AN ABSTRACT OF THE THESIS OF

Kim E. Ruyle for the degree of Doctor of Philosophy in Vocational Education presented on November 30, 1990.

Title: Developing Conventional and Intelligent Job Aids: A Case Study

Abstract approved: Redacted for Privacy
Warren N. Suzuki

Job aids are instruments used on the job to improve human performance by enhancing the knowledge and/or skills of performers. Conventional job aids are usually printed on paper; examples include checklists, recipes, and decision tables.

Expert systems are computerized job aids which interact with novices to help solve problems normally reserved for human experts. Because expert systems emulate human intelligence, they are sometimes called intelligent job aids.

The purpose of this study was to extend the body of knowledge concerning conventional and intelligent job aids. The intent was to learn what major differences and similarities exist in the design, development, and application of conventional and intelligent job aids. If meaningful differences in the application were found, an additional aim was to determine why they existed.

Job aids were developed to assist technicians in diagnosing problems with Robert Bosch electronic fuel injection systems found on certain John Deere diesel engines. The job aids were validated and then field tested by 42 John Deere technicians. Subjects used both job aids to solve problems with a mock fuel system. The diagnoses were video-taped for later evaluation, and subjects proffered their opinions about the job aids through questionnaires and in interviews.

For this project, the intelligent job aid contained more textual and graphical content and required significantly more time and resources to develop. In terms of accuracy and efficiency, the job aids were comparable. Most users preferred the intelligent job aid though it required more time to learn to use than the conventional job aid. The age, education, or experience of the users did not influence their opinions of the job aids. However, the order in which the job aids were used did affect opinions; subjects that used the conventional job aid prior to the intelligent job aid were more likely to prefer the intelligent job aid. Implications for job aid project selection, design, and application are provided.

Developing Conventional and Intelligent Job Aids: A Case Study

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed November 30, 1990

Commencement June 1991

APPROVED:

Redacted for Privacy

Associate Professor of Vocational Education in charge of major

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Date thesis is presented November 30, 1990

Typed by Kim E. Ruyle for Kim E. Ruyle

ACKNOWLEDGEMENTS

As I conclude this work I feel very grateful to have had opportunities to learn from some terrific people. I'm indebted to the professors, students, colleagues, clients, friends, and family who challenged and encouraged me; to the pioneers in performance and instructional technology who inspired me; to the invaluable writing of Thomas Gilbert, Robert Mager, Peter Pipe, Robert Gagne', Leslie Briggs, Geary Rummler, Joe Harless, William Deterline, Sivasailam Thiagarajan, and the few others of their genre; to Hank Sredl who helped me think big; to Ken Funk who introduced me to expert system technology; and to Bob Waggoner, a good friend who proved that a lively sense of humor, a balanced perspective of life, and a preposterously chaotic work schedule are not mutually exclusive.

I also appreciate the individuals who contributed to this study specifically. Dr. Sam Stern served as faculty advisor and major professor in the early stages of this study until his research took him to Japan for an extended stay. Dr. Warren Suzuki assumed the role of major professor after the dissertation was underway. He deserves a lot of credit for accommodating a doctoral student who was working 2000 miles away. Dr. Stern and Dr. Suzuki were instrumental in guiding the research and helping me improve my research skills; they asked the right questions at the right time.

Dr. Ken Funk, Dr. Ann Messersmith, Dr. Michael Murphy,

and Dr. Henry Sredl, members of the dissertation committee, provided very helpful comments and graciously tolerated student-imposed time and distance impediments.

This study was made possible by the support of Deere and Company and the John Deere Engine Works Service Department. Mr. Stanley Jagodzinski, Service Manager at the John Deere Engine Works, provided consistent and enthusiastic support throughout the entire project. Other members of the Engine Works management team involved with this project include: Mr. Ron McDermott, Mr. Paul DeLong, Mr. Del Kaufmann, and Mr. Carlo Pensyl. Without their backing, this work would not have happened.

Mr. Mike Finnegan and Mrs. Peg Homolar, both of the John Deere Engine Works Service Department, provided invaluable assistance throughout the project. They made arrangements for facilities, equipment, and participants. They performed pilot testing of training and problem solving activities, and they facilitated the diagnostic procedures and data collection. This involved time away from their families while they were lugging equipment to three different John Deere facilities. They are highly regarded colleagues and friends.

Mr. Hollis Hohensee of John Deere Production Engineering in Moline, Illinois and Mr. John Nyweide of the John Deere Engine Works provided technical assistance with hardware and software issues. Mr. Lloyd Tull and Mr. Marv Farr, at

the time of the study with the John Deere Production Engineering Center in Waterloo, Iowa, served as subject matter experts. Mr. Robert Hogan of the John Deere Tractor Assembly Division and Mr. Deve Detloff of the John Deere Harvester Works provided scheduling and administrative assistance. Ms. Cheryl Davis and Ms. Lara Kneppe, both of the John Deere Engine Works Service Department, transcribed the interviews.

Mr. Benjamin Ruyle and Ms. Emily Ruyle evaluated the video-recorded problem solving sessions. Mr. Peter Pipe and Ms. Susan Zagorski, both experts in the development of job aids, shared resources.

I have spent the past decade engaged in study; two particularly arduous years were invested in this research. During this time my dear wife and eight precious children have endured neglect and made great sacrifices for me. They have my deepest love and thankfulness.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF TABLES

"Since [expert] systems are job aids, they are obviously relevant to our work. On the one hand, they are being developed outside the performance technology field. On the other, they are not apt to fulfill their potential until people who know how to develop good job aids are involved in their creation."

Clay Carr, Performance & Instruction, April, 1990, p. 45.

DEVELOPING CONVENTIONAL AND INTELLIGENT JOB AIDS: A CASE STUDY

Chapter 1

Introduction

Human performance technology (HPT) is an emerging science that seeks to develop systematic methods for improving human performance (Geis, 1986; Rosenberg, 1990). Practitioners of HPT, performance technologists, apply a performance improvement intervention only after careful study of the performers and a comparison of both existing and desired performances. Interventions implemented are those that will ameliorate the performance problem, will produce meaningful return on the investment, and will be viewed as beneficial and practical by both the performer and the organization (Gilbert, 1978, 1988; Stolovitch, 1982).

Human performance technology has been proposed as a field of practice for the training and development (T&D) profession (Jacobs, 1988). While the primary mission of the HPT and T&D disciplines is the same, the improvement of human performance, their scopes differ.

Training can be defined as a performance improvement intervention that is "directed solely at furnishing knowledge or skill that individuals need to carry out present work duties efficiently and effectively" (Sredl & Rothwell, 1987, p. 390). Training is the prominent intervention of choice among T&D professionals, but training

only improves human performance when there is a lack of knowledge or skills. Other possible reasons for poor human performance, illustrated in Figure 1, include a lack of clear direction about what to do, a lack of motivation to perform, and inability to perform because of physical limitations or other restrictions in the work system (Daniels & Rosen, 1982; Mager & Pipe, 1984; Ruyle, 1990d).

Human performance technology is more comprehensive than training and development in that it addresses all the above reasons for less than optimum human performance by systematically applying several interventions, as required, in addition to training. These interventions include feedback and reinforcement systems, personnel selection techniques, organizational development, job redesign, and job aids (National Society for Performance & Instruction, 1986).

There are several disciplines that are committed to improving human performance; human factors engineering is one that shares certain methods with HPT. Although there is no universally accepted model showing the relationship between human factors engineering and HPT, Figure 1 presents a proposed performance technologist's viewpoint. Human factors engineering is primarily concerned with optimizing "the interaction between people and machine elements of the system" (Kantowitz & Sorkin, 1983, p. 4). Human factors engineering works to improve the work system by designing

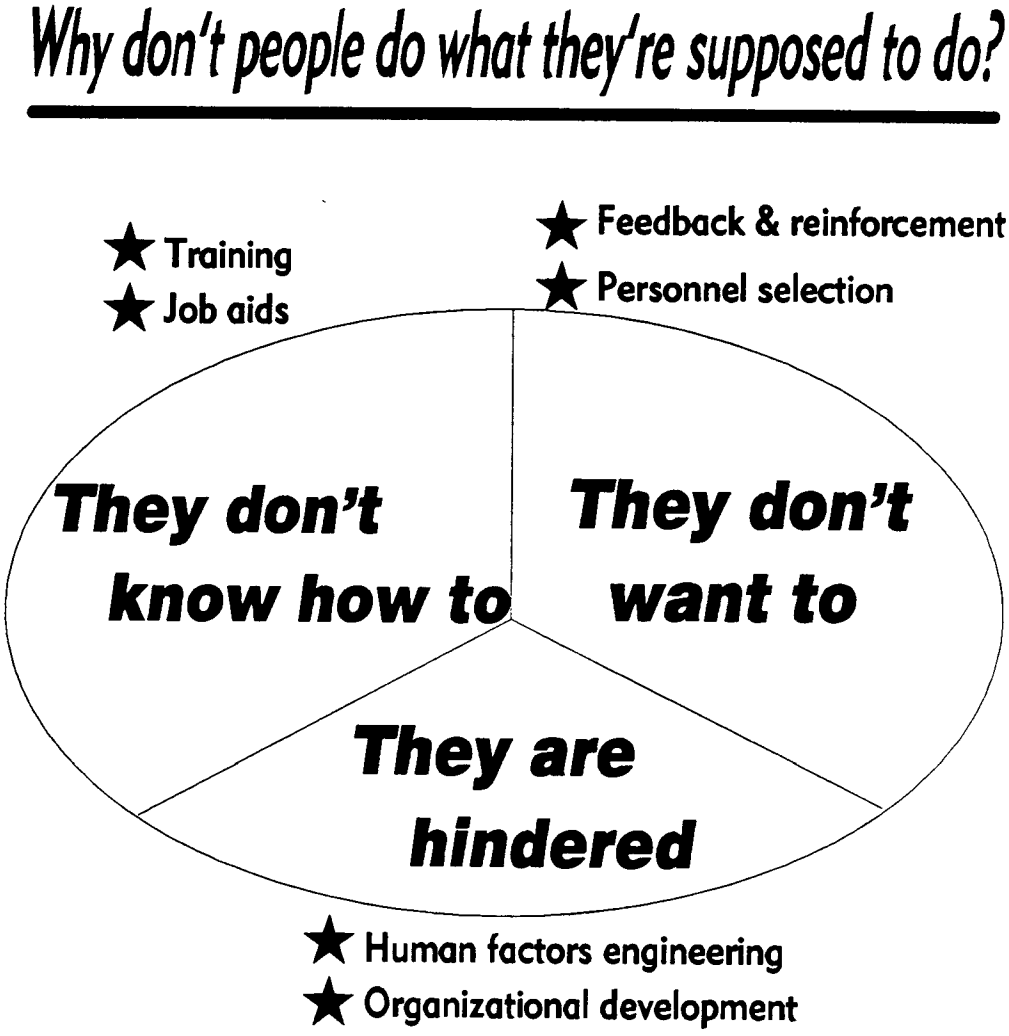


Figure 1: Scope of Human Performance Technology

better interfaces between humans and machines in the system. The individual-to-individual and group-to-group interfaces, the "non-machine" elements within the system, are addressed by organizational development and job redesign (Donovan, 1989; Rummler & Brache, 1990; Ruyle, 1990d; Sherwood, 1989; Uhlfelder & Werner, 1989).

When performers do not know how to perform, training or job aids are employed to correct the situation. Job aids are instruments used on the job to improve human performance by enhancing the knowledge and/or skills of a performer (Boothe, 1989; Ruyle, 1990c). Job aids have the same purpose as training, but training implies instruction and learning. After effective training, trainees can do something they could not do before training because of what they have learned.

Job aids are considered instructional interventions because they also mediate knowledge/skills problems. However, job aids are not really intended to produce learning--they substitute for learning. Learning that does occur as a result of using the job aid (surely considerable at times) is incidental (Richardson, 1983; Ruyle, 1990c).

Some common examples of job aids include checklists, decision tables, recipes, algorithms, and worksheets (Cox & Stum, 1985; Lineberry & Bullock, 1980). Such job aids are typically paper instruments which are laminated or otherwise protected to endure in the particular work environment. The

introduction of computers to the work place produced an opportunity to develop an entirely new class of job aids, computer-based job aids, which have potential to automate and improve many conventional paper job aids (Scanland & Scanland, 1981).

The most notable computer-based job aids are specialized computer programs called expert systems. Expert systems embody an expert's knowledge and, somewhat like expert consultants, can interact with novices to help them solve problems normally reserved for human subject matter experts (Ruyle, 1988; Waterman, 1986). Expert systems have been labeled intelligent job aids and identified as being important to the HPT field (Carr, 1989b; Harmon, 1986; Romiszowski, 1987; Wilson & Welsh, 1986).

Besides differences in the media, intelligent job aids differ from conventional job aids in some significant ways. Intelligent job aids generally assist the user with making complex decisions, e.g., diagnosing diesel engine problems or selecting plastics for a new product design (Ruyle, 1986a, 1989a). Conventional job aids generally are used to reduce dependence on memory (Harless, 1986); the tasks are usually fixed and less prone to interference by complicating factors. For instance, a pilot's pre-flight checklist and printed instructions for assembling a piece of furniture are both paper-based conventional job aids which refer to procedures that do not vary much, if at all, from situation

to situation.

Expert systems are less user-directed, more system-directed, than conventional job aids. The user is typically guided through a consultation session by the expert system which varies the content and sequence of the questions from one session to the next, depending upon the information it acquires. On the other hand, conventional job aids are more liable to be manipulated in unanticipated ways, for better or worse, by the user (Ruyle, 1989d).

Finally, intelligent job aids are usually much better able to deal with probabilities and ambiguous situations than conventional job aids. For instance, there is no really satisfactory method of developing an algorithm that allows the user to choose a "probably yes, but maybe no" response at a decision point (Lewis, 1970; Wheatley & Unsin, 1972). An expert system can be built to accommodate such responses (Romiszowski, 1987; Ruyle, 1989d, 1990a).

Both conventional and intelligent job aids have been shown to be effective tools for improving human performance (Duncan, 1985; Feigenbaum, McCorduck, & Nii, 1988; Harmon & King, 1985). Most of the empirical research on job aids has been conducted by the military to prove the value of a particular job aid (e.g., Booher, 1978; Chalupsky & Kopf, 1967; Foley, 1973; Schultz & Wagner, 1981).

Problem

While job aids have been shown to be effective tools, there has been little empirical evidence accumulated to assist performance technologists with the task of designing, selecting, and implementing job aid interventions. Most of the "how-to" job aid literature, while helpful, only gives anecdotal evidence of the value of the methods suggested, especially concerning implementation.

The accepted method of solving performance problems is to start with an investigation referred to in HPT literature by several terms, including needs assessment (Kaufman, 1986), needs analysis (Rossett, 1986; Zemke & Kramlinger, 1982), and front-end analysis (FEA) (Harless, 1975). Data garnered through a front-end analysis are used to identify a performance problem (if one does indeed exist), determine the value of correcting the problem, and suggest methods best suited to that end. If data suggest an instructional intervention, job aids should be considered to support or substitute for training.

Boothe (1989), Harless (1986), Lineberry and Bullock (1980), Pipe (1981), and others have identified factors that suggest the application of job aids, but there is a lack of published evidence from which to systematically develop a methodology to guide performance technologists in creating and implementing both conventional and intelligent job aids.

This study endeavored to extend the body of knowledge pertaining to conventional and intelligent job aids by addressing the following questions:

1) **What are the major differences and similarities in the design and development of intelligent and conventional job aids?**
2) **Are there important differences in the application of intelligent and conventional job aids?**
3) **If there are meaningful differences in the application of conventional and intelligent job aids, why do they exist?**

Related Literature

The purpose of the following section is to review the professional literature related to conventional job aids and intelligent job aids/expert systems. Additionally, because the introduction of expert systems to the work place can be a significant technological change, literature pertaining to the diffusion of innovation and impact of technological change is reviewed.

Conventional Job Aids

Practicing performance technologists do not all agree on a common definition, or even a common appellation, for "job aid." Pipe (1981, 1986b) favors the label "performance aid" because the focus is on the performance of a task and not necessarily on a job. Pipe takes a broad brush stroke, claiming that performance aids are "whatever it takes to get the job done right by the people who have to do the job" (1986b, p.131). Harless (1986) states that job aids are used during actual performance of the task, provide cues on when and what to do, and reduce the performer's dependence on memory. Boothe (1989) has pointed out that job aids are instructional interventions which frequently can be substituted for training, usually very cost-effectively.

Examples of conventional job aids. Job aids come in several varieties, even when limited to paper instruments. Widely used job aids include checklists, recipes, decision tables, flow chart algorithms, and worksheets.

One of the simplest of all job aids is the checklist; the archetype is the pilot's pre-flight checklist. A checklist enables the performer to confirm the completion of steps which otherwise might be forgotten. Checklists can be designed to accommodate tasks that are performed in a fixed sequence as well as tasks that can be done in a variable sequence. Figure 2 is an example of a checklist that drill press operators might employ to guide routine

DRILL PRESS MAINTENANCE

Daily

__ Lube all zerk fittings (3) with #2 lubricant
__ Lightly oil the table with SAE 10 oil

Check for:
__ Loose screws and bolts
__ Worn belts
__ Worn, damaged, or missing parts
__ Loose gibs
__ Excessive play in adjustment wheels
__ Loose electrical connections

Weekly

__ Lube thrust bearings with #8 lubricant
__ Lube knee bracket with #8 lubricant

Figure 2: Example of a Checklist (Ruyle, 1990c, p.29)

maintenance tasks for which they are responsible.

A recipe, one of the most widespread type of job aid, is a set of written instructions. Diagrams, photographs, or sketches can be added to recipes to create illustrated instructions. Figure 3 shows illustrated instructions which could be used by drill press operators when changing and adjusting drive belts.

Checklists, recipes, and illustrated instructions are primarily used to supplement the performer's memory about the sequence and/or content of the tasks in a given performance. When the performance requires significant decision making, as in diagnostic or selection processes, there are other job aid formats that might be more suitable.

Figure 4 is an example of an "if-then decision table." This useful job aid assists a drill press operator in deciding how to solve problems with faulty drill operation. Pipe (1985, 1986a), a strong proponent of decision tables, has dubbed them a "poor person's answer to expert systems."

A flow chart algorithm, illustrated in Figure 5, is related to the decision table in its function but has a significantly different format. While decision tables are usually limited to about four decision points, flow charts can handle many. Also, flow charts can more easily provide complete information about the sequence and content of tasks. They are, however, usually more difficult to construct than decision tables.

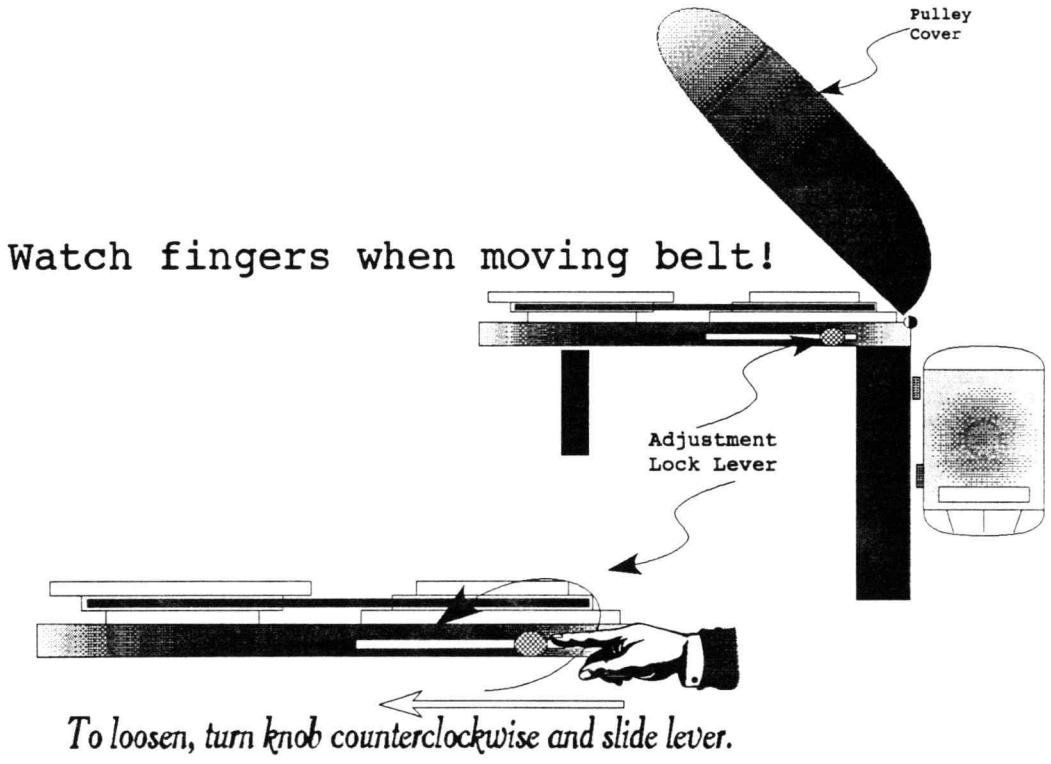
TO ADJUST OR REPLACE DRIVE BELT

1) Turn off main power switch and install lock-out

2) Lift belt pulley cover

3) Loosen adjustment lock lever and slide to the left

4) Carefully slide belt to new position



When belt is in position, be sure to:

- slide lock lever to right and secure
- replace belt pulley cover

Figure 3: Example of Illustrated Instructions

USE THIS DECISION TABLE WHEN DRILL PROBLEMS OCCUR		
IF THIS HAPPENS...	**CHECK FOR...**	**AND DO THIS...**
Rapid wearing of cutting edge corners	RPM too fast	Reduce cutting speed
	Work too hard	Sandblast castings; Anneal tool steel
Chipping of cutting edge or drill margin	Jig bushing too small	Replace drill bushing
	Insufficient lip clearance	Regrind to proper lip clearance
	Feed too fast	Reduce feed rate
	Coolant flow interrupted	Maintain continuous flood cooling
Surface finish is poor quality	Drill point incorrectly ground	Exchange drill at toolroom
	Feed too fast	Reduce feed rate
	Coolant flow interrupted	Maintain continuous flood cooling
	Poor clamping or workpiece	Reposition and securely clamp workpiece

Figure 4: Example of a Decision Table (Ruyle, 1990c, p.29)

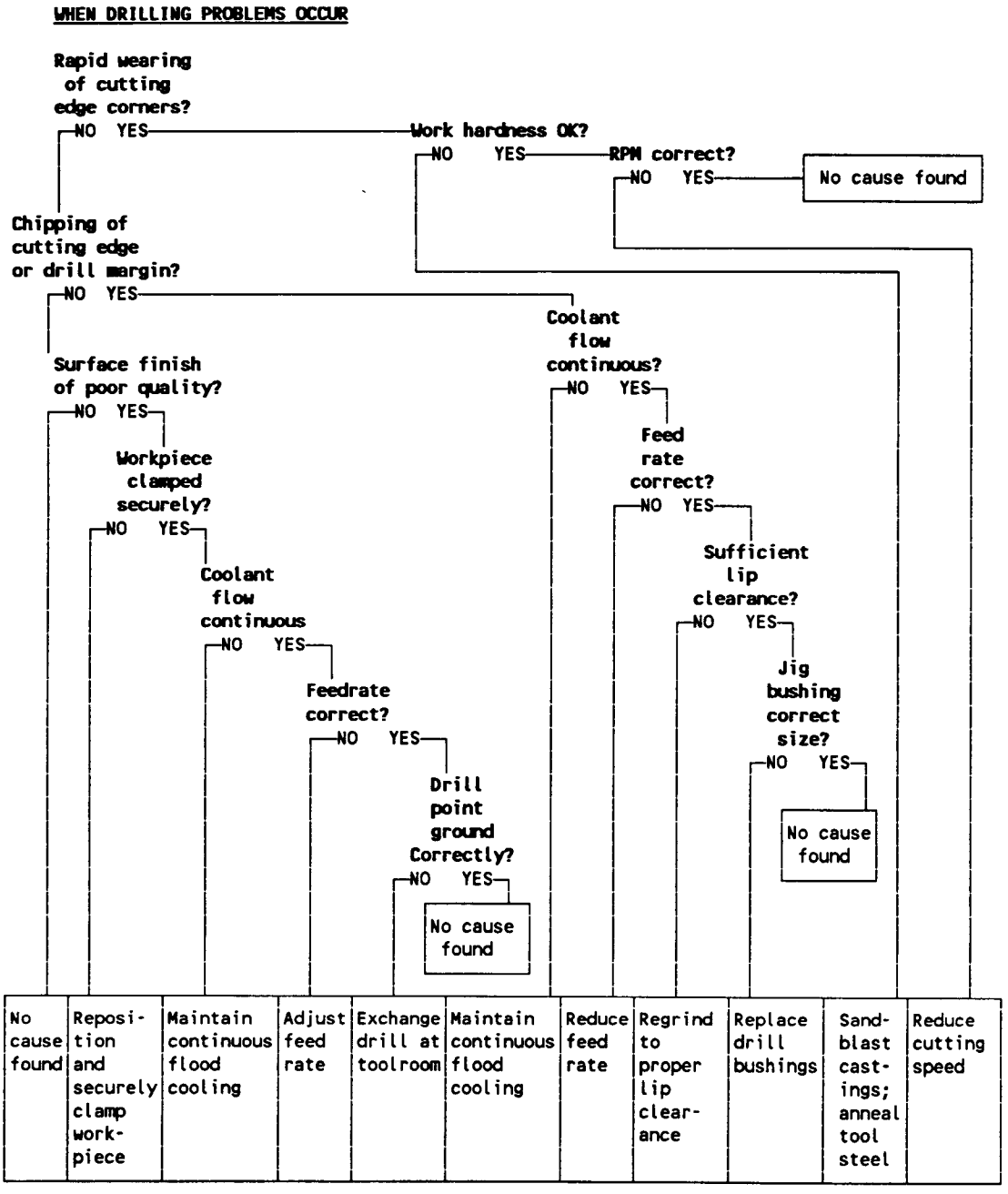


Figure 5: Flow Chart Algorithm Example (Ruyle, 1990c, p.30)

Worksheets can be adapted to a wide variety of tasks and include elements of the other job aids described above. The worksheet shown in Figure 6 could be used by a drill press operator when setting up for a new job. As illustrated in the example, worksheets permit the inclusion of extensive instructions, accommodate decision points, and provide for documentation of the performance if desired.

Classification of conventional job aids. Chalupsky and Kopf (1967), in an attempt to bring order to the study of job aids, suggested five possible classification schemes: 1) by impact on task content; 2) by time of use; 3) by information function; 4) by presentation format; and 5) by sensory channel. The first method of classifying job aids is by their impact on task content. Using this method, job aids fall into one of two groups: task-supporting or task-modifying job aids. The checklist shown in Figure 2 is an example of a task-supporting job aid because the performer does the job the same way with or without the job aid. The recipe shown in Figure 7, however, is a task-modifying job aid. Using the chart on the job aid removes a step from the calculation of drill revolutions per minute.

The second way in which job aids can be classified is by their time of use. Off-line job aids are those that are used just prior to the physical performance of a task--instructions which are read and remembered during the performance, for instance. On-line aids are those which

USE THIS WORKSHEET FOR PROCESSING TORQUE CONVERTER IMPELLERS #3806, #1492, and #5613

ATTENTION: These parts all use the same blank. They may be cast iron or machine steel. Do NOT use coolant on cast iron pieces.

Operator _____

Attach order tag here

Part #3806 BLUE ORDER TAG

__ Use blue template jig #14
__ Drill center hole with 11/16" core drill (blue shank)
__ Drill four 5/16" holes (blue shank)

Part #1492 GREEN ORDER TAG

__ Use green template jig #20
__ Drill center hole with 21/32" core drill (green shank)
__ Ream center hole with 11/16"machine reamer (green shank)
__ Drill four 5/16" holes (green shank)

Part #5613 ORANGE ORDER TAG

__ Use orange box jig #4
__ Drill center hole with 11/16" core drill (orange shank)
__ Drill six 5/16" holes (orange shank)

Figure 6: Example of a Worksheet

TO DETERMINE DRILL RPM, USE YOUR CALCULATOR TO:

1) Convert drill size into a decimal fraction

2) Divide recommended cutting speed by drill size to get RPM

Work piece	Cutting speed
Machine steel	400
Cast iron	320
Aluminum & brass	800
Tool steel	240
Cast steel	460

Example: Drilling cast iron with 7/16" drill

1) 7 ÷ 16 = .4375"
2) 320 ÷ .4375 = 731 RPM

Figure 7: Task-Modifying Recipe (Ruyle, 1990c, p.29)

are used during the physical performance (Chalupsky & Kopf, 1967).

Sorting job aids into one of three information functions is the third classification method. Job aids can support or modify information input, information processing, or information output. A diagnostic job aid which includes side-by-side illustrations to contrast typical wear patterns of a machine component is classified as an information input job aid. The decision table and flow chart algorithm in Figures 4 and 5 would be considered information processing job aids. "Information output aids can be visualized as those which support terminal behaviors, such as overlays which are used to indicate where certain electronic elements should be attached to circuit boards" (Chalupsky & Kopf, 1967, p. 54).

Job aids can also be categorized according to the format they use for presenting information. The information format groups include: verbal, pictorial, numerical, and mockups. It would appear difficult to use this classification method because there are many job aids which have some combination of verbal, pictorial, and numerical information presented (Chalupsky & Kopf, 1967).

The final method of classifying job aids is according to the sensory channel employed. The three groups suggested are visual, auditory, and audiovisual. Chalupsky and Kopf (1967) did not include tactile, olfactory, and gustatory

sensory channels, though these are possibilities.

Pipe (1981) has suggested a helpful classification scheme which, like the preceding one, includes five major groups. Pipe groups job aids according to their function; there are job aids to: 1) supplant, 2) enhance, 3) prompt, 4) boost, and 5) inhibit.

Supplanting job aids remove some part of the task from the control of the performer. Pipe describes two types of supplanting job aids: prepack and control. Both of these modify the task indirectly by modifying the system in which the task is performed. A prepack modifies the task so that some portion is always accomplished for the operator--it is prepackaged. Pipe's examples of prepacks include: frozen TV dinners, palletized shipments, and disposable diapers. A control job aid only modifies the task as necessary. An example is some method of queuing jobs so other performers assist during peak periods of activity (Pipe, 1981).

Enhancing job aids consist of tools which extend the capabilities of the performer. The three varieties of enhancing job aids include mental processors, physical processors, and interlocks. Mental processors are job aids like flow charts, structured lists, and decision tables; they simplify mental activity. Physical processors are tools, e.g., wrenches, which simplify physical activity. Interlocks prevent premature performance of some part of a task. An example is forcing a computer operator to answer

a question confirming the command to delete all files in a directory.

Prompts are traditional, memory-reducing job aids. Pipe (1981) enumerates six of them: checklist, label, diagram, rule, mnemonic, and coding.

Boosting job aids are meant to improve the information received by the performer. The three types of boosting job aids are: enrichment, feedback, and signal. An enrichment job aid improves the quality of inputs to the performer by upgrading the caliber of the information itself or changing the conditions under which it's received. In accord with his lenient definition of job performance aids, Pipe's examples of enrichment job aids include: increased lighting, distinctive typefaces, and tally sheets for score keeping. Feedback job aids provide the performer with help to determine the adequacy of performance. Feedback job aids would include graphs of performance, work standards, and oral or written comments from a supervisor. The final type of boosting job aid is a signal. Signals are a form of feedback in which the performer is alerted through some attention-getting method, often when the performance is seriously inadequate. Examples of signals are smoke alarms, rail crossing signals, and sand in an egg-timer (Pipe, 1981).

The final group in Pipe's scheme is for job aids which inhibit. Job aids in the single subgroup of this category

block irrelevant inputs to the performer. Curtains, sound-proof work areas, and polarized lenses in traffic lights are examples of such job aids (Pipe, 1981).

When to use conventional job aids. Job aids, like training, should only be specified as an intervention when there is a bona fide performance problem caused by a lack of knowledge or skills. Once it is determined through a front-end analysis that the target population, a person or group of people, is not performing as desired because of a lack of knowledge or skills, there should be additional investigation into the nature of the performance.

Grau (1986) suggests that job aids might sometimes improve performance problems caused by a lack of motivation because they can create the expectancy of good performance, reduce the effort to achieve good performance, and improve the value of the performance to the performer. This notion seems reasonable for those performance problems which have knowledge or skill deficiency as a root cause. It is entirely possible that a performer who is hampered by a lack of knowledge or skill will exhibit low motivation.

When deciding on whether to implement job aids, a performance technologist will need to answer several questions (Cox & Stum, 1985; Ruyle, 1990c):

- How difficult is the performance?
- How often is the performance executed?
- How quickly must the performance be executed?

- What are the consequences of imperfect performance?
- What environmental conditions affect the performance?
- How do performers view the use of job aids?

Job aids should be considered **before training** as a performance improvement method when some or all of the following criteria are met:

- The performance is relatively difficult.
- The performance is executed infrequently.
- The performance does not have to be done very quickly.
- The consequences of imperfect performance are serious.
- The environment does not impede the use of a job aid.
- Performers do not have reasons to avoid using a job aid.

Any one of these factors, if contrary and exerting enough influence, could prevent the successful application of a job aid (Cox & Stum, 1985; McCampbell, 1989; Ruyle, 1990c).

There are many types of jobs which are performed in harsh environments, awkward positions, and physically limiting circumstances. These situations do not preclude the application of all job aids; they do, however, require a careful analysis of the performance to determine if there is an aid that can improve the operator's skill during completion of the task.

Job aid design. Though job aids are ubiquitous in the work place and in the home, Chalupsky and Kopf concluded that most are haphazardly designed and, as a result, "job aids are more often remembered for their frustrating

inadequacy instead of for their contribution to fostering human performance" (1967, p.3).

That claim is contradicted by the examples from everyday life recounted by Probst (1985). Probst refers mostly to ergonomic solutions of simple performance problems to promote his thesis that performance technologists can learn a lot by observing the effectiveness of many job aids in common use. The self-service gasoline pump, Polaroid cameras and film cartridges, and aircraft controls are a few of the job aid applications Probst uses to enlighten his audience.

While the relative distribution of "good" versus "poor" job aids can be debated, it is certain that significant variability can be found in existing job aids when they are evaluated according to critical criteria such as user acceptance, effectiveness in improving performance, cost-effectiveness, etc. Attention to job aid design is vital to successful applications.

It is possible for temporary, "quick and dirty" job aids to be constructed by the performer (as opposed to a performance technologist) to assist with on-the-job training (Nelson, J., 1989). But for a more refined product, Mockovak (1983) describes a design process consisting of five steps: 1) task analysis; 2) specification of training objectives; 3) determination of job tasks covered in training, those covered by job aids, and those covered by

a combination of training and job aids; 4) design of job aids and learning activities which make use of the job aids; and 5) validation of training and job aids.

Well designed job aids are to be used while doing a task and should not interfere with the performance by including unnecessary information. Directions about when and how to use the job aid should be included only if really required by the performer. Explanations of why it is used should be avoided altogether. Instructions should be concise, clear, specific, and use simple terminology and the active voice. Underlining, italics, or bold-faced letters should be used to highlight important information (Boothe, 1989; Bullock, 1982; Lawson, 1986; McCampbell, 1989; Ruyle, 1990c).

Simple illustrations are usually preferable to words. As with verbal information, graphics should be simple and straightforward. Line drawings are, as a rule, superior to photographs. If the job aid is to guide a psychomotor task, fingers, hands, eyes--whatever plays a critical part in the task--should be included. Arrows should be used to show direction of movement (Boothe, 1989).

Principles of human factors engineering can be applied to the design of job aids to ensure that the interaction between performer and job aid is optimized. Human factors considerations include the mental and physical capabilities of performers, design of displays and controls, and methods of communicating information (Bailey, 1982; Kantowitz &

Sorkin, 1983; Pipe, 1986b; Probst, 1985; Sanders & McCormick, 1987; Snow & Newby, 1989). Application of human factors principles should result in a job aid that is easy to use.

The job aid should be durable enough to withstand its anticipated environment. It should be field tested in that environment with the intended performers before widespread distribution to ensure it does what it is supposed to and will be accepted by the target population (Bullock, 1982; Ruyle, 1990c; Stum, 1987).

Zagorski (1989) has compared the task of creating a job aid to Zen artistry. According to Zagorski, a good job aid is unobtrusive; it looks like it could have been created by anyone in a short amount of time with minimal effort. The well designed job aid will promote an awareness of the task, not consciousness of the job aid. "If the performer gives no thought or response to the job aid, you have achieved your art" (p. 19).

Military applications of conventional job aids. Utilization of prescribed conventional job aids by the United States military goes back at least as far as World War I when instructional plates were placed on equipment and flight crews were provided checklists for airplanes (Olsen & Bass, 1982). According to Duncan (1985), who cites studies as early as 1958, the results of formal military research of job aid applications support the premise that

job aids can: 1) increase training content without increasing course length; 2) reduce training development time and cost; 3) decrease paperwork; and 4) improve soldier performance.

Typical of the military research are studies which compare the performance of unskilled and inexperienced personnel who use job aids to the performance of skilled, experienced personnel who do not use job aids. In their landmark work, Chalupsky and Kopf (1967) reviewed both military and civilian research as part of an investigation into the impact of job aids on industrial human resource utilization. In one of the studies they summarized, inexperienced electronics maintenance technicians learned to use a job aid in a very short time and, using the job aid, could adequately perform some tasks, such as fault localization, that gave experienced technicians difficulty.

Another study involved three groups of Navy personnel: experienced technicians, trainees from an electronics school, and personnel with little or no training in electronics. One half of each group was allowed to use a job aid, a conversion chart, during a measurement conversion test. The remaining half of each group took the test without the benefit of the job aid. Within each of the three groups of performers, those using the job aid performed better than those that did not. Also, each of the trainee groups that used the job aid performed as well as

the experienced technicians on the test (Chalupsky & Kopf, 1967).

Similar results have been recorded in other studies. Foley (1973) reported that inexperienced maintenance personnel using a well-designed conventional job aid performed as well or better than more experienced workers using typical reference materials.

In order to improve performance, job aids have to be accepted and used by the target population. Several studies of military job aid applications have shown that when job aids are indeed effective in improving performance, they are readily accepted by performers.

Schultz and Wagner (1981) conducted research to evaluate the effect of job aids on the performance of laypersons who were designing instruction using an instructional systems development (ISD) procedure. Several ISD models, sets of strategy components, were adopted by the United States Army, Navy, and Air Force during the 1960s to guide course development (Knirk & Gustafson, 1986). In the Schultz and Wagner study, all of the participants interviewed after using job aids to assist in instructional design tasks thought the job aids were good or excellent.

The study by Johnson, Thomas, and Martin (1977) into user acceptance produced similar results. Maintenance technicians viewed job aids favorably even though they did not have input into the development of the job aids.

Business and industrial applications of conventional job aids. Chalupsky & Kopf (1967) reviewed studies of job aid applications in 12 electronics assembly operations and in 12 patient care units in hospitals. They concluded that well-designed job aids could improve the quality and the quantity of work performed and serve as ersatz skill for performers handicapped by lack of training and experience. They found the effect of job aids was most notable when they were mediating complex or lengthy tasks.

Mockovak (1981a, 1981b) conducted an important study of the utilization of job aids by census enumerator-interviewers who received training to prepare for the 1980 U.S. census. Training for the subjects was developed using two methodologies. The first development approach followed an instructional systems design (ISD) model (Knirk & Gustafson, 1986). The second method used to develop training was a modified ISD procedure which redesigned job reference materials into job aids; simplified training content was built around the application of the job aids.

> Both training approaches were very successful in terms of positive ratings by trainees. JPA [job performance aid] trainees, however, gave significantly higher ratings of training quality, job preparedness, reading ease of training materials, adequacy of training length, and ratings of specific activities. They also reported significantly higher levels of on-the-job manual use and better coverage of critical job tasks during training. Supervisors familiar with both training approaches expressed preference for the JPA training (Mockovak, 1981a, abstract).

When job aids are a focal point in the design of instruction and instructional materials, training is likely to be more efficient and enjoyable to trainees; training materials are likely to be more streamlined, easier to use, and more visual in orientation (Mockovak, 1983).

The review of the literature to this point has dealt with the development and application of various conventional job aids that are predominantly created in a paper medium. Conventional job aids can also be formatted in an electronic medium and delivered by computer. The electronic medium alone does not classify a job aid as "intelligent." Intelligent job aids are system-directed and emulate the problem solving techniques of human experts. A flow chart algorithm, a recipe, or some other form of conventional job aid can be automated and delivered electronically but is not considered intelligent.

Stone and Hutson (1984) conducted research to gain understanding of ways computer-based job aids (but not necessarily intelligent, expert system job aids) can assist people in performing complex tasks. They provided subjects with a computer-based job aid which employed hypertext that included textual instructions, a dictionary, and a graphical help section. The researchers tracked how subjects, who directed their own search path, maneuvered within the system while they were engaged in assembling a miniature loading cart. No predominant search scheme emerged from tracking

the subjects, but all information sections of the knowledge base were accessed by most users. It was concluded that users may benefit from having access to a variety of kinds of information in a technical information system for job aiding. It was suggested that users be allowed a high degree of control over requests for information.

Intelligent Job Aids

The intent of both conventional job aids and expert systems is performance improvement for individuals who have a shortcoming in knowledge or skills. However, there are significant differences in methods of development, operation, and management of conventional job aids and expert systems. These differences have prompted professionals in the human performance technology field (e.g., Carr, 1989b; Harmon, 1986) to refer to expert systems as intelligent job aids. The terms "expert system" and "intelligent job aid" are used interchangeably in the ensuing discussion.

Artificial intelligence. Expert systems are an outgrowth of the field of artificial intelligence (AI), the branch of computer science that is attempting to create smarter, more useful machines (Winston & Prendergast, 1984). Intelligent machines, according to Barr and Feigenbaum (1981), will "exhibit the characteristics we associate with intelligence in human behavior--understanding, language, learning, reasoning, solving problems, and so on" (p. 1).

The AI field has made significant contributions to our understanding of thinking and problem solving, but many would argue that meaningful progress toward duplicating human intelligence in a machine has been minuscule. Hofstader (1979) says it this way:

> Historically, people have been naive about what qualities, if mechanized, would undeniably constitute intelligence. Sometimes it seems as though each new step towards AI, rather than producing something which everyone agrees is real intelligence, merely reveals what real intelligence is **not**. If intelligence involves learning, creativity, emotional responses, a sense of beauty, a sense of self, then there is a long road ahead, and it may be that these will only be realized when we have totally duplicated a living brain (p. 573).
>
> To create true intelligence, AI workers will just have to keep pushing to ever lower levels, closer to brain mechanisms, if they wish their machines to attain the capabilities which we have (p. 579).

The history, methods, controversies, and future of AI are not addressed in this literature review; these topics have been discussed by Bolter (1984), Jackson (1985), McCorduck (1979), Schank (1984), Winston (1984), and others.

In spite of the difficulties of reproducing human intelligence, AI has contributed to business success in at least three major ways according to Schutzer (1990). First, AI has, in some cases, improved traditional processing systems and services (for examples see Carroll, 1990, and Miska, 1989). Second, AI has simplified and enhanced means of access to information through better, more natural man-machine interfaces, and more intelligent data retrieval.

Third, and potentially most valuable, AI has provided support for decision making in uncertain and risky situations. It is in the decision making and problem solving arena in which expert systems make their primary contributions.

Working within a relatively narrow knowledge domain, an expert system reasons with uncertain data, explains its logic when requested, and delivers advice (and hopefully a profit) to its owners/users (Forsyth, 1986).

Expert systems. An expert system then is a specialized computer program that embodies a human expert's knowledge about a particular, restricted domain. In operation, an expert system typically conducts a consultation session with a person needing assistance. During the consultation the system queries the user to obtain information about the problem to be solved, much the same as a physician, a lawyer, or a mechanic would query a client to obtain information (Ruyle, 1988).

Expert systems differ from customary computer programs in the method of searching for a problem solution. Regular computer programs use algorithmic search methods. They are exhaustive and effective but do not appear intelligent. Expert systems, however, use heuristic search methods, shortcuts used by human subject matter experts to solve problems. Heuristics are not exhaustive like algorithms, but they appear intelligent because they limit the search

for the solution (Ruyle, 1988).

An illustration of this concept is a physician diagnosing a sore throat. One would expect the physician to peer into the patient's throat, make her say "Ahh," take her temperature, prescribe some pills, and instruct her to return in a week. Such behavior seems intelligent because the search is limited. If, in order to diagnose a sore throat, the physician administered an exhaustive battery of tests including X-rays, blood tests, and a computerized axial tomography (CAT) scan, one would probably wonder about the physician's intelligence in spite of the possibility of a more accurate diagnosis (Ruyle, 1989a; 1990b).

Heuristic strategies are common to expert systems, but there are a variety of presentation formats and features available. Many expert systems require the user to answer questions by selecting a response from a menu; others accept numeric and text-string input. Some systems employ extensive graphics, almost all have help screens available for the user, and numerous expert systems allow the user to ask the system to explain the heuristic rules that provide its logic (Ruyle, 1989c; 1990a).

Organizations that have begun to implement expert system job aids are realizing very significant benefits of the technology. One of the most important is the preservation of corporate experience and knowledge resources. Since expert systems, unlike humans, permanently reside in the

organization, concerns about retirements and employee turnover are reduced. Expert systems leverage the performance of the all employees with resulting improvements in product quality, efficiency, and customer service (Feigenbaum, McCorduck, & Nii, 1988; Ruyle, 1989d; Schoen & Sykes, 1987).

Military organizations are among those seeking to take advantage of artificial intelligence and expert system technology. The United States Air Force, for example, is working to formally apply AI to training, performance measurement, and job aid applications. Richardson (1983) describes efforts in this area and claims that expert systems are obfuscating the distinctions between training, job aids, and automated test equipment.

Gray, Pliske, and Psotka (1985) describe United States Army applications of artificial intelligence to tutoring systems. While intelligent tutoring systems are related to expert systems, they are beyond the scope of this literature review. For information about intelligent tutoring systems, intelligent computer-assisted instruction, and expert systems applications in training, see Clancy (1987a, 1987b), Fletcher (1985), Ford (1984), Kearsley (1987), Kearsley and Seidel (1985), Kirrane and Kirrane (1989), Knezek (1990), Lippert (1990), Petersen (1984), Romiszowski (1987), Ruyle (1986b, 1987, 1988, 1990b), and Sleeman and Brown (1982).

The success of a handful of commercial expert systems has been widely publicized. Examples include the XCON/XSEL expert systems which configure VAX computer systems for Digital Equipment Corporation, the Authorizer's Assistant expert system which makes credit authorization decisions for American Express, the PROSPECTOR expert system for mineral exploration, and the Cooker Maintenance Advisor expert system which diagnoses hydrostatic sterilizers for Campbell Soup Company (Duda & Gaschnig, 1985; Feigenbaum, McCorduck, & Nii, 1988; Harmon, 1986; Herrod, 1988; Leonard-Barton & Sviokla, 1988).

Expert systems as intelligent job aids. Smith (1987) describes a Ford Motor Company project to develop an expert system to diagnose ASEA robot systems. Originally conceived as a classroom training tool for robot technicians, the system emerged as a type of intelligent service manual. The Ford system for troubleshooting ASEA robots is a typical intelligent job aid application--an expert system replaces or complements a conventional job aid (in this case, a service manual) which assists with problem solving and decision making.

The major differences in intelligent and conventional job aids are: 1) the media used--electronic for intelligent versus paper (usually) for conventional; 2) the complexity of the decisions addressed--intelligent job aids are better able to handle complex decisions; 3) the manner in which the

system searches for a solution--intelligent job aids are more system-directed than conventional job aids; and 4) intelligent job aids are usually much better able to deal with probabilities and ambiguities than conventional job aids.

When to use intelligent job aids. The previously listed guidelines for when to implement conventional job aids also apply to intelligent job aids: the performance should be difficult, executed infrequently, something important, and should not have to be done very quickly; the environment should not impede the use of a job aid, and performers should not have strong reasons to avoid using a job aid. Additionally, the task addressed by an expert system should be one that can be performed by the human expert in a reasonably short period of time. If it takes an expert anywhere from a few minutes to several hours, it might be appropriate. If it takes a full day or more, the problem is too complex to be manageable (Ruyle, 1989d, 1990a).

The environment deserves special attention when considering intelligent job aids because of the computer hardware involved. The computer equipment delivering a diesel engine diagnostic expert system might survive the greasy, relatively harsh environment in the service bay; it might not survive being bounced around in a service truck and exposed to even harsher elements if used during field service work.

The job that the system deals with should be important, but not fraught with urgency. Medical diagnosis was one of the very first tasks addressed by an expert system application, and an appropriate one. However, it would not be appropriate for a surgeon to attempt to use an expert system to select a life-saving maneuver in the operating room. The proper method to address such tasks is training, over-training so the task can be done without conscious effort (Ruyle, 1989c; 1989d).

Another factor to consider before selecting an intelligent job aid is the level of acceptance afforded by users, the users' peers, and observers. Some mechanics only use the troubleshooting guide in a service manual as a last resort because they feel it reflects a lack of competence; they don't want their peers to witness their dependency on a manual. If such a phenomenon can happen (and it does) with service manuals that can be used rather discreetly, it may be even more likely to interfere with the use of intelligent job aids (Ruyle, 1990a).

Acceptance of intelligent job aids will obviously be hampered if users are not computer-literate. Difficulties and frustrations encountered with computer operation could serve as punishers that provide an excuse to skirt the system altogether and resort to customary but inferior methods of performing the task. Also, users might view a struggle with computer commands as just one more reflection

on their competence (or lack of competence) and yet another excuse to avoid the job aid.

Successful intelligent job aid applications are sometimes thwarted because observers (clients of the expert system user) deem the application inappropriate. People might not mind seeing a mechanic use an expert system to diagnose automobile problems, but might strenuously object to teachers using expert systems to assign grades to and make promotion/retention decisions about their children (Ruyle, 1989c).

Expert system development. Figure 8 illustrates the customary development process for expert systems. End users of the job aid only see the screens presented by the expert system's user interface; they never see what goes into developing the program. Similarly, users of a spreadsheet or word processing program only see the user interface and not the hundreds of lines of computer code that make up the program.

The knowledge engineer (KE) is a vital person (or team) in the development process. The KE works with a subject matter expert (SME) to acquire the human's knowledge and problem solving strategies. Then, using a computer language or programming tool, the KE represents the knowledge so that the system can employ it to make inferences and judgements during a consultation with the end user.

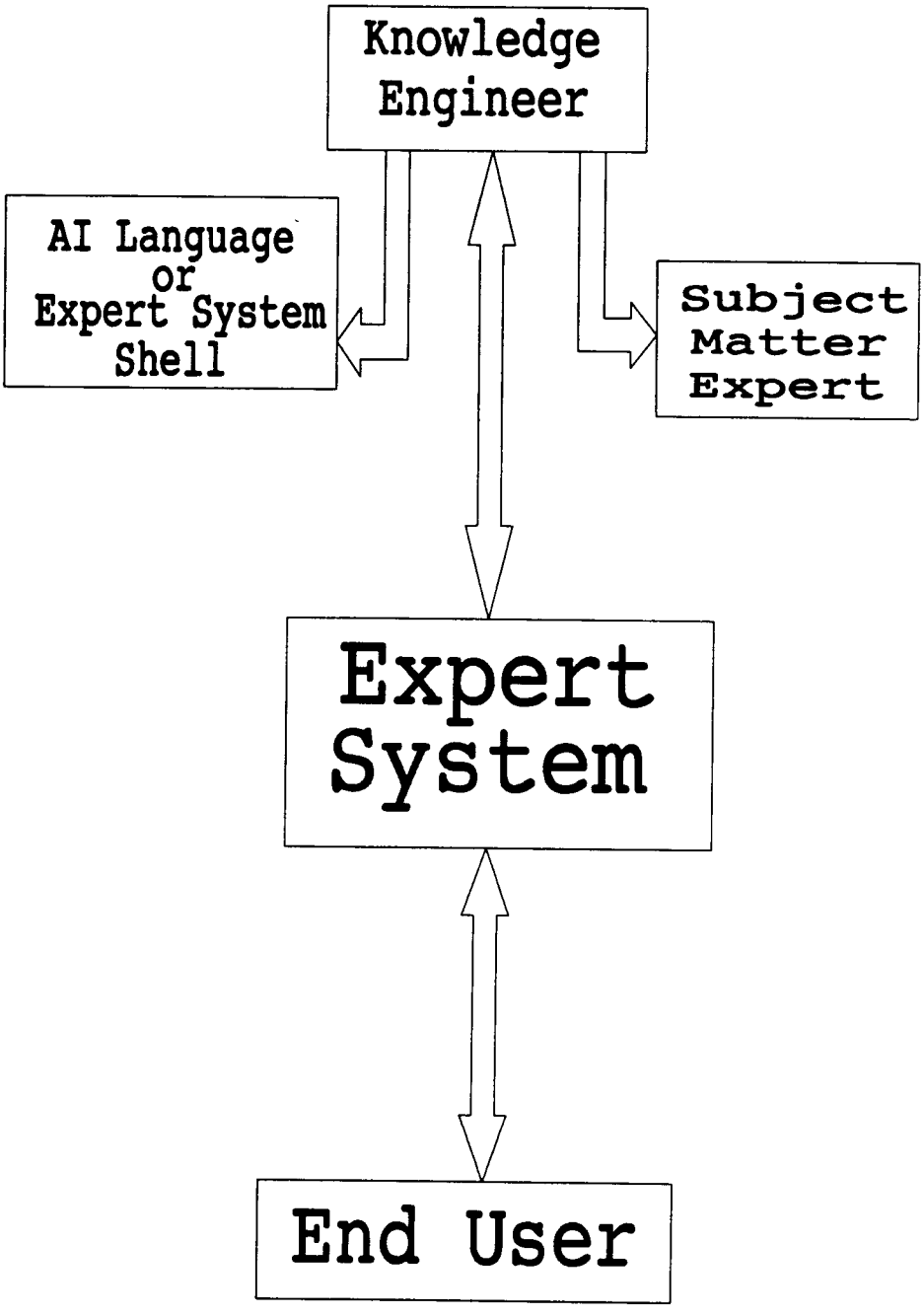


Figure 8: Expert System Development Process

The first expert systems were programmed in distinctive AI languages, such as LISP, on mainframe computers or on specialized AI computer workstations. Likewise, the end product had to be delivered with powerful computer hardware. The knowledge engineer had to have a high level of computer programming skills to represent the knowledge and create the expert system's inference mechanism (called an inference engine) and user interface (Ruyle, 1989d; Schoen & Sykes, 1987).

The expert system itself consists of four essential components: 1) the knowledge base; 2) the inference engine; 3) the knowledge acquisition module; 4) the explanatory interface (Forsyth, 1986). The knowledge base contains information pertinent to the subject matter domain--facts, relationships, and possible conclusions. The inference engine makes decisions, based on information received from the end user, about the system's search for a solution. The inference engine determines which questions are asked of the end user and the order in which they are asked based on certainty factors--probabilities of a given solution being correct according to the evidence accumulated during a consultation. The knowledge acquisition module requests information from the end user and provides a method for the user to provide input. The explanatory interface provides the end user with brief explanations of system operation by revealing current operations of the inference engine. The

user usually accesses this information by asking why a question is asked or how a conclusion was reached (Forsyth, 1986).

There are now expert system authoring tools, or shells, that greatly simplify the development task by providing an inference engine, knowledge acquisition procedure, and user interface. A shell then is basically an expert system sans knowledge, a skeletal structure which the KE fleshes out with domain knowledge (Ruyle, 1987).

At the lower end of the price-power-complexity range of development software are personal computer-based (PC-based) authoring tools which typically sell for about the same price as a good word processing or spreadsheet package. These software tools enable non-computer programmers to create intelligent job aids on desktop personal computers (Ruyle, 1987; Wilson & Grabinger, 1989).

Bielawski and Lewand (1988) describe the characteristics of three major types of expert system development tools. Rule-based tools require the KE to represent the knowledge as if-then rules. Rule-based tools are appropriate when the knowledge is easily expressed in this format. Inductive tools, somewhat more sophisticated than rule-based tools, construct rules for the KE who tells the system about known facts and relationships and examples of successfully solved problems. Hybrid tools combine some of the features of rule-based and induction-based tools; they are useful when

more flexibility is needed for knowledge representation.

Knowledge engineering. Rolston (1988) describes an expert system development life cycle which consists of three major phases, each consisting of two developmental steps. Problem revision, the first phase, involves selecting the problem and then constructing a prototype. The second phase, formalism revision, entails standardization and completion of the knowledge base and then implementing the expert system. The final phase, evolutionary revision, is the evaluation and long-term evolution of the system. These phases are roughly equivalent to seven steps Harmon (1987) describes: 1) front end analysis; 2) task analysis; 3) prototype development; 4) system development; 5) field testing; 6) implementation; and 7) maintenance.

Knowledge engineering tasks are performed in each phase of the development cycle. Primarily, these tasks consist of: 1) knowledge acquisition from the SME; 2) organization of the acquired knowledge to make it more meaningful; 3) analysis of facts, concepts, rules, relationships, and goals of the knowledge base; and 4) representation of knowledge in a final, usable format for the system. Most authors explaining knowledge engineering arrange the aforementioned tasks in two rather comprehensive stages: knowledge acquisition and knowledge representation.

Prior to the introduction of PC-based authoring tools, knowledge engineers were typically computer programmers who

had some knowledge of psychology or psychologists who had programming skills. The availability of inexpensive and rudimentary PC-based shells has prompted some authors to suggest that trainers, instructional designers, and subject matter experts perform the knowledge engineering function (Ruyle, 1989b, 1989c, 1990a; Siegel, 1989).

Others, however, have raised objections. With regards to instructional design, Richards (1989) asserts there has been too little research conducted by developers working on real-world systems to form valid conclusions about the similarities of knowledge engineering and instructional design. In addition, instructional designers are not typically prepared to select appropriate authoring tools and use them effectively. Their lack of experience with the technology makes it difficult to estimate the size and complexity of a project and may make them inclined to exaggerate expected results.

Hart (1986) and Bowerman and Glover (1988) claim that it is usually inappropriate for SMEs to perform knowledge engineering because they lack familiarity with software and knowledge representation methods and have difficulty articulating their own knowledge in a lucid, thorough, and accurate manner. On the other hand, Cooke and McDonald (1986) maintain that the ideal situation is when the domain expert is also experienced in knowledge engineering.

While questions may remain about who is best suited for the job, there are no doubts about the challenges involved in knowledge engineering. One of the difficulties to be surmounted includes interacting with various SME personalities. Some are recalcitrant, some egotistical, some speak in a foreign technical language, some are unappreciative of the knowledge engineering project, some speak so rapidly it is incomprehensible, and others speak with maddening torpidity (Indermill, 1986).

A case which illustrates the adversity and obstacles often encountered in knowledge engineering is described by Rose (1988). Two young knowledge engineers had considerable difficulty capturing and effectively representing the expertise of a 55-year old civil engineer, an expert on earthen dams. From the KEs' perspective, the SME was recalcitrant and provided equivocal explanations of the workings of the dam in question. On the other hand, the SME believed the KEs were bothersome and slow to grasp the most fundamental concepts.

Hart (1986) lists characteristics of a successful knowledge engineer: intelligence, good communication skills, diplomacy, patience and persistence, creativity, self confidence, knowledge of the subject matter, and programming knowledge. Also, KEs will benefit from a broad educational background because they will be better able to recognize analogies between the SME's expertise and other knowledge

domains (Rolston, 1988). Presumably, this characteristic will enhance their ability to organize knowledge from an unfamiliar domain.

Knowledge acquisition. The knowledge acquisition process is a vital key to organization and representation of the knowledge base. It is vital that a recognized expert (Rolston, 1988, recommends the expert that the organization wants least to part with) is available. It would be very unlikely, contrary to the suggestions of Edosomwan (1988), that more than one or two experts are involved in contributing to the knowledge base. If two or more SMEs are involved, their contributions must be in agreement.

In the early stages of an expert system development project, the KE will spend time becoming familiar with the subject matter and problem to be addressed by the system by reading books or manuals, investigating pertinent case studies, and informally conversing with and studying the behaviors of domain experts and practitioners. Familiarization is then followed by formal interviewing, observation and task analysis, and elicitation of knowledge structures (Bowerman & Glover, 1988; Martin & Oxman, 1988; Nelson, W., 1989)

The development team, consisting of the knowledge engineer(s) and subject matter expert, start with system goals and work backwards after carefully delineating the system boundaries. The system's end results are determined,

and the factors to be considered by the system are normally established before examples and rules are recorded and related certainty factors are specified (Bielawski & Lewand, 1988).

Writing from the perspective of an instructional designer/performance technologist, Indermill (1986), describes strategies for establishing credibility with an SME. She explains how to establish rapport, set the context for the knowledge acquisition process, and create an atmosphere conducive to a fruitful interview and working relationship. These techniques are very useful and apropos to knowledge engineering.

The processes of interviewing and protocol analysis (formal interview and observation) can include requests for:

1) Descriptions of interesting cases;
2) Lists of problem symptoms or characteristics, and possible resolutions;
3) Lists of intermediate and final goals and decision points;
4) Groupings and reclassification of symptoms;
5) Summaries of actions and thought processes as the expert thinks aloud while at work; and
6) In-depth analyses of decision making processes (Cooke & McDonald, 1986; Hart, 1986).

Evanson (1988) endorses application of introspectionist psychology to enhance the interviewing process. The intent

is to invoke an expression of the SME's feelings, mental images, and tacit, self-dialogues. Cooke and McDonald (1986), however, argue that introspection is one of the major weaknesses of interviews; they suggest more formal, automated methods of knowledge acquisition.

Knowledge representation. Knowledge possessed by human experts can be classified in one of two ways (Harmon, 1987; Harmon & King, 1985). "Surface" knowledge includes the heuristics and subject matter-specific knowledge gained through work experience. "Deep" knowledge, generally derived from formal schooling and books, consists of the underlying theories and principles that form a foundation of the subject matter. The knowledge bases of most expert systems entail just representation of the SME's surface knowledge; inclusion of deep knowledge would encumber the system (Harmon & King, 1985).

The common methods of representing knowledge include: if-then rules, semantic networks, object-attribute-value triplets, frames, and logical expressions (Grabinger & Jonassen, 1989; Harmon & King, 1985). These representation schemes correspond to various types of authoring software.

Rolston (1988) encourages selection of a scheme for "knowledge representation as soon as possible, even though it may not be the optimal (or final) representation" (p. 165). However, Cooke and McDonald (1986) and W. Nelson (1989) warn against selecting a representation scheme and

authoring software prior to knowledge acquisition because it will unduly influence the KE during knowledge acquisition and limit modes of representation which may more accurately exemplify the SME's expertise.

Hart (1986) describes several ways to represent and manipulate knowledge to attain greater accuracy and usefulness. She suggests, for instance, it is sometimes possible to apply laws of probability and statistics to the decisions suggested by experts; the repertory grid and cluster analysis are two techniques she proposes to facilitate knowledge elicitation and representation.

Managing expert system technology. While there are certainly similarities in the development and application of conventional and intelligent job aids, the professional literature focuses on management concerns about intelligent job aids; management of conventional job aid applications is virtually ignored. Management becomes an issue because expert systems involve a new and highly visible technology, utilize relatively sophisticated hardware and software, generally cost more than conventional job aids, and applications are expected to increase rapidly in the future.

Paul Harmon, a practicing performance technologist, is perhaps the leading authority on intelligent job aid applications. His view is that "despite any potential problems, the number of workshops and manuals developed will steadily decline, while intelligent job aids will gradually

become the primary media used by those who develop training for business, industry, and government" (1987, p. 192).

Koska and Romano (1988), in a landmark study for the Society of Manufacturing Engineers, support predictions of vigorous growth. They estimate that only about 10 percent of manufacturing engineers currently use expert systems on their jobs, but that 50 percent will be required to use them regularly to solve problems on the job by the year 2000.

Leonard-Barton and Sviokla (1988) describe three types of talent needed for large-scale expert system projects: subject matter talent, technical knowledge engineering talent, and managerial talent. They claim that, of the three, managerial talent is most likely to be neglected in spite of the difficulty in managing an expert system project well. "Managing any software development project requires a rare combination of technical ability and interpersonal skills, but because ESs [expert systems] explore complex and ill-defined domains, they pose a particularly tough managerial challenge" (p. 96).

According to Vedder (1987), one of the first management decisions is to determine whether to perform the knowledge engineering in-house or to use an external consultant. Complicating the issue is the severe shortage of trained and experienced knowledge engineers and the very high cost of training personnel to become proficient in knowledge engineering functions.

Probably more challenging than the matter of knowledge engineering resources are issues with legal implications. Vedder (1987) raises some thorny questions. Who owns the SME's expertise? What rights does an SME have when transferring intellectual property to an expert system? What of the SME's job security once expertise is conveyed to an expert system? Who is liable when an expert system makes an error? Who is liable if end users alter the system? Can a company or organization be sued if they abstain from using an available expert system? Who is at fault or liable when a human expert and expert system disagree? In addition to these challenges, management must deal with possible opposition by workers intimidated or annoyed by a new technology that has the potential to significantly affect the way they do their jobs.

Resistance to Innovation and Technological Change

Although the advantages of expert system technology for organizations have been rather well documented (Feigenbaum, McCorduck, & Nii, 1988; Leonard-Barton & Sviokla, 1988), there is no unanimity of predictions about the effect of expert system technology on the work force. Any technology has potential for both propitious and deleterious effects. The discussion that follows describes possible effects of expert systems on the work force and suggests means of facilitating the introduction of the technology.

Distinctive changes that can be effected by expert system technology. Computers, irrespective of expert systems, are without doubt a powerful force in shaping the nature of work. They have the potential to expedite many work processes and furnish workers with the information they need to assume greater work responsibility (Zuboff, 1988). Unfortunately, they may also contribute to dehumanization and de-skilling of many jobs and a resulting reduction in the number of desirable jobs (Garson, 1988). The AI technology that expert systems add to conventional computer programs could possibly contribute to negative effects produced by computerization.

Stern and Fichter (1985) present a model of the evolution of technological processes in which the control of the system passes from operator to tool (or machine) as the technology becomes more sophisticated. At the lowest level of technology the tool is simply an extension of the human body, a shovel for example. The human provides power, controls the tool, monitors the work, performs maintenance, and designs/plans the production process. At the highest level of technology, the tool provides power, control, monitoring, and even performs planning and design functions; the operator is left with little to do but try to fix the system when it fails.

Evolution of tools and production systems prior to this century was a prolonged development. Power was mostly

supplied by humans or animals until the Eighteenth Century. Although the Jacquard loom, which controlled weaving of prefigured fabrics, preceded numerical control (NC) machine tools by at least one hundred years, it has only been during the last twenty or thirty years in which manufacturing processes have been dramatically affected by programmable automation (Childs, 1982; Derry & Williams, 1960; Hartman, 1939). An examination of the effects of programmable automation, which removes substantial system control from performers, might shed light on the possible effects of expert systems in the work place.

