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ABSTRACT

Reported is the development of a set of behavior anchored scales (BAS) for evaluating the job performance and technical updating activities of engineers. A total of 327 engineers and technical supervisors participated in the various phases of this project. Separate groups: (1) identified 11 factors related to job performance and technical updating: (2) generated examples of behaviors related to these factors: (3) categorized these examples according to the specific behavior represented: (4) rated the favorability of the behavioral examples: and (5) evaluated engineers by using the finalized rating scales. Validity analyses suggest that the BAS instruments developed in this project appear to be psychometrically sound and useful devices. (Author/WB)

Behavior Anchored Scales - A Method for Identifying Continuing Education Needs of Engineers

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Table of Contents

Acknowledgements

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Abstract

A set of behavior anchored scales (BAS) to measure eleven factors related to the technical job performance and technical updating activities of engineers was developed. A total of 327 engineers and technical supervisors from 94 organizations participated in the various phases of the project. Separate groups of engineers and supervisors developed the factors relevant to performance and updating, generated behavioral examples of the factors, classified the behavioral examples according to the factors, scaled the favorability of the behavioral examples, and evaluated engineers using the final scales. Data collected in the last phase of the project suggested that the final set of scales could be used to describe the technical performance and updating activities of engineers. The factor scales: (a) were moderately intercorrelated, suggesting a minimum of halo error; (b) demonstrated sufficiently large standard deviations of ratings, suggesting that raters were differentiating among ratees; and (c) had mean ratings above the middle point of the scale which probably approximated the objective performance level of the ratees, although leniency error cannot be ruled out as possibly existing.

The set of BAS instruments appears to be useful in detecting possible technical job performance deficiencies that may suggest technical updating needs of the engineer. They may also be used to provide feedback to the engineer regarding performance and his or her current attempts at updating. They can also serve as input to the design of professional and career development plans for the engineer.

The scales are not intended to specify the exact kind of updating required by a particular engineer as they are designed to be useful to a wide variety of engineering disciplines and organizations. The major use of the scales would be to measure the general need for technical updating among engineers.

Behavior Anchored Scales - A Method for Identifying Continuing Education Needs of Engineers

Technical obsolescence among engineers has been identified as a critical problem facing American industry (Dubin, Shelton, and McCormick, 1973; Kaufman, 1974; National Science Foundation, 1976; Raudsepp, 1976; Ritti, 1971). Technical obsolescence refers to the lack of current technical knowledge and skills that are necessary for effective performance of job assignments. Much attention has been directed toward the reduction, and hopefully the prevention, of technical obsolescence among engineers. One approach to the reduction and prevention of obsolescence has been to focus upon technical updating activities in which engineers might engage. Technical updating activities refer to the various ways in which an engineer might learn about current technical developments and applications.

Although the need for an engineer to engage in technical updating throughout his or her technical career has been widely recognized (e.g., Dubin, et al., 1973; Kaufman, 1974; National Science Foundation, 1976), there has not existed an adequate method of determining who needs what kind of updating. Most investigations of technical updating and obsolescence have relied upon some form of self-assessment (e.g., Dubin and Marlow, 1965; Dubin and Regan, 1977; Ritti, 1971). Engineers have been asked what they perceive to be their own deficiencies in technical knowledge and skills. While this approach can produce valuable information, it is difficult to make direct comparisons between various engineers due to the subjective and somewhat unstructured nature of the data obtained. The accuracy of such deficiency estimates may be questioned also since it seems reasonable to assume that these estimates may typically be biased in the direction of reporting less deficiency than may actually exist.

Another approach to determining the technical updating needs of engineers is to seek information from the supervisors of engineers. Supervisory personnel are typically in a position to evaluate the work output of their subordinate engineers, to compare the technical work of various engineers, and to be knowledgeable concerning the technical needs of the organization. However, several studies (e.g., Dubin and Marlow, 1965; Landis, 1969; National Science Foundation, 1969) have reported that supervisors often do not take much interest in the continuing education and professional development of their subordinate engineers. Likewise, it has also been reported that supervisory personnel often do not give their subordinate engineers detailed performance feedback concerning their technical job duties. A possible reason for both the lack of interest in the continued professional development of subordinates and the lack of performance feedback to subordinates is the absence of a systematic method of identifying technical performance strengths and weaknesses.

It would be desirable, then, to have a method which would satisfy several needs. A technique is needed which would help to identify the technical updating needs of engineers that would allow comparison both within and between individual engineers, preferably which could be used by supervisory personnel to evaluate their subordinate engineers and by engineers for self evaluation. The technique should also aid supervisors in providing feedback to their subordinate engineers about their technical job performance and in establishing professional development programs for their subordinates. The method should be as objective as possible while recognizing the inherent subjectivity of such judgments and recognizing the variability inherent in job assignments, technical requirements, and developmental needs of various engineers and organizations.

An approach which appears to offer promise in the achievement of the objectives described above is the behavior anchored scale (BAS) method of developing rating scales. The BAS method and underlying assumptions are discussed in the next section. This discussion is followed by a consideration of the application of the BAS method to technical updating concerns.

Behavior Anchored Scales

In 1963, Smith and Kendall introduced a new method of rating scale development and utilization called behavioral expectation scaling. This scale format also became known as the behavior anchored scale method (BAS). The BAS rating scale format differs from other scale formats, namely the graphic rating scale, primarily in three respects: 1) Smith and Kendall philosophically differ from other psychologists in their approach to scale construction; 2) the philosophical difference is reflected in the difference between the procedure for BAS construction and the procedure for the construction of traditional formats; and 3) physically, the BAS format differs from the more traditional graphic rating scales. Each difference will be briefly discussed below.

First, Smith and Kendall state that psychologists tend to impose their own beliefs and interpretations about behavior and job performance upon raters. Many psychologists believe that this is necessary in order to obtain reliable and valid rating systems. For example, psychologists who favor trait theory construct scales which they believe reflect independent factors and those who believe performance is a composite of observed behaviors devise items reflecting good and poor performance (Smith & Kendall, 1963). The construction of these scales is primarily based on the psychologist's own values and beliefs. The raters who will be using the traditional rating scale are rarely consulted as to their interpretation of the dimensions and rarely participate in the construction of the scales. Constructing traditional scales based on the psychologists' values assumes: 1) that psychologists understand and agree upon the organization of the traits or dimensions relevant to the job in question, and 2) that raters agree with the psychologists on the interpretation of the traits. Without the participation and consensus of the raters in the scale construction process, Smith and Kendall state that agreement on the interpretation of the scale dimensions cannot be achieved. The BAS differs philosophically from the development of other scale formats in that the contribution of the raters and the ratees who will be subsequently using the form and evaluated by the form is believed to be an essential input in the construction process.

Second, the philosophic difference in the BAS approach is reflected in the differences between the procedures used in developing a traditional scale and the procedures used in BAS scale construction. In the traditional scale construction process, psychologists themselves generally develop the dimensions and items of the scale. However, the BAS procedure involves a four-step process in which at each step independent groups of raters and ratees participate in the construction of the scale. Each of the four steps involved in the construction of the behavioral anchored rating scale is discussed in a later section.

The third way in which the BAS differs from the traditional graphic rating scale is in physical appearance. Smith and Kendall (1963) describe the BAS format as a series of continuous graphic rating scales arranged vertically. Each scale which describes a specific dimension of performance is arranged with a label and dimension definition at the top. The anchors which appear at different intervals on the scale are examples of actual behaviors rather than adjectives or trait labels which are usually characteristic of traditional scales. The behavioral examples are intended to define a level (high, average or low performance) of a specific performance dimension.

<u>Proposed Advantages of the BAS</u>

The BAS has many proposed advantages (Smith and Kendall, 1963; Beatty, Schneier, and Beatty, 1977; Blood, 1974; Jacobs, Kafry and Zedeck, 1979) which can be categorized into three areas: 1) advantages for the organization; 2) advantages for the rater; and 3) advantages for the ratee. Each one of these areas is briefly discussed below.

<u>Organizational benefits</u>. Blood (1974) and Jacobs, et al. (1979) have suggested that the BAS procedure provides for an analysis within and between organizational levels on the agreement of policy. Blood (1974) states that item variances, obtained during the phase in which each item is scaled according to the level of performance it reflects, indicate

the agreement among managers or raters on the appropriateness of certain behaviors. Large variances indicate low agreement among managers about specific behaviors. In order to maximize the accuracy of a rating scale, agreement among the raters regarding which behaviors reflect appropriate and inappropriate behaviors is essential. It has been proposed that the BAS procedures allow for this type of analysis.

Blood (1974) has also suggested that the BAS procedure may be useful in assessing the accuracy of the communication of organizational policy between organizational levels. In the BAS procedure, items (reflecting specific performance dimensions) are scaled on the degree to which they reflect effective or ineffective performance. The scale value of an item is its mean rating. Mean item values can be collected from different organizational levels to determine how well organizational policy has been communicated among the levels. Poor communication may be indicated where mean item values vary substantially between organizational levels.

Another proposed organizational advantage in using the BAS procedure is that the behavioral items collected could provide a basis for training (Jacobs, et al., 1979). For example, if a task is not being performed effectively across departments, the organization can develop a training program to correct the noted deficiencies (Jacobs, et al., 1979)

<u>Advantages to the Rater (Supervisor)</u>. By evaluating individuals on specific performance dimensions and ordering the dimensions in terms of performance proficiency for a given individual, the supervisor has the necessary information to focus his/her attention where improvement in

the subordinate's performance is most needed (Jacobs, et al., 1979). The supervisor may also be able to identify training needs of individuals if, for example, many are rated low on a specific performance dimension. Thus, the supervisor can use the BAS in performing one of the most improtant supervisory duties, guidance and development of the employees.

Advantages to Ratees. The BAS method has the potential to identify strengths and weaknesses for each ratee because it is a multi-factor evaluation method. However, unlike many evaluation methods, the BAS provides a behavioral component which enables the ratee to compare his or her level of actual performance against actual job tasks (Jacobs, et al., 1979). This behavioral component is the explicit statement of effective and ineffective job behaviors. These behaviors can serve as performance goals for the employee. Feedback to the employee, when positive, may serve as a source of satisfaction or motivation. On the other hand, feedback indicating employee weaknesses may indicate certain areas where the employee needs training or additional education. The BAS procedure could be expected to lead to improved employee performance because of ratee participation in the development of the scale and because performance expectations are behaviorally specified. Improvement in employee performance could also be expected by implementing the scales as a feedback vehicle to specific employee behavioral deficiencies.

Limitations of BAS

Many researchers in this area agree that BAS are expensive to construct. The accepted procedure to develop this scale requires independent judges (raters, ratees or both) to develop the dimensions and dimension definitions, to develop behavioral examples of these dimensions, and to assign scale values to these behavioral examples. The effectiveness of the scale depends, in part, on the independence of the groups in each of the developmental stages (Landy & Farr, 1980). Thus, the investment of time is extensive in the development of BAS. Since the time and expense involved in constructing this scale is considerable, one would expect that behavior anchored scales would have some advantage (more error-free) over other methods. There have been several extensive reviews of the advantages of the behavior anchored scale (Schwab, Heneman, & DeCotiis, 1975; Bernardin, et al., 1976; Bernardin, 1977; Landy & Farr, 1980) that indicate that they are not much better psychometrically than <u>carefully</u> constructed graphic scales or summated checklists (Landy & Trumbo, 1980). The procedures for developing a behavior anchored scale almost guarantee that the scales will be carefully developed. However, this is not necessarily the case with other formats. The multi-step process of developing a behavior anchored scale insures some quality in the final result (Landy & Trumbo, 1980). A more detailed description of the BAS developmental procedures appears in the next section.

Steps in the Development of a Behavior Anchored Rating Scale

The development of the behavior anchored scale requires that the participants in each of the construction phases have work experience similar to those who are later to use the scales. The language of the scale should reflect the "jargon" or language of the job. It is hoped that these goals are met by using the following four steps (Jacobs, et al., 1979).

Phase I. Dimension Generation and Example Development

A group of raters meet to identify and define an exhaustive list of job dimensions or factors which are necessary for successful performance. Participants are encouraged to discuss the generated list of dimensions in order to eliminate redundancies and to combine overlapping terms. The result of this phase is usually a list of labels depicting factors relating to general areas of job performance.

A second group of individuals is asked to take the dimensions generated earlier and provide behavioral examples of high, average and low performance on each of those dimensions.

