AC 2010-2110: A SYSTEMS APPROACH TO ENERGY CONSERVATION:CHALLENGING INDUSTRIAL AND EDUCATIONAL PARADIGMS

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A Systems Approach to Energy Conservation: Challenging Industrial and Educational Paradigms

Abstract

Rising costs of fuel and a greater sense of environmental responsibility have increased interest in energy efficiency. Great emphasis has been placed on the use of alternative sources of energy, though conservation efforts that rely on existing technologies offer the greatest opportunity for immediate benefits. This is particularly true in traditional, energy intensive manufacturing plants that rely on mature technologies. In such plants, where certain requisite criteria are met, opportunities for simple energy savings are substantial. This paper presents a case study of a food manufacturing plant with characteristics common to many manufacturing facilities. Through an integrated design process, this facility was able to reduce energy consumption considerably. Based on comparison with industry-standard implementations of similar equipment and processes, the new facility reduced energy consumption by more than 70% for some aspects of the production operation. Building on the lessons learned from this design exercise, it is proposed that similar energy savings are possible in a wide variety of industries for which certain criteria are met. Criteria for successful implementation are proposed, including recommendations for changes to both industrial and educational paradigms that perpetuate sub-optimal system designs and implementations. Possible changes to existing curricular structures are explored, and recommendations for an integrated, multidisciplinary curriculum are proposed.

Introduction

One of the most significant challenges facing humankind today is that of energy. Engineers and scientists of every stripe have been challenged to address the world's energy needs. Though there is a great deal of excitement and public attention focused on alternative energies, most of that research represents high risk with the potential of high reward. Over the long term, breakthrough technologies that free us from our reliance on fossil fuels are a must. However, the benefits of alternative energies generally have an implementation horizon that ranges from years to decades and rely on technologies that have yet to be made technologically or economically viable.

In the near-term, conservation efforts must be developed concurrently. Such efforts offer great opportunity for immediate reduction of the energy problem. The magnitude of benefits that can be achieved from conservation can be observed in the consumer market. Hybrid vehicles and compact fluorescent lighting use only a fraction of the energy required by their traditional counterparts. It is increasingly apparent that energy savings of comparable magnitudes can be achieved in traditional industry.

Researchers at Youngstown State University, working with industry, have identified that surprising reductions in energy consumption are achievable through the application of conventional technology in innovative ways. The magnitude of the available savings typically ranges from 20 to 70%, and can often be achieved with paybacks one year or less. The effects are typically achieved through a combination of rethinking traditional industrial paradigms and exploring better opportunities for systems integration.

Presented here is a case study of a local manufacturing company that engaged the help of YSU faculty and students as part of an integrated design team. By challenging conventional wisdom, this team was able to achieve surprisingly high efficiencies with relatively modest modifications to commercially available equipment. This paper explores some of the lessons learned from that exercise. It identifies some of the industrial conventions and paradigms that have left those opportunities unexplored and considers the role that engineering education may play in preparing students to better address those opportunities.

Case Study

A small pasta sauce producer on the outskirts of Youngstown, Ohio, was looking to expand the capacity of their manufacturing line. The level of production automation in the existing facility was minimal and management sought the help of YSU faculty to augment their technical abilities. As the scope of the project grew, so did the ambitiousness of the project. What began as a small plant expansion grew into a vision for an environmentally friendly world-class manufacturing facility. The new plant was to be the first privately owned building in the county to comply with the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification criteria. The plant was to serve as the centerpiece of the company's environmentally responsible public image. To that end, the design team was challenged to push the boundaries of what is currently considered state-of-the-art within the industry.

It was agreed that a core multidisciplinary group would be assembled to help lead the project. This group would work in an advisory capacity to ensure that factors were considered from all points of view. Though multidisciplinary teams of this sort have become common in some product design environments, the degree of integration used by this team was not commonly found in production facility design.

Typically, manufacturing facilities of this size represent an integration of many discrete pieces of equipment. The building serves largely as a shell within which that equipment is housed. With the exception of space requirements, architectural considerations are usually handled independently from equipment selection. Equipment purchases are usually handled with individual equipment suppliers and integration is generally limited to material handling considerations between pieces of equipment.