Blumberg and Gerwin (1984, 1985) conducted research in work environments in which flexible manufacturing systems (FMSs) were implemented. These systems incorporate sophisticated, computer numerically-controlled (CNC) machine tools and material handling devices. Introduction of the technology has a profound effect on the work of skilled machinists who must perform different and often de-skilled tasks when working with an FMS. Skilled machinists turned FMS operators generally felt a loss of autonomy, experienced high levels of job-related stress, and reported reduced satisfaction with their jobs. Feelings of personal pride and mastery were no longer valid in an environment in which the machine, not the machinist, held tolerances. The large capital equipment expenses associated with FMSs prompted greatly heightened management expectations; machinists were

expected to produce better quality products in less time but had less control over the manufacturing process. Feelings of frustration and futility occurred because many skills that had taken years to mature were not used with the new technology.

Expert systems technology applied to FMSs (or any other computerized process) could conceivably compound the frustrations of workers because the system can be used to make decisions for the operator. For instance, in the traditional FMS, the operator might be responsible for monitoring processes and deciding when to change tools based on observations of surface finish. The operator might also have responsibility for troubleshooting many of the simpler system malfunctions commonly encountered. Expert system technology could be applied to an FMS to make decisions about tool changing based on input through sensors which detect changes in horsepower requirements caused by dulling tools. The system might query the operator about surface condition, nature of the chips being removed, coolant flow, etc. and then recommend a tool change, perhaps to an entirely different tool material or configuration. An on-line expert system could also be used to perform the troubleshooting tasks mentioned above.

The possibility of detrimental effects stemming from expert system applications is only that, a possibility. Some argue that, properly applied, expert systems will prove

an ennobling technology that permits technologically illiterate workers to perform at an acceptable level (Siegel, 1989).

Schoen and Sykes (1987) relate the contents of a talk given by Dr. Joseph Harrington, a pioneer in the development of computer-integrated manufacturing (CIM). He believed the division of labor created by automation of industrial processes reduced the dignity inherent in the skilled trades prior to the Industrial Revolution. Harrington's view was that "as the capability of design-related AI systems increases, it will be again possible for the designer to have an overall view of the entire process and resume the role of the master craftsman" (p. 10).

Carr, in a series of articles (see especially 1989a, 1990a, 1990b, 1990c, 1990d), envisions a future in which organizations will blend the contributions of humans and intelligent computer technologies.

> The **bionic organization** is the organizational form which is beginning to emerge in contemporary organizations--and which will become the dominant organizational pattern of the 90s and beyond. These are its three primary characteristics:
> * Many of the key roles in the organization are taken by computer-based actors, created by humans using intelligent technologies. Both human and computer-based actors will form a work community. When effective, each will help maximize the contribution of the other.
> * All of the actors, human and computer-based, will have access to the **Universal Encyclopedia of Knowledge and Know-How.**
> * All of the actors, human and computer-based, will be connected with everyone else (Carr, 1990d, p.45).

The "bionic organization" described by Carr is a far cry from the "electronic sweatshop" foreseen by Garson (1988) in which computers monitor and control work and workers to the point of sinister manipulation. In Carr's view, intelligent computer technologies will perform as coaches, as mentors to assist workers in their professional development. "One of the reasons why production workers are generally low skilled is that they're serving as add-ons to very dumb machinery. As the machinery become more and more intelligent, the humans must also" (Carr, 1990a, p.43).

Expert system technology, like any technology, can be blessing or curse--it primarily depends on the way the technology is implemented and managed. If it is astutely applied with prescience and benevolence, in all likelihood it will be endorsed by management and workers alike and will be diffused without complication.

Diffusion of innovation. Rogers (1983), in his landmark work, states that "**diffusion** is the process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas" (p. 5). Diffusion involves social change in a community, a work force, or some other group of people.

The change process, without exception, consists of four primary elements (Rogers, 1983). The first element is the innovation--an idea, device, or method that, regardless of

chronological age (or age compared to related innovations), is perceived as novel by members of the social system. A hand-held electronic calculator, for instance, would currently be regarded as an innovation in some regions of the world, but certainly would not be in other areas.

Communication channels are the second essential element in the change process. Communication channels enable innovators, those who have already adopted or at least have some knowledge of the innovation, to share information with others in the group.

The social system is the third change process factor. It consists of individuals (or other units) who share common goals and are potential adopters of the innovation. Depending on their propensity to innovate, adopters can be categorized in five groups: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards (Rogers, 1983).

The fourth and final component of the change process is time. Every adopter in the system, regardless of adopter category, must at some point choose to adopt or reject the innovation. As part of the process, the adopter passes through five phases. In the first phase knowledge about the innovation is obtained. An opinion is formed in the second step in the process, and the decision is made as the third step. In the final two phases of the decision making process, the adopter implements the innovation and, finally,

confirms the suitability of the decision (Rogers, 1983).

Decisions can be of three main types. Those made by an individual independently of others in the system are called optional innovation-decisions. Decisions reached by consensus among group members are collective innovation-decisions. The decisions made by powerful members in the social system and then imposed on the group are authority innovation-decisions (Rogers, 1983).

Three aspects of time are significant to the diffusion process. There is the elapsed time required to make a decision to adopt or not adopt the innovation. There is time measured as earliness or lateness of the adoption when comparing individual adopters within the group. Finally, there is the rate of adoption within a system, measured as numbers of adoptions occurring in a given time period.

Reasons for resistance. Since there is no guarantee that technological innovation and change are sound, it is understandable that some performers in an organization resist change. Klein (1976) argues that some opposition to change in social systems is rational, even meritorious. Resistance deemed irrational often stems from opposition to the people proposing the change or from valid concerns for the welfare of the system.

Change agents, those who help clients adopt innovations, must comprehend the causes of irrational resistance to innovation in order to minimize it. Any of the elements in

the change process can contribute to resistance, i.e., resistance to innovation can stem from the innovation itself, problems with communication channels, relationships in the social system, and the time frame in which the innovation is proposed.

Five basic characteristics of the innovation affect its appeal to potential adopters (Rogers, 1983). The first characteristic is the perceived advantage an innovation has over the conventional. Rather obviously, resistance to innovation diminishes as the perceived advantage increases. Compatibility, the second characteristic, is concerned with the innovation's ability to suit the needs and values of the adopters. Innovations that violate social conventions and protocols will face serious resistance. The innovation's complexity, as perceived by adopters, is the third characteristic; as perceived complexity increases, so does resistance. The fourth characteristic is the "triability" of the innovation, the degree to which limited experimentation can occur. Innovations that can be demonstrated and tested are more amenable to adopters. The fifth and final characteristic, observability, is the extent to which adopters are able to see results stemming from application of the innovation. Innovations with salient features and outcomes are less likely to face resistance. (Lin & Zaltman, 1973; Rogers, 1983).

Resistance to adoption is likely to be reduced when the innovation does not have a high cost to the adopter. Cost can be financial or social. "Social cost may come in the form of ridicule, ostracism, or even exclusion or explusion [sic] from some relevant reference group" (Lin & Zaltman, 1973, p. 101).

Communications channels are more effective when they are straightforward and unencumbered by bureaucratic procedures and checkpoints (Lin & Zaltman, 1973). Also, ideas transfer more readily between individuals who are homophilous, i.e., have similar backgrounds, values, and points of reference (Rogers, 1983).

The social system might impede diffusion of innovation if group leadership uses poor management methods. Kanter (1983) lists ten ways in which organizational management can stifle innovation in the work force. They are:

1. Regard any new idea from below with suspicion --because it's new, and because it's from below.
2. Insist that people who need your approval to act first go through several other levels of management to get their signatures.
3. Ask departments or individuals to challenge and criticize each other's proposals. (That saves you the job of deciding; you just pick the survivor.)
4. Express your criticisms freely, and withhold your praise. (That keeps people on their toes.) Let them know they can be fired at any time.
5. Treat identification of problems as signs of failure, to discourage people from letting you know when something in their area isn't working.

6. Control everything carefully. Make sure people count anything that can be counted, frequently.
7. Make decisions to reorganize or change policies in secret, and spring them on people unexpectedly. (That also keeps people on their toes.)
8. Make sure that requests for information are fully justified, and make sure that it is not given out to managers freely. (You don't want data to fall into the wrong hands.)
9. Assign to lower-level managers, in the name of delegation and participation, responsibility for figuring out how to cut back, lay off, move people around, or otherwise implement threatening decisions you have made. And get them to do it quickly.
10. And above all, never forget that you, the higher-ups, already know everything important about this business (p. 101).

In the same vein, Ordiorne (1981) describes how resistance to innovation and change often has its origin in management foibles. Ordiorne claims that management's penchant for crisis management produces an aversion to planning, a key activity in the conception and successful implementation of change. Further, Ordiorne claims that consensus decision making and what he terms "groupthink" have detrimental effects if work teams have poor leadership.

Time can play a role in the diffusion of innovation. Lin and Zaltman (1973) refer to a window of time in which adoption of innovation is most desirable. The point at which this window of opportunity closes is called a terminal. Identifying an innovation's terminal(s) is important to guide the management of the introduction of an innovation.

Rogers (1983) has performed a valuable service by summarizing the characteristics of early adopters, those who are among the first to be convinced by the innovators to embrace a new idea or technology. Some characteristics of early adopters follow.

> Earlier adopters...are not different from later adopters in age....have more years of education than later adopters have....are more likely to be literate than are later adopters....have higher social status than later adopters....have a greater degree of upward social mobility than later adopters....have a more favorable attitude toward credit (borrowing money) than later adopters....have greater empathy than later adopters....may be less dogmatic than later adopters....have a greater ability to deal with abstractions than later adopters....have greater rationality than later adopters....have greater intelligence than later adopters....are more able to cope with uncertainty and risk than later adopters....have a more favorable attitude toward science than later adopters....are less fatalistic than later adopters....have higher levels of achievement motivation than later adopters....have higher aspirations (for education, occupations, and so on) than later adopters....have more social participation than later adopters....have more change agent contact than later adopters....have greater exposure to interpersonal communication channels than later adopters....seek information about innovations more actively than later adopters....have a greater knowledge of innovations than later adopters....have a higher degree of opinion leadership than later adopters (Rogers, 1983, pp. 251-252, 257-259).

These characteristics can be compared to what is known about the target population to get an indication of how the potential adopters will respond to the introduction of an innovation. If the target population possesses many of the general characteristics of early adopters, the diffusion

process will likely be smooth. If, on the other hand, there are few individuals in the target population possessing these characteristics, the diffusion process is apt to be difficult.

Facilitating change and technological innovation. Dormant (1986) has provided some extremely helpful guidelines for performance technologists involved in fostering change. Her model of change consists of four elements: the adopters, the blackbox (the innovation), the change agent, and the domain (social system affected by the change).

Dormant advises change agents to assume different roles for each of the five phases of the adopter's decision making process. In the early stages of the process, as the adopter becomes aware of an innovation and forms an initial opinion, the change agent functions as advertiser and counselor. When the adopter begins to experiment and implement the innovation, the change agent serves as demonstrator and instructor. Finally, when the adoption is culminated, the change agent acts as technical assistant (Dormant, 1986).

There are also strategies for the change agent to use to deal with various characteristics of the blackbox. If the blackbox is:

* Hard to understand....Communicate the relevant factors, advantages, disadvantages to adopters. Give...bottom-line overview.
* Expensive....Provide cost-effectiveness figures; emphasize payoff. Document costs...

* Low/slow payoff....Reassess the worth of blackbox to your adopters. Be ready with tradeoffs. Appeal to team spirit.
* Inconsistent with past practice ....Identify and emphasize aspects similar to past practice. Match old values to new ones (From Dormant, 1986, Figure 17-3, p. 247).

Attention to the social system and organizational dynamics associated with adoption of an innovation is warranted. Diffusion will be more successful when change agents are not outsiders; potential adopters should be made to feel some ownership of the change. Additionally, adoption decisions should be made by consensus and backed by ardent support from top management (Watson, 1973). "Potential adopters must perceive that the persons who have power to provide or withhold rewards--money, advancement, recognition, approval and so forth--are themselves in favor of adoption" (Dormant, 1986, p. 252).

Research Questions

The purpose of this study was to extend the body of knowledge pertaining to the development and application of conventional and intelligent job aids. The review of related literature supported an investigation in these questions and suggested others.

1) **What are the major differences and similarities in the design and development of conventional and intelligent job aids?** For instance, is there a difference in the time required to develop corresponding conventional and intelligent job aids? Are the skills required to design

conventional and intelligent job aids comparable? Is there a difference in the costs involved in developing analogous conventional and intelligent job aids?

2) **Are there important differences in the application of conventional and intelligent job aids?** If so, what are they? For example, are well designed conventional and intelligent job aids equally effective in improving the quality (accuracy) of human performance? Are well designed conventional and intelligent job aids equally effective in improving the efficiency (productivity) of human performance? Are well designed conventional and intelligent job aids equally acceptable to and usable by the target population?

3) **If there are meaningful differences in the application of conventional and intelligent job aids, why do they exist?** What are the crucial factors that must be considered by the performance technologist before selecting and implementing a job aid? Does the age of the target population have an effect on user acceptance? Do the users' level of subject matter experience, education level, or computer experience influence the job aid application?

These issues were addressed by collecting and analyzing data from an actual situation in which both conventional and intelligent job aids were implemented to improve human performance.

Chapter 2

The Case

Following the literature review and identification of research questions, this study passed through the following phases:

1) Front end analysis of a perceived performance problem that could be mediated by the application of a job aid;
2) Creation of an intelligent job aid, a computer-based expert system, applicable to the situation;
3) Creation of a conventional, paper-based job aid that performs the same function as the intelligent job aid;
4) Validation of both job aids for the accuracy of content and usability;
5) Accounting of time spent and activities involved in the first four phases;
6) Development of diagnostic exercises to provide an opportunity for the target population to utilize the job aids and facilitate the collection of data to shed light on the research questions;
7) Development and delivery of training to enable the target population to begin using the job aids;
8) Development of a methodology for the evaluation of video-recorded diagnostic exercises;
9) Development and administration of survey instruments to obtain data needed to answer certain research questions;
10) Collection and analysis of data;

11) Reporting of results.

The execution of these tasks involved a combination of quantitative and qualitative research methods. The research methods, setting, and results of the first ten phases of this study are explained in this chapter.

Methods

The nature of this investigation suggested the use of qualitative research methods. Qualitative methods produce descriptive data by using such techniques as participant observation, in-depth interviews, ethnographic studies, and case studies. In contrast, quantitative research methods entail the application of procedures such as experiments, performance tests, and statistical analyses (Bogdan & Taylor, 1975; Reichardt & Cook, 1979).

Jacobs (1985) submits five points which provide a rationale for using qualitative research methods in the HPT field: 1) the occurrence of a paradigm shift across the social sciences which invites a "more balanced approach to the use of quantitative and qualitative methods" (p.20); 2) qualitative methods provide a common sense approach to research; 3) qualitative methods allow a more flexible role for the researcher; 4) qualitative methods, when used in conjunction with quantitative methods, increase confidence in the results; 5) qualitative methods are good for the researcher's professional development and the HPT field in general.

Patton (1980) proposes a checklist to help determine if qualitative methods are appropriate for a given evaluation situation. Included in the checklist is a question related to the implementation of job aids, especially intelligent job aids. "Is there the possibility that the program may be affecting clients or participants in unanticipated ways and/or having unexpected side effects...?" (p.89). A "yes" answer lends support for qualitative research methods.

The appropriateness of qualitative research methods for this study was indicated by the nature of the research questions, the context of the study, and the researcher's desire to employ triangulation in the investigation. Triangulation, the use of a combination of investigative methods, was employed to curtail researcher bias and provide a richer, more reliable, and more comprehensive source of data (Jacobs, 1985; Patton, 1980; Taylor & Bogdan, 1984). Quantitative analyses of the results of questionnaires administered to subjects were used to bolster observation and interviews.

Developing the Interventions

The performance mediated by the job aid interventions is the diagnosis of malfunctions in Robert Bosch electronic fuel injection systems. This task is one of a much larger set of tasks that would include diagnosis of all engine-related problems. Indeed, the Robert Bosch job aid is one component of a much larger expert system, the Engine Service

Advisory System (ESAS), which at the time of this writing is still under development by the John Deere Engine Works.

Setting

The impetus to begin work on ESAS came from people at the corporate level within Deere and Company who were looking for an opportunity to apply expert system technology. In effect, they had a technological solution looking for an application. The diagnosis of diesel engine problems emerged as a likely candidate.

The John Deere Engine Works Service Department, however, was not aware of problems with engine diagnosis. They were more concerned about the workload required by the newly-created Engine Works Dealer Technical Assistance Center (D-TAC).

The Dealer Technical Assistance Center is a support system in place at major Deere factories to serve the network of Deere dealers. The D-TAC operates as a telephone help desk to provide technical assistance to dealers who access the system by calling a toll-free (in most cases) telephone number to the factory that assembled the equipment in question. If D-TAC technical representatives at the factory are not able to solve an engine problem, they will seek help at the Engine Works D-TAC.

In spite of some questions about the value of an engine diagnostic expert system, the Engine Works responded to the proposal by retaining the investigator to assist with the

design, development, and implementation of ESAS before any front end analysis was conducted.

Front End Analysis

To determine if there was tangible justification to continue with an extensive knowledge engineering project, the investigator and a supervisor from the Service Department conducted a front-end analysis which focused on two major areas of concern: a burgeoning D-TAC workload and inordinate warranty claim costs to the organization.

Engine Works service personnel were consulted to define the desired and existing performance situation with respect to the D-TAC workload. The desired condition was that dealers and technicians would use on-site reference materials to assist with solving as many problems as possible and use D-TAC only when on-site reference materials were insufficient. The actual situation was described as dealers' service departments using D-TAC for problems that were recurring and could be solved with existing on-site reference material.

The results of this discrepancy between desired and existing performance was a massive workload for D-TAC because of the large number of recurring and relatively trivial problems presented. The workload prevented D-TAC technical representatives from providing timely service and accomplishing other valuable tasks such as warranty claim analysis.

Possible causes for the discrepancy were proposed:

* Dealer service departments/technicians did not know they were "abusing" D-TAC by not first thoroughly using their other resources.
* Dealer service departments/technicians did not know enough about existing on-site reference materials to use them effectively.
* Dealer service departments/technicians lacked necessary troubleshooting knowledge or skills and were therefore not well served by existing on-site reference materials.
* Existing on-site reference materials were not rewarding to use; D-TAC was more rewarding to use than existing on-site reference materials.
* Existing on-site reference materials were "punishing" to use; D-TAC was less difficult to use than existing on-site reference materials.
* Troubleshooting skills were not used frequently enough by the dealer service departments/technicians for them to maintain their effectiveness.

To acquire evidence to support or refute the speculated causes, a survey was conducted of area service managers (ASMs), Deere field service employees who are assigned to provide administrative and technical support to a group of independent John Deere dealers. Area service managers were surveyed because they have opportunities to observe the primary users of D-TAC during troubleshooting tasks. Also,

a survey of ASMs, because they are Deere employees, was less sensitive than a survey of independent dealer technicians. The complete FEA survey instrument and cover letter is included in Appendix A.

Within a week there were 75 respondents to the survey which was administered by electronic mail to approximately 130 area service managers through their regional branch managers. The final return rate was slightly more than 60 percent. Precise survey results are proprietary, but some findings can be reported in general terms. Respondents estimated that less than half of all service technicians had received any formal training in their current jobs, including Deere-specific training. Respondents estimated that only about 30 percent of service technicians have had any formal diesel training of any kind. Less than half of respondents agreed that service technicians usually used Component Technical Manuals when troubleshooting an engine problem. About 80 percent of respondents indicated that desired troubleshooting information could not be found in Component Technical Manuals in one minute or less. Almost 45 percent of respondents identified specifications as the most valuable section in Component Technical Manuals. Less than three percent named the table of contents/index as most valuable, and almost 30 percent of respondents identified the table of contents/index as the least valuable section in the Component Technical Manuals. About 20 percent of

respondents believed troubleshooting sections were the least valuable sections in the Component Technical Manuals. Respondents believed, almost unanimously, that the most common reason for calls to D-TAC was that the answer to a service problem could not be found in a Component Technical Manual.

To supplement the survey, an evaluation of engine-related D-TAC cases was performed to discover if the type of problems addressed by D-TAC were apt to be resolved if presented to an expert system. If most of the D-TAC cases were specific to one or to a small number of vehicles (within a certain serial number range, for instance), it would be unlikely that an effective expert system could be created because the knowledge base would contain a great many enigmatic solution paths.

A review of more than 200 engine-related cases representing five factories revealed that about 65 percent of them could be addressed by an engine diagnostic expert system. Also, it appeared that typical problems would be solved more quickly by an expert system than by conventional telephone consultation methods which, on the average, required D-TAC technical representatives to spend a little more than one hour per case to achieve resolution and closure.

Taken together, the survey of area service managers and the analysis of D-TAC cases strongly suggested that there

was indeed an opportunity to reduce the D-TAC workload with an intelligent job aid.

To determine the extent of unjustified warranty claims, one engine component was selected and analyzed. Similar to the survey described above, the information obtained from the analysis is proprietary and confidential. In general terms, though, the inquiry revealed that, for this particular component, at least 30 percent of those returned for a warranty claim were not defective; they had been replaced by Deere dealer technicians erroneously. This resulted in an unnecessary service parts expense of $48,000 for a 12-month period for one engine component. It was determined that a sustained annual savings of several hundred thousand dollars could be realized by reducing unjustified warranty claims for all engine components by just 20 percent.

The investigation of warranty claims provided evidence that dealer technicians were applying, to some extent, a hit-or-miss parts replacement approach to diagnosis and repair. These findings, as did the ASM survey results, lent credence to the proposal to create an expert system which might reduce warranty costs substantially by decreasing the incidence of indiscriminate part replacement. An Engine Service Advisory System would compel the technician to follow a logical diagnostic procedure and perform the appropriate tests before replacing parts.

Project Scope

As a result of the front-end analysis, knowledge engineering for the Engine Service Advisory System commenced. Currently, ESAS is a massive collection and organization of general knowledge about Deere diesel engines. Though at the time of this writing it is not complete, ESAS is presently capable of guiding a user through a consistent and effective diagnosis of a wide range of starting, performance, and system failure problems. Through a series of questions, ESAS leads the user through test procedures to identify the root cause of the engine problem and then provides repair instructions. In effect, the expert system functions as an intelligent, electronic technical manual; it even contains graphics to illustrate procedures.

After a prototype ESAS was completed, the Engine Works Service Department initiated knowledge engineering work on an electronic fuel injection pump expert system that would stand alone or be a component of the comprehensive ESAS expert system. The decision was made because of rapid growth in numbers of electronic fuel systems installed on Deere engines. The growth of electronic fuel injection pump applications was already placing additional demands on D-TAC. Electronic fuel injection systems were expected to contribute disproportionately to the D-TAC caseload when compared to most other product innovations because they

oblige technicians to deal with a completely new technology. Most diesel technicians are familiar with mechanical and simple electro-mechanical systems but not with digital electronic systems.

There are currently two manufacturers of electronic fuel injection systems for Deere engines: Robert Bosch and Nippondenso. The Robert Bosch fuel system was the first to be engineered into an expert system and a conventional job aid. These job aids form the focal point for this study.

The conventional job aid is included as Appendix C; a description and overview of the expert system is provided in Appendices D, E, and F.

Target Population

Several groups of people are potential beneficiaries of the job aids. In addition to Deere dealer technicians, the target population consists of all Deere employees who might be involved in troubleshooting electronic fuel injection systems.

Figure 9 represents a simplified view of the flow of information involved in troubleshooting electronic fuel injection system problems within the Deere organization. Diesel engines, some equipped with Robert Bosch electronic fuel injection systems, are manufactured at the Engine Works in Waterloo, Iowa. These engines are then installed in Deere equipment at the Tractor Works in Waterloo or at the Harvester Works in Moline, Illinois. After testing, tractors

Flow of Engine-related D-TAC Information

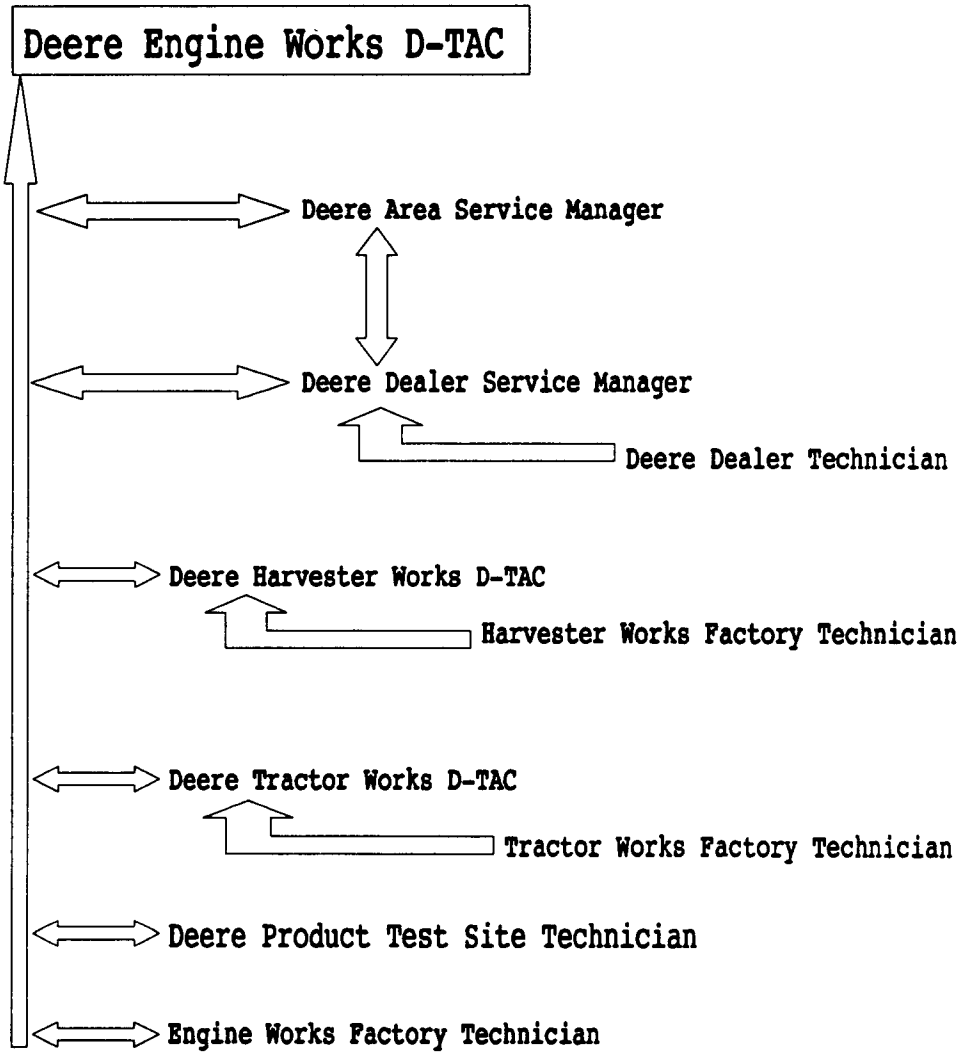


Figure 9: Flow of Troubleshooting Information

and combines are distributed to independently-owned Deere equipment dealerships.

Problems with the fuel system normally turn up in three different places: first, at one of the Deere factories during pre-delivery testing; second, in the customers' fields; third, at Deere product test sites where research and development work is done.

When a fuel system problem occurs at the factories, trained factory technicians attempt to fix it. If not successful, they can seek help through on-site D-TAC resources. If Harvester Works or Tractor Works D-TAC technical representatives are not able to solve the problem, they will consult the Engine Works D-TAC.

Technicians working at a dealership have several resources for technical assistance. In addition to maintaining D-TAC, Deere publishes technical manuals which contain extensive troubleshooting and repair procedures. The ASMs are also available for consultation when a stubborn equipment problem is encountered by a dealer. An ASM, facing a perplexing problem, may in turn consult D-TAC.

Problems encountered at a test site are handled the same way they are at a factory. Technicians attempt to remedy the situation and, if unsuccessful, might call D-TAC.

The subjects participating in this study were drawn from the pool of D-TAC technicians, factory mechanics, and ASMs described above. Also included were several technical

trainers and technical writers considered potential users of the job aids. It was not feasible to include dealer technicians because they are not employees of Deere and Company. Selection criteria for the study was determined by managers at the three factories where the study was conducted. Managers were asked to consider their subordinates and assign all potential users of the job aids to participate in the study. At each of the three sites, only those potential users who were absent from work at the time of the study (e.g., those who were on vacation, sick, or away from the factory on work assignments) or were involved in work that could not be interrupted did not participate.

Knowledge Engineering Activities

The first phase of this study was the front end analysis described previously. Although an FEA would not customarily be regarded as part of the knowledge engineering phase of a project, it must be performed before knowledge engineering commences. The second through fifth phases of this study involved extensive knowledge engineering and development of both an intelligent job aid and a conventional job aid.

The two job aids, for all practical purposes, were developed concurrently by the investigator. The knowledge acquisition and validation procedures were the same for each job aid. Substantial variations in development time occurred because of the demands of programming and graphics

development for the expert system.

The knowledge engineering tasks consisted of:

1) Familiarization with the subject matter domain precursory to knowledge engineering;
2) Consultation with SMEs and reference materials to acquire knowledge;
3) Drafting of flow charts and extensive notes to facilitate job aid construction;
4) Construction of first drafts of the job aids, i.e., writing a preliminary troubleshooting guide as a conventional job aid and programming a rapid prototype of the expert system;
5) Initial validation of the first drafts of the job aids;
6) Revision and completion of the job aids including development of graphics;
7) Validation of both job aids for accuracy of content and usability;
8) Refinement of both job aids;
9) Field testing, evaluation, and final revision of both job aids.

A simple diary was kept during these activities to track time spent on the development tasks for each of the two job aids. The investigator logged time (rounded to the nearest hour) spent on the various project activities on a calendar. Although this process was complicated by administrative tasks (e.g., meetings with management, etc.) and occasional

hardware malfunctions that interrupted the work flow, the values recorded accurately reflect the hours spent on the various knowledge engineering activities. Table 1 lists these activities and associated time required for each.

Table 1 does not include the time invested in developing and administering FEA instruments, analyzing and reporting survey results, and interviewing key personnel. The time involved was not tracked, but it was estimated by the two individuals who conducted the FEA that a total of 50 hours was spent performing FEA tasks. This does not include time spent by interviewees and respondents to the survey.

About 44 hours were spent after the FEA was conducted for the knowledge engineer (the investigator) to become familiar with the subject matter and acquire necessary knowledge to begin job aid development. Most of this time was spent studying Deere technical reference materials. Occasionally SMEs in the Deere organization were consulted to clarify questions about reference material. At one point in the knowledge acquisition process, a brainstorming session which lasted most of a day was conducted by the knowledge engineer with two SMEs.

Following (and to some extent, during) knowledge acquisition, flow chart algorithms were produced to represent the knowledge and guide the programming and writing tasks. Examples of three of the flow charts are included as Appendix B. The three flow charts displayed

Table 1: Time Required for Development Tasks

Task	Both job aids	Conventional job aid	Intelligent job aid
Familiarization with domain	14 hrs.	--	--
Consultation with SMEs/references	30 hrs.	--	--
Construction of flow charts	38 hrs.	--	--
First draft of conventional	--	9 hrs.	--
Rapid prototype of intelligent	--	--	96 hrs.
Validation of conventional	--	11 hrs.	--
Validation of intelligent	--	--	32 hrs.
Revision of conventional	--	3 hrs.	--
Revision of intelligent	--	--	54 hrs.
Develop graphics for intelligent	--	--	66 hrs.
Second validation of conventional	--	6 hrs.	--
Second validation of intelligent	--	--	19 hrs.
Refinement of conventional	--	2 hrs.	--
Refinement of intelligent	--	--	45 hrs.
Field testing of conventional	--	4 hrs.	--
Field testing of intelligent	--	--	6 hrs.
Final revision conventional	--	1 hr.	--
Final revision intelligent	--	--	35 hrs.
TOTAL HOURS	82 hrs.	36 hrs.	353 hrs.

represent just the portion of the knowledge base related to practice problems addressed by participants in the study. In toto, more than 20 flow charts were developed for this project.

Figure 10 summarizes and provides a comparison of the time spent in the development activities of both job aids. Included is an estimate of time spent on front end analysis.

All knowledge engineering activities were performed by the investigator. Since the knowledge engineer's education and experience significantly affect the time required to complete the development tasks, they must be considered as part of this case study. Accordingly, the investigator's vita is included in Appendix G.

Conventional job aid. Several possible formats for the conventional job aid were considered before the structured list format was selected. A series of flow charts would have been very appropriate if there was less information required to support each decision point. The need to include substantial text at various points was a deciding factor in the decision to use the structured list, basically a series of if-then statements. This format is the same as that currently used in the John Deere Component Technical Manual, CTM-11 (Deere and Company, 1989), that provides electronic fuel injection system diagnostic procedures; it is a format familiar to Deere service technicians.

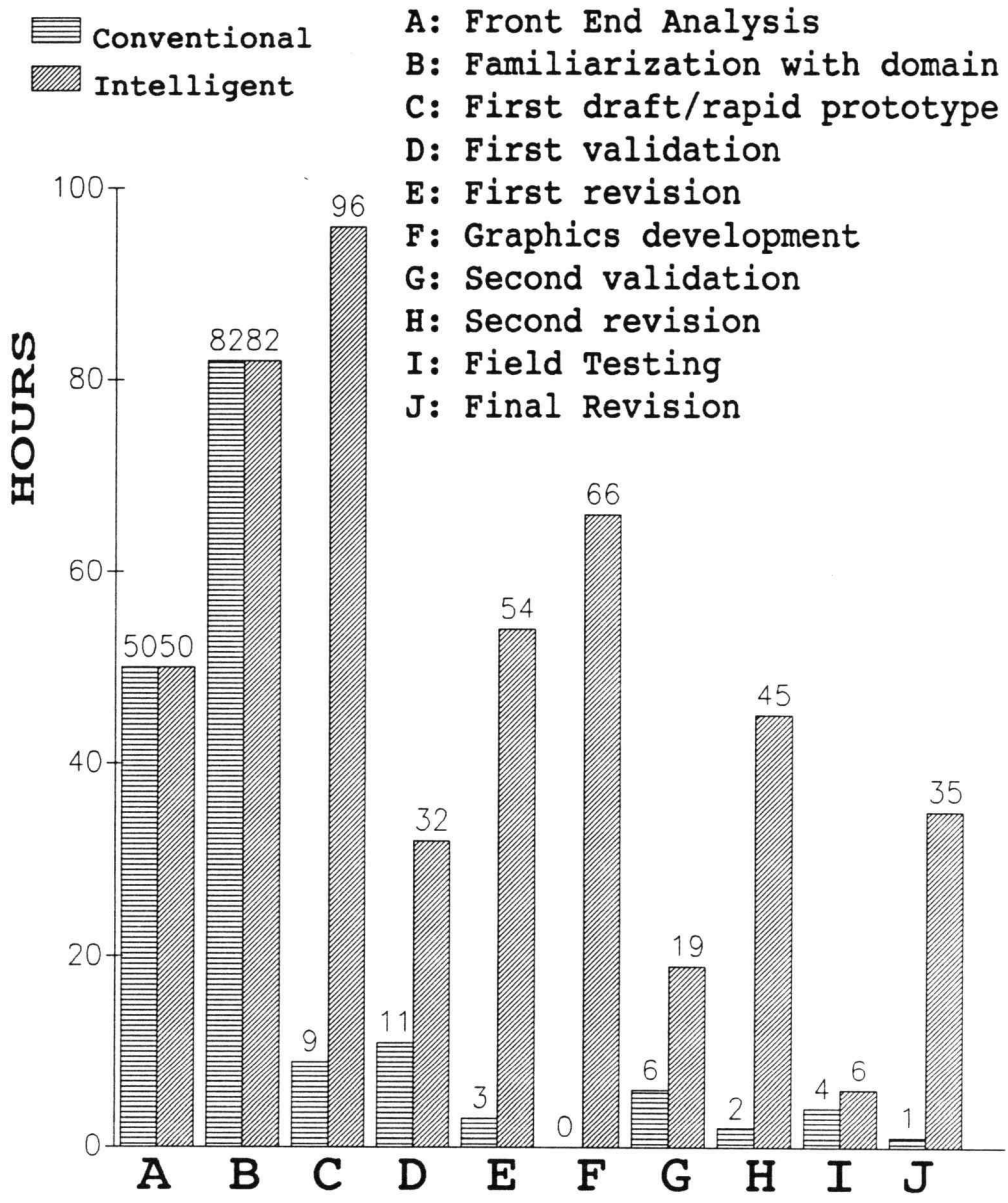


Figure 10: Time Spent on Job Aid Development

The conventional job aid is represented in Appendix C. The job aid was bound in a clear plastic jacket that, when creased, allowed the pages to stay open when lying flat on a work surface. The size and spacing of text and margins, as shown in this document, were altered from the original instrument to allow for binding. Illustrations are from Component Technical Manual 11 (Deere and Company, 1989).

Intelligent job aid. The intelligent job aid was developed on a Texas Instruments Explorer workstation using Testbuilder Version 1.0 software from the Carnegie Group. Graphics were developed using Dr. Halo III Version 3.0 from International Microcomputer Software, Inc. A graphical representation of the knowledge base showing relationships between "objects" is provided in Appendix D. The objects are elements which represent some piece of knowledge about the domain. Details of that portion of the knowledge base corresponding to the three flowcharts mentioned above are in Appendix E.

Most test and repair objects included in Appendix E list pictures. These refer to computer graphics embedded in the expert system as supporting material. There are 84 graphics used in the entire Robert Bosch expert system, and 43 of these are referenced in the portion of the knowledge base covered in Appendices D and E. They are displayed in Appendix F. Unfortunately, the printed version of the graphics presented in this document are noticeably inferior

to their presentation on a computer monitor, especially when a color monitor is used.

Validation. Both job aids were validated to assure accuracy and usability of the instruments. Two individuals, subject matter experts employed at the John Deere Production Engineering Center in Waterloo, Iowa, validated the accuracy of the first and subsequent drafts of both systems.

The SMEs were provided with the flow charts used to represent the knowledge as well as copies of the job aids. They in turn provide written feedback to guide revision. The investigator also engaged in several conversations with the SMEs to get additional clarification.

The conventional job aid required little refinement because it was relatively straightforward and closely followed existing reference materials. However, the intelligent job aid required extensive revision after the initial prototype was constructed.

Applying the Interventions

The second and third research questions concern the application of job aids. To evaluate the application of both job aids, four criteria suggested by Bailey (1982) were considered. The four measures, which Bailey suggests are standards for evaluating human performance systems, are: accuracy, speed of performance, skill development time, and user satisfaction.

These factors were evaluated by observing participants during simulated problem solving experiences with the job aids, through the use of a questionnaire administered at the conclusion of the subjects' experience with the job aids, and through interviews.

Development of Diagnostic Exercises

A nearly complete fuel system was "bugged" to provide opportunity for subjects to realistically apply both job aids. The mock fuel system consisted of a fuel injection pump, electronic control unit (ECU), wiring harnesses with connectors, and a power source which allowed voltages to various components to be altered. The problems simulated were solved by following the diagnostic procedures listed under Diagnostic Codes 32, 35, and 37 in Appendix C and presented in that portion of the knowledge base shown in Appendices D, E, and F. Information about each of the system problems is provided in Appendix H.

Representatives from the target population, in groups of two, were given training in the use of the job aids and then provided an opportunity to use them to solve simulated problems on the mock fuel system. The training and problem solving activity for each group of two subjects was performed in a two-hour time period.

One half of the participants, selected at random, received exposure to the conventional job aid first and then the intelligent job aid. The remaining participants were

introduced to the job aids in reverse order. Randomization was attempted by simply drawing numbered slips (numbered consecutively from one to 20) from a container. It was decided beforehand that the first ten numbers drawn would represent the relative order of the groups that would use the conventional job aid first. The remaining ten numbers, through 20, would represent the groups that used the intelligent job aid followed by the conventional job aid. The order of the final, twenty-first group was to be arbitrary unless there was a need to substitute for another group because data were not usable for some reason. The order of the groups is shown in Table 2.

The sequence of events in the two-hour sessions is listed below. All times are approximate.

1) First 20 minutes: introduction and training on first job aid; completion of a pre-exercise survey;
2) Next 20 minutes: first subject solved first and second problems with first job aid; second subject took a break away from work area;
3) Next 20 minutes: second subject solved first and second problems with first job aid; first subject took a break away from work area;
4) Next 15 minutes: training on second job aid;
5) Next 20 minutes: first subject solved third and fourth problems with second job aid; second subject took a break away from work area;

Table 2: Order of Use of Job Aids

First ten numbers drawn:	1
	19
	5
	16
	2
	6
	9
	20
	18
	3

This led to the following schedule:

CONVENTIONAL FIRST	INTELLIGENT FIRST
Group 1	Group 4
Group 2	Group 7
Group 3	Group 8
Group 5	Group 10
Group 6	Group 11
Group 9	Group 12
Group 16	Group 13
Group 18	Group 14
Group 19	Group 15
Group 20	Group 17

6) Next 20 minutes: second subject solved third and fourth problems with second job aid; first subject completed questionnaire and was interviewed in an area away from the work area;

7) Next 15 minutes: second subject completed questionnaire and was interviewed.

The training on the intelligent job aid took longer than for the conventional job aid. If the expert system was the first job aid a group worked with, the introduction and training took about 30 minutes instead of 20, and training for the conventional job aid (without the introduction) was correspondingly shorter.

Design of training. The training was systematically designed instruction teaching the use of the job aids only. (See Dick and Carey, 1978, for a lucid overview of the instructional design process). There was no general instruction in the diagnosis of the Bosch fuel system. However, each of the subjects had previously participated in a four-hour training session conducted by John Deere when the fuel systems were introduced about one year prior to this study. In the training provided by Deere, subjects had been introduced to the operation, maintenance, and repair of electronic fuel injection systems. Their exposure to electronic fuel injection systems since their initial, introductory training varied considerably.

The training and experiences provided to subjects in this study were constrained in several ways. First, time was limited to two hours for each group of two participants. The instruction had to be delivered and opportunity for practice with the job aids had to be provided within the two-hour time frame. Second, management mandate required the entire experience be perceived by participants as agreeable. If not a learning experience, it was to at least be a practical and productive one that would not alienate employees from the Engine Works Service Department or their efforts to improve technical support materials. A document describing training development is included in Appendix I.

Pre-exercise Survey

Prior to any training, subjects were surveyed to acquire information about characteristics that might influence their inclination to prefer one type of job aid over another. The list of characteristics was limited to four, approximately one-tenth the number of subjects. This heeds the rule of thumb cited by Asher (1976) relating variables to the number of subjects in studies using multivariate analyses.

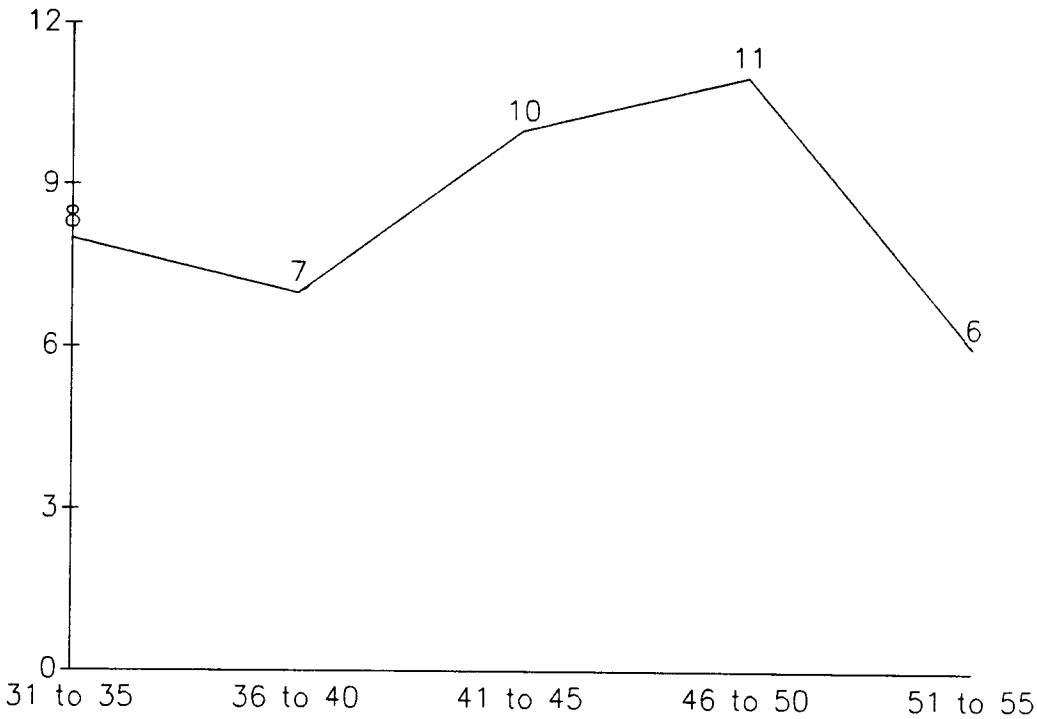
Based on the literature review, the survey asked subjects to relate their age, their level of education, their computer experience, and their technical subject matter experience (with fuel injection systems in general and electronic injection systems in particular). The complete survey is included as Appendix J.

Figure 11 shows the relatively even age distribution of subjects. Eight subjects (19 percent) were between 31 and 35 years; seven (about 17 percent) were between 36 and 40 years; ten (about 24 percent) were between 41 and 45 years; 11 (about 26 percent) were between 46 and 50 years; and six (about 14 percent) were between 51 and 55 years. The mean age was 42.8 years, the standard deviation was 6.98 years, and the range of ages was 31 to 55 years.

Figure 12 depicts the formal education levels of the subjects. Of the 42 participants in the study, 18 (about 43 percent) had a four-year college degree, seven (about 17 percent) had some college but no degree, five (about 12 percent) had received some vocational-technical education after high school, and the remaining 12 (about 28 percent) were high school graduates with limited formal educational experiences after high school.

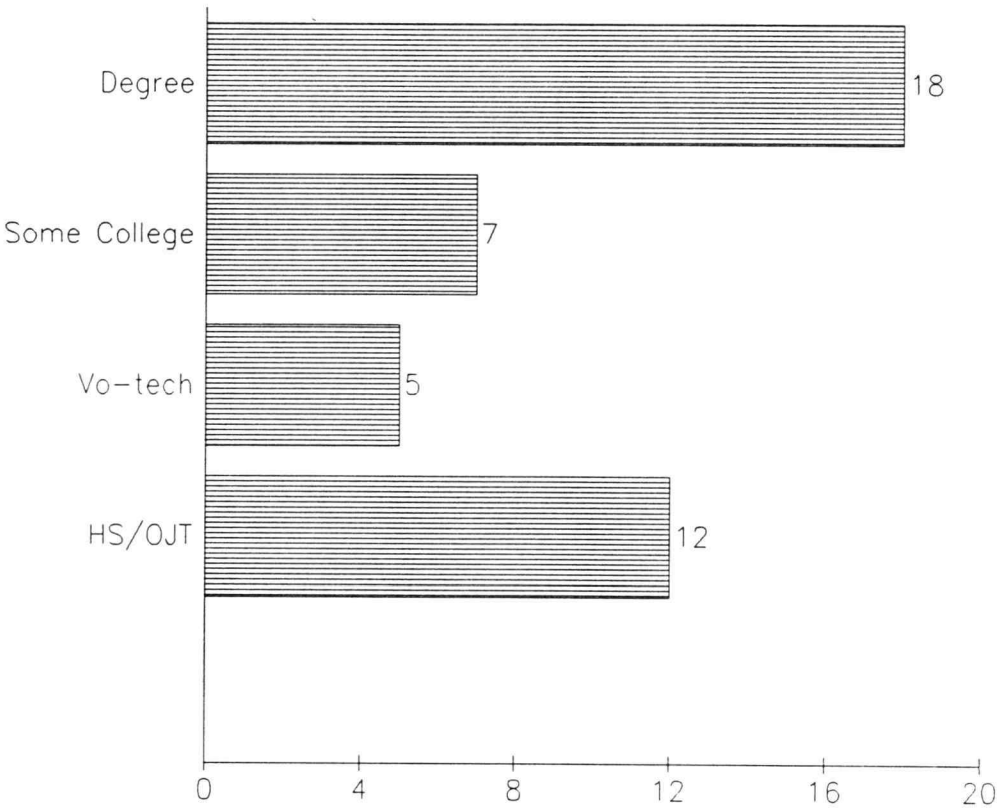
Figure 13 represents the computer experience of the subjects. There were 23 of the 42 subjects (about 55 percent) who reported having considerable experience with computers; 16 (about 38 percent) reported having some computer experience; and only three subjects (about seven percent) reported that they had basically no experience with computers.

Figure 14 shows subjects' experience with mechanical fuel injection systems, and Figure 15 show subjects' experience with electronic fuel injection systems. In order



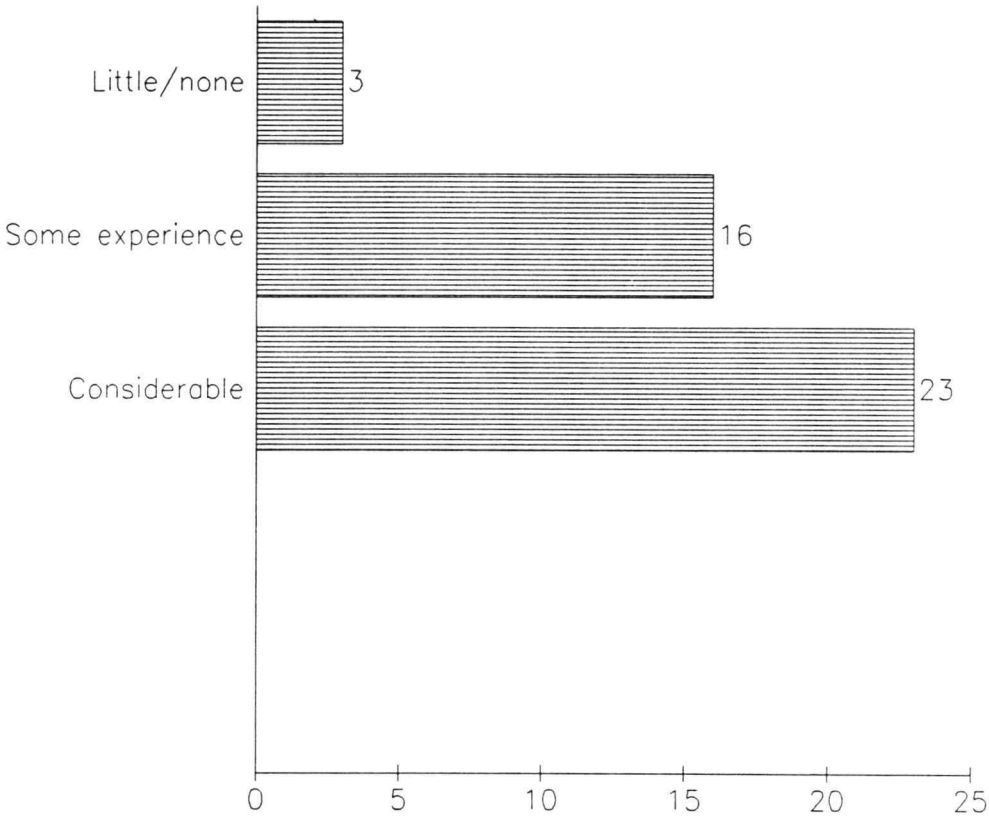
N = 42

Figure 11: Age of Subjects



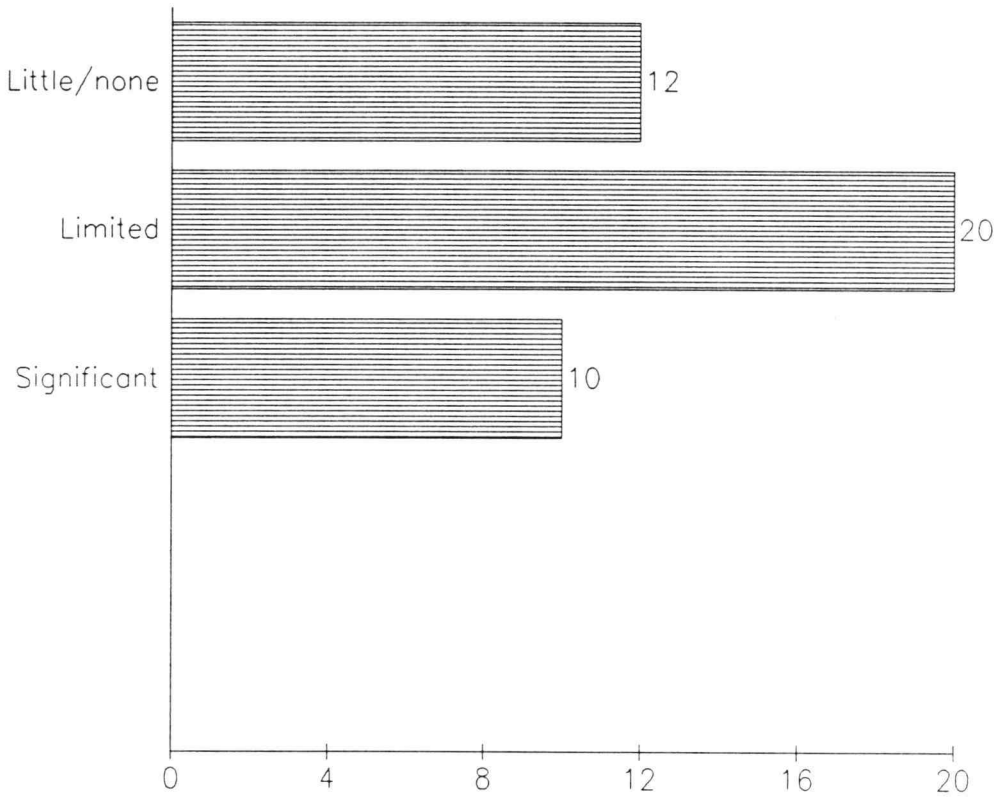
N = 42

Figure 12: Formal Education Levels of Subjects



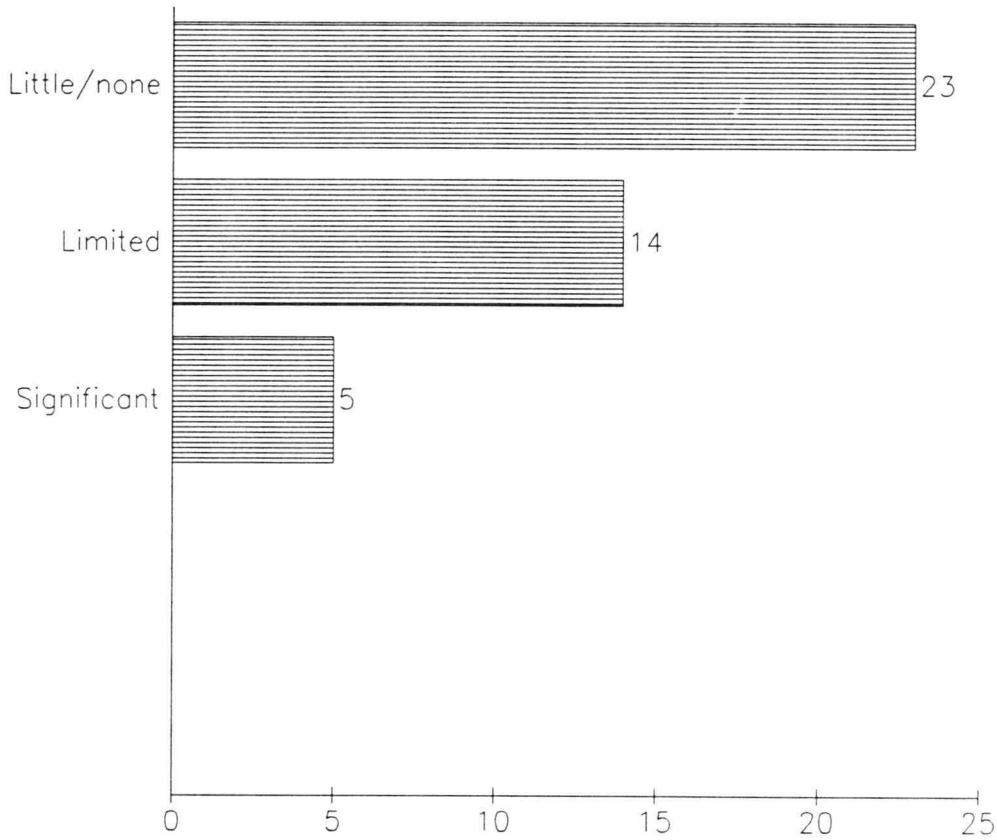
N = 42

Figure 13: Computer Experience of Subjects



N = 42

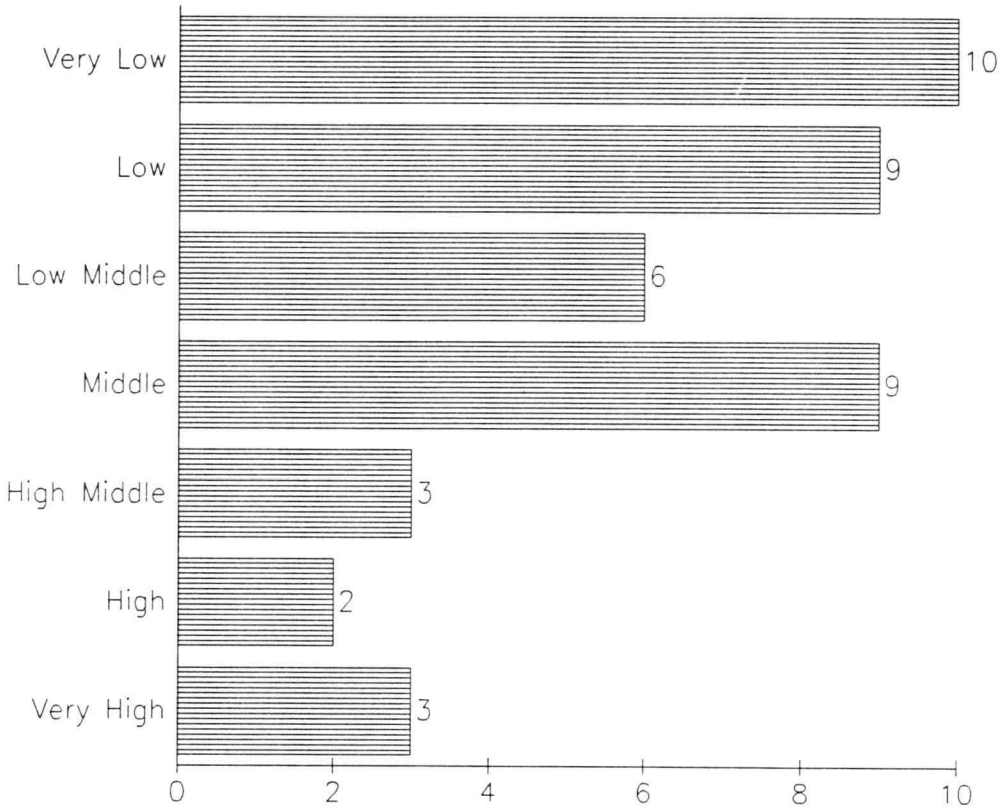
Figure 14: Experience with Mechanical Systems



N = 42

Figure 15: Experience with Electronic Systems

to make a realistic assessment of the experience levels of subjects, a composite measure of experience was devised. Based on consultation with several subject matter experts, experience with electronic fuel injection systems was deemed a more likely predictor of success in the exercises than experience with mechanical systems. Values were assigned to each of the possible responses to the pre-training survey questions dealing with experience. A response of "Have basically no experience" was given a value of one; a response of "Limited experience..." was given a value of two; and a response of "Significant experience..." was given a value of three. For each subject, the value related to electronic fuel injection systems was doubled and then added to the value for the mechanical fuel injection systems. The sums were then classified as follows: three, very low composite experience; four, low composite experience; five, low middle composite experience; six, middle composite experience; seven, high middle composite experience; eight, high composite experience; and finally, nine, very high composite experience. Figure 16 depicts the distribution of composite experience among subjects. Since none of the subjects said they had "basically no experience" with both mechanical and electronic systems, the lowest composite value was three. The average composite experience of the 42 subjects was 5.1, in the "low-middle" range of experience.



N = 42

Figure 16: Composite Fuel Injection Experience

Video-taped Performance

Following training, subjects were presented with a series of problems to diagnose. Each subject was video-taped during two, approximately 20-minute periods in which he (all subjects were males) used job aids to solve the simulated problems. Video equipment was focused on the subject and work area and ran unattended during the session. It took 20 two-hour video tapes to record troubleshooting activities of the 21 groups.

Because of management constraints placed upon the sessions, it was not acceptable to submit the participants to an experience in which they might "fail." This made direct measurement of user accuracy difficult if not untenable. A prompting procedure was devised in which a facilitator would assist subjects during the diagnostic session when they asked questions, made mistakes, or appeared puzzled for more than ten seconds.

An evaluation form, shown in Appendix H, was used to simplify the assessment of the video-recorded performances. Two independent evaluators simply counted prompts given by the facilitator and outright errors made by subjects. Both prompts and errors were classified as pertaining to the job aid or to the fuel injection system/test equipment.

To illustrate this evaluation system, consider a subject diagnosing Code 37, the second problem, with a conventional job aid. The first step is to check the resistance between

the two fuel temperature sensor pins. The subject reads the instructions, locates the fuel temperature sensor and picks up the multimeter probes. He pauses for several seconds studying the connector and sensor as if puzzled about where the measurement should be taken. The facilitator prompts, "Check resistance on the sensor. Be careful to only touch the pins with the probes." An evaluator, observing the performance on video tape, records one tally mark on the evaluation form in the system prompt column--the prompt dealt with the fuel system and not the job aid.

Continuing, the subject attempts to take the resistance reading but appears perplexed when he reads the meter. The facilitator waits for several seconds before prompting, "Remember to switch the meter from 'volts' to 'ohms.'" The evaluator records another tally mark in the system prompt column.

The subject then proceeds through the next step without prompts. However, at the third step, the subject branches to the wrong place in the diagnostic sequence and begins to make an incorrect test. At this point the facilitator interrupts the test and says, "I think you misread the last step in the diagnosis. Shouldn't you be checking the 35-pin connector?" The evaluator records another tally mark, this time in the job aid prompt column.

The only time errors were recorded was when subjects were proceeding in a self-assured manner, made a mistake,

and continued through at least one additional incorrect step before the facilitator realized they were off track.

Subjects were encouraged to talk out loud during the diagnosis to make it easier for the facilitator and the evaluators to follow along with the task. Comments and anecdotal information of interest were recorded by the evaluators while observing the video tapes.

Although the evaluation forms do break down each problem into steps, no attempt was made to match prompts or errors to a particular problem solving step. Tally marks from each column were simply added. No claim is made that this is an adequate measure of user accuracy. However, this method contributes additional information about the application of conventional and intelligent job aids and provides a means of comparison between the two job aids.

Table 3 summarizes the performances of subjects on the diagnostic exercises. Since the video equipment was inadvertently shut off during part of the performance of the 38th subject, performances of the 19th group (subjects 37 and 38) were dropped and the performances of the 21st group were included in the calculations.

There were a total of 58 prompts regarding the job aid given to subjects when they were using the conventional job aid, an average of about one and a half prompts per subject; there were 353 prompts related to the job aid given to subjects when using the intelligent job aid, almost nine

Table 3: Summary of Video-taped Performances

	TOTAL	MEAN
Conventional Job Aid Prompts	58	1.45
Intelligent Job Aid Prompts	353	8.83
Conventional Job Aid Errors	14	.35
Intelligent Job Aid Errors	5	.13
System Prompts Using Conventional Job Aid	99	2.48
System Prompts Using Intelligent Job Aid	53	1.33
System Errors Using Conventional Job Aid	22	.55
System Errors Using Intelligent Job aid	13	.33

N = 40

prompts per subject. Subjects using the conventional job aid made a total of 14 errors related to the use of the job aid, an average of slightly less than one half an error per subject; and a total of five errors related to use of the intelligent job aid were committed, an average of about one tenth of an error per subject.

While subjects were using the conventional job aid there were a total of 99 prompts given that were related to the fuel system/test equipment, an average of about two and a half prompts per subject; a total of 53 fuel system/test equipment prompts were given when subjects were using the intelligent job aid, almost one and a half prompts per subject. During work with the conventional job aid there were 22 errors related to the fuel system/test equipment, an average of about one half of an error per subject; and there were 13 fuel system/test equipment errors committed when subjects were using the intelligent job aid, an average of about one third of an error per subject. Figure 17 provides graphic comparison of the performance of subjects using the different job aids.

Post-exercise Questionnaire

Following both diagnostic problem solving sessions, subjects completed a questionnaire which asked them to express opinions about the two job aids. The questionnaire, which is exhibited in Appendix K, was constructed and field tested according to guidelines suggested by Zemke and

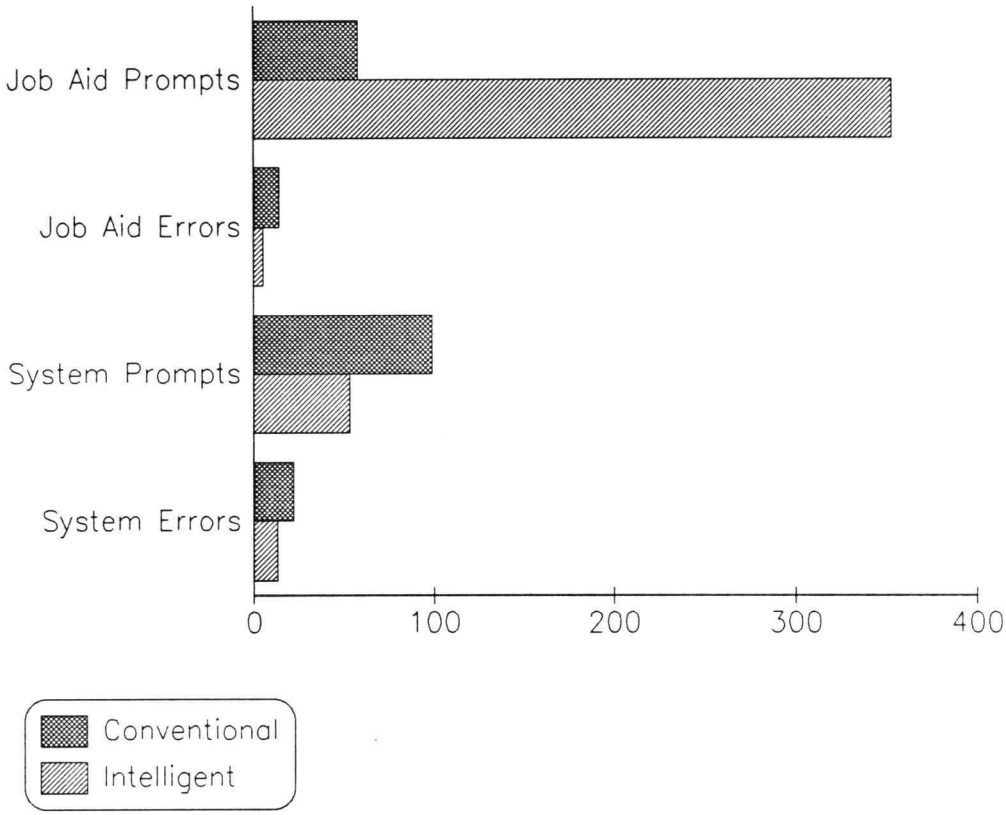


Figure 17: Prompts and Errors Using Two Job Aids

Kramlinger (1982). In addition to ascertaining subjects' general opinions contrasting the overall usefulness of the conventional and intelligent job aids, the questionnaire asked questions to discern why subjects held the opinions they did.

