BREWING

for professional brewers

ESTABLISHED 1958

Professional Brewing Programs

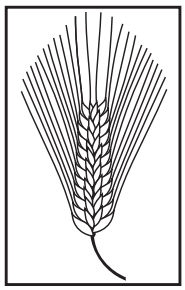
in Brewing Science and Brewery Engineering

UC Davis Extension
University of California, Davis

UCDAVIS EXTENSION

PROFESSIONAL AND CONTINUING EDUCATION

Accredited by the Board of Examiners, Institute of Brewing & Distilling



BREWING
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Professional Brewing Programs

in Brewing Science and Brewery Engineering

UC Davis Extension
University of California, Davis

- Master Brewers Program
- Professional Brewers Certificate Program

Michael J. Lewis
Coordinator and Academic Director

Accredited by the Board of Examiners,
Institute of Brewing & Distilling

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Master Brewers Program

Overview

The Master Brewers Program is a unique program that teaches in-depth knowledge of brewing science (malting, mashing, brewing, fermentation and finishing) and brewery engineering (fluid flow, heat and mass transfer, solid-liquid separation). Students explore these two broad fields by taking courses that are professional-level adaptations of University of California, Davis degree-program courses, seminars and tutorials in these fields.

The objective is to help students to prepare for the Diploma in Brewing Examination (formerly the AME) of the Institute of Brewing & Distilling (formerly the IGB) (London), which is a formal professional qualification in the field. Furthermore, the goal of the program is to provide students with the fundamental knowledge and insight necessary for successful practical brewing and employment in the profession at a high level of responsibility.

Classes are held at the UC Davis Extension classroom at Sudwerk Privatbrauerei Hubsch in Davis. This location allows observation of beer production by Sudwerk's two world-class systems: a fully automated 65-barrel Steinecker system and their original 15-barrel Caspary brewhouse. Laboratory sessions, including pilot brewing, are held on the UC Davis campus in the Department of Food Science and Technology's brewing laboratory.

The program comprises one eight-week and one six-week session, plus a three-week review session. Students study brewing science and brewery engineering in parallel courses that include university-level lectures, tutorials and seminars supported, as required, by laboratory and in-brewery demonstrations, pilot plant experiments and other practical work. In addition to such directed studies, students expand their brewing knowledge through guided library research, assigned reading and writing exercises, as well as extensive contact with the brewing community in Northern California.

The first eight-week session is an intensive introduction to brewing science and an introduction to brewery engineering where students become well versed in the fundamentals of these topics. The program follows a logical progression from barley to beer, as well as relevant engineering topics. The intent of the first session is to build a solid framework of understanding of brewing science and

technology and the scientific boundaries within which successful brewing is done. In parallel with this, the engineering program introduces the most essential engineering principles relative to brewing processes and equipment design at a conceptual and relatively non-numerical level. The first session comprises daily lecture sessions of up to six hours per day, four days per week; the fifth day is given over to review and examinations.

The second six-week session of the program deals with the same topics in lecture format, but uses additional instructional strategies, including laboratory and pilot plant experience, observations in working breweries, seminars and tutorials, extensive reading and writing assignments, and library study. The objective is to continue building on the fundamentals established in the first semester, but to explore brewing topics in much more depth and to acquire a mature understanding of the brewing process as a unified whole, especially the relation of raw materials and processes to product quality. The engineering program similarly repeats the topics of the first quarter, but with a quantitative (mathematical) approach and introduces an additional range of topics. The days of instruction in brewing science are shorter to provide time for private study, extensive writing exercises, and significant laboratory, pilot plant and brewery observations. Engineering instruction can comprise up to six to nine hours per week.

The three-week review session ends the period of formal instruction. This three-week period of study is designed to prepare students intensely for the IBD Diploma in Brewing Examination. Former examination questions are used as well as sample examination writing exercises. This provides excellent experience in clear writing, which is the faithful companion of clear thinking, and absolutely necessary for success in the examination. Little new knowledge should be introduced at this stage. Students should focus on manipulation of the knowledge already gained, a deeper understanding of it, expressing ideas in written form and developing a seamless relationship between theory and practice.

Objectives

The primary objectives of the Master Brewers Program are two-fold: (1) to prepare students to pass with confidence the Institute of Brewing & Distilling Diploma in Brewing Examination and (2) to enable students to become knowledgeable and thoughtful, accomplished and professional practical brewers who are eagerly sought by employers in today's brewing industry. Students who pass the IBD DBE prove to the international brewing community that they have a professional's level of understanding of the art and science of commercial brewing practices. Such a credential is not only useful to those seeking employment in the brewing industry, but also to those brewery personnel who require further training for advancement, and for those in allied trades wishing to make a credible presentation in the industry. The program is based on the curriculum provided by the IBD and accreditation of the program confirms that this standard is met.

Students who successfully complete the Master Brewers Program at the level of expectation set by the examination are well prepared to undertake the following tasks whether alone, as a leader or as a member of a team:

1. Evaluate and select raw materials for specific brewing and product objectives. Efficiently operate the brewhouse for wort production. Manage yeast and fermentation to meet product objectives, and finish and package the product to contemporary standards of excellence. Conduct a quality control program suited to the brewery and product.
2. Design a brewery unit, or make educated input to a brewery design team. Wisely select, or help to select, equipment from among several choices. Oversee installation of it to contemporary standards. Make logical and useful evaluations of processes used in a brewery and select appropriate options.
3. Undertake a wide variety of problem-solving tasks related to product quality, process efficiency or plant design.