To achieve the lofty efficiency goals put forward by the company's management, all aspects of the design were challenged by the integrated design team. Because many team members came to the table without preconceived notions of what was possible or conventional within the other disciplines, standard practices within the various industries were frequently challenged. Such challenges were initially met with resistance. However, as members of the design team became more comfortable with one another, it became apparent that customary does not always equate with optimal or necessary. When team members became willing to challenge conventional paradigms, many new opportunities for energy savings emerged.

It is beyond the scope of this paper to go through a detailed discussion of all the innovations and how they evolved. For the purposes of this paper, it should be adequate to summarize some of the key innovations, their magnitude, and to discuss how they challenge conventional expectations.

Key Innovations

Improvements that were made to the production systems at the new plant were made primarily through changes that conflicted with industry-standard designs. The innovations presented here are indicative of the small but controversial changes that were made and the magnitude of their impact on overall system performance.

A significant cost of operation for this manufacturing facility is related to cooling finished product. Hot jars of pasta sauce pass through a cooling tunnel where they are showered with cool water. Heat from the jars is transferred to the cooling water and subsequently extracted from the water through a heat exchanger and mechanical chilling system. A conventional system configuration is shown in Figure 1. Major energy consumers in the process are the pumping required to shower the jars with thousands of gallons of water per minute and the refrigeration system required to chill the cooling water.

