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Technical Editor's Page

Pressure Vessel and Piping Technology: Two Decades of Progress and Future Challenges

First Annual Irwin Berman Lecture given by D. H. Pai[1]

The organizational and technological advances of the last two decades in the U.S. Pressure Vessel and Piping (PVP) Technology are first traced. Highlights of growth in the major organizations supporting PVP technology: ASME Boiler and Pressure Vessel Code, Pressure Vessel Research Committee, and the ASME Pressure Vessels and Piping Division, are given, along with highlights in the technological advances in Design Analysis, Materials and Fabrication. Future challenges in key technological areas for PVP engineers are discussed, including the role of the PVP engineer in developing technologies such as BIOTECHNOLOGY, SUPERCONDUCTIVITY, MICRO-ELECTRONICS, ENERGY, ENVIRONMENTAL ENGINEERING, and ADVANCED MATERIALS. This paper concludes with a discussion of two major institutional challenges of our time: winning public acceptance of technology; competitiveness and foreign trade.

It is indeed a double honor for me to receive the PVP Award and also to be the first to deliver the Annual Irwin Berman[2] Lecture. There is a deep personal meaning for me to give this lecture since Irwin recruited me to work for Foster Wheeler, and he also encouraged and supported me to actively participate in ASME activities, particularly the activities of the Pressure Vessels and Piping Division.

As many of you know, the PVP Division celebrated its 20th Anniversary last year. Irwin Berman was one of the founding members of the Division; therefore, I thought it appropriate to share with you some of the progress of the past two decades and to briefly outline some of the many challenges that lie ahead for our profession.

Organizational Growth

The ASME Code plays a central role in the orderly progress of the Pressure Vessel and Piping Industry in the U.S.A. For R&D back-up, the ASME Code draws upon the Pressure Vessel Research Committee (PVRC) frequently for support. Finally, the Pressure Vessel and Piping (PVP) Division provides the broad forum where much of the research information and new ideas are exchanged. In the following I shall briefly highlight some of the major milestones of these three organizations.

The ASME Code. The ASME Code has had a long and illustrious history, having officially started back in 1914. It occupies a unique position in the world of commerce and technology. It is accepted in the United States and Canada as a legal document, and thus, is considered a standard of quality by which products are judged throughout the world. In fact, 30 percent of the current Code Stamp holders are from countries other than the U.S. or Canada. The fact that it is a voluntary standards organization makes it that much more significant. The Nuclear Code, Section III, is a prime example of a monumental task well done during the 1960s and 1970s. To outdo itself, the Code took on the problem of Elevated Temperature Design and managed to codify a very difficult technological area. Many of you had a direct role in this accomplishment. Another example of major accomplishments of the past two decades was the completion of the High-Pressure Code, which is a direct contribution of the OAC Committee of the PVP Division.

The Pressure Vessel Research Committee (PVRC). The PVRC provides an excellent example of cooperation between competitors to solve common pressure vessel-related problems. It has also enlisted the support of our European and Japanese colleagues to sponsor research leading to the solution of many problems in Design, Fabrication, and Materials. For example, the PVRC coordinated the major effort, sponsored jointly by government and industry, to perform low-cycle fatigue experiments (from uniaxial specimens to full-scale vessels) in order to validate the design methods for low-cycle fatigue as it exists today in Section III of the Code. Very recently, through its ongoing Task Force on Nuclear Piping, the PVRC provided peer review and acted as the catalyst agency to assist the Nuclear industry and the NRC in the critical review of existing piping design practices. Some far-reaching recommendations on damping values and snubber design have already been made by that group. Of course, most of you in the audience are familiar with the many WRC Bulletins (e.g., WRC 107), which became indispensable references to the

[1] 1987 Recipient of The ASME Pressure Vessel and Piping Award. Presented at the Fifth National Congress on Pressure Vessels and Piping Technology, San Diego, California, June 28–July 2, 1987, of The American Society of Mechanical Engineers.

[2] A tribute to Irwin Berman is included at the end of this paper.

vessel engineer. In as much as a stagnation of funding has curtailed the growth of the PVRC, that body fought a war of survival and is holding its own. It continues to sow seeds of development. Those of you who helped keep the PVRC activities alive and meaningful, should be congratulated on your efforts.

