THE UNIVERSITY OF MICHIGAN

TEACHING AND RESEARCH IN MATERIALS

October 5, 1959

ABSTRACT

This report presents a summary of the Materials Activities in teaching and research at The University of Michigan. It indicates those areas of work which can be expanded immediately and also presents a long range program, oriented to a logical total growth of the College of Engineering. It presents a proposal for support for research in Materials as well as expansion of facilities.

TABLE OF CONTENTS

I. INTRODUCTION

The University of Michigan has a long, well established history of development leading to the present scope of activity directed toward a basic understanding of Materials and their behavior. At present, approximately 70 academic appointees, approximately 40 graduate students actively working on Ph.D. theses in the field of Materials, approximately 25 full time research personnel and 150 project employed undergraduate and graduate students are working in the area of Materials technology. The annual rate-of-support for the research activity in Materials is in the order of $1,250,000. Support for the teaching and research activity comes from academic budgets, grants, and contracts from industrial and government sources. Many small projects in the several technological areas as well as a limited large-scale research effort contribute to the over-all strength of the University.

Historically the concentrated teaching and research effort directed toward the study of Engineering Materials coincides with the contributions of Professors Edward DeMille Campell, A. H. White, and A. E. White beginning about 1890. The early use of X-ray in physical metallurgy contributed in a very large measure to the present strength of the Materials program at the University. The work of Professors Upthegrove, Wood, and Thomassen on oxidation and decarburization is well known. The research into the properties of high temperature alloys was begun after World War I by Professor A. E. White, extended by Professor C. L. Clark, and is being continued under the direction Professor J. W. Freeman.

Many publications have resulted from past research efforts. Several outstanding text books on the subject of Materials are in print. Professor A. H. White's nationally known text "Engineering Materials" was a requirement in all engineering programs for many years.

The studentsin engineering programs have been continually introduced to new knowledge as research and understanding progressed. Two new texts, dealing with the subject of Materials are now in use. These books are, "Elements of Materials Science," by Professor L. H. Van Vlack and "Solid State for Engineers" by Professor M. J. Sinnott.

The organizational structure within the College of Engineering is departmental in character and oriented toward professional engineering divisions. The interaction, however, between these groups, the association of research workers with like scientific interests, the exchange of information that brings about an intimate knowledge of the complete spectrum of activity is encourgaged by several important developments.

Since the inception of the first building program for the College of Engineering, no structure has ever been assigned to one department. Space assignments have been made to groups in accordance with their needs and the suitability of the available space for their occupancy. The faculty offices and laboratories of a department are located near each other so that the department can function as a group. The several departments are located adjacent to each other and use the same classrooms; and where possible, use the same laboratories, and share certain common facilities. The result is an interdisciplinary activity in many of the technological areas.

The future plans of the College of Engineering are based upon the same principle of departmental development. Inherent flexibility in order to accommodate the needs of a rapidly changing technology is a first consideration in our planning activity.

II. PRESENT ACTIVITY IN MATERIALS

The present teaching and research effort in the technological area of Materials is a continuation of the work that has been an integral part of the University programs. Although teaching and research programs must continue in a close relationship, they are being separately discussed in this report. In either case the amount of expansion that can evolve is dependent upon an increased level of research support, support for additional facilities, and support for equipment programs to accommodate the expansion. Only a limited expansion of the programs can occur within the present space limitations.

(A) Academic Programs in Materials

Eleven interdisciplinary departments of the University are enthusiastically pursuing teaching and research which contributes to the understanding of the basic structure of Materials and their characteristics. Expansion plans have been made. The departments in the Engineering College are Aeronautical and Astronautical Engineering, Chemical and Metallurgical Engineering, Civil Engineering, Electrical Engineering, Engineering Mechanics, Mechanical Engineering, and Nuclear Engineering. The Departments of Mineralogy, Chemistry and Physics in the College of Literature, Science, and the Arts are engaged in course work and research leading to a better understanding of Materials. The Wood Technology program in the School of Natural Resources is actively engaged in Materials research.

The Materials Engineering undergraduate academic program in the College of Engineering was developed in 1952 to focus all the related work into a program of study in which the student could concentrate his attention. It was the first such program in the country to receive ECPD accreditation. It is built on a basic science background of mathematics, physics and chemistry, requiring additional physical chemistry, organic chemistry, and solid state physics as prerequisites for senior courses in metallurgy, ceramics and polymers. The undergraduate student must include a sequence of engineering design courses in one of several departments. The description of this program and its curriculum is described in Appendix A.

The academic teaching and research activity has been extended into graduate programs leading the MSE and Ph.D degrees. The graduate program was established in early 1957. The Master's degree program emphasized the science of Materials on a graduate level. Again the three fields of metals, ceramics and polymers are equally emphasized and a Materials research problem is required. The doctoral program in Materials requires still greater depth.in the science of Materials and of course requires the normal original research activities. Statements of requirements for the MSE and Ph.D degrees are found in Appendix B and C respectively.

The Engineering Materials MSE and Ph.D degree programs are a part of the total interdesciplinary effort that is directed toward the broad field of Materials. Appendix D is a partial list of titles of current thesis topics being developed in several departments of the University, all of which are related to the technology of Materials.

The undergraduate and graduate degree programs are supported by a wide range of formal courses offered by several of the departments of the University including not only those developed within the Engineering College but by other colleges. Principal outside contributors to the Engineering College programs are the Departments of Chemistry, Physics, and Mathematics which are attached to the College of Literature, Science, and the Arts. A partial list of these course offerings are found in Appendix E.

(B) Current Research Programs in Materials

All research program supervisors or directors have academic appointments in The University of Michigan. These persons may be attached to the teaching staffs of the departments or they may be engaged in full-time research within department or at the Willow Run Laboratories. Appendix F names this group and indicates the major interest of each person. Any one person will also have cognate interests.

The present research activities at The University of Michigan can be roughly classified into seven major areas.

1) Defect Structures in Solids.

2) Extreme Temperature Properties of Materials,

3) Materials for Energy Conversion and Measurement,

4) Mechanism of Deformation and Fracture,

5) Processing of Materials,

6) Relationship of Properties to Micro-and Macrostructure.

7) Surface Structures and Surface Reactions.

A brief statement to indicate the diversification of effort surrounding these areas, the interested personnel and the scope of the present activity may be found in Appendix G. A partial list of current specific project topics and the sponsoring agency may be found in Appendix H.

III. EXPANDED MATERIALS PROGRAM

The desire on the part of all groups associated with Materials for expanded programs in teaching and research is very great for many reasons. It is realized that the upper boundary on many technological advances is fixed by the characteristics and capabilities of Materials. A limited amount of increased research and teaching activities can occur within the present space availability. The long range expansion of the various disciplines in teaching and research will have its direct and important impact when the need for facilities are recognized as a necessary part of an expanded student body. A total expansion program, therefore requires that attention be given to both immediate and long range possibilities.

