Final Report

GRADUATE TRAINING PROGRAM IN OCEAN ENGINEERING

Edited by

Henry R. Frey

Supported by
National Sea Grant Program
Grant GH-13

N. Y. State Science & Technology Foundation
Grant SSF(8)-9

New York University
School of Engineering and Science
University Heights, New York, N.Y. 10453
Geophysical Sciences Laboratory GSL 71-14

Research Division

December 1971

New York University
School of Engineering and Science
Bronx, New York 10453

Final Report

GRADUATE TRAINING PROGRAM IN OCEAN ENGINEERING

Edited by

Henry R. Frey

Submitted to

National Sea Grant Program
National Oceanographic and Atmospheric Administration
U.S. Department of Commerce
Rockville, Maryland 20852
(Grant GH-13)

and to

The New York State Science and Technology Foundation
112 State Street
Albany, New York 12207
(Grant SSF(8)-9)

15 May 1968 to 31 May 1971

December 1971

ABSTRACT

Activities during the first three years of New York University's Ocean Engineering Program are described including the development of new courses and summaries of graduate research projects. This interdepartmental program at the master's level includes aeronautics, chemical engineering, civil engineering, mechanical engineering, metallurgy, and physical oceanography. Eleven courses were developed to supplement courses already in existence and germaine to ocean engineering. There were 204 student registrations in these courses, and fourteen seed research projects were initiated.

TABLE OF CONTENTS

Table of Contents (cont.)

1. INTRODUCTION

The New York University Graduate Division of the School of Engineering and Science instituted an ocean engineering program at the master's level during May 1968. This educational/research program was supported by the National Sea Grant Program under the project category (Grant GH-13); matching funds were provided both by the New York State Science and Technology Foundation (Grant SSF(8)-9) and by New York University. The grants were awarded for a two-year period and were subsequently extended to a three-year period without an increase in funding.

In the initial planning of the N. Y. U. Ocean Engineering Program, the dominating point-of-view was that engineers must become thoroughly competent in a traditional engineering discipline prior to specialization in ocean engineering. Also, it was felt that the program should be designed to be superposed on the existing departmental structure of the School of Engineering and Science without creating a new department. An option in ocean engineering within a traditional engineering discipline, rather than a degree in ocean engineering, was decided upon. A modest program was then designed to take maximum advantage of both the existing curricula and the existing administrative structure of the School of Engineering and Science.

The emphasis for this program is at the master's level. Students pursuing a master's degree may elect to take the Ocean Engineering Option by completing at least 15 credits of subsidized ocean engineering courses, or they may take fewer ocean engineering courses, without the option, to satisfy their individual needs in accordance with their career goals.

Master of Science degrees with the Ocean Engineering Option are offered by the following departments:

Aeronautics and Astronautics
Chemical Engineering
Civil Engineering
Mechanical Engineering
Metallurgy and Materials Sciences

In addition to the ocean engineering courses offered by the various departments, research projects have been carried out by graduate research assistants, in some cases with faculty participation. These projects are summarized later in this report.

The Department of Meteorology and Oceanography provides the management for the Ocean Engineering Program and offers courses related to the program in ocean engineering and in oceanography, but does not offer the Ocean Engineering Option with its M.S. degree. The management of the program is conducted principally by a Program Director, with fiscal tasks delegated to an Administrative Assistant. The coordinating liaison with participating departments is accomplished through an interdepartmental Ocean Engineering Committee consisting of:

Dr. Michael H. Chen - Dept. of Mechanical Engineering
Dr. Erick R. Gidlund - Dept. of Civil Engineering
Dr. Henry R. Frey (Chairman) - Dept. of Meteor. and Ocean.
Dr. Harold Margolin - Dept. of Metallurgy and Materials Sciences
Dr. Willard J. Pierson, Jr. - Dept. of Meteorology and Oceanography
Dr. Henry G. Schwartzberg - Dept. of Chemical Engineering
Dr. Jack E. Werner - Dept. of Aeronautics and Astronautics

2. SUBSIDIZED OCEAN ENGINEERING COURSES

Fourteen courses were planned to supplement the science and engineering courses already in existence and germaine to ocean engineering; eleven of these were developed and offered. The new courses are listed below and registration histories are given for the first three academic years of the program. The total number of registrations for the subsidized ocean engineering courses was 204 for the first three years of the program: 98 for 1968-69, 34 for 1969-70, and 72 for 1970-71.