The well thought out, tightly-focused and intense mixture of theory, observation and practice available in the Master Brewers Program is available in very few places in the world, and those who complete the program join an elite cohort in the international brewing industry.

Prerequisites

Success on the Institute of Brewing & Distilling Diploma in Brewing Examination (IBD DBE) requires a sound background in biology, microbiology, biochemistry, chemistry, physics, mathematics and engineering topics. Though a college degree in one of these areas is preferred, it is not necessary for admission to the program. Nevertheless, some relevant college-level work is required in the areas mentioned below for a candidate to have a reasonable chance of passing the IBD DBE. The breadth of topics covered in the program and the examination is wide, and few candidates will be adequately prepared in all areas. Candidates therefore should have (a) adequate preparation in mathematics (pre-calculus) and (b) relevant preparation in at least two other areas listed below.

- Biological sciences (e.g., biochemistry, cell (plant) biology/ physiology or microbiology)
- Chemistry (e.g., inorganic, organic or analytical)
- Physics (e.g., heat and mechanics or process control)
- Engineering (topics in mechanical and/or chemical engineering)

Practical brewing experience is not required for entrance into the program and will not substitute for adequate preparation in science. Nevertheless, for a candidate with adequate science preparation, practical experience is a positive factor in selection.

Explanation About Course Requirements

Mathematics — The brewery engineering program does not require calculus for success, but competent and confident algebra skills are necessary. These skills are best described as "pre-calculus," meaning the most advanced mathematics course before a calculus course may be taken. The engineering program and the practice questions from the IBD DBE provide a great deal of opportunity for computation in class and homework, and candidates should not be intimidated by this.

Biological sciences — These courses, along with chemistry, are the foundation of our brewing science studies, which is about two-thirds of the total effort. Candidates should have courses that are general in approach, including cell structure and function, the chemistry and biology organelles and the cell components (e.g., proteins) and the biochemical pathways that drive the life of cells. Many courses in this field are oriented towards health sciences or towards environmental issues, ecosystems and wildlife. These are not suitable preparation for this program.

Chemistry — Inorganic chemistry is a necessary start in this field covering the nature of matter (including e.g., atoms, chemical bonds, gases, liquids and solids, solutions, colloids and change of state) and the elements. A similar introductory course in organic chemistry is also desirable as almost all of the molecules relevant in brewing are organic. Candidates should understand nomenclature, structure, bonding/bonds and isomerism of organic molecules, the properties of functional groups on alcohols, esters, organic acids, aldehydes and ketones (including sugars) and aromatic compounds.

Physics — Physics is a fully acceptable substitute for engineering courses, and candidates without engineering course experience should complete some physics coursework. Physics courses on heat (temperature and thermal properties of matter and heat transfer) and mechanics (mechanical properties of matter, motion, work/energy, momentum, gas laws) are useful. Those on electricity, magnetism and light are not as useful. Process control courses are not a substitute for physics courses, but have their own value for parts of the curriculum.

Engineering — Candidates with engineering courses (whether or not a degree was granted) are likely to have adequate physics and math skills and probably a sufficient grasp of chemistry. Such candidates are often under-prepared in biology, and, if preparing for this program, they should concentrate on biology courses. Students without engineering preparation should concentrate on mathematics and physics.

*No person should be discouraged from applying because of these recommended prerequisites, as a suitable program of preparation can be advised for many candidates. Note that the IBD prerequisites could be satisfied by excellent high school preparation in mathematics and science.

Instructional Outline of the Master Brewers Program

The following outline is a general guide to the format and content of the program. The precise program curriculum will be tailored to the needs of the class as it develops.

First Session (eight weeks)

(a) Brewing Science: Barley to Beer (UNEX-X402.1)

(b) Brewery Engineering: Physical Principles in Brewing (UNEX-X403.1)

(c) Weekly Examinations

Second Session (six weeks)

(a) Brewing Science: Linkages and Relationships; Brewing Processes and Beer Quality (UNEX-X402.2)

(b) Brewing Science: Practical and Laboratory Experience (UNEX-X402.3)

(c) Brewery Engineering; Quantitation and Calculation (UNEX-X403.2)

Review Session (three weeks)

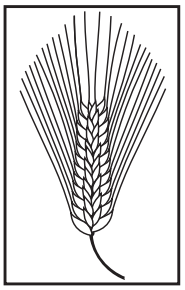
(a) Brewing Science: Materials and Wort-DBE Module 1

(b) Brewing Science: Yeast and Beer-DBE Module 2

(c) Brewery Engineering: Packaging and Process Technology-DBE Module 3

Diploma in Brewing Examination

First Tuesday and Wednesday in June



First Session

Brewing Science and Technology **UNEX-X402.1**
Brewery Engineering **UNEX-X403.1**

Learning Objective

At the end of the first session, students should have a sound understanding of the following topics at the level of a fine journeyman brewer. This level of understanding should be adequate for solving most practical problems and resolving most day-to-day issues that arise in a brewery context. Students should have the ability to work independently in a brewery environment under the leadership of a more educated and experienced brewer. The first session provides a solid base for further education and training in the field.

