2006-2402: MOVING ENGINEERING PRACTICE INTO THE CLASSROOM: USING THE NEW INTERACTIVE REFERENCES

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Moving Engineering Practice into the Classroom: Using the New Interactive References

A New Concept in Engineering Education

The practice of engineering requires the skill to continually gain reliable understanding of previously unfamiliar subjects, which will be used by the engineer as the basis for decisions affecting the welfare of clients and the public. The great variety of issues that an engineer must address requires that principles and data must be found and assimilated into a project quickly.

The professional engineers' licensing examination tests the candidate's ability to find information reliably and quickly by asking questions about many subjects that the student probably has not studied. The successful candidate knows the maxim that an engineer is defined by his bookshelf. The candidate will enter the test, as well as his professional career, knowing where to find information within the references of his field.

Engineering education has not reflected this aspect of engineering practice. Students typically gain only a passing familiarity with the references that will become their prime professional tools, and typically acquire their own professional bookshelves only after leaving school. The heft and high cost of engineering references makes it impractical for students to own the references for all the subjects covered in school. But, using references in the institution's library is tedious and problematic, especially if an entire class is seeking the same information.

From the standpoint of faculty, reference books in paper form are not suitable as classroom teaching tools, because there is no effective way to search them or display their contents in a classroom setting.

These obstacles are on the verge of being abolished. Recent advances have coalesced to make it possible for engineering schools to bring most professional references into the classroom. The Knovel Library now makes them available on the Internet. The Internet brings the information into the classroom. And, computer screen projectors have become suitable for classroom use.

The purpose of this paper is to explain this revolution in engineering education. To illustrate, we will show how the Knovel Library presents and enhances the *Energy Efficiency Manual*, the primary professional reference for energy conservation in buildings and industry. Then, we will take it into the classroom for a demonstration.

Knovel Revolutionizes the Knowledge Base

The Knovel Library appeared in 1999. It is the realization of a monumental idea, to make the complete contents of all major engineering references immediately available on the Internet from a single source.

Knovel allows users to search the entire library simultaneously by using keywords. A search yields all relevant information almost instantly, and ranks the search results by relevance. With a single click, a subscriber can go to any of the search results. Or, a single click will provide information about a selected reference. With two clicks, the subscriber can see the table of contents of a selected reference, and with another click, go anywhere within the reference.

The Knovel Library provides access to information with a speed and scope that was previously unimaginable. The content of the Knovel Library provides exhaustive coverage of most fields of engineering, and the number of resources continues to grow. No individual – and few engineering firms – could afford to acquire and update such a comprehensive collection.

The time expended in searching for information is now virtually eliminated. Excerpts from all references can be imported into homework assignments and projects efficiently, allowing the student to concentrate on learning the subject matter.

In addition to offering the references in their original form, Knovel has created significant enhancements of selected references, providing capabilities beyond those contained in the original books. The most prominent of these is the *Energy Efficiency Manual*, which we will use to illustrate the ability of the Knovel Library to bring references into the classroom for real-time use.

Energy Efficiency, the Newest Challenge of Engineering Education

Energy efficiency emerged as a dominant societal interest in 1973, the year of the first Arab oil embargo, when the continued availability of energy resources was called into question. Today, attention is returning to the analysis of fossil fuel depletion that was begun by M. King Hubbert in the 1950's, which shows that conventional oil and gas resources will be exhausted by the middle of this century.

It now seems likely that replacement energy supplies will fall far below present levels and that all energy supplies will become expensive enough to limit their use. These changes will occur during the working lives of today's engineering students. The only reliable solution is to radically improve the efficiency of our energy usage. The present generation of engineering students must learn how to use efficiency to save civilization.

Engineering schools have stressed efficiency in large machines ever since energy emerged as a scientific concept. But until recently, little attention was given to efficiency in the end use of energy. In particular, energy was not stressed in the design of buildings. And although much attention was given to the efficiency of specific industrial processes, industrial plants overall are commonly wasteful of energy.

Buildings account for 39% of total U.S. energy consumption, and industry accounts for 34%. The percentages in other major energy consuming countries are similar. Therefore, radical improvement of energy efficiency in buildings and industry comprises the largest part of the engineering challenge.