2.1 Department of Aeronautics and Astronautics

T. 10.1111-1112 Hydrodynamics I and II

Associate Professor J. E. Werner

3 credits per term

Prerequisites:

Fundamentals of Aerodynamics II (UG)*

Vector Analysis and Functions of Several Variables (UG)

Infinite Series with Applications to Ordinary Differential Equations (UG)

Or, permission of the instructor

First term:

General theorems of hydrodynamics, analytical techniques including the formulation of boundary conditions.

Discussion of physical phenomena such as underwater jets and wakes, vorticity, waves, cavities, free surfaces, unsteady flow, hydrodynamic stability, impulsive motion.

Second term:

Analysis of hydrofoils, planing, cavitating propellers and hydrofoils, flow about partially submerged bodies, wave drag, underwater propulsion, cascades, surface impacts, geophysical problems.

Registration History:

	1968-69	1969-70	1970-71	Total
T10.1111	13	6	5	24
T10.1112	5	4	3	12

*(UG): undergraduate course.

2.2 Department of Chemical Engineering

T24.1153 Materials for Underseas Operations

Associate Professor Y. Okamoto

3 credits, first term

Prerequisite: written permission of the instructor.

Intended to familiarize the student with the properties, characteristics, availability, cost, and manufacturing techniques of organic and metallo-organic materials that may be used as components of apparatus and equipment for undersea exploration and operation. Also treats organic and inorganic coatings for metal components.

Registration History:

1968-69	1969-70	1970-71	Total
1	1	3	5

T24.1154 Ocean Industrial Operations

Associate Professor H. Schwartzberg

3 credits, second term

Prerequisites:

Undergraduate course in fluid flow and heat transfer.

Or, written permission of the instructor.

Provides flow sheets, process variables, and the economics of industrial processes for the recovery of chemicals, including food, from the ocean and from the ocean bed. Among the topics covered are desalination, production of magnesium and bromine from sea water and desalination brines, mining of manganese from the ocean floor, and recovery of oil, sulfur, and plankton.

Registration History:

1968-69	1969-70	1970-71	Total
2	5	5	12

2.3 Department of Civil Engineering

T26.2231 Forces on Marine Structures

3 credits, first term

Forces on marine and harbor structures due to wave action, currents, and tides. Applications of stochastic processes to problems in static and dynamic loading.

Registration History:

Not given

T26.2232 Marine Structures

Professor C. Birnstiel

3 credits, second term

Prerequisites:

Substructure Analysis and Design (UG)

Design and analysis of hydraulic structures such as breakwaters, seawalls, locks, dolphins, piers, and cofferdams. Studies of deep-sea cable mooring systems, off-shore towers, and fendering systems.

Registration History:

1968-69	1969-70	1970-71	Total
22	not given	11	33

T26.2233 Coastal Engineering

Associate Professor E. Gidlund

3 credits, first term

The entrainment, movement, and deposition of sedimentary materials. Sediment transport in alluvial channels and erosion and shoaling in tidal waters.

Registration History:

1968-69	1969-70	1971-72	Total
9	6	12	27

2.4 Department of Mechanical Engineering

T64.1111 Design and Analysis of Underwater Structures & Vessels

Professor A. H. Church

3 credits, first term

Prerequisites: Mechanics of Materials I (UG) or equivalent.

Analysis and design considerations by matrix methods of underwater structures and submersibles under both static and dynamic conditions. Includes current advances in the field and special topics drawn from current practice.

Registration History:

1968-69	1969-70	1970-71	Total
not given	2	5	7

T64.1112 Environmental Engineering and Control in Confined Spaces

3 credits, second term

Prerequisite: Thermodynamics II (UG) or equivalent.

Atmospheric control in underwater enclosures, Heat load requirements, toxicity control, waste disposal, regeneration. Effect of chemical composition in artificial atmospheres on human performance.

Registration History:

Not given

2.5 Department of Metallurgy and Materials Sciences

T66.1111 High-Pressure Effects in Metallurgy

3 credits, first term, alternate years

Prerequisites: Engineering Materials (UG) and Metallurgical Thermodynamics I (UG) or the equivalent.

Effects of pressure on mechanical properties of solids. Thermodynamics of high pressure, effects of pressure on phase equilibria of pure metals and alloys. Experimental methods of creating and measuring high pressure.

Registration History:

Not given

T66.1112 Corrosion and Corrosion Control

Adjunct Professor A. Foroulis

3 credits, second term, alternate years

Prerequisite: Metallurgical Thermodynamics I (UG) or equivalent.