Brewing (UNEX-X402.1)

- barley physiology and malting science and practice
- malt specifications and their interpretation for practical brewing
- grain handling and malt milling for specific brewing applications
- mashing and wort properties
- necessary calculations for wort production
- mash separation techniques and extract recovery
- hops and hop products, hop specifications and their interpretation
- wort boiling and hop utilization for specific applications
- yeast propagation and handling and practical fermentation practices
- control of beer quality through manipulation of wort and yeast
- solid-liquid separation
- beer finishing practices for practical applications
- statistical quality control and analysis
- sanitation and microbiology
- sensory analysis of beers

Engineering (UNEX-X403.1)

- mass and energy balance
- heat transfer and refrigeration
- properties of steam
- pumps, pipes and fluid flow
- pressure/volume/temperature relationships (carbonation)
- solid-liquid separation
- packaging (introduction)

Brewing Science and Technology

(UNEX-X402.1)

Brewing Science: Barley to Beer

Course Goals

This course provides a thorough knowledge and understanding of the science and technology of ale and lager brewing and to give familiarity with the specialized language and concepts of the brewing industry. This is accomplished by a sequential study of brewing raw materials, brewing processes and quality control methods of the industry. The influence of raw material quality and process control on beer character is a recurring theme in order to illustrate the scientific and practical confines within which successful brewing is performed. When candidates complete the first session, they will have a good understanding of what constitutes beer quality and how this is achieved by contemporary methods of manufacture.

Texts may include

Brewing, Michael Lewis and Tom Young, 2nd Edition, Kluwer Academic/Plenum Publishers (New York)

Technology of Brewing and Malting, (in translation) Wolfgang Kunze, VLB (Berlin)

Course Format

Up to 20 hours per week of instruction; eight weeks

Topical Outlines

- The history of brewing. Brewing and beer around the world. Overview of the process from barley to malt. A review of basic science relevant to brewing.
- Technology of malting from selection of barley to specialty malts. Biochemistry of malting and malt quality and analysis. Malt handling, mills and milling.
- Brewhouse calculations and technology. Biochemistry of brewhouse processes, starch, amylases and the control of wort properties. Water quality and adjustment.
- Technology of production of hops and hop products. Hop chemistry. Kettle boil. Yeast propagation and handling. Fermenters and technology of fermentation.
- Biology of yeasts. Biochemistry of fermentation and fermentation kinetics. Production of beer flavor compounds. Beer maturation, finishing and filtration.
- Carbonation and stabilization of beers, beer analysis and quality control methods. Microbiology and sanitation. Packaging and dispense. Brewery effluents.

Brewing Exercises

Candidates will have the opportunity to observe some of the principles covered in the first session by observing brewing at the Sudwerk breweries (15 and 65 barrel units), observing the laboratory and pilot plant at UC Davis, visiting other breweries and at beer tastings. However, there will be insufficient time for significant structured teaching and learning outside of the lectures in the classroom.

Brewery Engineering

(UNEX-X403.1)

Physical Principles in Brewing

Course Goals

This course introduces the physical and engineering principles that have important applications in the brewing industry. Primary attention is given to understanding those principles that relate to, illuminate and permit the solution of realistic problems and explain brewing equipment design. Special attention is given to those aspects of engineering that are important in breweries, including fluid flow (equipment such as pumps, pipes and valves); properties of steam, energy balances, heat transfer and refrigeration (boilers, calandria, heat exchangers and refrigeration plant); and the gas laws (carbonation and dispense). The objective is not to make the candidates into professional engineers, but to develop skills of deductive reasoning, to give a basis for informed judgment, to provide background for intelligent discussions with engineers and to evaluate engineering proposals.

Texts may include

Introduction to Food Engineering, Singh, R. P. and Heldman D. R., Academic Press

The Institute of Brewing & Distilling Blue Book "Engineering"

Course Format

Up to 10 hours per week of instruction; eight weeks.

Topical Outline

- Physical principles of engineering. Introduction to engineering.
- The properties of steam, including phase diagrams and steam tables. Conservation of energy. Energy balance.
- Fluid flow, measurement, streamline/turbulent flow, valves, pipes and pumps.
- Pressure, volume and temperature relationships. Carbonation.
- Modes of heat transfer: conduction, convection and radiation.
- Refrigeration.

Engineering Exercises

Candidates compute solutions to typical engineering problems that arise in breweries, and examine equipment and demonstration devices designed to illustrate the principles discussed in the lecture material at working breweries and at the UC Davis pilot plant.

Second Session

Brewing Science Lecture and Tutorial
UNEX-X402.2

Brewing Science Laboratory
UNEX-X402.3

Brewery Engineering Lecture and Tutorial
UNEX-X403.2

Learning Objectives

At the end of the second session, students should have a solid understanding of the topics listed below at the level of a master brewer. This level of understanding should be adequate for solving all practical problems and day-to-day issues that arise, and for providing outstanding technological leadership in a brewery context. Upon completion of the second session, students should be prepared intellectually to take significant reponsibility for a brewery and provide the technological guidance required for successful operation.

Brewing (UNEX-X402.2, X402.3)

The depth of study, techniques of teaching and orientation of exposure to the material are different from the first session. Thus, understanding of the topics is more complete and intimately integrated across the whole process, with focus on final beer properties.

- barley physiology and malting science and practice
- malt specifications and their interpretation for practical brewing
- grain handling and malt milling for specific brewing applications
- mashing and wort properties, necessary calculations for wort production
- mash separation techniques and extract recovery
- hops and hop products, hop specifications and their interpretation
- wort boiling and hop utilization for specific applications
- yeast propagation and handling and practical fermentation practices
- control of beer quality through manipulation of wort and yeast
- beer finishing practices for practical applications

Brewing Science Lecture and Tutorial

(UNEX-X402.2)

Linkages and Relationships; Processed Beer Quality

Course Goals

To provide an in-depth theoretical knowledge and intimate practical understanding of malting and brewing raw materials, processes and products from the point of view that all aspects of beer-making are interlinked biochemically. Candidates therefore expand considerably on the somewhat unidimensional approach of the first session. This is done by exploring chosen themes or issues in brewing that are of both practical and theoretical consequence, taking special note of the interdependence and multifaceted aspects of these issues. The focus of the seminar and tutorial course is to provide a sophisticated appreciation of the subject matter at a level appropriate to the IBD DBE. Candidates who complete this part of the course will be able to think and act over a broad spectrum of brewing knowledge to evaluate and elucidate problems, will have a firm grasp of what is known and what is assumed, and will develop a healthy regard for the difference.

