

FUTURE OF THE PUMP INDUSTRY

by

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Dušan Florjancic is an Independent Consultant for special problems related to hydraulic machines/systems. He retired as Technical Director of Sulzer Pump Division in 1989 after almost 50 years with the company, but remained Chief Consultant of the Pump Division until 1994. From 1988 through 1993, while still employed by Sulzer, Dr. Florjancic was elected as lecturer of the ETH/Zurich, lecturing on the design aspects of turbomachinery. He has lectured all over the world, has more than 50 published articles, and performs educational seminars in Germany.

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Mr. Chairman, ladies and gentlemen!

INTRODUCTION

The title I refer to the Sixteenth Symposium is dedicated to the future of the pump industry at the beginning of the new millennium.

I would like to thank the organizer of the symposium who gave me the opportunity and honor to present the welcome address.

I intend to give you—in a very short time—an overview of the past, today's state-of-the-art, and finally my vision of the future tasks and targets of the pump industry.

An old proverb says, "If one wishes to speak about the future, one must know something about the past." As you know quite well, the great importance of pumps for the transport of water has been recognized for thousands of years, a fact which is substantiated quite clearly by the old drawings shown the kind of pumping at the times of Archimedes (Figure 1).

Let us first consider the strategic importance of water—the most important liquid for mankind—for the future. Although the world's reservoir of water amounts to approximately 1400 million km³, only about four million km³ of it is freshwater. Without extensive treatment, however, only a small quantity of this freshwater is suitable for drinking purposes.

The annual worldwide consumption now amounts to about 3000 km³, of which about 90 percent is used for industrial purposes and the rest for the provision of drinking water.

Due to the rising standard of living and also the growth of the world population, the consumption of water will increase markedly in the next decades. It is safe to assume that this element, which is essential to life, will become a scarce commodity if more consistent efforts are not made to reduce consumption and to further recycling.

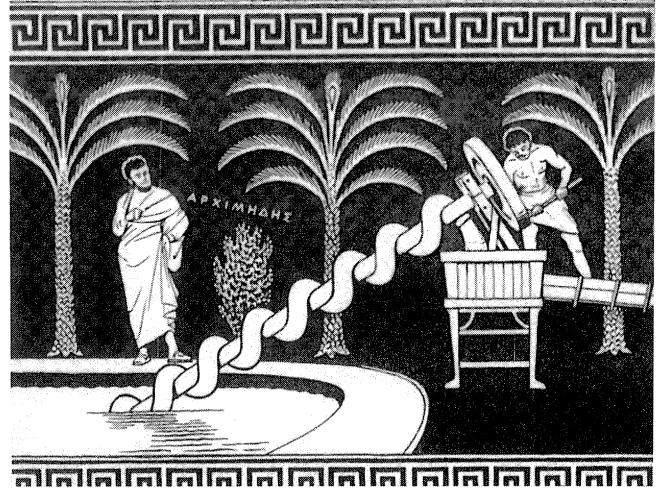


Figure 1. Picture of One of the First "Turbopumps."

It is therefore a matter of decisive importance to give every attention to the economic management of water consumption in the world, in order to avoid a possible catastrophic situation due to the unequal distribution of water in the future. In this way, we may even be able to prevent possible potential wars between nations which could result through disputes about the deficient quantities of water that are needed by them to preserve their respective civilization.

Similar considerations can also be made with regard to the petrochemical liquids, whereby a reduction can even be envisaged in the future because nothing renewable is expected.

We require pumps for the economic transport of liquids. Their importance is clearly reflected in the enormous number of the pumps that are now employed—approximately six billion—a figure which is more or less identical with the population of the world. It may be assumed that at least 75 percent of these machines are centrifugal pumps. Since their distribution among the individual countries differs a great deal, it already implies something for the future.

In general, it may be said quite specifically that hardly any other machine has such a long history of development as the pump and, in particular, the centrifugal pump.

In our modern civilization of today, we know that most industrial processes require liquid-transport possibilities. The continuous research in the field of fluid dynamics and the development of the hydraulic components have not only enabled the pump manufacturers to enhance efficiency, but also availability and the operational possibilities.

In the following three parts of this paper, I should like to reflect briefly on the early historical development of the centrifugal pump (period of time up to the great "leap" forward, that is to say up to the end of this century) and also consider the trends of development in the future.

