

# AN OPEN LETTER TO THE PUMP INDUSTRY

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## ABSTRACT

Every industrial process which underlies our modern civilization involves the transfer of liquids from one level of pressure or static energy to another level, and, as a result, pumps have become an essential part of all industrial processes. Carried further, this means that pumps are an integral part of all modern economic and social development.

If this be so, it follows that the role of the pump industry in our economy must be much more than the development of various lines of pumps, the selling of these pumps, and their manufacturing. It must also include efforts to build more efficient and longer-lived equipment—to do so with a lesser expenditure of natural resources, and to educate pump users in the practices which in turn consume less energy, provide trouble-free operation for longer periods of time and reduce the incidence of sudden premature failure.

The recent setbacks to the U.S. economy have led to the conclusion that we have lost our competitive edge in the area of innovation and that the dangers we continue to face are created by the fact that short range goals too often outweigh long range thinking in the American industrial planning process. This accusation is quite valid and could easily be documented.

But it is not our intention to point the finger at whoever it is who "killed cock robin." Instead, we want to protect the cock robins of tomorrow and—if we may stretch the metaphor a bit further—to build a defense wall around the proverbial goose whose sole function in life is to lay golden eggs.

These are the considerations which have led us to prepare this open letter to the pump industry, an industry to which we have devoted our entire professional career. And what we are going to say is buttressed by three fundamental concepts:

- The need for technological change is predictable.
- The direction of technological change is predictable.
- The time when we must take action is predictable . . . and it is now!

## AUDIT OF EXISTING PUMP LINES AND CONSIDERATION OF CERTAIN CONSTRUCTION IMPROVEMENTS

First and foremost, we would recommend that each member of the pump industry conduct a thorough audit of their present pump lines, both from the points of view of hydraulic performance and mechanical design. We do not intend to present herein a complete list of what is to be examined, but to limit ourselves to some of the major areas that should be considered. Such an audit will lead to improvements of the existing lines, the renewal of obsolete or obsolescent designs and, very probably, the addition of some new pump types.

In the area of hydraulic performance, the three most important items to be examined are attainable pump efficiencies, the proper margins to be provided over and above the required NPSH, and the effect of internal recirculation in the impeller.

## PUMP EFFICIENCIES

Our suggestion to conduct an audit of the efficiencies attained by all the pump lines does not imply that we have any reason to believe that pump manufacturers have not been doing this right along. The problem is that the standard against which such audits have been conducted in recent years is no longer valid. New available information on this subject was released in May 1986 with the presentation of the Sabini-Fraser paper "The Effect of

### Specific Speed on the Efficiency of Single-Stage Centrifugal Pumps" [1].

The chart which has now been superseded had not been updated for almost 40 years. In addition to being based on old data, it suffered from the disadvantage of recognizing only two of the factors which affect pump efficiency: specific speed and pump capacity. There are a number of other characteristics which affect commercially attainable efficiencies—characteristics such as surface finish, internal clearances, Suction Specific Speed and the effect of internal recirculation at the suction and discharge of the impeller. In order to provide a workable set of efficiency charts, certain specific constraints were selected for each one of these characteristics and some general indications were given as to the effect of deviations from these constraints. Two separate charts are now provided: one for single stage end suction and double suction pumps and a second one for the bowl efficiencies of wet pit centrifugal pumps.

It is against this latest standard that an audit of efficiencies should be conducted. The original paper has been updated [2] to broaden the usefulness of the charts provided by giving quantitative corrections applicable for any deviation from the selected constraints—such as, for example, for rougher or smoother surface finishes or for greater or smaller internal clearances as well as for the effect of multistaging centrifugal pumps.

We should add that we are nearing the time when further efficiency improvements can no longer be achieved economically or without seriously endangering the reliability of the pumps, in other words, when the centrifugal pump reaches the practical optimum in performance for whatever service conditions need be met.

We cannot avoid making some remarks about the other side of the medal. On occasion, enthusiastic optimism outruns prudent caution and efficiencies may be guaranteed that cannot be met on test. This should not be permitted to happen. Practice among manufacturers varies, but some companies protect themselves and their clients against such occurrences by having all their employees sign compliance documents which, in essence, state that willful distortion of facts will be considered as a cause for dismissal. It seems to us that a more general use of such compliance agreements would be beneficial.