Phase II. Behavioral Example Allocation

A third group of raters is given a list of the dimensions (and their definitions) and a randomized list of the behavioral examples generated in Phase I. They are asked to assign each behavioral example or item to the category or dimension that it best represents (Jacobs, et al., 1979). Examples consistently assigned to a dimension (usually using a criterion of 60-70 percent of respondents) are retained. If behavioral examples cannot be allocated to a dimension (do not meet the agreement criterion), they are considered ambiguous and are eliminated from further phases.

Phase III. Assignment of Scale Values to Behavioral Examples

A fourth group is provided with the dimensions and their corresponding items that met the criteria in Phase II. They are asked to assign scale values to each behavioral example, indicating the level of performance on the specific dimension that the particular example represents (Landy & Trumbo, 1980). The means and standard deviations are computed for each example. According to Landy and Trumbo (1980), examples are selected if they meet the following criteria: 1) the set of examples have mean values which provide anchors for the entire scale and 2) they have relatively small standard deviations. When an example has a large standard deviation, it suggests that the example is either ambiguous or that raters cannot agree on the performance level that the example represents. The behavioral examples meeting the criteria for Phases II and III are then used in the final behavior anchored scale.

Phase IV. Use of the Scales

After the BAS for each factor or dimension of performance has been constructed, the set of rating scales is next used by supervisory personnel to evaluate the performance of their subordinates. These ratings are examined with regard to psychometric properties such as the mean ratings, the standard deviations of the ratings, and the rating intercorrelations. Desirable psychometric characteristics of the BAS are a mean rating relatively near the midpoint of the scale; a reasonably large standard deviation of the ratings which indicates that the raters are differentiating among ratees; and relatively low rating intercorrelation, indicating that the raters are differentiating the relative strengths and weaknesses within individual ratees.

Application of BAS Methodology to Technical Updating

Most of the applications of BAS methodology have been in the area of job performance evaluation and appraisal. The use of the BAS approach to rating scale development in the area of technical updating is a relatively straightforward adaptation of the general logic of BAS. First, it may be assumed that the technical job performance level of an engineer provides information about the degree of technical up-to-dateness of that engineer. The engineer who performs technical assignments well is, by definition, at least adequately current with technological developments relevant to work assignments. The engineer who does not perform technical assignments well may suffer from technological obsolescence, although other factors may also affect job performance (such as poor work motivation or situational constraints). Thus, one promising indicant of the need for technical updating is the profi-iency an engineer demonstrates in current technical job assignments. BAS instruments which measure the supervisor's judgment about an engineer's technical job performance would serve as good diagnostic devices concerning the need for technical updating.

Furthermore, the BAS methodology readily lends itself to the measurement of behaviors other than job performance. The measurement of various possible updating activities in which an engineer might engage should be readily possible using the BAS technique. Measurement of the types of updating activities engaged in by an engineer can provide a basis for comparison between current behavior and ideal or desirable updating behavior. This comparison should aid supervisory personnel and their subordinate engineers in determining a professional development plan which is likely to enhance the technical proficiency of the engineer.

General Sampling Strategy

Initial Sampling Procedure

In order to construct the behavior anchored scales, it was originally proposed that ten workshops be conducted. The ten workshops were to be divided into four phases of data collection and verification. The participants desired at the workshops were to be technical managers or supervisors of practicing engineers, representing a number of small and medium manufacturing companies located in Pennsylvania, New York, New Jersey, Massachusetts, and Ohio. The manufacturing companies would be selected on a random sampling basis. Table 1 gives the desired workshop arrangement.

For the purpose of this study, a technical manager or supervisor was defined as a person in charge of a minimum of five practicing engineers who deals with day-to-day company problems and who holds an engineering degree. In addition, a practicing engineer was defined as having completed a Bachelor of Science degree in engineering from an accredited college of engineering and having had five years' work experience. Finally, a small manufacturing company was defined as having up to 500 employees and a medium one as having 500 - 5000 employees.

Seven locations were selected for the ten workshops in such a way that each of the five states were represented at least once, and each location had an adequate population of private manufacturing companies from which to draw a sample. For each location, a sample of

Table 1

Proposed BAS Workshop Arrangement

Phase	Workshop No.	Location	No. of Managers	No. of Companies
I	1	A	10 - 12	2 - 4
Dimension	2	B	10 - 12	2 - 4
Identification	3	C	10 - 12	2 - 4
II	1	D	10 - 12	2 - 4
Allocation	2	E	10 - 12	2 - 4
III	1	F	10 - 12	2 - 4
Scaling	2	G	10 - 12	2 - 4
IV	1	A - G*	10 - 12 old	2 - 4 old
Application			10 - 12 new	2 - 4 old
	2	A - G*	10 - 12 old	2 - 4 old
			10 - 12 new	2 - 4 new
	3	A - G*	10 - 12 old	2 - 4 old
			10 - 12 new	2 - 4 new

*Each of the workshops of Phase IV was to be held in a location already used in Phase I, II or III. New participants as well as past participants were to be included in these workshops.

approximately thirty companies was drawn, using various industrial directories. (See Reference List) In addition, for three of the locations, a second sample of companies was drawn for Phase IV. The total sample drawn consisted of an equal mix of small and medium companies. For each company, an individual was identified who would be interested in updating problems faced by engineers. These individuals held such titles as chief engineer, plant engineer, general manager, manager of engineering, plant manager, vice-president of engineering, and president.

A letter, which explained the purpose of the research and asked for their participation, was sent to each of the first twenty companies in the sample for each of the seven locations. In a second mailing, letters were sent to the remaining companies on each of the seven lists.

Table 2 summarizes the results of the mailing. As can be seen from the table, 72.9 percent did not respond to the letter, and, <u>of those who did respond</u>, 62.5% (13.6% of the total mailed) replied "No." Thus, out of 220 companies, 190 (86.3%) were unwilling to participate in the project. On a somewhat positive note, of the eighteen companies who replied "yes" or "maybe," twelve (66.7%) actually took part in a workshop. However, the number of companies willing to participate was not sufficient to conduct the seven workshops. Therefore, the original sampling procedure was modified in order to obtain a sufficient number of workshop participants.

<u>Modified Procedure for Obtaining Workshop Participants</u>

During the same time frame as this project, the project team was involved with a related National Science Foundation project entitled

Table 2

Results of BAS Mailing

Phase-Workshop Number	Desired Workshop Location	Number Mailed		Results					Participated in Workshop
		First Mailing	Second Mailing	Not Delivered	No Reply	Replied			
						No	Maybe	Yes	
I - 1	Philadelphia Area	20	11	4 (12.9)*	22 (71.0)	3 (9.7)	0 (0.0)	2 (6.4)	1 (3.2)
I - 2	New York City Area	20	10	1 (3.3)	20 (66.7)	6 (20.0)	3 (10.0)	0 (0.0)	0 (0.0)
I - 3	Boston Area	20	13	2 (6.1)	24 (72.7)	6 (18.2)	1 (3.0)	0 (0.0)	0 (0.0)
II - 1	Cleveland Area	20	11	1 (3.2)	22 (71.0)	6 (19.4)	0 (0.0)	2 (6.4)	2 (6.4)
II - 2	Pittsburgh Area	20	11	3 (9.7)	20 (64.5)	3 (9.7)	3 (9.7)	2 (6.4)	4 (12.9)
III - 1	Newark, NJ Area	20	14	1 (2.9)	26 (76.5)	4 (11.8)	1 (2.9)	2 (5.9)	3 (8.8)
III - 2	Harrisburg Area	20	10	0 (0.0)	26 (86.7)	2 (6.7)	1 (3.3)	1 (3.3)	2 (6.7)
TOTALS		140	80	12 (5.5)	160 (72.7)	30 (13.6)	9 (4.1)	9 (4.1)	12 (5.5)

*The numbers in parentheses are the percentages of total mailed.

"Relationships Among Individual Motivation, Work Motivation and Updating in Engineers" (Grant No. SED78-21941).*

In carrying out this research effort, workshops with engineers and engineering managers were also required. The primary difference in the workshops for the two projects was the size of the companies contacted for help. The behavior anchored scales (BAS) workshops were to be composed of engineers employed by small and medium companies, and the work motivation workshops composed of engineers employed by medium and large companies. There were also to be work motivation workshops composed of engineers and engineering managers working for governmental agencies.

Thus, letters were sent for the work motivation workshops at about the same time as the BAS letters. The results of this mailing (see Table 3) were better than the BAS mailing. Of the 200 industries contacted, 23 (11.5%) actually participated in a workshop, as compared to the 5.5% BAS result. With the governmental agencies included, the results were even better in that 57 out of 315 (18.5%) organizations participated. Even though the response for the work motivation workshops was better than the BAS, we did not have enough industry participants to carry out the desired ten work motivation workshops.

An obvious partial solution to the shortage of workshop participants for both projects was to combine workshops where possible. The major problem in doing this for the BAS project was that the industrial workshops would be primarily composed of medium and large companies and would not include the desired number of smaller companies.

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*This project will be referred to as the work motivation project.

Table 3

Results of Work Motivation Project Mailing

Desired Workshop Location	Number Mailed	Results: Not Delivered	Results: No Reply	Results: Replied: No	Results: Replied: Maybe	Results: Replied: Yes	Participated in Workshop
<u>Industry Workshops</u>							
New York City Area	20	0 (0.0)*	14 (70.0)	3 (15.0)	0 (0.0)	3 (15.0)	3 (15.0)
Bergen County, NJ Area	20	0 (0.0)	14 (70.0)	3 (15.0)	0 (0.0)	3 (15.0)	2 (10.0)
Scranton/Wilkes-Barre, PA Area	20	0 (0.0)	16 (80.0)	4 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)
Cleveland Area	20	2 (10.0)	12 (60.0)	2 (10.0)	1 (5.0)	3 (15.0)	2 (10.0)
Buffalo Area	20	2 (10.0)	17 (85.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Allentown, PA Area	20	0 (0.0)	12 (60.0)	4 (20.0)	1 (5.0)	3 (15.0)	3 (15.0)
Rochester, NY Area	20	0 (0.0)	13 (65.0)	5 (25.0)	0 (0.0)	2 (10.0)	2 (10.0)
Erie, PA Area	20	0 (0.0)	8 (40.0)	4 (20.0)	4 (20.0)	4 (20.0)	8 (40.0)
Trenton, NJ Area	20	1 (5.0)	17 (85.0)	2 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)
Lewisburg/Williams-port, PA Area	20	0 (0.0)	12 (60.0)	3 (15.0)	0 (0.0)	5 (25.0)	3 (15.0)
Industry Subtotals	200	5 (2.5)	135 (67.5)	31 (15.5)	6 (3.0)	23 (11.5)	23 (11.5)

Table 3 (cont'd)

Results of Work Motivation Project Mailing

Desired Workshop Location	Number Mailed	Results					Participated in Workshop
		Not Delivered	No Reply	Replied			
				No	Maybe	Yes	
<u>Government Workshops</u>							
Philadelphia Area	19	0 (0.0)	7 (36.8)	2 (10.5)	4 (21.1)	6 (31.6)	9 (47.4)
Harrisburg Area	36	0 (0.0)	10 (27.8)	12 (33.3)	4 (11.1)	10 (27.8)	10 (27.8)
Pittsburgh Area	14	0 (0.0)	6 (42.9)	3 (21.4)	0 (0.0)	5 (35.7)	4 (28.6)
Washington, DC Area	20	0 (0.0)	4 (20.0)	8 (40.0)	4 (20.0)	4 (20.0)	5 (25.0)
Boston Area	26	0 (0.0)	12 (46.2)	7 (26.9)	3 (11.5)	4 (15.4)	6 (23.1)
Government Subtotals	115	0 (0.0)	39 (33.9)	32 (27.8)	15 (13.1)	29 (25.2)	34 (29.6)
TOTALS	315	5 (1.6)	174 (55.2)	63 (20.0)	21 (6.7)	52 (16.5)	57 (18.1)

*The numbers in parentheses are the percentages of total mailed.

In reviewing the results of the BAS mailing in more detail, it was found that, of the 220 letters mailed, 115 were sent to small companies. Even though this represents 52.3% of the companies, only two of the twelve companies that participated in workshops were small. This represents a very poor 1.7% participation level.

Because of the mailing results, and the timetable constraint, it was decided to abandon the search for small companies and to use medium and large companies in the workshops for both the BAS and work motivation projects. (Actually, 13 of the 68 companies that participated in workshops were small by definition.)

