# Attitudes Toward Computer Software and Its Exchange in the Pressure Vessel Industry[1]

**H. KRAUS**

Professor of Mechanics,
Hartford Graduate Center,
Rensselaer Polytechnic Institute,
Hartford, Conn.
Mem. ASME

*A survey of computer software use in the pressure vessel industry was conducted by means of a questionnaire that reached 707 active professionals in the industry. 249 filled-in questionnaires were returned. These were analyzed by standard statistical techniques in order to determine the following: the respondents' background, the extent of their involvement with computer software in pressure vessel analysis and design, their attitudes toward computer software and their attitudes toward the creation of an active technology transfer effort for that software. The study verifies that a generally positive attitude toward software and its exchange exists among those who actually write and/or use computers. However, it was found that supervisors of those who write and/or use software would be unwilling to share most their programs with an active technology transfer effort for software.*

## Introduction

The widespread use of computer software in modern pressure vessel engineering, for example, is well known (see, e.g. [1][2]). Analysis and design tasks which formerly involved great difficulties have now become routine. Others, which were too complex to consider have become feasible. Within the constraints of time, funding and machine capacity engineers can now contemplate just about any type of calcualtion.

This fortunate situation has not, of course, arrived without an attendant set of new problems. Thus, the engineer is now faced with considerations such as access to software, verification of software, user qualification, duplication of effort and a host of others. These indicate that the computer has necessitated a shift from purely technical and theoretical concerns to management and administrative concerns. The verification of software and the qualification of the user have been actively described in several publications of the ASME Pressure Vessels and Piping Division [2, 3]. The access and duplication of effort problems have also been tackled by several cooperative ventures such as Project STORE of the Office of Naval Research, the COSMIC Computer Center of NASA, the Argonne Reactor Code Center of the AEC and the Library of Structural Mechanics Programs at IITRI. Some of these efforts are described in [4]. These have been characterized as "passive" activities in that they have acted basically as libraries and have not participated in any way in the coordination, monitoring or development of software.

A "dynamic" type of technology transfer effort for software has recently been presented for discussion. In particular representatives of the civil engineering community met in Boulder, Colorado in 1971 to discuss such an effort for their profession. The National Science Foundation sponsored this "Workshop on Engineering Software Coordination" [5–8] in order to explore means by which software could be shared more widely. The conference adopted the following formal resolution:

> In principle, the Special Workshop on Engineering Software Coordination recommends the establishment of a national effort to optimize common use of engineering software. We further recommend the immediate establishment of a demonstration pilot program, initially limited to software for the civil engineering profession and the related construction community, to: 1) collect, evaluate, and verify software from all available sources; 2) to encourage the development of new programs; and, if necessary, 3) to initiate the development of new programs in order to advance the state-of-the-art. Programs determined to possess transferable merit would be improved as required, would be translated into such form as will facilitate their use by the engineering profession, and would be made generally available to the profession.

Later on, the National Science Foundation sponsored a survey of the ASCE by K. Medearis in which the feasibility of a so-called National Civil Engineering Software Center was explored [9]. He concluded that the respondents to his questionnaire favored no more than a center that provides information concerning available software. He recommended further that the ASCE establish such a center. Thus, the conclusions of this particular survey were certainly not in accord with those of the Boulder conference. This could be attributed to a difference in population. The attendees at Boulder were the most active users

[1]Work supported by National Science Foundation Grant GK-36084.

[2]Numbers in brackets designate References at end of paper.

Contributed by the Pressure Vessels and Piping Division and presented at the Winter Annual Meeting, New York, November 17–22, 1974, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Manuscript received at ASME Headquarters, July 31, 1974. Paper No. 74-WA/PVP-1.

and writers of software in the industry while the Medearis questionnaire went to the general ASCE membership.

As a result it became of interest to the NSF to expand the investigation of the feasibility of the transfer effort further. Consequently, it was decided to carry out the survey of the pressure vessel industry whose results are reported here. Since analysts and designers in that industry tend to be affiliated with ASME such a study would also bring a segment of that society into the picture along with ASCE. To fix our ideas it is appropriate at this point to describe in some detail the technology transfer effort for software that is being presented for consideration:

> In contrast to much of recent experience with passive library functions the currently envisioned technology transfer effort would be more dynamic in structure and philosophy. It would be endowed with the personnel, policy making, physical and monetary resources that are required to accomplish the following objectives:
>
> 1 To collect all engineering software developed under publicly supported activities as well as through donation or contractural agreements with private individuals and organizations.
>
> 2 In cooperation with recognized technical-professional committees, to separate those elements having a distinct utility. These would be validated and then transformed by a variety of processes such as documentation, translation, testing and continued maintenance into packages suitable for use in a wide variety of operational environments.
>
> 3 For other elements having a lower degree of general utility, to provide cataloging and abstracting services.
>
> 4 To provide an effective distribution system (perhaps including network and/or satellite concepts) with feedback loops for all collected software elements.
>
> 5 To provide a reference source of documentation standards suitable for voluntary adoption.
>
> 6 To conduct professional educational activities of the type and level required to assure a continued and broad scale growth of national capability in the practice of engineering as related to utilization of the computer.
>
> 7 To provide a discernible, responsible entity to which hardware and computer science specialists can turn for the definition of new needs.

With this description in mind we turn to the results of our survey. These will be presented in four parts. First, we discuss the gathering of the data. Second, we present a summary of the data. Third, we give statistically significant correlations in the data and, fourth, we discuss the conclusions that are indicated by the data.