A summary of responses to the questionnaire is in Table 4. There were 23 of 42 subjects (about 55 percent) who selected the intelligent job aid as most appropriate for new technicians; 32 of 42 subjects (about 76 percent) selected the intelligent job aid as most appropriate for experienced technicians. There were also 32 subjects who picked the intelligent job aid as most likely to lead to a correct diagnosis; the same number, 32 subjects, identified the intelligent job aid as the easiest to use. Although there were ten subjects selecting the conventional job aid in each of the last three measures, only four of the ten made the same choices on all three items.

Subjects also ranked the two job aids for overall usefulness on a six-point Likert scale (Likert, 1958, 1961) (a value of one being most useful). The mean ranking of the conventional job aid was 2.7; the mean ranking of the intelligent job aid was 1.8. Figure 18 and Figure 19 illustrate the results of the questionnaire.

Table 4: Summary of Post-exercise Questionnaire

Most appropriate for **new technician**		
	Conventional	19
	Intelligent	23
Most appropriate for **experienced technician**		
	Conventional	10
	Intelligent	32
Most likely to lead to **correct diagnosis**		
	Conventional	10
	Intelligent	32
Easiest to use on the job		
	Conventional	10
	Intelligent	32

42 Subjects selecting conventional or intelligent job aids

Overall usefulness		
Conventional		
	Mean ranking	2.71
	Standard deviation (s)	1.07
Intelligent		
	Mean ranking	1.81
	Standard deviation (s)	0.94

42 subjects ranking job aids on six-point scale (1 = extremely useful; 6 = not at all useful)

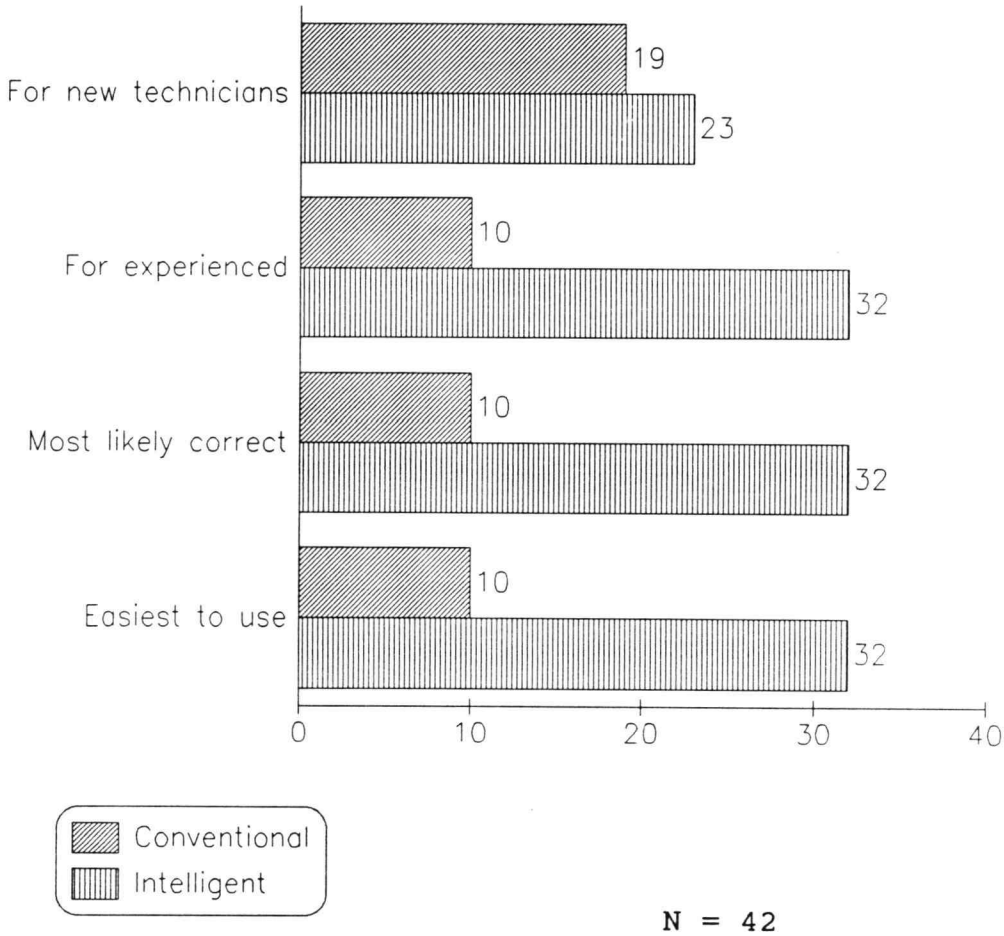


Figure 18: Contrasting Opinions on Four Criteria

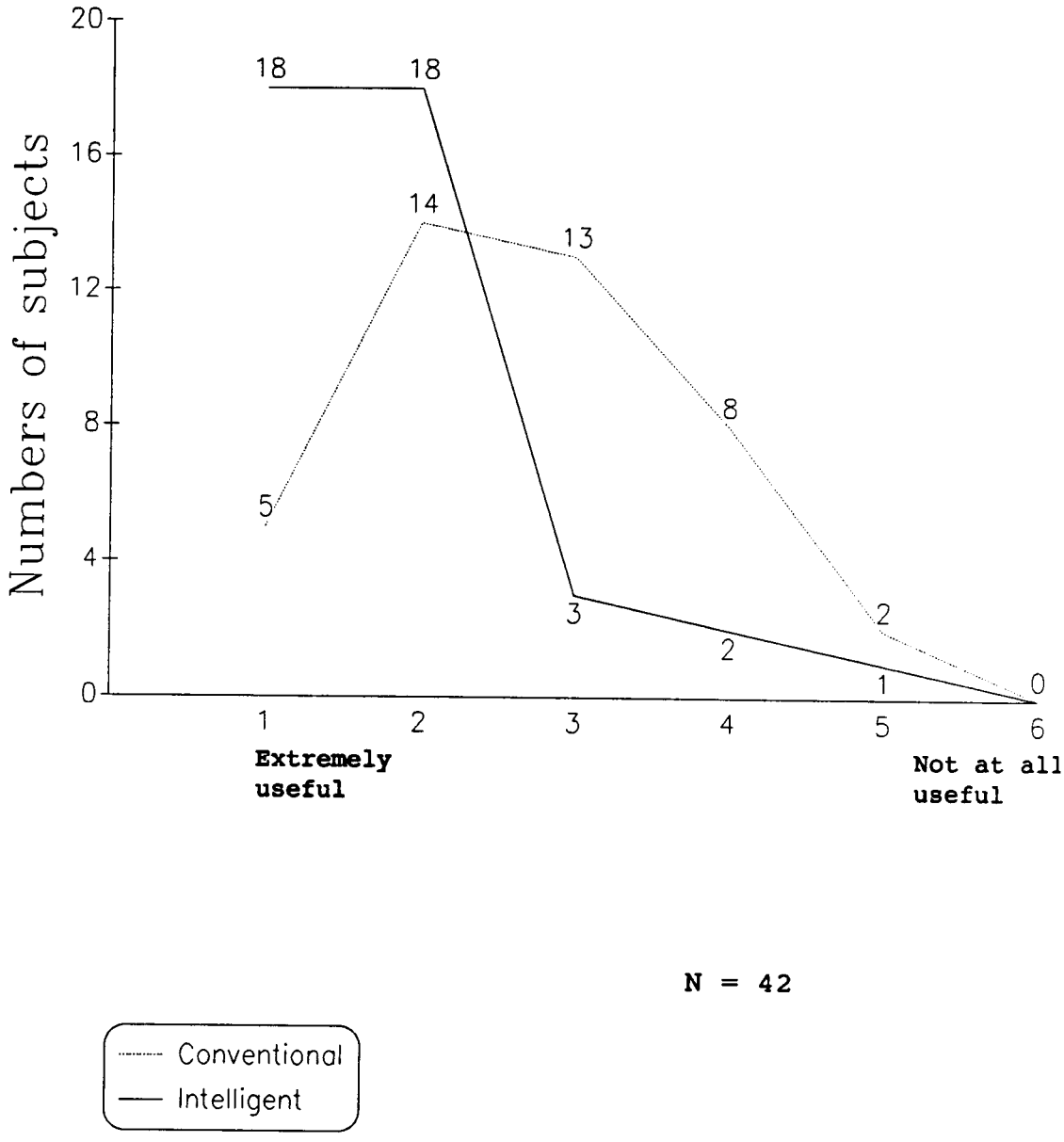


Figure 19: Rankings for Overall Usefulness

Post-exercise Interviews

At the end of the diagnostic problem solving session, after subjects had used both job aids, they were interviewed individually to provide another means for them to express their opinions comparing the two job aids. Information about development and application was solicited during the interviews which were tape recorded. Appendix L contains the entire transcribed text of the interviews.

A list of structured interview questions was prepared to guide the investigator during the interviews. Deviation from the list was often done during the interviews in an effort to "ask questions in such a way as to enable the subjects to talk about what...[was] on their minds and what...[was] of concern to them without forcing them to respond to the observer's interests, concerns, or preconceptions" (Bogdan & Taylor, 1975, p. 57).

Questions prepared for the interviews are listed below:

1) You've had a chance now to work with two tools that can help you troubleshoot electronic fuel injection systems. Which of these do you think would be the most help to you on your job?
2) Why?
3) How would you compare the use of the troubleshooting guide (conventional job aid) to the use of CTM-11 (the current Deere publication covering electronic fuel injection diagnosis)?

4) What concerns would you have about using the expert system on your job?

5) What are the most important features of the troubleshooting guide (conventional job aid)?

6) Why?

7) What are the most important features of the expert system?

8) Why?

9) What type of person do you think would prefer the troubleshooting guide over the expert system.

10) Now describe the person you think would prefer the expert system.

11) Is there anything else you would like to comment on concerning the two job aids?

A summary of responses made to the second, third, and fourth questions was made by analyzing the content of the transcribed interviews. The reasons given below are not comprehensive, but rather represent a minimum number of similar responses given by subjects.

As common statements supporting the conventional job aid: six cited greater portability and/or convenience; three claimed it was easier to use; three referred to the ability to look ahead or look back in the text; and one mentioned it was easier to learn to use.

As typical statements supporting the intelligent job aid: twelve claimed it was easier to use (one of whom

reversed his position after saying earlier in the interview that the conventional was easier); ten said it was faster; eight mentioned better graphics; at least four expressed a preference for seeing just one "page" at a time; and three stated it would be easier to up-date.

As common concerns about using the expert system: ten mentioned reduced portability; six referred to the effect of sunlight on the screen; six cited the need for increased training/experience; six said it was difficult to move between screens; five mentioned concerns about the durability of the hardware; three referred to dirt and debris harming the keyboard; two were concerned about the cost; one mentioned the possibility of theft; and one felt the expert system took the "fun" out of the problem solving and did too much of the work for him.

Of the 42 subjects, 22 expressed a definite preference for the conventional job aid over the current Deere technical manual and just one subject expressed a definite preference for the current Deere technical manual over the conventional job aid. Two subjects qualified their statements of preference: both preferred the current Deere technical manual for inexperienced technicians but preferred the conventional job aid for experienced technicians. The remaining subjects had no clear preference or had mixed opinions.

Chapter 3

Compendium

The purpose of this study was to extend the body of knowledge concerning conventional and intelligent job aids. Specifically, the intent was to learn what major differences and similarities exist in the design, development, and application of conventional and intelligent job aids. In case meaningful differences in the application were found, an additional goal was to determine why they existed.

Limitations. The method employed to achieve the stated purposes was a case study in which analogous conventional and intelligent job aids were developed to solve a real performance problem in an industrial setting. The limitations for the case reported in this study include the following:

* The number of subjects participating in the study was limited to 42.
* Participants were limited to Deere employees, although the target population for the job aids includes a much larger population (up to 30,000 technicians worldwide according to one manager's prognostication).
* Time allowed for training, execution of diagnostic exercises, completion of questionnaires, and interviewing was limited to two hours per subject.
* Management mandated that the diagnostic exercises would not be tests in which performers might fail.

* The diagnostic exercises were performed in a simulated work setting with a mock fuel injection system.

Equivalency of the job aids. With regard to the job aids developed for this study, there is one important point that must be made. Both interventions accomplish the same thing: they assist technicians with the diagnosis of problems with Robert Bosch electronic fuel injection systems. They both function with the same knowledge base. There is no question that both interventions can and do work. However, it is not possible to claim that the two job aids are "equal."

Two different forms of transportation, an automobile and a bicycle, for instance, can be used to reach a desired destination, but no one would suggest that they are "equal" forms of transportation. In fact, there are occasions when each type of vehicle is preferable to the other. As the results of this study are presented, it is important to keep in mind that this is not a referendum on or "beauty contest" between job aids. Both job aids take end users to the same destination, though possibly at different speeds or "levels of comfort." For this particular case, one type of job aid may be evidently superior to the other by some measures, but case studies in another subject area and with a different target population could produce different conclusions.

The ensuing discussion will address each of the research questions in light of data gathered in this study. The

implications for practicing performance technologists will then be addressed.

Research Question One

The first research question asks about major differences and similarities in developing intelligent and conventional job aids. Related factors that are evaluated in this study include: time to develop, capital resources required for development, human resources required for development, and the total cost differences in development.

Time to develop. As shown previously in Figure 10, there was a substantial difference in the time required to develop the two different job aids. The difference can be, to a large extent, ascribed to the **amount** of material developed for the expert system. Since the knowledge engineer had previous experience with expert system development and had formerly learned to use the authoring tool, the "learning curve" had already been climbed and was not a factor.

Examining time spent on various knowledge engineering tasks, it is apparent that programming and development of graphics account for the major differences in time. For example, the first draft of the conventional job aid was completed in nine hours while the intelligent job aid required 96 hours. The intelligent job aid required 66 hours for graphics development which was not needed for the conventional job aid. (The three pages of graphics in the

conventional job aid were photocopies of existing Deere line art; development time was not available and, as a result, was not included in the time analysis).

There were certain complexities to be resolved in programming the expert system which contributed to the time expended in development. However, the major reason for the time differential is the increased content in the expert system. For example, the procedure to diagnose a symptom of "code 32 displayed" requires less than two pages of text in the conventional job aid. The same procedure in the intelligent job aid requires more than 50 "objects," each of which must be constructed with the authoring tool.

The conventional job aid employs terse commands and questions; it provides very abbreviated instructions to guide test procedures and a paucity of instructions for repair procedures. Such a format is entirely appropriate for a job aid of this variety--a condensed troubleshooting booklet.

The expert system on the other hand possesses properties which allow extensive text and graphics to be "hidden" to the user until asked for. It is entirely appropriate to make use of these properties when developing an expert system since additional text and graphics do not make the job aid more cumbersome by contributing weight and pages (they just take up more disk space). The end user does not have to contend with them if they are not needed to perform

the diagnosis; however, substantive information is there when needed.

The intelligent job aid required more time to develop because there was greater content to develop. If the knowledge engineer had not been proficient with the authoring software, there would have undoubtedly been a much greater difference in development time.

Capital resources required for development. Precise costs for this project are proprietary, but Figures 20 and 21 present ranges of values that could be used to estimate capital (hardware and software) expenditures of projects of similar scope and complexity which utilize equivalent software. The costs listed are very general and subject to the fluctuations of a volatile market; they are based on the investigator's knowledge of what was spent on this project and awareness of comparable products available. As hardware and software costs fall over time (a virtual certainty), the cost disparity will fade correspondingly. At present, for any individual item listed in Figures 20 or 21, products can be found that cost less than the low value given and others can be found that cost more than the highest value given. However, the range of costs are typical.

The total hardware/software costs for the conventional job aid, shown in Figure 20, range from a low of $3,475 to a high of $8,600. For the intelligent job aid, the total costs displayed in Figure 21 range from a low of $9,225 to

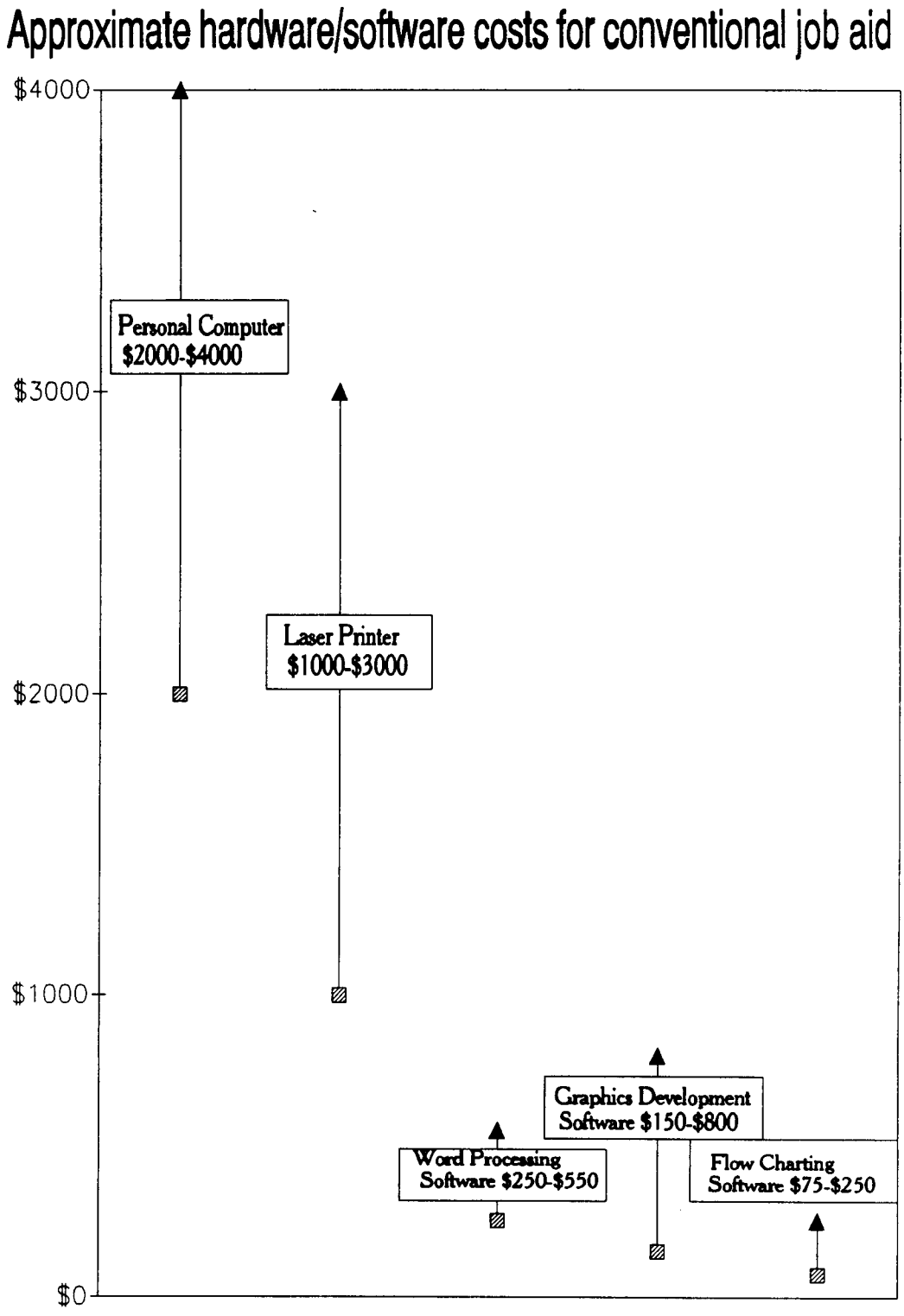


Figure 20: Hardware/software for Conventional Job Aid

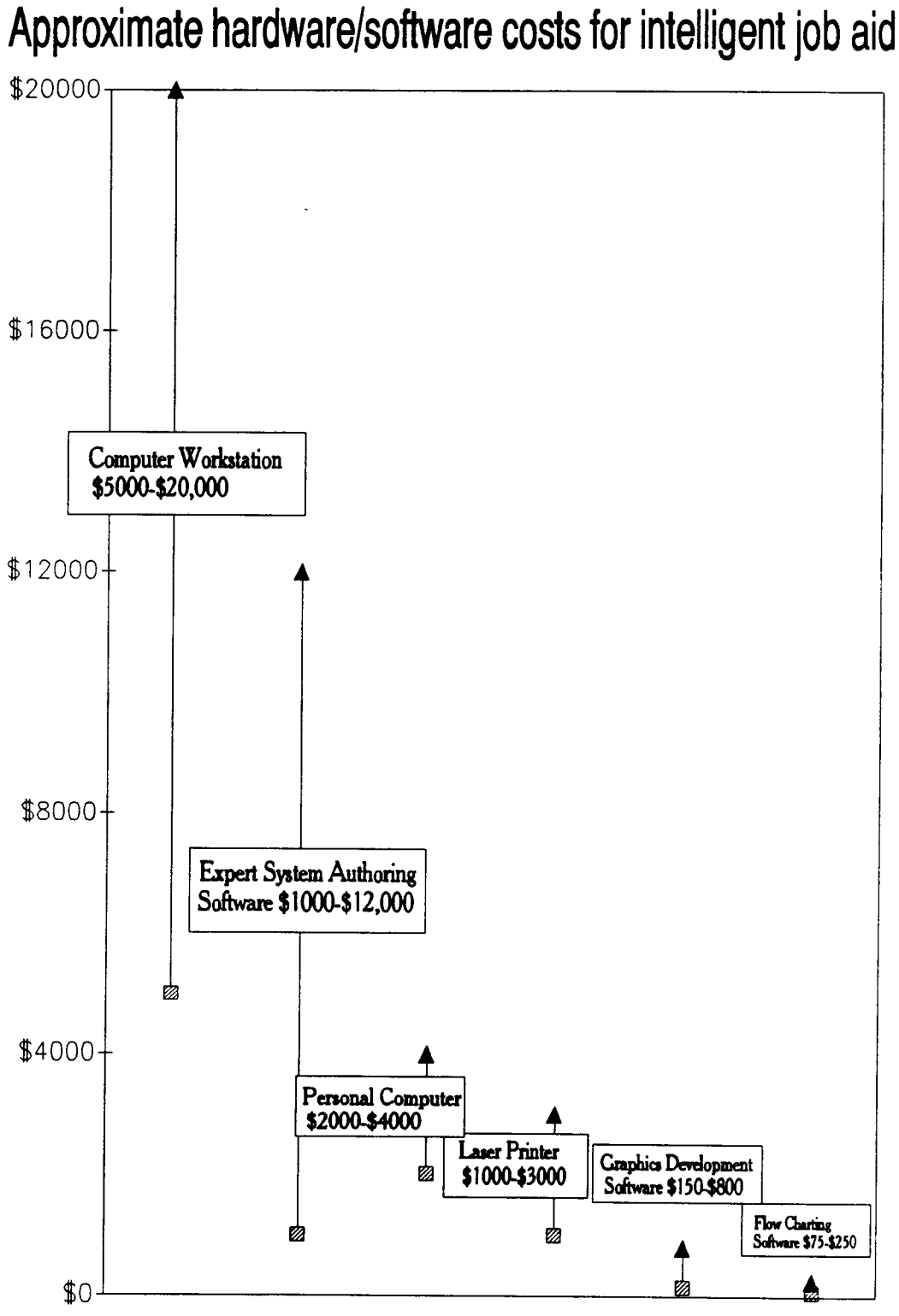


Figure 21: Hardware/software for Intelligent Job Aid

a high of $40,050. Expenditures for hardware and software for this project were near the high end of the ranges given.

Human resources required for development. Capital expenditures for a project of this scope and complexity, although variable, will be considerable; however, the capital expenditures will be rivaled or exceeded by the cost of human resources to complete such a project.

To get an indication of the relative costs of developing the job aids described in this study, the hours required for development can be simply multiplied by hourly labor costs. If external knowledge engineering consultants are utilized, costs will typically range from $100/hour to $175/hour plus expenses. There were a total of 118 hours required to develop the conventional job aid and 435 hours required to develop the intelligent job aid. Using $100/hour, the labor costs would be $11,800 for the conventional job aid and $43,500 for the intelligent job aid (ignoring travel, lodging, and related expenses). If $175/hour is used to calculate the labor costs, the conventional job aid would cost $20,650 and the intelligent job aid $76,125.

Total cost differences in development. Figure 22 compares the ranges of total costs (hardware/software and human resources) for the conventional job aid. At the low end, the figures represent the lowest typical costs for hardware/software and a figure of $100/hour for labor. At the high end, the figures represent the highest typical

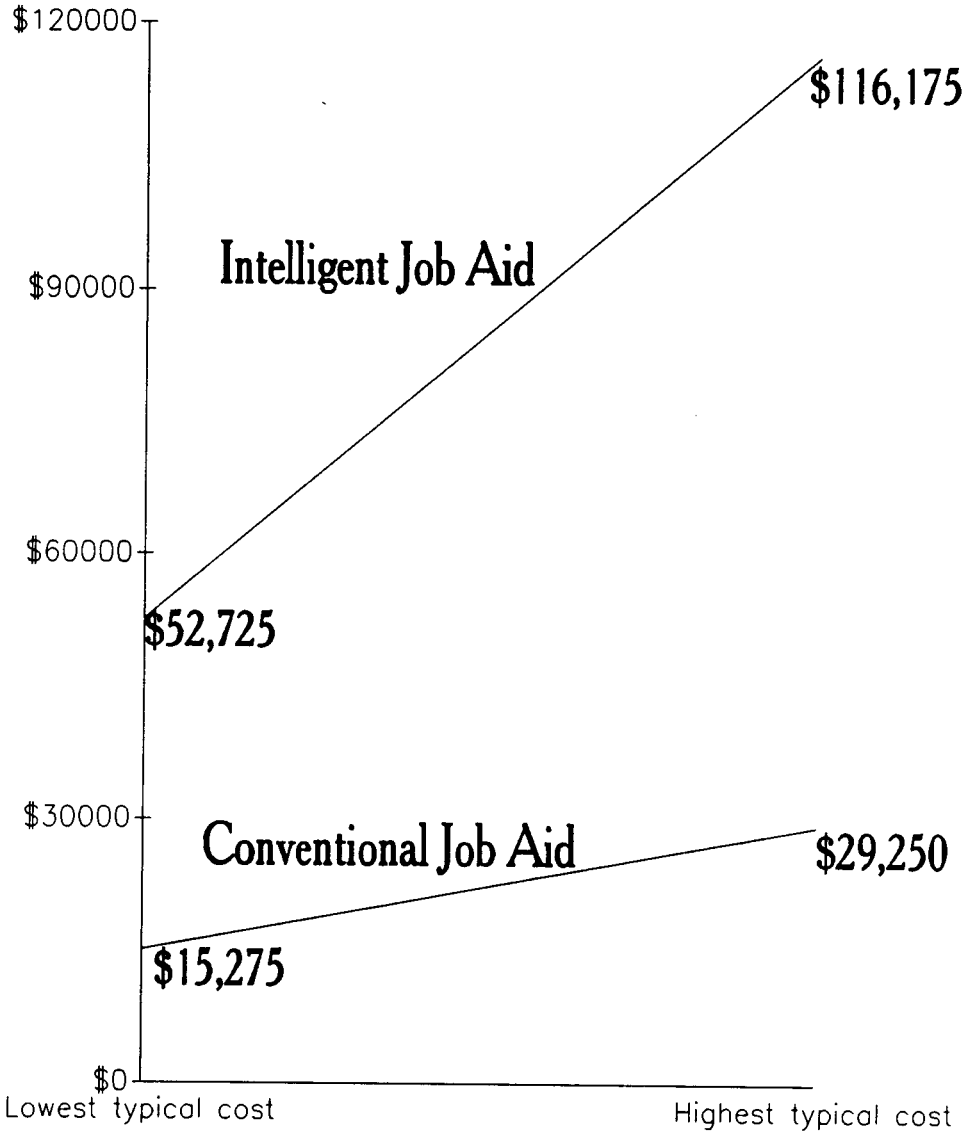


Figure 22: Ranges of Total Development Costs

costs for hardware/software and a figure of $175/hour for labor.

For the conventional job aid, the total costs range from $15,275 to $29,250. For the intelligent job aid, the range is $52,725 to $116,175. These ranges represent the typical costs of executing development projects as described in this case study; assuredly, it is possible to spend more or less on similar projects.

Research Question Two

The second research question is an inquiry into the differences and similarities of applying intelligent and conventional job aids. This issue is addressed by considering the following factors: accuracy, efficiency, user acceptance, and time required to learn to use the job aids.

Accuracy. When subjects who had used both job aids were asked which was most likely to lead to a correct diagnosis, about 76 percent selected the intelligent job aid. These responses were reinforced by comments made during the interviews with regard to "getting lost" in the conventional job aid. One subject said it like this: "With the manual there was so much flipping around....With the computer I always knew where I was at [sic]." Since the expert system "turns the pages" for the user and only presents one frame at a time, the user only gets "lost" by inadvertently selecting the wrong response to a question.

Subjects' perceptions of an intelligent job aid's advantage in accuracy were not completely supported by data gathered during diagnostic problem solving exercises. Significantly fewer prompts ($t = 7.39$, $df = 39$, $p < .05$) were given to subjects when they were using the conventional job aid (Table 5). On the other hand, significantly fewer errors ($t = 3.36$, $df = 39$, $p < .05$) were committed by subjects using the intelligent job aid (Table 6).

The difference in subjects' perceptions and performance with regard to prompts can possibly be attributed to time constraints which prevented most subjects from becoming adept at operating the expert system. Several subjects expressed a desire for more training and/or practice on the expert system, and it is likely that it was not until the end of the problem solving session (during which they required some prompting) that they attained a level of proficiency that convinced them the expert system could be more accurate.

Efficiency. There were no precise measurements made of the speed with which subjects diagnosed problems, and subjects were not told "solve the problems as quickly as possible." A cursory examination of the video-taped performances does not reveal a discernible difference in the speed with which subjects performed with the different job aids. However, subjects' opinions, as reflected in the post-exercise questionnaire, favored the intelligent job aid

Table 5: Correlated *t*-Test for Job Aid Prompts

	Conventional		Intelligent
Mean	1.45		8.83
S.D.	2.28		6.96
N		40	
df		39	
Calculated *t*-value		7.39	
p		< .05	

Table 6: Correlated *t*-Test for Job Aid Errors

	Conventional		Intelligent
Mean	0.35		0.13
S.D.	0.48		0.33
N		40	
df		39	
Calculated *t*-value		3.36	
p		< .05	

with regard to ease of use by a better than three-to-one margin. The ease with which a job aid can be used would presumably affect the efficiency of the performance, and subjects concurred with that assessment in interviews. At least ten subjects stated the intelligent job aid was faster than the conventional job aid; none said the conventional job aid was faster.

User acceptance. The intelligent job aid was widely accepted by participants in the study. During the interviews there were about three times as many positive comments made about the intelligent job aid as about the conventional job aid. Some of the reasons expressed by subjects, as related previously, include: ease of use, speed, improved graphics, ease of up-dating, and the expert system's method of presenting only one screen at a time.

On the post-exercise questionnaire, subjects selected the intelligent job aid over the conventional job aid as most appropriate for new technicians (about 55%) and most appropriate for experienced technicians (about 76%).

The fact that the intelligent job aid compared so well to the conventional job aid is especially significant because subjects almost universally regarded the conventional job aid as superior to the existing Deere technical manual for diagnosing electronic fuel injection equipment.

A correlated *t*-test contrasting the responses of subjects evaluating the overall usefulness of the two job aids supports the findings of the interviews and other questionnaire items. As presented in Table 7, the mean ranking of the intelligent job aid is significantly better than the mean ranking for the conventional job aid (t = 4.21, df = 41, $p < .05$)

Learning time. Although participants maintained the intelligent job aid was easier to use by a three-to-one margin, none claimed it was easier to **learn** to use. In interviews the issue of learning time was mostly ignored by participants, although at least one stated the conventional job aid was easier to learn to use and at least six others indicated a desire for more training and experience with the intelligent job aid. This opinion would be expected because the conventional job aid so closely paralleled existing Deere technical reference material and was therefore quite familiar.

The correlated *t*-test results shown in Table 5 support the view that the conventional job aid is easier to learn to use; there were fewer prompts given to subjects using the conventional job aid, another indication of the ease of learning.

Table 7: Correlated *t*-Test for Opinions of Usefulness

	Conventional		Intelligent
Mean	2.71		1.81
S.D.	1.07		0.94
N		42	
df		41	
Calculated *t*-value		4.21	
p		< .05	

Research Question Three

The third and final research question is an attempt to understand why differences do exist in the application of conventional and intelligent job aids.

Accuracy. Both job aids are accurate instruments if used correctly; the accuracy of both job aids was validated by subject matter experts. Nevertheless, subjects perceived the intelligent job aid to be more accurate, and there were fewer errors made by subjects when using the intelligent job aid.

A plausible explanation can be found by analyzing and comparing the tasks performed when using the two job aids. As an example, consider a technician diagnosing a tractor that will not start; an ECU code 32 is displayed on the machine's diagnostic code read-out. The symptom's cause (unknown, of course, to the technician) is an open circuit between the battery and the ECU (electronic control unit). The major steps in diagnosing the problem with assistance of the conventional job aid include:

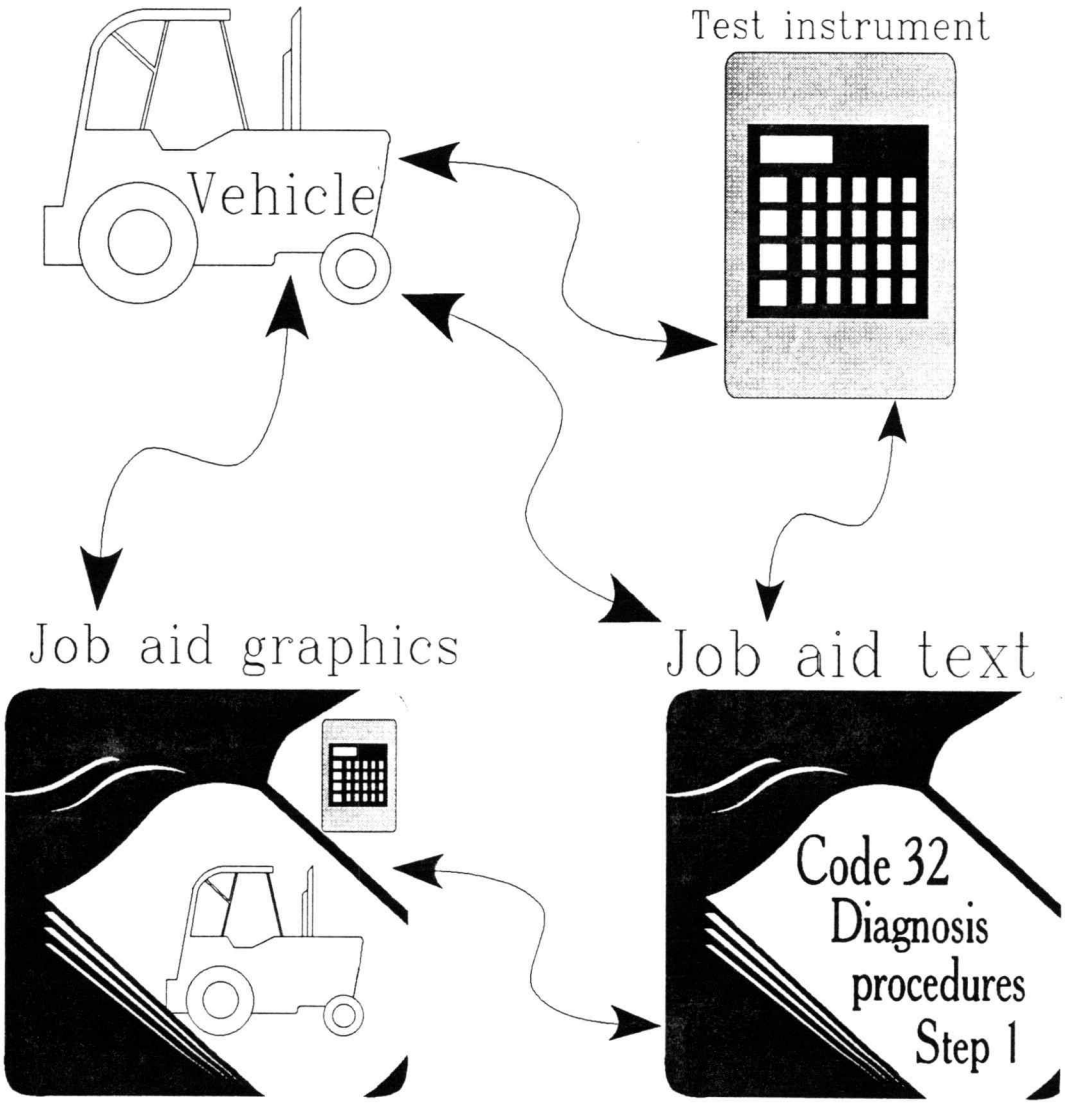
1. a) Locate the section in the troubleshooting guide pertaining to the diagnosis of code 32.
   b) Turn ignition off.
   c) Determine the location of the J7/J8 connectors by referring to the job aid graphics.
   d) Locate and disconnect the J7/J8 connectors.
   e) Inspect the J7/J8 connectors.

2. a) Determine the location of the J8 sockets A and B by referring to the job aid graphics.
   b) Measure the resistance between J8 sockets A and B.
   c) Based on the resistance value, determine where to branch for the next step in the diagnosis.
3. a) Determine the location of the J1 connector by referring to the job aid graphics.
   b) Locate and disconnect the J1 connector.
   c) Inspect the J1 connector.
4. a) Determine the location of terminals 3 and 21 on the J1 connector referring to the job aid graphics.
   b) Measure resistance between J1 terminals 3 and 21.
   c) Determine the location of J7 pin B by referring to the job aid graphics.
   d) Measure resistance between J1 terminal 3 and J7 pin B.
5. a) Determine the location of the J9 connector by referring to the job aid graphics.
   b) Locate and disconnect the J9 connector.
   c) Measure resistance between J1 terminal 3 and all other J1 terminals except terminal 21.
6. a) Reconnect the J1 connector.
   b) Determine the location of J7 pin A by referring to the job aid graphics.
   c) Turn the ignition on.
   d) Measure voltage from J7 pin A to ground.

Figure 23 illustrates where a technician's attention is directed during the steps in this process. Although the problem solved during this procedure is not particularly difficult compared to other problems, the technician could refer to written instructions 11 times, refer to the graphics six times, perform operations with the vehicle 13 times, and use the test instrument five times; all this assuming the technician does everything one time, without mistakes or false starts. Of course, every time the technician moves from one task to the next there is the possibility of losing his/her place.

If the intelligent job aid is indeed more accurate, it is due, in large measure, to a reduced chance of operator error. The technician using the intelligent job aid sees only one step at a time rather than two facing pages, each containing many steps. There is less opportunity to lose one's place. To view system graphics, the technician using the intelligent job aid simply toggles between text and graphics screens with a single key stroke. In contrast, pages must be turned in the conventional job aid to view graphics.

Other factors which might contribute to greater accuracy of the intelligent job aid are the details in the graphics, as evidenced in Appendix F, and the more extensive written instructions. There are many graphics in the intelligent job aid which illustrate, for instance, the specific pin and



Job aid text: 1a, 1c, 2a, 2c, 3a, 4a, 4c, 5a, 5c, 6a, 6b
Job aid graphics: 1c, 2a, 3a, 4a, 5a, 6b
Vehicle: 1b, 1d, 1e, 2b, 3b, 3c, 4b, 5b, 5c, 6a, 6c, 6d
Test instrument: 2b, 4b, 4d, 5c, 6d

Figure 23: Diagnosis with Conventional Job Aid

socket locations where tests are made; the conventional job aid, on the other hand, has only a few graphics which are more general in nature. As stated earlier, the intelligent job aid has more thorough instructions for test procedures and does include repair procedures which are lacking in the conventional job aid.

Efficiency. There were no quantifiable measures of the efficiency of subjects using the two job aids, but of those subjects stating an opinion during interviews, all regarded the intelligent job aid to be more efficient. The most likely reasons for the intelligent job aid to be faster are the same reasons that cause subjects to rank the intelligent job aid easier to use and more accurate.

An examination of video-taped problem solving sessions revealed that, even when the diagnosis is performed on a table top with a mock fuel system, a relatively small percentage of the total time required to diagnose a problem is spent using the job aid. More time is spent performing the test procedures. Also, it is apparent when viewing the video tapes that it takes about the same amount of time to read and comprehend test procedures and study graphics with one job aid as it does with the other.

If the intelligent job aid really is more efficient, it is probably because it is more likely for the technician to get confused or lost, make inappropriate tests, and have to start over when using the conventional job aid.

One subject, during an interview, stated that the intelligent job aid took him "by the nose" and led him to the answer. He felt that the fun of problem solving was taken away and the intelligent job aid made it "almost too easy." However, when asked who would prefer the intelligent job aid, the same subject said it would be "the owners of the dealerships because they are the ones paying the bill and they want answers **quicker** [emphasis added]. The system is correct too. If I was an owner I would demand that all my mechanics do it that way."

User acceptance. Both job aids, when compared with existing Deere reference materials for troubleshooting, were highly regarded by subjects. The intelligent job aid, as stated previously, was preferred by more subjects than the conventional job aid. Reasons emerging from the interviews have already been stated; the intelligent job aid was seen by many to be easier to use, faster, enhanced with superior graphics, less likely to confuse the user, and easier to update.

When subjects were asked during interviews to identify characteristics of people that would prefer the intelligent job aid, age was the most common factor cited. Education and computer experience were also frequently mentioned. If a profile of the typical person preferring an intelligent job aid was constructed from interview responses, it would describe a young, well educated person familiar with

computer operation.

Chi square tests of independence were conducted to determine if age, educational attainment, subject matter domain experience, or computer experience did indeed influence subjects' opinion of the job aids. The results showed that all of these factors, without exception, were independent of subjects' opinions on which job aid was most appropriate for new technicians, which was most appropriate for experienced technicians, which was most likely correct, and which was easiest to use.

One additional factor, the order of job aid use, was analyzed with a chi square test of independence. Three of the four questionnaire items were not independent of the order of use. Contrary to the interviewees' speculations, the age, level of education, and experience of subjects did not influence how they regarded the job aids. The one factor that did influence subjects' opinions was the order in which they used the job aids (Table 8). Subjects who used the conventional job aid initially, followed by the intelligent job aid, were more apt to state the intelligent job aid was preferable for new technicians ($\underline{X}^2 = 6.16$, $df = 1$, $p < .05$), was the most likely to lead to a correct diagnosis ($\underline{X}^2 = 9.28$, $df = 1$, $p < .05$), and was the easiest to use ($\underline{X}^2 = 9.28$, $df = 1$, $p < .05$).

Table 8: Chi Square Tests for Independence

Appropriateness for new technicians

	Conventional	Intelligent	
Conventional First	6	16	22
Intelligent First	13	7	20
	19	23	42

$\chi^2 = 6.16$ $p < .05$ $df = 1$

Most likely to lead to a correct diagnosis

	Conventional	Intelligent	
Conventional First	1	21	22
Intelligent First	9	11	30
	10	32	42

$\chi^2 = 9.28$ $p < .05$ $df = 1$

Easiest to use

	Conventional	Intelligent	
Conventional First	1	21	22
Intelligent First	9	11	30
	10	32	42

$\chi^2 = 9.28$ $p < .05$ $df = 1$

A likely explanation emerges when the diagnostic exercises are considered. The great majority of subjects were not experienced in diagnosing electronic fuel injection systems. There was a certain amount to learn (or relearn) related to system components and operation of the test equipment. Those subjects solving problems with the familiar conventional job aid first were able to focus on the system rather than the job aid. After solving a couple of problems with the conventional job aid, the location of electrical connectors and the operation of test equipment were mastered and attention could then be focused on the intelligent job aid.

For subjects using the intelligent job aid first, there was much more to attend to during the first few problems. In addition to the system components and test equipment, there was the computer keyboard to contend with.

Learning time. The conventional job aid was patterned after existing Deere reference materials for diagnosing electronic fuel injection systems. There was little or nothing new for the subjects to learn to enable them to use the conventional job aid to participate in this study. It is not surprising then that it took longer to learn to use the intelligent job aid than the conventional job aid.

Based on subjects' favorable opinion of the intelligent job aid, especially concerning ease of use, and the results of the chi square test in Table 8, it seems likely that

learning required to operate the intelligent job aid was mastered by most subjects after solving two practice problems. This was especially true for subjects who used the conventional job aid first, thus recalling information related to the fuel injection system.

Implications

This study has been concerned with the development and application of a conventional and an intelligent job aid. The performance enhanced by these job aids is the diagnosis of Robert Bosch electronic fuel injection systems found on certain John Deere engines. This task requires complex decision making in an area which is intimidating to many performers. Since electronic systems are unfamiliar to most diesel technicians, there is solid motivation for performers to accept any aid that will make the diagnosis easier.

Booher (1978) claims that adequate job aids exist for troubleshooting mechanical and electrical systems, while job aids for diagnosing perplexing electronic systems are in short supply. Richardson (1983) agrees with Booher and concludes that electronic equipment troubleshooting is an open door of opportunity for those developing training and job aids. This research study, taken in its entirety, supports that supposition.

In this project, conventional and intelligent job aids to assist diesel equipment technicians were successfully developed and field tested. The intelligent job aid

contained more textual and graphical content and required significantly more time and resources to develop. In terms of accuracy and efficiency, the job aids were comparable. Users tended to prefer the intelligent job aid though it did require more time to learn to use than the conventional job aid. The age, education, or experience of the users did not influence their opinions of the job aids. However, the order in which the job aids were used did affect opinions; subjects that used the conventional job aid prior to the intelligent job aid were likely to prefer the intelligent job aid. These results have several implications for performance technologists.

Implications for job aid project selection. It can be helpful when faced with a performance problem to think about a transportation problem as an analogy. When faced with a transportation problem, transportation engineers (or travel agents, or shipping clerks, etc.) consider the passengers and cargo; they consider the destination, the point of embarkation, and possible routes connecting the two; and finally they consider and select the most appropriate vehicle. Into the decision they factor the desires (and stamina) of the passengers, the fragility and perishability of the cargo, the nature of the route (land, water, or air), the schedule constraints, and the operating costs of various vehicles.

Confronted with a human performance problem, performance technologists make similar considerations. The point of embarkation is the current performance; the destination is the desired performance. An intervention (or interventions) is the mode of transportation, the vehicle which will be utilized according to an implementation strategy, the route. The performers are passengers served by the vehicle, and the cargo is made up of the other elements in the work system (machines, tools, etc.).

The objectives of the performance technologist, like that of the transportation engineer, are to ensure that passengers and cargo reach the destination in the least time, at the lowest cost, and at acceptable levels of passenger comfort and safety.

The additional time and resources required to develop the intelligent job aid in this study were significant and are likely to be duplicated in projects of similar scope. It will therefore behove performance technologists to carefully appraise the performance problem before committing resources to the intelligent job aid "vehicle."

There can be several reasons for considering an expert system development project. The idea for an expert system application for John Deere was conceived by forward-thinking engineers who were enamored by the technology rather than by line managers who were urgently searching for a solution to a performance problem. Surely, the desire to

develop a competitive advantage can be a valid reason to tinker with the technology. Tom Peters, writing in the forward to The Rise of the Expert Company (Feigenbaum, McCorduck, & Nii, 1988) claims that organizations that are not at least dabbling with expert system technology are precariously behind the times.

However, this project was somewhat floundering until the organization conducted a front end analysis at the urging of an external consultant. Line managers and many other important decision-makers in an organization are soon jaded by costly, experimental forays into faddish technologies. It is critical, therefore, that the starting point for an intelligent job aid project is always a genuine performance problem.

As pointed out previously, job aids are developed to deal with knowledge/skill deficiencies. If the performance requires considerable decision making, an intelligent job aid may be appropriate. The diagnosis of the Robert Bosch electronic fuel injection system is an example of such a performance. The solution paths contain dozens of decision points and are too complex to be readily represented with any detail by flow charts and decision tables. However, for those performances which tax simple memory more than they do perspicacity, conventional job aids are almost certainly preferable.

Given the potentially high cost of developing an intelligent job aid, the financial justification is an especially important aspect of a front end analysis. For the case described in this study, there were potentially thousands of end users and tens of thousands of dollars to be saved through improved equipment diagnosis, reduced workload for D-TAC service representatives, and decreased warranty claims. There was financial justification for a substantial investment. Many performance problems, while meaningful, do not result in financial losses large enough to justify an extensive expert system development project.

Consideration of the characteristics of performers, the target population, is another important aspect of a front end analysis. Based on the results of this study, the age, experience, education, and even computer literacy of the performers are of less concern than their motivation. Subjects in this study encountered a challenging performance problem that tended to divest them of self-confidence and their traditional problem solving methods. Performance problems of this nature are good candidates for intelligent job aid interventions. When performers are less motivated, and therefore less encouraged to employ a job aid, a conventional job aid will be a more prudent intervention.

Summarizing the implications for project selection, just as performance problems vary greatly, so do the resources required for job aid development. It is not possible to

generalize and conclude that one type of job aid is "better" than the other; the best choice depends on the nature of the performance problem. Performance technologists who do a good job of analyzing performance problems and are cognizant of the resources required for job aid development will be able to make sound decisions regarding project selection. Intelligent job aids will be recommended when there are genuine performance problems caused by knowledge/skill deficiencies, the performance requires complex decision-making, there is financial justification for the relatively costly development, and when the target population is highly motivated to use a job aid. For most other performance problems, conventional job aids are appropriate.

Implications for job aid design. Both of the job aids developed for this research study were designed according to guidelines found in the professional literature and reviewed earlier in this study. Based on subjects' favorable opinions of both job aids, those guidelines seem to be correct and useful.

One facet of job aid development, the production of graphics, warrants some discussion. At least eight subjects specifically cited the merit of the graphics used in the intelligent job aid; they are an important element in both types of job aids. Guidelines for graphics development are found in the literature on conventional job aids but are scarce in the expert system literature. Based on this

study, performance technologists should give just as much attention to the development of graphics for intelligent job aids as they would for conventional job aids.

The computer graphics display medium entails special considerations. Unless art is scanned in, the artist will have to be adept in generating art with graphics development software. The computer opens up the possibility of using animation and other computer-generated effects that are not possible with conventional job aids. These factors should be considered during the early stages of the project.

Determination of who is involved in job aid design is another issue of concern. Job aids can be developed by existing employees (if they possess the requisite skills) or by external consultants. The development of intelligent job aids requires all the skills needed for conventional job aid development and, additionally, some programming/computer operating skills. It is certainly possible to complete job aid development projects with existing employees and little or no assistance from outside consultants. The decision to train or hire qualified employees to perform job aid development tasks should be based on consideration of several factors:

* Will the final product be used in-house exclusively, or will it be seen by the "outside world" of customers and competition?

* Will the job aid be the only one developed within the organization or one of several?
* Are there currently employees available that have the obligatory skills needed for knowledge engineering and job aid development? If not, is the organization willing to hire them?

If the job aid will be used internally, to aid machine operators on the manufacturing floor, for instance, it is a likely candidate for in-house development. If, on the other hand, the job aid will be seen by customers, it is probably advisable to obtain professional assistance, especially with the knowledge engineering of expert systems to insure the job aid is effective, easy to use, and enhances the organization's image.

If there will be multiple job aids developed within an organization, it is readily apparent that there will be more justification for training existing employees to engage in knowledge engineering. Unfortunately, since intelligent job aids can be quite costly, it is difficult to predict an organization's future involvement in the technology until the first project is complete. Ensuing projects are often ratified or vetoed based on the success of the first project.

The difficulty of obtaining competent personnel to perform job aid development, especially the knowledge engineering required for intelligent job aids, is very

easily underestimated. Hart (1986), Rolston (1988), and others have discussed characteristics of successful knowledge engineers: intelligence, good communications skills, diplomacy, patience, creativity, self confidence, persistence, knowledge of the subject matter, programming knowledge, and a broad educational background. This is a formidable list, describing an exceptional individual. Yet management is likely to take these skills for granted when making personnel decisions about knowledge engineering functions.

Training employees for knowledge engineering so they are able to complete an expert system that is comparable to the one described in this case study can, if all expenses are considered, cost as much or more than contracting the project to an outside consultant. However, once employees are qualified, substantial savings can be incurred.

Implications for job aid implementation. Job aid implementation obviously occurs after design and production, but planning for implementation should begin in the early stages of design. Although this study was formally concluded prior to widespread distribution of the expert system within the John Deere organization and dealer network, planning for the implementation was an on-going activity. Several items emerged during this activity as matters of concern for performance technologists.

In the case of intelligent job aid development projects, organizational management must be kept especially well informed from project inception so they form and maintain realistic expectations of resource requirements, the project schedule, and likely outcomes.

It is very helpful if a line manager emerges as a "champion" of the project. A single line manager who understands and appreciates the performance addressed and who believes in and promotes an intelligent job aid will do far more to boost the project credibility than several management "champions" from the corporate office or the information systems department.

This study has pointed to the importance of preparing performers to be successful during their initial use of an intelligent job aid. The subjects in this study who were better prepared (because they had first practiced with the conventional job aid) had a more favorable opinion of the intelligent job aid. The success of the implementation of an intelligent job aid could conceivably hinge on the effectiveness of the methods used to prepare performers.

Job aids are devised to replace or at least partially substitute for training because training is expensive, it usually restricts the schedules of instructors and trainees, and its outcomes are often transient. Clearly, performance technologists should endeavor to create job aids that require little or no training. Otherwise, training to

perform the task is to some extent replaced by training to use the job aid.

In this case study, the training given to subjects took 20 to 30 minutes; about ten minutes of the time period was used to introduce the problem solving exercise and complete the pre-exercise survey; the remainder was devoted to instruction in fuel system diagnosis with the job aids. During interviews several subjects expressed a desire for more training and/or experience with the intelligent job aid. However, most subjects seemed conversant with it after two practice problems (based on an examination of the video tapes).

These outcomes affected planning for the widespread distribution of the intelligent job aid to John Deere factories. A conventional job aid was created (see Appendix M) to replace all training that had been given subjects in this study. The target population would receive three or four diskettes (depending on the format), the laminated job aid, and a cover letter which would provide general installation and operation instructions. This approach allows the intelligent job aid to be used without preparatory training and extensive accompanying documentation.

<u>A potential problem</u>. Finally, performance technologists must look beyond the short-term implementation of job aids, especially intelligent job aids. Harmon (1987) raises an

interesting and portentous question: What are the prolonged effects of intelligent job aids on performers?

> It is perhaps worth mentioning that the extensive use of intelligent job aids may lead to some potential problems. To the degree that we develop intelligent job aids that ask questions and then recommend solutions, we "deprive" users of the experience of "messing" with a problem until they figure it out. In other words, we deny the users the rich period of experimentation that normally leads to the development of an expert. By automating troubleshooting and problem solving we will undoubtedly increase the quality and consistency of human performance in the near term. In the long run, however, we may find that we will need more sophisticated simulation programs (more education rather than training) to create the experts who will ultimately create and update the intelligent job aids that most employees will increasingly depend on (p. 189).

As subject #40 in this study commented during the interview:

> I'm still a strong believer in the fact that people are technicians because they like to think and come up with their own solutions....There is [sic] a lot more vocational schools out there today because some people want to go out there and discover the problem on their own. He [a technician] doesn't get that satisfaction if he's lead to the answer. Even though your system might be better, you're still taking something away from them....The only way I can learn is to do it myself. With the conventional I can do that.

If intelligent job aids retard the maturation of human experts, expertise (scarce by definition) could all but vanish. A short-term solution to a manageable performance problem could lead to a long-term, intractable dilemma.

A central tenet of human performance technology is that performance problems are best solved by appraising the whole performance system and considering the entire spectrum of interventions. Performance technologists are noted for their repugnance of myopic solutions to performance problems; nevertheless, devising a prudent solution to the short- and long-term need for diagnosis of complex equipment will challenge the best of performance technologists.

Nawrocki (1987) refers to four performance improvement components of a equipment diagnosis/maintenance system: 1) the engineering of a high degree of reliability into the equipment so problems are rare; 2) self-diagnostic systems that are designed into the equipment; 3) job aids to assist technicians; and 4) training technicians to improve their performance. The inter-relationship of these methods are illustrated in Figure 24.

> The evidence to date strongly suggests that all four solutions are required to ensure adequate maintainability and that what varies from equipment to equipment is the proportion of the maintenance system devoted to each of the solutions. Ironically though, advances in state-of-the-art technologies for the engineering, built-in diagnostic, and job aid approaches have potentially increased the difficulty of providing effective training. That is, the most predictable and quantifiable equipment problems can generally be dealt with by a combination of the first three approaches, reducing the need for large numbers of human technicians. Yet maintenance problems that remain are often highly complex and unique diagnostic problems such as those due to intermittent or interactive malfunctioning components. Thus fewer but higher-skilled technicians may be needed (Nawrocki, 1987, p. 136).

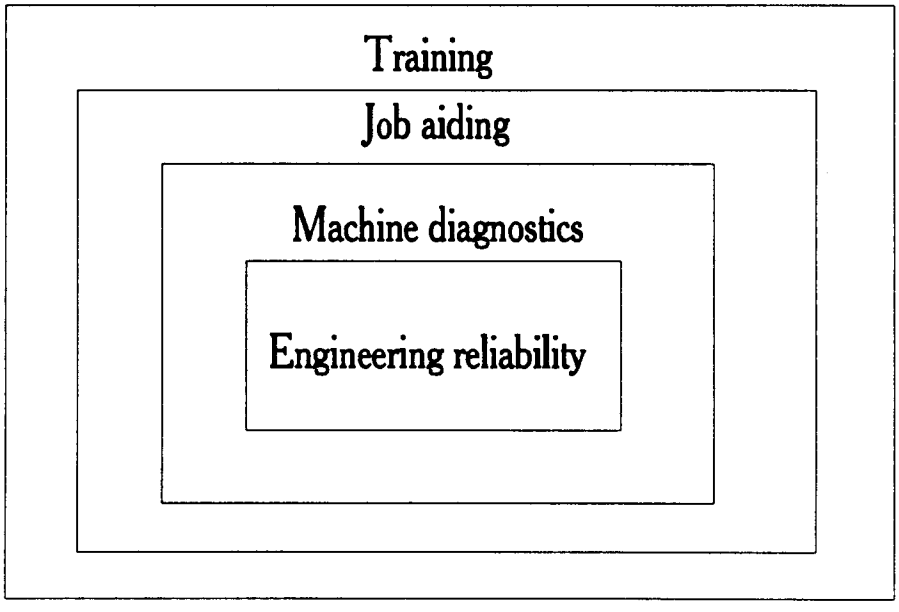


Figure 24: Diagnostic System (Nawrocki, 1987, p. 137)

The logical, but possibly short-sighted approach to creating an effective maintenance system, is to decrease the role of each component moving out from the center of the model. Engineering reliability would have the predominant role and training a very minor role. The net effect, though, could be user dissatisfaction and a degradation of the skills of performers.

A possible solution. Intelligent job aids are so-called because they emulate the intelligence of human experts. Perhaps it would be wise to, in some cases, elevate the "intelligence" and expand the role of intelligent job aids. Surely this is possible. An intelligent-adaptive job aid could be designed to adapt to the needs of the performer and intentionally provide a learning environment when appropriate.

Figure 25 illustrates some critical components of such a system. The performer would interact with the job aid which is governed by a control module which optimizes the amount of control afforded the user. Models of performers, profiles of their skill levels and learning styles, could be constructed over time to provide information for the control module.

Based on an individual performer's need, the control module would direct the job aid to be more or less system-directed and instructional in nature. An experienced, highly skilled performer would have maximum control of the

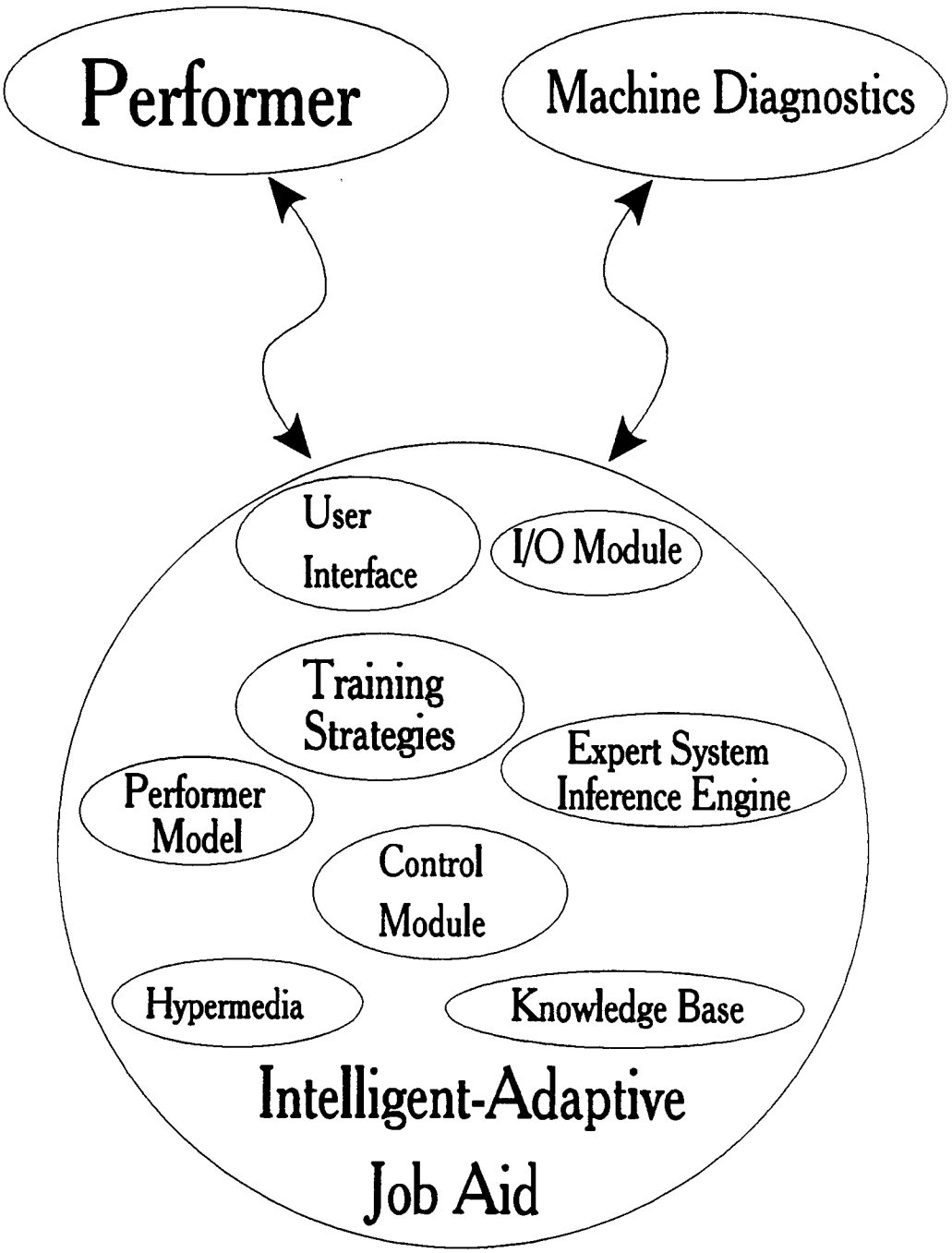


Figure 25: An Intelligent-Adaptive Job Aid

system which would function as an electronic reference manual. The performer could access the knowledge base through a hypermedia component which would allow the user to select text, graphics, video segments, etc. randomly.

On the other hand, for an inexperienced, less skilled performer, the system could retain more control and function as an expert system diagnostic tool. If the user requested, the adaptive system could also serve as an intelligent tutoring system. A training strategies module might even select the instructional presentation method best suited to individual learning style.

An intelligent-adaptive job aid would certainly require some additional time and resources to develop, but how much is uncertain. The knowledge base, inference engine, and user interface are part of an intelligent job aid anyway. Creating the hypertext links between chunks of information in the knowledge base would not be difficult. Most extra work to develop the intelligent-adaptive job aid would probably go in the training strategies module.

This research has shown that intelligent job aids can be effectively applied to improve performance in certain situations. Additional research is recommended to develop and evaluate intelligent-adaptive job aids and other interventions which might be suited for those performance problems not satisfactorily addressed by conventional and intelligent job aids.

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APPENDICES

Appendix A

Front End Analysis

28 June 1989

Dear Area Service Manager:

Following is a survey related to John Deere service technicians and their troubleshooting methods and skills. Please fill out this survey to help us better understand how to serve our dealers and their technicians with reference materials and diagnostic helps.

The survey results will be analyzed to determine if existing resources, especially the Engine Component Technical Manuals and the Dealer Technical Assistance Centers, are meeting the needs of the users. We want to improve these resources and possibly provide others to assist with troubleshooting and diagnosis of service-related problems.

Please complete this survey using the office mail shell provided. Return to the John Deere Engine Works on their office mail, SRGSERV. We would appreciate your response by 12 July 1989 or as soon as it is possible.

Thanks for your consideration and prompt response.

Best regards,

John Deere Engine Works Service Department

This survey is to be filled out by John Deere Area Service Managers. All questions ask you to consider the **service technicians working in your service area only.** Answer the questions frankly and as well as you are able given your knowledge of the technicians in your area. The surveys are confidential--your name will not be identified or linked with the results in any way. The results of this survey will help us serve the technicians who maintain and repair John Deere equipment. Thank you for your help.

Part I: Technicians and their jobs

These first questions ask you to consider the education and experience of service technicians in your service area.

1. Consider the "average" technician. How many years experience would you estimate he has servicing diesel engines (of any make)? ____

2. How long would you estimate the same technician has worked in a John Deere service department? ____

3. Consider the education of service technicians. What percentage of technicians would you estimate have the following education?

   High school ____%

   Some courses in diesel or ag mechanics at a vocational or technical school? ____%

   Diploma or degree from a vocational or technical school program in diesel or ag mechanics? ____%

   Classroom training in diesel mechanics as part of their current job? ____%

Part II: Technicians and John Deere Component Technical Manuals

The following questions ask you to tell us how you think technicians use and regard John Deere Engine Service Manuals.

4. Technicians usually refer to John Deere Component Technical Manuals when making major **engine** repairs.

Agree ____

Disagree ____

5. Technicians usually refer to John Deere Component Technical Manuals when **troubleshooting** an engine problem.

Agree ____

Disagree ____

6. When technicians want to find **troubleshooting** information in a John Deere Component Technical Manual, they can usually find it in less than one minute.