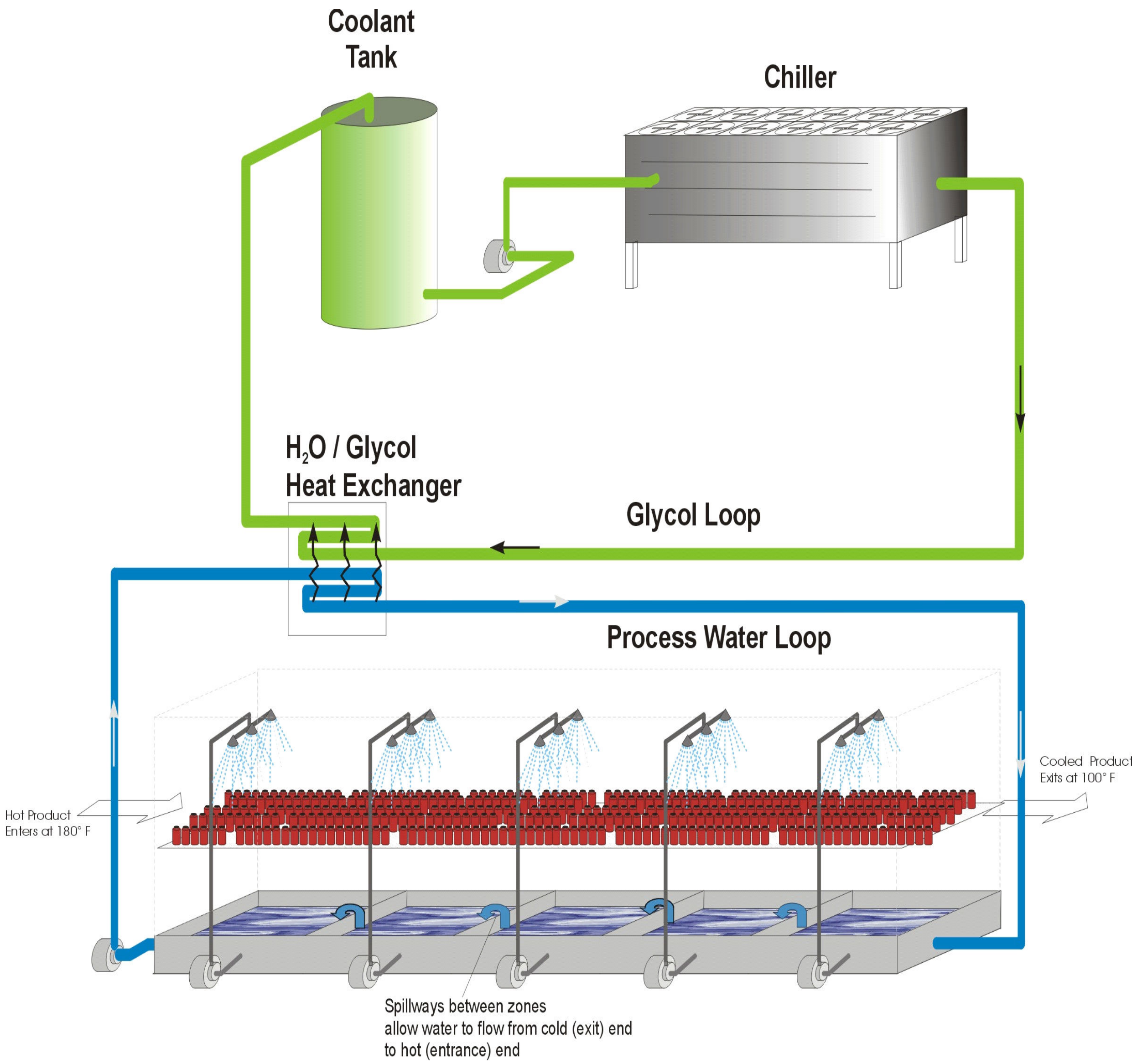

FIGURE 1: TYPICAL COOLING SYSTEM CONFIGURATION [(1)]

In a conventionally designed facility, the equipment sizing process might follow a procedure of this sort:

- Rate of product production would be established
- Thermal rejection requirements (BTU/hr) for full production would be supplied to the cooling table manufacturer to specify a cooling table.
- Temperature requirements and heat rejection data would be supplied to a refrigeration contractor to specify an appropriate cooling system.

- Independently sized and optimized units would be integrated on-site within the predefined architectural envelope.

This scenario fails to optimize the design at a systems level and relies on suppliers to provide engineering expertise. This process misses several opportunities for substantial cost savings:

- Waste heat from the process can be incorporated into the HVAC system of the building.
- Remaining waste heat can be dissipated by evaporative coolers rather than mechanical chillers
- Energy consumed by pumping can be substantially reduced the pressure drops are high.

At first glance, these findings seem obvious. However, in examining the system that is proposed by equipment vendors and traditional methods of integration, we find that it does not incorporate any of these features. At the conclusion of the integrated design process, we find that it is possible to reduce pumping costs by more than 70%, recover more than 300,000 BTU/hr of usable heat, and to virtually eliminate the 120 tons of mechanical chilling. These changes result in an added project cost of approximately $50,000 with a 14 month payback based on only a one shift operation [2] [3] [4]