It is first necessary to give consideration to an expanded program which will supply a flow of information for immediate technical needs but within the present space confines. The second is a long range expanded program as it is now visualized. It will include adequate integrated space and an expanded student body.

A limited expanded research program is possible at The University of Michigan and is necessary if the basic information needed by some of the project work is developed by the present research groups. This expansion, for which support is being asked, must occur in the main in inadequate facilities which are available to the University.

An immediate expansion in activity can occur in the "Defect Structure of Solids" work particularly with reference to measurements on the energy levels and relaxation times of paramagnetic ions in solids at longer wavelengths, to the effects of radiations on photoconductivity, and the studies of phosphors and electro-luminescence. The area of "Materials for Energy Conversion and Measurement," in which many laboratories are heavily engaged can expand by providing additional funding for needed equipment and graduate student support. The information from this important area is vitally needed in not only the government sponsored "Project Michigan", but also the activities in radio-astronomy, electro magnetic radiation research and the important problems associated with guidance, re-entry, and location.

"Processing of Materials" should be expanded immediately since the preparation of now unavailable, novel compounds and crystals are necessary to be advancement of a basic understanding of Materials. This expansion requires new laboratory equipment.

Certain new activities can be accommodated in locations remote from the campus. A program is micro-acoustics with emphasis on induced nuclear and electron spin transitions is planned. A program of research is planned on surface effects of bulk semiconductors. A third new program is planned on the electrical and optical properties of organic dyes to assess their value as infrared dector and transistor Materials.

The long range direction of research in Materials is more difficult to assess due to the many rapid developments. Certainly, a planned expansion must take into consideration the probable growth of an institution. Fortunately, this information can be carefully predicted. The planning of projected teaching and research program is less difficult if those engaged in the activity are permitted the freedom to guide the programs as the need for new information is indicated by a changing technology. At this writing, it appears to the faculty that all seven areas, set forth in the preceding section, should expand in varying degrees. The suitability of space for the future needs for research is of paramount, immediate importance. Flexibility of design, ample and flexible utility capacity, and easy alteration of interior walls seems to be the primary requisite to satisfy future needs.

IV. ORGANIZATION

The College of Engineering includes twelve budgetary units or departments. Nine of the departments offer Bachelor of Science degree programs in Engineering, all of which are accredited by the Engineering Council for Professional Development. The tenth budgetary unit is the Nuclear Engineering Department. Each department, including the Nuclear Engineering Department, offers graduate work leading to both the Master of Science degree in Engineering and the Ph. D degree. The Department of Engineering Mechanics is one of two such groups in the United States that is accredited.

Although the organizational structure exists, the built-in flexibility at the University of Michigan in the College of Engineering makes it possible to develop degree programs of study where interdisciplinary academic activity can add to the strength of the program. Six interdisciplinary programs are functioning in the College, three of which, namely Engineering Materials, Engineering Mathematics, and Engineering Physics, offer the Bachelor of Science degree program accredited by the Engineering Council for Professional Development; and the fourth, the Science Engineering Program which was recently inspected prior to its first accreditation. The Materials Engineering program was the first in the United States to be accredited. The degree program in Meteorology has not been in existence long enough to request accreditation. Four of the six educational programs, namely the Materials Engineering, Science Engineering, Instrumentation Engineering and Meteorology offer graduate programs leading to the Master of Science degree and the Ph. D degree. Twelve of the Departments offer a six-year program leading to a professional degree in Engineering.

All degree programs are serviced by interdisciplinary related University academic teaching. All Chemistry, Mathematics and Physics courses are given in the College of Literature Science and the Arts. Several of the research activities related to the atom are supported by the Phoenix Memorial Laboratory which includes the Ford Nuclear Reactor.

The University of Michigan Research Institute and the Willow Run Laboratories likewise serve to strengthen the educational program of the College of Engineering. These two organizations are University-wide, interdisciplinary groups who perform valuable support functions for the faculties of the University.

The University of Michigan Research Institute is an administrative unit without laboratory facilities organized to assist the faculty in handling of funds and supplying supporting services for grants, and contract research work in which the faculty is priviledged to engage. These funds originate in both industrial organizations and in government agencies.

The Willow Run Research Laboratory is an administrative unit which is organized to accept and execute through use of its own laboratories as well as educational laboratories large project types of research for both industry and government sponsorship. The administrative group for this laboratory is assisted by an Executive Committee selected by the President of the University from the faculty of the University. Personnel used by this agency included faculty, graduate students, full time research engineers and scientists and technical assistants as may be required to carry out their project functions. The Willow Run Laboratory is necessarily interdisciplinary in character.

V. SUPPORT REQUIREMENTS

The requests for funds to expand the teaching and research programs in the technological area of Materials at the University of Michigan are set forth in three categories: (a) Research Support - Present Space Limitations, (b) Research Support - Adequate Space Provisions, and (c) Support for Facilities Expansion that is required to match the programs supported by category (b).

(A) Research Support - Present Space Limitations

A careful study has indicated that immediate support is required for a limited expansion of the present Materials teaching and research effort and certain new work that can be accommodated within the confines and limitations of the present space. The major areas of research at the present are indicated in Appendix G. Section III presented a general statement of the needs for an immediate program of expansion and the planned direction for long range program of expansion.

The University of Michigan requests immediate research support in an amount of $400,000 to expand activities within the confines of present space limitations.

(B) Research Support - Adequate Space Provisions

A detailed study to assess the probable expansion of the College of Engineering at the University of Michigan has been completed. Based upon this study recommendations for future needs of the college has been made to the Administration of the University. Data quoted in Appendix I, Section 1 are taken from the report, "Space Study and Recommendations," dated January, 1959.

Our past extensive research program experience in many areas indicate that the annual support level per academic appointee who is teaching and directing graduate research is in the order of $30,000. This estimate will vary depending upon the cost of specialized equipment that may be required. This following tabulated budget is based on a progressively increasing number of faculty that can be expected to participate in some phase of Materials research.

Year	Annual Research Support
1960	$2,300,000
1961	$2,570,000
1963	$3,130,000
1965	$3,660,000

(C) Support for Facilities Expansion

The College of Engineering has completed a detailed analysis of the use of the present available space occupied by the Engineering College. These data along with a projection of facility needs for future expansion are set forth in Appendix I, Sections 1 and 2. Of particular importance to this proposal, however, is addition information that is not immediately recognizable in the study. The effect of obsolescence on the teaching and research program is extremely difficult to document. Complete obsolescence of the present space for teaching and expanded frontier research programs is a matter of fact.

The recommendations by the College of Engineering for space on the new North Campus have been determined by the faculty in Table V. When compared with similar studies that have received wide attention, the recommendations are conservative. It should be particularly noted that the major portion of the recommended space is for offices and laboratories. The study of present space indicates that major deficiencies exist for these occupancies.

Table VI is a proposed building schedule for facilities on North Campus. The immediate need for new space is quite apparent.