Texts may include

Brewing, Michael Lewis and Tom Young, 2nd Edition; Kluwer Academic/Plenum Publishers (New York)

Malting and Brewing Science, Volume 1 & 2, Hough, Briggs, Stevens and Young, Chapman & Hall, London

The Institute of Brewing & Distilling Blue Books (all volumes)

Technology of Brewing and Malting, (in translation) Wolfgang Kunze, VLB (Berlin)

Review papers and research publications selected from the original literature. (IBD reading list)

Course Format

Comprises two three-hour sessions weekly.

Topical Outline

- Malt, malting processes and malt components in wort and beer and their role in beer quality with special focus on haze, foam and microbiological stability. The non-volatile components of beer and their origin in the biochemistry of malt, their modification by process decisions and their role in beer quality.
- The chemistry of hops and their measurement and the role of hop compounds in beer quality, including flavor, foam and stability. Brewing water and brewing calculations (e.g., for beer formulation and for adjustment of brewing).

- Wort production: the chemistry of carbohydrates. The spectrum of these compounds present in worts and beers and their origin and role in product quality. Extract yield and the variables that influence it (e.g., milling, mash thickness, mash temperature and solid-liquid separation). Wort stabilization and composition relative to yeast nutrition.
- Yeast and fermentation: the yeast cell, fermentation and fermenter design, yeast physiology, normal and abnormal beer flavors and their relation to wort composition, beer quality and the brewing processes that produce them. Evaluation of yeast quality and amount and its relation to consistent fermentations.
- Maturation and finishing: the challenge of beer finishing for sale, especially maturation, clarification, carbonation, stabilization and their relation to raw materials and brewing processes. Influence of raw materials selection and brewing processes on beer quality, especially stability and finishing processes.

Brewery Engineering Lecture and Tutorial

(UNEX-X403.2)

Brewery Engineering; Quantitation and Calculation

Course Goals

This course continues with the physical and engineering principles introduced in UNEX-X403.1. Although the course is concerned with concepts, computation is a major theme applied to the solution of realistic problems, including brewing equipment design. Special attention is given to those aspects of engineering that are important in breweries, such as fluid flow, but new topics are also introduced as required by the engineering curriculum of the IBD, including psychometrics and solid-liquid separations (filtration). The objective is not to make the candidates into professional engineers, but to develop skills of deductive reasoning and computation, to give a basis for informed judgment, to provide a background for intelligent discussions with engineers and to evaluate engineering proposals.

Texts may include

Introduction to Food Engineering, Singh, R. P. and Heldman, D. R., Academic Press

The Institute of Brewing & Distilling Blue Book "Engineering"

Course Format

Six to nine hours per week of lecture and computation workshops.

Topical Outline

- Materials handling and size reduction (milling).
- Psychometrics. Gas-vapor mixtures, humidity and drying.
- Heat transfer.
- Solid-liquid separation and filtration performance.
- Fluid flow. Pumps, pipes and fluid flow. Friction factors. Rheology.
- Refrigeration.

Engineering Exercises

Candidates will compute solutions to typical problems that arise in breweries and examine equipment and demonstration devices designed to illustrate the principles discussed in the lecture material, at working breweries, at the UC Davis pilot plant and in the laboratory.

The Review Sessions

Course Goals

"Review and revise" describes the objective of these last three weeks (six days per week). No new material should be introduced during this time as the objective is to familiarize the candidate with the material to the level required for the IBD DBE and to practice manipulation of that information in written form and in calculations.

Week 1: Malts, malting processes, malt quality and beer. Brewhouse operations, wort production and beer quality.

Week 2: Yeast, fermentation and finishing and beer quality. Quality control techniques and waste streams.

Week 3: Material of construction, combustion, instrumentation and process control. Fluids and mass transfer. Heat transfer, refrigeration, and psychometrics.

Course Format

The course will meet daily for up to five hours to review a selection of topics, in lecture and discussion format, with many short writing exercises based on analysis of previous examination questions relevant to the topics under review. The evenings will be free for independent study.

Professional Brewers Certificate Program

Overview

This intensive eight-week program meets five hours a day, four days a week plus a fifth day of review and examinations. The curriculum duplicates the first session of the Master Brewers Program. Through lectures, the program provides participants with a solid understanding of brewing science and engineering. Student learning is measured through weekly exams and written exercises. Individuals who successfully complete the program are awarded the Professional Brewers Certificate.

The program provides students with an understanding of:

- grain handling, malting, malt analysis and the effects of these in brewing
- brewhouse processes and the control of wort quality as a result
- yeast and fermentation processes and their effects on beer quality
- beer filtration and finishing and packaging (introduction)
- flow of fluids in pipes and through pumps in a brewery setting
- heat transfer through flat and curved surfaces and the effects of insulation and fouling on efficiency
- theory and practice of carbonation including mixed gas technology
- theory and practice of refrigeration in the brewery

Objectives

The certificate program is designed to provide a legitimate, university-approved qualification to individuals wishing to enter the brewing industry, as well as to brewery personnel with no formal scientific training who wish to advance their careers.