HISTORICAL RETROSPECT

Pumps are one of the oldest driven machines in the service of mankind. The first known centrifugal pump in technical history

was already employed in the 15th century (according to our calendar) for the drainage of a Portuguese copper mine in Santo Domingo. The impeller of this pump, which was made of wood, is exhibited in the Musée de Conservatoire National, in Paris.

The technical principle of the centrifugal pump was developed towards the end of the 17th century. Even though Leonardo da Vinci had already considered the idea of using centrifugal force for the purpose of transport in the 16th century, it was the idea of Denis Papin, the French physicist (1647 to 1714), that first bore the fundamental characteristics of the modern centrifugal pump.

The device shown in Figure 2 was described by Papin under the name "Rotalis Suctor et Pressor Hessiacus," in 1689. Although as a whole, it tends to give the impression of being a physical toy, it could still be used for experimental purposes. Various improvements were proposed by Papin in 1705, among other things the spiral casing. In other words, although the principle of the centrifugal pump was already known for hundreds of years, it was only used on rare occasions. The famous "Massachusetts" centrifugal pump (Figure 3) with an estimated efficiency of 20 percent was built in the USA around about 1820, and undoubtedly triggered off the industrial fabrication of the centrifugal pump and its ever wider application in public water utilities.

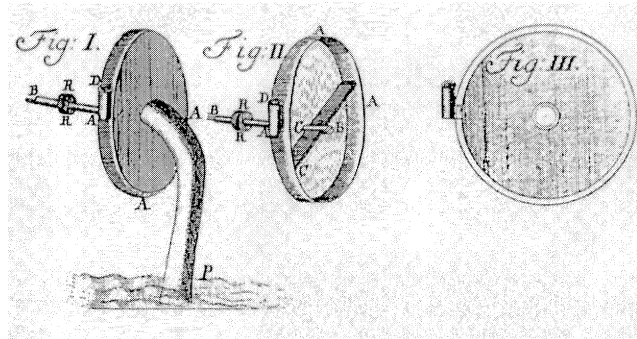


Figure 2. Cross-Section and Function Principle of One-Stage Centrifugal Pump Invented by Denis Papin (according to his patent from 1689).

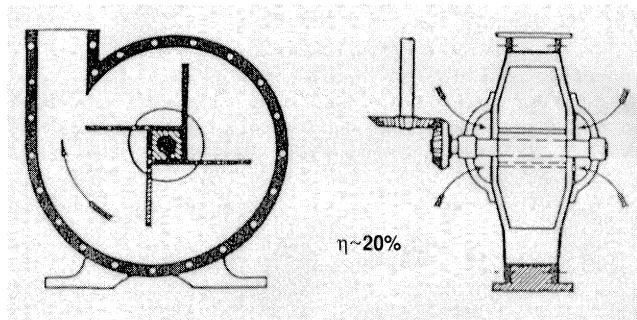


Figure 3. Cross-Section of the Massachusetts Pump (USA) From 1818.

Nevertheless, a great many years were to pass by before practical and really usable centrifugal pumps were manufactured for industrial application.

The development of the centrifugal pump really took off with the invention of the electric and combustion engine. This trend of development was accelerated even more through the increasing demand for centrifugal pumps for water supply systems and also sewage-disposal plants towards the end of the 19th century.

Systematically conducted and well-founded scientific investigations took place—in Europe and also the USA—shortly before the end of the 19th century. The product that resulted from such investigations can be seen in Figures 4 and 5. There is a

marked similarity between this single-stage, double-suction centrifugal pump and a machine of present-day design. This also applies when a comparison is made with the multistage centrifugal pumps of today. They already feature all the characteristic hydraulic components. It was especially this multistage design, which was characterized by its very good operational experience, that helped pave the way for the application of multistage pumps. As a result, centrifugal pumps were able to be employed instead of the successful reciprocating pump, and thus contributed appreciably not only to the further increase in the power concentration, but also the economic operation.