Agree ____

Disagree ____

7. What is the **one most useful** section of John Deere Component Technical Manuals?

_____ Diagnosing malfunctions/Troubleshooting

_____ Explanation of systems operation

_____ Illustrations/diagrams/photos

_____ Repair procedures

_____ Specification lists

_____ Table of contents/index

_____ Test instructions (from Operation and Test Groups)

8. What is it specifically that makes the section helpful?

9. What is the **one least useful** section of John Deere Component Technical Manuals?

_____ Diagnosing malfunctions/Troubleshooting

_____ Explanation of systems operation

_____ Illustrations/diagrams/photos

_____ Repair procedures

_____ Specification lists

_____ Table of contents/index

_____ Test instructions (from Operation and Test Groups)

10. What is it specifically that makes the section not helpful?

Part III: Technicians and the John Deere Dealer Technical Assistance Center (D-TAC).

The following questions ask you to tell us how you feel about D-TAC.

11. How many times **in a 90 day period** would you estimate technicians are involved in a problem that requires a call to D-TAC?

_____ 0

_____ 1 to 2

_____ 3 to 6

_____ 7 to 10

_____ 10 or more

12. Who normally determines the need to call D-TAC?

_____ Service Technician

_____ Shop Foreman

_____ Service Manager

13. Please rank in order of importance (1 most important) the genuine reasons for calls to D-TAC.

_____ To save time spent finding information in service manuals.

_____ The answer to my service problem could not be found in the service manual.

_____ To report a product problem and explain our solution if we had one.

_____ To serve as a marketing tool by demonstrating John Deere resources to a customer.

_____ To confirm (or disconfirm) my own diagnosis of a problem.

_____ To obtain a troubleshooting checklist prior to dispatching a technician to the field.

_____ Other. (Please explain below)

14. D-TAC meets the needs/expectations of its users.

_____ Agree

_____ Disagree

15. What is one specific thing you would do to improve D-TAC?

Appendix B

Flow Chart Algorithms

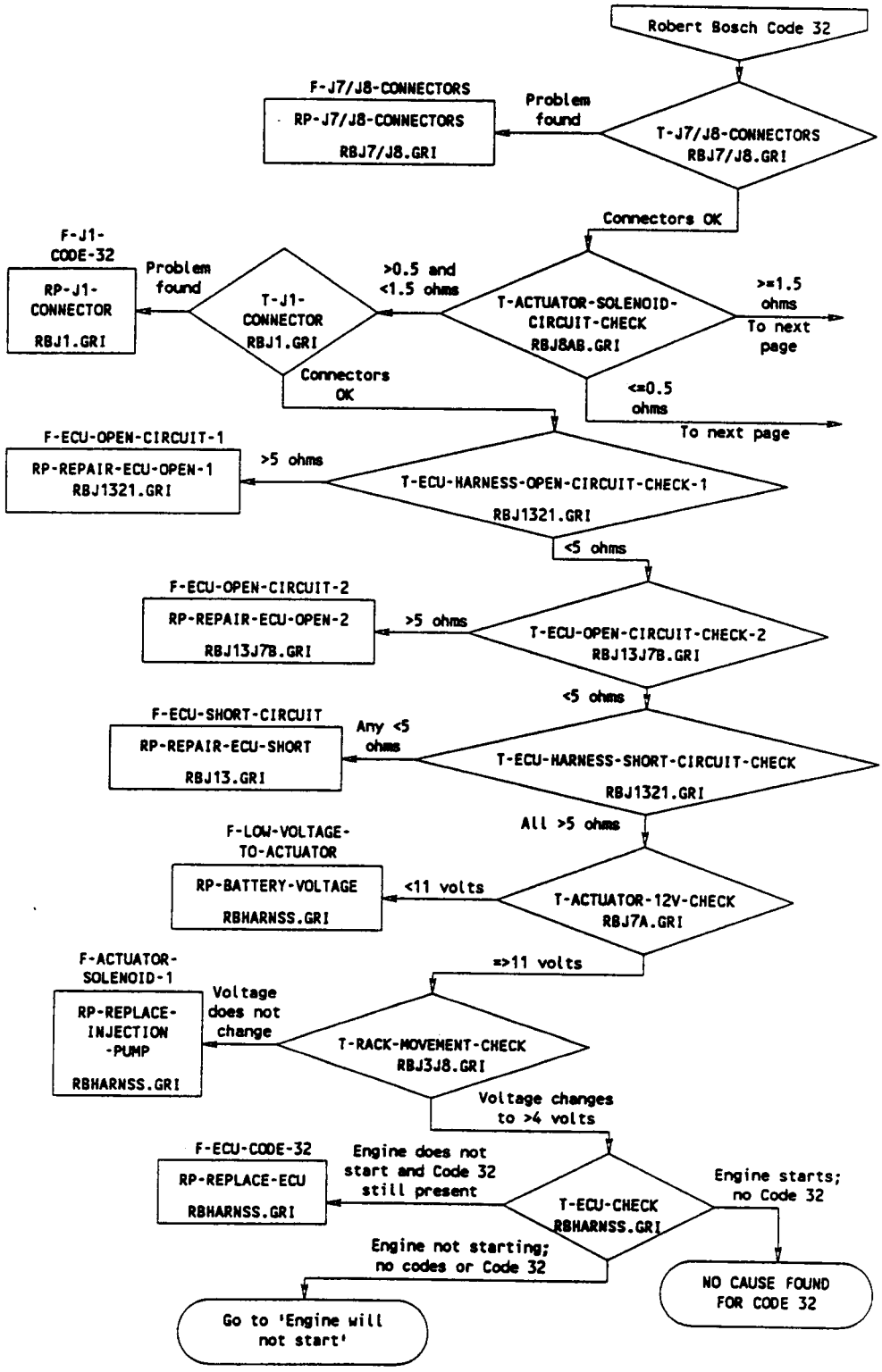


Figure 26: Code 32-A Flow Chart

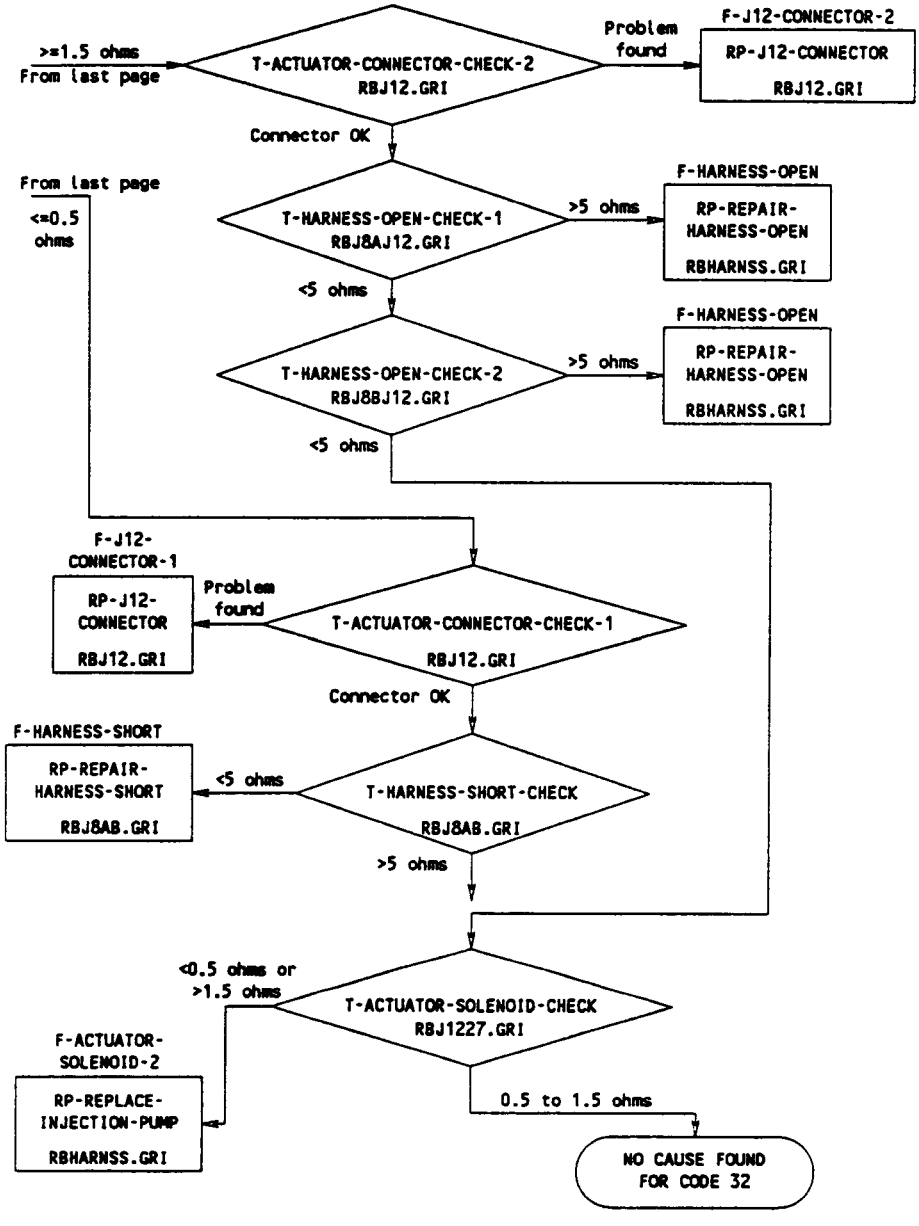


Figure 27: Code 32-B Flow Chart

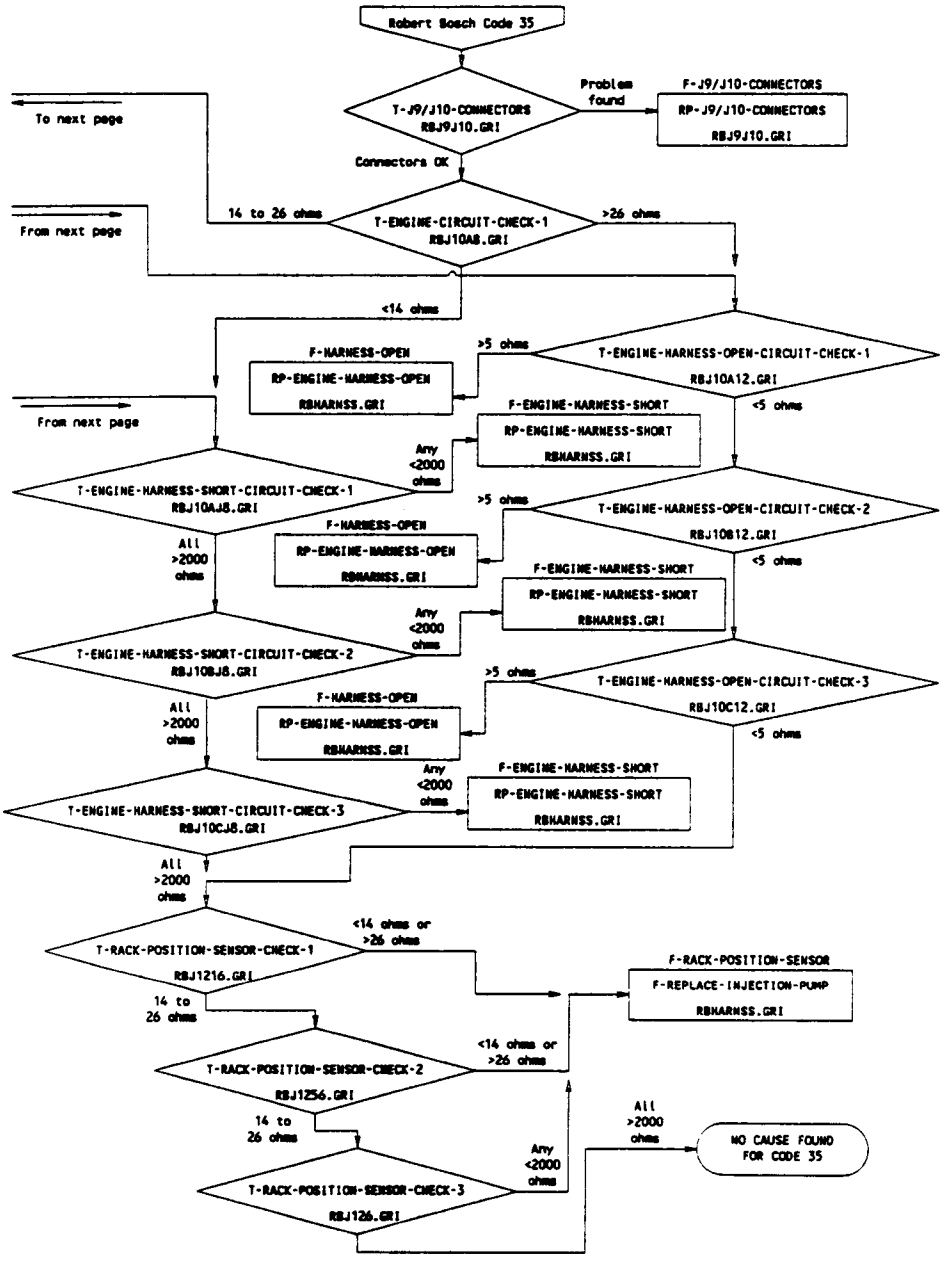


Figure 28: Code 35-A Flow Chart

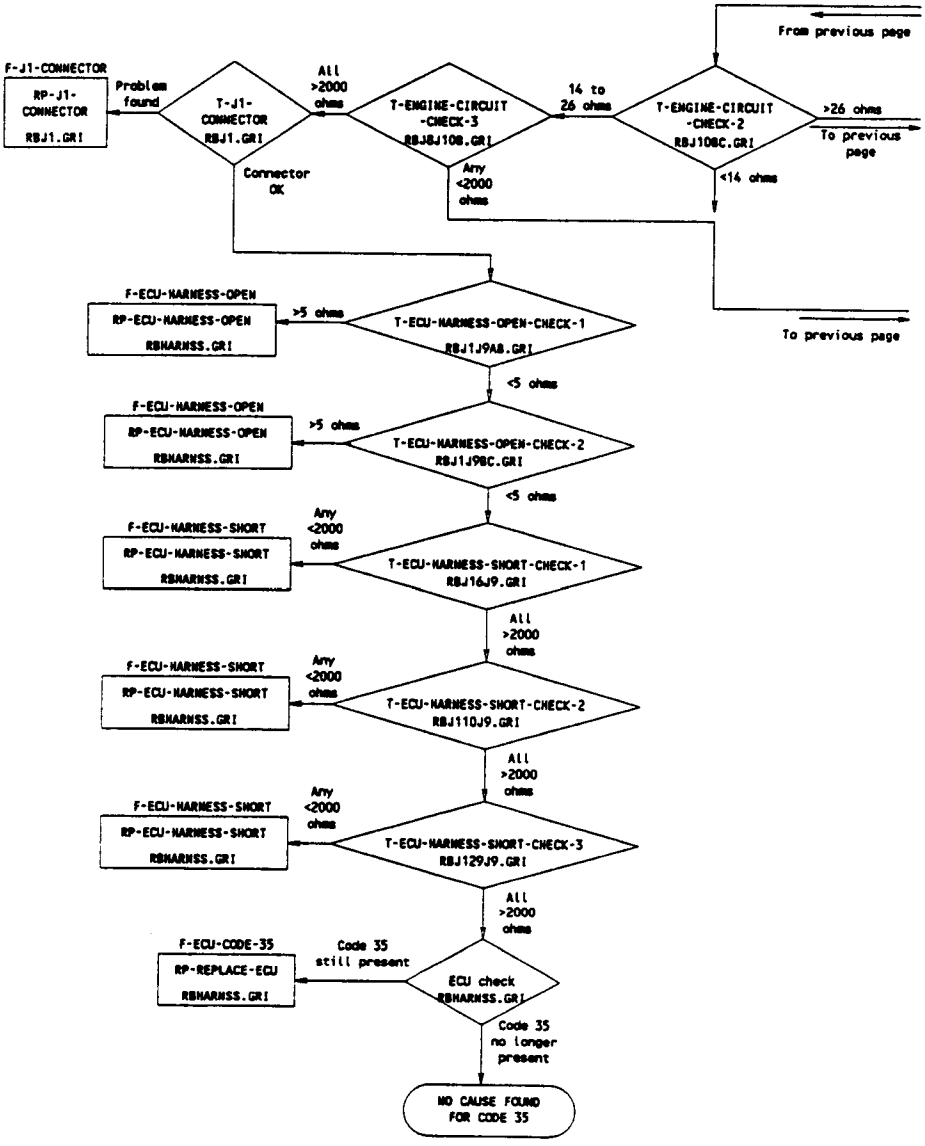


Figure 29: Code 35-B Flow Chart

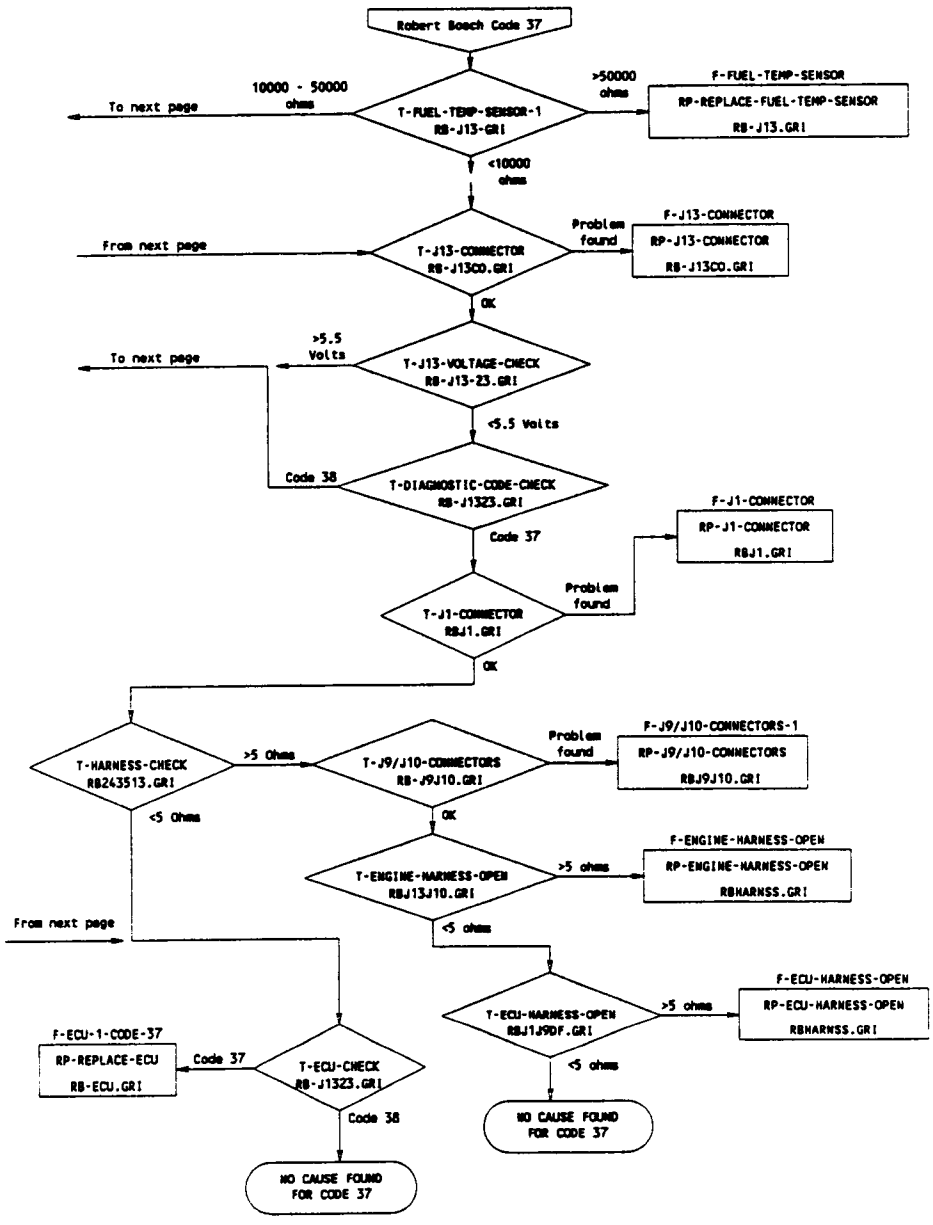


Figure 30: Code 37-A Flow Chart

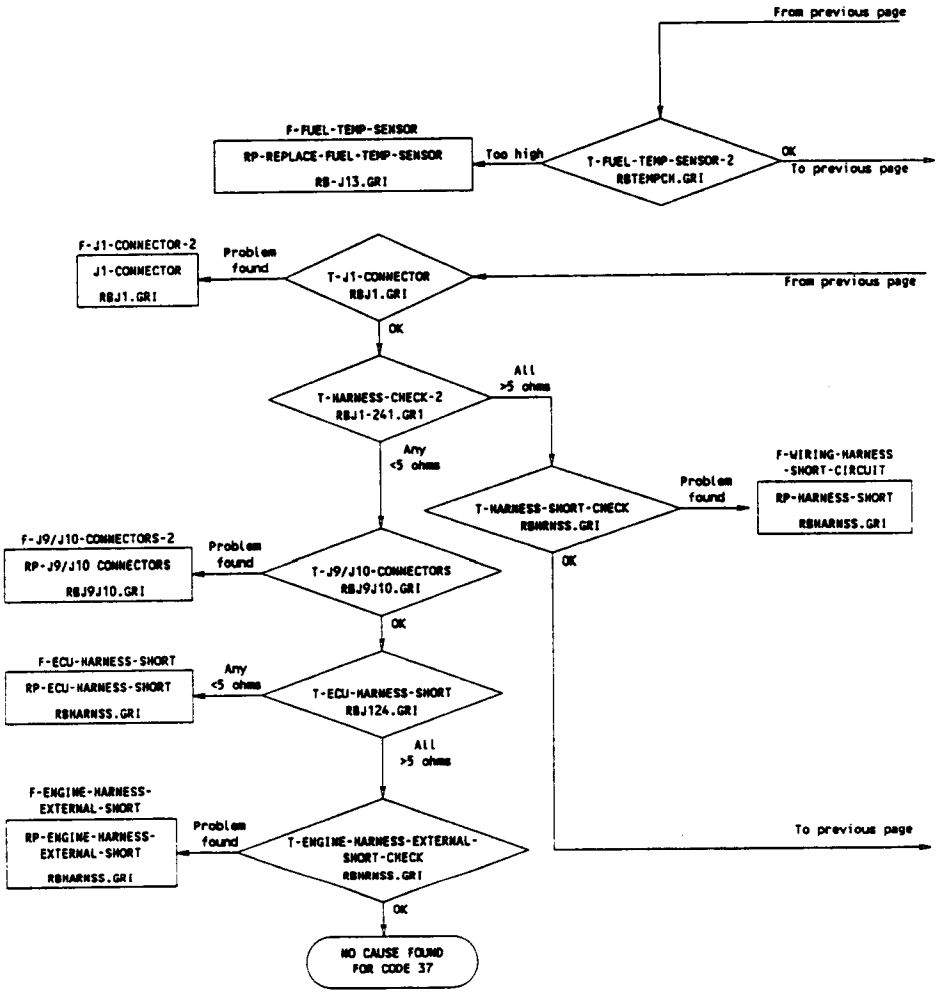


Figure 31: Code 37-B Flow Chart

Appendix C

Conventional Job Aid

TROUBLESHOOTING THE ROBERT BOSCH ELECTRONIC FUEL INJECTION SYSTEM

USE THIS TROUBLESHOOTING GUIDE WHEN

1) - A diagnostic code is displayed by the system
or 2) - The injection system is suspected of causing engine problems

YOU WILL NEED

1) - Digital multimeter (JT05791 or equivalent)
2) - Diagnostic reader (John Deere Electronic Governor Tester JT05829
or - On-board diagnostic code read-out device
3) - Jumper wires
4) - Basic electrical service repair kit

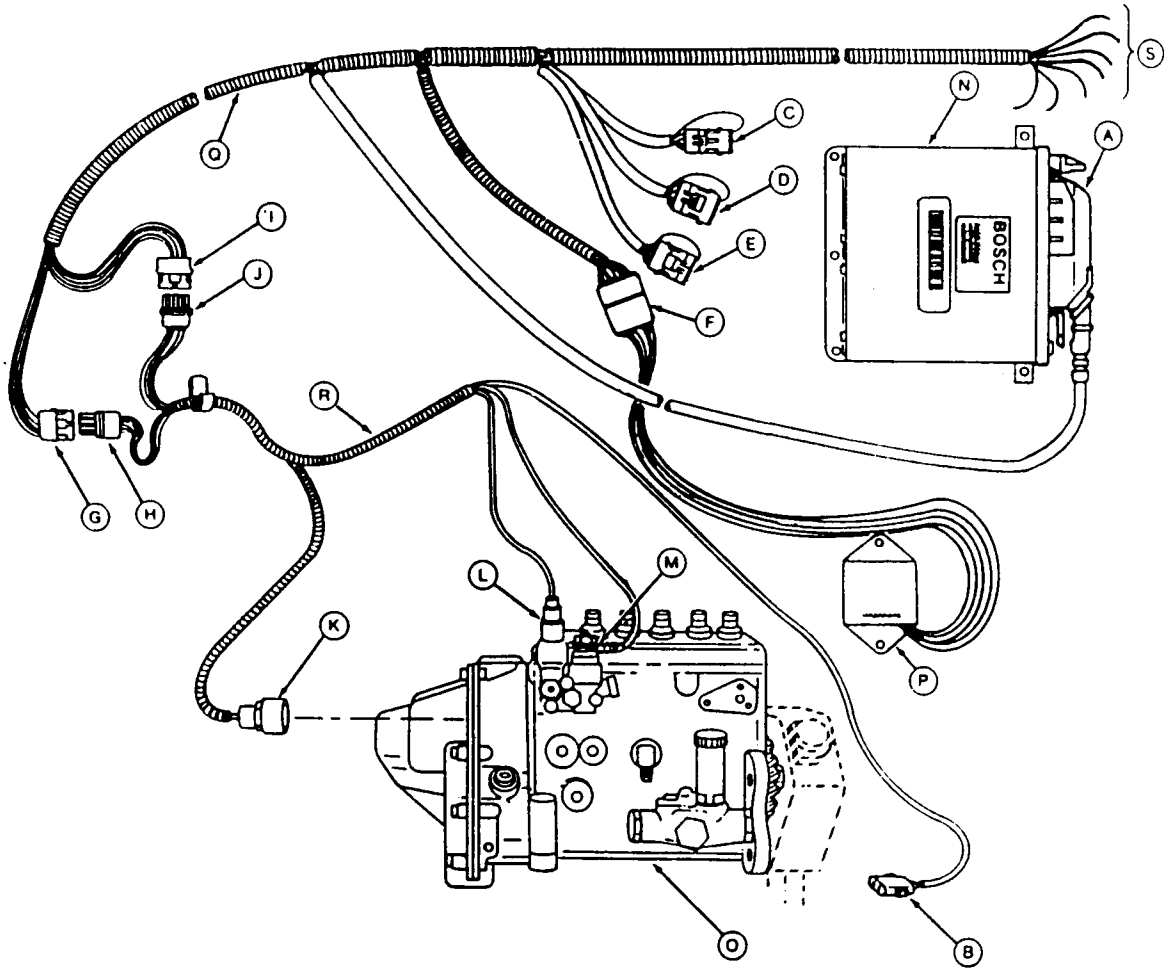
MAKE SURE THE FUEL SUPPLY SYSTEM AND ENGINE ELECTRICAL SYSTEM ARE OPERATING CORRECTLY BEFORE DIAGNOSING THE ELECTRONIC FUEL INJECTION SYSTEM.

IF THE:

DIAGNOSTIC READ-OUT DISPLAYS CODE

ALWAYS CHECK FOR AND DIAGNOSE CODES **BEFORE** OTHER SYMPTOMS

ELECTRONICALLY CONTROLLED FUEL INJECTION SYSTEM WITH WIRING HARNESSES



A—J1 Engine Controller Connector
B—J2 Auxiliary Speed Sensor Connector
C—J3 Diagnostic Voltages Connector
D—J4 Diagnostic Reader Connector
E—J5 Service Connector
F—TVP Connector
G—J7 In-Line Connector
H—J8 In-Line Connector
I—J9 In-Line Connector
J—J10 In-Line Connector
K—J12 Actuator Connector
L—J13 Fuel Temperature Sensor Connector
M—J11 Fuel Shutoff Solenoid
N—Engine Controller
O—Fuel Injection Pump
P—TVP Module
Q—Application Wiring Harness
R—Engine Wiring Harness
S—Unterminated Wires

NOTE: Connectors J2, J8, J10, J11, J12, J13 are located on the Engine Wiring Harness (R) (short harness). Connectors J1, J3, J4, J5, J7, J9, are located on the Application Wiring Harness (Q) (long harness). On some applications, J6 (not illustrated) is also located on the same pigtail as the J3, J4, and J5 connectors. J6 is a service connector only.

CODE 11 -- PRIMARY ANALOG THROTTLE INPUT IS TOO HIGH

1) **With ignition on, slowly move throttle lever through entire travel noting the diagnostic code display.**

If Code 11 is only present at upper portion of throttle lever travel, adjust throttle sensor according to machine technical manual.
Otherwise, go to 2.

2) **Check throttle linkage and verify that throttle sensor does move through its range of travel as the throttle lever is moved from slow to fast idle.**

If linkage restricts movement, repair as required.
Otherwise, go to 3.

3) **Disconnect throttle sensor connector. Inspect terminals on both connector halves for damage, corrosion, and poorly positioned pins or sockets.**

If problem with connector is found, repair as required.
Otherwise, go to 4.

4) **With ignition on and sensor still disconnected, measure the voltage between harness throttle connector terminals C (+) and A (-).**

If greater than 4 volts, go to 5.
Otherwise, go to 6.

5) **Turn ignition off. Disconnect connector J1 at the ECU. Install a jumper wire between throttle sensor harness connector terminals A and B. Measure the resistance between J1 pins 13 and 35.**

If less than 5 ohms, replace the throttle sensor.
Otherwise, repair open circuit between J1 pin 35 and throttle connector pin A.

6) **Turn ignition off. Disconnect connector J1 at the ECU. Inspect terminals of both connector halves for damage, corrosion, and poorly positioned terminals.**

If problem with connector is found, repair as required.
Otherwise, go to 7.

7) **With ignition off, measure the resistance between J1 connector terminal 13 and all other J1 terminals.**

If any measurement is less than 5 ohms, repair the short circuit.
Otherwise, go to 8.

8) **With ECU and throttle sensor disconnected, turn ignition to the "ON" position. Measure the voltage from J1 connector pin 13 (+) to J1 pin 19 (-).**

If greater than 1 volt, repair short circuit in harness between J1 pin 13 and some voltage source.
Otherwise, go to 9.

9) **Reconnect connector J1 to ECU but leave throttle sensor disconnected. Turn ignition to "ON" and check diagnostic codes.**

If Code 11 is displayed, replace the ECU.
Otherwise, no cause found for Code 11.

CODE 12 -- PRIMARY ANALOG THROTTLE INPUT IS TOO LOW

1) With ignition on, slowly move throttle lever through its entire travel noting the diagnostic code display.

If Code 12 is only present at the lower portion of the throttle lever travel, adjust throttle sensor according to machine technical manual.
Otherwise, go to 2.

2) Check throttle linkage and verify that throttle sensor does move through its range of travel as the throttle lever is moved from slow to fast idle.

If linkage restricts movement, repair as required.
Otherwise, go to 3.

3) Disconnect throttle sensor connector. Inspect terminals on both connector halves for damage, corrosion, and poorly positioned pins or sockets.

If problem with connector is found, repair as required.
Otherwise, go to 4.

4) With throttle connector disconnected, install a jumper wire between throttle sensor harness connector terminals B and C. Check the diagnostic codes.

If Code 11, replace throttle sensor.
Otherwise, go to 5.

5) Turn ignition off. Disconnect connector J1 at the ECU. Inspect terminals of both connector halves for damage, corrosion, and poorly positioned terminals.

If problem with connector is found, repair as required.
Otherwise, go to 6.

6) With jumper wire installed between throttle connector terminals B and C, measure the resistance between J1 harness connector pins 13 and 17.

If greater than 5 ohms, repair open circuit in harness in wire to J1 pin 13 or wire to J1 pin 17.
Otherwise go to 7.

7) With jumper wire still installed between throttle connector terminals B and C, measure the resistance between J1 connector pin 13 and all other J1 pins.

If any measurement is less than 5 ohms, repair short circuit in ECU harness.
Otherwise, go to 8.

8) Reconnect connector J1 to ECU. With jumper still installed between throttle terminals B and C, turn ignition to the "ON" position. Check the diagnostic code display.

If Code 12 is displayed, replace the ECU.
Otherwise, no cause found for Code 12.

CODE 13 -- SECONDARY ANALOG THROTTLE INPUT IS TOO HIGH

1) With ignition on, slowly move throttle lever through its entire travel noting the status of the diagnostic codes.

If Code 13 is only present at upper portion of throttle lever travel, adjust secondary throttle sensor according to machine technical manual.
Otherwise, go to 2.

2) Check throttle linkage and verify that throttle sensor does move through its range of travel as the throttle lever is moved from slow to fast idle.

If linkage restricts movement, repair as required.
Otherwise, go to 3.

3) Disconnect throttle sensor connector. Inspect terminals on both connector halves for damage, corrosion, and poorly positioned pins or sockets.

If problem with connector is found, repair as required.
Otherwise, go to 4.

4) With ignition on and sensor still disconnected, measure the voltage between harness throttle connector terminals C (+) and A (-).

If greater than 4 volts, go to 5.
Otherwise, go to 6.

5) Turn ignition off. Disconnect connector J1 at the ECU. Install a jumper wire between throttle sensor harness connector terminals A and B. Measure the resistance between J1 pins 34 and 35.

If less than 5 ohms, replace the secondary throttle sensor.
Otherwise, repair open circuit between J1 pin 35 and throttle connector pin A.

6) Turn ignition off. Disconnect connector J1 at the ECU. Inspect terminals of both connector halves for damage, corrosion, and poorly positioned terminals.

If problem with connector is found, repair as required.
Otherwise, go to 7.

7) With ignition off, measure the resistance between J1 harness connector terminal 34 and all other J1 terminals.

If any measurement is less than 5 ohms, repair the short circuit.
Otherwise, go to 8.

8) With ECU and throttle sensor disconnected, turn ignition to the "ON" position. Measure the voltage from J1 connector pin 34 (+) to J1 pin 19 (-).

If greater than 1 volt, repair short circuit in harness between J1 pin 34 and some voltage source.
Otherwise, go to 9.

9) Reconnect connector J1 to ECU but leave throttle sensor disconnected. Turn ignition to "ON" and check diagnostic codes.

If Code 13 is displayed, replace the ECU.
Otherwise, no cause found for Code 13.

CODE 14 -- SECONDARY ANALOG THROTTLE INPUT IS TOO LOW

1) With ignition on, slowly move throttle lever through its entire travel noting the diagnostic code display.

If Code 14 is only present at the lower portion of the throttle lever travel, adjust secondary throttle sensor according to machine technical manual.
Otherwise, go to 2.

2) Check throttle linkage and verify that throttle sensor does move through its range of travel as the throttle lever is moved from slow to fast idle.

If linkage restricts movement, repair as required.
Otherwise, go to 3.

3) Disconnect throttle sensor connector. Inspect terminals on both connector halves for damage, corrosion, and poorly positioned pins or sockets.

If problem with connector is found, repair as required.
Otherwise, go to 4.

4) With throttle connector disconnected, install a jumper wire between throttle sensor harness connector terminals B and C. Check the diagnostic codes.

If Code 13, replace throttle sensor.
Otherwise, go to 5.

5) Turn ignition off. Disconnect connector J1 at the ECU. Inspect terminals of both connector halves for damage, corrosion, and poorly positioned terminals.

If problem with connector is found, repair as required.
Otherwise, go to 6.

6) With jumper wire installed between throttle connector terminals B and C, measure the resistance between J1 harness connector pins 34 and 28.

If greater than 5 ohms, repair open circuit in harness in wire to J1 pin 34 or wire to J1 pin 28.
Otherwise go to 7.

7) With jumper wire still installed between throttle connector terminals B and C, measure the resistance between J1 connector pin 34 and all other J1 pins.

If any measurement is less than 5 ohms, repair short circuit in ECU harness.
Otherwise, go to 8.

8) Reconnect connector J1 to ECU. With jumper still installed between throttle terminals B and C, turn ignition to the "ON" position. Check the diagnostic code display.

If Code 14 is displayed, replace the ECU.
Otherwise, no cause found for Code 14.

CODE 32 -- ACTUATOR SOLENOID CIRCUIT IS FAULTY

1) Turn ignition off. Disconnect connectors J7/J8. Inspect both connectors for damage, corrosion, and poorly positioned pins and sockets.

If problem found with the connectors, repair as required.
Otherwise, go to 2.

2) Measure the resistance between J8 sockets A and B.

If less than 0.5 ohms, there is a short circuit in the actuator circuit. Go to 9.
If greater than 1.5 ohms, there is an open circuit in the actuator circuit. Go to 11.
If between 0.5 and 1.5 ohms, go to 3.

3) With ignition off, disconnect J1 connector at ECU. Inspect both connector halves for damage, corrosion, and poorly positioned terminals.

If problem is found with connector, repair as required.
Otherwise go to 4.

4) Connectors J1 and J7 should be disconnected and ignition off. Measure the resistance between J1 terminals 3 and 21, and between J1 terminal 3 and J7 pin B.

If any measurement is greater than 5 ohms, repair open circuit between measured points.
Otherwise, go to 5.

5) With ignition off and connectors J1, J7, and J9 disconnected, measure the resistance between J1 terminal 3 and all other J1 terminals <u>except</u> terminal 21.

If any measurement is less than 5 ohms, repair short circuit between measured points.
Otherwise, go to 6.

6) Reconnect J1 to ECU. Turn ignition to "ON." Measure voltage from J7 pin A (+) to ground (-).

If less than 11 volts, correct the battery charge or repair open circuit from battery to ECU.
Otherwise, go to 7.

CAUTION: DURING THE FOLLOWING TEST, BE CAREFUL TO KEEP THE JUMPER LEADS ISOLATED SO THAT THE BATTERY IS NOT SHORTED TO GROUND. ALSO, IF THE RACK ACTUATOR IS FUNCTIONING CORRECTLY, ABOUT 20 AMPS OF CURRENT WILL BE CONDUCTED DURING THIS CHECK AND A SPARK WILL OCCUR WHEN THE CIRCUIT IS BROKEN. THIS CONDITION SHOULD NOT BE CONTINUED BEYOND A FEW SECONDS.

7) a) Locate and uncap connector J3. With ignition in the "ON" position, measure voltage from J3 socket C (+) to J3 socket D (-).
b) Next, connect one jumper wire from J8 socket B to chassis ground and second jumper from J8 socket A to +12V battery voltage.
c) While connection is made, again measure voltage from J3 socket C (+) to J3 socket D (-).

If measured voltage does not change from a value of 0.5 ± 0.1 V to a value greater than 4.0 V when +12V is applied to the actuator solenoid, replace the fuel injection pump.
If voltage does change as described, go to 8.

8) With ignition off, remove jumpers and reconnect all connectors. Attempt to start the engine. If engine does not start, be sure to crank continuously for at least 4 seconds.

If engine does not start and Code 32 is still present, replace ECU.
Otherwise, no cause found for Code 32.

9) Disconnect J12 connector from injection pump. Use a crowsfoot wrench (JDG646) and be careful not to damage the plastic threads on the connector. Inspect the connector for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required. J12 connector should be tightened to 7 - 15 lb-ft during installation.
If connector is OK, go to **10**.

10) Measure resistance between J8 sockets A and B and inspect harness for short circuit locations.

If less than 5 ohms or there is a possible short circuit location, repair short circuit as required.
Otherwise, go to **13**.

11) Disconnect J12 connector from injection pump. Use a crowsfoot wrench (JDG646) and be careful not to damage the plastic threads on the connector. Inspect the connector for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required. J12 connector should be tightened to 7 - 15 lb-ft during installation.
If connector is OK, go to **12**.

12) Measure the resistance between J8 socket A and J12 socket 7, and between J8 socket B and J12 socket 2.

If either measurement is greater than 5 ohms, repair open circuit between measured points.
Otherwise, go to **13**.

13) Measure the resistance between the actuator connector pins 2 and 7 on the injection pump.

If less than 0.5 ohms or greater than 1.5 ohms, replace the pump.
Otherwise, no cause found for Code 32.

CODE 34 -- RACK POSITION ERROR

1) With ignition on but engine not running, check diagnostic codes.

If a code other than Code 34 is displayed, diagnose that symptom first.
Otherwise, go to **2**.

2) Attempt to start the engine.

If the engine starts and runs normally, go to **3**.
If the engine starts but then runs up to overspeed, turn off ignition and go to **5**.

3) Set the engine speed to fast idle and check the diagnostic code display.

If a code other than Code 34 is displayed, diagnose that symptom first.
If only Code 34 is displayed or if previous engine operation has resulted in irregular operation with Code 34 occurring, the problem is probably in the injection pump/actuator or in the ECU. Go to **4**.

4)Replace the fuel injection pump and run the engine at varying loads at full throttle.

If Code 34 is still present (pump was probably good), replace ECU.
If ECU replacement does not remove Code 34, no cause found for symptom.

5) **With ignition off, disconnect J7/J8 connectors and inspect for damage, corrosion, and poorly positioned terminals looking especially for short circuit possibilities.**

If problems with connectors found, repair as required.
Otherwise, go to 6.

7) **Measure the resistance between J8 socket B and the pump housing.**

If less than 5 ohms, repair short circuit as required.
Otherwise, go to 8.

8) **Disconnect J1 connector at the ECU. Measure the resistance between J7 pin B and chassis ground and inspect harness for potential short circuit locations.**

If less than 5 ohms or possible short circuit location seen, repair as required.
Otherwise, go to 9.

9) **Disconnect J12 connector from injection pump. Use a crowsfoot wrench (JDG646) and be careful not to damage the plastic threads on the connector. Inspect the connector for damage, corrosion, and poorly positioned terminals looking especially for short circuit possibilities.**

If problem found with connector, repair as required. J12 connector should be tightened to 7 - 15 lb-ft during installation.
If connector is OK, go to 10.

10) **Measure the resistance between the actuator connector pin 2 and fuel injection pump housing.**

If less than 5 ohms, replace the injection pump.
Otherwise, no cause found for Code 34.

CODE 35 -- RACK POSITION VOLTAGE IS TOO HIGH

1) **Turn ignition off. Disconnect J9/J10 connectors. Inspect for damage, corrosion, and poorly positioned terminals.**

If problem found with connectors, repair as required.
Otherwise, go to 2.

2) **Measure the resistance between J10 sockets A and B, and between J10 sockets B and C.**

If either measurement is less than 14 ohms, short circuit exists. Go to 12.
If either measurement is greater than 26 ohms, open circuit exists. Go to 15.
If both measurements are between 14 and 26 ohms, go to 3.

3) **Disconnect the J8 connector. Measure resistances between J10 socket B and the following points:**
   a) J10 sockets D, E, F;
   b) J8 sockets A, B, C, D; and
   c) chassis ground.

If any measurement is less than 2000 ohms, short circuit exists. Go to 12
If all measurements are greater than 2000 ohms, go to 4.

4) **Disconnect J1 connector. Inspect connector halves for damage, corrosion, and poorly positioned terminals.**

If problem found with connector, repair as required.
Otherwise, go to 5.

5) With J1 and J9 disconnected, install jumper wire between J9 pins A and B. Measure resistance between J1 pins 6 and 10.

If greater than 5 ohms, repair open circuit between J1 pin 10 and J9 pin A or between J1 pin 6 and J9 pin B.
Otherwise, go to **6**.

6) J1 and J9 should still be disconnected. Move jumper to J9 pins B and C. Measure resistance between J1 pins 6 and 29.

If greater than 5 ohms, repair open circuit between J1 pin 29 and J9 pin C or between J1 pin 6 and J9 pin B.
Otherwise, go to **7**.

7) Remove jumpers from J9 and measure resistance between J1 pin 6 and all other J1 pins.

If any measurement is less than 2000 ohms, repair short circuit between J1 pin 6 and other circuit.
If all measurements are greater than 2000 ohms, go to **8**.

8) With connectors J1 and J9 disconnected and jumper wires removed, measure the resistance between J1 pin 10 and all other J1 pins.

If any measurement is less than 2000 ohms, repair short circuit between J1 pin 10 and other circuit.
If all measurements are greater than 2000 ohms, go to **9**.

9) With connectors J1 and J9 disconnected and jumper wires removed, measure the resistance between J1 pin 29 and all other J1 pins.

If any measurement is less than 2000 ohms, repair short circuit between J1 pin 29 and other circuit.
If all measurements are greater than 2000 ohms, go to **10**.

10) Replace the ECU with a unit known to be good. Turn ignition on and check diagnostic codes.

If Code 35 is still present, the first ECU was probably good. Go to **11**.

11) Check for intermittent problems with the wiring or the rack position sensor.

If problems found, repair as required.
Otherwise, no cause found for Code 35.

12) Disconnect the J12 connector. Use caution when threading plastic connector half. Crowsfoot wrench (JDG646) simplifies removal. Also remove J8 and J10 connectors if needed. Measure the resistance between J10 socket A and the following points:
a) all other J10 sockets;
b) J8 sockets A, B, C, D; and
c) chassis ground.

If any measurement is less than 2000 ohms, repair short circuit in harness as required.
If all measurements are greater than 2000 ohms, go to **13**.

13) Measure the resistance between connector J10 socket B and the following points:
a) all other J10 sockets;
b) J8 sockets A, B, C, D; and
c) chassis ground.

If any measurement is less than 2000 ohms, repair short circuit in harness as required.
If all measurements are greater than 2000 ohms, go to **14**.

14) Measure the resistance between connector J10 socket C and the following points:
a) all other J10 sockets;
b) J8 sockets A, B, C, D; and
c) chassis ground.

If any measurement is less than 2000 ohms, repair short circuit in harness as required.
If all measurements are greater than 2000 ohms, go to **18**.

15) Disconnect the J12 connector. Use caution when threading plastic connector half. Crowsfoot wrench (JDG646) simplifies removal. Also remove J10 connector if needed. Measure the resistance between J10 socket A and J12 socket 1.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to **16**.

16) Measure resistance between J10 socket B and J12 socket 6.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to **17**.

17) Measure resistance between J10 socket C and J12 socket 5.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to **18**.

18) Measure the resistance between the actuator connector pins 1 and 6.

If less than 14 ohms or greater than 26 ohms, replace the fuel injection pump.
Otherwise, go to **19**.

19) Measure the resistance between the actuator connector pins 5 and 6.

If less than 14 ohms or greater than 26 ohms, replace the fuel injection pump.
Otherwise, go to **20**.

20) Measure the resistance between the actuator connector pin 6 and the following points:
a) actuator connector pins 2, 3, 4, 7;
b) actuator housing.

If any measurement is less than 2000 ohms, replace the fuel injection pump.
If all measurements are greater than 2000 ohms, no cause found for Code 35.

CODE 36 -- RACK POSITION VOLTAGE IS TOO LOW

1) With the ignition in the "ON" position but engine not running, measure the voltage from J3 socket C (+) to J3 socket D (-).

If greater than 0.5 volt, replace the ECU.
Otherwise, go to **2**.

2) Turn ignition off. Substitute an ECU or a fuel injection pump in the system. Connectors can be swapped without removing existing part until a determination is made. Turn ignition "ON" and check codes.

If Code 36 is still present, the swapped part did not correct the problem so the original is probably OK. Swap the remaining part to remove Code 36.

CODE 37 -- FUEL TEMPERATURE INPUT IS TOO HIGH

1) Disconnect J13 connector. Measure resistance between the two sensor pins.

If greater than 50,000 ohms, replace sensor.
If between 10,000 ohms and 50,000 ohms, go to 2.
If less than 10,000 ohms, go to 3.

2) Refer to temperature vs. resistance table to see if sensor resistance corresponds to the sensor temperature.

Temperature Sensor Characteristic	
Temperature degrees C (F)	Resistance in ohms
-20 (-4)	15300
0 (32)	5840
20 (68)	2500
40 (104)	1180
60 (140)	600
80 (176)	327
100 (212)	188

If sensor resistance is higher than it should be for the current sensor temperature, replace sensor.
If sensor resistance is OK, go to 3.

3) Inspect both halves of connector J13 for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to 4.

4) Turn ignition "ON" and measure voltage from J13 socket 3 (+) to J13 socket 2 (-).

If less than 5.5 volts, go to 5.
If greater than 5.5 volts, go to 9.

5) Install a jumper wire between J13 sockets 2 and 3. With ignition "ON," check diagnostic codes.

If Code 37, go to 6.
If Code 38, go to 9.

6) Turn ignition off and disconnect J1 connector. Inspect for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to 7.

7) With jumper still installed between J13 sockets 2 and 3, measure the resistance between J1 pins 24 and 35.

If greater than 5 ohms, there is an open circuit in harness either in wire to J1 pin 24 or to J1 pin 35. Go to 12.
If less than 5 ohms, go to 8.

8) With jumper on J13 sockets 2 and 3. Reconnect the J1 connector to the ECU. Turn the ignition "ON" and check the diagnostic codes display.

If Code 37 is displayed, replace the ECU.
If Code 38 is displayed, no cause was found for the Code 37.

9) Turn ignition off and disconnect J1 connector from the ECU. Inspect for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to **10**.

10) Remove the jumper wire on the J13 connector and leave connectors J1 and J13 disconnected. Measure the resistance between J1 harness connector pin 24 and all other J1 pins.

If any measurements are less than 5 ohms, there is a short circuit in the harness between J1 pin 24 and another circuit. Go to **15**.
If all measurements are greater than 5 ohms, go to **11**.

11) Inspect the routing of the engine wiring harness from the governor, looking for any location where a possible short with another harness or device could be present.

If a problem with the harness is found, repair as required.
Otherwise, go to **8**.

12) Disconnect J9/J10 connector and inspect for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to **13**.

13) With jumper installed between J13 sockets 2 and 3, measure the resistance between J10 sockets D and F.

If greater than 5 ohms, repair open circuit between J10 and J13, either in wires to J10 socket D to J10 socket F.
If less than 5 ohms, go to **14**.

14) Install jumper wire between J9 pins D and F. Measure resistance between J1 pins 24 and 35.

If greater than 5 ohms, repair open circuit between J1 and J9, either in wire to J1 pin 24 or in wire to J1 pin 35.
If less than 5 ohms, no cause was found for Code 37.

15) Disconnect J9/J10 connector and inspect for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to **16**.

16) Measure the resistance between J1 pin 24 and all other J1 pins.

If any measurement is less than 5 ohms, repair short circuit in ECU harness between J1 pin 24 and another circuit.
If all measure greater than 5 ohms, go to **17**.

17) Inspect the engine harness looking for short circuits between J10 socket D and another circuit.

If problem found, repair as required. Otherwise, no cause found for Code 37.

CODE 38 -- FUEL TEMPERATURE INPUT IS TOO LOW

1) Disconnect J13 connector. Measure the resistance between the two temperature sensor pins.

If less than 50 ohms or less than table of resistance versus temperature indicates, replace sensor.
If greater than 50 ohms and in agreement with table of resistance versus temperature, go to 2.

Temperature Sensor Characteristic	
Temperature degrees C (F)	Resistance in ohms
-20 (-4)	15300
0 (32)	5840
20 (68)	2500
40 (104)	1180
60 (140)	600
80 (176)	327
100 (212)	188

2) Inspect both halves of connector J13 for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to 3.

3) With sensor still disconnected, turn ignition "ON" and check diagnostic codes.

If Code 37 displayed, no cause found for Code 38.
If Code 38 displayed, go to 4.

4) Disconnect J9/J10 connector and inspect for damage, corrosion, and poorly positioned pins.

If problem found with connector, repair as required.
Otherwise, go to 5.

5) With J9 and J10 still disconnected, to ignition to the "ON" position. Check diagnostic codes.

If Code 37 displayed, repair short circuit in engine harness between J10 socket D and another circuit in the harness or between J10 socket D and something external to the harness.
If Code 38 displayed, go to 6.

6) Turn ignition off and disconnect J1 connector from the ECU. Inspect both connector halves for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required.
Otherwise, go to 7.

7)Measure the resistance between the J1 connector pin 24 and all other J1 pins.

If any value is less than 5 ohms, repair short in harness between J1 pin 24 and other circuit.
If all measurements are greater than 5 ohms, go to 8.

8) Inspect ECU harness routing. Look for location where a possible short could be present.

If problem with harness found, repair as required.
Otherwise, go to 9.

9) Reconnect J1 to ECU but leave connectors J9/J10 disconnected. Turn ignition "ON" and check diagnostic codes.

If Code 38 is displayed, replace the ECU.
If Code 37 is displayed, no cause found for Code 38.

CODE 39 -- PRIMARY SPEED INPUT ERROR

1) Turn ignition off and disconnect the J9 and J10 connectors. Inspect both connectors for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connectors, repair as required.
Otherwise, go to 2.

2) Measure the resistance between J10 sockets E and F.

If less than 600 ohms, there is a short circuit in the harness or sensor. Go to 9.
If greater than 1500 ohms, there is an open circuit in the harness or sensor. Go to 12.
If measurement is between 600 and 1500 ohms, go to 3.

3) Measure resistance between J10 socket E and all other J10 sockets and between J10 socket E and chassis ground.

If any value is less than 600 ohms, repair short in harness between J10 socket E and other circuit.
If all measurements are greater than 600 ohms, go to 4.

4) Disconnect J1 at the ECU and inspect for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required.
Otherwise, go to 5.

5) With connectors J1, J9, and J10 still disconnected, install a jumper between J9 pins E and F. Measure the resistance between J1 harness connector pins 31 and 35.

If greater than 5 ohms, repair open circuit between J1 pin 31 and J9 pin E or between J1 pin 35 and J9 pin F.
If less than 5 ohms, go to 6.

6) Remove jumper from the J9 connector. Measure resistance between J1 harness connector terminal 31 and all other J1 pins.

If any value is less than 5 ohms, repair short in harness between J1 pin 31 and another circuit.
If all measurements are greater than 5 ohms, go to 7.

7) Reconnect all connectors and start engine. Check diagnostic codes.

If Code 39 is no longer displayed, no cause for the symptom found.
If Code 39 is displayed, go to 8.

8) Replace the ECU with one known to be good. Start the engine and check the diagnostic codes.

If Code 39 is no longer displayed, the ECU fixed the problem.
If Code 39 is still displayed, check for intermittent wiring/sensor problems.

9) Disconnect the J12 connector. Use caution when threading plastic connector half. Crowsfoot wrench (JDG646) simplifies removal. Inspect connector for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required.
Otherwise, go to 10.

10) With connectors J10 and J12 disconnected, measure resistance between J10 socket E and all other J10 sockets.

If any measurement is less than 5 ohms, repair short circuit in harness as required.
If all measurements are greater than 5 ohms, go to 11.

11) Measure the resistance between pump connector pins 3 and 4.

If less than 600 ohms, replace fuel injection pump.
Otherwise, no cause found for Code 39.

12) Disconnect the J12 connector. Use caution when threading plastic connector half. Crowsfoot wrench (JDG646) simplifies removal. Inspect connector for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required.
Otherwise, go to 13.

13) With connectors J10 and J12 disconnected, measure the resistance between J10 socket E and J12 socket 3.

If greater than 5 ohms, repair open circuit between J10 socket E and J12 socket 3.
If less than 5 ohms, go to 14.

14) With J10 and J12 still disconnected, measure resistance between J10 socket F and J12 socket 4.

If greater than 5 ohms, repair open circuit between J10 socket F and J12 socket 4.
If less than 5 ohms, go to 15.

15) Measure the resistance between actuator connector pins 3 and 4.

If greater than 1500 ohms, replace fuel injection pump.
If less than 1500 ohms, no cause found for Code 39.

CODE 41 -- START SIGNAL IS MISSING

1) With ignition off, disconnect J1 connector at ECU. Inspect connector, especially pin 33, for damage, corrosion, and poorly positioned terminals.

If problem found, repair as required.
Otherwise, go to 2.

2) Turn ignition switch to "START" position while monitoring voltage from J1 pin 33 (+) to chassis ground. (The engine will crank but will not start with ECU disconnected.)

If less than 9 volts, start signal is not present at the ECU. Check the condition of the starting circuit, including the battery, fuses, starter switch, and wiring. Repair as required.
If voltage measures at least 9 volts, go to 3.

3) With ignition off, reconnect J1 connector to the ECU. Disconnect J7/J8 connectors. Turn ignition to the "ON" position but do not start. Check the diagnostic code display.

If Code 41 is not present, go to 4.
If Code 41 is present, go to 6.

4) With connectors J7/J8 still disconnected, put ignition switch in the "START" position for at least 2 seconds. (Engine will not start with J7/J8 disconnected.) Check the diagnostic code display. Ignore Code 32.

If Code 41 is present, replace the ECU.
Otherwise, go to 5.

5) Reconnect connectors J7/J8. With ignition in "ON" position, check stored codes for Code 41. Make written note of all stored codes. Then clear stored codes. Operate engine at various speeds in order to generate Code 41.

If Code 41 reappears, there is probably intermittent power to the ECU. Look for poor power or ground connections between the battery and the ECU.
If Code 41 does not reappear, no cause for Code 41 found but system is corrected.

6) Check the governor harness for open or short circuits and interference with other devices.

If problem is found with governor harness, repair as required.
Otherwise, replace the ECU.

CODE 42 -- ENGINE IS OVERSPEEDING

1) Check with the vehicle operator to determine if Code 42 might have been caused by rapid down-shifting, or by coasting downhill while towing a heavy implement, wagon, etc.

If Code 42 was caused by operating conditions, take precautions that overspeeding does not reoccur.
If the symptom was not caused by operating conditions, go to 2.

2) Disconnect J12 connector. Use caution when threading plastic connector. Crowsfoot wrench (JDG646) simplifies removal. Check the connector for looseness, damage, corrosion, and poorly positioned pins.

If a problem with connector is found, repair as required. The J12 connector should be tightened to 7 - 15 lb-ft during installation.
If connector is OK, go to 3.

3) Replace the fuel injection pump with one known to be good.

If Code 42 still is present, look for intermittent wiring problems in the governor harness or intermittent failure within the actuator housing.

CODE 43 -- PWM THROTTLE INPUT ERRATIC, TOO SHORT, TOO LONG

The PWM throttle input originates from another system and can be connected to the governor system in various ways depending on the application. The service technician should refer to the machine technical manual for details of the PWM throttle harness connections. However, the following procedure is given in general terms to assist in diagnosing this system.

1) Check the signal source system for the if possible to verify that it is functioning properly.

If problem found, repair as required.
Otherwise, go to 2.

2) With ignition off, disconnect J1 connector at the ECU. Inspect the J1 connector, especially terminal 27, for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair are required.
Otherwise, go to 3.

3) Obtain wiring information on this application and determine the source of the PWM throttle signal. Locate this source and inspect the connector for damage, corrosion, and poor contact positioning.

If problem is found with the PWM source connector, repair as required.
Otherwise, go to 4.

4) Measure the resistance between the PWM source connector and J1 connector pin 27.

If greater than 5 ohms, repair open circuit as required.
If less than 5 ohms, go to 5.

5) Measure the resistance between J1 pin 27 and all other J1 pins and between J1 pin 27 and all other pins on the signal source connector.

If any measurement is less than 5 ohms, repair short circuit as required.
If all measurements are greater than 5 ohms, go to 6.

6) Reconnect all connectors, start engine, and operate system. Check diagnostic codes.

If Code 43 is no longer displayed, no cause was found for symptom.
If Code 43 is still displayed, go to 7.

7) Replace the ECU with one known to be good. Start the engine and check the diagnostic codes.

If Code 43 is no longer displayed, the ECU fixed the problem.
If Code 43 is still displayed, check the signal source system for problems.

CODE 44 -- AUXILIARY SPEED INPUT ERROR

1) Inspect sensor installation. Verify sensor is fully inserted and secured in mounting hole.

If problem found with sensor mounting, repair as required.
Otherwise, go to **2**.

2) Turn ignition off and disconnect J2 connector at speed sensor. Inspect connector for damage, corrosion, and poorly positioned pins and sockets.

If problem found with connector, repair as required.
Otherwise, go to **3**.

3) Measure resistance between sensor connector terminals (results assume Deere RE12180 sensor).

If less than 300 ohms or greater than 700 ohms, replace sensor.
If between 300 and 700 ohms, go to **4**.

4) Disconnect J7/J8 and J9/J10 connectors. Inspect terminals of these connectors for damage, corrosion, and poorly positioned pins and sockets.

If problem found with connectors, repair as required.
Otherwise, go to **5**.

5) With J2, J7/J8, and J9/J10 disconnected, measure the resistance between J8 socket D and all other J8 and J10 sockets.

If any measurement is less than 5 ohms, repair short circuit in harness as required.
If all measurement are greater than 5 ohms, go the **6**.

6) Measure the resistance between J2 pin A and J8 socket D.

If greater than 5 ohms, repair open circuit between measured points as required.
If less than 5 ohms, go to **7**.

7) Measure the resistance between J2 pin B and J10 socket F.

If greater than 5 ohms, repair open circuit between measured points as required.
If less than 5 ohms, go to **8**.

8) Disconnect J1 connector at the ECU. Inspect both connector halves for damage, corrosion, and poorly positioned terminals.

If problem found with connector, repair as required.
Otherwise, go to **9**.

9) With connectors J1, J7/J9, and J9/J10 disconnected, install a jumper between J7 pin D and J9 pin F. Measure the resistance between J1 harness connector pin 9 and pin 35.

If greater than 5 ohms, repair open circuit between J1 pin 9 and J7 pin D or between J1 pin 35 and J9 pin F.
If less than 5 ohms, go to **10**.

10) Remove the jumper from J7 and J9. Measure the resistance between J1 connector pin 9 and all other J1 pins.

If any measurement is less than 5 ohms, repair short circuit between J1 pin 9 and another circuit.
If all measurements are greater than 5 ohms, go to **11**.

11) Reconnect all connectors and start the engine. Allow engine to run for several minutes and then check diagnostic codes.

If Code 44 is no longer present, no cause was found for the symptom.
If Code 44 is still displayed, go to 12.

12) Replace the ECU with one known to be good. Start the engine and check the diagnostic codes.

If Code 44 is no longer displayed, the ECU fixed the problem.
If Code 44 is still displayed, check for intermittent wiring/sensor problems.

CODE 47 -- DE-RATED TORQUE CURVE IS SELECTED

1) If the engine has not been intentionally de-rated, look for causes for increased air intake temperature. Inspect the air intake system to make sure there are no leaks or restrictions. Check the radiator fins for clogging.

If problem with air intake system found, repair as required. Otherwise, no cause found for Code 47.

CODE 71 -- DIAGNOSTIC CODES OUTPUT SIGNAL IS STUCK HIGH

1) Turn ignition off. Disconnect J1 connector and inspect for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connector, repair as required.
Otherwise, go to 2.

2) Uncap or disconnect J4 connector. Inspect for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connector, repair as required.
Otherwise, go to 3.

3) With ignition OFF, measure resistance between J1 pin 14 and all other pins of the J1 connector.

If any measurement is less than 5 ohms, repair short between connector J1 pin 14 and other circuit.
If all measurements are greater than 5 ohms, go to 4.

4) Measure the resistance between J1 pin 14 and J4 socket D.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to 5.

5) Turn ignition to "ON" position. Measure voltage between J1 pin 1 (+) and J1 pin 19 (-).

If less than 9 volts, check condition of starting circuit, including the battery, fuses, starter switch, and wiring. Repair as required.
If voltage measures at least 9 volts, go to 6.

6) Replace ECU with a unit known to be good. Check diagnostic codes.

If Code 71 still displayed, no cause found.

CODE 72 -- DIAGNOSTIC CODES OUTPUT SIGNAL IS STUCK LOW

1) Turn ignition off and disconnect J1 connector at ECU. Inspect connector for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connector, repair as required.
Otherwise, go to 2.

2) Uncap/disconnect J4 connector. Inspect for damage, corrosion, and poorly positioned sockets.

If problem found with connector, repair as required.
Otherwise, go to 3.

3) With ignition off, measure resistance between J1 pin 14 and all other pins of the J1 connector.

If any measurement is less than 5 ohms, repair short between connector J1 pin 14 and other circuit.
If all measurements are greater than 5 ohms, go to 4.

4) Measure the resistance between J1 pin 14 and J4 socket D.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to 5.

5) Turn ignition to "ON" position. Measure voltage between J1 pin 1 (+) and J1 pin 19 (-).

If less than 9 volts, check condition of the starting circuit (battery, fuses, starter switch, wiring). Repair as required.
If voltage measures at least 9 volts, go to 6.

6) Replace ECU with a unit known to be good. Check diagnostic codes.

If Code 72 still displayed, no cause found.

CODE 73 -- FUEL FLOW/THROTTLE OUTPUT SIGNAL IS STUCK HIGH

1) Turn ignition off and disconnect J1 connector at ECU. Inspect connector for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connector, repair as required.
Otherwise, go to 2.

2) Uncap/disconnect J4 connector. Inspect for damage, corrosion, and poorly positioned sockets.

If problem found with connector, repair as required.
Otherwise, go to 3.

3) With ignition off, measure resistance between J1 pin 7 and all other pins of the J1 connector.

If any measurement is less than 5 ohms, repair short between connector J1 pin 7 and another circuit.
If all measurements are greater than 5 ohms, go to 4.

4) Measure the resistance between J1 pin 7 and J4 socket E.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to 5.

5) Turn ignition to "ON" position. Measure voltage between J1 pin 1 (+) and J1 pin 19 (-).

If less than 9 volts, check condition of starting circuit, including the battery, fuses, starter switch, and wiring. Repair as required.
If voltage measures at least 9 volts, go to 6.

6) Replace ECU with a unit known to be good. Check diagnostic codes.

If Code 73 still displayed, no cause found.

CODE 74 -- FUEL FLOW/THROTTLE OUTPUT SIGNAL IS STUCK LOW

1) Turn ignition off and disconnect J1 connector at ECU. Inspect connector for damage, corrosion, and poorly positioned pins or sockets.

If problem found with connector, repair as required.
Otherwise, go to 2.

2) Uncap/disconnect J4 connector. Inspect for damage, corrosion, and poorly positioned sockets.

If problem found with connector, repair as required.
Otherwise, go to 3.

3) With ignition off, measure resistance between J1 pin 7 and all other pins of the J1 connector.

If any measurement is less than 5 ohms, repair short between connector J1 pin 7 and another circuit.
If all measurements are greater than 5 ohms, go to 4.

4) Measure the resistance between J1 pin 7 and J4 socket E.

If greater than 5 ohms, repair open circuit as required.
Otherwise, go to 5.

5) Turn ignition to "ON" position. Measure voltage between J1 pin 1 (+) and J1 pin 19 (-).

If less than 9 volts, check condition of starting circuit, including the battery, fuses, starter switch, and wiring. Repair as required.
If voltage measures at least 9 volts, go to 6.

6) Replace ECU with a unit known to be good. Check diagnostic codes.

If Code 74 still displayed, no cause found.

ENGINE HAS LOW POWER

Throttle adjustment OK?
YES NO
└─Adjust throttle

Parasitic load on engine (hydraulic implement engaged, etc.)?
NO YES
└─Remove parasitic load.