Electrode potentials, polarization and corrosion rates, passivity. Effect of stress, atmospheric corrosion, spray current corrosion, corrosion of specific alloys. Cathodic and anodic protection, protection by coating, inhibitors, and passivators.

Registration History:

1968-69	1969-70	1970-71	Total
19	not given	12	31

2.6 Department of Meteorology and Oceanography

T69.2269 Oceanography and Space Technology

Professor W. J. Pierson, Jr.

3 credits, first term

Theory of electromagnetic sensing of oceanographic parameters from orbital and suborbital vehicles. Detection of sea ice, icebergs, waves, currents, and ocean surface temperature from space.

Registration History:

1968-69	1969-70	1970-71	Total
12	2	6	20

T69.2270 Electromagnetic Properties of Seawater

Assistant Professor E. S. Posmentier

3 credits, first term

Application of the theory of electricity and magnetism to problems peculiar to the ocean. The entire spectrum of electromagnetic energy is covered. Electromagnetic properties of seawater and how they are affected by the temperature and salinity. Transmission and attenuation of electromagnetic waves. Reflection, refraction, and scattering of electromagnetic energy at the sea surface.

Registration History:

1968-69	1969-70	1970-71	Total
6	5	3	14

T69.2272 Transmission of Sound in Seawater

Assistant Professor E.S. Posmentier

3 credits, first term

Development of the general theory of sound transmission. Emphasis on the interrelation of thermodynamic variables on the transmission process. Theory of refraction, reflection, and attenuation of sound waves. Discussion of general features of the temperature and salinity distribution in the ocean and their effects on sound rays.

Registration History:

1968-69	1969-70	1970-71	Total
9	3	7	19

3. RELATED UNSUBSIDIZED ENGINEERING COURSES

The courses initiated through Sea Grant support were designed to supplement engineering courses that were in existence already, and thus to provide a more complete ocean engineering curriculum. Forty-four existing courses with direct pertinence to the ocean engineering program are listed below.

3.1 Department of Aeronautics and Astronautics

Dynamics of Structures
Aeroelasticity and Hydroelasticity

3.2 Department of Chemical Engineering

Chemistry and Technology of Surface Treatments for Corrosion Protection and Decorative Purposes
Surface Technology Laboratory
Process Equipment Design
Industrial Chemistry
Diffusional Operations
Theory of Chemical Engineering Transport Processes
Heat Transfer
Fluid Flow
Fluid-Solid Dynamics

3.3 Department of Civil Engineering

Sanitary Chemistry
Disposal of Radioactive Wastes
Chemistry for Sanitary Engineers
Water and Wastewater Treatment
Sanitary Microbiology
Analysis of Stream and Estuary Pollution
Hydrology I and II
Numerical Methods in Civil Engineering
Advanced Hydraulic Problems

Advanced Fluid Mechanics for Civil Engineers I and II
Advanced Foundation Engineering
Structural Dynamics
Theory of Elastic Stability
Elastic and Inelastic Stability of Structures
Reinforced Concrete Structures I and II

3.4 Department of Mechanical Engineering

Mechanical Vibrations
Vibration Analysis
Advanced Strength of Materials
Limit Analysis of Structures
Theory of Elastic Stability
Theory of Plates and Shells
Dynamic Stability of Structures
Mechanical Instrumentation
Fundamentals of Solid Mechanics
Heat Transfer
Engineering Applications
Viscous Flow
Fundamentals of the Thermal Sciences

3.5 Department of Meteorology and Oceanography

Oceanography for Engineers I and II
Physical Oceanography
Geophysical Hydrodynamics
Dynamic Oceanography
Analysis and Forecasting of Ocean Waves

4. RESEARCH PROJECTS

The grants were modified to allow for support of research projects during the final year, from 1 September 1970 to 31 May 1971. The Ocean Engineering Committee concluded that meaningful graduate education in an interdisciplinary ocean engineering program requires that formal courses be complemented by student involvement in research projects. Research projects were carried out by 14 graduate research assistants under the supervision of 10 faculty advisers, and two research projects were conducted by faculty investigators.

Such projects provide material not only for theses, but also provide nurturing material for courses. Thus, the research projects form an information loop with the ocean engineering courses, optimizing the overall program. Also, the tuition remission privilege of research assistantships aids in populating the ocean engineering courses.

4.1 On the State-Of-The-Art of Undersea Salvage Techniques

Teaching Assistant: Mr. Fred Mogolesco, Dept. of Aeronautics and Astronautics

Faculty Supervisor: Prof. W. J. Pierson, Jr. and Prof. A. D. Kerr

Objective: To perform a critical literature review of undersea salvage techniques.