Prerequisites

While a degree is not required for acceptance to this program, college-level work in the subject areas listed below is suggested for success in the program.

- Mathematics (pre-calculus)
- Biological sciences: microbiology, cell physiology or biochemistry
- Chemistry: organic, inorganic or analytical
- Physics: heat and mechanics or process control
- Engineering: topics in mechanical or chemical engineering

Practical brewing experience is a plus, but is not required for entrance to the program.

*No person should be discouraged from applying because of these recommended prerequisites, as a suitable program of preparation can be advised for many candidates, including intensive review of mathematics and science at the high school level.

Program Curriculum

Brewing Science and Technology **UNEX-X402.1**
Brewery Engineering **UNEX-X403.1**

This program duplicates the first eight weeks of the Master Brewers Program.

Learning Objective

At the end of this program, students should have a sound understanding of the following topics at the level of a fine journeyman brewer. This level of understanding should be adequate for solving most practical problems and resolving most day-to-day issues that arise in a brewery context. Students should have the ability to work independently in a brewery environment under the leadership of a more educated and experienced brewer. The certificate program provides a solid base for further education and training in the field.

Brewing (UNEX-X402.1)

- barley physiology and malting science and practice
- malt specifications and their interpretation for practical brewing
- grain handling and malt milling for specific brewing applications
- mashing and wort properties
- necessary calculations for wort production
- mash separation techniques and extract recovery
- hops and hop products, hop specifications and their interpretation
- wort boiling and hop utilization for specific applications
- yeast propagation and handling and practical fermentation practices
- control of beer quality through manipulation of wort and yeast
- solid-liquid separation
- beer finishing practices for practical applications
- statistical quality control analysis
- sanitation and microbiology
- sensory analysis of beer

Engineering (UNEX-X403.1)

- mass and energy balance
- heat transfer and refrigeration
- properties of steam
- pumps, pipes and fluid flow
- pressure/volume/temperature relationships (carbonation)
- solid-liquid separation
- packaging (introduction)

Brewing Science and Technology

(UNEX-X402.1)

Brewing Science: Barley to Beer

Course Goals

This course provides a thorough knowledge and understanding of the science and technology of ale and lager brewing and to give familiarity with the specialized language and concepts of the brewing industry. This is accomplished by a sequential study of brewing raw materials, brewing processes and quality control methods of the industry. The influence of raw material quality and process control on beer character is a recurring theme in order to illustrate the scientific and practical confines within which successful brewing is performed. When candidates complete the first semester, they will have a good understanding of what constitutes beer quality and how this is achieved by contemporary methods of manufacture.

Texts may include

Brewing, Michael Lewis and Tom Young, 2nd edition, Kluwer Aademic/Plenum Publishers (New York)

Technology Brewing and Malting, (in translation) Wolfgang Kunze, VLB (Berlin)

Course Format

Up to 20 hours per week of instruction, eight weeks

Topical Outline

- The history of brewing. Brewing and beer around the world. Overview of the process from barley to malt. A review of basic science relevant to brewing.
- Technology of malting from selection of barley to specialty malts. Biochemistry of malting and malt quality and analysis. Malt handling, mills and milling.
- Brewhouse calculations and technology. Biochemistry of brewhouse processes, starch, amylases and the control of wort properties. Water quality and adjustment.
- Technology of production of hops and hop products. Hop chemistry. Kettle boil. Yeast propagation and handling. Fermenters and technology of fermentation.
- Biology of yeasts. Biochemistry of fermentation and fermentation kinetics. Production of beer flavor compounds. Beer maturation, finishing and filtration.
- Carbonation and stabilization of beers, beer analysis and quality control methods. Microbiology and sanitation. Packaging and dispense. Brewery effluents.

Brewing Exercises

Candidates will have the opportunity to observe some of the principles covered in this course by observing brewing at the Sudwerk breweries (15 and 65 barrel units), observing the laboratory and pilot plant at UC Davis, visiting other breweries and at beer tastings. However, there will be insufficient time for significant structured teaching and learning outside of the lectures in the classroom.

Brewery Engineering

(UNEX-X403.1)

Physical Principles in Brewing

Course Goals

This course introduces the physical and engineering principles that have important applications in the brewing industry. Primary attention is given to understanding those principles that relate to, illuminate and permit the solution of realistic problems and explain brewing equipment design. Special attention is given to those aspects of engineering that are important in breweries, including fluid flow (equipment such as pumps, pipes and valves); properties of steam, energy balances, heat transfer and refrigeration (boilers, calandria, heat exchangers and refrigeration plant); and the gas laws (carbonation and dispense). The objective is not to make the student a professional engineer, but to develop skills of deductive reasoning, to give a basis for informed judgment, to provide background for intelligent discussions with engineers and to evaluate engineering proposals.

Texts

Introduction to Food Engineering, Singh, R. P. and Heldman D. R., Academic Press

The Institute of Brewing & Distilling Blue Book "Engineering"

Course Format

Up to 10 hours per week of instruction.

Topical Outline

- Physical principles of engineering. Introduction to engineering.
- The properties of steam, including phase diagrams and steam tables. Conservation of energy. Energy balance.
- Fluid flow, measurement, streamline/turbulent flow, valves, pipes and pumps.
- Pressure, volume and temperature relationships. Carbonation.
- Modes of heat transfer: conduction, convection and radiation.
- Refrigeration.