ECU de-rating engine?
NO YES
└─See Code 47 on page 21.

Fuel quality problems?
NO YES
└─Drain problem fuel.
Refill tank with clean fuel of proper grade

Fuel supply pump pressure OK?
YES NO
└─Check for:
Fuel level in fuel tank
Fuel tank shut-off valve
Hand primer left up or not secured
Air in the fuel
Plugged fuel supply pump filter
Plugged fuel tank vent
Supply pump fuel line restriction
Incorrect supply pump mounting
Faulty supply pump

High pressure fuel delivery OK?
YES NO
└─Check for:
Air in the fuel
Plugged fuel filter
Faulty fuel check valve assembly
Supply pump to injection pump line restriction
Plugged fuel return

Fuel injection nozzles OK?
YES NO
└─Replace defective nozzles

└─Check for:
Improper fuel pump timing
Improper injection pump calibration
Insufficient turbocharger boost

ENGINE WILL NOT START OR STARTS AND THEN DIES

Battery voltage to ECU?

```
YES      NO
 |        └─Check for:
 |             Discharged battery
 |             Blown starting circuit fuse
 |             Damaged ECU harness
 |             Defective battery
 |             Corroded cable
 |             Faulty starter switch
 |
```

Possible problem with rack position and/or actuator solenoid --follow diagnostic sequence for Codes 32, 34, 35, and 36.

ENGINE OVERSPEEDS

Possible primary speed input error--follow diagnostic sequence suggested for Code 39.

ENGINE OPERATES ERRATICALLY

ECU de-rating engine?

```
NO       YES
 |        └─See Code 47 on page 21.
 |
```

Lubricating oil correct viscosity?

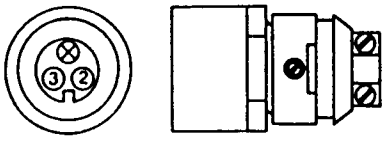
```
YES      NO
 |        └─Change engine oil.
 |
```

Fuel shut-off solenoid operating correctly?

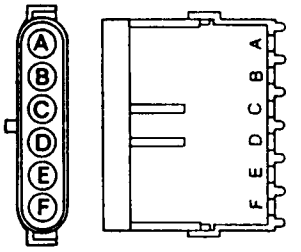
```
YES      NO
 |        └─Check for:
 |             Poor electrical connection at solenoid
 |             Low voltage to solenoid
 |             Defective shut-off solenoid
 |
```

Check for:

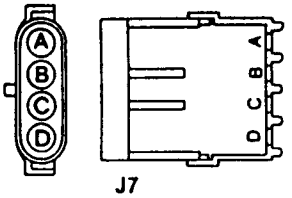
- Problem with rack position and/or actuator solenoid--follow diagnostic sequence suggested for Codes 32, 34, 35, and 36.
- Primary speed input error--follow diagnostic sequence suggested for Code 39.
- Primary throttle problems--follow diagnostic sequence suggested for Codes 11 and 12.
- Faulty fuel temperature sensor--follow diagnostic sequence suggested for Codes 37 and 38.



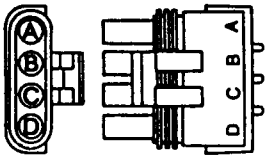
Fuel Temperature Sensor Connector
J13



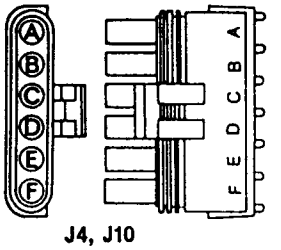
J5, J9



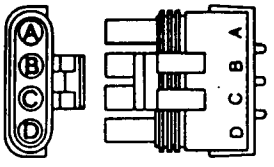
J7



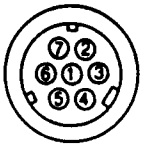
J8



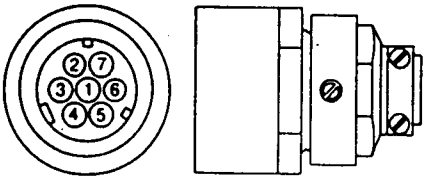
J4, J10



Diagnostic Connector
J3

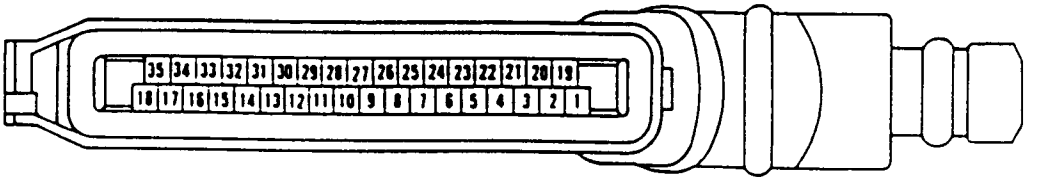


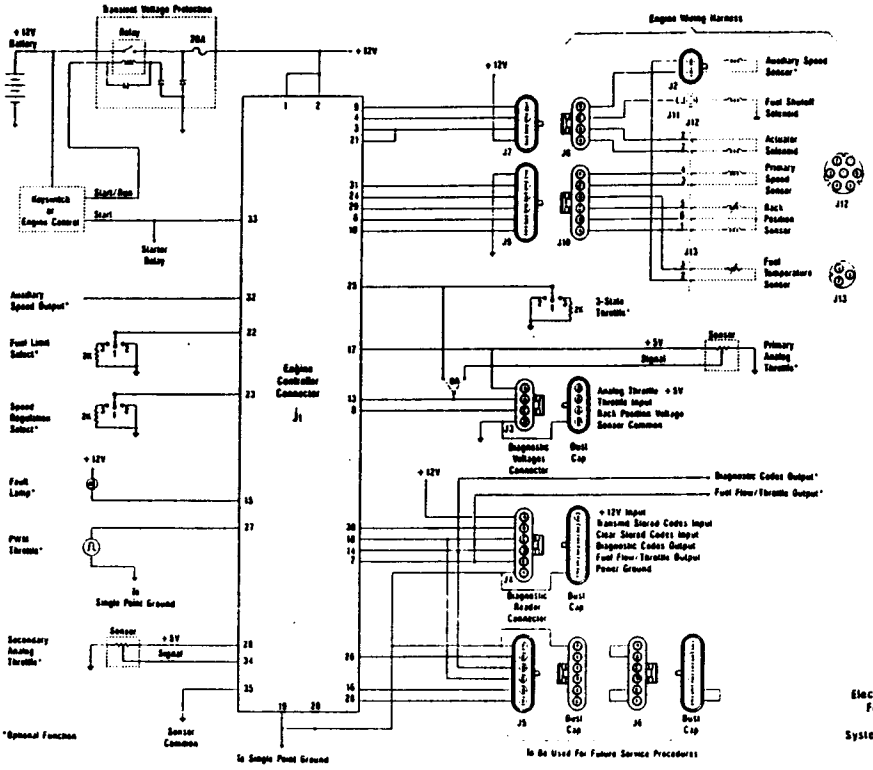
Actuator Connector
(Actuator Side)



Actuator Connector
(Harness Side)
J12

ECU Connector
J1





Robert Bosch
Electronically Controlled
Fuel Injection System

System Wiring Schematic

Appendix D

Knowledge Base Representation

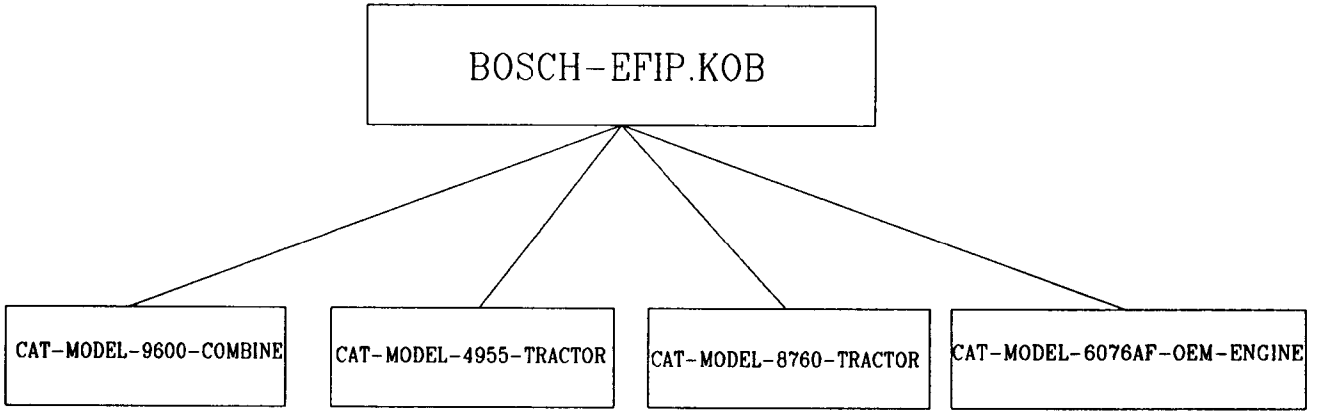


Figure 33: Robert Bosch KOB Level Tree Structure

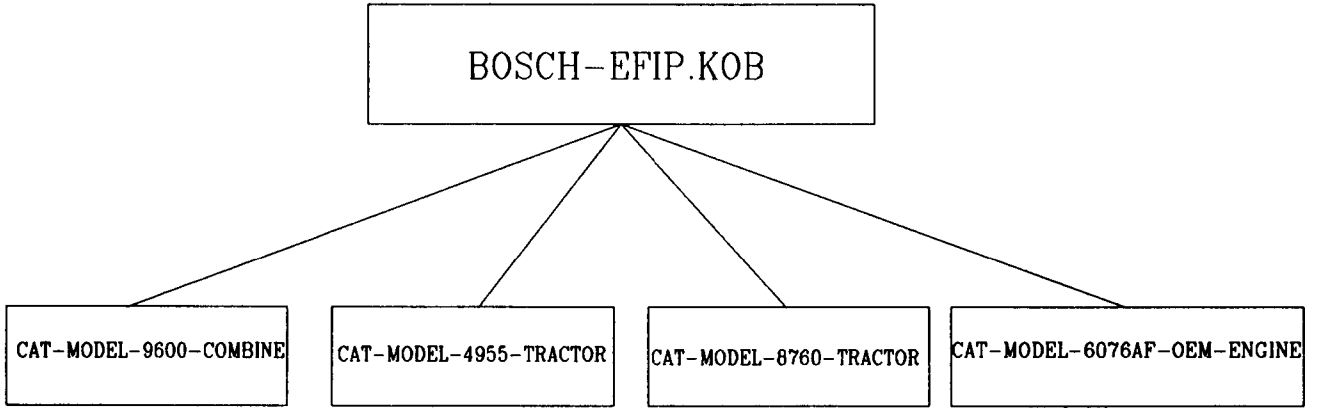


Figure 33: Robert Bosch KOB Level Tree Structure

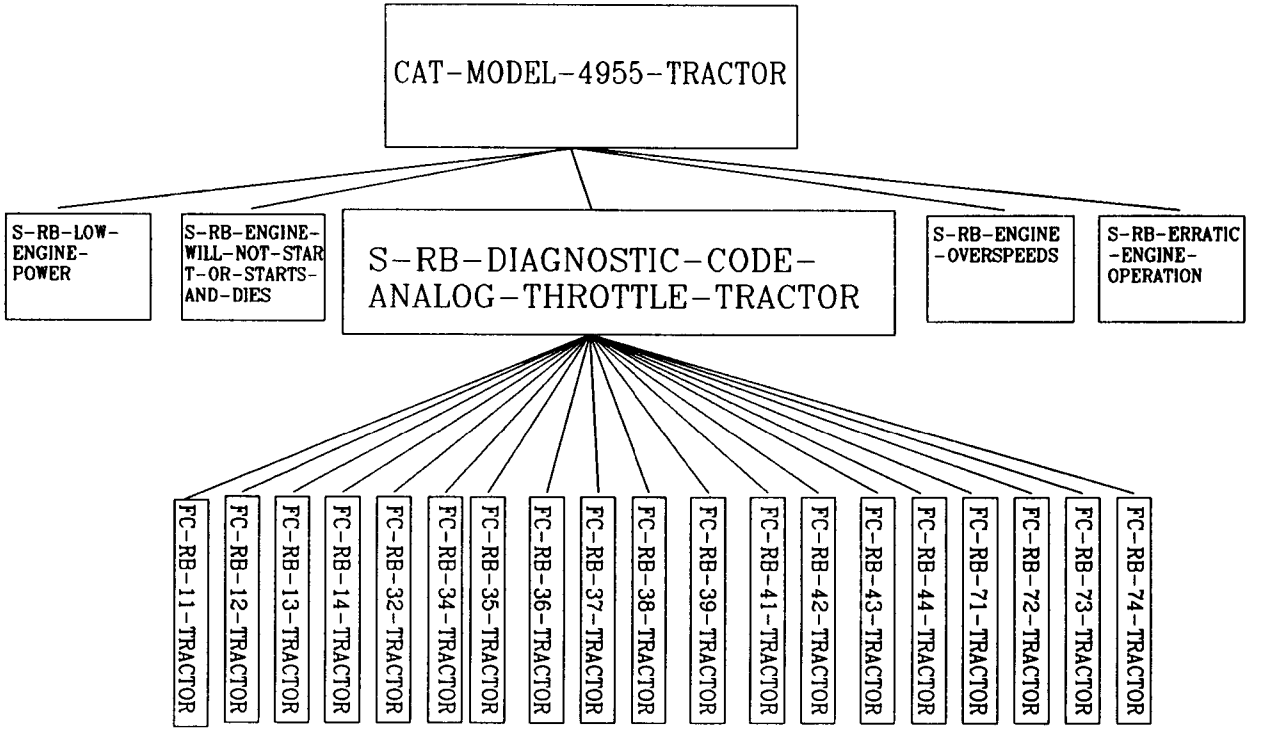


Figure 34: 4955 Tractor Category Level Tree Structure

Figure 35: Code 32 Symptom Level Tree Structure

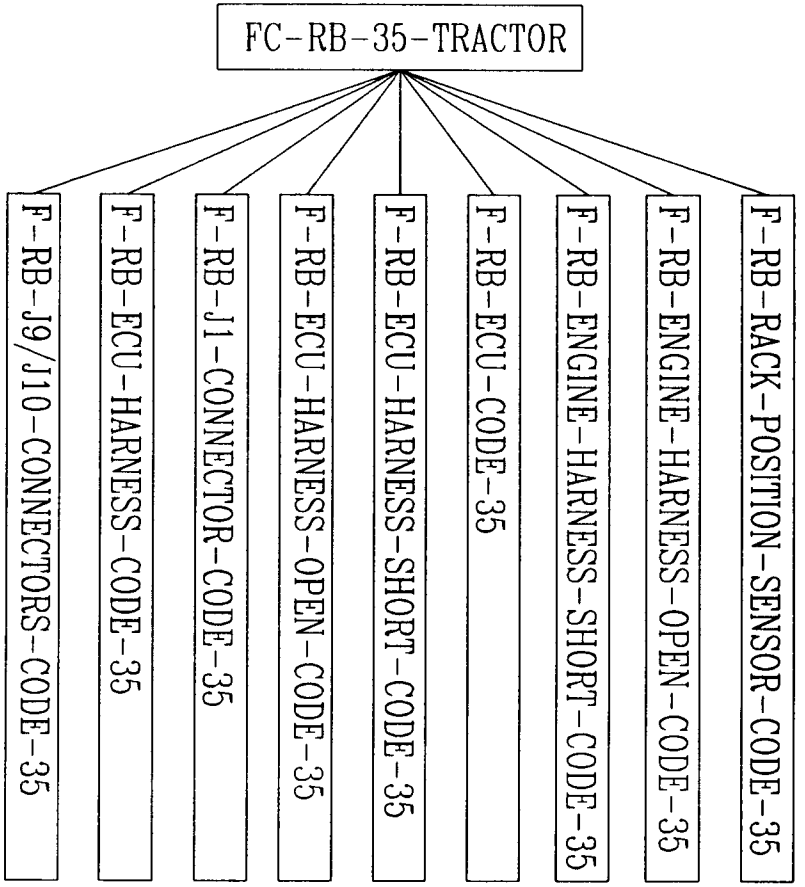


Figure 36: Code 35 Symptom Level Tree Structure

Figure 37: Code 37 Symptom Level Tree Structure

Appendix E

Details of Knowledge Base

EFIP.KB

Files: BOSCH-EFIP.KOB#>

Start-up Message:

Welcome to the John Deere Electronic Fuel Injection System Advisor.

Session Questions: T-WARNINGS
Condition: *NO-VALUE*

Diagnosis Questions: *NO-VALUE*

Symptom Order for Investigation: *NO-VALUE*

Banner Text: ELECTRONIC FUEL INJECTION SYSTEM ADVISOR

System Prompt: "Select the engine application:"

Problem Message: *NO-VALUE*

Problems Message: *NO-VALUE*

Quit Warning Message: *NO-VALUE*

Unattached Local Objects: T-THIS-IS-A-DUMMY

Author: RUYLE

Date Created: "1-Dec-1989 13:09:15 CST"

Date Last Modified: "2-Feb-1990 14:40:40 CST"

Changes Made: *NO-VALUE*

Comment: *NO-VALUE*

Source: *NO-VALUE*

Figure 38: Example of KB Object

BOSCH-EFIP.KOB

Top Level Global Objects: CAT-MODEL-9600-COMBINE
CAT-MODEL-4955-TRACTOR
CAT-MODEL-8760-TRACTOR
CAT-MODEL-6076AF-OEM-ENGINE

Unattached Local Objects: T-EFIP-DUMMY
J-J1
T-J12
T-J13
T-WIRING
T-INTERMITTENT-ANALOG
T-INTERMITTENT
T-ANALOG

Date Last Modified: "2-Mar-1990 10:55:25 CST"

Date Created: "1-Dec-1989 14:17:10 CST"

Author: "RUYLE"

Figure 39: Example of KOB Object

CAT-MODEL-4955-TRACTOR

Object Type: CATEGORY

Description: "Model 4955 Tractor"

Has Symptoms: S-RB-DIAGNOSTIC-CODE-ANALOG-THROTTLE-TRACTOR
S-RB-LOW-ENGINE-POWER
S-RB-ENGINE-WILL-NOT-START-OR-STARTS-AND-DIES
S-RB-ENGINE-OVERSPEEDS
S-RB-ERRATIC-ENGINE-OPERATION

Results Restrictions: *NO-VALUE*

Symptoms Prompt: "Select the current symptom(s):"

Author: "RUYLE"

Date Created: "1-Dec-1989 17:10:05 CST"

Date Last Modified: "3-Mar-1990 06:42:50 CST"

Changes Made: *NO-VALUE*

Source: *NO-VALUE*

Comment: *NO-VALUE*

Figure 40: Example of Category Object

S-RB-DIAGNOSTIC-CODE-ANALOG-THROTTLE-TRACTOR

Object Type: SYMPTOM

Description: "Diagnostic code displayed"

Caused By:
FC-RB-11-TRACTOR FC-RB-12-TRACTOR FC-RB-13-TRACTOR
FC-RB-14-TRACTOR FC-RB-32-TRACTOR FC-RB-34-TRACTOR
FC-RB-35-TRACTOR FC-RB-36-TRACTOR FC-RB-37-TRACTOR
FC-RB-38-TRACTOR FC-RB-39-TRACTOR FC-RB-41-TRACTOR
FC-RB-42-TRACTOR FC-RB-43-TRACTOR FC-RB-44-TRACTOR
FC-RB-71-TRACTOR FC-RB-72-TRACTOR FC-RB-73-TRACTOR
FC-RB-74-TRACTOR
Expect Multiple Causes: *NO-VALUE*
Are Causes Exhaustive: YES

Caused By Rules:

REM-RB-11-TRACTOR	**Query Allowed:**	YES
REM-RB-12-TRACTOR	**Query Allowed:**	YES
REM-RB-13-TRACTOR	**Query Allowed:**	YES
REM-RB-14-TRACTOR	**Query Allowed:**	YES
REM-RB-32-TRACTOR	**Query Allowed:**	YES
REM-RB-34-TRACTOR	**Query Allowed:**	YES
REM-RB-35-TRACTOR	**Query Allowed:**	YES
REM-RB-36-TRACTOR	**Query Allowed:**	YES
REM-RB-37-TRACTOR	**Query Allowed:**	YES
REM-RB-38-TRACTOR	**Query Allowed:**	YES
REM-RB-39-TRACTOR	**Query Allowed:**	YES
REM-RB-41-TRACTOR	**Query Allowed:**	YES
REM-RB-42-TRACTOR	**Query Allowed:**	YES
REM-RB-43-TRACTOR	**Query Allowed:**	YES
REM-RB-44-TRACTOR	**Query Allowed:**	YES
REM-RB-71-TRACTOR	**Query Allowed:**	YES
REM-RB-72-TRACTOR	**Query Allowed:**	YES
REM-RB-73-TRACTOR	**Query Allowed:**	YES
REM-RB-74-TRACTOR	**Query Allowed:**	YES

Can Multiple Rules Fire: YES
Query Allowed: YES

Diagnosis Questions: Q-RB-DIAGNOSTIC-CODE-TRACTOR
Condition: *NO-VALUE*

Author: "RUYLE"
Date Created: "2-Dec-1989 09:36:15 CST"
Date Last Modified: "3-Mar-1990 11:19:20 CST"
Changes Made: *NO-VALUE*
Source: *NO-VALUE*
Comment: *NO-VALUE*

Figure 41: Example of Symptom Object

FC-RB-32-TRACTOR

Object Type: FAILURE-CLASS

Description: "Actuator solenoid circuit fault"

Caused By: F-RB-J7/J8-CONNECTORS-CODE-32
F-RB-ACTUATOR-CIRCUIT-CODE-32
F-RB-J1-CODE-32
F-RB-ECU-OPEN-CIRCUIT-1-CODE-32
F-RB-ECU-OPEN-CIRCUIT-2-CODE-32
F-RB-ECU-SHORT-CIRCUIT-CODE-32
F-RB-LOW-VOLTAGE-TO-ACTUATOR-CODE-32
F-RB-ACTUATOR-SOLENOID-1-CODE-32
F-RB-ECU-CODE-32
F-RB-J12-CONNECTOR-1-CODE-32
F-RB-HARNESS-SHORT-CODE-32
F-RB-ACTUATOR-SOLENOID-2-CODE-32
F-RB-J12-CONNECTOR-2-CODE-32
F-RB-HARNESS-OPEN-CODE-32
F-RB-ACTUATOR-SOLENOID-3-CODE-32
Expect Multiple Causes: *NO-VALUE*

Caused By Rules: *NO-VALUE*
Can Multiple Rules Fire: *NO-VALUE*
Query Allowed: *NO-VALUE*
Has Tests: Q-RB-DIAGNOSTIC-CODE
Confirming Results: CODE-32
Confirming Results rules: *NO-VALUE
Disconfirming Results: NOT-USED
Disconfirming Results rules: *NO-VALUE*
Has Test Rules: *NO-VALUE*
Can Multiple Rules Fire: *NO-VALUE*
Query Allowed: *NO-VALUE*

Author: RUYLE

Date Created: "8-Dec-1989 06:44:50 CST"

Date Last Modified: "4-Mar-1990 19:18:20 CST"

Changes Made: *NO-VALUE*

Source: *NO-VALUE*

Comment: *NO-VALUE*

Figure 42: Example of Failure Class Object

F-RB-J1-CODE-32

Object Type: FAILURE

Description: Damaged 35-pin ECU connector

Caused by: *NO-VALUE*

Expect Multiple Causes: *NO-VALUE*

Are Causes Exhaustive: *NO-VALUE*

Caused by Rules: *NO-VALUE*

Can Multiple Rules Fire: *NO-VALUE*

Query Allowed: *NO-VALUE*

Has Tests: T-RB-J1-CONNECTOR-CODE-32

Confirming Results: PROBLEM-FOUND-WITH-CONNECTOR

Confirming Results Rules: *NO-VALUE

Disconfirming Results: NOT-USED

Disconfirming Results Rules: *NO-VALUE*

Has Test Rules: *NO-VALUE*

Can Multiple Rules Fire: *NO-VALUE*

Query Allowed: *NO-VALUE*

Must Confirm Repair: NO

Verify When Finished: NO

Author: RUYLE

Date Created: "22-Dec-1989 08:04:35 CST"

Date Last Modified: "16-Feb-1990 9:02:50 CST"

Changes Made: *NO-VALUE*

Source: *NO-VALUE*

Comment: *NO-VALUE*

Figure 43: Example of Failure Object

T-RB-J1-CONNECTOR-CODE-32

Object Type: TEST
Description: "Check the condition of 35-pin ECU connector"
Possible Results: 35-PIN-ECU-CONNECTOR-OK
PROBLEM-FOUND-WITH-CONNECTOR
Possible Results Rules: *NO-VALUE*
Can Multiple Rules Fire: *NO-VALUE*
Query Allowed: *NO-VALUE*
Preprompt: The ECU is connected to the rest of the system through only one connector. The connector is rectangular with 35 pins total--one row of 18 pins and one row of 17 pins. Pin numbers are not labeled. Therefore, the graphics (seen by pressing the F5 key) must be used to identify pin numbers.¦¦The connector is disconnected by releasing the spring latch beneath the wire exit end of the connector and pivoting the wire end away from the controller. This will allow the tip of the other end of the connector to be released from under the locking lip of the controller housing.¦¦Attaching the connector is done by reversing these steps. The tip of the connector is inserted beneath the locking lip of the controller housing. Then the connector is pivoted toward the controller until the spring latch locks the wire end of the connector in place.
Prompt: Turn key switch OFF. Disconnect 35-pin connector at the ECU. Inspect both connector halves for damage, corrosion, and poorly positioned pins or sockets.
Picture: RBJ1.GRI
How: With key switch OFF, disconnect the 35-pin connector at the ECU. Inspect both connector halves for damage, corrosion, and poorly positioned pins or sockets.
How Picture: RBJ1.GRI
Warning: Care should be used during diagnostic procedures to avoid damaging the pins of the 35-pin ECU connector. Probes should only be touched against pins (not poked into them) or damage will result.
Use Unknown: NO
Multiple Valued: NO
Results Restrictions: *NO-VALUE*
Test Family Preview Message: *NO-VALUE*
Validate KBD Entry: *NO-VALUE*
External Data Source: *NO-VALUE*
Author: RUYLE
Date Created: "22-Dec-1989 08:33:40 CST"
Date Last Modified: "16-Feb-1990 9:06:25 CST"
Changes Made: *NO-VALUE*
Source: *NO-VALUE*
Comment: *NO-VALUE*

Figure 44: Example of Test Object

Q-RB-PRIMARY-ANALOG-THROTTLE-SENSOR-CODE-11

Object Type: QUESTION

Description: "Check primary analog throttle sensor adjustment"

Possible Results: CODE-11-ALWAYS-PRESENT
CODE-11-ONLY-PRESENT-AT-UPPER-PORTION-OF-THROTTLE-TRAVEL
Possible Results Rules: *NO-VALUE*
Can Multiple Rules Fire: *NO-VALUE*
Query Allowed: *NO-VALUE*

Preprompt: If Code 11 is intermittent (on-again, off-again), the throttle sensor (or sensors) may need to be adjusted. An intermittent code may also mean that something is beginning to fail. Some failures are related to vibration. Because of the cost of replacing the injection pump, the condition of the wiring and connectors should be checked first.¦¦When diagnosing electrical system problems, take special note of the condition of wiring and connectors since many problems originate here. Check first for disconnected, loose, or dirty connectors. Inspect connector vicinity looking for wires that have pulled out of connector terminals, damaged connectors, poorly positioned terminals, and corroded or damaged terminals. Look for broken wires, damaged splices, and wire-to-wire shorts.

Prompt: Turn key switch ON and slowly move throttle lever through its entire travel range noting the status of the diagnostic codes.¦What is displayed as throttle is moved through its entire range of travel?

Multiple Valued: NO

Use Unknown: NO

Validate KBD Entry: *NO-VALUE*
Results Restrictions: *NO-VALUE*
Test Family Preview Message: *NO-VALUE*

Author: RUYLE
Date Created: "12-Dec-1989 10:43:55 CST"
Date Last Modified: "19-Jan-1990 22:32:15 CST"
Changes Made: *NO-VALUE*
Source: *NO-VALUE*
Comment: *NO-VALUE*

Figure 45: Example of Question Object

RP-J1-CONNECTOR-CODE-32

Object Type: REPAIR

Description: Repair or replace 35-pin ECU connector

Picture: RBJ1.GRI

How: "Repair or replace the 35-pin ECU connector as required."

How Picture: RBJ1.GRI

Warning: *NO-VALUE*

Author: RUYLE

Date Created: "22-Dec-1989 10:18:00 CST"

Date Last Modified: "2-Mar-1990 13:13:15 CST"

Changes Made: *NO-VALUE*

Source: *NO-VALUE*

Comment: *NO-VALUE*

Figure 46: Example of Repair Object

F-RB-J7/J8-CONNECTORS-CODE-32
T-RB-J7/J8-CONNECTORS-CODE-32
RP-RB-J7/J8-CONNECTORS-CODE-32
F-RB-ACTUATOR-CIRCUIT-CODE-32
T-RB-ACTUATOR-SOLENOID-CIRCUIT-CHECK-CODE-32
DP-RB-ACTUATOR-SOLENOID-CIRCUIT-CHECK-CODE-32
T-RB-ACTUATOR-SOLENOID-CIRCUIT-CHECK-CODE-32
F-RB-J1-CODE-32
T-RB-J1-CONNECTOR-CODE-32
RP-RB-J1-CONNECTOR-CODE-32
F-RB-ECU-OPEN-CIRCUIT-1-CODE-32
T-RB-ECU-HARNESS-OPEN-CIRCUIT-CHECK-1-CODE-32
RP-RB-REPAIR-ECU-OPEN-1-CODE-32
F-RB-ECU-OPEN-CIRCUIT-2-CODE-32
T-RB-ECU-HARNESS-OPEN-CIRCUIT-CHECK-2-CODE-32
RP-RB-REPAIR-ECU-OPEN-2-CODE-32
F-RB-ECU-SHORT-CIRCUIT-CODE-32
T-RB-ECU-HARNESS-SHORT-CIRCUIT-CHECK-CODE-32
RP-RB-REPAIR-ECU-SHORT-CODE-32
F-RB-LOW-VOLTAGE-TO-ACTUATOR-CODE-32
T-RB-ACTUATOR-12V-CHECK-CODE-32
RP-RB-BATTERY-VOLTAGE-CODE-32
F-RB-ACTUATOR-SOLENOID-1-CODE-32
T-RB-RACK-MOVEMENT-CHECK-CODE-32
RP-RB-REPLACE-INJECTION-PUMP-CODE-32
F-RB-ECU-CODE-32
T-RB-ECU-CHECK-CODE-32
RP-RB-REPLACE-ECU
RP-RB-OTHER-CODES-CODE-32
REM-RB-REPLACE-ECU-CODE-32
REM-RB-OTHER-CODES-CODE-32
F-RB-J12-CONNECTOR-1-CODE-32
T-RB-ACTUATOR-CONNECTOR-CHECK-CODE-32
RP-RB-J12-CONNECTOR-CODE-32
F-RB-HARNESS-SHORT-CODE-32
T-RB-HARNESS-SHORT-CHECK-CODE-32
RP-RB-REPAIR-HARNESS-SHORT-CODE-32
F-RB-ACTUATOR-SOLENOID-2-CODE-32
T-RB-ACTUATOR-SOLENOID-CHECK-CODE-32
RP-RB-REPLACE-INJECTION-PUMP-CODE-32
F-RB-J12-CONNECTOR-2-CODE-32
T-RB-ACTUATOR-CONNECTOR-CHECK-CODE-32
RP-RB-J12-CONNECTOR-CODE-32
F-RB-HARNESS-OPEN-CODE-32
T-RB-HARNESS-OPEN-CHECK-1-CODE-32
T-RB-HARNESS-OPEN-CHECK-2-CODE-32
RP-RB-REPAIR-HARNESS-OPEN-CODE-32
F-RB-ACTUATOR-SOLENOID-3-CODE-32
T-RB-ACTUATOR-SOLENOID-CHECK-CODE-32
RP-RB-REPLACE-INJECTION-PUMP-CODE-32

Figure 47: List of Code 32 Objects

```
F-RB-J9/J10-CONNECTORS-CODE-35
   T-RB-J9/J10-CONNECTORS-CODE-35
   RP-RB-J9/J10-CONNECTORS-CODE-35
F-RB-ECU-HARNESS
   T-RB-ENGINE-CIRCUIT-CHECK-1-CODE-35
   DP-RB-ENGINE-CIRCUIT-CHECK-CODE-35
     T-RB-ENGINE-CIRCUIT-CHECK-1-CODE-35
   DP-RB-ENGINE-CIRCUIT-CHECK-2-CODE-35
     T-RB-ENGINE-CIRCUIT-CHECK-2-CODE-35
     DP-RB-ENGINE-CIRCUIT-CHECK-3-CODE-35
       T-RB-ENGINE-CIRCUIT-CHECK-3-CODE-35
F-RB-J1-CONNECTOR-CODE-35
   T-RB-J1-CONNECTOR-CODE-35
   RP-RB-J1-CONNECTOR-CODE-35
   DP-RB-J1-CODE-35
     T-RB-J1-CONNECTOR-CODE-35
F-RB-ECU-HARNESS-OPEN-CODE-35
   T-RB-ECU-HARNESS-OPEN-CHECK-1-CODE-35
   T-RB-ECU-HARNESS-OPEN-CHECK-2-CODE-35
   RP-RB-ECU-HARNESS-OPEN-CODE-35
F-RB-ECU-HARNESS-SHORT-CODE-35
   T-RB-ECU-HARNESS-SHORT-CHECK-1-CODE-35
   T-RB-ECU-HARNESS-SHORT-CHECK-2-CODE-35
   T-RB-ECU-HARNESS-SHORT-CHECK-3-CODE-35
   RP-RB-ECU-HARNESS-SHORT-CODE-35
F-RB-ECU-CODE-35
   Q-RB-ECU-CHECK-CODE-35
   RP-RB-ECU-REPLACEMENT-CODE-35
F-RB-ENGINE-HARNESS-SHORT-CODE-35
   T-RB-ENGINE-HARNESS-SHORT-CHECK-1-CODE-35
   T-RB-ENGINE-HARNESS-SHORT-CHECK-2-CODE-35
   T-RB-ENGINE-HARNESS-SHORT-CHECK-3-CODE-35
   RP-RB-ENGINE-HARNESS-SHORT-CODE-35
F-RB-ENGINE-HARNESS-OPEN-CODE-35
   T-RB-ENGINE-HARNESS-OPEN-CHECK-1-CODE-35
   T-RB-ENGINE-HARNESS-OPEN-CHECK-2-CODE-35
   T-RB-ENGINE-HARNESS-OPEN-CHECK-3-CODE-35
   RP-RB-ENGINE-HARNESS-OPEN-CODE-35
F-RB-RACK-POSITION-SENSOR-CODE-35
   T-RB-SENSOR-CHECK-1-CODE-35
   T-RB-SENSOR-CHECK-2-CODE-35
   T-RB-SENSOR-CHECK-3-CODE-35
   RP-RB-REPLACE-INJECTION PUMP-CODE-35
```

Figure 48: List of Code 35 Objects

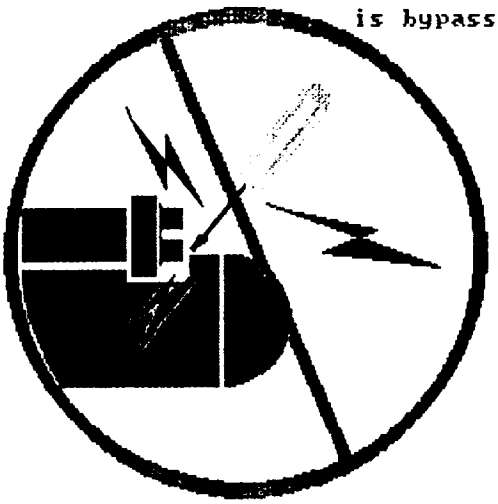
```
F-RB-FUEL-TEMP-SENSOR-CODE-37
   T-RB-FUEL-TEMP-SENSOR-1-CODE-37
   T-RB-FUEL-TEMP-SENSOR-2-CODE-37
   RP-RB-REPLACE-FUEL-TEMP-SENSOR-CODE-37
F-RB-J13-CONNECTOR-CODE-37
   T-RB-J13-CONNECTOR-CODE-37
   RP-RB-J13-CONNECTOR-CODE-37
F-RB-HARNESS-PROBLEM-1-CODE-37
   T-RB-J13-VOLTAGE-CHECK-CODE-37
   DP-RB-J13-VOLTAGE-CHECK-CODE-37
     DP-RB-DIAGNOSTIC-CODE-CHECK-CODE-37
F-RB-J1-CONNECTOR-CODE-37
   T-RB-J1-CONNECTOR-CODE-37
   RP-RB-J1-CONNECTOR-CODE-37
F-RB-HARNESS-PROBLEM-2-CODE-37
   T-RB-HARNESS-CHECK-CODE-37
   DP-RB-HARNESS-CHECK-1-CODE-37
F-RB-ECU-1-CODE-37
   T-RB-ECU-CHECK-CODE-37
   RP-RB-REPLACE-ECU-CODE-37
F-RB-J1-CONNECTOR-2-CODE-37
   T-RB-J1-CONNECTOR-CODE-37
   RP-RB-J1-CONNECTOR-CODE-37
F-RB-WIRING-HARNESS-SHORT-CIRCUIT-CODE-37
   T-RB-HARNESS-CHECK-2-CODE-37
   T-RB-HARNESS-SHORT-CHECK-CODE-37
   RP-RB-ENGINE-HARNESS-EXTERNAL-SHORT-CODE-37
   DP-RB-HARNESS-CHECK-2-CODE-37
F-RB-ECU-2-CODE-37
   T-RB-HARNESS-CHECK-2-CODE-37
   T-RB-ECU-CHECK-CODE-37
   RP-RB-REPLACE-ECU-CODE-37
F-RB-J9/J10-CONNECTORS-1-CODE-37
   T-RB-J9/J10-CONNECTORS-CODE-37
   RP-RB-J9/J10-CONNECTORS-CODE-37
F-RB-ENGINE-HARNESS-OPEN-CODE-37
   T-RB-ENGINE-HARNESS-OPEN-CODE-37
   RP-RB-ENGINE-HARNESS-CODE-37
F-RB-ECU-HARNESS-OPEN-CODE-37
   T-RB-ECU-HARNESS-OPEN-CODE-37
   RP-RB-ECU-HARNESS-CODE-37
F-RB-J9/J10-CONNECTORS-2-CODE-37
   T-RB-J9/J10-CONNECTORS-CODE-37
   RP-RB-J9/J10-CONNECTORS-CODE-37
F-RB-ECU-HARNESS-SHORT-CODE-37
   T-RB-ECU-HARNESS-SHORT-CODE-37
   RP-RB-ECU-HARNESS-SHORT-CODE-37
F-RB-ENGINE-HARNESS-EXTERNAL-SHORT-CODE-37
   T-RB-ENGINE-HARNESS-EXTERNAL-SHORT-CHECK-CODE-37
   RP-RB-ENGINE-HARNESS-EXTERNAL-SHORT-CODE-37
```

Figure 49: List of Code 37 Objects

Appendix F

Expert System Graphics

CAUTION: Avoid possible injury. Do not start engine by shorting across starter terminals. Machine may start in gear if normal circuitry is bypassed.



NEVER start engine while standing on ground. Start engine only from operator's seat with transmission in park or neutral.

Wear tight-fitting clothing. Keep clear of moving parts and hot surfaces while making adjustments.