The *Energy Efficiency Manual* Arrives

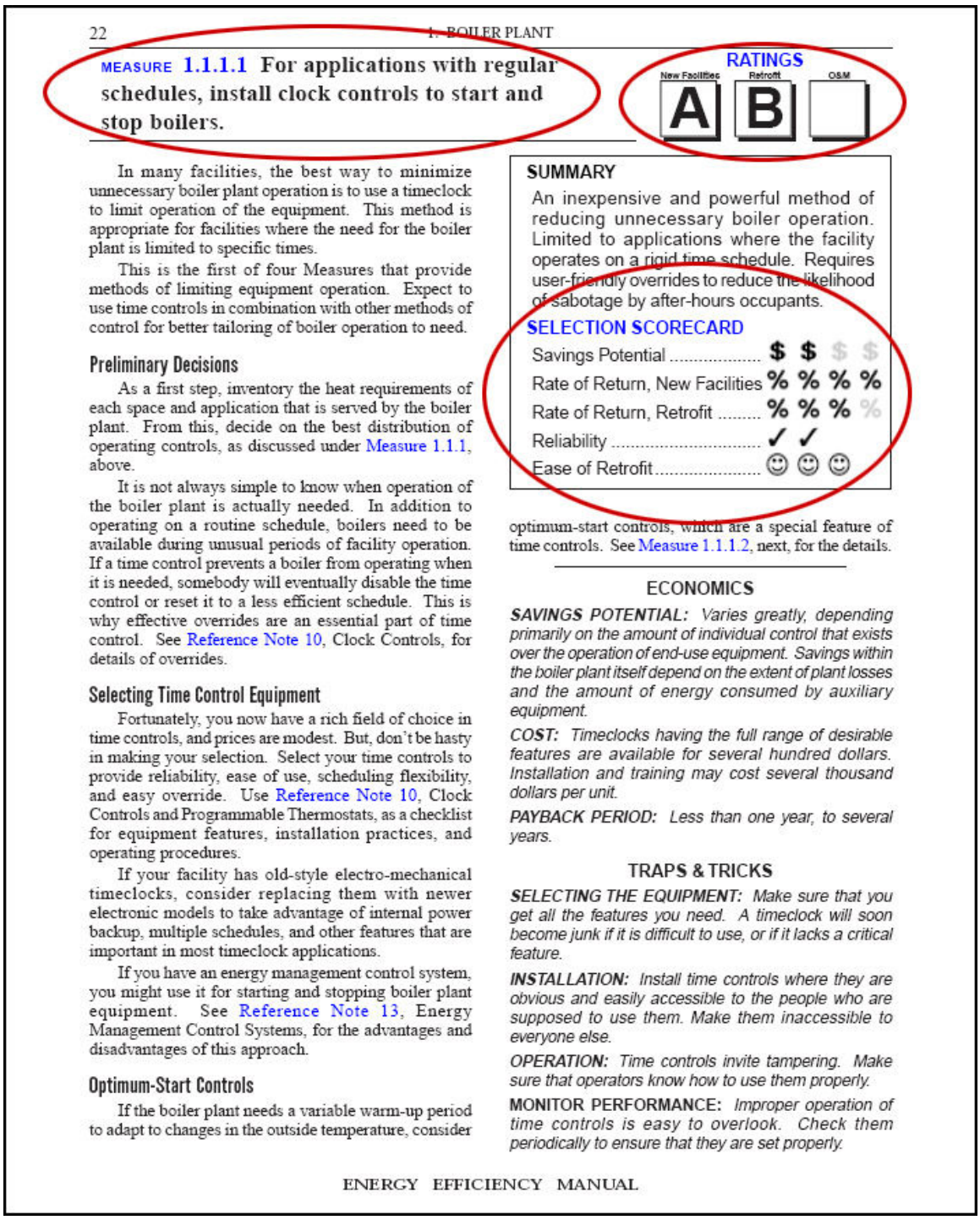
Engineering schools responded quickly to the energy tumult of the 1970's, but they struggled to make energy efficiency a coherent field of study in the absence of coherent information. Knowledge in this new field grew chaotically and in piecemeal fashion, without providing a firm base for educating engineers.

The chaos ended in 2000 with the publication of the *Energy Efficiency Manual* ("*EEM*"). The *EEM* organizes the principles and techniques of energy efficiency in buildings and industry. It quickly became the primary professional reference on energy efficiency around the world.

The *EEM* was organized, researched, and written over a period of 20 years of intensive work. It stresses thorough integration of the information. For example, the efficiency of lighting in a building has strong effects on heating and air conditioning requirements. Also, energy efficiency has interactions with indoor health, fire safety, resistance to terrorist attack, esthetics, and the costs of construction and maintenance. For the first time, the *EEM* made all these linkages.