Engineering Exercises

Candidates compute solutions to typical engineering problems that arise in breweries, and examine equipment and demonstration devices designed to illustrate the principles discussed in the lecture material at working breweries and at the UC Davis pilot plant.

Appendix 1

Professional Brewing Programs Textbook List

Students will have access to a variety of books and other reading materials throughout the different programs. Some examples include:

Brewing, M.J. Lewis and T.W. Young, 2nd Edition, Kluwer/ Acacemic/Plenum Publishers (New York)

Malting and Brewing Science, Vol. 1 and 2, Hough, Briggs, Stevens and Young, Chapman and Hall, London

Introduction to Food Engineering, R.P. Singh, D.R. Heldman, Academic Press

Technology Brewing and Malting, (in translation) Wolfgang Kunze, VLB (Berlin)

Brewing Science and Technology, Series II and III, Vol. 1-4, The Institute of Brewing & Distilling "Blue Books"

The Institute of Brewing & Distilling (journal articles)

Recommended readings list

Barley, D.E. Briggs, Chapman and Hall

Manual of Good Practice, Vol. 1-3: Beer Pasteurisation, Brewery Utilities, and Hops and Hop Products, Betranke-Fachverlag

Handbookof Brewing, W. Hardwick, Diekker

The Practical Brewer, Master Brewers Association of the Americas

Beer Packaging, Master Brewers Association of the Americas

Rice, 2nd Edition
Barley Chemistry & Technology
Sorghum and Millets
Enzymes Handbook
Craft Brewers Lab Methods

} All from American Society of Brewing Chemists

In addition, multiple copies of numerous texts appropriate to brewing (e.g., food science and engineering books) will be available to candidates along with a satisfactory range of brewing and brewing-related journals. These library texts include those that address basic science subjects, including physics, biology, microbiology, biochemistry, organic and physical chemistry and statistics, as well as those very specialized books devoted to brewing topics, such as barley and malt, hops and hop chemistry, yeasts, brewing microbiology and sanitation, water quality, and the ASBC Methods of Analysis. Journal sets include the *Journal of the Institute of Brewing and Distilling* and *Ferment*, *The Brewer*, *Brewer's Digest*, *Brewing and Distilling International*, *Brauwelt* (English edition), European Brewing Convention proceedings, *Journal of the American Society of Brewing Chemists* and the *MBAA Technical Quarterly*.

(Textbooks and publications vary from year to year based on instructor choices)

Diploma in Brewing Examination Examples

Brewing

Module One: Materials and Wort

(3 hours)

Answer any SIX questions

All questions carry the same mark of 20

[The marks allocated to parts of questions are shown in parentheses ( ) and you are strongly advised to allocate your time accordingly)

1) Describe the structure of the barley grain. (10)

   Explain the role of gibberellins in modification of the endosperm. (10)

2) Outline the operational stages involved in processing barley into mals. Explain the main aims of each stage and how these aims are achieved. (20)

3) What are the requirements of a good quality malt for brewing? (20)

4) What is the role of calcium ions in wort production? (8)

   Describe the techniques available for removal of any **two** of the following from water from water used for brewing:

   Iron (6)
   Manganese (6)
   Nitrate (6)

5) Describe basic principles of temperature-programmed mashing and explain its merits compared to a single temperature process with respect to final wort composition. (20)

6) Discuss the range of liquid adjuncts that are used in a brewery to provide fermentable extract. For each adjunct, describe its composition, basis of manufacture, and effect on brewing. (20)

7) Discuss the constituents of hops that are relevant to brewing and give a detailed explanation of why. (15)

   What changes in quality can occur during storage of whole hops? (5)

8) Explain the meaning of the terms **repeatability** (r95) and **Reproducibility** (R95). (5)

   Describe the basic principles enshrined in Quality Assurance concepts (15)

DIPLOMA IN BREWING EXAMINATION

Brewing
Module Two: Yeast and Beer
(3 hours)

Answer any SIX questions

All questions carry the same mark of 20

[The marks allocated to parts of questions are shown in parentheses ( ) and you are strongly advised to allocate your time accordingly]

1) Write detailed notes on:

   a) the principles of preserving pure cultures of brewing yeasts in the laboratory (10)

   and

   b) the practical features involved in propagating pure yeast for brewery fermentations. (10)

2) Describe the origins, measurement and control of beer colour. (20)

3) Outline the available methods for the detection of and quantification of beer spoilage aerobic and anaerobic bacteria and wild yeasts in filtered beer and in packaged beer.

4) Write an essay on the conditioning/maturation of beer. (20)

5) Discuss, in detail, how the levels in wort of:
   assimilable amino nitrogen
   and zinc ions
   will influence the progress of a brewery fermentation (20)

6) Describe the factors that can affect flavour stability during prolonged storage of (20)

7) Write detailed notes on TWO of the following topics:

   a) flocculation of yeast (10)

   b) how hop bittering substances can influence beer quality (10)

   c) the methods of predicting and measuring non-biological haze (10)

8) Describe the features required for satisfactory cleaning systems for brewery fermentation vessels (8)

   Outline:

   a) the range of appropriate cleaning and sterilising materials, (6)

   and

   b) the procedures available to monitor for residual surface contamination (6)

DIPLOMA IN BREWING EXAMINATION

Brewing
Module Three: Process Technology
(3 hours)

Answer any SIX questions

All questions carry the same mark of 20

[The marks allocated to parts of questions are shown in parentheses ( ) and you are strongly advised to allocate your time accordingly)

