), the territorial waters between the extreme high-water marks in the three-mile marine boundaries surrounding the islands of Rose, Tutuila, and Guam, in the Pacific Ocean, are hereby established and reserved as naval defensive sea areas for purposes of national defense, such areas to be known, respectively, as "Rose Island Naval Defensive Sea Area", "Tutuila Island Naval Defensive Sea Area", and "Guam Island Naval Defensive Sea Area"; and the airspaces over the said territorial waters and islands are hereby set apart and reserved as naval airspace reservations for purposes of national defense, such reservations to be known, respectively, as "Rose Island Naval Airspace Reservation", "Tutuila Island Naval

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APPENDIX C

SAILING DIRECTIONS FOR THE PACIFIC ISLANDS

Vol III, The South-Central Groups,
6th Ed. 1952, pp. 354-357

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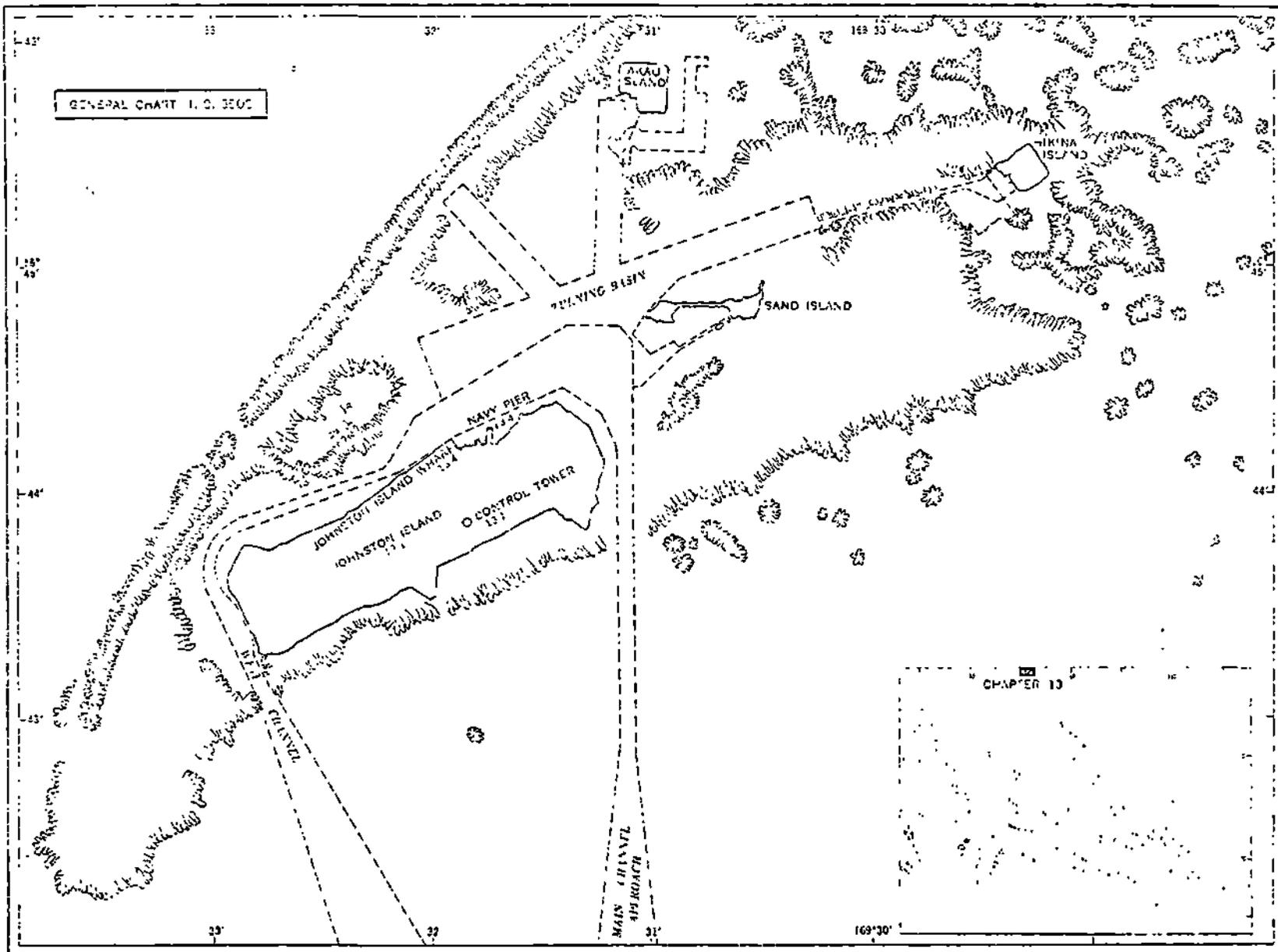


Chart data shown are of the best scale charts issued to naval vessels by the U.S. Naval Oceanographic Office.
Section numbers refer to the place in the text where a description of the designated locality begins.

CHAPTER 13—GRAPHIC INDEX

JOHNSTON ATOLL

13-1 JOHNSTON ISLAND (Johnston Atoll) (16°45'N., 169°11'W.), a possession of the United States, consists of four islets that lie on a reef about 9 miles long in a northeast and southwest direction. The southwesternmost of the islets, known as Johnston Island, is about 3,500 yards long in a northeast and southwest direction, and about 700 to 1,200 yards wide. The smaller island, about 3/4 of a mile to the northeastward is known as Sand Island. An airfield is located on Johnston Island. Two small artificial islands, known as Akau and Hikina Island, are located at about 1 1/2 miles northward and 2 1/3 miles east-northeastward, respectively, of the east end of Johnston Island.

Johnston Island is a Naval Defense Sea Area and Airspace Reservation and is closed to the public. The airspace entry control has been suspended, but is subject to immediate reinstatement without notice. The administration of Johnston Island is under the jurisdiction of the Joint Chiefs of Staff, Defense Atomic Support Agency and Joint Task Force Eight.

Johnston Island Air Force Base is closed to all traffic except emergency landings and flights directed or approved by Commander Joint Task Force Eight, or by the island commander, Commander, Joint Group 8.6.

No vessels, except those authorized by Commander, Joint Task Force Eight or Commander, Joint Task Group 8.6, shall be navigated within the three-mile limit. For merchant vessel entrance procedure see section 1-22. In addition to these procedures authorities at Johnston Atoll must receive ship visit requests a minimum of 5 days in advance, and include certifications of masters' and ships' crew security clearances in the request.

WINDS-WEATHER.—Weather is usually excellent for navigation.

Winds average 10 to 15 knots in summer, and 15 to 25 knots in winter. They are from east to northeast about 90% of the time. During kona weather, the occasional Hawaiian Island storms are characterized by stormy southerly or southwesterly winds and heavy rains.

Brief showers occur frequently, but protracted bad weather is rare. Average rainfall varies from 30 to 50 inches.

Visibility is good, usually over 12 miles. There is no fog.

TIDES.—The high-water interval at full and change is 3h. 15m. The mean range of the tide is 1.8 feet.

DEPTHS-DANGERS.—A barrier reef extends in an arc from west to northeast of the islands. Depths outside the reef line drop off to 182.9m (100 fm.) in about 700 yards. With heavy breakers on the reef, a 0.6m (2 ft.) to 0.9m (3 ft.) surge exists in the lagoon. From northeast, via south, to southwest is a foul area with very irregular bottom. The 182.9m (100 fm.) curve lies 4 miles due south of the center of Johnston Island proper, however, there are 10.4m (34 ft.) shoals lying as close as 550 yards inside the curve and to the southeastward of the island. From south of Johnston Island the 182.9m (100 fm.) curve extends to the eastward about 063° about 11 miles, thence veering off northwestward. From this same point, 4 miles due south of the center of Johnston Island, the 182.9m (100 fm.) curve continues on about 248° for a distance of least 2 1/2 miles.