Based upon the studies, the results of which are outlined in Appendix I, Section 1 and 2, and based upon an estimate of the numbers of faculty and students who will be engaged in an interdisciplinary teaching and research effort in the area of Materials, the University of Michigan is requesting funds for facilities commensurate with the estimated Materials activities and in accordance with the building schedule set for in Section II.

Year to Start Construction	Requested Funds for Construction
1960	$2,300,000
1962	$2,300,000
1967	$2,300,000

The University of Michigan is in a position to consider alternate methods of negotiating an agreement whereby the funds as outlined may become available for its use. Real estate on North Campus is available for building construction. Direct complete grants may be accepted, or suitable contractual arrangements permitting amortization of facilities may be entered into between the parties.

APPENDIX A

MATERIALS ENGINEERING (UNDERGRADUATE)

Program Adviser: Professor Van Vlack, 4215 East Engineering. With the rapid development of new and better Materials to meet the more exacting demands of industry and government agencies there has developed a demand for engineers with a sound understanding of Materials and the factors that determine their various properties. Materials engineers must have sound foundation in physics and chemistry, as well as in engineering and in the Materials used and manufactured by industry. They must also understand the utility, properties, and applications of Materials such as metals, alloys, cements, plastics, ceramics, and protective coatings. They are particularly valuable in manufacturing plants where it frequently is desirable to replace present materials for the purpose of improving the product, reducing costs, reducing service failures, or because of shortages of specific raw materials. They find opportunies in the development of new products, specification of new Materials or combinations of these for existing products, development of new applications, or in the sales field. This program as designed also offers work in specifications, methods of fabrication, corrosion, high temperature properties of metals, and stress analysis.

Requirements

Candidates for the degree of Bachelor of Science in Engineering (Materials Engineering) are required to complete one of the following programs:

Schedule	Hours T	Hours S
A. Subjects to be Elected for Equivalent Proficiencies to be demonstrated		
Total, normally	44-53	47-49
B. Professional Subjects and Electives		
Math, 103, Differential Equations	3	
Math, 150, Adv. Math for Engineers, or Math 161, Statistical Methods I		4 or 3

APPENDIX A (CONT'D)

Schedule	Hours T	Hours S
Eng. Mech. 1, 2, 3, Statics Strength and Elasticity, Dynamics, or Eng. Mech. 5, 3, 126, Statics and Stress Analysis....................................	10 & 9	
Eng. Mech. 12, 13, Strength of Materials, Dynamics.		7
Eng. Mech. 4, Fluid Mechanics 4, or equivalent.....	3	
Chem. 20, Qualitative, or Chem. 23, Analytical.....	3 or 4	3 or 4
Chem. 61, Organic................................	6	6
Chem. 182, 183, Physical.........................	6	6
Sci. Eng. 110, or Chem. -Met. Eng. 111, or equivalent, Thermodynamics...................................	3	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits.	4	4
Chem. Met. Eng. 16, or Chem.-Met. Eng. 124, or Elec. Eng. 136, Laboratory Measurements..................	3	3
Chem.-Met. Eng. 118, Structure of Solids, or equivalent...	3	3
Chem.-Met. Eng. 122, Ceramic Materials.............	4	4
Chem.-Met. Eng. 125, Introduction to High Polymers.	4	4
Chem.-Met. Eng. 127, 128, Physical Metallurgy......	7	7
Electives in English, Anthropolgy, Classical Studies Economics, Geography, Fine Arts, History, Journalism, Music, Languages, Political Science, Psychology, Sociology, Speech. One course in English and others in at least two of the departments names...........	16	16
Group Options*.....................................	9	9
Electives..	4 or 2	5-3
Total, Professional subjects and electives....	87	86

*In satisfying the group option requirement, courses are to be elected within one engineering area with the advance approval of the program adviser.

APPENDIX B

MATERIALS ENGINEERING (MASTERS DEGREE)

Advisory Committee: Professors Young, York, Van Vlack, and Associate Professors Ragone and Gordon.

A candidate for this degree is required to have a background essentially equivalent to that represented by the program leading to the degree of Bachelor of Science in Engineering (Materials Engineering) at The University of Michigan. This includes chemistry, through organic and physical, structure of materials, mechanics of materials, and thermodynamics. Thirty semester hours of additional work are required, which are to be selected with the approval of the advisory committee of the program and which will include Chemical and Metallurgical Engineering 208 or 218.

Academic Program	Credit Hours
Advanced Principles	9
Materials (Ceramics, Metals, Polymers)	9
Research Problem	4
Cognate	8
	30

APPENDIX C

MATERIALS ENGINEERING (DOCTORATE)

The doctor's degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly announced graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in some subdivision of the selected field and must present the results of his investigation in the form of a dissertation.

Applicant for the Doctorate

A student becomes an applicant for the doctorate when he has been admitted to the Graduate School and has been accepted in a field of specialization. No assurance is given that he may become a candidate for the doctorate until he has given evidence of superior scholarship and ability as an original investigator.

There is no general course or credit requirement for the doctorate. In most areas a student must pass a comprehensive examination in his major field of specialization, which tests his knowledge in that field and in the supporting fields, before he will be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of course and in preparation of the dissertation.

A reading knowledge of German and French is required. A student must meet the language requirements for the doctorate before he can be accepted as a candidate for the degree.

APPENDIX D

TITLES OF CURRENT PH.D THESES INVESTIGATING THE
BASIC CHARACTER AND BEHAVIOR OF MATERIALS

Doctoral Student	Topic
D. Adams	"Use of New Magnetic Materials in Electrical Circuitry"
R. E. Balzhiser	"Solubility Relationships in U-Bi Solutions Involving Third Elements"
G. C. Berry	"Relationships Between Structure and Physical Properties of Solids"
T. Butler	"Use of New Ferroelectric Materials in Electric Circuitry"
A. P. Coldren	"Effect of Creep Induced Changes in Substructures Upon High Temperature Strength"
T. Cullen	"Basic Causes of Weld Cracking in Stainless Steels"
R. Denton	"Walker Modes in Magnetic Resonance"
A. Emmons	"Spectral Dependence of Radiation Damage"
S. Floreen	"Effect of Elastic Strain of Surface Energy of Solids"
J. A. Ford	"Kinetics of Temper Embrittlement"
J. Gallini	"Stereospecific Polymerization of Pentene"
A. Henkin	"The Influence of Some Physical Properties on Machinability"
D. R. Jenkins	"Fracture of Metals Under Complex Stress States"
R. Knox	"Magnetostriction"
D. Kraai	"Effect of Liquid Environments on Fracture of Solids"
H. B. Kristinsson	"Investigation of the Relationship of Surface Structure to Light Reflectance Properties"
R. LaBotz	"Thermoelectric Semiconductor Materials"
K. Ludema	"On Process Variables in Extrusion"
G. Makhov	"Amplitude Stability of a MASER Oscillator"
E. J. Myers	"Energy Damping Characteristics of High Temperature Alloys"
H. O'Bryan	"Mass Transfer in Solids"
D. F. O'Kane	"Ternary Semiconductor Materials"
J. F. Piazza	"The Thermodynamic Properties of Uranium Carbide"
D. Ray	"Low Temperature Study of Magnetite for an Investigation of Phase Transitions"
W. Raymond	"Anisotropy Effects in Oriented Ferroplanes"
J. P. Rowe	"Effect of Overtemperature on Residual Properties of Nickel Base Alloys"