As mentioned previously, combining workshops was only a partial solution in obtaining enough participants for the workshops. In order to obtain the remaining workshop participants, personal contacts were used to obtain cooperation from a number of companies. In some cases, a single company was willing to furnish enough participants for a workshop. In the other cases, the company furnished from one to five participants to attend workshops made up of participants from more than one company.

Again, this represented a deviation from the proposed procedure in the following ways. These companies were not randomly selected but "hand picked," based on personal contacts which the project investigators had with companies. Also, there were a number of "single company" workshops instead of a mix of companies at each workshop. After reviewing these deviations, it was felt that they were of minimal consequence since the companies contacted represented both a wide range in product and in size (small, medium and large), and the inputs from the engineers and managers seemed to be candid and diverse.

The contact/participation rate was dramatically improved via the personal contact approach. In total, forty-nine companies were asked to participate and forty-two agreed (85.7%). These contacts resulted in 205 workshop participants.

As was mentioned before, workshops with engineers and managers from governmental agencies were arranged for the work motivation project. Even though it was not originally planned to include governmental agencies in the BAS project, the decision was made to use some of them in order to increase the number of participants in the project and to increase the variety of employers.

Given these modifications, the workshops were arranged for project phases I, II, and III. Due to the modifications, it was possible to increase the number of workshops conducted at each phase. Table 4 summarizes the number of workshops held for each phase and Appendix A gives, in detail, the workshops and participating organizations.

Phase IV of the project occurred after the data from Phases I, II and III were collected and evaluated. This information was then used to construct the necessary BAS scale for each factor identified as being an important component in the technical performance and updating of engineers (there were eleven such factors identified). BAS scales were then to be used by managers of engineers to describe the technical job performance and updating of subordinate engineers.

Instead of executing Phase IV in a workshop environment, as was originally proposed, it was decided that a mailing would be used to accomplish this phase of the project. The main reason for this deviation was the geographical dispersion of the individuals who were

Table 4

Summary of Workshops Held for Each Phase

Phase	Number of Workshops: Single Organization	Number of Workshops: Multi-Organizations	Number of Workshops: Total	Total Number Participating: Organizations	Total Number Participating: Individuals
I	6	2	8	18	66
II	4	11	15	67	133
III	9	0	9	9	88
TOTALS	19	13	32	94	287

By comparing Tables 1 and 4, one can see that 32 workshops were held instead of the proposed seven and that input was received from 287 individuals instead of the proposed 70-84.

The final data collection phase of the project, Phase IV, required a deviation from the proposed plan.

potential participants in this phase of the project. Of the total of 98 persons contacted, 61 (62.2%) had been participants of workshops in Phase I, II or III. The remaining 37 (37.8%) had not participated in the project previously. Each manager was asked to rate two subordinate engineers, using the BAS scales. Of those contacted, 42 (42.8%) responded, having used the scales to describe 84 engineers.

Summary of Sampling Strategy

Although a number of deviations were made from the proposed sampling procedure, it is felt that, in each case, the deviation was made for the betterment of the project. The actual sampling strategy produced a 457% (32 vs 7) increase in the number of workshops, a 210% (327 vs 156) increase in the number of participants, and a 181% (94 vs 52) increase in the number of organizations over the numbers proposed in the original sampling strategy.

Fifty-two of the 94 organizations (55.3%) which participated in the project were chosen randomly from various industrial directories. The remaining 42 organizations (44.7%) were chosen through personal contacts within the organization. Thus, the sampling strategy is not totally random. However, it is felt that the sample bias is minimal since the participating organizations ranged from small to large in size and represented a large variety of services and products.

Results

Phase I. Dimension Identification and Definition and Behavioral Statement Development

As a result of the first three workshops conducted in Phase I of the project, an initial set of ten factors related to updating in engineers was developed and tentative definitions of each factor were written. Participants in the first three workshops were mailed copies of the ten factors and definitions and asked for commentary. The set of factors and their definitions were also distributed for discussion at subsequent workshops. On the basis of the input from the various workshop participants, some of the initial factor definitions were modified, and an eleventh factor was added to the set. The final set of eleven factors and their definitions is shown in Table 5.

Once the set of factors relevant to technical job performance and updating activities had been developed, it was necessary to develop for each factor a number of items on statements which gave behavioral examples relevant to the factor. These behavioral statements would serve as the set of potential scale anchors for each factor.

These behavioral statements were developed from several sources. Some statements were written from notes of the discussions of the initial workshops which were the basis of the set of factors. Frequently, as part of the discussion of a particular factor, the workshop participants would describe the specific job behavior of an engineer relevant to the factor. A second source of behavioral statements was a mailing to a sample of 65 members of the American Society of Engineering Education. This mailing included a questionnaire which asked for behavioral examples of the job performance of the technically up-to-date engineer and for examples of the job performance of the technically obsolete engineer. Thirty individuals returned this questionnaire (46.2% of the sample). A third source of the behavioral statements was workshop participants. Individuals in five workshops

Table 5

Factors Related to Technical Job Performance and Updating in Engineers

A. Technical Communication - the ability to transmit and receive written and oral information related to technical projects and assignments.

B. Scientific and Technical Knowledge - the possession of fundamental scientific, mathematical, and engineering knowledge necessary for adequate completion of a project or assignment.

C. Organization and Planning - the ability to manage projects, and assignments including establishing priorities, meeting deadlines, and attending to details.

D. Problem Recognition and Definition - the ability to understand the cause(s) of the symptoms of a problem.

E. Development of Alternative Solutions - the ability to create several possible solutions to a problem which are technically feasible.

F. Evaluation of Alternative Solutions - the use of theoretical, analytical, and empirical methods to determine the likely consequences of alternative solutions.

G. Implementation of Chosen Alternative - the ability to make an alternative operational by fitting the solution to the particular situation.

H. Professional Activities - the extent to which the engineer participates in professional registration and society activities.

I. Continuing Education Attempts - the type of procedure used by the engineer to maintain or obtain up-to-date technical skills.

J. Work Assignments Sought - the type of job activities desired and pursued by the engineer.

K. Technical Interest and Curiosity - The interest and curiosity shown by the engineer regarding technology, science, and recent developments in both.

were asked for examples of the job performance of engineers related to the factors. Examples of above average, average, and below average levels of performance were solicited.

The results from the various sources of input to this phase of the project were edited by the project staff to reduce redundancies among the behavioral statements and to write the statements in a common grammatical format. This editing process yielded a total of 240 behavioral statements which were divided into two sets, each of which contained 120 items, for the next phase of the project. Appendices B and C present the two sets of behavioral items developed in this phase of the project.

Phase II. Behavioral Statement Allocation

The two sets of 120 behavioral statements described in the previous section were next administered to workshop participants who had had no previous contact with the project. These participants were asked to clarify or allocate each behavioral statement in one of the two sets to one of the eleven factors related to the technical job performance and updating activities of engineers. Instructions given to the participants are shown in Appendices B and C along with each set of statements. A participant allocated the behavioral statements in only one of the two sets or a total of 120 statements. Sixty-five participants allocated the statements given in Appendix B, and sixty allocated the statements in Appendix C.

Following the gathering of the allocation data, a frequency tabulation was prepared. For each behavioral statement, the frequency of allocation to each factor was determined. Since a consensus of allocation judgments was desired, it was decided to retain for further project work only those behavioral statements that were allocated to one performance and updating factor by a minimum of 60% of the participants. This allocation criterion resulted in the retention of a total of 148 behavioral statements. The remaining 92 statements were dropped because of their apparent ambiguity with regard to what factor they represented.

Appendix D shows the behavioral statements, organized by factor, which were retained for further project work.

Phase III. Scaling of Behavioral Statements

The behavioral statements shown in Appendix D were administered in a questionnaire to 88 participants in nine workshops. None of these participants had taken part in any of the earlier phases of the project. The participants were instructed to rate on a nine-point scale each behavioral statement for all factors with regard to the level of performance or amount of the factor described by the statement. The specific instructions and the rating scale to be used are also presented in Appendix D. After the rating or scaling data were obtained from the 88 workshop participants, mean ratings and associated standard deviations were computed for each behavioral statement and are also shown in Appendix D. As a result of the scaling phase, behavioral statements were chosen to anchor the rating scale to be developed for each of the eleven factors related to the technical job performance and updating activities of engineers.

The criteria used for choosing behavioral statements to be used as scale anchors were several. First, for each factor the relevant behavioral statements were grouped into three classes: (a) more than an adequate level of performance or amount of the factor; (b) an adequate level of performance or amount of the factor; and (c) a less than adequate level of performance or amount of the factor. Statements were grouped into one of the three classes on the basis of the mean rating given by the workshop participants, with statements with a mean rating of greater than 6.5 being grouped in the more than adequate category and statements with a mean rating of less than 3.5 being grouped in the less than adequate category. Within each of these three general classes, it was desired to select from two to four behavioral statements to act as specific examples of the general class. Within each general class, statements with the smallest standard deviations were chosen to be used as anchors with the additional criterion of content variability, i.e., it was desirable that a set of anchors have heterogeneous content rather than homogeneous content. In a few instances, only a single example for a given level which met all the criteria was available. Table 6 presents the final set of rating scales developed for the eleven factors related to the technical job performance and updating activities of engineers.

<u>Phase IV. Use of the Rating Scales</u>

Two sets of the rating scales for the eleven factors were sent to 98 individuals, of whom 61 had participated in an earlier phase of the project and 37 had not. All supervised other engineers. These individuals were asked to evaluate two of their subordinate engineers anonymously and to provide some demographic information on the rated engineers. Appendix E presents the instruction sheet and demographic information questionnaire which accompanied the set of rating scales.

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Table 6

Final Rating Scales for the Eleven Factors Related to Technical Job Performance and Updating Activities of Engineers

Factor A. Technical Communication - the ability to transmit and receive written and oral information related to technical projects and assignments

Numerical Scale		Examples of Performance
9, 8, 7	more than adequate or acceptable typical performance on this factor	- Can tailor technical presentations to fit the audience - Is able to instruct other engineers in new technology - Can sell a technical improvement to management which is initially opposed to change - Is able to ask questions of technical experts which obtain the appropriate and needed information
6, 5, 4	adequate or acceptable typical performance on this factor	- Reports only the information pertinent to the problem at hand - Communicates well only with engineers within his or her specific technical discipline
3, 2, 1	less than adequate or acceptable typical performance on this factor	- Writes technical reports which are too wordy - Has difficulty documenting technical results - Rarely contributes information to engineering staff discussions of technical problems - Frequently has a proposed project rejected by a manager because of a poor presentation

_________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor B. Scientific and Technical Knowledge - the possession of fundamental scientific, mathematical, and engineering knowledge necessary for adequate completion of a project or assignment

Numerical Scale		Examples of Amounts of this Factor
9 8 7	more than an adequate or acceptable typical amount of this factor	- Performs assignments with minimum supervision - Is considered the technical expert in the department
6 5 4	an adequate or acceptable typical amount of this factor	- Has a good working knowledge of calculus and differential equations - Has fundamental grasp of heat transfer and thermodynamics - Is aware of recent solid state technology - Understands statistical inference and sampling techniques
3 2 1	less than an adequate or acceptable typical amount of this factor	- Sometimes makes mathematical errors on an assignment - Is unfamiliar with the precise technical definitions of many scientific terms - Often needs technical help from colleagues in order to complete an assignment - Has difficulty understanding basic electronic designs

_______ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor C. Organization and Planning - the ability to manage projects, and assignments including establishing priorities, meeting deadlines, and attending to details

Numerical Scale		Examples of Performance
9, 8, 7	more than adequate or acceptable typical performance on this factor	- Prepares schedules identifying project milestones - Is capable of reorganizing a project due to schedule or technical specification changes - Able to establish project priorities without the specific guidance of the supervisor - Offers ideas developed from current projects as proposals for possible future projects
6, 5, 4	adequate or acceptable typical performance on this factor	- Sometimes misses non-critical project deadlines - Is able to use systematic scheduling procedures such as Gantt and PERT methods - Spends too much time on details
3, 2, 1	less than adequate or acceptable typical performance on this factor	- Does not follow up through implementation after the major components of a project are completed - Often misses deadlines for completing an assignment - Uses excessive manpower and equipment resources due to poor project management - Drags out each assignment to the maximum

__________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor D. Problem Recognition and Definition - the ability to understand the cause(s) of the symptoms of a problem