In addition to serving as the main reference of the field, the *EEM* is designed to serve as a textbook and practical field manual. The first part of the book presents 400 individual energy efficiency improvements, which are organized by areas of energy usage and by professional discipline. Each of the 400 efficiency improvements is called a "Measure" (short for "energy conservation measure"). This organization creates a taxonomy of energy efficiency, making it possible to delve into each area of energy efficiency thoroughly, just as a biologist can focus on a particular species.

The book introduces novel aids to help the user find the most relevant information for the application. Each Measure includes three separate Ratings, which rank the desirability of the action for new construction, as an improvement for existing facilities, or for operations and maintenance, respectively. In addition, each Measure includes a Selection Scorecard, which rates the Measure in terms of its potential savings, economic rate of return, reliability, and ease of accomplishment. See Figure 1.



22 1. BOILER PLANT

MEASURE 1.1.1.1 For applications with regular schedules, install clock controls to start and stop boilers.

RATINGS

New Facilities	Retrofit	O&M
A	B	

In many facilities, the best way to minimize unnecessary boiler plant operation is to use a timeclock to limit operation of the equipment. This method is appropriate for facilities where the need for the boiler plant is limited to specific times.

This is the first of four Measures that provide methods of limiting equipment operation. Expect to use time controls in combination with other methods of control for better tailoring of boiler operation to need.

Preliminary Decisions

As a first step, inventory the heat requirements of each space and application that is served by the boiler plant. From this, decide on the best distribution of operating controls, as discussed under Measure 1.1.1, above.

It is not always simple to know when operation of the boiler plant is actually needed. In addition to operating on a routine schedule, boilers need to be available during unusual periods of facility operation. If a time control prevents a boiler from operating when it is needed, somebody will eventually disable the time control or reset it to a less efficient schedule. This is why effective overrides are an essential part of time control. See Reference Note 10, Clock Controls, for details of overrides.

Selecting Time Control Equipment

Fortunately, you now have a rich field of choice in time controls, and prices are modest. But, don't be hasty in making your selection. Select your time controls to provide reliability, ease of use, scheduling flexibility, and easy override. Use Reference Note 10, Clock Controls and Programmable Thermostats, as a checklist for equipment features, installation practices, and operating procedures.

If your facility has old-style electro-mechanical timeclocks, consider replacing them with newer electronic models to take advantage of internal power backup, multiple schedules, and other features that are important in most timeclock applications.

If you have an energy management control system, you might use it for starting and stopping boiler plant equipment. See Reference Note 13, Energy Management Control Systems, for the advantages and disadvantages of this approach.

Optimum-Start Controls

If the boiler plant needs a variable warm-up period to adapt to changes in the outside temperature, consider optimum-start controls, which are a special feature of time controls. See Measure 1.1.1.2, next, for the details.

SUMMARY

An inexpensive and powerful method of reducing unnecessary boiler operation. Limited to applications where the facility operates on a rigid time schedule. Requires user-friendly overrides to reduce the likelihood of sabotage by after-hours occupants.

SELECTION SCORECARD

Savings Potential	$	$	$	$
Rate of Return, New Facilities	%	%	%	%
Rate of Return, Retrofit	%	%	%	%
Reliability	✓	✓		
Ease of Retrofit	☺	☺	☺	

ECONOMICS

SAVINGS POTENTIAL: *Varies greatly, depending primarily on the amount of individual control that exists over the operation of end-use equipment. Savings within the boiler plant itself depend on the extent of plant losses and the amount of energy consumed by auxiliary equipment.*

COST: *Timeclocks having the full range of desirable features are available for several hundred dollars. Installation and training may cost several thousand dollars per unit.*

PAYBACK PERIOD: *Less than one year, to several years.*

TRAPS & TRICKS

SELECTING THE EQUIPMENT: *Make sure that you get all the features you need. A timeclock will soon become junk if it is difficult to use, or if it lacks a critical feature.*

INSTALLATION: *Install time controls where they are obvious and easily accessible to the people who are supposed to use them. Make them inaccessible to everyone else.*

OPERATION: *Time controls invite tampering. Make sure that operators know how to use them properly.*

MONITOR PERFORMANCE: *Improper operation of time controls is easy to overlook. Check them periodically to ensure that they are set properly.*

ENERGY EFFICIENCY MANUAL

Figure 1

A separate "Economics" sidebar for each Measure estimates the potential savings, the cost, and the payback period. A "Traps & Tricks" sidebar provides practical field experience for the aspiring engineer about the pitfalls of each activity and advises how to stay out of trouble.