## Gathering The Data

In order to gain the desired information on the attitudes toward software use and its exchange in the pressure vessel industry a five-part questionnaire was designed and is reproduced in the Appendix. This was sent to the most active engineers in the field of pressure vessel analysis and design as covered by the memberships of the following professional groups:

I American Society of Mechanical Engineers
- *A* Boiler and Pressure Vessel Committee
- *B* Pressure Vessels and Piping Division
  - 1 Design and Analysis Committee
  - 2 Computer Technology Committee
- *C* Policy Board—Communications
  - 1 Computer Technology Policy Committee
- *D* Policy Board—Research
  - 1 Research Committee on Computer Software
- *E* Applied Mechanics Division
  - 1 Committee on Computing in Applied Mechanics

II Pressure Vessel Research Committee
- *A* Main Committee
- *B* Design Division
  - 1 Subcommittee on Shells
  - 2 Subcommittee on Stresses in Ligaments
  - 3 Subcommittee on Reinforced Openings and External Loadings
  - 4 Subcommittee on Bolted, Flanged Connections
  - 5 Subcommittee on Elevated Temperature Design
  - 6 Subcommittee on Piping, Pumps and Valves

As could be expected the memberships of these groups overlap widely. After the duplications were eliminated a mailing of 707 questionnaires was sent out in February 1973. By the end of August 1973, after two reminders had been sent out, the total number of filled-in responses reached 249 or 36.6 percent.

The rate of return is itself interesting because it is virtually the same as that obtained by Medearis in his previously cited survey [9]. He had a rate of response of 32 percent on a questionnaire made up of 17 questions, compared to our 148, which he sent to 2000 randomly selected members of ASCE. In addition another survey of computer software use by 360 members of the ASCE Soil Mechanics Division was carried out by Woodward-Clyde and Associates [10]. Their questionnaire had 20 questions and they received 110 filled-in forms, or 30.6 percent. It thus became interesting to investigate the significance of the roughly one in three response that was experienced in our survey and, indirectly, in the other two surveys.

After a consideration of several factors it was concluded that the filled-in forms were received from persons who are actually involved with computer software either as direct users and/or writers or as supervisors of such people. The nonrespondents are essentially uninvolved and, therefore, reluctant to fill in the fairly long questionnaire. This conclusion was reached as follows:

First, the ASME Boiler and Pressure Vessel Committee is known to have a large number of members who are in vessel inspection, insurance or fabrication or who work for regulatory agencies concerning labor and safety in various state governments. These are not likely to be conversant with, or interested in, software and its exchange. Second, one of our questions asks the respondent to indicate the scope of his involvement with software. The answers to that question indicate that 198 of the respondents write and/or use programs or supervise persons who do; that is 79.5 percent of the persons who filled in the form. Furthermore, Medearis [9] found a similar percentage for the rate of return (83 percent) on a preliminary questionnaire that he sent to 89 individuals who were actively involved with computer software, that is, the attendees of the Special Workshop in Boulder to which we referred previously. As a result we reached our conclusions that our forms were filled in and returned by most of the individuals in our audience who had direct involvement with computer programs. Apparently our survey and those of Medearis [9] and Woodward-Clyde [10] have discovered that about one out of three engineers in the industries covered work with computers. Because of this we were also led to the conclusion that the results of the survey should be meaningful. In the next sections we shall discuss these findings and their implications upon the creation of the contemplated technology transfer effort.

## Summary of the Response Data

The frequencies of response to each choice on the 148 multiple choice questions are listed on the sample questionnaire that appears in the Appendix. These data will now be discussed with the goal of determining the background of the respondents, the extent of their involvement with computer software, how they feel about software and their reactions to the proposed technology transfer effort. After presenting the broad picture of the responses here we will, in the next section, present statistically significant

correlations in the data.

**I Personal Identification.** A glance at the frequency counts in this particular section of the questionnaire tells us the following information about the respondents:

1 While there is a large spread in their ages most of the respondents are between 35 and 50 yr old. Correspondingly, more than half have up to 15 yr of pressure vessel experience.

2 The highest degree earned by most of the respondents is the MS while the rest are almost equally divided between the BS and the PhD. Virtually all respondents studied engineering.

3 Almost all of the respondents are employed by corporations in the power generating equipment industry. Most of these are concerned with nuclear, as opposed to conventional, power generation. However, many indicated both. The single occupational description that describes their work is technical management. However, when design engineering and R&D engineering are combined the total is greater than for management.

4 The vessels dealt with by the respondents are of the advanced type which operate at elevated temperatures, in a radiation environment at pressures above 1000 psi.

5 The professional involvement of the respondents is high. More than half belong to 1 to 3 professional committees, while four out of five belong to at least one. About half of them attend 1 to 3 technical conferences per year. They read a technical publication at least weekly and many do so daily. About half of them attended a formal course within a year prior to the survey.

**II Computer Involvement.** In this section we sought to determine some details of the respondents' involvement with computer software. Here we found that most of them actually use computer programs or supervise people who do. Moreover, they are involved both in writing programs and in using programs written by others. They have been doing this well over three years. Other, very general, conclusions follow:

1 They are involved with programs of all sizes and besides writing programs and using other people's programs many also modify other people's programs.

2 Most of the respondents learned computer program writing and use on their own. Many also learned from courses in their organization or in universities.

3 Many of the respondents use the computer daily, their problems run mostly in minutes and they perfer to receive their results the same day or the next day. The computer they use is generally located in their own building or nearby, it is accessed by taking the deck to it or by terminal and it is not operated by their department.

When the respondents use programs written elsewhere the following facts are noteworthy:

1 They find out about such programs mostly from colleagues, technical publications and conferences.

2 The programs are mostly purchased or given to them by colleagues.

3 The use of the programs is learned by study of the manual or by obtaining instruction from the colleague.

4 The validity of the deck is generally verified by running a problem solved previously or by performing an experiment.

5 Many problems are encountered when other people's decks are used. The main ones appear to be documentation machine compatibility, programming errors, input preparation and output interpretation.

When the respondents write their own programs this takes up to 12 man-months of effort in most cases. They tend not to train users of decks outside of their organizations. Moreover, their decks tend not to be used too much outside of their organizations.

We also sought to determine which computing equipment was being used in the pressure vessel industry. Not all respondents supplied this information while many used more than one machine. Thus, the Central Processor Units used by respondents to the survey are listed in the forthcoming. Note that these are not numbers of CPU's since many large organizations were represented by more than one respondent.