1) A beer, which has been filter-sterilised, is to be packaged so that the end product is still microbiologically stable. Explain fully the basic principles of the additional precautions (excluding pasteurisation) that are required to ensure the microbiological stability of the packaged product. (20)

2) Describe the diffrences between laminar and turbulent flow including sketches of velocity profiles in pipes. Discuss the relevance of the two regimes in brewing and explain the significance of the Reynolds number in describing fluid flow. (8)

   Cold wort with a density of 1080 kg m^{-3} and viscosity 0.003 kg m^{-1} s^{-1} flows down at 50 mm diameter circular pipe at a rate of 3.5 kg s^{-1}. Find the mean velocity (u) of the wort in the pipe and determine the centre-line velocisty (u_{cl}) given that:

   $u = 0.5\ u_{CL}$ for laminar flow

   $u = 0.82\ u_{CL}$ for turbulent flow (6)

   The wort is delivered to a tank through an outlet nozzle of 15 mm diameter (point B), which is situated 3 m above the 50 mm diameter section of pipe (point A). If the pressure at point A is 150 kN m^{-2} calculate, neglecting frictional effects, the pressure at the outlet.

3) Describe the basic principles of in-place cleaning (CIP) in a packaging plant. (10)

   How would you ensure microbiological integrity and chemical cleanliness of a specified returnable package? (10)

4) Hot condensate is collected from four points in a brewery and combined before being used in a pre-heat exchanger. What will be the temperature and flow rate of the combined stream if the flow rates and temperatures of the individual streams are as follows? (6)

   3 kg s^{-1} at 70°C
   0.75 kg s^{-1} at 92°C
   1.5 kg s^{-1} at 85°C
   1.25 kg s^{-1} at 68°C

It is proposed to use the combined stream in a counter-current heat exchanger to pre-heat a liquor from an initial temperature of 20°C to within 5°C of the combined condensate stream temperature. Calculate the heating area required. (14)

Data:

Specific heat capacity of all the condensate streams = 4.2kJ $kg^{-1}K^{-1}$

Overhall heat transfer coefficient of the heat exchanger = 1200 W m^{-2} K^{-1}

Flow rate of liquor to be heated = 8 kg s^{-1}

Specific heat capacity of liquor to be heated = 3.6 kJ^{-1} K^{-1}

5) Describe three techniques for dissolving gases in beer and discuss their relative merits. (12)

   How does supersaturation occur in beer and what are its effects and threats to beer quality? (8)

6) Define the terms "stainless steel" and "Austenitic stainless steel". (4)

   Name three commonly used Austenitic stainless steel alloys and distinguish them in terms of their composition and relative cost. (8)

   Describe the relevant features of stainless steels suitable for use in brewing. (8)

7) Describe what is meant by the term pasteurisation and illustrate graphically the relationship between time, temperature and lethal rate. (6)

   Define the pasteurisation unit (PU) and discuss the effects of pasteurisation on different organisms. (6)

   Beer containing 1.8 volumes of carbon dioxide (CO_2) per volume of beer at standard temperature and pressure (STP) is pasteurised at 73°C. Assuming beer has the same molecular weight and density as water, calculate the mole fraction of CO_2 in the beer and the presuure required to maintain it in solution at the pasteurisation temperature. (8)

   Data:

   Density of water is 1000 kg m^{-3}
   Molecular weight of carbon dioxide is 44.
   Molecular weight of water is 18.
   Henry's constant for carbon dioxide in beer at 73°C is 440 MPa mole $fraction^{-1}$.
   Note: STP is 0°C, 0.1013 MPa.

8) By reference to a **suitably labelled diagram**, explain the means by which the temperature of a cylindroconical fermenter may be controlled during the course of a fermentation. In giving your answer, make particular reference to: (10)

a) the control loop involved
b) the type of sensor used to measure the temperature of the fermenter contents

A cylindroconical fermenter containing 500 hl of beer is cooled from 15°C to 12°C in 1 hour 45 minutes by coolant flowing at 3.2 kg s^{-1} which enters the cooling jacket at minus 5°C. Calculate the average rate of heat removal from the beer (Js^{-1}) and the outlet temperature of the coolant. (10)

Data:
Density of the beer is 1008 kg m^{-3}
Specific heat of the beer is 4.15 kJ kg^{-1} K^{-1}
Specific heat of the coolant 3.5 kJ kg^{-1} K^{-1}

9) Choosing a particular form of primary packaging, describe its basic properties. Discuss the marketing and legal implications and environmental effects of your chosen packaging. (15)

What impact might the choice of packaging type have on the properties of the beer? (5)

Appendix II

More About the Diploma in Brewing Examination

The Diploma in Brewing Examination (DBE) will be held each June on the UC Davis campus.

The examination comprises three modules (three hours each):

1. Brewing Science and Technology 1 (raw materials, the biochemistry and practice of wort production).
2. Brewing Science and Technology 2 (biochemistry and microbiology of fermentation and post-fermentation processes, quality control).
3. Brewing Science and Technology 3 (physics and engineering as applicable to brewing and packaging).

Pass with Distinction will be awarded to candidates who reach a sufficiently high standard.

Candidates may sit the whole examination in one year (DBE 1,2,3) or may sit one or two sections each year. It is quite common to attempt DBE 1 and 2 together and DBE 3 the following year.

UC Davis Extension staff will complete the application forms for membership and for the DBE for each Master Brewers Program student as required by the IBD. The completed forms and appropriate fees will be routed to the IBD to meet their deadlines.