APPENDIX D (CONT'D)

Doctoral Student	Topic
A. Ruskin	"Fractionation of High Polymers"
T. Schriber	"Catalytic Activity of Ruthenium"
R. C. Schwing	"Preparation of New Polymeric Materials"
D. Sponseller	"Relationship Between Atomic Radius and Solubility of Alkali and Alkaline Earth Metals in Iron"
R. G. Squires	"Thermoelectric Properties of Particulate Systems"
C. Stickles	"Effects of Strain on Liquid Contact Angles at Grain Boundaries"
P. K. Trojan	"Solubility of Magnesium in Fe-C Alloys"
R. G. Wells	"Equilibria in the FeO-ZrO_2-SiO_2 System"
J. White	"Variable Elevated Temperature Properties of Stainless Steels"
W. Wolf	"Phosphors"

APPENDIX E

COURSES PRESENTING BASIC INFORMATION ABOUT MATERIALS

(a) Underclass courses providing background to advanced courses.

Engineering Materials. Introductory level.
Materials Processing. Introductory level.
Materials Science. Sophomore level. Established in early 1959 to utilize a basic science background.
Structure of Solids. Upperclass level. Solid State Physics for Engineers.
Engineering Structures at Elevated Temperatures.
Ceramic Materials.
X-ray Studies of Engineering Materials.
Introduction to High Polymers.
Physical Metallurgy.
Materials of Electrical Engineering.
Optical Crystallography.
X-ray Crystallography.

(b) Partial List of Specialized Graduate Studies.

Polymerization Principles.
Metals at High Temperatures.
Thermodynamics of Metals.
Corrosion and High Temperature Resistance of Metals.
Theoretical Metallurgy.
Solid State Kinetics.
Solid State Chemical Principles of Semiconductors and Catalysts.
Advanced X-ray Studies of Materials.
Nuclear Metallurgy.
Organic Chemistry of Synthetic Polymers.
Heterogeneous Equilibra.
Electron and Semiconductor Devices.
Electric and Magnetic Properties of Materials.
Theory of Solid-State Electronic Devices.
Interaction of Radiation and Matter.
Radiation Shielding.
Physics of the Solid State.
Atomic and Molecular Structure.
Kinetic Theory of Matter.
Physics of Continuous Media.
Quantum Theory and Atomic Structure.
Molecular Spectra and Molecular Structure.
Molecular Vibrations.
Petrography.

APPENDIX F

ACADEMIC APPOINTMENTS

List A. Those who have made extensive contributions on the basic characteristics of Materials to recent technical journals.

Staff Member	Position	Department or Laboratory	Major Materials Interest
W. C. Bigelow	Assoc. Prof.	Chem. Met. Engr.	Electron Microscopy
L. O. Brockway	Professor	Chemistry	Chemical Structures
L. V. Colwell	Professor	Mechanical Engr.	Machinabililty of Metals
R. M. Denning	Assoc. Prof.	Mineralogy	Crystal Properties
P. J. Elving	Professor	Chemistry	Organic Materials and Analytical Procedures
R. A. Flinn	Professor	Chem. Met. Engr.	Casting Processes
J. W. Freeman	Professor	Chem. Met. Engr.	High Temperature Properties of Metals
D. M. Grimes	Assoc. Prof.	Electrical Engr.	Magnetic Materials
E. E. Hucke	Assoc. Prof.	Chem. Engr.	Surface Energy & Fracture
E. Katz	Professor	Physics	Solid State Physics
C. Kikuchi	Professor	Nuclear Engr.	Magnetic Resonance
J. J. Lambe	Research Phys.	Willow Run Lab.	Magnetic Resonance
D. R. Mason	Assoc. Prof.	Chem. Met. Engr.	Semiconducting Materials
G. Parravano	Assoc. Prof.	Chem. Met. Engr.	Reaction Kinetics in Solids
D. V. Ragone	Assoc. Prof.	Chem. Met. Engr.	Thermodynamics of Metals
L. S. Ramsdell	Prof. & Chrm.	Mineralogy	Crystallography
M. J. Sinnott	Professor	Chem. Met. Engr.	Solid Surface Reactions
R. W. Terhune	Research Phys.	Willow Run Lab.	Masers and Maser Materials
L. H. Van Vlack	Professor	Chem. Met. Engr.	Metal Processing and Ceramic Materials
E. F. Westrum	Professor	Chemistry	Cryogenics
W. L. Wolfe	Research Assoc.	Willow Run Lab.	Optical Properties

List B. Those who are participating to a major extent in current research and teaching activities in the area of Materials.

H. Allen	Research Engr.	Aeronautical Engr.	High Temp. Materials Applications
L. C. Anderson	Professor & Chrm.	Chemistry	Polymers & Elastomers
S. K. Clark	Assoc. Prof.	Engr. Mechanics	Complex Stress States
R. M. Caddell	Asst. Prof.	Mechanical Engr.	Processing of Materials

APPENDIX F (CONT'D)

Staff Member	Position	Department or Laboratory	Major Materials Interest
H. Diamond	Asst. Prof.	Electrical Engr.	Ferroelectric Materials
J. Datsko	Assoc. Prof.	Mechanical Engr.	Processing of Materials
H. E. Early	Research Engr.	Electrical Engr.	High Temp. Energy Sources
D. F. Edwards	Assoc. Res. Phys.	Willow Run Lab.	Optical Properties
J. H. Enns	Assoc. Prof.	Engr. Mechanics	Complex Stress States
P. A. Franken	Asst. Prof.	Physics	Magnetic Resonance
J. R. Frederick	Asst. Prof.	Mechanical Engr.	Ultrasonic Properties
J. V. Gluck	Research Assoc.	Chem. Met. Engr.	High Temp. Prop. of Metals
F. G. Hammitt	Assoc. Prof.	Nuclear Engr.	Cavitation Corrosion
R. B. Haythornthwaite		Engr. Mechanics	Complex Stress States
G. Hok	Professor	Electrical Engr.	Electronic Materials
W. S. Housel	Professor	Civil Engr.	Soils
L. W. Jones	Asst. Prof.	Physics	Optical Behavior
W. Kerr	Professor	Nuclear Engr.	Shielding Materials
J. S. King	Assoc. Prof.	Nuclear Engr.	Neutron Diffraction
L. M. Legatski	Professor	Civil Engr.	Construction Materials
F. E. Legg	Assoc. Prof.	Civil Engr.	Construction Materials
E. J. Lesher	Assoc. Prof.	Aeronautical Engr.	High Temperature Materials
R. T. Liddicoat	Professor	Engr. Mechanics	Complex Stress States
C. Lipson	Professor	Mechanical Engr.	Fatigue
G. Mahkov	Research Assoc.	Willow Run Lab.	Maser Materials
J. C. Mouzon	Professor	Electrical Engr.	Electrical Materials
J. C. Mazur	Asst. Prof.	Mechanical Engr.	Processing of Materials
D. W. McCready	Assoc. Prof.	Chem. Met. Engr.	Plastics
J. Mudar	Research Assoc.	Willow Run Lab.	Infrared Detectors
S. Nudelman	Research Phys.	Willow Run Lab.	Optical and Luminescent Behavior
R. K. Osborn	Assoc. Prof.	Nuclear Engr.	Neutron Diffraction
W. V. Farr	Assoc. Prof.	Civil Engr.	Construction Materials
R. W. Parry	Professor	Chemistry	Inorganic Synthesis
M. L. Perl	Asst. Prof.	Physics	Optical Behavior
C. W. Peters	Asst. Prof.	Physics	Optical Properties
W. B. Pierce	Asst. Prof.	Chem. Met. Engr.	Casting Processes
F. A. Reiss	Assoc. Res. Chemist	Willow Run Lab.	Crystal Preparation
J. E. Rowe	Assoc. Prof.	Electrical Engr.	Electron Physics
R. H. Sands	Asst. Prof.	Physics	Magnetic Resonance
R. Schneidewind	Professor	Chem. Met. Engr.	Cast Metals