The second part of the book, called Reference Notes, explains 37 essential topics in energy conservation and renewable resources. Subjects include the properties of fossil fuels, renewable energy sources, the basis for pricing electricity, the characteristics of refrigerants in light of ozone depletion and global warming, how the major types of lighting work, the types of boilers, how variable-speed motor drives work, and much more. The self-contained Reference Notes are an easy introduction to important energy topics for students and practicing engineers.

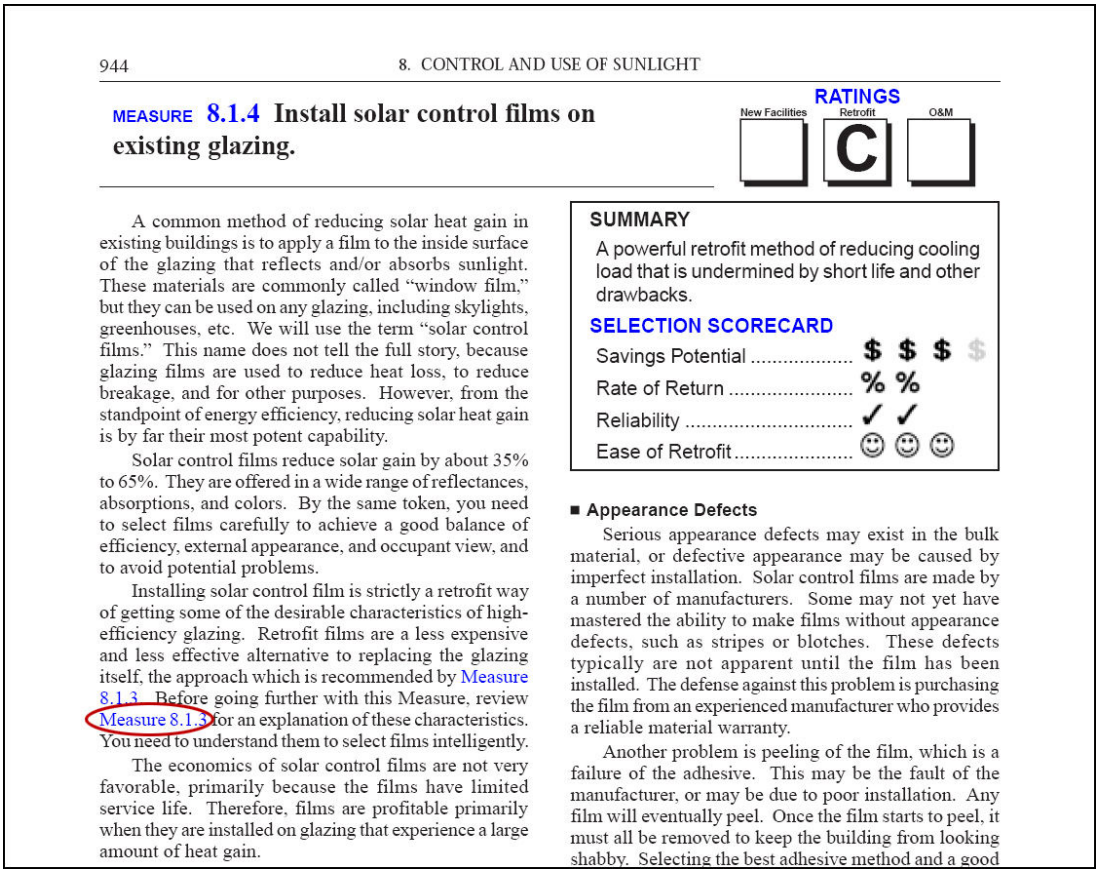
The *Energy Efficiency Manual* enhances its features with over 800 illustrations and hundreds of examples drawn from actual field experience. It won major publishing awards in the book trade for its physical appeal and ease of use. It continues to receive enthusiastic reviews in both the book trade and the technical press.

Engineers who work in fields involving energy efficiency will acquire their personal copies of the book. But, at 1,536 pages, a weight of four kilograms, and a current price of $200, the paper version of the *EEM* is a big investment for students. Knovel allows students to use it for their educations without buying it, giving them a head start when entering the work force.

Knovel Enhances the *Energy Efficiency Manual*

The *Energy Efficiency Manual* became part of the Knovel Library in 2005. It is the most heavily enhanced resource in Knovel, an archetypical example of the power of the Knovel Library.

