Abstract - This paper describes the structure of a Design Contest, that is followed by a Prototype Contest, offered to undergraduate Engineering and Engineering Technology students in Brazil. The event, known as the TMT-Motoco Program for the Incentive of Technological Creativity, or Program TMT-ITC, started in February 2004 and is meant to be repeated annually. TMT-Motoco do Brasil Ltda, a manufacturer of engines and transmissions, is a Brazilian subsidiary of the Tecumseh Products Company, from Michigan, U.S. A report on the program's operation in 2004 and an early progress report for 2005 is also presented. In the two phases, design and prototype, the selection of the best products is based upon the optimization of an index of merit which emulates a benefit/cost ratio. For the TMT-ITC 2004, the diversity of the engineering solutions brought out by the participants was extraordinary, serving well to demonstrate the difference between the solution of a scientific problem and the solution of a technological problem.

Index Terms - Creativity, Design Contest, Engineering and Engineering Technology, Prototype Contest.

INTRODUCTION

The pedagogical strategy of Design Contests has been used successfully by a number of educators as an alternative to foster creativity and to stimulate the development of fundamental attitudes in engineering and in engineering technology students with respect to the art and technology of design.

In the paper Engineering Education 2001 [1], a report on the evaluation of engineering programs at the Technion - Israel Institute of Technology, of Haifa, Israel, an excellent analysis is presented of the evolution of engineering curricula in the recent decades. A drift towards science in the courses is identified (and justified), resulting in the sprouting, growth, and eventual predominance of the Engineering Sciences. The consequent natural adoption of the scientific method, which is based mainly in analysis, is commented, as well as the, also consequent, overshadowing of activities involving synthesis within the curricular structures.

It must be remembered, however, that the act of designing is mostly an activity of synthesis; it is an activity associated with the reunion of parts and, through it, the generation of added values; a negation, therefore, of the Cartesian paradigm, that equates the “value” of a whole to the summation of the “values” of its parts.

In design contests the aim is, traditionally, to expose the participants to a simulation of “real world” conditions, in the sense that a technological design problem is open to many solutions, fruit, each one, of the particular set of heuristics chosen by the designer. The object problem is not closed, that is, it does not have one correct solution. Of the many acceptable solutions, one is the best. Its identification is possible through the maximization of an objective function, here named the “figure of merit”, defined as a benefit/cost ratio, as complete as one chooses to specify.

This kind of orientation has been used, for example, by the pioneers E. W. Gaylord and C. F. Zorowski [2][3], and by their successor S. Eshghy [4], all at the Carnegie Institute of Technology, in Pittsburgh, USA, where the contest has been promoted as part of a curricular structure. The same kind of activity is described by O. A. Andrés [5], from the National University of Bahia Blanca, Argentina, as part of the students’ activities for a Civil Engineering Structural Design course. Another example, a more recent one, is described by P. H. Gregson and T. A. Little [6], for an Electrical Engineering program at the University of Dalhousie, in Halifax, Canada.

All of these cases are or were of local breadth, involving students of the same class or of the same school. In 1990 a design contest was proposed out of an agreement signed between the School of Engineering at São Carlos, of the University of São Paulo, and CLIMAX Indústria e Comércio S.A., a white-line home-appliance manufacturer. Twenty one students from 13 schools in 5 different States of the Brazilian Federation participated of that old seed-project initiative [7][8].

The TMT-Motoco Program for the Incentive of Technological Creativity, TMT-ITC for short, was scheduled to start its operation in the academic year of 2004. The academic year in Brazil runs from February through December. The TMT-ITC, that proposes a technological design contest as a first step, and culminates with a hands-on...
prototype contest, is meant to operate upon a different technical theme-problem each year.

The main rules and the deadlines for the competition are described in the sequence.

**TMT-MOTOCO PROGRAM FOR THE INCENTIVE OF TECHNOLOGICAL CREATIVITY**

**Internal Strategies for the Contest.** The definition of the design object-problem, as well as the rules for the processes involved must be very careful. The proposal that describes the objectives to be met by the designers is meant to present the problem in a way that will make it easier to understand. The role of the participant is similar to the role of a competitor bidding for a service. To win his or her proposal must be “the best”.