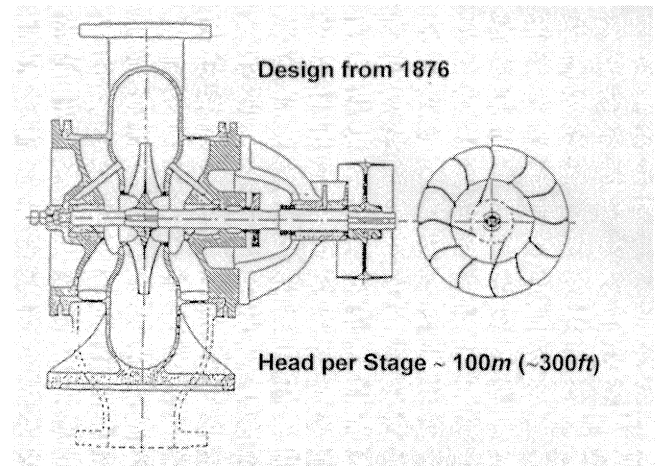


Figure 4. Generic Development of One-Stage, Double-Entry Pump. (Design from 1876.)

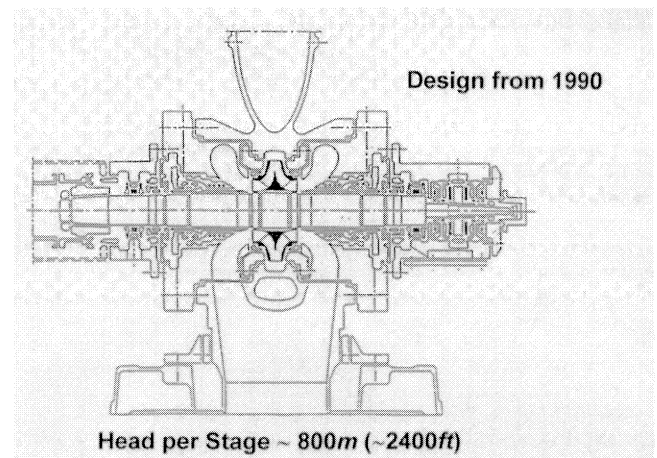


Figure 5. Generic Development of One-Stage, Double-Entry Pump. (Design from 1990.)

STATE-OF-THE-ART AS OF TODAY

To begin with, it must be pointed out that the present centrifugal pump is a real example of matured technology.

As far as centrifugal pumps are concerned, we cannot expect any revolutionary inventions to be made in the field of liquids transport. With positive-displacement pumps, however, the possibility of innovations cannot be ruled out. The development trends of the centrifugal pumps under consideration here can be subdivided into two periods of time.

The first, which extended up to the Second World War, is characterized by the development—on the basis of tests—for the purpose of improving the hydraulics. These pumps were then employed in sewage-disposal plants and the process industry.

The general economic situation in the 1930s, however, did not yield any particular impulses for the development, from either the side of energy generation or the process industry.

The second stage of development has taken place in the postwar period. Due to the rapidly increasing demand for electric energy, a large number of classical thermal power stations were built. For economic reasons, it was necessary to move onto continuously larger power station units as the years passed by. This necessitated not only powerful boiler installations, but also powerful boiler feed pumps. Figure 6 shows this development as a function of time for both the feed pump and Figure 7 for the boiler.

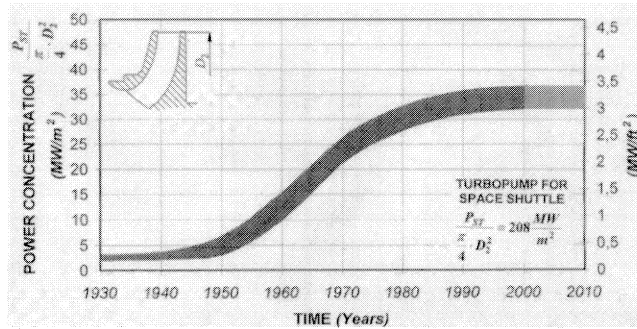


Figure 6. Power Concentration Per Stage of a Multistage Boiler Feed Pump for Thermal Power Plant (Europe) in Function of Time.