LANDMARKS.—The control tower and aviation beacon on Johnston Island and the towers on Sand Island are prominent. A tank, with a dish antenna, marked by an obstruction light and located on the northeast side of Johnston Island, is prominent.

The 640-foot loran tower on Sand Island was reported visible at 27 miles. The towers and buildings on this island show as separate radar targets. The outline of the island does not show until within 10 miles of the island.

HARBOR.—The harbor consists of a turning basin within the lagoon about midway between Sand Island and Johnston Island. The turning basin and harbor area are dredged to 10.7m (35 ft.). The berthing area alongside the main pier has been dredged to 9.1m (30 ft.) 1968. Vessels may anchor in the turning basin or berth at Johnston Island Navy Pier or Main Wharf. Mooring buoys are moored in the turning basin between 550 yards and 1,000 yards northeastward of the pier head.

The main entrance channel is entered southeastward of Johnston Island and is indicated on the chart by dashed lines. The channel, which bears true north and south, was dredged (1964) to a depth of 10.7m (35 ft.). Maximum draft for vessels entering the harbor under normal conditions is 0.5m (28 ft.) (1968). The navigable width of the channel is 400 feet. The largest ship that has entered and docked (1966) was 523 feet in length with a beam of 68 feet.

The channel to Sand Island narrows from about 200 feet to 100 feet as the dock is approached, Sand Island dock, approximately 60 feet long, is suitable only for small craft.

A channel with a least depth of 4.6m (15 ft.) (1967) has been dredged from the southwestern corner of the turning basin through the reef close westward and close southwestward of Johnston Island.

13-2 NAVIGATIONAL AIDS.—Johnston Atoll Fairway Entrance Buoy, equipped with a radar reflector and painted in black and white vertical stripes, is moored in about 36 feet in position 16°41'54.5"N., 169°31'07.3"W. Johnson Atoll Channel Entrance Lighted Buoy 2 is moored in approximately 16°43'N., 169°31'W. and is equipped with a radar reflector. Channel Lighted Buoy 3, is moored about 1/2 mile northward of Buoy 2, on the west side of the channel. Channel Buoy 4, moored 150 yards eastward of Buoy 3, is equipped with a red reflector. The remainder of the channel to the turning basin is marked as follows: the west side by square concrete pile beacons fitted with green reflectors; the east side by square concrete pile beacons fitted with red reflectors, the beacons are at the channel limits. Several beacons have lights.

The channel from the turning basin to Johnston Dock is marked by buoys.

Range lights, marking the entrance channel are shown from rectangular-shaped daymarks; the front beacon is located at the northeastern corner of the turning basin; the rear beacon is 360° from the front beacon, distant about 640 yards.

A light is shown from the northeast end of the island.

A light is shown on the seaward end of the breakwater on Johnston Island.

A light is shown near the northeastern corner of the Navy Pier.

Obstruction lights are shown from the loran tower on Sand Island.

An aeronautical radio beacon transmits from a tower near the center of Johnston Island.

REGULATIONS.—The following regulations are in effect:

As of April 1968, entrance to the harbor is not recommended at night. Ships are requested to night steam or anchor 3 miles southward of Johnston Island to wait for daylight.

Observe carefully rules and regulations prescribed by the Commandant for navigation in harbors and anchorages of Johnston Island, and have on board an officer familiar with these waters while underway in these areas.

All persons on board shall be U.S. citizens. No photographs will be taken from the vessel. All cameras will be kept in the custody of the Master so long as the vessel is within waters contiguous to Johnston Island.

While anchored the vessel will maintain steam up and be prepared to get underway.

Dogs, cats, and other animals shall be confined on board.

Plants and fruits will not be imported without specific authority of the Commander of Johnston Island.

No garbage or ashes will be dumped overboard within three miles of Johnston Island. Ships will normally dump garbage before entering the channel. During the stay in port garbage and trash removal will be arranged.

Rat guards will be placed promptly on all lines, chains, hawsers, etc., used to make fast.

No oil or oily bilges may be pumped while in the harbor.

CAUTION.—An explosives dumping area has been established southwestward of Johnston Island, between the parallels of 16°25' N., and 16°35' N., and between the meridians of 169°45' W., and 169°53' W.

13-3 ANCHORAGES.—It is suggested that vessels drawing more than 8.5m (28 ft.) anchor in the channel approach area south of the channel entrance.

Emergency Anchorage can be taken in the turning basin. As soon as practicable ships will be moved pier-side or to a mooring buoy. The bottom in the turning basin is sand and coral, poor holding ground.

CAUTIONS.—A submarine cable is laid from the east end of Johnston Island southward down the main channel for about 2 1/4 miles.

Submarine cables are laid between Johnston Island, Sand Island, and Akau Island. Submarine cables are laid between the latter island and Hikina Island. (See H. O. Chart 5505.)

PILOTS.—No licensed pilots are available. Ships normally may not enter at night or when cross-channel winds exceed 25 knots. The harbor master will board ships at the fairway entrance buoy with current information as to channel and harbor conditions. A navy tug is available for cocking.

DIRECTIONS.—Vessels bound for Johnston Island ship channel should approach the channel from southward passing through position 16°41'00"N., 169°31'08"W., thence proceed northward to the fairway entrance buoy. When abeam the fairway entrance buoy they should heave to and await the boarding officer. While heave to, a drift to the westward will usually be experienced. This drift must be checked, because the exact limits of the foul area on the port hand are not determined. There is usually a current in the channel, determined by tidal conditions. During the rising tide the current flows north and during the falling tide it flows south. It attains a rate of 1 knot to 2 knots. At low tide transition (low plus or minus 1 1/2 hours) the current flows southwestward at a rate of about 1 knot. At high tide transition (high plus or minus 1 hour) the current flows northward but is weak. Vessels with low power or with a relatively high wind area should favor the eastern side of the channel. A minimum speed of 3 knots should be maintained to overcome the effect of wind and current and increased proportionally with unusual conditions. During periods of heavy swell on the barrier reef, a strong easterly set may be encountered at the junction of the entrance channel and the turning basin, particularly during ebb tide.

13-4 FACILITIES.—Johnston Island Naval Pier is 400 feet long by 50 feet wide with pierhead of 186°, and has a timber deck supported by steel piling. Ships tie up starboard side to. The pier will accommodate ships with a maximum draft of 4.6m (15 ft.) Diesel oil pipelines are installed on the deck.

Johnston Island Main Pier, 570 feet in length with pierhead of 236° is constructed of steel piling with concrete cap and has a depth of about 9.1m (30 ft.) alongside.

There is a small boat dock with five 50-foot slips. It has a depth of 2.4m (8 ft.) alongside, and is located westward of the Navy Pier.

At Sand Island there is a 60-foot long lumber quay wall, which is used only by station craft.

Cargo handling facilities include one 60-ton capacity crane and two 45-ton capacity cranes.

Fresh Water can be furnished to transient ships.

Repair facilities are available for local small craft.

COMMUNICATIONS with the island is under military control. When ships are within 100 miles, they are requested to contact the harbor master by voice radio on 2716 kc. The voice call Johnston Control is used and this frequency has a 24 hour guard. Radio contact can also be established on other marine frequencies if prior arrangements are made. The island uses zone +10 time.

13-5 OFF-LYING BANKS.—A bank with a depth of 12.8m (7 fm.) to 14.6m (8 fm.) over it, lies at a distance of about 7 3/4 miles eastward from the eastern end of Johnston Island.