What would also be desirable would be the publication of guideline charts similar to those presented in References 1 and 2 in the Hydraulic Institute Standards. This would, no doubt, require a thorough review of the data involved by a technical committee of the Institute. But, if guidelines on NPSH values are considered as proper material for the Standards, so is the case of commercially attainable efficiencies.

### REEXAMINATION OF NPSH GUIDELINES

Recently numerous attempts have been made to reconsider our knowledge of cavitation phenomena, leading to various recommendations to change the well-established convention of defining NPSH required as that value of NPSH available under which the total head drops by exactly three percent. As a matter of fact, one of the authors [3] suggested that this redefinition be made to correspond to a head drop of 0 percent. On reflection, he recanted and suggested later [4] that the present definition be left alone, but that guidelines be established to indicate the effect of various factors on the life of the impeller. After all, the user cares nothing about all sorts of theoretical considerations; all he wishes to know is a reasonable prediction about the life of the pump components. An attempt to set up such guidelines has been made by Doolin [5]. The refining of these data and the publication of industry-wide predictive guidelines would be a worthwhile contribution to the users.

### INTERNAL RECIRCULATION

That abnormal flows could occur in and around impellers under certain conditions was first suggested by Smith [6] (reported by Gibson [7]) in 1902. In 1909, Stewart [8] measured prerotation upstream of an impeller. Carrard [9], addressing impeller flow separation in 1923, suggested that continuity would dictate separation at the channel inlet as the through flow was reduced. Fischer and Thoma [10] visualized recirculating flow in 1932. Stepanoff [11], dealing with centrifugal pump performance in 1948, ascribed the departure of the actual power curve from the theoretical to the onset of "secondary flows" within the impeller.

For centrifugal pumps, abnormal flows in and around the impeller remained largely a hydraulic curiosity until the late 1950s and early 1960s. Around this time, the introduction of higher head per stage designs was attended by very unfavorable behavior whenever these pumps were operated at reduced flows. On frequent occasions, the impellers of these pumps showed premature wear in their suction areas and, sometimes, near their discharge tips. In some extreme cases, even catastrophic failures occurred, including the destruction of impellers and volutes or diffusers. And while the majority of these problems may have been most acutely noted in the area of such equipment as multistage boiler feed pumps, equally unwelcome difficulties were being encountered with pumps on less severe services. For example, a number of single stage high-head pumps in the medium range of heads per stage exhibited similar problems, though possibly of a lesser magnitude.

It was in the 1960s that the symptoms just described were first associated with the phenomenon of internal recirculation in the impeller, either at the suction or the discharge and, sometimes, at both locations. Minami, et al. [12], provided insight into the connection between suction recirculation and cavitation type erosion of the impeller. Various other authors [13, 14, 15] tendered qualitative explanations on the causes of recirculation. And in 1972, Fraser [16] developed a proprietary mathematical model of the relationships that exist between the geometric configuration of an impeller and the onset of internal recirculation. With the understanding that these field problems were caused by internal recirculation, various general guidelines were developed that would permit users to avoid field problems during operation at low flows.

Finally, in 1981, Fraser [17, 18] published two papers dealing quantitatively with recirculation. These two papers represented a substantial contribution to the art of centrifugal pump design and application. They set down a simple means of calculating the onset of recirculation for known impeller geometry, the means of estimating same when the geometry is not known, guidelines for pump operation based on recirculation flows and, finally, suggestions for correcting or accommodating existing recirculation problems.

Fraser presented the first published means of calculating the onset of recirculation. In some quarters, the initial reaction to this work was to argue that the complex, three dimensional flow prevailing within an impeller could not be modelled in so simple a manner. From a strictly scientific point of view, that argument had some truth, but it overlooked the essential point which was whether the method gave results good enough to identify, correct, and ultimately, avoid problems caused by recirculation. Field experience has shown the method satisfies the essential criterion and has, thus, transformed criticism into efforts aimed at improving the accuracy of calculation, refining application guidelines and extending pump rangeability. Of note in this connection is the work of Oshima [19], Bosman and Ahrabian [20], Palgrave [21], and Gopalakrishnan [22].

Despite what is now known about recirculation, it is an unfortunate fact that there is still some resistance to using safe and sound guidelines, both in choosing Suction Specific Speed values and in setting minimum flow restrictions. In this last connection, one might sometimes suspect that the minimum recommended flow for one and the same value of Suction Specific Speed seems to vary inversely with a manufacturer's desire to obtain an order. This is not a sound way to ensure a safe, reliable and troublefree installation. Such practice should be discouraged.