Summary:

A report was issued jointly by the Dept. of Aeronautics and Astronautics and the Dept. of Meteorology and Oceanography during June 1969. This work was performed under a teaching assistantship prior to the commencement of the research projects described later in this section. The abstract is quoted below:

"It is necessary to develop the capability of recovering large objects with deadweights approaching 1000 tons. Until recently, underwater salvage techniques were basically the same as those used in 1939 when the U.S. submarine SQUALUS

was successfully raised from a depth of 240 feet. The technique evolved from the SQUALUS incident is limited by the maximum working depth and the time duration for divers.

The systems recently developed will make use of diving support systems, modern lifting devices and chemicals that will provide internal buoyancy for refloating. The purpose of this study is to review the practical and theoretical aspects of undersea salvage problems."

Status: Complete

4.2 A Critical Review of Manned Submersibles Used in Oceanographic Research

Research Assistant: Mr. Philipp Lange

Faculty Supervisor: Prof. Willard J. Pierson, Jr.

Objective: To compile information about submersibles employed in research.

Summary:

A report was issued during February 1970 by the Dept. of Meteorology and Oceanography. The abstract is quoted below.

"A review of major biologic, geologic and physical oceanographic research that has been performed from manned submersibles is presented. Further possible applications of the submersible for physical oceanographic research are briefly mentioned. A brief description of the 'state of the art' of submersible design, and a reference list of existing submersibles are provided."

Thesis: This work represented a review paper in lieu of a thesis, and partially satisfied the requirements for an M.S. in Oceanography, February 1970.

Status: Complete. Mr. Lange is currently employed at the Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey.

4.3 The Spreading of Oil Spills

Faculty Investigator: Assoc. Prof. Henry G. Schwartzberg, Dept. of Chemical Engineering

Objective: To determine spreading rate correlations and ultimate thicknesses for radially symmetric oil spills.

Summary:

Investigations on the spreading and movement of oil spills have been carried out. A significant result is that when the spill spread has been restricted by the addition of a surfactant (which causes the oil to form lenses), the lens form will persist as the oil drifts downwind (i. e. the surrounding surfactant drifts as fast as the oil). The original large lenses break up into smaller lenses, but since the lens thickness is only a very weak function of lens diameter and the dispersive spreading of the small lens as relative to another appears to be slow, this appears to be a promising technique for limiting spill spreading.

These results have been incorporated as part of a paper 'The Movement of Oil Spills" which is being published in the Proceedings of the June 1971 Washington, D. C. Conference on the Prevention and Control of Oil Spills, sponsored by the American Petroleum Institute, Environmental Protection Agency, and the United States Coast Guard.

Additional work has involved the measurement of the limiting thickness of non-lens forming oil spills. The reproducibility of this work has been poor. It appears that trace contaminants are the curve of the observed large variation in film thickness.

Status: Incomplete. This research may continue with support from another agency.

4.4 Synthesis and Evaluation of the Marine Anti-Fouling Organic Polymers

Research Assistant: Mr. R. Homsany, Department of Chemical Engineering.

Faculty Supervisor: Research Assoc. Prof. Yoshiyuki Okamato

Objective: To develop an effective and long-lasting anti-fouling organic polymer/matrix system.

Summary:

The work of 1970/71 was initiated by a literature survey of the available anti-foulants. The ones mostly used were found to be copper oxides, some inorgano and organo lead compounds which are sometimes required in relatively large quantities, thus constituting an environmental hazard. We decided upon selenium because it is known to be potentially toxic even in micro amounts. It was never used as an anti-foulant. When incorporated in organic polymers rather than simple organic compounds, it is possible to control the solubility of the polymers and hence their leaching rate. Also, these compounds can be easily blended with available polymer based marine points.

Several new compounds were synthesized. These samples were sent to the R. T. Vanderbilt Company for bacterial and fungal screening. The results indicated that some of them were very effective. The anti-fouling properties of these compounds are now being studied by the International Paint Company at their testing station in England.

The second year work on this project will develop the practical application of these compounds. In addition, several other polymers containing heteratoms such as sulfur, tin and zinc will be prepared and evaluated as the marine anti-foulant.

Thesis: Mr. Homsany has elected to take the Ocean Engineering Option. This work will constitute his M.S. thesis.

Status: Continuing with support from National Sea Grant No. 1-36105.