APPENDIX F (CONT'D)

Staff Member	Position	Department or Laboratory	Major Materials Interest
C. A. Siebert	Professor	Chem. Met. Engr.	Corrosion
C. B. Sharpe	Assoc. Prof.	Electrical Engr.	Materials for Microwave Applications
W. A. Spindler	Asst. Prof.	Chem. Met. Engr.	Casting Processes
G. H. Suits	Research Phys.	Willow Run Lab.	Infrared Detectors
J. A. Sweeney	Asst. Prof.	Mechanical Engr.	Processing of Materials
M. R. Tek	Asst. Prof.	Chem. Met. Engr.	Rheology
L. Thomassen	Professor	Chem. Met. Engr.	X-ray Diffraction
V. A. Vis	Assoc. Res. Engr.	Willow Run Lab.	Optical Prop. of Materials
H. R. Voorhees	Assoc. Res. Engr.	Chem. Met. Engr.	High Temp. Materials
L. E. Wagner	Asst. Prof.	Mechanical Engr.	Metal Joining
C. T. Yang	Assoc. Prof.	Mechanical Engr.	Plastic Deformation
P. F. Zweifel	Assoc. Prof.	Nuclear Engr.	Nuclear Materials

APPENDIX G

MATERIALS RESEARCH IN PROGRESS

1) Defect of Structures in Solids

Participating Departments	Staff
Chem. - Met. Engineering	Mason, Thomassen, Parravano
Electrical Engineering	Diamond, Grimes, Hok
Mineralogy	Denning
Nuclear Engineering	Kikuchi, Zweifel
Physics	Katz
Willow Run Laboratories	Lambe, Makhov, Nudelman, Suits, Terhune, Wolfe

SCOPE:

Present activity has been focused on phosphors, electro-luminescence, photo-conductors and semiconductors as they are related to luminescent and optical properties. Spin resonance has been a powerful tool in studying radiation damage, diffusion and absorption.

Increased emphasis is being placed on (1) an extension of the program of measurements on energy levels and relaxation times of paramagnetic ions in solids to include the longer wavelengths, (2) studies on the effects of nuclear radiation on photoconductivity, and (3) an expansion of phosphor and electron luminescent studies.

2) Extreme Temperature Properties and Behavior of Materials

Participating Departments	Staff
Aeronautical and Astronautic Engineering	Allen, Lesher
Chem. - Met. Engineering	Flinn, Freeman, Gluck, Voorhees, Van Vlack
Chemistry	Westrum
Electrical Engineering	Early, Grimes

SCOPE:

Creep and stress rupture properties of metals at high temperatures is a strong area of technology which has developed through the years. Research studies on refractory alloys and ceramics is well represented. The helium cryostat facility has made possible research on the heat capacity and studies of magnetic resonance of Materials.at low temperatures.

There is a minimal need to expand facilities or activity in the field of conventional measurement of high temperature properties. However, there is considerable desire to expand activities which interrelate these properties to (1) severe gas and particle environments, and (2) complex stress states. Currently, high energy sources are being sought to aid some of these activities.

Our facilities for producing liquid helium must be expanded to support the increased use of cryogenic techniques for basic studies on the structure of Materials.

3) Materials for Energy Conversion and Measurement

Participating Departments	Staff
Chem. - Met. Engineering	Churchill, Mason
Chemistry	Parry
Electrical Engineering	Diamond, Grimes, Hok, Mouzon, Rowe, Sharpe
Mineralogy	Denning
Nuclear Engineering	Kerr, Kikuchi
Physics	Jones, Katz, Perl, Peters, Sands
Willow Run Laboratories	Edwards, Mudar, Nudelman Suits, Terhune, Wolfe

SCOPE:

Research in this area is the largest in volume and widest in participation of all programs. The programs include basic research on 1) Materials for direct energy conversion (thermoelectric and piezo-electric); 2) Materials for energy measurement and amplification (masers, semiconductors, ferroelectrics), 3) Materials for energy detection (infrared sensors) and 4) Materials for energy generation (catalytic surfaces, nuclear fuels).

It is desirable to extend each of the present activity areas which are listed above. In addition, specific emphasis should be placed upon (1) free radial reactions at surfaces, (2) Materials for ultra-high ($>5000°K$) temperature sources, (3) plasma thermocouple, (4) optical pumping in solids and (5) the initiation of a micro-acoustical program with emphasis on induced nuclear and electron spin transitions.

4) Mechanisms of Deformation and Fracture

Participating Departments	Staff
Chem - Met. Engineering	Bigelow, Flinn, Hucke
Civil Engineering	Housel
Engineering Mechanics	Clark, Enns, Haythornthwaite, Liddicoat
Mechanical Engineering	Caddell, Colwell, Datsko, Hammitt, Lipson, Sweeney, Yang

SCOPE:

The approach to the problems of deformation and fracture has been through studies of stress patterns introduced into Materials. Specific attention has been given to machinability, loading, buckling, notch strength, hole stress and fatigue.

The trend which has been established includes: (1) electron microscopy studies of deformation structures, (2) the role of microstructure upon fracturing, and (3) an extension of deformation studies into more complex stress states.

5) Processing of Materials

Participating Departments	Staff
Chem. - Met. Engineering	Flinn, Freeman, Mason, McCready, Parravano, Pierce, Ragone, Sinnott, Van Vlack
Chemistry	Anderson, Parry
Mechanical Engineering	Spindler
Willow Run Laboratories	Hess

SCOPE:

The present research activities include thermodynamic studies of equilibrium, chemical synthesis, and processing reactions.