The Pressure Vessels and Piping (PVP) Division. The PVP Division was formed in 1966 at the urging of the ASME Code personnel. Over the 20-yr span, it has grown to a Division consisting of 3834 primary interest and 10,605 secondary interest members. Along the way, the Division helped foster two other ASME Divisions:

- The Computers in Engineering Division was given much impetus in its formation by members of the PVP Computer Technology Committee.
- The NDE Engineering Division had its start as part of the PVP Materials and Fabrication Committee. Our most immediate past Chairman of the PVP Division, Jeffrey Fong, was instrumental in helping to organize this new division.

Exciting activities sponsored by this Division are well known. For example, international conferences in famous capitals (such as Delft, Tokyo, London, and of course, next year in Beijing) bring together worldwide talents in our field. Another major contribution made by this Division is in the area of Continuing Education, where the PVP Division is a forerunner. It continues to offer a great variety of courses for our members and guests. Lastly, I want to congratulate the excellent job our authors, editors, session developers are doing to uphold the tradition of efficient and high quality information dissemination. The many papers and special publications are a continuing tribute to the many hours of voluntary time put in by some very dedicated individuals.

It is interesting to note that even though the PVP Division is "maturing," having just had its 21st birthday, I am gratified to note at this Conference that the excitement is undiminished. I am confident the continued progress of this Division is assured with active participants such as yourselves.

Today, we can look back with satisfaction, knowing that in the U.S., PVP industry is well supported by the ASME Boiler, Pressure Vessel, and Piping Codes, with the help of the PVP Division and the PVRC.

Technological Advances

The last two decades saw great strides made in PVP technology. During this period, one underlying development that drastically changed the landscape of our industry, was the steep rate of improvement of the digital computer. In the 1960s, the use of the computer began to make an impact on design and analysis. The rapid development of finite element software and the continuing increase in computing speed and storage capacity of the computer, has afforded us the luxury of carrying out detailed design/analysis of hardware. Initially, in the early to mid-1970s, because of the limitations on computer turn-around time, detailed finite element analyses were generally reserved for confirmatory analyses. Today, we are able to accomplish these tasks routinely, in an interactive mode, using micro-computers. As a natural corollary to this development, Computer Aided Design (CAD), and now, Computer Aided Manufacturing (CAM), are becoming commonplace even for relatively small organizations. The rapid development of expert systems, artificial intelligence, and super-computers will further enhance the rate of progress in this area.

Although there have been no major breakthroughs in the last two decades in the area of Materials and Fabrication, comparable to those created by the computer for design/analysis, many refinements were achieved. Specific examples are:

- Better control of material elements
- Improved processing techniques
- Ability to tailor materials for specific environments
- Higher deposition rates for welding
- Automated welding through robotics

All of these refinements lead to better quality.

Another area of rapid advancement in the last two decades is in Non-Destructive Examination (NDE) methods. The advances in Ultrasonics, Eddy Current, X-Ray, and Acoustic Emission techniques have provided us with much more powerful and reliable NDE tools. This has, in turn, helped us in upgrading the quality of manufacturing and in doing a better job at ISI (In-Service Inspection), and ultimately, help to prevent or reduce failures.

No attempt has been made herein to be comprehensive; a detailed description, by discipline, of our industry's progress is well summarized in the *Decade of Progress* [1-3] published by ASME, with the full participation of the personnel in this division.

Future Challenges

There are many challenges we must face in the remainder of this century and beyond; some technological, and others, institutional. I would like to highlight some of the challenges to our profession from the point of view of an "over-the-hill" PVP engineer.

Technical Challenges. Before discusssing some of the technical challenges facing us, it is instructive to review the more global technical challenges facing the technical community. I believe that the majority of the technical community will agree that we are on the verge of major breakthroughs in **Biotechnology** and **Superconductivity**. We have made much progress in **Micro-Electronics**, but much more progress is in store for us. In the area of **Energy**, the world will continue to struggle for more. The U.S., in spite of our abundance in natural resources, will continue to depend on foreign oil supply and be vulnerable to future oil crises. In the area of **Environmental Engineering**, we are already behind in our efforts to stem the tides of pollution. Enormous amounts of work will be needed just to make a dent in our solid waste disposal and hazardous waste cleanup problems. Of course, the solutions to acid rain problems remain in limbo due to deliberate political impediments. Finally, no list of this nature is complete without the inclusion of the development of **Advanced Materials** for engineering.

