

# PUMPS—2000 AND BEYOND

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## INTRODUCTION

It is an honor and a privilege to *welcome* you to the event that, more than any other, *facilitates* who we are and what we are *becoming* as an industry. It is also my privilege to have served on the Advisory Committee all those years since the first Pump Symposium in 1984. The associations with other hydraulic engineers such as I am—and with the many users whose concerns I never would have appreciated—have given me a perspective that could have been acquired in no other way. The benefits of this perspective in many others besides myself have accrued not only to the users but also to our own companies—because our efforts in response have led to new products and design improvements that make me happy to have spent most of my professional life in the pump business. They are indeed fascinating devices that come in every imaginable configuration. Thus, the unique fact about this Seventeenth International Pump Users Symposium—and the others before it—is that we all are here this week. You, the users, manufacturers, consultants, including rotating machinery and design engineers, maintenance and field service experts, sales, marketing, purchasing, and management personnel are among the major players in this huge industry worldwide.

We have ended the millennium with an ever broadening product mix and a host of technical advances. Why did this happen? What exactly did we do? And how did we do it? Not too long ago, some of us who were organizing ASME fluids engineering sessions asked three prominent pump technologists to help us understand—and to provide us with some vision for the future. Their assessments were surprisingly complementary—without much overlap (Table 1). In my opinion, they clearly demonstrate that

what we have been doing in the pump users symposium has been part and parcel of the pulse of our industry. First, Professor Hideo Ohashi, of Kogakuin University in Tokyo, provided the framework as to *why*. He identified the socioeconomic phases or trends (Table 2) to which the pump industry has responded and still is responding. Peter Hergt of KSB gave us an idea of *what* the industry did. He indicated the product range and developments that have evolved in this response, and Dr. Gopalakrishnan of Flowsolve told us *how*—by emphasizing the advanced technologies that have made the results possible (Ohashi, et al., 1997).

Table 1. Vision for the Future.

<b>Why</b> (Ohashi)	<b>What</b> (Hergt)	<b>How</b> (Gopalakrishnan)
<b>Socio-Economic Phases or Trends influencing the pump industry</b>	<b>Range of Pump Products in response to this influence</b>	<b>Advanced Pump Technologies that fueled the response</b>
<b>User input through the pump symposium</b>		

Table 2. Socioeconomic Phases/Trends.

<b>Phase 1: Expansion</b> Increasing production of all types and sizes; larger high-energy pumps
<b>Phase 2: Conversion (Environment)</b> Redesign and deployment for energy conservation and emissions control
<b>Phase 3: Globalization</b> Competition and consolidation of companies Emphasis on quality, manufacturing efficiency

The user input at this annual symposium has had a profound impact on the *what* and the *how* of this scenario. You users were truly the technology drivers. The necessity of the problems you brought to the table was the mother of the often inventive technical solutions. And the problems themselves arose because the three socioeconomic phases were creating the product demand.

## THE PAST

### *The Expansion Phase*

The first phase was the expansion of the industry in the post-World War II period, in which the whole world sought to address the pent-up wartime demand, building pumps of all types and sizes in great quantities, as well as building ever larger and more powerful pumps. We are all familiar with the range of pump types that are represented here at the symposium, running the gamut from high-pressure reciprocating pumps through the several rotary types and into the impeller pumps of increasing specific speed out to the high-flow propeller type. In addition, there are the specialty types such as multiple-disk pumps, pitot pumps, and jet pumps, to name a few. This product mix applies to the variety of niches that exist for moving fluids; e.g., a family of submersible pumps represents only one of many pumping configurations—almost too many to number.

In terms of size, at the low end of the spectrum, Peter Hergt speaks of small home heating circulating pumps. He reports that 15 million of these 70 Watt pumps are being manufactured in Europe annually, with five million being fitted in new installations and consuming over 300 MW of power. As such, in the next socioeconomic phase (the environmental one), this little pump became the focus of a redesign effort to save energy.