## THE UPGRADED MEDIUM DUTY PUMP

Several chemical process and petrochemical companies have noted with some dismay that the mean time between failures of their standard single stage ANSI type pumps is far from being satisfactory. It is true that, and we shall speak of it later, some of the causes of this shortfall in life expectancy are directly traceable to improper operating and maintenance practices. Still, the industry feels that pump manufacturers can contribute materially to the reduction of operating and maintenance costs by providing an intermediate design between the two standards presently used, that of the ANSI type pumps and the API-610 construction. Recommendations have been made by a number of users that a new intermediate standard be created, the so-called "Upgraded Medium Duty" Centrifugal Pump [23]. Its range of services would extend to 300 psi and 350°F. Such pumps would incorporate the following features:

- Oversized stuffing boxes, to accommodate more sophisticated and more reliable mechanical seals
- Magnetic bearing housing seals, to reduce or eliminate lubricant contamination
- Duplex angular contact thrust bearings, mounted back to back
- Dramatically reduced shaft deflections
- One-piece steel bearing frame and adapter
- Oil mist lubrication, preferably.

Whether such a new standard is warranted or not is debatable. Our opinion is that it may be preferable to incorporate these various improvements in construction into the ANSI standards in the form of individual options, with customers being given the choice as to how many of them they wish to purchase as extras. Time will tell whether the "all-or-nothing" or this "options" approach will prevail. Very frankly, it doesn't matter all that greatly, as the customer will benefit from either one of them.

## SOME THOUGHTS ON MATERIALS

We find little reason to change positions from those one of the authors expressed on this phase of the subject in the past [24]. If anything, our beliefs in some of the predictions and recommendations made then have grown in strength. This is why we are urging the pump industry to devote serious thought and effort to the study of alternate material selections. Large pumps must depart from our traditional approach of using cast iron or cast steels and shift towards the use of cast/weld fabricated construction. In some cases, clad metals can be used very effectively. And we must find better means of coating the wetted areas of our pump casings and of other components with wear and corrosion resistant materials. We can no longer afford to expend our natural resources by using pump components made entirely of such materials.

## THE ROLE OF THE PUMP INDUSTRY IN THE EDUCATION OF PUMP USERS

We cannot deny that a great deal of progress has already taken place in this area. Through the publication of articles in many magazines, and through the holding of frequent technical seminars and symposiums (such as the International Pump Users Symposium), major steps have been taken towards providing users with the information they require to improve the reliability and life expectancy of their pumping equipment. We do need to offer a word of caution in this connection—engineers from the pump industry must make sure that their articles and the papers they present at various meetings not be used only as vehicles to discuss subjects that are possibly of great interest to ourselves as pump designers, but can contribute nothing but confusion to the users. We should guard ourselves against the temptation to discuss the theoretical intricacies of velocity diagrams, vane angles or other design details. A Doctorate in Fluid Dynamics should not be a prerequisite to understanding what the user must do to achieve a successful pump installation.

Another educational tool which is generally badly neglected is the "Instruction Book." Consider that a great number of plant operators and maintenance people do not have access to technical magazines, nor do they all attend Pump Seminars. The average "Instruction Book" seems to assume that those who will read it have all the prerequisite knowledge to understand why this or that phenomenon occurs or why such and such an operating practice is recommended; the average "Instruction Book" merely lays the law down and gives peremptory orders. These are not likely to be obeyed—a man must understand why something happens or why something must be done, if you want him to carry out his appointed task intelligently.

One final suggestion with respect to education. In the past, all engineering curricula invariably included a course on pumps and compressors. Today, such courses are no longer given to engineering students; and yet, they would be most useful to pump users, be they mechanical, civil, chemical, or even some other kind of engineers. The pump industry might possibly lobby with our technical institutions to reincorporate such a course in the standard engineering.

We cannot list all of the areas in which the user needs education, but let us consider a few of the most important ones.

## PUMPS AND ENERGY CONSERVATION

While the waste of energy is always a deplorable practice and has become particularly so in this last quarter of our century, the problem is magnified many times today. There are four areas of potential power savings in pump installations: [25]

- The avoidance of oversizing
- The use of variable speed operation
- Running one pump instead of two whenever possible
- Restoring of internal clearances at the most cost-effective moment.