**Central Processors Cited by Respondents**

| | | |
|---|---|---|
| *IBM:* | 370 | 46 |
| | 360 | 43 |
| | 1130 | 10 |
| | Misc | 5 |
| | All | 104 |
| *CDC:* | 7600 | 32 |
| | 6600 | 43 |
| | Misc | 17 |
| | All | 92 |
| *Univac:* | All | 26 |
| *GE-Honeywell:* | All | 22 |
| *DEC:* | All | 6 |
| *Burroughs:* | All | 5 |

**III Attitudes Toward Use of Software.** In this section the respondents' attitudes toward software were sought by making certain statements about it and asking for reactions on a four-step scale labelled "agree strongly," "agree," "disagree," "disagree strongly." First, we observe that on the whole the respondents "agree strongly" only with the statement that the complexity of modern pressure vessels makes computerized analysis and design a necessity. There is no statement in part III with which they "disagree strongly."

They tend to *agree* that:

1 improved access to software will make their work easier

2 software developers make reasonable claims for the capabilities of their programs

3 management generally favors computerized analysis and design

4 engineers need aides to do computerized analysis and design

5 the engineering department has too little to say about which computer gets purchased

6 computer programs shoud be proprietary

7 computer programs should be completely debugged before release

8 professional journals do not pay enough attention to computer programs

9 articles which describe computer programs are worthy contributions to the literature and should be published by learned journals

10 programs should be endorsed by some reputable neutral body in the industry

11 the industry needs a certification scheme to insure the qualifications of software users

12 the available short courses on general purpose finite element programs are valuable to the software user.

They tend to *disagree* that:

1 lack of computer of sufficient capacity limits their ability to take advantage of existing software

2 the cost of computerized analysis and design is too high

3 they do not have time to get involved with computerized analysis and design

4 most computer program manuals are adequately written

5 computer programs should be patentable

6 The computing center administration is not responsive to user needs.

Note that some of the disagreements are with negative statements. These were phrased in this manner to insure that the questions were being read carefully. These responses indicate a rather positive outlook regarding the respondents' experience with software. They feel that it could be given greater status via publications, they are in favor of some type of neutral endorsement of programs and certification of users. They are not satisfied with program manuals. While they agree (slightly) that software can be proprietary, they do not think it should be patentable.

**IV Attitudes Towards a Technology Transfer Effort for Software.** Given the background, the computer involvement and the attitudes toward software that were elicited in the first three parts of the questionnaire this section was meant to determine the respondents' feelings toward a technology transfer effort for software of the type that was described previously.

Using the same scale of responses that was used in part III it was found that on the whole there was no sense of *strong* agreement or disagreement with a collection of statements that describe the activities of the contemplated effort. The respondents did not tend to agree with only one of the statements; namely, that the staff of the effort should write programs to fill gaps. The respondents tended to agree that:

1 absence of such an effort is a barrier to wider use of computer programs in the industry
2 the effort should deal only in fully debugged programs
3 it should put on courses for the use of programs it stores
4 all programs selected should be written in the same language
5 the effort should give financial support for the writing of new programs to fill gaps
6 the effort should encourage the development of programs to fill gaps
7 it should charge its clients for services
8 it should publish program manuals
9 it should publish a journal of articles pertaining to software
10 the effort should buy programs from developers.

The responses to the other questions in part IV indicated that there were mixed feelings about sharing programs with the effort. Half said they would share most or all of their decks while half said they would share a few or none with it. It was also felt that the effort should deal in programs of all complexities, that it should maintain the decks that it holds, that there should be one national effort per technical field and that all types of organizations of various sizes would benefit from it. As to its operation the respondents felt mainly that programs held by the effort should be accessed either by remote terminals or by the mailing of decks to subscribers. They felt that the effort ought to be run by a professional society although many favored an industrial cooperative.

Finally, in response to a question on whether or not they favor, in general, the creation of such an effort the respondents voted yes 209 to 23 with 17 giving no response.

It thus appears that the effort and its various features and activities have been endorsed by the writers and users of software in the pressure vessel industry.

**V General Comments.** Some additional insight to the response was gained from the remarks made by 116 of the respondents under Part V General Comments. For the sake of brevity we shall not quote all of these comments. We will, however, give our own summary of them.

We found that the general comments tend to express the same feelings whether the respondent favored the creation of the effort or not. The main sense of the comments is that:

1 Organizations will not wish to relinquish their competitive edge by sharing their latest software. Thus, the effort will be limited to programs that are behind the times.
2 Many were concerned with the problem of verification which plagues the most sincere and honest efforts to share software. One never really knows when the last bug is out of a deck.
3 Some felt that current efforts such as COSMIC, IITRI, etc., are sufficient.
4 Many expressed the fear that one would never be able to obtain the level of funding that would be required to do the job properly, especially at the outset.

These reactions consititute a significant modification of the generally positive attitudes toward software and its exchange that were shown by the answers to the multiple choice questions.

## Statistically Significant Correlations Among the Response Data

At this point it is interesting to consider the possibility that there are some statistically meaningful correlations among the responses given to the questions on the survey. To determine the existence of such correlations we applied the standard chi-squared test to all of the questions two at a time. Using IBM Scientific Subroutine CHISQ [11] on the IBM-1130 computer we sought correlations at the 90 percent level of confidence and higher. We will not go into the details of the chi-squared test as its description would be beyond the practical scope of this discussion. It is well described in many texts, e.g., Siegel [12].

In applying the statistical tests for significance we noted the small numbers of response to many of the choices on the questionnaire. To maximize the chance of obtaining valid correlations we therefore used the accepted statistical strategy of combining response categories in many questions. For example, in the questions which asked for reactions on a four step scale from "strongly agree" to "strongly disagree" we combined the two categories of agreement into one. Similarly, the two categories of disagreement were combined into one. As a further illustration we revised the age categories in the first question to three groups: 20–35, 35–50, over 50.