On the other hand, at the high end, the expansion of electric power plants demanded huge high-energy pumps that supplied the boilers. Similar scenarios undoubtedly explain the appearance and upgrades of many other pump types that were developed for new and larger processes. Some of these pumps were ahead of their time and suffered from problems that were not well understood and which were creating reliability and maintenance headaches. This is the situation that existed when the pump users symposium was established. The participants presented and discussed the *problems* (Table 3)—as well as those afflicting many smaller pumps. *Solutions* in fact did emerge and were presented in the lectures and tutorials. Moreover, the means or tools for getting the job done were explained by technologists representing both the manufacturers and the users.

Table 3. Addressing Pump Reliability.

<u>Problem</u>	<u>Solution</u>	<u>Tools</u>
<b>Vibration: Rotor &amp; Structural</b>	Quality mfg, balance Stabilizing features FEA	Rotordynamics codes, coefficients Modal analysis Field monitoring
<b>Cavitation</b>	Special blades, Inducers, materials	Life prediction eq's Flow visualization
<b>Hydraulic Instability</b>	Lower $N_{ss}$ Optimized Gaps A, B	Appl. guidelines Min. flow prediction

Vibrations were and still are the primary measure of the operational health of a pump installation. Prodigious efforts were made in finding solutions to both rotor- and structure-related vibrations. Dr. Gopalakrishnan, as well as Dusan Florjancic and others, contributed to our understanding of *rotordynamics* and to the improvements that were forthcoming in this area. Important data on coefficients for computing rotor behavior were obtained, and features such as swirl brakes were introduced to aid rotor stability. *Structural* modal analysis—both finite-element (FEA) and experimental—became common as an aid to the design and improvement of the pump components and mounting configurations.

*Cavitation* affects both performance and pump life, inducers being adopted where high suction specific speeds are unavoidable. Don Sloteman and others viewed cavitation in real pumps in the laboratory (Figure 1), and this led to improved blade shapes that have eliminated cavitation damage in some important applications (Figure 2) (Cooper, et al., 1991). Materials have played a role in the erosion phenomenon, which Johann Gülich quantified with a method for computing the life of an eroding impeller. Using his method as a basis allows us to establish what the limits are on the pressure rise of a centrifugal pump stage to ensure the achievement of a required life—e.g., 40,000 hours.

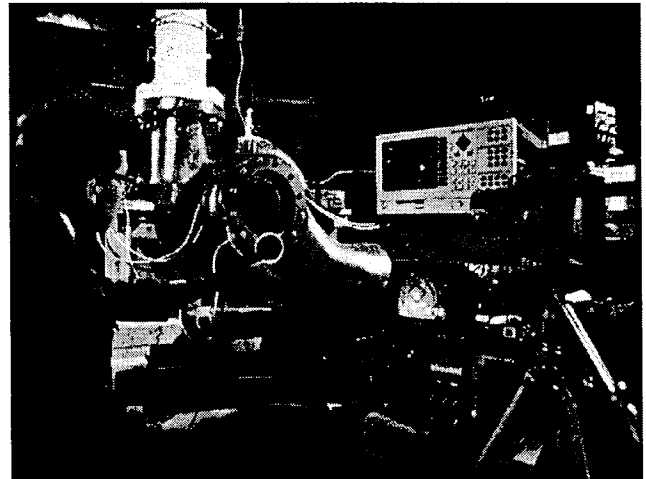
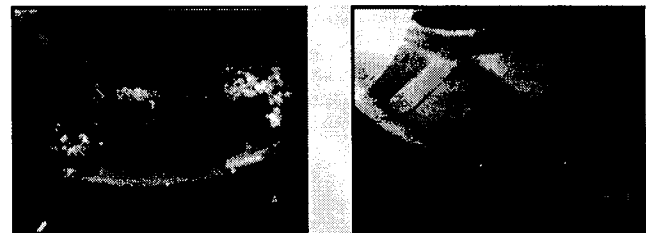


Figure 1. Viewing Cavitation.



**Conventional  
impeller design**

**Improved impeller  
blade shape**

Figure 2. Eliminating Cavitation.

Beginning with the first pump symposium in 1984, Dr. Elemer Makay provided hundreds of case histories to prove that optimizing the impeller OD gaps would substantially reduce the pressure pulsations and eliminate the structural failures connected with the *hydraulic instabilities* of low-flow operation. He provided us with illustrations of damaged impellers to dramatize why these improvements are necessary. Axial shuttling was cured by this technique.