Student Services

Participants in the Master Brewers Program and Professional Brewers Certificate Program will be issued a library card application upon payment of enrollment fees. A pass allowing use of the Activities & Recreation Center (ARC) can be purchased by the day, month or quarter. UC Davis Extension students may purchase computer time at university user rates with the signature of their instructor. No other student services are available through UC Davis Extension.

Student Parking

Participants may purchase permits to park on campus from Parking Services, located in the Transportation and Parking Services Office on Extension Center Dr. (south of Lot 30, near the Recreation Pool). A permit of some type is required on weekdays and weeknights for automobile, motorcycle or moped parking on campus. Students may be required to present their course confirmation receipt (or other proof of enrollment) and a driver's license when applying for a permit. For additional information please call Parking Services at (530) 752-3729 or (530) 752-TAPS.

Financial Assistance

While participants in the Professional Brewing Programs do not qualify for student aid, loans or grants through the University of California, there are several agencies we are aware of that offer educational benefits or loans to students in approved continuing education programs.

Veteran's Administration

The Master Brewers Program has been approved by the Veteran's Administration to allow education benefits to those who qualify. You should contact your local VA office to request eligibility information.

TERI

The Education Resources Institute (TERI) offers a Continuing Education Loan to students who are enrolled in approved continuing education programs. The loan amount of up to $5,000 can be repaid in monthly installments for up to 10 years. The interest rate is competitive — Prime rate plus 1.5%. For information and details, contact TERI at 1-800-255-8374.

Citibank

UC Davis Extension, University of California, Davis, in cooperation with Citibank, is pleased to offer the CitiAssist Loan. The CitiAssist Loan from Citibank is a sensible borrowing solution that can help meet your education funding needs while you invest in your education. CitiAssist Loan benefits include no loan fees, straightforward pricing, no payments due while in school, flexible repayment options and reasonable loan limits. To receive a detailed brochure, contact the UC Davis Extension Registration office at 1-800-752-0881.

Deferred Student Loan Payments

For those who are currently making monthly payments for past student loans, you may be eligible to postpone payments during your participation in an educational program. You should contact your loan agent for details.

Housing Choices in Davis

Finding housing in Davis can be difficult because the vacancy rate is quite low and there is strong competition for all available rentals. A sample listing and average rent costs is listed below. While we will do what we can to assist students to find housing, we strongly encourage you to act as early as possible.

A private room in a house with kitchen privileges: $425/month and up

Studio apartment: $600/month and up

Sharing an apartment or house with another student: $500/month and up per person

1 bedroom apartment: $800/month and up

2 bedroom apartment: $1000/month and up
2 bedroom house: $1,200/month and up

3 bedroom apartment: $1,400/month and up
3 bedroom house: $1,500/month and up

Rates listed are averages.

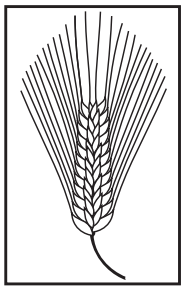
Monthly rent does not include telephone service or gas/electric service.

Some apartments or houses are furnished, but most are rented unfurnished. Basic furnishings can be purchased either new or used from several businesses in the area.

Agencies handling rentals include:

The Community Housing Office on campus	530-752-1990
The Davis Enterprise — city newspaper	530-756-0800
The California Aggie — campus newspaper	530-752-0208
Acadian Properties	530-753-2303
College Town Realty	530-753-1500
King Properties	530-753-0121
Jon Berkley Management	530-753-5910
PHM Property Management	530-757-2818
Tandem Properties	530-756-5075

If you are interested in sharing housing with other program participants, complete the Roommate Form and return it with your application package.



Roommate Form

If you are interested in sharing an apartment or house with other program participants, please complete this form and return it with your application package. A compiled list of names and phone numbers of those interested in sharing an apartment or house will be mailed to you. You are responsible for contacting the other participants directly.

Please check the appropriate box for the program in which you will be participating.

❏ Master Brewers Program
Date:_____

❏ Professional Brewers Certificate Program
Date:_____

_____
Name

_____
Address

_____
City State Country Zip Code

(____)_____(____)_____
Daytime telephone Fax number

(_____)_____
Evening telephone Email address

When is the best time to contact you?_____

Do you smoke? ❏ yes ❏ no

Will you require a location that allows pets?
❏ yes ❏ no

If yes, what kind of pet?_____

Any special preferences/requirements:

_____

_____

_____

Appendix III

Admission Application

Name_____

Please indicate which program(s) you are applying for:

❑ **Master Brewers Program**

❑ **Professional Brewers Certificate Program**

To apply for admission to the Master Brewers Program or the Professional Brewers Certificate Program, the application package must include:

- Completed application form.
- Copies of college transcripts supporting the academic prerequisites.
- Resume listing any practical experience related to brewing, food science, engineering, etc.
- $45 nonrefundable application fee. Payment may be made by check (make checks payable to UC Regents), purchase order or credit card (Discover, Visa, American Express or MasterCard.)

–continued–

Admission Application *(continued)*

Please print:

Name (first, middle initial, last)

Address

City State Country Zip Code

Job title

Company name

( ) ( )
Daytime phone Evening phone

( )
FAX Email address

Date of birth

MAIL YOUR COMPLETED APPLICATION PACKAGE TO:

Melissa Marbach
Professional Brewing Programs
UC Davis Extension
University of California
1333 Research Park Drive
Davis, CA 95618-4852

For more information

If you have additional questions, please call Melissa Marbach at (530) 757-8899 or email mmarbach@unexmail.ucdavis.edu.