Annually a new object-problem shall be presented to the community of participating schools. In each case, the following points relative to the problem and to the judging criteria should be met:

- The problem must reflect the main characteristics of a technological problem with practical application in the real world.
- The problem must be defined in such a way as to instill in the student the conscience and the necessity of making use of applied science and art as components of original and creative design-proposals.
- The evaluation of the projects must be straight and objective.
- The evaluation of the prototypes must be quantitative, based on a pre-defined parameter, the “figure of merit” of the system under test.
- The manufacture of the prototypes must involve machines and tools readily accessible and simple operations.

The act of designing is one of the factors that differentiate Engineering from Science. Likewise, the technological method differs from the scientific method. Definitely, engineering is not an exact science: a scientific problem has, generally, a single solution, while a technological problem may have a large number of solutions. Among these, which one is “the best”, the so called the optimal solution?

It can be said, for example, that the optimal solution is the one that maximizes a benefit/cost ratio clearly specified in the definition of the design object-problem. This is, in the present proposal, the role for the “index of merit”.

**Details for the TMT-ITC Program.** The TMT-Motoco Program for the Incentive of Technological Creativity institutes each academic year an original theme-problem, object of the corresponding Design Contest and Prototype Contest. The description of the object-problem is defined in a tender or proposition to be put forward during the first week of the academic year.

Undergraduate students regularly enrolled in engineering or engineering technology programs are the target population. The participation is individual. A number of openings is offered to each school that chooses to join officially the program through the enrollment of one or more of its professors. If the number of interested students is larger than the number of positions made available to a school, it is recommended that a local pre-selection be made to select the applicants, using the same rules as for the TMT-ITC.

Of the projects received, the “best” 10 (ten) are selected for the following phase, the manufacturing of the prototypes.

The selection of the ten best projects is made by a committee composed by professionals from TMT-Motoco and P+E, a consulting firm; optionally an invited external examiner may be invited when necessary.

For this selection, several attributes of technical nature are to be considered:

- A concept that promotes a high design value (prediction) for the “figure of merit”;
- Adequacy and correction of the methods and operations presented to support the general design and the prediction of its “figure of merit”;
- Sufficiency, clarity, and graphical quality of the drawings presented;
- Sufficiency, clarity, and written quality of the texts presented;
- Attention to technical standards (ABNT, the Brazilian standards institute, when applicable).

Each students whose design is selected receives from TMT-Motoco, through his or her school officials, a financial allowance for the prototype construction. The prototype is to be built according to the specifications of the respective selected design.

The prototypes are tested, in accordance to the Program specifications, in a test bench specially designed and built for the duty.

The bench tests of the prototypes have as objective the determination of their actual performances and, in particular, the characterization of the actual “figure of merit” for each entry, as defined in the original tender, to be used as the final classifying parameter for the competition.

The overall results are to be presented during a special section, held in December, with the presence of the participants and of representatives of their schools.

The ten participants in this phase are eligible to receive awards in the form of formal certificates for this important achievement. The authors of the three best products additionally are awarded prizes in money. Travel and lodging expenses for the ten participating students as well as for their school advisors are covered or reimbursed by TMT-Motoco.

**Set of Instructions for the Program in 2004.** The TMT-Motoco Program for the Incentive of Technological Creativity started at the beginning of the academic year of 2004. The general instructions were made available in the site http://www.tmt-motoco.com.br/concurso.htm.
For the future editions of the Program, with the TMT-Motoco plant in full operation for the production of engines, transmissions, and other products, it could be advisable that these products be involved in the design challenges. This would foster the marketing permeability of these products and possibly contribute with the generation of novel applications for the TMT products.

For the first experience with the TMT-ITC, however, as this possibility was still missing, an offline type of product design was chosen as the starting test for the Program: the design of a compact heat exchanger.

The set of instructions for the TMT-ITC 2004 contained the following description:

“The object of the design is a shell-tube heat exchanger to heat up a primary stream of cold water with flow rate 1.5 liters/minute, originally at 25 °C to at least 30 °C (a ΔT equal to or larger than 5.0 °C), using a secondary hot water flow rate of 10 liters/minute and original temperature of 50,0 °C.

The two streams are to be kept under absolute immiscibility. The heat exchanger must be designed to stand a relative static pressure of 5.0 meters of water column in each circuit without leaking or having visible permanent deformations. The designer must specify which of the two water-currents flows inside the tubes.

The exchanger must be designed and built in such a way that the bank of tubes can be disassembled for cleaning the interior and the exterior of the tubes, and the interior of the shell. To facilitate the internal cleaning of the tubes, they must be straight in their entire extension.