And low-flow instabilities were at the same time identified with pump failures. The users, notably, J. L. Hallam, convinced the manufacturers to return to lower suction-specific-speed centrifugal pumps. The actual effect of the design value of suction specific speed on minimum flow was soon quantified by Dr. Gopalakrishnan and Charlie Heald in new minimum-flow prediction methods.

## THE PRESENT

### *The Environmental Phase*

These new tools for improving pumps also found application in meeting the challenges of the second socioeconomic phase—in

which there has been a conversion of our design philosophy as well as the product design itself. The design process moved away from a strictly performance-oriented activity to one driven by the environmental concerns of energy conservation and emissions control (Table 4). Sophisticated, computerized hydraulic analysis and design software had been developed in response to the earlier performance goals and had helped in meeting those goals. This capability was now directed at the energy savings objective and so became the basis for upgrading and redesigning many pumps—as well as designing new, often downsized pumps.

Table 4. Addressing the Environment.

<b><u>Problem</u></b>	<b><u>Solution</u></b>	<b><u>Tools</u></b>
<b>Energy consumption</b>	<b>Efficiency Improvement</b>	<b>Hydraulic design software</b>
	<b>Matching pumps to systems</b>	<b>Electronic pump selection systems</b>
<b>Emissions</b>	<b>Sealless pumps</b>	<b>Bearing lubrication analysis software</b>
	<b>Advanced mechanical sealing systems</b>	<b>Seal design and analysis software</b>
	<b>Gas seals</b>	

But pumps that were otherwise quite good had been routinely mismatched to the systems in which they were installed and were running off-design at low-efficiency, and near minimum flow. User John Joseph has chronicled the practice of piling safety factor on top of safety factor as the pump passes through the hands of different persons in the chain from specification through the purchasing, design, and operation processes. Some suppliers—including Dr. Tryg Dahl in my own company—developed electronic pump selection software that makes it easier for users to optimize the deployment of one or more pumps—so as to share properly the pumping task and to maximize the efficiency of the whole system.

The emissions issue became paramount in the environmental phase, and this caused a major change of emphasis not only in the industry, but also in the pump symposium, which shifted dramatically to meet this challenge—mechanical seal professionals becoming major planners and participants. Sealless magnetic-drive pumps were introduced; but here again these products were ahead of their time. The complexities of assuring a supply of cooling and lubricating flow to the new product-lubricated bearings were not well understood and led to failures. Software to compute these flows and ensure application only where they work reliably did not come immediately, and not all manufacturers of these pumps had access to such information. In the meantime, we witnessed, in a relatively short length of time, a quantum improvement in mechanical sealing technology, accompanied by the tools to realize these advances in dramatically reducing emissions. Gas sealing is among the major achievements of this initiative. Once an exotic concept, these seals are finding increasing application in pumps. The symposium provided synergy that helped the industry move forward on this issue, and as we will see in this Seventeenth International Pump Users Symposium, there is more to come. The environmental challenge continues.

**THE FUTURE**

*Globalization*

Yet, in the midst of this we are now faced with the third or “globalization” phase. Unlike the other two phases, there is no

demand by society to explain this trend. Rather, it simply follows from the ease of communication and access to world markets. We are indeed seeing the combination of many familiar pump companies. Many of the old names are changing—some disappearing—and greater multinational companies are being formed. Is it simply global economics that fuels this trend? In the past decade, modern industrial management has developed a renewed focus on satisfying the customer, and the world’s users are demanding afresh what they have always wanted. In this atmosphere of today’s pump industry, these needs have a better chance of being satisfied than ever before. The list is not unfamiliar and, as seen in Table 5, includes lower cost, better efficiency and performance, shorter delivery times, simplicity (particularly with regard to installation and operation), reduced and easier maintenance, durability (and reliability), and rapid response to problems from purchase to field service. These are the drivers, and globalization promises to be the catalyst for more rapid progress forward by manufacturers in responding to them.

Table 5. User Needs—Drivers for 2000 and Beyond.

- **Lower cost**
- **Better efficiency and performance**
- **Shorter delivery**
- **Simplicity**
- **Reduced and easier maintenance**
- **Durability**
- **Rapid response**

How will we in the pump industry address these needs in 2000 and beyond? In fact, these drivers have created new goals for the industry (Table 6). I will try to go through some of them; perhaps you will have others. I will also indicate some of the approaches that could be taken to reach these goals—together with some examples from my own experience. You will certainly be able to add to them.