In view of the fact that there were 148 questions on the form it is obvious that the number of correlations to be tested was extremely large. Thus, it was necessary to limit this phase of the study to a manageable yet important and interesting number of questions. As a result we will discuss the correlation of the responses with three basic questions. The first concerns the identification of the typical individual's involvement with software. The second pertains to his willingness to share programs with the contemplated effort. The third establishes his feeling toward the establishment of the effort. In each case the study is limited further by making correlations only with questions that appear on the form before each of the three cited questions.

**Question 2.1 Scope of Involvement With Computerized Analysis and Design.** Testing of the responses to this question and to other questions that precede it on the form led us to conclude that:

Writers and/or users of software generally,

1.1 are 20 to 35 yr old (0.999)[3]
1.2 have an MS or PhD degree (0.999)
1.5 have 0 to 10 yr of experience (0.99)
1.17 serve on three or less professional committees (0.999)
1.19 last attended a formal course less than a year before the survey (0.98).

Supervisors of writers and/or users of software generally,

1.1 are 35 to 50 yr old
1.2 have a BS degree

[3]The number before the statement is the question number. The number in parentheses after the statement is the confidence level. The latter are given only once in each set of correlations.

1.5 have more than 10 yr of experience
1.17 serve on 3 to 5 professional committees
1.19 attended a formal course more than a year prior to the survey.

Those respondents who are uninvolved with software use and/or writing generally,

1.1 are more than 50 yr old
1.17 serve on more than 5 professional committees
1.19 attended a course more than a year prior to the survey.

Thus, we observe that software is being written and/or used in the industry by young highly educated persons with some professional involvement. The supervisors of such people are older, less educated but more experienced and professionally involved than they are.

**Question 4.12 Willingness to Share Programs With the Transfer Effort.** Correlations between responses to this question and others preceding it in the survey led us to conclude that:

Those who would share all, or most, of their programs with the effort tend to,

1.2 hold a PhD degree (0.98)
2.1 write and/or use software (0.95)
2.35 obtain decks from colleagues (0.95)
2.66 have decks available free of charge (0.999)
3.12 think decks should not be proprietary (0.95)
4.1 think absence of the effort is a barrier to wider use of software (0.98).

Those who would share few, or none, of their programs tend to,

1.2 hold a BS or MS degree
2.1 supervise writers and/or users of software; hold views on questions 2.35, 2.66, 3.12 and 4.1 that are opposite to those held by people willing to share with the effort.

These correlations indicate a certain consistency of attitudes. They show that those who would share are the highly educated persons who are involved with the direct use of software and who are used to operating in an open atmosphere. Those who would not share are the slightly less educated supervisors of writers and/or users of software who are operating in a closed atmosphere.

**Question 4.31 Favor Establishment of Transfer Effort or Not?** Responses to this question and to other questions preceding it on the form indicate that:

Those who generally favor the establishment of the transfer effort for software tend to,

2.20 find out about decks from clearinghouses (0.99)
2.35 get decks from colleagues (0.95)
3.18 favor endorsement of programs (0.999)
3.19 favor user certification (0.90)
4.1 think its absence is a barrier to wider use of software (0.99)
4.5 want the effort to support the filling of gaps (0.95)
4.16 want the effort to maintain the decks it holds (0.95)
4.19 want access to the programs through remote terminals (0.98)
4.12 be willing to share most or all of their programs with it (0.999).

Those who do not favor the establishment of the effort hold opposite views on all of the foregoing except question 4.19 where they show no preference regarding access to the effort through terminals.

As in the previous question these correlations indicate a certain open, positive attitude on the part of those who favor the effort. They are used to free exchange of information and decks, they would share their programs and accept a need for user certification and deck endorsement. Those who do not favor the effort have a consistently negative mode of operation.

As a summary to the correlations we may note that in all but one case the levels of confidence are, in fact, 0.95 or greater. They indicate, as we noted in the summary of the response data, that there is a fairly positive, open attitude toward software and its exchange in the industry. One negative fact has, however, been introduced into the conclusions by the result that supervisors of software writers and users would share few or none of their programs with the proposed effort. This coupled with the additional correlation that the supervisors are more active professionally than the writers and users indicates that they will be likely to have a significant influence on any decision regarding the creation of the proposed transfer effort.

## Conclusions

We have surveyed the use of software and attitudes toward its exchange among highly active professionals in the pressure vessel industry. The rate of return on our questionnaire indicates that one out of three engineers in the industry is directly involved with computer software either as a writer, user or supervisor. This is in line with similar conclusions that were reached about civil engineers in studies carried out by Medearis [9] and Woodward-Clyde [10].

Many detailed features of the respondents' backgrounds, use of software, attitudes toward software and attitudes toward a dynamic technology transfer effort for software were brought out by their responses to 148 questions. These are described in the foregoing and will not be repeated here.

The sense of our findings is that the respondents have an overall positive attitude toward software and its exchange. They favor 209 to 23 the establishment of the proposed technology transfer effort for software. However, a study of the response data, of the statistical correlations that exist in the data and of the written remarks that about half of the respondents made indicates that some significant conditions on this endorsement exist in the pressure vessel industry. These, briefly, concern the feeling that organizations will not share their latest software with such an effort in order to maintain their competitive edge, that the verification problem must be solved, that current efforts are adequate and that sufficient funds to guarantee the success of the effort will not be available. It was also found that those who write and/or use software have a very positive, open attitude regarding its use and sharing with the contemplated effort. On the other hand supervisors of such poeple would not be willing to share programs with the effort. Since we also found that these supervisors are more involved with professional committees than are writers and users we can conclude that they will have the greater influence on any decision regarding the creation of such an effort.

Therefore, our findings tend to be similar to those of the Special Workshop on Engineering Software Coordination [5] but different from those of the Medearis survey [9]. The former recommended a pilot program while the latter recommended that no more than an information center for software be set up.