NOVELTY SHOAL.—Captain F. Herriman, master of the schooner Novelty, reported in 1897 that with the eastern end of Johnston Island bearing 257°, distant 12 miles; in approximately 16°49'N. latitude, 169°14'W. longitude, he obtained soundings of 5 1/2 fathoms, rocky coral bottom. The bottom was visible for half an hour after taking the soundings while the vessel ran north 2 miles. Light breakers were seen about 3 miles to the eastward while the vessel was passing over the shoal.

APPENDIX D
INCINERATION OF ORANGE HERBICIDE

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APPENDIX D

INCINERATION OF ORANGE HERBICIDE

A. GENERAL INFORMATION: The purpose of this appendix is to provide basic information concerning the combustion of Orange herbicide, to review all previous Orange herbicide incineration studies, and to comment on the applicability of incineration as a method of Orange herbicide disposal. It is noted that an incineration method known as "moisten salt incineration" is not included in the review of previous studies contained in paragraph C. This method has been favorably applied to certain pesticide incineration studies; however, the method has not been applied to Orange herbicide incineration and therefore no Orange incineration data is available. The limited data on this system preclude any judgment as to its application to the large scale disposal of Orange. In addition, the fate of TCDD in this system will require investigation in view of concern over possible TCDD production at the temperature, pressure, and in the sodium environment in which the reactions occur (Baughman and Meselson b, 1973).

1. COMPLETE COMBUSTION: The theoretical products of combustion of Orange herbicide are carbon dioxide, hydrogen chloride, and water. Fifty pounds of normal butyl 2,4-D and 50 pounds of normal butyl 2,4,5-T would require 74 pounds and 67 pounds of oxygen, respectively, for complete combustion. Therefore, approximately 141 pounds of oxygen is required for the complete combustion of 100 pounds of herbicide. With the oxygen supplied in air, 610 pounds or 8200 cubic feet of air at 25°C, 760 mm is required for the combustion of 100 pounds of herbicide.

2. TEMPERATURE REQUIREMENTS: The Mississippi State, U.S. Department of Agriculture Report on Thermal Decomposition of Orange Herbicide, referenced in paragraph B, 1, reports the temperatures required for the complete combustion of Orange herbicide. The analysis was accomplished by the differential thermal analysis method utilizing a "Deltatherm" Model D2000, Technical Equipment Corporation, differential thermal analyses apparatus. The following is quoted from the referenced report: "The results show that both 2,4-D and 2,4,5-T analytical standard materials (free acids) are readily combusted between 330 and 360°C (Table 2). Esterified materials, i.e., normal butyl esters of 2,4-D and 2,4,5-T and the isooctyl ester of 2,4,5-T, on the other hand, require roughly twice as high a temperature for degradation as do their counterpart free acids. All three esters are combusted between 550 and 700°C. Dioxin (TCDD) is completely combusted between 980 and 1000°C. The bulk of the TCDD molecule, however, appears to be disintegrated at 850°C as indicated by an extremely large exothermic peak on the DTA curve (Figure 7). It is estimated (please note estimated) that about 70% of the TCDD molecule is degraded at that temperature alone. Two small exothermic peaks are shown at the completion of burning at 955 and 975°C with complete burning taking place at 980 to 1000°C. Similarly Orange and Orange II herbicides are completely combusted between 960 and 980°C. The normal butyl 2,4,5-trichlorophenoxyacetate containing 0.1 ppm dioxin (TCDD) is thermograded in the same temperature range as the esters without TCDD. Apparently the TCDD concentration was too small to be of any consequence, although it was conspicuous with Orange and Orange II herbicides." The caloric value of the Orange is 10,000 Btu per pound. This data was obtained on the basis of 200 samples collected at random from the Gulfport stock and analyzed at the Aerospace Fuels Laboratory, Wright-Patterson AFB, Ohio. The theoretical adiabatic flame temperature for complete combustion, under the test conditions described in Appen-

dix E, i.e., 1.55 pounds per second of air at 520°F and 0.185 pounds of herbicide per second at 77°F, is calculated to be greater than 3,000°F.

B. PREVIOUS STUDIES ON ORANGE INCINERATION

1. MISSISSIPPI STATE UNIVERSITY AND THE U.S. DEPARTMENT OF AGRICULTURE, STATE COLLEGE, MS.

a. Report: Technical Report on Thermal Decomposition of Orange Herbicide under the Amendment No.2 to the U.S.D.A. Cooperative Agreement No. 12-14-100-10, 673(34); submitted by Mississippi Agricultural and Forestry Experiment Station and Plant Science Research Division of the United States Department of Agriculture to the Department of the Air Force, Headquarters San Antonio Air Material Area (AFLC) Directorate of Aerospace Fuels, Kelly Air Force Base, Texas 78241; June 1, 1972 State College, Mississippi 39762. This report was prepared by Mr. B.J. Stojanovic, Mr. M.V. Kennedy and Mr. W.C. Shaw.

b. Objectives: The objectives as quoted from the report are: "The objective of this laboratory study was to determine temperatures required for complete thermal degradation, the degradation products, and the volatile gases of Orange herbicides containing dioxin (TCDD) and evaluate suitable scrubbing agents to remove toxicants from the effluent. Another phase of this project was to determine the biological activity (phytotoxicity) of the residues resulting from Orange herbicide incineration."

c. Type of Incineration: Herbicide samples were placed in ceramic combustion boats which were placed in a Vycor glass combustion tube (length 121 cm, O.D. 2.5 cm). The tube was placed in a resistance-type furnace; the total heated length of the tube was 80 cm. A silica combustion tube (30" x 1" I.D.) replaced the Vycor tube after some initial experiments. Commercial oxygen or air was passed through the combustion tube at a prescribed rate.

d. Quantity of Orange Incinerated: A series of experiments were conducted at various temperatures, 700 to 1000°C to determine chloride recovery, particulate recovery, scrubber efficiency, and carbon monoxide and carbon dioxide recovery. Experiments were conducted for mass spectrophotograph analysis of exhaust gas samples and extracts of particulate filters. Experiments were also conducted for phytotoxicity analysis. Herbicide and TCDD analyses were accomplished throughout these experiments. The ceramic combustion boat was usually loaded with 100 mg of test material for each experiment; in all, approximately 5-6 grams of Orange and Orange II (isooctyl ester) were incinerated.

e. Monitoring: All of the carrier/combustion gas for each experiment was passed through collection devices, particulate traps, impingers, which utilized selective collecting medias depending on the analyses to be performed.

f. Results: The results were excellent as regards herbicide and TCDD destruction; the chlorine is released as essentially all hydrogen chloride as opposed to chlorine; particulate levels were significant; and the carbon was released essentially as carbon dioxide. No TCDD was indicated in any of the tests performed for TCDD. The phototoxicity experiments showed that hydrogen chloride is very phytotoxic (as expected) and that alkaline scrubbers are very efficient in entraining hydrogen chloride and any other phytotoxic gaseous compound in the combustion gas from Orange incineration.