As PVP engineers, where do we fit into this overall scheme of things? I personally believe our training and experience have prepared us to make major contributions in all of the above areas. Some specific examples will help illustrate my point:

Biotechnology. One of the main challenges in Biotechnology is to scale-up laboratory or benchscale experiments to production. Equipment, such as bio-reactors, will require careful consideration by PVP engineers both in terms of design and material selection. Even though the operating conditions (temperatures and pressures) are usually benign by our traditional industry standards, the consequences of leakage and equipment failure could be severe because of sensitivity of the public to perceived or real threats of unknown microorganisms. I am sure I need not convince you that this field holds tremendous promise in bringing us a higher quality of life. It deserves our attention and talents in order to make the processes safe.

Superconductivity.[3] 1987 may go down in history as the year when superconductivity made a quantum leap in progress. In a short span of a few months, we saw dramatic increases in the temperature at which superconductivity can be achieved through the judicious use of alloyed materials. That is, temperatures achievable using liquid nitrogen instead of the much more expensive liquid helium. Many problems remain to be solved before commercial application can begin. For example, the new crop of materials, which have shown to exhibit superconductivity at higher temperatures, are also limited in current density that they can carry. Another problem is that these new superconducting materials are difficult to work with in manufacturing. Nevertheless, the implications of these discoveries are enormous, ranging from greatly improved micro-electronics to greatly reduced cost of electricity transmission. The PVP engineer will, no doubt, be called upon to design and build cryogenic systems both for manufacturing of components and for underground transmission conduits. This is a very exciting development, one which will touch our daily lives in so many ways.

Micro-Electronics. I have already spoken about the impact of the digital computer on our profession. The ability of the electronics industry to miniaturize components and equipment is limited by the ability of the design engineer to come up with ways to dissipate heat generated by the equipment during operations. With the development of newer and more exotic materials, the power of the chips will increase at the same time, the desire to further miniaturize these components remains. Thus, the problems of heat dissipation, packaging, and shock-proof design, etc., of these systems will continue to mount. The PVP engineer, with a practical flair in heat transfer and shock design/analysis can also make an impact in solving some of these problems.

Energy. There are endless challenges to the PVP engineer in the energy industry. I will just list a few examples of some energy systems, which have the potential to satisfy future needs, to illustrate how we PVP engineers can contribute.

1 Fluidized Beds: For small to medium size (up to 200 MWe) power plants, fluidized bed systems could be an excellent candidate because of its sulfur removal capability and the system's adaptability to modularization. The first-generation atmospheric "bubbling" beds have proven the case for fluid beds in spite of some of the problems associated with in-bed tube erosion and lack of fuel flexibility. The second-generation atmospheric "circulating" beds will overcome these shortcomings. To carry the technology one step further, we are now working on pressurized fluidized beds. Basically, this is a fluidized bed contained in a pressure vessel. The advantage of pressurization is to increase the efficiency and reduce component size, and hence, reduce electricity cost. In fact, studies have shown that with this scheme, one can build all major components in the shop and thus reduce field erection time. A good description of all three types of units can be found in reference [4]. The design and manufacturing problems associated with all of these units are "bread and butter" to the majority of the audience in this room. I am sure some of you are already contributing your talents to solving these problems. In time, others will also, given the opportunity.

2 Advanced Pulverized Coal Power Plants: The Electric Power Research Institute (EPRI) has identified pulverized coal, once-through, supercritical plants as having a high potential to become the central fossil station of the future. The operating conditions for such units are targeted ultimately at:

Turbine throttle pressure:	4500 psi
Superheater temperature:	1200°F
Reheat (double reheat) temperature:	1200°F

As you can see, these are conditions reminiscent of the Eddystone Station (where a major failure of a high-pressure/high-temperature piping occurred), except that these are more severe. At these temperatures and pressures, we must be careful with material selection, high temperature design methods, welding and construction quality control.

3 Inherently Safe Reactors: TMI-2 and Chernobyl have proven to us conclusively that Murphy is still working overtime! Therefore, every effort should be made to assure that future reactors are "inherently" safe; i.e., able to shut down safely *with* or *without* active human intervention, and be tied to an on-site integral fuel cycle to prevent proliferation. Judging by preliminary designs of the PRISM (Power Reactor Inherently Safe Module) [5] and SAFR (Sodium Advanced Fast Reactor) [6] programs, coupled with the April 1986 safe shutdown tests at EBR-II [7], we have proven that it is possible to design an inherently safe reactor. The main challenge remaining is one of cost, and social acceptance. Again, PVP engineers have played a major role in these projects and are expected to continue their significant contributions.