Numerical Scale		Examples of Performance
9–7	more than adequate or acceptable typical performance on this factor	- Able to recognize the existence of a technical problem before all the negative symptoms are apparent - Is able to identify a specific problem as being an example of a general class of problems which has certain possible solutions - Goes to the location of a problem to get direct information about it - Able to distinguish between symptoms and causes of a problem
6–4	adequate or acceptable typical performance on this factor	- Accepts other people's opinions about the cause of a problem - Usually determines the cause of a problem as the project progresses
3–1	less than adequate or acceptable typical performance on this factor	- Often attacks the first symptoms of a problem, rather than looking for its real causes - Often misses one or two important factors in a problem - Usually is not able to see which problem symptoms are related to each other and treats each symptom as if it were a separate problem

________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor E. Development of Alternative Solutions - The ability to create several possible solutions to a problem which are technically feasible

Numerical Scale		Examples of Performance
9 – 7	more than adequate or acceptable typical performance on this factor	- Is always looking for a better way to do a job - Usually offers several solutions to a technical problem for management to choose from - Creates imaginative solutions to long-term problems
6 – 4	adequate or acceptable typical performance on this factor	- Develops a second approach to a problem only when the first approach fails - Requires prompting by the supervisor to look for more than one possible solution to a problem
3 – 1	less than adequate or acceptable typical performance on this factor	- Will propose and defend the first solution to come to mind - Doesn't consider challenging the "status quo" of a traditional approach to an engineering problem

__________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor F. Evaluation of Alternative Solutions - the use of theoretical, analytical, and empirical methods to determine the likely consequences of alternative solutions

Numerical Scale		Examples of Performance
9 – 7	more than adequate or acceptable typical performance on this factor	- Selects a solution based upon well-documented analysis - Attempts to quantify all costs and benefits associated with the possible consequences of proposed solutions - Quickly finds the strong and weak points of alternatives
6 – 4	adequate or acceptable typical performance on this factor	- Does not prejudge any possible solution before the evaluation data are complete
3 – 1	less than adequate or acceptable typical performance on this factor	- Sometimes cannot point out the comparative advantages and disadvantages of two alternatives

________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor G. Implementation of Chosen Alternative - the ability to make an alternative operational by fitting the solution to the particular situation

Numerical Scale		Examples of Performance
9 – 8 – 7	more than adequate or acceptable typical performance on this factor	- Is prepared to accept minor changes in solution in order to gain its implementation - Anticipates implementation problems and plans for their solution - Can usually overcome small obstacles to the implementation of a solution
6 – 5 – 4	adequate or acceptable typical performance on this factor	- Forces the chosen alternative solution into operation, compromising some of the desired goals of the project - Is able to make an idea operational although it may not function at rated capacity - Expects every solution to work as smoothly as possible upon implementation
3 – 2 – 1	less than adequate or acceptable typical performance on this factor	- Sticks with the original solution for too long, until it is not working in a satisfactory manner - Tries to implement a new production line layout before being sure that production management fully understands it - Rigidly adheres to textbook solutions without considering the specific situation

_________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor H. Professional Activities - the extent to which the engineer participates in professional registration and society activities

Numerical Scale		Examples of Activities Related to this Factor
9, 8, 7	more than usual amount of typical activity or effort related to this factor	- Usually presents a paper at a regional or national technical society meeting each year - Teaches a P.E. refresher course for the local professional society chapter - Seeks leadership roles in professional societies
6, 5, 4	usual amount of typical activity or effort related to this factor	- Has never submitted a paper for presentation at a technical society meeting - Attends most chapter meetings of the technical society
3, 2, 1	less than usual amount of typical activity or effort related to this factor	- Joins professional societies solely to pad the resume - Has no interest in professional registration

_________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor I. Continuing Education Attempts - the type of procedure used by the engineer to maintain or obtain up-to-date technical skills

Numerical Scale		Examples of Activities Related to this Factor
9 8 7	more than usual amount of typical activity or effort related to this factor	- Devotes a substantial portion of spare time to reading technical publications and taking technical courses - Has made definite plans for self-development in technical areas - Enrolls in university courses on advanced technical topics - Attends as many company-sponsored technical seminars and short courses as possible
6 5 4	usual amount of typical activity or effort related to this factor	- Expects the organization and its management to initiate all continuing education efforts - Rarely enrolls in technical courses or seminars held outside the company
3 2 1	less than usual amount of typical activity or effort related to this factor	- Never attends an in-house technical seminar - Reads technical literature only when told to by the supervisor - Frequently content to rely upon co-workers for learning about new techniques

__________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor J. <u>Work Assignments Sought</u> - the type of job activities desired and pursued by the engineer

Numerical Scale		Examples of Activities Related to this Factor
9 – 8 – 7	more than usual amount of typical activity or effort related to this factor	- Prefers assignments which involve several technical disciplines - Is willing to accept an assignment which has an uncertain chance of success - Tries to get assignments which focus on different applications of a specific technical interest - Tells the supervisor of interest in attending technical seminars
6 – 5 – 4	usual amount of typical activity or effort related to this factor	- Tends to remain with assignments in which he feels comfortable - Desires assignments which are more administrative than technical - Never expresses reluctance to accept an assignment
3 – 2 – 1	less than usual amount of typical activity or effort related to this factor	- Prefers to work on rather routine and mundane assignments - Is content to remain in current job for an indefinite amount of time - Tries to avoid assignments in unfamiliar technical areas

________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

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Factor K. Technical Interest and Curiosity - The interest and curiosity shown by the engineer regarding technology, science, and recent developments in both

Numerical Scale		Examples of Amounts of this Factor
9, 8, 7	more than an adequate or acceptable typical amount of this factor	- Is curious about all technical areas - Is excited about technical developments - Works extra hours on own initiative
6, 5, 4	an adequate or acceptable typical amount of this factor	- Sometimes displays a negative attitude toward new ideas - Occasionally reads journals in related technical areas
3, 2, 1	less than an adequate or acceptable typical amount of this factor	- Is pessimistic and cynical about new technical developments - Has little curiosity about technologies related to own - Is bored with job - Adopts an attitude of "if it's important, someone will tell me about it" toward developments

________ Numerical Description for this Factor

Specific instance(s) of this individual's work activities related to this factor:

Data were received from 42 individuals or a total of 84 rated engineers of which 82 were usable. Means, standard deviations, and intercorrelations were computed for the ratings on the eleven factors. Table 7 presents the means and standard deviations of the ratings. Table 8 presents the intercorrelations among the eleven ratings. The median intercorrelation among the ratings was .38.

The typical engineer who was rated in this phase of the project was described on the demographic information sheet as having a bachelor's degree, being under the age of 40, and having been with the current organization from one to seven years. About two-thirds of the ratees were in the fields of mechanical, industrial, and electrical engineering. The supervisor who rated them had typically been the engineer's superior for several years.

Discussion

The objectives of the project appear to have been realized by its outcomes. The set of BAS instruments is an appropriate instrument for obtaining evaluations of engineers' technical proficiencies and technical updating attempts. The psychometric characteristics of the data obtained in Phase IV of the project suggest that the BAS developed for the eleven factors related to the technical job performance and technical updating activities of enginneers are quite satisfactory measurement devices. The scale intercorrelations were in general low to moderate, thus avoiding the problem of strong halo that is common with many rating scales. Halo is the tendency of a rater to give highly similar evaluations on all rating dimensions to the ratee which results

Table 7

Means and Standard Deviations of the Ratings

on the Eleven Factors

Factor	Mean	S.D.
A. Technical Communication	6.60	1.49
B. Scientific and Technical Knowledge	6.86	1.50
C. Organization and Planning	6.39	1.71
D. Problem Recognition and Definition	6.87	1.34
E. Development of Alternative Solutions	6.54	1.45
F. Evaluation of Alternative Solutions	6.48	1.33
G. Implementation of Chosen Alternative	6.81	1.28
H. Professional Activities	4.62	2.05
I. Continuing Education Attempts	6.38	1.46
J. Work Assignments Sought	7.02	1.32
K. Technical Interest and Curiosity	7.01	1.32

Note: N=82

Table 8

Intercorrelations among the Ratings of the Eleven Factors

Factor	B	C	D	E	F	G	H	I	J	K
A	.38	.48	.41	.57	.36	.48	.20	.35	.54	.40
B	-	.23	.61	.50	.40	.32	.06	.46	.42	.53
C		-	.34	.36	.41	.29	.20	.23	.44	.27
D			-	.62	.49	.35	.07	.15	.27	.24
E				-	.49	.34	.17	.32	.43	.38
F					-	.44	.15	.20	.47	.42
G						-	.06	.27	.53	.39
H							-	.44	.24	.12
I								-	.48	.39
J									-	.56
K										-

Note: N=82

in very high rating scale intercorrelations. The factors and scales apparently are sufficiently well-defined and meaningful to the raters that they are able to distinguish among the various dimensions of performance and updating and can differentiate the relative strengths and weaknesses of their subordinate engineers.

The means of the ratings obtained in Phase IV are generally above the midpoint of the nine-point scale used with the BAS. This could be interpreted as evidence for leniency error, that is, the tendency of raters to rate the ratees more favorably than might be objectively warranted. However, it is probably reasonable to expect that the mean rating received by a group of engineers who typically had been employed for several years with an organization would be above average. That is, the objective mean performance level of the rated group is likely to be better than average so that the mean rating of their performance also should be above average. Thus, the finding that the mean rating exceeded the scale midpoint is not surprising and may well reflect the true performance level of the rated group. However, the possible existence of some leniency error cannot be ruled out. The standard deviations of the various ratings were of sufficient size to indicate that the raters had differentiated adequately among the ratees. Small standard deviations would have indicated that every ratee had received about the same evaluation and, thus, the BAS had not been used to make comparative judgments about the various ratees. A measurement instrument is of little value as a diagnostic device if everyone receives approximately the same score or rating.

The various goals of the present research project in terms of possible uses of the BAS instruments which were developed also appear to have been met. The BAS instruments should be useful in the evaluation of the need for technical updating among the engineers of an organization. They should aid the technical supervisor in the difficult task of providing accurate and meaningful feedback to subordinate engineers about their technical strengths and weaknesses. The scales should also be helpful in planning for the continued professional development of the engineers.

A basic tenet of the present project was to develop a set of rating scales which could be used in many organizations with engineers in many different disciplines. Thus, the procedures employed by the project were well suited. The generalizability of the resulting BAS should be good because of the large numbers of organizations, engineers, and engineering fields in the project sample.

The BAS scales which emerged from the careful development process have several desirable measurement properties. They are reasonably "objective" instruments designed for a very subjective problem. The use of agreement statistics as criteria for inclusion of the behavioral examples as anchors on the various scales reduces the amount of ambiguity provided by most types of rating scale anchors. The reliance upon behavioral examples as scale anchors permits the rater to move away from global and vague concepts such as "average" or "excellent" toward a more concrete and specific description of the behavior of the ratee. The scales also provide for the generalizability of their use due to the inclusion of many different groups of engineers and organizations in the developmental process. Thus, the results of scale development are not dependent upon the (perhaps) idiosyncratic judgments of a single group.

The BAS approach has several advantages when compared to possible alternatives for the development of updating measures. It focuses upon specific, observable behaviors of engineers rather than discussing the issue of continuing education needs in vague, ambiguous terms. The method is predicated upon a form of consensual validation, i.e., each step in the process of developing the measuring instruments requires that subject matter experts agree upon the particular decision to be made at that step. Thus, the resulting instruments represent dimensions of continuing education needs anchored by specific behavioral items at various levels of the dimension which have been agreed upon by the participants in the development process. The instruments are not the product of a few individuals with little or no expertise in the content area, but rather represent a broad opinion of informed and experienced engineers and supervisors. A potential disadvantage is that minority views, which may be valid, may tend to be dropped by the process due to the agreement criteria. If it is accepted that general instruments are desired, however, then the loss of somewhat idiosyncratic opinions is not a serious problem.

The use of a diverse sample of individuals, organizations, and disciplines does result in a set of measurement instruments that must be at a fairly general level. That is, the use of only the BAS developed in this project cannot inform a supervisor about the exact nature of the technical updating which a subordinate engineer needs in order to perform the job more competently. In order to establish the precise content of the updating requirement, it would be necessary to develop a set of BAS for each engineering discipline and each type of job assignment within each discipline. The set of BAS developed in this project can alert the supervisor and engineer to a potential technical deficit, but the task of specifying the knowledge or skill which is needed remains for them to establish.

