HAND-HELD ELECTRONIC DATA COLLECTION AND PROCEDURE ENVIRONMENT

EVAN KENNEDY[1] and KAREN DONIZ[2]

[1]Atomic Energy of Canada Limited
Control Centre Technology Branch
c/o Centre for Nuclear Energy Research
Incutech Building, MacKay Drive
Fredericton, NB E3B 6C2

[2]Atomic Energy of Canada Limited
c/o Environmental Qualification Dept.
Bruce A Nuclear Division, B06
P.O. Box 3000
Tiverton, ON N0G 2T0

ABSTRACT

As part of a CANDU[1] Owners Group project, AECL has developed a hand-held electronic data collection and procedure environment. Integral to this environment is the "Computerized Procedure Engine". The development of the CPE allows operators, maintainers, and technical support staff to execute virtually any type of station procedure on a general-purpose PC-compatible hand-held computer. There are several advantages to using the computerized procedures: less paper use and handling, reduction in human error, reduction in rework in the field, an increase in procedural compliance, and immediate availability of data to download to databases and plant information systems. The paper describes: the advantages of using computerized procedures, why early forms of computerized procedures were inadequate, the features that the "Computerized Procedure Engine" offers to the user, the streamlined life cycle of a computerized procedure, and field experience. The paper concludes that computerized procedures are ready for pilot applications at stations.

INTRODUCTION

Nuclear power station operations, maintenance, and technical support activities are prescribed by many hundreds of procedures, including:

- orders-to-operate,
- standard operating sequences,
- system and component test,
- technical surveillance,
- field instrument reviews,
- field data acquisition, and
- maintenance.

Typically they prescribe: sequences of operating switches, valves, and circuit breakers; the manual collection of field data from instruments, components, and special data acquisition systems; doing field calculations; and performing maintenance operations. Operators, maintainers, and other technical support staff carry a clipboard and pen, follow the steps of the procedure, and fill-in the paper forms where required. Once completed, a supervisor reviews it to ensure that all steps of the procedure were completed, any anomalies were recorded, and corrective actions are taken. Where necessary, important data is typed into a computer for later analysis.

The development of a hand-held electronic data acquisition and procedure environment simplifies and enhances the work processes associated with the execution of station procedures. It eliminates configuration management problems associated with tracking paper and electronic versions, enhances the execution of procedures through the implementation of numerous computerized features, and enables the seamless flow of information gathered through

[1] CANadian Deuterium Uranium

the execution of the procedure with the subsequent users of the data. This paper describes such an environment, previous experience with similar technology, the features and benefits of the Computerized Procedure Engine (CPE), the resulting procedure life cycle, the field trials and experience to date.

PREVIOUS EXPERIENCE WITH HAND-HELD COMPUTERS

For several years people have been interested in taking computers into the field for many reasons:

- Entering data into a computer in the field would eliminate the need for subsequent users to re-type the data into their own computer programs and databases for subsequent analysis.
- Data already in electronic form, such as supporting documents, engineering drawings and technical specifications, procurement information, etc., would be accessible without the need to carry a large amount of paper-based documentation.
- Complex calculations could be performed faster and with fewer mistakes.
- Procedural compliance could be improved through the enforcement of sequential operations and through the use of equipment or component identification via bar-coding or other technologies.
- Paper usage, handling, storage and distribution could be reduced or eliminated. An example of this are safety system tests at a typical four unit station that each year require 500 000 sheets of paper to be printed, distributed, filled-out and archived.

Early types of computerized procedures have been used successfully in other industries to collect field data in tasks such as taking inventory. However, in the past, these systems have not been as easy to use as paper or suitable to the complex type of procedures used in nuclear stations because:

- Transferring paper-based procedures to electronic form resulted in two versions requiring complicated configuration management activities.
- Limitations in past computer technology made older hand-held computers ill-suited to performing complex field procedures. In particular:
    - Hand-held computers previously had small screens, e.g., 7 lines of 25 characters, that limited the amount of text displayed. Long paragraphs of information were awkward to read. Only one step at a time could be displayed and hence it was difficult to read a step in context and get the gist of it. Also, no drawings or other graphics could be displayed.
    - Hand-held computers previously had tiny keyboards making it awkward and slow to enter data. Sometimes the keyboard was limited to buttons for the ten digits and "yes" and "no". Furthermore, sketches could not be made if circumstances required it.
    - Hand-held computers had less powerful central processing units making their use slow and tedious.
    - Hand-held computers were heavy, usually weighing several kilograms.
    - Some hand-held computers required attaching cables in order to transfer information to other computers.