First, Knovel fully exploits the native features of the *EEM* that provide rapid searching, sorting, and cross referencing. Hyperlinks travel instantly between the many cross references in the text. See Figure 2. Hyperlinks from the Ratings and Selections Scorecards of each Measure access the key that explains them. In the index, each listing has hyperlinks to the pages and to related listings. See Figure 3. The hyperlinks reduce to a minimum the time that is required to assemble a complete picture of any aspect of energy efficiency.



944 8. CONTROL AND USE OF SUNLIGHT

MEASURE 8.1.4 Install solar control films on existing glazing.

RATINGS

New Facilities	Retrofit	O&M
	C	

A common method of reducing solar heat gain in existing buildings is to apply a film to the inside surface of the glazing that reflects and/or absorbs sunlight. These materials are commonly called "window film," but they can be used on any glazing, including skylights, greenhouses, etc. We will use the term "solar control films." This name does not tell the full story, because glazing films are used to reduce heat loss, to reduce breakage, and for other purposes. However, from the standpoint of energy efficiency, reducing solar heat gain is by far their most potent capability.

Solar control films reduce solar gain by about 35% to 65%. They are offered in a wide range of reflectances, absorptions, and colors. By the same token, you need to select films carefully to achieve a good balance of efficiency, external appearance, and occupant view, and to avoid potential problems.

Installing solar control film is strictly a retrofit way of getting some of the desirable characteristics of high-efficiency glazing. Retrofit films are a less expensive and less effective alternative to replacing the glazing itself, the approach which is recommended by Measure 8.1.3. Before going further with this Measure, review Measure 8.1.3 for an explanation of these characteristics. You need to understand them to select films intelligently.

The economics of solar control films are not very favorable, primarily because the films have limited service life. Therefore, films are profitable primarily when they are installed on glazing that experience a large amount of heat gain.

SUMMARY

A powerful retrofit method of reducing cooling load that is undermined by short life and other drawbacks.

SELECTION SCORECARD

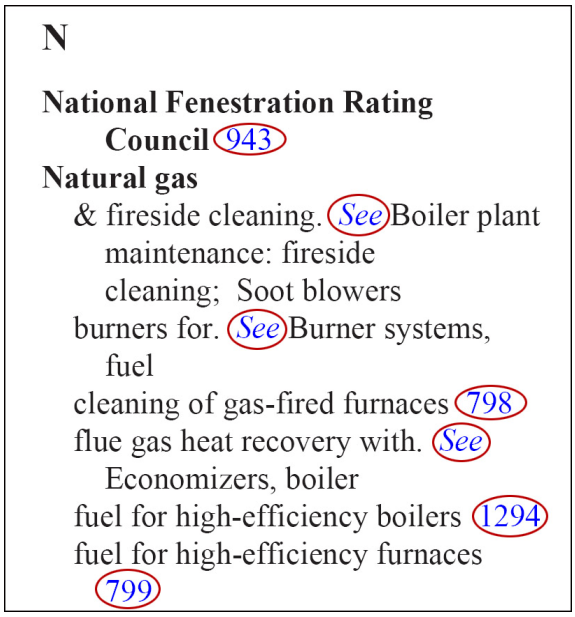
Savings Potential	$ $ $ $
Rate of Return	% %
Reliability	✓ ✓
Ease of Retrofit	☺ ☺ ☺

■ Appearance Defects

Serious appearance defects may exist in the bulk material, or defective appearance may be caused by imperfect installation. Solar control films are made by a number of manufacturers. Some may not yet have mastered the ability to make films without appearance defects, such as stripes or blotches. These defects typically are not apparent until the film has been installed. The defense against this problem is purchasing the film from an experienced manufacturer who provides a reliable material warranty.

Another problem is peeling of the film, which is a failure of the adhesive. This may be the fault of the manufacturer, or may be due to poor installation. Any film will eventually peel. Once the film starts to peel, it must all be removed to keep the building from looking shabby. Selecting the best adhesive method and a good

Figure 2



N

National Fenestration Rating Council 943
Natural gas
& fireside cleaning. See Boiler plant maintenance: fireside cleaning; Soot blowers
burners for. See Burner systems, fuel
cleaning of gas-fired furnaces 798
flue gas heat recovery with. See Economizers, boiler
fuel for high-efficiency boilers 1294
fuel for high-efficiency furnaces 799

Figure 3

Next, Knovel builds on the unique features of the *EEM* to create new tools that improve the speed of access and the quality of information. The Table of Contents is expanded to provide direct links to each of the 400 Measures.