Research and Application

The BAS instruments developed in the present project appear to be psychometrically sound and useful devices. However, the scales have not yet been applied in an operational setting to determine if supervisory personnel and their subordinate engineers can use them as aids to the process of developing professional education plans. Such use of the scales is really the "acid test" of their utility to organizations and engineering personnel. It would be of great interest to investigate the effect of using the BAS as a performance appraisal and feedback device over a period of time on the performance, technical updating, and career development programs of the engineers.

More basic data on the scales should be obtained. More raters should evaluate subordinate engineers so that the scale intercorrelations, means and standard deviations can again be calculated as a replication of the findings presented in this report. It would also be desirable to obtain interrater agreement data, that is, to have two raters each evaluate the same set of ratees. The degree of agreement among the two raters can then be calculated. It was intended to obtain such data in the present project, but the samples of organizations and individuals which were available for data collection did not permit it. There were too few instances in which there were two raters who knew a common set of subordinate engineers well enough to provide meaningful evaluations. The value of such data is that information is then available on the extent to which the BAS are able to elicit similar evaluations from two raters. If the scale dimensions and anchors are sufficiently objective and non-ambiguous, there should be good agreement among different raters.

The BAS instruments developed in the present project should also be used as dependent variables in future research concerned with organizational and individual factors that affect the technical performance and updating of engineers. Instruments developed in the National Science Foundation funded Grant Number SED78-21941 entitled, "Relationships Among Individual Motivation, Work Motivation and Updating in Engineers," conducted by the present project staff, should be used in conjunction with the BAS to investigate this area of interest. Such an investigation should be longitudinal in nature so as to study the long-term, as well as short-term, effects of the work environment and individual motivation on technical updating and performance. This type of study will provide valuable information about how an organization can positively influence the technical updating and job performance of its engineers and how an organization can avoid inhibiting desirable levels of these behaviors.

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APPENDIX A

Organizations Participating in Each Phase of Workshops

WORKSHOP ID AND LOCATION	ORGANIZATIONS PARTICIPATING	NUMBER OF ENGINEERS PARTICIPATING
I - 1 State College, PA 3-12-79	Applied Research Laboratory	2
	Cerro Metal Products	1
	Centre Engineering, Inc.	1
	H R B - Singer, Inc.	2
	Management Engineering The Pennsylvania State University	1
	Sutton Engineering Company	3
I - 2 State College, PA 3-14-79	H R B - Singer, Inc.	1
	C. H. Masland and Son	2
	Corning Glass Works	1
	Piper Aircraft, Inc.	2
	Sperry New Holland	2
	Sprout Waldron Koppers	1
	Standard Steel Division, TMCA	2
I - 3 Altoona, PA 3-22-79	Consolidated Rail Corporation	8
I - 4 New Holland, PA 4-23-79	Sperry New Holland	7
I - 5 Lancaster, PA 4-24-79	Armstrong Cork Corporation	6
I - 6 Hershey, PA 4-24-79	Hershey Chocolate Company	8
I - 7 West Point, PA 4-30-79	Merck, Sharp & Dohme	7
I - 8 Moorestown, NJ 5-1-79	RCA	9

WORKSHOP ID AND LOCATION	ORGANIZATIONS PARTICIPATING	NUMBER OF ENGINEERS PARTICIPATING
II - 1 Cleveland, OH 5-3-79	Cleveland Twist Drill Company	2
	Joy Manufacturing Company	1
	Parker Hannifin Corporation	2
	Scott & Fetzer Company	1
II - 2 Cleveland, OH 5-4-79	Republic Steel Corporation	6
II - 3 Warren, OH 5-4-79	Packard Electric	7
II - 4 Rochester, NY 5-9-79	Xerox Corporation	7
II - 5 Rochester, NY 5-9-79	Eastman Kodak Co.	11
II - 6 Pittsburgh, PA 5-24-79	Bloom Engineering Co., Inc.	1
	Pennsylvania Dept. of Environmental Resources	1
	Pennsylvania Dept. of Transportation	2
	U.S. Army Corps of Engineers	2
	U.S. Department of Housing & Urban Urban Development	1

WORKSHOP ID AND LOCATION	ORGANIZATIONS PARTICIPATING	NUMBER OF ENGINEERS PARTICIPATING
II - 7 Pittsburgh, PA 5-25-79	Koppers Co., Inc.	2
	Matthews International Corporation	1
	Neville Chemical Co.	1
	Universal-Cyclops Specialty Steel Division	2
II - 8 Boston, MA 6-4-79	Massachusetts Bureau of Building Construction	2
	Massachusetts Dept. of Labor & Industries Division of Occupational Hygiene	2
	Massachusetts Dept. of Public Works	1
	Massachusetts Division of Air & Hazardous Materials	1
	Massachusetts Division of Water Pollution Control	1
	U.S. Department of Transportation Transportation Systems Center	2
II - 9 New York, NY 6-5-79	Canrad-Hanovia, Inc.	2
	Grumman Aerospace Corporation	1
	Hoke, Inc.	2
	Leviton Mfg. Co., Inc.	2
	Sperry Division Headquarters	2
	Thomas J. Lipton, Inc.	3
	Weston Instruments	1
	Wilbur B. Driver Co.	1
II - 10 Williamsport, PA 6-7-79	Kawneer Company	1
	Marathon Carey McFall Co.	1
	Pennsylvania House Furniture Co.	1
	Shop-Vac Corporation	2
	TRW, Inc.	1
	Weis Markets, Inc.	1
	Zenith Audio Division	1

WORKSHOP ID AND LOCATION	ORGANIZATIONS PARTICIPATING	NUMBER OF ENGINEERS PARTICIPATING
II - 11 Allentown, PA 6-11-79	Air Products & Chemicals, Inc.	5
	Fuller Co.	1
	General Electric Co.	2
	Ingersoll - Rand Co.	2
	Mack Trucks, Inc.	1
	New Jersey Zinc	1
	Pennsylvania Power & Light Co.	2
II - 12 Harrisburg, PA 6-12-79	International Signal & Control	2
	New Cumberland Army Depot	2
	Pennsylvania Dept. of Environmental Resources, Bur. of Water Quality Mgt.	1
	Pennsylvania Dept. of Transportation	3
	Pennsylvania Public Utility Commission	2
	Pennsylvania Turnpike Commission	2
II - 13 Harrisburg, PA 6-12-79	Pennsylvania Dept. of General Services	1
	Hamilton Technology	1
	Pennsylvania Dept. of Transportation	5
II - 14 Erie, PA 6-15-79	American Sterilizer Co.	2
	Copes-Vulcan, Inc.	1
	Corry Jamestown Corporation	1
	Geosource, Inc.	2
	Bucyrus Erie Co.	2
	General Electric Co.	2
	Teledyne Penn Union	1
	Zurn Industries	1
II - 15 Washington, DC 6-19-79	Federal Aviation Administration	2
	U.S. Department of Energy	1
	U.S. Department of Transportation Research & Special Programs Admin.	1
	U.S. Department of Transportation Urban Mass Transportation Admin.	1
	U.S. Defense Nuclear Agency	2

WORKSHOP ID AND LOCATION	ORGANIZATIONS PARTICIPATING	NUMBER OF ENGINEERS PARTICIPATING
III - 1 Belleville, PA 8-9-79	Sperry New Holland	12
III - 2 Burnham, PA 8-9-79	Standard Steel Division, TMCA	8
III - 3 Aliquippa, PA 8-13-79	J & L Steel	7
III - 4 Warren, OH 8-13-79	Packard Electric	9
III - 5 Alliance, OH 8-14-79	Babcock & Wilcox Research Center	12
III - 6 Bethlehem, PA 8-20-79	Bethlehem Steel Corporation	15
III - 7 Allentown, PA 8-20-79	Air Products & Chemicals, Inc.	7
III - 8 Newark, OH	Rockwell International	9
III - 9 State College, PA	H R B-Singer, Inc.	9

APPENDIX B

First Set of 120 Behavioral Statements Developed for Factor Allocation

Examples Describing the Job Performance of Engineers

Listed below are some examples which describe how an engineer might perform his or her job. We are interested in your judgment about which factor related to updating in engineers is most relevant to each example. That is, we would like for you to classify or assign each example to the updating factor to which that example seems most applicable.

Read over carefully the eleven factors related to updating in engineers on the form you have been given. Then, for each example listed below, write in the space to the left of the example the letter code of the factor which you think the example best represents or describes.

To illustrate this better, suppose that example 1 was:

__A__ 1. Writes technical reports which are readily understood by organizational management.

If you wrote an "A" in the space to the left of the example, this would mean that you believe that this example best represents or describes the factor of Technical Communication.

Do this for all of the examples listed below. Please do not skip any examples.

_____ 1. Has difficulty documenting technical results.

_____ 2. Usually has analytical back-up for decisions which have been made.

_____ 3. Prepares schedules identifying project milestones.

_____ 4. Usually works on interesting projects first without regard for other priorities.

_____ 5. Can adequately explain a technical problem to peers.

_____ 6. Is able to meet the cost and time schedules of most projects.

_____ 7. Generally has difficulty determining the consequences of a solution.

_____ 8. Is able to list almost all potential causes of the symptoms of a problem.

_____ 9. Can sell a technical improvement to management which initially is opposed to the change.

_____ 10. Never attends an in-house technical seminar.

_____ 11. Is able to make an idea operational although it may not function at rated capacity.

_____ 12. Usually solves problems by a trial and error approach.

_____ 13. Is able to specify the operational characteristics of a piece of equipment needed for a project.

_____ 14. Is frequently asked to make oral presentations to higher management concerning technical matters.

_____ 15. Usually determines the cause of a problem as the project progresses.

_____ 16. Determines the possible consequences of the chosen solution, but not those of alternatives.

_____ 17. Develops a second approach to a problem only when the first approach fails.

_____ 18. Forces the chosen alternative solution into operation, compromising some of the desired goals of the project.

_____ 19. Accepts work assignments as given.

_____ 20. Is uncomfortable with the use of probabilistic methods in problem solving.

_____ 21. Uses frequently the organization's technical library.

_____ 22. Seeks new technical skills when required by an assignment.

_____ 23. Skims technical journals and reads those articles relevant to current projects.

_____ 24. Has difficulty getting new projects started.

_____ 25. Develops graphs, diagrams, and calculations for the evaluation of alternatives.

_____ 26. Drags out each assignment to the maximum.

_____ 27. Usually understands technical material with one reading.

_____ 28. Knows the appropriate sources for necessary technical information.

_____ 29. Enrolls in university courses on advanced technical topics.

_____ 30. Often has only a vague idea about how much time each part of a project will require.

_____ 31. Uses mathematical techniques of maximizing or minimizing alternative functions to develop options.

_____ 32. Applies statistical models to develop simulation studies of alternatives.

_____ 33. Has a good working knowledge of calculus and differential equations.

_____ 34. Is able to use systematic scheduling procedures such as Gantt and PERT methods.

_____ 35. Is able to identify a specific problem as being an example of a general class of problems which has certain possible solutions.

_____ 36. Discusses with the supervisor his or her interest in assignments involving computer-based analytical methods.

_____ 37. Tries to implement new production line layout before being sure that production management understands it fully.

_____ 38. Communicates well only with engineers within his or her specific technical discipline.

_____ 39. Creates imaginative solutions to long-term problems.

_____ 40. Often makes changes that merely manage the symptoms of a problem.

_____ 41. Is knowledgeable about technical methods which first appeared in relevant engineering textbooks about ten years ago.

_____ 42. Can adequately develop a project which was given in only general terms and with vague goals.

_____ 43. Rigidly adheres to textbook solutions without considering the specific situation.

_____ 44. Attends technical presentations suggested by the supervisor.

_____ 45. Usually follows the technical suggestions of others without first questioning their appropriateness.

_____ 46. Can delegate appropriate parts of a project to other personnel.

_____ 47. Offers ideas developed from current projects as proposals for possible future projects.

_____ 48. Often needs someone else to clean up the details of an assignment.

_____ 49. Must always offer excuses for why a project is not completed on time.

_____ 50. Rarely can develop more than one possible solution to a technical problem.

_____ 51. Seeks the ideas of knowledgeable co-workers when faced with a difficult assignment.

_____ 52. Uses statistical inference as basis for choosing alternatives.

_____ 53. Sometimes is not able to foresee problems which may be encountered in a project.

_____ 54. Usually is not able to see which problem symptoms are related to each other and treats each symptom as if it were a separate problem.