Light-weight hand-held computers are now available that have overcome many of the deficiencies associated with the hardware. However, generating useable computerized procedures requires more than simply using forms and templates in conjunction with word processors and spreadsheets such as Microsoft Word, Excel, and Access. The reasons for this are:

- The user interfaces of off-the-shelf products assume the existence of a keyboard. When ported to a pen-based computer the user interface is, at best, awkward.
- Functionality, such as compliance checks, dynamically striking out text, automatic calculations, limit checking, and other features as described in the next section would be missing. In the case of word processors, extracting results from the surrounding text to download to other applications, such as a database, would be very difficult.

Another problem with running early forms of computerized procedures was that they had no provision for a paper backup. For nuclear stations, a means of producing a paper backup version is required because:

- paper provides an inexpensive backup in case the computer fails, is broken, or is unavailable,
- when changes must be made to procedures quickly, usually under special circumstances in the field, paper may be easier to use, and
- it allows the transition from paper to computerized procedures to be introduced gradually.

A solution to many of the limitations described above would be to write a custom computer program with all the "bells and whistles" for each procedure. However, there are several drawbacks to this approach:

- The cost of coding and maintaining several hundred computer programs; each one could take several weeks of work by a computer programmer.
- The cost involved with having a parallel review process for the computer programs.
- The time delay to get a procedure issued for use (programmers would only start once the paper version was issued).
- The high likelihood of discrepancies appearing between the paper and computerized versions.

Another previous effort is that of the US Department of Defense who have developed interactive electronic technical manuals (IETM) primarily for equipment diagnosis and repair tasks[5, 6]. The main motivation for their development is the cost savings of completely doing away with paper due to the significant quantity of documentation involved. Because of this emphasis, there is no provision for producing a paper backup. Indeed, there is no linear structure to these IETMs, unlike paper, which in turn leads to the electronic documentation having to be maintained by specially trained personnel. For these reasons they too are ill-suited for use by nuclear power stations.

THE HAND-HELD ELECTRONIC DATA ACQUISITION AND PROCEDURE ENVIRONMENT

The need to address the above problems led to the COG-sponsored development of the hand-held computer data acquisition and procedure environment for use in nuclear stations. The result was a system that allows the complete life cycle of most station procedures to be computerized. Furthermore, station staff can prepare and revise procedures with a minimal amount of training. In the field, the computerized procedure is easy to use and provides features not present in paper procedures. Typical station procedures that can be computerized are:

- safety system testing,
- technical surveillance and monitoring,
- mechanical maintenance,
- instrumentation maintenance and calibration, and
- field reading and data collection.

Overview

The hand-held environment consists of the following elements:

- the computerized procedure engine,
- the hand-held computer hardware, and
- procedure generation, storage, and archival.

These components are shown within the context of the overall procedure life cycle in Figure 1.

The Computerized Procedure Engine

The CPE is the heart of the hand-held electronic data collection and procedure environment. The CPE provides all the functionality associated with paper procedures:

- It can display several hundred words of text on a page.

- Numbers, text, signatures, sketches, comments, dates, times, and badge numbers, can be entered using a special pen without the need for a keyboard. Hand printed characters and numbers can be recognized and edited when desired. A pop-up keyboard on the screen can also be used if desired.
- The above information is permanently recorded.

In addition, the CPE has features to reduce the time to complete a procedure and minimize human error (see Figures 2, 3 and 4). It is these features that distinguish it from merely running Microsoft Word or other off-the-shelf applications on a hand-held computer. They are:

- Calculations are performed automatically by the computer once all data required to do the calculation has been entered. Results of calculations can either be numeric or textual (e.g., "3.456" or "Transmitter 1F is out of range"). This on-the-spot calculation ability can alert users, while still in the field, to incorrect entries and failed steps eliminating the need to take another set of readings later.
- Warnings and cautions can be displayed in a pop-up window that require operators to acknowledge that they have been read before they can proceed.
- The operator can be alerted to when entered values are out of range. This is a subset of the above functionality with the same purpose, that of reducing rework.
- Text can be changed from a regular font to a ~~strike-out font~~ based on entered data. This can help operators correctly choose the correct sequence of steps to perform. For example, if an operator checks off that the reactor is at low power, then all steps related to high power operation are shown in a strike-out font. This functionality will also allow procedure writers to check the logic of their own instructions on when to skip steps.
- Tag names can be updated at run time to reflect the channel or unit under test. For example, where a paper procedure has a wild card character to indicate the channel under test (e.g., 68220-PB-5*), the computerized version will show 68220-PB-5E once the user has indicated that channel E is under test elsewhere in the procedure. This feature is important as it reminds an operator exactly what equipment should be operated after an interruption thus reducing the chance for error.
- Data resident in the computer (i.e., the time and date), is filled in automatically, thus reducing unnecessary actions and ensuring accuracy.
- By clicking on a button, users can access drawings and other supporting technical information that are available on the hand-held's disk or anywhere on the station's local area network.
- Each user action is time-stamped automatically for later analysis, should it be needed.
- The current step is always highlighted.
- Data that is entered in one location can be displayed in many other locations in the procedure. This saves transcription errors, page turning, and can be used to provide summary pages.
- Users and their supervisors can check for completeness by pressing a single button. A pop-up window takes a user directly to the steps that were missed.
- Users can jump to any section by clicking on section titles displayed in the table of contents available in a pop-up window. The table of contents is generated automatically by the application.
- Data can be both acquired and results transmitted via the station's local area network and plant data systems due to a built-in infra-red communications interface. Infra-red interfaces can easily be installed within the station allowing wireless communications without concern for electromagnetic and radio frequency interference.

In the near future it is planned to add a bar code reader to assist in verification and procedural compliance. This will allow the computer to verify that the user is at the appropriate piece of equipment for that step in the procedure or to alert them that they are about to operate the incorrect piece of equipment.

Figures 2, 3 and 4 show sample displays from the system that illustrate many of the above features. Figure 2 shows a blank procedure while Figure 3 shows a filled-in procedure. Figure 4 shows that handwritten sketches and notes can be recorded.

Using the hand-held computer with CPE is simple. The CPE is started automatically when the computer is turned on. Users then click with their pens on the 'Forms' button at the bottom of the page to pop-up a window that allows them to choose the appropriate procedure for execution. (The procedures for the shift would have been copied into the appropriate directory earlier by supervisory or administrative staff.) Once the procedure is selected, the CPE loads the computerized procedure, formats it, and paginates it within a few seconds. It is now ready for execution. Along with the procedure, the CPE is ready to display all supporting information that is linked to the procedure, such as, engineering drawings and specifications, procurement information, and potentially the past results of previous exercises. The CPE then guides users through the procedure by highlighting the current step and crossing out inappropriate steps. Users must acknowledge that they have read warnings prior to executing the associated step. Prior to completion, users can check that all steps were completed using the Gap button. At the conclusion of the procedure, users store the completed procedure using the Save/Quit button. The procedure can be stored on the hand-held computer's hard disk or it can be immediately transferred to the supervisor's computer desktop or to databases, via e-mail or shared disk drives. As a result, the data and information obtained during the execution of the procedure are immediately available to many people simultaneously in electronic form. No transcription is required, thereby eliminating transcription errors. Supervisory staff and other technical and administrative support groups can view the completed procedure on their desktop computer.

The Hand-Held Computer Hardware

The computer hardware used for this project is a significant improvement over hand-held units used for early computerized procedures. The hand-held computer used within this project was a fully functional PC compatible computer that:

- does not require a keyboard since users can use a special pen to click on-screen buttons or have the computer recognize hand-printed characters,
- has a 12.3 cm x 16.2 cm screen with a 640 x 480 VGA display capable of displaying almost a full page of text as well as flow sheets,
- has a 50 MHz 80486 processor providing fast response,
- weighs only 1.1 kilograms,
- connects to a station's local area network via infra-red or spread-spectrum radio frequency communications with appropriate attachments,
- has a 500 MB disk drive and capable of carrying the equivalent of stacks of paper documentation, and
- runs the Windows for Pen Computing operating system, a version of Microsoft Windows 3.1.

In summary, it can be used as easily as a clipboard and is comparable to the notebook computers available today but does not have a keyboard.

Procedure Generation, Storage, and Archiving

Supporting the CPE is a cost-effective way to write and/or convert existing procedures and produce a paper version for backup purposes with little or no additional cost. The key to its cost effectiveness is the use of a set of tags that complies with the Standard Generalized Markup Language (SGML) [4]. Station staff write just one procedure using a standard word processor (e.g., Microsoft Word with an SGML add-on), or a special editor. Within Microsoft Word, this appears as a new set of pull-down menu features making the addition of tags a point-and-click operation. The resulting word processor file is the only one required to create the paper-based copy or the electronic procedure. The CPE directly interprets the resulting procedure for use on the hand-held computer and the paper copy can be printed using standard features of the word processor. This eliminates the need for specialized typing personnel to format, the need for programmers, and concerns that the two versions differ.