4.5 Evaluation of Submerged Oxidation for Wastes of Ocean-Going Vessels and for Wash-Out Tanks

Research Assistant: Mr. J. Young, Dept. of Chemical Engineering.

Faculty Superviser: Adjunct Prof. Richard F. Shaffer

Objective: To determine the feasibility of employing submerged oxidation for ship-borne wastes.

Summary:

Ship-owners have been interviewed to obtain the characteristics of bilge and other wastes and of boiler room designs. With this data, the practicability of using submerged oxidation has been evaluated. A cost estimate for the installation of such a unit in a typical boiler room has been prepared, and this cost is compared with the other recommended method of handling such wastes (storage on board and transfer to port treating facilities). A preliminary examination of the use of submerged oxidation for oil wash-out wastes has indicated that experimental work is needed to determine the practicability of submerged oxidation because of the high speed of the reaction.

Thesis: Feasibility Study of Submerged Oxidation for Wastes of Ocean-Going Vessels and for Washings from Oil Tankers. M.S. Thesis, June 1971.

Status: Completed.

4.6 Phosphates in Long Island Sound

Research Assistant: Mr. Raphael J. Szechtman, Dept. of Civil Engineering.

Faculty Supervisor: Assoc. Prof. Erick R. Gidlund .

Objectives:

To estimate the magnitude of phosphate input from the major sources and determine why they cause the phosphates to assume the distribution found in the Sound. To compare the 1969 data on phosphates measured in the Sound with Riley's phosphate data from 1953.

Summary:

The major phosphate sources were found to be:

1. East River flow into the Sound.
2. Sewage treatment plants located around the Sound.
3. Land drainage

It is estimated that East River flow contains some 70.5% of the total phosphate entering Long Island Sound. About 40% of these phosphates have their origin in New York City sewage treatment plants. Calculations

indicate the percent of total phosphates from treatment plants around the Sound to be 15.5% . The percent of phosphates from land drainage is estimated to be 14.0% .

A comparison of the 1953 phosphate data on Long Island Sound with the 1969 data shows substantial increases in the amount of phosphates present. The percent increase in sewage flow to the Sound is not large enough to account totally for that increase.

Mr. Szechtman and a second research assistant, Mr. A. Schoenewaldt, assisted in the reduction of data for the two research projects described immediately below, which was supported by FWPCA Research Fellowships. These projects were supervised by Prof. E. Gidlund.

Velocity Gradients and Their Influence on Dispersion in Oscillating Shear Flow

(Ph. D. Thesis: Dr. Burton Segall, June 1971)

The spatial and temporal distribution of velocity for a two-dimensional oscillating flow system was derived from the Navier-Stokes equation. A plot of the resulting velocity equation shows the characteristic steady flow parabolic curves at maximum flood and ebb tides. However, the equation predicts a time lag from the water surface to the estuary bottom over the tidal cycle. Near slack water flow reversals are predicted first near the bottom. These reversals have been observed in field data.

An expression for the coefficient of dispersion was determined by considering the first and second moments of the concentration distribution. The resulting equation can be used to estimate the spread of pollutants in the uniform density sections of estuaries in which tidal motion is the predominant mechanism of dispersion.

Model studies conducted in an oscillating shear flow system showed that the derived equation yields a reasonable estimate of the dispersion coefficient.

The Effect of Wind on Dispersion in a Vertically Homogeneous Estuary

(Ph.D. Thesis: Dr. Francis Lutz, June 1971)

Wind is shown to be a significant parameter affecting estuarine dispersion. Several experiments are performed in the NYU estuary model to predict dispersion coefficients both from solute concentration distributions and hydraulic parameters. Data recorded include tidal stage, windwave characteristics, air and water velocities, and solute concentration. Dispersion is shown to be affected by wave height, length and period as well as wind drift.

Thesis: M.S. thesis not required by Dept. of Civil Engineering. Results will be submitted for publication by the Journal of the Water Pollution Control Federation.

Status: Complete

4.7 Planning Criteria for Ocean Engineering Projects with Emphasis on Economical Analysis

Research Assistant: Mr. Wing-Chee Lo, Dept. of Civil Engineering.

Faculty Supervisor: Prof. Alvin S. Goodman.

Objective: To develop and critically discuss economic criteria that are appropriate for formulating and justifying ocean engineering projects.