Two areas should receive specific attention beyond the prescent scope. (1) Solid and liquid kinetics as applied to Materials processing. Specifically this would involve more work on catalysis and solid diffusion. (2) Preparation facilities for specialized research materials. This would not be a service facility. Rather it would provide the means for necessary experimentation to prepare unavailable, novel compounds and crystals that are not used in the basic studies of Materials.

6) Relationships of Properties to Micro and Macrostructures

Participating Departments	Staff
Chem. - Met. Engineering	Bigelow, Freeman, Hucke, Schneidewind, Siebert, Sinnott, Tek, Voorhees, Van Vlack
Civil Engineering	Housel, Legatski
Electrical Engineering	Grimes
Mechanical Engineering	Colwell, Datsko

SCOPE:

The inter-relationship of properties and structures have involved a full range of activity from polycrystalline metals and ceramics to concrete soil. Recent studies involve the effect of surface energies upon the strength of Materials and the effect of grain size upon the magnetic effect of spinels.

A general increase in emphasis on this area is desired. Greater attention should be placed on the inorganic, non-metallic Materials, and with the polyphase compositions.

7) Surface Structure and Surface Reactions

Participating Departments	Staff
Chem. - Met. Engineering	Parravano, Siebert, Sinnott
Chemistry	Brockway
Mechanical Engineering	Hammitt

SCOPE:

Surface absorption and corrosion studies have been the major activity in this area.

Since these activities have been limited to date, the area of surface studies would receive the greatest proportional increase in emphasis of the several which have been outlined. Expanded activities would include studies of (1) surface structure, (2) surface catalysis, (3) electrical absorption, and (4) surface diffusion.

APPENDIX H

A PARTIAL LIST OF CURRENT RESEARCH PROJECTS PERTAINING TO THE BASIC CHARACTERISTICS OF MATERIALS

Title	Principal Investigator(s)	Department	Sponsor
Basic Factors Affecting Heat Resistants Alloys	J. W. Freeman	Chem. Met. Engr.	Industrial
Basic Research Efforts in Ferromagnetism and Ferroelectricity	D. Grimes	Electrical Engr.	O.S.R.
Cavitation Corrosion of Materials by Liquid Metals	F. G. Hammitt	Nuclear Engr.	NASA
Coefficient of Friction in Wire Drawing		Mechanical Engr.	Faculty Res. Fund
Creep Rupture under Biaxial Stresses	H. R. Voorhees	Chem. Met. Engr.	Industrial
Cryogenic Magnetic Measurements	Staff	Elect. Engr. & Willow Run Lab.	Project Mich. (Signal Corps)
Crystal Defects by Spin Resonance	C. Kikuchi, J. J. Lambe	Nuclear Engr. & Willow Run Lab.	Air Force
Crystal Defects	R. Terhune, J. J. Lambe	Willow Run Lab.	O.S.R.
Distribution and Size of Precipitate Particles in Age Hardening Nickel Base Alloys	W. C. Bigelow	Chem. Met. Engr.	Faculty Res. Fund
Ductility Requirements for High Temperature Alloys	H. R. Voorhees	Chem. Met. Engr.	Industrial

APPENDIX H (CONT'D)

Title	Principal Investigator(s)	Department	Sponsor
Elastic Properties of Rubber Laminates	S. K. Clark	Engr. Mechanics	Industrial
Effect of Prior Creep on Mechanical Properties of Materials	J. V. Gluck	Chem. Met. Engr.	WADC
Effect of Size and Coherency upon Elevated Temperature Properties of Heat Resistant Alloys	R. A. Flinn	Chem. Met. Engr.	ONR
Effects of Superimposed Ultrasonic Vibrations on the Mechanical Working of Aluminum	J. R. Frederick	Mechanical Engr.	Industrial
Effects of Surface Energy on Fracture of Solid Metals	E. E. Hucke	Chem. Met. Engr.	OSR
Effects of Trace Elements on Structure and High Temperature Strength of Refractory Alloys	J. W. Freeman	Chem. Met. Engr.	NASA
Fracture Studies Under Biaxial Stress States	S. K. Clark	Eng. Mechanics & Mechanical Engr.	WADC
Heterogeneous Catalysis	G. Parravano	Chem. Met. Engr.	OSR
High Loss, Low Reflective Ferrimagnetic Materials	D. Grimes	Electrical Engr.	Rome Air Div. Center
Infrared Cells	D. Edwards	Willow Run Lab.	Project Mich. (Signal Corps)

APPENDIX H (CONT'D)

Title	Principal Investigator(s)	Department	Sponsor
Infrared Detectors and Phosphor Displays	G. Suits S. Nudelman	Willow Run Lab.	Project Mich. (Signal Corps)
Infrared Information & Analysis	W. Wolfe	Willow Run Lab.	ONR
Investigation of Plastic Materials for Gear Applications	K. W. Hall	Mechanical Engr.	Industrial
Ionic Conductivity of Solids	E. Katz	Physics	ONR
Machining of Steel	L. V. Colwell	Mechanical Engr.	Industrial
Maser Development	R. Terhune G. Makhov	Willow Run Lab.	Project Mich. (Signal Corps)
Maser Material Properties	R. Terhune	Willow Run Lab.	Project Mich. (Signal Corps)
Masers for Radio Astronomy	R. Terhune	Willow Run Lab.	Project Mich. (Signal Corps)
Nonmetallic Inclusions in Steel	L. H. Van Vlack	Chem. Met. Engr.	Industrial
Optical Properties of Semiconductors	D. Edwards	Willow Run Lab.	Project Mich. (Signal Corps)
Preparation of Maser Materials	F. Reiss	Willow Run Lab.	Project Mich. (Signal Corps)
Properties of Noble Metals and Their Compounds	G. Parravano	Chem. Met. Engr.	Industrial

APPENDIX H (CONT'D)

Title	Principal Investigator(s)	Department	Sponsor
Radiation Effects on Electronic Materials	Staff	Nuclear Engr.	Industrial
Semiconducting Materials	D. R. Mason E. Katz	Chem. Met. Engr. & Willow Run Lab.	Project Mich. (Signal Corps)
Sintering of Metal Oxides	G. Parravano	Chem. Met. Engr.	OSR
Spin Resonance in Rubber	C. Kikuchi	Nuclear Engr.	Industrial
Steels for High Temp. Service	J. W. Freeman	Chem. Met. Engr.	Industrial
Stress-Strain Relations in Soils	R. B. Haythornthwaite	Engr. Mechanics	Detroit Arsenal
Studies of Heat Resistant Alloys	J. W. Freeman	Chem. Met. Engr.	WADC
Target Detection Techniques	G. Suits	Willow Run Lab.	A.F.
Thermodynamic Properties of Solid Surfaces	G. Parravano	Chem. Met. Engr.	Industrial
Thermodynamic Properties of UC, ThC, and ZrC	M. J. Sinnott	Chem. Met. Engr.	Phoenix
Thermodynamics of U-Bi Solutions	D. V. Ragone	Chem. Met. Engr.	AEC
Transient Thermal Stresses	S. K. Clark	Engr. Mechanics	NSF
Uranium Carbide	D. V. Ragone	Chem. Met. Engr.	Industrial