The computerized procedures can be reviewed using either of two basic approaches:

- by running the display application on a desktop computer, and/or
- reviewing a paper copy with or without a print-out of the embedded calculations.

Stations and staff can choose based upon station needs and preferences.

Having the procedure in electronic format has additional advantages as other steps in the procedure life cycle can be done electronically without the need for further clerical support. Procedures can be issued and distributed electronically by an authorized person copying files into appropriate directories on a station's local area network. Procedures can be electronically transported from the supervisor's computers to other staff via electronic mail. Data is no longer transcribed by a clerk into a database for trending, but is rather extracted directly from the completed electronic procedure using built-in operating system utilities or database macros. Archiving, where necessary, is as simple as copying the data to permanent storage media, such as an optical disk.

SYSTEM TESTING AND FIELD TRIAL EXPERIENCE

Computerized procedures for the hand-held environment have been written for demonstrations and tests in several areas:

- safety system testing procedures from Bruce B and Point Lepreau [1, 2, 11, 12]
- an operator test procedure from Darlington [3],
- control room and field instrument readings for NRU [7, 8], and
- a standard operating sequence for the regeneration of the ion exchange resin of the condensate polisher at Point Lepreau [9, 10].

Both the safety system testing procedures and condensate polisher regeneration procedure underwent field trials.

In all cases, users have been able to learn how to use the hand-held system in a matter of minutes. They found it as easy to use as paper and commented favorably on the advanced features such as the pop-up warning windows, the use of strike out text, automatic calculations, and immediate access to supporting engineering information and drawings. Supervisors have been pleased with the ability to have data collected in electronic form and immediately ready for analysis, and the opportunity to ensure better procedural compliance.

Converting existing station procedures for evaluations and demonstrations has shown that it takes one to three hours to train technical staff or operators, who have some computer literacy, how to use a special editor to tag files. Once trained, it has taken two to three hours to type in and convert a conventionally formatted procedure of about 20 pages; and four to six hours to convert a unconventionally formatted one. This will take less time if an ASCII text version of the procedure is readily available. For example, the condensate polisher regeneration procedure was the longest and most complicated being over 50 pages in length and including calculations, conditional steps, and references to several engineering flowsheets. The computerized version of this procedure was produced from the original WordPerfect document in less than one afternoon. Despite what advertising for commercial products may imply, no commercial tools can completely convert existing procedures into computerized ones. This is because new information specifying the advanced features such as embedded calculations, must be done manually - no software can guess this for the writer.

CONCLUSION

Advances in computer hardware coupled with a software development effort have made possible a useable form of computerized procedure for nuclear power stations. Benefits of computerized procedures include:

- the elimination of the need to transcribe data,
- reduced paper usage and handling,
- reduced human errors,
- greater procedural compliance, and
- time savings compared with the paper procedures now in use.

Typical application areas are safety system test procedures, maintenance procedures, standard operating sequences and field instrument readings. The hand-held data acquisition and procedure environment allows operators to carry out procedures in the field easily while providing advanced navigation, calculation and compliance not present in paper based ones. The way the procedures are prepared allows both a computerized and a paper version to be prepared. Field experience has been confirmed that procedures are easy to convert and prepare. Overall, the field trials have been considered a success and the hand-held data collection and procedure environment is ready for more advanced pilot application use at stations.

ACKNOWLEDGMENT

Funding for this work was provided by the CANDU Owner's Group under WPIR 1643.

REFERENCES

[1] Bruce Nuclear Generating Station B, Safety System Test, 09034.1 SST 1.1 Panel Checks.

[2] Bruce Nuclear Generating Station B, Safety System Test, 09034.9 SST 9.0 Panel Checks.

[3] Darlington Nuclear Generating Station, Operator Test Procedure, D-OTP-66110.04 Unit Zero Main Control Room Panel Checks.

[4] GOLDFARB, C.F., "The SGML Handbook", Oxford University Press, 1990.

[5] MIL-M-87268, MANUALS, INTERACTIVE ELECTRONIC TECHNICAL: GENERAL CONTENT, STYLE, FORMAT, AND USER-INTERACTION REQUIREMENTS, US Department of Defense, 1992.

[6] MIL-D-87269, DATA BASE, REVISEABLE: INTERACTIVE ELECTRONIC TECHNICAL MANUALS, FOR THE SUPPORT OF, US Department of Defense, 1992.