The graphs in the book are made interactive, so that a student can actually plot directly on the graph and extract data. See Figure 4.

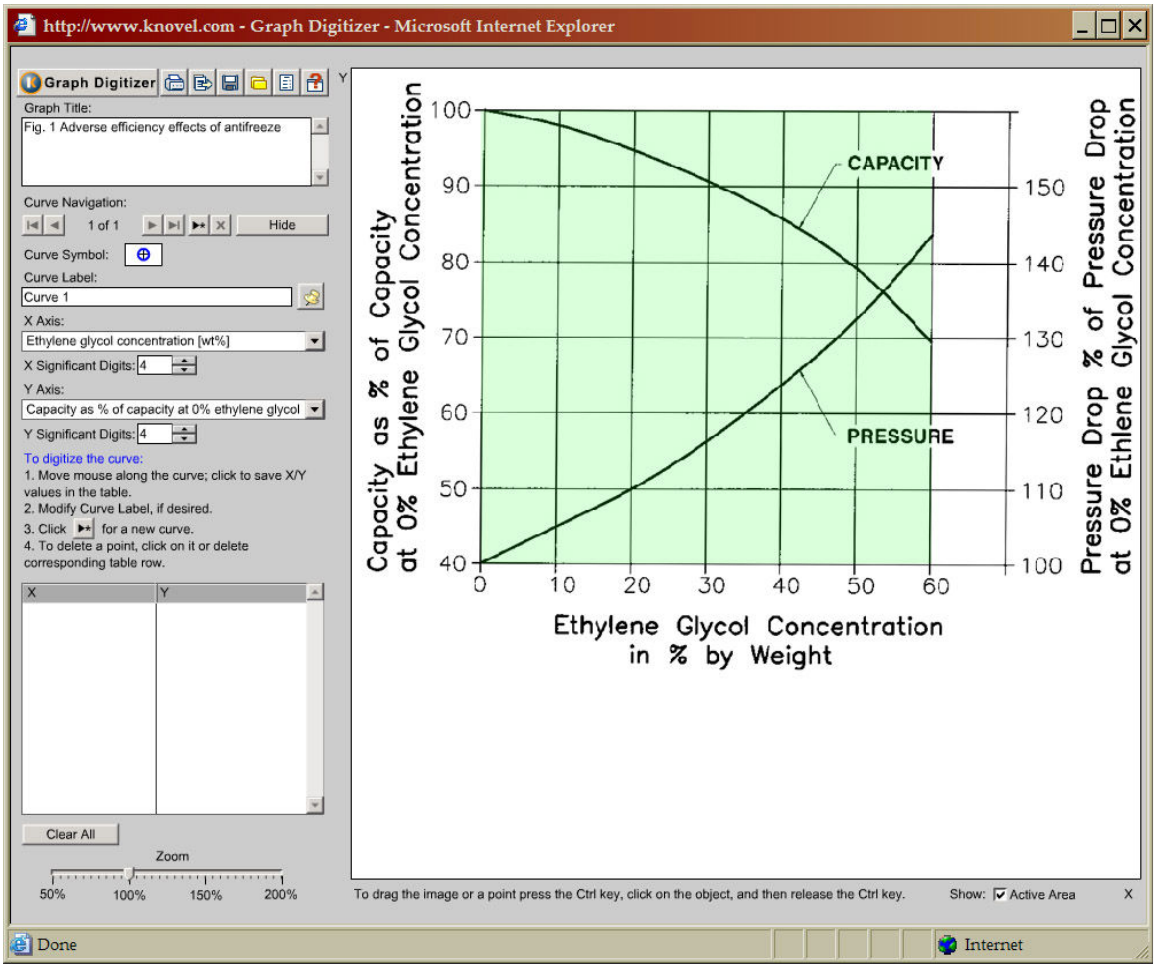
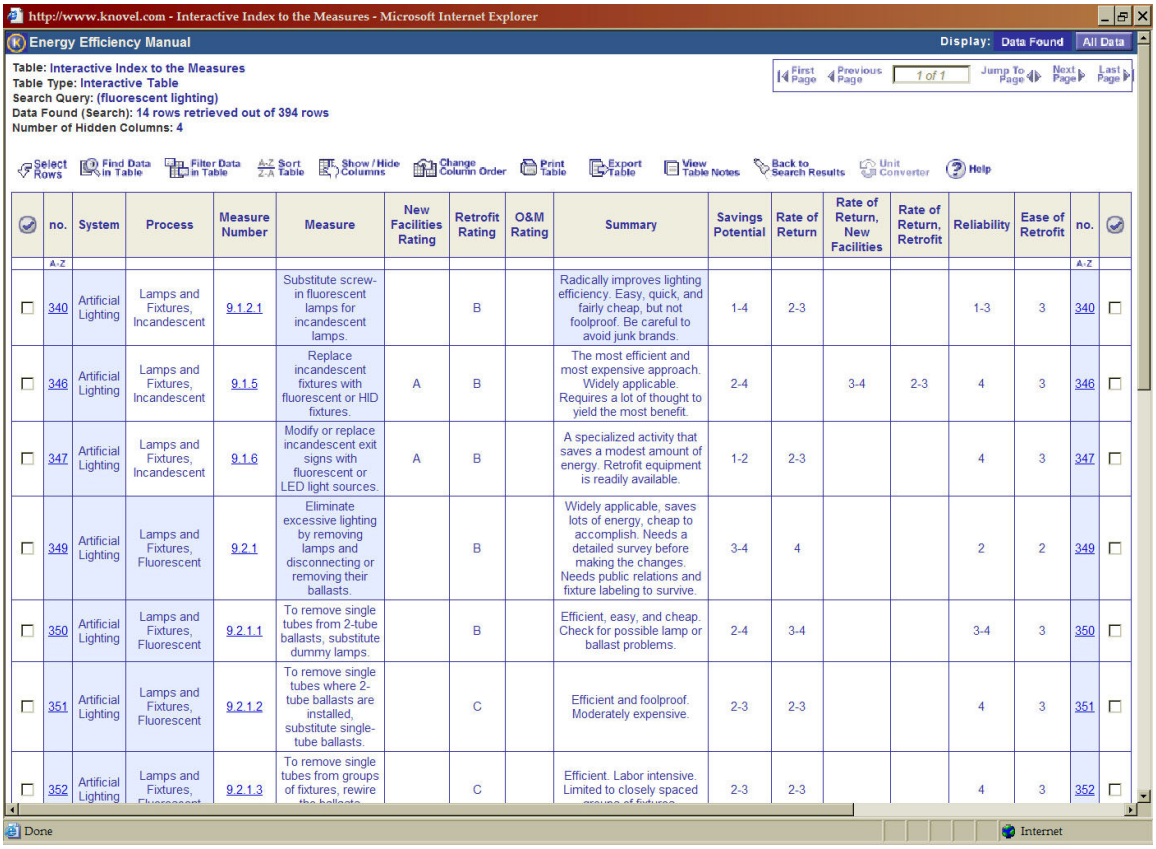


