Engineering Economy: A Two-Step Approach to Energy and Environmental Strategies

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Abstract

This paper proposes a two-course sequence to introduce the fundamental concepts and applications of engineering economy. The main idea being explored in this paper is to introduce discipline-specific case studies and their analysis using engineering economic methods. The advantage of this approach will be a better appreciation of engineering economy by non-IE majors.

Introduction

The traditional objective of the required Engineering Economy course in engineering programs has been to satisfy the requirements of ABET and EIT. The ABET/EAC curriculum guide explicitly requires that the engineering design experience involve economic factors. Additionally, the Fundamentals of Engineering (EIT) examination has a number of questions relating to engineering economy. Therefore, the conventional Engineering Economy course introduces basic concepts of time value of money, and various techniques for cost justification of capital expenditure. Unfortunately, this course is not integrated with the remainder of the curriculum. For instance, after taking this course, an EE or ME major rarely sees the tools employed in a sequel course within his major.

This issue has been addressed by a multi-university project funded by the National Science Foundation [1]. Tasks accomplished by this coalition during the period 1991 - 1992 include the following: (i) Integration of economic principles in a Thermosystems Design Analysis course, (ii) Development of a economic design simulator for estimating cost to manufacture for various thermal components, (iii) Development of case studies focusing on economic principles in design, and (iv) Development of course materials for a course entitled Economics of Engineering Design.

There is a need to improve the structure of Engineering Economy study in the engineering curriculum such that students appreciate practical applications within their respective disciplines. This idea is explored in this paper using a two-course sequence model for teaching Engineering Economy.

The relationship of the Engineering Economy course with the remainder of a major's program is also investigated in this paper. Suggestions are made to enhance the delivery of the material to involve all the different majors who take this course in a way that encourages them to appreciate the relevance and importance of the concepts and techniques of Engineering Economy.

This paper suggests a different approach to teaching Engineering Economy. The approach is centered around a two-course sequence. The first course is similar in nature to the traditional Engineering Economy course. The second course should involve actual case studies drawn from practical experiences and applications from within a particular major.

First Course in Engineering Economy

This 2-semester course includes principles of time value of money, interest factors, cash flow equivalence, techniques for comparing alternatives, depreciation methods and income tax considerations. However, detailed derivations of formulas and computer use may be eliminated from the course. Clearly, this course is similar to the traditional approach used by most colleges. Generally a first course in calculus is sufficient prerequisite for the introductory Engineering Economy course. A number of well written texts are available to support this course (for example, [2],[3],[4],[5]).

Second Course in Engineering Economy

The second course is also a 2-semester hour course with an emphasis on practical case studies aimed at energy conservation and environmental protection. Students need to have the opportunities to experience systems and problems in the classroom that are similar to the systems and problems that they will be confronted with in industry [6].

In this second course, students will be exposed to various strategies for conserving energy. The discussion will be practical in nature and will serve to reinforce prior coursework involving industrial motors, compressors, industrial lighting, furnaces, boilers and insulation. Students will be expected to work in teams to develop ideas for conserving energy and reduce environmental waste. The ideas will be justified by the use of Engineering Economy principles learned in the First Course. This course may either be required for all majors or be offered as an elective after the first course.

A plant trip that actively involves students in an energy audit is highly recommended. In addition, students may be required to write term papers concerning energy conservation and environment issues in their respective disciplines.

Prerequisites for this sequel course should include courses in Thermodynamics, Fluid Mechanics, Electric Circuits and Machines, and Strength of Materials. Since the course will entail the application of Engineering Economic Justification principles to efficient operation of boilers, compressors, heating, cooling and ventilation, and heat recovery from manufacturing systems, the above prerequisites will be necessary. If the First Course is taken in the Sophomore year, the Second Course will probably will suitable in the Senior Year.

To support the delivery of this course, there will be a need to develop presentation materials. The authors know of no one text that would cover all the requirements of this course. However, some case studies have been developed by one of the authors and are available upon request [7]. To illustrate, three representative examples are presented in this paper. The case study material only includes the case, not the solution. The solutions and additional case studies are available from the authors.

Case 1: Insulation of Heated Tank

A manufacturing facility has a tank which contains a liquid that is heated to 196 ^{o}F with natural gas. The ambient air temperature is 100 ^{o}F. The tank has a total surface area of 190 ft^2 and is presently not insulated which results in a loss of heat from the tank to the surrounding environment. The present overall heat transfer coefficient for the tank is 1.8 BTU/hr*ft^2 *^{o}F.

A proposal has been submitted which recommends that the heat loss be reduced by insulating the tank with 2" thick insulation, thus reducing the amount of gas required to heat the liquid in the tank. The insulation of the tank will also reduce the amount of energy required to cool the surrounding environment and decrease the possibility of injury to workers due to exposed heated surfaces. The cost of this project has been estimated to be $1,330 for materials and labor. After the proposed project the overall heat transfer coefficient is given as 0.127 BTU/hr*ft^2*^{o}F. The savings of gas conserved, BC_g with units BTU/yr, can be calculated as follows:

$$BC_g = \frac{(U_1 - U_2)(A)(T_1 - T_a)(H)}{N_g}$$

Where:

U_1 = Present overall heat transfer coefficient.
U_2 = Proposed overall heat transfer coefficient.
A = Total surface area of tank.
T_1 = Temperature of liquid in tank.