On the basis of our findings, as described in the foregoing, that our respondents have endorsed, with conditions, the establishment of a technology transfer effort for software it is our contention that the time is not yet right for a full scale attempt to create the effort. To overcome the conditions that we have discovered it is our conclusion that the pilot study recommended by the Special Workshop [5] is the best way to begin the creation of the effort. By demonstrating the operation of such a project the industry will have a specific example to which they can respond. After that one will be able to decide whether or not the reservations that this study has uncovered will in fact limit the success of the effort.

## Afterword

We should like to emphasize that the choice of data to discuss

was our own as was the intrepretation of the general comments written in by the respondents. Readers who wish to study other correlations or to use the data should feel free to contact the author.

## Acknowledgments

We are indebted to the National Sicence Foundation for sponsoring this research. In particular we would like to mention the guidance of Mr. C. A. Babendreier and Dr. M. P. Gaus of the Engineering Mechanics Division.

Many individuals made important direct contributions to the work which we would like hereby to acknowledge: Dr. J. D. Goldhar of RPI of Connecticut aided in the design of the questionnaire. Mr. L. Stone of RPI of Connecticut carried out the statistical calculations. Dr. A. C. Gangadharan of the Foster Wheeler Corporation, Professor H. Schaeffer of the University of Maryland, Dr. R. E. Nickell of the Sandia Corporation, Dr. D. S. Griffin of Pittsburgh, and Professor R. L. Schiffman of the University of Colorado reviewed the questionnaire. Professor B. Baldwin of Central Connecticut State College and Professor R. Pichey of the Univeristy of Connecticut gave advice on determining the significance of the rate of return.

Finally, we wish to extend our gratitude to the 249 individuals who filled in and returned their questionnaires. Without them the study would not have been possible.

## References

1 Kraus, H., "Computers and the Analysis of Pressure Vessels," *Computers and Structures*, Vol. 2, 1972, pp. 757–769.

2 Berman, I., ed., *Engineering Computer Software: Verification, Qualification, Certification*, ASME, New York, 1971.

3 Kraus, H., ed., *The Software User: Education and Qualification*, ASME, New York, 1972.

4 Kraus, H., ed., *Use of the Computer in Pressure Vessel Analysis*, ASME, New York, 1969.

5 Schiffman, R. L., "Report on the Special Workshop on Engineering Software Co-ordination," Computing Center Report 72-2, University of Colorado, Boulder, Colo., Mar. 1972.

6 Schiffman, R. L., papers prepared for the Special Workshop on Engineering Software Coordination, Computing Center Report 72-4, University of Colorado, Boulder, Colo., April 1972.

7 Schiffman, R. L., transcript of the Special Workshop on Engineering Software Coordination, Computing Center Report 72-17, University of Colorado, Boulder, Colo., June 1972.

8 Fenves, S. J., Schiffman, R. L., and Baron, M. L., "A Position Paper on Computer Based Technology Transfer in Civil Engineering, International Colloquium on Integrated Systems in Civil Engineering," C.E.P.O.C., Liege University, Belgium, Aug. 1972.

9 Medearis, K., "An Investigation of the Feasibility of Establishing a National Civil Engineering Software Center," Report to N.S.F., Jan. 1973.

10 Personal correspondence: L. N. Beckreck of Woodward-Clyde and Associates to R. L. Schiffman, University of Colorado, April 17, 1973; and R. L. Schiffman to C. A. Babendreier, N.S.F., May 21, 1973.

11 CHISQ, IBM 1130 Scientific Subroutine Package 1130-CM-02X, Publication No. H20-0252-3, pp. 50–51.

12 Siegel, S., *Non-Parametric Statistics*, McGraw-Hill Book Company, New York, 1956.

# APPENDIX

## Pressure Vessel Software Use and Attitude Survey Questionnaire

We reproduce here the questionnaire that was used in our survey. In each question the numbers (M) signify the response frequencies for the various choices. Recall that the total number of respondents was 249.

### I Personal Identification

1.1 What is your age?

1 20–25 (3) 4 35–40 (40) 7 50–55 (33)
2 25–30 (8) 5 40–45 (36) 8 55–60 (23)
3 30–35 (58) 6 45–50 (31) 9 Over 60 (16)

1.2 What is your educational attainment?

1 High school diploma (12) 3 Master's degree (103)
2 Bachelor's degree (68) 4 Doctor's degree (65)

1.3 What is the nature of your education?

1 Engineering (228) 4 Liberal Arts (0)
2 Science (4) 5 Computer Science (2)
3 Business (0) 6 Other (specify) (0)

1.4 What is the nature of your current occupation?

1 Design engineering (49) 6 Technical management (59)
2 R & D engineering (38) 7 Consulting (22)
3 Test engineering (3) 8 Academic (13)
4 Materials engineering (16) 9 Production (0)
5 Computing (5) 10 Other (specify) (0)

1.5 How many years of pressure vessel experience do you have?

1 0–5 (54) 4 15–20 (27) 7 30–35 (9)
2 5–10 (48) 5 20–25 (28) 8 35–40 (4)
3 10–15 (51) 6 25–30 (20) 9 Over 40 (5)

1.6 What is the nature of your employer?

1 Corporation (180) 4 Foundation (4)
2 Government (34) 5 Self-employed (6)
3 University (12) 6 Partnership (5)
7 Other (specify) (6)

1.7 What is the nature of your organization's business?

1 Conventional power equipment (9)
2 Nuclear power equipment (62)
3 Petrochemical equipment (10)
4 Process equipment (8)
5 Utility (16)
6 Aerospace (1)
7 Education (13)
8 Consulting (21)
9 Computing (1)
10 Other (specify) (0)

1.8 How many people does your organization employ?

1 Under 50 (32)
2 50–100 (10)
3 100–1000 (57)
4 1000–5000 (70)
5 5000–10,000 (24)
6 10,000–50,000 (47)
7 50,000–100,000 (1)
8 100,000–150,000 (2)
9 Over 150,000 (1)