APPENDIX H (CONT'D)

Title	Principal Investigator(s)	Department	Sponsor
Weld Cracking in Stainless Steel	J. W. Freeman	Chem. Met. Engr.	Industrial
Wood Adhesives	A. Marra	Wood Technology	Industrial
X-ray Spectrometer Resonance in Radiation Effects	H. Gomberg W. Kerr	Nuclear Engr.	AEC
Zone Fractionation of Solid Compounds	G. Parravano	Chem. Met. Engr.	NSF

APPENDIX I

SPACE STUDY AND RECOMMENDATIONS

Several years ago the Administration of the University of Michigan started a real estate development plan that would provide land area upon which to build needed physical plants for the future. This acquisition of 1000 acres of land became known as the North Campus. It is located approximately one and one-half miles from the Main Campus.

It has been the general plan that new facilities for the College of Engineering beginning after 1952 would be constructed on North Campus. It was further understood that only the Junior, Senior, and Graduate level of teaching and research would be transferred to the new facilities. The Mortimer E. Cooley Memorial Laboratory, The Phoenix Memorial Laboratory, The Ford Nuclear Reactor, and the Automotive, Fluids, and Aeronautical Engineering Laboratories have been built on this new site. The North Campus Planning Committee of the Engineering College is a facilities planning group for new facilities.

Section I

Analysis of Present Space

The North Campus Planning Committee, which included all of the disciplines within the College of Engineering at the University of Michigan, participated in a study during the past year from which data for this document are taken. The study included 1) statistical information on past enrollment trends; 2) projection of enrollment based upon population statistical information; 3) planned programs for teaching and research; 4) an analysis of present space and its usage; and 5) a projection of space requirements based upon present space deficiencies, the projections of enrollment, the requirements for space to meet the needs of an expanded teaching and research program in engineering. This report, "Space Study and Recommendations" was published in January, 1959.

Enrollment Study

Enrollment predictions, particularly the long-range tendency, is an essential part of any budget and building program study. Before presentation of the results of this study it is necessary that an understanding of its limitation be established. Minor variations from predictions will occur. Several different sources of information have been used for the study. Certain considerations that may actually affect predictions have not been taken into account. For instance, no consideration was given to the fact that the rate-of-increase of college enrollment of those eligible to enter college is approximately 1% per year. Further, no consideration has been given to the tremendous publicity directed toward the need for engineers.

Two sources of data were used as bases for enrollment predictions. The Russell Report data was taken from a study concerning the needs for education sponsored by the Michigan State Legislature. Similar data on population statistics were taken from a report prepared by Dean Robert L. Williams at the University of Michigan. Figure 1 is a plot of data from the Russell Report No. 11, data from Dean Williams' report and enrollment data from the record of the college secretary. All data were referenced to the 100% point established by the report, "Public Engineering Education in Michigan," accepted by the Council of State College Presidents in May, 1955. Minimum, average, and maximum rates-of-increase of enrollment are plotted; the minimum being established approximately parallel to the Russell and Williams data; the maximum being the straight line extrapolation through the peak points of the Junior, Senior and Graduate enrollment, and the average plotted midway between the extremes.

The enrollment projection of Freshmen and Sophomores was based on the minimum rate-of-increase since it is believed that the Junior and Community Colleges will carry an increased burden at these levels. The average rate-of-increase is used at the Junior, Senior and Graduate levels since those students who are preparing for a career in engineering must, by necessity, transfer from the Junior Colleges to a school offering professional and research educations opportunities. The College of Engineering should reasonably expect that it will receive its proportional number of the transfer students.

Table I is the result of the enrollment study.

Study of Present Occupancy

The committee studied the present occupancy of space assigned to the Engineering College. This work included both an analysis of the actual use of space without reference to its suitability and the condition of occupancy for space assigned to offices of the teaching faculty. Table II and III are prepared to show the resulting information.

FIGURE I. THE UNIVERSITY OF MICHIGAN COLLEGE OF ENGINEERING
SPACE STUDY

STUDENT ENROLLMENT VS. YEAR. BASIS: MICHIGAN COUNCIL OF STATE COLLEGE PRESIDENTS — 1955 REPORT
100% = RECOMMENDED MAX. ENROLLMENT AT THE UNIVERSITY OF MICHIGAN.