g. Incomplete Combustion: Orange contains roughly three times as much carbon and oxygen; incomplete combustion could result in particulate matter and possibly carbon monoxide. In addition, roughly one-third of Orange herbicide is chlorine; therefore, certain chlorine compounds could result from the combustion of Orange. The technical report lists the following theoretical compounds which could result from the complete/incomplete combustion of Orange: chlorine, chlorine monoxide, chlorine dioxide, chlorine hexoxide, chlorine heptoxide, chlorates, hydrogen chloride, hydrochloric acid, chlorinated water, hypochlorous acid, chlorous acid, chloric acid, perchloric acid, chlorine hydrate, and phosgene. All of these compounds are highly corrosive and toxic, about one-third are gases at normal temperature. The technical reports that "thermo-chemically speaking, however, hydrogen chloride and hydrochloric acid may be expected to be the chief, if not the only, chlorinated compounds released upon incineration of Orange herbicide." The experiments, as noted above, revealed the chlorine to be released as hydrogen chloride. In the experiments conducted for mass spectrograph analysis, the combustion gas was passed through a particulate trap (pyrex wool) and three impingers (benzene) in series. The analyses of the impinger samples for herbicide and TCDD was negative. The particulate matter traps were extracted with hexane and then with sodium hydroxide. The results are quoted from the technical report:

"Trace quantities (2.0-200 ppb) of 2,4-D and 2,4,5-T free acids were detected in the NaOH extracts of the particulate matter (Table 12). The 2,4-D n-butyl ester and 2,4,5-T isooctyl ester were, however, present in quantities ranging from 0.70 to 370 ppb in both the hexane and NaOH extracts of each particulate matter trap. The presence of 2,4,5-T isooctyl ester in the traps was unexpected as the 2,4,5-T component of Orange herbicide is the n-butyl ester. The origin of this compound cannot definitely be established on the basis of these investigations. It is, however, suspected to be an artifact, formed during combustion of the herbicide, which has an elution time coinciding with that of 2,4,5-T isooctyl ester and appears as such on the chromatogram. The gas chromatograms of the hexane extracts of the particulate matter traps indicated the presence of approximately 20 additional compounds which were not identified. Dioctylphthalate was identified as a contaminant by infrared spectroscopy. The results of this experiment have shown that at 1000°C traces of herbicides may be volatilized and be carried out of the burning range of the furnace. From a practical point of view, none of these materials would be expected to pass an alkaline scrubber where they would very likely be trapped and destroyed by the alkali."

h. Conclusions and Recommendations: The conclusions and recommendations are quoted from the technical report:

(1) Conclusions:

- "a. A minimum temperature of 1000°C is necessary to insure complete combustion of pure dioxin (TCDD).
- b. The bulk of the TCDD molecule (estimated 70%) is disintegrated at 850°C.
- c. Both Orange and Orange II herbicides are completely combusted at 980°C, whereas normal butyl 2,4,5-T herbicide containing less than 0.1 ppm TCDD is combusted at 550°C.

- d. More than 95% chlorine is recovered from burning orange herbicides at 800°C. The chlorine is released chiefly if not entirely as hydrogen chloride gas.
- e. Dioxin (TCDD) was not detected in the incombustible residue (including the particulate matter) and the effluent scrubbing solutions following incineration of orange herbicides at 750, 800, and 850°C.
- f. Incineration of herbicides under these experimental conditions does not produce carbon monoxide as none was detected in the effluent gas stream.
- g. Oxygen supply during the incineration process appears to be less critical for dehalogenation than for cleavage of carbon-to-carbon bonds of herbicides.
- h. Sodium hydroxide solutions of appropriate strength are for all practical purposes found to be the most efficient and desirable scrubbers for the effluent stream.
- i. Unscrubbed effluent gases are found to be extremely toxic to young tomato plants. Hydrogen chloride in itself causes almost instantaneous kill.
- j. One or more secondary burning chambers appear to be necessary for efficient incineration of orange herbicides."

(2) Recommendations:

- "1. Even though the procedures used to obtain the preliminary data on thermal degradation of orange herbicides yielded important and very useful fundamental information, this information cannot be extrapolated and applied directly to a commercial incinerator.
- 2. A series of incineration runs with orange herbicides should be conducted within a short-term testing program in a research pilot incineration system.
- 3. The testing program should have as its chief objective the establishment in the shortest possible time of feasible parameters for the complete and safe incineration of Orange herbicides.
- 4. It is considered most urgent that the testing program should involve determination of the following:
 - a. Temperature profile in the system
 - b. Herbicide flow-rate (dwell time)
 - c. Products of combustion by monitoring effluent gases, and
 - d. Scrubber efficiency and composition of residues. Other factors may possibly also have to be considered but these could be established during the incineration tests.

5. Based on the tests currently being conducted by the investigators (with a pesticide pilot incineration system), it is estimated that a minimum of 90 days will be necessary to carry out the testing program and translate the laboratory research to a practical incineration system."

2. USAF ENVIRONMENTAL HEALTH LABORATORY, KELLY AFB TX

a. Report: Technical Report, Incineration of Orange Herbicide, July 1972, EHL(K) 72-7, USAF Environmental Health Laboratory, Kelly AFB TX. This report was prepared by Dr. R.A. Callahan.

b. Objectives: The scope of the laboratory work described in this report is to: 1) determine the feasibility of using Gas Liquid Chromatography (GLC) alone to analyze combustion gases and scrubbing blow-down water for the herbicide esters and TCDD, and 2) development of efficient methods of extracting the normal butyl esters and TCDD from gaseous and water discharges. In addition, the status of the Orange disposal via incineration including trip reports, impact statement comments, etc. was documented in this report.

c. Type of Incinerator: A small continuous burning flow through incinerator which approximated the fuel/air injection method, dwell time, air/fuel ratios and temperatures anticipated in commercial facilities was configured for the laboratory experiments. The incinerator chamber consisted of a Vycor-Pyrex tube with a length of 33 cm and a volume of 156 cc. This tube was placed in a Lindberg heavy duty furnace equipped with heating elements capable of operating at 1200°C. The system functioned as follows:

"Fuel (Orange Herbicide) was continuously delivered at a metered rate (via Hamilton 2.5 ml gas syringe mounted on a Sage Model 350M pump) to the tip of a blunted stainless steel 22 gauge needle. The tip of this needle was sealed in a stainless steel Luer Lock syringe fitting. Compressed air was metered into this fitting via a 0-1 ml/min rotometer. The Orange was continuously aerosoled from the tip of the fuel probe into the furnace tube. The air/fuel mixture was then deflected upwards by a dispersing cup. The combusting gases passed directly up and out of the furnace tube. The aerosol injection probe was a 20 gauge stainless steel pudental needle; the dispersing cup was also stainless steel."

d. Quantity of Orange Incinerated: Fourteen test runs are reported with a total of 14.12 ml of Orange incinerated. The run time for the experiments averaged 12 minutes with a minimum of 10 and a maximum of 30 minutes. The temperature of the combustion gases at the exit of the tube ranged from 740 to 950°C.

e. Monitoring: The entire combustion gas volume was passed through a sampling train consisting of midjet impingers and a freeze trap. The apparatus was all glass and both tapered and fritted impingers were used. The impinger media was either distilled water or benzene. The sampling time was the same as the above mentioned run time; the air flow rate was usually 0.65 liters/min; therefore, the sample size was approximately 8.0 liters.

f. Results: Twelve runs were sampled, analyzed, and reported for herbicide; of these two were monitored, analyzed and reported for TCDD. The TCDD concentration in the Orange used for these two runs was 14 ppm while that of the remaining runs was <0.1 ppm. A summary of the results from the report is quoted:

"The destruction of the NB esters and TCDD in the model incinerator at 920°C, 2-3 second dwell times, and 150-180 percent stoichiometric air exceeded 99.999 percent for the esters and 93 percent for the TCDD. Total discharges of the combined esters ranged from 8.0-50.0 ppb (parts per billion) in the untreated gas discharges. The TCDD discharged when burning Orange containing high concentrations of TCDD were 3.0 and 18.0 ppb. Detailed data is presented in Appendix A, pg. 8."

g. Incomplete Combustion: The identification of incomplete combustion products or intermediate pyrolyzates was not within the scope of this project. Two chromatograms are shown in the technical report to depict the difference between a "clean" chromatogram - showing only residues of the herbicide esters and TCDD, and, a "less clean" chromatogram in which the peaks of five chlorinated pyrolyzates are present along with the peaks of herbicide esters and TCDD. The difference was attributed to temperature and excess air with the run having the higher temperature and greater excess air having the clean chromatogram.

h. Conclusions and Recommendations: Those conclusions and recommendations pertaining to the laboratory incineration test runs are quoted from the technical report.