1.9 How many engineers does your organization employ?

1 None (2) 4 50–100 (15) 7 1000–5000 (54)
2 0–10 (33) 5 100–500 (60) 8 5000–10,000 (9)
3 10–50 (33) 6 500–1000 (37) 9 Over 10,000 (1)

1.10 What fraction of the engineers in your organization spend most of their time on pressure vessels?

1 None (14) 4 40–60 percent (19)
2 0–20 percent (142) 5 60–80 percent (16)
3 20–40 percent (37) 6 80–100 percent (15)

1.11–1.15 In which of the following regimes do the pressure vessels you deal with operate?

| | | Yes | No |
|---|---|---|---|
| 1.11 | Creep range | 1 (147) | 2 (66) |
| 1.12 | Pressures above 1000 psi | 1 (195) | 2 (24) |
| 1.13 | Radiation environment | 1 (149) | 2 (57) |

1.14 Cyclic operation 1 (208) 2 (16)
1.15 Other (specify if yes) 1 (57) 2 (20)

1.16 How often do you attend professional conferences?

1 Never (9)
2 Every 3 yr (17)
3 Every 2 yr (25)
4 1–3 per yr (123)
5 3–5 per yr (43)
6 More than 5 per yr (31)

1.17 How many professional committees, subcommittees, task groups, etc., do you belong to?

1 None (49)
2 1–3 (107)
3 3–5 (49)
4 5–10 (33)
5 10–15 (4)
6 Over 15 (5)

1.18 How often do you read any kind of a technical journal, magazine or other publication of current interest?

1 Daily (75)
2 Weekly (128)
3 Monthly (38)
4 Quarterly (3)
5 Semi-annually (0)
6 Annually (0)
7 Hardly ever (1)

1.19 When did you last attend any type of formal course relating to your work in your company, a university or elsewhere?

1 Last week (16)
2 Last month (8)
3 Last year (87)
4 Two years ago (33)
5 Three years ago (19)
6 Over three years ago(82)

## II Computer Involvement

2.1 Indicate the scope of your involvement with computerized analysis and design:

(135) 1 I write and/or use computer programs. (Go to Question 2.2.)

(63) 2 I do not write and/or use computer programs but my employees do. (Go to question 2.2.)

(23) 3 Neither I nor my employees write or use computer programs but others in my organization do. (Skip to Question 2.75.)

(16) 4 No one in my organization writes or uses computer programs. (Skip to Question 2.75.)

*The next set of questions should be answered only if you circled 1 or 2 in the previous question. If you circled 1 answer them on your own behalf. If you circled 2 answer them from the point of view of your employees.*

2.2–2.7 What is your specific computer involvement (or that of your employees)?

| | | Yes | No |
|---|---|---|---|
| 2.2 | Write own special purpose programs | 1 (165) | 2 (26) |
| 2.3 | Use others' special purpose programs | 1 (173) | 2 (10) |
| 2.4 | Write own general purpose programs | 1 (85) | 2 (82) |
| 2.5 | Use others' general purpose programs | 1 (162) | 2 (14) |
| 2.6 | Modify others' special purpose programs | 1 (121) | 2 (48) |
| 2.7 | Modify others' general purpose programs | 1 (109) | 2 (58) |

2.8–2.14 What is your training in computer program writing and/or use (or that of your employees)?

| | | Yes | No |
|---|---|---|---|
| 2.8 | A degree in computer science | 1 (15) | 2 (119) |
| 2.9 | Courses run by my organization | 1 (79) | 2 (68) |
| 2.10 | University short courses | 1 (90) | 2 (63) |
| 2.11 | Self-taught | 1 (142) | 2 (18) |
| 2.12 | Course given by another organization | 1 (65) | 2 (74) |
| 2.13 | Course given by outside consultant | 1 (27) | 2 (103) |
| 2.14 | Other (specify if yes) | 1 (12) | 2 (65) |

2.15 How often do you (or your average employee) use the computer for pressure vessel analysis and design?

1 Daily (67)
2 A few times a week (34)
3 A few times a month (38)
4 A few times a year (55)

2.16 How long do your computer problems run (or those of your employees)?

1 Seconds (14)
2 Minutes (101)
3 Hours (11)
4 Varies (62)

2.17 When you (or your employees) use the computer you are satisfied if the results come back no later than the

1 Same day (72)
2 Next day (95)
3 Same week (15)
4 Following week (2)
5 Varies (12)

2.18 Where is the computer that is used by your organization located?

1 In our building (59)
2 In a nearby building (58)
3 Across town (24)
4 Out of town (in state) (13)
5 Out of state (24)

2.19 How many years have you (or your average employee) been using the computer?

1 0–1 (0)
2 1–3 (17)
3 3–5 (56)
4 5–10 (67)
5 10–15 (43)
6 Over 15 (20)

2.20 What computer(s) is(are) used by your organization?
Central Processor Unit
Manufacturer:
Model:
Auxiliary core storage:
Peripherals:

2.21 How is the computer accessed?

1 Taking the deck to it (55)
2 Mailing the deck to it (5)
3 Teletype terminal (17)
4 Computer terminal (59)
5 Other (specify) (3)

2.22 Who operates the computer?

1 Our department (20)
2 Another department (134)
3 Commercial facility (23)
4 Other (specify) (6)

2.23 Do you (or your employees) use programs written elsewhere?

1 Yes (176)
(Go to question 2.24)
2 No (24)
(Skip to Question 2.61)

2.24–2.31 When you (or any of your employees) use programs written elsewhere you find out about them from:

| | | Yes | No |
|---|---|---|---|
| 2.24 | My supervisor | 1 (49) | 2 (74) |
| 2.25 | Technical publication | 1 (125) | 2 (24) |
| 2.26 | Technical meetings | 1 (125) | 2 (21) |
| 2.27 | Colleagues | 1 (146) | 2 (8) |

| | | | | | |
|---|---|---|---|---|---|
| 2.28 | Course work | 1 | (35) | 2 | (92) |
| 2.29 | User's groups | 1 | (81) | 2 | (58) |
| 2.30 | Clearinghouses | 1 | (84) | 2 | (52) |
| 2.31 | Others (specify if yes) | 1 | (23) | 2 | (68) |