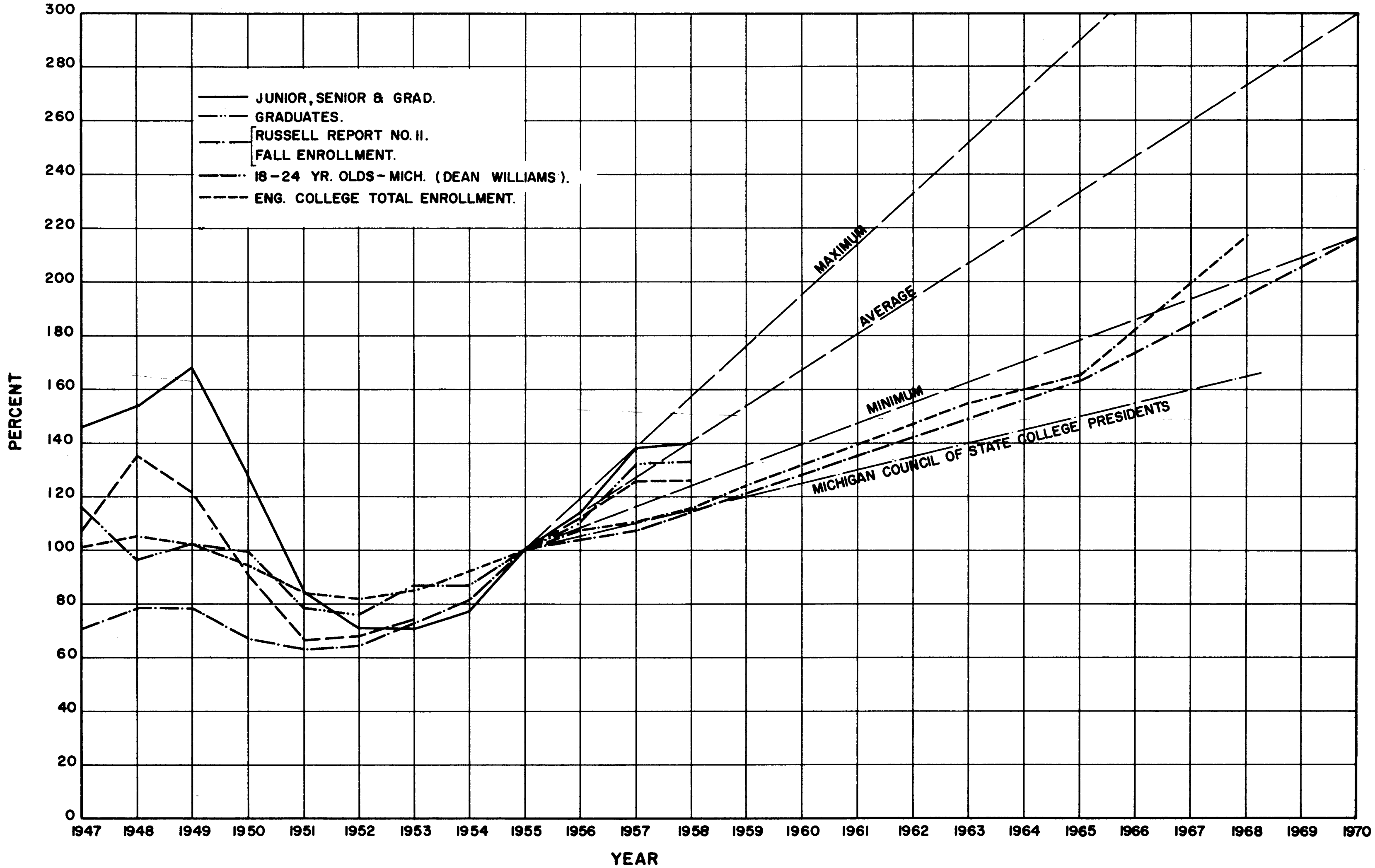

TABLE I

THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

PREDICTION OF STUDENT ENROLLMENT

BASIS: Michigan Council of College Presidents May 1955 Report

YEAR	FRESHMEN & SOPHOMORES (Min. Rate)		JUNIOR, SENIOR GRADUATE (Average Rate)		Total No.	GRADUATE ONLY (Average)	
	%	No.	%	No.		%	No.
1947	116.0	1933	146.0	2444	4477	116.0	627
1948	102.8	1710	154.0	2586	4296	96.5	521
1949	67.0	1112	168.0	2809	3921	101.5	548
1950	53.8	895	123.0	2054	2949	99.0	538
1951	45.5	757	82.5	1382	2139	78.5	424
1952	65.0	1080	70.5	1180	2260	75.7	408
1953	73.0	1217	71.0	1184	2401	86.5	467
1954	84.5	1405	77.5	1299	2704	86.8	469
1955	100.0	1664	100.0	1673	3337	100.0	542
1956	105.0	1745	110.0	1852	3597	114.0	615
1957	110.5	1845	132.0	2209	4054	138.5	746
1958	112.0	1862	133.0	2228	4090	140.0	758
1970	214.0	3555	300.0	5020	8575	300.0	1625

TABLE II

THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
PRESENT SPACE OCCUPANCY

Building	Location	Construction Date	Gross Area	PRESENT OCCUPANCY*					
				Offices*** Sq. Ft.	Labs. Sq.Ft.	Class Rooms Sq.Ft.	Design Rooms Sq.Ft.	Total Sq.Ft.	% Gross
W. Engineering Building	Main Campus	1904	157,518	36,291	36,977	26,890	20,274	120,432	78.9
East Hall	Main Campus	1883	20,194	2,800	0	9,800	0	12,600	62.7
East Engineering Building	Main Campus	1923-47	273,071	41,470	94,435	34,892	30,503	201,390	73.8
sub-total			450,783	73,011	126,612	64,977	50,777	334,442	73.2
Automotive Lab.***	North Campus	1956	62,120	2,335	19,644	2,620	0	24,599	39.6
Aero Laboratory	North Campus	1956	18,059	1,840	13,235	0	0	15,075	83.5
sub-total			80,179	4,175	32,879	2,620	0	39,674	
TOTALS			530,962	77,186	159,491	67,597	50,777	374,096	70.5

NOTE: * Corridors, building service areas, dark rooms, storage, mechanical equipment, rest rooms, etc., not included.

** UMRI Shops (4250 sq.ft.) and mechanical equipment room for test cells (14,000 sq.ft.) are not included.

*** Designated areas include space that may be partially assigned to laboratory activity, and includes the space assigned to Placement and Interview, now in a rehabilitation program.

TABLE III

THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

OFFICE OCCUPANCY 1958 - 1959

PRESENT OCCUPANCY

Academic Rank	Number	Men/ Office	Net Sq. Ft./ Man
Professor	98	1.280	156
Associate Prof.	62	1.635	130
Assistant Prof.	52	1.945	126
Instructor	43	2.030	129
Grad. Students			
M. S.	477	0	0
Ph.D.	270	0	0

SECTION 2

Project Space Requirements

Space Recommendations

The Committee studied the space needs of the College of Engineering based upon the projected student enrollment and the requirement of adequate space to conduct an expanded teaching and research program in the several disciplines. Table IV and V are recommendations established by the Committee upon which to plan additional facilities.

At the time of publication of the "Space Study and Recommendations," based upon actual numbers of students enrolled in the College of Engineering in 1958 and upon the recommended space requirements as shown in Tables IV and V, the net space deficiency for the College of Engineering was determined to be 240,000 square feet. The space requirements as set forth by the faculty in Table V are actually some what conservative when compared with other studies that have received wide attention. The major portion of the space deficiency was the lack of office and laboratory space. No space improvement has been affected since the study.

TABLE IV

THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING

RECOMMENDED OFFICE SPACE

Academic Rank	Men/ Office	Office Shortage No.	Net Sq.Ft. Office
Professor	1.0	22.0	130
Associate Professor	1.0	26.0	130
Assistant Professor	1.0	25.0	130
Instructor	2.0	1.0	190
Graduate Student			
M. S.	8.0	119.0	260
Ph.D.	4.0	67.0	260

TABLE V

THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

RECOMMENDATION FOR MINIMUM NET SPACE OCCUPANCY

NORTH CAMPUS PLANNING COMMITTEE

SPACE OCCUPANCY	RECOMMENDATION Net Sq. Ft.	% Area Cl. Rm. Office & Laboratory
Class Rooms		
sq. ft. per student	13.6	9.5
Design Rooms		
sq. ft. per student	9.5	6.4
Laboratories		
sq. ft. per student		
(a) large labs	26.7	67.2
(b) small labs	70.0	
Total Labs.	96.7	
Offices		
sq. ft. per faculty		
(a) faculty	130.0	
(b) secretary and supporting files	104.0	16.9
(c) administrative & student activities	53.0	
Total Off.	287.0	

TABLE VI

NORTH CAMPUS BUILDING PROGRAM

(Net Sq. Ft.)

YEAR	Schedule for Occupying Building	Net Addition of Space	Total No. of Junior Senior & Grad Std.	Total Number of Faculty on N.C.	Total Space Deficiency on North Campus
1960	Fluids II	53,500	2800	306	288,600
1961	Office, Lab I	240,000	3030	343	77,470
1963	Office, Lab II	240,000	3480	418	31,175
1968	Office, Lab III	240,000			
1970			5020	561	29,255