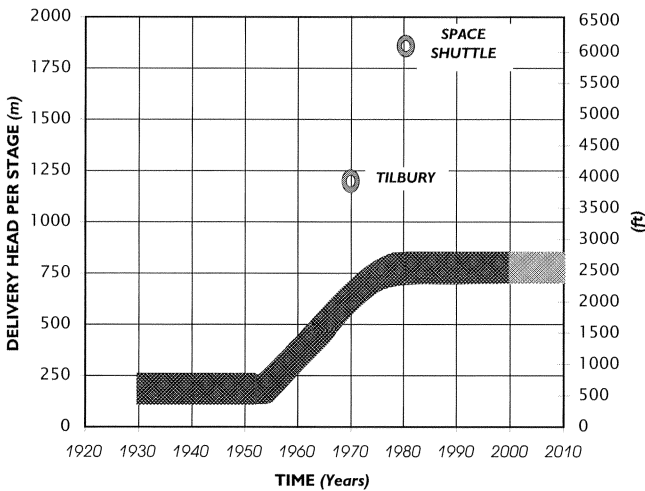


Figure 7. Head Per Stage of a Multistage Boiler Feed Pump for Thermal Power Plant (Europe) in Function of Time.

Like other machines, the boiler feed pump—as the most “exclusive representant” of the pump technology—had to follow the market requirements, too. In the case of the design layout, great importance was therefore attached to the saving of energy and the availability of the pump.

Once again for economic reasons, that is to say with regard to the size, efficiency, and availability of the pump, the designers were forced to increase the power concentration continuously by raising the delivery head per stage of this multistage pump (Figure 8). However, this was only possible through intensive research and development in the field of fluid engineering (efficiency, cavitation, part-load behavior), by the strength requirements (optimum material selection, optimum shape or form of components for the operational transient conditions), the rotordynamics and the arrangement of the pumps in the installation.

The following must also be said at this point: the significant contribution to the corroboration and deepening of the knowledge

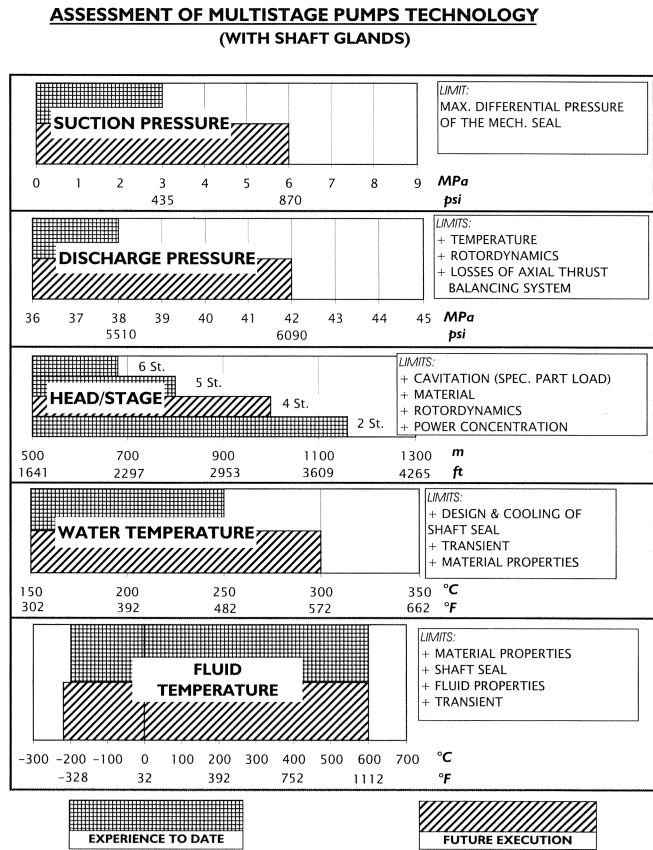


Figure 8. Assessment of Multistage Pumps Technology (with Shaft Glands).

for the multistage boiler feed pumps was realized through the pumps that were built in connection with the contracts placed by the CEGB (United Kingdom) in the 60s and later by EPRI in 1983, on behalf of the US utility industry.

The research assignments of EPRI were triggered off through the analysis of the downturn in the availability of the thermal power stations in the USA. The purpose of this analysis was to ascertain the principal causes of this reduction. It is not surprising to learn that the boiler feed pump was adjudged to be one of the culprits and, in this case, it was attributed to the ever-increasing requirements that were being placed on the operational behavior of the “heart” of the power plant, that means the BFP.