Environmental Engineering. Few of us will dispute the fact that we have not done a good job in safeguarding our environment. The problems of solid waste disposal and hazardous waste cleanup are taking on crisis proportions. Densely populated states, such as my home state of New Jersey, are running out of landfills for municipal waste disposal. One very effective way to reduce the volume of solid waste and recover energy from the waste is by means of Municipal Solid Waste (MSW) incineration in which solid waste is used as fuel to fire a boiler that in turn provides steam for power generation or other uses. Although most of the equipment is not new, the question of equipment reliability takes on more binding meaning, since any prolonged, unscheduled down-time will cause garbage to pile up, resulting in public health concerns. Also, many of these plants are built, owned and operated by the same consortium and down-time equals lost revenue and poor cash flow!

With respect to hazardous waste, the $8.5 billion Superfund Amendment Reauthorization Act has underscored Congressional resolve. Much hard work lies ahead. Currently, the two leading candidate methods of disposing hazardous waste are incineration and ground containment. The former is usually very expensive, and the latter is not desirable since we have merely left the poison in the ground for posterity to worry about. Thus, opportunities exist for engineers to be innovative in our search for more effective means of hazardous waste cleanup.

Advanced Materials. For as long as I have been an engineer, I have always felt a sense of frustration at the limits placed on our engineering options by materials. Often times we are limited by low material strength at high temperatures; other times, we are hard pressed to find an economic material to withstand the environment (e.g., corrosion, erosion). As of late, much progress is being made in ceramic and composite materials technology. Of course, the method of joining these materials to themselves and to other materials remains a major challenge. I am sure we will be called upon to develop design and fabrication methods for these new and exciting materials.

[3]Strictly speaking, one can argue that Superconductivity is a subset of Advanced Materials development. I have singled it out here for emphasis.

Institutional Challenges

So much for the exciting things that we can look forward to in the challenging technical arena. However, we are not going to be very successful in the final analysis unless, and until, we learn how to deal with some of the major institutional challenges we face today. In the following I would like to touch upon two major issues:

- Public acceptance of technology
- Competitiveness and world trade

As some of you know, Foster Wheeler (my employer) is in the MSW (Municipal Solid Waste) incineration business, among other things. Recently, I had an occasion to chat with one of our MSW project directors, an excellent engineer and program manager. He is in the midst of spearheading a project through the tedious permitting process. It was interesting to hear his account of a project review meeting he had just attended the previous day on the project. There were eleven people at the meeting; he was the only engineer! Of the remaining ten attendees, five, or exactly one-half, were lawyers (local government attorney plus an outside counsel, the county government attorney plus two outside counsels). Two were county and local government officials respectively, one was the State DEP (Department of Environmental Protection) representative, one was a banker, and one was an investment advisor. Each of these wanted a piece of my colleague's hide!! Here, ladies and gentlemen, is a microcosm of a modern engineer's lot. He must satisfy the myriad of demands from the legal to the regulatory to the financial communities before he and his team can even get up to bat!!

As you can see, engineering and building the plant is going to be easy compared to all the legal and regulatory hassles. Unfortunately, this is going to be the norm, not the exception, to most projects, particularly projects affecting public health and safety. Since a pressure vessel or piping system, by definition, has safety connotations, we had better learn how to deal with the public. In our current litigious society, with an anti-technology bias, it is no longer sufficient to just do a good job of engineering. The engineer, if he wants his project to be accepted by the public and to succeed, must be an active advocate of technology. He must communicate his cause to the end user showing cost/benefits or less desirable alternatives, if necessary, so as to mobilize public opinion. Therefore, we engineers must not only be good with our trade but be in tune with the socio-economic demands of the times. We must seize every opportunity to improve public relations with the rest of the populace. Striving for flexibility and adaptability without sacrificing technical excellence is going to be our mission.