Table 6. Goals for Pumps in the Third Millennium.

<b>Goal</b>	<b>Approaches</b>
• <b>Low life cycle cost</b>	• <b>Integral motor pumps and advanced seals</b>
• <b>Zero emissions</b>	• <b>Variable speed</b>
• <b>Operating efficiency</b>	• <b>Artificial intelligence</b>
• <b>Global designs</b>	• <b>Patterns via CAM</b>
• <b>Rapid manufacturing</b>	• <b>Six sigma quality</b>
• <b>Lower MTBF</b>	• <b>CFD, Mag. bearings</b>
• <b>New technologies</b>	• <b>R&amp;D Alliances</b>
• <b>Match to application</b>	

First and foremost, we are now beginning to realize that the primary driver of “low cost” is leading the user, manufacturer, and consulting engineer alike to address the total picture, not just the first cost. Weaved into this picture is the continuing environmental challenge: zero emissions. Here again, technology enters. The ever improving sealing technologies will continue to play a role, and the

goal of simplicity will be one of the challenges here. Igor Karassik and Terry McGuire, in past addresses, predicted what promises to be the ultimate in simplicity, namely the integral motor pump; i.e., a pump and motor combination in which the impeller is the rotor of the driving motor. Looking at this pump, one looks in vain for the motor. The only connections with the outside world are the suction and discharge flanges and the electric wires. The speed is variable, enabling the unit to be exactly matched to the system and so to meet the operating efficiency goal. The power of rare earth magnets is making this concept a reality, a 400 hp double suction pump having been demonstrated (Figure 3) (Sloteman and Piercey, 2000). A low horsepower ANSI/ISO version, in comparison to a conventional, close-coupled motor and pump, shows the size advantage of such a concept, and simplicity is again evident (Figure 4). The variable-speed feature allows the smaller sizes to run at higher speeds than those of conventional motors. In fact, considerably higher speeds are possible with such a concept if it can be applied to a similarly small, high-head, single-stage inducer-fed pump.

400 hp  
3000 gpm  
400 ft  
2300 rpm  
Variable-speed  
Double-suction

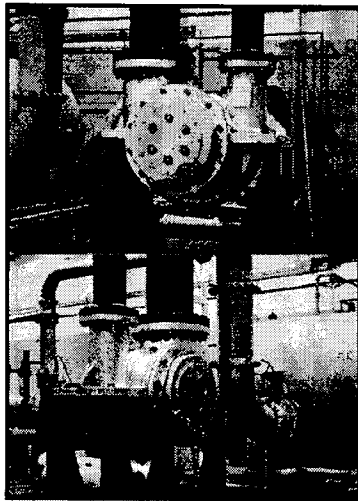


Figure 3. Large Integral Motor Pump.

Sealless  
integral  
motor pump

Example of a close-coupled  
commercial process pump using  
mechanical shaft seals

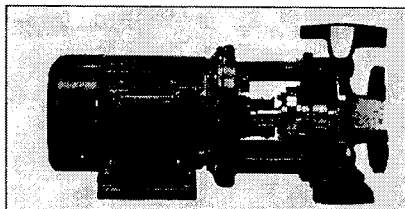
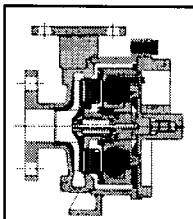


Figure 4. Comparison of Integral-Motor ANSI/ISO Pump with Conventional Pump.

Many pump types will be of global design—an efficient way for a global manufacturer to meet performance goals while satisfying the largest possible body of users. An example of such a product is the ring section pump, which is being built in all sizes for many different uses. Peter Hergt cited a high-energy boiler feedpump from his product range as an example of such a machine.

In the restructuring that is happening as an adjunct to globalization, much knowledge is being lost. Yet, there is on the horizon the mathematical concept of neural networks, which have the power of decision making—once they are “trained” by experts.

This kind of artificial intelligence will increasingly find its way into the design process that is demanded in the development of global products. In fact the concept can be expected to find application in every aspect of the business—from design to field troubleshooting.