Figure 50: Graphic RBNDWARN

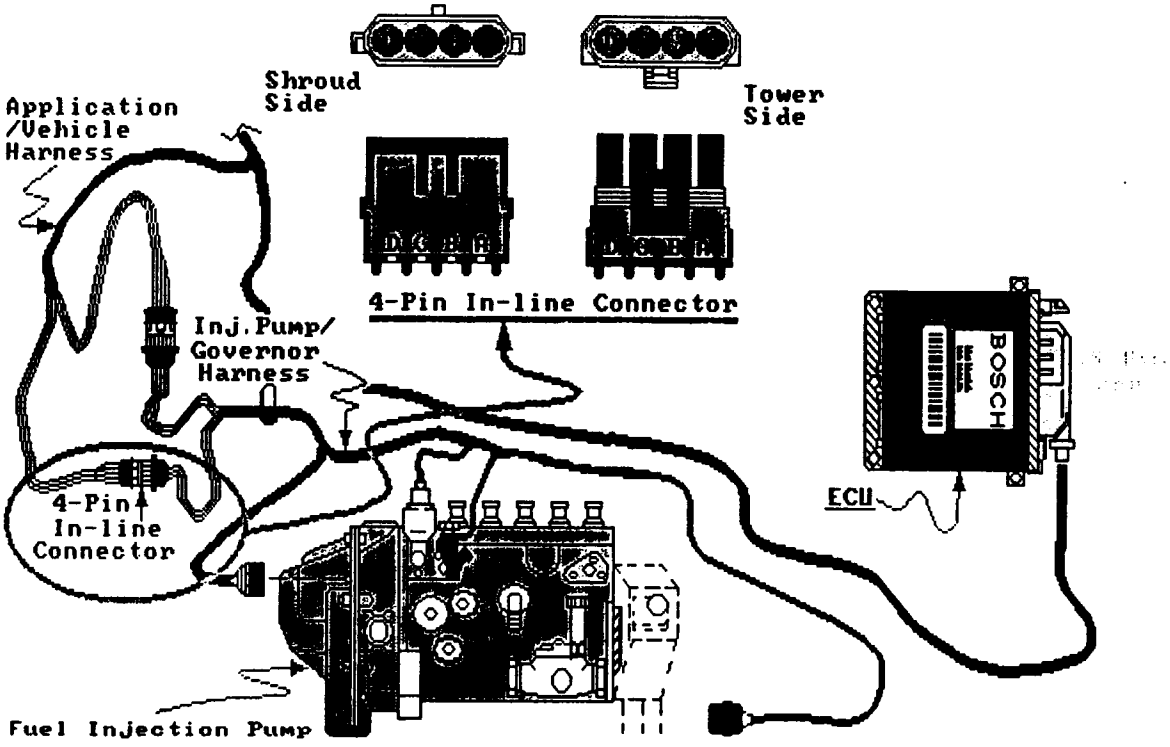


Figure 51: Graphic RBJ7J8

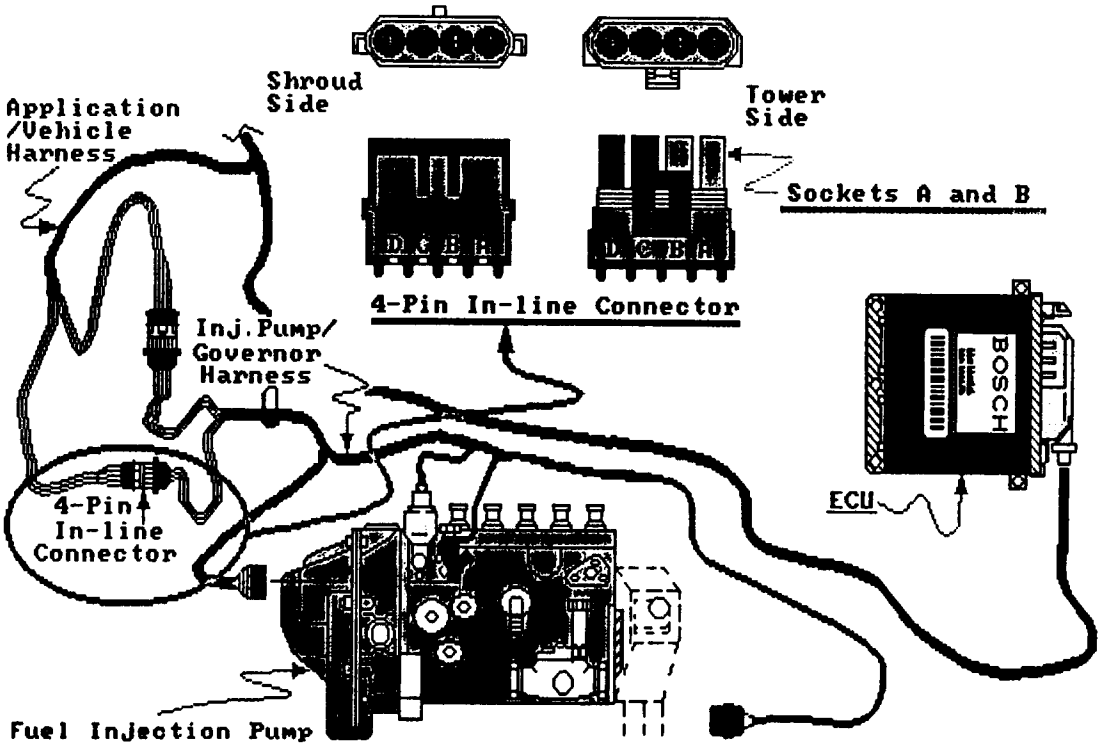


Figure 52: Graphic RBJ8AB

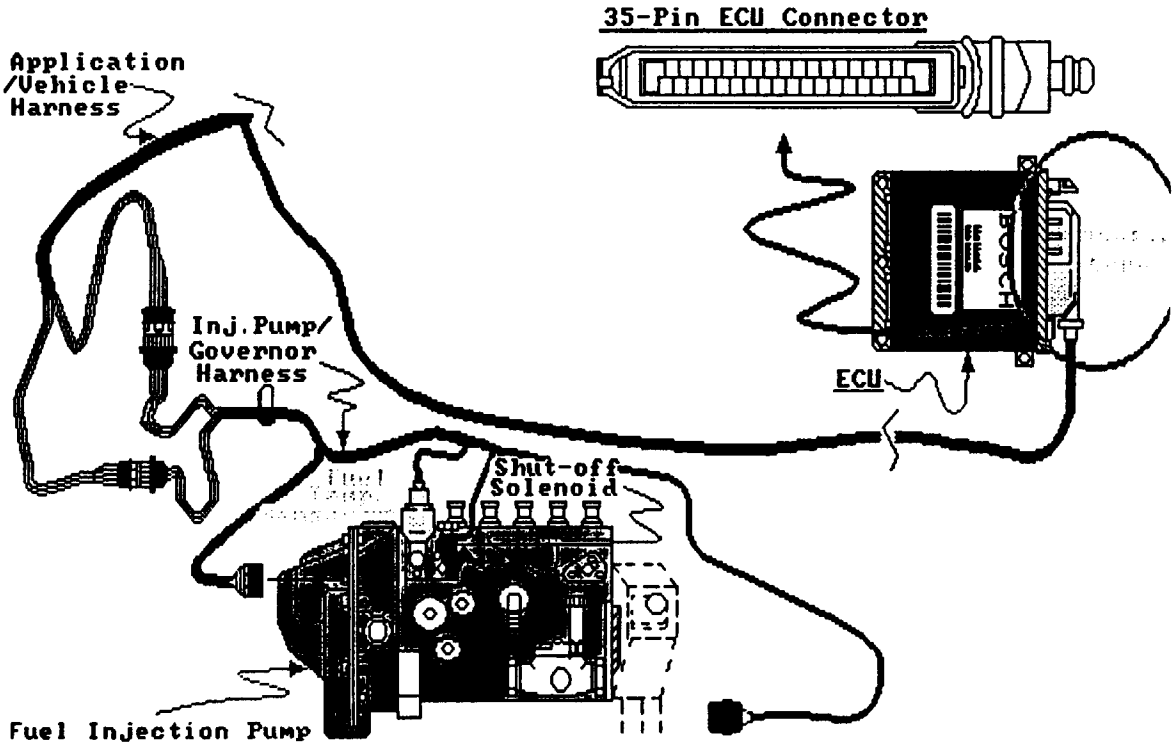


Figure 53: Graphic RBJ1

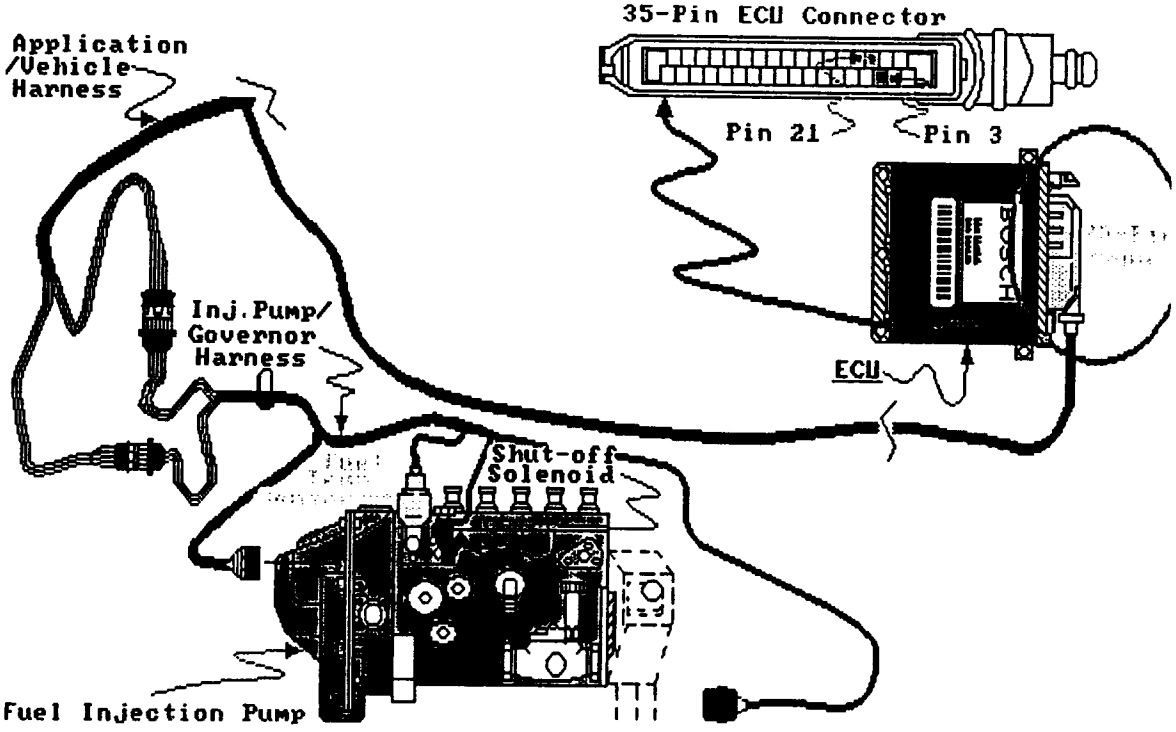


Figure 54: Graphic RBJ1321

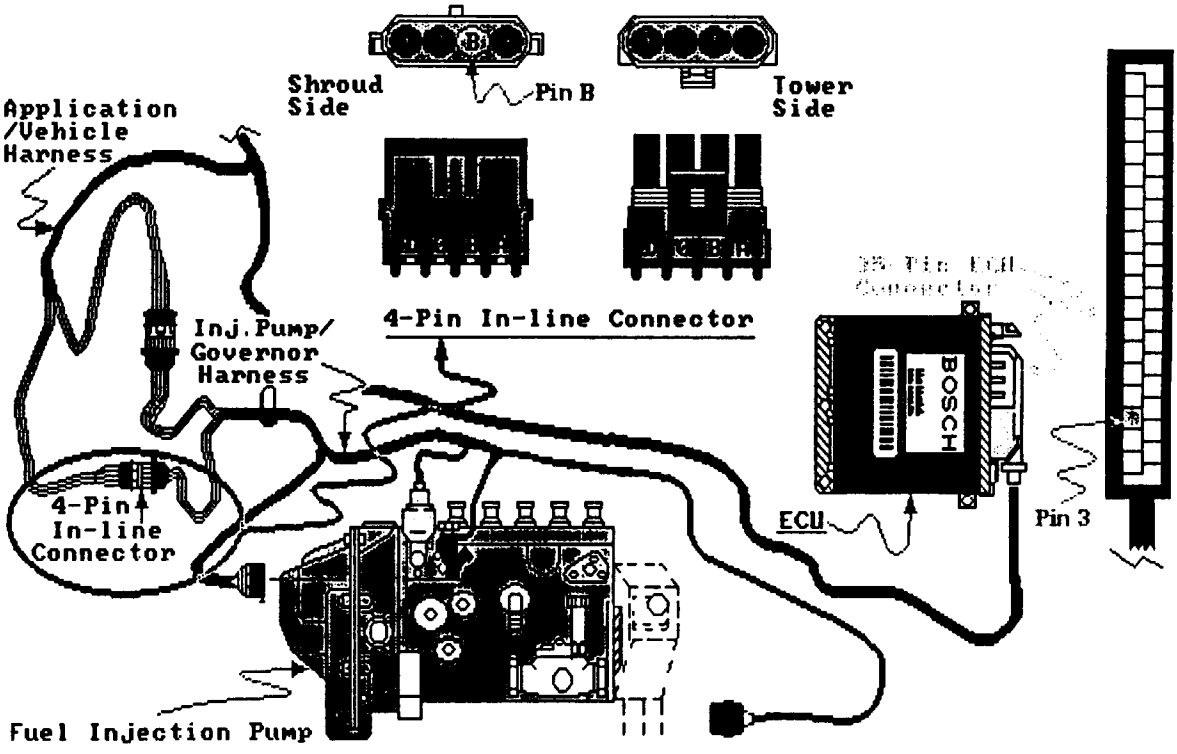


Figure 55: Graphic RBJ13J7B

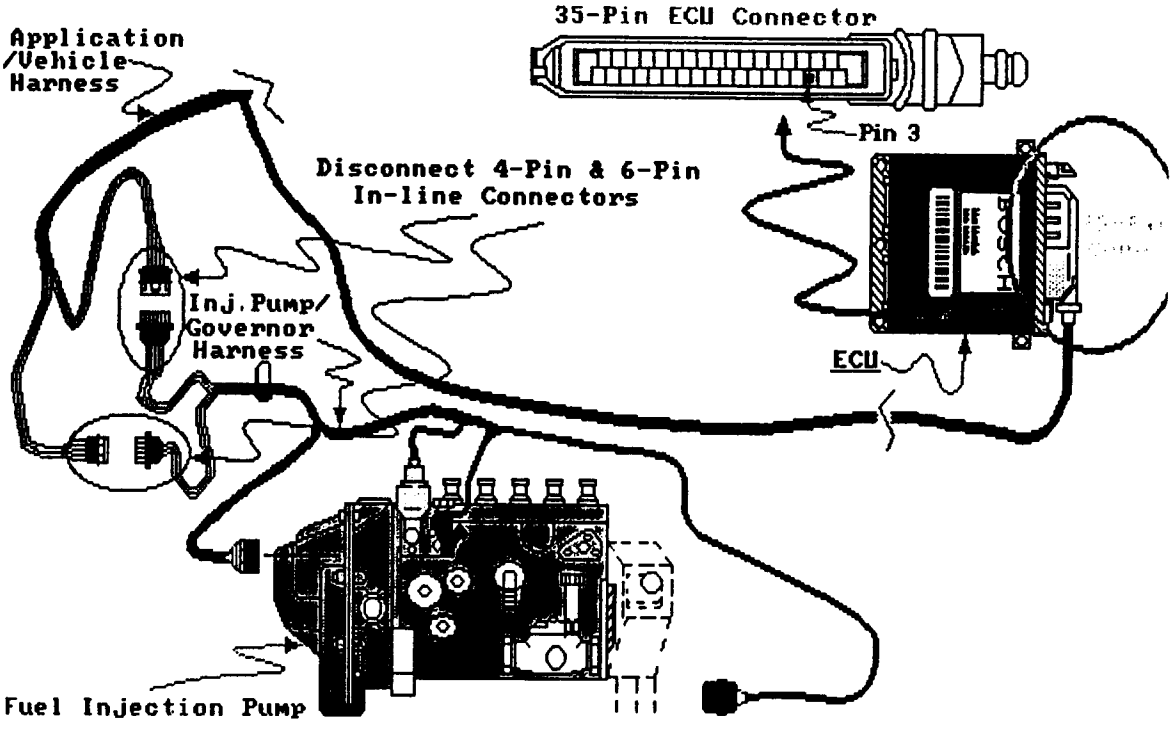


Figure 56: Graphic RBJ13

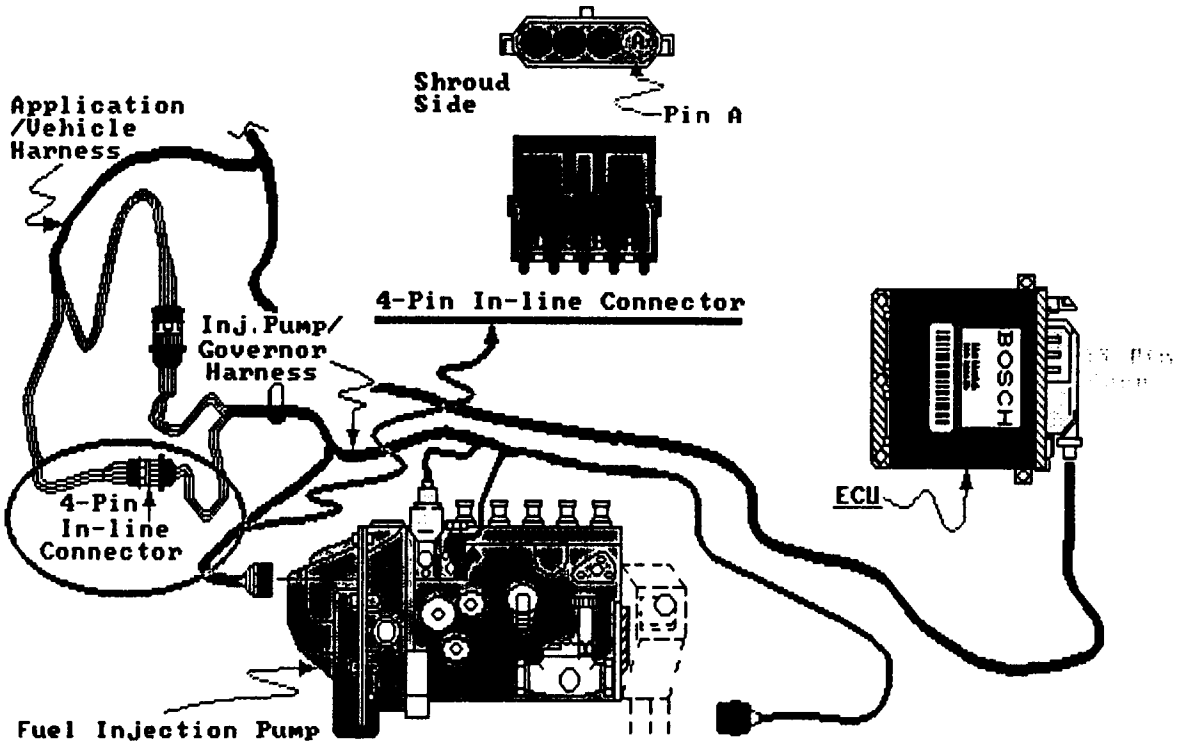


Figure 57: Graphic RBJ7A

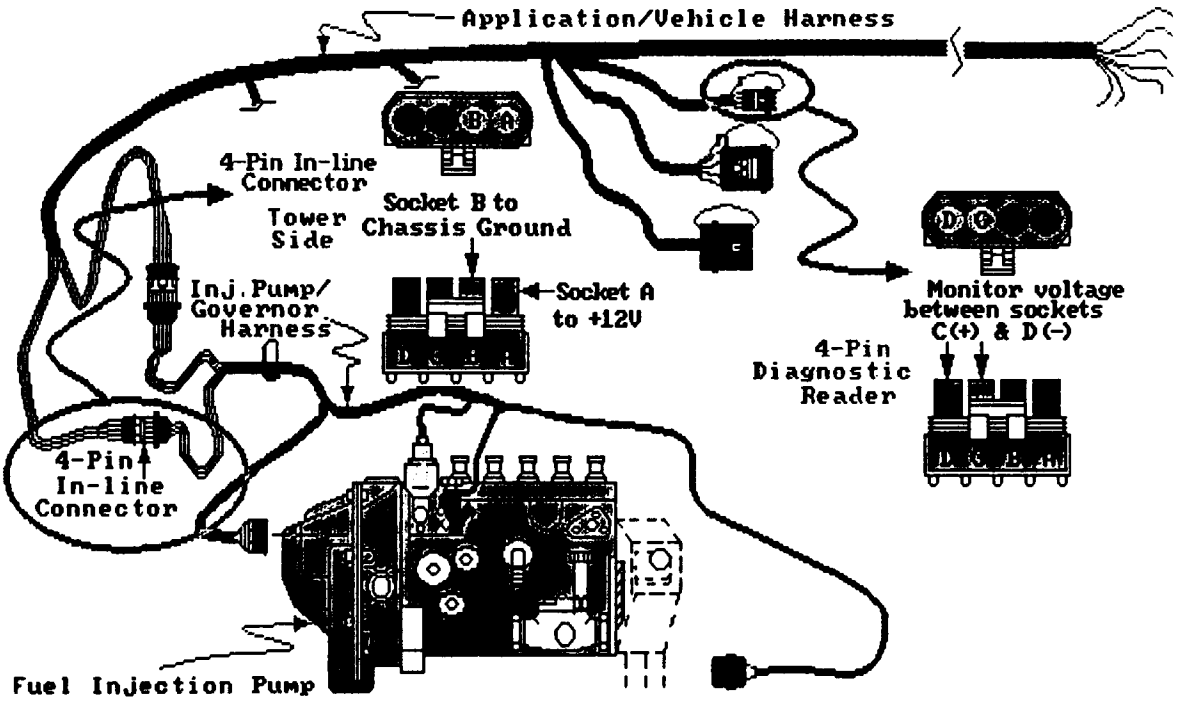


Figure 58: Graphic RBJ3J8

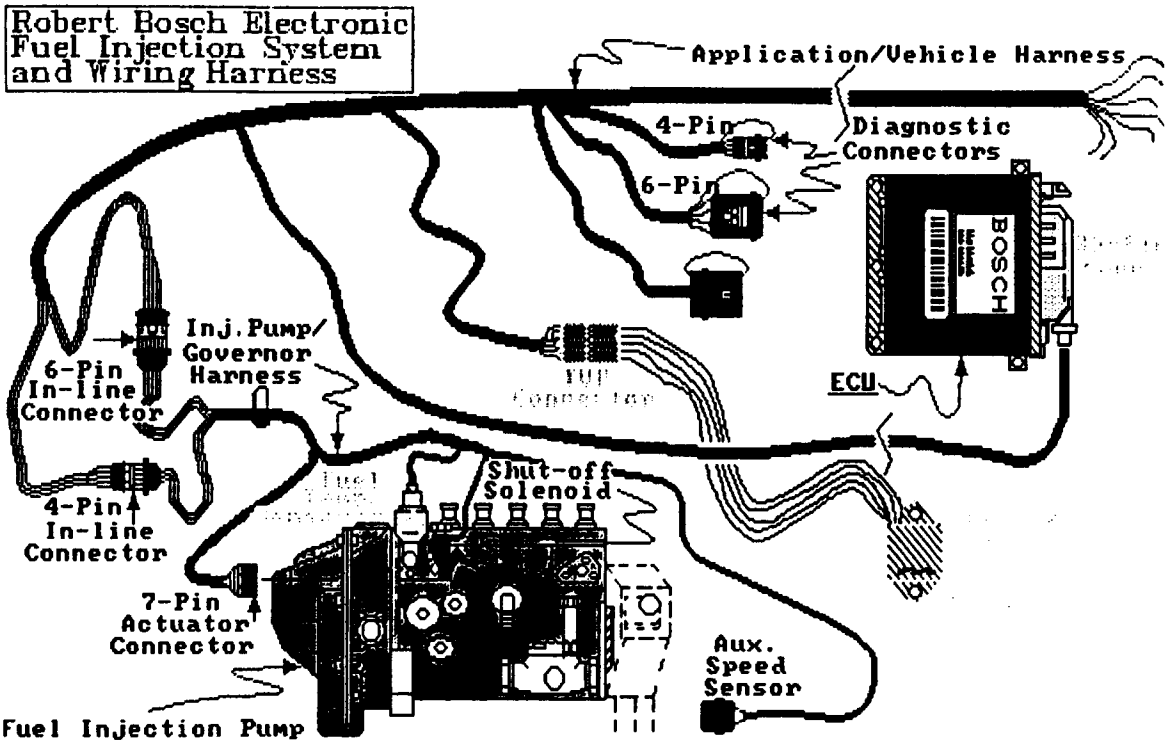


Figure 59: Graphic RBHARNSS

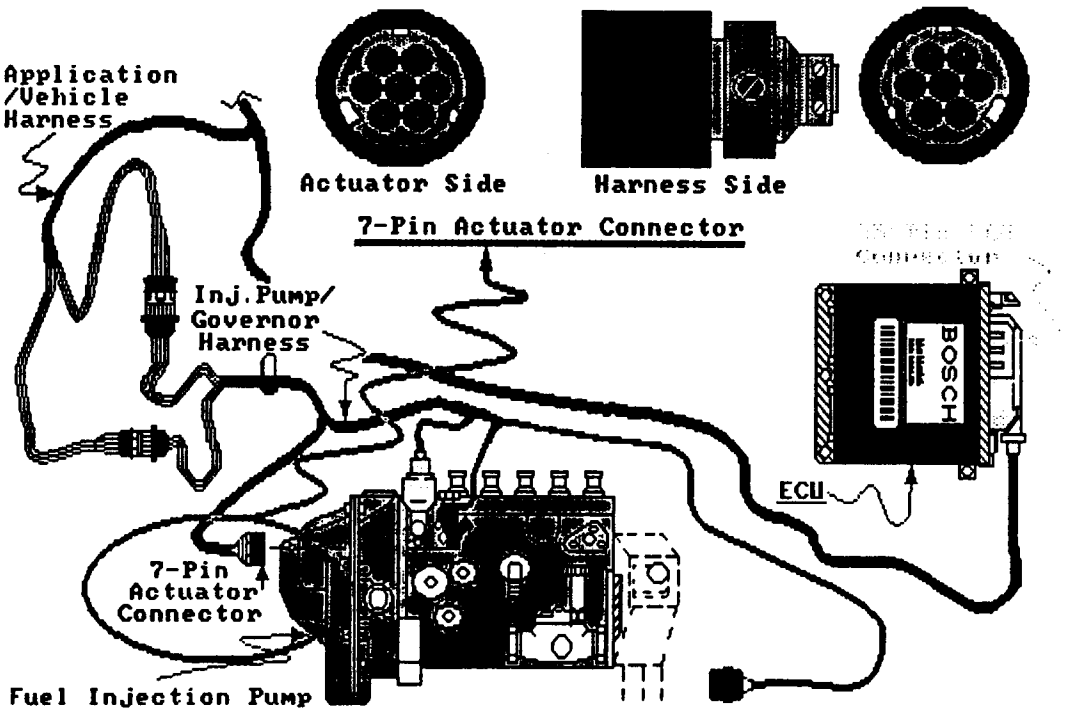


Figure 60: Graphic RBJ12

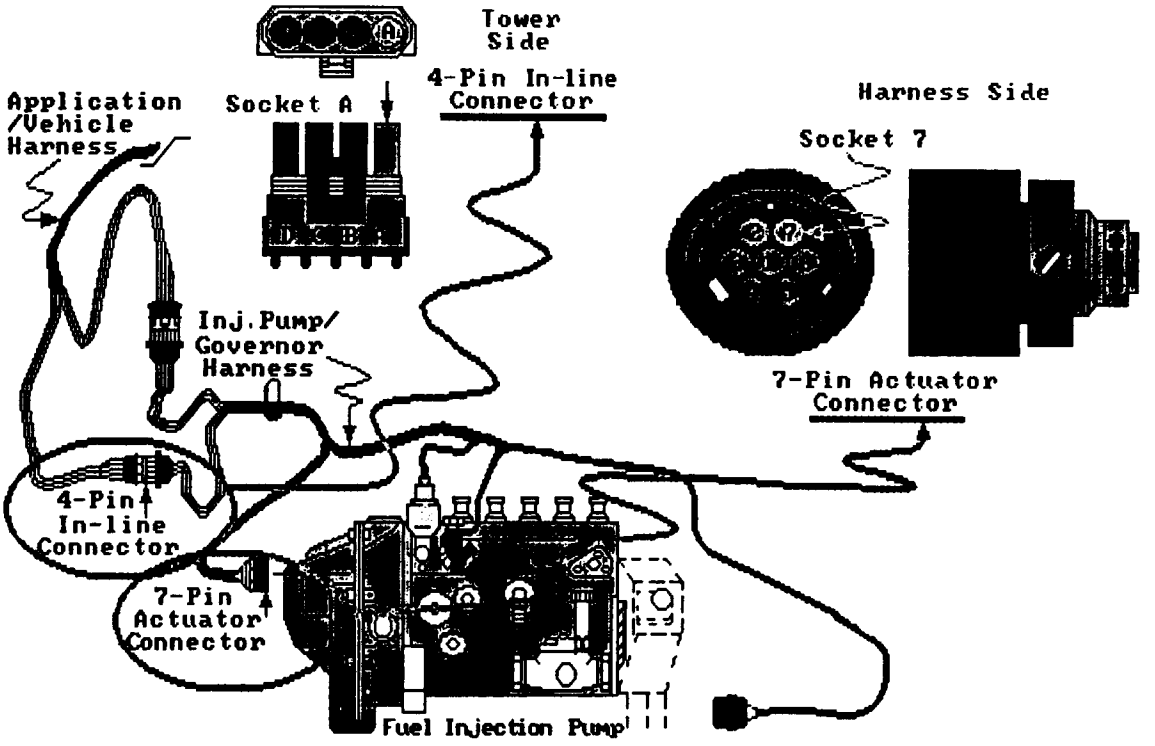


Figure 61: Graphic RBJ8AJ12

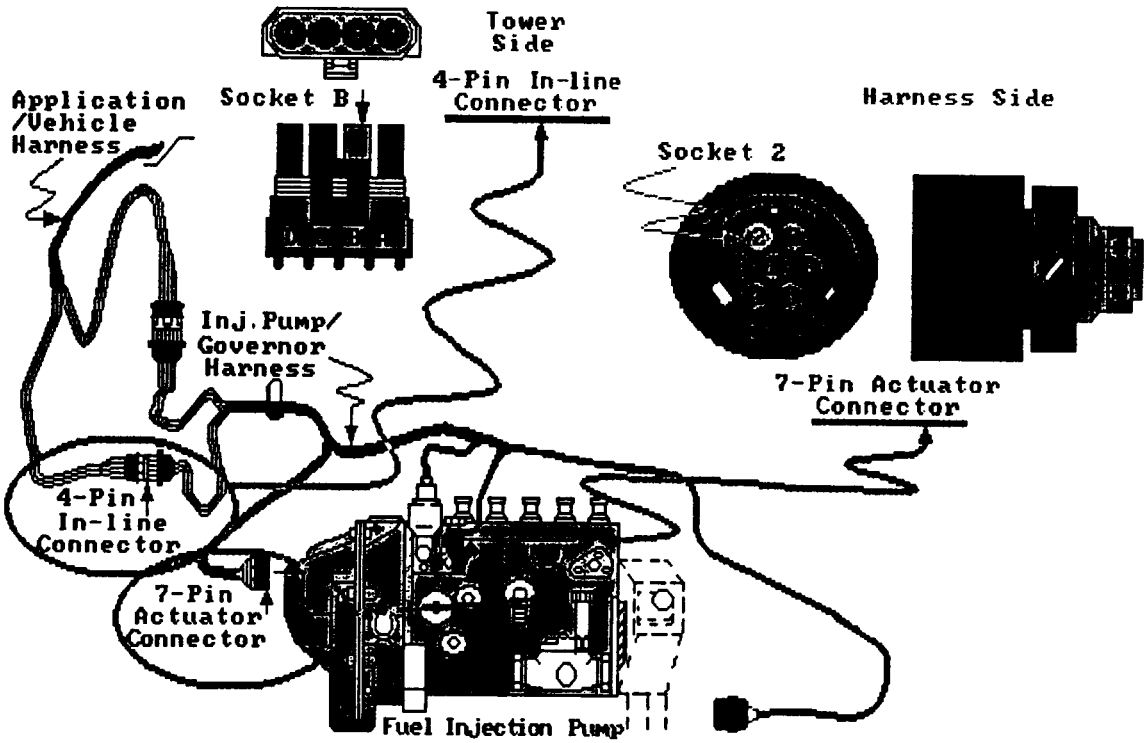


Figure 62: Graphic RBJ8BJ12

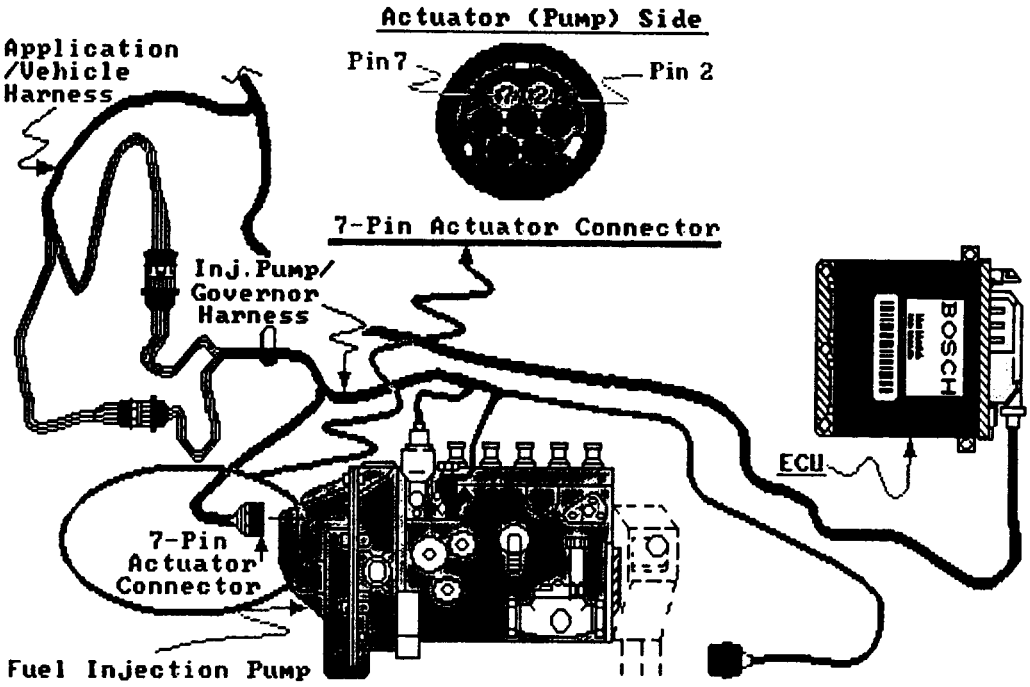


Figure 63: Graphic RBJ1227

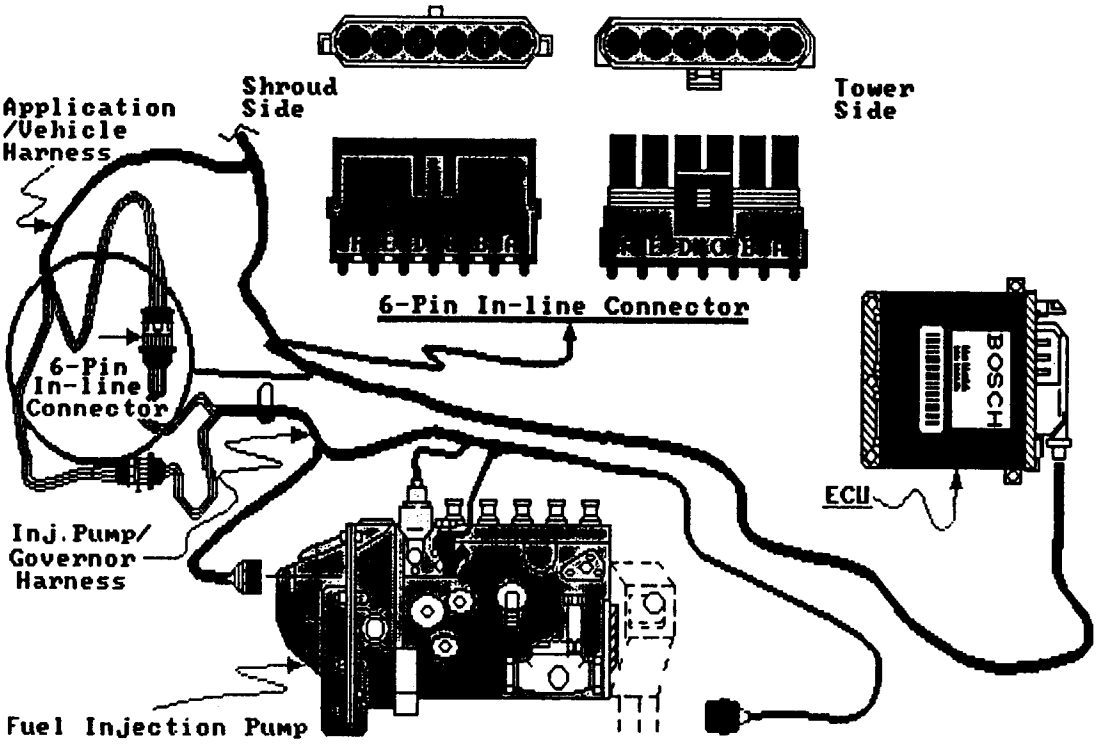


Figure 64: Graphic RBJ9J10

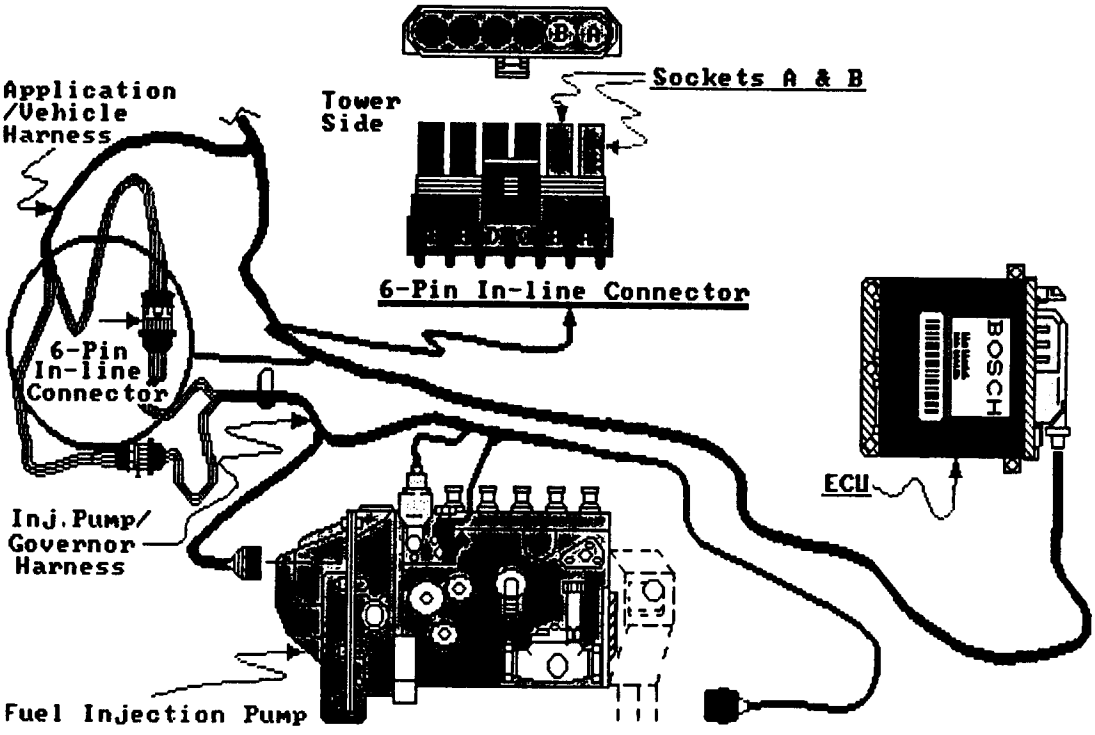


Figure 65: Graphic RBJ10AB

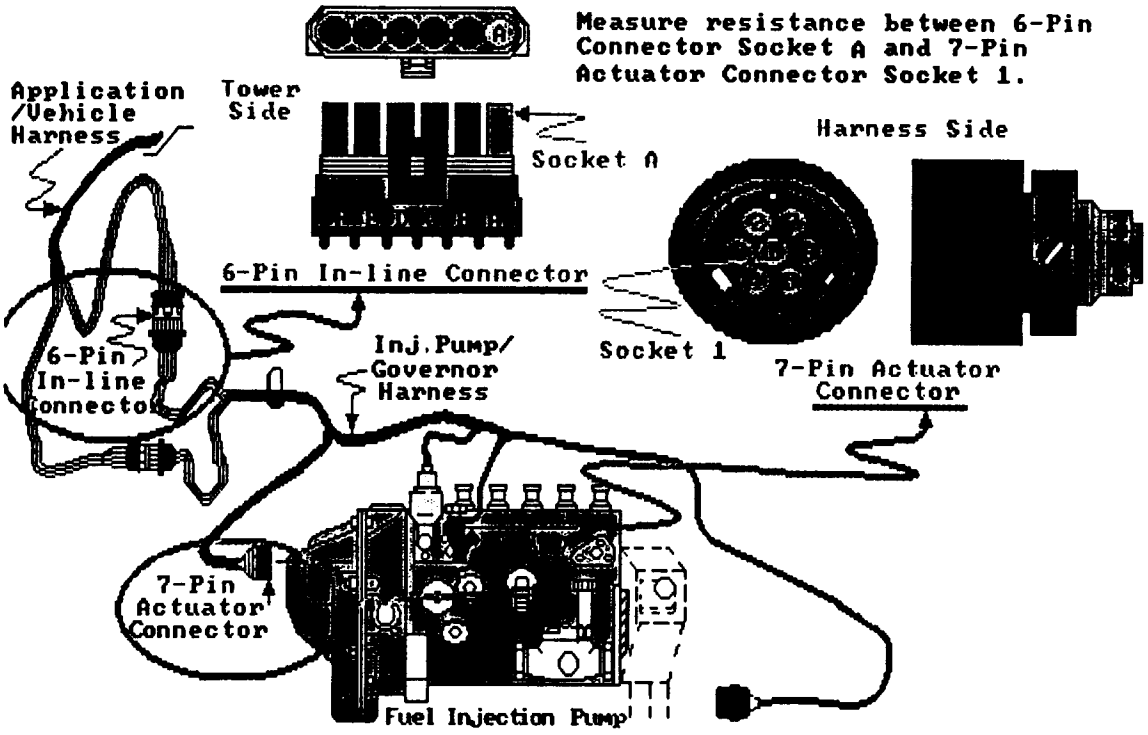


Figure 66: Graphic RBJ10A12

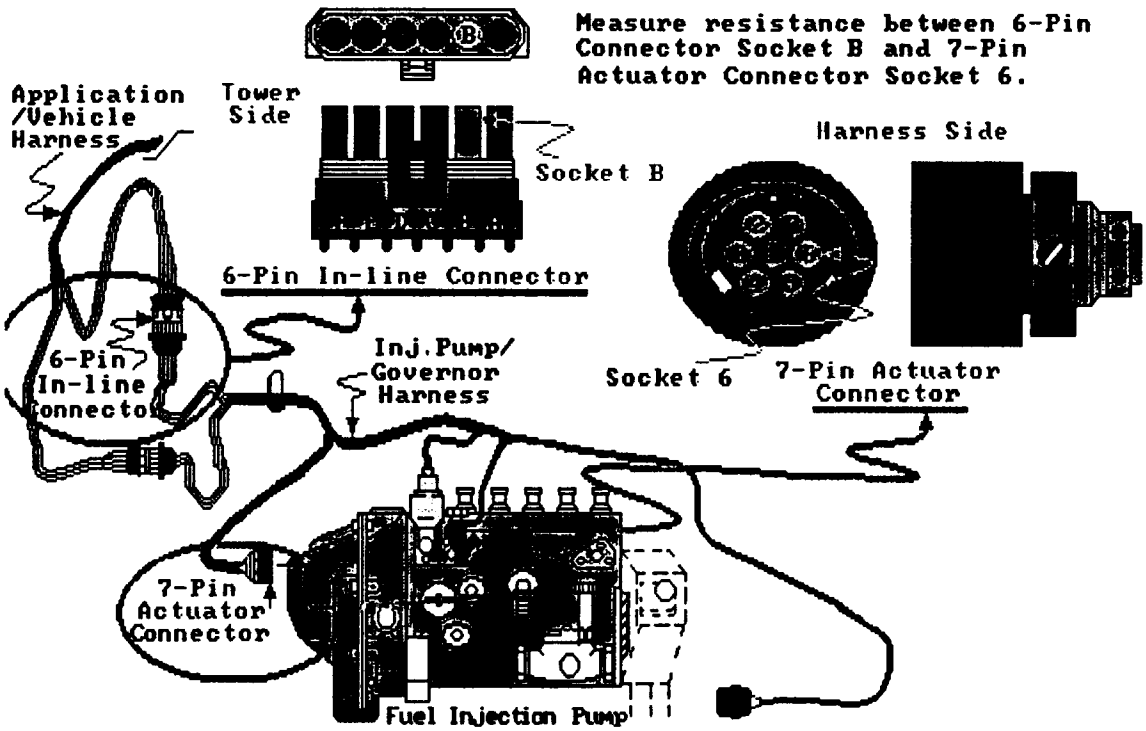


Figure 67: Graphic RBJ10B12

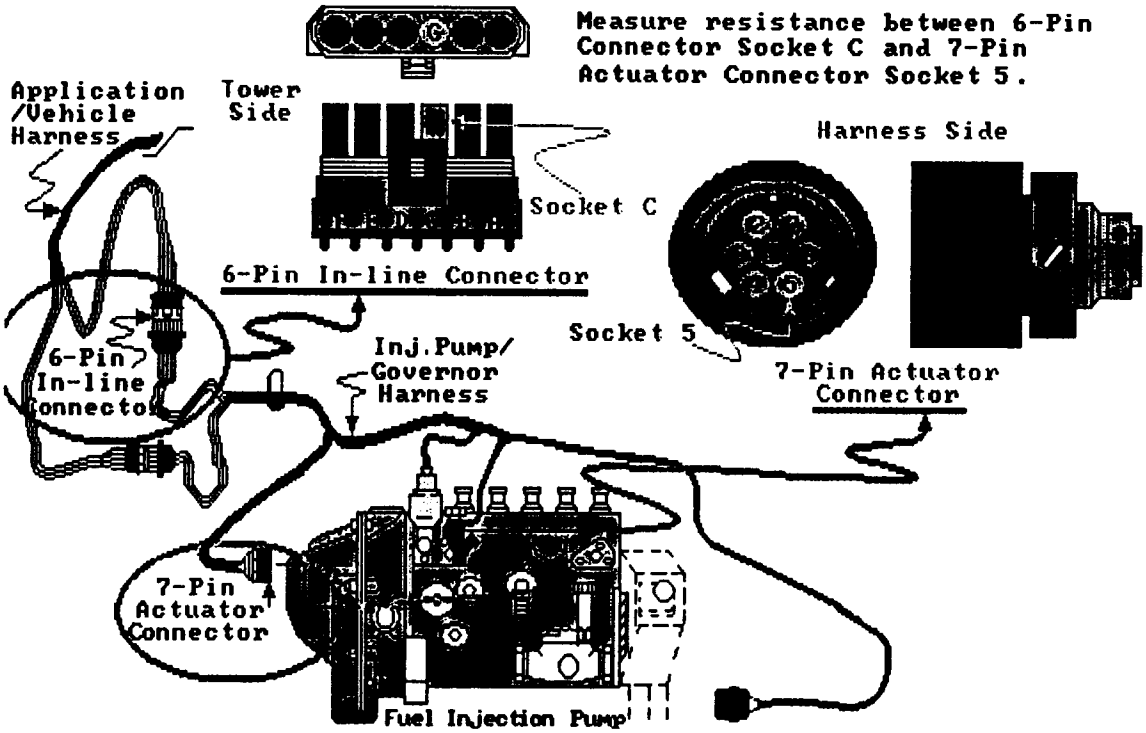


Figure 68: Graphic RBJ10C12

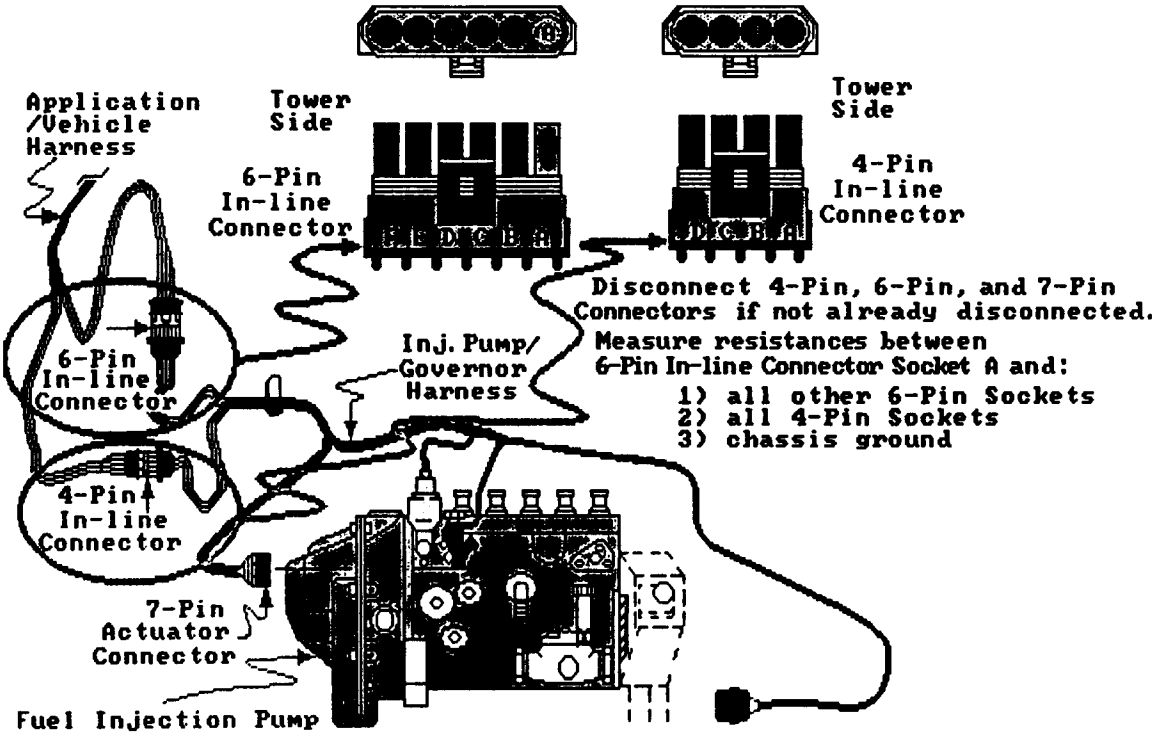


Figure 69: Graphic RBJ10AJ8

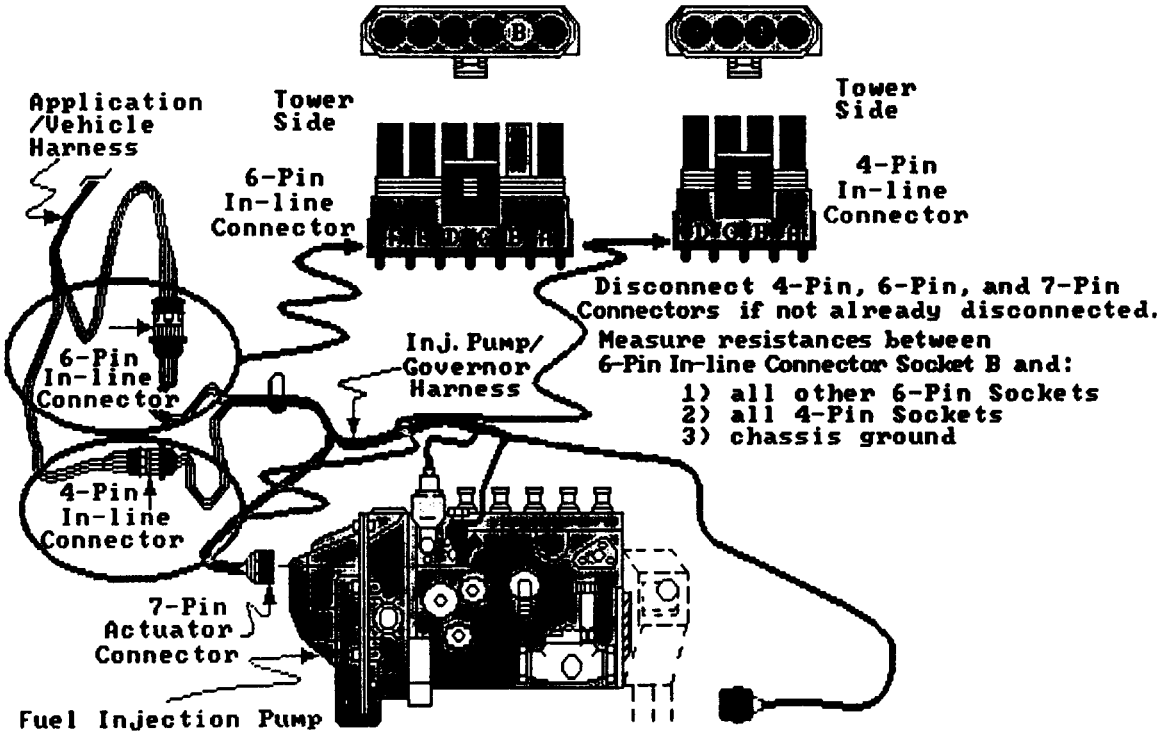


Figure 70: Graphic RBJ10BJ8

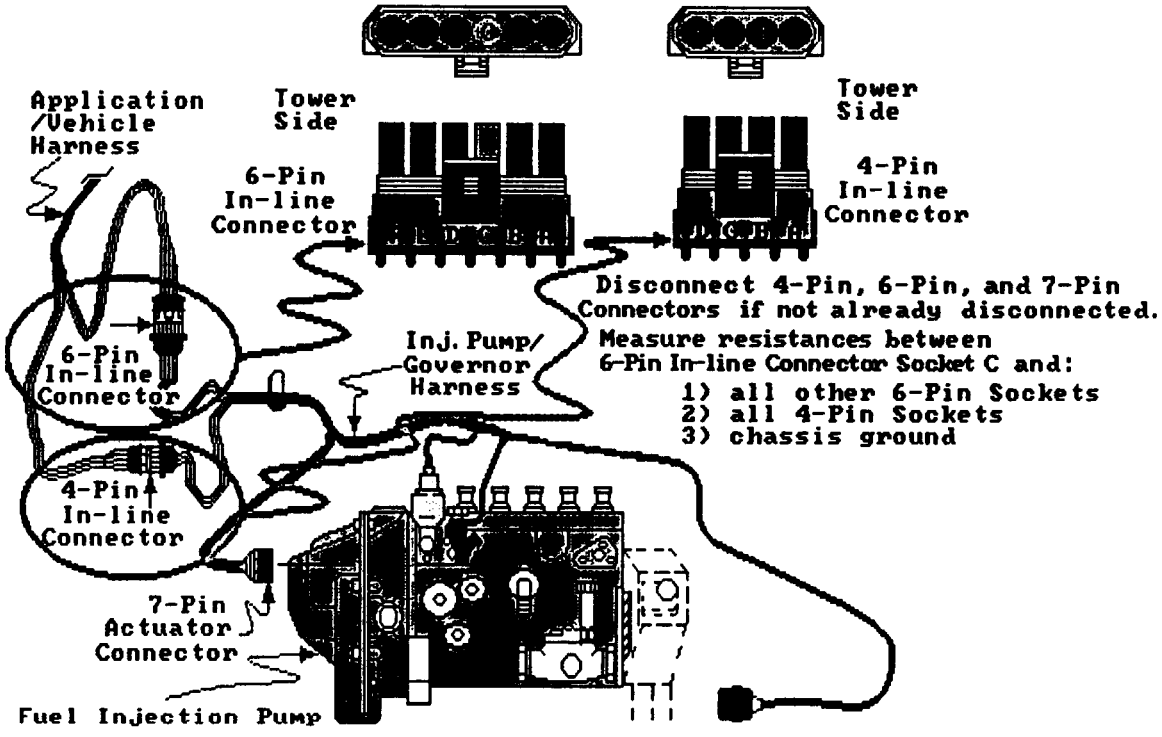


Figure 71: Graphic RBJ10CJ8

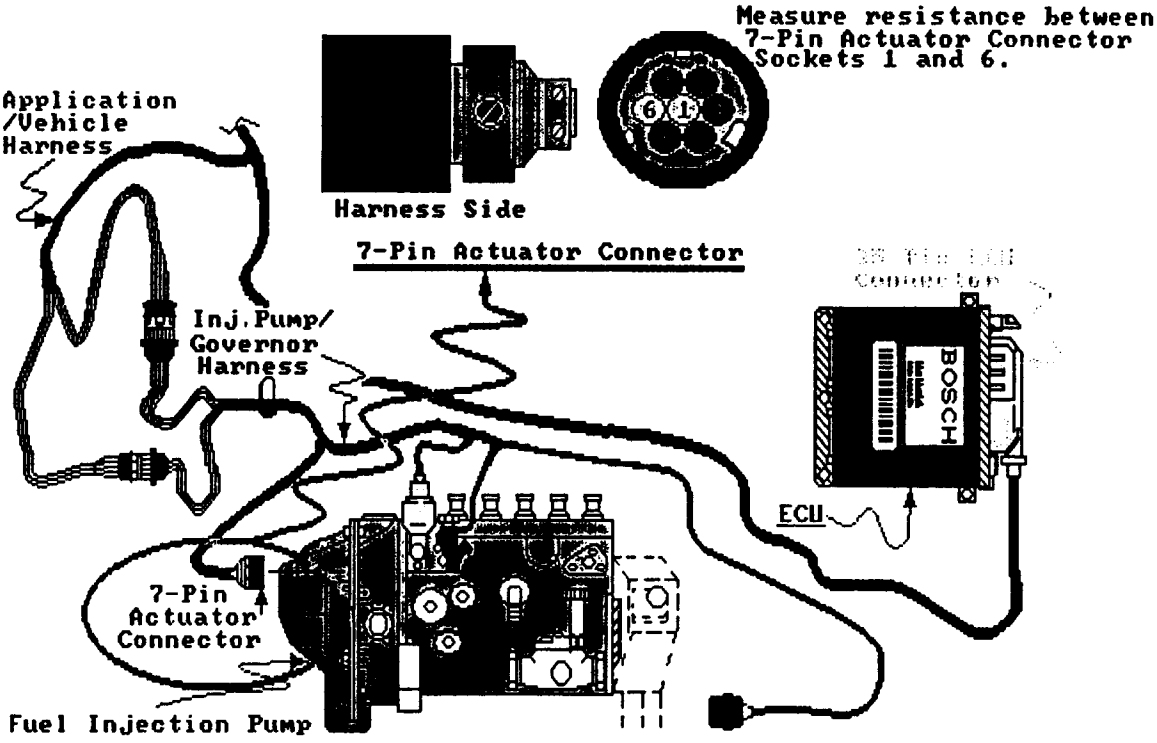


Figure 72: Graphic RBJ1216

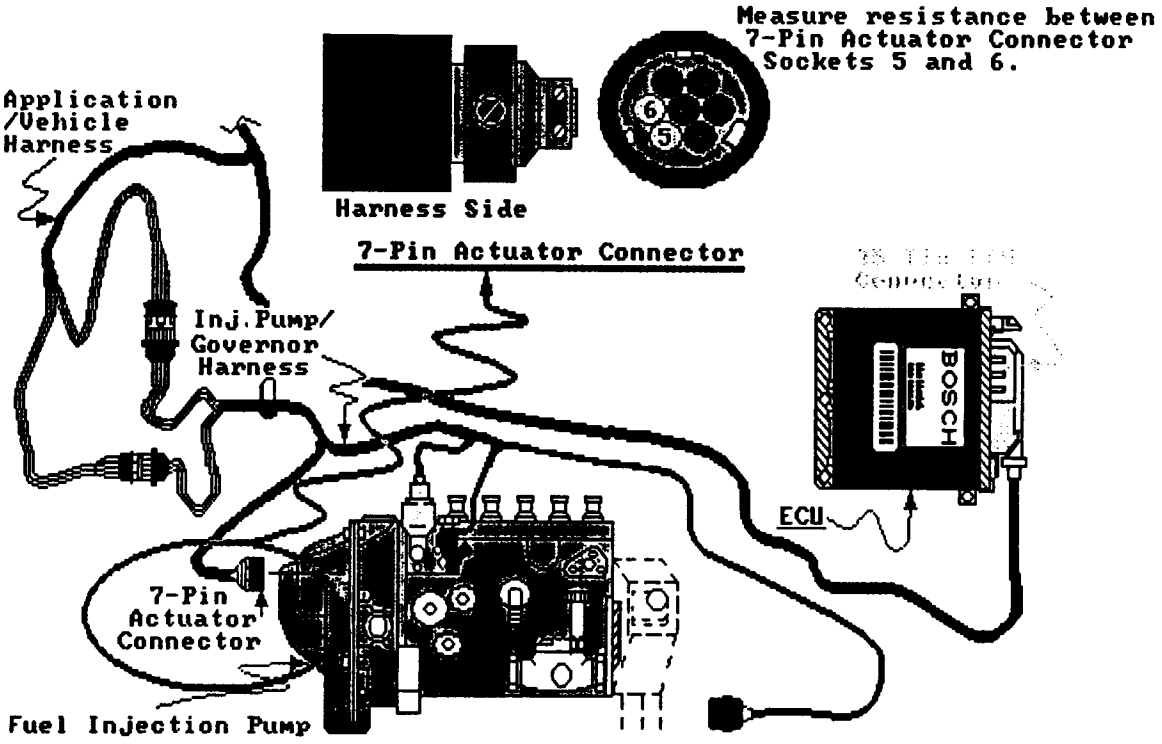


Figure 73: Graphic RBJ1256

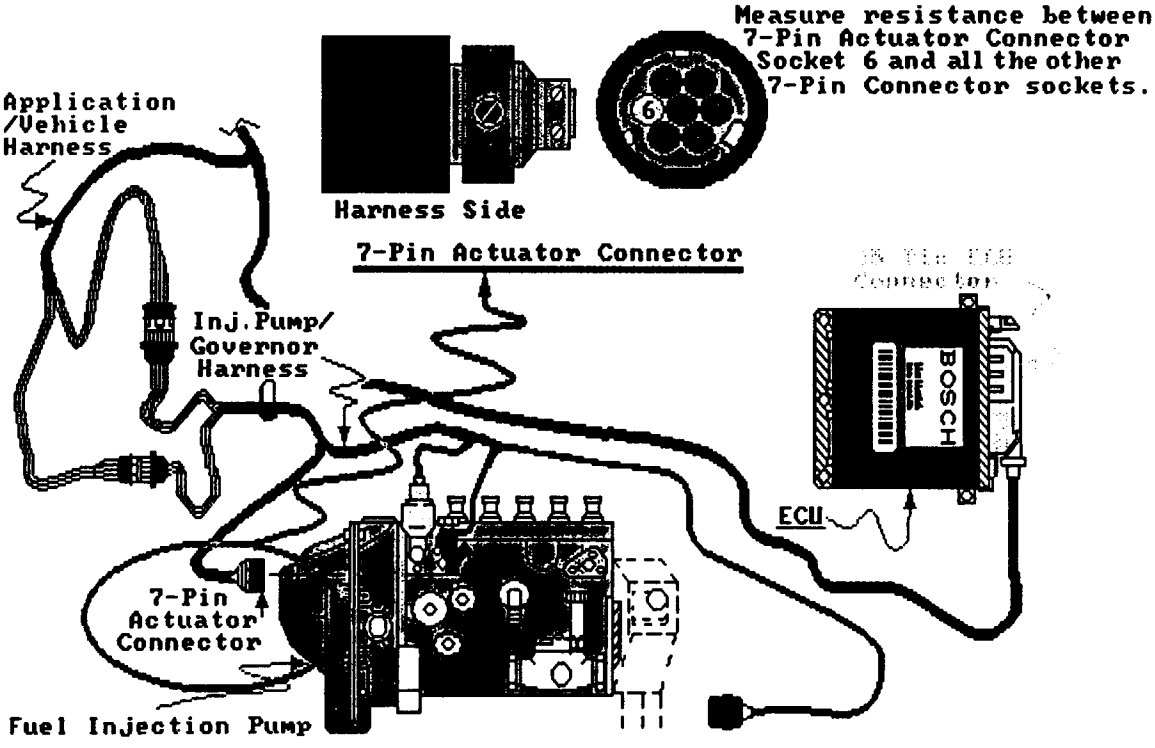


Figure 74: Graphic RBJ126

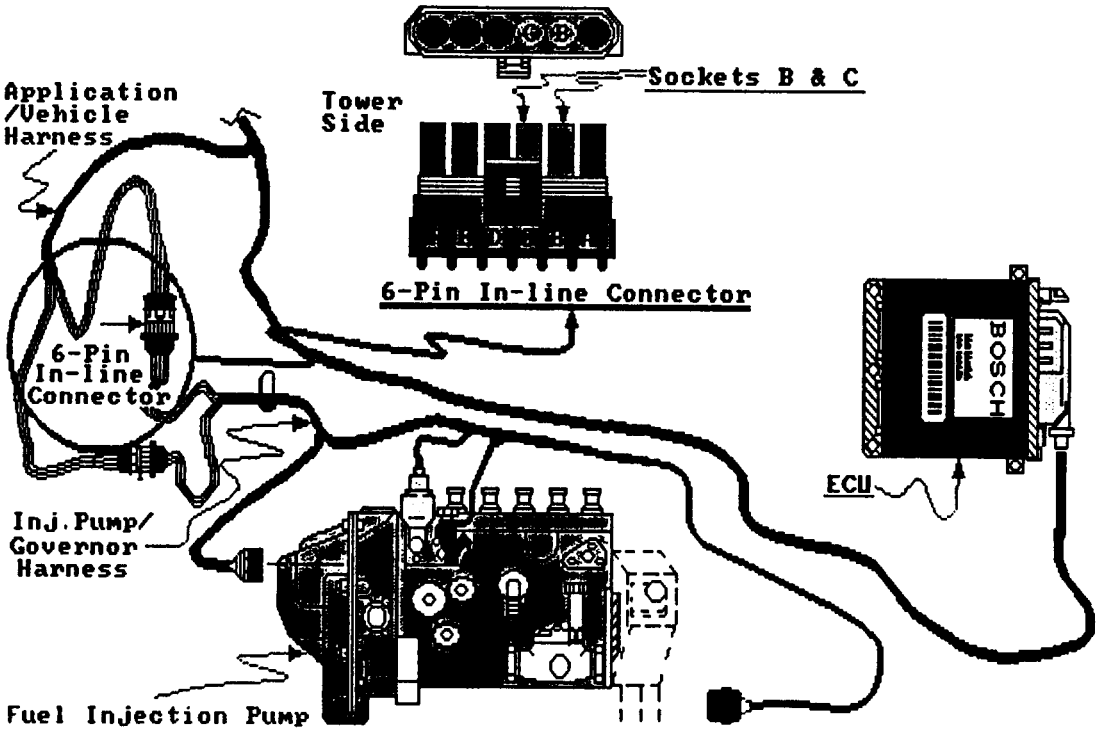
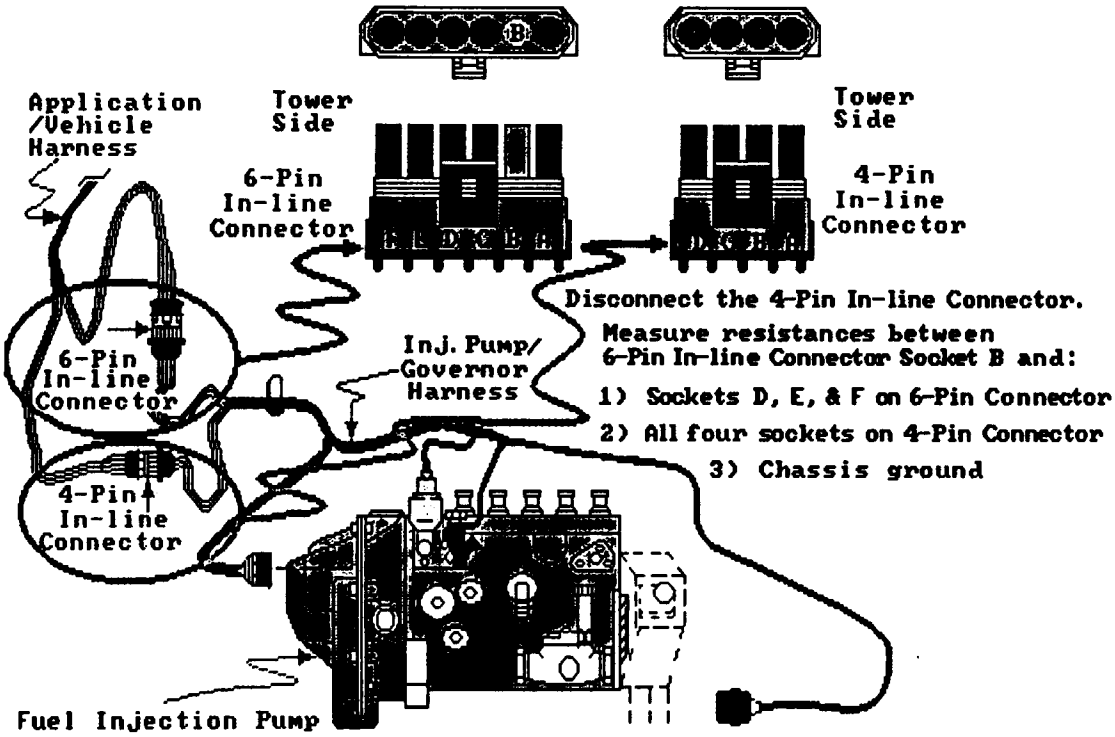


Figure 75: Graphic RBJ10BC



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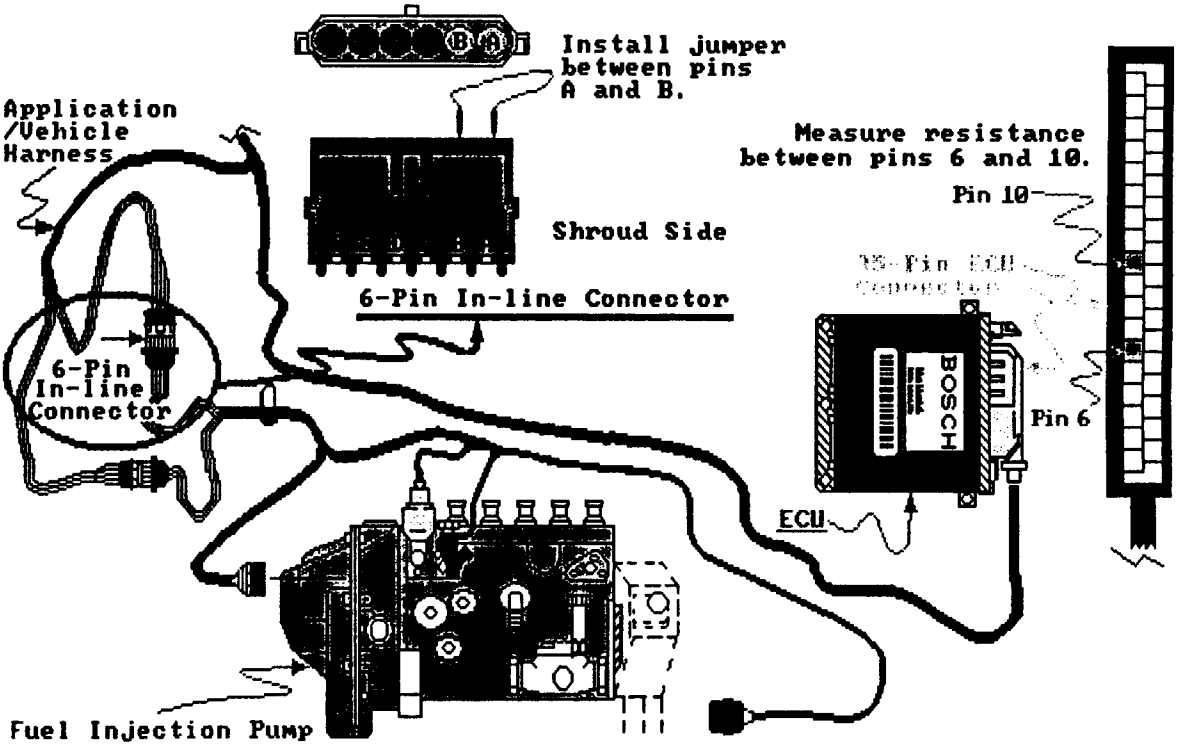
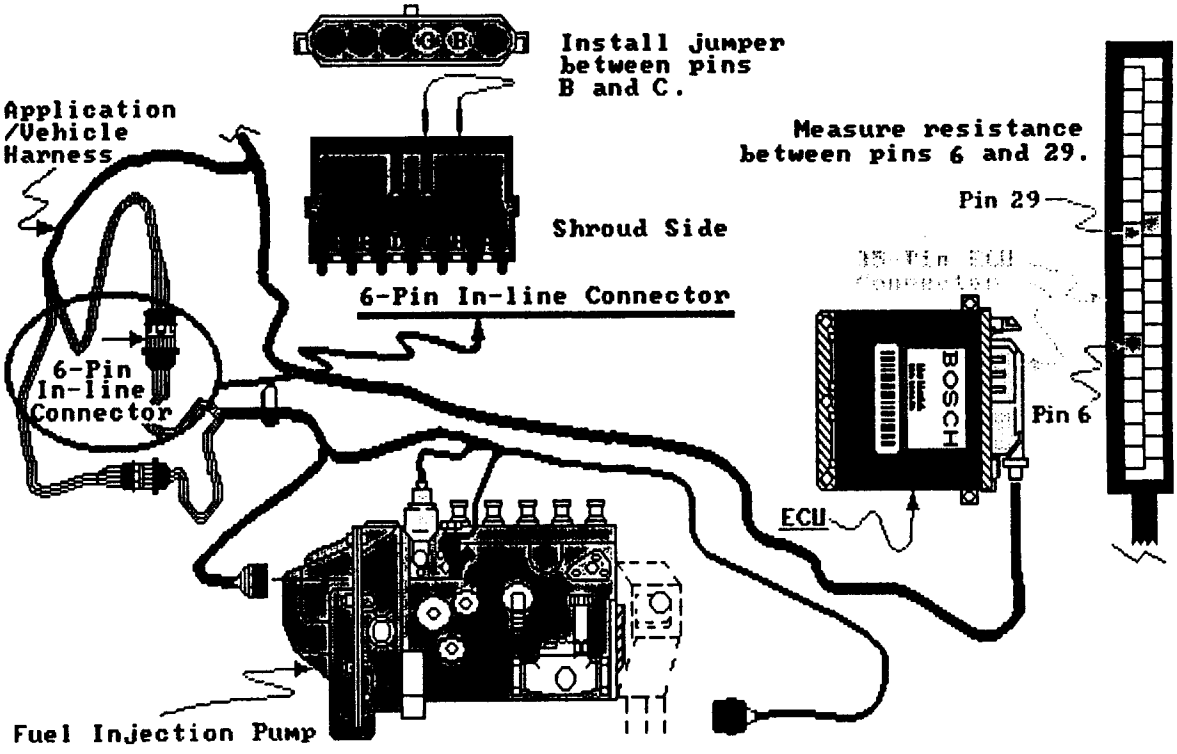


Figure 77: Graphic RBJ1J9AB



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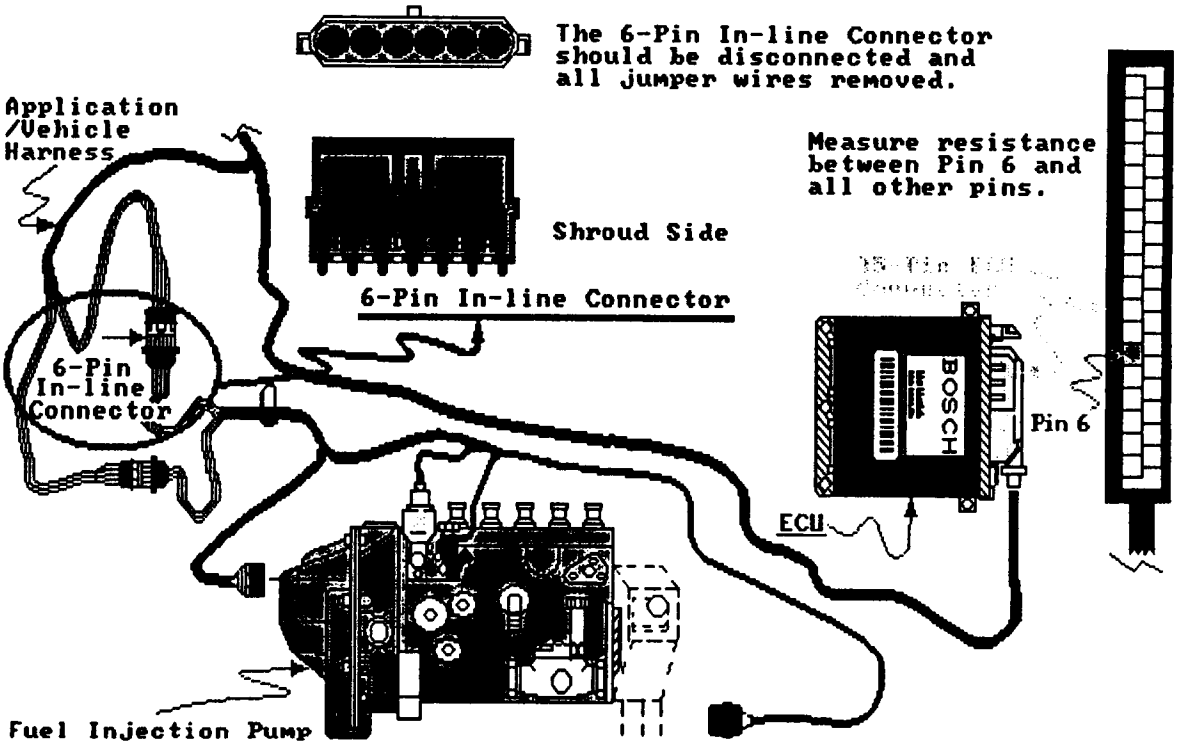