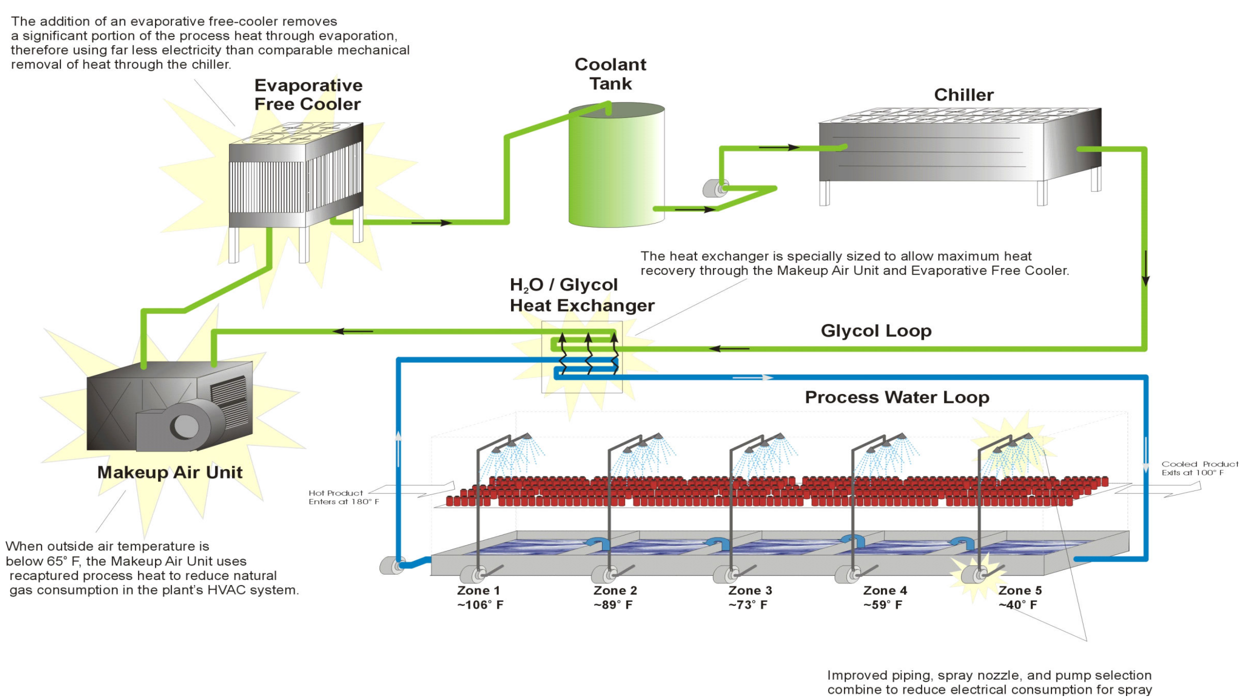

FIGURE 2: REDESIGNED COOLING SYSTEM [1]

The requirements of this plant are consistent with many such plants. It is, therefore, somewhat perplexing that energy savings of more than 70% are so easily achieved. The question is begged, "How can this be possible?" Based on retrospective consideration of this case study, a variety of factors are identified. By considering these factors and how they interact in a systems level. We may explore opportunities to improve industrial systems design and incorporate those findings into engineering education so that graduates may exploit these opportunities.

Generalization of Lessons Learned

Claims of 70% reductions in energy use seem outrageous on their face. Despite being demonstrable, many will argue that this is an isolated case and not representative of broader industry. However, one need only look back at the American automobile industry of the 1970's and '80's to appreciate how such innovations may have slipped beneath the radar of industry. While the "Big Three" automakers comfortably gauged their competitiveness based on industry standards and the performance of their peers, foreign automakers explored product and process design from a systems perspective. By embracing a systems engineering approach and the philosophies of Deming, Japanese automakers challenged American automakers with an approach that was incompatible with the established industry paradigms (5). The result has put American automakers, and the manufacturers who supply them, on their heels for more than 25 years.

It has been a long, hard struggle for automobile manufacturers to apply the lessons of systems engineering to their design and production processes. Under those circumstances, the companies are very large, supported by a tremendous and diverse engineering team, and with very flexible control of the design of the product and all of its components.

As we propose to apply a similar systems approach to traditional industrial facility and equipment integration, the objective of the optimization is now to consider energy efficiency. Unfortunately, though the facilities are often much smaller, they also lack the vertical integration of the automobile industry. The facilities typically have minimal in-house engineering support and rely extensively on vendors and sub-contractors for system design and implementation. Under these conditions, the opportunities for improvement at a systems level are vast, as are the challenges. Efforts must be coordinated between a large, disparate group of experts. Also, deeply rooted conventions and paradigms must be challenged at all levels of the system; this includes the inflexible paradigms of academia.

Despite the great challenges, the benefits offered by a true multidisciplinary systems approach to energy conservation offer great hope for traditional industry. Particularly at a time when American industry is struggling to remain competitive, a 20-70% reduction in energy costs with short payback periods translates to increased competitiveness. In terms of its impact on the energy crisis, conservation is the single best near-term option we have for addressing the world's energy needs. Even so, these opportunities appear to have gone largely unnoticed and unexplored. A retrospective analysis of this and other faculty experiences of implementing designs of this sort yields some general observations that may be applicable to broader industries:

Stagnation of Mature Industries

Manufacturing, and much of the equipment that supplies the manufacturing industry, are commonly considered to be mature industries. These industries have largely stagnated. There is a widely held perception that this decline in innovation is the result of those industries having reached the pinnacle of what is possible. However, as the above case study shows, what is commonly accepted as state-of-the-art within the industry may be as little as 30% of the efficiency that is possible. Because mature industries look almost exclusively to their peers as gages of their competitiveness, the aggregation of incremental technological advancements outside the industry may present opportunities for transformational new approaches to the industry. It can be shown that great opportunities exist, but innovation has largely been stifled by stasis, a lack of competitive drive, and the absence of cross-disciplinary integration.