_____ 55. Sometimes is able to apply to assignments information obtained at a professional society lecture.

_____ 56. Tries to get assignments which focus on different applications of a specific technical interest.

_____ 57. Rarely sees any possible use of new technical methods.

_____ 58. Frequently has a proposed project rejected by a manager because of a poor presentation.

_____ 59. Attends seminar series on microprocessors on own time.

_____ 60. Usually discusses technical problems with other engineers following the regular staff meeting.

_____ 61. Frequently has project proposals accepted after the first presentation with little revision necessary.

_____ 62. Sometimes makes mathematical errors on an assignment.

_____ 63. Has the ability to complete daily project routine despite occasional interruptions.

_____ 64. Is able to get a new production line into operation on time and within quality control standards.

_____ 65. Teaches a P.E. refresher course for the local professional society chapter.

_____ 66. Has never become an E.I.T.

_____ 67. Is content to remain in current job for an indefinite amount of time.

_____ 68. Periodically attends technical seminars at own expense.

_____ 69. Sometimes displays a negative attitude toward new ideas.

_____ 70. Writes technical reports which are too wordy.

_____ 71. Is able to ask questions of technical experts which obtain the appropriate and needed information.

_____ 72. Usually spends some time actually observing the problem or situation before developing a solution.

_____ 73. Sometimes cannot point out the comparative advantages and disadvantages of two alternatives.

_____ 74. Is pessimistic and cynical about new technical developments.

_____ 75. Occasionally reads journals in related technical areas.

_____ 76. Is not aware of recent solid state technology.

_____ 77. Constantly readjusts the schedule of a project to allow for more time for its completion.

_____ 78. Works extra hours on own initiative.

_____ 79. Often misses one or two important factors in a problem.

_____ 80. Usually thinks of alternative solutions, but needs some direction to fully develop them.

_____ 81. Usually attends the meetings of the local technical society.

_____ 82. Is able to understand and apply state of the art technology after an explanation by a more knowledgeable engineer.

_____ 83. Doesn't adapt well to rapid change in technology.

_____ 84. Failed to understand a technical paper resulting in the misapplication of a new method to a problem.

_____ 85. Is curious about all technical areas.

_____ 86. Rarely talks to colleagues about technical developments.

_____ 87. Follows a program of professional development which his or her supervisor suggested.

_____ 88. Has never submitted a paper for presentation at a technical society meeting.

_____ 89. Relies usually on traditional methods of engineering design.

_____ 90. Is excited about technical developments.

_____ 91. Desires assignments which are more administrative than technical.

_____ 92. Volunteers to give talks on new technical developments to engineers employed in the organization.

_____ 93. Has made definite plans for self-development in technical areas.

_____ 94. Tends to remain with assignments in which he feels comfortable.

_____ 95. Is willing to accept an assignment which has an uncertain chance of success.

_____ 96. Is willing to admit a lack of knowledge in a technical area.

_____ 97. Often needs technical help from colleagues in order to complete an assignment.

_____ 98. Always takes the same approach to engineering design tasks.

_____ 99. Is rarely consulted by co-workers for technical knowledge.

_____ 100. Usually won't make technical decisions about a project without first getting information from peers and the supervisor.

_____ 101. Rarely contributes information to engineering staff discussions of technical problems.

_____ 102. Tries to avoid assignments in unfamiliar technical areas.

_____ 103. Tries to make contacts at technical society meetings with other engineers working in similar areas.

_____ 104. Is able to instruct other engineers in new technology.

_____ 105. Is unfamiliar with the precise technical definitions of many scientific terms.

_____ 106. Does not follow up through implementation after the major components of a project are completed.

_____ 107. Is registered as a P.E.

_____ 108. Seeks to understand the process or system in which a technical problem has occurred.

_____ 109. Selects a solution based upon well-documented analysis.

_____ 110. Builds the solutions to possible implementation problems into the initial proposal.

_____ 111. Able to recognize the existence of a technical problem before all the negative symptoms are apparent.

_____ 112. Tends to look at problems from a common sense, rather than scientific point of view.

_____ 113. Expects the implementation of every solution to work as smoothly as possible.

_____ 114. Attends technical seminars to please the supervisor rather than for knowledge that might be gained.

_____ 115. Attempts to quantify all factors of a problem when making a technical decision.

_____ 116. Prefers assignments which involve several technical disciplines.

_____ 117. Implementation of a solution is often stymied by small obstacles.

_____ 118. Prefers to work on rather routine and mundane assignments.

_____ 119. Doesn't monitor a chosen solution until it has been fully implemented.

_____ 120. Attempts to quantify all costs and benefits associated with the possible consequences of proposed solutions.

APPENDIX C

Second Set of 120 Behavioral Statements

Developed for Factor Allocation

Examples Describing the Job Performance of Engineers

Listed below are some examples which describe how an engineer might perform his or her job. We are interested in your judgment about which factor related to updating in engineers is most relevant to each example. That is, we would like for you to classify or assign each example to the updating factor to which that example seems most applicable.

Read over carefully the ten factors related to updating in engineers on the form you have been given. Then, for each example listed below, write in the space to the left of the example the letter code of the factor which you think the example best represents or describes.

To illustrate this better, suppose that example 1 was:

__A__ 1. Writes technical reports which are readily understood by organizational management.

If you wrote an "A" in the space to the left of the example, this would mean that you believe that this example best represents or describes the factor of Technical Communication.

Do this for all of the examples listed below. Please do not skip any examples.

_____ 1. Attends in-house technical seminars.

_____ 2. Frequently offered job opportunities by other units of the organization.

_____ 3. Has difficulty applying rigorous mathematical techniques to technical problems.

_____ 4. Tends to look for administrative rather than technical assignments.

_____ 5. Volunteers to give talk on new technical developments to other engineers in the organization.

_____ 6. Is able to apply concepts from other engineering and scientific disciplines to own work.

_____ 7. Distrusts the use of computer simulations to evaluate engineering ideas.

_____ 8. Sometimes displays a negative attitude toward new ideas.

_____ 9. Is always looking for a better way to do a job.

_____ 10. Has definite career goals and plans for self-development in technical areas.

_____ 11. Has little curiosity about technologies related to own specific area.

_____ 12. Tends to stretch out assignments in which he feels comfortable.

_____ 13. Willing to accept assignments with uncertain chance of success.

_____ 14. Able to admit a lack of knowledge in a technical area.

_____ 15. Often needs help from colleagues in order to complete an assignment.

_____ 16. Inflexible in approach to engineering design tasks.

_____ 17. Exhibits self-confidence regarding work.

_____ 18. Performs assignments with minimum supervision.

_____ 19. Is rarely consulted by co-workers for technical advice.

_____ 20. Is pessimistic and cynical about new technical developments.

_____ 21. Works extra hours on own initiative.

_____ 22. Has ordered task priorities in accordance with their importance to the project.

_____ 23. Uses time deadlines and budget limits as reasons for not trying new ideas.

_____ 24. Usually won't make technical decisions alone.

_____ 25. Likes to work with recent engineering graduates.

_____ 26. Welcomes the chance to discuss and debate technical issues with other engineers.

_____ 27. Is bored with the job.

_____ 28. Rarely contributes to staff discussions involving technical decisions.

_____ 29. Desires feedback about quality of job performance.

_____ 30. Reluctant to become involved in technical society affairs.

_____ 31. Teaches an evening course in engineering at a local college.

_____ 32. Devotes four hours a week reading technical and trade journals.

_____ 33. Resists assignments in unfamiliar technical areas.

_____ 34. Doesn't adapt well to rapid changes in technology.

_____ 35. Usually presents a paper at a regional or national technical society meeting each year.

_____ 36. Initiates the use of new statistical techniques for evaluating system performance.

_____ 37. Doesn't consider challenging the "status quo" of a traditional approach to an engineering problem.

_____ 38. Adopts an attitude of "if it's important, someone will tell me about it" toward technical developments.

_____ 39. Rarely enrolls in technical courses or seminars held outside the company.

_____ 40. Expects the organization and its management to initiate all continuing education efforts.

_____ 41. Seeks out for discussion at technical society meetings other engineers working in similar areas.

_____ 42. Likes to experiment with new hardware.

_____ 43. Has filed for a patent based upon a solution to a technical problem.

_____ 44. Is challenged by technical advances.

_____ 45. Is curious about all technical areas.

_____ 46. Usually asks questions at technical presentations.

_____ 47. Is able to train other engineers in new technology.

_____ 48. Lacks knowledge of technical language and jargon.

_____ 49. Does not follow up after the major components of a project are completed.

_____ 50. Accepts other people's opinions about the cause of a problem.

_____ 51. Requires prompting by the supervisor to look for more than one possible solution to a problem.

_____ 52. Tells the supervisor of interest in attending technical seminars.

_____ 53. Is not persistent in "de-bugging" a project.

_____ 54. Has become a P.E.

_____ 55. Works on the details of one solution rather than researching alternative solutions.

_____ 56. Becomes involved in and "learns" the process or system in which a technical problem has occurred.

_____ 57. Is capable of reorganizing a project due to schedule or technical specification changes.

_____ 58. Can present information in a logical sequence.

_____ 59. Often misunderstands the basic objective of a technical assignment.

_____ 60. Cannot defend recommended solution.

_____ 61. Frequently develops a unique solution for an old problem.

_____ 62. Able to distinguish between symptoms and causes of a problem.

_____ 63. Always able to give to the supervisor an immediate synopis of a project's status.

_____ 64. Often misses deadlines for completing an assignment.

_____ 65. Will propose and defend the first solution to come to mind.

_____ 66. Is prepared to accept minor changes in solution in order to gain its implementation.

_____ 67. Seeks leadership roles in professional societies.

_____ 68. Frequently content to rely upon co-workers for learning about new techniques.

_____ 69. Never expresses reluctance to accept an assignment.

_____ 70. Develops a recommended solution based upon well-documented analysis.

_____ 71. Usually offers several solutions to a technical problem for management to choose from.

_____ 72. Anticipates implementation problems and builds their solution into the proposal.

_____ 73. Willing to spend own time and money to attend outside educational functions.

_____ 74. Is never asked to rewrite own technical reports.

_____ 75. Is always able to select the proper engineering technique required by the problem.

_____ 76. Often attacks the first symptoms of a problem, rather than looking for its real causes.

_____ 77. Able to establish project priorities without the specific guidance of the supervisor.

_____ 78. Details the possible consequences of each alternative solution in all proposals.

_____ 79. Able to recognize the existence of a technical problem before negative consequences are apparent.

_____ 80. Is able to instruct others in a phase of technical specialty.

_____ 81. Has no interest in professional registration.

_____ 82. Tends to look at problems from a common sense point of view.

_____ 83. Can always describe a technical problem so that non-technical people can understand it.

_____ 84. Reads technical literature only when told to by the supervisor.

_____ 85. Goes to the location of a problem to get direct information about it.

_____ 86. Expects each solution to work as smoothly as possible.

_____ 87. Believes that all technical societies are a waste of time.

_____ 88. Attends technical seminars for political rather than knowledge reasons.

_____ 89. Joins professional societies solely to pad the resumé.

_____ 90. Attends as many company-sponsored technical seminars and short courses as possible.

_____ 91. Attempts to quantify all factors to a problem.

_____ 92. Prefers to solve a problem from one's desk rather than in the field.

_____ 93. Knows own discipline well but doesn't venture outside it.

_____ 94. Uses inaccurate or misleading terminology in reports.

_____ 95. Sometimes misses non-critical project deadlines.

_____ 96. Sticks with the original plan for too long when it isn't working in a satisfactory fashion.

_____ 97. Is biased against suggestions from other engineers.

_____ 98. Quickly finds the strong and weak points of alternatives.

_____ 99. Is satisfied with own ability to do the job.

_____ 100. Likes assignments involving several technical disciplines.

_____ 101. Can tailor technical presentations to fit the audience.

_____102. Spends too much time on details.

_____103. Makes extensive inquiries regarding problem symptoms.

_____104. Projects are sometimes completed late but they are always successful.

_____105. Is easily stymied by small obstacles to implementing a solution.

_____106. Attends most chapter meetings of the technical society.

_____107. Subscribes with own money to several technical publications.

_____108. Does best work on mundane assignments.

_____109. Is able to coordinate projects with well-defined objectives.

_____110. Remains open to new alternatives even after a solution has been chosen.

_____111. Doesn't re-evaluate a solution until a project is completed.

_____112. Uses excessive manpower and equipment resources due to poor project management.

_____113. Accepts other's opinions as facts supporting the chosen alternative.

_____114. Attempts to quantify all costs and benefits associated with proposed solutions.

_____115. Does not prejudge any possible solution before the evaluation data are complete.

_____116. Shows "tunnel vision" regarding approaches to technical problems.

_____117. Is hesitant to select an alternative solution for implementation.

_____118. Devotes a substantial portion of spare time to reading technical publications and taking technical courses.

_____119. Procrastinates choosing an alternative to implement until options are lost by the delay.

_____120. Reports only the information pertinent to the problem at hand.

APPENDIX D

Instructions and Behavioral Statements for the Eleven Factors for the Statement Scaling Phase and Resulting Means and Standard Deviations

Instructions

Attached are a rating scale and groups of statements or examples related to the technical job performance and technical updating activities of engineers. Each group of examples has been placed under the performance or updating factor which the examples best describe (as judged by previous groups of engineers). For each example listed for each of the performance or updating factors, we would like for you to judge the effectiveness of the performance, the quality of the updating activity, or how much of the factor is shown by the example.