The principal cause was ascribed to the fact that the operating requirements placed on the boiler feed pumps had changed quite considerably (load cycles, with daily starts and stops) over the years. And the existing designs were no longer suitable or able to meet these new operating requirements.

It was the great contribution made by Dr. E. Makay who, together with EPRI, introduced the systematic investigations, postulated the development plans, and also ultimately implemented their results. It is an undisputed fact that the “products” resulting from this development work contributed very much to the deepening of the knowledge in various fields of pump engineering (cavitation, characteristic stability, rotordynamics, plant problematics), which influenced the designs of the multistage boiler feed pumps decisively and also gave rise to retrospective modifications in the case of the multistage pump designs for the petrochemical industry and for water injection, etc.

A further important aspect is the development of the duplex materials that resulted in this period. Thanks to these new, extremely corrosion-resistant materials, it was possible to meet the growing demands of the process industry and, in particular, those associated with injection pumps (transport of the formation water).

The major increase in the power concentration, however, also necessitated a very close examination of the reliability of secondary elements. Bearings, couplings, and dynamic shaft seals had to be considered. The now existing, deep-founded knowledge of the influence of the limiting quantities on the dynamic behavior of the multistage pump called for a change, namely from the hitherto conventional journal bearings to multisegment bearings with a larger specific load per unit surface.

Furthermore, considerable improvements were made to the flexible-gear and membrane couplings because of the great influence that the design had on the rotordynamic behavior of the high-speed multistage pumps especially.

Experience shows additionally that it is the mechanical seal, in particular, that determines the reliability of the complete unit in many cases.

As result of the increase in the circumferential speed, the design of the dynamic shaft seal had to be changed as well, that is to say from the classical stuffing-box packing through the floating-ring oil seal to the mechanical seal.

This strategic pump element was the subject of extensive development work, and particularly in connection with the operating limits that are influenced by the liquid medium, shape of the sealing surfaces, and their cooling.

Since the ecological conditions are becoming more and more stringent, pumps without a mechanical seal are being operated on an increasing scale for processes in which the employment of centrifugal pumps with mechanical seals could result in the escape of large quantities of noxious or explosive liquids into the atmosphere. Although the use of two-stage mechanical seals certainly constitutes a good solution for such requirements, the additional costs for a sealing system of this kind can frequently outweigh the disadvantages of the limited power output of a pump without a mechanical seal (designed with a "canned type motor" or with a magnetic-coupling drive). At the same time, one must also consider the power limitations of the above-mentioned pump units without mechanical seals (determined through the total efficiency due to the high influence of the frictional losses) as well as the supporting capacity of the hydrodynamic bearing lubricated by the transport medium.

As far as electric drives are concerned, the thyristor-regulated electric motors were developed especially for higher power classes during the last decade. Nowadays, they are available in the power range of up to about 30 MW and in the speed range of up to about 5500 rev/min. Transistor-controlled electric motors for smaller outputs of up to about 100 kW are also on offer at a very reasonable price.

They are especially suitable for those processes which—due to the respective requirements—operate in a wide and diversified speed range and have to exhibit high economic efficiency. The additional costs associated with the employment of these units must be justified by the cost analysis of the various possible drive mechanisms as well as the efficiency for the different load stages. (The calculation of the life-cycle costs (LCC) is becoming the most suitable method of analysis and basis for the procurement decision.)

Without any doubt, this type of drive constitutes a very interesting possibility for the future, and especially for use in the process industry.

For economic reasons, it is extremely important to monitor the pump unit at all times, and especially for higher pump output and systems with low redundancy in the installation. Figures 8 and 9 provide an overview of the technical limits that are attained nowadays for the individual parameters of centrifugal pumps.

