CRITERION 9. PROGRAM CRITERIA

The program criteria consist of both curriculum and faculty requirements and are as follows for a metallurgical engineering program:

Curriculum Criteria

The program must demonstrate that graduates have

1. the ability to apply advanced science (such as Chemistry and Physics) and engineering principles to materials systems implied by the program modifier: metals;

2. an integrated understanding of the scientific and engineering principles underlying the four major elements of the field: structure, properties, processing, and performance related to material systems appropriate to the field

3. the ability to apply and integrate knowledge from each of the above four elements of the field to solve materials selection and design problems

4. the ability to utilize experimental, statistical and computational methods consistent with the program educational objectives.

Faculty Criteria

The faculty expertise for the professional area must encompass the four major elements of the field.

Quantitative satisfaction of the curriculum criteria is shown in Table 9-1 where program outcomes corresponding to the program criteria are mapped to specific program outcome assessments. The program criteria numbers in columns 3-6 correspond to the numbering of the criteria above. The average score card assessment for each outcome shown in the rows is entered into the correctly mapped location and averaged for years 2008 and 2009. The average for both years is 3.9. According to the scale used for assessing outcomes (ref. Appendix E, Metrics), 3.0 is moderate performance and 5 is exemplary performance. Therefore, the program is meeting the program criteria satisfactorily; however, the intent of the CIS system is continual performance improvement.

Table 9.1 Program criteria evaluation from corresponding outcome assessments

2009			Program Criteria			
Course	**Outcome**	**Instrument**	**1**	**2**	**3**	**4**
MET_320	(a)	FinalExam	3.8			
MET_465	(a)	LocalExam	5.0			
MET_231	(b)	HardnessandStatisticsLabs				3.3
MET_465	(b)	LocalExam			2.3	
MET_465	(c)	FinalDesignReports			3.7	
MET_465	(c)	DesignFairPresEvals			4.4	
MET_465	(c)	LocalExam			5.0	
MET_321	(e)	FinalExam(orAllExams)		3.3		
MET_465	(e)	LocalExam		2.7		
MET_465	(k)	LocalExam				4.7
			4.4	**3.0**	**3.9**	**4.0**

2008			Program Criteria			
Course	**Outcome**	**Instrument**	**1**	**2**	**3**	**4**
MET_320	(a)	FinalExam	3.8			
MATH_373	(a)	ProjectReports	2.0			
MET_422	(a)	FinalExam			4.1	
MET_310	(a)	SelectedHourExam	3.2			
MET_465	(a)	LocalExam	4.7			
MET_231	(b)	HardnessandStatisticsLabs				3.3
MET_440	(b)	SPCAssignments				4.5
MET_465	(b)	LocalExam		4.1		
MET_440	(b)	HardnessQCLabSim				4.7
MET_465	(c)	FinalDesignReports			4.4	
MET_310	(e)	FinalExam(orAllExams)		3.8		
MET_440	(e)	FinalExam(orAllExams)		3.9		
MET_465	(e)	LocalExam		3.3		
MATH_373	(k)	ProjectReports				3.9
MET_465	(k)	LocalExam				4.6
			3.4	**3.8**	**4.3**	**4.2**

Curriculum Criteria

In terms of curricular activities, program students engage in a full spectrum of course work and extracurricular activities that firmly support the program criteria. A description of these is presented here.

The program satisfies the criteria that the program graduates have the following:

<u>The ability to apply advanced science (such as Chemistry and Physics) and engineering principles to materials systems implied by the program modifier</u>

Each Metallurgical engineering graduate must complete PHYS 211 (University Physics I, 3 cr.) and PHYS 213 (University Physics II, 3 cr.), and PHYS 213L

(University Physics II Laboratory, 1 cr.), all of which are calculus-based. MATH 123 (Calculus I) is prerequisite for enrollment in PHYS 211.

Additionally, each metallurgical engineering graduate must complete CHEM 112 (General Chemistry I, 3 cr.), CHEM 112L (General Chemistry I Lab, 1 cr.). Students are given an option between CHEM 114 (General Chemistry II, 3 cr.), CHEM 114L (General Chemistry II Lab, 1 cr.), or BIOL 151/153 (General Biology I/II, 3 cr.), BIOL 151L/153L (General Biology Lab I/II, 1 cr.). Additionally, each graduate must complete six additional credit hours of science electives. Science courses frequently taken by our students include, but are not limited to, CHEM 316 (Fundamental of Organic Chemistry); CHEM 342 (Physical Chemistry I); CHEM 452 (Inorganic Chemistry) and PHYS 361 (Optics). Thus, the above mentioned science requirements (21 credits total) serve as the foundation for the application of science to metallurgical systems.