Summary:

Mr. Lo worked with Prof. A.S. Goodman on library research and preliminary conceptual planning on the topic. It was determined that very little published material is available on the above subject and that the subject was worth further investigation. The principal sources of economic criteria for Federally sponsored or supported water resources projects are Senate Document No. 97, dated May 29, 1962 entitled "Policies, Standards for Planning Water and Related Land Resources" and recently proposed Water Resources Council Standards for Planning Water and Land Resources, dated July 1970, which are intended (when approved) to supersede S.D. 97. Since these documents are primarily

applicable to inland waters planning, the extension of principles to ocean projects appears particularly important.

Mr. Lo's work was limited to one semester's effort. He expects to produce a chart classifying ocean projects and the applicable economic criteria by extending the WRC proposals.

Thesis: M.S. Thesis not required by the Dept. of Civil Engineering.

Status: Continuing under support by N.Y.U. teaching program without external funding. Mr. Lo has transferred to part-time status, and is employed by Army Corps of Engineers (Coastal Engineering).

4.8 Transport Processes

Faculty Investigator: Assoc. Prof. Michael M. Chen, Dept. of Mechanical Engineering.

Research Assistants: Mr. C.C. Lin and Mr. K. C. Chung

Objective: To further the quantitative understanding of the transport processes of pollutants both in suspension and as bottom sludge.

Summary:

Density differences arising from variations in temperature, salinity, and particulate concentration play important roles in the transport processes of estuarine and ocean waters. Their understanding is of importance to (a) the prediction of nutrient distribution in connection with productivity studies and aquaculture considerations; (b) estimates of the distribution and flux of dissolved and suspended pollutants; (c) environmental considerations in connection with the site selection and design of marine installations. The present investigation has focused on two aspects of such transport processes.

1. When density decreases with increasing depth, the fluid is unstable, and vertical mixing occurs. The resulting eddies significantly enhance the effective shear stress and the diffusion processes, but their understanding is incomplete. In the present project, a model of such

turbulent eddies has been formulated which correctly predicts several important flow characteristics, including the gross transport rates. Further refinement for this model is currently in progress. An experimental program designed to complement and to scrutinize the theoretical results has also been initiated.

2. When a viscous sludge of slightly higher density is introduced in water, it often forms a sluggish layer at the bottom which resists mixing. This phenomenon is found in the dumping grounds of sewage sludge and industrial waste in the New York Bight. The rate of spread of such pools, governed by gravity acting on the gently sloping sludge-water interface, is of obvious environmental interest. In the present program, several simple cases dealing with the sludge spreading rate on horizontal bottoms have been analyzed. For example, the diameter of a circular sludge pool of fixed mass has been found to increase as the $1/8^{th}$ power of time.

Plans are now being made to extend the analysis to more complex geometries, such as non-horizontal bottoms, with the hope of arriving at a predicative ability for sludge pool migrations. Part of this effort was presented as "A Model for Turbulent Thermal Convection in Horizontal Fluid Layers" at the Annual Fluid Dynamics Conference of the American Physical Society, La Jolla, 22-24 November 1971, an abstract of which appeared in the Bulletin of the American Physical Society, Volume 16, No. 11 (1971).

The following reports are in preparation:

"A Model of Turbulent Diffusion Due to Gravitational Instability" by M. M. Chen.

"Gravitational Instability of the Stagnation Boundary Layer" by M. M. Chen and C. C. Lin.

"Cellular Flow in Infinitely Deep Fluid Layers Due to Unstable Density Gradients", by M. M. Chen and K. C. Chung.

"The Spreading of a Very Viscous Sludge Layer on Horizontal Surfaces" by M. M. Chen.

Thesis: Mr. K.C. Chung is continuing to investigate turbulence in stratified layers with relevance to chemical and particulate transport, toward a Ph.D. in Mechanical Engineering.

Status: Mr. K.C. Chung is continuing with support from National Sea Grant No. 1-36105. Mr. C.C. Lin is continuing his efforts with support from another grant.

4.9 Factors Affecting Corrosion Pitting of Aluminum in Aqueous Solutions Containing Chloride Ions

Research Assistant: Mr. Mahadeo Thubrikar, Dept. of Metallurgy and Materials Sciences

Faculty Supervisor: Prof. John P. Nielsen

Objective: To determine the mechanism of pitting and the role of the aluminum oxide film in pit initiation and growth.

Summary:

Presently available knowledge in this area is inadequate. Better understanding of the mechanism of pitting may eventually lead to means of prevention of corrosion pitting of aluminum and its alloys.