CONSIDERATION FOR THE FUTURE

Introduction

In the majority of applications, the centrifugal pump is only a component part of the installation and can be procured at a relatively

ASSESSMENT OF TECHNOLOGY FOR GLANDLESS PUMPS (CANNED TYPE)

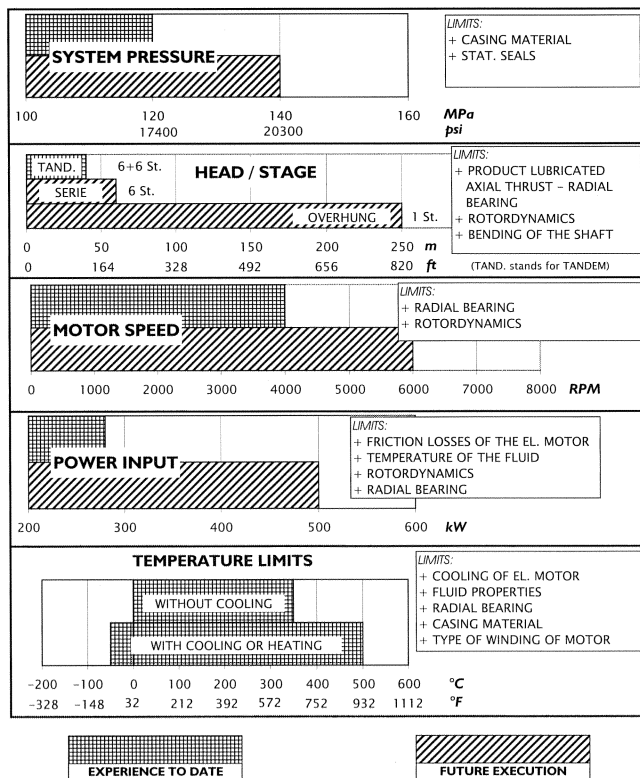


Figure 9. Assessment of Technology for Glandless Pumps (Canned Type).

low investment cost. Nevertheless—as its heart—it determines the total availability and economic operation of the plant. Consequently, it is obvious that the operator of this unit will attach more attention to it in the future. Proceeding from the fact that the centrifugal pump is a completely matured product, its further development will have to follow—firstly—the market requirements and also meet the new, still unknown process requirements.

The considerations expounded in this chapter describe the future research and development strategies in the field of centrifugal pumps. They are based primarily on the results of diverse investigations in Europe (in particular those of the Committee of Pump Experts in the VDMA, the Association of German Engineering Institutes), the results of the discussions held during the various workshops, as well as my own considerations. The studies are based on surveys conducted according to the Delphi method at the premises of the operators and pump manufacturers, as well as with scientists engaged in the various fields of knowledge. They conveyed not only the expected development of the market, but also the fundamental technological direction.

Due to the limited means available for the execution of the future research and development assignments, preference must be given in future to the tasks which offer the best prospects for the greatest market success of the necessary product development.

The results of such an analysis, made by the VDMA, are shown in Figure 10. They show the development priorities for the future principal fields of the research and development projects.

The subsequent centrifugal pump development will probably have an impact on the following three areas:

- Enhancement of the reliability, operational safety, and service life
- Achievement of an "intelligent" behavior through diagnostic capability and early fault recognition
- Reduction of the life-cycle costs through lower operating costs

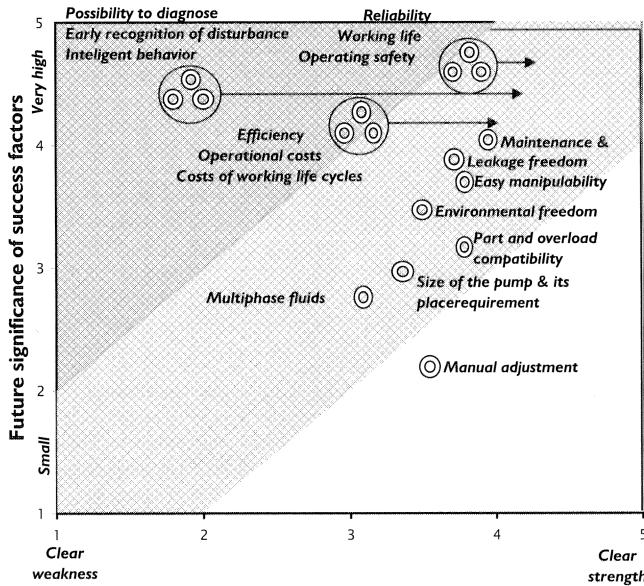


Figure 10. Position in Year 2005 at Retention of Today's Achievement State. (Courtesy of VDMA/Germany)

To enable the state of technology to be improved even further in the future, the specified fields of development will have to be moved medium or long-term wise to the field "higher success factors."