Figure 4

The most powerful enhancement is the Interactive Index of the Measures. A keyword search will result in a spreadsheet of all the Measures that are relevant to those keywords. The subscriber can then sort the Measures using any of the Ratings or any of the criteria in the Selection Scorecard. This enhancement reduces unproductive searching to a bare minimum, while providing a highly effective overview of an energy efficiency topic.

For example, the *EEM* has a category of Measures for improving the efficiency of fluorescent lighting. The Interactive Index can be used to list them all in order of potential savings, or ease of accomplishment, or other criteria. See Figure 5.



	no.	System	Process	Measure Number	Measure	New Facilities Rating	Retrofit Rating	O&M Rating	Summary	Savings Potential	Rate of Return	Rate of Return, New Facilities	Rate of Return, Retrofit	Reliability	Ease of Retrofit	no.	
	A-Z															A-Z	
☐	340	Artificial Lighting	Lamps and Fixtures, Incandescent	9.1.2.1	Substitute screw-in fluorescent lamps for incandescent lamps.		B		Radically improves lighting efficiency. Easy, quick, and fairly cheap, but not foolproof. Be careful to avoid junk brands.	1-4	2-3			1-3	3	340	☐
☐	346	Artificial Lighting	Lamps and Fixtures, Incandescent	9.1.5	Replace incandescent fixtures with fluorescent or HID fixtures.	A	B		The most efficient and most expensive approach. Widely applicable. Requires a lot of thought to yield the most benefit.	2-4		3-4	2-3	4	3	346	☐
☐	347	Artificial Lighting	Lamps and Fixtures, Incandescent	9.1.6	Modify or replace incandescent exit signs with fluorescent or LED light sources.	A	B		A specialized activity that saves a modest amount of energy. Retrofit equipment is readily available.	1-2	2-3			4	3	347	☐
☐	349	Artificial Lighting	Lamps and Fixtures, Fluorescent	9.2.1	Eliminate excessive lighting by removing lamps and disconnecting or removing their ballasts.		B		Widely applicable, saves lots of energy, cheap to accomplish. Needs a detailed survey before making the changes. Needs public relations and fixture labeling to survive.	3-4	4			2	2	349	☐
☐	350	Artificial Lighting	Lamps and Fixtures, Fluorescent	9.2.1.1	To remove single tubes from 2-tube ballasts, substitute dummy lamps.		B		Efficient, easy, and cheap. Check for possible lamp or ballast problems.	2-4	3-4			3-4	3	350	☐
☐	351	Artificial Lighting	Lamps and Fixtures, Fluorescent	9.2.1.2	To remove single tubes where 2-tube ballasts are installed, substitute single-tube ballasts.		C		Efficient and foolproof. Moderately expensive.	2-3	2-3			4	3	351	☐
☐	352	Artificial Lighting	Lamps and Fixtures, Fluorescent	9.2.1.3	To remove single tubes from groups of fixtures, rewire		C		Efficient. Labor intensive. Limited to closely spaced	2-3	2-3			4	3	352	☐