Rapid manufacturing and quality are becoming the major concerns for the new global companies and will largely determine which ones survive. The technologies we have seen in the production of prototypes from a three-dimensional CAD file that describes the part have advanced considerably—having started with stereolithography several years ago. The promise of this approach lies in the generation by such methods of patterns—and of tooling for precision castings. The quality issue is being formally addressed in many companies today—including my own—by the techniques of the “six sigma” process. A rudimentary example of how this process impacts the product design comes through a formal “failure mode effects analysis” (FMEA) that has the goal of reducing the mean time between failures (MTBF). Beginning with input from users, this formalism focuses attention on those design improvements that will minimize life-cycle costs (Figure 5).

- Overall lost time = (Total time / MTBF) x Down time per failure
- Increase MTBF
  - Identify failure modes
  - Examine causes of failures
  - Introduce corrective design features
  - Take failure prevention actions

Figure 5. Failure Mode Effects Analysis (FMEA).

Other new technologies are appearing, some having already reached the stage of practicality. Computational fluid dynamics (CFD) promises to take the guesswork out of predicting the pump performance curves. Missing the performance on a new design has been a costly element of the pump business for a long time. Johann Gülich, Ed Graf, and others have computed the performance curves of a variety of centrifugal and axial-flow pumps using a commercially available CFD code. On 30 pumps that he analyzed with this code, Johann has demonstrated an error of only 2 percent in the head curve from shutoff flow to runout.

Another technology is inspired by the vision of a noncontacting bearing, namely one that suspends the shaft and holds it to within a mil of the required position—in effect, a nonbearing. Currently quite expensive to implement, this concept has nonetheless been demonstrated on a 600 hp, eight-stage centrifugal pump in boiler feed service, where the maintenance is far less than on an identical sister pump with conventional bearings and a full lubrication system. Another 800 hp pump was recently retrofitted with magnetic bearings and tested in IDPs lab for Aramco. If the price comes down, the vision can be realized. But, so far, this concept as applied to pumps has traveled a rocky road; and some are of the opinion that product lubricated bearings with intelligent position monitoring and lubrication-flow control are a better alternative, especially in terms of cost.

The last goal listed in Table 6—matching the pump to the application—is a way of reducing the life-cycle cost through operating efficiencies. There are many aspects of applying a pump correctly—especially when a new concept is involved for both pump and system. The optimum approach could be determined by another dimension of the already powerful and popular cost saving concept of alliances. An alliance that has a research-and-development aspect could become a feature of

future cooperation between user and manufacturer. An example is the relatively new concept of subsea multiphase pumping systems. For over a decade, some pump manufacturers have been trying to interest the oil companies in deploying multiphase pumps. They have been making progress lately, and there was a tutorial on the subject in the Thirteenth International Pump Users Symposium in 1996. There are now many surface installations, but the very few that have been established subsea have been and are being accomplished as cooperative R&D efforts. Such a concept could move more rapidly under the sponsorship of more such alliances.

## CONCLUSIONS

### *2000 and Beyond*

So, if where we have been and where we are going in the pump business is any indication, we would have to admit that long-term progress toward any goal like those just mentioned is inexorable (Table 7). It will happen, if not in 2000, certainly not too far beyond. Our friends here and abroad who have made this symposium so much a part of their agenda would say the same. Users Ed Nelson, John Joseph, Bob Hart, and many others told us what the problems are, and people like Dusan Florjancic and Elemer Makay came up with solutions. That beneficial interchange will continue this week. With that knowledge, there isn't much room for pessimism. The optimists will rewrite the rules of engagement. They will transform the product and its deployment worldwide. The whole civilization builds on past successes and experience, and the pump industry is no exception. So, the mission for the representatives of the users and manufacturers and for the other interested persons who are here this week—is to create new synergies to help achieve the goals that are set before us. Let's all learn from each other and enjoy this Seventeenth International Pump Users Symposium!

Table 7. *2000 and Beyond.*

- **Long-term progress is inexorable**
- **Optimists will rewrite the rules**
  - Transform the product and its deployment
  - Apply new technologies globally
- **Build on past successes, experience**
- **Users, manufacturers, all attendees**
  - Create new synergies to achieve goals
  - Learn from and enjoy the Pump Symposium

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