The mechanism of pit initiation of high purity aluminum in aqueous solutions containing chloride ions was investigated by potentiostatic and potentiodynamic methods. Observations indicate that pit initiation requires a minimum field strength as indicated by the existence of a critical potential value across the aluminum-aluminum oxide-water electrolyte interfaces, at and above which pit initiation occurs. This critical potential value is found to be related to such factors as chloride ion concentration, temperature, pH and thickness, structure and composition of the aluminum oxide film.

Additional experiments were carried out to relate spontaneous pit initiation (at open circuit potential) with pit initiation under the anodic potentiostatic conditions. It is possible, as a result of the

research done, to explain why pitting can occur at open circuit potentials.

Results on the time dependence of pit initiation at constant interface potential indicate that the diffusion of chloride ions through the oxide film is rate determining.

Thesis: It is anticipated that Mr. Thubrikar will be awarded an M.S. degree during February 1972.

Status: Completed.

4.10 The Role of Microstructure on the Fatigue Behavior of an Alpha-Beta Titanium Alloy

Research Assistant: Mr. Hung Lee Hoo, Dept. of Metallurgy and Materials Sciences

Faculty Supervisor: Prof. Harold Margolin

Objective: To relate microstructure and fatigue behavior in an alpha-aged beta titanium alloy.

Summary:

Data in the literature was confusing on this point and since some correlation had been established between tensile and fracture toughness, it appeared desirable to undertake a study of fatigue.

A correlation between alpha particle size and both low cycle and high cycle fatigue was observed. The larger the alpha particle the lower is both the low cycle or high cycle fatigue resistance. Grain boundary and Widmanstatten alpha are more deleterious to the initiation of fatigue than equiaxed alpha.

It has also been found that the fatigue crack is attracted by alpha particles. The spacing of alpha particles along a fatigue crack is closer than it is along a random line.

It thus appears that there is a definite albeit complex relationship between fatigue crack propagation and microstructure. The size, distribution and morphology of alpha all affect crack propagation behavior.

Thesis: This project represents the Master's thesis of Mr. Hung Lee Hoo. Mr. Hoo received an M.S. (in Metallurgy) on 25 October 1971.

Status: Completed.

4.11 The Interrelationship of Microstructure and Fatigue Behavior in an Alpha-Beta Titanium Alloy

Research Assistant: Mr. Hoon Park, Dept. of Metallurgy and Materials Sciences.

Faculty Supervisor: Prof. Harold Margolin

Objective: To relate microstructure and fatigue behavior in an alpha-aged beta titanium alloy.

Summary:

Mr. Hung Lee Hoo has shown a relationship between fatigue life, crack propagation behavior and alpha particle size, distribution and morphology. This work is undertaken to elucidate how these factors interact to nucleate a crack and affect its propagation.

Thesis: The study will form part of the Master's thesis of Mr. Hoon Park.

Status: Continuing with support from National Sea Grant No. 1-36105.

4.12. The Hardness of Alpha Titanium as a Function of Alpha Size in an Alpha-Beta Titanium Alloy.

Research Assistant: Mr. Hoon Park, Dept. of Metallurgy and Materials Sciences.

Faculty Supervisor: Prof. Harold Margolin.

Objective: To determine the hardness of alpha titanium in a beta matrix of fixed strength as the alpha size is varied.

Summary:

Work on fatigue, tensile and fracture toughness behavior had suggested that alpha titanium had a variable yield strength on hardness,

depending on its size and the strength of the beta matrix.

The work has not as yet been completed. However, the data obtained do show that alpha is softer than beta and that alpha becomes softer as its size increases.

Thesis: This work is part of the Master's thesis of Mr. Hoon Park.

Status: Continuing with support from National Sea Grant No. 1-36105.

4.13 Age Hardening of Tantalum Alloys

Research Assistant: Mr. Daryoush Assadi, Dept. of Metallurgy and Materials Sciences

Faculty Supervisor: Assoc. Prof. Ernest N. Levine

Objective: To investigate the feasibility of age hardening binary tantalum alloys with Zr, Ni and Cr.

Introduction:

Tantalum is one of the most corrosion resistance materials available. It is also an extremely ductile material and can be worked into complex shapes. The main disadvantage to tantalum is that it has a relatively low yield strength. Most attempts to strengthen tantalum have been centered on solid solution hardening, but this only results in a modest increase. The current study was undertaken to see if a controllable age hardening system of tantalum could be found and, if so, what are the resulting physical properties as related to microstructure. To this end suitable binary systems of tantalum were chosen for study and evaluation.