Advanced science concepts are applied throughout all required metallurgical engineering courses. Applied chemistry is most notably present in the following required courses: MET 232, MET 220, MET 310, MET 320, MET 321, and MET 422. Applied chemistry is also present in the following directed elective courses: MET 445, MET 443 and MET 426. Applied physics is most notably present in the following required courses: MET 232, MET 320, MET 330, MET 332 and MET 440. Applied physics is also present in the following directed elective courses: MET 443, MET 430, and MET 426. Other sciences (e.g. geology, biology) are present and applied in courses such as MET 220, MET 310, MET 320 and MET 321. The design sequence (MET 351, MET 352, MET 464, MET 465) employs science concepts throughout.

With respect to applying engineering principles, the following required courses serve as the foundation for such application: GE 130 (Introduction to Engineering, 2 cr.), EM 214 (Statics, 3 cr.), and EM 321 (Mechanics of Materials, 3 cr.). MET 110 is replacing GE 130 in the program curriculum, but it will serve the same function as GE 130 with respect to program criteria.

Advanced engineering concepts are applied throughout all required Metallurgical engineering courses most notably MET 310, MET 320, MET 321, MET 422, MET 330, MET 332, MET 443 (directed elective), MET 445 (directed elective), MET 426 (directed elective) and MET 440. In addition, the design sequence (MET 351, MET 352, MET 464, MET 465) involves extensive use of engineering concepts.

An integrated understanding of the scientific and engineering principles underlying the four major elements of the field: structure, properties, processing, and performance related to material systems appropriate to the field

Program graduates are well prepared in the matters of structure, properties, processing, and performance be it in extractive or materials aspects of the discipline.

Structure

Scientific and engineering principles related to material structure are covered in MET 231, MET 232, MET 330 and MET 332. Specific structure topics covered include basic crystallography, x-ray diffraction, dislocations, slip phenomena, grain boundaries, vacancies, annealing, and solid solutions. These topics are covered primarily from a scientific perspective. Structure topics are also covered from an engineering perspective including elastic and plastic deformation under different force systems, dislocation theory, fracture, internal friction, fatigue, creep, residual stresses, recovery, recrystallization and grain growth. When these criteria were first adopted by ABET, structure was deemed to include the extractive processing elements by considering the structure of an extractive process, its properties, etc. [Dr. Gerald Liedl's example for this was an iron blast furnace and its structure, properties, processes, and its performance]. In that sense the structure of such processes is covered in courses such as MET 310, MET 321, and MET 426 (directed elective).

Properties

Scientific and engineering principles related to material properties are covered in MET 231, MET 232, MET 330, MET 332 and MET 440. Topics covered include elastic and plastic deformation under different force systems, fracture, internal friction, fatigue, creep, residual stresses. In the extractive processing aspect of the discipline, the properties of extractive processing equipment such as large-scale equipment are covered in MET 310, MET 321, and MET 426.

Processing

Scientific and engineering principles related to material processing are covered in MET 220, MET 330, MET 332, MET 440, MET 443 (directed elective), MET 321, MET 310, MET 422. Specific processing topics covered include heat treatments, hot and cold working, Thermomechanical processing, oxidation/reduction processes, smelting, electrorefining, comminution, sizing, solid/liquid separations, leaching, ion exchange, solvent extraction, flocculation, froth flotation, and electrostatic separation.

Performance

Scientific and engineering principles related to material performance are most heavily covered in MET 231, MET 231, MET 330, MET 332, MET 440, and MET 443 (directed elective). Specific performance topics covered include hardness, strength, ductility, fracture, fatigue, and product purity.

the ability to apply and integrate knowledge from each of the above four elements of the field to solve materials selection and design problems

Scientific and engineering principles related to solving material selection and design are covered in MET 231, MET 232, MET 310, MET 321, MET 330, MET 332, MET 440, MET 422 and the design sequence (MET 351/MET 352/MET 464/MET 465). Specific class projects where the application and integration of metal structure knowledge is required include: a Cu-Ni solid solution project (MET 330L) and an Al alloy project involving grain size control (MET 440L). Class projects where the application and integration of metal processing knowledge is required have included: a Pb/Zn purification project (MET 321), a MoS_2 roaster (MET 321) project, a series of mineral processing unit operation projects (MET 310L), and an Al alloy project involving grain size control (MET 440L), and composites design (MET 443)

the ability to utilize experimental, statistical and computational methods consistent with the program educational objectives.