In this connection, we want to make a special point of discussing the use of variable frequency drives (VFD) [26].

Among some of the advantages of VFD are the power savings that can be derived from variable speed drive, the absence of high slip losses at part speed, the lack of the need to cut down impellers in order to meet exact conditions of service and the ability of using odd speeds between synchronous speeds, such as 2000 or 2500 rpm, etc. And, most importantly:

- VFD provides a soft start, eliminating the high starting current experienced with standard induction motors. This reduces

the demand charge which, in many cases, is equivalent to the "use" charge.

- VFD permits more frequent starts and stops for 2-pump installations and encourages shutting down one pump whenever a single pump can carry the required load.

## ADEQUACY OF SUCTION PIPING

It is amazing that so frequently pump users will take all the necessary precautions to provide adequate NPSH to their pumps and to operate within reasonable flow ranges, only to neglect the most elementary precautions in the layout of the suction piping leading to these pumps. This is not to say that guidance is lacking in the technical literature to help pump users to avoid the disastrous consequences of poorly engineered suction piping. For instance, several articles [27] have been devoted to illustrate some of the most glaring errors in this connection, such as the wrong positioning of elbows, the improper sloping of the piping, the incorrect use of reducers and the provision of inadequate submergence over the piping inlet, which leads to the formation of vortices and the entrainment of air or gases into a pump.

When such guidance is provided and is not followed, it may well be that more drastic measures are required. It might be worthwhile to institute the practice of requesting pump customers to provide the manufacturer with a layout of the suction piping for the purpose of examining it and correcting the sources of trouble *before the trouble happens*.

## MONITORING PUMP PERFORMANCE

The lack of proper monitoring can lead to unexpected and unscheduled shutdowns, with a costly result on the production of the plant served by centrifugal pumps. At best, it prevents a reasonable assessment of the need to replace internal renewable parts so that initial pump efficiencies can be restored most economically. This subject has been covered extensively in the literature [27].

## LUBRICATING PRACTICES

The B-10 life of antifriction bearings used in ANSI and API-610 pumps is supposed to be 24,000 and 40,000 hours, respectively. What this means is that 90 percent of the bearings should still be serviceable after approximately three years for ANSI pumps and after five years for API-610 pumps. In practice, this isn't what happens. When one talks to maintenance people who do keep records, one finds that on the average the life expectancy of the bearings falls short by as much as 50 percent or more.

This is not because pump manufacturers do not know how to size bearings or are too optimistic and cut corners. It happens generally because of one or two reasons:

- The actual load on the bearings exceeds the predicted load, or
- The load which the bearings can carry falls short of the basic bearing load rating, because of bearing environment conditions.

The first can be caused by a variety of circumstances such as pump misalignment, excessive forces and moments exerted on the pump by the piping, pump cavitation, operation below recommended minimum flows, poor suction piping, etc. The second stems from lack of lubrication, the use of wrong lubricants, water contamination of the lubricant, inadequate cooling, excessive cooling, oil-ring debris in the oil sump, etc.

Of this last list, water contamination in the lubricant is probably the greatest and most frequent offender. Figures are cited showing that as little as 0.002 percent water contamination will reduce bearing life by a dramatic 48 percent. This is one of the reasons for the recommendations made by Bloch [23] for magnetic bearing housing seals and the preference for oil mist lubrication.

There is no question that education of pump users in the proper lubricating practices is the only way to reduce the failure rate attributable to bearings.

## CONCLUSIONS

As we have said, the appointed role of our industry in the economy of our country must be more than just manufacturing and selling pumps. We must constantly improve our products, and we must educate their users in how best to install, operate and maintain them most effectively.

On occasion, it has been stated that the centrifugal pump is a mature product and that changes in the future will have more of an evolutionary than a revolutionary character. But we must also think of technological breakthroughs which take place even in the life cycle of a mature product. We firmly believe that there is still a fertile field for pump designers to work. There is much to do and we better get to it right away. Innovation, as we have said, can take place even when one deals with a mature product, such as the centrifugal pump. It can manifest itself in a better understanding of the relationships that exist between the life of a given component and the operating practices in the exploitation of the product. It can involve the development of better guidelines in the installation, operating and maintenance practices for the pump. Finally, it can manifest itself in providing better education for all the personnel involved in the selection and application process.

We repeat, there is much to do and many a mile before we sleep.

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