The development factors shown in Figure 11 assume that:

- The customers will orient themselves more to the life-cycle costs in future, and that these costs will be a decisive factor for their decision to purchase. (The EU is making efforts to publish corresponding guidelines. The work being carried out at present by a Joint Work Group of EUROPUMP and the Hydraulic Institute will serve as a basis for this.)
- There will be close cooperation between the operators and pump manufacturers in the pre and post sales phases.
- The modern communications techniques, as a integrating part of the "intelligent" centrifugal pump unit, will be incorporated completely in the pump technology.
- Standard designs will be utilized for the electronic components of the "intelligent" centrifugal pump and that low-cost multifunctional sensors will be developed.
- The life-cycle of the pumps will be similar to that of the installation.

Ways to Enhance the Reliability

The results of the aforementioned studies clearly indicate the need for a further increase in the reliability of the pump. Any improvement in the reliability, however, is—first and foremost—dependent on the pump manufacturers. It involves new measures, e.g., diagnostics, teleservice, service friendliness of the design (training of the operators' personnel and clearly defined operating instructions!).

In other words, improved reliability can be realized not only through the further development of the hydraulics, the rotordynamics and the materials, the individual components of the centrifugal pump (bearings, mechanical seals) and the motor, but also through an intelligent behavior of the pump, e.g., by means of an adaptive automatic control system. All of these together determine the total reliability of the centrifugal pump unit.

As a result of the improved reliability, a decrease in the redundancy of the pump group is possible in installations. This would lead automatically to improved economic operation and

consequently to a reduction in the spare parts requirement as well; all in all to lower life-cycle costs.

In future, inexpensive sensors will also be fitted in standard centrifugal pumps to increase the reliability. They will facilitate the continuous acquisition of the strategically important operating data. This information facilitates the recording of symptoms that indicate possible faults at an early date. (The future, early recognition of faults is not a monitoring system for limit values, as is usual nowadays—particularly in the case of large power station pumps—but rather a trend and fault analysis, which is made possible by means of neuronal networks or fuzzy logic). This will enable the necessary measures, based on the "predictive maintenance" strategy, to be adopted in due time.

On the basis of the respectively determined "condition" of the centrifugal pump (indicated either by an increase in the leakage as a result of a worn throttling gap and thus a deterioration in efficiency or through an increase in the vibration of the rotor, also attributable to the widening of the throttle gap or alternatively the incorrect manner in which the pumps are driven), the operator will be able to decide on the necessary service intervals for the pump.

Vision of The Focal Points of Development for the Centrifugal Pump

Figure 11 provides an overview of the probable future research work. This, in turn, indicates the objectives of these projects.

1. Rise of power concentration and efficiency through further development of the computer added analyzing tools and with the support of LDA (Laser Doppler Anemometry).
2. Further development of the cavitation-, corrosion- and wear- resistant materials.
3. Replacement of the expensive materials by synthetic or ceramic materials.
4. Further development of the metallic and ceramic coatings.
5. Design optimization of the highly stressed components through the employment of FE and FV calculations.
6. Further development of the multi-stage pumps for the transport of two-phase mixtures in a wide range of applications of the GLR (Gas Liquid Ratio).
7. Further development of a sealless centrifugal pump for higher system pressures, fluid temperatures and power inputs.
8. Equipment of centrifugal pumps with reliable sensors for early fault diagnosis with the aid of expert systems.

Figure 11. The Future Focal Points of Research for Centrifugal Pumps.

The Future Focal Points of Probable Research Work for the Components of the Centrifugal Pump

Figure 12 provides an overview of the research work for the strategically important components of centrifugal pumps. The objectives speak for themselves.

The majority of the specified research projects have to be executed, first and foremost, by the component manufacturers. At the same time, close cooperation with the centrifugal pump manufacturer is a really decisive prerequisite for success.

1. Development of inexpensive, easy-to-service, speed-controlled hypersynchronous motors.
2. Further development of product lubricated bearings.
3. Further development of magnetic radial bearings to improve the rotordynamic behavior of hermetically sealed, multi-stage centrifugal pumps with higher power input.
4. Further increase in the circumferential speed and sealing pressure of mechanical seals.
5. Further development of the gas seal in tandem arrangement for high circumferential speeds.