Overreliance on "Experts" and Industry Standards

As industry, society, and academia have adopted a model that emphasizes specialization over generalism, there has become an increasing reliance on others to be responsible for technical decisions. Manufacturers, who are in the business of producing a product, not making machines to make that product, have offloaded responsibility for equipment design to vendors. In so doing, they have lost direct input to the design and improvement of that equipment. At the equipment supplier level, technical decisions are not necessarily driven by what is best for the manufacturer, nor do they necessarily challenge the technical decisions of their subcomponent suppliers.

Lack of Technical ownership

Innovation involves risk. Those who would innovate must also be willing to accept the responsibilities that come with innovation. Engineers and technical professionals at all levels of the design process must be encouraged and empowered to make technical decisions that involve risk. If innovation of the scale that has been demonstrated in this case study is available, managers and administrators must be made aware of the opportunities that exist and the importance of investing in technological advancement.

Void of Academic Interest

Throughout the most productive periods of American manufacturing, manufacturing and production were an integral part of the engineering curriculum. For a variety of reasons, including funding models and an emphasis on high technology, engineering faculty, infrastructure, and research activities have shifted away from traditional manufacturing. Practitioners working in industry typically remain within one subset of manufacturing; academicians typically will work in a variety of areas. The ability of academic practitioners to facilitate technology transfer between industrial subsets is an innovation driver that has been largely overlooked. As academic research becomes increasingly specialized, many of the systems-level opportunities for substantial improvement are going unnoticed. Students are not gaining exposure to traditional industrial settings and are not gaining a breadth of skills necessary to innovate in the traditional industrial workplace.

Challenging Industry Paradigms

A major obstacle to innovation has been the lack of technical ownership. At the level of the manufacturer, engineering expertise is generally focused on process rather than equipment. In many manufacturing plants, the formal engineering presence is nonexistent or is relegated to a role of maintenance. The responsibility for technical requirements of equipment is handed off to equipment suppliers. There are a variety of reasons for this including a lack of expertise and capabilities at the level the manufacturer as well as deference to equipment manufacturers as experts. A comparison of equipment within an industry finds that differences between competing machines are often trivial. Within the industry there have come to be certain expectations of how the machine should work and what their accepted criteria for performance should be. It should be noted however, that industry best practices and conventions do not represent innovation. They merely represent conformance with standards of performance that are often decades-old.

One of the early findings of the design team was that the design of the equipment had not taken energy utilization into consideration. Despite the machine being considered state-of-the-art within the industry, the basic design was nearly 50 years old. At the time of the machine's conception, energy use was not a major consideration. When members of the design team challenged the equipment manufacturer’s choice of spray nozzles, the critique was poorly received. It was pointed out that the machine was consistent with that of many competitors, and that the machine manufacturer has been making machines of this sort decades. However, with a nozzle catalog in hand, some basic flow calculations confirmed that a simple change in nozzle selection could reduce the energy required for pumping by more than a third. This finding inspired the design team to be more aggressive in their challenges of conventional paradigms.

Applying a similar thought process, it was noted that many centrifugal pumps are sized by using cut-down impellers. Using a smaller impeller in the large housing reduces the horsepower required to spin it at the rated speed of the motor. However, there is a substantial reduction in pump efficiency. Because all the pumps that would be used on this machine were equipped with variable frequency drives, there was no reason that the smaller pumps could not be used with the larger, higher efficiency impellers. That is, however, except for the pump supplier’s willingness to provide pumps in that configuration.

A small motor driving a pump with a full-sized impeller, if simply plugged in, would quickly overload because of the horsepower requirements at the rated speed of the motor. The pump manufacturer, wanting only to be responsible for their product, was very resistant to provide a pump that would require additional control circuitry to ensure that it was not overloaded. With pressure from the design team, the manufacturer of the cooling equipment was persuaded to assume technical responsibility for that design choice, freeing the pump manufacturer from responsibility. The benefit of assuming this responsibility was a 10% to 20% improvement in pumping efficiency and a significant reduction in the cost of the pump motors.