Students are required to use Microsoft Excel® as their primary computation tool other than handheld calculators. Excel use includes use of Goal Seek® and Solver® for optimization as well as the writing of MACROS to perform more complex problems. In MET 321 students must create a worksheet solution for a substantial heat and mass balance problem suitable for use by a technician. The worksheet must be clear and concise and free from corruption by a novice user of the application. Excel is also used in MATH 373 to solve PDQs describing heat transfer problems in solids. In MET 321 and MATH 373 students use MathCad® or MATLAB® to solve systems of ODEs. IN MET 320- students are required to perform equilibrium computations in mixed systems using Thermocalc®. An exhaustive list of computation instruction follows.

The campus requires each student have a standardized notebook computer. The university provides robust server services including many software packages for student use as part of their tuition. Software routinely used and available on the campus network includes:

- Microsoft Office Pro (Excel, Power Point, Outlook, Publisher, Word. Project.)
- MATHCad
- MATLAB
- C++
- BASIC
- AutoCad
- Maple
- Solid Works
- Internet services
- Materials Property Data Base prepared by ASM International
- ThermoCalc/Dictra
- Abacus
- Fluent

The Metallurgical engineering Program promotes the development of student's knowledge and competency in the use of computers to solve computational problems and to control processes.

Specific computer applications that are developed in Metallurgical engineering and related courses are given below:

- MET 220/220L -Mineral Processing and Resource Recovery (4 cr.): Students are required to use PCs to write and edit formal laboratory reports. Included in these reports are plots generated by Microsoft Excel.
- MET 231 - Properties of Material Laboratory (1 cr.): Students are required to use PCs to write and edit formal laboratory reports, use Microsoft Excel to make calculations. Included in these reports are plots, which require use of graphical software.
- MET 310/310L - Aqueous Extraction, Concentration and Recovery (4 cr.). Students use Microsoft Excel and MATHcad in report writing and design component.
- MET 321 - High Temperature Extraction, Concentration, and Recycling (4 cr.): Students are required to use Microsoft Excel and MATHcad to solve heat and mass balance problems. The purpose of these exercises is to reinforce the algebraic solution o f such problems. Students are required to use EXCEL SOLVER to solve linear and non-linear optimization problems, MatLab and MATHCad to model control systems and solve ordinary differential equations, and EXCEL to solve one and two dimensional unsteady-state problems in heat and mass transfer. Students also use these same tools when completing laboratory reports and design projects.

- MET 330L - Physics of Metals Laboratory (1 cr.); Students are required to use Microsoft Excel to help develop an understanding of X-ray diffraction, resolved shear stress and grain growth and grain size phenomena. Basic word processing and Excel are used in report writing.
- MET 440/MET 440L - Mechanical Metallurgy (4 cr.): Microsoft Excel is used to generate solutions for fatigue analysis and model deformation process: e. g. rolling. In addition, basic word processing is used in report writing.
- MET 464/465 - Metallurgical Design (4 cr.): Many of the engineering projects selected by students require the use of the computer. For example, many projects involve the use computer for process control. In addition, CPM software is used to schedule projects. A material property database (ASM International) is available. All students are required to prepare reports and graphics using the computer. CAD packages (AutoCad, SolidWorks), spreadsheet support (Excel), Microsoft Word , MATHCad and MatLab are some of the computer software available and used by students in design.
- MATH 373 **–** Students make extensive use of Microsoft Excel including SOLVER®, Goal Seek®, VBA's, iterative routines, instructor-provided macros for learning PDQ and LP solutions, matrix operations using matrix Add-Ins® by Leonardo Volpi in additional to the simplistic, but common, uses of Excel.   The students also use MATHCad® or MATHLAB® for Runge-Kutta solutions to ODE systems.

Statistics are taught and used throughout the Metallurgical engineering curriculum. Through repeated, contextual use, students have an excellent fundamental working knowledge of the meaning and use of statistics. Following is a synopsis of statistics instruction in several departmental courses. In addition to the statistics use described below, each course description includes a synopsis of statistics instruction.

- MET 220, 310/301L
    1. Linear regression analysis with confidence limit. Students are encouraged to use, whenever applicable, the conventional linear regression analysis. In addition, they are encouraged to use the confidence limit with the help of the t-table to see the spread of their data around the regression lines.
    2. Linear regression analysis with confidence limit. Students are to carry out chemical analysis on a porphyry copper ore. This exercise includes ore sampling through coning and quartering. In addition, students are asked to perform 90% and 95% confidence limits for the mean copper value of this ore after chemical analysis using an atomic adsorption spectrophotometer.
- MET 440/440L
  Students are expected to recognize that mechanical property measurement results depend on the state of the material, measurement practice, and other unknown factors. Therefore, students are expected to report measured mechanical properties in a statistical form. In addition, students perform a repeatibilty and reproducibility hardness laboratory.
- MET 321
    1. Statistical Process Control: Subjects covered in this course segment include the concepts of precision and accuracy, sampling, grand standard deviation versus the standard deviation of the group means, the generation of range and control charts including the concept of control lines and their relationship to statistical distribution, the significance of length of runs, and number of runs.