[7] NRU Operations Branch, Form 150-89, Control Room.

[8] NRU Operations Branch, Form 150-35, Heavy Water Purification System.

[9] Point Lepreau Generating Station, Standard Operating Sequence, Condensate Polishing System, SOS 43240-1, Regeneration of Ion Exchange Resin.

[10] Point Lepreau Generating Station, Standard Operating Sequence, Water Treatment Plant, SOS-71600-6, 1-7162-IX6 Regeneration.

[11] Point Lepreau Generating Station, Operating Manual Test, Shutdown System No. 1, 68200.3 High Log N Rate Trip of SDS #1.

[12] Point Lepreau Generating Station, Operating Manual Test, Shutdown System No. 2, 68300.12, Log N Rate Trip Test From MCR 66110-PL2.

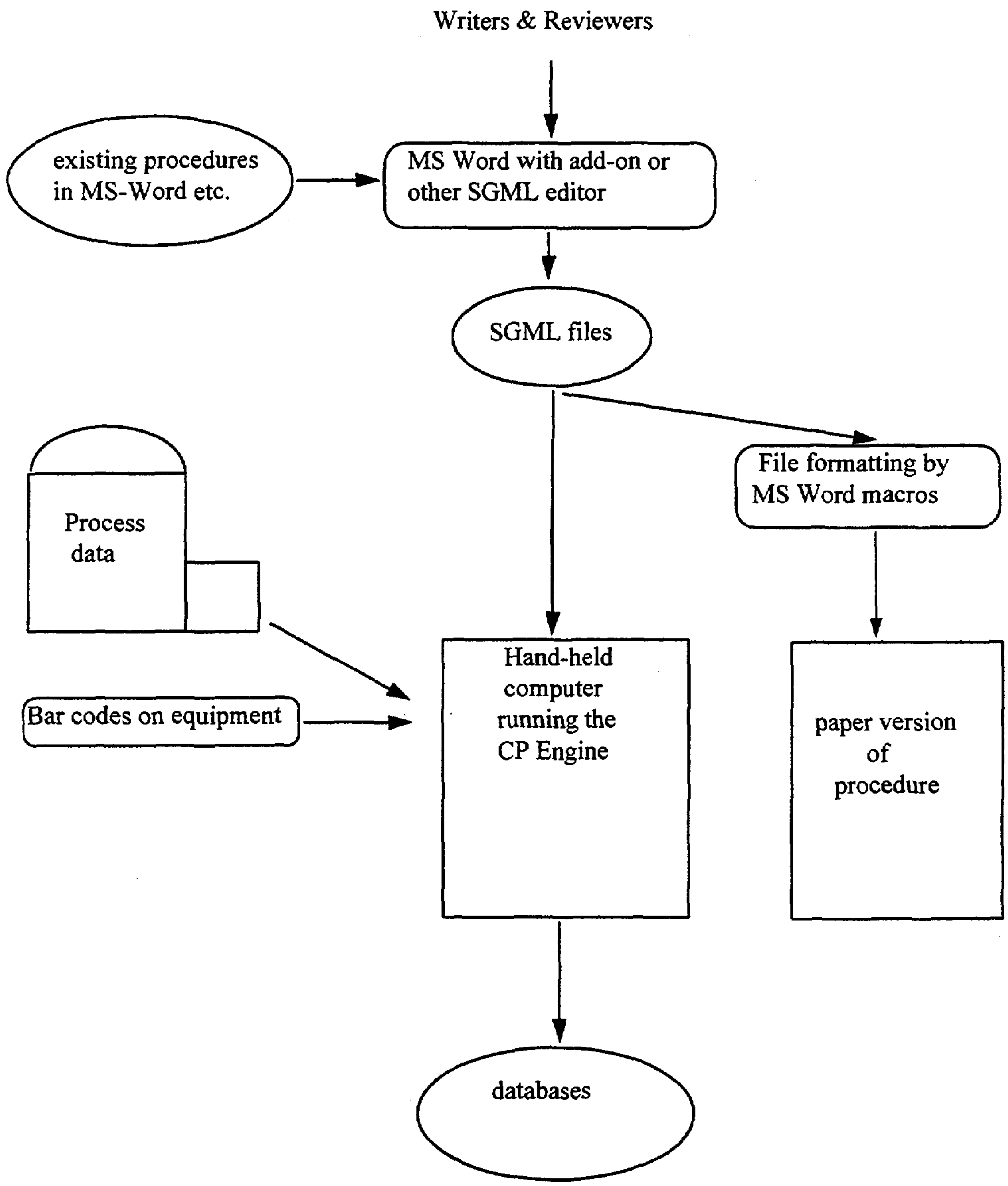


Figure 1: The Life Cycle of a Computerized Procedure

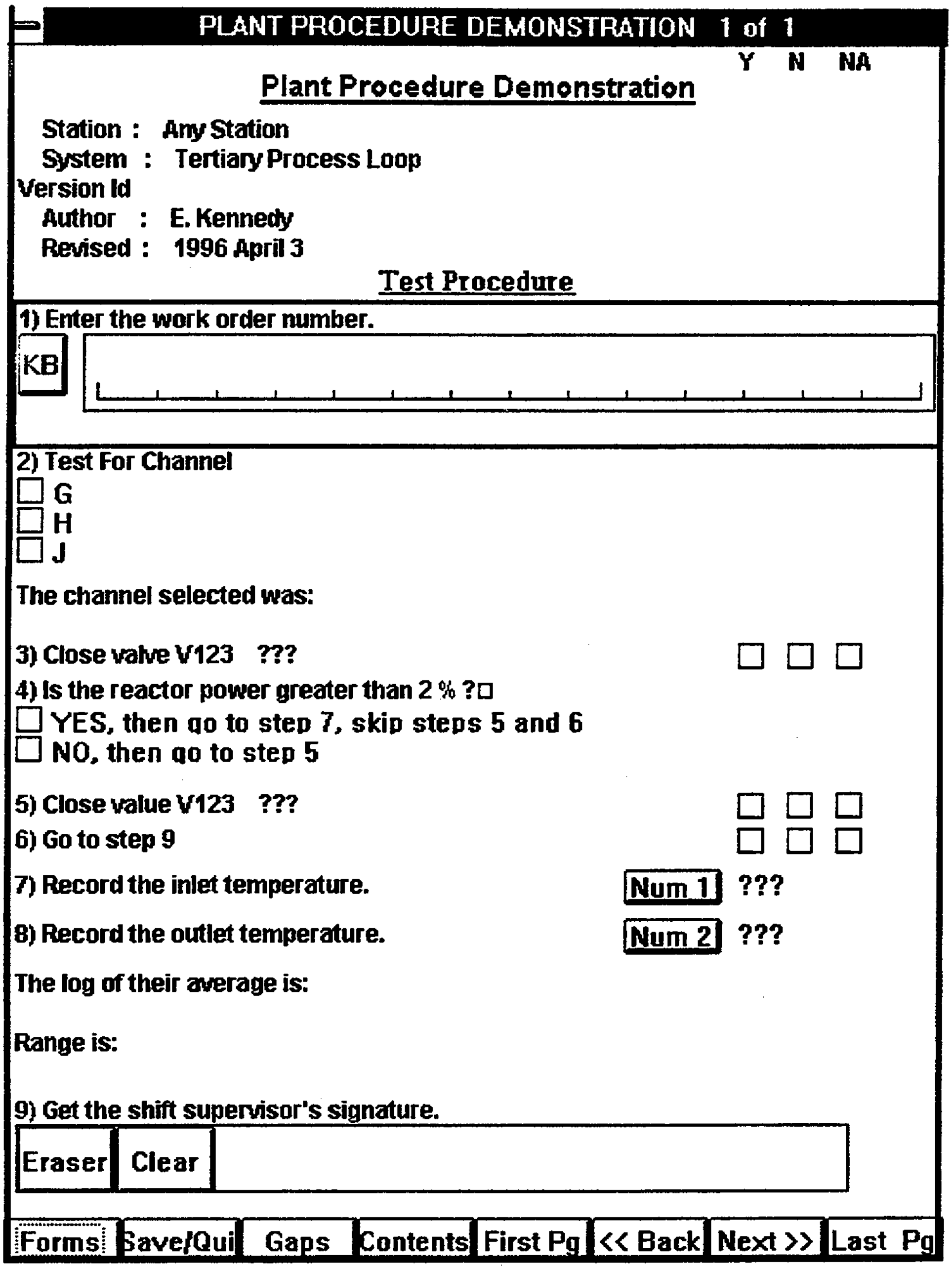
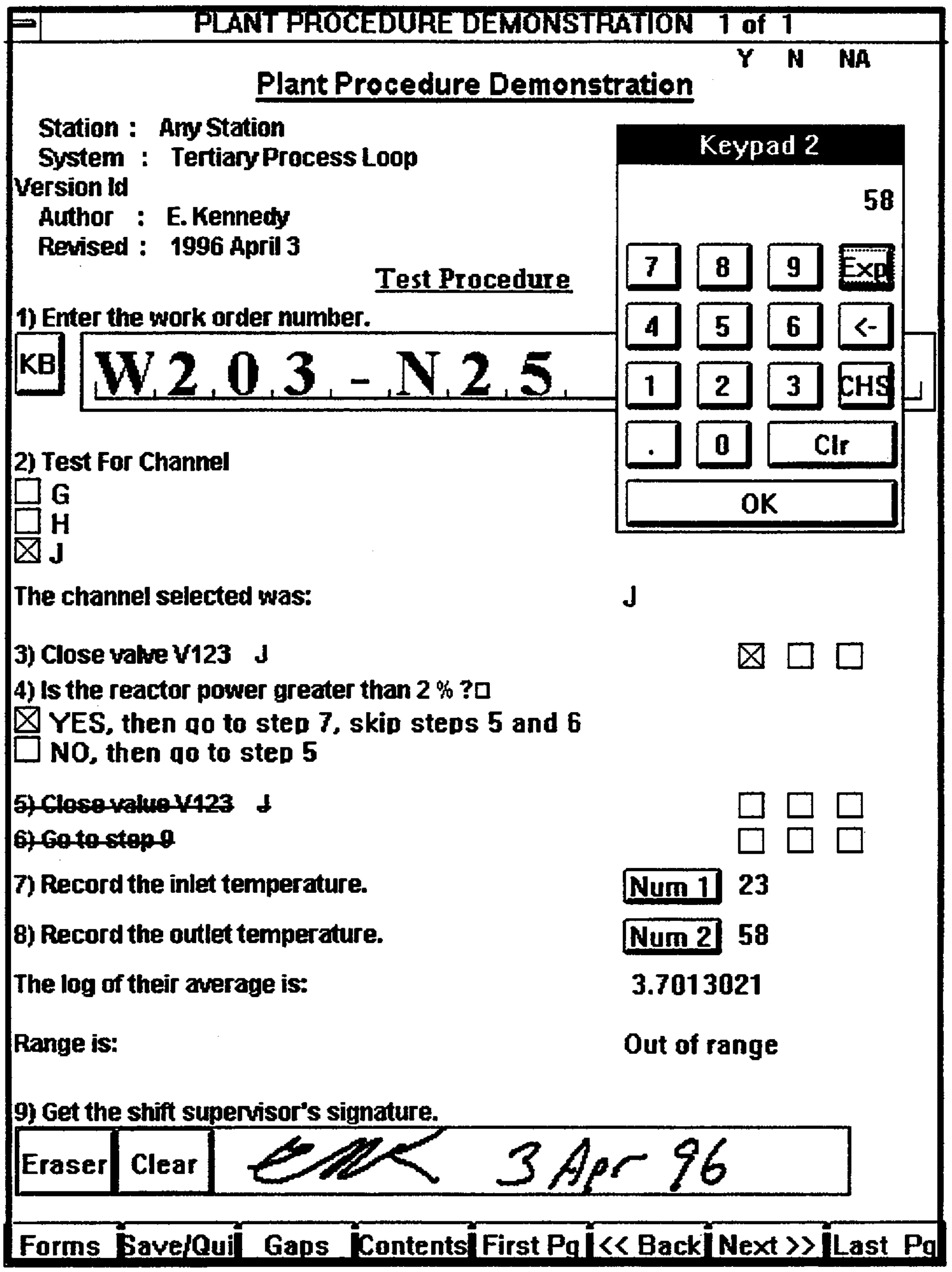