The objective of the design is the maximization of the “figure of merit” f, defined as:

\[ f = \frac{\Delta T}{M(\Delta p_q + \Delta p_f)} \]

in which,

- \( \Delta T \) is the temperature increase in the cold stream (°C);
- \( M \) is the dry mass of the heat exchanger (kg);
- \( \Delta p_q \) is the total pressure drop along the hot stream (kPa);
- \( \Delta p_f \) is the total pressure drop along the cold stream (kPa).

Note that \( f \) (°C/kg kPa) quantifies a benefit/cost ratio as \( \Delta T \) stands for the benefit (heating) to be reached, while \( M \) is proportional to the capital cost, and \( \Delta p_q \) and \( \Delta p_f \) are proportional to the operational costs of pumping.

The lower limit and upper limit for the nominal tube diameter are 5.0 mm and 20.0 mm, respectively”.

Financial Support and Prizes. The number of participants in the prototype phase ended up being 14 instead of 10, due to the difficulty found in the discrimination among the last five entries in the design phase to select the number 10. Each one of the participants selected for the prototype phase were granted an stipend of R$1000.00 (one thousand reais, equivalent to US$400.00), made available through officials of his or her school by TMT-Motoco do Brasil, to support the manufacturing of the prototype and its transportation/delivery to the test site.

The authors of the 14 prototypes, as well as their advisors and their schools were awarded honor certificates. The authors of the three best finalists, according to the prototype tests, were awarded special honor certificates and were granted cash prizes.

RESULTS FOR THE TMT-ITC PROGRAM 2004

The 14 prototypes are shown in Figure 1. Diversity was expected for the solution of an open ended design problem such as the present one. But the diversity of the outcomes was extraordinary, serving well to demonstrate the difference between the solution of a scientific problem and the solution of a technological problem.

As far as the prototype mass is concerned, the limits were 0.756 kg for the lightest and 41.2 kg for the heaviest. The sizes too varied very much; the longest heat exchanger measured 1.6 m, while the shortest was only 18 cm long. The figure of merit \( f \) ranged from 2.42 °C/kg kPa to 0.111 °C/kg kPa. But one of the several products was “the best”, according to the restrictions imposed.

FIGURE 1
GENERAL DISPLAY OF THE 14 PROTOTYPES.

FIGURE 2
TMT-ITC 2004 FIRST PRIZE.
Figure 2 exhibits the heat exchanger developed by the ME student Giovanni F. Bernardo, from the Centro Universitário FEI, that was tested with a figure of merit of 2.42 °C/kg kPa and won the first prize.

Figure 3 shows the three winners. The one on the right was developed by the student Paola Scarassatti Sant’Anna, and won the second prize; its index of merit was 1.15 °C/kg kPa. The heat exchanger at the top was developed by the student Leandro Iezzi, and won the third prize with an index of merit equal to 0.609 °C/kg kPa. They are both ME students at the Escola de Engenharia de São Carlos – USP.

A complete report on the final two-day activities of the TMT-ITC 2004, with the presence of all the students and their advisors, can be found on the site http://www.tmt-motoco.com.br/concurso.htm.

Both students and professors present at the award ceremony were unanimous in the praising of the TMT-ITC initiative for its motivational potential. A point largely stressed was the hands-on opportunity, at an industrial level, offered to the students through the financial support provided for the construction of the prototypes, a novelty, according to them, when compared to classical Design Contests for students.

THE TMT-ITC PROGRAM IN 2005

The proposal for the TMT-ICT 2005 was made public in the end of February of 2005, with a timetable very similar to the one used in 2004.

As the plant is already in production, the proposed design for the TMT-ITC 2005 involved de composition of one out of three engines shown in www.tmt-motoco.com.br/produtos, respectively, Formula LV 148EA, Formula OV195EA e Formula LV 195EA, with a centrifugal water pump. Out of this basic configuration, the students are invited to elaborate over one out of two themes:

- The design of an autonomous system for firefighting, and
- The design of an autonomous system to back up crop irrigation.

Students from different areas should feel comfortable with these two themes. Probably, students from Mechanical and Civil Engineering/Engineering Technology should feel more comfortable with the first theme, while students of Agricultural or Environmental Engineering/Engineering Technology would prefer the second.

Authors of a total of 14 designs will be invited to participate of the prototype phase with rules similar to the ones adopted in 2004.

At the time this paper was finished (March 5, 2005) the TMT-ITC Program 2005 had been launched for only two weeks. Even though the number of schools enrolled was still low (11), a significant number of hits (4,252) on the Program site raises a positive expectation for 2005.

REFERENCES