In a similar fashion, the independent operations of various contractors and equipment suppliers served as the underlying reason that waste heat from the production process would not normally have been recovered for HVAC purposes. Under normal circumstances, the cooling system would have been sized to accommodate the heat rejection from the process. The heat exchanger would be sized to minimize flow losses. Using those criteria, the temperature of the hot glycol, leaving the heat exchanger would only have been about 70°F. At that low temperature, it would be impractical to try to extract heat from the glycol for any useful HVAC purposes. Additionally, at that low temperature, mechanical chilling is the only viable option for heat extraction throughout the year.

Optimization of heat exchangers is ordinarily based on maximizing heat transfer efficiency and minimizing flow losses [(6)]. However, considering the overall operation from a systems level, the design team was able to recognize that if the temperature of the glycol could be increased substantially opportunities existed for heat recovery and possible secondary heat extraction. The team opted to choose a sub-optimal heat exchanger design that brought the exiting glycol temperature to within just a few degrees of the temperature of the hot water. Looking at this choice at the component level, one would question the optimization. However, the costs of flow losses through the heat exchanger are more than offset by the heat recovery that is possible when the temperature of the glycol is increased to nearly 100°F. at that temperature, 300 to 500,000 BTU per hour are able to be extracted to heat the production floor. The remainder of the up to 1.4 million BTU per hour of heat that must be rejected from production can be extracted through evaporative cooler under almost all ambient weather conditions. The 120 ton mechanical chiller, sized to handle the full load of the plant, remains virtually unused one year after its installation.

Small to medium sized manufacturers make up the majority of the nation's manufacturing base. It is at that level that the greatest opportunities for innovation exist. However, industry must recognize the opportunity for innovation and embrace changes that facilitate those innovations. At the heart of the problem is the lack of integration of subcomponents, equipment, manufacturing processes, and facilities. Integration of these many factors requires a level of interaction in the design process that does not presently exist. In the case study presented here, the systems integration was achieved through the use of a cross-functional design team. Though this approach works well, it requires an extensive commitment of resources and personnel from all stakeholders.

One of the benefits of a cross-functional design team is that the members of the design team become better informed about the concerns and possible contributions of the many stakeholders. Through that process, each team member becomes more generalized. Recognizing that small to medium sized manufacturers typically have minimal engineering staff, it becomes important that engineers in this context have great breadth of technical expertise. Technical generalists who have an understanding of systems engineering principals are able to facilitate the design of integrated systems. Such engineers, particularly in technologically stagnant industries, are a rarity.

Magnitude of Opportunities

The significance of the findings at the sauce plant is directly dependent upon how broadly those results can be duplicated throughout industry. Though it is clear that some manufacturers at higher levels of technology have embraced cooperation with universities [7] , this does not seem to be the case for many industries or universities. The fact remains that the challenges of working with universities cause many traditional industries to shy away from working with academia [8]. Based on assumptions about the similarities between this case study and many other industrial processes, and considering the nature of the opportunities that have been missed, there are compelling reasons to believe that the scope and magnitude of similar opportunities in industry are enormous.

In many of the industries that we now consider to be mature, it has become uncommon to find full-time engineers with traditional 4-year engineering degrees. Among the many reasons that this may be true, we must consider that the companies may have failed to find the value added in hiring engineers. This may speak to a problem with how the companies utilize engineers. However, it may also speak to a problem of the skill sets those engineers possess.

Throughout modern history, many of the greatest advances we've achieved have been developed as a result of the integration of existing technologies in new ways. As engineers have come to rely more heavily on specialists and vendors to perform the tasks of engineering, they often play a less direct role in the design process. As engineering education has become more focused on specialization (being most frequently taught by the highest order of specialists), many graduated engineers lack sufficient breadth of education or experience to be proficient at systems level design. It is in this poorly defined area of technical competence and generality that great opportunities may exist for advancing, traditional industries and addressing complex problems such as energy.

To estimate the scope of opportunities for innovation with existing technology, we may refer to the work of Genrich Altshuller, inventor of TRIZ. While he considered the problem of inventive problem solving, he attempted to categorize problem solutions and their level of inventiveness. Based on his findings, five levels of inventiveness were identified. They are presented in Figure 3.