Figure 2: A Blank Procedure



PLANT PROCEDURE DEMONSTRATION 1 of 1

Y N NA

Plant Procedure Demonstration

Station : Any Station
System : Tertiary Process Loop
Version Id
Author : E. Kennedy
Revised : 1996 April 3

Keypad 2
58
7 8 9 Exp
4 5 6 <-
1 2 3 CHS
. 0 Clr
OK

Test Procedure

1) Enter the work order number.

KB W203-N25

2) Test For Channel
☐ G
☐ H
☒ J

The channel selected was: J

3) Close valve V123 J ☒ ☐ ☐

4) Is the reactor power greater than 2 % ?☐
☒ YES, then go to step 7, skip steps 5 and 6
☐ NO, then go to step 5

~~5) Close value V123 J~~ ☐ ☐ ☐

~~6) Go to step 9~~ ☐ ☐ ☐

7) Record the inlet temperature. Num 1 23

8) Record the outlet temperature. Num 2 58

The log of their average is: 3.7013021

Range is: Out of range

9) Get the shift supervisor's signature.

Eraser Clear EMK 3 Apr 96

Forms Save/Quit Gaps Contents First Pg << Back Next >> Last Pg

Figure 3: A Completed Procedure

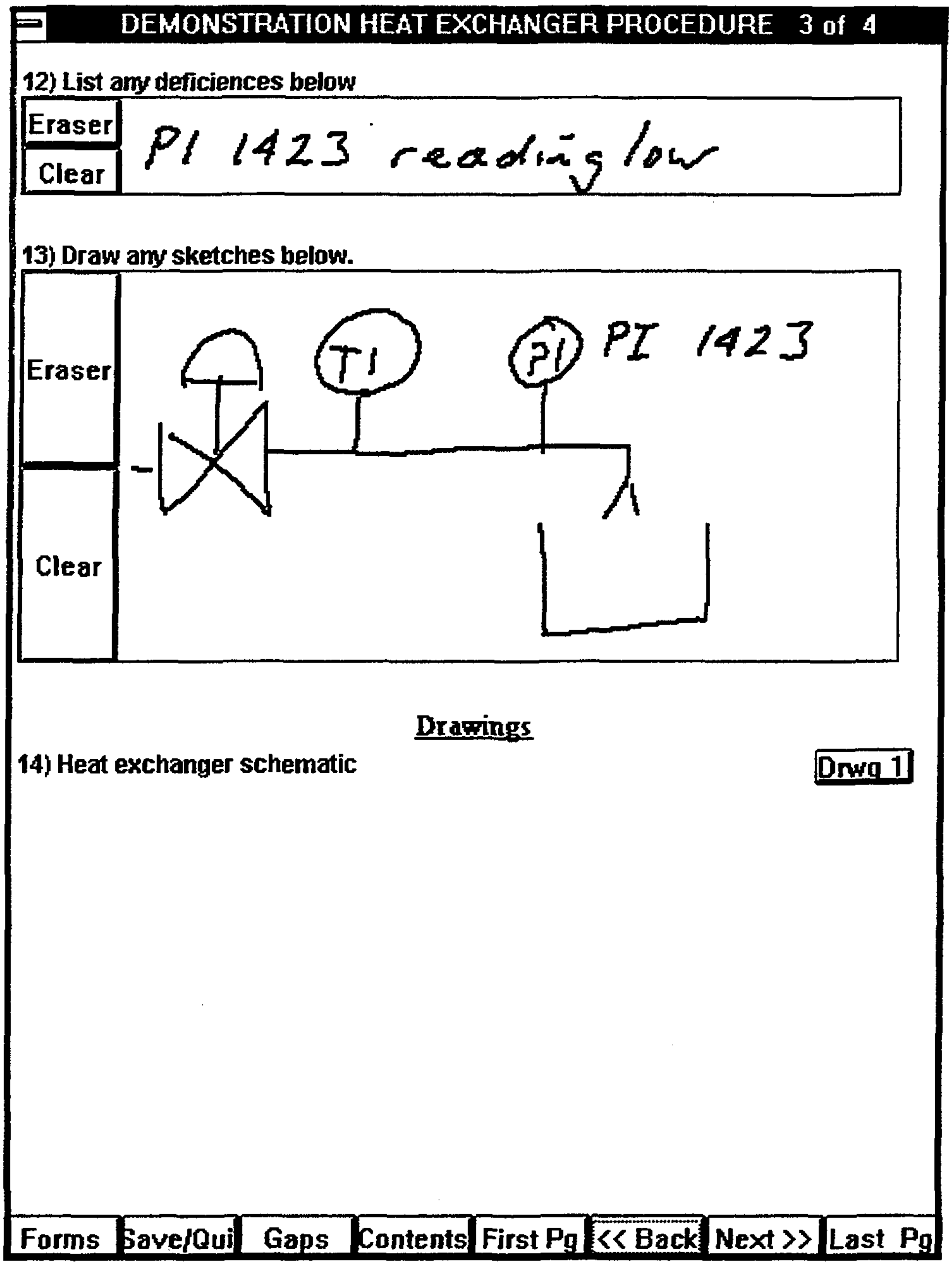


Figure 4: A Procedure Showing Handwritten Sketches and Notes