A discussion of challenges to our profession will not be complete without touching on the subject of competitiveness and foreign trade. The restructuring of the U.S. industries is in full force. Few of us in this room have not been affected by it in some form. In fact, the heavy vessels industry has born the brunt of this down-turn because of the slow-down in the power and petrochemical industries. Even the efficient Japanese shops, with their cradle to grave employment tradition, are laying off workers because of lack of demand worldwide. It is not clear to me whether the U.S. vessels manufacturing industry will ever return to its glory days of old when the demand for power and petroleum picks up again. This is because of a natural shift of work towards the cheapest qualified and available labor pool (e.g., from the U.S. to Japan to South Korea, etc.). As our standard of living rises, it is natural to see a shift in labor-intensive manufacturing to other developing centers of the world. If South Korea is beginning to make an impact, can Taiwan be far behind? How about the People's Republic of China, with its enormous human resources? I submit that this is a natural tide of events, and we must learn how to survive and thrive in it. The key here is to **think international**. In fact, it is dangerous to entertain isolation or protectionism. History is filled with failed "protected" enterprises.

I do not know how things are going to shake out, or if they ever will; but I do know we need to continue building better "mouse traps" whether these be better software, NDE tools, welding methods, or super-conducting supercomputers! In short, we must be constantly on our toes in striving to be innovative and be ahead in technology. Only then will we be able to bring substance to the table when we try to collaborate with our friends overseas so as to pool together our resources to compete in the international arena.

In summary, we have come a long way; but many battles remain to be won. The old Chinese saying about learning is just as applicable for our profession today in order to prepare us for the next century:

"Xaw zu li sui shin zȟo, bu jin ze tway"

I will try to paraphrase it here: "Learning is like rowing a boat upstream, we either advance or we will be swept away."

Judging by some of the papers I have heard at this conference, we have not lost our touch. I am sure you ladies and gentlemen will be worthy competitors in the upcoming battles to excel.

References

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A TRIBUTE TO IRWIN BERMAN

Much is known about Irwin Berman's many professional accomplishments and his contributions to ASME. A few highlights will serve to start our discovery of Irwin Berman—the person.

- He was a founding member of the ASME PVP Division, and became its Chairman in 1972.
- In 1981 he became the first Chairman of the ASME Council on Engineering, and later (1983) was named Senior Vice President of the Society.
- He was elected to the Board of Governors in 1985 and served on that body until his untimely death.
- He worked at Foster Wheeler for over 30 years and was instrumental in bringing to the company new and innovative

methods of design, analysis and fabrication of equipment and structures. At the time of his death, he was Chairman of the Technical Directorate, a council of outstanding technical experts in the major disciplines affecting the company's business.

- He was an energetic innovator, with over 50 publications and 15 patents to his credit.
- He was also active in advising higher education by serving on advisory committees (e.g., he was Chairman of the New Jersey Institute of Technology, Advisory Committee for Mechanical Engineering).

These outstanding professional accomplishments are known to many in our midst. What is not well known is Irwin Berman – the person.

Irwin was born in 1926 in Brooklyn, New York, into a Russian Jewish immigrant family. From a very humble beginning, Irwin struggled against hostile environments and succeeded in entering the City College of New York at the very young age of 16. Before he could complete his college education, World War II interrupted. He served as an infantryman in the European theater and fought against the Nazis. Because of his facility with Yiddish, he became a translater in his unit. For a brief period after the war, he even became the unofficial mayor of a town occupied by his infantry unit! He returned to CCNY after the war to complete his studies and received his B.S. in M.E. in 1948. Upon his graduation from CCNY, he was employed by the Curtiss Wright Corporation, where he designed ram-jet engines. While at Curtiss Wright, he studied part-time at Stevens Institute of Technology and received his M.S. in Applied Mathematics in 1953. He left Curtiss Wright in 1956 and enrolled at the Brooklyn Polytechnic Institute (now, New York Institute of Technology), from which he received his Ph.D. in Applied Mechanics in 1959. At Brooklyn Poly he did research in Plasticity under Professor Phillip Hodge. His interest in Plasticity led him eventually to work for Foster Wheeler, where he introduced many of his ideas in metal fabrication, and design and analysis of vessels, piping, and heavy structures.

Irwin was a nice guy! A simple, but all encompassing tribute! He was kind and considerate to his co-workers. He was tolerant of views of others. His hard work and enthusiasm rubbed off on all of us. It was difficult to say "no" to Irwin.

Irwin was a very devoted family man. The love of his two sons is legend among friends who knew him.

We will all miss him.