Figure 79: Graphic RBJ16J9

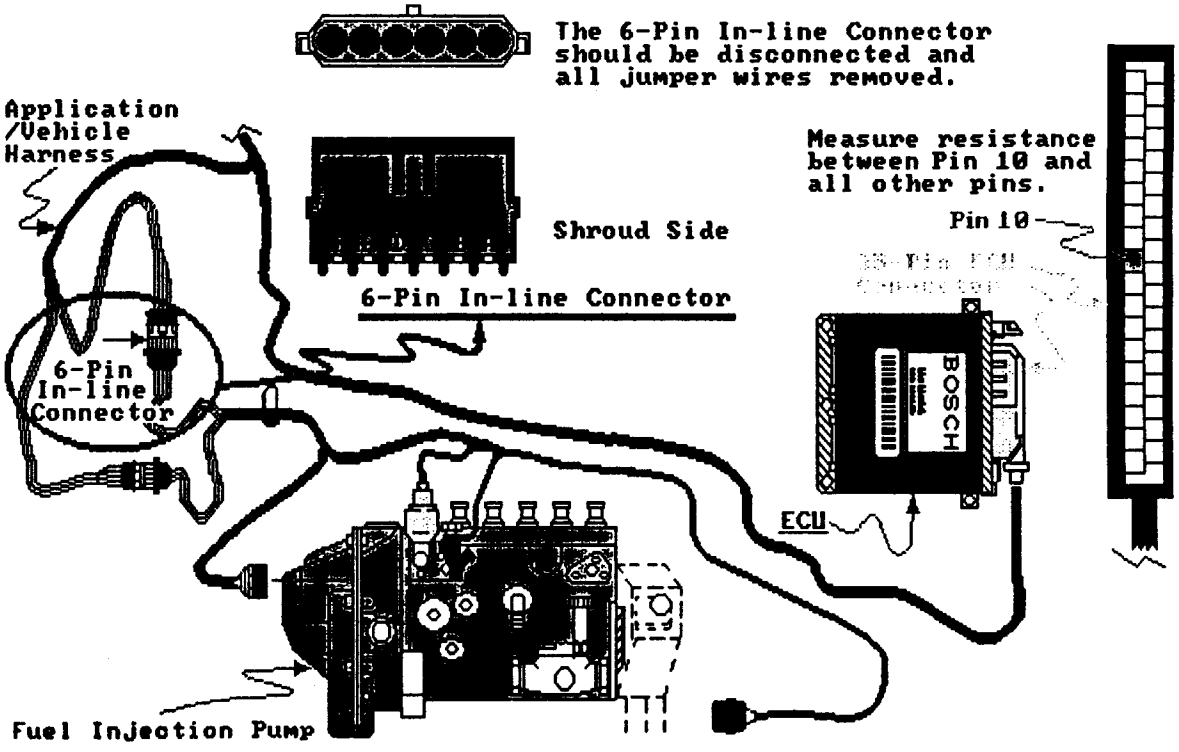


Figure 80: Graphic RBJ110J9

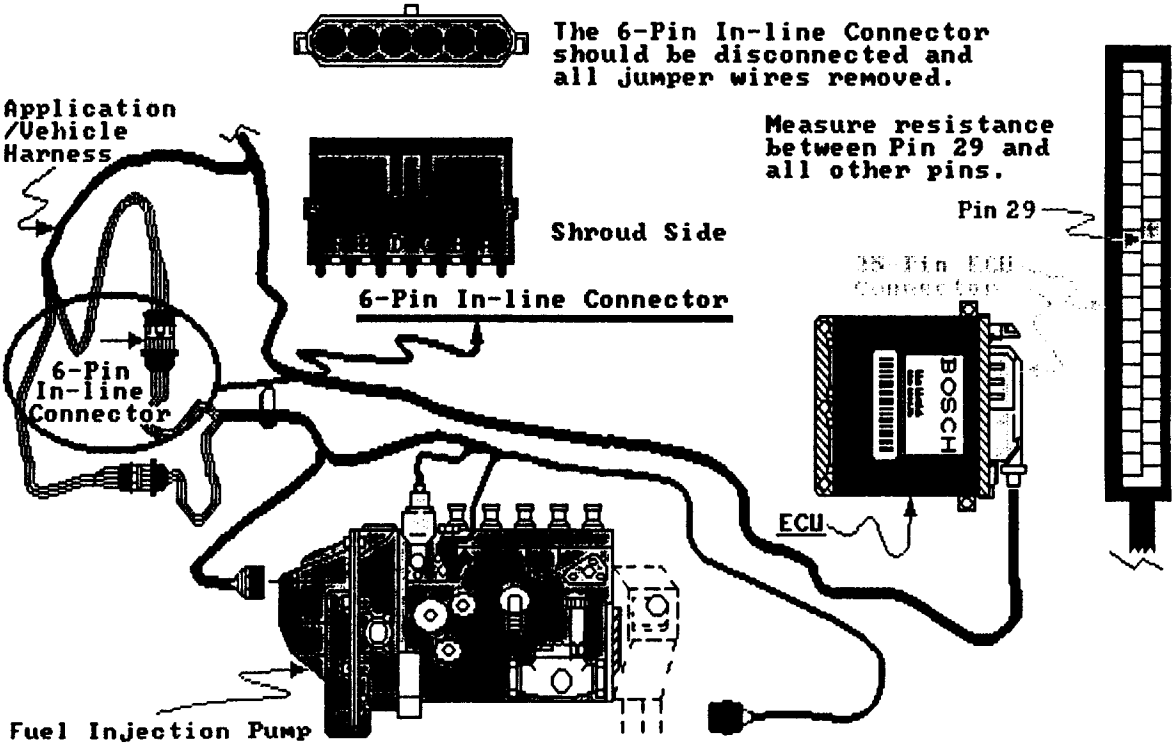


Figure 81: Graphic RBJ129J9

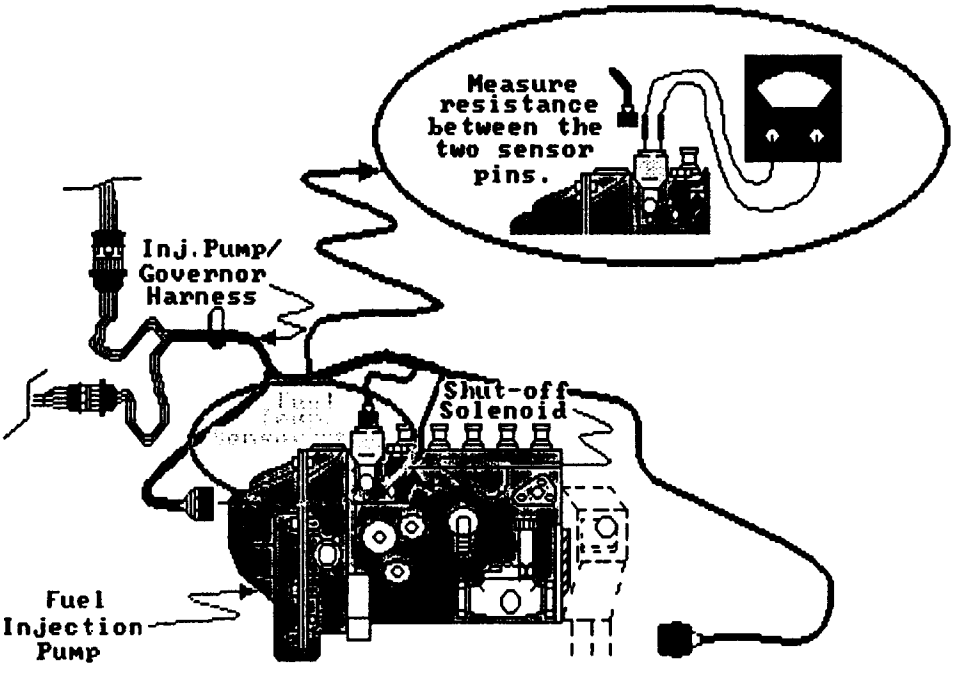


Figure 82: Graphic RB-J13

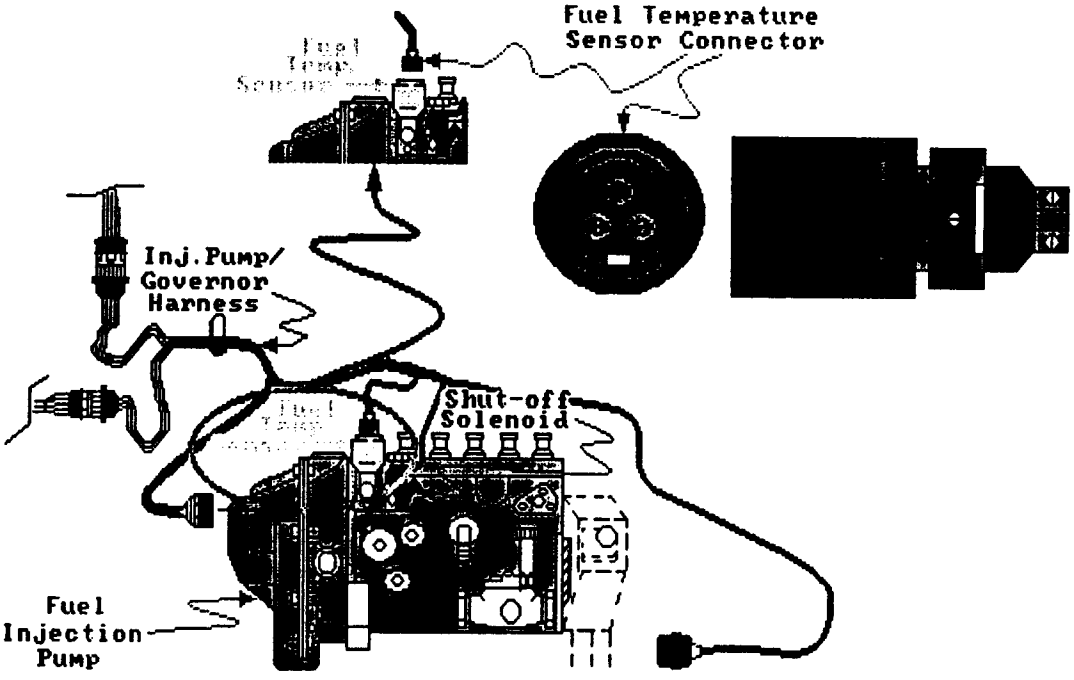


Figure 83: Graphic RB-J13CO

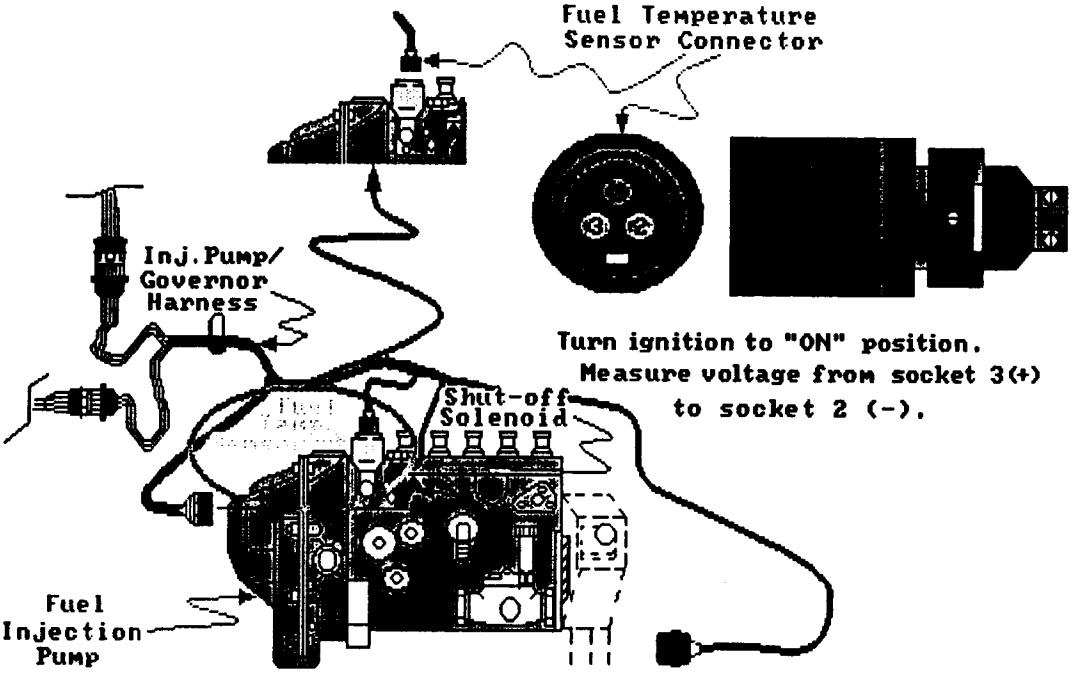


Figure 84: Graphic RBJ13-23

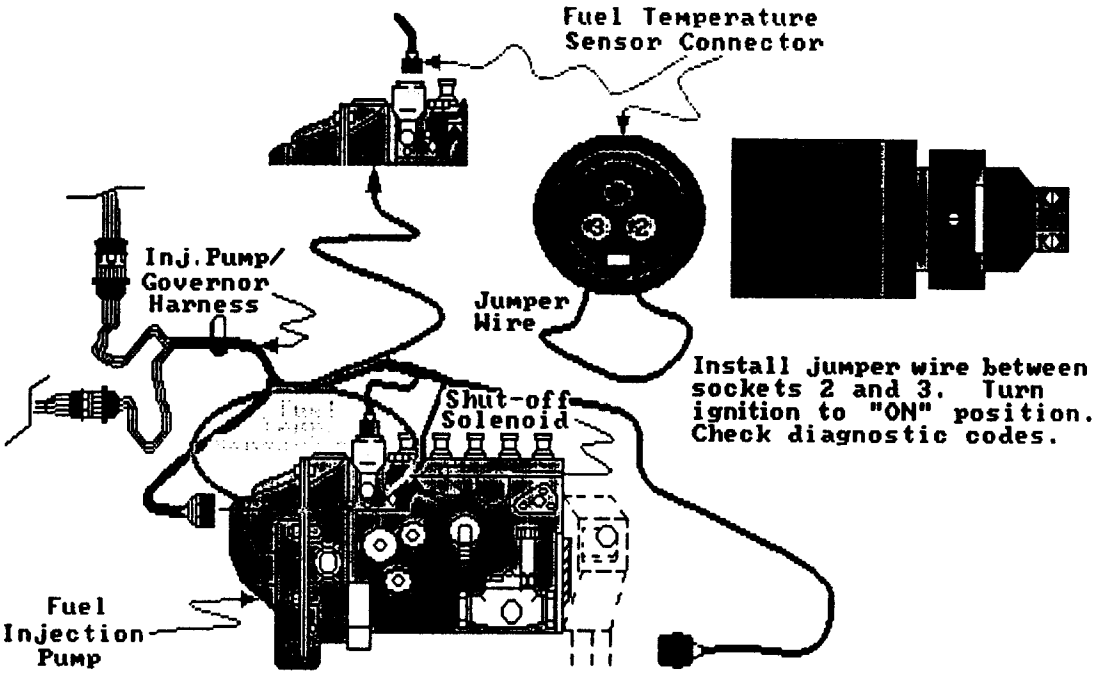


Figure 85: Graphic RB-J1323

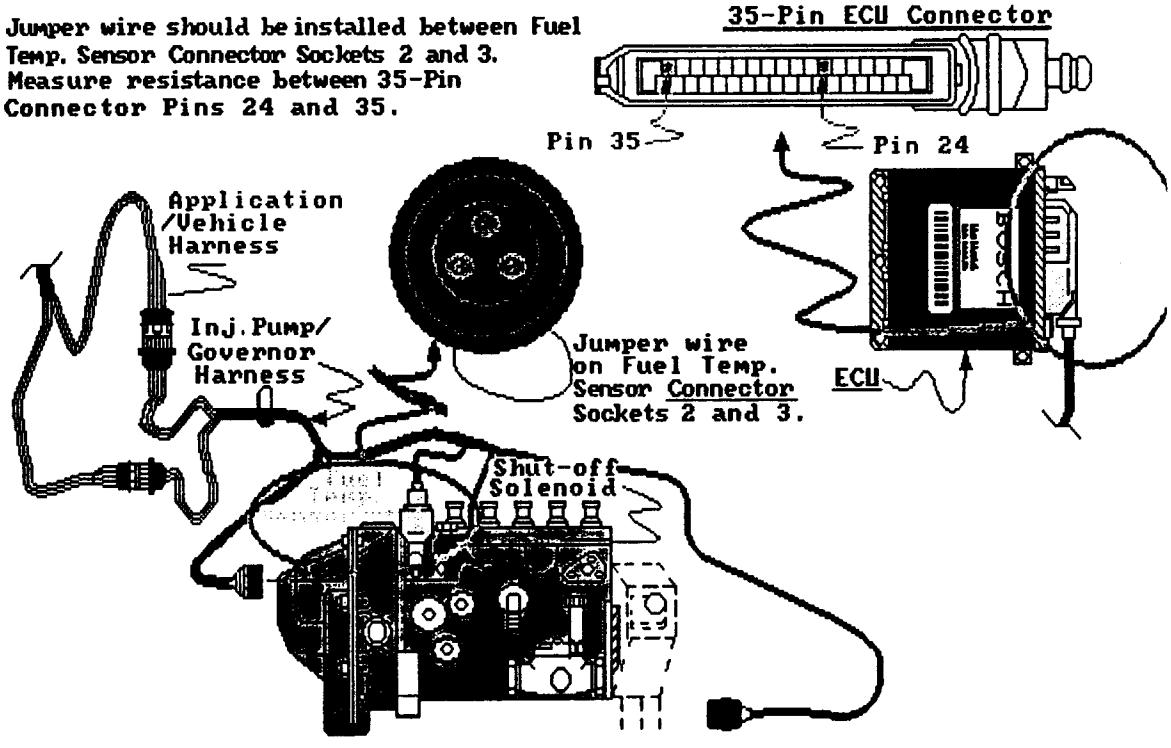


Figure 86: Graphic RB243513

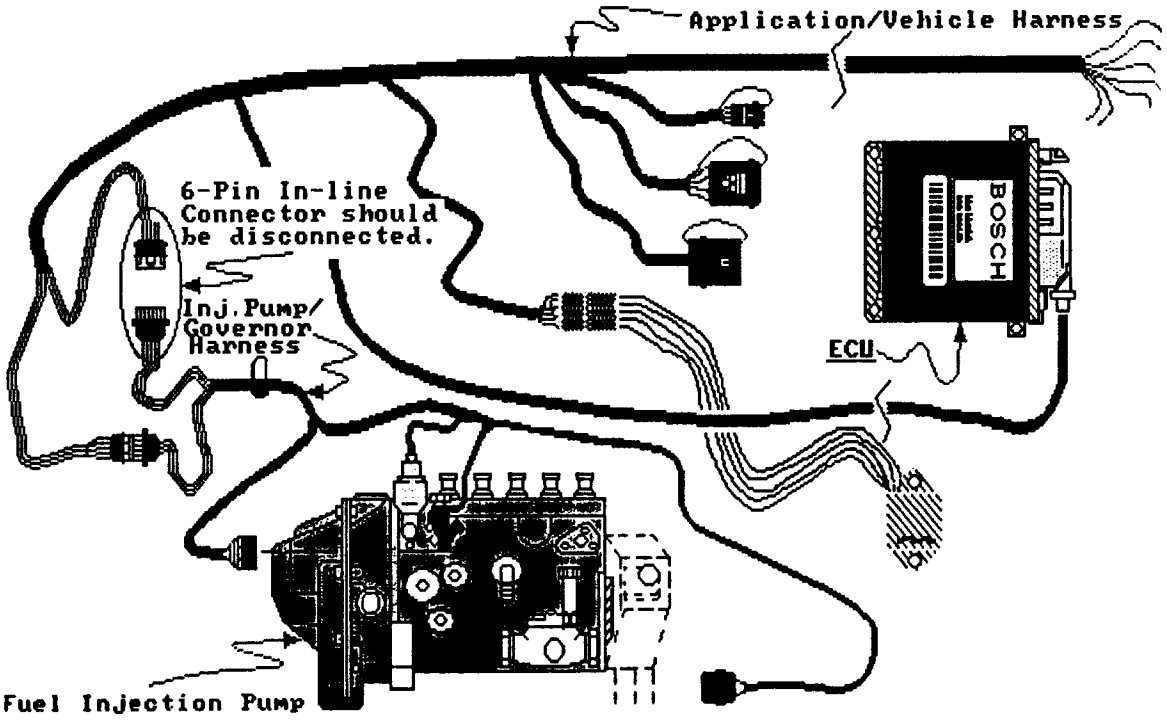


Figure 87: Graphic RB-J9J10

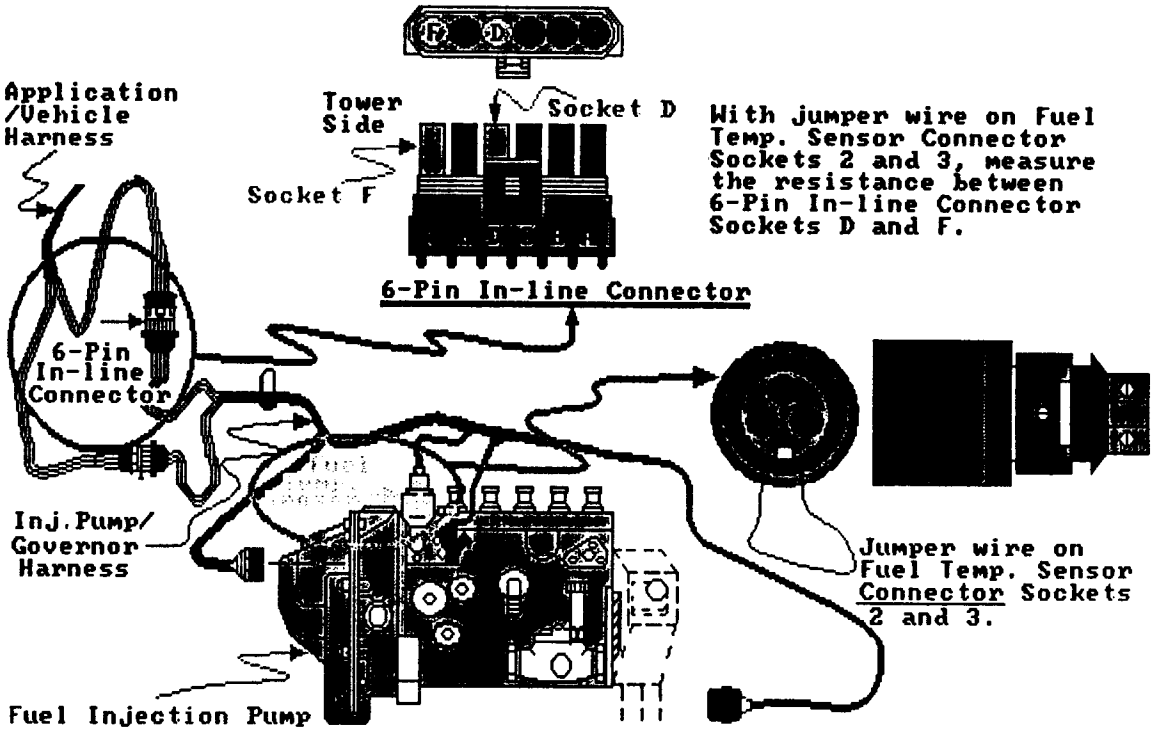


Figure 88: Graphic RBJ13J10

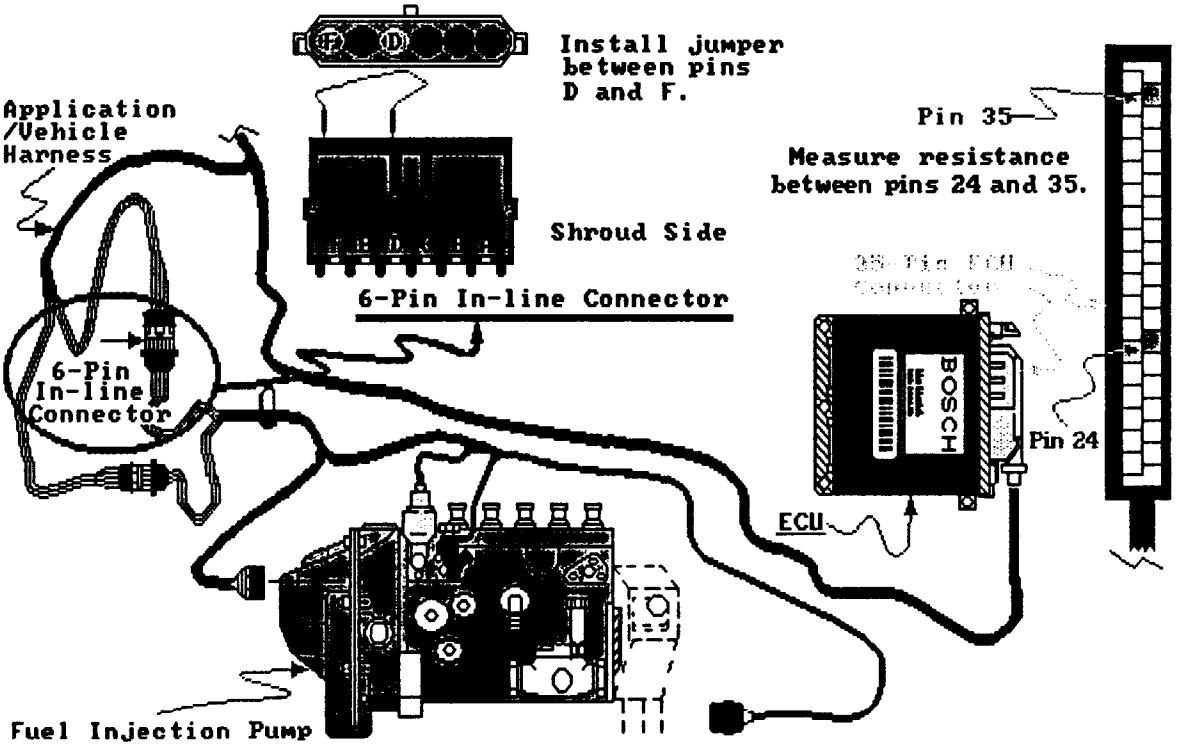


Figure 89: Graphic RBJ1J9DF

Temperature Sensor Characteristic

Temperature (Deg. C)	Resistance (Ohms)
-20	15300
0	5840
20	2500
40	1180
60	600
80	327
100	188

Figure 90: Graphic RBTEMPCH

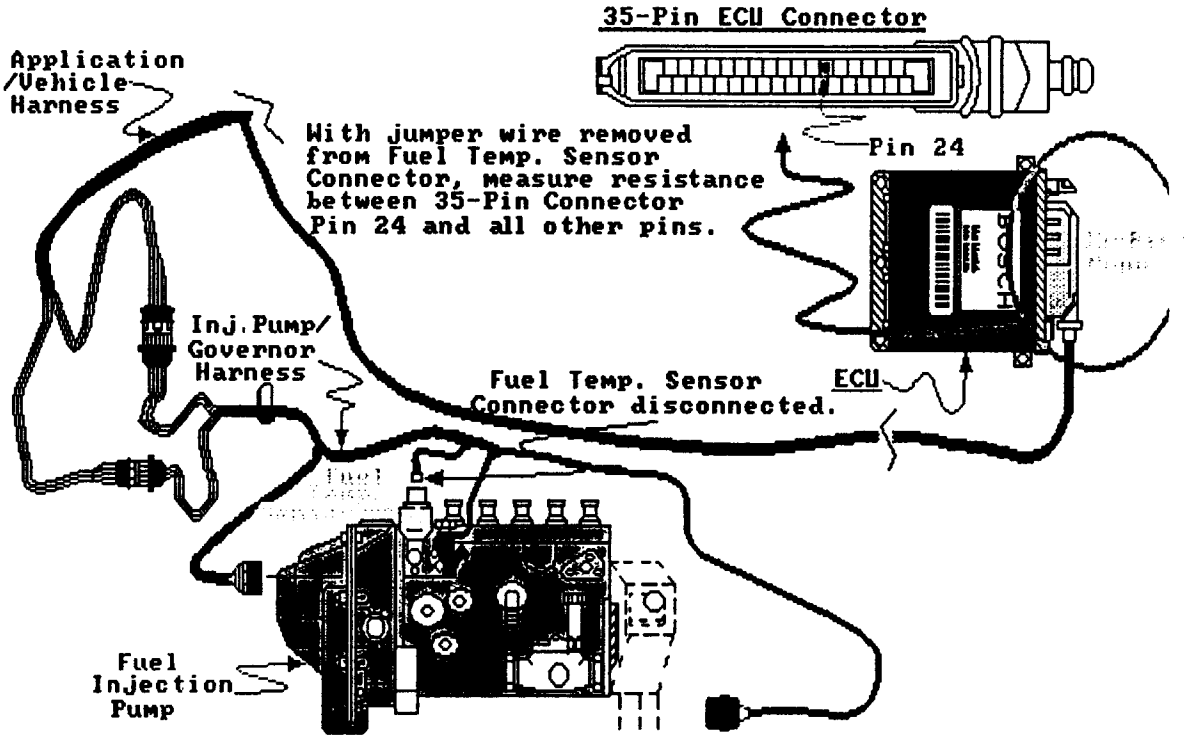


Figure 91: Graphic RBJ1-241

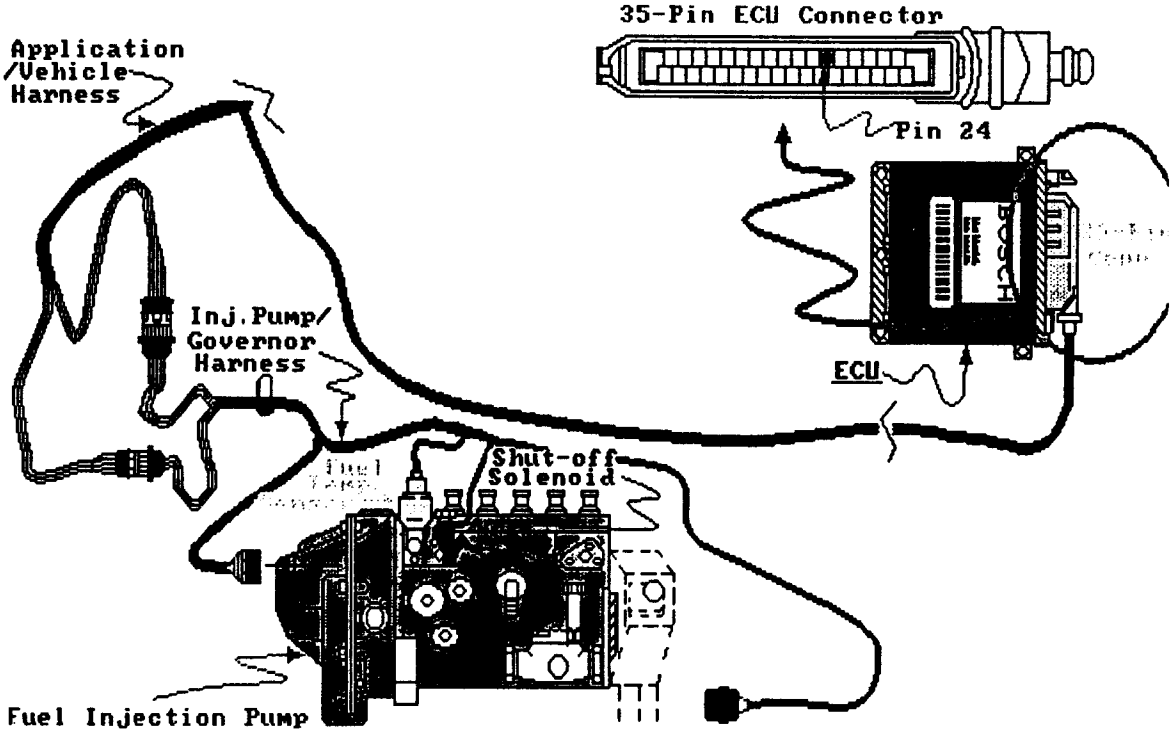


Figure 92: Graphic RBJ124

Appendix G

Knowledge Engineer's Vita

Kim E. Ruyle

Office
130 South First Street
PO Box 40
Galesville, WI 54630
(608) 582-4610

Home
612 Lake Court
Galesville, WI 54630
(608) 582-4573

Work Experience

President; Plus Delta Performance. Managing consulting organization which provides performance technology service to business and industry. Services include knowledge engineering/development of conventional and intelligent job aids, instructional design for technical and skills training programs, organizational development, and feedback and reinforcement systems. 7/90-Present.

Assistant Professor of Industrial Technology Management; University of Wisconsin-Platteville. Taught manufacturing processes and technology management, conducted research, provided community service. 9/88-7/90.

Manager, Human Resource Development; ICI/Fiberite Composite Materials. Developed and managed company-wide managerial, statistical process control, and technical skills training programs. Delivered employee training at sites nationwide. Facilitated inter- and intra-unit relationships and assisted with organizational development. 6/87-9/88.

Instructor of Industrial/Manufacturing Engineering; Oregon State University. Taught manufacturing processes, machining, and tool design. Advised students. Developed and managed instructional manufacturing lab. Taught graduate courses for the Dept. of Industrial Ed. in computer-aided manufacturing, advanced plastics, and power mechanics. 6/85-6/87.

Manager, Instructional Shop Facility; Oregon State Univ. Managed instructional lab facility: coordinated instruction, managed inventory, directed maintenance, supervised student employees. 6/85-9/85.

Instructor, Adventures in Learning Program; Oregon State University. Instructed beginning and advanced robotics courses in special summer program for talented and gifted middle school students. 7/85 and 7/86.

Curriculum Developer/Instructor; Rogue Community College. Consulted with faculty and administrators. Wrote curriculum for a new program in High Technology Studies. Visited and reported on innovative instructional programs in northeast U.S. in automated manufacturing technology. Instructed courses in CNC Programming and Robotics on RCC campus to prepare instructors to teach new technologies. 1/85-6/85.

Work Experience (cont.)

Graduate Teaching Assistant; Oregon State University. Taught advanced machining, plastics, metal casting, and welding courses for the Dept. of Industrial Education. 9/84-6/85.

Instructor, Mechanical Engineering Technology; Rochester Community College. Taught engineering materials & processes. 3/84-6/84.

Instructor of Industrial Education; Winona State University. Taught manufacturing, beginning and advanced machining, plastics, metal casting, and industrial safety for the Industrial Education Department. 9/83-6/84.

Diesel and Heavy Equipment Mechanic/Welder/Machinist. Extensive experience gained over an 11-year period diagnosing, repairing, and fabricating a wide range of industrial, agricultural, and construction equipment, including: diesel and gasoline engines, transmissions and torque converters, and electrical machinery.
- Winona Attrition Mill Co. 3/81-9/83.
- LaCrosse Concrete Co. 12/79-12/80.
- Inland Machinery Co. 7/75-12/79.
- U.S. Army; 225th Heavy Equip. Repair Co. 7/72-7/75.

Education

Ph.D. Oregon State University. 1990.
Vocational-Technical Ed; Training & Development emphasis.
Minors: Industrial Engineering
Instructional Technology
Dissertation: Developing Conventional and Intelligent job aids: A Case Study.

M.Ed. East Texas State University. 1988.
Educational Technology; Instructional Design emphasis.

M.S. Oregon State University. 1986.
Trade & Industrial Education; Computer-Aided Mfg. emphasis.
Minor:Industrial Engineering
Thesis: Effectiveness of an Expert System for Teaching Casting Defect Diagnosis in Engineering and Technical Education.

B.S. Magna Cum Laude. Winona State University. 1983.
Industrial Education; In-depth Major.

Other schooling:
Qualpro. Experimental Design Techniques. 1988.
Institute for Prof. Ed. Tough Positive Management. 1987.
Learning International. Cert. Trainer--Supervision. 1987.
University of Wisconsin-Stout. Robotics Seminar. 1983.
Western Wisc. Tech. Inst. Voc. Welding Certificate. 1981.
International Corresp. Schools. Diesel Mechanics. 1979.
Yakima Valley College. Fuel Inj. 1979. Diesel Engines. 1978.
Wayne School. Diesel Mechanics. 1977.
Great Plains Vo-Tech. Small Engines. 1974. Machining. 1974.
Advance Schools. Engine Service and Vehicle Repair. 1974.
U.S. Army Engr. Engr. Equipment Repair. 1973. Maint. 1972.
Highland High School. Diploma. 1972.

Professional Associations and Service

National Society for Performance and Instruction (NSPI)
American Society for Training and Development (ASTD)
South Central Wisconsin Chapter ASTD
Society of Manufacturing Engineers (SME)
Editorial Advisory Committee of Technical & Skills Training (1990-Present)

Publications, Presentations, Grants

Ruyle, K. E. (1985). Instructor's manual: Computer-aided manufacturing I. Grants Pass, OR: Rogue Community College.

Ruyle, K. E., Long, L., & Yu, S. (1985). Human-robotics interfacing and applications for pacing manual assembly tasks. Unpublished manuscript. Oregon State University, Dept. of Industrial & Manufacturing Engineering.

Ruyle, K. E. (1985). Instructor's manual: Robotics systems. Grants Pass, OR: Rogue Community College.

Mullaly, L., & Ruyle, K. E. (1985). A view from Rogue Community College: Perspectives on high technology studies in the New York/Boston industrial corridor. Grants Pass, OR: Rogue Community College.

Ruyle, K. E. (1985, October). Teaching problem solving skills. Presentation for the Oregon Vocational Association Fall Conference. Oregon City, OR.

_____ (1985, December-January). Cellular concrete. Fine Homebuilding, p.76.

_____ (1986). Effectiveness of an expert system for teaching casting defect diagnosis in engineering and technical education. Unpublished master's thesis, Oregon State University, Corvallis, OR.

Publications, Presentations, Grants (cont).

_____ (1986). Telecast [Expert system]. Corvallis, OR: Oregon State University, Dept. of Industrial & Manufacturing Engineering.

_____ (1986). Artificial intelligence: A developing technology. Industrial Education, 75(7), 18-20.

_____ (1986). How artificial intelligence impacts industrial education. Industrial Education, 75(8), 42, 44, 60.

_____ (1987, January). Effectiveness of an expert system for teaching technical subject matter. Paper presented at the 4th International Symposium on Modeling and Simulation Methodology. Tucson, AZ.

_____ (1987). [Review of EXSYS: Expert system development package]. Journal of Industrial Teacher Education, 24(2), 102-106.

_____ (1987). Making cooperation happen. Vocational Education Journal, 62(4), 21-22.

_____ (1987). FLITE: Fiberite Leadership In Total Excellence. The Carbon Copy, 2(1), 3. Greenville, TX: ICI/Fiberite Composite Materials.

_____ (1987, October). Using tools of artificial intelligence to train effective problem solvers. Presentation for the American Society for Training and Development National Conference on Technical Skills Training. Cincinnati, OH.

_____ (1987). Creating the climate for excellence. The Carbon Copy, 2(2), 1,8. Greenville, TX: ICI/Fiberite Composite Materials.

_____ (1987, October). Expert system applications in training: An introduction and demonstration. Seminar sponsored by the Dept. of Educational Media and Technology, East Texas State Univ. Commerce, TX.

_____ (1988, January). Introduction to artificial intelligence. Seminar sponsored by the East Texas Chapter, American Society for Training and Development. Tyler, TX.

_____ (1988). SPC: Or, what do you do if you have really unusual feet? FLITE, 1(1), 3, 8. Greenville, TX: ICI/Fiberite Composite Materials.

Publications, Presentations, Grants (cont).

_____ (1988). Media. [Expert system]. Commerce, TX: East Texas State University, Dept. of Educational Media and Technology.

_____ (1988). The RITE stuff for FLITE stuff. The Carbon Copy, 2(3), 2-3, 13. Greenville, TX: ICI/Fiberite Composite Materials.

_____ (1988). Leadership. The Carbon Copy, 2(4), 3. Greenville, TX: ICI/Fiberite Composite Materials.

_____ (1988, October). Expert system applications in training. Paper presented at the American Society for Training and Development Region 7 Annual Conference. San Antonio, TX.

_____ (1988, November). Expert system applications in technical and skills training. Presentation for the American Society for Training and Development National Conference on Technical and Skills Training. Indianapolis, IN.

_____ (1988). Artificial intelligence and expert systems in education. Educational Resources & Techniques, 27(3), 26-28.

_____ (1988, November). Artificial intelligence in the work place. Presentation for the Society of Manufacturing Technologists, University of Wisconsin-Platteville. Platteville, WI.

_____ (1988). Expert system technology in the Industrial Studies curriculum--EXSYS. Grant proposal resulting in the donation of software from EXSYS, Inc. $795.

_____ (1988). Expert system technology in the Industrial Studies curriculum--Personal Consultant Plus. Grant proposal resulting in the donation of software from Texas Instruments, Inc. $4990.

_____ (1989, February). Expert systems for instructional design. Paper presented at the Association of Educational Communications and Technology Annual Convention. Dallas, TX.

_____ (1989, March). Statistical process control: Tool for training evaluation and improvement. Paper presented at the National Society for Performance and Instruction Annual Conference. Denver, CO.

_____ (1989). Expert systems: They're here now. Tech Trends, 34(1),41-43.

Publications, Presentations, Grants (cont).

Ruyle, K. E., & Clifton, J. M. (1989). Expert system development workshops. Grant proposal resulting in funding of a series of workshops for area business and industry. $1000. University of Wisconsin-Platteville Foundation. Platteville, WI.

Ruyle, K. E. (1989). To improve training . . . reduce variation. Performance & Instruction, 28(2), 9-16.

_____ (1989, April). Using artificial intelligence to improve training. Presentation for the 1989 Professional Development Institute sponsored by the South Central Wisconsin Chapter of the American Society for Training and Development. Madison, WI.

_____ (Speaker). (1989, September). Improving human performance with expert system technology. Presentation for the American Society for Training and Development National Conference on Technical Skills Training. Detroit, MI. (Cassette Recording No. 89TS-W13). Washington, DC: American Society for Training and Development.

_____ (1989, October). Artificial intelligence and human performance technology: Enhancing the workforce. In R. Bolin & L. Green (Eds.), Conference Proceedings of Building a Quality Workforce: A National Priority for the 21st Century (pp.25-31). Menomonie, WI: University of Wisconsin-Stout.

_____ (1989). Projects offer 'real world' experience--Christmas tree stand typifies benefits of project approach. School Shop, 49(5), 30-31.

_____ (1990, January). Expert system technology for administrative data processing professionals. Presentation for the Department of Administrative Data Processing, University of Wisconsin. Madison, WI.

_____ (1990). Expert systems: They're here now. In Hirschbuhl, J. J., & Konet, R. M. (Eds.), Computers in education. Guilford, CT: Dushkin Publishing Group.

_____ (1990, March). Artificially intelligent tools for the technical educator's toolbox. Paper presented at the American Technical Education Association Annual Conference, Oklahoma City, OK.

Publications, Presentations, Grants (cont).

_____ (1990, April). Shaping corporate culture: The role of the training professional. Presentation for the 1990 Professional Development Institute sponsored by the South Central Wisconsin Chapter of the American Society for Training and Development. Madison, WI.

_____ (1990). Developing great job aids. Technical & Skills Training, 1(1), 27-31.

_____ (1990, October). Business archaeology 101: What every training professional should know about corporate culture. Presentation for the American Society for Training and Development Region 5 Annual Conference. Milwaukee, WI.

Ruyle, K. E., & Smidt, W. (1990, October). Expert system development for technical trainers. One-day workshop by invitation for the American Society for Training and Development National Conference on Technical and Skills Training. Baltimore, MD.

Ruyle, K. E. (1990). Developing conventional and intelligent job aids: A case study. Doctoral dissertation, Oregon State University, Corvallis, OR.

_____ (In press). Developing intelligent job aids intelligently. Technical & Skills Training.

Appendix H

Troubleshooting Exercises

Video tape #_____ Type of job aid: _____ Conventional

Subject #_____ _____ Intelligent

Problem #1--Code 32 (#1)

Diagnostic step	**Prompts**		**Errors**	
	System	Job Aid	System	Job Aid
1) Inspect J7/J8	_____	_____	_____	_____
2) Check resistance, J8 socket A to J8 socket B	_____	_____	_____	_____
3) Inspect J12	_____	_____	_____	_____
4) Check resistance, J8 socket A to J8 socket B; inspect harness	_____	_____	_____	_____
5) Check resistance, actuator connector pins 2 and 7	_____	_____	_____	_____

Video tape #_____ Type of job aid: _____ Conventional

Subject #_____ _____ Intelligent

Problem #2--Code 37

Diagnostic step	**Prompts**		**Errors**	
	System	Job Aid	System	Job Aid
1) Check resistance, temperature sensor pins	_____	_____	_____	_____
2) Inspect J13 connector	_____	_____	_____	_____
3) Measure voltage, J13 socket 3 to J13 socket 2	_____	_____	_____	_____
4) Inspect J1 connector	_____	_____	_____	_____
5) Check resistance, J1 pin 24 and all other J1 pins	_____	_____	_____	_____
6) Inspect J9/J10 connectors	_____	_____	_____	_____
7) Check resistance, J1 pin 24 and all other J1 pins	_____	_____	_____	_____

Video tape #_____ Type of job aid: _____ Conventional

Subject #_____ _____ Intelligent

Problem #3--Code 35

Diagnostic step	**Prompts**		**Errors**	
	System	Job Aid	System	Job Aid
1) Inspect J9/J10 connectors	_____	_____	_____	_____
2) Check resistance, J10 sockets A & B, J10 sockets B & C,	_____	_____	_____	_____
3) Check resistance, J10 socket A and J12 socket 1	_____	_____	_____	_____
4) Check resistance, J10 socket B and J12 socket 6	_____	_____	_____	_____
5) Check resistance, J10 socket C and J12 socket 5	_____	_____	_____	_____

Video tape #_____ Type of job aid: _____ Conventional

Subject #_____ _____ Intelligent

Problem #4--Code 32 (#2)

Diagnostic step	**Prompts**		**Errors**	
	System	Job Aid	System	Job Aid
1) Inspect J7/J8	_____	_____	_____	_____
2) Check resistance, J8 socket A to J8 socket B	_____	_____	_____	_____
3) Inspect J1 connector	_____	_____	_____	_____
4) Check resistance, J1 pins 3 and 21	_____	_____	_____	_____
5) Check resistance, J1 pin 3 and J7 pin B	_____	_____	_____	_____
6) Check resistance, J1 pin 3 to other J1 pins except 21	_____	_____	_____	_____
7) Measure voltage to J7 pin A	_____	_____	_____	_____

Appendix I

Instructional Design

Introduction

This document explains the instruction design procedure used to prepare the training lessons that were given to subjects prior to the troubleshooting exercises.

At least some instructor-led training was considered necessary for several reasons:

* The intelligent job was a new device to all the subjects. Although the system is extremely easy to use, subjects would need some instructions about the commands used to operate the system.
* Since few of the subjects had more than a cursory exposure to the electronic fuel system, review of system components was advisable.
* While the above needs could be addressed by instructional text or other medium, personal contact was desirable to adequately explain the nature and purpose of the exercise, answer individual questions, assure anonymity, and place subjects at ease.

Instructional Goals

Two instructional goals were identified as requisite to successfully perform the troubleshooting exercises. After training, subjects would be able to:

1) Use the conventional job aid to diagnose Robert Bosch electronic fuel injection system problems.
2) Use the intelligent job aid to diagnose Robert Bosch electronic fuel injection system problems.

Entry Behaviors, Characteristics of T-pop

The target population for this training consisted of D-TAC technicians, Deere area service managers, factory mechanics, and technical trainers working at the Deere factories and training centers. Several Deere personnel familiar with the target population were consulted in order to formulate the following notes which describe expected characteristics of the subjects.

Age range expected: 25 to 60 years

Gender expected: Predominantly male

Educational level expected:

Wide range--high school graduates to college graduates, some with vocational education.

Experience:

Most will have had very little or no experience with electronic fuel injection systems. Experience with mechanical fuel injection systems will vary from almost none to extensive. Computer literacy will vary from almost none to moderate applications-type experience.

Special considerations:

Involvement will be mandated from management. Some may feel confused as to what's going on, especially when they hear new terms ("expert systems," "artificial intelligence," etc.).

Instructional Analysis

The analysis of each of the instructional goals is represented in Figure 93 and Figure 94.

Performance Objectives

The instructional analysis guided development of the following performance objectives. After training, participants will be able to:

* When given various engine symptoms, identify those that can be diagnosed by the conventional job aid.
* When given an appropriate symptom to diagnose, locate the correct diagnostic section in the conventional job aid in less than a minute.
* When given a list of electronic fuel injection system components, the conventional job aid, and a fuel system, locate all identified components on the fuel system.
* When given a symptom, conventional job aid, necessary test equipment, and a real or mock fuel system, correctly diagnose the symptom.
* When given various engine symptoms, identify those that can be diagnosed by the intelligent job aid.
* When given a list of symptoms and the intelligent job aid, correctly enter the diagnostic sequence using the system menu.
* When given a list of symptoms and the intelligent job aid, execute the prescribed troubleshooting sequence using all the function keys correctly as needed.
* When given a list of electronic fuel injection system components, the intelligent job aid, and a fuel system, locate all identified components on the fuel system.
* When given a symptom, intelligent job aid, necessary test equipment, and a real or mock fuel system, correctly diagnose the symptom.

Evaluation of Performance Objectives

Following training, evaluation was conducted by providing subjects with test equipment, mock fuel system, and a symptom to troubleshoot. Facilitators observed performance and provided feedback.

Instructional Strategy and Instructional Materials

The lessons plans used are displayed below. The lesson introduction was only delivered during the first of the lessons. Instructional materials used were the same as those used by subject to perform the troubleshooting tasks: the mock fuel injection system, real tools and test equipment, and job aids.

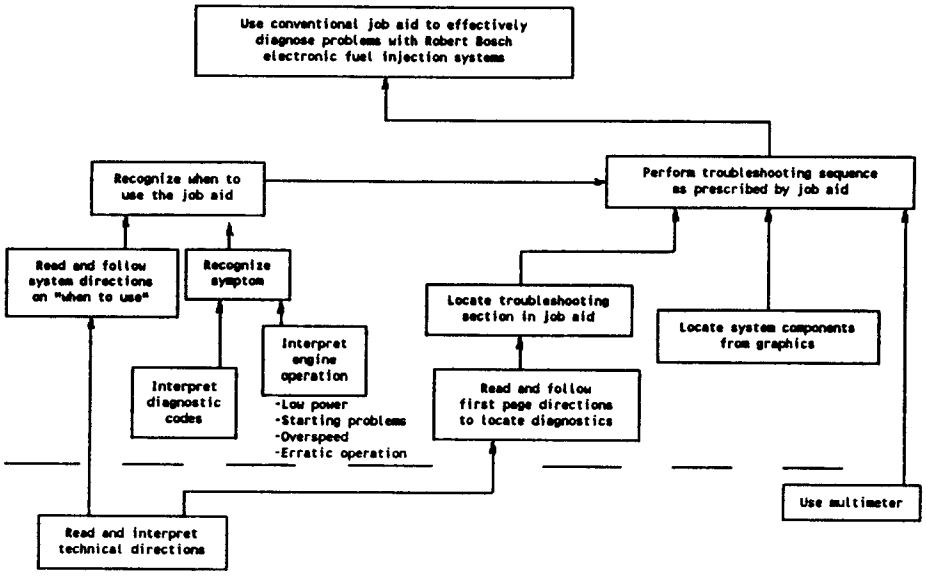


Figure 93: Instructional Analysis of First Goal

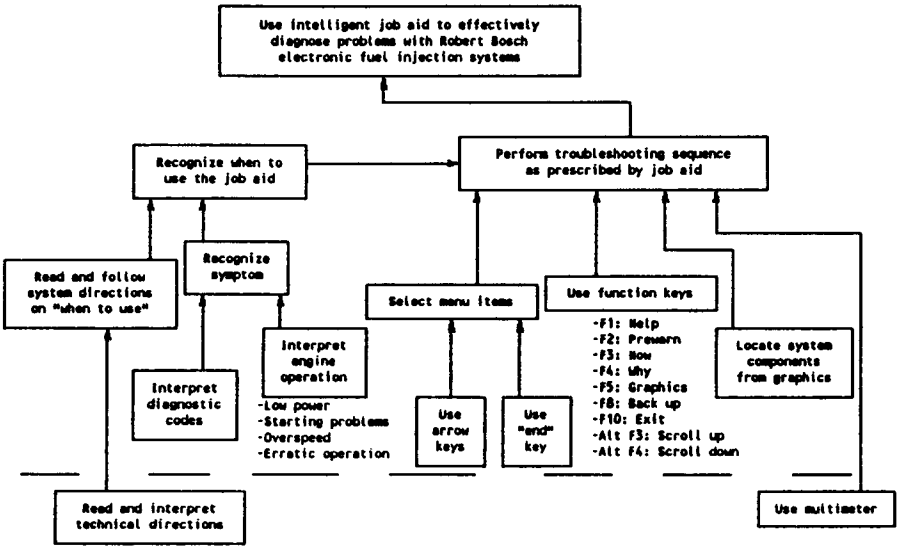


Figure 94: Instructional Analysis of Second Goal

CONVENTIONAL JOB AID LESSON

Objectives:

* When given various engine symptoms, identify those that can be diagnosed by the conventional job aid.
* When given an appropriate symptom to diagnose, locate the correct diagnostic section in the conventional job aid in less than a minute.
* When given a list of electronic fuel injection system components, the conventional job aid, and a fuel system, locate all identified components on the fuel system.
* When given a symptom, conventional job aid, necessary test equipment, and a real or mock fuel system, correctly diagnose the symptom.

Content:

I. Introduction--15 minutes
   A. Presenter introduction and welcome
   B. Lesson objectives
   C. Pre-lesson survey--explain "why"
   D. Overview of Robert Bosch fuel system
   E. Overview of conventional job aid

II. Demonstrate job aid--10 minutes
   A. Appropriate problems
   B. Diagnostic sections
   C. Graphics
   D. Finding a solution

III. Conclusion--5 minutes
   A. Summary
   B. Questions and closure

Materials needed: Conventional job aid
Digital multimeter
Jumper wires
Mock fuel injection system

INTELLIGENT JOB AID LESSON

Objectives:

* When given various engine symptoms, identify those that can be diagnosed by the intelligent job aid.
* When given a list of symptoms and the intelligent job aid, correctly enter the diagnostic sequence using the system menu.
* When given a list of symptoms and the intelligent job aid, execute the prescribed troubleshooting sequence using all the function keys correctly as needed.
* When given a list of electronic fuel injection system components, the intelligent job aid, and a fuel system, locate all identified components on the fuel system.
* When given a symptom, intelligent job aid, necessary test equipment, and a real or mock fuel system, correctly diagnose the symptom.

Content:

I. Introduction--15 minutes
   A. Presenter introduction and welcome
   B. Lesson objectives
   C. Pre-lesson survey--explain "why"
   D. Overview of Robert Bosch fuel system
   E. Overview of intelligent job aid

II. Demonstrate job aid--10 minutes
   A. Selecting menu items
   B. Using function keys
   C. Graphics
   D. Finding a solution

III. Conclusion--5 minutes
   A. Summary
   B. Questions and closure

Materials needed: Intelligent job aid
Digital multimeter
Jumper wires
Mock fuel injection system

Appendix J

Pre-exercise Survey

Robert Bosch Electronic Fuel System Study

To help us better estimate the value of the tools you will be using in the training today, please answer all of the following questions to the best of your ability.

You will not be personally identified with the results of this questionnaire or with any other data gathered in this study.

Thanks very much for your participation and assistance.

Tell us about your experience troubleshooting diesel fuel systems.
Check the one most appropriate response in each column.

Mechanical fuel injection systems		Electronic fuel injection systems
_____	Have basically no experience	_____
_____	Limited experience -- Have worked on probably less than ten problems and seldom need to in my current job	_____
_____	Significant experience -- Have worked on more than ten problems and must do so as part of my current job	_____

Tell us about your experience with computers.
Check the one response that best describes your experience.

_____ Have basically no experience

_____ Have some experience, but don't normally use a computer in my job

_____ Have considerable experience --regularly use a computer in my job

Check the one response that best describes your level of formal education.

_____ High school and on-the-job training

_____ Vocational-technical schooling after high school

_____ Some college but no degree

_____ College degree

What is your age? _____

Appendix K

Post-exercise Questionnaire

Robert Bosch Electronic Fuel System Study

Please answer the following questions to help us evaluate the diagnostic tools you have used today. Thanks for your assistance!

1. Which of the two job aids do you think would be most appropriate for **new technicians**? Check one.

   ____ Conventional (paper) job aid

   ____ Intelligent (computer) job aid

2. Which of the two job aids do you think would be most appropriate for **experienced technicians**? Check one.

   ____ Conventional (paper) job aid

   ____ Intelligent (computer) job aid

3. Which of the two job aids do you believe is most likely to lead you to a **correct** diagnosis? Check one.

   ____ Conventional (paper) job aid

   ____ Intelligent (computer) job aid

4. Which of the two job aids do you believe would be the easiest to use **on the job**? Check one.

   ____ Conventional (paper) job aid

   ____ Intelligent (computer) job aid

5. Rate the overall **usefulness of the conventional job aid.** Circle one.

Extremely useful — Not at all

1 — 2 — 3 — 4 — 5 — 6

6. Rate the overall **usefulness of the intelligent job aid.** Circle one.

Extremely useful — Not at all

1 — 2 — 3 — 4 — 5 — 6

Appendix L

Post-exercise Interviews

Subject #1

I: You've had a chance to use two job aids, the computer and the paper one, which do you think would be more valuable to you in the troubleshooting that you do?

Being in the field, we have Compaqs [portable computers] now that we carry with us to do our field reports with, and I don't know if that could be the same as computer aid. That would be what I would go to.

I: So, if you could use the existing computer, you say the intelligent would be more valuable?

Yes.

I: Why would you choose that over the other?

Because I can put the screen up and look at the screen and move back and forth quicker, and it tells you step by step exactly what to do and where to go, where in the book I have to remember what page I was on and flip back and forth. It [the book] uses your hands.

I: Compare using this small troubleshooting guide and a CTM-11 or TM. How would you compare using the condensed version as opposed to using the whole manual?

I would go for the condensed.

I: Why is that?

Handier, less pages, quicker.

I: Is that enough information for you?

I don't have the experience [with electronic fuel injection systems] to say whether it would or not.

I: Think about a problem--the kind of troubleshooting that you would be more commonly doing, maybe general engine problems, hydraulic problems, or whatever. If you are working with a system that you are fairly familiar with, would like to see a smaller troubleshooting guide?

Smaller troubleshooting guide, yes.

I: What concerns do you have about using the expert system, the computer job aid?

Just that it was user-friendly, that each menu was explained simply, and that if you pushed the wrong button it wouldn't screw things up for you. You could get in and out of it easy. Last year the Compaqs [for field reports] were not user-friendly. We had a lot of trouble with it and re-did it this year.

I: If you were going to give me some advice about developing a paper troubleshooting guide, what is one feature that you would say I should pay attention to?

Uh...

I: Something extremely important that I need to make sure is done well?

On the paper part, the terminology or the wording of the instructions.

I: What about with the expert system, what is the one thing I should pay attention to?

The diagrams, the graphics, and the menus.

I: Did you find the graphics pretty helpful on the expert system?

Yes.

I: What kind of person do you think would choose the conventional, the paper job aid, over the expert system?

The old timers, the ones afraid to work with computers.

I: Have you had much computer experience?

Yes, I volunteered to do all my field reports with the Compaq.

I: What kind of person do you think would choose the expert system over the paper?

Someone who would be more efficient, quicker.

I: Any other comments you'd like to make?

Both systems being available in a dealer or repair shop would be beneficial. Give us more training on the [expert] system.

Subject #2

I: You had a chance today to use this job aid and the expert system. For you, which do your think would be the most valuable?

If I was out on a combine, up on a combine, I feel that the printed one would be better. If I was sitting at my desk I would use the computerized one. If I had more experience with the computer I would probably like it a lot better. It would be a lot quicker.

I: Compare using this condensed version to the CTM-11 or another big TM.

I think this one is more condensed, where in one area I know where to find it, it's right here. The big one, the first thing you have to decide is where the part is that you are going to be working on, which code or section of the book that contains that. This one here [conventional job aid] was a lot easier than the other one [technical manual].

I: You mentioned that you had a concern about crawling up and down on the combine for using the computer. What other concerns would you have about the using expert system?

Practice. I think one concern would be getting dirt in the keys, or finding a place where the sun doesn't hit the screen, you'll have to find some way to shield the screen.

I: The keyboard is sealed. Some ASMs used these out in the field all last summer. The sunlight is another matter with the back-lit screens.

But there is disadvantage to this one [conventional job aid] too. I have to find a rock or something to hold the page and you get dirt on the pages.

I: What advice would you give me if I was developing a paper job aid like this? What is the one feature that you think deserves special attention?

I think you ought to be really explicit on descriptions. Connectors J7 and J8....I have to keep turning back in the book to find it. J7 is G, the wire end. There is a lot of turning back and forth.

I: So maybe if it said 'J7 (4-pin connector harness end)'?

Yes. And what am I checking when I check pins A and B? Is that a continuity, is it a coil, a capacitor? Maybe some people don't care but I do.

I: Let's take the same question for the expert system. What is the one feature I should pay special attention to?

I think it is the same thing. I'm reading them both. The picture on the temp sender...I didn't think the arrows were too plain there.

I: Yeah. All those graphics were drawn free-hand with a mouse.

The one I'm thinking of is...it shows wires coming in, and then in the big part the temp sender points to here and the connector points to here. Would it help to dot the arrow so the person knows its inside?

I: Maybe so. OK, now tell me, what kind of person would select a paper job aid over the expert system?

Uh...

I: Describe the person who would prefer this.

Somebody that doesn't use a computer, somebody who thinks they can't learn a computer. I think within Deere there are some of those people around. Almost everybody has had to do something on the computer. You get out to some dealer technicians and some have never touched a computer before. I think we have a lot of people in the assembly area who will be using a computer for the first year on a PC. Last year they were trained and they had their option of using the computer or not, and they did not use it.

I: What kind of person is going to select the expert system over the paper job aid? Is it just the ones with computer experience?

No. If I'm sitting here at my desk I got my keyboard in front of me I think it's great, but if I'm on top of a combine I need to find a place to set it out of the sun. It's easy to fold paper up and put it in a pocket.

I: Any other comments you'd like to make?

Highlight the drawings....I like computers and I like the system.

Subject #3

I: You've now had a chance to use a paper job aid, a condensed CTM, and the computer expert system. Which do you think would be most advantageous for you and why?

The current system is the most advantageous for me on my job because I already have one computer on my desk. It's a lot more convenient for me to open up a book. It takes up less space and you can go through and mark pages and reference back to them.

I: This system can go on your current computer.

Then I would prefer to go with the expert system.

I: OK. Well, compare using this troubleshooting guide with the complete CTM.

It's just that--condensed, and that is good. Space and searching for something....how many chances there are for error? You are clearing the fog away. Anytime you can condense something and not take vital information away, it's good.

I: You mentioned a concern for increased hardware, are there any other concerns about using the expert system?

No, because the more we use the system, the better off we all are and the more efficient we are. The computer and all the programs are here to stay.

I: If I was to ask you for a piece of advice about developing a paper job aid, what would you say is the most essential thing to pay attention to?

Illustrations. Very Important they resemble the real thing. If "G" is bigger than "I", make it bigger. Details are very important. Connector shapes and sizes--make them as close to the real thing as possible.

I: What about for the expert system? Anything different that I would have to pay attention to?

The clarity of the instructions. Simplicity of terminology. No word usage that technicians won't understand.

I: What kind of people would select this paper job aid over the expert system?

The majority of our technicians today would use the paper because everyone is afraid of computers. Now, in-house people think the trend is computers, but once again it will depend on the age group. Younger people will go for the computer, and the older ones will go for the paper just because it [the computer] is an unknown. In the field, they will stay with the paper. Cost will be a factor. I think the trend would be to go to the paper. I don't think cost is a factor for the user, but for the employer.

I: So you've mentioned something about age and computer experience. At the dealer level, more technicians are younger than older, but maybe they don't have much computer experience.

Yeah. Technicians knowledgeable in computers are few and far between.

I: Any other comments that might help us out?

For the Engine Works benefit, and I can't be specific but wish I could be, the Harvester tech manual and the engine electronic injection system areas have connectors numbered and named that do not match the CTM-11 and CTM-6.

I see that the expert system is in the early stages and it doesn't always get a fair chance.

I have a hard time with losing the description of the part so I can identify it. The steps have to be kept to a minimum. It would be nice if one key was descriptions.

Can't have to worry about where to set the computer so it's out of the sun, no glare.

Subject #4

I: You've had a chance to work with both job aids, the paper and the computer. Which do think would be the most valuable for you and why?

I'm probably considered to be the old school, but I like the computer. I like what we can do with it, but I sometimes like to be able to see where I've been, where I'm going. And sometimes I lose that with having only one question in front of me.

I: Do you think that it is going to be the experienced mechanic or the novice mechanic that will be more likely to want to be able to see the big picture?

To tell the guy what he is trying to sort out at this point in the diagnostic procedure....if I knew what I was after was to determine whether the fuel temp sensor is bad, or whether the rack position sensor was open, or rack position actuator was bad....if I knew what I was going after, then I wouldn't have to see the big picture as much as I do when I'm not sure what I'm trying to find.

I: OK. Compare using this abbreviated troubleshooting manual to the full manual. How do you feel about that?

Full manuals tend to be too big, uneasy, get lost, and having an abbreviated one helps that. There is a lot of things that are missing from this, but I'm not sure how much more is given in the full.

I: What concerns would you have about using the expert system on the job?

None, but need more training to be able to sit down at the computer and feel at ease. If you have a person who cannot relate to the computer, it doesn't matter what you have in it as far as diagnostics routine because he is flustered immediately. Generally, our service people [at dealers] do not tend to be your ten-year experienced. It's one of those things where people come and go. It's a new position. There is the intimidation factor of the computer, I don't think we have a lot of four-year college degree service people. The service manager and people with many years experience could probably handle it. Don't be afraid that you are giving too much information...describing what is happening.

I: If you were to give me some advice to help me develop a paper job aid like this, what is one feature I should pay special attention to?

Flowcharts--they say yes or no, check this and go on. It gives you the whole picture. This [conventional job aid] is not formatted that way. And [you need] an easy way to get back into it if called away from your desk. Test marketing would be a suggestion also.

I: Any features on the expert system that you would say I should take a hard look at, that are extremely important?

I think we talked about most of them.

I: What kind of person do you think is going to choose the paper job aid over the expert system?

The old and stubborn one who is set in his ways.

I: OK. Now, do you have any other comments about either job aid?

Well, as we get more and more complex technical equipment, we got to have this. The ability to change and update from time to time is a big benefit.

Subject #5

I: Do you do much troubleshooting on your job?

Yes, quite a bit.

I: OK. You've had a chance to use two different job aids. Which one would be more valuable to you?

For me, I like the laptop. It is compact. [It allows] bouncing back with keystrokes rather than flipping pages.

I: Compare using this condensed version to the full-blown CTM or TM?

Condensed is all right, I didn't have a problem with it.

I: What concerns would you have about using the expert system on your job?

No, none really at all. I'm used to using PCs. We do a lot of our work, field and office, on PCs.

I: OK, now give me some advice. When I'm developing a job aid, a manual like this, what's one thing I should pay particular attention to?

You've done a good job. Directions are short, straight forward, step-by-step form. One thing you might periodically reference is your graphics.

I: What about the expert system, any important feature there I should pay attention to?

The only thing, probably keep the user more aware of what direction he is going. I like it that here [referencing the conventional job aid], it tells you what code 11 means.

I: What kind of person is going to reach for the paper job aid first, given the choice of paper or computer?

The older, more experienced are going to grab the paper, something they are more comfortable with. I think you get the newer people coming more and more computer oriented. They will identify with it a lot quicker.

I: So, it is primarily a function of age and computer literacy? A combination of the two?

Yes, computer literacy is a big part of it.

I: Any additional comments you'd like to make?

You got a real good start on it, graphics are good.

Subject #6

I: You indicated a minute ago that you like the intelligent job aid better. Do you do much troubleshooting on your job?

We don't so much with this injector [injection pump], but we do in the wiring.

I: Why do you prefer the expert system over the paper job aid?

It is so much more simpler once you understand it. With a little training you can understand it clearer.

I: Have you used the CTM-11?

No.

I: You used this job aid, how would you compare it to using a manual, a TM?

We use manuals.

I: OK. Manuals have a lot of information. How do you feel about using something like this [conventional job aid] which gives less information?

Uh...

I: Let's say you had to do troubleshooting on wiring problem on a combine, which one would you rather carry out to the job?

The smaller one, as long as it follows step by step, if you can get it in a small book.

I: OK. Now about the computer system. What concerns would you have about using it on your job?

It would be all right. But you got to have electricity.

I: It has battery power.

Oh.

I: What about if you set it on a tool box, or have to work with greasy hands?

We don't deal with that [in the factory]. We don't see any problems with it.

I: If you were going to design a troubleshooting guide, what is the most important thing to include in a job aid like this?

You want to include all your connections, diagrams, and step-by-step instructions.

I: What about designing a computer job aid? What do you think is the most important feature there?

It is much simpler once you learn how to operate it. You can work a lot faster. It cuts down the time, where in the book you have to read it, but this [expert system] will show you a lot of the problems wrong.

I: What kind of person would prefer this kind of job aid over the computer?

The one that hasn't ran computers. I have a little bit, not a lot. But I would select the computer myself because it is so much simpler. Farmers aren't in to this. Computers are just getting stronger and more known.

I: What kind of person would prefer the computer expert system?

Someone familiar with computers. The computer is so much more simpler.

I: Any thing else you can think of to comment on?

You should be able to go back to the last diagram. Ability to back up. The computer...it was hard to back up. It takes a while to get the hang of it.

Subject #7

I: You've had a chance now to work with two tools to diagnose electronic fuel systems. Which one would be most help to you on your job?

The computer is intelligent. I see flipping back and forth through pages a real problem, trying to remember what pin you were on.

I: How would you compare using this job aid to a CTM-11?

It seems like a pretty big book, the CTM-11. This would be a lot better than the CTM. It is more compact.

I: What concerns would you have about using the computer on your job?

Unless there is a mistake in it, there is no problem.

I: OK. Would you be doing any diagnostics out in the field with the system?

Yes.

I: And do you see any problems with it?

No, but have a tendency to have a hard time seeing that [screen].

I: Assume you had to write one of these job aids or you were going to give someone else some advice. What is the most important feature to include in a job aid like this paper one?

Diagrams for the pins. It probably needs more on using a meter.

I: What about the expert system? What is the most important feature?

The graphics. I like the why on there too.

I: If I was going to offer one of these systems to someone, what kind of person would prefer the paper job aid over the computer?

The older technician that is used to paper and not computers, or that just don't want to learn. I think that would be common until he gets familiar.

I: What type of person will prefer the computer then?

The new technicians. I think the age would make a difference.

I: OK. Now you have an opportunity to comment on anything else related to either job aid--anything you think might help us out.

I like to be able to back up. You will probably get more from ones who have worked with computers.

Subject #8

I: You've had a chance to work with two different job aids, which one would you prefer?

I think I would prefer the intelligent because of the prompting. It is easier to see rather than in the text.

I: OK. Compare the use of the CTM-11 with this [conventional job aid]?

I can't. I have never used it.

I: What concerns would you have about using the expert system on your job?

I don't know. I don't do enough difficult troubleshooting to know.

I: OK. Then imagine a user of the system, what kind of person would be likely to select the paper job aid over the computer?

Someone like myself that doesn't use a computer much. I did like it better. Mainly a function of computer experience.

I: Now, what kind of person would use the computer over the paper?

The younger, more educated people. The older people are more set in their ways.

I: Any other comments you'd like to make?

I didn't like flipping back and forth on the paper guide.

Subject #9

I: You've had a chance to use two job aids for troubleshooting. Which job aid would you prefer for your job?

I think I would prefer the computer job aid once I got some experience with it. Part of the problem I see is that you need experience in working through it a few times. If you don't use it real often, probably the paper aid would be easier.

I: Compare this [conventional job aid] with the CTM-11?

Uh...

I: Is this one better? Is it worse?

I can't say I've used the CTM much, I think this is probably better for troubleshooting electronic injection systems because it tends be more condensed in one area, easier to follow.

I: What concerns do you have with using the computer expert system? Consider the places you will be using it.

The problem I might have with it is with the computer you are paging through it one screen at a time, and what if I have a question on what I saw three screens ago, you have to page back and forth. But like with paper, you can lay out two or three pages at once and get straight.

I: If you were developing a paper job aid like this, what is the most important feature to include?

The most important feature is it needs to be very detailed in the steps you have to take as you are working through the diagnostic procedure, because after a person gets used to working with the diagnosis, a lot of the steps become presumed, and the person not familiar with that area or hasn't done it very often will miss those.

I: What about with the expert system? What's important?

Has to have the detail and the explanations of the steps you need to take as you work through it. Clear, complete instructions.

I: Does anything in the how and why and the graphics stand out to you as being very valuable?

I think the why is important. The computer system can transfer a lot more data and can communicate more, where with paper it would take volumes of pages. The screen you can page through or pass it on by.

I: What kind of person would choose the paper job aid over the computer?

People who have less experience with computers. That tends to be the older generation that are not comfortable. Most of our field mechanics would tend to use the paper because that is all they have ever done. A lot of technicians and engineers would probably tend to use the paper too.

I: OK. Do you have any other comments about either system?

On the paper type, we should have clearer instructions on what people are doing and why they are doing it, detailed instructions of the steps. It is also good to have a section that would have some of the why separate from instructions.

On the computer system, it should be user-friendly so that with a reasonable amount of training a person can understand how to work their way through the system. Have good pictorial information. There needs to be some documentation of the expert who wrote this so that if we get into a problem we can call somebody. And so they don't talk over peoples heads, too technical, et cetera.

Subject #10

I: Now that you've had a chance to work with both job aids, tell me which one you prefer and why.

Working conditions are most straining on the paper. You are covered with diesel fuel, wind, dust. Pages do not stay open. There are interruptions and that, and climbing up and down. As far as the computer, it stays with where you are. I'm interested in finding the problem right now. I don't care what steps I go through, or theory. I don't need to see anything but what I need to fix. If the paper could tell me this is the symptom--change this part, it would be fine. But diagnosing takes so much paper. When books are two, three, or four inches thick, it becomes difficult to deal with in the environment. Environmental concerns are major.

I: So you prefer the expert system?

Yeah.

I: OK. Now compare the use of the troubleshooting guides, the condensed version to the CTM.

I have a personal problem with that [structured list format] when I look at that you require absolute total obedience and almost non-thinking as you execute it. The minute you begin to think this routine screws up. I like to see where I'm going. With a flowchart, the person could look ahead and see the path. I have a lot of knowledge of the machine and its operating environment. This way [flowchart] they can decide which path to go, one may be more relevant than the other, or one more indicated than the other. There is an advantage in the paper flowchart: it is like looking at a road map. But when you get to somewhere and it's not where you want to be, you have to go all the way back to the beginning and that is time consuming and slow. There is also the pressure of having a customer standing over your shoulder watching you while you are doing this, and there is a great deal of egocentricity to these people that they don't want to look stupid. Looking at a book in front of a customer is deficient. Using a computer effectively is high tech. Both are the same, but different. CTM-11 is just too big. All of our books are too big.

I: All right. What concerns would you have in using the expert system on the job?

I really don't have any major concerns. One interesting aspect is you learn your way out of using. You accidentally receive training. You go through the methods they want you to. After you do that a couple of times with the computer, I'm not going to use the computer. I know I'll always check certain things in certain order, if I see those problems often enough, why should I even get the box out. That is a major advantage. The concern about using the expert system is where the data came from. It's very difficult to find true experts.

I: What are the most important features of a troubleshooting guide like this?

Some kind of path, graphics. Convenient to not go through so many keystrokes. A flip of the page is easier in an office environment. Sitting out in the field, the pages are blowing in my book and that is very distressing. There is still the attitude that you can take and write notes in it. Again it [conventional job aid] is immediately accessible.

I: Most important features of the expert system?

The capability to take and pull you through easily without having to deal with the flips. And when I do it, I don't have to look at 12 steps on a page to determine where I came from. I have one thing to look at. And that is my task at the moment. You have to be task-driven. One step at a time. For the experienced user, in my opinion, [they] are going to want to see the big picture. For the novice, they are going to want to see one piece at a time. Flowcharts are an excellent way for troubleshooting.

I: What type of person do you think would prefer the expert system?

I was biased. I thought it would be a younger person [with] higher skill levels than the older people. But it has a much broader appeal in my opinion. The people really want simple solutions to complex problems. The fact that it is on a computer is a little intimidating, but if it helps me solve the problem better... One person commented that one thing he hates more than computers is electronics on the machine. If the computer will help me troubleshoot the electronics, I'll master the computer. These people are not so much against the computer, it is the philosophy. I think properly presented, properly written, we could solve some of our training problems by simply orienting ourselves more toward basic skill as an educational level.

I: OK. Anything else you'd like to comment on?

My major concern is screen presentation. There are too many screens, because the typical person would like to use arrow keys and enter key only. But nice presentation. I like the hands-on.

Subject #11

I: You've had a chance to work with two job aids, paper and the expert system. Which one is going to be more helpful to you in troubleshooting?

I think the expert system will be much easier. You have all the paperwork, paper files, parts books, diagnostic books, in the field, and you got wind blowing, pages blow away. This is a step-by-step procedure. Just go to what you want to investigate.

I: Compare using something like this [conventional job aid] to the big TM's.

This is much simpler. You haven't got any paperwork. You got 1000 pages down to 20 pages. I think this is just great. I think we need it for everything. More pictures, more diagrams.

I: You've used the lap top computers out in the field some. What problems do you have with them?

Sunlight. Some different colors of the screen you can see better. You have to read everything on the screen or else you'll miss something. I think the location of instructions or headings should be different or closer to the diagnostic boxes.

I: What do you think is the most important feature on the expert system?

I like pictures. You got to have some kind of diagram to show you how.

I: What if we were going to offer someone the choice of a job aid like this and an expert system? What kind of person would choose this paper one over the expert system?

An individual in a small operation, he would choose this. But if he was in a big operation with multiple combines, they would go with the computer. I think cost might be a factor.

I: Let's think of the technician, the mechanic. If he was offered a choice, what would he think?

After he played with it a little bit, he would definitely go with the computer.

I: Any other comments about either system?

For the mechanic trying to make money, this is too slow. The computer is much faster, but you have to get used to it. Keep it simple, no extra wording, and to the point. I'm for it.

Subject #12

I: You've had a chance to work with two job aids, this paper one and the expert system. In the trouble shooting that you do, what would be more valuable to you?

I think of the type of trouble shooting that I do, Kim, and what my job requirement is, and the amount of stuff I have to take to the field with me: I think initially I would go with this [conventional job aid]. The only reason is that it is more condensed. Now if I had a computer that would allow me to do other jobs while I am on the road, maybe I would say the computer. And what I am talking about there is one of the responsibilities I have is updating the Ag Sales Manual. Ok, so if I could have a disk with me so I could be updating the Ag Sales Manual as I am using the lap computer when I am not trouble shooting, than yes I would take the lap computer with me to do it. It would be more useful to me in that respect.

I: OK. Now compare the use of this, kind of a condensed version troubleshooting guide, to the use of the full CTM-11.

No comparison, this here is a lot better. The paper, the condensed, is better because you're not flipping through, I don't know how many pages are in the CTM, but you're not flipping through 500 pages when you use this one compared to what you would be with the CTM. I like...to me I like things that are condensed, things that will take me right to the problem so I don't have to do a lot of fumbling to figure out what I need to do.

I: You mentioned that the computer is another piece of baggage to have along. What other concerns would you have about using the expert system on the job?

The sunlight. I think one of the things that would be difficult to overcome is that when you're out there troubleshooting the dealer's machine or a customer's machine, I think you're going to have to kind of prompt him, to say, "Hey, I've got this little box that is going to make the job a lot easier, and I can do it a lot quicker than I could before because it's going to take me very rapidly through the diagnostics of the system." I think you're going to have to prepare the customer for that to let them know that you can do it, that the computer is going to give you the same information as what is in the book.

I: So you think without some kind of an explanation the customer or owner of the combine may have some resistance to it?

Yes, because I think he feels the tech is supposed to be the expert (which he is), and I [the customer] have always seen him use the book before, and now all of the sudden he is carrying this computer out with him and he does not have the book. How can he fix my problem? I think part of the thing, you know, may be the first time you go visit the customer and you get him involved. Show him what you're doing with it and things like that. I think the intelligent system is going to be much quicker, which means two things: it saves the customers money because it should not take as long to troubleshoot it, and I think the technician is going to be able to better utilize his time--maybe do more service calls in a given day or, you know, do more troubleshooting.

I: What advice can you give me about developing this kind of a job aid, a conventional paper job aid?

Make it as simple as possible to follow. You want to give him as much information that is required to do the job but you also want to make that information as condensed and as simple as possible so that he does not have to sit there and do a lot of hunting to find an answer. As we go through the prompts make sure everything is there. Like one of the things we mentioned earlier--do you leave the connector disconnected or do you connect it back up? Give him as much information as possible to do the job, but also make that information as simple as possible so that he can understand it.

I: Anything other than that which would apply to developing a computer job aid?

No, because I would assume that if you have paper or a computer you can put both the same amount of information in either one of them. they both should be the same so that if a person knows how to use this and knows how to use a computer he could pick either one of them, go out to the job and feel comfortable using either one.

I: Imagine that you had this job aid and the computer job aid available for use. Describe the person who would choose this one over the computer?

Choose the paper over the computer? OK. I think it will be somebody who has no experience with the computer. He almost has a fear of the computer. He does not really understand what a computer does and how much easier it can make his job, somebody who has probably never had any

experience with the computer. If he has the two to pick up, he will pick up the paper because a lot of times computer... Well, unless a person has been using it for a while he spends more time figuring out how to use it than he does using the paper. Here [with the conventional job aid] he can open it up directly to the page and start doing it, and where with the computer you have to play with the keyboard and get to that point. I think again, probably in one word to describe it, that would be experience with the computer.

I: OK. Then what kind of person would select the computer over the paper?

Again, I think somebody who has had experience with the computer because he knows it's really going to get him there faster. Once people see how really easy it is to use a computer and how quick it is, they're going to select and use it.

I: OK. Now I want to give you an opportunity to speak about either type of job aid, to comment on anything you haven't had a chance to yet.