Figure 5

Using Knovel in the Classroom

Now, we are ready to see how Knovel can be used in the classroom to teach the way that engineers actually work. As an example, the professor presents a project in which an engineer is hired to improve the lighting efficiency of an existing building. (The professor might select the building in which the classroom is located.) As would be typical, the engineer probably does not know much about lighting efficiency, so he is obliged to learn about this unfamiliar subject quickly and make the best possible recommendations.

The class, acting as the engineer, is able to go through the process without interruption for searching for information or cross referencing because Knovel performs these functions instantly. The entire Knovel Library is available in the classroom by way of the Internet, a computer, and a projector. The students' entire time is devoted to learning.

First, the class conducts a keyword search for "lighting efficiency." Knovel instantly produces a list of all references dealing with that subject. In this case, it is apparent that one reference, the *Energy Efficiency Manual*, is the dominant source. Clicking on the table of contents for the *EEM* shows that it has a Section devoted to lighting efficiency. Knovel makes it possible to quickly scan the arrangement of information within this Section.

From this, it is apparent that one of the Subsections is devoted specifically to efficiency in fluorescent lighting. Since the sample building has mostly fluorescent lighting, the class decides to do that part of the project first. The introduction to the Subsection has a hyperlink to one of the Reference Notes that explains how fluorescent lighting works. A single click goes to that Reference Note. The professor, working from his own copy of the *EEM*, has already prepared an explanation of fluorescent lighting, which he presents.

Or, if the project is spread over several days, the students themselves can study the background material by accessing the Knovel subscription from their dorm rooms or from any Internet connection.

Based on their newly acquired understanding of fluorescent lighting, the class uses the Interactive Table of the Measures to identify all the Measures that explain how to improve efficiency in fluorescent lighting, as explained previously.

The class then decides which Measures to accomplish. The class will base its decisions on issues that are explained within each of the Measures. These will include visual quality, ease of maintenance, equipment cost, the effect of lighting on cooling load, and so forth. These issues are hyperlinked within the *EEM*, requiring only one click to instantly find an explanation of each issue.

If the professor desires, the class will continue in this way for the other aspects of lighting in the building. By the time the project is complete, in no more than a few hours of class time, the class will have a solid understanding of a new and complex subject. Just like engineering in the real world.

This example follows one possible thread in accomplishing the project. However, it is not necessary to follow any particular sequence or to learn any complex search procedures. Because of the extensive hyperlinking within the reference, a student can start in many ways and acquire the needed information by many paths.

Low Cost for School, Students, and Faculty

The cost of this revolutionary capability is extraordinarily low. Institutional subscriptions to Knovel Library packages start at $1,200 per year, increasing with the size of the institution. The cost for each student and faculty member is typically less than the cost of one day's meals at the cafeteria.

In fact, Knovel provides a large net saving to students by giving them access to the major tools of their trade without the need to purchase the physical books. By the same token, it provides access to a much larger professional library than an engineer's usual collection.

The Knovel Library also reduces the school's cost by making it unnecessary to purchase multiple library copies of books and to buy updated editions. The Knovel Library continually updates its references, often adding updates and enhancements before a new edition is published. And, it saves faculty preparation and research time.

Thus, the Knovel Library actually provides a net saving for all parties.

The Final Step

Many schools presently subscribe to Knovel, making it available in their libraries and on the desks of the faculty. The final step is to cross the threshold into the classroom itself. Everything is ready for this revolutionary advance in engineering education.