Use the scale values which are given and defined on the attached rating scale. Write the scale value which represents your judgment in the space to the left of each example.

To illustrate this more specifically, consider the following:

a. Suppose that the first example listed under Factor A. Technical Communication was:
__3__ 1. Reports sometimes have spelling and punctuation errors.

Writing a __3__ in the space to the left of the example would indicate that you felt that this represented low effectiveness in the performance factor of Technical Communication.

b. Suppose that the first example listed under Factor I. Continuing Education Attempts was:
__7__ 1. Subscribes to five technical journals related to discipline.

Writing a __7__ in the space to the left of the example would indicate that you judged this to be a good way to maintain up-to-date technical skills.

c. Suppose that the first example listed under Factor K. Technical Interest and Curiosity was:
__5__ 1. Likes to tinker with mechanical gadgets.

Writing a __5__ in the space to the left of the example would indicate that you felt that this represented an average amount of the factor of Technical Interest and Curiosity.

d. Suppose that the first example listed under Factor C. Organization and Planning was:
__6__ 1. Attends to most of the details of a project.

Writing a __6__ in the space to the left of the example would indicate that you judged this to represent performance which was more than moderately effective but less than fully effective.

Thank you for your cooperation.

Rating Scale - Degree of Technical Performance or Updating Activity

Scale Value	Definition of Scale Value
1	Completely ineffective performance and/or very poor way to maintain or update technical skills and/or very low amount of the factor.
2	
3	Low effectiveness in performance and/or marginal way to maintain or update technical skills and/or low amount of the factor.
4	
5	Moderately effective performance and/or reasonable way to maintain or update technical skills and/or average amount of the factor.
6	
7	Effective performance and/or good way to maintain or update technical skills and/or high amount of the factor.
8	
9	Optimal performance and/or excellent way to maintain or update technical skills and/or very high amount of the factor.

Factor A. Technical Communication - the ability to transmit and receive written and oral information related to technical projects and assignments.

Mean	S.D.	Examples Related to this Factor
7.35	1.26	1. Can tailor technical presentations to fit the audience.
6.34	1.87	2. Reports only the information pertinent to the problem at hand.
7.24	1.72	3. Can always describe a technical problem so that non-technical people can understand it.
4.80	2.43	4. Is never asked to rewrite own technical reports.
2.30	1.70	5. Uses inaccurate or misleading terminology in reports.
3.33	1.06	6. Writes technical reports which are too wordy.
7.20	1.13	7. Is able to instruct others in a phase of technical specialty.
7.91	1.37	8. Can sell a technical improvement to management which initially is opposed to the change.
7.50	.98	9. Is able to ask questions of technical experts which obtain the appropriate and needed information.
6.71	1.74	10. Frequently has project proposals accepted after the first presentation with little revision necessary.
2.90	1.25	11. Rarely contributes information to engineering staff discussions of technical problems.
3.81	1.73	12. Communicates well only with engineers within his or her specific technical discipline.
7.18	1.37	13. Is frequently asked to make oral presentations to higher management concerning technical matters.
7.19	1.23	14. Can adequately explain a technical problem to peers.
7.49	1.07	15. Is able to instruct other engineers in new technology.
2.66	1.33	16. Frequently has a proposed project rejected by a manager because of a poor presentation.
2.65	1.30	17. Has difficulty documenting technical results.
7.47	1.16	18. Can present information in a logical sequence.

Factor B. Scientific and Technical Knowledge - the possession of fundamental scientific, mathematical, and engineering knowledge necessary for adequate completion of a project or assignment.

Mean	S.D.	Examples Related to this Factor
3.43	1.46	1. Sometimes makes mathematical errors on an assignment.
3.68	1.53	2. Has difficulty applying rigorous mathematical techniques to technical problems.
5.52	1.80	3. Has a good working knowledge of calculus and differential equations.
7.49	1.30	4. Performs assignments with minimum supervision.
3.44	1.48	5. Is unfamiliar with the precise technical definitions of many scientific terms.
3.35	1.42	6. Often needs technical help from colleagues in order to complete an assignment.
7.56	1.34	7. Is considered the technical expert in the department.
6.57	1.61	8. Is able to use mathematical techniques of maximizing or minimizing functions in attacking a problem.
3.45	1.50	9. Has difficulty understanding basic electronic designs.
5.51	1.65	10. Has fundamental grasp of heat transfer and thermodynamics.
5.17	1.92	11. Is aware of recent solid state technology.
6.17	1.57	12. Understands statistical inference and sampling techniques.
6.68	1.42	13. Can apply basic mechanics to problems.
4.74	1.30	14. Often needs help if an assignment requires any knowledge of chemistry.

Factor C. Organization and Planning - the ability to manage projects, and assignments including establishing priorities, meeting deadlines, and attending to details.

Mean	S.D.	Examples Related to this Factor
4.79	1.30	1. Sometimes misses non-critical project deadlines.
7.41	1.12	2. Has ordered task priorities in accordance with their importance to the project.
7.34	1.21	3. Prepares schedules identifying project milestones.
6.44	1.26	4. Projects are sometimes completed late but they are always successful.
7.09	1.26	5. Always able to give to the supervisor an immediate synopsis of a project's status.
5.70	1.89	6. Is able to use systematic scheduling procedures such as Gantt and PERT methods.
3.14	1.44	7. Often misses deadlines for completing an assignment.
7.00	1.36	8. Is capable of reorganizing a project due to schedule or technical specification changes.
7.28	1.17	9. Is able to meet the cost and time schedules of most projects.
7.61	.97	10. Able to establish project priorities without the specific guidance of the supervisor.
3.48	1.27	11. Often has only a vague idea about how much time each part of a project will require.
2.28	1.23	12. Uses excessive manpower and equipment resources due to poor project management.
7.17	1.15	13. Is able to coordinate projects with well-defined objectives.
7.92	1.14	14. Is able to get a new production line into operation on time and within quality control standards.
2.70	1.39	15. Drags out each assignment to the maximum.
7.29	1.02	16. Offers ideas developed from current projects as proposals for possible future projects.
4.01	1.53	17. Spends too much time on details.
7.34	1.12	18. Can delegate appropriate parts of a project to other personnel.

3.30	1.18	19. Has difficulty getting new projects started.
6.63	1.16	20. Has the ability to complete daily project routine despite occasional interruptions.
3.51	1.40	21. Often needs someone else to clean up the details of an assignment.
3.62	1.48	22. Constantly readjusts the schedule of a project to allow for more time for its completion.
3.06	1.15	23. Does not follow up through implementation after the major components of a project are completed.

Factor D. Problem Recognition and Definition - the ability to understand the cause(s) of the symptoms of a problem.

Mean	S.D.	Examples Related to this Factor
7.46	1.06	1. Able to recognize the existence of a technical problem before all the negative symptoms are apparent.
5.72	1.97	2. Accepts other people's opinions about the cause of a problem.
3.29	1.97	3. Often attacks the first symptoms of a problem, rather than looking for its real causes.
3.10	1.31	4. Often misses one or two important factors in a problem.
2.92	1.46	5. Usually is not able to see which problem symptoms are related to each other and treats each symptom as if it were a separate problem.
6.77	1.66	6. Usually spends some time actually observing the problem or situation before developing a solution.
6.95	1.30	7. Makes extensive inquiries regarding problem symptoms.
7.39	1.19	8. Is able to list all potential causes of the symptoms of a problem.
7.25	.95	9. Is able to identify a specific problem as being an example of a general class of problems which has certain possible solutions.
6.44	1.36	10. Usually determines the cause of a problem as the project progresses.
7.23	1.21	11. Goes to the location of a problem to get direct information about it.
3.66	1.64	12. Often makes changes that merely manage the symptoms of a problem.
7.51	1.41	13. Able to distinguish between symptoms and causes of a problem.

Factor E. Development of Alternative Solutions - the ability to create several possible solutions to a problem which are technically feasible.

Mean	S.D.	Examples Related to this Factor
7.96	1.20	1. Is always looking for a better way to do a job.
5.90	1.11	2. Usually thinks of alternative solutions, but needs some direction to fully develop them.
3.61	1.43	3. Rarely can develop more than one possible solution to a technical problem.
4.15	1.59	4. Develops a second approach to a problem only when the first approach fails.
2.84	1.48	5. Will propose and defend the first solution to come to mind.
7.01	1.71	6. Frequently develops a unique solution for an old problem.
4.30	1.31	7. Works on the details of one solution rather than researching alternative solutions.
6.60	1.58	8. Usually offers several solutions to a technical problem for management to choose from.
3.70	1.22	9. Requires prompting by the supervisor to look for more than one possible solution to a problem.
3.27	1.41	10. Doesn't consider challenging the "status quo" of a traditional approach to an engineering problem.
7.44	1.36	11. Creates imaginative solutions to long-term problems.

Factor F. Evaluation of Alternative Solutions - the use of theoretical, analytical, and empirical methods to determine the likely consequences of alternative solutions.

Mean	S.D.	Examples Related to this Factor
7.39	1.20	1. Selects a solution based upon well-documented analysis.
7.18	1.13	2. Attempts to quantify all factors of a problem when making a technical decision.
3.35	1.44	3. Sometimes cannot point out the comparative advantages and disadvantages of two alternatives.
6.31	1.81	4. Does not prejudge any possible solution before the evaluation data are complete.
7.10	1.41	5. Attempts to quantify all costs and benefits associated with the possible consequences of proposed solutions.
6.95	1.44	6. Details the possible consequences of each alternative solution in all proposals.
6.76	1.38	7. Develops graphs, diagrams, and calculations for the evaluation of alternatives.
7.45	1.03	8. Quickly finds the strong and weak points of alternatives.
6.52	1.69	9. Applies statistical models to develop simulation studies of alternatives.
6.35	1.79	10. Uses statistical inference as basis for choosing alternative.

Factor G. Implementation of Chosen Alternative - the ability to make an alternative operational by fitting the solution to the particular situation.

Mean	S.D.	Examples Related to this Factor
4.15	1.68	1. Forces the chosen alternative solution into operation, compromising some of the desired goals of the project.
6.70	1.19	2. Is prepared to accept minor changes in solution in order to gain its implementation.
5.72	1.46	3. Is able to make an idea operational although it may not function at rated capacity.
7.56	1.12	4. Anticipates implementation problems and plans for their solution.
4.32	1.91	5. Expects every solution to work as smoothly as possible upon implementation.
3.01	1.43	6. Sticks with the original solution for too long, until it is not working in a satisfactory manner.
3.20	1.41	7. Tries to implement a new production line layout before being sure that production management fully understands it.
2.62	1.34	8. Rigidly adheres to textbook solutions without considering the specific situation.
6.75	1.24	9. Can usually overcome small obstacles to the implementation of a solution.

Factor H. Professional Activities - the extent to which the engineer participates in professional registration and society activities.

Mean	S.D.	Examples Related to this Factor
3.53	1.45	1. Reluctant to become involved in technical society affairs.
5.71	2.22	2. Is registered as a P.E.
2.79	1.54	3. Joins professional societies solely to pad the resume.
3.47	1.62	4. Has no interest in professional registration.
6.28	2.19	5. Usually presents a paper at a regional or national technical society meeting each year.
5.71	1.88	6. Usually attends the meetings of the local technical society.
3.77	1.49	7. Has never submitted a paper for presentation at a technical society meeting.
5.49	1.81	8. Attends most chapter meetings of the technical society.
6.40	2.13	9. Teaches a P.E. refresher course for the local professional society chapter.
3.73	1.74	10. Has never become an E.I.T.
2.64	1.47	11. Believes that all technical societies are a waste of time.
6.79	1.80	12. Seeks leadership roles in professional societies.