Figure 12. The Future Focal Points of Research for Centrifugal Pump Components.

Development Priorities

The research tasks specified above are extensive, call for personnel with a high level of education, and also give rise to very high costs. Due to the high financial expenditure involved, it is possible that the respective appointed tasks can only be fulfilled successfully by switching over to a national or, even better, an international joint research model. In the case of projects accomplished successfully on an international basis (CEGB, EDF, EPRI), fundamental knowledge and methods that had to be researched was gained which confirms quite clearly the feasibility of such joint research work in the future.

The advantages gained through the internationalization of the research projects, namely through the setting up of research alliances, could reduce the high financial expenditure and also the technical risk for the individual pump manufacturers to a considerable extent.

The results of the VDMA study are certainly of interest, because they show the success potential of the various research subjects as a function of the expenditure (Figure 13). The future priorities can be split into regions as follows:

- Field with the highest potential, which includes the research tasks that are associated with the early recognition of faults on the pump
- Field with the average potential that has included the “conventional” fields of research up to now, for example, cavitation, rotordynamics, characteristic stability, efficiency, and material development, to name just the most important

Despite the intense reserve exercised with regard to joint research, which is attributable to the fear of competition among the pump manufacturers—and here I am speaking on the basis of my past experience in Europe—this path will have to be taken sooner or later for economic reasons. The joint research should concentrate, first and foremost, on the mutual fundamental developments that are common to the precompetition field. The acquired results will then constitute the basis for the innovative, specific product development in the companies. This development domain must also remain in the future, namely in the respective development fields of the individual pump manufacturers.

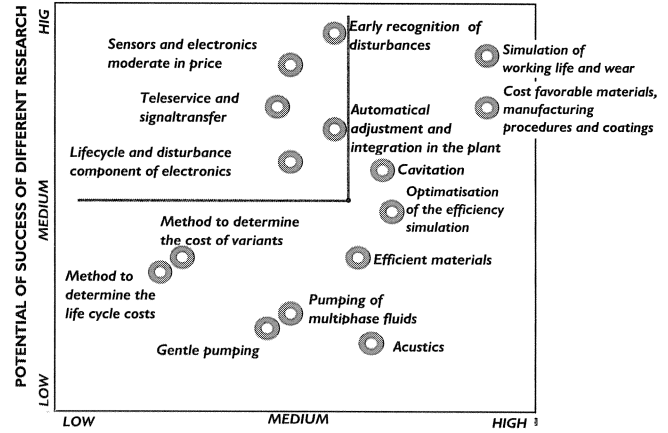


Figure 13. Research Effort. (Courtesy of VDMA/Germany)

Following the foundation of the European Research Fund (ERF), the reality of international joint research on a wide basis is near at hand. The practice of distributing the basic research assignments is based on the voluntary participation of the respective pump associations or the individual pump manufacturers. On the strength of the positive experience gained during the execution of national as well as international research assignments, I believe that such a futuristic vision of a joint strategy is realistic and will be successful.

To sum up, it must be said that the accents (priorities) of the future research assignments have moved from the so-called “conventionals” to those tasks that increase the service life and decrease the life-cycle costs.

CONCLUSION

The vision of the future development of centrifugal pumps that I have expounded is based on the expected market developments and also the economically justifiable and technical possible innovations.

To achieve these objectives, however, we need not only the financial means, but also excellently trained specialist personnel. Whereas it is safe to assume that the market will be the driving force behind technological development, the “curiosity” of the researcher and developer, which contributes considerably to the “excellence” of the products, should not be underestimated either. The strength of this curiosity can create new impulses for further innovations in the case of the product “centrifugal pump.”

Although the centrifugal pump is no longer a “youthful turbomachine,” the “old lady” is still fascinating. Further peak performances can be expected from the engineers as a result of the development of their creativity.

Finally, we must remember that it is the entrepreneur, who furthers research and development—and predominantly independent of the run of the business—that has the brightest prospects in the fiercely contested market of the future.

The financial requirements of research on the one hand, and the continuous furtherance of the highly qualified specialist personnel on the other, will deepen the knowledge of the company and thus also ensure work for a great many people in the future.

I would like to thank to Dr. Holzhüter, the president of the committee of the pump experts in the VDMA for his support.

Thank you for your attention.