2.32–2.37 When you (or any of your employees) use programs written elsewhere you obtain them by:

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.32 | Purchasing the deck | 1 | (125) | 2 | (27) |
| 2.33 | Running at a commercial facility | 1 | (81) | 2 | (49) |
| 2.34 | Through a user's group | 1 | (73) | 2 | (57) |
| 2.35 | Getting deck from a colleague | 1 | (100) | 2 | (40) |
| 2.36 | Paying a consultant to run the deck | 1 | (36) | 2 | (89) |
| 2.37 | Other (specify if yes) | 1 | (20) | 2 | (54) |

2.38–2.44 When you (or any of your employees) use programs written elsewhere you learn how by:

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.38 | Having a colleague show us | 1 | (103) | 2 | (38) |
| 2.39 | Studying the manual | 1 | (161) | 2 | (4) |
| 2.40 | Attending a course in our organization | 1 | (61) | 2 | (68) |
| 2.41 | Attending a university course | 1 | (16) | 2 | (104) |
| 2.42 | Attending a consultant's course | 1 | (60) | 2 | (72) |
| 2.43 | Attending a commercial computer facility course | 1 | (54) | 2 | (74) |
| 2.44 | Other (specify if yes) | 1 | (10) | 2 | (60) |

2.45–2.50 When you (or any of your employees) use programs written elsewhere you verify their validity on the basis of:

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.45 | Faith in the source | 1 | (39) | 2 | (84) |
| 2.46 | A colleague's word | 1 | (46) | 2 | (81) |
| 2.47 | A consultant's word | 1 | (26) | 2 | (95) |
| 2.48 | Running a problem solved previously | 1 | (168) | 2 | (4) |
| 2.49 | Running an experiment | 1 | (102) | 2 | (36) |
| 2.50 | Other (specify if yes) | 1 | (17) | 2 | (54) |

2.51–2.60 In our experience with programs written elsewhere we have found:

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.51 | Documentation problems | 1 | (149) | 2 | (9) |
| 2.52 | Machine compatibility problems | 1 | (133) | 2 | (23) |
| 2.53 | Programming errors | 1 | (131) | 2 | (23) |
| 2.54 | Analysis errors | 1 | (95) | 2 | (43) |
| 2.55 | Errors in numerical procedure | 1 | (83) | 2 | (49) |
| 2.56 | Cards missing or out of order | 1 | (83) | 2 | (52) |
| 2.57 | Input preparation problems | 1 | (137) | 2 | (14) |
| 2.58 | Output interpretation problems | 1 | (110) | 2 | (28) |
| 2.59 | Cards mis-punched | 1 | (59) | 2 | (67) |
| 2.60 | Other (specify if yes) | 1 | (15) | 2 | (47) |

2.61 Do you (or any of your employees) write programs?

1 Yes (175) 2 No (29)

(go to Question 2.62) (skip to Question 3.1)

2.62 On the average how many man months of effort are put into the production of a significant program by you or your employees?

| | | | |
|---|---|---|---|
| 1 | 0–3 (64) | 6 | 24–30 (2) |
| 2 | 3–6 (57) | 7 | 30–36 (0) |
| 3 | 6–12 (27) | 8 | 36–42 (0) |
| 4 | 12–18 (8) | 9 | 42–48 (0) |
| 5 | 18–24 (5) | 10 | Over 48 (0) |

2.63 Do you (or any of your employees) train users of your decks outside of your organization?

1 Yes (53) 2 No (125)

2.64 To what extent are programs written by you (or your employees) used by persons outside of your organization?

1 Widely (12) 3 Hardly (46)
2 Moderately (42) 4 Not at all (57)
5 Do not know (18)

2.65–2.74 Programs written by you (or your employees) are available to others:

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.65 | Not at all | 1 | (58) | 2 | (77) |
| 2.66 | From us at no cost | 1 | (41) | 2 | (65) |
| 2.67 | From us at a fee | 1 | (48) | 2 | (66) |
| 2.68 | Through government agency at no cost | 1 | (32) | 2 | (72) |
| 2.69 | Through government agency at a fee | 1 | (10) | 2 | (85) |
| 2.70 | Through a computer firm at no cost | 1 | (3) | 2 | (91) |
| 2.71 | Through a computer firm at a fee | 1 | (20) | 2 | (79) |
| 2.72 | Through a user's group at no cost | 1 | (15) | 2 | (80) |
| 2.73 | Through a user's group at a fee | 1 | (11) | 2 | (86) |
| 2.74 | Through other channels (specify if yes) | 1 | (18) | 2 | (52) |

*Skip to question 3.1*

2.75–2.79 *The next set of questions should be answered only if you circled 3, or 4 in question 2.1*

Computers are not used by myself, my employees or others in my organization because

| | | Yes | | No | |
|---|---|---|---|---|---|
| 2.75 | They are not applicable to our work | 1 | (15) | 2 | (8) |
| 2.76 | Proprietary barriers prevent use of the ones we need | 1 | (2) | 2 | (11) |
| 2.77 | Our computer work is farmed out | 1 | (5) | 2 | (8) |
| 2.78 | Geographic limitations | 1 | (1) | 2 | (11) |
| 2.79 | Other (specify if yes) | 1 | (12) | 2 | (2) |

**III Attitudes Toward Use of Software.** *In the following indicate your response by circling the number which corresponds to it according to the scale:*