Factor I. Continuing Education Attempts - the type of procedure used by the engineer to maintain or obtain up-to-date technical skills.

Mean	S.D.	Examples Related to this Factor
6.79	1.52	1. Devotes a substantial portion of spare time to reading technical publications and taking technical courses.
6.71	1.36	2. Attends technical presentations suggested by the supervisor.
6.58	1.39	3. Follows a program of professional development which his or her supervisor suggested.
7.27	1.32	4. Has made definite plans for self-development in technical areas.
6.85	1.72	5. Enrolls in university courses on advanced technical topics.
6.25	[illegible]86	6. Subscribes with own money to several technical publications.
6.33	1.94	7. Periodically attends technical seminars at own expense.
2.53	1.42	8. Never attends an in-house technical seminar.
6.75	1.45	9. Attends as many company-sponsored technical seminars and short courses as possible.
2.65	1.30	10. Reads technical literature only when told to by the supervisor.
6.40	1.94	11. Willing to spend own time and money to attend outside educational functions.
3.68	1.60	12. Expects the organization and its management to initiate all continuing education efforts.
3.80	1.14	13. Rarely enrolls in technical courses or seminars held outside the company.
6.54	1.26	14. Attends in-house technical seminars.
3.14	1.37	15. Frequently content to rely upon co-workers for learning about new techniques.
5.86	2.09	16. Attends seminar series on microprocessors on own time.

Factor J. Work Assignments Sought - the type of job activities desired and pursued by the engineer.

Mean	S.D.	Examples Related to this Factor
7.15	1.22	1. Prefers assignments which involve several technical disciplines.
3.13	1.42	2. Prefers to work on rather routine and mundane assignments.
6.66	1.43	3. Is willing to accept an assignment which has an uncertain chance of success.
4.56	1.60	4. Tends to remain with assignments in which he feels comfortable.
6.06	1.33	5. Discusses with the supervisor his or her interest in assignments involving computer-based analytical methods.
6.54	1.28	6. Tries to get assignments which focus on different applications of a specific technical interest.
3.45	1.36	7. Is content to remain in current job for an indefinite amount of time.
4.63	1.64	8. Desires assignments which are more administrative than technical.
5.68	1.90	9. Never expresses reluctance to accept an assignment.
6.92	1.16	10. Tells the supervisor of interest in attending technical seminars.
5.90	1.40	11. Accepts work assignments as given.
3.40	1.48	12. Tries to avoid assignments in unfamiliar technical areas.

Factor K. Technical Interest and Curiosity - The interest and curiosity shown by the engineer regarding technology, science, and recent developments in both.

Mean	S.D.	Examples Related to this Factor
7.19	1.32	1. Is curious about all technical areas.
2.73	1.33	2. Is pessimistic and cynical about new technical developments.
2.98	1.20	3. Doesn't adapt well to rapid change in technology.
7.18	1.28	4. Is excited about technical developments.
3.56	1.40	5. Sometimes displays a negative attitude toward new ideas.
2.80	1.58	6. Has little curiosity about technologies related to own specific area.
6.72	1.54	7. Works extra hours on own initiative.
2.47	1.45	8. Is bored with the job.
2.62	1.44	9. Adopts an attitude of "if it's important, someone will tell me about it" toward technical developments.
5.25	1.71	10. Occasionally reads journals in related technical areas.

APPENDIX E

Cover Letter, Instr..ctions, Demographic Information Sheet for the Final Rating Scales

THE PENNSYLVANIA STATE UNIVERSITY
615 BRUCE V. MOORE BUILDING
UNIVERSITY PARK, PENNSYLVANIA 16802

December 7, 1979

Project for
Technical Updating of Engineers

Area Code 814
863-1734

As you know, we are involved in an N.S.F. sponsored project concerning technical updating of engineers. As part of this project, we are developing rating scales which can be used by a supervisor to describe the technical job performance and technical updating activities of subordinate engineers. We are asking you, as someone who has helped us in earlier phases of this project, to participate in the final step in the development of these scales.

We have assembled a set of eleven rating scales, one for each factor which was identified in earlier phases of the project as important to the technical performance and updating of engineers. In addition to the numerical scale values usually found on rating scales, examples of the particular performance or activity are given to help define the various levels of each scale. These examples were suggested by groups of engineers in earlier phases of the project and were judged by other groups in terms of the appropriate level of performance which they exemplified.

We would like you to describe two engineers whom you supervise, in terms of the eleven factors. Two sets of scales are provided for this purpose with some additional instructions. Please do not identify by name the engineers whom you are describing. We do ask for some information on them on the first page of each set of scales. All information and ratings will be kept confidential, and no data on any individual will be released.

We would appreciate any comments you might have concerning the scales and their potential usefulness for a supervisor, particularly in the area of counseling or developing subordinate engineers in terms of their technical performance.

Please return the two sets of rating scales and any comments which you have in the envelope which is enclosed. Thank you in advance for your cooperation. Call one of us (Enscore - 814-863-2353; Farr - 814-863-1734) if we can answer any questions. We would appreciate your returning the ratings within the next two weeks.

Sincerely,

E. Emory Enscore, Jr., Ph.D.
Assoc. Prof. of Industrial Engineering

James L. Farr, Ph.D.
Assoc. Prof. of Industrial Psychology

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Instructions

Each of the following pages represents a factor which has been previously identified by groups of engineers as being an important component of the technical performance or the technical updating process of engineers. For each factor, a vertical scale is presented with numerical values ranging from 1 - 9. We would like you to describe the typical work activity of the engineer whom you have selected to evaluate on each of the eleven factors. Place the number indicating your judgment in the space provided below the vertical scale. Limit your judgment to one decimal place (for example, 6.2 or 5.0 or 3.5). To the right of the vertical scale are various examples which have been suggested by previous groups of engineers as relating to this factor. Use these examples as a guide for the numerical ratings which you give. These examples are grouped into three general performance categories: more than adequate, adequate, and less than adequate. These examples should help you understand what kinds of performance or activity correspond to the various numerical values on the scale.

At the bottom of each page is a space for you to give an example or examples of the typical work activity of the engineer relevant to the particular factor. Indicate in this space an example or examples of the work activity of the engineer which led you to give the engineer the particular numerical rating which you placed in the space above. The example or examples stated here might be thought of as indicating the work activities which would justify the numerical value.

Remember to describe the <u>typical</u> work activities of the individual, <u>not</u> the unusually good or bad. Please be sure that you have not skipped or omitted any of the eleven factors. (Note that the scales are printed on both sides)

Describe the engineer whom you are evaluating by checking the appropriate categories below:

Educational level:

_____ Bachelor's degree

_____ Master's degree in technical area

_____ M.B.A.

_____ Doctorate

_____ Other (specify__________________)

Age:

_____ < 30

_____ 30 - 39

_____ 40 - 49

_____ 50 - 59

_____ > 60

Engineering Discipline:

_____ A.E.

_____ Ch.E.

_____ C.E.

_____ E.E.

_____ I.E.

_____ M.E.

_____ Systems E.

_____ Other (specify__________________)

Years with Organization:

_____ < 1

_____ 1 - 3

_____ 3 - 5

_____ 5 - 7

_____ > 7

Years under your supervision:

_____ < 1

_____ 1 - 3

_____ 3 - 5

_____ 5 - 7

_____ > 7

APPENDIX F

Alphabetical List of Participating

Industrial Organizations and Government Agencies

Industrial Organizations

Air Products & Chemicals, Inc., Allentown, PA

American Sterilizer Co., Erie, PA

Applied Research Laboratory, University Park, PA

Armstrong Cork Corporation, Lancaster, PA

Babcock & Wilcox Research Center, Alliance, OH

Bethlehem Steel Corporation, Bethlehem, PA

Bloom Engineering Co., Inc., Pittsburgh, PA

Bucyrus Erie Co., Erie, PA

Canrad-Hanovia, Inc., Newark, NJ

Centre Engineering, Inc., State College, PA

Cerro Metal Products, Bellefonte, PA

Cleveland Twist Drill Company, Cleveland, OH

Consolidated Rail Corporation, Altoona, PA

Copes-Vulcan, Inc., Lake City, PA

Corning Glass Works, State College, PA

Corry Jamestown Corporation, Corry, PA

Eastman Kodak Co., Rochester, NY

Fuller Co., Bethlehem, PA

General Electric Co., Allentown, PA

Geosource, Inc., Erie, PA

General Electric Co., Erie, PA

Grumman Aerospace Corporation, Bethpage, NY

H R B-Singer, Inc., State College, PA

Hamilton Technology, Lancaster, PA

Hershey Chocolate Company, Hershey, PA

Hoke, Inc., Cresskill, NJ

Ingersoll-Rand Co., Allentown, PA

International Signal & Control, Lancaster, PA

J & L Steel, Aliquippa, PA

Joy Manufacturing Company, Bedford Gear Division, Solon, OH

Kawneer Company, Bloomsburg, PA

Koppers Co., Inc., Pittsburgh, PA

Leviton Mfg. Co., Inc., Little Neck, NY

Mack Trucks, Inc., Allentown, PA

Management Engineering, The Pennsylvania State University, University Park, PA

Marathon Carey McFall Co., Montoursville, PA

Masland, C. H. and Son, Lewistown, PA

Matthews International Corporation, Pittsburgh, PA

Merck, Sharp & Dohme, West Point, PA

Neville Chemical Co., Pittsburgh, PA

New Cumberland Army Depot, New Cumberland, PA

New Jersey Zinc, Palmerton, PA

Packard Electric, Warren, OH

Parker Hannifin Corporation, Cleveland, OH

Pennsylvania House Furniture Co., Lewisburg, PA

Pennsylvania Power & Light Co., Allentown, PA

Piper Aircraft, Inc., Lock Haven, PA

RCA, Moorestown, NJ

Republic Steel Corporation, Cleveland, OH

Rockwell International, Newark, OH

Scott & Fetzer Co., Stahl Division, Cleveland, OH

Shop-Vac Corp., Williamsport, PA

Sperry Division Headquarters, Great Neck, NY

Sperry New Holland, Belleville, PA

Sperry New Holland, New Holland, PA

Sprout Waldron Koppers, Muncy, PA

Standard Steel Division, TMCA, Burnham, PA

Sutton Engineering Company, Bellefonte, PA

TRW, Inc., Danville, PA

Teledyne Penn Union, Edinboro, PA

Thomas J. Lipton, Inc., Englewood Cliffs, NJ

Universal-Cyclops Specialty Steel Division, Bridgeville, PA

Weis Markets, Inc., Sunbury, PA

Weston Instruments, Division of Sangamo Weston, Inc., Newark, NJ

Wilbur B. Driver Co., Newark, NJ

Xerox Corporation, Rochester, NY

Zenith Audio Division, Watsontown, PA

Zurn Industries, Erie, PA

Government Agencies

Federal Aviation Administration, Washington, DC

Massachusetts Bureau of Building Construction, Boston, MA

Massachusetts Dept. of Labor & Industries, Division of Occupational Hygiene, Boston, MA

Massachusetts Dept. of Public Works, Boston, MA

Massachusetts Division of Air & Hazardous Materials, Boston, MA

Massachusetts Division of Water Pollution Control, Boston, MA

Pennsylvania Dept. of Environmental Resources, Pittsburgh, PA

Pennsylvania Dept. of Environmental Resources, Bureau of Water Quality Management, Harrisburg, PA

Pennsylvania Dept. of General Services, Harrisburg, PA

Pennsylvania Dept. of Transportation, Harrisburg, PA

Pennsylvania Dept. of Transportation, Pittsburgh, PA

Pennsylvania Turnpike Commission, Harrisburg, PA

Pennsylvania Public Utility Commission, Bureau of Rates, Harrisburg, PA

U.S. Army Corps of Engineers, Pittsburgh, PA

U.S. Defense Nuclear Agency, Washington, DC

U.S. Department of Energy, Germantown, MD

U.S. Department of Housing & Urban Development, Pittsburgh, PA

U.S. Department of Transportation, Research & Special Programs Administration, Washington, DC

U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA

U.S. Department of Transportation, Urban Mass Transportation Administration, Washington, DC