(1) Conclusions:

1. Monitoring the NB esters of 2,4-D and 2,3,5-T and TCDD in water and gas effluents resulting from commercial incineration appear feasible.

2. Limits of detection for each of the NB esters in effluent gas and water are 2.0 and 1.0 ppb respectively. The corresponding limits for TCDD are 3.0 and 1.0 ppb respectively.

3. Interference from other pyrolyzates will be negligible at temperatures of 1000°C, dwell times of 3 seconds and stoichiometric air/fuel ratios of 150%.

4. The very high water content of the gas samples taken from the incinerator stacks may interfere with the benzene charged fritted impinger extraction system. This condition is readily detectable. Substituting ethylene glycol for benzene in the first impinger should overcome this potential problem. Other alternatives are available.

5. Emissions of the NB esters of 2,4-D and 2,4,5-T and TCDD when burned at 1000°C with 150% air and a dwell time averaging 3 seconds will be very low and safe to all forms of life. Incineration in tandem with the monitoring program developed above and outlined in detail in Appendix B of this report will offer negligible risks to the environment or human health from emissions of NB herbicide esters or from TCDD."

(2) Recommendations: "Identification of other pyrolyzates formed during the incineration of Orange herbicide should be accomplished as soon as possible. Pyrolysis of herbicide in such experiments should be accomplished in a continuously burning liquid injection incinerator as described herein to provide valid results."

3. THE MARQUARDT COMPANY, VAN NUYS, CA

a. Report: Report S-1224, "Report On The Feasibility of Destroying Herbicide Orange by Incineration Using the Marquardt SUE Burner," August 1972,

the Marquardt Company, Van Nuys, CA. This report was prepared by Mr. R. Babbitt and Mr. J.L. Clure.

b. Objectives: The objective as described in the technical report was: "A test program was conducted to determine the feasibility of destroying herbicide Orange by means of combustion. Particular emphasis was placed on the ability to destroy the trace quantities of dioxin present in the herbicide. Attention was also placed on the ability to destroy the herbicide itself and to determine the nature and extent of the undesirable components in the exhaust gases and in the scrubbing liquid used to cool and scrub the exhaust gases."

c. Type of Incinerator: The incinerator system consists of a 12" diameter SUE Burner with a 48" air cooled combustion chamber and a 120" uncooled reaction tailpipe. The SUE stands for "sudden expansion" which describes the injection and combustion of fuel within the combustion chamber. The fuel injection system is at the entrance to the combustion chamber (a poppet valve was used in these test runs) and an alkaline scrubber device (a venturi scrubber) is connected to the exit of the reaction tailpipe. The scrubber is connected to a gas/water separator and stack. The incinerator system is described fully in Appendix E.

d. Quantity of Orange Incinerated: A total of 56 test runs were made, 34 were in Phase I - Exploratory Testing, and 22 were in Phase II - Data Gathering Test Program. Of the 22 in Phase II, 11 were with the incineration of Orange only and no auxiliary fuel. The run time of the Phase II burns ranged from <1 to 5 minutes and the fuel flow rate and air flow rate ranged from 0.032 to .200 and 0.979 to 1.525 pounds per second, respectively. The temperature, measured about half way down the reaction tailpipe, ranged from 1730° to 2360°F. In all, approximately 37 gallons of Orange was incinerated in the Phase II testing.

e. Monitoring: During Phase II, samples of the combustion gases (near the exit of the reaction tailpipe), stack gas, and spent scrubber water were collected. Collection devices and techniques are described below; impinger trains were not used. The following is quoted from an Appendix of the report; the Appendix was prepared by the West Coast Technical Services Inc., Cerritos, CA, who performed the analytical analysis.

"APPENDIX A: The combustion products from the various test runs on the Marquardt Company SUE Burner have been analyzed by gas chromatography and mass spectroscopy. The gas analyses were performed by mass spectroscopy while the condensable materials were analyzed by gas chromatography and combined gas chromatography-mass spectroscopy.

I. SAMPLING PROCEDURES

A. Combustion Gases

An air-cooled probe was inserted into the center of the combustion tube immediately before the venturi scrubber. The entrance to the probe was restricted with an 0.015 in diameter orifice. The sample probe was then attached to a glass trap containing a built-in electrostatic precipitator. The outlet of the glass trap was attached to a

vacuum system equipped for flow measurement. The glass trap was cooled to 0°C in an ice bath and the electrostatic precipitator attached to a 3000 VDC. The samples were taken when the combustion system had reached equilibrium by opening the trap to the vacuum system. The flow rate and time were recorded. At the end of the desired sampling time the valves on the sample trap were closed.

The gases contained within the trap were analyzed by mass spectroscopy. The probe and glass traps were then washed with methylethylketone and chloroform. The washings were concentrated and analyzed by gas chromatography or combined gas chromatography-mass spectroscopy.

B. Grab Samples (Combustion Chamber Gases)

These samples were taken using the air-cooled sample probe described in "A" above. A standard glass sample bomb was used in place of the glass tray. The sample was taken by evacuating the bulb and purging the system with combustion gases. The bulb was allowed to fill with gas after which it was removed from the system. The gases were analyzed by mass spectroscopy.

C. Scrubber Exhaust Gases

The gases leaving the scrubber were purged through a glass sample tube. They were then analyzed by mass spectroscopy.

D. Scrubber Liquid

A sample liquid from the scrubber tank was removed. The sample was acidified with sulfuric acid and extracted with diethylether and carbontetrachloride. The extracts were dried over anhydrous sodium sulfate and removed by distillation. The concentration was treated with diazomethane in ether to convert the acidic compounds into their methyl esters or ethers. The methylated extracts were then analyzed by either gas chromatography or combined gas chromatography-mass spectroscopy."

f. Results: For ten runs analyzed for condensable products in the combustion gas, the results were less than the detectible limit for herbicide components (<20 ng) and TCDD (<15 ng). For one run, a total herbicide concentration of 19 ppm was detected in the combustion gases. During this run, the sample volume was increased 10 fold from the usual 14 liters to 140 liters. The results of analysis of scrubber gas is given for two runs, one of the runs being the same as the above mentioned run in which herbicide was measured in the combustion gases; both analyses revealed no herbicide or chlorinated compounds above the detection limit (.1 µg per liter of gas). Samples of spent scrubber water was analyzed from 6 test runs. All samples were below the detection limit for TCDD (.015 ppb) and the concentration of chlorinated compounds ranged from 0.4 to 17.0 ppb. Analyses of samples of spent scrubber water from two additional runs revealed total herbicide concentration of 172 ppb and 2,199 ppb. In addition, the combustion and scrubber exhaust gases were analyzed for the components: nitrogen, oxygen, argon, carbon dioxide, hydrocarbons as butane, hydrogen chloride, nitric oxide and phosgene. These were all within acceptable limits.

g. Incomplete Combustion: Eleven samples of combustion gas and 14 samples of scrubber exhaust gas were analyzed for phosgene, all results were reported as 0.0 mole percent. From a thermochemical standpoint, a computer program for the calculation of complex chemical equilibrium compositions was used to obtain theoretical combustion temperatures and products for Orange/natural gas/air ratios. The computer program is contained in NASA Report SP-273, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions, Rocket Performance, Incident and Reflected Shocks, and Chapman-Jouguet Detonations by Sanford Gordon and Bonnie J. McBride," 1971. The computer output is presented in graph form in the technical report as a function of temperature and auxiliary fuel to air ratio. For a temperature of 2000°F and no auxiliary fuel, the predicted combustion products to a volume >99.9% are nitrogen, oxygen, water, carbon dioxide and hydrogen chloride.

h. Conclusions and Recommendations: The conclusions and recommendations are quoted from the technical report.