Well, we have spoken about some of the things earlier: giving as much information as possible because one of the questions I raised, you know, do you connect the connector back up or do you leave them disconnected--that type of thing. Put the information there so the guy, once he does something, he does not have to go back and say 'do I plug the connector back together or do I disconnect it?' I think if he goes through that process, if it is a paper aid or a computer aid, he will realize that there are certain times he has to leave it connected and certain times he does not. Again the thing that I like about what is happening here with this paper aid here and the computer aid versus the CTM is that they are much more condensed. You can get there faster and I think in today's environment that is what you have to be able to do--localize that problem to fix as quickly as possible. The other thing that you want to do is when you do that fix you want to make sure it is right, so that you do not have to go out and make another service call. [Make sure] whatever information is out there is accurate, and I do not if there is going to be a feedback loop in this process because I'm sure what we are doing with the ECU and electronic governor is a fairly new process. But I'm sure we have not seen all the problems that can happen, and the thing that would concern me is, after the system has been out there for four or five years in the customer's hands and has been exposed to all the environmental conditions--dust, rain, snow, heat, there is probably going to be new problems come up that we may not be totally aware of. So it is important that we have that

feedback loop so that we are constantly updating the information.

Subject #13

I: You had a chance today to work with two job aids--this conventional job aid and the computer expert system. Which would be more useful to you?

I think the paper would be myself because of the ease of it. I could take it right up to the engine compartment with me and I have it there where with the computer I have to running back and forth to the truck.

I: OK. Compare using this job aid [condensed, paper job aid] to CTM-11.

This would be easier because it is not as involved. I thought it was easier to follow too.

I: You said that you like the conventional job aid better because you could carry it up on the machine; besides portability, what other concerns would you have about using the expert system?

Oh...having dirt getting in it and kill the situation.

I: Anything else?

I believe it is faster than the paper. It keeps you on the page that you're following easier than this other. It [conventional job aid] goes back and forth a lot.

I: If you were to give some advice to someone who is developing this paper job aid, what feature would you say is most important?

Uh...

I: Do you understand my question?

No.

I: I'm asking you for some advice because I want to develop a good troubleshooting guide. What is the one thing I have to have in here? Is it graphics? Should I be using some different text format or flowcharting method?

You have it pretty well put together, just that back page where you have the connectors. I can see them [placed] up next to the harness. And the front page, where you have

your diagnostic read-out displays: I'd like to see them with that [harness diagram] hanging behind them. It would be quicker. A lot of times you get a code come up and you are starting the combine and you are not worried about it because there is not a problem there any way. There was a 9400 last year that coming up that the ECU was not on. The 9400 doesn't have an ECU--it had a 9600 tach in a 9400. Code 70 something would keep displaying every time.

I: What about in developing an expert system? What's the most important feature of the expert system?

Quickness I suppose. I don't know what kind of answer you're looking for.

I: That's OK. Let's say I had this job aid [conventional] and the computer expert system to offer somebody. What kind of person is going to select this one over the computer?

The type of person who does not know about a computer at all.

I: But that was not the reason you did not select it. You were more concerned about the portability of it and cleanliness.

Yeah, I guess.

I: So you think that a person's experience with a computer is going to be a big factor in whether or not they go for it?

Right.

I: Anything else?

It is easier to use probably.

I: The computer is easier to use?

Yes. I think it is easier to follow with the computer than with this paper.

I: So you think the person who would choose the computer would be looking for an easier way to do it?

Yes.

I: Now I want to give you a chance to comment on either one of these job aids. Anything besides what you have already said you want to talk about?

Well, after this test season is over, and if I happen to have one of these diagnostic things with me, I'd like to have the same conversation with you--after I've had more experience with it.

I: That's a possibility.

Subject #14

I: You've had a chance to work with two job aids. Which one do you think would be most useful for the troubleshooting you do?

I would feel that the paper would be for me because I'm not a computer person.

I: All right. Tell me about using this job aid. Compare using this condensed troubleshooting guide to the CTM or TM.

I found this very helpful. I mean, it was step-by-step down through this to get you where the solution was, so I think this would be more useful to me than the big tech manual would be. This does not tell me how to repair once I find the problem, but hopefully a technician would be able to.

I: Actually, the CTM does not either; it has just about the same wording. Some place you can find it, but you might have to go to the vehicle manual. Now, what concerns would you have about using the expert system on your job?

The only problems I can see with the expert system is having the computer with you--a semi-bulky piece of equipment--and climbing around on the machine maybe, carrying that with you, setting that down, get your logic up on the screen and being in a confined space. This [conventional job aid] would be much easier to drag along because not only do you have to have this, you have to have a meter.

I: The troubleshooting you would do would primarily be in the field and not at your desk?

Me? Personally, I'm a field service rep so that is where I'm going to do the troubleshooting, not to say that I would not do it at the phone, too. But I would suspect most of the times I would be in the field. If I were a D-TAC specialist, then maybe having that all on the screen in front of me would be better.

I: OK. Imagine now that you're the designer of a job aid like this [conventional job aid]. What is the one thing that you would include or do to make it effective?

I don't know. I think this is put together very well. If you could put all diagrams together...like this particular document...the diagrams together...in another document that might not be true. With this particular document with what I did with it, I can not see a lot to do with it other than putting the diagrams together...saying this is the connector I want and this is the male or female plug without paging back and forth.

I: What about for designing an expert system? What features are most important and should be paid attention to?

On the computer then? I would like to see that system flow a little bit easier.

I: How?

Well...the questions. If you could have the instructions and pictures on the page and the menu in the same page, you could go over and hit your answer. Even if you could have the pictures of the connectors on the same page [as the prompts] it would make it easier.

I: OK. Now, if I had a paper job aid like this and a computer job aid, what kind of person is going to select the paper?

The type of person that would do that? Probably I'm not a computer person because I do not have the opportunity to work with them, I get on office mail and D-TAC once in awhile, but other than that I do not work with computers. Maybe if I understood them better and worked with them more my opinion might change a little bit. The way I see this, I can not see this for a dealer technician using the computer, because the normal guy who is the dealer tech, I would say would probably not use that [computer] if this [conventional job aid] was available. For one, because he probably, like me, has not had the chance to become familiar with computers. Unless people use computers a lot, they become afraid of computers. Just the part of the mechanic or technician in the shop...the type of environment that he is in...dirty and greasy...would [cause technician to] refrain from getting close to the computer because it will get all grimy and things like that. So will this [paper job aid], but this will be easy to replace once it gets dirty. But I also believe that in dealing with a lot of technicians at dealerships that there are some that would pick the expert system over the paper.

I: Do you feel the expert system was too difficult to use?

Just my own personal using of it for a short period of time found that, there again, because we're jumping [from screen] to screen, I was not sure if I was at the screen I was supposed to be at. And that probably would make me shy away from using it again if I had this [conventional job aid] available.

I: What kind of person would prefer the expert system?

I think the expert system...if I was a person sitting at the desk in an office taking telephone calls and answering questions and leading someone on the other end through a diagnostic procedure, because I'm already on a computer anyway, [like a] D-TAC specialist, that system would be to my advantage.

I: OK. You've been real helpful. Now I want to give you a chance to comment on anything you have not had a chance to.

The one positive thing that the expert system would have that I can see is that you only have one procedure in front of you at a time. That you must go through this procedure before I can get to the next procedure. With a tech manual or something like this I can assume things and jump steps and jump to conclusions before I should be jumping. That is a disadvantage to a paper system. With the expert system I must go through each step-by-step.

I: Do you think that is a greater benefit to a new mechanic or experienced mechanic?

No, that is a greater benefit to a new mechanic. Well, I think it can be a benefit to an experienced mechanic because a lot of the time the experienced mechanic may think he knows where the problem is, and they too will skip down through a lot of things because they use the tech manuals. They can not remember everything. They have a tendency to think they know where the problem is and they skip a lot of things right off the bat. A lot of the time it is the simplest things can go wrong; they think that it can not be the problem because it is way too simple. In electronics [for instance], people are looking for a more difficult problem than what is actually there. Any time there is a black box involved, I think that people think that it is where the problem is.

Subject #15

I: You've been able to use two different types of job aids. Which do you think would be more valuable to you in your job?

More valuable to me would be the expert system. The time frame...the people that I deal with...when you are on the telephone and leading them through step-by-step, the expert system is more convenient than getting lost easily on here from one paragraph to another.

I: This job aid has condensed the information in CTM-11. How does it compare to using CTM-11?

I like this a lot better, it is clearer. I have got lost a couple times in CTM-11 and had to go back and chase myself back, and I do not know how the dealer feels on the other end of the line. I'm sure he is confused more than I am.

I: What concerns would you have about using the expert system?

Not really any. The more you use it, the more it will get user-friendly, and it is that way with any software. I did get a little bit lost in a couple places and got ahead of myself, which more hands on time would remedy that. I think in the same token, out in the field aspect, if an area service manager had it or possibly a dealership, they would feel comfortable with it not reading between the lines and getting carried away.

I: OK. Now if I was to ask your advice to help me develop a conventional, paper job aid, what is the one feature that I should pay the most attention to?

The most important thing is verbiage. Anything with the tech manual, anything like this, you have to write it with the assumption that everybody out there has an 8th grade education. That is the bottom line. If you put it in a simplistic form anyone can follow it.

I: What about the expert system, any feature there that is especially important?

Just as far as the help hints at the bottom...as far as what the "F" keys do. The more of that you put in there the better. As far as...maybe a direction, like an overall view direction, as far as how the process works. Like say when you got to the prompt or one of those keys, when you hit enter it would take you back. It would toggle you back and forth, so people don't get lost.

I: If I offered the expert system or this job aid to people, what kind of a person would select the paper job aid over the expert system?

The old time, old hand person, mechanic that has done away with any electronic help at all would grab this first. I have seen a lot of guys get away from the Fluke [brand of] meters and go back to the old meters because they are afraid of some of the updated technology advances. I think that is just the drawing line to get them over the edge.

I: So do you think that it is a function of age or experience or a general reluctance to change?

Yes, reluctance to change. I have seen a lot of older guys that have been around for years that when they see it will say it's the next best thing to sliced bread because they look at the manual and the flow charts and they just throw their hands up in the air. You can take them a page at a time and show them what their end results will be and they just think its great.

I: OK. Then what kind of person would select the expert system over this?

I suppose we could just say the converse of that: not reluctant to change.

I: Anything other characteristics that would describe the person that would grab the expert system?

I would say most anyone that is...that wants to cut their time frame, that is looking for the easiest route, and one that poses a challenge to them. They know that this has got to be faster than the paper route so they grab the expert system.

I: OK. This has been real helpful. Now I want to give you a chance to comment on anything we haven't had a chance to cover. Anything at all.

Well, as far as the paper work or the expert system, I have no problems except it would have been nice to have had this earlier. It's [hindsight] always twenty-twenty. I think it is great more and more dealers are getting computers. They have the accessibility, and from what I have found out at Phoenix, when we show them some what possibly could be coming down the line, their feeling is that more and more dealers are going to spend the money for lap tops. They are going to make them available and make everybody's life a lot easier, especially with our complex combine. With all the electrical diagnostics, usually most people think it takes

two people. The expert system...with your expert system, one guy could go to the field and diagnose any problem. As opposed to spending money for two men. I think it would save a lot of time and money on the dealership's part.

Subject #16

You had a chance to use two types of job aids today--a computer-based job aid and a paper job aid. For the troubleshooting that you are involved in, what do think would be most helpful to you?

I'm partial to computers so I would have to say that... BATTERY FAILED.

Subject #17

INFORMATION LOST

Subject #18

I: Today you've had a chance to work with two job aids--the paper booklet and the computer expert system. For the troubleshooting you do, which would be most valuable to you?

The paper would be an easier access out in the field, in the truck. We would not have to worry about the sunlight on the screen, having a good picture. To me it would be just a little easier to flip pages on the paper between your main diagnostic page, your terminal diagnostic page and your...then you go back to page 29 where you have your connectors. Especially if you were up in an engine compartment doing a job right there.

I: What about the difference between using this abbreviated booklet and the CTM-11 or TM? Compare them for me.

Well...

I: Say you've got the booklet and the CTM-11. Which is easier to use, more valuable?

The little booklet would be much easier, unless somebody took it from you. It might be a little easier to lose or misplace, but you are cutting out all the alternator diagnostics. If you are up in an engine and the wind starts to blow you have 800 pages floating around [with CTM-11].

I: You mentioned a some concerns you had about using the expert system, like sunlight on the screen. What other concerns would you have?

Only other concern is that it easier to turn 3 pages in a book than flipping back and forth [between screens].

I: If you would give me advice on developing a troubleshooting booklet, a paper job aid like this, what would you tell me?

Well, it is hard for you to do, but pictures are worth a thousand words, and in a repair manual, the more pictures the better they are.

I: OK. What about with an expert system?

Still, the pictures. An expert still needs to refer back and, like I commented earlier, a lot of times you read what you want to read and you do not read the real statement and you get yourself off-base. Even though maybe your pictures or graphics people would turn through, they might not be working on that certain area, and they will turn through graphics and look for and can refer to the problem.

I: Let's say I had a fully developed and refined expert system and a corresponding paper job aid. What kind of person is going to select the paper job aid over the computer?

The person who has not had the time to be familiarized with the computer. Everybody in our department, nobody has ever ran one of those.

I: You don't have much experience with a computer?

No. Since we are out in the field by ourselves, we can't have phone contacts back in the plant. A lot of times that person is not available. If you are 30 or 40 miles from town, that piece of paper would be more helpful. You are concerned with having problems with the computer out in the field, and then you have two things to figure out: the computer and the combine. You know with the paper you only have ten pages--it has to be in there somewhere. With the computer, you have to be familiar with it.

I: OK. Then what kind of person would select the computer over the paper?

I imagine that computer is used for a lot more than just ECU [electronic fuel injection system] units. It has to be an expanded system to no end.

I: Well, what you have said is real helpful, but I want to give you an opportunity to talk about anything that I did not ask you about--anything at all.

I guess I don't have anything to say.

Subject #19

I: You've had a chance now to work with two tools to help you in troubleshooting a Robert Bosch fuel system. In your job, which system would be more valuable to you?

I think the intelligent system would be because I think it can be brought up faster on a computer and be there handy to use. I think it would be mostly the speed.

I: You've used the CTM-11?

Yeah.

I: How would you compare this job aid to it?

It [CTM-11] would be a little clumsier to carry, but I think the place you use it, I don't think it would be a big problem. Not much different.

I: What concerns would you have about using the expert system on your job?

Other than possibly damaging it, really none. I think if a person is careful with it, I don't think there would be a problem.

I: What do you think are the most important features of the paper job aid?

Other than the pictures to refer back to, if that was instilled in the smart system, I don't think there would be any. I think the graphics are.

I: What do you think are the most important features of the expert system?

I think the biggest is the speed. It's there without having to flip pages.

I: Think about the type of person who might prefer the conventional job aid over the expert system and tell me about that person.

Education would enter into it a lot. If they just wanted to take their time thumbing through pages... Education has to do with memory. The person more educated would prefer the expert system. Reluctance of change has a lot to do with it.

I: So a more educated person would prefer the expert system?

Yes. I think a better trained, better educated person would be more apt to pick the expert system.

I: OK. Do you have any additional comments to help us out?

The only thing I see is the expert system might be more expensive on the floor. If it was being used properly, I think it would pay for itself. I'd like to see it out there.

Subject #20

I: You've had a chance to work with two tools to troubleshoot Robert Bosch systems. One is the paper job aid very similar to the CTM-11, the other is the computer expert system. Which do you think would be the most help to you on your job when troubleshooting?

The electronics [expert system]. All you have to do is push a few buttons instead of flipping through pages and pages. Sometimes when you go through a catalog you lose your place. On the computer all you have to do is push the button and you're on the screen.

I: What concerns would you have about using the expert system on your job?

None. But if somebody walks away with it...

I: What do you think is the most important feature of this job aid?

Diagrams, locating them. Graphics.

I: What do you think is the most important feature of the expert system?

It is easier. Less complicated.

I: Imagine you had this and the expert system, and you were going to have someone choose which one they wanted to use. What kind of person do you think would choose this over the expert system?

A person without computer experience. But if somebody had the basic knowledge of the computer, they would pick the computer.

I: All right. Do you have any other comments that might help us out--anything at all?

The computer is easier. You find your problem out faster.

Subject #21

I: You've had a chance to work with two tools to help you troubleshoot Robert Bosch fuel systems. On your job, which do you think would be more valuable?

I really haven't had a chance to go out in the field and do that type of thing, but I see some advantages in the computer-aided thing. It is more direct. It gets things done quicker.

I: Have you used a CTM-11 to do any troubleshooting?

No, just some classes we had.

I: I was going to have you compare this job aid to the CTM.

I can see that the condensed version would be a lot better than the whole manual.

I: What concerns do you have about using the expert system on your job?

The delicacy of the computer. I think when you are out in the field, it could be knocked off easy. The battery life also. Working out in weather conditions: rain, wind, etc.; direct sunlight.

I: What do you feel is the most important feature of this [conventional] job aid?

It gives you an overall view of the different possibilities of where you could go. It's kind of like knowing the basics of math versus handing someone a calculator. You've got to know what went into building the thing before you can appreciate it and use it. It is valuable to know the paper end of it, then you can better understand the computer

portion of it.

I: What do you think is the most important part of the expert system?

It streamlines, and it gets rid of having to page back through and refer to other documents. I think it speeds it up and focuses in a straight line.

I: Say you had both job aids here to offer to someone. What kind of a person would choose the conventional job aid?

Somebody who hasn't been around computers, someone who is afraid of computers. I think they would prefer the paper. A lot of people are intimidated by computers. I myself am not all that comfortable with them, but that system seems to be pretty user-friendly. If the person has read a manual for years, of course he would be resistant to change.

I: Besides an experienced computer user, what kind of person would for sure use the expert system?

Somebody younger who is familiar with computers and feels comfortable with it.

I: OK. Now take an opportunity to comment on anything else that might help us out.

I think the fact that it is delicate, we are going to be in some rugged conditions out there, a lot can happen to the computer.

Subject #22

I: You've had a chance to work with two job aids to help you troubleshoot Bosch electronic systems. Which do you think would be the most helpful to you on your job?

With familiarity either one would function. As far as expediting the process, I can see some advantages to the bulletin form rather than hardware, software forms. I think the ability to update that would exist. From a functional standpoint, the way we were set up in the room, the expert system gave us an edge speed-wise, and it prompts you in the right direction. You can't get misguided to the wrong page.

I: You said set up in the room, do you think it would be different in the real world?

I believe so in that some of the locations on the machine where you have to get to, I don't know if you would want to

carry that piece of hardware around up on the machine where you might dump it off. It may increase the amount of walk time to and from the machine, where as you could have a folded-up, condensed version in your pocket.

I: Compare the use of this condensed version to the CTM.

I can see where I personally would find it helpful, rather than carrying around TM's. It would be a lot easier for me. The dealers may have all the technical information in the conventional form. It may be to their advantage to have the software package and the computer just to get them in to the right section quicker, and the prompting that it does starts them down a path and makes some decisions for them based on the data that you give it rather than reading the data and risk having them misinterpret the data.

I: What concerns do have about the expert system, other than the hardware concern you mentioned previously?

Some of the technicians might be reluctant to use something like this. When these guys spent their career mastering their expertise in this [technical manual], and all of a sudden someone lays as much knowledge and expertise in front of a first week employee... Certainly it would be an advantage to the dealership there. Possibly for that reason, the older ones might not be too happy.

I: They wouldn't be happy because it equalizes the work force and makes their expertise a little less valuable. Is that what you are saying?

Yes, I think so. I think in that note it is a positive statement towards the package [expert system]. The fact that it can take a new technician and lead them down a path and help them with conclusions, not rely on them to follow the path and make the wrong conclusions, is a plus.

I: If you were going to develop a paper troubleshooting guide, what do you think would be the most important feature?

The flowchart and the procedure that you go through to isolate that component or circuit that is having the problems. That is true in either option though.

I: Well, what do you think is the most important feature for the expert system?

Having the graphics right there rather than remembering what page it was on. The way that the software has been written, it steers you down a path, speeds you down a path.

I: What kind of person would use the conventional job aid rather than the expert system?

Someone who had become used to using it in the past, the guy with seniority, the guy who had always done it this way and wanted to continue to do it this way. At the same time, a lot of those people do want to continue to learn and will be happy to see a system like this. If the system proves to be better and more beneficial, they will like it. A new, higher type of individual would be more prone to the software package. You take a kid who hasn't had much of an opportunity to work on that, he has a lot more self-esteem.

I: OK. Any other comments you'd like to make to help us out?

I think the customary paper job aid doesn't lend itself to react quickly, in that any changes that might come about are costly. The updating of a disk is not nearly as costly.

Subject #23

I: You've had chance to work with two diagnostic tools. For your job, which one would be most helpful to you?

I guess at this point in time, the computer-based one. If you have a reasonable grasp of the overall system, this cuts right to the quick of it. I think initially, if you are extremely inexperienced of the system, sometimes the written literature gives you a better overview of the full system, descriptions, etc.

I: Have you used CTM-11?

No.

I: OK. Compare using the condensed troubleshooting guide to one of the tractor TMs.

In the smaller, condensed one there is only one place you can find the information. It is very cut and dried in that respect. The tech manuals have pieces here and there.

I: Do you see any problems using the computer-based system on your job?

The biggest thing is where it will sit out in the field, taking into consideration the weather, the location. It is a little easier to lay a book beside you on a combine.

I: What do you think is the most important feature of a troubleshooting guide like this one?

I like the systems schematic. Of course, it wouldn't be much of a guide without some kind of flowchart or step-by-step procedure. The system schematic is like an exploded parts catalog.

I: What about the expert system, what is the most important feature?

I don't really think there is just one. I don't know.

I: OK. What kind of person do you think would choose this rather than the computer-based job aid?

Somebody that maybe has a hunch of what some of the answers are, has done it before. And they may skip ahead because they have seen it before.

I: Earlier you said you think this would be better for the novice mechanic. How does that fit in here?

What is good in here for the novice mechanic is different for what is good for the experienced mechanic. I think for the new mechanic, the CTM-11 could be overwhelming. You see it all at once. For the expert system you only see one thing at a time. That may be easier. Going through the step-by-step procedure, the computer there is better.

I: Then what kind of person would use the expert system?

If you went up to the machine with no idea what to do, you may need a step-by-step procedure, and it seems the computer-based system might offer that.

I: OK. Any other comments that might help us out?

One thing I would like to see is something that would put a little more information on one screen. A flowchart would allow you to pick a path and go through it. With computers, you just launch down a path and put in what you think the answer would be, and go to the next question. Then you see the end result. It would be nice to get in between that. I like the computer-based diagnostics in general. When you are in the step where you are actually doing something, it gives you a very black and white procedure.

Subject #24

I: You've had a chance now to work with two tools, this condensed troubleshooting guide and the expert system. Which would be more valuable to you in your job?

The expert system, once a person learns how to run it.

I: Can you compare this troubleshooting guide to the CTM-11?

I think there's adequate information in the condensed version.

I: What concerns would you have about using the expert system?

Learning the system, getting in and getting through the computer. I've used a computer in the field, in a truck, and in a motel room. It ran the battery down, but I was just worried about someone breaking in my truck and stealing it. It is a pretty expensive tool.

I: In developing a job aid like this paper one, what feature do you think is the most important?

The pictures.

I: OK. What kind of person would select the paper job aid?

An old mechanic that has been there for 100 years. He is set in his ways. A young student out of college that has worked with computers would choose the computer job aid.

I: OK, but other than a college graduate, what kind of person would select the expert system?

An engineer.

I: You've been real helpful. Anything else you might be able to comment on to help us out?

Make it simple getting in and out, which you've done. I feel doing enter every time keeps it consistent, instead of doing different things every step. It wasn't hard to follow; everything was very clear. It was interesting.

Subject #25

I: You had a chance to work with two tools for troubleshooting, which do you think is more valuable?

I think it would be the conventional. It is easier. It [troubleshooting electronic fuel systems] is something I don't do that often, but if you do, you are going to be able to remember what to do using the computer. If you don't use it [often], it is easier on paper.

I: What about the people who frequently refer to the TMs and CTMs. Do you think they have a different perspective?

If he is going to be using it daily, yes. I don't know if you are going to have that many problems every day.

I: Do you use a CTM for troubleshooting?

No, we don't do that much diagnostic work.

I: Well, can you try to compare using this condensed version to an entire technical manual?

I think the condensed version would be more readily available and handy than the big CTM.

I: What would be the most important feature in developing a paper job aid like this?

Your connectors aren't numbered or highlighted like they should be.

I: OK. What would be the most important feature in developing an expert system?

Pictures could be enlarged.

I: What concerns would you have about using the computer on your job, besides what you've already mentioned?

Daily usage. With the computer you have to get up in the back of a combine. It is hard enough to get yourself up on there let alone a PC. If you have a book and you drop it, big deal. If you dropped a PC on the ground, you got a problem. I've been up there and there is not much room to work.

I: OK. What kind of person would choose the paper job aid over the computer?

Your older people. The younger people are familiar with PCs and are not afraid of them. You get somebody like me, I'm 45 years old, at first you're scared of them--thinking if you push one button it might blow up on you.

I: Do you have any other comments that might help us out?

Just all the connectors that are out there, why not put J7 and J8 right on the molding of the plastic?

Subject #26

I: You've had a chance now to work with two different job aids. Which do you think is the most valuable one?

I like the computer because I am more familiar with them. Carrying around a big book out there and flipping through pages gets cumbersome sometimes, with your hands full of oil.

I: Compare using a condensed troubleshooting guide like this to a complete CTM.

It's easier than taking a big CTM or TM out, but you still have to flip through pages.

I: What concerns would you have about using the computer?

It is going to take a while get broke in on it, and get someone out in the field used to the procedures of it. I think if you got used to the procedures you'd like it. Overall, they will get their work done faster. It is a chance to boost their levels of productivity.

I: OK. Tell me, what is one feature that is very important in developing a paper job aid?

The writing should be bigger.

I: What about with the expert system?

I think the biggest thing there is go back into diagnostics in TM's and see how they are written, because people get used to doing things a certain way.

I: What kind of person would reach for the paper job aid before the expert system?

I think the guy who has been out there quite awhile, it is what he is used. I think it is the age and the fact that it is a computer, where a lot of younger people coming in have worked on computers in school and training, and they are not as apprehensive about them as an older person would be. Depends on training.

I: OK. Do you have any other comments, anything at all, that might help us out?

Training. You need to make sure those people get the right training or they won't use it. It's the same in anything.

Subject #27

I: You've had a chance to work with two job aids now. Which do you think would be most valuable for you?

Both of them are valuable. Probably the one I feel more comfortable with: the paper one.

I: You are more comfortable with this [conventional job aid]. Compare using this condensed version to using the CTM.

The condensed version is so much better. You tend to get more lost in a bigger book when jumping around from one spot to another. At least here everything is condensed and you know you only have so many pages to go through.

I: What are your concerns about using the computer?

There is some spots in there where you didn't know what you were looking for, as far as value of resistance. The computer aid told you measure resistance. You weren't sure if you were looking for two ohms or ten ohms. Whereas in the book, you can look down here and see what you're looking for before you look up the meter. You need a better handle on which way you are going from one screen to the next, and also there is some places where you used "F8" to backup and "enter" to backup. It confused me. It would be better if it was all consistent.

I: OK. Now give me some advice about developing a paper job aid. What is important?

Try to keep it as simple as possible. Try not to give us too many choices from step one to step two. If you can, eliminate it to one or two choices.

I: Anything else about developing an expert system?

I like it that it is user friendly. It needs to be easy to use or else they aren't going to use it.

I: Given a choice between the two job aids, what kind of person is going to choose the paper?

I think a person who has limited experience with computers, and he is more familiar with this [conventional job aid]. Most people would prefer the paper if it involves hooking up the computer to an external source.

I: What kind of person is going to lean towards the computer?

I guess the guy who likes to stay a step ahead of everybody else, likes to keep up with technology, and maybe has a computer at home and is comfortable with it.

I: OK. Now I'd like to just let you comment on anything you can think of that might help us out.

Well, the main disadvantage would be to try and maintain two different systems. If we are still going to keep the paper system, then it takes a certain amount to keep that up. With the computer system you can update it. It easier to keep one system up to date rather than two. Gain some experience with using the computer and the general run-of-the-mill technician has very little experience with them at all. As far as parts changes, if there is already a PIP program [Deere part up-date] on something, there should be something in the system indicating that so you don't have to go through it.

Subject #28

I: You've had a chance now to work with two job aids, the paper one and the computer one. For the troubleshooting you are involved in, what type of job aid do you think would be most valuable?

The computer. It is quicker. For a mechanic on the job, I would say the paper because you can take it with you and have it right there to look at all the time.

I: All right. Compare using this condensed guide to the CTM.

This [conventional job aid] is easier. There is enough information.

I: What concerns do you have about using the computer, other than the portability?

If you inadvertently hit the wrong key, you are on a different screen and you don't know it. You start making checks, and it is not the one you want. It could have been the keyboard or enter key because it was very touchy.

I: If you were going to give me some advice about developing a paper job aid, what is one feature I should pay special attention to?

Diagrams. While I was going through that, I noticed the numbers being so small. I wasn't reading it right. And the diagrams should be placed in a 12 o'clock position.

I: Is there anything else I should be pay close attention to when developing an expert system?

The text is great. Just the graphics, if you can see it, it helps, and [with] the conventional you can flip back to something really quick. On the computer, and maybe I'm not used working with them, it's how quick can you get there and get back.

I: OK. Given the choice between a paper job aid and an expert system, what kind of person do you think would choose the expert system?

Three years ago I would have chosen the paper because computers scare me, but remember my age. The 35- to 50-year old mechanic out there is going to choose the paper if he hasn't worked with computers. Once you get them broke into it, like me: I just as soon use a computer now--but once you get them over that fear, it is just like flying in

an airplane. It's OK.

I: So it's a matter of familiarity with computers?

People are afraid they are going to hurt the computer.

I: Well, now I'd like to give you an opportunity to comment on anything else you think might help us out.

You guys have done a super job. Graphics are so much help, especially for someone without hands-on experience.

Subject #29

I: You had a chance to use two job aids, the paper and the expert system. For troubleshooting that you would be involved in, which do you think would be the most valuable to you?

It seemed like the paper one would be. It flowed better.

I: So you liked this [conventional job aid]. Compare using it to the CTM-11.

I like this better. It is easier to use than the CTM-11, but you really wouldn't know if it had enough information in it until you got into some complex problems.

I: What are your concerns about using the expert system?

It might be more time-consuming than using the paper, just because you can reference back and forth a lot quicker [with the conventional job aid].

I: OK. What is the one feature in a [conventional] job aid like this that is most important?

Diagrams that match with your text.

I: Is there any feature in the expert system that needs special attention?

It seems like you are going through a lot of steps, going to your prompt, menu, graphics, and back to menu.

I: OK. What kind of person is going to reach for the paper if given the choice between the two?

More inexperienced, not familiar with the system.

I: And the expert system?

Whatever one is used to, if it is the paper or computer.

I: All right. Do you have other comments that might be useful?

I was surprised. This is the first time I really got to sit down and go through it [electronic fuel injection system diagnosis]. It was fluent--the paper, but it was not that bad on the computer either. I can foresee when you are on a telephone and you're trying to go through some diagnostics like this with somebody on the other end, you have a natural instinct to always trying to stay two steps ahead, with relating to the customer on the other end. I could see it [the operation of the expert system] could cause some problems and it could get confusing. It is going to be what you get used to.

Subject #30

I: You've had a chance to use two different job aids. For the troubleshooting you would be involved in, which do think would be more valuable?

I like the paper one better. I like to keep reading back where I've been. I had problems with the computer asking me questions and in order to go on it's good to look back.

I: OK. How does this job aid compare to the full CTM?

I don't think it makes much difference other than the CTM is heavier. The layout is somewhat the same.

I: What concerns would you have about using the computer other than pausing to go back a screen?

Nothing really. The experience I have had is there is no place to set it [when working in the field].

I: Now give me some advice about developing a troubleshooting guide. What especially important?

Having the pictures on the same page where you are going to be working.

I: Given the choice between the two, what kind of person is going to choose the paper job aid?

A person that hasn't been trained in computers, isn't comfortable with them. I personally don't like to break it down as to how old you are [cite age as a factor].

I: Do you think a person could learn to use a CTM and find their way around in it faster than they could learn to operate the computer?

Only because most people are used to looking at books. Books are what we have grown up with. I like computers, but I'm not sure about them.

I: This has been real helpful. Can you think of anything else that might help us out?

I think the computer has some real advantages if you keep it up-dated. It is easier to up-date. You don't have publishing costs or time and money to modify it and rewrite it. If we can keep the information current, I think that is going to be nice. It is a lot of work. Jumping back and forth in this system [expert system] is hard, and if you loose your place you have to start over. If you push the wrong button, you don't know where you are at. I don't know how the note pad feature works, but it would be nice to have something like that to use in referring to. Being able to key in a value that you read in and let the computer decide if it is less than or greater than, between this, none of the above, overload and underload, that all would be nice.

Subject #31

I: After your experience with the two job aids, which do you personally prefer?

The computer. Because with the manual there was so much flipping around. And if you wanted to see if you read something right, you had to go back and figure out where in the world I was in the manual, and I had forgotten the page number I was on. With the computer I always knew where I was at. I didn't have to go through the entire book to find it.

I: OK. Compare using the condensed version like this to the full-blown CTM.

I would say this [conventional job aid] would be better, but is still isn't as good as the computer.

I: What concerns would you have about using the expert system on your job?

Putting it someplace I can use it if I'm on piece of machinery. You know trying to find a place I can set it down and plug it in. I don't know how durable the thing is.

I: If you were going to give me some advice about developing a paper job aid, what would you suggest to me?

First, where you had the wiring diagram, the connectors ought to be in a close space in that location. I shouldn't have to flip back to the page to find what connector is over here. The next thing I ask is how many connectors are alike that I might get confused with. Instead of going H, I, J, K, why don't we go J8, J9, and just forget the alpha characters in front of it. The next thing is you don't assume anything in this book. When I got done, when I as working with the computer I didn't just assume I should plug it back in. When I would go through the manual, I would. When I got done checking I just assumed I should just plug it back in, plug the two connectors together, and I never once caught myself doing that with the computer. I think it was the way it was worded, and the sequence I was going through. It was natural for me not to do it because I was going from this connector and now I'm going to check this with that one. When I went through the paperback version I thought I was done with this and I can plug it back in. And I found myself doing that three times. The computer eliminated the problem of loosing my spot, all I had to do is flip back and there it was again. The next thing is terminology. Pins. One time it said check the pins on the sensor, the next thing was check the pins on the connector. I didn't see a connector or sensor, I saw pins when I read it. I keyed in the word pin and consequently, if that is a pin on the sensor on the injection pump, why isn't it a pin on the ECU. If you are going to call a pin a pin, it should be something that sticks up in the air. The next thing is assuming I should hook the wire back up. That should be underlined or defined some way that just because you have checked it, don't put it together yet.

I: Good. Now what about the expert system?

For me, being able to flip over to the location of the connector in the wiring harness, and a closeup of what that connector looks like, and then going back and saying what pins do I want to check in this. Without my expertise in computers, I would have gotten lost going down through the menus trying to get to it. For the person who is not familiar with it, they will be mind-boggled. But that particular segment I thought they carried it through real

well.

I: What kind of person do you think would prefer the paper job aid?

Person that is afraid of the computer. Computer illiteracy. To me it is unbelievable the number of people that are just scared to death of them. I guess the durability and accessibility of it would be my main question. How easy is it for me to get goofed up, and how easy is it to learn?

I: OK. Do you have any other comments?

I know that the computer was a lot easier for me. I bet it shortened up my repair time in half.

Subject #32

I: Which of the two job aids do you think would be most valuable to you?

To me, the computer is most valuable because of the fact that there is all kinds of information in that computer and I didn't have to look at all of it. The only thing I had to look at was what we were told to look at on the computer.

I: What about this troubleshooting guide? Compare the use of this job aid the full-blown CTM.

This is just like a CTM, except it isn't big. You still have to flip pages. Not much difference.

I: What concerns would you have about using the expert system?

Do we have the computer technology today to live in our environment as a dealer technician...the physical environment. As far as taking the unit to the machine, finding a place to set it, you can do it. You don't have to worry about it blowing away. Dust is bad and will be tough on the machine.

I: What advice would you give me to help me develop a paper job aid like this?

Once you have the problem identified, you give me a flip where that problem is identified, and let me just follow through without flipping a bunch of pages.

I: What kind of things should I pay particular attention to in developing an expert system?

The thing you got to be careful of is things that are obvious to you, [which, for example,] aren't obvious to me. Don't assume that the technician knows how the system works.

I: OK. What kind of person is going to choose the paper job aid before the expert system if given the chance?

Everybody is going to choose the paper because that is what they are used to, until they get used to the computer. When they get the computer, they can see how they can go through the systems, and they will throw the paper away. It is a matter of familiarity of the computer.

I: Any other comments? Anything at all?

Don't assume that the people know anything.

Subject #33

I: You had chance to work with both job aids. Which do you think would be better for you?

The computer. Because of time. Time is money. If the tech manual and the computer system is accurate, then time is a factor.

I: Compare this condensed version to the full-blown manual?

I don't like condensed manuals as a first time diagnosis. I do like condensed information after I am familiar with it. I think this [conventional job aid] is for experienced people.

I: What concerns would you have about using the expert system?

The debris and dirt. Mainly debris...probably includes the transportation of the unit, durability, withstanding all abuse that even a manual takes. I think the workability of the system, it is fine. [There is] possibility of error by using it, but possibility is probably even greater in a manual.

I: What kind advice could you give me to help me develop a troubleshooting guide like this?

I like an outline format. We [John Deere tractor service manuals] do have some things in a five-column format. We

start out with preliminary checks, then go on to check other things. For example, in the electrical section there is basically six starting complaints you can have . So that is broken down in the six and then you work through the different complaints.

I: What features does the computer have that are significant when you compare it to the paper job aid, other than time?

Some people think our procedure [in tractor service manuals] is too long. But when you go through the computer, all the extra steps are hidden. You are only going to see what comes on the screen. I think that is very encouraging. If you aren't familiar with the product or the procedure, then it will take a lot of time to get through the procedures. If we have a very thorough procedure for less experienced, and a follow-up, condensed for the person that is very knowledgeable, it is still a checklist for him to follow.

I: OK. What kind of person is going to prefer the paper job aid to the expert system?

It is going to be the older people that are not wanting to relearn something new. They are familiar with the manual, comfortable with it. The ones coming in the dealership that have had computers in school, the younger ones, they would pick the computer. Testimonials from other people would be a factor. If one says it is a time saver, then the older ones may pick up on it.

I: Do you have any other comments, anything at all, that might help us out?

In my time with the company, I find when I take a person and go through a normal system, get them familiar with it, it takes a little bit of the fear away from it. As follow-up, have a live problem.

Subject #34

I: You've had a chance to work with two job aids, the paper and the computer. For the work you do, which do you think would be more valuable?

Paper. It takes a very short period of time to become familiar with the paper. Once you have been exposed to a system like that, it is pretty straightforward. As far as my job, it [the expert system] would be a constraint because the time required to flip screens. I can go to the tech manual and be done with it.

I: OK. Compare using the condensed version to the complete CTM.

This is probably somewhat easier in that I didn't have a massive book to work with. I was just as awkward to work with because of jumping back and forth to identify connectors, and that is a deficiency with publication.

I: Other than the speed, what other concerns do you have about using the expert system on your job?

I don't think I have any other concerns.

I: Besides locating the graphics more effectively, what other advice could you give me that would help me develop a troubleshooting booklet?

If you were to use the paper booklet, like today, with the picture of the connectors, the pin numbers on them, put small on every page....the guy knows where to go, what connector to pull apart, which pin to look at. It is done. He doesn't have to flop back and forth.

I: What kind of recommendations could you make about designing an expert system?

Sometimes there appears to be an extra step. I believe it might be the pre-prompt. It tells you do to something, and then you have to remember that you have to go an additional step down. I don't need that. Tell me this, and show me a picture, and that way I'll know.

I: OK. Now, what kind of a person do you think would choose the paper job aid over the expert system?

The new guy will probably use this system because he is not afraid of computers, because he has grown up with them. Once he has diagnosed this system a couple times it will not be of any value to him. At that point, he is very familiar with where it is and how it works, and he will be able to take paper with him and a book and not have to worry about loading a disk, loading it on to hard disk. He takes the paper with him, he doesn't break the computer, nobody has got to buy one. Initially, as a training aid, I think they are tremendous. But I don't think long haul it is really that valuable. It is going to depend on people's education though. Once they have been there for 5 years they won't need it.

I: All right. Any other comments that might help us out?

It is a very good system; I hate to even knock it. I don't see the dealers being able to use it very well. Initially they will train their people, but after that I don't think the need will be there. They don't allow their people time to sit and go through it...greasy hands, $2000 purchase, but each situation is also different.

Subject #35

I: You've had a chance to work with two types of job aids: a conventional, paper one and a computer-based one. Which of the two systems do you think would be more valuable?

I think the intelligence system has the most potential value. What I really saw here was the menus were somewhat confusing. But I do like not having to flip back through pages and carry a bunch of manuals around. You can go and get the graphics you need without flipping pages [with the expert system]. Somehow it has to be such that it should be easy to move around. I would guess working on it for a half a day, a guy would be happy with it.

I: Compare the use of a condensed troubleshooting guide like this with the full-blown CTM. What's the difference?

Well, the beauty of the computer-aided system is that the technician doesn't know whether it is abbreviated or not so he does not get scared by that whole wad of paper.

I: But this [conventional job aid] versus the CTM?

It may be handier. You don't have to flip through so many pages.

I: What concerns would you have about using the computer on the job?

I guess I'd be concerned about durability of the computer system. People can steal them, and things of that nature. You are going to have to read the thing in all kinds of light conditions, a lot of difference in temperatures, greasy fingers.

I: If you were to give me some advice about developing a troubleshooting booklet, what would be most important?

I think getting the graphics you need with the step, if possible, to eliminate the jumping around.

I: What about developing an expert system? Other than the number of screens, anything else?

I can't think of anything. Make sure the graphics are all there. The expert putting things in the expert system needs to be an expert himself, both on the computer program and the system he is writing the procedure for. As long as you work as a team, and work together, it should be fine.

I: What kind of person is going to choose the paper job aid rather than the computer?

Probably the person that is afraid of technology, resistance to change. They have been doing things for years that way and want to continue to do so.

I: All right. Anything else you can think of to help us out?

No. I'm just really happy for this opportunity to look at this kind of thing.

Subject #36

I: You've had a chance to work with two different types of job aids, the computer and the paper. Which one do you think is the most valuable?

The computer because I am used to working with them and that is what is more comfortable for me rather than leafing through instructional sheets of paper.

I: What about using this condensed guide? Compare it to the complete CTM.

I don't know. To me, the computer is easiest. Out in the field, the older technician who is more familiar with computers will definitely have an easier time with the computer rather than the paper. Paperwork gets lost, instructions get lost, a computer doesn't get lost.

I: Would you have any concerns about using the expert system?

Could be more condensed as far as combining graphics and pictures. I think it is just a matter of absorbing the steps you have to take. I think six times you would have it down decent.

I: If I was making a troubleshooting guide like this, what recommendations could you make to me in terms of things to pay attention to?

Keep the wording simple. Make sure it is readable, print is not too small. Make sure that the direction is explicit enough that each step is followed. Important sentences should be highlighted.

I: What about in developing the expert system. Is there anything else I should be doing?

I don't see anything. From what I see it is very simple. I don't know if you have all the information in that computer that you will need. It will be a continual source of improvement.

I: What kind of person would choose the paper job aid over the computer?

The technicians at dealership level would probably feel more comfortable with the paperwork, because a lot of the people out there are not comfortable with computers. Computer literacy... I think once the computer is learned by them, it is going to be a lot handier for them. Once he gets accustomed to it, that is the route he is going to pick.

I: OK. I'd like to give you an opportunity to comment on anything else you think might help us out.

I guess that's all.

Subject #37

I: Which of these two job aids do you think would be most useful and why?

As far as useful, it depends on the technician. If he is an experienced technician, to him the book is probably the most helpful thing he can find because he can put his hand on it and he can move back to something, and he is not used to using the computer at all. If he is a new technician, he is probably a young person and at least had some experience or some knowledge of a computer and he may feel more comfortable in using it, and it eliminates the possibility that he is going to get lost in the "go-to's." But there is something more to that, and it has to do with the layout in how you presented it. Each time it takes you to another question or another step, it is very helpful to have a statement of what you are trying to check. In electrical [system diagnosis] it is very difficult while we are trying

to check if there is juice going over here, but the technician can handle what he is doing if he has an idea of what he is trying to accomplish, what he might be looking for along the way. The minute a guy starts a step he should have a mental image of what he is trying to accomplish and all he has to do is follow the steps and when he is done he can say, "I have accomplished something." Each time I went to another question on this system I was frustrated by not feeling I had accomplished something. I simply had to answer some more questions and some more questions. It needs to lead a person and encourage them to say I have found this question now I'm going to find another one.

I: OK. That's real helpful. Now, we had a condensed version of CTM-11. Compare using a condensed troubleshooting guide to the flow-blown CTM-11.

I think as far as finding a problem, if the technician would use it, he will find his problem quickly if he bypasses an understanding of the system and how the system works. So if he will trust this diagnosis, he will probably find his problem. I don't know what your expectation of covering a particular problem is, but I think _____ shoots for 80% on hydraulics--that he is going to cover 80% of the potential failures. If the guy does not have the 80%, he has got [a problem to diagnose from] some of the 20%. If your little booklet covers only the diagnosis, he is really out now because he can not even figure out how the system works.

I: OK. What other concerns would you have about using a computer-based job aid for troubleshooting?

Of course the first thing you think of is it may be damaged, and the solution to that is to have it situated and have to connect so you can set it in one position so you can use it from there. If you have to carry it into the hinge area of a four-wheel tractor where you have to reach in and find a connection...now if I want to see which one of these six connectors was it, I have to get back to my computer and I have to find it. I had to look at the connector and I had to look at the computer. That is where the real difficulty comes in. The book is not a lot better, but at least he can drag it around and in between the hoses and use it a little bit better. So the computer has drawbacks as far as being usable in tight situations, upside down and all kinds of places it has to go.

I: You've written technical instructional materials, and I'd like to get your advice on how to design a troubleshooting guide like this. What's important?

If you are looking at paper you have to have a flow. All of the systems seem to have a flow. The first box should indicate what the check is and what you're checking and what you're looking for. Then you should have--this is my opinion, it's not the way the books [Deere manuals] are written--instructions on how to step up and how to perform that check followed by art, if necessary showing just what they are looking for. Then you have to have a "go-to" at the end of that. Did that answer your question or not?

I: Good. Anything else to consider in terms of design? What about other formats besides the structured list, like if-then tables and flow charts?

Yes, but since I do not work with them I'm not familiar with them. But the other side of that coin is that our people are using these [structured lists] and are used to them, and there is a movement to go to a flow chart type of set up. And even moving to a flow chart I think could cause more confusion. People like flow charts because flow charts show examples and they flow right through it, but when you get down to reality there is never a simple flow chart like that. The ones we've seen gone to print are very confusing. So what I'm saying is that I think this is the best.

I: What about designing an expert system? What could you tell me to help design a computer-based job aid?

Well, I guess I have to reflect on what you have in there right now and work from there. You started out--and you are probably well aware of this--that you start out by telling them what to do, but you have to go to another screen and the second screen shows the result rather than the location how to. Then if he needs to say, "Well how do I do that," it never gives you those instructions unless you ask for them. I had to back up again to find the results. That backing up procedure, it gets confusing. You say, "Oh, I need to back up." Then I have to look at the art again, et cetera. Is there an easy way to solve that?

I: We are trying to do that. It means fitting a question and some simple instructions and the menu on one screen. It's not easy.

Are you considering a paper booklet to go along with this?

I: No. I think the intent is to carry the computer around and that's enough. It's one or the other, not both.

I imagine that the people that are financing this thing are wondering the same thing. If we're going to have this computer in addition to a paper manual, then what is the point?

I: Now, you might have already answered this when we first started, but what kind of person would select a paper-based job aid rather than the computer?

There's probably two types: the older person who is not familiar with the computer, and the one who has used the paper, is almost certainly going to go with the paper. The younger person, if he does not understand the procedure that we use and if he finds it a little confusing and it looks long--that is one of the problems with our paper is that is 50 steps, and people do not want to start it....if people start with a computer, they have no idea how many steps there are, and what we try to tell them on paper--you only do a small fraction of these, you don't have to do them all. With the computer he can not see how long it is, and he finds out right away that it was only a few steps at the end. It is easier. If he could see all the steps in the computer he would say, "Oh, no!"

I: Anything else you can think of that can help us out?

I guess I'd say I like the set-up [expert system] and what you're doing with it. I'm not a great lover of computers, but it is probably about the only choice we have for the future.

Subject #38

I: You've had a chance to work with two types of diagnostic tools, and you mentioned that you preferred the expert system. Tell me about that. Why do you like it?

Any complex diagnosis on paper requires multiple page turning unless you have a very good memory. The computer turns the pages for me because it knows where I need to go, and it will keep its thumb in the page for me. When I hit the F5 key it goes over and says, "Oh, yes. Here's the picture you need." And it looks at it to see what is going on. Then I can go right back, and it kept its thumb on the other page to the diagnostic step I need. That's one thing. Secondly, the computer can bring all important information to me with out flipping through the pages we normally have. And the multitude of words, I guess, that tends to drive

people away from reading the words. Keep the verbiage as small as possible, [then] you have a better chance of people reading what we are putting in front of him: cautions, specifications, and how-to procedures. I think a down-side that turns out to be an up-side is that you are unable to figure out where the devil you are. I'm used to be looking at a paper diagnosis where I can go back from page to page. On a computer you can not do that as easily. You may have a sub-routine that allows me to find my way back. It would be nice, but because I can not readily to that, what it does, it keeps me on task the whole time, watching the whole time to see what is happening and not to see, well, I do not like this result--shouldn't it have been something else? It keeps me going, and I'm sure once I was used to it, I wouldn't be as confused as I could be. Going through it the first couple times here, the confusion just means that I have attention to task and am not bothered by other things like: the last time I went through this it was not this result--why is it this time? All I'm doing is following step-by-step because it is terrifying me into doing that.

I: How do you feel about using a condensed version like this as opposed to the flow-blown CTM for trouble shooting?

As long as the guide has the material you need, I have no problem whatsoever. The less verbiage the technician has to work, with the better off we are going to be as far as diagnosis is concerned. That is from my stand point as a diagnostician and an instructor. The more little hints and everything I can get, the better. I can explain how it works so I see that as an advantage. I guess the small physical size...the smaller the diagnosis [job aid] is, the better chance you have for somebody to look at it. The problem then is can you get all the information you need in the small size. All the information you need is not the same to you as the writer as it is me the technician. And we run into that often, adding more and more information.

I: What concerns would you have about using a computer-based job aid for troubleshooting?

My concern as the technician: would it do everything I'd want it to do? There are times when I would sit and scratch my head and wonder why it took me where it took me.

I: You can ask it why.
I thought I saw it on there. That is fine. It is great. With menus you do not have to put that on the screen every time, and I always know it is there. If I was the boss, operating the diagnostic crew, I guess my concern would be the life span of my computer and the costs. If the computer is so expensive, and the dealership can only afford one of

them, you are going to see small usage, depending upon the size of the dealership. Once it's proven itself, they will invest the money, but if an AT laptop will do it instead of a 486 machine, then you need to have it on an AT machine. It will be the only way you can sell the system.

I: You've already given me some good information about this kind of troubleshooting guide. Is there else you can tell me about designing a paper job aid?

We have already discussed this a little bit. I realize there are things that your expert system writing program can not do, so what I'm going to tell you is the way it should be.

I: The paper first.

Okay. This book we worked with today--if you want to make it smaller, that is fine. If you want to take diagrams off of everything [detach them from book], that is fine. Any diagrams or these fold-outs that I can keep the diagram out so I can see the diagram while I see the page [are fitting]. Having one in the front and one in the back so I can have the whole thing open four pages wide is a good idea. I guess as far as the paper is concerned, it is not that bad. The one problem I had was keeping my place on it. If you have some graphics in there or some way to break it up so I do not have to make marks in the book every time, that would be a big help. I realize it would be expensive to do, but it would be nice to put a note pad along side, and you could do it yourself with a piece of mylar tape. You could write in there and erase it. Thumb tabs, a tab for each code so I know the code and all I have to do is go to each page. That is about it. You don't have the why or how-to information in here because you have narrowed it down.

I: The CTM-11 does not have that either.

That is the way most tech manuals have it. I was looking at this to see if I could follow my path backwards, I guess I can not.

I: Now you are anxious to tell me about the expert system.

Yes. Anytime there is a piece of art that I need to see, if you could, drag along any specific instruction in that diagram because that is where I'm going to be. Warnings or cautions--I like the way you can toggle back and forth. Color would be nice [graphics are in color, but exercises were performed on a laptop computer with an LCD monitor that displayed four shades of gray], things like that. There is cost involved. I doubt if a dealership...if I'm a

technician, I can not take a PC out to a tractor, most likely. The best you are going to get is somebody, figure five years down the road, he will take this and hook his five-inch LCD TV to it and maybe have color that way. At the cost we are looking at, we need to always design for the worst case which you are just going to have two colors to work with. I need a note pad...let's say connector 21 had three-tenths of an ohm. Then I can drag the notepad back and can see whatever I want. When you go to diagnostic codes right now, you scroll down through the available list of diagnostic codes. It might be helpful for the guy who has to do this a lot if there's fewer keystrokes. The other option I would have: I would not mind having all of them on there [all codes in the menu]. It would also be helpful if I could enter the code, especially if is one I had never seen before and does not really exist because we have that happen. He goes to the list and the code does not exist, what do I do? Well, enter that code and maybe it always had standard line, and since this code does not exist you have to do such and such. The other thing you need to look at, for at least the tractors, is that people do not see the ECU or HCU code and they go to their engine diagnosis when the code says HCU 27 [indicating a problem with the tractor's electronic hitch rather than the electronic fuel injection system], and they will not find it because they forgot that it said HCU instead of ECU. Because you use the display system in the vehicle, there is a whole bunch of new problems.

BATTERY FAILED.

Subject #39

I: You had a chance to work with two job aids: the paper and the computer-based. For the troubleshooting you do, which would be more valuable to you?

The computer type. I think it can be up-dated quicker and easier. The old, conventional, paper type can get messed up and dirty, oily. The computer software you can update instantly. The old tech manual-type, it takes awhile to go through the printer.

I: How do you feel about using a condensed, troubleshooting guide like this, compared to a full-blown CTM?
This would be more...the condensed would be better.

I: Any reason?

Just better.

I: OK. Would you have any concerns about using the computer on your job?

The break in period would probably be the, you know, getting used to running it. But once you got it...there is always that period of break in time.

I: I was not in there when you were using it. Did you feel pretty comfortable?

I did, yes. I guess...I do not know if the system is capable. Could you type in or add something to it yourself?

I: Yes, sort of. There is a note pad feature so you can keep notes to yourself.

A lot of times out here now--not so far as the ECUs, but the hitch controller--you can write things down so next time you know what the diagnostic procedure was and different codes.

I: OK. I develop computerized job aids; I also develop flow charts and other kinds of paper job aids. Give my your advice about developing a troubleshooting guide like this. What's important? What could I leave out?

I wouldn't leave anything out. The wording can really screw a person up. On one system it said "connect" and on the other system it was "reconnect." It seemed like you could pick "reconnect" up easier than "connect." If you go to read something, if you are like me, you think before you read the whole thing.

I: What about with the expert system? We have to pay attention to the wording there too. Anything else?

No, everything is well handled.

I: What kind of person do you think would prefer a booklet like this to a computer if given the choice?

The older person who does not want to change his ways. He does not believe in technology. The younger service man would go to the computer because he wants to. The older ones are set in their ways.

I: Anything else besides age?
No. I mean, the years they have been on the job, not years in age.

I: Then you're talking about experience, too. So you think the person who is more inexperienced and younger is more likely to choose the computer?

Yes.

I: What other things could you tell us that would help us out? Anything at all.

If you are going to put it [the expert system] in the field, it should be put in the factory too.

I: Actually, it would be used in D-TAC and the factory before the field. We will prove it there.

I think it would be time saving in the factory.

I: Anything else?

No. Put it in the factory before the field.

Subject #40

I: You had a chance to use a computer and a conventional, paper job aid. Now, give me some honest feedback. Which do you prefer?

The conventional, because I can cheat. I can skim through things. I can take all the problems I know exist and I can start going down the list--yes, it has this problem and symptom and it does not have this--and start eliminating things and skipping steps. Now, the problem with that is if I screwed up and I was not forced to do everything, so your experience is going to determine how much you screw up. The longer you have been out there doing it, the less screw-ups you are going to make. To me, I still like the conventional. On the computer I can not see the whole picture.

I: How do you feel about using a condensed booklet opposed to the complete CTM?

Like a flow chart?

I: This condensed version versus the thick CTM.

I would have to stay with the thick one. It has all the information I want, and if I get a condensed-type version, there is something missing. [For instance,] a specification that I am looking for, and that is the step I needed. I want the spec right there when I need it. I like the fat

one. The more information they have, the better I feel about it.

I: Beside the things you just told me, what other concerns would you have about using the expert system?

The first concern would be the time to learn it. I fumble around. It takes time to learn this thing. To me, I do not want some customer standing over my shoulder, then I won't use it--I will go the conventional way. Once he does know that [how to use the expert system well], I would have a lot of concerns as far as I'm still a strong believer in the fact that people are technicians because they like to think and come up with their own solutions. If you're just taking me by the nose and leading me to the answer, I have taken what he wants to do for the rest of life away from him. I do not like that. It is almost too easy. There is a lot more vocational schools out there today because some people want to go out there and discover the problem on their own. He doesn't get that satisfaction if he's lead to the answer. Even though your system might be better, you're still taking something away from them.

I: OK. Now, if you were to give me advice about developing a booklet like this, what recommendations would you give me?

I guess the first thing would be that if you think one person out of 100 might care about it, it better be in there. All the information that you can possibly get in there--it will make it so much easier for the guy learning the system. Give me all the information you can possibly give me, in order. I want the information with the ECU that goes with the ECU. I do not want to be thumbing around. On the manuals, the art work has to be good, I want to look at that picture and tell where it is located on the tractor or vehicle and, like you had the connectors broken and the pins, that has to be in there, too.

I: Anything about designing an expert system? You mentioned the art work.

I want all that art work on one screen where I can get an overall view, or maybe box in a section where I can get a closer look. I would like all that in one color. I like color. Another thing, if you do it in the hydraulics, I want to know where the flow is--what way the hydraulic flow is actually going through. I want arrows or graphics moving the oil.

I: OK. You may have already have answered this question, but what type of person is going to choose the conventional job aid over the computer?

Someone who does not want to be told what to do, [who wants to] find out on their own. The only way I can learn is to do it myself. With the conventional I can do that. I can see all through the paper, whereas with the computer, it leads me down a path where I can not keep track of my thoughts well.

I: What kind of person do you think is going to choose the computer?

Someone who does not know any better. I would say the owners of the dealerships because they are the ones paying the bill and they want answers quicker. The system is correct too. If I was an owner I would demand that all my mechanics do it that way.

I: Anything else you could tell us that might help us out?

I guess to me right now you have picked something very simple, and you have done that for a reason. If it was long, a guy like me would really loose train of thought. The challenge to me would be the hydraulic system on a tractor: a 55 Series Tractor where everything is combined, everything has to be working together. It will be the real challenge. If you can get that down, and I will not be lead down the wrong paths, then you will have it made. There is so many variables, so many branches.

Subject #41

I: You had a chance today to work with a paper job aid and a computer job aid. For the trouble shooting you might be involved in, which do you think would be more valuable to you?

In my current job, the computer-aided one would work better for me because I found the biggest problem I had in there was going to step A and getting misdirected as you go through the steps. The computer is kind of keeps that order for me. So from my level, I need something more rigid.

I: You have used CTM-11 for troubleshooting. Compare that to using something condensed like this [conventional job aid].

I would like to know more of the background...the whys and what we are doing, and if something is not right, more than

what this real short version gives us. The short version, I see the most usefulness here, is probably for people with more experience than myself where they just need kind of a reminder where they are headed.

I: OK. Now tell me what concerns you would have about using the expert system?

It's availability. This [conventional job aid] could be nice to pull out of a drawer.

I: So your concerned because of hardware mainly?

It is getting to be where pretty much everybody has a PC on their desk. There are two bases [from which] I can answer that question. For my own use say, I could probably get to a computer easy enough--as easy as this [conventional job aid]. I'm still implying that this would be eventually be taken out into the dealer network somewhere where some guy [is] out in the shop making his walks back and forth to wherever this computer is, and it would be a little less handy from what a document would be. So from my own point of view, either one might be equal.

I: Any other problems you might have using the expert system?

It kind of bothered me a little bit where it kept telling me it repeated the disconnection even though they had already been so. That could be confusing because I had already done those and could get annoyed by this, it told me four or five times to be careful about moving that one connector. So it does not do a good job of keeping track of where you have come from. It was just annoying. It was not that confusing.

I: OK. If you were going to give me advice on designing or developing a paper job aid like that, what is one feature that you would tell me I should pay special attention to?

The pictures are always great. All these lines kind of look the same after awhile. Of course you did not want to make it very big. You just [should] have some of the graphics a little closer to the section. That is about it. I found myself flipping back and forth. Then this cross-referencing the connecters to the letters is kind of confusing. Trying to balance information on pages.

I: All right. Now what about developing an expert system?

The problem I had truly with an expert system is that I could see where he [a technician] might know of a particular

problem that he has had trouble with over and over with, and may want to zap right to that section and check. Although it may not make sense in general, he may want to go a specific location down inside the program somewhere. He may know he has had problems with those temp probes and just want to check that. But he doesn't know what the resistance should be.

I: So, in terms of development, include that kind of knowledge in the expert system?

Well, if possible. It did not appear to be as flexible to the expert user as this piece of paper. You get some of the software written where it is user-friendly but it is kind of "expert-annoying." It is asking you all these basic questions. But that would apply more to the expert.

I: If given the choice between this job aid and the expert system, what kind of person is going to choose the paper?

As far as people who work for the company, I'd say there is not very many people in our office. Like _____, he might want the piece of paper, just because he is a lot more familiar with it. The majority of the people might be more comfortable with the expert system in the office environment anyway.

I: What you have said has been real helpful. I'd like you to just comment on anything that you have not been given the opportunity to comment on--anything at all.

Well, it seems like our hard disks are getting as cluttered, you know, as having this paper in your file cabinet. I do not know if that is better or worse than having another program on your hard disk. Maybe things are getting that much more complicated. I guess one of the things we are charged with in our department is that a real added value has to be there before you computerize something. That [computerization] does not always make it easier of faster. There are some gains to be made there. And this is memory hungry with the graphics. Each graphic takes a lot of storage. I was amazed to see the other day I was looking at a portable with a 20-meg [capacity hard disk drive] on it, and there is only three-something left. If it's [expert system] on a network, I suppose I can get to it.

Subject #42

FIRST PORTION OF INTERVIEW UNINTELLIGIBLE

I: What kind of person would choose the paper job aid rather than the computer if given a choice?

Most techs, if they had a choice between those two, they would pick up the paper first until you trained them on the laptop, because there is going to be a tremendous fear factor for those computers no matter how simple you make it. Until you can get to the point where you can talk to the computer and it will talk back to you, then they might pick it up before the paper. That is our job. It is going to be a tremendous educational process, and anything, any slight glitch, has to be ironed out of that system before you hand it to the technician. It will only take one person to say, "This is junk" [to discourage others]. It has to be as close to perfect as it can be. Terms on there like "toggle" I try to rewrite those so that the ordinary guy can relate to or use them. Maybe there needs to be some other words used. Make a help screen so that you could change the words right on the computer. I can pick the word "switch" and that would mean the word "toggle." There may be areas in the work for some the words you picked that will work for some of the words you're trying to use. Anybody in Service Publications works with that all the time.

I: OK. What kind of person would like the computer then? Is it just computer literacy?

Yeah. The recent tech school grad, somebody who enjoys this kind of stuff at home. My guess would be the kind of person who has a VCR and does not mind programming it so he can watch a Celtics game at night. If he is that comfortable, it should not be hard to grasp a computer. If he has a VCR and the thing still flashes 12:00, and all he uses it for is to have his kids load movies for him so he can watch whatever movie he wants to watch, then he is not going to be comfortable with it [the expert system].

I: Anything else that would help us out?

Whenever you come out with a new version of diagnosis, you should highlight any changes so the technician will be sure to mark that as he goes through and notice it.

Appendix M

A Job Aid for the Intelligent Job Aid

John Deere
Electronic Fuel Injection System
Advisor

Use the advisor to diagnose problems with Robert Bosch and Nippondenso Electronic Fuel Injection Systems.

TO START: At the C:\EFI>, enter "EFI"

TO PAGE DOWN: For additional text in a window, enter "ALT-F4"

TO PAGE UP: Enter "ALT-F3"

TO RECORD COMMENTS, CORRECTIONS: Enter "F6"

TO QUIT: Enter "F10"

Installation problems? Call John at (319) 292-3900.

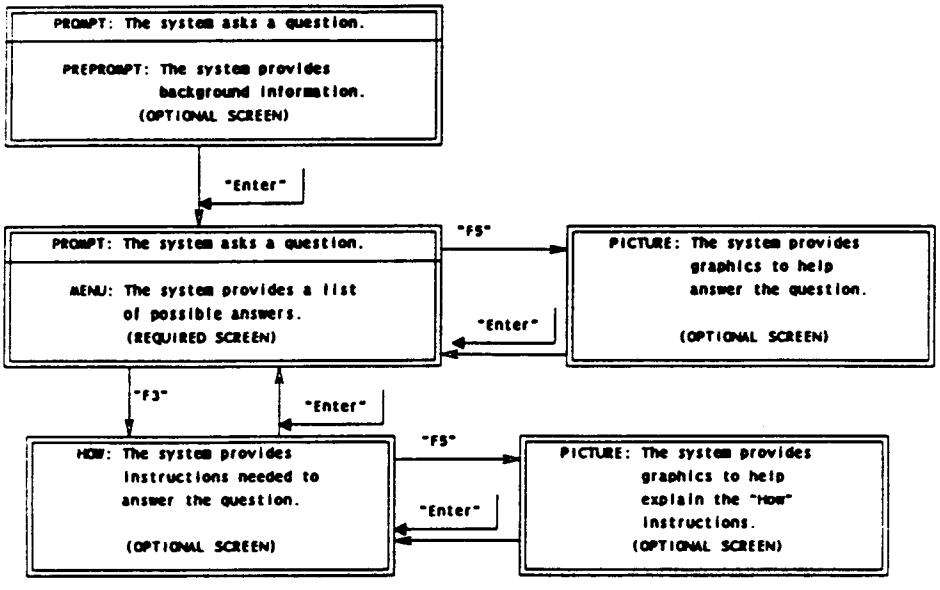
Other problems? Call Peg at (319) 292-6014.

See other side for information about movement between screens.

Figure 95: Job Aid for a Job Aid--Side 1

John Deere Electronic Fuel Injection System Advisor

Use this diagram to guide movement between screens.



See other side for operating instructions.

Figure 96: Job Aid for a Job Aid--Side 2