Level	Nature of solution	Number of trials to find the solution	Origin of the solution	% of patents at this level
1	Parametric	None to few	The designer's field of specialty	32%
2	Significant improvement in paradigm	10–50	Within a branch of technology	45%
3	Inventive solution in paradigm	Hundreds	Several branches of technology	18%
4	Inventive solution out of paradigm	Thousands to tens of thousands	From science—physical/chemical effects	4%
5	True discovery	Millions	Beyond contemporary science	1%

FIGURE 3: ALTSHULLER'S LEVELS OF INVENTIVENESS (9)

The majority of the American industrial base is rooted in what would be termed mature industries. As these industries tend to be driven by established processes and industry best practices, they tend not reach much beyond the boundaries of their specific technology sector. Based on Altshuller's levels of inventiveness, the capabilities to innovate within these industries will include levels 1 and 2 with occasional innovations pushing up into inventiveness level 3. One might generously suggest that of all possible solutions, most mature industries are able to access the bottom 90% of inventive solutions.

In the academic arena, the past 50 years have pushed faculty further and further along the path of engineering science and away from application (10). The emphasis is on basic research and scientific discovery. Those pursuits are geared toward findings at the upper end of level 4 and level 5 – the upper 2-3% of inventive problem solutions.

Comparing the capabilities of industry and the emphasis of academia, we find that there is a large gap – approximately 7% of the upper 10% of problem solutions, that is not addressed by either current industry or the current academic emphasis. This is troubling, as the solutions that exist in the region between level 3 and level 4 inventiveness have historically been among the most impactful on society.

Challenging Educational Paradigms

Most traditional engineering programs embrace specialism over generalism. Engineering disciplines draw territorial lines in the sand and educate their undergraduate students within the confines of what the discipline deems relevant. As academia has increased the focus on engineering science, often to the exclusion of hands-on practice, faculties have developed an increasingly narrow view of engineering expertise. Even for students in Industrial and Systems Engineering programs, where a broader perspective is implicit, the emphasis is on financial considerations and mathematical modeling of systems, often to the near exclusion of fundamental engineering sciences such as thermodynamics and fluid mechanics.

Looking at the relationship between the practice of engineering, the needs of industry, and the education of young engineers, an interesting systems problem emerges. Hands-on practice has been largely been relegated to the less academically prestigious ranks of engineering technology programs – programs that largely emphasize standard industry practices. Meanwhile, the opportunities for transformative change in industry rely on innovations that require advanced technical skill consistent with traditional engineering programs coupled with a level of breadth not found in industry or current engineering curricula.

The value of generalists and their importance to the profession of engineering is a matter of some debate. Those who have noted the importance of creative generalists have also noted the degree to which current academic paradigms do not fill this need [11] [12]. This is not in any way an attempt to downplay the importance of specialization. Rather, it is to point out that technically skilled generalists are a necessity to small-scale systems integration and serve a much needed and largely unfulfilled purpose.

The shift from engineering art to engineering science in the modern curriculum is comfortable from the perspective of the research model of academia. Faculty generally hold doctoral degrees and have a high level of specialization. Though all are generally qualified to teach a wide range of fundamental undergraduate courses, few work actively with industry in capacities outside their narrow band of expertise. They practice only as narrowly focused specialists.

Outside the world of academia, however, the engineering process of design and synthesis is as much art as science. The process involves creativity and the integration of a wide range of constraints that extend well beyond the technical realm. Though some engineers who work in very large companies may be given a narrow focus within their own group of engineers, that is not the norm in most industries. Engineers working in industry are often required to be jacks of all trades. It is possibly a result of the specialist approach to education that has led practicing engineers to increasingly rely on vendors and outside specialists rather than their own technical abilities. The lack of consideration of how these technical considerations must interact is also indicative of a lack of systems perspective in their education.

The opportunities for engineers who have a breadth of expertise, rather than just depth, have been identified by a variety of experts in the field. Dr. Jim Jones, an active curriculum reformer and co-chair of Purdue's mechanical engineering program has referred to these engineers as "Renaissance Engineers." He sees them as playing an important role in the future of engineering, but acknowledges that the nontraditional skill set required to be competitive in the future makes some uncomfortable. In his opinion, engineers need "a strong technical foundation and a broader non-traditional skill set" that is not readily available in traditional curricula. A growing concern is emerging in the literature with regard to the ability of engineering graduates to communicate and to apply knowledge and creativity in the context of the multidisciplinary workplace [(13; 14)].