(1) Conclusions:

"1. Herbicide Orange can be effectively and safely destroyed by combustion.

2. The absence of raw herbicide, phosgene, hydrogen chloride and dioxin in the scrubber gases indicates that the impact on the atmospheric environment is not damaging. The impact on the ground and water environment is dependent on the type of scrubber material used and the ultimate disposition of the expended neutralizer.

3. Exotic type materials are not required. The 310 stainless steel material used for the combustion chamber and reaction tailpipe showed no evidence of deterioration due to the interaction of the hot exhaust gases with the metals. The durability of refractories for this application was not evaluated.

4. The incinerator must be gas tight up through the scrubber, otherwise hydrogen chloride vapors will be emitted and pose a serious problem.

5. A full scale incinerator system should have very large filter capacity with two parallel filter systems. This arrangement will permit cleaning one system while the other system is in use."

(2) Recommendations: "Additional design study and testing should be funded to determine the most feasible and economical type scrubbing system and scrubber material. The study should also include ways of disposing of the expended neutralizer."

4. THE MARQUARDT COMPANY, VAN NUYS CA AND THE USAF ENVIRONMENTAL HEALTH LABORATORIES, MCCLELLAN AND KELLY AFB.

a. Report: Report on the Destruction of Orange Herbicide by Incineration, 1974; this report was prepared by the Marquardt Company with inputs prepared by the USAF Environmental Health Laboratories. The Marquardt Company was primarily responsible for Orange handling and incineration operations; the Air Force conducted the majority of the

monitoring effort, and the West Coast Technical Services, Inc. performed, under contract to the Marquardt Co, most of the analytical chemistry. A FINAL DRAFT copy of this report is included as Appendix E to the Environmental Statement. The report was accomplished by Mr. R.J. Haas, Mr. R.P. Babbitt, and Mr. J.E. Hutson of the Marquardt Co. (TMC), with appendices prepared by Captains C.W. Bullock and J.W. Jackson of the USAF Environmental Health Laboratories. The scope of the project reported on was to incinerate the contents of 28 drums of Orange herbicide, with complete operational and environmental monitoring, in test incineration runs of approximately 3 hours' duration. The objectives and conclusions are quoted below:

(1) Objectives

Test Objectives: The objectives of the contract effort, as listed in the Statement of Work, were as follows with agencies of prime responsibility noted:

a. Determine the capability of an incinerator system to destruct the "Orange" Herbicide over a range of selected incineration conditions (TMC and EHLs).

b. Obtain the necessary engineering data to adequately monitor, control, and document the incinerator operation during the project (TMC).

c. Evaluate the test burns' effects and project the long term effects of the combustion gases on the material of the incinerator unit (TMC).

d. Determine the combustion gas, scrubbed effluent gas, and "spent" scrubber water discharge mass rates of herbicide constituents and any other organic compounds which may be detected (EHLs).

e. Determine the presence of herbicidal pyrolyzates and hydrolyzates, if any, in the combustion gases, scrubbed effluent gases, and "spent" scrubber water (EHLs and Analytical Chemistry Laboratory).

f. Determine the toxicity of "spent" scrubber water to several aquatic indicator organisms (EHL/K).

g. Evaluate the noise produced by an incineration system and assess its occupational hazard to operators (EHL/K).

h. Evaluate the effectiveness of a proposed drum cleaning procedure (EHL/K)."

(2) Conclusions

"14.0 CONCLUSIONS (Prepared by USAF EHL/K, EHL/M and TMC)

14.1 Destruction of 'Orange' Herbicide by Incineration

"Orange" Herbicide was effectively and safely destroyed by incineration. No "Orange" Herbicide constituent was detected

in any system effluent when operating with the slot nozzles, and only in one spent scrubber water sample (Burn III) when operating with the poppet nozzle. Likewise, very favorable relative pyrolysis efficiencies were obtained, ranging from 99.98% to 99.999%. Also, no chlorinated phenolic compound was detected in any of the scrubbed effluent gas samples, and only in one combustion gas sample. The spent scrubber water from all burns contained monochlorophenol but at a level not exceeding 0.14×10^{-6} grams/liter in the last five burns or 53×10^{-6} grams/liter in all burns.

14.2 Engineering Data

Preheat of "Orange" Herbicide fuel prior to injection in the combustion chamber was an important combustion efficiency parameter. The RPE was improved significantly where the "Orange" Herbicide fuel was preheated to 175°F. Preheat of "Orange" Herbicide fuel to at least 90°F was required to accomplish acceptable fuel injection characteristics.

The method of fuel injection was an important combustion efficiency parameter. The radial slot nozzles produced a higher RPE (Appendix I) and only about 1/20 the mass of combustion chamber coke deposits produced when central poppet nozzles were used. In the incineration system utilized, the slot nozzles provided satisfactory results at higher fuel/air mass ratios and combustion temperatures and therefore permitted a higher destruction rate of the "Orange" Herbicide.

The basic flow control required for this incinerator was quite simple in that only fuel and air mass flow regulation was required once steady state was achieved. Transients were performed without incident due to the ease of ignition of "Orange" Herbicide into an established flame. The manual control systems were quite satisfactory in these regards and the only real flow control monitoring needed was to correct for minor changes in flow caused by changes in facility air storage pressure or changing fuel properties. It can be concluded that "Orange" flow regulation is no problem as long as temperature is maintained within a reasonable band as determined by system sizing and is properly filtered to prevent plugging of fuel nozzles. Basic incinerator control therefore consisted of fuel and air flow regulation with monitoring of the combustion gas temperature to verify the presence of combustion and provide a relative indication of combustion and consistency of operating parameters. Air and fuel mass flow depended on delivery system pressure. The burner system pressure provided an indication of combustion gas flow and downstream conditions. These control parameters were conventional and could be readily automated using existing process industry control components. Such systems quite routinely monitor and control flow and combustion processes and take appropriate corrective action in the event of system anomalies. From purely a combustion point of view, this incineration process was not much different than when using conventional fuels. However, the serious differences were in the structural integrity (safety) of the incinerator and the safety aspects of storage and delivery of the "Orange" Herbicide.

Scrubbing of the combustion gases and neutralization of acids was accomplished satisfactorily. Optimization of this system was not within the scope of this effort and it is recognized that other types of

scrubbers may be more desirable.

The on-line gas analyses equipment used was adequate for CO, NO_x, and HC monitoring of scrubbed effluent gas only. Gas analyses equipment incorporating additional features would be suitable for sampling of combustion gas. However, the application of on-line sampling analysis to a production process would require additional study beyond the scope of this effort.

14.3 Effects on Incinerator Materials

Considering the absence of structural or sealing problems in the physical combustion chamber enclosures, the lack of evidence indicating physical deterioration in the materials utilized, the qualities of the materials used, and prior experience in similar systems, it can be concluded that the basic incinerator design would provide a unit of considerable longevity. There are design considerations that would be required, "external" to the basic combustion process, which could further ensure longevity and provide a reliable unit. Such design factors do not appear to be particularly unusual or exotic in nature. It can also be concluded that durability would be enhanced by long term continuous operations where start-stop transients are minimized.