2. Data Adjustment: Students use Excel Solver to perform regression analysis on data constrained by mass balances in process flow sheets to arrive at best-fit values for each process stream.

Regression Analysis: Students are taught in MATH 373 and MET 321 how undetermined coefficients in their own mathematical models of engineering systems may be determined through regression analyses using Excel's Solver. Students perform statistical-related assignments in regression analysis as it pertains to data adjustment, curve fitting, and optimization.

.

Table 9-1 Summarizes the metallurgical engineering courses and their emphasis in applying and integrating knowledge for materials selection and design.

Table 9-1 Metallurgical engineering courses and emphasis in applying and integrating knowledge for materials selection and design.

MET 220/220L Mineral Processing and Resource Recovery	Optimal flotation chemistry systems are designed with the objective of optimizing reagent consumption to maximize product recovery and grade at minimal cost
MET 231 Structures and Properties of Materials Lab	Design is emphasized throughout the lab experiments. An emphasis is statistics as used to measure properties of materials and how to evaluate materials in a design environment.
MET 232 Properties of Materials	The presentation of a design component in the presentation of properties of materials is inseparable. Students receive information about mechanical, thermal and manufacturing processing of materials as well as the science and technology information regarding thermal - mechanical processing of materials.
MET 310/310L Aqueous Extraction, Concentration, and Recycling	Mineral processing plant operations are designed with selection and sizing of hydrocyclones, screens, comminution equipment and other equipment for recovery of copper, nickel, gold and silver from electronic scrap. Process flow sheets are created and economic analyses are performed.
MET 320 Metallurgical Thermodynamics	The objective of this course is to determine the effect of T, P, and concentration on phase transformations and CHEMical reactions and, therefore, is essential to the proper selection of materials.
MET 321/321L High Temperature Extraction, Concentration, and Recycling	A method is designed for recovering Zn from an imperial smelting furnace requiring students to propose methods of recovering Zn from the ISF, supported by their thermodynamic calculations and statistical process control. Methods must be compared their methods with those from conventional practice.

MET 445 Oxidation and Corrosion of Metals (directed elective)	Material selections are made based on corrosion resistance considerations and economics for various corrosive environmental conditions with the requirement for consideration of alternate materials.
MET 330/330L Physics of Metals	Design component involves advanced thermal processing of materials.
MET 332 Thermomechanical Treatment	Course concepts are applied to the design of microstructures, thermo-mechanical treatments, and materials selection.
MET 351/352 Engineering Design I/II	Course concepts are applied to the design of materials and structural components in order to prevent failure.
MET 422 Transport Phenomena	This course includes fluids, heat transfer, and some mass transfer. Insofar as these phenomena determine conditions materials encounter, they are important to material selection.
MET 426 Steelmaking (directed elective)	This course is primarily the thermochemistry of steel making
MET 433 Process Control-Hower	Design single-loop feedback control systems with appropriate mathematical modeling including: a. Sketch block diagrams b. Fit FOPDT parameters c. Discuss stability/controllability and establish appropriate controller action, d. Propose tuning parameters
MET 440/440L Mechanical Metallurgy	Course concepts are applied to the measurement of mechanical properties and the application of these properties to materials selection and processing
MET 443 Composite Materials (directed elective)	Material selections are made based on weight and performance considerations. Multi-disciplinary teams of Metallurgical and Mechanical Engineering students are involved.
MET 464/465 Engineering Design III/IV	This course involves the use of each student’s selection of materials skills.

The design sequence is clearly a critical component to satisfying specific program criteria. The current design program consists of integrated junior-senior teams of primarily, but not exclusively, metallurgical engineering students. Nearly all students are engaged in a design project to recreate from local ore a finished Samurai sword.

Students take IENG 301, Basic Engineering Economics, which is a two credit hour course. Students are exposed to the concepts of economic evaluation regarding capital investments, including the time value of money and income tax effects. These courses are followed by a final course in metallurgical design, MET 465. This is an integrated design course in which each student must complete a comprehensive, integrated design.

Faculty Criteria

The program faculty expertise and experience satisfy the program criteria as described in sections 6D and 6E and as documented by the vitae in Appendix B.