T_a = Ambient air temperature.
H = Time tank is in use.
N_g = Efficiency of boiler supplying heat to the tank.

If energy cost is given to be $4.20/MMBTU and the efficiency of the boiler is 80%, determine the annual cost savings. Assuming that the company expects 15% return on investments and the proposed investment has a life of 10 years with a zero salvage value, prepare the necessary information for management to make decision to accept or reject this project.

Case 2: Relocation of Air Compressor Intake

Outside air can be ducted to the intake of the plant air compressor(s). By utilizing the outside air as the supply, it is possible to reduce the energy requirement. Outside air is (on average) cooler and therefore more dense and needs to be compressed less than indoor air.

The compressor work for the usual operating conditions in manufacturing plants is proportional to the absolute temperature of the intake air. Thus, the fractional reduction in compressor work, WR, resulting from lowering the intake air temperature is estimated as:

$$WR = (WI - WO)/WI$$

$$WR = (TI - TO)/(TI + 460)$$

Where

WI = Work of compressor with inside air, hp
WO = Work of compressor with outside air, hp
TI = Average temperature of inside air, °F
TO = Annual average outside air temperature, °F

The annual energy savings, ES, can be estimated from the following relationship:

$$ES = C \times H \times W \times L \times PLF \times WR / EFF$$

where

C = Conversion constant, BTU/HP*hr = 2545
H = Hours per year of compressor operation, hr/yr
W = Compressor rating, HP
L = Fraction of time compressor is loaded, no units
PLF = Motor part load factor, no units
EFF = Efficiency of compressor motor, no units

A facility currently has in operation two 25 hp air compressors located inside the production area with an intake temperature of 85^{o}F. The motor part load factor is 0.75, fraction of time compressor is loaded is 0.80, efficiency of compressor motor is 0.90 and the compressors are in operation for 4000 hrs/yr. Assuming energy costs are given at $0.053/kwh, what annual energy costs savings can be expected if the intake is moved to the outside where the average temperature is 60^{o}F. If implementation costs are estimated to be $750 including materials and labor, calculate the NPW, Simple Payback Period, Discounted Payback Period, and the IRR of the proposed project where MARR=15%. The life of this project is estimated to be 20 years.

Case 3: Add Floating Balls to Heated Cleaning Tanks

A manufacturing facility which produces metallic cabinets for military use has 10 cleaning tanks. These tanks are used for cleaning aluminum and steel materials after the manufacturing processes are performed. Each tank has an open surface area of approximately 25 ft^2. The chemicals in the tank are heated to an average of approximately 130^{o}F using natural gas. The tanks are presently uncovered, however, management once tried to use 2 inch insulated fiber glass covers when the tanks were not in use to avoid heat and chemical loss. This procedure had to be discontinued dud to operational problems in removing the covers in the morning and replacing them in the evening.

A recommendation has been made suggesting that hollow plastic balls in either a spherical or wafer shape be used in the tanks to reduce heat loss and evaporation. The balls floating on the surface of the liquid act as a "blanket" cover. The balls will arrange themselves uniformly on the liquid and adjust to obstacles in the fluid so that a work piece can be easily immersed and removed.

The annual energy savings resulting from this proposed project, ES with units MMBtu/yr, can be estimated as follows:

$$ES = (Q) \text{ x } (A) \text{ x } (H) \text{ x } (PA) \text{ x } \left(\frac{N}{EFF}\right) \text{ x } (C)$$

Where:

Q	=	Heat lost per unit area, Btu/ft^2*h
A	=	Area of each tank, ft^2
H	=	Annual hours the tanks are heated, h/yr
PA	=	Fractional reduction in the heat loss, no units
N	=	Number of tanks
EFF	=	Efficiency of the tank heating system, no units
C	=	Conversion constant, 1 MMBtu = 1000000 Btu

The heat lost per unit area is 706 Btu/ft^2*h. The manufacturer of the floating balls claims that 66% of the heat loss from 130^oF can be avoided. Thus the fractional reduction in heat loss is 0.66. If the tanks are heated 8,400 h/yr and the efficiency of the gas fired boiler is 80%, calculate the possible energy savings.

The total energy cost savings, CS, is given by:

CS = ES X (Unit Energy Cost)

Calculate the energy cost savings where the unit cost of natural gas is $6.50/MMBtu.

If implementation cost is estimated to be $1,850, determine the NPW, simple and discounted payback period and IRR where MARR = 15%. The life of the project is 5 years.

Summary

This paper proposes a two-course sequence of courses to teach the concepts and applications of Engineering Economy to students of all disciplines in engineering. The advantage of this two-course sequence of 4 semester hours is that students will appreciate the relevance of Engineering Economy in practical situations instead of the usual manner in which students often view this course as a somewhat irrelevant appendage to their program of study.

References

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