14.4 Mass Discharge Rates of "Orange" Herbicide Constituents.

TCDD was detected in the spent scrubber water from Burn III at 0.25×10^{-6} grams/liter. Otherwise, no "Orange" Herbicide constituent was detected in any scrubbed effluent gas sample or in any spent scrubber water sample. "Orange" Herbicide constituents were detected in the combustion chamber coke deposit from Burn III but these deposits were contained and the mass of the "Orange" Herbicide constituents in the coke was 64.4 mg.

Table 5 presents the maximum potentially undetected "Orange" Herbicide constituents that could have been discharged without being detected. The TCDD in the spent scrubber water from Burn III was included in the discharge. The average mass that could have been discharged in the scrubbed effluent gas during each burn was 9.3 mg ($\Delta = 2.7$ mg). The average mass that could have been discharged in the spent scrubber water was 3.4 mg ($\Delta = 1.4$ mg).

14.5 Spent Scrubber Water Quality

Spent scrubber water inorganic quality was directly related to applied caustic. Mineral content of spent scrubber waters would be minimized and acid gases effectively scrubbed if applied caustic were 2.0 (± 0.1) times that required to neutralize the theoretically expected amount of HCl. Primary settling, and dechlorination, and adjustment of pH to about 9 may be required before discharging the spent scrubber water to natural waterways. For burns using the slot nozzles, the total average hydrocarbons were less than 20 $\mu\text{g/L}$ and no hydrocarbons were detected in the water's suspended carbon particles. Of the 20 $\mu\text{g/L}$ total hydrocarbons, less than 1.5 percent of them could have been undetectable compounds of the original herbicide feed.

14.6 Pyrolyzates and Hydrolyzates

All of the detected unchlorinated aliphatics, aromatics, and biphenyls were considered pyrolyzates. The total mass of these pyrolyzates in the scrubber water, combustor coke deposit, and scrubbed effluent gas averaged 1.32 gms as carbon per drum of herbicide incinerated in the less efficient burns (I, II, III) and was an order of magnitude less (0.42 gms as carbon per drum) in the high efficient burns (IV through VIII).

All of the detected monochlorophenol and dichlorobenzene were considered hydrolyzates. Since they were detected in only one effluent stream from the incinerator scrubber water, their total effluent mass averaged 0.86 grams as carbon per drum of herbicide incinerated in the less efficient burns (I, II, and III). These effluent masses of hydrolyzates decreased three orders of magnitude to an average of 0.006 grams as carbon per drum of herbicide incinerated during the more efficient burns.

14.7 Air Sampling

It was concluded that the data from the Beckman 109A hydrocarbon analyzer was not an indicator of RPE (Appendix I).

The formation of dichlorobenzene, dichlorophenol, and monochlorophenol by the reaction of nonchlorinated aromatic hydrocarbons with HCl, Cl₂ and Cl was indicated in locations of rapid combustion gas cooling. The quantity of these compounds that might be formed in other systems would not be expected to exceed the mass of aromatic hydrocarbons existing in the gas.

14.8 Bioassays

Conclusions about bioassay data will be published under separate cover by USAF EHL/K.

14.9 Noise Hazards

Unprotected personnel occupationally working within fifty feet of the incinerator(s) should be provided ear protection and be monitored via a hearing conservation program. The conventional masonry control room walls effectively protected the operators from the incinerator's hazardous noise levels and provided them an area quiet enough for reliable communication. Masonry walls around the incinerator pad would preclude ambient incinerator noises from interfering with any adjacent operations.

14.10 Drum Cleaning

Data of this study can be used to determine the volumetric rinses of used or contaminated JP-4 needed to meet any prescribed drum cleaning requirements. Under the following constraints, separate rinse procedures should be used to obtain maximal removal of the 450 (\pm 25) grams of herbicide in the drained drums:

a. Some cleaning required but \leq 5 gallons of clean or contaminated JP-4 available per drum. Use the five gallons in a single rinse

to obtain 70 percent herbicide removal.

b. Maximal cleaning required but ≤ 10 gallons of clean or contaminated JP-4 available per drum. Use two rinses of five gallons each to remove 79.1 percent of the herbicide.

c. Third rinses of less than five gallons of JP-4 did not improve overall herbicide removal by more than three percent.

Removing drum ends and spraying the rinse downward through the open drum would provide better rinse drainage. Depending on rinse volumes used, such a rinse application technique may improve herbicide removal efficiencies by 10 to 25 percent over the results of this study."

5. COMBUSTION POWER COMPANY INC., MENLO PARK, CA

a. Report: Technical Report TR 73-7, Progress Report of Determining the Feasibility of Disposing of Air Force Liquid Wastes in the LSW-500 Industrial Prototype, August 15, 1973, Contract No. F29601-73-C0128 for Air Force Weapons Laboratory (AFSC), Kirtland AFB NM 87117, by Combustion Power Inc, Menlo Park CA. This report is not a final report but is a progress report, the last revision was incorporated as of 18 Jan 74.

b. Objectives: To determine the feasibility of disposal of selected Air Force liquid waste including paint stripping waste, petroleum based wastes, wash rack wastes, and Orange herbicide via fluidized bed incineration.

c. Type of Incineration: The incinerator unit used is the LSW-500 Industrial Prototype. The combustion zone is 3 feet in diameter and the bed material is normally sand. Air is used to fluidize the bed and the velocities through the unit have been usually 4 to 6 feet per second. For acid gas control, dolomite or limestone is placed into the unit as part of the bed material. The acid gas produced by the incineration is then absorbed chemically within the fluidized bed. As the limestone is used up, it has to be removed and replaced with fresh limestone. This method eliminates the need for a liquid scrubber for acidic combustion gases. The combustion gases are presently passed through three separators for particulate removal and sand recovery. Prior to incineration of Orange, tests were conducted with dichloro-benzene to determine the efficiency of dolomite in hydrogen chloride absorption.

d. Quantity of Orange Incinerated: Five test runs of Orange have been conducted; the total volume of Orange incinerated, in a chronological order per run, was 3.10, 2.18, 5.5, 10 and 18.3 gallons respectively. The feed rates for these runs were 0.505, 0.705, 2.36, 2.79 and 3.25 pounds per minute. In the first two runs the bed material was all dolomite, the bed temperature was 1500°F and the superficial velocity was 4 and 6 feet per second respectively. For the third run the bed material was 50 percent dolomite and 50 percent sand, the bed temperature was 1490°F and the freeboard temperature was 1150°F, and the superficial velocity was 4.0 feet per second. The bed material for test 4 and 5 was a combination of sand and limestone and the average bed temperature was 1530°F and 1510°F respectively.

e. Monitoring: The exhaust gas of each run was sampled for subsequent herbicide and TCDD analyses by Combustion Power Co personnel using an impinger train with benzene as collecting media. In addition, monitoring was accomplished

for oxygen, carbon dioxide, carbon monoxide, hydrocarbons, sulfur dioxide, and oxide of nitrogen. The analyses of herbicide components and TCDD is to be accomplished by Stoner Laboratories, Inc, Santa Clara CA. At present, the results have been documented for the first three runs for the herbicide components and no results have been attained for TCDD. The TCDD analyses has been delayed due to problem associated with obtaining a laboratory standard; however, action has been taken to be sure that the TCDD samples will be analyzed.

f. Results: The concentrations of herbicide components in the exhaust gases, corrected to 10% O₂, were as follows: Run 1: 4.068 ppb nb 2,4-D, 10.96 ppb nb 2,4,5-T, 0.2913 ppb 2,4-D acid and 0.5044 ppb 2,4,5-T acid; Run 2: 0.3196 ppb nb 2,4-D, 2.370 ppm nb 2,4,5-T, and none detected (ND) for either acid, and Run 3: 0.5221 ppb nb 2,4-D, 0.5418 nb 2,4,5-T, and ND for either acid. The ranges of the other constituents were all within acceptable limits.

g. Conclusions: This report being reviewed is a progress report whose function is primarily to report data. A discussion of data and conclusion will be contained in the final technical report to be prepared by Combustion Power Co. It is apparent that practically all of the ester components herbicide are being destroyed by the incineration process.

C. SUMMARY AND CONCLUSION: The results of two laboratory, two full scale, and one industrial prototype scale Orange incineration projects have been reviewed. The methods of incineration have included heating, flame, and fluidized bed. The data and conclusions of the investigations have revealed incineration an efficient method of large scale destruction of Orange herbicide. The essentially complete destruction of the herbicidal components of Orange as reported in all of the projects, dictates that the herbicidal effect of combustion gases will be minimal to non-existent. Therefore, such gases could be discharged into a remote, non-vegetative environment. The hydrogen chloride generated by the incineration process is phytotoxic; the removal of hydrogen chloride via alkaline scrubbing is extremely efficient and is also positive as regards removal of particulates from the combustion gas. The data shows that the discharge of alkaline scrubbed combustion gases via a stack would be acceptable to practically any environment. The discharge of spent scrubber water will require consideration for its impact on the receiving water. The TCDD situation requires placement into proper perspective. The total amount of TCDD in the entire Orange stock is approximately 50 pounds. All the reviewed projects revealed the TCDD concentration in the exhaust streams to be non-detectable or extremely small. Under high temperature incineration, the data indicated that essentially all of the TCDD will be destroyed. Orange destruction efficiencies of 99.9 to 99.999 percent appear feasible for the large scale incineration project. This will respectively result in a total discharge of 0.05 to 0.0005 pounds of TCDD via the exhaust streams over the duration of the project. The exhaust streams would, in turn, be diluted in the environment into which they are discharged. When judged against certain alternatives, for example, storage under conditions where a catastrophic event could result in gross detrimental environmental impact, the incineration of Orange, with due considerations for the extreme toxicity of TCDD, is an acceptable method of disposal. In addition, USDA (1970) reports that some 9.0 million pounds of 2,4,5-T were being applied annually in the United States when in April 1970, restrictions were placed on its use. If these nine million were assumed to have 2 mg/kg of TCDD, the same as that of the Orange stock, then the TCDD released to environment annually during application was about 18 pounds. The possible incineration effluent discharge noted above, 0.05 to 0.0005, re-

presents only 0.27 to 0.0027 percent of the estimated release which had occurred during one year of application of 2,4,5-T. The situation as regards pyrolyzates and hydrolyzates of Orange herbicide incineration has been addressed in this review. Existing data, together with theoretical considerations and applied thermochemistry, show that such products are minimized with efficient, high temperature incineration. The data also indicate that if such products were present their concentrations would be extremely small and environmentally insignificant. In view of the above, it is concluded that incineration, with proper concern for the environment in which such incineration will take place, is an environmentally safe method for disposal of Orange herbicide.

APPENDIX E

FINAL REPORT

REPORT ON THE DESTRUCTION OF
"ORANGE" HERBICIDE BY INCINERATION

A

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B

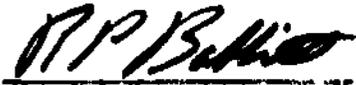
FINAL REPORT

REPORT ON THE DESTRUCTION OF
"ORANGE" HERBICIDE BY INCINERATION

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During this project, personnel from the USAF Environmental Health Laboratories performed the gas sampling, scrubber water sampling, biomonitoring, noise testing, and analyses of data for certain portions of this report. Team members from the USAF Environmental Health Laboratory Kelly AFB TX (EHL/K) were Majors Carlton R. Williams and Roger C. Inman, Capt Charles W. Bullock, TSgt Jerrold C. Akey, SSgt John J. DiLorenzo, AIC Gregory S. Knerl and Mr. Leopoldo L. Rodriguez; and team members from the McClellan AFB, CA (EHL/M) laboratory were Maj John J. Gokelman, Captains Jerry W. Jackson, Marlin L. Swegart and Kenneth E. Hundley, and Staff Sergeants Fred Ward and Henry F. Pauley.

Capt Charles Bullock (EHL/K) prepared Appendices C, Sample Code Designations; E, Scrubber Water Monitoring; F, Drum Cleaning, Disposal, and Analyses of Drum Rinse Samples; and J, Noise Monitoring. Capt Jerry Jackson (EHL/M) prepared Appendix D, Combustion and Scrubbed Effluent Gas Monitoring. Both Captains Bullock and Jackson prepared Appendix I, Evaluation and Discussion of Organic Analyses of Blended Herbicide, Scrubber Water, Combustion Gas, Scrubbed Effluent Gas, and Residues.

FOREWORD

The work reported herein is submitted in fulfillment of Contract No. F41608-74-C-1482, let by USAF, AFIC, San Antonio Air Materiel Area (SAAMA), Procurement Directorate, Kelly Air Force Base, Texas. The project was monitored by USAF Environmental Health Laboratory, Kelly Air Force Base, Texas, in coordination with SAAMA Procurement.

This report was written and concluded jointly by The Marquardt Company, Van Nuys, California; USAF Environmental Health Laboratory, Kelly Air Force Base, Texas (USAF EHL/K); and USAF Environmental Health Laboratory, McClellan Air Force Base, California (USAF EHL/M).

The work was accomplished between 8 October 1973 and 21 December 1973 at the Air Force-Marquardt Jet Laboratory (AF-MJL) at Van Nuys, California. Activities were conducted and monitored by a team consisting of The Marquardt Company, the USAF EHL/K, and the USAF EHL/M. Organic analyses of samples from test burns were performed by West Coast Technical Service, Inc. (WCTS) of Cerritos, California. Inorganic analyses of test burn and drum cleaning samples were performed by the EHL's.

The Marquardt Company has no proprietary interests or restrictions on this report.

ABSTRACT

A test program was conducted to evaluate the incineration of "Orange" Herbicide in a commercial incinerator over a range of selected incineration conditions. Particular emphasis was placed on the ability to destroy the parts per million quantities (11-16 mg/kg) of 2,3,7,8-tetrachlorodibenzo-p-dioxin present in the herbicide. Extensive sampling was conducted to evaluate the unscrubbed combustion gases, the scrubbing liquid used to cool and scrub the combustion gases, scrubbed effluent gases and any solid residues deposited in the system. Additional objectives were: to obtain engineering data relative to controlling and monitoring the incineration process, to evaluate noise produced by the incineration system, to evaluate long term effects of herbicide combustion on incinerator materials, to evaluate the effectiveness of a proposed drum cleaning procedure, to assess the toxicity of discharged scrubber water to several aquatic organisms, and to assess the effects of scrubbed effluent gas on tomato plants.

The program was conducted using a Marquardt incinerator system. Samples were analyzed by mass spectroscopy, flame ionization gas chromatography, and atomic absorption.

A total of 30.5 hours of burn time on undiluted "Orange" Herbicide fuel was accumulated during eight record burn periods. Test data demonstrated that the incineration system operated very satisfactorily using undiluted "Orange" Herbicide as a fuel and that the herbicide was effectively and safely destroyed in the combustion process; i.e., gaseous and spent scrubber water effluents, within the analytical limits of detection, did not contain any of the compounds identified in the herbicide feed. Criteria were also established regarding effluent biological impact, incinerator noise generation, drum cleaning procedures, and incinerator process system functions.

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