Several schools have differentiated themselves from the research-centric universities by emphasizing excellent undergraduate education and hands-on application. Rose Hulman, Harvey Mudd, and Olin College stand out as having successful educational models that emphasize this philosophy [(15)].

Throughout society there is an arguably mistaken perception that scientific discovery is at the heart of solving the problems of the world. Though scientific innovation fertilizes the soil of technological innovation, it is the adaptation and integration of those discoveries into existing technology that has the greatest impact. Ingenuity relies on the creative application of existing technologies. Science generally adds to the variety of tools that are available, but seldom provides a fully-realized solution.

Many of the greatest innovations in modern history have evolved because of connections made by applying known technology in a novel way. Often, such innovations have been the result of technology transfer between groups that ordinarily operate with little interaction. Industry changing innovations like seatbelts and airbags have saved more lives than crash avoidance technology and did not depend on fundamentally new science.

The key for most substantial innovations is to identify an opportunity that can be solved by applying existing resources in a new and novel way. When done properly, they represent the solutions that leave everyone slapping their foreheads wondering why they didn't think of it first. Prior to the 1968 Olympics, high jumpers used a variety of jumping techniques to clear the bar. When Dick Fosbury jumped over the bar backward, his unconventional method was dubbed the "Fosbury Flop." It was an unconventional approach that applied the mechanics of the human body in a previously unimagined way to meet the challenge of jumping over an elevated bar [(16)]. Since Mr. Fosbury's gold medal performance, all other methods have become obsolete.

The realm of the engineer has historically been that of the innovator – one who applies a combination of technical expertise and ingenuity to solve novel problems. Though engineers certainly have a place in scientific discovery, the blurring of the lines between engineering and science has led to an arguably unfortunate redefining engineering education. What has resulted is a growing chasm between application and science. Many students coming out of traditional engineering programs are not at a sufficiently high level of expertise to contribute to engineering science, but lack sufficient grounding in practice to be prepared to innovate beyond industry standards.

Universities must offer students an avenue of study that better empowers them to work as practitioners in industry. Through collaboration with industry, expectations of what is possible must be raised. Traditional industries must redevelop an appreciation that engineering, properly applied, offers a path to great innovation – including innovation in energy conservation. This can only be achieved if the relationships between industries, education, and government are redefined in ways that recognize the funding challenges associated with supporting applied engineering programs. Once industries can be shown that transformational outcomes are achievable and cost effective, they must be willing to invest in the system, including the educational system, to achieve those outcomes.

Engineering students of every stripe must learn to consider their work from a systems perspective and recognize that optimization at the component or subcomponent level may not represent optimization of the system. They must be empowered with an understanding of systems integration that includes technical and nontechnical requirements beyond their field of expertise. This can only be achieved by breaking down walls of isolation between specialties within engineering disciplines and with other relevant disciplines such as business and marketing.

Conclusions

The difference in focus between engineering and technology programs has grown increasingly wide as they attempt to differentiate themselves. As engineering programs become increasingly based on engineering science, the practical component of traditional engineering curricula grows weaker. In many programs it is reduced to a single senior capstone project conducted with classmates of the same discipline. Throughout all levels of the system, both industry and academia, over-specialization has created an environment in which cross disciplinary innovation has stagnated. Substantial changes to the paradigms in both industry and academia must be explored to help fill the huge opportunity for innovation that has evolved.

As nations wrestle with energy independence and industrial competitiveness issues, the role of engineers becomes more important than ever. The emphasis of engineering science as a means to scientific innovation has been strongly and embraced in the academic community. However, it must be recognized that many of the greatest innovations in human history have been based on the application of existing technologies in new and revolutionary ways. The ability to innovate and integrate has traditionally been the realm of the engineer, but demonstrable and substantial opportunities are being overlooked under the current paradigm. Engineering solutions that are fundamentally systems based in nature offers the greatest hope for immediate results.

Further work must be done to validate the supposed size of these opportunities in industry. As the volume of evidence grows to support this avenue of innovation, the scholarly nature of these pursuits must be embraced at the academic level. The talents of engineering faculty must be brought to bear on the problem, and industries and universities must partner and adapt to better address the emerging challenges.

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