Summary:

Alloys of tantalum with 10 and 15 atomic percent Zr, Cr and Ni were prepared by arc melting. After homogenization at temperatures from 1800-2200°C the alloys were quenched into molten metal at 150°C. Aging curves were established by heat treatments for 100 hours at temperatures from 450 → 900°C in 50°C intervals. The results suggested a suitable temperature for aging was between 700 - 900°C.

Isothermal curves were obtained at these temperatures. The system Ta-Cr did not show any aging response in contradiction to reported results in the literature. The TaNi system was two phase at the homogeneization temperature and it appears that Ni is virtually insoluble in tantalum at all temperatures. This is in contradiction to a reported phase diagram. The Ta 10% Zr and 15% Zr proved capable of age hardening with hardness going from 250 VHN as quenched to over 550 VHN after aging between 700 and 900°C. Light optical micrographs of the overaged samples showed the presence of a finely dispersed second phase. Transmission electron microscopy of these samples is in progress. Thus the TaZr system may be a practical system for hardening Ta. More studies will be conducted at decreased Zr concentrations in order to find a lower limit for age hardening in this alloy system.

Thesis: This was to be part of Mr. Daryoush Assadi's doctoral thesis.

Status: Discontinued.

4.14 Strengthening in Ductile Two Phase Alloys

Research Assistant: Mr. Steven Hayden, Dept. of Metallurgy and Materials Sciences

Faculty Supervisor: Prof. Ernest Levine

Objective: To investigate the effect of volume fraction, morphological variations, dispersion, size, and interparticle spacing of the soft ductile alpha phase on the mechanical properties of an alpha-beta titanium alloy.

Introduction:

It is known that differences in alpha with respect to the above mentioned parameters can severely alter such mechanical properties as fracture toughness, dutcility, yield strength, stress corrosion susceptibility and fatigue life. In each of these areas there is only limited understanding of the reasons behind the particular mechanical behavior of these ductile two phase alloys, but it is thought that the

deformation behavior of the alpha, when surrounded by beta, must play a large role in determining some or all of the above physical properties. In this particular study we have chosen to investigate the variation in yield strength and initial strain hardening rate, as affected by various changes in alpha in order to better understand the restraining role of beta in the deformation process. A basic understanding of this phenomenon would aid in optimizing microstructure of titanium alloys for service under hostile environments such as sea water.

Summary:

The system chosen for the work is TiMn two phase alloys. Ingots of these alloys of eight different compositions are being prepared in order to cover a full range of volume percent of alpha. Small arc melted buttons have also been prepared and are in the process of being homogenized. Sheet specimens of Ti-8Mn which were obtained from commercial sources have been homogenized at 700°C, which will be the homogenization temperature for all succeeding alloys. In order to find the limits of beta strengthening possible, aging curves have been obtained up to 600°C. Hardening, however, was observed up to 450°C.

Thesis: This work is part of the Master's thesis of Mr. Steven Hayden. It is anticipated that Mr. Hayden will receive an M.S. degree during February 1973.

Status: Continuing with support from a grant under the National Defense Education Act.

5. SUMMARY

The first three years of New York University's Ocean Engineering Program resulted in:

the development of 11 courses to supplement 44 existing and related courses,

204 student registrations in the 11 courses,

seed research projects carried out by 14 graduate research assistants under the supervision of 10 faculty advisers,

2 seed research projects conducted by faculty researchers,

continuing support from other agencies for 3 research projects,

4 theses towards Master of Science degrees,

2 technical reports,

2 research papers,

5 manuscripts in preparation.

The items listed above are easily quantifiable, but there are other aspects of the Ocean Engineering Program that are also significant and worthy of reporting.

Activities related to ocean engineering had been an integral but informal part of the School of Engineering and Science for many years prior to the inception of the Ocean Engineering Program. These activities took place among small groups working in different departments. There was, of course, a dialogue between the various faculty and students with oceanic interests but there was no solidifying framework to unify the effort prior to the initiation of the Ocean Engineering Program. One of the most important spinoffs of the program is the increased cross-germination of concepts involving several or more of the disciplines. Students move freely across department boundaries to take courses of particular interest to them, and there is greater

interdepartmental communication and cooperation among faculty and research staff having mutual interests in oceans and estuaries.

Another benefit of the Ocean Engineering Program is that it provides specialized and essential training for a relatively small number of students without a large overhead burden. The program is superposed on the departmental structure of the School of Engineering and Science in an effective manner, and it is carried out within a modest budget.