1 Agree strongly
2 Agree
3 Disagree
4 Disagree

| | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 3.1 | Complexity of modern pressure vessels makes computerized analysis and design a necessity | (152) | (70) | (16) | (2) |
| 3.2 | Improved access to software will make my work easier | (81) | (112) | (38) | (2) |
| 3.3 | My lack of computer of sufficient capacity limits my ability to take advantage of existing software | (18) | (34) | (119) | (59) |

| | | | | | |
|---|---|---|---|---|---|
| 3.4 | Software developers make reasonable claims for the capabilities of their programs | (4) | (144) | (64) | (6) |
| 3.5 | Management generally favors computerized analysis and design | (29) | (161) | (37) | (5) |
| 3.6 | The cost of computerized analysis and design is too high | (27) | (63) | (119) | (15) |
| 3.7 | I do not have enough time to get involved with computerized analysis and design | (14) | (38) | (112) | (69) |
| 3.8 | Engineers need aide(s) to do computerized analysis and design | (51) | (124) | (45) | (10) |
| 3.9 | Most computer program manuals are adequately written | (1) | (75) | (118) | (27) |
| 3.10 | In organizations with centralized computing facilities engineering jobs will have lower priorities than accounting or administrative jobs | (32) | (84) | (97) | (12) |
| 3.11 | The engineering department has too little to say about which computer gets purchased | (38) | (89) | (75) | (15) |
| 3.12 | Computer programs should be proprietary | (19) | (101) | (81) | (22) |
| 3.13 | Computer programs should be patentable | (18) | (66) | (110) | (32) |
| 3.14 | Computer programs should be completely debugged before release outside of the originating organization | (78) | (103) | (38) | (11) |
| 3.15 | The professional journals do not pay enough attention to computer programs | | | | |
| 3.16 | Articles which describe computer programs are worthy contributions to the technical literature and should be published by learned journals | (34) | (146) | (37) | (5) |
| 3.17 | The computing center administration is not responsive to user needs | (12) | (63) | (130) | (10) |
| 3.18 | Computer programs should be endorsed by some reputable neutral body in the pressure vessel industry | (49) | (111) | (48) | (20) |
| 3.19 | The pressure vessel industry needs a certification scheme to insure the qualifications of software users | (44) | (107) | (57) | (17) |
| 3.20 | The available short courses on general purpose finite element programs are in general valuable to the software user | (24) | (164) | (20) | (22) |

**IV Attitudes Toward a Technology Transfer Effort for Software.** *Use the same scale of responses as was given for part III.* In approaching the next set of questions consider that such an effort would collect, store and disseminate computer software throughout the industry. Its general features are described in the letter of transmittal.

| | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 4.1 | Absence of such an effort is a barrier to wider use of computer programs in the pressure vessel industry | (31) | (132) | (56) | (6) |
| 4.2 | The effort should deal only in fully debugged programs | (53) | (118) | (40) | (11) |
| 4.3 | The effort should put on courses for the use of programs it stores | (38) | (152) | (26) | (5) |
| 4.4 | All programs selected by the effort should be written in the same language | (36) | (102) | (68) | (15) |
| 4.5 | The effort should give financial support for the writing new programs to fill gaps it perceives | (24) | (137) | (51) | (9) |
| 4.6 | The staff of the effort should write programs to fill gaps | (10) | (87) | (102) | (19) |
| 4.7 | The effort should encourage the development of programs to fill gaps that it perceives | (42) | (170) | (8) | (2) |
| 4.8 | The effort should charge its clients for services rendered | (24) | (175) | (19) | (3) |
| 4.9 | The effort should publish program manuals | (39) | (165) | (13) | (3) |
| 4.10 | The effort should publish a journal of articles pertaining to software | (35) | (158) | (25) | (4) |
| 4.11 | The effort should buy programs from developers | (17) | (142) | (41) | (9) |

4.12 Would you be willing to have your programs or those of your organization become part of the effort?

1 All (29) 3 A few (70)
2 Most (73) 4 None (28)

4.13–4.15 The effort should deal in:

| | | Yes | No |
|---|---|---|---|
| 4.13 | Special purpose programs | 1 (166) | 2 (39) |
| 4.14 | Medium general purpose programs | 1 (191) | 2 (13) |
| 4.15 | Large general purpose programs | 1 (156) | 2 (43) |

4.16 Responsibility of maintianing the programs held by the effort should lie with

1 The originating organization (92)
2 The effort (123)

4.17 There should be

1 One effort per technical field (140)
2 One effort for all fields (71)

4.18 The effort should consist of

1 Regional facilities (71)
2 One national facility (143)

4.19–4.22 Programs held by the effort should be accessed by:

| | | Yes | No |
|---|---|---|---|
| 4.19 | Remote terminals | 1 (152) | 2 (39) |
| 4.20 | Mail or messenger delivered input data | 1 (85) | 2 (80) |
| 4.21 | Mailing decks to subscribers | 1 (155) | 2 (29) |
| 4.22 | Other (specify if yes) | 1 (13) | 2 (48) |

4.23–4.29 The effort will benefit

| | | Yes | No |
|---|---|---|---|
| 4.23 | Large corporations | 1 (156) | 2 (40) |
| 4.24 | Medium corporations | 1 (188) | 2 (9) |
| 4.25 | Small corporations | 1 (192) | 2 (11) |
| 4.26 | Individual practitioners | 1 (169) | 2 (23) |
| 4.27 | Software developers | 1 (154) | 2 (29) |
| 4.28 | Computer companies | 1 (144) | 2 (33) |
| 4.29 | Other (specify if yes) | 1 (21) | 2 (30) |

4.30 The effort should be organized and operated by a

1 Professional society (85)
2 Federal agency (18)
3 Computer company (1)

4 University (7)
5 Private corporation (14)
6 Industrial co-operative (46)
7 Federal Laboratory (8)
8 Other (specify) (11)

4.31 Do you, in general, favor the establishment of a technology transfer effort for software?

1 Yes (209) 2 No (23)

**V General Comments.** It would greatly enhance the value of the results of this survey if you would describe the reactions that enter your mind when you contemplate the establishment of a technology transfer effort for computer software: